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BANGLADESH WATER DEVELOPMENT BOARD

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COASTAL EMBANKMENT IMPROVEMENT PROJECT, PHASE-I (CEIP-I)

FINAL REPORT

VOLUME I: MAIN REPORT

Joint Venture of

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Abbreviation and Acronyms

ADCP	Acoustic Doppler Current Profiler
ARIPO	Acquisition and Requisition of Immovable Property Ordinance
BIWTA	*Bangladesh Inland Water Transport Authority*
BMD	Bangladesh Meteorological Department
BOQ	Bill of Quantities
BTM	Bangladesh Transverse Mercator
BWDB	Bangladesh Water Development Board
BM	Bench Mark
BoBM	Bay of Bengal Model
CC	Climate Change
CDPo	Coastal Development Policy
CDMP	Comprehensive Disaster Management Program
CDS	Coastal Development Strategy
CDSP	Char Development and Settlement Project
CEGIS	Center for Environmental and Geographic Information Services
CEIP	Coastal Embankment Improvement Program/Project
CEP	Coastal Embankment Project
CERP	Coastal Embankment Rehabilitation Project
CES	Coastal Embankment System
CPP- I	Cyclone Protection Project - I
CPP- II	Cyclone Protection Project - II
CZE	Coastal Zone Embankment
CZWMP	Coastal Zone Water Management Program
CSPS	Cyclone Shelter Preparatory Study
DAE	*Department of Agriculture* Extension
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DOE	Department of Environment
DOF	Department of Fisheries
EA	Environmental Assessment
EMF	Environmental Management Framework
EMP	Environmental Management Plan
ECA	Environmental Conservation Act
ECR	Environmental Conservation Rules
ECRRP	Emergency Cyclone Recovery and Restoration Project
ED	Executive Director
EDP	Estuary Development Program
EIA	Environmental Management Framework

EMP	Environmental Management Plan
EPG	Embankment Protection Group
ES	Embankment Settlers
FAP -7	Flood Action Plan -7
FCD	Flood Control & Drainage
FGD	Focus Group Discussion
FFG	Foreshore Forestry Group
FM	Flood Management
GIS	Geographic information systems
GOB	Government of Bangladesh
GPP	Guidelines for People's Participation
GPS	Global Positioning System
GRRP	Gorai River Restoration Project
IBRD	International Bank for Reconstruction & Development
ICB	International Competitive Bidding
ICZMP	Integrated Coastal Zone Management Plan
IDA	International Development Agency
IPCC	Intergovernmental Panel on Climate Change
IPSWAM	Integrated Planning For Sustainable Water Management
ITC	Information and communication technologies
IUCN	International Union for Conservation of Nature
IWM	Institute of Water Modelling
IEE	Initial Environmental Examination
KJDRP	Khulna Jessore Drainage Rehabilitation Project
KAFCO	Karnaphuli Fertilizer Company Limited
KII	Key Informant Interview
LGED	Local Government Engineering Department
LGI	Local Government Institution
LRP	Land Reclamation Project
MES	Meghna Estuary Studies
MIS	*Management information systems*
MOEF	Ministry of Environment and Forest
MOFDF	Ministry of Food and Disaster Management
MOWR	Ministry of Water Resources
NCB	National Competitive Bidding
NEMAP	National Environment Management Action Plan
NGO	Non Government Organizations
NWMP	National Water Management Plan
OP	Operation Policies

RMS	Root Mean square
RTK	Real Time Kinematic
PAP	Project Affected People
PD	Project Director
PDC	Polder Development Committee
PIU	Project Implementation Unit
PMU	Project Management unit
PPCR	Pilot Programme for Climate Resilience
PW-3	Procurement of works-3
PMIS	Polder Management Information System
PWD	Public Works Department
RAP	Resettlement Action Plan
PRA	Participatory Rapid Assessment
SIA	Social Impact Assessment
SLR	Sea Level Rise
SPARSO	Space Research & Remote Sensing Organization
SRP	System Rehabilitation Project
SRDI	Soil Resource Development Institute
SWMC	Surface Water Modelling Centre
SWZ	South Western Zone
SZ	Southern Zone
SOB	Survey of Bangladesh
SWRM	South West Region Model
SEA	Strategic Environmental Assessment
SMRPF	Social Management & Resettlement Policy Framework
TRM	Tidal River Management
TOR	Terms of reference
WARPO	Water Resources Planning Organization
WB	World Bank
WMIP	Water Management Improvement Project
WRS	Water Retention Structures
WSIP	Water Sector Improvement Project
WUA	Water Users Association

EXECUTIVE SUMMARY

ES-1 Introduction

The coastal zone in southern Bangladesh adjoining the Bay of Bengal is characterized by a delicately balanced natural morphology of an evolving flat Delta subject to very high tides and frequent cyclones coming in from the Bay of Bengal encountering very large sediment inflows from upstream. The strength of the tides and the flatness of the delta causes the tides to influence river processes a long way upstream in the southern estuaries. This entire area is called the coastal zone (see Figure 1.1). The coastal zone, in its natural state, used to be subject to inundation by high tides, salinity intrusion, cyclonic storms and associated tidal surges etc.

The Government decided to construct polders surrounded by embankments along the entire coastal belt to protect the people and agriculture of the coastal zone and crops from tidal inundation and saline water intrusion and release a large extent of land for permanent agriculture. In this regard the first major project taken up was the Coastal Embankment Project (CEP) implemented during the 1960's& early 1970's.

Major tropical cyclonic disasters in 1970 and 1991 were estimated to have killed an estimated 500,000and 140,000 people respectively. The severe cyclone which occurred in November 1970 was followed by one in May 1985, one in November 1988, one in April 1991 one in May 1997, the severe cyclone SIDR in November, 2007 and lastly the cyclone AILA in May, 2009.

After cyclones SIDR and AILA struck the coastal zone causing severe damage to the infrastructure, life and property, the Government of Bangladesh (GOB) obtained an IDA/credit for Emergency Cyclone Recovery and Restoration Project (ECRRP), 2007 and proceeds from this credit would be used to meet the expenses for the proposed Coastal Embankment Improvement Project Phase-1 (CEIP–1).

Overall Objectives

The main objective of the consultancy services is to support Bangladesh Water Development Board (BWDB) in preparation of comprehensive Coastal Embankment Improvement programme (CEIP) and implementation of first program project CEIP-1 to be carried out in two steps as follows:-

- Prepare a long term phased programme for the rehabilitation of the embankment system where the polders are selected for each phase according to agreed criteria. Detailed feasibility study for the polders selected in the first phase according to the international standard which will form the basis for project appraisal by the World Bank and Government of Bangladesh at the end of the first assignment (Assignment-A). This will also cover detailed design and preparation of tender documents and implementation schedule for the first batch of polders selected from within the first assignment.
- Contingent upon the satisfactory outcome of the first assignment and availability of fund for the implementation of project (CEIP-1), this consultant would be responsible to continue for detailed design and supervision of the CEIP-1 works as second Assignment (Assignment-B) that would be implemented through International Contracting practice.

Specific Objectives of Assignment A

The CEIP-1 Assignment A comes in three important phases. They are

- The first stage involves the development of a Strategic Plan for implementing CEIP. This requires a strategic examination of the coastal embankment system to determine priority investments based on risks and vulnerability assessment in light of technical, economic, social and environmental considerations. The work involves the updating of the environmental baseline and carrying out a Strategic Environmental Assessment and using extensive modelling to determine present and future storm surge levels affecting embankment stability over a period of 20-25 years. The future scenarios would include probable climate change effects. This part of the study will establish the framework for the future phased development of the Coastal Embankment System.

  Although the original concept was that the first group of polders for feasibility study was to be selected based on this assessment, circumstances arose that made it necessary to proceed with that selection of 17 polders independently in order to keep the project on its time line. However, the Strategic Master Plan would nevertheless have to be prepared for future phases of the project.

- The second stage involves more detailed studies leading to Feasibility Study Report for improving the first group of 17 priority polders selected for improvement in CEIP-1. This work is based on the review of existing studies and reports, detailed topographical, environmental and sociological surveys in the field and detailed hydraulic modelling. The design proposals will be subjected to detailed consultation with stakeholders and economic analyses before they are finalised. Although common approach will be used in carrying out the studies, it is important to treat each polder as a separate entity having its own problems that require solutions individually tailored to its needs. The interventions proposed for polder will be subjected to an initial environmental examination (IEE). It is essential that the feasibility of the interventions proposed for each polder is established before proceeding with implementation.

- The final stage is for carrying out the detailed design for five polders selected from among the 17 priority polders from Stage 2. Design drawings and tender documents will be prepared. Tenders will be called and evaluated. Award of contracts, contract administration and construction supervision will be carried out as a part of Assignment B. A Resettlement Action Plan and An Environmental Impact Assessment would also be prepared.

ES-2 Project Background

The topography of Bangladesh is dominated by the low lying delta created by three mighty rivers Ganges, Brahmaputra and Meghna which discharge into the Bay of Bengal through its territory. The south east corner of the country lies outside this delta and the Chittagong Hill Tracts are the only real mountainous area within Bangladesh and this area drains thorough a narrow strip of land into the Bay of Bengal. The premier sea port of Chittagong lies on River Karnaphuli which passes through this strip of land.

The Bangladesh Delta is formed by the interaction of the very large summer discharges of both water and sediment from the Ganges, Brahmaputra (Jamuna) and Meghna Basins with the tides in the Bay of Bengal which could vary in range from 3m in the west to nearly 6m in the north-eastern corner of the Bay near Sandwip.

While the loss of life during cyclones that regularly strike the coastal zone, is being progressively reduced by means of improved storm warnings and continuing construction of cyclone shelters, the continuing damages to property, livestock, crops and livelihoods continue to take their toll.

The Coastal Zone of Bangladesh has been defined as the area within which the rivers flows are influenced by the tide. Given the high tidal range and the very low river gradients, the tide reaches very far landwards, particularly in the dry season. If the upstream freshwater inflows are reduced in the dry season, salinity can also intrude very far upstream within the river system which comprises a number of very large estuaries.

Coastal Embankment Project

The Coastal Embankment Project (CEP) was initiated in the 1960s to reclaim or protect areas in the coastal zone that lay below the highest tide levels for periodic inundation by saline water. These lands could now be used for agriculture by providing drainage structures capable of evacuating excess water during low tide. This system worked well for many years and 1.2 million hectares are now under the protection of the coastal embankment system bringing immense benefits. However, there have been unintended consequences of this project. The very act of preventing the high tides from spreading over the land and confining them within the river channels initially increased the tidal range by about 30 per cent which might have had an immediate beneficial impact on drainage. However, the reduction of upstream and overbank storage also decreased the tidal cubature (i.e. the volume of water displaced during a tidal cycle). The reduction in cubature induced sedimentation or more correctly a reduction in cross sectional areas of the rivers of all types – the large rivers such as the Pussur which have sandy bottoms and clay/silt banks and the smaller rivers which have an excess of silt and clay. The consequent choking of smaller rivers resulted in drainage congestion within some internal polders, and navigation problems in some.

The embankment system was designed originally to keep out the highest tides, without any consideration of possible storm surges. Recent cyclonic storm damages and the anticipation of worse future situations on account of climate change, has caused this strategy to be revised. Additional problems have also been identified – the direct impact of sea level rise on salinity intrusion into the coastal zone as well as on polder drainage.

The CEIP Initiative

It is well recognized that infrastructural interventions in the coastal areas by embankments and Cyclone shelters have significantly reduced its vulnerability to natural disasters at least partially and thus the poor people have some assurance of safety to their lives and crops. However, some of the effectiveness of the infrastructure in many cases has been compromised through poor and inadequate maintenance and sometimes by having to shift the embankments landwards to avoid progressive river bank erosion. With the occurrence of the frequent storms in the recent period the Coastal Embankment Systems (CES) has weakened and calls for systematic restoration and upgrading.

After cyclone SIDR struck the coastal area causing severe damage to the infrastructure, lives and property in the coastal belt, the Government of Bangladesh (GOB) obtained an IDA credit for Emergency Cyclone Recovery and Restoration Project (ECRRP, 2007) and the proceeds from this credit would also be used to meet the expenses for preparation of the proposed Coastal Embankment Improvement Project, Phase-1 (CEIP-1).

It had been appreciated that undertaking the rehabilitation of coastal embankment system under one or two localized projects will not bring any convincing change in such a vast area. To resolve this multi-dimensional problem a strategic approach in the name of Coastal Embankment Improvement Programme (CEIP) was felt necessary. It incorporates a longer term perspective in a programme spread over a period of 15-20 years, composed of at least 3-4 phases.

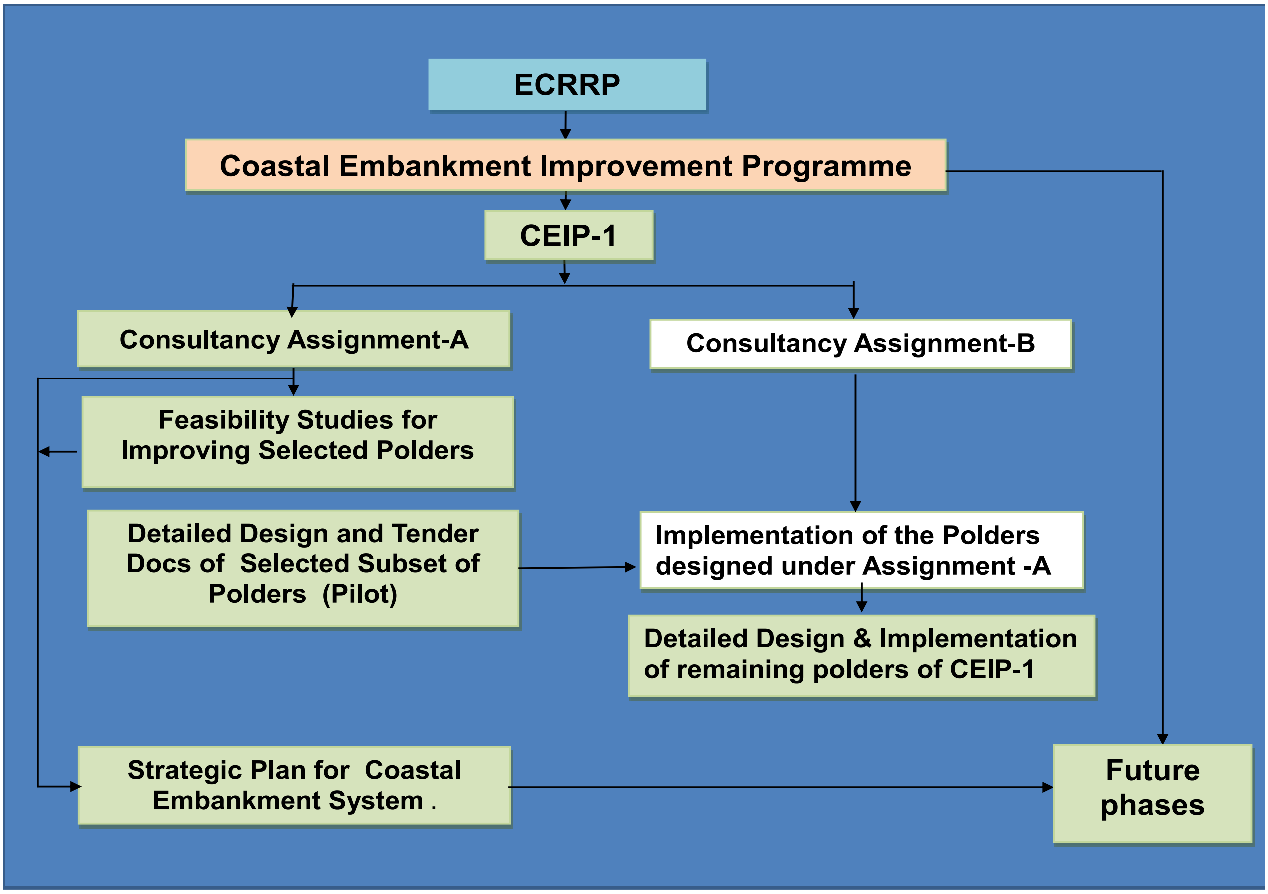


Figure ES-1 Project Structure

Figure ES-1 shows how this project fits into the Coastal Embankment Improvement Programme which arose from the Emergency Cyclone Recovery and Restoration Project (ECRRP) which was setup after Cyclone Sidr and its relevance was further emphasised by Cyclone Aila. Because of initial difficulties encountered by the project the selection of polders was carried out using a simplified multi-criteria analysis. This process was described in the Final Inception Report (2011).

The deficiency in performance of the first phase will be removed from the next through an enrichment of knowledge and understanding the lacunae in design. The purpose of this project is also to prepare the strategic plan for coastal embankment improvement program (CEIP) and for carrying out the detail feasibility study for the first program covered in CEIP-1 for reconstruction and upgrading of coastal embankments, at a cost of about US$ 300 million or 25 percent of the tentative estimated cost of rehabilitation of the whole project under CEIP. This will include detailed design, preparation of tender documents and implementation program for rehabilitation of judiciously selected extremely vulnerable polders at a cost of about US$50-75 million.

The previous projects that addressed the issues in the Coastal Zone usually addressed damage caused by previous disasters. CEIP is the first comprehensive programme to address the issue strategically.

Establishing a Verifiable Level Datum for the Project

The National Mean Sea Level datum used by the Survey of Bangladesh (and Survey of Pakistan before 1971, and Survey of India before that) was based on a Mean Sea Level established in India and transferred along several long lines of levels respectively to the North West, South West and South Central Regions, to the Dhaka Region and to the South East. The PWD datum which has been used to set out all structures constructed by BWDB (and by EPWAPDA before) was assumed to be related to the SoB MSL datum by a fixed level difference which set the PWD datum 0.46m below the accepted MSL datum. It is also thought that BWDB Hydrology pillars are also related to the SoB (we will call these Old SoB pillar levels).

Bangladesh established its own 'First Order Levelling Network' during 1991-1995 under a grant aided project. During that period Survey of Bangladesh established a 'Tidal Observatory' at Rangadia, Chittagong, a 'National Vertical Datum' at Gulshan, Dhaka, 465 benchmarks on about 2386 km first order levelling route covering 70% area of the country excluding coastal and hill tract districts.

This new Levelling Network is now well established and (New) SoB pillars (ie pillars depicting the revised MSL levels) are available for use throughout the Coastal Zone except at Hiron Point. All the Old SoB pillars were re-surveyed by SoB and it was found that there were errors of up to 50cm between the new MSL and the old MSL in the Coastal Zone – but that in other places (in the North West) the error was much smaller. It was clear to us during our discussions with SoB officials that we cannot convert new SoB to old SoB everywhere using a constant difference. Therefore, we cannot recover the old PWD level of a structure or a PWD pillar because the conversion factor varies from place to place – due to land subsidence and possible errors in the original levelling network which brought thousands of kilometres from MSL determined in Visakhapatnam in India.

For these reasons all the surveys for CEIP was based on the New SoB network. As it was customary to express levels in mPWD – the project expressed every level in “mPWD” obtained by adding 0.46m to the level measured above the New MSL datum. It is important to note that this mPWD has no relation to the old PWD datum which does not exist anymore.

All levels used by the CEIP are given in this datum (called “new PWD” internally for convenience). This includes

a) All embankment surveys

b) All cross sectional survey of drainage khals

c) Surveys of existing structures

d) All designs made and documented by the project

The water levels used in the IWM models were also converted to this same datum.

ES-3 Polder Assessment and Development Planning

The drainage network and the embankments 17 polders were surveyed by IWM to map the drainage network and to record the detailed cross sections and long sections the embankment and the drainage canals sections. As mentioned earlier in section 2.9 all surveys have been connected to the National Mean Sea Level grid established by the Survey of Bangladesh (SoB) in 2005.

Table ES-1 shows the main dimensions of the polders and their main features.

Table ES-1 Summary of Main Features of 17 Polders

S/No.	Polder No.	Location Name of Thana	Gross Protected Area (ha)	Cultivable Land			Main Project Feature				* Polder Population
				Total (ha)	Crop (ha)	Shrimp (ha)	Length of Embk'ment (km)	Regulators (No)	Flushing Inlets (No)	Drainage Channel (km)	
1	32	Dacope	8,097	6,500	6,497	5,328	49.50	13	23	45.00	38,397
2	33	Dacope	8,600	7,600	5,120	1,280	52.50	13	17	20.00	62,305
3	35/1	Sharankhola	13,058	10,700	10,400	300	63.00	18	20	106.00	99,182
4	35/3	Bagerhat	6,790	5,090	5,090	-	40.00	4	9	75.00	31,075
5	39/2C	Matbaria	10,748	8,500	3,800	-	55.00	13	12	54.75	43,077
6	14/1	Koyara	2,933	2,350	1,880	470	25.00	4	0	0.00	20,578
7	15	Shymnagar	3,441	2,925	900	2,025	27.00	5	0	0.00	31,788
8	16	Paikgacha, Tala	10,445	8,102	3,050	5,052	45.00	12	0	11.00	118,616
9	17/1	Dumuria	5,020	4,000	4,000	-	45.80	11	0	43.50	23,919
10	17/2	Dumuria	3,400	2,700	2,700	-	11.00	5	0	21.00	34,070
11	23	Paikgacha	5,910	4,872	1,048	3,824	37.00	11	36	36.00	23,888
12	34/3	Bagerhat	3,656	2,930	2,930	-	17.00	10	6	13.00	65,399
13	40/2	Pathargatha	4,453	3,300	3,300	-	35.53	25	18	47.00	41,317
14	41/1	Barguna Sadar	4,048	3,440	3,440	-	33.81	22	14	33.00	41,051
15	43/2C	Galachipa	2,753	2,000	2,000	-	25.70	6	40	26.10	14,851
16	47/2	Kalapara	2,065	1,850	1,850	-	17.50	4	5	29.50	5,411
17	48	Kalapara	5,400	3,715	3,715	-	38.00	10	0	16.00	26,260
			100,817	**80,574**	**61,720**	**18,279**	**618.34**	**186**	**200**	**577**	**721,184**

* Note: Population of each polder in 2011 was estimated from the population density in each union. Total population of each union in 2001 was projected to the year 2011 with growth rate of 2001 population census. Accordingly, the population density of each union was calculated . Then population for each union and part of different unions were calculated and total population in each polder has been obtained

Problems Faced in Polders

The 17 priority polders selected for Phase 1 development are all clustered in five districts Khulna, Bagerhat, Pirojpur, Barguna, Patuakhali and Satkhira mainly in the South West region. The polders are shown in Figure 3.1. Although they are clustered, they are spread over an area that has examples of almost every type of major physical problem that afflict the polder system. Some of the problems have been greatly exacerbated because of the lack of systematic repair and maintenance over 40-50 years of operation. These problem areas are briefly described below:

a) Drainage congestion within the polders due to siltation of peripheral rivers:

b) Vulnerability to storm surges and other high water levels

c) Deteriorated condition of embankments:

d) Poor condition of drainage structures:

e) Sedimentation in drainage khals:

f) Riverbank erosion:

g) Wave erosion of embankment slopes:

There are other social and environmental constraints that have to be kept in mind when trying to find solutions to the physical problems listed above:

h) Authorised and un-authorised settlements that might need to be disturbed to relocate and/or raise embankments

i) Squatter families tend to be the most deprived segments of the population and re-settlement options are limited.

j) Conflicts among fisheries, agriculture and other users of the available land must be resolved in the management of water within the polder.

k) Urgent need for sustainable longer term operations and maintenance of the facilities.

Planned Interventions in the Polders

The following guidelines were followed when making choices of interventions regarding embankments:

- Mechanical compaction has to be ensured for construction and reconstruction of embankment.
- Retirement of embankments will be discouraged as far as possible by putting protective works instead if necessary to avoid impacting settlements.
- Backing of embankments, where necessary, may be provided which should include slope protection as well as strong afforestation on the foreshore area.
- The height of embankment where needed should be increased in consultation with the local people.
- Replacement of the existing sluices constructed in 1960-1970 is essential providing long lasting structures compatible with project objective keeping provision for flushing cum-drainage.
- Strong design with high quality construction materials are to be used for all construction works.
- Damaged structures to be re-constructed and where needed new structures to be constructed. New structures should be constructed to facilities drainage in rainy season and control water in winter season so that farmers can save T. Aman crops from water logging and cultivate winter crops.
- Drainage / Irrigation channels should be re-excavated and new drainage channels may be excavated as per demand of the local people facilitating storage of sufficient water for winter irrigation.
- Arrangement to be made with the local people (through formation of WMA) to control the structures as per need (to open/shutdown).
- It should also be confirmed that the Gher owners cannot cut the embankment to take in saline water in to the polders for cultivation of shrimp under any circumstances.
- DAE may be involved for advising the farmers for better crops production activities and switching over to high value crops resulting economic benefit of the farmers.

Table ES-2 summarises the proposed physical interventions in the 17 polders.

The design criteria for embankments, hydraulic structures and drainage channels were determined in line with standard BWDB practice. The detailed design report carries a full explanation of how the design was carried out. Embankment crest levels were determined after extensive model studies carried out by IWM and also taking into account other considerations such as land subsidence.

The detailed studies made in each polder have been incorporated in a *Polder Report* have been prepared for each of the 17 priority polders.

The final set of proposals for rehabilitation of drainage structures in given in Table ES-3.

Table ES-2 A Summary of Recommended Interventions

Intervention / Polder No	32	33	35/1	35/3	39/2C	14/1	15	16	17/1	17/2	23	34/3	40/2	41/1	43/2C	47/2	48
Re-sectioning of embankment	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Backing of embankment towards C/S	√	√	√	√											√	√	√
Retirement of embankment	√	√	√	√	√	√	√	√		√	√						
Advancing of embankment	√		√														
Slope protection work	√	√	√	√	√	√	√	√			√		√	√	√		√
Bank protection work	√	√	√	√	√	√	√			√					√	√	
Afforestation on the foreshore area	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Repair of existing sluice	√	√	√					√	√	√	√	√	√	√		√	√
Replacement/relocation of existing sluices	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√
Construction of additional sluices	√		√	√	√	√		√	√						√		√
Demolition (without replacement) of strucutre	√	√	√	√				√		√	√		√	√			
Re-excavation of drainage khals	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Re-excavation of peripheral river or TRM*			√					√	√	√		√	√				√

Table ES-3 List of Drainage Structures to be Repaired or Replaced

Sl No.	Polder No.	No of existing regulators			No of regulators to be replaced by CEIP			No of regulators to be repaired			No of additional/new regulators to be provided			No of Structures Demolished	Total No of Drainage Structures Designed	Remarks
		RCB	RCP	Total	RCB	RCP	Total	RCB	RCP	Total	RCB	RCP	Total			
1	32	6	9	15	3	3	6	0	0	0	1	0	1	3	7	A total of 6 sluices already undertaken under GoB Aila Fund
2	33	13	0	13	13	0	13	0	0	0	0	0	0		13	1 sluice will be taken up under AILA.
3	35/1	17	1	18	12	1	13	2	0	2	2	0	2		15	DS-9 is in good condition.
4	35/3	3	0	3	3	0	3	0	0	0	1	0	1		4	The new regulator replaces an existing flushing inlet
5	39/2C	0	0	0	0	0	0	0	0	0	13	0	13		13	13 new sluices will be constructed.
Detailed Design Total							**35**			**2**			**17**		**52**	
6	14/1	3	3	6	0	1	1	0	0	0	2	0	2		3	
7	15	5	0	5	4	0	4	0	0	0	0	0	0		4	DS-1 is in good condition.
8	16	9	4	13	5	4	9	2	0	2	1	0	1		10	DS-1 is not needed but 1 additional sluice is required to be constructed.
9	17/1	12	0	12	8	0	8	2	0	2	1	0	1		9	DS-8 A has taken up under GoB fund and 1 additional sluice is required to
10	17/2	6	0	6	1	0	1	3	0	3	0	0	0		1	1 sluice is not required and 1 sluice in good condition.
11	23	7	5	12	6	4	10	1	0	1	0	0	0	1	10	
12	34/3	3	0	3	3	0	3	0	0	0	0	0	0		3	
13	40/2	6	7	13	3	7	10	3	0	3	0	0	0		10	
14	41/1	6	0	6	6	0	6	0	0	0	0	0	0		6	
15	43/2C	7	2	9	6	2	8	0	0	0	1	0	1		9	
16	47/2	3	1	4	3	1	4	0	0	0	0	0	0		4	
16	48	8	2	10	4	2	6	2	0	2	2	0	2		8	
Total for Feasibility Level Design							**70**			**13**			**7**		**77**	

RCB : Reinforced Concrete Box RCP: Reinforced Concrete Pipe

ES-4 Hydraulic Modelling for obtaining Design Parameters

A suite of numerical models developed by IWM were deployed to assess the effectiveness of existing drainage system and embankment crest levels and devising improvement measures considering extreme flood events and storm surge in the changing climate, Simulation results provided essential information for setting design parameters for crest levels and polder drainage. The modelling exercise is described in detail in the modelling report (IWM, 2012) so only the details most pertinent to explaining the rationale of the model application is presented in this chapter.

Storm Surges and their Probability of Occurrence

In the last 52 years there have been 19 major cyclones which have been sufficiently documented sufficiently to allow them to be modelled using the Bay of Bengal Model. It is clear that the tracks are more densely packed in the eastern side of the Bay. While there is a temptation to fill in the “gaps” on the western side of the Sundarbans by adding a few synthetic storms, there is no statistical basis for doing this and our return period computations would then be skewed by an unknown factor. Thus the statistical analysis based on 2x22 cyclone simulations (twice 19 actual and 3 additional synthetic tracks) presented in the Mid-Term Report was erroneous and it was considered necessary to revert to 19 historic cyclones repeated once with opposite tidal phase.

The maximum surge height was obtained from 106 pre-selected locations in the model domain, for each cyclone of the 38 cyclone simulations. The locations were selected so that it was possible to have sufficient coverage of the storm surges approaching all 139 polders with additional points to cover the 17 polders in detail. The 38 values obtained for each location were then analysed to obtain the 10, 25, 50 and 100 years return period storm surge levels. As the return period values were obtained by a curve fitting method, the standard deviation from the fitted curve was also recorded.

The scenario with climate change (2050) assumed a sea level rise of 50cm and an increase of 10 per cent in the wind velocity in the corresponding cyclone with an identical track based on AR4 of IPCC.

Storm Induced Waves

The embankments have to resist more than the maximum surge height. It is necessary to allow sufficient freeboard to resist wave overtopping. The wave heights generated by the cyclonic wind speeds are quite considerable along the sea-facing dykes and the dykes along the wide estuaries in the south. A wave model was run using the cyclonic wind field and storm surge as input for each of the 19 naturally occurring cyclones. The maximum significant wave height (H_{m0}) and the corresponding wave period T_p were extracted for each point of interest and the significant wave heights (H_{m0}) with return periods of 10, 25, 50 and 100 years were obtained at each location using a GEV distribution for sea facing polders and polders facing the largest rivers near the sea based on the 19 maximum H_{m0} values at each point.

Monsoon Flood Levels and Freeboard

Monsoon floods can raise water levels very high in some upstream areas. This occurs outside the two annual cyclone seasons. Particularly in these upstream areas, it is possible that the maximum water levels occur during the monsoon floods. The 25 years return period water levels in the river system were determined from a long simulation of the South West Region Model with climate change. The model was run for the period 1986 to 2009 after applying a sea level rise of 50 cm to the downstream tidal boundary and the increased monsoon precipitation (by 13% to 26% as presented in the AR4 of IPCC) in the NAM rainfall runoff model over the entire region.

Land Subsidence

The lower deltaic area of Bangladesh is located on two active troughs, Faridpur Trough and Hatiya Trough. In this area, three types of subsidence are recognized (Hoque and Alam 1997):

- Tectonic subsidence
- Compaction of peat layers; and
- Human induced subsidence.

There is some controversy about the precise quantum of land subsidence rate and how it differs from place to place. Considering the data available it was decided that as a temporary measure for CEIP-1, to assume a subsidence rate of 10 mm per year and to apply an upward correction of 30 cm (10 mm per year for 30 years) to the design crest levels.

Determining Design Crest Levels for Embankments

After considering the results of the storm surge analysis and the project life, it was decided that the design return period should be 25 years. The selection of crest levels for CEIP designs are based on the modelling outcomes.

a) The 25 years return period storm surge level
b) Alternatives for freeboard depending on overtopping limit of 5l/m/s for several possible embankment slopes and roughness.
c) 25 year return period monsoon level
d) 25 year return period monsoon freeboard
e) Allowance for subsidence

It is easiest to explain the decision making process with an example from one of the polders. Polder 35/1 is chosen for demonstration because of the extremely high incident waves computed by the model on the Baleswar Estuary almost directly facing the Bay of Bengal. The computation is shown in Table ES-4. The table uses two possible river side slopes, with or without added roughness. Eventually 1:5 slope with the southern part with roughness added, along the Baleswar to limit wave run up.

Table ES-4 Computation of Crest Levels along the Baleswar

WITH CLIMATE CHANGE : FREE BOARD COMPUTED ONLY FOR 5l/s/m OVERTOPPING

25 YEARS RETURN PERIOD FOR STORM SURGE MONSOON FLOOD LEVEL

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mPWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mPWD)	Modelled Storm Surge level (mPWD)	Standard Deviation (m)	***Sidr Simulated***	***Aila Simulated***	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level**	**Slope**	**Roughness**	**Crest Level recommended by Technical Committee**
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**
31	Morrelgonj,Fanguchhi River	4.88	3.80	3.50	0.22	*4.07*	*3.18*	1:3	1.92	1.34	0.30	5.72	**5.94**	5.14	5.36	3.50	0.57	0.50	4.30	**6.00**	1:3	1	**6.00**
32	Mathbaria,Baleswar River	4.88	3.80	3.62	0.27	*4.16*	*3.17*	1:3	2.40	1.92	0.30	6.32	6.59	5.84	6.11	3.48	0.79	0.80	4.58	**1:3 slope not used**			
33	Sarankhola,Baleswar River	4.88	3.80	4.19	0.35	*4.75*	*3.22*	1:3	3.60	2.88	0.30	8.09	8.44	7.37	7.72	3.47	1.01	1.20	4.97				
31	Morrelgonj,Fanguchhi River	4.88	3.80	3.50	0.22	*4.07*	*3.18*	1:5	1.08	0.84	0.30	4.88	5.10	4.64	4.86	3.50	0.57	0.30	4.10	**1:5 slope not used**			
32	Mathbaria,Baleswar River	4.88	3.80	3.62	0.27	*4.16*	*3.17*	1:5	1.44	1.08	0.30	5.36	**5.63**	5.00	5.27	3.48	0.79	0.50	4.28	**6.00**	1:5	1	**6.00**
33	Sarankhola,Baleswar River	4.88	3.80	4.19	0.35	*4.75*	*3.22*	1:5	2.04	1.68	0.30	6.53	6.88	**6.17**	6.52	3.47	1.01	0.60	4.37	**6.30**	1:5	0.8	**6.50**

Table ES-5 shows the summary of design crest levels for all 17 polders obtained using the procedure developed above.

Table ES-5 Summary of Design Crest Levels for all 17 Polders

Polder Number	Reach (Chainages)		Design Crest Level (mNewPWD)	Slope		ROUGHNESS (1.00 = smooth paved or turfed)
	From (km)	To (km)		R/S	C/S	
32	0.000	5.500	5.00	1:3	1:2	1.00
	5.500	44.000	4.50	1:3	1:2	1.00
	44.000	49.500	5.00	1:3	1:2	1.00
33	0.000	52.050	4.50	1:3	1:2	1.00
35/1	0.000	13.500	6.00	1:3	1:2	1.00
	13.500	26.000	6.50	1:5	1:2	0.80
	26.000	62.500	5.00	1:3	1:2	1.00
35/3	0.000	39.500	4.50	1:3	1:2	1.00
39/2C	0.000	33.700	4.50	1:3	1:2	1.00
	33.700	52.180	5.50	1:3	1:2	1.00
	52.180	61.500	5.00	1:3	1:2	1.00
14/1	0.000	30.000	4.50	1:3	1:2	1.00
15	0.000	30.500	4.50	1:3	1:2	1.00
16	0.000	44.830	4.50	1:3	1:2	1.00
17/1	0.000	38.000	4.50	1:3	1:2	1.00
17/2	0.000	11.000	4.50	1:3	1:2	1.00
23	0.000	7.500	4.50	1:3	1:2	1.00
	7.500	16.500	5.00	1:3	1:2	1.00
	16.500	36.500	4.50	1:3	1:2	1.00
34/3	0.000	16.200	4.50	1:3	1:2	1.00
40/2	0.000	3.750	6.00	1:7	1:2	0.80
	3.750	11.000	5.00	1:3	1:2	1.00
	11.000	21.750	6.00	1:7	1:2	0.80
	21.750	33.750	5.00	1:3	1:2	1.00
41/1	0.000	14.140	5.50	1:5	1:2	1.00
	14.140	33.640	5.50	1:3	1:2	1.00
43/2C	0.000	12.530	5.00	1:3	1:2	1.00
	12.530	25.280	5.50	1:5	1:2	1.00
47/2	0.000	17.055	5.00	1:3	1:2	1.00
48	0.000	17.000	6.00	1:3	1:2	1.00
	17.000	37.360	7.00	1:7	1:2	0.80

Simulation of Polder Drainage

It was not possible to model the malfunctioning structures in a repeatable manner in the drainage simulation. Thus in all simulations the structures were assumed to function correctly. The following simulations were carried out:

a) Present drainage system without climate change – (structures in good order)
b) Present drainage system with climate change (Option 1)
c) Improved drainage system(Options 2 and 3) with climate change

The effectiveness of the drainage system was examined on the basis of the three day inundation duration maps for the climate change scenario.

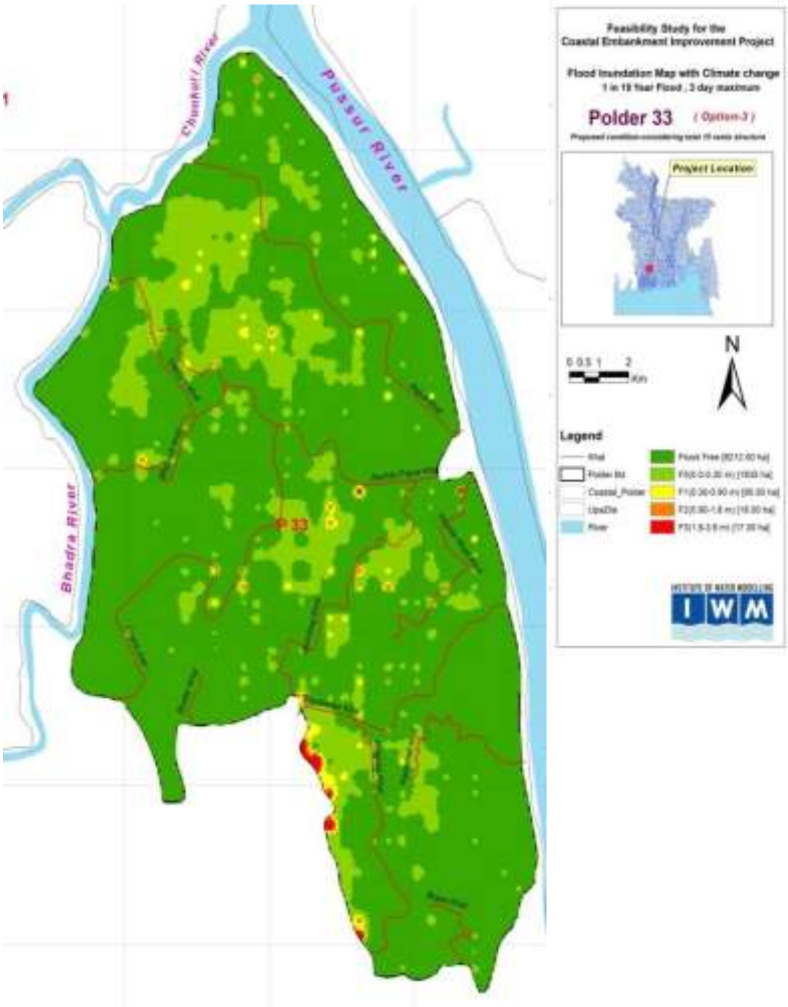


Figure ES-2 Improvement Typical Inundation Duration Map

ES-5 Land Use within Polders

The protected land and water area within each polder is used for several purposes

a) Human Settlements
b) Common amenities such as shops, schools, religious buildings etc
c) Commercial activities
d) Roads and other infrastructure
e) Agriculture
f) Aquaculture
g) Rearing livestock and poultry
h) Forestry (mainly in the unprotected foreshore area)

The quality of the land resource has often been degraded because of water-logging and saline intrusion. It is one of the main objectives of this project to increase the quality of the land within the polder to enable the optimum use of all protected land and water bodies within the polder. This is to be brought about primarily by improving the drainage system to the extent that it will be possible to maximise agricultural output even in the face of climate change and land subsidence.

The water demand regime within the polder system has changed over the years. There has been considerable demand for more flushing inlets than were provided in the original design. Despite some flushing inlets being provided by the Fisheries Projects, almost every polder has seen unauthorised flushing inlets being installed without consideration for the safety of the embankment. Interference with the existing drainage sluices to convert them to two way sluices has also resulted in damage to the gates and the loose apron. *These existing operational requirements are taken into account in the new design with most drainage sluices designed to operate as flushing inlets as well.* The number of flushing inlets has been optimised. This process has involved conversion of drainage sluices, closure of redundant flushing inlets and providing additional flushing inlets where they are needed.

ES-6 Sociological Impacts and Re-Settlement Issues

The CEIP-1 project is being implemented in the 45 Unions of 13 Upazila under 6 districts of the coastal region i.e. Khulna, Satkhira, Bagerhat, Pirojpur, Barguna and Patuakhali. A total of 139 polders have been primarily selected in the whole coastal zone under the Coastal Embankment Improvement Programme of which 17 polders have been selected to be improved under CEIP-1. Out of these 17 polders, 5 polders have been considered for detailed design under the first year program package of the CEIP-1.

The Social Impact Assessment prepared for 17 polders based on primary data collected through structured questionnaires, participatory rapid assessment (PRA) and secondary data obtained from the Population Census 2001 (Community Series and national Series) of the Bangladesh Bureau of Statistics (BBS). The Social Management and Resettlement Policy Framework (SMRPF) has also been prepared for 17 polders. A detailed socioeconomic survey has been conducted and the Resettlement Action Plan (RAP) has been prepared following World Bank OP 4.12. The SMRPF is also in Volume VII. The RAP is to be found in the Detailed Design Report.

A total of about 100,000 ha of land have been considered as the gross protected area in the 17 polders. Many people lost property and became vulnerable due to Aila and Sidr and the most of them are living on the embankments of these polders. As per census survey over 14000 entities (households, shops and common properties) were found on the 620 km long embankment (summing up all 17 polders) with a total of 65,235 people including 34,420 (52.76%) male and 30,815 (47.24%) female.

There will major social impacts when a large labour force (almost exclusively male) is brought into the polder and camps are established for this labour to live in over several years. There will be strains on the social fabric while there will be also be employment business opportunities in providing goods and services to the project and to the labour force. There will be disruption of settlements and agricultural activity by the land taken temporarily to service the contractors' activities and additional land that is acquired permanently for embankment retirement and re-sectioning. The necessary eviction of embankment settlers – at least for the period when the embankment is being re-sectioned – is a very serious matter that had to be handled with sensitivity.

These and other factors have been taken into account in formulating the Resettlement Action Plan.

ES-7 Environmental Impacts and Mitigation

Coastal areas are endowed with both fresh and brackish water resources. The fresh waters are available in upstream part of rivers, ponds, wetlands and groundwater. Brackish waters are mainly in the estuarine part of the rivers and tidal cannels/ creeks. There are no systematic records maintained of the net water discharge of the rivers in the coastal area. However, long simulations of the south west region model are available for computing the net discharges.

There are many beels, baors and ponds in the coastal area which are used as freshwater sources for people, fisheries and wildlife. Most of the beels and baors are located in the GTPW and GTPE zone. In addition, shallow groundwater aquifer provides almost 80% of drinking water supply to the coastal communities. Moreover, rainwater is being used in some areas through different rainwater harvesting technologies.

During the monsoon, there is abundant fresh water, whereas during the winter, water becomes a scarce resource. Due to reduced flows in the rivers in winter, both surface water and groundwater systems suffer from saline water intrusion, making the resource unsuitable for agricultural, domestic and industrial purposes. Furthermore, arsenic contamination in groundwater is becoming a severe threat to public health.

There are many sources of water pollution in the coastal zone such as domestic sewage, industrial wastewater and oil spills from river transport, which occur mainly in major cities like Chittagong, Khulna. Data on surface water quality are available in some stations in major rivers in Khulna and Chittagong and are presented in the SEA Report. Beside water pollution, salinity in surface and ground water is very important concern for agriculture, drinking water supply and aquaculture in the coastal area. Although the danger has not been flagged yet, it is likely that contamination of surface and groundwater by pesticides and other agrochemicals and pollution through excessive release of nutrients into the rivers and khals as the agricultural and fisheries activities become more intensive will be an inevitable consequence of economic development.

The major water related environmental problems presently encountered in the coastal zone are shown in Table ES-6.

Table ES-6: Major water related environmental problems encountered in the Coastal Zone of Bangladesh

Water Related Environmental problems/ hazards	Main Cause(s)	Affected Areas	Affected Sectors	Severity
Cyclone and storm surge	Natural by aggravated by Climate Change	Whole coastal zone	Agriculture, fisheries, public health, education, housing business and others	1
Drainage congestion/ water logging	Sedimentation driven by polder building and sea level rise	Mainly in GTPW and GTPE	Agriculture, fisheries, public health, education, housing business and others	2
Salinity intrusion	Aggravated by upstream diversions and sea level rise	Mainly in GTPW, GTPE and MDP	Agriculture, fisheries, public health	3
Riverbank erosion	Natural sometimes aggravated by unplanned river works	Mainly in GTPE and MDP	Agriculture, Settlements, infrastructure	3
Coastal erosion	Natural but could be aggravated by construction	Mainly in GTPE and MDP	Settlements and infrastructure	3
Sedimentation in river bed	Polder building, sea level rise, unplanned river closures	Mainly in GTPW, GTPE and MDP	Agriculture, Fisheries and navigation	3
Arsenic in ground water	Naturally occurring in geological strata	Mainly in GTPW, GTPE and MDP	Public health	3
Land subsidence	Natural in areas protected from flooding/sedimentation	Whole coastal zone	Agriculture, infrastructure	3

Air pollution problems too are generally restricted to the two large cities Chittagong and Khulna.

There are many existing problems connected to sedimentation in the project area. These problems will not in general be worsened by the project, although a lack of care in earth handling could have serious adverse impacts. It is also an objective of the project to mitigate some of the sedimentation problems, especially those responsible for drainage congestion.

Regional Environmental Impacts

It should be mentioned at the outset that CEIP will address, where possible, any environmental issues such as local sedimentation and water logging that could be addressed in the project design. The interventions proposed by the project are generally too small to have a long term regional impact. As mentioned before the construction of the polder system had a profound environmental impact on entire coastal region – particularly in the area of sedimentation. The present project would raise and strengthen the existing embankments but not make any measurable change to the way in which the tide interacts with the rivers and estuaries. This is true, except during a major cyclone.

While the raising and strengthening of the system of embankments has no influence on the normal tidal regime, during a cyclone there is a major difference in how the land is inundated (or not). The new higher and stronger embankment will to a great extent prevent inundation of land. Water levels will be driven higher when the flood water cannot be allowed flow onto the land. While the strengthening and raising of a few polders by CEIP-1 will have a small to moderate impact on raising surge heights in adjacent polders, this effect will be magnified as the more polders come under the subsequent phases of CEIP.

The morphology of the river and estuary system in the coastal zone is determined by the runoff of water and sediments from the catchment and by the tidal regime. The inexorable ebb and flow of the tide determines the shape (morphology) of the water ways. Rare events such as cyclones, though devastating in their impacts on land, have little or no influence on morphological development. While the CEIP project interventions would not have a regional morphological impact, sea level rise is expected to have a major impact on estuarine morphology. The overall impact would be to raise river bed levels – but the speed of this increase and where it will take place in the face of a 1 cm per annum increase in sea level has to be investigated by modelling.

Local Impacts

The local impacts of the project interventions (once completed) are mainly neutral because they are restoring the state of the polders to the situation they were in after the CEP when they were functioning well, (say) in the mid-1970s. We are assuming that no attempt is being made to revert to the pristine state of the delta before any polders were constructed. Serious environmental disruption can however be caused in the following unless safeguards are put in place:

During the construction phase:

a) During the construction phase: all activities connected with land preparation and earthwork, disposal of spoil etc. have to be regulated. The contractor’s work camp, influx of large numbers of workers, would set up serious social and public health challenges.

b) The amount of land required for the contractor's yard, offices, workers camp as well as fresh water, sanitation facilities, landing points, access roads etc., would require the temporary acquisition of more land.

c) There will be inevitable disruption of agricultural activities because of the construction activity.

d) A very large volume of earth will be moved from borrow pits to the site. This will create a very high erosion risk on site before the earth is compacted and eventually turfed over. There is risk of spillage that would also find its way into the river.

It should be possible to return the polder to a state better than its original condition before the site returned to BWDB.

During the operational phase (long term impacts):

a) The raising and strengthening of the embankments will not have any long term impacts on the environment except for raising the maximum storm surge level for the more intense storms.

b) Sea level rise will cause adverse conditions for drainage – which are allowed for in the design.

Sea level rise will also cause increased saline intrusion in the river system. This will reduce the number of days in the year when fresh water will be found in the peripheral rivers for agricultural use through the use of flushing inlets.

Initial Environmental Examination (IEE) reports have been prepared for each of the 17 polders. The reports also present draft terms of reference for the Environmental Impact Assessment Reports that have to be prepared for each of the 5 polders where the detailed design has been carried out.

Navigation Impacts including Transnational Navigation Impacts

The CEIP-1 project itself does not interfere with the normal morphodynamics of the river and estuarine system. The higher and stronger embankments will come into contact with river flow only during a cyclonic storm. The morphological impacts of such storms are transient and negligible, except in cases where there is a disastrous and massive embankment failure which brings an enormous amount of sediment into the river. This project is designed just to avoid such a failure.

The types of impacts the project could conceivably have on the waterways under consideration are ;

a) Changes in flow characterisitics (discharges, water levels, peak velocities, flooding etc)
b) Changes in water quality (in this case mainly salinity, and possibly nutrient changes, pollution)
c) Morphological changes (bed levels/flow depth, bank erosion etc)

As stated elsewhere in the report, it is worthwhile reiterating that the project comprises mainly the strengthening and raising of embankments together with (hydraulically) rather minor changes in channel alignment. The new part of the embankment does not even interact with the flow in the rivers except during a storm event which might typically occur during one tidal cycle in ten years – less than once in 5000 tidal cycles. Thus the overall hydraulic behaviour of the system is not changed by the project interventions except during this rare occurrences for which the project has been designed.

The relative morphological impacts of the normal tidal flow regime and the occasional severe cyclonic storm are also similar in nature and their corresponding magnitude. Thus the long term morphological development of the Delta is not affected by the project. Any excessive scouring that might be observed after one extreme event will be erased by repeated tidal cycles that will take place for years following the event. However, the scouring that could occur during an extreme event could be more severe after the project is implemented because of greate flow concentration in some channels due to reduction of embankment overtopping. Nevertheless, this effect would also be erased by the large number of subsequent normal tidal cycles.

The slightly raised maximum surge levels which will result from the additional confining effect on extreme water levels will happen at very rare intervals. These brief events – although very destructive of unprotected infrastructure – do not have any impacts on navigation.

There is further discussion of this topic in the Strategic Plan (see Volume 2B of this report).

ES-8 Sedimentation and Morphology

The sedimentation and drainage congestion problems encountered in the tidal rivers in the South West Region have been the subject of much study as well as much speculation. The principal mechanism of this sedimentation process is the movement of the tremendous volume of very fine silt and clay particles that are found in the tidal rivers and creeks in the southwest region. There is, at all times, a very high concentration of these fine particles held and carried in suspension. All larger rivers, even in the tidal part of the region, have sandy bottoms and are fringed with unconsolidated deposits of this fine mud which can be mobilised easily by the flow. There are other consolidated deposits that are not easy to mobilise. While there has been disagreement about the source of this sediment – whether these sediments originate in the Ganges or in the Bay of Bengal – the fact remains that there is sufficient mud already present within the system and in deposits just offshore to keep the sedimentation processes active for an indefinite period. It has been observed that high sediment deposition occurs during March to May at the upstream of the tidal rivers such as Kobadak, Betna, Hari, Upper Bhadra and Teligati Rivers where tidal prism has substantially decreased (IWM, 2010). It is believed that high sediment supply during dry season is due to tidal pumping.

While some sediment is washed further into the Bay of Bengal and removed from the river system, the only other sink available is the retention of some sediment on the land that is occasional flooded by high tides. This process is now restricted to the area presently occupied by the Sundarbans Mangrove Forest. Before the creation of a large number of polders from the 1960s onwards, there was a much larger sink for absorbing the silt deposits. The net effect of the CEP was:

a) A large reduction of tidal cubature caused by preventing tidal flooding in a large area of land now protected by embankments,

b) A general increase in the tidal range throughout the region. (e.g., 50 per cent increase in the tidal range at Chalna Port[1])

[1] The second port of Bangladesh was located in Chalna until to was moved to Mongla due to loss of navigation depth following the implementation of the Coastal Embankment project in the 1960s and 1970s. er

The increased tidal range initially improved the performance of the flap gate drainage regulators installed to provide drainage of polder lands. However, the reduction of tidal volumes set in motion sedimentation processes that were very detrimental to the efficient functioning of some parts of the river system in recent years, especially in upstream stretches of the tidal rivers which experienced considerable siltation.

The above concept applies equally to the small rivers as well as the larger rivers with sandy beds. This process of adjustment was not yet complete even in 1994 (DHI, 1994). The large river whose adaptation has had an economically significant impact has been the Rupsa-Pussur. Siltation of this river affected the navigation route from Hiron Point originally to the Port of Chalna and later to Mongla Port. Mongla Port began experiencing navigation depth problems in the 1980s.

The sedimentation mechanism is known and it has been proved time and again that clearing the sediment deposits by dredging or excavation *is at best a temporary solution*. This is because increasing the cross section of a river beyond its equilibrium level would only induce more rapid sedimentation which would try to return the river to its older cross section.

Tidal River Management for Maintaining River Depth

Tidal River Management (TRM) is the name given to the mechanism that has been proposed as a solution. The concept which was developed during the KJDRP project was based on increasing the tidal flow volumes in selected areas by allowing controlled flooding of certain low lying lands in a planned manner. Although the concept was initially controversial – there appears to be growing acceptance of the methodology after several years of experience. The TRM process is in itself not a permanent solution. The area that is flooded will eventually fill up with sediment and after several years not be usable as a tidal basin.

Project Impact on Waterways and Navigation

The CEIP-1 project itself does not interfere with the normal morphodynamics of the river and estuarine system. The higher and stronger embankments will come into contact with river flow only during a cyclonic storm. The morphological impacts of such storms are transient and negligible, except in cases where there is a disastrous and massive embankment failure which brings an enormous amount of sediment into the river. This project is designed to avoid just such failures.

ES-9 Institutional Arrangements for Sustainability

The CEIP is intended to improve the performance of the polders from the point of view of safety and effectiveness in providing for the water management needs of the polder population over the entire intended lifetime of the project (30 years) and longer, without significant negative social and environmental impacts. Very good design and execution is not sufficient to ensure this. The continued good performance of the ‘hardware” (ie, the drainage system, the flushing inlets and the embankment) does depend on excellent operation and maintenance. Excellent operation and maintenance does not happen automatically; it needs resources and an effective institutional arrangement to make good use of resources. This too is not sufficient. It is even more important that the users of the variety of services provided in the polder are able to avail themselves of those services amicably and without conflict. Thus it is possible to say that even the best engineering designs will need to be supported by an effective institutional arrangement to provide the "software" to sustain the project over a long period.

Operation and Maintenance

Past experiences show that preventive maintenance of polders (embankments, structures, canals and foreshore) through community participation is a successful strategy. This has been the most effective O&M strategy due to its organisational simplicity, robustness in nature and cost effectiveness. Success however depends on the active participation of the local stakeholders. To make participation worthwhile and meaningful, stakeholders should be allowed to express their ideas freely right from the planning process to actual implementation stages.

The prioritization of maintenance works when there is a shortage of funds, interaction with local government, NGOs etc. in organising a sustainable maintenance regime is discussed in detail in Volume X of this report.

Community Participation

The Embankment Settlers and the functional groups with the responsibilities of preventive maintenance may be allowed a particular reach of embankment, borrow pit, or foreshore lands as the case may be with the condition that they will live (preferably by erecting suitable houses at the country side toe at their own) here and/or enjoy the usufructuary rights of plantation in lieu of effective preventive maintenance of the infrastructure only. So the groups would have the understanding and belief at the very initial stage of settlement that whatever assistances are being allowed to them are only for the sake of preventive maintenance of the embankment, structures, canals and foreshore and for nothing else. Success however depends on the active participation of the local stakeholders. To make participation worth and meaningful, stakeholders should be consulted right from the planning process to actual implementation.

There should have some accountability on the part of the community based organizations (CBO) involved in the O&M activities. Continuous guidance and monitoring the performance of CBOs by BWDB Field staff may make the CBOs more accountable and preventive maintenance program will also become successful. In the process of this joint verification and assessment, the Local Government Institutions (LGIs) i.e. Union Parishad leaders/representatives (Ward Members) should be involved for active support and cooperation.

Institutional Arrangements

<u>Participation</u>

The need for sound institutional arrangements and communitiy participation in maintenance has already been discussed above. A multi-user facility like a polder system requires to be operated efficiently and without conflict. This can be done only through community participation. Much of the relative strength of rural people's knowledge lies in what can be observed locally and over a sustained period, and in what touches directly their lives and livelihoods. Most obviously, this applies to their knowledge of customs and practices. Descriptive and conceptual terms also provide points of departure for scientific investigation which may be more practical and useful than the externally determined categories of outsiders' knowledge.

The participation of the community and other stakeholders is best actuated through the formation of several bodies such as Polder Development Committee (PDC), Water Management Organisation (WMO). Proposals for constituting these bodies have been given in the Institutional Report (Volume X of this report).

Institutional Basis to Promote Community Participation

From the consultation held with local people and considering the objectives of CEIP it seems that at the bottom level Water Management Organizations can be developed on the basis of Hydrological units to be constructed within the framework of this project. This refers to the fact that a Water Management Organization will be formed for each hydrological unit involving different classes of people including poor and women living within the benefitted area of that particular unit.

To make these WMOs more beneficial to local communities, efforts need to be made to include different conflicting classes of people in this water management organization like farmers and fishermen always have their different position on the issue of water management for crop and fish cultivation. In principle this WMO will be the real user/ owner of the infrastructure by providing their services for day-to-day operation and maintenance of the structures to be developed.

ES-10 Economic and Financial Analyses

Out of 139 polders, 17 polders have been considered for feasibility study of which five polders are considered for detailed design under the first year programme package. Out of the 17 Polders, 35/1 14/1, 15, 40/2, 41/1, 43/2c, 47/2, 48 and 39(2c) are considered as storm surge affected polders and polders nos. 35/3, 16, 17/1, 17/2, 23 and 34/3 are diagnosed as flood affected polders. Polders 32 and 33 are affected nearly equally by both storm surges and floods. They were, however, classified as flood affected only for computing the benefits arising from avoiding damages due to overtopping. In other words, out of seventeen polders selected for study, nine polders are classified as storm surge affected polders and remaining 8 polders are considered as flood affected polders. The design of the polders (embankment, protection works and drainage system) were based on the need to resist both storm surge and flood impacts, each of return period 25 years. The benefits that would accrue from project interventions included the benefits of avoiding damages due to either storm surge or floods and not from both. Therefore the estimate of this type of benefit is conservative.

Basic Assumptions

The primary benefits from the planned improvement program for embankments are:

i) Benefits in the form of damages avoided due to less frequent overtopping;

ii) Benefits in avoidance of water logging within the polders; and

iii) Benefits from the foreshore afforestation program.

The first category of benefits will be the result of raising and strengthening the embankment; the second category of benefits emanate from restoring and improving the drainage systems of the polders in order to ensure adequate drainage capacity even under future adverse conditions induced by climate change (to eliminate water logging) better regulate water flow into and out of the polders to serve the present and future needs of the community. The foreshore afforestation, where sufficient land is available for planting, dissipates wave energy and partially or fully protects the embankments from slope erosion as well as reducing overtopping due to wave run-up. There are other economic benefits that follow from managing the plantations through a social forestry initiative.

Overtopping and Inundation

In the cases of polders threatened by storm surge, it has been assumed that once an existing embankment is overtopped, it is highly likely that the embankment will be breached. The principal underlying reasons behind this assumed scenario are: most of the embankments were built almost forty years ago, and have now spent their designed life span; suffer from poor maintenance; have been weakened by unauthorized installation of flushing inlets, and were manually compacted instead of being mechanically compacted. When an embankment is breached, the water depth reaches a minimum of 1.5 to 1.75 meters. The depth of the saline water, along with the speed with which it flows, causes the damage. However, the water starts to recede within a few hours. On the other hand the breached embankment could open the polder to flooding at every high tide making agricultural activity impossible until the breached are repaired and the saline water evacuated through the drainage system (where it is still functioning).

On the other hand, for the polders threatened by river severe flooding, when and once the water overtops the embankment, it continues to flow in for a few days at a stretch. This results in complete inundation of the whole polder.

Reduction of Probability of Overtopping

In order to estimate the benefits from the incremental height of an embankment, it is essential to first estimate the reduction in the risk or probability of overtopping and inundation. The reduction in the probability of overtopping is then to be multiplied by the mean damages inflicted by a storm surge/river flood to arrive at the expected damages in the absence of the CEIP-I.

Method of Damage Estimation

A way of obtaining estimates for future damage scenarios, is to get estimates from a past storm surges and then deduce the probable damage estimates for other storm surges, which may be stronger or weaker than the past one. With regard to the estimation of damage due to river flood, the fundamental assumption here is that the whole polder will remain inundated for at least 5 to 7 days. In low lying areas, the inundated period will be even longer. In the cases of river flood induced overtopping, we have assumed different parameters of damages for different sectors.

Return Period

IWM has estimated that the return period of the existing embankment of storm surge polders is only 6 years, whereas the storm surge "Sidr" had a return period of 35 years for some of the storm surge polders directly affected. As a result, the embankment was overtopped. However, when the newly designed embankments are in place, the return period of the newly erected embankment will be 55 years, mainly because sea level rise, subsidence, and an increment in wind speed will take place only in the future (the design will resist a 25 years return period storm occurring 30 years in the future). The storm surge level caused by Sidr, with a 35 year return period, was well below the height of the planned new embankment.

Prices

All costs and benefits are adjusted to market prices of 2011. Parity prices of major traded commodities are calculated based on World Bank Commodity Price Projections (See Volume VI). Financial prices of agricultural inputs and outputs used for farm budget analysis are collected from respective Upazilla/Union Parishads (U/P) Agricultural Offices, Upazilla Statistical Offices, from field visits by interviewing the local farmers. The discount rate is taken as 12% which is the standard practice in Bangladesh. For the purpose of economic analysis, assumptions are made as per FAP Guidelines for Project Assessment (GPA).

Investment Cost

The engineering cost estimates were taken as the starting point. These costs include taxes. The schedule of works considered as one that reflects the priorities for implementing the structures/equipment in conjunction with the annual envisaged investment flows. The project cost is based on constant 2011 prices, including direct and indirect charges and are expressed in foreign currency (US$) and local currency (BDT). The total project cost includes physical contingencies @ 5 percent and design, supervision & administrative charges @ 5 percent. Economic costs exclude resettlement cost, tax & duties and price contingencies. The exchange rate assumed for the project is US$1 = BDT 82. The proposed total financial investment cost estimated for the project amounts to BDT 25996.42 million or US$ 317.03 million (Table ES-7). The proposed total economic investment estimated for the project amounts to BDT 18947.28 million or US$ 231.06 million in 2011 prices.

Table ES-7 Summary of Project Costs (Financial) for Seventeen Polders

A. Civil Works	Polder 32	Polder 33	Polder 35/1	Polder 35/3	8 Storm Affected Polders	5 Flood Affected Polders	Total
1. General Mobilization	8.46	10.79	24.57	6.92	58.35	22	**131.08**
2. Embankment	387.8	310.33	742.13	364.53	2,425.88	940.36	**5,171.04**
3. Re-Excavation of Drainage Khals	16.83	137.22	127.7	120.98	122.68	66.04	**591.45**
4a. Hydraulic Structures	272.3	502.08	646.24	221.56	2440.8	1358.84	**5,441.81**
4b.Protective Work	383.66	502.95	1805.15	233.98	3203.49	257.88	**6,387.10**
4c.Other Works	144.62	59.69	64.14	33.44	228	160.45	690.34
5. O & M during construction /**a**	30.34	38.08	85.25	24.53	211.98	70.14	**460.32**
Subtotalfor Civil Works	1,244.00	1,561.15	3,495.17	1,005.93	8,691.18	2,875.71	**18,873.14**
B. Afforestation & Resettlement	176.29	190.63	175.12	80.06	1192.41	475.82	2290.32
C. Land Acquisition	80.4	30	75	18	403.15	98.1	**704.65**
D. EMP	27.26	47.94	24.06	30.4	199.34	69	**398**
E. Consultancy Service for supervision and monitoring	52.59	67.1	152.73	43	318.63	124.2	**758.25**
F. O&M Training for staffs and beneficiaries	0.8	0.85	1	0.75	5.08	3.25	**11.73**
G. Engineering and Administration /b	31.1	39.03	87.38	25.15	217.28	71.89	**471.83**
H. Provisional Sum /c	31.1	39.03	87.38	25.15	217.28	71.89	**471.83**
Total Baseline Cost	**1,643.55**	**1,975.72**	**4,097.84**	**1,228.45**	**11,244.34**	**3,789.86**	**23,979.75**
Physical & Price Contingencies	82.18	98.79	204.89	61.42	562.22	189.49	**1,198.99**
Inflation (Local & Foreign)	55.06	67.87	142.27	42.25	380.9	129.33	**817.68**
Total Project Cost	**1,780.78**	**2,142.38**	**4,445.00**	**1,332.11**	**12,187.46**	**4,108.68**	**25,996.42**

a/2.5% of Civil w orks b/2.5% of Civil w orks c/2.5% of Civil w orks

Project Benefits

At the outset, we acknowledge enormous difficulties and limitations in assessing damages and losses. Given the large uncertainties about the magnitude and timing of the added risks from climate change, it is essential to identify the potential damage and losses caused to agriculture and allied sectors production and loss, properties, assets and other infrastructure due to a cyclone of the magnitude of Sidr. Embankments will protect all polders both from storm surges as well as river floods. For the purpose of our analysis, we have considered either storm surge or river flood impact whichever has the major dominant cause with respect to a particular polder.

Potential damages and losses in each of the major economic sectors resulting from cyclones or river floods are computed. They are determined by applying sector-specific damage and loss functions to the affected assets and activities in the sector assessed. Those sector specific damage and loss functions are either derived from the Sidr experience or have been arrived at after consultation with relevant experts. The major economic impacts on different sectors are likely to be the same in terms of magnitude and scale as that of those which incurred damages and losses during cyclone Sidr in 2007.

Damages include complete or partial destruction inflicted on assets. Losses refer to the goods and services that are not produced or rendered ineffective due to a disaster. Losses also include increases in disaster-induced cost being incurred in continuing and maintaining essential services. Data about damages and losses caused due to SIDR was obtained from Upazilla office of respective storms and flood affected polders. For the purpose of economic analysis, we extrapolated the average percentage of damages and losses for polder no. 35/1 for different major economic sectors to arrive at figures, as close as possible, for the storm surge affected polders. The extrapolated values so obtained for different specific economic sectors were used for assessing damages and losses for storm surge polders.

For river flood affected polders, we have assumed different parameters of damages for different sectors. Those parameters were arrived at after extensive consultation with the relevant experts, and after taking into account the uniqueness of the flooding mechanism in the coastal polders. We extrapolated the average percentage of damages and losses of polder nos. 32, 33, and 35/3 for different major economic sectors to arrive at figures for the remaining flood affected polders.

Expected changes in the Bangladesh economy, including growth in population and income, and structural shifts in the economy, are applied uniformly to assess the expected assets and activities for seventeen polders over the next thirty years. The current spatial distribution of assets and activities provides the starting point for identifying the assets and activities that will be exposed to inundation risks for the next thirty years. The avoided damages/benefits identified and assessed are:

- Avoidance of Storm Surge/Flood to Crop Damage,
- Estimation of Water Logging damage to Agricultural Output
- Livestock Benefit,
- Fishery Benefit,
- Afforestation Benefit
- Housing Damage(Property) Benefit
- Road Damage Benefit
- Human lives Benefit and
- Commercial Benefit
- Avoidance of Storm Surge/Flood to Crop Damage

Crop losses resulting from a cyclone are determined in detail for all major crops both under storm surge and flood conditions. By 2042-43, the agriculture sector is expected to grow at an annual average growth rate of 2.4 percent, largely through increases in yields (Yu et al. 2010). As a result, by 2042-43, yields for Aman, Aus, Boro and other crops are expected to rise. The net estimated financial values of avoided agricultural damages and loss through implementation of CEIP-1 works out to be about BDT 1095.46 million or US$ 13.36 million annually and given in Table-9. The net estimated economic values of avoided agricultural damages and loss through implementation of CEIP-1 work out to be about BDT 1075.10 million or US$ million annually.

The total incremental benefits are shown in Table ES-8

Table ES-8 Total Incremental Benefits (BDT Millions)

Project Benefits	Items	P-32		P-33		P-35/1		P-35/3		8 Storm Surge Polders		5 Flood Affected Polders		Total	
		Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.
Total Avoided damage	Value of Life lost	-	-	-	-	2,952	2,663	-	-	1,320	1,191	-	-	4,272	3,854
	Property Damage	215	194	216	195	584	527	102	92	1,590	1,434	798	720	3,504	3,161
	Road Damage	428	386	967	873	206	186	898	810	1,419	1,280	2,246	2,026	6,164	5,560
	Crop Damage*	78	79	60	60	219	212	60	60	488	474	190	191	1,095	1,075
	Livestock	2	2	3	3	76	68	7	6	129	116	7	7	223	201
	Fisheries	14	13	36	32	148	134	307	277	864	779	219	198	1,589	1,433
	Non-gricultural Productive Sectors**	29	27	51	46	165	149	54	49	229	208	136	124	664	602
	Total Annual avoided damage	**766**	**699**	**1,333**	**1,208**	**4,350**	**3,939**	**1,427**	**1,293**	**6,039**	**5,483**	**3,598**	**3,265**	**17,512**	**15,886**
Annual Benefit	Annual Expected value of damage	108	98	187	170	580	525	201	182	805	731	506	459	2,386	2,165
	ESS & FS	3	3	3	3	1	1	2	1	10	9	6	6	25	23
	Water logging	148	117	163	152	235	205	117	97	964	934	959	924	2,586	2,429
	Total Direct Benefits	**259**	**218**	**353**	**324**	**816**	**731**	**319**	**280**	**1,779**	**1,674**	**1,471**	**1,389**	**4,997**	**4,617**

Cost Benefit Analysis

To test the viability of the project, the Economic Internal Rate of Return (EIRR) and Financial Internal Rate of Return (FIRR) have been calculated based on a comparison of incremental cost and benefit streams. A time horizon of 30 years has been used for evaluating the project from the end of the project's construction period. Project implementation period has been assumed as three years, considering availability of BWDB fund and timely land acquisition, if any. In other words accruing of project full benefits are assumed to be achieved from the fourth year of project life i.e. after completion of the investment program. Individual components of the project may have a lifetime lower or higher than the analytical life assumed for the project. The sunk costs have not been considered for economic analysis. The B/C ratios and the Internal Rate of Return for the proposed investment on retired embankments, re-sectioning of embankments, drainage structures, drainage channels, protective works, afforestation and environmental mitigation for all seventeen polders is given in Table ES-9.

Table ES-9: IRR, NPV and B-C Ratio

Particulars	Criteria	IRR (%)		NPV (BDT Million)		B/C Ratio	
		FIRR	EIRR	Fin.	Eco.	Fin.	Eco.
Polder no.32	Base case	17.57%	19.51%	1191.5	1258.4	1.71	2.01
Polder no. 33	Base case	19.00%	21.95%	1892.7	2109.4	1.91	2.37
Polder no.35/3	Base case	25.50%	28.32	2555	2457.8	3.01	3.6
Polder no.35/1	Base case	17.47%	20.48%	2343.4	2823.2	1.55	1.9
Eight Storm Surge Polders	Base case	14.73%	17.85%	3352.7	5648.4	1.28	1.66
Five Flood Affected Polders	Base case	29.50%	34.59%	10257.3	10359.5	3.55	4.51

Sensitivity Tests and Switching Values

ES-10 Example of Sensitivity Test for Polder 32

Particulars	EIRR	NPV (BDT Million)	FNPV in Million US$	Sensitivity Indicator(SI)	Switching Values(SV) %
Base Case	19.51%	1258.39	15.35	-	-
Case 1: Main investment +20%	17.43%	1022.70	12.47	1.76	56.88
Case 2: Main O%M +20%	19.20%	1197.25	14.6	3.03	33
Case 1+Case 2	17.23%	985.64	12.02	1.85	54.08
Case 3: Life Protection -20%	19.44%	1234.31	15.05	5.39	18.56
Case 4: Property Protection -20%	18.90%	1119.38	13.65	3.53	28.34
Case 3+Case 4	18.90%	1119.38	13.65	3.53	28.34
Case 1+Case 2+Case 3+Case 4	16.72%	870.71	10.62	2.15	46.48
Case 5: Agriculture Benefit -20%	19.28%	1202.32	14.66	3.75	26.7
Case 6: Livestock Benefit -20%	19.44%	1233.68	15.04	5.28	18.95
Case 5+Case 6	19.28%	1201.69	14.65	3.73	26.78
Case 7: Fish -20%+ Case 6	19.25%	1195.49	14.58	3.67	27.24
Case 8: Water Logging -20%	18.54%	1081.57	13.19	2.82	35.52
Case 8: Case 1 through 8	14.79%	491.95	6.00	2.51	39.77

The detailed sensitivity tests for each polder or group of polders are shown in Volume VI of this report. Table ES-10 is an example of this. The sensitivity of EIRR to the 8 cases considered is compared in Table ES-11 for all polders and groups of polders.

Table ES-11 Sensitivity of EIRR

Particulars	Polder 32 EIRR	Polder 33 EIRR	Polder 35/1 EIRR	Polder 35/3 EIRR	Group 1 EIRR	Group 2 EIRR
Base Case	19.51%	21.95%	20.48%	28.32%	17.85%	34.59%
Case 1: Main investment +20%	17.43%	19.59%	17.76%	25.29%	15.70%	30.87%
Case 2: Main O%M +20%	19.20%	21.55%	19.92%	27.97%	17.47%	34.23%
Case 1+Case 2	17.23%	19.34%	17.49%	25.10%	15.45%	30.62%
Case 3: Life Protection -20%	19.44%	21.84%	18.70%	28.20%	17.53%	34.53%
Case 4: Property Protection -20%	18.90%	21.49%	19.76%	27.98%	17.29%	34.03%
Case 3+Case 4	18.90%	21.49%	18.20%	27.98%	17.05%	34.03%
Case 1+Case 2+Case 3+Case 4	16.72%	19.02%	15.67%	24.90%	14.81%	30.16%
Case 5: Agriculture Benefit -20%	19.28%	21.74%	20.08%	28.07%	17.64%	34.41%
Case 6: Livestock Benefit -20%	19.44%	21.83%	20.19%	28.19%	17.73%	34.53%
Case 5+Case 6	19.28%	21.74%	20.03%	28.06%	17.61%	34.41%
Case 7: Fish -20%+ Case 6	19.25%	21.68%	19.93%	27.42%	17.38%	34.28%
Case 8: Water Logging -20%	18.54%	20.91%	19.49%	27.35%	16.55%	32.03%
Case 8: Case 1 through 8	14.79%	16.62%	14.51%	21.74%	12.93%	26.39%

ES-11 Project Implementation

This report documents the Feasibility Study of 17 Polders included in CEIP-1. However, there has been another component of CEIP-1 running in parallel which addresses the detailed design of 5 of these 17 polders up to and including the following:

- *Preparation of detailed designs and bidding documents for the first contract covering works of about US$50-75 million in value, preparation of the corresponding full resettlement action plan (RAP) and environmental management plan (EMP)for these works along with cost estimates, and institutional and implementation arrangements;*
- *Support in procurement of works, bidding procedures, pre-qualification of and constructors if necessary evaluation of tender and preparation of the bid evaluation report;*

The above activities are nearly complete and will be reported through another series of reports submitted under the title **"Detailed Designs for 5 Polders".** The RAP and EMP will be included in this series of reports. Five Environmental Impact Assessments have also been carried out in order to obtain environmental clearance from the department of the environment.

The implementation of the construction phase was to be awarded as single contract package. Any difficulties arising out of the fat that the 5 polders fall within the jurisdictions of three Executive Engineers working under two Superintending Engineers was to be overcome by bringing all 5 polders under the direct control of the Project Director and his staff.

The implementation milestones are shown in Table ES-12.

Table ES-12 Project Implementation Sequence

	Milestone	Probable Date
1	Appraisal of the Feasibility Study Report by the Pre-Appraisal Mission of World Bank.	03 Oct 2012
2	Approval of the Feasibility Report by the competent authority of BWDB.	13 Nov 2012
3	Commncement of Land Acquisition process	15 Nov 2013
4	Preparation of Draft Development Project Proposal (DPP) by the Project Director, CEIP	01 Jan 2013
5	Review & Recommendation of the Draft DPP by BWDB & sending to the MOWR.	12 Mar 2013
6	Review & Recommendation of the Draft DPP by the Rationalization Committee in the Ministry of Water Resources (MOWR)	27 Mar 2013
7	DPP Sending to Planning Commission	10 Apr 2013
8	Review & Recommendation of the Draft DPP in the Pre-Pre-ECNEC meeting in the Planning Commission & sending to the Pre-ECNEC meeting.	15 May 2013
9	Review & Recommendation of the Draft DPP by the Pre-ECNEC & sending to the ECNEC	30 May 2013
10	Approval of the Draft DPP by ECNEC.	15 June 2013
11	Preparation and approval of estimate of the physical works by the competent authority of BWDB,	15 July 2013
12	Finalisation of Bidding Documents	31 July 2013
13	Pre- qualification of contractor by the competent authority of BWDB.	20 Sep 2013
14	Floating of Tender among the pre-qualified contractors.	25 Sep 2013
15	Pre-bid meeting	25 Oct 2013
16	Receive Tenders	15 Nov 2013
17	Evaluation of Tender by the standing Evaluation Committee,	05 Dec 2013
18	Approval of contract by Cabinet Committee for Govt. Purchase (CEGP)	31 Dec 2013
19	Award of contract,	07 Jan 2014
20	Signing of Contract	15 Jan 2014
21	Commencement of Implementation of physical works.	21 Jan 2014
22	Completion of Contract	20 Jan 2018
23	Defect Liabilities & Finalization of Reimbursement Claims etc.	19 Jan 2019

ES-12 Conclusions and Recommendations

Feasibility of CEIP-1

This report documents the Feasibility Study of 17 Polders included in CEIP-1. The study concludes that proposed project to improve 17 polders is technically, financially and economically feasible. However, it should be re-iterated that the performance levels anticipated in the economic analyses will be reached if a proper institutional arrangement is put in place with the agreement of all stakeholder groups.

The implementation of the construction phase is to be awarded as single contract package with the expectation of bringing in an experienced and reputed International Contractor. Any difficulties arising out of the fact that the 5 polders fall within the jurisdictions of three Executive Engineers working, under two Superintending Engineers, is to be overcome by bringing all 5 polders under the direct control of the Project Director and his staff.

Conclusions & Recommendations

- The project has developed a viable methodology for designing polder improvements to protect the polders from storm surges and to correct drainage problems within polders. The designs proposed by the project are tailored not only for the present conditions but also to cater to future climate change scenarios.
- The project has identified some areas of uncertainty that could be removed before the next phases of CEIP are put into action.
- The project has identified the need to monitor land subsidence at selected stations all over the coastal zone.
- The first phase (Assignment A) was to serve as a pilot programme to show the way for future stages
- The project has emphasised the need for quality control in all construction activities and most importantly in the resistance of embankments to overtopping erosion and the need for excellent mechanical compaction.
- The project recognised that even the best and most effective physical interventions cannot be sustained without a viable plan for maintenance a sound institutional arrangement for efficient operation of the system without conflict between users.
- Conflicts among fisheries, agriculture and other users of the available land must be resolved in the management of water within each polder.
- Sustainable longer term operations and maintenance of the facilities provided by the project should be ensured with a suitable institutional/consultative arrangement.
- Replacement of the existing sluices constructed in 1960-1970 is essential providing long lasting structures compatible with project objective keeping provision for flushing cum-drainage.
- Strong design with high quality construction materials are to be used for all construction works.
- Damaged structures are to be re-constructed and where needed new structures to be constructed. New structures should be constructed to facilitate drainage in the rainy season and control fresh water in winter season so that farmers can save T. Aman crops from water logging and cultivate winter crops.
- Drainage / Irrigation channels should be re-excavated and new drainage channels may be excavated as per demand of the local people to provide storage of sufficient water for winter irrigation.
- Arrangements are to be made with the beneficiaries (through formation of WMOs) to control and facilitate smooth operation of structures as necessary.
- It should also be confirmed that the Gher owners cannot cut the embankment to take in saline water in to the polders for culture of shrimp under any circumstance.
- DAE may be involved for advising the farmers for better crops production activities and switching over to high value crops resulting economic benefit of the farmers.

Recommendations for Follow up Action for Future CEIP use

The following actions are recommended as necessary to ensure better quality designs and elimination of uncertainties for improving future CEIP designs:

- Set up a GPS based land subsidence monitoring programme as a continued long term programme to support all planning and design activities in the coastal zone, including Clime Change Adaptation. The project could be appended to the present GPS monitoring programme of the Dhaka University Earth Observatory (DUEO) and coordinated by a Steering Committee with representatives from SoB, BIWTA, Bangladesh Geological Survey, BWDB, IWM and CEGIS
- Set up a Wave Flume Testing Facility in River Research Institute in Faridpur and train engineers and laboratory staff to carry out flume tests, data processing and analysis initially for servicing CEIP needs.
- Set up a directional wave measurement and recording programme at two or three carefully selected location offshore in the Bay of Bengal within the control of an organisation (such as Chittagong Ports Authority) with the marine deployment and recovery capabilities. The ownership of the data to be shared between CPA, BWDB and RRI who will maintain separate databases.

1.0 INTRODUCTION

1.1 Background

The coastal zone in southern Bangladesh adjoining the Bay of Bengal is characterized by a delicately balanced natural morphology of an evolving flat Delta subject to very high tides and frequent cyclones coming in from the Bay of Bengal encountering very large sediment inflows from upstream. The strength of the tides and the flatness of the delta causes the tides to influence river processes a long way upstream in the southern estuaries. This entire area is called the coastal zone (see Figure 1.1). The coastal zone, in its natural state, used to be subject to inundation by high tides, salinity intrusion, cyclonic storms and associated tidal surges etc.

The Government decided to construct polders surrounded by embankments along the entire coastal belt to protect the people and agriculture of the coastal zone and crops from tidal inundation and saline water intrusion and release a large extent of land for permanent agriculture. In this regard the first major project taken up was the Coastal Embankment Project (CEP) implemented during the 1960's& the early 1970's; a few more polders have been added to this in recent decades.

Major tropical cyclonic disasters in 1970 and 1991 were estimated to have killed an estimated 500,000and 140,000 people respectively. The severe cyclone which occurred in November 1970 was followed by one in May 1985, one in November 1988, one in April 1991 one in May 1997, the severe cyclone SIDR in November, 2007 and lastly the cyclone AILA in May, 2009.

After cyclones SIDR and AILA struck the coastal zone causing severe damage to the infrastructure, life and property, the Government of Bangladesh (GOB) obtained an IDA/credit for Emergency Cyclone Recovery and Restoration Project (ECRRP), 2007 and proceeds from this credit would be used to meet the expenses for the proposed Coastal Embankment Improvement Project Phase-1 (CEIP–1).

1.2 Overall Objectives

The main objective of the consultancy services is to support Bangladesh Water Development Board (BWDB) in preparation of comprehensive Coastal Embankment Improvement programme (CEIP) and implementation of first program project CEIP-1 to be carried out in two steps as follows:-

- Prepare a long term phased programme for the rehabilitation of the embankment system where the polders are selected for each phase according to agreed criteria. Detailed feasibility study for the polders selected in the first phase according to the international standard which will form the basis for project appraisal by the World Bank and Government of Bangladesh at the end of the first assignment (Assignment-A). This will also cover detailed design and preparation of tender documents and implementation schedule for the first batch of polders selected from within the first assignment.
- Contingent upon the satisfactory outcome of the first assignment and availability of funds for the implementation of project (CEIP-1), this consultant would be responsible to continue for detailed design and supervision of the CEIP-1 works as second Assignment (Assignment-B) that would be implemented through International Contracting practice.

Figure 1.1 The Topography of Bangladesh

1.3 Specific Objectives of Assignment A

The CEIP-1 Assignment A comes in three important phases. They are

- The first stage involves the development of a Strategic Plan for implementing CEIP. This requires a strategic examination of the coastal embankment system to determine priority investments based on risks and vulnerability assessment in light of technical, economic, social and environmental considerations. The work involves the updating of the environmental baseline and carrying out a Strategic Environmental Assessment and using extensive modelling to determine present and future storm surge levels affecting embankment stability over a period of 20-25 years. The future scenarios would include probable climate change effects. This part of the study will establish the framework for the future phased development of the Coastal Embankment System.

  Although the original concept was that the first group of polders for feasibility study was to be selected based on this assessment, circumstances arose that made it necessary to proceed with that selection of 17 polders independently in order to keep the project on its time line. However, the Strategic Master Plan would nevertheless have to be prepared for future phases of the project.

- The second stage involves more detailed studies leading to Feasibility Study Report for improving the first group of 17 priority polders selected for improvement in CEIP-1. This work is based on the review of existing studies and reports, detailed topographical, environmental and sociological surveys in the field and detailed hydraulic modelling. The design proposals will be subjected to detailed consultation with stakeholders and economic analyses before they are finalised. Although common approach will be used in carrying out the studies, it is important to treat each polder as a separate entity having its own problems that require solutions individually tailored to its needs. The interventions proposed for polder will be subjected to an initial environmental examination (IEE). It is essential that the feasibility of the interventions proposed for each polder is established before proceeding with implementation.

- The final stage is for carrying out the detailed design for five polders selected from among the 17 priority polders from Stage 2. Design drawings and tender documents will be prepared. Tenders will be called and evaluated. Award of contracts, contract administration and construction supervision will be carried out as a part of Assignment B. A Resettlement Action Plan and An Environmental Impact Assessment would also be prepared.

  There are other tasks described in detail in Chapter 3 and the Terms of Reference (Volume X of this report).The actual tasks being undertaken are described in the following chapters.

1.4 Contents of this report

This report contains the results of the Feasibility Study of 17 Polders under CEIP-1. This the Draft Final Report mentioned in the Terms of Reference. All studies that are relevant to the whole coastal zone (Strategic Plan) and to all 17 polders selected to study are reported in the nine volumes of this report. However, the detailed description of the studies leading to detailed design of 5 selected polders and related environmental assessments and re-settlement plans are given is a separate family of reports termed “Detailed Design of Five Polders” published in parallel with this report.

The Draft Final Report comprises Volume I (Main Report) and eight other volumes. The Main Report comprises the 12 Chapters listed below:

1 Introduction
2 Project Background
3 Polder Assessment
4 Modelling for Design Parameters
5 Land Use Improvements in The Project Area
6 Sociological Impacts and Re-Settlement Issues
7 Environmental Impacts and Mitigation
8 Sedimentation and Morphology
9 Institutional Arrangements to Ensure Sustainability
10 Economic Analysis
11 Project Implementation
12 Conclusions and Recommendations

The other volumes are as follows:

Volume II: Strategic Plan for Coastal Embankment Improvement Programme

a) Strategic Environmental Assessment
b) Strategy for Coastal Embankment Improvement

Volume III: Modelling and Survey Report

a) Topgraphic and Bathymetric Surveys Of 17 Polders
b) Storm Surge and Wave Propagation Modelling
c) Polder Drainage Modelling

Volume IV: Polder Reports

Volume V: Land Use Reports

a) Agriculture
b) Fisheries
c) Livestock
d) Forestry

Volume VI: Economic And Financial Analyses

Volume VII: Feasibility Level Design Report (17 Polders)

Volume VIII: Social & Environmental Reports :

a) Social Impact Assessment

b) Social Manangement and Resettlement Policy Framework

c) Environmental Management Framework

Volume IX: Initial Environmental Examination Of 17 Polders:

Volume X: Sustainability Reports:

a) Operation and Maintenance

b) Institutional Matters

2.0 PROJECT BACKGROUND

2.1 Coastal Zone of Bangladesh, Geography and Climate

The topography of Bangladesh is dominated by the low lying delta created by three mighty rivers Ganges, Brahmaputra and Meghna which discharge into the Bay of Bengal through its territory, as already shown in Figure 1.1. The south east corner of the country lies outside this delta and the Chittagong Hill Tracts are the only real mountainous area within Bangladesh and this area drains thorough a narrow strip of land into the Bay of Bengal. The premier sea port of Chittagong lies on River Karnaphuli which passes through this strip of land.

The Bangladesh Delta is formed by the interaction of the very large summer discharges of both water and sediment from the Ganges, Brahmaputra (Jamuna) and Meghna Basins with the tides in the Bay of Bengal which could vary in range from 3m in the west to nearly 5m in the north-eastern corner of the Bay near Sandwip.

The climate of Bangladesh is semi-tropical and is dominated by the southwest monsoon which provides significant rainfall between the months of June and September. However, cyclonic storms, occasionally of severe intensity, can occur in the months of March-May and October-November, accompanied by storm surges, high winds and intense rainfall.

While the loss of life during these cyclones is being progressively reduced by means of improved storm warnings and continuing construction of cyclone shelters, the damages to property, livestock, crops and livelihoods continue to take their toll.

The Coastal Zone of Bangladesh has been defined as the area within which the rivers flows are influenced by the tide. Given the high tidal range and the very low river gradients, the tide reaches very far landwards, (see Figure 2.1) particularly in the dry season. If the upstream freshwater inflows are reduced in the dry season, salinity can also intrude very far upstream within the river system.

The same topographical reason that increases the range as the tide moves up the Bay also has the same effect on storm surge levels. In addition the very large estuaries in the west (Raimangal, Malancha, Pussur-Sibsa, Baleswar) that very long ago carried the main stem of the Ganges provide access for the tides and storm surges to travel far upstream into the south west region.

2.2 Coastal Embankment Project, its History and Development

The Coastal Embankment Project was initiated in the 1960s to reclaim or protect areas in the coastal zone that lay below the highest tide levels for periodic inundation by saline water. These lands in the level range 1 to 1.5 mPWD could be used for agriculture by providing drainage structures capable of evacuating excess water during low tide. This system worked well for many years and 1.2 million hectares are now under the protection of the coastal embankment system bringing immense benefits. Figure 2.2 shows the existing polders. The original CEP polders are shown in one colour and the subsequent additions in two different colours.

However, there have been unintended consequences of this project. The very act of preventing the high tides from spreading over the land and confining them within the river channels initially increased the tidal range by about 30 per cent (see DHI, 1992) which might have had an immediate beneficial impact on drainage.

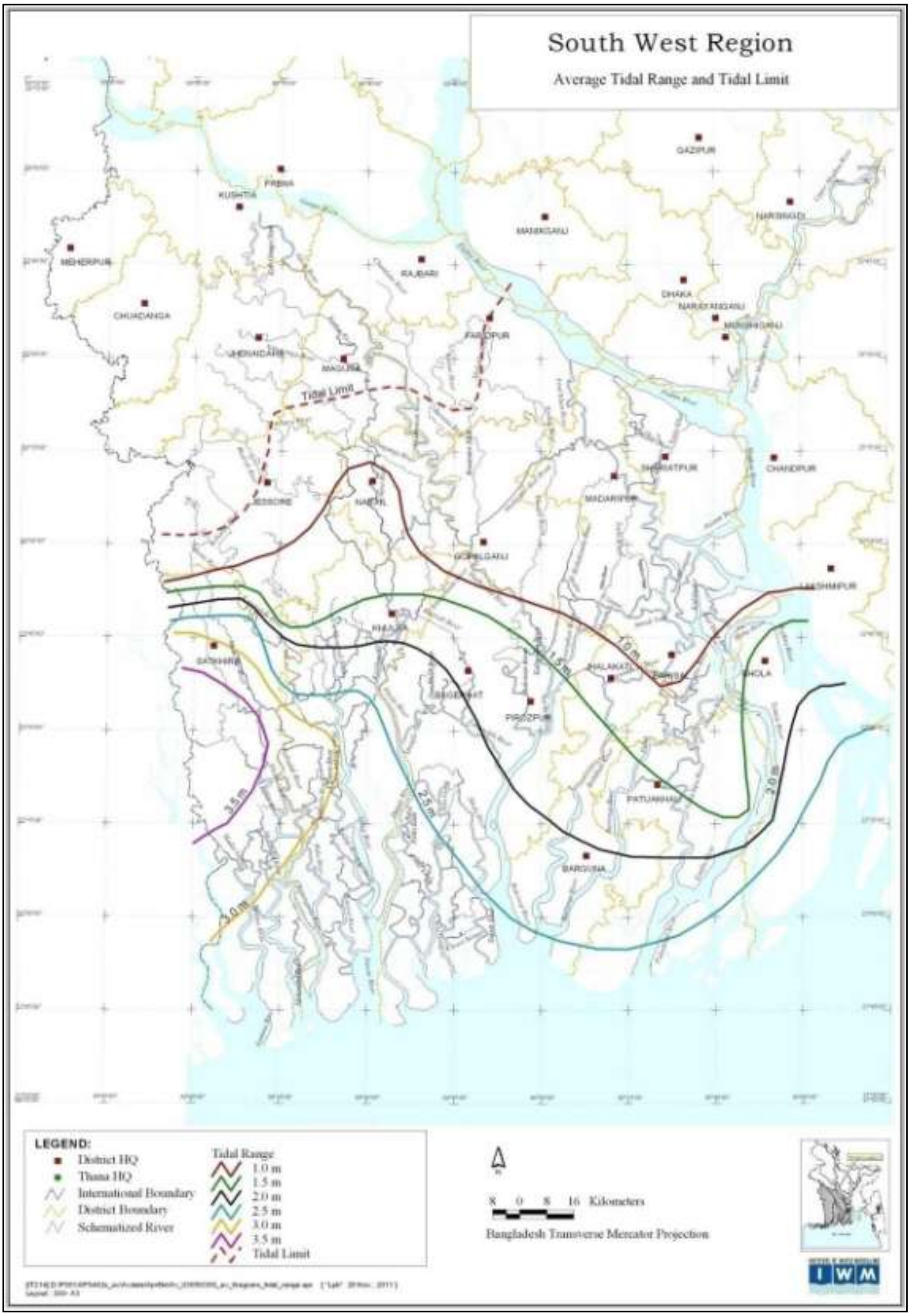


Figure 2.1 Tidal Propagation in Bangladesh

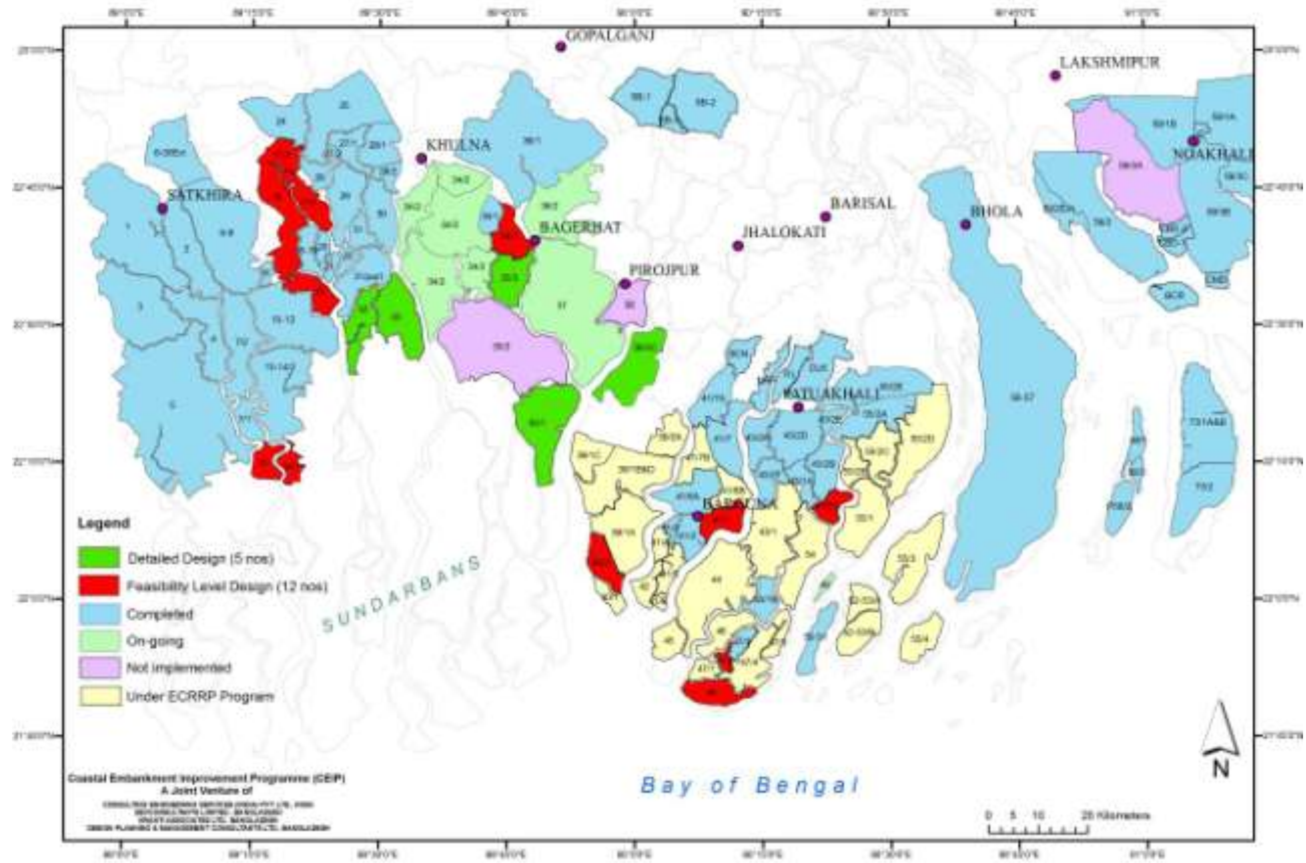


Figure 2.2 Polders Selected for the First Year of the Programme

However, the reduction of upstream and overbank storage also decreased the tidal cubature (i.e. the volume of water displaced during a tidal cycle). The reduction in cubature actually reduced the mean velocities in the river channels which in turn induced sedimentation or more correctly a reduction in cross sectional areas of the rivers of all types – the large rivers such as the Pussur which have sandy bottoms and clay/silt banks and the smaller rivers which have an excess of silt and clay. The consequent choking of smaller rivers resulted in drainage congestion within some internal polders (e.g., Beel Dakatia in Polder 25 which was an extreme example). This inherent consequence of polder construction has been amply demonstrated and cannot be ignored in any future development project.

The embankment system was designed originally to keep out the highest tides, without any consideration of possible storm surges. Recent cyclonic storm damages and the anticipation of worse future situations on account of climate change, has caused this strategy to be revised. Additional problems have also been identified – the direct impact of sea level rise on salinity intrusion into the coastal zone as well as on polder drainage.

2.3 Present Physical Threats to Infrastructure, Population and Livelihoods

The Coastal Zone of Bangladesh is low lying with natural land levels that are in the inter-tidal range. This land is subject to continuous and slow subsidence which, in its natural state, was more than countered by the accumulation of deltaic deposits (now 22 km deep in places) continuously brought down by massive sediment laden river flows. It is only logical that in a densely populated country such as Bangladesh, this newly created land will be colonised for human habitation wherever feasible.

This has happened with the Coastal Embankment Project and its subsequent extensions into newly accreted areas. The spreading of population into the more marginal lands has increased risk and/or increased the number of people at risk from natural hazards.

The principal coastal hazards in Bangladesh are known to be caused by the following phenomena - (i) cyclones and storm surges (ii) river bank erosion and vulnerability of islands and chars, (iii) sea level rise, iv) saline intrusion (vi) coastal erosion. These hazards are interconnected.

Climate change is responsible for sea level rise and the occurrence of more intense cyclones and increases several types of damage. Monsoon precipitation is also predicted to increase as a result of climate change. Overtopping of embankments, salination of lands by flooding are some of these impacts. Saline intrusion is exacerbated by rising sea levels as well as reduction of upstream fresh water flows. Sea level rise would cause long term bed level rise in all estuaries. These bed level rises would propagate upstream at a speed commensurate with the morphological time scale of each river.

Although tsunamis are a major risk factor in the southern part of the Bay of Bengal, particularly in the area adjacent to the tectonic subduction zone along the Sundar Trench, tsunami risk to Bangladesh is widely believed to be minimal. However, there is ample evidence that the major earthquake of 1746 triggered a tsunami and caused significant changes to the coast line of the Chittagong Coastal Plain.

2.4 The CEIP Initiative

Since 1960 to early 1970 to date, Bangladesh Water Development Board (BWDB) has constructed 139 polders in the coastal region. These polders have been planned and designed considering for protecting low lying coastal areas against tidal flooding and salinity intrusion and considering only the tidal effects but ignoring the effects of wind waves and cyclone storm surges.

For the past about 40 years, these polders have been playing a vital role in safeguarding the region, increasing agricultural production, improving livelihoods of the people, and mitigating environmental damages. However, the coastal polders are now vulnerable to storm surge, high tide, river flood, land erosion and drainage congestion and also climate change effect. In many polders the structures, as originally constructed, have not been found adequate to cater to multiple needs of local farmers. Changes in the land use have also created unforeseen water management needs requiring the structures to allow flow of water through the embankments both ways.

It is well recognized that infrastructural interventions in the coastal areas by embankments and Cyclone shelters have significantly reduced its vulnerability to natural disasters at least partially and thus the poor people have some assurance of safety to their lives ad crops. However, some effectiveness of the infrastructures in most cases has been compromised through poor and inadequate maintenance and sometimes by shifting the embankments towards country sides. With the occurrence of the frequent storms in the recent period the Coastal Embankment Systems (CES) has weakened and calls for systematic restoration and upgrading.

After the implementation of the second CERP project SIDR and AILA visited the coastal area causing severe damage to the infrastructures, lives and properties of the coastal belt. At this stage, the Government of Bangladesh (GOB) obtained an IDA/credit for Emergency

Cyclone Recovery and Restoration Project (ECRRP, 2007) and proceeds from this credit would be used to meet the expenses for the proposed Coastal Embankment Improvement Project, Phase-1 (CEIP-1).

It has been appreciated that undertaking the rehabilitation of coastal embankment system under one or two localized projects will not bring any convincing change in such a vast area. To resolve this multi-dimensional problem a strategicapproach in the name of Coastal Embankment Improvement Programme (CEIP) was felt necessary. It incorporates a longer term perspective in a programme spread over a period of 15-20 years, composed of at least 3-4 sub-phases

The deficiency in performance of the one will be removed from the next through an enrichment of knowledge and understanding the lacunae in design. The purpose of this project is to prepare the strategic plan for coastal embankment improvement program (CEIP) and for carrying out the detail feasibility study for the first program covered in CEIP-1 for reconstruction and upgrading of coastal embankments, at a cost of about US$ 300 million or 25 percent of the tentative estimated cost of rehabilitation of the whole project under CEIP. This will include detail design, preparation of tender documents and implementation program for rehabilitation of judiciously selected extremely vulnerable polders at a cost of US$50-75 million.

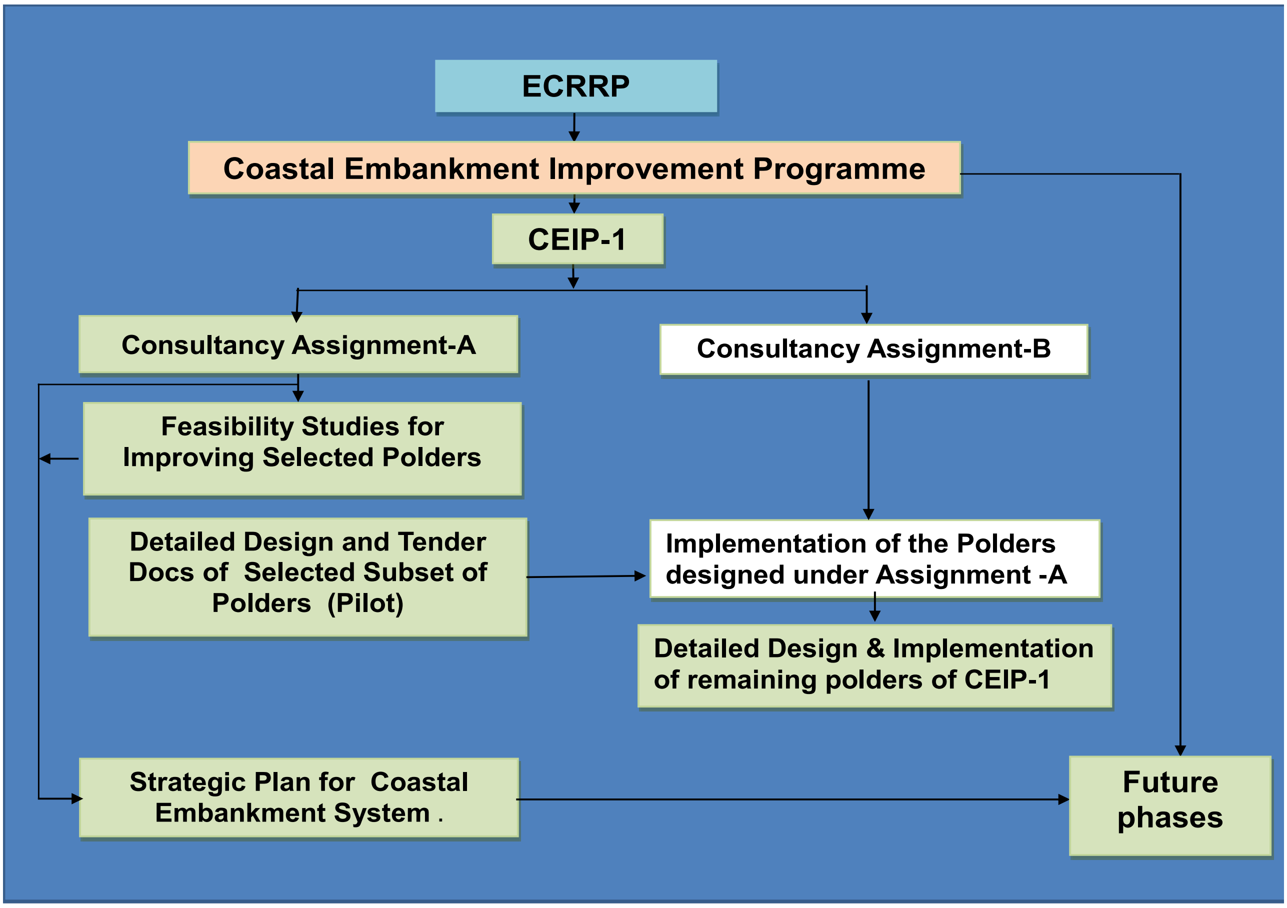


Figure 2.3 Project Structure

2.5 Project Strategy

Figure 2.3 shows how this projects fits into the Coastal Embankment Improvement Programme which arose from the Emergency Cyclone Recovery and Restoration Project (ECRRP) which was setup after Cyclone Sidr and its relevance was further emphasised by Cyclone Aila. The logical sequence set out for Assignment-A could not be followed because of difficulties encountered in carrying out the modelling work required to produce results needed for all three stages of the project. The delays that ensued made it necessary to use an alternative strategy for selecting the first set of priority polders for Feasibility Studies and the sub-set of that for Detailed Design before the formal Strategic Plan for the improving entire coastal embankment system. The selection of polders was carried out using a simplified multi-criteria analysis. This process was described in the Final Inception Report (2011).This report describes the Feasibility Study of 17 Selected Polders as well as the Strategic Plan. The Report on the detailed design of 5 polders selected from among these 17 polders *will be published as a separate set of reports*. The work on the Strategic Plan would continue in parallel with the feasibility study and will be published as a separate volume of this Final Report.

2.6 Other Previous Development Initiatives relevant to CEIP[2]

A number of initiatives were taken in the past for the safety of the coastal zone in respect of life and property, agriculture, fisheries and livestock. These are as follows:

1) *Coastal Embankment Project (CEP)*

The primary objective of the Coastal Embankment Project was to increase agricultural output by protecting the low-lying coastal lands from regular saline tidal flooding with a view to enhancing the extent of cultivated area as well as its productivity. This was accomplished by empoldering areas with peripheral dykes and the closure of some tidal creeks.

2) Land Reclamation Project (LRP)

The main objective of Land Reclamation Project (LRP) was based on the premise that social and economic benefits could accrue from the accretion of land in the delta area. Initially the focus was on surveys and trials to promote accretions, but later it shifted towards the consolidation of existing young land. Throughout much of the project period, the construction of embankments and settlement of newly accreted land in the southern portion of Noakhali district was developed in a multi-disciplinary way. In order to pursue the various kinds of activity more effectively, the project was split into two and after an interim period of several years, the Char Development and Settlement Project started in 1994 and the Meghna Estuary Study in 1995.

3) Cyclone Protection Project-1 (CPP-1)

After the severe cyclone of November1970, the Coastal Area Rehabilitation and Cyclone Protection Project was started. The project aimed in the first place at providing emergency relief. It included the following subprojects**:**

- establishment of meteorological Early Warning System (the loss of human life would have been lower in the 1970 cyclone if the surge had been predicted and the information relayed to the people);

[2] A more complete list of related projects and their descriptions may be found in the Final Inception Report (October 2011)

- a telecommunication subproject for use of warning and rescue operations following a cyclone;
- a cyclone shelter subproject including the construction of some 260 cyclone shelters in the coastal area;
- a primary road subproject linking some coastal area with the main road system by all-weather roads and
- a feeder roads subproject linking all cyclone shelters and port terminals with the main road system.

4) Cyclone Protection Project - II (CPP-II)

Following the cyclone of 1985, BWDB compiled a "long term plan for structural measures against cyclone surges," The plan consisted of two components**:**

- a Mid-Term Plan for the rehabilitation and strengthening of the existing coastal embankments.
- a Long Term Plan for extending the system of coastal embankment to cover also the newly accreted lands.

The plan aimed at project implementation over a total period of 5 years i.e. 1986-90 with the Mid Term Plan covering the first 3 years.

Apart from schemes for emergency repair of the more badly damaged areas, the various proposals resulted in a financial agreement in 1987 between GOB and the EEC. This resulted in the Cyclone Protection Project CPP-II, a feasibility and design study of protection measures against cyclone flooding, based on the BWDB Mid Term and Long Term Plan

5) Coastal Embankment Rehabilitation Project (CERP)

In April 1991, during the preparation of the feasibility and design study for CPP-II, a severe cyclonic storm hit the coast of Bangladesh. So, instead of the planned improvement conceived in CPP-II for the coastal embankment system, it became immediately necessary to rehabilitate the damaged embankments; and the Cyclone Protection Project–II was renamed the Coastal Embankment Rehabilitation Project (CERP).

6) Second Coastal Embankment Rehabilitation Project (2nd CERP)

Following the cyclone of May 1997, the damage to infrastructure was assessed and future problems that required attention. On this ground, the idea of a Second CERP was launched.

The major components of this project were proposed to be:

- rehabilitation and improved operation and maintenance (O&M) of the sea and estuary facing embankments by Bangladesh Water Development Board (BWDB), including embankment and foreshore afforestation;
- rehabilitation and improvement of medium size water sector infrastructure in coastal polders and management transfer to Local Government Institutions;
- rehabilitation and improvement of small water infrastructure in coastal polders (mainly drainage channels and regulators) and management transfer to Water Management Association (WMA);
- project management

7) The Meghna Estuary Study (MES)

The Meghna Estuary Study (MES)was started in 1994 and was created from the Land Reclamation Project that started in 1978. The objectives of this study were as follows:

- a Master Plan comprising a 25-year rolling programme for the development of the estuary;
- a Development Plan concentrating on the first five years and comprising feasibility studies for the first batch of projects and pre-feasibility studies for projects to be implemented in the second five-year period.

8) Char Development and Settlement Project (CDSP)

The Char Development and Settlement Project (CDSP), like MES, is another successor of the Land ReclamationProject. The main objectives of the project are as follows:

- to promote an institutional environment that sustains the proposed CDSP II interventions
- to accumulate and disseminate data and knowledge on coastal development
- to improve the economic and social situation of the people of the coastal chars in a sustainable way.

9) Khulna-Jessore Drainage Rehabilitation Project (KJDRP)

The Khulna - Jessore Drainage Rehabilitation Project is located in eight thanas in Khulna and Jessore districts. The main objective of the project is to improve agricultural production and reduce poverty in the area by removing drainage congestion. Polders established in the area in the 1960s restricted damage to agriculture from flooding and tidal inundation and produced benefits for a number of years. However, a long term effect of the embankments was to reduce the tidal volume and, accompanied by the reduction in the flow from upstream, this led to worsening drainage congestion in the area. This congestion resulted in the inundation of farm land and residential area, disruption to communications in the area and environmental degradation. Improving the drainage will overcome these problems. To achieve this objective, the project activities include the establishment of tidal basins, construction of regulators, rehabilitation of embankments and the dredging or re-excavation of rivers and khals.

10) Gorai River Restoration Project (GRRP)

The Gorai River is the main distributary from the Ganges into the south west region of the country. After the operation of the Farakka Barrage began in the late 1980s, the silting up of the off take and upper reaches of the river increased, hampering and eventually halting dry season flow in the river. After the signing of the Ganges Water Treaty with India in December 1996, measures to improve the flow into the Gorai during the dry season were initiated.

11) Integrated Coastal Zone Management (ICZM)

The objectives of the Integrated CoastalZone Management Programme aresummarised as follows:

- mitigate against and better manage natural disasters as a result of storm surges caused by cyclones (reducing the risk of loss of life and damage to property);

- improve the management of natural resources in the coastal zone and mitigate against the negative effects of human induced natural resources degradation, bio-diversity/habitat loss, climate change and environmental pollution;
- create opportunities for sustainable economic development.

12) Coastal Zone Water Management Programme

The purpose of this project is to prepare aCoastal Embankment Rehabilitation Project. The main objective of the project is to carry out of the feasibility studies detailed design and tender documents for a limited amount of rehabilitation.

13) Coastal Embankment Rehabilitation Project (Stage-II)

The Coastal Embankment Rehabilitation Project (Stage-II) is absolutely an implementation project. It includes the O&M of Coastal polders in respect of routine maintenance and periodic maintenance, embankment toe erosion, community organizing for improved O&M, embankment afforestation, foreshore afforestation etc.

14) Estuary Development Programme (EDP):

The main objective of the studies are as follows:

- Mitigation against and better management of natural disasters as a result of storm surges caused by cyclones. The specific aim is to reduce risk of loss of life and damage to property;
- Improved management of natural resources in the coastal zone and mitigation against the negative effects of human induced natural resources degradation, biodiversity/habited loss, climate change, environmental pollution; and
- Creation of opportunities for sustainable development.

15) *Integrated Planning for Sustainable Water Management (IPSWM) Programme.*

The main objectives of the programme are:

- To ensure **People's Participation at all stages** of the water resources infrastructure rehabilitation (selection, planning, implementation, operation & maintenance (O& M) and monitoring and evaluation (M & E).
- To establish **sustainable water management** in the selected sub projects with active participation of stakeholders and to develop and improve local people's traditional knowledge, skills and capacity in planning, implementing and managing their water resources and systems.
- To **transfer the management responsibilities** (full or partial) from BWDB to the people of the community through democratically established Water Management Organization (WMO)

A fuller description of a larger number of previous projects may be found in the Final Inception Report.

2.7 Current Development Initiatives relevant to CEIP[3]

There are four on-going projects sponsored by the BWDB, each at a different stage of completion that could affect some aspects of the outcome of the CEIP if they are implemented. They are

- Mathematical Modelling for Off-take Management of Gorai river
- Gorai River Restoration Project, Phase-II
- Ganges Barrage Project
- Feasibility Study of Capital Dredging and Sustainable River Management in Bangladesh

All these projects will affect only one aspect of the CEIP, viz. salinity intrusion. The first two projects aim to moderately increase dry season fresh water flows down the Gorai River by construction of carefully designed and managed diversion structures at its mouth. The third project is much more ambitious but more likely to succeed because it would divert a vastly increased volume of fresh water and at three diversion points (into Hisna, Gorai and Chandana rivers). The fourth project would help to kick-start all three projects by carrying out initial capital dredging. The Ganges Barrage Project is the least in need of capital dredging because it begins by raising the water level in the Ganges to a very high level in the dry season to the extent that a regulator has to be built at the mouth of the Gorai to prevent excessive diversion of water.

2.7.1 Parallel Projects in the Coastal Zone

Water Management Improvement Project (WMIP)

The main objectives of this project are:-

- To improve water resources management by rehabilitating damaged water related infrastructure, piloting the role of local communities and enhancing the institutional performance of the water management institutions particularly under BWDB and WARPO.
- To reduce vulnerability and enhanced livelihood opportunities for the beneficiaries and create a favourable environment for improved water resources management by the core water institutions, in partnership with the beneficiaries and to change a centralized top down approach to a more decentralized and participatory water sector management approach for efficient and sustainable operations and management of the existing Flood Control &Drainage (FCD) and Flood Control Drainage & Irrigation (FCDI) schemes.

In order to achieve the above objectives the project consists of 4(four) different components out of which component-4 (Rehabilitation Works including FDR 2007 and Cyclone "AILA" 2009 Damaged Infrastructure) has covered some polders taken up under CEIP-1. These are Polders 14/1, 35/1, 35/3 and 48. This matter has already been taken up with the Project Coordinator, CEIP study, who has taken initiative to harmonise the activities with CEIP designs.

[3]A more complete list of related projects and their descriptions may be found in the Final Inception Report (October 2011)

Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)

Cyclone Sidr which occurred on 15th of November 2007 inflicted severe damage to life and property in 30 Districts of Bangladesh. The worst affected districts were Patuakhali, Barguna and Pirojpur. Considering the need to support the restoration and recovery, the World Bank extended support to the Government of Bangladesh for the implementation of emergency 2007 Cyclone Recovery and Restoration Project (ECRRP). The project has covered 30 polders in the coastal zone among which Polder-39/2C was in the list. Later on, BWDB with the consent of World Bank has omitted this polder from the list of ECRRP project. It is now under CEIP study.

Emergency Rehabilitation Works of Cyclone AILA damages- SAIWRPMP-AILA.

AILA occurred on 25 May2009 affecting 47 polders in the Coastal Zone of which 43 polders were in Khulna, Bagerhat and Satkhira districts and 4 polders in Jessore and Gopalganj Districts. In order to rehabilitate the damaged embankments and other infrastructure of the affected polders the BWDB has taken up the Emergency Rehabilitation works of Cyclone AILA damages from the savings of the South-West Integrated Water Resources Planning and Management Project financed by ADB. Among others, the project has included Polder-34/3, 35/1, 35/3 in Bagerhat district, Polders 14/1 and 15 in Satkhira district and Polder17/1, 23, 32 and 33 under Khulna district, which have overlapped with CEIP-1. The matter has taken up with the Project Coordinator, CEIP study with the request to modify the designs to match the CEIP designs.

2.7.2 Impact of Ganges Barrage Project on CEIP

From the point of view of CEIP the increased negative impact of saline intrusion due to sea level rise would be gradual and thus the larger improvement provided by the Ganges Barrage, which might take a long time to implement, would nevertheless be key to (partially) counteracting the effect of rising sea levels on salinity intrusion, not only downstream of the Gorai – even more importantly in the western sector in the Mathabhanga-Kobadak system, which the other interventions do not deal with the large number of restoration projects undertaken after Cyclones Sidr and Aila are presently under implementation.

2.8 Establishing a Verifiable Level Datum for the Project

2.8.1 Mean Sea Level and the Old PWD Datum:

The National Mean Sea Level datum used by the Survey of Bangladesh (and Survey of Pakistan before 1971, and Survey of India before that) was based on a Mean Sea Level established in India and transferred along several long lines of levels respectively to the North West, South West and South Central Regions, to the Dhaka Region and to the South East. The Brahmaputra/Jamuna presented a great obstacle which could be circumvented by traversing through Assam. This created considerable uncertainty and sources of error which were confirmed in the 1990’s during the Flood Action Plan.

The PWD datum which has been used to set out all structures constructed by BWDB (and by EPWAPDA before) was assumed to be related to the SoB MSL datum by a fixed level difference which set the PWD datum 0.46m below the accepted MSL datum. Many, if not most of the network of TBMs established showing mPWD levels all over Bangladesh were surveyed from the nearest permanent SoB pillar and assigned a PWD level accordingly. It is also thought that BWDB Hydrology pillars are also related to the SoB (we will call these Old SoB pillar levels)

Bangladesh established its own 'First Order Levelling Network' during 1991-1995 under a grant aided project. During that period Survey of Bangladesh established a 'Tidal Observatory' at Rangadia, Chittagong, a 'National Vertical Datum' at Gulshan, Dhaka, 465 benchmarks on about 2386 km length of first order levelling route covering 70% area of the country excluding coastal and hill tract districts.

This new Levelling Network is now well established and (New) SoB pillars (ie pillars depicting the revised MSL levels) are available for use throughout the Coastal Zone except at Hiron Point. All the Old SoB pillars were re-surveyed by SoB and it was found that there were errors of up to 50cm or more between the new MSL and the old MSL in the Coastal Zone – but that in other places (in the North West) the error was much smaller. Whether the error was due to the length of the original levelling lines or due to subsidence is not established. The reasonable assumption is that the error was due more to subsidence of the Coastal SoB pillars.

What was made clear to us during out discussions with SoB officials was that we cannot convert new SoB to old SoB everywhere using a constant difference. Therefore, we cannot recover the old PWD level of a structure or a PWD pillar because the conversion factor varies from place to place – due to land subsidence and possible errors in the original levelling network which brought thousands of kilometres from MSL determined in Visakhapatnam in India.

2.8.2 CEIP Level Datum

For these reasons all the surveys for CEIP was based on the New SoB network. As it was customary to express levels in mPWD – the project expressed every level in "mPWD" obtained by adding 0.46m to the level measured above the New MSL datum. It is important to note that this mPWD has no relation to the old PWD datum which does not exist anymore.

All levels used by the CEIP are given in this datum (called "new PWD" internally for convenience). This includes

a) All embankment surveys

b) All cross sectional survey of drainage khals

c) Surveys of existing structures

d) All designs made and documented by the project

The water levels used in the IWM models were also converted to this same datum:

a) Bay of Bengal Model southern boundary uses a global tidal model which is expressed in height above the true mean sea levels. The model datum was converted to new PWD. This model therefore needed no adjustment.

b) The South West Region Model uses Hiron Point as main boundary, where the datum has been corrected over the years to conform to old PWD which matched the BWDB Hydrology Network used to calibrate the model. This needed correction. The correction was made by adjusting the datum value until the model matched water levels recorded at several calibration points (such a Mongla Port) – after conversion to new PWD - because new SoB bench marks were available at these points. A 50 cm correction at Hiron Point and similar corrections at other downstream boundaries was sufficient to obtain a working model which could be used for modelling polder drainage consistently. Figure 2.4 shows the relationship between the old datum and the new datum at Hiron Point.

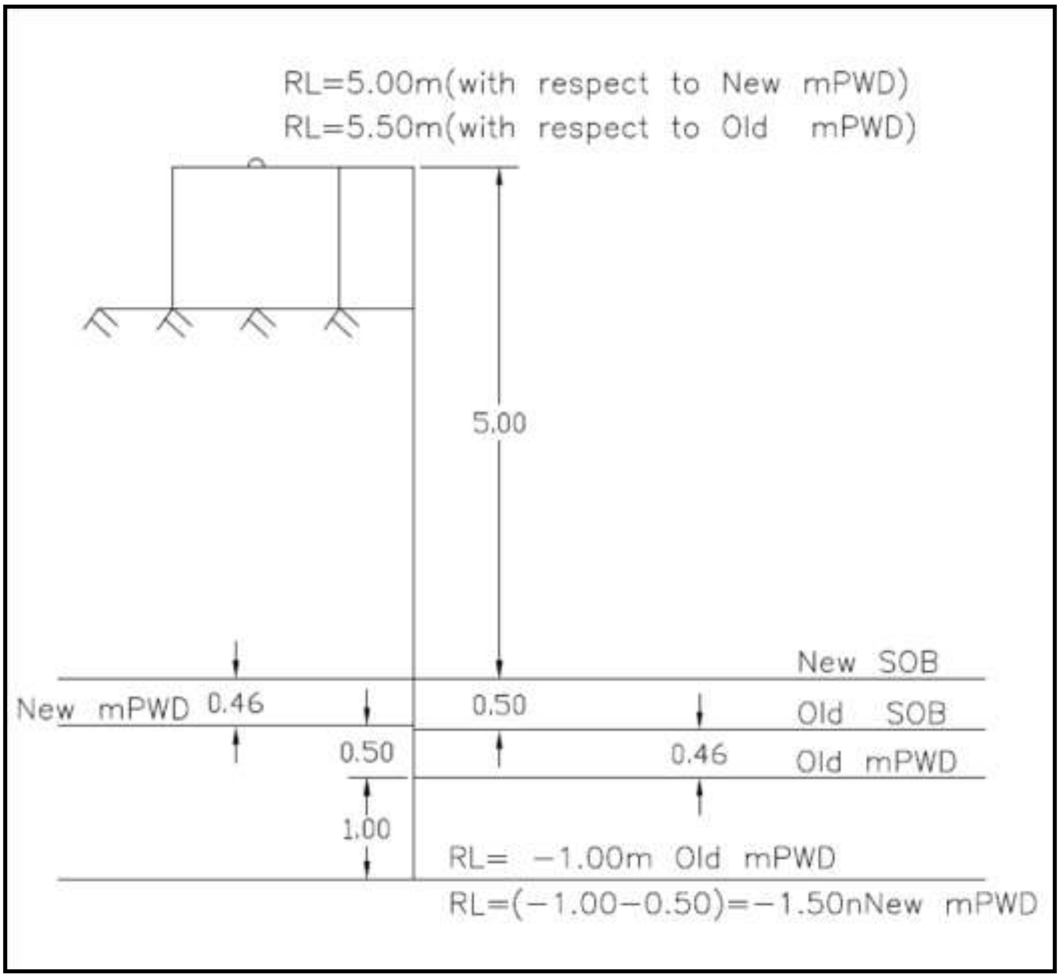


Figure 2.4 Datum Correction at Hiron Point

It should be noted that the relationship between New PWD and Old PWD is not the same all over the project area.

2.9 Adoption of a Common Level Datum

Throughout the studies conducted for this project difficulties were encountered when interpreting the damage inflicted by Sidr and Aila with respect to water levels, existing embankment crest levels because of the lack of a reliable and universal level datum. Similar difficulties arose when comparing modelled storm surge levels (derived from a global tidal model related to the current true sea level) with levels observed in the field during the events, or deduced from damages and water marks left immediately afterwards.

The difficulties of reconciling levels measured from different bench mark pillars at different times over 60 years, each experiencing subsidence at a rate as yet not fully determined, required that a new approach was needed. Thus the “new PWD” datum based on the current Survey of Bangladesh MSL datum (offset by 0.46m) was used in all the following activities of CEIP.

a) Embankment Surveys (longitudinal crest elevation and cross sections)

b) Drainage Canal Surveys (channel cross sections and long sections)

c) Existing hydraulic structures on the embankments (dimensions and invert levels)

The surveys revealed many discrepancies between original design levels (in "Old PWD") and the actual measured levels due to several possible reasons.

1) Discrepancy between the original mean sea level and the updated uniform sea levels. This discrepancy is not uniform everywhere and this has been confirmed by SoB themselves.

2) Local settlement – due to foundation failures in some structures deficiencies or local failure of the embankment – or underground peat layers

3) General subsidence which would be nearly uniform over a single polder but subject to regional variation.

The invert levels of the drainage structures which were originally designed to be uniform in each polder showed a very wide range of divergence – in some instances more than 1 metre.

It should be kept in mind that the two datums Old PWD and New PWD cannot be compared because of the revision of the mean sea level by SoB. However, it is clear that the embankment crest which was once of uniform height is no longer so. The difficulties can be illustrated by Tables 2.1 and 2.2 shows the survey results for some existing crest levels and invert levels of structures.

Table 2.1 An example of crest levels in Polder 32

Chainage along embankment (km)	LDL design Level (Old mPWD)	Actual Crest Level Surveyed (new mPWD)	New CEIP Design Level (new mPWD)
0.00	4.27	3.26	5.00
0.50	4.27	3.67	5.00
1.00	4.27	3.10	5.00
1.50	4.27	3.01	5.00
2.00	4.27	3.43	5.00
2.50	4.27	4.28	5.00
3.00	4.27	4.49	5.00
3.50	4.27	4.23	5.00
4.00	4.27	3.87	5.00
4.50	4.27	3.41	5.00
5.00	4.27	3.68	5.00
5.50	4.27	3.20	5.00/4.50
6.00	4.27	3.31	4.50
6.50	4.27	3.56	4.50

What is apparent from Table 2.1 is that the existing embankment crest is of variable height. It would only be necessary to exceed the crest level at the lowest point to begin the entry of flood water. If the embankment at such a point is already weakened by human actions or due to natural causes – the possibility of failure and breaching is increased with disastrous consequences.

A similar variability may be found in the existing drainage structures. An example of some structures from Polder 35/1 is shown in Table 2.2. It is not clear whether this is due to foundation failure or local ground subsidence or both. It is also known that the original structures were all built to a uniform invert level of -0.6m Old PWD, which again is not comparable with the new PWD datum.

Table 2.2 An example of invert levels of existing structures in Polder 35/1

Structure ID	Structure type	Design invert level (old mPWD)	Surveyed level (new mPWD)	Proposed level (new mPWD)
DS-1	Drainage	-0.60	-0.79	-1.00
DS-2	Drainage	-0.60	-1.17	-1.00
DS-4	Drainage	-0.60	-1.45	-1.00
DS-7	Drainage	-0.60	-1.26	-1.00
DS-9	Drainage	-0.60	0.79	-1.00
DS-10	Drainage	-0.60	-0.96	-1.00
DS-11	Drainage	-0.60	-1.4	-1.00
DS-12	Drainage	-0.60	-1.36	-1.00

3.0 POLDER ASSESSMENT AND DEVELOPMENT PLANNING

3.1 Characteristics of the 17 Priority Polders

The drainage network and the embankments 17 polders were surveyed by IWM to map the drainage network and to record the detailed cross sections and long sections the embankment and the drainage canals sections. As mentioned earlier in section 2.xx all surveys have been connected to the National Means Sea Level grid established by the Survey of Bangladesh (SoB) in 2005.

Table 3.1 shows the main dimensions of the polders and their main features.

Table 3.1 Summary of Main Features

S/No.	Polder No.	Location Name of Thana	Gross Protected Area (ha)	Cultivable Land			Main Project Feature				* Polder Population
				Total (ha)	Crop (ha)	Shrimp (ha)	Length of Embk'ment (km)	Regulators (No)	Flushing Inlets (No)	Drainage Channel (km)	
1	32	Dacope	8,097	6,500	6,497	5,328	49.50	13	32	45.00	38,397
2	33	Dacope	8,600	7,600	5,120	1,280	52.50	13	17	100.00	62,305
3	35/1	Sharankhola	13,058	10,700	10,400	300	62.50	18	20	70.50	99,182
4	35/3	Bagerhat	6,790	5,090	5,090	-	40.00	4	11	75.00	31,075
5	39/2C	Bhandaria	10,748	8,500	3,800	-	61.50	13	12	57.23	84,853
6	14/1	Koyara	2,933	2,350	1,880	470	30.50	6	4	30.00	20,578
7	15	Shymnagar	3,441	2,925	900	2,025	30.28	5	8	40.00	31,788
8	16	Paikgacha, Tala	10,445	8,102	3,050	5,052	45.00	12	20	21.00	118,616
9	17/1	Dumuria	5,020	4,000	4,000	-	38.50	12	0	43.00	23,919
10	17/2	Dumuria	3,400	2,700	2,700	-	11.00	5	0	21.00	34,070
11	23	Paikgacha	5,910	4,872	1,048	3,824	37.00	11	25	36.00	23,888
12	34/3	Bagerhat	3,656	2,930	2,930	-	16.75	3	6	35.00	65,399
13	40/2	Pathargatha	4,453	3,300	3,300	-	35.58	12	14	50.00	41,317
14	41/1	Barguna Sadar	4,048	3,440	3,440	-	33.81	6	24	84.00	41,051
15	43/2C	Galachipa	2,753	2,000	2,000	-	25.70	6	18	26.00	14,851
16	47/2	Kalapara	2,065	1,850	1,850	-	17.55	4	6	30.00	5,411
17	48	Kalapara	5,400	3,715	3,715	-	37.88	8	4	45.00	26,260
			100,817	**80,574**	**61,720**	**18,279**	**625.55**	**151**	**221**	**809**	**762,960**

* Note: Population of each polder in 2011 was estimated from the population density in each union. Total population of each union in 2001 was projected to the year 2011 with growth rate of 2001 population census. Accordingly, the population density of each union was calculated . Then population for each union and part of different unions were calculated and total population in each polder has been obtained

Problems Faced in Polders

The 17 priority polders selected for Phase 1 development are all clustered in five districts Khulna, Bagerhat, Pirojpur, Barguna, Patuakhali and Satkhira mainly in the South West region. The polders are shown in Figure 3.1. Although they are clustered, they are spread over an area that has examples of almost every type of major physical problem that afflict the polder system. Some of the problems have been greatly exacerbated because of the lack of systematic repair and maintenance over 40-50 years of operation. These problem areas are briefly described below:

I) Drainage congestion within the polders due to siltation of peripheral rivers: This is a direct consequence of the impact of polder construction which has reduced the tidal exchange volumes by about 40 percent of the volume under natural tidal regime before polders were constructed. The consequence has been the reduction of water conveyance cross sections of all rivers – with disastrous consequences for the smaller rivers in the more remote polders far upstream. (e.g. Polders 17/1, 17/2, 16, 34/3 etc) Re-excavation has proved to be only a very temporary solution because it does not address the basic driving force viz., reduced tidal volumes. Construction of cross dams has had an even stronger but more local impact on this process.

m) Vulnerability to high water levels: All embankments except for those (for example 17/1, 17/2, 16, etc) distant from the Bay of Bengal are subject to overtopping by very high storm surges travelling up the river system. Further from the bay, the monsoon high water could even determine the embankment crest level.

n) Deteriorated condition of embankments: The resistance to high water levels has been impaired by the lowering of crest levels due to local settlement and general subsidence. Combined with the weakening of embankment due to poor maintenance and active interference for constructing unauthorised inlets has resulted in the frequent occurrence of failures and breaches, sometimes even before overtopping takes place. Although subsidence is a recognised process there are no formal

o) Poor condition of drainage structures: Many drainage structures are in poor physical and operational condition. The poor condition of the concrete structure with corroded reinforcements exposed to the elements in many places makes it necessary that they are replaced. There are many structures with damaged gates that are unable to keep out saline water. Some are left permanently open with gates missing. Some polders which were breached and flooded during Sidr and/or Aila – have remained flooded with saline water for several years because of the inability to evacuate the excess water through defective structures.

p) Sedimentation in drainage khals: The internal drainage system in negatively affected by the gradual silting up in the network of khals which serve both as the drainage network and as a set of irrigation ditches. Re-excavating these khals will not only serve to improve drainage and minimise water logging but also to increase the volume of fresh water that could be stored within the polder in the post monsoon period.

q) River Bank Erosion: The peripheral rivers around the polders are of all sizes – varying from mighty rivers like the Baleswar, Sibsa and Pussur to the smallest tidal creek. These larger rivers, though the flow is dominated by the tide, have a tendency toward a (relatively) small amount of lateral movement of their banks. These small movements could translate into a serious bank erosion problem, particularly on large rivers. Bank erosion is already threatening some embankments having already consumed the setback and berm. Protection works are necessary – if not the embankment has to be retired.

r) Wave erosion of embankment slopes: Erosive waves can be generated by high winds at high tide on embankments that face the sea or one of the large estuaries.

There are other social and environmental constraints that have to be kept in mind when trying to find solutions to the physical problems listed above:

s) Authorised and un-authorised settlements that might need to be disturbed to relocate embankments

t) Squatter families tend to be the most deprived segments of the population and re-settlement options are limited.

u) Conflicts among fisheries, agriculture and other users of the available land must be resolved in the management of water within the polder.

v) Sustainable longer term operations and maintenance of the facilities provided by the project should be ensured with a suitable institutional/consultative arrangement.

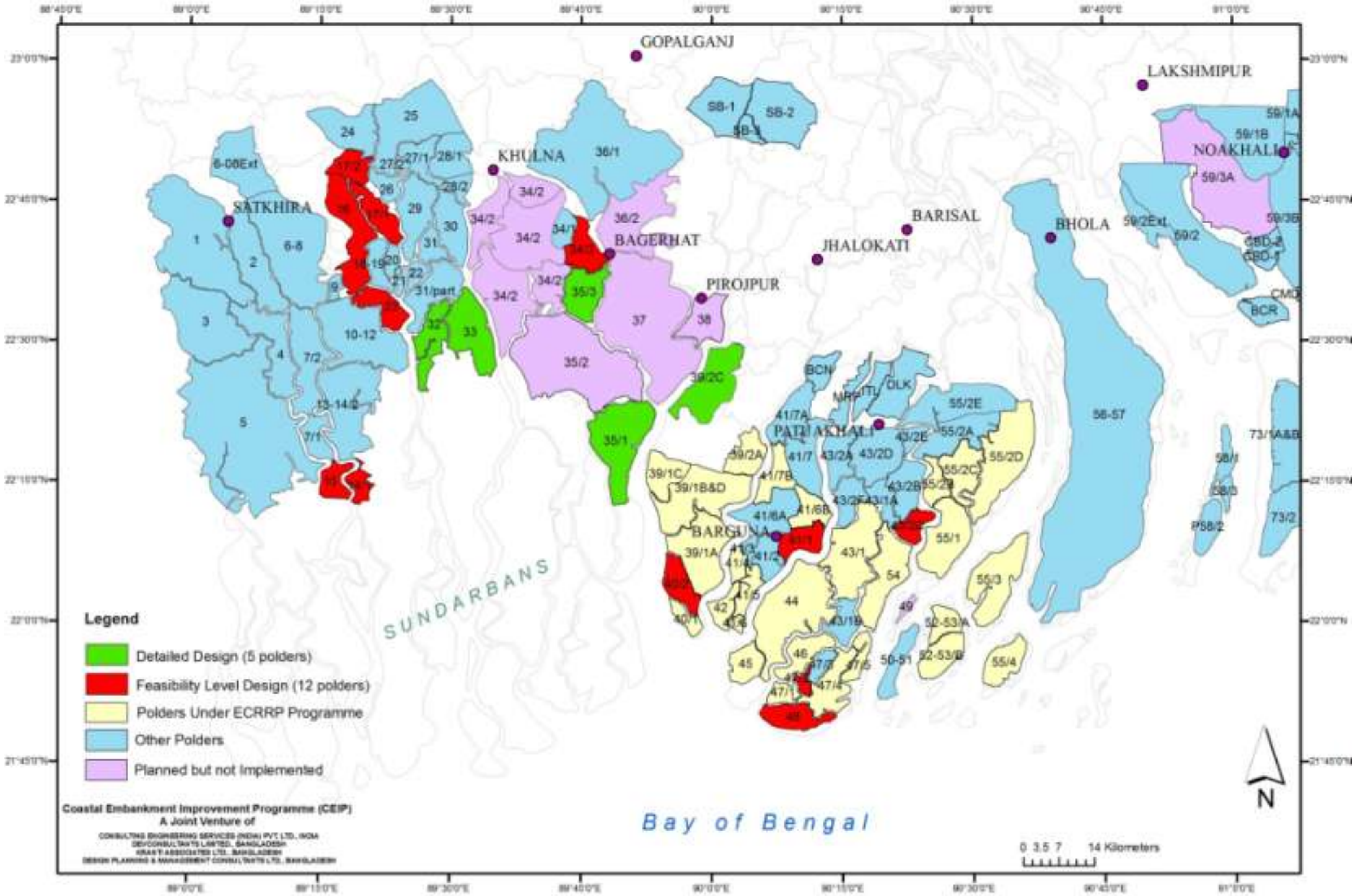


Figure 3.2: Selected Priority Polders

3.2 Initial Polder Assessment

3.2.1 Methodology

The basic data for each polder were gathered first from secondary sources including satellite images as well as specific surveys carried out by the project (see Chapter 5). The sociological surveys already carried out are reported in greater detail in Volume III of the Mid-Term Report (2011) and in Chapter 6. The physical features of each polder have been mapped and entered in the GIS. The agricultural and fisheries data have also been gathered for each polder (see Fisheries and Agriculture Reports).The rehabilitation/improvement plan for each polder begins with an assessment of the current state of the polder giving particular attention to the following:

- The physical condition of the embankment, whether the embankment is under attack by river erosion, wave action and threat or fact of overtopping by a previous storm surge.
- Drainage system and whether deficiencies are due to inadequate design, poor condition of structures etc. or whether the peripheral river receiving drainage water is blocked for any reason.
- Agriculture and fisheries activities and how these have been affected by recent events (such as Sidr and Aila)
- Population centres and settlements, livelihoods, socio-economic conditions and public infrastructure including cyclone shelters, poverty and landlessness.
- Impact of project activities such as moving and raising embankments on marginal populations including squatters.
- Environmental conditions, recent habitat changes, pollution, water logging etc., possible long term cumulative impacts.

A census and socioeconomic survey have been conducted in each of the 17 polders with structured questionnaires to determine their social and economic profile (see Chapter 6 and Volume VII). It was realised very early in the assessment that rehabilitation proposals will require that all or major parts of the embankment would have to be re-sectioned, retired or repositioned. This will inevitably require that many households and other entities living on or near the embankment be relocated temporarily or permanently leading to acquisition of land, displacement of households and loss of livelihood. The Social Impact Assessment and Social Management Resettlement Policy Framework has been developed to facilitate the planning process. The actual Resettlement Action Plan will be finalised only after the proposals are further refined during the Detailed Design Stage (see Chapter 11).

3.3 Planning and Finalising Physical Interventions

The proposed improvements were formulated so that the physical and operational conditions in the polder are made satisfactory under the present conditions *as well as under the future conditions*, taking into account climate change projections and changes brought about by other projects currently underway or being contemplated by the Government. The design parameters to be applied have been determined by using hydraulic models to simulate the present and future scenarios taking into account the impact of sea level rise and enhanced storm surge heights. The proposals are finalised only after they are tested against environmental and social impacts. Further fine tuning of the proposals is done only prior to carrying out the detailed design, in this case only in the 5 pre-selected polders.

The planning of physical interventions was based on the following:

- *Topographic and Hydrographic Survey*

The consultant engaged IWM to carry out the topographic and hydrographic surveys of all 17 polders. These surveys have ensured that there are up-to-date measurements of cross-sections and long-section of the embankment, and the layout and cross sections of the drainage network. An inventory of the drainage structures was also made together with levels and dimensions of structures in each of the polders. Bathymetric surveys conducted in the larger rivers were also available. It should be reiterated that the surveys were carried out according to the new (2005) Survey of Bangladesh levelling network. The structures being

- *Physical interventions*

The first set of design proposals were developed by synthesising all the different strands of data gathered and using the detailed surveys – guided by several additional field inspections by the designer. The consultants visited all the probable damaged/weak points in the embankments identified on the basis of the cross section surveys and inventory of the structures and physically identified the necessary interventions. Type of dykes with required specifications, nature of protection with appropriate location, length & location of retired[4] embankment, backing[5] of embankment towards the country side and exact location of afforestation have to be identified. The existing structures are also to be visited on the basis of the reports from IWM and tentative decisions taken for its repair, replacement and modification. In fact a vast majority of the structures were not considered to be in a good enough condition to be repaired. The Consultants' design team will interviewed local people and discussed with the field level engineers and obtained their views on the appropriate interventions necessary and their suggestions for appropriate rehabilitation of the polder.

The following guidelines were followed when making choices of interventions regarding embankments:

- Mechanical compaction has to be ensured for construction and reconstruction of embankment.
- Retirement of embankments will be discouraged as far as possible by putting protective works instead if necessary or *by providing alternate designs such as flood walls etc. only in sections that would cause serious hardship to settlers and excessive re-settlement costs.*
- Backing of embankments, where necessary, may be provided which should include slope protection as well as strong afforestation on the foreshore area.
- The height of embankment where needed should be increased in consultation with the local people.
- Replacement of the existing sluices constructed in 1960-1970 is essential providing long lasting structures compatible with project objective keeping provision for flushing cum-drainage.
- Strong design with high quality construction materials are to be used for all construction works.

[4]Retired embankment is a new embankment run along a new trace further inland from the old (possibly damaged) embankment. The alignment of this embankment will merge smoothly with the non-retired portion of the embankment.
[5]Backing refers to a minor landward displacement of the embankment axis which allows much of the material which forms the old embankment to be re-used.

- Damaged structures to be re-constructed and where needed new structures to be constructed. New structures should be constructed to facilities drainage in rainy season and control water in winter season so that farmers can save T. Aman crops from water logging and cultivate winter crops.
- Drainage / Irrigation channels should be re-excavated and new drainage channel may be excavated as per demand of the local people facilitating storage of sufficient water for winter irrigation.
- Arrangement to be made with the local people (through formation of WMA) to control the structures as per need (to open/shutdown).
- It should also be confirmed that the Gher owners cannot cut the embankment to take in saline water in to the polders for cultivation of shrimp against the opinion of the farmers.
- DAE may be involved for advising the farmers for better crops production activities and switching over to high value crops resulting economic benefit of the farmers.

Despite the additional cost it was considered important that all the hydraulic structures, rather strict rules were applied for deciding whether any structure was to be considered repairable, particularly as many of them had already passed their design life.

The major reasons of proposing replacement of an enormous number of drainage and flushing sluices are given below:

A. Most of the drainage sluices were constructed as 0.90 m dia pipe in the year of 1960-70 which are now in a vulnerable condition and cannot be expected to last long.

B. The existing sluices are not functioning well for various reasons or are of insufficient capacity to meet the new design requirements of this project. .

C. These sluices have provision for drainage only but it is now necessary to provide for flushing as well in order to satisfy user demands.

D. The existing embankment has to be raised substantially to satisfy the new design requirements for climate proofing. As a result the deck slab of the existing structures cannot withstand the surcharge load of the raised embankment and the slopes of wing walls may not be compatible with the slopes of proposed raised embankment.

E. The existing structure is not repairable to a level compatible with their continued use until the expected project lifetime.

F. The damage to C/S and/or R/S loose apron has caused severe erosion which endangers the adjacent embankment.

G. The concrete surfacesof the structure has deteriorated and reinforcement is corroded and exposed thus accelerating the rusting of internal reinforcement

H. Damage to barrel walls & floor and deck slab have given rise to large leakage flows that have caused severe piping and created sink holes and blow holes on unprotected embankment surfaces placing the entire embankment under risk of collapse.

I. Stuctures are severely threatened by river erosion and wave action.

Table 3.2 A Summary of Recommended Interventions

Intervention / Polder No	32	33	35/1	35/3	39/2C	14/1	15	16	17/1	17/2	23	34/3	40/2	41/1	43/2C	47/2	48
Re-sectioning of embankment	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Backing of embankment towards C/S	√	√	√	√											√	√	√
Retirement of embankment	√	√	√	√	√	√	√	√		√	√						
Advancing of embankment	√		√														
Slope protection work	√	√	√	√	√	√	√	√			√		√	√	√		√
Bank protection work	√	√	√	√	√	√	√			√					√	√	
Afforestation on the foreshore area	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Repair of existing sluice	√	√	√					√	√	√	√	√	√	√		√	√
Replacement/relocation of existing sluices	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√
Construction of additional sluices	√		√	√	√	√		√	√						√		√
Demolition (without replacement) of strucutre	√	√	√	√				√		√	√		√	√			
Re-excavation of drainage khals	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Re-excavation of peripheral river or TRM*			√					√	√	√		√	√				√

* Re-excavation will be recommended only if there is a likelihood that immediate and rapid sedimentation is not triggered.

The design criteria for embankments, hydraulic structures and drainage channels were determined in line with standard BWDB practice. The detailed design report carries a full explanation of how the design was carried out. Embankment crest levels were determined after extensive model studies carried out by IWM and also taking into account other considerations such as land subsidence. A description of how the design parameters were obtained from model studies and how the design crest levels were ultimately designed are given in Chapter 4. A full description of the models is given in a separate report on mathematical modelling (Volume III, Modelling Report).

The drainage capacity of the structures polders were also tested using model studies. The invert levels to be used in the polder were determined afresh based on land and channel levels within the polder. The number of drainage structures and their sizes were optimised by using the drainage model (see Chapter 4 and Volume III: IWM Modelling Report) which allowed inundation depth duration maps to be prepared for each alternative. The drainage performance was tested for the present conditions and climate change conditions which included 50cm sea level rise and a 20 percent increase in monsoon precipitation.

The design of individual structures was based on hydraulic parameters obtained from the polder model. The design procedure is described in detail in the Detailed Design Report (2012). The drainage network was designed based on the discharges obtained from the drainage model, the invert level and the land levels in the drainage area.

There are a large number of flushing inlets installed in the embankments of almost every polder. Some have been installed recently and properly under the 3rd and 4th Fisheries Projects, and are in very good condition. Some others are poorly constructed, without permission and are a danger to the stability of the embankment. These will be demolished and removed. However, after consultation with the users, several new flushing inlets will be installed by the project. In addition all drainage regulators newly installed will be designed as drainage cum flushing regulators to allow them to operate in both modes.

The final set of proposals for rehabilitation of drainage structures in given in Table 3.3.

Table 3.3 List of Drainage Structures to be Repaired or Replaced

Sl No.	Polder No.	No of existing regulators			No of regulators to be replaced by CEIP			No of regulators to be repaired			No of additional/new regulators to be provided			No of Structures Demolished	Total No of Drainage Structures Designed	Remarks
		RCB	RCP	Total	RCB	RCP	Total	RCB	RCP	Total	RCB	RCP	Total			
1	32	6	9	15	3	3	6	0	0	0	1	0	1	3	7	A total of 6 sluices already undertaken under GoB Aila Fund
2	33	13	0	13	13	0	13	0	0	0	0	0	0		13	1 sluice will be taken up under AILA.
3	35/1	17	1	18	12	1	13	2	0	2	2	0	2		15	DS-9 is in good condition.
4	35/3	3	0	3	3	0	3	0	0	0	1	0	1		4	The new regulator replaces an existing flushing inlet
5	39/2C	0	0	0	0	0	0	0	0	0	13	0	13		13	13 new sluices will be constructed.
Detailed Design Total							**35**			**2**			**17**		**52**	
6	14/1	3	3	6	0	1	1	0	0	0	2	0	2		3	
7	15	5	0	5	4	0	4	0	0	0	0	0	0		4	DS-1 is in good condition.
8	16	9	4	13	5	4	9	2	0	2	1	0	1		10	DS-1 is not needed but 1 additional sluice is required to be constructed.
9	17/1	12	0	12	8	0	8	2	0	2	1	0	1		9	DS-8 A has taken up under GoB fund and 1 additional sluice is required to
10	17/2	6	0	6	1	0	1	3	0	3	0	0	0		1	1 sluice is not required and 1 sluice in good condition.
11	23	7	5	12	6	4	10	1	0	1	0	0	0	1	10	
12	34/3	3	0	3	3	0	3	0	0	0	0	0	0		3	
13	40/2	6	7	13	3	7	10	3	0	3	0	0	0		10	
14	41/1	6	0	6	6	0	6	0	0	0	0	0	0		6	
15	43/2C	7	2	9	6	2	8	0	0	0	1	0	1		9	
16	47/2	3	1	4	3	1	4	0	0	0	0	0	0		4	
16	48	8	2	10	4	2	6	2	0	2	2	0	2		8	
Total for Feasibility Level Design							**70**			**13**			**7**		**77**	

RCB : Reinforced Concrete Box RCP: Reinforced Concrete Pipe

The flushing regulators that are being retained are in very good condition. However, the re-sectioning of the embankment – usually with a significant increase in crest level - would increase the embankment width at the level where the flushing inlets are installed. However, it is possible to adapt these inlets, on a case by case basis, to enable them to continue to function even after the embankment in re-sectioned. The number of flushing inlets to be constructed is given in Table 3.4.

Table 3.4 List of Flushing Inlets to be Repaired or Replaced

Sl No.	Polder No.	No of Flushing Inlets			No of Flushing Inlets to be replaced			No of Flushing Inlets to be repaired			No of additional/new Flushing Inlet to be provided			Demolish	Remarks
		RCB	RCP	Total	RCB	RCP	Total	RCB	RCP	Total	RCB	RCP	Total		
1	**32**	*13*	*22*	**35**	*0*	*1*	**1**	*3*	*18*	**21**	*0*	*0*	**0**	**3**	10 flushing inlets will suffice
2	**33**	*19*	*0*	**19**	*11*	*0*	**11**	*5*	*0*	**5**	*0*	*0*	**0**	**3**	
3	**35/1**	*13*	*12*	**25**	*5*	*12*	**17**	*3*	*0*	**3**	*1*	*0*	**1**	**3**	2 flushing Inlets to be replaced
4	**35/3**	*12*	*0*	**12**	*11*	*0*	**11**	*0*	*0*	**0**	*1*	*0*	**1**		DS-4 and FS-2 will be replaced
5	**39/2C**	*15*	*0*	**15**	*0*	*0*	**0**	*3*	*0*	**3**	*12*	*0*	**12**		All the structures are new
6	**14/1**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	*4*	*0*	**4**		At least 4 new flushing inlets required
7	**15**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	*8*	*0*	**8**		At least 8 new flushing inlets required.
8	**16**	*20*	*10*	**30**	*20*	*0*	**20**	*0*	*0*	**0**	*0*	*0*	**0**	**10**	
9	**17/1**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**		No flushing inlets are required
10	**17/2**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**	*0*	*0*	**0**		No flushing inlets are required
11	**23**	*22*	*21*	**43**	*14*	*8*	**22**	*8*	*0*	**8**	*0*	*0*	**0**	**13**	
12	**34/3**	*6*	*0*	**6**	*1*	*0*	**1**	*5*	*0*	**5**	*0*	*0*	**0**		
13	**40/2**	*6*	*14*	**20**	*2*	*7*	**9**	*3*	*0*	**3**	*0*	*0*	**0**	**7**	Out of remaining & FS-11 is in good
14	**41/1**	*13*	*15*	**28**	*11*	*11*	**22**	*2*	*0*	**2**	*0*	*0*	**0**	**4**	4 flushing Inlets to be demolished.
15	**43/2C**	*2*	*14*	**16**	*1*	*14*	**15**	*0*	*0*	**0**	*1*	*0*	**1**		
16	**47/2**	*7*	*0*	**7**	*2*	*0*	**2**	*3*	*0*	**3**	*1*	*0*	**1**		1 flushing Inlet to be replaced
17	**48**	*0*	*4*	**4**	*0*	*4*	**4**	*0*	*0*	**0**	*0*	*0*	**0**		
				Total	**260**			**135**			**53**			**28**		

RCB : Reinforced Concrete Box RCP : Reinforced Concrete Pipe

3.4 From Feasibility Level Design to Detailed Design

Although the feasibility study is to span 17 polders, the early pre-selection of 5 polders made it possible to pay more attention to the examination of these 5 polders. The detailed design exercise was to an extent a pilot study for validating the methodologies selected for this stage and make it possible to apply these method (suitably modified if necessary) on a large scale. On the other hand it is not possible to call this selection a representative microcosm of the 17 priority polders because some important elements are absent. The need to keep the 5 polders clustered together made it necessary to avoid a few important aspect of the problems encountered in the coastal zone. These are

a) extreme drainage congestion due to sedimentation in peripheral rivers (e.g., P17/1, P17/2)

b) wave attack on a directly sea facing embankment (e.g., P 48)

c) the polders emphasising aquaculture and subject to a more saline environment. (P14/1, P15)

d) some polders (e.g., P 48) offered tremendous scope for afforestation in new accreted lands whereas the 5 polders offered very little scope for afforestation except along a narrow strip of land outside embankment.

As such these four areas did not receive the detailed examination of all issues that must occur before the detailed design is carried out in the next stage.

Once the final package of interventions is determined in accordance with the conditions above, the overall plan (which will include the IEE and SIA) will be presented at a workshop to be organised involving the stakeholders which will include local people, the local elite, district administration and BWDB field Engineers for a day long examination and discussion which could give rise to further adjustment of the plan. After obtaining all the information by field visit and by taking interviews with local people and discussing with the BWDB field Engineers, the consultants have to prepare an overall planning. The 5 polders have been subject to this type of consultation.

3.5 Polder Reports

The detailed studies made in each polder have been incorporated in a *Polder Report* have been prepared for each of the 17 priority polders. Each report contains the following information:

a) Background and location

b) Main Features

c) Present Condition of the Polder

d) Damages sustained and Proposed interventions

e) Map of the polder showing all features, existing and proposed structures, proposals for embankment (re-section, retirement, backing etc), bank protection, drainage network etc)

It must be mentioned here that the reports of the 5 polders selected for detailed design (32, 33, 35/1, 35/3 and 39/2C) have had the benefit of the design proposals being further refined and brought to their final form. The reports on the other 12 polders contain only feasibility level design proposals.

The 17 Polder Reports are assembled in Volume IV of this report.

4.0 MODELLING FOR DESIGN PARAMETERS

4.1 Hydraulic Models used for obtaining Design Parameters

A suite of numerical models developed by IWM were deployed to obtain essential information for setting design parameters for crest levels and polder drainage. The modelling exercise is described in detail in the modelling report (IWM, 2012) so only the details most pertinent to explaining the rationale of the model application is presented in this chapter. There are other model applications that pertain more to the impacts on the region as a whole. Those model applications will be explained in the Strategic Plan (Volume-IV of this report). The cyclone surge is relevant to both aspects and would thus be addressed in both Volumes I and IV.

Some uncertainties that arose about the consistency of the datum used to obtain the land, embankments and water levels used for setting up and calibrating the models (see Section 2.8 of this report). All model simulations were repeated after all the level datums were harmonised. The datum used in the models and in the designs of the project Are referred to as New PWD. The New PWD level of any point is obtained by adding 0.46m to the measured level above the ***present*** Survey of Bangladesh mean sea level. All the levels in the all the models are compatible with each other now – the datum being identical with the datum used in all IWM surveys. The polder designs are also made to the same datum level.

The original design and construction of the embankments and structures for CEP, as well as subsequent repairs done over the years have all been based on the old PWD datum which was related to the nearest MSL bench marks obtained by transferring levels from the Survey of India using - in some instances – very long levelling lines. The recent update of the SoB levelling network has shown that the old MSL values were on a variable datum – thus making it impossible to make a unique relationship between the old PWD level and the new levels that are based on the new Bangladesh MSL datum. The difficulty is illustrated in Tables 2.1 and 2.2 in Chapter 2.

The following models were used for determining design parameters for CEIP:

One Dimensional Models:

Figure 4.1 Polder 35/1

Southwest Region Model (SWRM): This is a well-established river network model, based on MIKE11 Software, which has been continuously developed and updated for 20 years. This model contains all the peripheral rivers into which the CEIP polders drain. The model also contains a rainfall runoff models that can take into account all precipitation on the south west region as well as, where necessary, provided additional runoffs that could be generated by any increases in precipitation predicted for climate change scenarios. A 23 year simulation of the SWRM is also used to process the results all over the model domain, to obtain 25 year return period water levels during the dry season, pre-monsoon, monsoon and post monsoon periods. Figure 4.1 shows an example of an internal drainage network inside a polder and Figure 4.3 shows the SWRM channel network as well as the locations of the project polders within that network.

Polder Drainage Models: These models contain a network of the main drainage khals within a group of polders each connected via a drainage structure (with specified dimensions and operating regime) to its respective peripheral river in the SWRM. The polder drainage network drains under gravity when the outside river level falls below the internal water level. The climate change scenarios are applied to precipitation and external flows into the SWRM and the downstream sea levels applied to the SWRM. The polder drainage models use MIKE11-GIS and the availability of a Digital Elevation Model (DEM) for each polder enables the model result to be used to prepare inundation duration maps, which is the final test of the effectiveness of the drainage network. The khals, the location of the surveyed cross section and the drainage structures linking the network to the SWRM river model are also shown in Figure 4.1.

Two Dimensional Models:

Bay of Bengal Model: This is a two dimensional rectangular, nested grid model which extend from southern boundary stretching between India and Myanmar, and encompassing the northern half of the Bay of Bengal. The finest grid is 200mx200m and this extends into all the major estuaries and rivers with widths exceeding 400m. Figure 4.2 shows the nested model grid and coverage. Some of the narrower peripheral rivers of the project polders are not included in this model. This model is driven by the tidal water levels applied to the southern boundary and the Meghna discharge applied at Chandpur. In addition there is another driving force – that due to a cyclone. That is represented by a cyclone of a particular intensity and diameter which is travelling along a specified path. This is simulated by a Cyclone Model that will provide the Bay of Bengal Model with the additional driving force of a moving pressure field and wind field over the entire model domain.

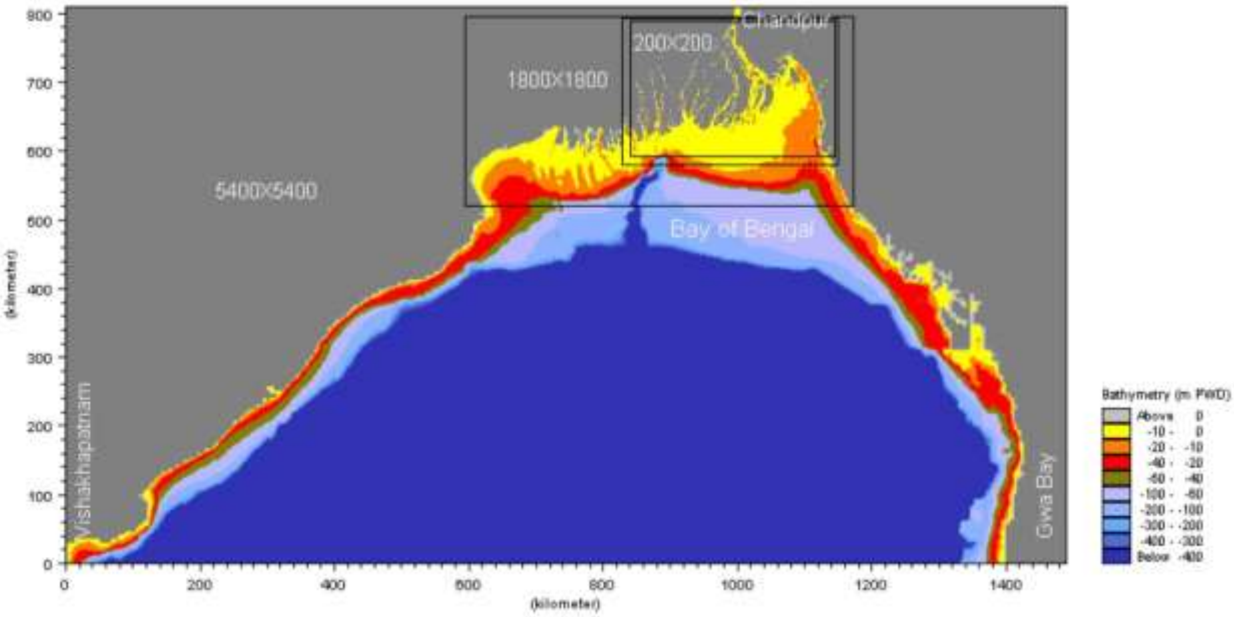


Figure 4.2 Nested Model of the Bay of Bengal

Figure 4.3: South West Region Model Network

Bay of Bengal FM Model: This model is based on a flexible mesh with allows higher resolution of the model grid in areas of special interest without resorting to a nested grid. The computational grid is shown in Figure 4.4.This model was used for simulation of the wave field (direction, height and period) over the model domain. This provided the incident waves on the sea facing or estuary facing embankments for the duration of the cyclone attack.

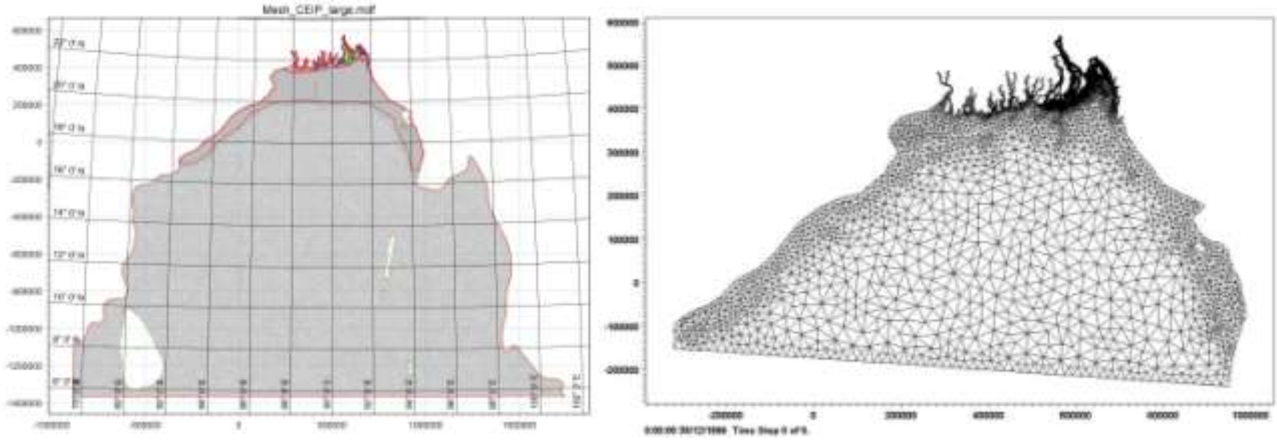


Figure 4.4 Grid Layouts of the Bay of Bengal FM Wave & Salinity Models

4.2 Storm Surges and their Probability of Occurrence

In the last 52 years there have been 19 major cyclones which have been sufficiently documented sufficiently to allow them to be modelled using the Bay of Bengal Model. These events are listed in Table 4.1 and their tracks are shown in Figure 4.5. It is clear that the tracks are more densely packed in the eastern side of the Bay. While there is a temptation to fill in the “gaps” on the western side of the Sundarbans by adding a few synthetic storms, there is no statistical basis for doing this and our return period computations would then be skewed by an unknown factor. Thus the statistical analysis based on 2x22 cyclone simulations (twice 19 actual and 3 additional synthetic tracks) presented in the Mid-Term Report was erroneous and it was considered necessary to revert to 19 historic cyclones repeated once with opposite tidal phase.

Table 4.1 19 Major Cyclones from 1960 onwards

No	Name/Year	Date	Maximum Wind velocity	
			(m/Sec)	(km/h)
1	1960	1960/10/31 18:00	57.80	208.08
2	1961	1961/05/09 09:00	40.80	146.88
3	1963	1963/05/29 00:00	55.60	200.16
4	1965	1965/12/16 06:00	58.10	209.16
5	1965	1965/05/12 00:00	44.70	160.92
6	1966	1966/11/02 18:00	44.30	159.48
7	1970	1970/11/13 00:00	61.70	222.12
8	1974	1974/11/28 06:00	44.70	160.92
9	1983	1983/11/09 13:00	33.63	121.07
10	1985	1985/05/25 09:00	46.75	168.30
11	1986	1986/11/10 18:00	32.20	115.92
12	1988	1988/11/30 00:00	48.84	175.82
13	1991	1991/04/30 03:00	62.50	225.00
14	1995	1995/11/25 18:00	64.13	230.87
15	1997	1997/05/18 09:00	61.11	220.00
16	1997	1997/09/26 09:00	36.11	130.00
17	1998	1998/05/20 08:00	45.83	164.99
18	Sidr-2007	2007/11/15 06:00	69.00	248.40
19	Aila-2009	2009/05/25 12:00	36.78	132.41

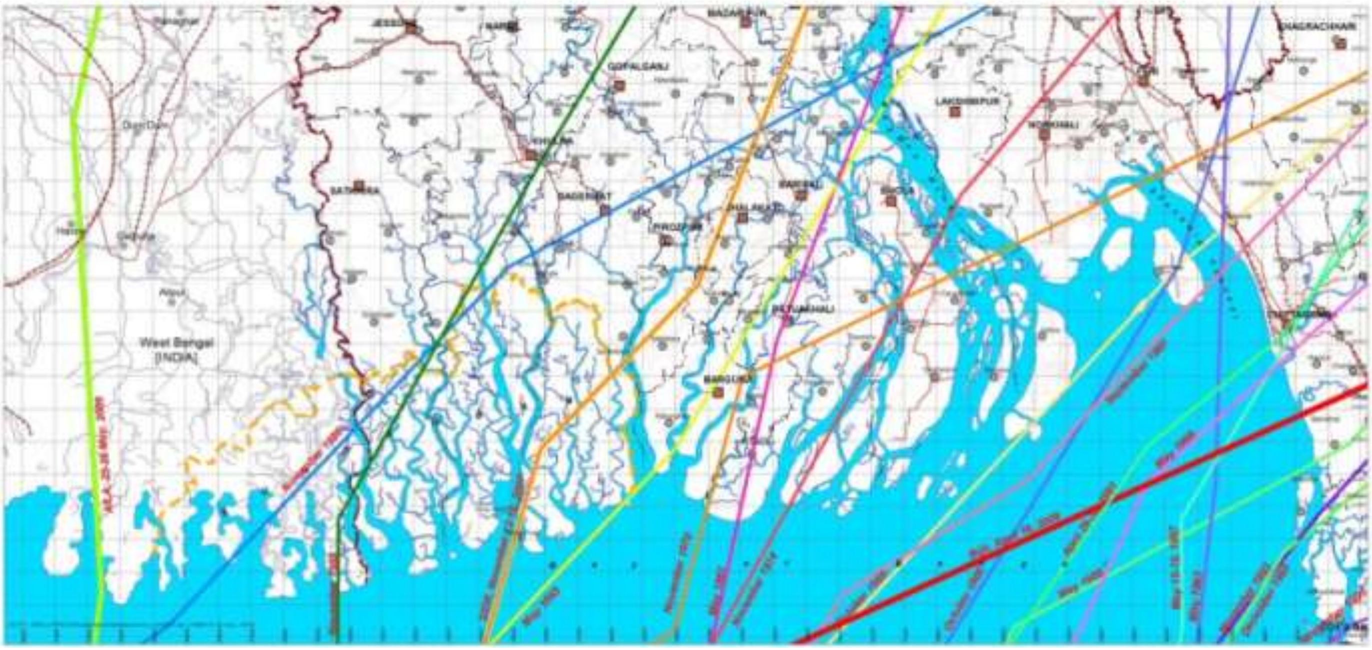


Figure 4.5 Tracks of Major Cyclones (1960-2009)

The maximum surge height was obtained from 106 pre-selected locations in the model domain, for each cyclone of the 38 cyclone simulations. The 38 values obtained for each location were then analysed to obtain the 10, 25, 50 and 100 years return period storm surge levels. The analysis is described in detail in the IWM Modelling Report. As the return period values were obtained by curve fitting method, the standard deviation from the fitted curve was also recorded. Figure 4.6 shows the locations of the location of the points within the western part of the coastal zone from which storm surge levels and wave data were extracted to obtain design parameters. There were, in fact, 106 points from which data was extracted. The locations of these 106 points are given in Volume III, the modelling and Survey Report. Tables 4.2a and 4.2b lists the maximum surge levels obtained for all sampling locations for the four return periods for simulations carried out without and with climate change.

The scenario with climate change (2050) assumed a sea level rise of 50cm and an increase of 10 per cent in the wind velocity in corresponding cyclone with an identical track.

The extreme value analysis employs curve fitting. It is therefore necessary to remain aware of the goodness of fit and shown by the standard deviation in order to decide whether an additional margin should be left for safety.

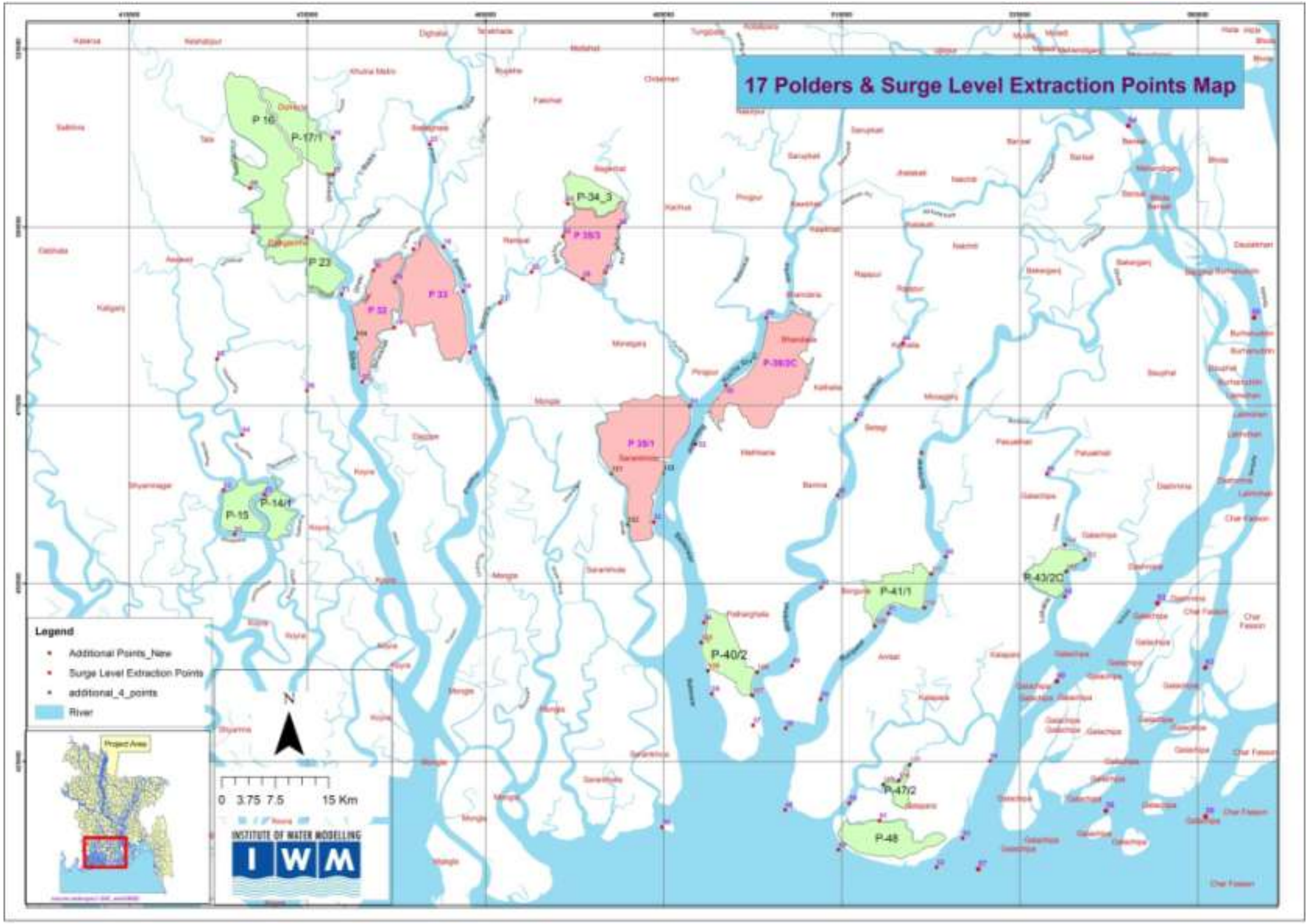


Figure 4.6 Surge Height Sampling Locations

Table 4.2a: Computed Maximum Surge levels

	Without Climate Change Max Surge Height (New mPWD)				With Climate Change Max Surge Height (New mPWD)			
Location No	10yr Ret. Period	25yr Ret Period	50yr Ret Period	100yr Ret Period	10yr Ret. Period	25yr Ret Period	50yr Ret Period	100yr Ret Period
1	2.49	3.07	3.52	3.96	2.81	3.27	3.62	3.96
2	2.54	3.15	3.61	4.07	2.85	3.26	3.56	3.87
3	2.49	3.09	3.54	4.00	2.81	3.35	3.62	3.96
4	2.62	3.23	3.70	4.17	2.96	3.49	3.89	4.29
5	2.36	2.81	3.14	3.47	2.71	3.12	3.42	3.72
6	2.25	2.71	3.05	3.40	2.62	3.07	3.41	3.74
7	2.66	3.42	3.98	4.54	2.84	3.64	3.73	4.11
8	2.10	2.50	2.81	3.11	2.55	3.06	3.45	3.83
9	2.18	2.59	2.89	3.20	2.60	3.09	3.45	3.81
10	2.45	2.97	3.36	3.76	2.80	3.25	3.59	3.92
11	2.36	2.82	3.17	3.52	2.74	3.26	3.64	4.02
12	2.17	2.66	3.03	3.40	2.65	3.20	3.61	4.02
13	2.77	3.51	4.07	4.63	3.20	3.55	4.30	4.76
14	2.39	2.90	3.28	3.67	2.71	3.16	3.38	3.67
15	2.49	3.06	3.49	3.92	2.90	3.27	3.77	4.14
16	2.42	2.95	3.34	3.74	2.71	3.27	3.35	3.62
17	2.38	2.88	3.26	3.63	2.64	3.03	3.24	3.49
18	2.33	2.77	3.10	3.43	2.55	2.85	3.08	3.30
19	2.37	2.92	3.32	3.73	2.65	3.00	3.25	3.50
20	2.51	3.11	3.57	4.03	2.80	3.21	3.57	3.89
21	2.36	2.90	3.31	3.71	2.61	2.97	3.23	3.49
22	2.23	2.79	3.22	3.64	2.48	2.80	3.04	3.28
23	2.28	2.58	2.81	3.03	2.49	2.76	2.96	3.15
24	2.17	2.57	2.88	3.19	2.35	2.60	2.78	2.96
25	2.17	2.57	2.88	3.19	2.36	2.50	2.82	3.01
26	2.16	2.60	2.92	3.25	2.39	2.57	2.98	3.23
27	2.14	2.59	2.94	3.28	2.41	2.62	3.01	3.26
28	2.19	2.67	3.03	3.39	2.44	2.64	2.99	3.22
29	2.54	3.24	3.77	4.29	2.85	3.36	3.73	4.11
30	2.50	3.24	3.78	4.32	2.88	3.44	3.85	4.26
31	2.59	3.34	3.90	4.47	2.97	3.50	4.04	4.49
32	2.52	3.29	3.86	4.43	2.95	3.62	4.05	4.51
33	2.51	3.31	3.90	4.49	3.03	4.19	4.34	4.90
34	2.48	3.28	3.90	4.51	3.06	3.91	4.54	5.16
35	2.50	3.35	3.99	4.63	3.15	4.05	4.72	5.39
36	2.40	3.22	3.85	4.47	2.98	3.82	4.45	5.07
37	2.45	3.27	3.89	4.51	3.14	4.06	4.74	5.42
38	2.49	3.36	4.01	4.67	3.22	4.16	4.86	5.55
39	2.37	3.15	3.74	4.33	2.94	3.72	3.72	4.88
40	2.38	3.15	3.73	4.31	3.08	3.96	4.61	5.26
41	2.34	3.05	3.60	4.14	2.76	3.39	3.85	4.31
42	2.22	2.80	3.24	3.68	2.49	2.89	3.19	3.49
43	2.24	2.77	3.18	3.59	2.47	2.83	3.10	3.36
44	2.28	2.82	3.24	3.65	2.52	2.89	3.17	3.45
45	2.17	2.79	3.26	3.73	2.49	3.04	3.45	3.86
46	2.26	2.95	3.48	4.00	2.72	3.41	3.93	4.44
47	2.39	3.16	3.75	4.33	2.92	3.69	4.26	4.83
48	2.42	3.26	3.90	4.53	3.16	4.09	4.78	5.46
49	2.41	3.24	3.87	4.50	3.30	4.35	5.13	5.91
50	2.47	3.33	3.98	4.62	3.13	4.01	4.66	5.31
51	2.54	3.45	4.14	4.83	3.07	3.93	4.56	5.19
52	2.58	3.49	4.18	4.87	3.37	4.57	5.46	6.35
53	2.74	3.69	4.41	5.12	3.46	4.70	5.61	6.52

Table 4.2b: Computed Maximum Surge levels

	Without Climate Change Max Surge Height (New mPWD)				With Climate Change Max Surge Height (New mPWD)			
Location No	10yr Ret. Period	25yr Ret Period	50yr Ret Period	100yr Ret Period	10yr Ret. Period	25yr Ret Period	50yr Ret Period	100yr Ret Period
54	2.675	3.537	4.189	4.84	3.286	4.363	5.161	5.954
55	2.797	3.839	4.627	5.414	3.183	4.139	4.848	5.552
56	2.485	3.305	3.925	4.545	2.826	3.607	4.186	4.761
57	2.679	3.592	4.282	4.972	3.402	4.571	5.439	6.3
58	2.818	3.825	4.587	5.349	3.647	4.99	5.986	6.975
59	2.855	3.93	4.743	5.556	3.633	4.974	5.968	6.955
60	2.92	4.039	4.885	5.731	3.128	4.065	4.76	5.45
61	2.92	4.039	4.885	5.731	3.56	4.808	5.735	6.654
62	2.967	4.165	5.072	5.979	3.69	4.961	5.904	6.84
63	2.659	3.62	4.347	5.073	3.006	3.86	4.494	5.124
64	2.673	3.47	4.074	4.678	2.783	3.679	4.344	5.004
65	3.418	4.542	5.393	6.243	4.018	5.827	7.169	8.502
66	2.454	3.398	4.111	4.825	4.018	5.827	7.169	8.502
67	3.359	4.409	5.203	5.997	3.885	5.168	6.12	7.064
68	2.923	3.886	4.614	5.343	3.486	4.731	5.656	6.573
69	2.901	3.855	4.578	5.3	3.486	4.731	5.656	6.573
70	2.878	3.817	4.528	5.238	3.496	4.771	5.717	6.657
71	3.008	3.989	4.73	5.472	3.641	4.921	5.87	6.812
72	3.187	4.208	4.98	5.752	3.749	5.042	6.002	6.954
73	3.356	4.485	5.34	6.194	3.923	5.188	6.127	7.059
74	3.641	4.657	5.426	6.195	4.268	5.574	6.544	7.506
75	3.679	4.846	5.728	6.61	4.168	5.394	6.303	7.206
76	4.039	5.301	6.256	7.21	4.543	5.868	6.851	7.827
77	5.439	7.092	8.342	9.593	5.941	7.709	9.02	10.321
78	5.307	6.987	8.257	9.528	5.822	7.554	8.838	10.113
79	5.043	6.678	7.915	9.153	5.595	7.38	8.704	10.019
80	4.69	6.2	7.343	8.485	5.179	6.783	7.972	9.153
81	4.261	5.661	6.721	7.78	4.768	6.252	7.353	8.446
82	4.508	5.852	6.869	7.885	5.068	6.545	7.641	8.728
83	4.168	5.395	6.323	7.251	4.771	6.205	7.269	8.325
84	3.628	4.547	5.241	5.936	3.958	4.88	5.565	6.244
85	3.97	5.178	6.091	7.005	4.556	5.928	6.945	7.955
86	3.971	5.235	6.191	7.147	4.565	5.995	7.056	8.109
87	3.88	5.10	6.02	6.94	4.48	5.88	6.92	7.95
88	3.99	5.36	6.40	7.44	4.61	6.12	7.24	8.35
89	3.84	5.12	6.09	7.06	4.61	6.12	7.24	8.35
90	3.68	4.90	5.82	6.74	4.27	5.64	6.65	7.66
91	3.53	4.66	5.52	6.37	4.18	5.58	6.63	7.66
92	3.24	4.12	4.79	5.46	3.91	5.16	6.09	7.01
93	3.49	4.62	5.47	6.32	4.15	5.52	6.55	7.56
94	3.12	4.00	4.66	5.32	3.78	4.98	5.86	6.75
95	3.20	4.17	4.90	5.63	3.85	5.07	5.98	6.89
96	3.01	3.87	4.52	5.17	3.70	4.89	5.78	6.66
97	2.58	3.20	3.67	4.15	3.39	4.46	5.26	6.05
98	3.00	3.80	4.40	5.01	3.91	5.33	6.39	7.43
99	2.76	3.45	3.96	4.48	3.81	5.18	6.19	7.20
100	2.72	3.39	3.89	4.39	3.87	5.31	6.37	7.43
101	2.36	2.93	3.36	3.79	2.69	3.18	3.55	3.91
102	2.55	3.32	3.91	4.50	2.99	3.71	4.24	4.78
103	2.57	3.34	3.92	4.50	2.98	3.67	4.18	4.69
104	2.74	3.49	4.06	4.63	3.04	3.68	4.50	5.12
105	3.08	3.90	4.51	5.13	3.10	3.88	4.62	5.26
106	3.15	3.99	4.63	5.27	3.11	3.97	4.67	5.33

4.3 Storm Induced Waves

The embankments have to resist more than the maximum surge height. It is necessary to allow sufficient freeboard to resist wave overtopping. The wave heights generated by the cyclonic wind speeds are quite considerable along the sea-facing dykes and the dykes along the wide estuaries in the south. A wave model was run using the cyclonic wind field and storm surge as input for each of the 19 naturally occurring cyclones. The maximum significant wave height (H_{m0}) and the corresponding wave period T_p were extracted for each point of interest and the significant wave heights (H_{m0}) with return periods of 10, 25, 50 and 100 years were obtained location using a GEV distribution for sea facing polders and polders facing the largest rivers near the sea based on the 19 maximum H_{m0} values at each point. Please refer the IWM Modelling Report for further details. The T_p values associated with each wave height was obtained by using the relation $T_p = A * \sqrt{(H_{m0})}$, where A for each polder was obtained from the 19 data points at that station.

The freeboard necessary to limit wave overtopping volumes to acceptable levels was computed using the methodology given in the Eurotop Manual (2007)[6]. Figure 4.7 shows the parameters used in the overtopping computation. The height H_1 refers to the storm surge level and it should be noted that the additional freeboard H_2 required is more than the maximum level of the wave crests. H_2 may be reduced by reducing the river facing slope of the embankment and/or increasing the surface roughness.

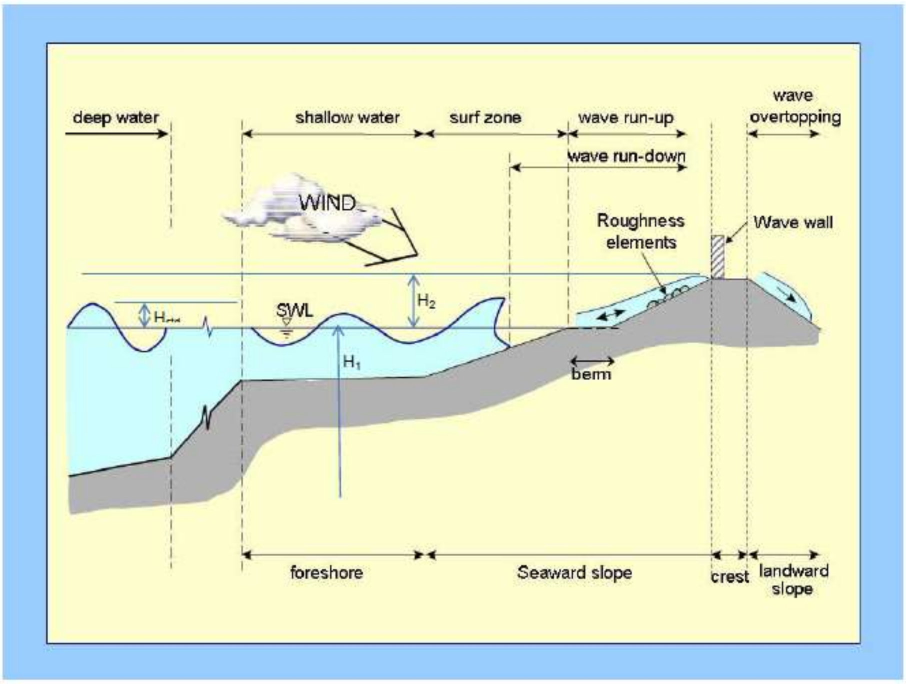


Figure 4.7: Layout for Wave Overtopping Calculation

4.4 Monsoon Flood Levels and Freeboard

Monsoon floods can raise water levels very high in some upstream areas. This occurs outside the two annual cyclone seasons. Particularly in these upstream areas, it is possible that the maximum water levels occur during the monsoon floods. The 25 years return period water levels in the river system were determined from a long simulation of the South

[6]EurOtop, Wave Overtopping of Sea Defences and Related Structures, Assessment Manual, August 2007".

West Region Model with climate change. The model was run for the period 1986 to 2009 after applying a sea level rise of 50 cm to the downstream tidal boundary and the increased monsoon precipitation predicted by IPCC in the NAM rainfall runoff model over the entire region. The external inflows (e.g. Gorai) were also increased in line with the climate change predictions in the Ganges Basin. A freeboard computation was carried out using the Eurotop methodology for surface waves generated using the 25 year return period wind speed obtained from the Khulna wind record. A detailed explanation may be found in the IWM Modelling report. The embankment crest levels were checked against the 25 years return period monsoon flood levels and the required free board.

4.5 Land Subsidence

The lower deltaic area of Bangladesh is located on two active troughs, Faridpur Trough and Hatiya Trough. In this area, three types of subsidence are recognized (Hoque and Alam 1997):

- Tectonic subsidence
- Compaction of peat layers; and
- Human induced subsidence.

Tectonic subsidence

Tectonic subsidence has relevance in understanding the impact of climate change and variability. The subsidence of the Bengal Basin is largely the result of tectonic forces, and can be attributed to two major factors. One is related to the isostatic adjustment of the crust (sediment load and the rise of the Himalayas), while the other is related to dewatering and compaction (or consolidation) of the sediments of the Bengal Fan. Tectonic subsidence usually occurs over a large extent of area, and unlike the subsidence due to groundwater withdrawal, is relatively uniform and proceeds at a slow rate. Areas subjected to tectonic subsidence are generally bounded by active faults or hinge zones-as is the case in the Bengal Basin.

Compaction of peat layers

Parts of lower deltaic plain are underlain by several layers of peat; in some places, even within 35m of depth. The compaction of these peat layers and swamp mud often results in ***local subsidence*** in the coastal area. A large tract of agricultural land and land under vegetation in coastal areas is subjected to this type of subsidence (Hoque & Alam 1997). Moreover, Subsidence may also occur due to abstraction of groundwater in mining situation in local area because the water extraction decreases the groundwater pressure while coastal basins consist of large volumes of unconsolidated sediment overlying by peat layers.

Human induced subsidence

Another type of subsidence in local dimension is human-induced. Human-induced sedimentation impacts when human activities affect the river systems, catchment areas and deltas, the sediment supply processes are disturbed. Embankments along river channels keep sediment out of the adjacent land. The construction of dams and reservoir in upstream areas for flood protection, power supply, and irrigation can stop or strongly decrease the downstream supply of sediment.

The above mechanisms of land subsidence are widely accepted. However, there is disagreement on the magnitude of subsidence – which has been estimated between 0.9 to 13 mm per year at various locations. One difficulty is that analysis of water level records is unable to disaggregate the effects of land subsidence and sea level rise The results based on the analysis of past 22 years of tidal data of the Bangladesh coast reveal that the annual mean tidal level in eastern Bangladesh coast is rising at an alarmingly high rate of 7.8 mm/year, which is almost twice the observed rate in the western region (O. P. Singh, Marine Geodesy- 2002).

Direct measurement of subsidence is possible by the use of GPS technology. This is a part of the on-going investigation by Dhaka University Earth Observatory (DUEO) in collaboration with Lamont-Doherty Earth Observatory of Columbia University, New York. GPS stations have been installed in several places including in the project area. The actual displacements of the GPS stations with respect to the International Terrestrial Reference Frame (ITRF) are being monitored. While the measurements are on-going, preliminary estimates point to high rates of subsidence in the range 9.1mm to 13.9mm per year in Patuakhali and Khulna. Further investigations are planned, including the installation of a station at Hiron Point which could make it possible to disaggregate the sea level rise and subsidence components of the water level record.

As temporary measure for CEIP-1, it has been decided to assume a subsidence rate of 10 mm per year and to apply an upward correction of 30 cm (10 mm per year for 30 years) to the design crest levels. ***This is done together with a strong recommendation that a long term programme of monitoring a more extensive network of GPS stations be initiated immediately so that the subsequent phases of CEIP could benefit from the a more accurate set of subsidence (and sea level rise) data.***

4.6 Determining Design Crest Levels for Embankments.

After considering the results of the storm surge analysis and the project life, it was decided that the design return period should be 25 years. The selection of crest levels for CEIP designs are based on the modelling outcomes described in the preceding sections:

f) The 25 years return period storm surge level
g) Alternatives for freeboard depending on overtopping limit of 5l/m/s for several possible embankment slopes and roughness.
h) 25 year return period monsoon level
i) 25 year return period monsoon freeboard
j) Allowance for subsidence

It is easiest to explain the decision making process with an example from one of the polders. Polder 35/1 is chosen for demonstration because of the extremely high incident waves computed by the model on the Baleswar Estuary almost directly facing the Bay of Bengal. The computation is shown in Table 4.3. The sampling points along the Baleswar are shown in Figure 4.8.

Table 4.3 Computation of Crest Levels along the Baleswar

WITH CLIMATE CHANGE : FREE BOARD COMPUTED ONLY FOR 5l/s/m OVERTOPPING
25 YEARS RETURN PERIOD FOR STORM SURGE MONSOON FLOOD LEVEL

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mPWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mPWD)	Modelled Storm Surge level (mPWD)	Standard Deviation (m)	*Sidr Simulated*	*Aila Simulated*	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level**	**Slope**	**Roughness**	**Crest Level recommended by Technical Committee**
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
31	Morrelgonj,Fanguchhi River	4.88	3.80	3.50	0.22	*4.07*	*3.18*	1:3	1.92	1.34	0.30	5.72	**5.94**	5.14	5.36	3.50	0.57	0.50	4.30	**6.00**	1:3	1	**6.00**
32	Mathbaria,Baleswar River	4.88	3.80	3.62	0.27	*4.16*	*3.17*	1:3	2.40	1.92	0.30	6.32	6.59	5.84	6.11	3.48	0.79	0.80	4.58	**1:3 slope not used**			
33	Sarankhola,Baleswar River	4.88	3.80	4.19	0.35	*4.75*	*3.22*	1:3	3.60	2.88	0.30	8.09	8.44	7.37	7.72	3.47	1.01	1.20	4.97				
31	Morrelgonj,Fanguchhi River	4.88	3.80	3.50	0.22	*4.07*	*3.18*	1:5	1.08	0.84	0.30	4.88	5.10	4.64	4.86	3.50	0.57	0.30	4.10	**1:5 slope not used**			
32	Mathbaria,Baleswar River	4.88	3.80	3.62	0.27	*4.16*	*3.17*	1:5	1.44	1.08	0.30	5.36	**5.63**	5.00	5.27	3.48	0.79	0.50	4.28	**6.00**	1:5	1	**6.00**
33	Sarankhola,Baleswar River	4.88	3.80	4.19	0.35	*4.75*	*3.22*	1:5	2.04	1.68	0.30	6.53	6.88	**6.17**	6.52	3.47	1.01	0.60	4.37	**6.30**	1:5	0.8	**6.50**

The table shows how the crest levels were computed for three locations (31, 32 and 33) on the eastern embankment of Polder 35/1 (Sharankhola) that face the Baleswar Estuary. The normal river-facing slope of an internal dyke is 1:3. However, because of the high wave action we have also considered 1:5 slope in the wave run up computations. Column A shows the original LDL design level)in Old PWD. These levels are not directly convertible to the present New PWD values. All other levels shown in the table are for New PWD datum (see Section 2.7 of this report)

Figure 4.8 Polder 35/1 - Location of Stations along Baleswar River

The designer is presented with several options with regard to selection of slope and surface roughness. He also has a choice of being more cautious by adding the standard deviation to the surge height. The designer's selection of crest level, slope and slope roughness are shown in Columns S, T and U. The Technical Committee's approval is shown in Column V.

In this context it should be noted that there are other safety factors built into this methodology. The 25 year return period is applicable to the environment with climate change effects in year 2050. In earlier years the design would have a higher degree of protection. We have assumed that the highest wind driven waves will occur exactly when the maximum surge occurs – this also introduces a further factor of safety. Wave overtopping is intermittent with only the larger waves running over the embankment crest. This is different from sheet flow that would occur if the storm surge level exceeds the crest level. It is the sheet flow (in the absence of an embankment breach) that could cause severe flooding within the polder. Wave overtopping on the other hand, if excessive can erode the land side of the embankment. The total volume of water admitted to the polder will be small.

4.7 Final Embankment Crest Levels for 5 Polders

Figure 4.8 shows the surge height sampling locations for all 17 polders selected for the feasibility study. The detailed crest level computation tables for the 5 polders selected for detailed design are given on Tables 4.5 to 4.9. All the computations are for 25 years return period for storm surge, wave incidence and monsoon floods – **with climate change.**

Table 4.5 Crest Level Computation for Polder 32

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mNew PWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mNewPWD)	Modelled Storm Surge level (mNewPWD)	Standard Deviation (m)	*Sidr Simulated*	*Aila Simulated*	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level (mNewPWD)**	**Slope**	**Roughness**	**Crest Level recommended by Technical committee**
07	Sibsa river	4.27	3.30	3.64	0.25	*2.83*	*3.48*	1:3	0.94	0.76	0.30	4.87	5.12	4.69	4.94	3.81	0.59	0.50	4.61	**5.00**	**1:3**	**1.0**	**5.00**
07	Sibsa river	4.27	3.30	3.64	0.25	*2.83*	*3.48*	1:5	0.54	0.42	0.30	4.48	4.72	4.36	4.60	3.81	0.59	0.40	4.51	**1:5 slope not used**			
104	Sibsa river	4.27	3.30	3.68	0.22	*2.87*	*3.74*	1:3	0.94	0.76	0.30		5.14	4.74	4.96	3.81	0.59	0.40	4.51	**5.00**			**5.00**
13	Dacope,Sibsa River	4.27	3.30	3.55	0.20	*2.88*	*3.62*	1:3	0.48	0.37	0.30	4.33	4.53	4.22	4.42	3.91	0.42	0.30	4.51	**5.00**	**1:3**	**1.0**	**5.00**
14	Sutarkhali, Sibsa River	4.27	3.30	3.16	0.16	*2.66*	*2.94*	1:3	0.12	0.10	0.30	3.58	3.74	3.56	3.72	3.84	0.18	0.10	4.24	**4.27**	**1:3**	**1.0**	**4.50**
15	Dhaki River	4.27	3.30	3.27	0.16	*2.72*	*3.38*	1:3	0.18	0.12	0.30	3.75	3.91	3.69	3.85	3.89	0.22	0.10	4.29	**4.27**	**1:3**	**1.0**	**4.50**
16	Sutarkhali River	4.27	3.30	3.27	0.16	*2.64*	*2.97*	1:3	0.18	0.14	0.30	3.75	3.91	3.71	3.88	3.91	0.23	0.10	4.31	**4.27**	**1:3**	**1.0**	**4.50**

Table 4.6 Crest Level Computation for Polder 33

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mNew PWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mNewPWD)	Modelled Storm Surge level (mNewPWD)	Standard Deviation (m)	*Sidr Simulated*	*Aila Simulated*	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level (mNewPWD)**	**Slope**	**Roughness**	**Crest Level recommended by Technical committee**
14	Sutarkhali, Sibsa River	4.28	3.85	3.16	0.16	*2.66*	*2.94*	1:3	0.12	0.10	0.30	3.58	3.74	3.56	3.72	3.84	0.18	0.10	4.24	**4.28**	1:3	1.0	**4.50**
16	Sutarkhali River	4.28	3.85	3.27	0.16	*2.64*	*2.97*	1:3	0.18	0.14	0.30	3.75	3.91	3.71	3.88	3.91	0.23	0.10	4.31	**4.28**	1:3	1.0	**4.50**
17	Chunkuri River	4.28	3.85	3.03	0.14	*2.58*	*2.89*	1:3	0.20	0.17	0.30	3.53	3.67	3.49	3.64	3.93	0.26	0.10	4.33	**4.28**	1:3	1.0	**4.50**
18	Pussur River	4.28	3.85	2.85	0.11	*2.50*	*2.75*	1:3	0.55	0.44	0.30	3.71	3.82	3.60	3.71	3.89	0.46	0.30	4.49	**4.50**	1:3	1.0	**4.50**
19	Mongla,Pussur River	4.28	3.85	3.00	0.13	*2.56*	*2.91*	1:3	0.48	0.48	0.30	3.78	3.91	3.78	3.91	3.85	0.44	0.30	4.45	**4.50**	1:3	1.0	**4.50**
20	Mongla,Pussur River	4.28	3.85	3.21	0.16	*2.64*	*3.12*	1:3	0.80	0.65	0.30	4.32	4.48	4.16	4.32	3.78	0.48	0.40	4.48	**4.50**	1:3	1.0	**4.50**

The crest levels of the marginal dykes on the eastern and southern boundaries of the polder were set at 4.5mNewPWD.

Table 4.7 Crest Level Computation for Polder 35/1

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mNew PWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mNewPWD)	Modelled Storm Surge level (mNewPWD)	Standard Deviation (m)	*Sidr Simulated*	*Aila Simulated*	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level (mNewPWD)**	**Slope**	**Roughness**	**Crest Level recommended by Technical committee**
31	Morrelgonj, Fanguchhi River	4.88	3.80	3.50	0.22	*4.07*	*3.18*	1:3	1.92	1.34	0.30	5.72	5.94	5.14	5.36	3.50	0.57	0.50	4.30	**6.00**	1:3	1	6.00
32	Mathbaria, Baleswar River	4.88	3.80	3.62	0.27	*4.16*	*3.17*	1:3	2.40	1.92	0.30	6.32	6.59	5.84	6.11	3.48	0.79	0.80	4.58	**1:3 Slope not used**			
103	Baleswar	4.30	3.80	3.67	0.27	*4.72*	*3.38*	1:3	3.00	2.40	0.30	6.97	7.24	6.37	6.64	3.48	0.79	0.80	4.58				
33	Sarankhola, Baleswar River	4.88	3.80	4.19	0.35	*4.75*	*3.22*	1:3	3.60	2.88	0.30	8.09	8.44	7.37	7.72	3.47	1.01	1.20	4.97				
31	Morrelgonj, Fanguchhi River	4.88	3.80	3.50	0.22	*4.07*	*3.18*	1:5	1.08	0.84	0.30	4.88	5.10	4.64	4.86	3.50	0.57	0.30	4.10	**1:5 Slope not used**			
32	Mathbaria, Baleswar River	4.88	3.80	3.62	0.27	*4.16*	*3.17*	1:5	1.44	1.08	0.30	5.36	5.63	5.00	5.27	3.48	0.79	0.50	4.28	**6.00**	1:5	1	6.00
103	Baleswar	4.30	3.80	3.67	0.27	*4.72*	*3.38*	1:5	1.74	1.38	0.30	5.71	5.98	5.35	5.62	3.48	0.79	0.80	4.58	**6.00**	1:5	1	6.00
33	Sarankhola, Baleswar River	4.88	3.80	4.19	0.35	*4.75*	*3.22*	1:5	2.04	1.68	0.30	6.53	6.88	6.17	6.52	3.47	1.01	0.60	4.37	**6.50**	1:5	0.8	6.50
101	Bhola river	4.30	3.80	3.18	0.19	*3.41*	*3.08*	1:3	0.12	0.10	0.30	3.60	3.79	3.58	3.77	3.50	0.57	0.50	4.30	**4.50**	1:3	1	4.50
102	Bhola river	4.30	3.80	3.71	0.28	*4.98*	*4.35*	1:3	0.18	0.14	0.30	4.19	4.47	4.15	4.43	3.50	0.57	0.50	4.30	**5.00**	1:3	1	5.00

Table 4.8 Crest Level Computation for Polder 35/3

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mNew PWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mNewPWD)	Modelled Storm Surge level (mNewPWD)	Standard Deviation (m)	*Sidr Simulated*	*Aila Simulated*	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level (mNewPWD)**	**Slope**	**Roughness**	**Crest Level recommended by Technical committee**
24	Rampal, Daudkhali River	4.30	3.80	2.49	0.06	*2.36*	*2.35*	1:3	0.16	0.13	0.30	2.94	3.00	2.92	2.98	3.93	0.21	0.10	4.33	**4.50**	**1:3**	**1**	4.50
25	Rampal, Daudkhali River	4.30	3.80	2.50	0.06	*2.33*	*2.36*	1:3	0.24	0.19	0.30	3.04	3.10	2.99	3.05	3.87	0.27	0.10	4.27	**4.50**	**1:3**	**1**	4.50
26	Rampal, Katakhali River	4.30	3.80	2.57	0.08	*2.39*	*2.44*	1:3	0.23	0.18	0.30	3.10	3.18	3.05	3.13	3.81	0.24	0.10	4.21	**4.50**	**1:3**	**1**	4.50
27	Morrelgonj, Ghasiakhali River	4.30	3.80	2.62	0.09	*2.40*	*2.47*	1:3	0.32	0.26	0.30	3.25	3.34	3.19	3.28	3.81	0.29	0.10	4.21	**4.50**	**1:3**	**1**	4.50
28	Rampal, Bhairab River	4.30	3.80	2.64	0.08	*2.44*	*2.53*	1:3	0.36	0.36	0.30	3.30	3.38	3.30	3.38	3.88	0.27	0.10	4.28	**4.50**	**1:3**	**1**	4.50

Table 4.9 Crest Level Computation for Polder 39/2C

						for comparison		wave computation								Monsoon Levels				Selection (to be filled in by Design Team)			mNew PWD
Point_No.	Location	LDL Crest Level (mPWD)	Exisiting Ave. Crest Level (mNewPWD)	Modelled Storm Surge level (mNewPWD)	Standard Deviation (m)	*Sidr Simulated*	*Aila Simulated*	Recommended Slope	Free board for Grass or Smooth paved Roughness 1.0	Free board for Slope Roughness 0.8	Allowance for Subsidence	Rqd crest Level w/o roughness no std	Rqd crest Level w/o roughness + std	Rqd crest Level w roughness & no std	Rqd crest Level w roughness + std	25 year maximu in June-Sept period	Max wind wave height in June -Sept period	Free board w/o roughness	Rqd crest Level w/o roughness with subsidence and freeboard	**Crest Level (mNewPWD)**	**Slope**	**Roughness**	**Crest Level recommended by Technical committee**
29	Bhandaria, Kocha River	4.30	3.00	3.36	0.20	*3.53*	*3.03*	1:3	1.02	0.82	0.30	4.68	4.88	4.48	4.68	3.47	0.56	0.40	4.17	**5.00**	**1:3**	**1**	5.00
30	Bhandaria, Kocha River	4.30	3.00	3.44	0.21	*3.71*	*3.07*	1:3	1.44	1.20	0.30	5.18	5.39	4.94	5.15	3.50	0.65	0.60	4.40	**5.50**	**1:3**	**1**	5.00

4.8 Embankment Crest Levels for Feasibility Level Designs of 17 Polders

The design crest levels of the remaining 12 polders included in the feasibility study were determined using methodology described in sections 4.6 and 4.7. The design crest levels for all 17 polders are summarised in Table 4.10.

Table 4.10 Summary of Design Crest Levels for all 17 Polders

Polder Number	Reach (Chainages)		Design Crest Level (mNewPWD)	Slope		ROUGHNESS (1.00 = smooth paved or turfed)
	From (km)	To (km)		R/S	C/S	
32	0.000	5.500	5.00	1:3	1:2	1.00
	5.500	44.000	4.50	1:3	1:2	1.00
	44.000	49.500	5.00	1:3	1:2	1.00
33	0.000	52.050	4.50	1:3	1:2	1.00
35/1	0.000	13.500	6.00	1:3	1:2	1.00
	13.500	26.000	6.50	1:5	1:2	0.80
	26.000	62.500	5.00	1:3	1:2	1.00
35/3	0.000	39.500	4.50	1:3	1:2	1.00
39/2C	0.000	33.700	4.50	1:3	1:2	1.00
	33.700	52.180	5.50	1:3	1:2	1.00
	52.180	61.500	5.00	1:3	1:2	1.00
14/1	0.000	30.000	4.50	1:3	1:2	1.00
15	0.000	30.500	4.50	1:3	1:2	1.00
16	0.000	44.830	4.50	1:3	1:2	1.00
17/1	0.000	38.000	4.50	1:3	1:2	1.00
17/2	0.000	11.000	4.50	1:3	1:2	1.00
23	0.000	7.500	4.50	1:3	1:2	1.00
	7.500	16.500	5.00	1:3	1:2	1.00
	16.500	36.500	4.50	1:3	1:2	1.00
34/3	0.000	16.200	4.50	1:3	1:2	1.00
40/2	0.000	3.750	6.00	1:7	1:2	0.80
	3.750	11.000	5.00	1:3	1:2	1.00
	11.000	21.750	6.00	1:7	1:2	0.80
	21.750	33.750	5.00	1:3	1:2	1.00
41/1	0.000	14.140	5.50	1:5	1:2	1.00
	14.140	33.640	5.50	1:3	1:2	1.00
43/2C	0.000	12.530	5.00	1:3	1:2	1.00
	12.530	25.280	5.50	1:5	1:2	1.00
47/2	0.000	17.055	5.00	1:3	1:2	1.00
48	0.000	17.000	6.00	1:3	1:2	1.00
	17.000	37.360	7.00	1:7	1:2	0.80

4.9 Polder Drainage Modelling

4.9.1 General Description

The drainage network within each polder was surveyed, together with the dimensions of all the drainage structures. The each drainage model was based on MIKE11 software and comprised the entire South West Region Model (SWRM) connected to one or more polders. The polder drainage network is connected to the SWRM through every drainage structure. The structures are represented correctly and their operating rules are also individually programmed into the model.

The rainfall run-off model is based on a mosaic of sub-catchments covering the entire South West Region. The run-off from each sub-catchment is then routed to several segments of the river network, in proportion to the drainage area being served by each river segment. Within the polder the runoff is routed into the respective drainage khals in proportion to their respective drainage area. The full rainfall runoff model has to be employed because this is the only way in which the impact of climate change induced changes in precipitation can be accounted for both inside and outside the polders. The model is run with sea level boundaries at the southern end and external discharges into the region from the Ganges and Padma rivers. Both boundaries are also adjusted for climate change when necessary.

The drainage networks in many polders are in a poor state. Many structures are malfunctioning or permanently closed or permanently open. Waterlogging is present in many places due to poor drainage and/or due to parts of the polder being exposed to the tide. Siltation of peripheral rivers has made drainage congestion a permanent problem in some smaller rivers, particularly in the north western parts of the polder region.

It was however not possible to run the drainage model to simulate the effect of the many defective structures in the present condition. What was required was to assess the performance of the present drainage set up if they were instead in fully working order. What became apparent was that the original drainage design (CEP) would even now be fully capable of handling the polder drainage. In fact the designs were so conservative that they could, in some cases, even cope with the impacts of projected climate change.

4.9.2 Invert Levels

The invert levels for drainage structures (regulators) were fixed based on the following criteria keeping in mind the need for adequate drainage of the basin ensuring the crop does not suffer damage due to submergence.

- Lowest tidal level at outfall of the regulators
- Lowest basin elevation
- The level up to which submergence of the catchment area is allowed

Institute of Water Modelling carried out mathematical model studies and provided the lowest water level at outfall of corresponding proposed drainage regulator, the lowest basin elevation, the area of the basin under different elevations and the area elevation curve for each polder. Based on the model output the consultant finalized the invert level of the drainage regulators for individual polder.

The differences in survey datum made it necessary to set out all invert levels afresh, based on surveys carried out according to the “NewPWD” datum. (see Section 2.7 of this report). A uniform sill level was set for the drainage structures in each polder. Table 4.11 shows an example of Polder 32 where the selected invert level is compared with the existing (surveyed to New PWD datum) invert levels (of all structures earmarked for replacement) and the lowest tide level that could be encountered. The original uniform invert level for all these structures was -0.6m Old PWD.

Table 4.11 Selection of Invert Levels for Drainage Structures on Polder 32

Name of regulator	Name of outfall river	Lowest Tide level (mNewPWD)	Lowest elevation of basin	Existing Sill Level (mNewPWD)	Proposed Sill Level (mNewPWD)
FFDFK1	SIBSA	-1.91	0.41	-1.282	-1.20
FFDFK2	SIBSA	-1.91	0.41	-1.079	-1.20
DS-09	SUTARKHALI	-1.949	0.41	-0.699	-1.20
FFDFP-01	SUTARKHALI	-1.949	0.41	-1.409	-1.20
FFDFB1	SUTARKHALI	-1.723	0.41	-0.4046	-1.20
F-01	SUTARKHALI	-1.971	0.41	-1.86	-1.20
FFDFT-01	SIBSA	-1.905	0.41	-0.897	-1.20
FDB-05	SIBSA	-1.906	0.41	-1.327	-1.20
F0-02	SUTARKHALI	-1.971	0.41	-0.061	-1.20
FFDFS-02	SIBSA	-1.905	0.41	-1.135	-1.20
FFDFR-01	SUTARKHALI	-1.906	0.41	-1.809	-1.20
FFDFK3	SIBSA	-1.884	0.41	-1.384	-1.20
D-10	SIBSA	-1.884	0.41	-0.92	-1.20
DS-02	SIBSA	-1.884	0.41	-1.466	-1.20
FFDFE2	SUTARKHALI	-1.723	0.41	-1.687	-1.20
FFDFM1	SUTARKHALI	-1.971	0.41	-0.867	-1.20
FFDDQ-02	SIBSA	-1.931	0.41	-0.907	-1.20

4.9.3 Simulation of Polder Drainage

As stated earlier, it was not possible to model the malfunctioning structures in a repeatable manner in the drainage simulation. Thus in all simulations the structures were assumed to function correctly. The following simulations were carried out:

d) Present drainage system without climate change

e) Present drainage system with climate change (Option 1)

f) Modified drainage system[7](Options 2 and 3) with climate change

g) Modified drainage system[8] (Options 2 and 3) with climate change plus 30cm subsidence.

The parameters required for the design of all hydraulic structures were obtained from the model result for each structure. These included internal and external water levels, maximum structure discharges (seasonal) etc. for climate change scenarios. Drainage canal discharges were also obtained from these model runs.

The model simulations also made it possible to prepare inundation duration maps using

[7]Modifications included the provision of additional vents in existing structures, reduction of vents or even elimination of some structures altogether. These mdeifications also required the re-arrangement of the internal drainage network.
[8]Modifications included the provision of additional vents in existing structures, reduction of vents or even elimination of some structures altogether. These mdeifications also required the re-arrangement of the internal drainage network.

MIKE11-GIS software. The first simulations (with and without climate change) were made using the existing polder configuration. Later the new/proposed configuration were tried out to find the combination of structures and vent sizes etc. that would optimally serve the drainage needs with climate change and subsidence. Figures 4.9 and 4.10 are examples of inundation maps.

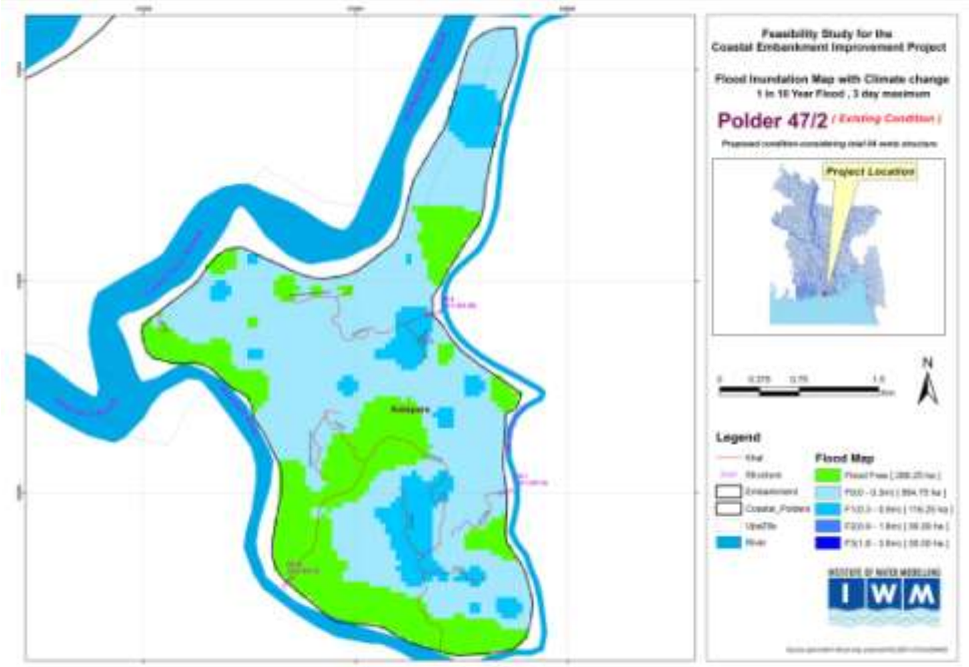


Figure 4.9 Inundation Duration Map: Polder 47/2 present configuration with Climate Change

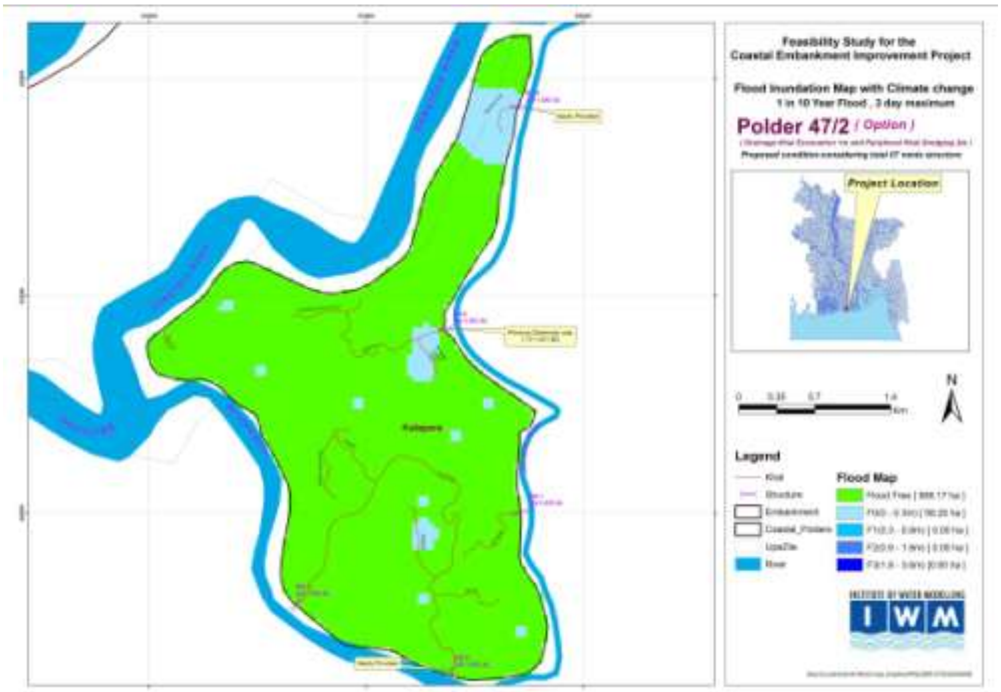


Figure 4.10 Inundation Duration Map: Polder 47/2 Final option with Climate Change

4.10 River Flow Data for Design of Bank Protection

Long simulations for the period 1986-2009(23 years) of the SWRM were carried out with both the present conditions and climate change conditions. The climate change simulations were used to obtain extreme water level statistics at all points of interest in the model domain. Maximum discharges and their related water levels were also obtained. These values were used in the design of riverbank protection and slope protection. Detail might be seen in the Detailed Design Report.

4.11 Conclusion

This chapter describes how the modelling work that was carried out at IWM was used to provide parameters for the designers. Although this process is described as a smooth one-way procedure, in reality there were several adjustments and iterations necessary to eliminate possible errors and establish harmony between the models and the final design.

This chapter does not describe the other modelling work carried out at IWM that do not relate directly to the design works. The remaining modelling work relating to broader, regional and strategic issues and would be described and discussed in Volume 2 of this report.

5.0 LAND USE IMPROVEMENTS IN THE PROJECT AREA

5.1 Introduction

The protected land and water area within each polder is used for several purposes

i) Human Settlements

j) Common amenities such as shops, schools, religious buildings etc

k) Commercial activities

l) Roads and other infrastructure

m) Agriculture

n) Aquaculture

o) Rearing livestock and poultry

p) Forestry (mainly in the unprotected foreshore area)

The quality of the land resource has often been degraded because of water-logging and saline intrusion. It is one of the main objectives of this project to increase the quality of the land within the polder to enable the optimum use of all protected land and water bodies within the polder. This is to be brought about primarily by improving the drainage system to the extent that it will be possible to maximise agricultural output even in the face of climate change and land subsidence.

The water demand regime within the polder system has changed over the years. There has been considerable demand for more flushing inlets than were provided in the original design. Despite some flushing inlets being provided by the Fisheries Projects, almost every polder has seen unauthorised flushing inlets being installed without consideration for the safety of the embankment. Interference with the existing drainage sluices to convert them to two way sluices has also resulted in damage to the gates and the loose apron. These existing operational requirements are taken into account in the new design with most drainage sluices designed to operate as flushing inlets as well. The number of flushing inlets has been optimised. This process has involved conversion of drainage sluices, closure of redundant flushing inlets and providing additional flushing inlets where they are needed.

The land use patterns within polders have also undergone many changes because of the advent of aquaculture as a very lucrative activity. Deficiencies in the drainage system, which had reduced the possibilities for agriculture in some areas, had also encouraged the changeover to aquaculture. At present all possible combinations of fisheries and agriculture are found in the 17 polders being addressed by the project. On one extreme (e.g., 14/1, 15) there are polders where agricultural activity is absent, others where the two activities are carried out side by side on separate parts of the polder, and still others where the land is seasonally rotated between aquaculture in the dry season and agriculture during the monsoon.

The subject specialists working for the consultants have examined the present land use patterns and proposed improved practices for the post project period. The detailed assessments may be found in the Agriculture, Fisheries and Livestock reports in Volume II (Land Use Reports). The summary of present practices and future land use projections are presented in Sections 5.2, 5.3 and 5.4 respectively.

Table 5.1 Present and Future Cropping Patterns

Present & Future Crop grown	P-32		P-33		P-35/1		P-35/3		P-39/2C		P-14/1		P-15		P-16		P-17/1		P-17/2		P-23		P-34/3		P-40/2		P-41/1		P-43/2C		P-47/2		P-48	
	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)	Present Crop Production (MT)	Future Crop Production (MT)
Sugarcane	150	150	240	240	6,000	6,000	175	175	300	300	210	210	-	-	-	-	-	-	-	-	210	210	750	750	600	600	360	360	-	-	-	-	-	-
Orchard	53	53	180	630	3,518	3,518	516	765	683	683	84	84	-	-	150	150	105	105	105	125	108	116	313	388	313	363	230	247	135	145	675	775	608	653
T. Aus (LV)	550	560	360	450	689	-	75	113	509	583	-	-	24	113	85	80	195	-	-	-	-	-	128	-	344	280	1,207	385	904	200	408	360	1,050	400
T. Aus (HYV/Hybrid)	851	2,940	1,674	2,880	4,071	10,680	-	1,400	8,961	11,617	243	455	41	158	135	175	225	1,008	68	185	167	287	550	1,159	1,069	3,136	1,485	5,075	1,107	4,095	1,283	2,502	1,350	5,611
B.Aus	144	72	504	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.Vegetables	4,032	6,720	2,520	5,476	2,300	4,950	4,874	5,890	1,620	3,525	945	1,350	780	975	1,875	2,250	3,125	4,000	2,650	3,286	1,525	1,830	1,863	2,167	1,000	1,200	576	713	500	620	938	1,238	3,075	3,813
T. Aman (LV/LIV)	3,629	2,820	1,265	880	9,148	8,925	4,544	3,700	8,405	4,423	620	1,098	628	1,110	580	840	2,690	1,917	724	450	240	360	1,780	630	2,110	2,643	3,730	1,767	2,000	540	800	375	2,196	2,394
T. Aman (HYV)	10,020	210,786	8,925	15,400	20,444	27,499	4,013	12,916	4,863	20,300	2,538	4,974	338	1,539	4,425	8,360	57,375	12,734	5,354	9,652	1,523	2,785	3,040	8,816	4,918	9,120	2,403	9,945	1,375	5,966	3,405	6,460	5,628	10,439
Wheat / Maize			-	-	104	304	780	1,125	-	-	-	-	-	-	1,100	1,540	385	525	-	140	-	-	-	-	400	560	-	-	-	-	-	-	-	-
Chilli	19	80	53	200	35	130	140	150	169	296	48	72	38	48	63	80	18	22	69	88	28	35	63	80	45	58	35	45	-	-	85	130	245	392
Pulses	188	1,020	250	800	4,530	5,485	158	1,160	491	2,084	144	192	98	191	345	540	255	1,512	90	544	120	270	383	910	500	666	1,545	1,650	473	380	480	740	377	502
Potatoes	-		3,420	3,620	1,500	1,500	810	2,000	1,344	1,920	544	680	640	191	1,550	1,950	210	273	776	987	341	429	270	360	1,842	2,477	279	351	930	1,170	155	200	155	195
Boro (LV)	750	-	-	-	-	-	556	536	-	-	-	-	-	-	-	-	-	-	-	-	-	-	675	-	-	-	-	-	34	-	-	-	-	-
Boro (HYV / Hybrid)		2,072	1,085	27,805	743	7,313	3,150	6,539	277	2,092	900	2,600	140	300	-	-	980	3,735	788	3,164	193	923	1,995	6,930	263	3,663	525	2,948	228	1,935	35	1,193	88	1,463
W.Vegetables	3,240	8,820	1,800	6,628	2,800	3,400	2,758	8,640	3,420	6,560	84	1,260	1,140	2,250	-	-	4,938	10,453	6,188	9,158	1,716	2,574	2,375	65,028	2,500	5,550	960	2,448	1,000	2,220	375	540	1,875	4,625
Spices	35	900	375	825	135	300	75	1,050	302	1,170	88	113	70	90	-	-	88	113	88	113	385	495	77	99	53	68	63	81	140	180	175	225	175	225
Oil Seeds	42	200	63	160	80	300	30	125	325	700	24	40	24	40	-	-	19	32	24	40	102	200	102	170	30	50	66	110	180	300	12	20	342	600
Water melon	-	8,000	8,000	30,000	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,420	8,560
Jute																							106	145	-	-	-	-	-	-	-	-	-	-

5.2 Agricultural Output

The improvement in drainage in the post project period will allow larger areas to be cultivated and a consequent increase in cropping intensity. The proposed cropping patterns are shown in Table 5.1. The increases in cropping intensities are shown in Table 5.2.

Table 5.2 Increases in Cropping Areas and Intensity

Polder Number	Present Cropped Area & Cropping Intensity		Future Cropped Area & Cropping Intensity		Increase in Cropping Intensity
	Area(ha)	%	Area(ha)	%	%
P 32	8,331	128.22	10,053	154.73	26.51
P 33	6,898	134.72	8,920	174.22	39.50
P 35/1	16,880	162.31	21,300	205.00	42.69
P 35/3	6,606	129.78	8,830	173.48	43.70
P 39/2C	12,653	148.64	15,620	183.76	35.12
P 14/1	2,080	110.64	2,870	152.65	42.01
P 15	854	94.89	1,320	146.66	51.77
P 16	4,446	145.77	5,770	189.18	43.41
P 17/1	4,000	125.50	6,820	170.50	45.00
P17/2	3,519	130.33	4,667	172.85	42.52
P 23	1,445	137.88	1,809	172.61	34.73
P 34/3	4,076	139.11	5,400	184.30	45.19
P 40/2	4,649	140.88	6,021	182.45	41.57
P 41/1	5,584	162.32	6,620	192.44	30.12
P 43/2C	3,465	173.25	4,280	214.00	40.75
P 47/2	2,870	155.13	3,540	191.35	36.22
P 48	5,836	157.00	7,095	191.00	34.00
Average		**145.3**		**183.4**	**38.1**

5.3 Fisheries Interventions

In the 17 polders area the total cultivable land is 79,881 ha out of which total fisheries resources area, as wetland, is 50,545 ha. Potential fisheries resources available in all the polders are found in khals, ponds, floodplain, borrow pit canals, flood control, drainage and irrigation canals (FCDI), bagda and galda ghers. Total present fish and shrimp/prawn production was estimated at 20,696 MT and this could be increased to an estimated 28,552 MT (incremental production 7,856 MT) if the following interventions are implemented after completion of the project. The following interventions both in terms of Fisheries Management and Improvement of water management in polders areas are has shown positive benefits (production, income) are shown in the tables 5.3, 5.4, 5.5.

Common Interventions needed for all polders to augment production

- Increase technical manpower in implementing Departments
- Providing appropriate training to fish and shrimp farmers
- Credit support to farmers

- Infrastructure development for fish and shrimp/prawn culture
- Continuing provision of financial assistance to improve fisheries
- Motivational campaign to convert derelict ponds to culture ponds, and popularize Galda culture both in ponds and Ghers as these are eco-friendly in nature
- Implementation of land zoning 2011 in all the polders immediately to reduce conflicts among user groups
- Indiscriminate catching of fish, prawn/shrimp fries and post-larvae must be stopped by DoF

Common interventions for Improvement of water management in all the polders:

- Drainage sluices and flushing inlets in all the polders to be repaired or replaced.
- Timely release and discharge of polder waters
- Ensure timely availability of water in polders
- Formation of sluice gate operation committee representing of proper user groups
- Timely open sluice gate to allow fish fries and Prawn/Shrimp PL to Polders area

It should be noted that all the recommended physical interventions are already a part of the development plan.

Specific polder-wise interventions:

These interventions, which will supplement the recommendations given above will allow improvements in productivity and profitability. The specific polder-wise interventions are shown in Table 5.3.

5.3.1 Management Strategies by Habitat

Openwater (khal)

Present per hectare production recorded can be increased up to maximum 500 kg subject to establishment of fish sanctuary, protection of catching of brood and young fish, implementation of fish act and restriction on using destructive gear such as behundi net, current net etc, keeping river free from pollution. Rivers are bounded all the polders.

Pond

Present production of homestead and commercial pond can be boost up to 2991 and 4000kg/ha and more if farmer follow proper stocking(rate per decimal 40-50 carp species) with feeding 2-3 % to body weight and timely fertilization and organize need based aeration in the pond. In addition, stocking of fast growing species such as mono sex tilapia and Pangas can augment production to 4 and 8 mt respectively.

Galda and Bagda

Three months interval stocking followed harvesting (double cropping pattern, initial per decimal 60-70 stocking of pl then 40-60 pl), aeration and assurance of quality feed and fertilizer used, adopting extensive method and improved traditional method can increased production 750 kg/ha galda and 668 kg/ha bagda.

Table 5.3 Specific Polder wise Recommendations

Polder	Recommended Interventions
35/1	Homestead ponds can be converted to cultured ponds
	Fish cum paddy culture can be extended
	Implementation of Dhaksin, Sarankhola union of Sarankhola Upazilla and Khauola union of Morelganj Upazilla for Agro-Fisheries zone
35/3	Protection of polder from water logging
	Fish cum paddy culture could be extended
	Karapara, Mulleker ber as Agro-Fisheries zone
	Galda culture can be extended in the Gher
39/2C	Protection of flooding and water logging
	Completion of construction of embankment
	Implementation of Ikri and Telekhali union could be used for Galda culture
	Derelict ponds can be converted to fish culture
	Fish cum paddy can be cultured in the floodplain areas
32	Introducing double cropping pattern i.e. shrimp in the winter and prawn in the rainy season
	Declaration of Kamarkhola and Sutarkhali union as Agro-Shrimp zone
33	Fish cum paddy can be popularized
	Banisanta, Bajua, and Lauodub can be used as Agro-Shrimp zone
14/1	Dhaksin Bedkhasi for Shrimp zone and Uttar Bed khasi union for Agro-Aquaculture zone
	Converting single pattern(shrimp) to double pattern (paddy cum shrimp) cropping
15	Salt tolerance paddy can be introduced in this polder
	Implementation of Gabura union only for Aqua-Shrimp zone
	Crab fattening can be popularised
16	Fish, prawn and paddy in the rainy season and shrimp in the winter season
	Khalilnagar for Agro-shrimp, Magurghona for galda with fish, Gadai union for shrimp zone, and Hari dai kaplimuni for Agro-Aquaculture zone can be implemented
17/1	Double cropping pattern can be introduced
	Altia, Magurkhali and Sobhana union for Ago-Aqua zone
17/2	Atlia union for Agro-Aquaculture zone
	Fish with paddy could be extended
	Local stakeholders are in support of bagda culture that can be done with discussions with other users
23	Drainage sluice and flushing inlet those constructed by DOF partly damaged by Aila could be repaired
	Introducing double cropping
	Implementation of Sholadana union for Agro-shrimp zone
34/3	Ponds can be converted to commercial fish culture by providing proper training to pond owners. This can be done by Department of Fisheries
	Existing short term leasing of water bodies for fish culture can be increased to 3 years and ensuring leasing to fish culturist
	People can use their lands as they wish
	Karapara and Shat gambuz union can be used for Agro-shrimp zone
40/2	Perennial water bodies should be kept as fish sanctuaries
	Training and expansion of mono sex tilapia in this polder
	Char duani for Agro-Fisheries zone
	Present traditional cultural system is to be converted to commercial culture
41/1	Monosex tilapaia and Pangas can be popularized
	Promotion of integrated fish farming
	Aylpatakata and Burrirchar for Agro-Fisheries
43/2C	Establishment of Prawn Hatchery in this area
	Golkhali union for Agro-Fisheries
	Intensive training on nursing and pond management for fish farmer
47/2	Borrow pit canal can be taken under fish culture
	Indiscriminate catching of fries and PL can be controlled by Department of Fisheries
	Dalbuganj for Agro-Fisheries
48	Extend polder near char gangamati for save the fisher as well as protecton of reserved forest
	Provide alternate sources of income to fisher through appropriate training

5.3.2 Expected Outputs and Net Benefits:

Pre-project fish, prawn and shrimp productions in 17 polders estimated 20695.8 MT. After completion of the project, production will be increased 28552.18 MT, and incremental production also estimated 7856.38 MT and the net benefit are shown in the Table 5.4 & 5.5.

Table 5.4 Increases in Total Fish and Shrimp Production

Polder No.	Total Water Area in ha	Pre Project Production in MT	Post Project Production in MT	Incremental Production MT
35/1	3,703	2,139	4,023	1,884
35/3	6,369	2,211	4,337	2,127
39/2C	1,468	940	1,213	273
32	456	219	281	62
33	4,473	1,194	1,403	209
14/1	1,560	559	691	132
15	4,467	1,713	2,044	331
16	7,593	3,881	4,306	424
17/1	2,151	1,525	2,073	548
17/2	1,293	818	1,063	245
23	3,527	1,095	1,773	678
34/3	3,966	1,466	1,594	128
40/2	1,935	614	665	52
41/1	1,755	870	1,119	249
43/2C	1,633	787	1,093	306
47/2	1,476	374	545	171
48	786	291	328	37
Total	**50,545**	**20,696**	**28,552**	**7,856**

Table 5.5 Incremental Benefit of Polders at post project

Polder	Post project Tk/crore	Present Tk/crore	Increment Tk/crore
32	1.97	1.63	0.34
33	5.21	4.13	1.08
35/1	17.4	13.67	3.73
35/3	74.64	62.5	12.14
39/2C	16.32	11.07	5.27
14/1	26.17	18.96	7.21
15	50.33	39.87	10.46
16	126.32	82.76	43.56
17/1	54.85	36.99	17.86
17/2	29.39	21.12	8.27
23	40.4	13.66	26.5
34/3	47.41	30.62	16.79
40/2	19.28	17.59	1.69
41/1	13.23	10.71	2.52
43/2C	14.11	8.24	5.87
47/2	4.71	1.21	3.5
48	3.25	1.15	2.1

5.4 Livestock Production Developments

The report of showing the present situation in livestock & poultry and estimate the potential future development of the sector in the project area (all 17 priority polders) may be found in the Land Use Report (Volume II of this report). The report deals with cross & indigenous breeds, dairy farm, milk production & their market value including major constraints and future improvement strategies in livestock sector. Similarly the poultry section deals with improved& local breeds, farming, egg production and their present market price including major constraints of poultry. The report also deals with present & future growth rate of livestock and poultry and their incremental value.

Table 5.6 summarises the total livestock (cattle, buffalo, goats and sheep) populations by polder. Their market value is also given.

Table 5.6 Polder-wise Livestock Population and their Value.

Polder Number	Cross Breed Number	Total Value Tk. (000)	Number of Indigenous Breeds	Total Value Tk. (000)	Total Value of all breeds TK. (000)
P 32	272	9,645	14,959	232,461	241,381
P 33	1,470	49,950	45,593	809,399	859,349
P 35/1	1,762	14,670	23,626	234,821	285,571
P 35/3	1,170	36,503	21,726	416,870	453,373
P 39/2C	5,190	157,695	36,860	860,235	1,017,930
P 14/1	-	-	8,456	73,940	73,940
P 15	8	236	1,783	28,244	28,480
P 16	14,422	463,205	40,360	535,577	998,782
P 17/1	18,253	636,500	45,369	578,313	1,214,813
P 17/2	30,245	1,038,475	25,194	310,688	1,332,888
P 23	1,651	41,509	11,508	126,734	168,243
P 34/3	1,104	32,428	11,103	182,583	215,011
P 40/2	785	18,100	5,730	66,795	84,895
P 41/1	8,389	168,891	79,258	1,352,285	1,521,176
P 43/2C	60	1,114	11,746	124,389	125,503
P 47/2	930	21,030	22,140	233,679	254,709
P 48	1,725	192,280	43,650	480,100	672,380
Total	87,436	2,882,231	449,061	6,647,113	9,548,424

Table 5.7 summarises the production of milk in the 17 polders. The production of buffalo milk (in 4 polders) is accounted for separately. This table does not include animals reared for milk in ordinary households.

Table 5.7 Polder-wise Distribution of Milk Production

Number of Polder	Type of animal	No of dairy farms	Number of total milk animals	Daily milk quantity (litre) /head	Total milk amount (litre) for six months	Price rate of milk/litre (Tk.)	Total Value (Tk.)
P 32	Cow	2	8	5	7,320	30	219,600
P 33	Cow	13	52	6	57,096	35	1,998,360
P 35/1	Cow	1	7	8	10,080	40	403,200
P 35/3	Cow	17	85	10	154,700	35	5,414,500
P 39/2C	Cow	76	1140	8.5	1,768,425	40	70,737,000
P 14/1	-	-	-	-	-	-	-
P 15	-	-	-	-	-	-	-
P 16	Cow	27	155	5	155,155	30	4,654,650
P 17/1	Cow	86	430	5	393,450	25	9,836,250
P 17/2	Cow	160	800	5	732,000	25	18,300,000
P 23	Cow	11	55	6	60,390	32	1,932,480
P 34/3	Cow	11	44	8	64,416	40	2,576,640
P 40/2	Cow	7	35	12	76,860	40	3,074,400
P 41/1	Cow	9	90	14	229,950	40	9,198,000
P 43/2C	Cow	2	10	5.5	10,038	35	351,313
P 47/2	Cow	2	10	6	10,950	35	3,832,500
P 48	Cow	5	35	6.5	41,519	45	1,868,344
Sub-total	**Cow**	**429**	**2801**		**3,772,348**		**134,397,236**
P 16	Buffalo	4	16	4	14,560	30	436,800
P 17/1	Buffalo	35	175	5	160,125	25	4,003,125
P 17/2	Buffalo	25	125	5	114,375	25	2,859,375
P 48	Buffalo	5	35	6.5	41,519	45	1,868,344
Sub-total	**Buffalo**	**65**	**335**	**20.5**	**330,579**	**125**	**9,167,644**
TOTAL	**ALL**	**494**	**3136**		**4,102,927**		**143,564,880**

The proposed improvements in livestock production and the expected increases in output are shown in Table 5.8

Table 5.8 Present and Future Value of Livestock

Polder Number	Livestock & Poultry	Present Number	Future Number after 25 years	Present Market Value (Tk'000)	Future Market Value (Tk'000)	Incremental value (Tk'000)
P 32	Livestock	15,231	23,268	241,381	277,836	36,455
	Poultry	54,060	108,587	9,905	19,909	10,004
P 33	Livestock	47,063	72,608	859,349	1,026,379	167,030
	Poultry	149,150	299,609	32,416	65,116	32,700
P 35/1	Livestock	25,388	39,246	275,571,000	354,025,689	78,454,689
	Poultry	193,685	390,000	45,292,500	101,026,510	55,734,010
P 35/3	Livestock	22,896	34,879	215,011	293,549	78,538
	Poultry	212,205	428,622	41,051	82,330	41,279
P 39/2C	Livestock	42,050	52,562	1,017,930	1,175,321	157,391
	Poultry	148,370	304,350	31,565	64,731	33,166
P 14/1	Livestock	8,456	15,214	73,940	112,591	38,651
	Poultry	10,800	22,556	2,588	5,390	2,802
P 15	Livestock	1,791	3,194	28,480	45,528	17,048
	Poultry	5,435	10,867	1,363	2,723	1,360
P 16	Livestock	54,782	82,240	998,782	1,167,733	168,951
	Poultry	358,760	692,912	1,082,420	1,331,889	249,469
P 17/1	Livestock	63,622	88,896	1,214,813	1,459,271	244,458
	Poultry	463,305	932,316	79,497	160,671	81,174
P 17/2	Livestock	55,439	72,162	1,332,888	1,482,146	149,258
	Poultry	266,040	534,318	45,068	90,634	45,566
P 23	Livestock	13,159	21,912	168,243	211,344	43,101
	Poultry	123,648	260,877	31,523	66,509	34,986
P 34/3	Livestock	12,207	19,967	215,011	293,549	78,538
	Poultry	139,010	279,025	41,051	82,330	41,279
P 40/2	Livestock	6,515	9,046	84,895	106,471	21,576
	Poultry	45,000	94,496	10,070	20,924	10,854
P 41/1	Livestock	87,647	112,683	1,521,176	1,734,280	213,104
	Poultry	39,300	83,086	9,657	20,330	10,673
P 43/2C	Livestock	11,806	17,515	125,503	163,156	37,653
	Poultry	53,937	194,844	11,223	40,159	28,936
P 47/2	Livestock	23,070	38,203	254,709	392,109	137,400
	Poultry	18,395	39,716	2,545	5,498	2,953
P 48	Livestock	45,375	74,890	1,113,750	1,426,299	312,549
	Poultry	2,741,730	6,087,497	507,875	1,034,551	526,676

Note: Assumes 10 percent mortality for Livestock and 20 percent mortality for Poultry

5.5 Coordination of Fisheries and Agriculture

The production from agriculture, fisheries and livestock production have to share common resources of land, water and infrastructure and are not carried by the same people. There is a considerable need for coordination and avoidance of conflicts. The quality of water being used by the agriculture and fisheries users is not identical, also leading to possible conflict. Cross contamination is another issue. Water management is therefore a very important subject and the institutional arrangement that will support this is dealt with in Chapter 9 of this report.

5.6 Afforestation

Under the CEIP 17 polders have been selected for improvement in the first phase. These polders are located in the 5 districts namely, Khulna, Satkhira, Bagerhat, Pirojpur, Patuakhali and Barguna. The polders are subject to strong river currents and wave action which can rapidly change the shape and position of the shore line. From the experience of the mangrove afforestation projects and the Second Coastal Embankment Rehabilitation Project (CERP- II), it was seen that afforestation in the foreshore area can play a very important role in protection of embankment against wave action and a systematic approach might reduce the maintenance cost of the polder embankments. The foreshore mudflat areas of these polders are regularly inundated by tides throughout the year and some scattered natural mangrove plants such as Keora, Bain Saila, Gewa, Golpata etc. are already growing there, indicating that the area is suitable for mangrove afforestation. So, establishment of greenbelts along the embankment foreshore can reduce the effect of toe and slope erosion due to wave action, river flow and promote land accretion. Moreover it will provide significant amount of revenue through harvesting of forest resources.

It will contribute in a small way to environmental improvement by reducing green-house gas emission, providing food and habitat to the variety of coastal species and migrating wildlife. The afforestation may be achieved through the implementation of social forestry mechanism which will generate employment for the rural poor people. The concept of social forestry forms an essential part of the 1994 Forest Policy of Government of Bangladesh. The Government’s forestry master plan considers social forestry as an important tool to involve rural people in managing and benefiting from local resources.

The initial forestry assessment was carried out using available data to plan the extent and types of afforestation in all 17 polders under study. The initial estiomates did not allow for any planting on embankment slopes. However, in the light of BWDB guideline allowing planting on the lowestr third of the emabankment slope and after further detailed inspections and analysis of the possible planting areas in the five polders selected, a more detailed estimate was made. The planting areas in the other 12 polders was estimated on a pro-rated basis. The additional slope areas were taken form the design drawings. This allowed a significant increase in the planting areas.

The Forestry Section of the Volume V (Land Use Report) has been updated using this latest information. Table 5.9 shows the extent of planting the various species as well as the cost.

Table 5.9: Cost of Afforestation

Polder #	Length of the polder in km	Golpata in Hectares for the Polder[9]	Enrichment in Hectares for the polder[1]	Keora Baen in Hectares for the polder[1]	Mound in Hectares for the polder[1]	Total Foreshore in Hectares for the polder	Total Slope Area in Hectares for the polder	Total Area Available for Afforestation for the Polder	Cost of Raising Golpata Plantation For the Polder in Million Taka	Cost of Raising Enrichment Plantation For the Polder in Million Taka	Cost of Raising Keora Baen Plantation For the Polder in Million Taka	Cost of RaisingMound Plantation For the Polder in Million Taka	Cost of Raising Slope Plantation For the Polder in Million Taka	Cost of Sustainability For the Polder in Million Taka	Polder Wise Total Afforestation Cost in Million Taka
32	49.5	6.7	4.8	3.2	4.3	19	16.4	35.4	2.479	1.392	0.9696	1.947901	8.117993	9.9000	24.806494
33	52.5	12.8	5.7	0.8	3.4	22.7	19	41.7	4.736	1.653	0.2424	1.540201	9.404991	10.5000	28.076593
35 by 1	62.5	2.2	0.6	0.4	0.6	3.8	22	25.8	0.814	0.174	0.1212	0.2718	10.88999	12.5000	24.77099
35 by 3	40	1	2	2.5	1.04	6.54	14.4	20.94	0.37	0.58	0.7575	0.47112	7.127993	8.0000	17.306614
39 by 2c	61.5	0	0	0	0	0	11.27	11.27	0	0	0	0	5.578645	12.3000	17.878645
Sub -Total 5 Polders	266	22.7	13.1	6.9	9.34	52.04	83.07	135.11	8.399	3.799	2.0907	4.231023	41.11961	53.2000	112.83934
14/1	30.5	2.60282	1.502068	0.791165	1.07094	5.966992	11.4	17.36699	0.963043	0.4356	0.239723	0.485136	5.642995	6.1000	13.866497
15	30.78	2.626714	1.515857	0.798429	1.080771	6.021771	0	6.021771	0.971884	0.439599	0.241924	0.48959	0	6.1560	8.2989965
40/2	35.58	3.036338	1.752248	0.92294	1.249313	6.960839	10.1	17.06084	1.123445	0.508152	0.279651	0.565939	4.999495	7.1160	14.592682
41/1	33.81	2.885289	1.665079	0.877026	1.187163	6.614558	13.2	19.81456	1.067557	0.482873	0.265739	0.537785	6.533994	6.7620	15.649948
43/2C	25.7	2.193195	1.265677	0.666654	0.902398	5.027925	8.4	13.42792	0.811482	0.367046	0.201996	0.408787	4.157996	5.1400	11.087308
47/2	17.55	1.497688	0.864305	0.455244	0.616229	3.433466	6.3	9.733466	0.554145	0.250648	0.137939	0.279152	3.118497	3.5100	7.8503811
48	37.88	3.232617	1.865519	0.982602	1.330072	7.410809	9.48	16.89081	1.196068	0.541	0.297728	0.602523	4.692596	7.5760	14.905916
16	45	3.840226	2.216165	1.167293	1.580075	8.803759	15.2	24.00376	1.420883	0.642688	0.35369	0.715775	7.523993	9.0000	19.657029
17/1	38.5	3.285526	1.896053	0.998684	1.351842	7.532105	22	29.53211	1.215645	0.549855	0.302601	0.612385	10.88999	7.7000	21.270476
17/2	11	0.938722	0.541729	0.285338	0.386241	2.15203	6.3	8.45203	0.347327	0.157102	0.086458	0.174967	3.118497	2.2000	6.0843504
23	37	3.157519	1.82218	0.959774	1.299173	7.238647	11.8	19.03865	1.168282	0.528432	0.290812	0.588526	5.840995	7.4000	15.817046
34/3	16.75	1.429417	0.824906	0.434492	0.588139	3.276955	9.2	12.47695	0.528884	0.239223	0.131651	0.266427	4.553996	3.3500	9.0701814
Sub-Total 12 Polders	360.05	30.72607	17.73179	9.339643	12.64236	70.43986	123.38	193.8199	11.36865	5.142218	2.829912	5.726992	61.07304	72.0100	158.15081
G.Total	**626.1**	**53.43**	**30.83**	**16.24**	**21.98**	**122.5**	**206.5**	**328.9**	**19.77**	**8.941**	**4.921**	**9.958**	**102.2**	**125.21**	**271**

[9] The numbers shown for the first 5 polders (5 lines) are obtained for field observations, while for the rest 12 polders these have been derived as described under section 3.3

6.0 SOCIOLOGICAL IMPACTS AND RE-SETTLEMENT ISSUES

6.1 Introduction

The CEIP-1 project is being implemented in the 45 Unions of 13 Upazila under 6 districts of the coastal region i.e. Khulna, Satkhira, Bagerhat, Pirojpur, Barguna and Patuakhali. A total of 139 polders have been primarily selected in the whole coastal zone under the Coastal Embankment Improvement Programme of which 17 polders have been selected to be rehabilitated under CEIP-1. Out of these 17 polders, 5 polders have been considered for detailed design under the first year program package of the CEIP-1.

The Social Impact Assessment (SIA – see Volume VII of this report)) was prepared for 17 polders based on primary data collected through structured questionnaire, participatory rapid assessment (PRA) and secondary data obtained from the Population Census 2001 (Community Series and national Series) of the Bangladesh Bureau of Statistics (BBS). The Social Management and Resettlement Policy Frameworks (SMRPF) have also been prepared for 17 polders. A detailed socioeconomic survey has been conducted and the Resettlement Action Plan (RAP) has been prepared following World Bank OP 4.12. The SMRPF is also in Volume VII. The RAP is to be published as a part of the Detailed Design Report of 5 Polders.

A total of about 100,000 ha of land have been considered as the gross protected area in the 17 polders. Many people lost property and became vulnerable due to Aila and Sidr and many of them are living on the embankments of these polders. As per census survey over 14000 entities (households, shops and common properties) were found on the 620 km long embankment (summing up all 17 polders) with a total of 65,235 people including 34,420 (52.76%) male and 30,815 (47.24%) female.

Some of the polder areas are Muslim dominated and some are Hindu dominated. Reportedly an average of about 76% population is Muslim and 24% are Hindu. This figure is different to the national average (Muslim 89.58% and Hindu 9.34%).

Education level of the coastal population is not up to a satisfactory level. According to the survey result more than 46% children do not go to the school and only 26.14% have crossed primary level. Only 0.97% people were found to be Bachelors and 0.44% Master's Degree holders. Nowadays the scenario is changing and the survey results say that a decent number, 27% males and 24% females are found to be students, which is a good sign for the future. Interestingly, the literacy rate in the project area is higher than the national average both for males and females.

The largest occupational groups in the polder areas earn their livelihood from agriculture (13.6%), business (14%) and wage labour (13.3%). A moderate number of the people (7.3%) are involved in fishing and fish culture.

Land is widely used for crop production in the coastal area. In some polder areas it is commonly used for both agriculture and shrimp. More than 72% land is used for crop production, 16.53% residential purposes, 4.30% as fish ponds and only 0.52% as orchards.

Due to establishment of residential structures on the embankment, some religious and social institutions such as Mosques, Schools, Madrasahs, Mandirs, clubs, etc. have been built to facilitate the community. Besides, some are built in the locality inside the polder and outside the polder. A total of 1502 common properties were identified in 17 polder areas of which 737 Schools, 500 Mosques, 101 Madrasahs and 91 Mandirs.

People have limited access to electricity in the polder areas. Only 17.76% households have access of it. Scarcity of drinking water is a major issue of the coastal area. People collect drinking water from deep tube wells of the distant villages. In some cases male members spend2-3 working hours in a day to collect it. Female have little scope of doing it due to the long distances. Sanitation practice of the coastal people is as expected. About 82% of the study population use water sealed latrines while 8% use sanitary latrine and remaining are using kachcha or hanging latrine or open space.

National NGOs as well as some local NGOs are working in the coastal area. After massive destruction due to Aila and Sidr, activities of the NGOs have been expedited and they have reached into the doorsteps of the poor people. National Banks and private banks are also in operation in the study area. People are taking microcredit support from these institutions. About 32% of the surveyed population have obtained loans from these NGOs and or Banks.

Women are mainly involved in household chores but after Aila & Sidr women were bound to earn their livelihood for survival. Literacy rate of the women in the study area is reported as 43.14% which is more than national figure (34.35%). In the decision making process women, have little scope in the family except in house maintenance, cooking, childcare, etc., rather than facing discrimination in social environmental issues. The project should keep provision of deployment of the women in civil work according to eligibility.

The project will have impacts on the population movement and due to the improved embankment people will use it as common road to move to other villages. Some people may purchase light vehicles such as motorcycles for transportation purposes. After construction of the embankment agriculture and crop production will be increased and local economic condition will be improved. Fish production will be uninterrupted due to minimum chance of overtopping of the embankment except during an extreme storm surge. During the construction period population influx will be an issue in the polder areas for the time being. Local administration and Union Parishad have vital role of preventing social unrest. Labourers are to be paid their wages in due course and all facilities related to health and hygiene should be ensured in the labour camp. In this regard, a clause may be incorporated in the contract document with the contractor. Awareness campaign on HIV/AIDS and other STDs should be held among the employees both in-migrated and local to avoid risks of health hazard.

The possible social impacts of the project were investigated though surveys and detailed stakeholder consultations. While it was agreed the benefits would accrue to all as a result of the improvement of the polders, there were some negative impacts that have to be avoided or mitigated. The impacts during the construction phase of three years and the post construction period are different.

The Social Impact Assessment Report (SIA) and the Social Management and Resettlement Policy Framework (SMRPF) are reproduced in Volume VII of this report. These reports apply to the 17 polders selected for this phase.

6.2 Social Impacts during Construction Period

Influx of a large Workforce from outside the polder

The project will require a huge quantity of manpower during construction stage. This manpower will usually be within the age of 18-50 years and mostly male population. So, that will be an unbalanced composition. There will also be income earning opportunities for the local population. They would reside for possibly three years in camps within the polder but will have a disruptive influence on the local communities. There will be a beneficial effect on the local economy – but there will be inflationary effects too. The impact on women is likely to be mainly negative.

Significant land areas have to be set aside as working space, storage areas and camp space for the contractor. Some agricultural land might have to be leased for this purpose. Some of these changes in land use might eventually become permanent.

The entire length of the embankment in every polder would have to be re-sectioned at the very least. Thus all settlements (no doubt temporary) built on the embankment would necessarily have to be dismantled, displacing probably the most disadvantaged section of the population in the polder, many of whom were camped there from the time AILA or SIDR destroyed their homes.

The project will generate work opportunities for the local people directly or indirectly and even temporarily. Besides, some backward linkage institutions will be established such as labour supply companies, contractors, food supply companies, etc. This will cause changes in the structure of the local economy including opening of a new market for products and services, increased demand for consumer goods, and inflation of local prices due to population influx during construction of the embankment.

Opportunities of local goods and services may not be sufficient to provide required support to the huge number of labourers. Local businessmen will make available vegetables, fruits and other necessary goods in the local market.

Most of the lands in the project influenced area are cultivated by owners and a few are sharecroppers. It is known that people are mainly dependant on agriculture and business. Equitable access to work opportunities for all groups of people i.e. local, in-migrated, poor, vulnerable, should be ensured. The local community should be preferred in getting preferential employment in the civil works. The local people will have to be benefited by the project directly or indirectly.

6.3 Longer Term Social Impacts

Population movement

The relocated families will lose their existing inter-personal relation, social formation etc. what they have built for years during living on the embankment. They knew each other and interacted accordingly. Now they have to build new society, new relation etc with new group of people. Social activities such as marriage, exchange, communications etc. they perform each other have to be reorganized. Project will have to consider issues of kinship bondage carefully during relocation of the affected people.

People have been living in their present location for few years and in some cases for few decades. They have some memorial themes with agricultural land, house, trees, ponds, paths, etc. Leaving this place will make them socially and culturally dislocated and yearning for opportunities to be resettled in their original cluster community.

People are known by their permanent addresses and these are recorded in different offices. Due to displacement they will lose their permanent address as known by others. Their Identity will not be affected due to displacement by the project if they can stay nearer to their present location.

Community Organizations and Local Institutions

The local government institutions and regulatory structures have a vital role in the project implementation and maintenance for their own safety and development. Demands from the local people will be directed towards local government, since it is supposed to play a role in project implementation in collaboration with the project authority. The government might be persuaded to allocate a higher budget to facilitate this work.

Some people living outside the polder or distant places may be settled in the polder area after completion of the project. The large number of in-migration may change the existing power structure and they may compete in different local elections.

Competent 'solution oriented local NGOs' may play role to help articulate/negotiate or act as 'honest broker' on behalf of communities. The NGO may disburse soft loan to the displaced people for house building and business development. Religious and Political institutions could also play important role. They should be consulted in decision making process in terms of maintenance of the project so that no one can damage the embankment by cutting earth or planting harmful trees on the embankment. Unless there is sufficient local involvement in decision making processes there could arise legitimacy problems which makes long term stability and sustainability of the project difficult to achieve.

Agriculture & Fisheries

Implementation of the project will lead to increased crop production inside the polder due to the improved drainage conditions and much higher sense of security engendered by the stronger and higher embankment. The present cropping intensity in the project area is in between 150 to 160. Implementation of the project may raise it up to 200. An increased variety of crops will be produce in all three seasons Kharif-1, Kharif-2 and Robi. The elimination saline intrusion would not make it necessary for the farmers to resort to '*AtmashiBandh*'[10], '*Dosherbandh*[11]' to protect individual crops.

There is a large area under fisheries including ponds and open space in the polder areas. People earn their livelihood from the fishing in the open water body and fish culture in the pond as occupation. Due to tidal effect unprotected fish ponds were washed away many times causing financial vulnerability of the people. The coastal people used to catch Hilsa, shrimp fry and other fishes from the river and sea. Implementation of the project will facilitate them uninterrupted movement by using the embankment as fishing boat landing stations and way of moving goods.

Improved water management would set up an orderly regime that would benefit both fisheries and agriculture.

Vulnerable groups

In the project influenced area three types of people could be considered as vulnerable i.e. marginal farmer having less than BDT 5000 income per month, fishermen, women heads of households without any adult male members in the family.

Local economy is mostly agriculture based and most of the land owners cultivate their land by themselves. Some of the landlords gave their land for sharecropping to marginal farmers and as well as to vulnerable group depending on income and land holding size. Some people of the project influenced area depend on fishing from the open water bodies.

[10] "8th month embankment"
[11] "10th month embankment" - temporary embankments built to keep out saline water

As per survey about 7.3% males and 0.20% females are involved n fishing or fish culture. Besides, almost all households catch fish for their daily use during monsoon.

Implementation of the project will increase fish production, create work opportunities; develop communication system so that the vulnerable group will be benefited by the project.

Employment and Labor

There are existing labour laws in the country mentioning all issues relating to labour deployment, health safety etc. Following IFC guide lines, International Labour Organization (ILO) convention and GoB laws apply to labourers. Deployment of children in harmful working environment is strictly prohibited by law in Bangladesh. There will be competition for jobs as unemployment is a major issue in Bangladesh. Preferential employment for the project affected persons is to be considered during preparation of the RAP.

Social Conflict

Skills employees will be deployed in the project mainly from outside the polders and unskilled work will done by the both local and in-migrated labourers. In this circumstance a conflict between these two groups may take place. Local power structure (Union Parishad) handles this issue brilliantly in Bangladesh. Union Parishad is to be consulted during any occurrences of unrest. The RAP suggests providing preferential employment for the local people.

Life style and culture

Improved communications within the polder and with outside influences could lead to changes traditional livelihoods and promote employment seeking within more business related activities. Social linkage among the population of the project influenced area will and kinship systems will broaden with more contact with a larger more diverse population.

Different types of people will be living in the project area during implementation such as businessmen, contractor, employees, etc. In that circumstances sexual harassment may take place in the local community. Other social evils such as drug abuse could also become prevalent. The Union Parishad and local community local NGO and relevant government agencies may undertake social awareness program, training on HIV/AIDS to the employees, etc, for safety of the people. In this context police and other law enforcement agencies should also play a role.

In some times labour unrest may take place within project area that causes delay of the project implementation. This generally takes place if the labourers are not paid their dues in time and facilities that required are not up to the mark. The project authority should take care of it and execute clauses of the contract agreement with the contractor properly especially regarding labour payment, labour shed, toilet and drinking water facilities etc.

Health

Now people are easily getting local vegetable, cow milk, fish, etc. from the local market. Local products are now sufficient to full fill requirements of the community and people can easily purchase goods. Population influx will require bringing of these goods and businessmen will procure from nearby districts. It is expected that income level of the people will increase and purchasing power will high. So they will be able to cope with the changing situation. Considering these things it is expected that nutrition status of the community will not be reduced.

Any accidents due to project may lead to increase mortality rate in the project area. But generally mortality and morbidity rate will remain same as present (except the case of Aila and Sidr).

It is known that the ground water in the area is arsenic contaminated and people collect drinking water from deep tube well from the distant villages to get arsenic free water and use surface water to meet their other daily needs. Water supply for drinking in the work site labor shed should be ensured during construction period. In-migrated employees may play vital role in bringing communicable diseases. Awareness creation through training on STDs, HIV/AIDS will bring positive result. Adequate preventive measures are to be taken and regular health check-up is required.

Equity

All groups of people like women, ethnic minorities, poor and vulnerable people, do not get equal treatment in getting development benefits. Equitable distribution of opportunities may lead to social justice and peace. All groups of people including vulnerable section will have to be consulted in decision making and development process.

The project affected people irrespective of rich and vulnerable will get compensation at replacement cost and other benefits as per WB OP 4.12 at their door steps. Compensation system will be formulated in the Resettlement Action Plan in fair and consistent manner.

6.4 Resettlement Issues

Basic Principles

In consideration of the potential adverse impacts associated with land acquisition and displacement of authorized and unauthorized private activities from its own (and other public) lands, BWDB will select, design and implement all polders in accordance with the following principles:

(1) Prior to selection of specific polder, BWDB will undertake community and stakeholder consultations about their objectives, scope, and social safeguard implications, especially with respect to land acquisition and displacement of businesses, trading and other activities from its own lands (and other public lands, if they are also likely to be used by the project). Consultations will inter alia include,

- All formal/informal local entities, such as Municipal Committees, Union Parishads, water management organizations (WMO), embankment management groups (EMG), local women's groups and others with direct and indirect stakes in the project who are deemed key actors to influence project design and implementation.
- The persons, such as landowners, business owners, traders, embankment settlers (squatters on embankment) and the like, who would be directly affected by the project.
- The persons who would be indirectly affected in terms of loss of livelihood and/or loss of access to common property resources.

(2) Unless absolutely required, BWDB will avoid private land acquisition and keep the improvement and rehabilitation works limited, to the extent feasible, to the existing right-of-

way to minimize displacement of economic and other activities from private and public lands, including its own.

(3) BWDB will avoid, to the extent feasible, project activities that will threaten the cultural way of life of APs; severely restrict their access to common property resources and livelihood activities; and affect places/objects of cultural and religious significance (places of worship, ancestral burial grounds, etc.).

(4) BWDB will undertake social screening of all polders to identify potential social safeguard issues, and adopt and implement impact mitigation measures consistent with the Bank's OP 4.12 and OP 4.10.

(5) Special attention will be given to female affected persons in the resettlement process and to the vulnerability of women and children in the project areas to social exclusion, trafficking, risks of HIV/AIDS infection following the policy guidelines of the World Bank on gender.

Safeguards Screening and Mitigation Guidelines

When displacement of people is unavoidable the following guidelines rules are supposed to apply:

Land Acquisition and Resettlement Framework: Contains principles, policies and guidelines for private land acquisition and use of public lands and adverse impact mitigation; mitigation measures; and implementation and monitoring arrangements for mitigation plans (Section B);

Indigenous Peoples Planning Framework: Contains principles and guidelines to identify and deal with adverse impacts on IPs, and a consultation framework for adoption of mitigation and development measures, where project would adversely affect them (Section C); and

Social Inclusion and Gender Framework: Contains principles and guidelines to identify and deal with non-safeguard social issues like gender inclusion, AIDS/STIs, beneficiary participation, benefit sharing, empowerment and vulnerability management (Section D).

Social Management and Resettlement Policy Framework (SMRPF)

SMRPF provides a comprehensive set of guidelines and procedures for the exercise of due care and sensitivity in resettling peoples and institutions displaced by the project. There are some very important and specific issues that have arisen in the case of this polder improvement project.

A large number of people are settled on the existing embankments. They are either the poorest (and landless) part of the population or those who lost their homes in Sidr or Aila. All these settlers would have to move during construction because every embankment would have its crest level increased. While those displaced by Sidr and Aila could be persuaded to return to their original lands behind a new strong embankment, the landless would have nowhere to go – except to return to the embankment after having been in (even more) temporary accommodation during construction.

The second issue is that there is a severe shortage of suitable state lands for resettling displaced people – except on top of the new embankments.

This is the major issue that has been addressed in the Resettlement Action Plan (RAP).

Resttlement of Embankment Dwellers

This issue has been the subject of much discussion – but the basic truth is that the embankment dwellers are usually landless and the poorest section of the polder community. Their life and livelihood are intimately woven around their own neighbourhood and resettling them a long way away would cause additional distress. It was therefore decided (subject to agreement from the authorities) to re-settle them on the embankment after incorporating a 10m wide berm (platform) on the country side of the embankment. The additional cost of earthwork and land acquisition would be small and the settlers would have to give an undertaking to look after and carryout minor maintenance on the embankment.

7.0 ENVIRONMENTALIMPACTS AND MITIGATION

7.1 Introduction

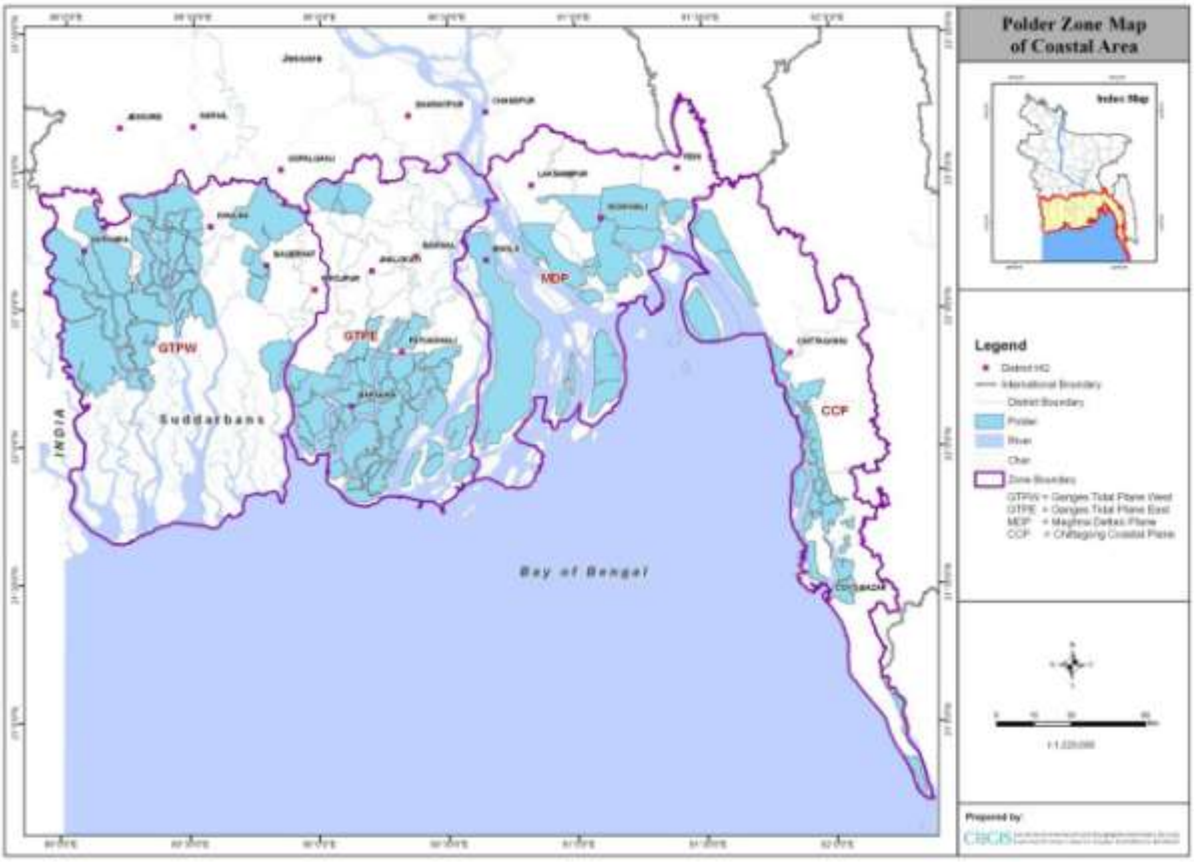


Figure 7.1 Sub-Divisions of the Coast Zone

GTPW: Ganges Tidal Plain West GTPE: Ganges Tidal Plain West
MDP: Meghna Deltaic Plain CCP: Chittagong Coastal Plain

The programme area is the entire coastal zone, which has been sub-divided in to 4 zones as shown in Figure 7.1. The present project of 17 selected priority polders all fall into two zones GTPW and GTPE.

The environment of the coastal zone of Bangladesh is vulnerable short duration hazards such as being struck by the storm surge of a cyclone. It is also subject to slowly developing hazards such as sea level rise and sedimentation in rivers and water logging of agricultural land. Although the storm surge damage can be devastating to people and infrastructure the environmental damage caused is transient. The longer lasting impacts are usually associated with severe damage to infrastructure which could take years to the repair. The trapping of saline water behind man-made embankments can cause extended damage to agricultural production where the system has not been designed for rapid recovery.

7.2 Environmental Issues Affecting the Coastal Zone

Water Resources

Coastal areas are endowed with both fresh and brackish water resources. The fresh waters are available in upstream part of rivers, ponds, wetlands and groundwater. Brackish waters are mainly in the estuarine part of the rivers and tidal cannels/ creeks. Major rivers flowing though the coastal area are the Gorai- Madhumati-Baleswar river and Rupsa-Pussur river in the GTPW zone; Buriswar river in GTPE zone; Meghna river in MDP zone; and Karnaphuli river and Feni river in CPP zone. The major estuaries in the south west are dominated by tidal flows. There are no systematic records maintained of the net water discharge of the rivers in the coastal area. However, long simulations of the south west region model are available for computing the net discharges.

There are many beels, baors and ponds in the coastal area which are used as freshwater sources for people, fisheries and wildlife. Most of the beels and baors are located in the GTPW and GTPE zone. In addition, shallow groundwater aquifer provides almost 80% of drinking water supply to the coastal communities. Moreover, rainwater is being used in some areas through different rainwater harvesting technologies.

During the monsoon, there is abundant fresh water, whereas during the winter, water becomes a scarce resource. Due to reduced flows in the rivers in winter, both surface water and groundwater systems suffer from saline water intrusion, making the resource unsuitable for agricultural, domestic and industrial purposes. Furthermore, arsenic contamination in groundwater is becoming a severe threat to public health.

There are many sources of water pollution in the coastal zone such as domestic sewage, industrial wastewater and oil spills from river transport, which occur mainly in major cities like Chittagong, Khulna. Data on surface water quality are available in some stations in major rivers in Khulna and Chittagong and are presented in the SEA Report. Beside water pollution, salinity in surface and ground water is very important concern for agriculture, drinking water supply and aquaculture in the coastal area. Although the danger has not been flagged yet, it is likely that contamination of surface and groundwater by pesticides and other agrochemicals and pollution through excessive release of nutrients into the rivers and khals as the agricultural and fisheries activities become more intensive will be an inevitable consequence of economic development.

The major water related environmental problems presently encountered in the coastal zone are shown in Table 7.1

Table 7.1: Major water related environmental problems encountered in the Coastal Zone of Bangladesh

Water Related Environmental problems/ hazards	Main Cause(s)	Affected Areas	Affected Sectors	Severity
Cyclone and storm surge	Natural by aggravated by Climate Change	Whole coastal zone	Agriculture, fisheries, public health, education, housing business and others	1
Drainage congestion/ water logging	Sedimentation driven by polder building and sea level rise	Mainly in GTPW and GTPE	Agriculture, fisheries, public health, education, housing business and others	2
Salinity intrusion	Aggravated by upstream diversions and sea level rise	Mainly in GTPW, GTPE and MDP	Agriculture, fisheries, public health	3
Riverbank erosion	Natural sometimes aggravated by unplanned river works	Mainly in GTPE and MDP	Agriculture, Settlements, infrastructure	3
Coastal erosion	Natural but could be aggravated by construction	Mainly in GTPE and MDP	Settlements and infrastructure	3
Sedimentation in river bed	Polder building, sea level rise, unplanned river closures	Mainly in GTPW, GTPE and MDP	Agriculture, Fisheries and navigation	3
Arsenic in ground water	Naturally occurring in geological strata	Mainly in GTPW, GTPE and MDP	Public health	3
Land subsidence	Natural in areas protected from flooding/sedimentation	Whole coastal zone	Agriculture, infrastructure	3

Air pollution problems too are generally restricted to the two large cities Chittagong and Khulna.

Morphology

On the other hand the processes of sedimentation, drainage congestion and water logging (they are usually inter-related) are long term and can become permanent. Although these problems are associated with human interference with natural processes – it is important not to forget that the entire Bengal Delta exists because of massive sedimentation over millennia. Even the phenomenon of sea level rise is not new. The Bay of Bengal level has risen and fallen though the previous geological era. The difference now is that there is large population living in the coastal zone and that they are dependent on infrastructure that have interfered with the sedimentation processes that have kept the delta growing over a very long period. To enumerate,

a) The development of the Ganges, Brahmaputra and Meghna Basins have resulted in increased sediment loads that have had to be re-distributed in the large number of estuaries that fringe the delta.
b) The deposition of sediments in river beds and on land have contributed to the formation of chars and increases in land levels
c) The compaction and consolidation of very thick (~20km) layers of sediment (sand, silt, clay and peat) and tectonic activity have contributed to land subsidence.
d) However in the natural system land formation always overcame the effect of subsidence
e) The construction of embankments to prevent flooding prevented the deposition of sediments required for overcoming subsidence (an unintended consequence).
f) The creation of more land downstream of the protected lands by natural means or by accelerated means by cross dam building has lengthened the drainage paths and led to additional drainage congestion

Land erosion and accretion are common natural phenomena in the coastal zone. Major stable accretions were found in the coastal belt of Patuakhali and southern part of Bhola district. The past rate of net accretion in this region was 12 sq. km per year. Erosion at the rate of 3 sq. km and accretion at the rate of 15 sq. km took place in the last 20 years. Islands in this region may grow by silting up of small channels. The past trend of erosion and accretion may continue to follow for the next 25 years (ICZMP, 2001).

Both erosion and accretion in the Meghna estuary region (i.e. northern part of Bhola district, Lakshmipur, Noakhali and Feni coastal belt, Hatiya arid Sandwip area) were found to be prominent. The past rates of erosion and accretion per year were detected as 20 sq. km and 28 sq. km respectively. So, net accretion rate was 8 sq. km per year. This past trend of erosion and accretion may continue in the future. Major threat of erosion in the next 25 years may be in the region of northern part of Bhola, Lakshmipur coastline, north and north eastern parts of Hatiya, north and western parts of Swandip. Slow accretion may take place in the southern part of Hatiya and Noakhali mainland. Erosion and accretion in the Feni coastal belt is expected to be insignificant.

Erosion and accretion in the regions of Harinbhanga River to Rabnabad channel and Feni River to Shahapari Island may be insignificant in the next 25 years. Small patches of erosions and accretions may take place here and there. The extreme shortage of land in Bangladesh has made it more difficult to set aside land for conservation or as buffers against riverbank migration. In fact, land once considered unsuitable for agriculture has been reclaimed by the construction of embankments to prevent tidal flooding. Large scale construction of permanent polders began in the 1960’s and at present 1.2 million hectares of land has been re-claimed for agriculture. The impact on the tidal regime was immediate. The tidal volume entering the coastal zone was reduced by 30 per cent and the tidal range increased by 40 per cent. However, the real unintended consequences of this massive exercise in polder building began to show only in the 1980s. This manifested itself as the accumulation of sediments in all tidal channels – but most significantly in smaller tidal rivers without a significant upstream catchment for flushing away any sediment deposits. There were many such rivers in the western delta which had been cut-off from the Ganges for several decades or more. The negative impacts of polder building were far outweighed by the benefits to the population. There was never any question of reversing the development that continues to benefit a coastal population of 35 million.

7.3 Environmental Impacts of Coastal Embankment Improvement

Regional Impacts

It should be mentioned at the outset that CEIP will address, where possible, any environmental issues such as *local* sedimentation and water logging that could be addressed in the project design. The interventions proposed by the project are generally too small to have a long term regional impact. As mentioned before the construction of the polder had a profound environmental impact on entire coastal region – particularly in the area of sedimentation. The present project would raise and strengthen the existing embankments but not make any measurable change to the way in which the tide interacts with the rivers and estuaries. This is true, except during a major cyclone.

While the raising and strengthening of the system of embankments has no influence on the normal tidal regime, during a cyclone there is a major difference in how the land is inundated (or not). The new higher and stronger embankment will to a great extent prevent inundation of land. Water levels will be driven higher when the flood water cannot be allowed flow onto the land. While the strengthening and raising of a few polders by CEIP-1 will have a small to moderate impact on raising surge heights in adjacent polders, this effect will be magnified as the more polders come under the subsequent phases of CEIP.

The morphology of the river and estuary system in the coastal zone is determined by the runoff of water and sediments from the catchment and the tidal regime. The inexorable ebb and flow of the tide determines the shape (morphology) of the water ways. Rare events such as cyclones, though devastating in their impacts on land, have little or no influence on morphological development. While the CEIP project interventions would not have a regional morphological impact, there is expected to be a major impact of sea level rise on estuarine morphology. The overall impact would be to raise river bed levels – but the speed of this increase and where it will take place in the face of a 1 cm per annum increase in sea level has to be investigated by modelling.

These regional impact issues are discussed fully in the Strategic Plan (Volume II of this report)

Local Impacts

The local impacts of the project interventions (once completed) are mainly neutral because they are restoring the previous state of the polders to the situation they were in after the CEP was functioning well, (say) in the mid-1970s. We are assuming that no attempt is being made to revert to the pristine state of the delta before any polders were constructed. Serious environmental disruption can however be caused in the following unless safeguards are put in place:

During the construction phase:

a) During the construction phase: all activities connected with land preparation and earthwork, disposal of spoil etc have to be regulated. The contractor's work camp, influx of large numbers of workers, would set up serious social and public health challenges.
b) The amount of land required for the contractor's yard, offices, workers camp as well as fresh water, sanitation facilities, landing points, access roads etc., would require the temporary acquisition of more land.
c) There will be inevitable disruption of agricultural activities because of the construction activity.
d) A very large volume of earth will be moved from borrow pits to the site. This will create a very high erosion risk on site before the earth is compacted and eventually turfed over. There is risk of spillage that would also find its way into the river.

It should be possible to return the polder to a state better than its original condition before the site returned to BWDB.

During the operational phase (long term impacts):

a) The raising and strengthening of the embankments will not have any long term impacts on the environment except for raising the maximum storm surge level for the more intense storms.
b) Sea level rise will cause adverse conditions for drainage – which are allowed for in the design.

Sea level rise will also cause increased saline intrusion in the river system. This will reduce the number of days in the year when fresh water will be found in the peripheral rivers for agricultural use through the use of flushing inlets.

7.4 Closure Dam at Nalian River (Polder 32)

Nalian Khal (sometimes referred to as Nalian River) was once a deep river that was closed by the original CEP project when Polder 32 was created in the 1960s. Thus it had been an internal fresh water body connected to the Sibsa River through a drainage regulator for more than 40 years. This water body received drainage water from a large part of Polder 32 both north and south of Nalian Khal and the original design provided an 8-pipe vent regulator to handle the drainage. This was later replaced with a 4 vent rectangular culvert regulator.

The cross dam was breached and the regulator destroyed during cyclone Aila in 2009. During the last three years Nalian Khal has been exposed to the full tidal regime of the Sibsa River. The BWDB constructed a low marginal dyke along the both banks of Nalian Khal to prevent further high tide inundation of the land. All drainage paths from the land north and south to Nalian Khal were closed. The land had to be drained (with difficulty) along alternative paths.

Under CEIP it is proposed that we will return Nalian Khal to the state it was in before Aila. This requires the construction of a closure dam and the reopening of drainage paths from the land towards Nalian. A bypass channel will connect the Nalian Khal to a new three vent drainage sluice which will flow into the Sibsa on the right bank of Nalian Khal. Returning the system to its original state should not really create any problem.

However, it was discovered during the project surveys that some parts of Nalian Khal is 18-20 m deep. It was not connected to the Sibsa for 40 years until Aila opened it up. It is possible by this time the entire volume of the Khal would have become fresh water. After the breach the natural tidal flow in and out of the Khal (this is driven by the surface area of the Nalian Khal) would have been rather small when compared with its volume (MIKE11 model results will show how high these velocities were). On the other hand the incoming water being heavier than the fresh water in the deepest parts of Nalian would have mixed in a made the water brackish/saline depending on the season.

When Nalian is finally closed (this is usually done in January/February for technical reasons) we will trap a large amount salty water (saltier than average because it is January/February) and all the subsequent fresh drainage water will float over this and flow out through a very shallow diversion channel to the drainage structure.

If a stable stratified water body is created in Nalian Khal - there could be oxygen depletion at the lower depths and negative impacts on fisheries. Whatever will take place after this closure would have happened once before in the 1960s. There are however no records available to find out whether any adverse situation arose, and if so how long it took to correct itself. The possibility of a (temporarily) adverse outcome could be reduced greatly if the closure took place (say) just after the monsoon when the salinity in the Sibsa is zero.

This problem could be investigated using a combination of field measurements and modelling and continued monitoring in the pre- and post-project period.

7.5 Navigation Impacts

The CEIP-1 project itself does not interfere with the normal morphodynamics of the river and estuarine system. The higher and stronger embankments will come into contact with river flow only during a cyclonic storm. The morphological impacts of such storms are transient and negligible, except in cases where there is a disastrous and massive embankment failure which brings an enormous amount of sediment into the river. This project is designed just to avoid such a failure.

The slightly raised maximum surge levels which will result from the additional confining effect on extreme water levels will happen at very rare intervals. These brief events – although very destructive of unprotected infrastructure – do not have any impacts on navigation.

Sea level rise would definitely have an impact on the morphology of the river with or without the project. Modelling carried out so far indicate that the bed levels will rise in the estuary of Pussur and Sibsa with the rise at the downstream end starting earlier and propagating upstream. In general the rise in bed level would continue until the actual sea level rise is “neutralised”. This also means that the average navigation depths will remain favourable becasaue the bed level rise will always follow the rise in sea level. However, this might be an oversimplification because there might be other three diensional effects that might cause lateral movement of the deep channel and make navigation difficult. Nevertheless all these phenomena will take place whether CEIP-1 is executed or not. The increase of polder crest levels has no impact on this phenomenon.

7.6 Transnational Waterways Impacts

The transnational waterways that could be affected by the Coastal Emabankment Improvement Programme (of which CEIP-1 is only the first phase) are those that are used for transnational navigation and the those rivers and estuaries that are situated along or adjacent to the international borders with India and, to a far lesser extent, Myanmar.

Before the project impacts are examined it is very important to separate out the climate change impacts that would have occurred whether or not the project was implemented from the impacts of the project itself. The fact that one of the project's objectives is to mitigate climate change impacts is also relevant.

The types of impacts the project could conceivably have on the waterways under consideration are ;

d) Changes in flow characterisitics (discharges, water levels, peak velocities, flooding etc)
e) Changes in water quality (in this case mainly salinity, and possibly nutrient changes, pollution)
f) Morphological changes (bed levels/flow depth, bank erosion etc)

As stated elsewhere in the report, it is worthwhile reiterating that the project comprises mainly the strengthening and raising of embankments together with (hydraulically) rather minor changes in channel alignment. The new part of the embankment does not even interact with the flow in the rivers except during a storm event which might typically occur during one tidal cycle in ten years – less than once in 5000 tidal cycles. Thus the overall hydraulic behaviour of the system is not changed by the project interventions except during this rare occurrences for which the project has been designed.

The relative morphological impacts of the normal tidal flow regime and the occasional severe cyclonic storm are also similar in nature and their corresponding magnitude. Thus the long term morphological development of the Delta is not affected by the project. Any excessive scouring that might be observed after one extreme event will be erased by repeated tidal cycles that will take place for years following the event. However, the scouring that could occur during an extreme event could be more severe after the project is implemented because of greate flow concentration in some channels due to reduction of embankment overtopping. Nevertheless, this effect would also be erased by the large number of subsequent normal tidal cycles.

The additional constricting effect of the higher embankment that only apply during very high water levels experienced during severe cyclones that would overtop existing embankments. The raising and strengthening of embankments under CEIP-1 (17 polders in the Ganges Tidal Plain) has only the limited impact on extreme water levels in some areas. The cumulative impact of the CEIP-1 improvements on the extreme water levels generated by Cyclone Sidr was simulated and presented in the Strategic Plan (Volume II, Part B, of the Final Report). It was found that the impacts of CEIP-I were small (maximum ~25 cm) and very local to the vicinity of the cyclone track. This implies that the impacts of the project on the extrem water levels in transborder rivers will be small, even after several phases of CEIP have been completed.

Sea level rise and changes of upstream precipitation can cause changes in bed levels and sedimentation patterns as well as the extent and intensity of slaine intrusion. However, it is very important to keep in mind that these climate change impacts will be the same whether the project was implemented or not.The improved drainage systems to be installed would help mitigate climate change impacts within the polders but these too will have a negligible impact on the river system outside the polders.

7.7 Initial Environmental Examination Reports

Initial Environmental Examination (IEE) reports have been prepared for each of the 17 polders. These reports are assembled in Volume IX of this report. The reports also present draft terms of reference for the Environmental Impact Assessment Report that has to be prepared for each of the 5 polders where the detailed design has been carried out.

8.0 SEDIMENTATION AND MORPHOLOGY

8.1 Introduction[12]

The sedimentation and drainage congestion problems encountered in the tidal rivers in the South West Region have been the subject of much study as well as much speculation. The principal mechanism of this sedimentation process is the movement of the tremendous volume of very fine silt and clay particles that are found in the tidal rivers and creeks in the southwest region. There is, at all times, a very high concentration of these fine particles held and carried in suspension. All larger rivers, even in the tidal part of the region, have sandy bottoms and are fringed with unconsolidated deposits of this fine mud which can be mobilised easily by the flow. There are other consolidated deposits that are not easy to mobilise. While there has been disagreement about the source of this sediment – whether these sediments originate in the Ganges or in the Bay of Bengal – the fact remains that there is sufficient mud already present within the system and in deposits just offshore to keep the sedimentation processes active for an indefinite period.

While some sediment is washed further into the Bay of Bengal and removed from the river system, the only other sink available is the retention of some sediment on the land that is occasional flooded by high tides. This process is now restricted to the area presently occupied by the Sundarbans Mangrove Forest. Before the creation of a large number of polders from the 1960s onwards, there was a much larger sink for absorbing the silt deposits. The major hydraulic impacts of the process of polderisation have been (DHI, 1994)

a) A large reduction of tidal cubature caused by preventing tidal flooding in a large area of land now protected by embankments,

b) A general increase in the tidal range throughout the region. (e.g., 50 per cent increase in the tidal range at Chalna Port)

The increased tidal range initially improved the performance of the flap gate drainage regulators installed to provide drainage of polder lands. However, the reduction of tidal volumes have set in motion sedimentation processes that have been very detrimental to the efficient functioning of some parts of the river system in recent years.

The large estuaries (Malancha, Raimangal, Pussur-Sibsa, Baleswar etc) in the South West Region were carved out by the main stem of the Ganges that flowed through them over successive millennia. In recent times these large channels have been maintained by the large semidiurnal tidal flows that flow in them, despite the continuing decline in the upstream fresh water flows that used to occur in the monsoon. The construction of the polders has however reduced the tidal cubature to such an extent that the river channels have slowly adapted themselves by reducing their cross sectional area so that they could approach a new equilibrium between the sediment laden tidal flow and the flow velocity in the channel.

The above concept applies equally to the small rivers as well as the larger rivers with sandy beds. This process of adjustment was not yet complete even in 1994 (DHI, 1994). The large river whose adaptation has had an economically significant impact has been the Rupsa-Pussur. Siltation of this river affected the navigation route from Hiron Point originally to the Port of Chalna and later to Mongla Port. The second sea port of Bangladesh was moved 18 km downstream from Chalna to Mongla in 1954 to accommodate large ocean-

[12]This chapter contains several extracts from the Morphology Report of the Ganges Barrage Study Project (2011)

going vessels. By the 1980s the operation of the Port of Mongla was severely hampered by the loss of navigational depth. It is important to re-iterate that the reduction in tidal cubature triggers a corresponding reduction in cross sectional area – whatever the bed material.

During the same period the progressive accumulation of muddy deposits was observed in in several of the smaller tidal rivers and creeks in the South West region. Wherever any regulating structure was built across a tidal waterway, the very rapid sedimentation was observed downstream of the structure, permanently closing off the structure in some instances. The loss of water depth eventually led to the choking of the tidal flow and rapid reduction of the tidal range. This problem was first taken seriously when the certain polders became waterlogged because the reduction in tidal range outside the polder. In the context of CEIP-1, the polders most affected are polders no. 17/1 and 17/2.

While upstream freshwater flows could help to keep some small rivers free of siltation, it would be a serious mistake to assume that restoring flow in the Gorai will contribute significantly to maintaining navigation depths at Mongla Port.

When discussing the causes of drainage congestion and remedial action it has to be kept in mind that the process of sedimentation and drainage congestion began with the construction of the polders and not with the construction of Farakka Barrage. The lack of fresh water induced by the dry season diversions at Farakka has a primary impact on saline intrusion. The impact on sedimentation is indirect.

Sea Level Rise: These processes of sedimentation would be impacted by the predicted gradual rise of sea levels over in the medium and long term. The overall impact would be a gradual rise of all bed levels in the estuaries which will attempt to keep up with the rise in sea level. This is a global effect which will be discussed in detail in the Volume II (Strategic Plan for CEIP) of this report.

8.2 Tidal River Management for Maintaining River Depth

Drainage congestion is the most serious problem faced by a large section of the population in the empoldered areas. Although it has been shown that much of the drainage congestion is caused by lack of maintenance of drainage structures, and in places due to the downright abuse of these structures, the sedimentiton in peripheral rivers is the main cause of waterlogging in the more inland polders bounded by small rivers. The sedimentation mechanism is known and it has been proved time and again that clearing the sediment deposits by dredging or excavation *is at best a temporary solution*. This is because increasing the cross section of a river beyond its equilibrium level would only induce more rapid sedimentation which would try to return the river to its older cross section.

Tidal River Management (TRM) is the name given to the mechanism that has been proposed as a solution. The concept which was developed during the KJDRP project was based on increasing the tidal flow volumes in selected areas by allowing controlled flooding of certain low lying lands in a planned manner. Although the concept was initially controversial – there appears to be wider acceptance of the methodology after several years of experience. *The TRM process is in itself not a permanent solution either*. The area that is flooded will eventually fill up with sediment and after several years not be usable as a tidal basin. However, the bed levels in this beel would have risen significantly allowing agriculture to make a comeback. The owner(s) of such lands would need to be compensated for the loss of agricultural output in the period (usually 6 years) that the land will be used as a tidal basin. The potential for fisheries would however be improved during this period.

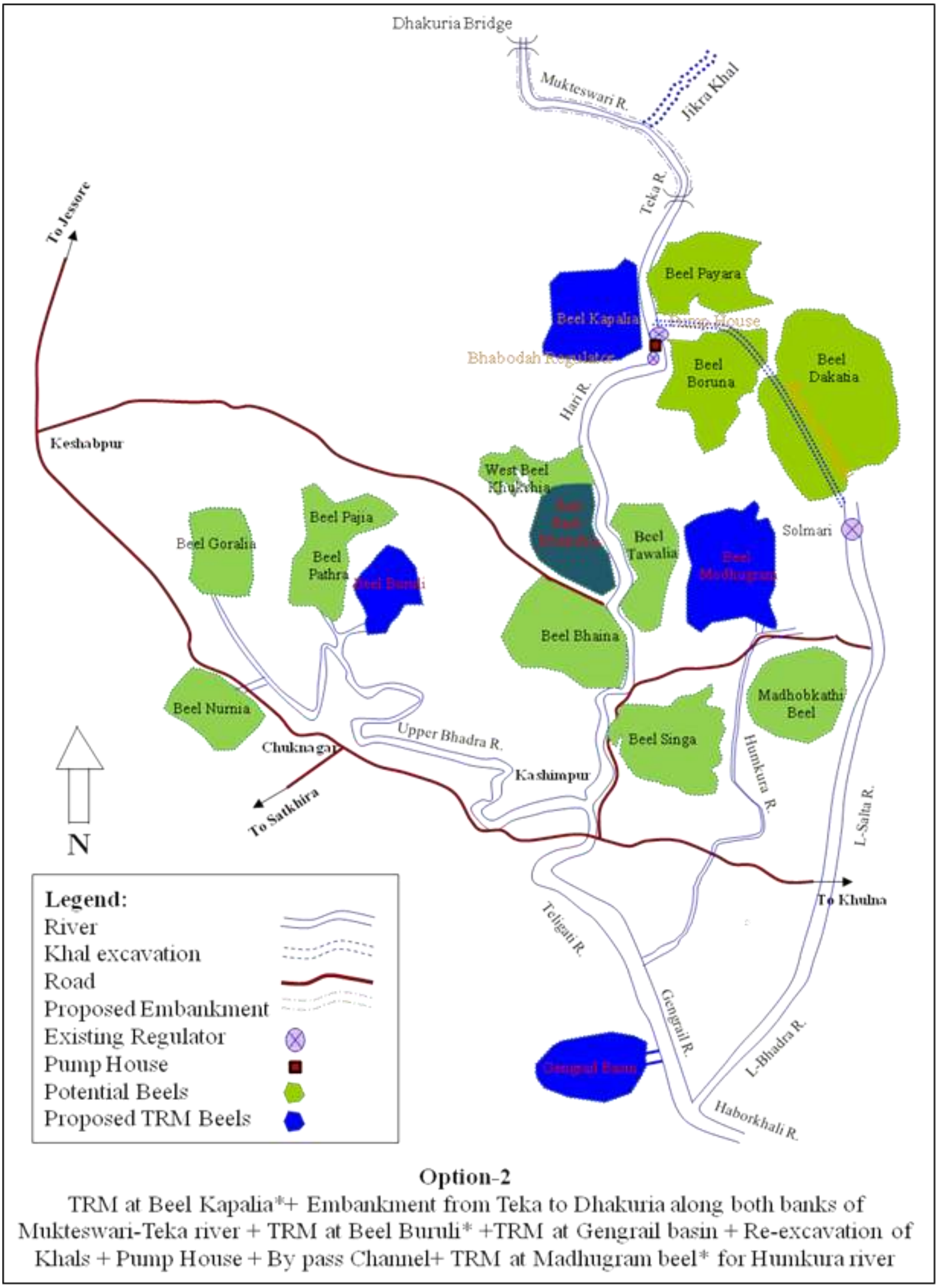
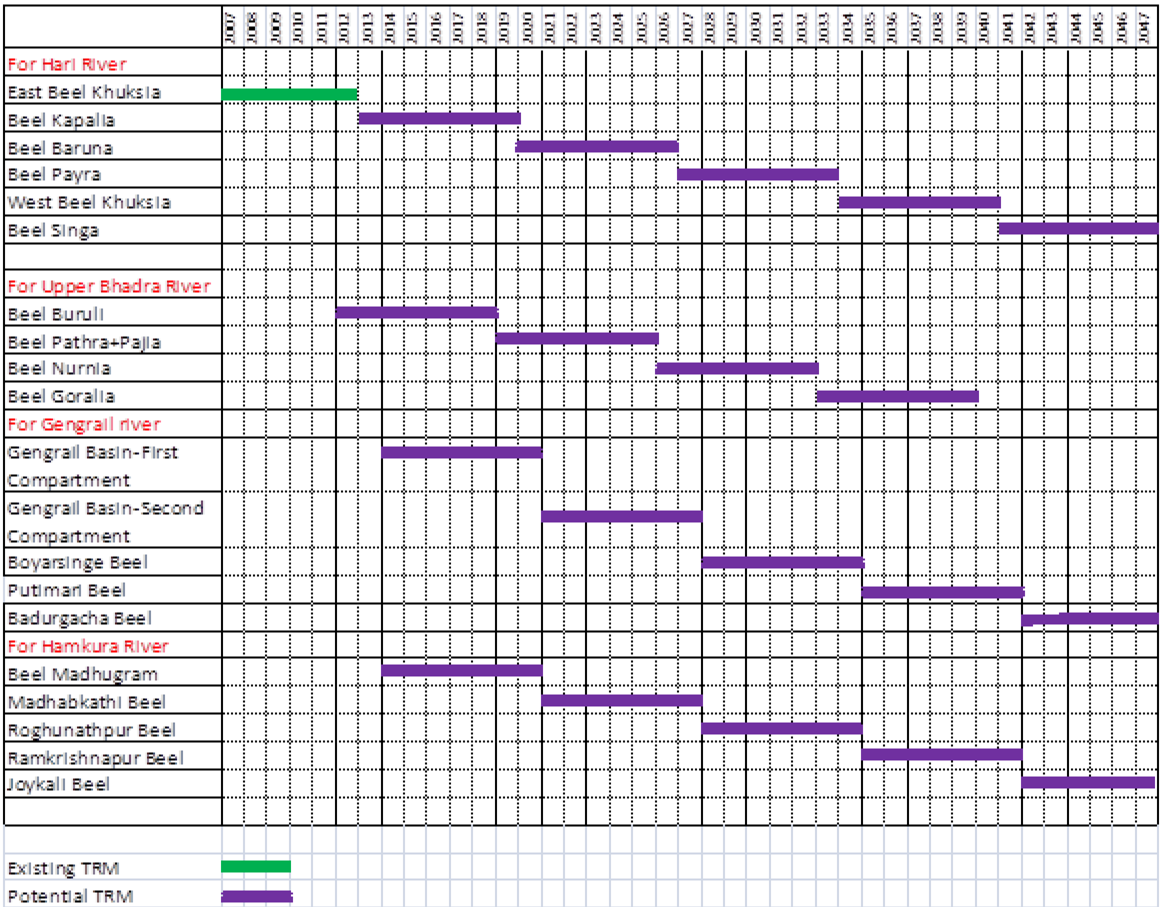


Figure 8.1 Potential Tidal Basins in Polders 24 and 25. (IWM, 2010)

Once a tidal basin is used up it will be necessary to move on to another beel that would function as the next tidal basin. The effectiveness of a tidal basin and its projected useful life can be assessed by modelling. For each river that is affected by drainage congestion one or more beels have to be selected to function as tidal basins. Figure 8.1 shows the areas drained by the Hari, Teligati/Gengrail, Hamkura and Bhadra rivers.

Table 8.1 shows a proposed sequence of TRM that could be implemented to keep four rivers (presently affected by drainage congestion) free of congestion for a period of 40 years. Nevertheless the solution will cease to be effective in 2047 of the embankment, structures, canals and foreshore and for nothing else.

Table 8.1 Sequence of Beels proposed for Drainage Control by TRM (IWM, 2010)



The long term approach to TRM and its importance with respect to the need to counter long term subsidence is discussed in Volume II (Strategic Plan for CEIP).

Alternative Approach to Managing Drainage Congestion

The TRM approach is comprehensive but requires wide consultation and agreement with stakeholders. There are however other approached possible. For example, when there are large active rivers on several sides of a polder and only one small peripheral khal that is prone to sedimentation, it is usually possible to rearrange the drainage network in such a way that the affected area is drained away from the silted channel into a larger peripheral river. Where this is not possible it might be necessary to excavate a peripheral river to restore drainge with the knowledge that this channel would require re-excavation at a later date.

8.3 Navigation Problems at Mongla Port

The navigation problems at Mongla Port have been studied many times from the 1970s onwards. The key studies are the Pussur Sibsa Study (DHI, 1993), FAP4, OGDA (2001) and IWM (2004). These studies have been very detailed and have been supported by extensive field measurements.

There are several elements to the navigation problem. They are:

a) Sedimentation in the approach channel from Jefford Point to the Fairway Buoy. This navigation approach channel crosses the outer bar along the Zulfiqur Channel which has shallow depths at several point.

b) Sedimentation in the vicinity of the port of Mongla had made it necessary to conduct regular dredging to maintain navigability. Capital dredging efforts have not been found to be sustainable.

The following observations can summarise the current understanding of the problem reached after the many credible studies the have been carried out in the past twenty years:

a) The reduction of the flow area of the Pussur River is the result of a general reduction in river cross sections that was triggered by the polder construction projects that began in the 1960s and continued into the 1970s. Main cause was the reduction in tidal volumes in all the rivers – which caused them to reduce in size to achieve a new equilibrium. DHI (1993) observed that the process had not yet reached equilibrium. The blockage some channels due to excessive sediment deposition could in turn reduce tidal volume even more – causing a continuing reduction in flow area.

b) Dredging the rivers to counteract the sedimentation process brings very temporary relief because the underlying cause has not been addressed.

c) While it is obviously not possible to dismantle the hugely productive and economically beneficial polder system – it is nevertheless necessary to restore tidal flows to some extent.

d) The TRM proposals for more peripheral polder areas are being considered as a longer term solution. These proposals, although they would have a small beneficial impact on the Pussur at Mongla would not make a practical difference to navigability. Creating new tidal basins will activate a TRM process to further increase tidal volumes in the Pussur.

e) Several studies have computed the impact of diverting large flows (~1000cumec) down the Gorai to “flush out” the sediments in the Pussur River. An improvement in the order of 5-10cm in navigation depths were predicted after such diversions are made!

f) Canalization of the river – i.e., constricting the river in crucial places to increase flow velocities has been found to be effective.

g) Sea Level Rise would effectively raise the bed – with probably not very much effect on flow depth.

The effect of Sea Level Rise is discussed in detail in Volume II.

8.4 Sedimentation & Erosion Problems in CEIP

River Bank Erosion

The large rivers that form the estuaries of the south west region undergo normal morphological processes where their thalwegs meander and propagate with the occasional consequences of erosion and accretion along some river banks. This process is constrained by the erodibility of the bank material and the stabilising influence of the mangrove forest. While there is a tendency towards net accretion in the more inland parts of the estuary (due to the polder effect), river banks of the larger estuaries would slowly move backwards and forwards cyclically. It is not possible to extrapolate the present rate of bank erosion for more than several years because the erosion (unless caused by some more permanent morphological mechanism) is likely to reverse itself after a number of years. Building a hard structure such as a revetment is not necessarily a permanent solution because the erosion zone would usually be displaced by the mere presence of the hard structure – requiring further intevention several years later.

There are a few locations where bank retreat is rapid and action has to be taken to protect (or move) the embankment. In most places, however, the bank retreat would be temporary and the most practical solution would be to provide adequate setback rather than provide expensive bank protection – unless the danger to the embankment is imminent. The monetary value of the land that needs to be acquired to accommodate the retirement of an embankment is usually much less than the cost of providing bank protection. Thus the only consideration that would allow us to provide bank protection is the disruption of settlements and displacement of people.

The act of raising and strengthening polder embankments do not have any adverse impact on river sedimentation. However, failure or breach of an embankment could cause disastrous erosion problems, mainly local to that point of failure and bring a massive amount of sediments into the river during the recession. The unusual flows that occur in the river system during the passing of a cyclone do not take place for a long enough period to cause significant morpohlogical change.

Drainage Congestion caused by Peripheral River Siltation of polders 16, 17/1 and 17/2

Among the 17 polders under CEIP-1, there are three instances of major drainage problems that were caused by siltation in the peripheral rivers in Polders 16, 17/1 and 17/2. These are acute because the northern reaches of Salta Riveris blocked by accumulated silt and previous experience indicates that re-excavation of this river would provide relief only for one or two years before it is silted up again. This is because Salta River is closed at its northern end by a closure dam and it cannot sustain itself by generating suffcient tidal volume. There is an on-going study by IWM of reviving this river by using a TRM process. The Kobadak River which forms the western boundary of Polder-16 is also badly silted up causing drainage problems on the entrie western flank of the region. Figure 8.2 shows the extent of siltation. The restoration of this river following the principles of TRM has been studied by IWM (2010)[13] and work in already in progress eliminating the drainage difficulties of the western boundary of Polder 16.

[13] Feasibility Study for Sustainable Drainage and Flood Management of Kobadak River Basin under Jessore & Satkhira District

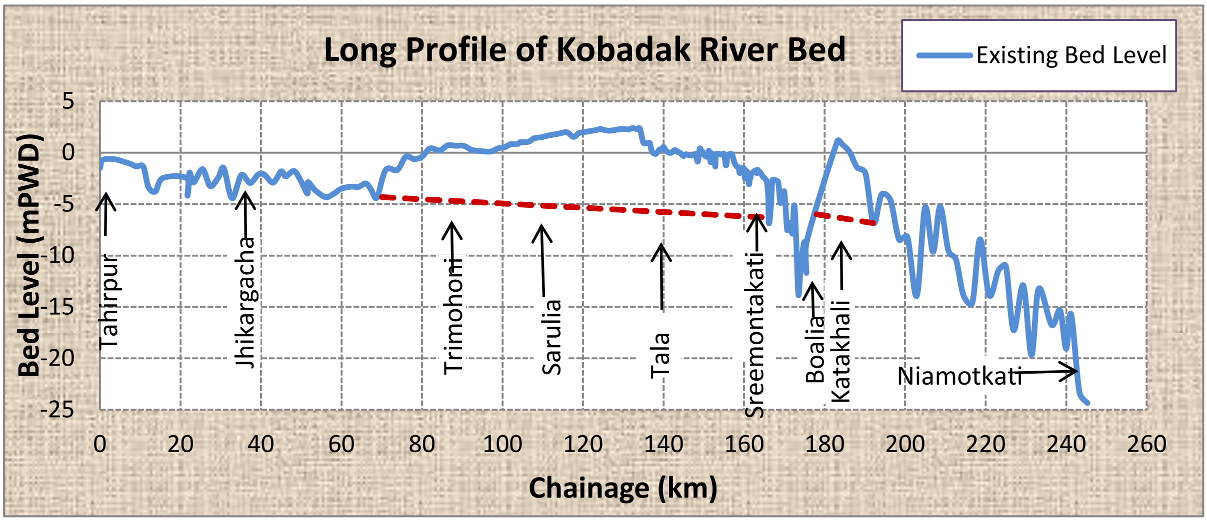


Figure 8.2: The Present Long Profile of Kobadak River

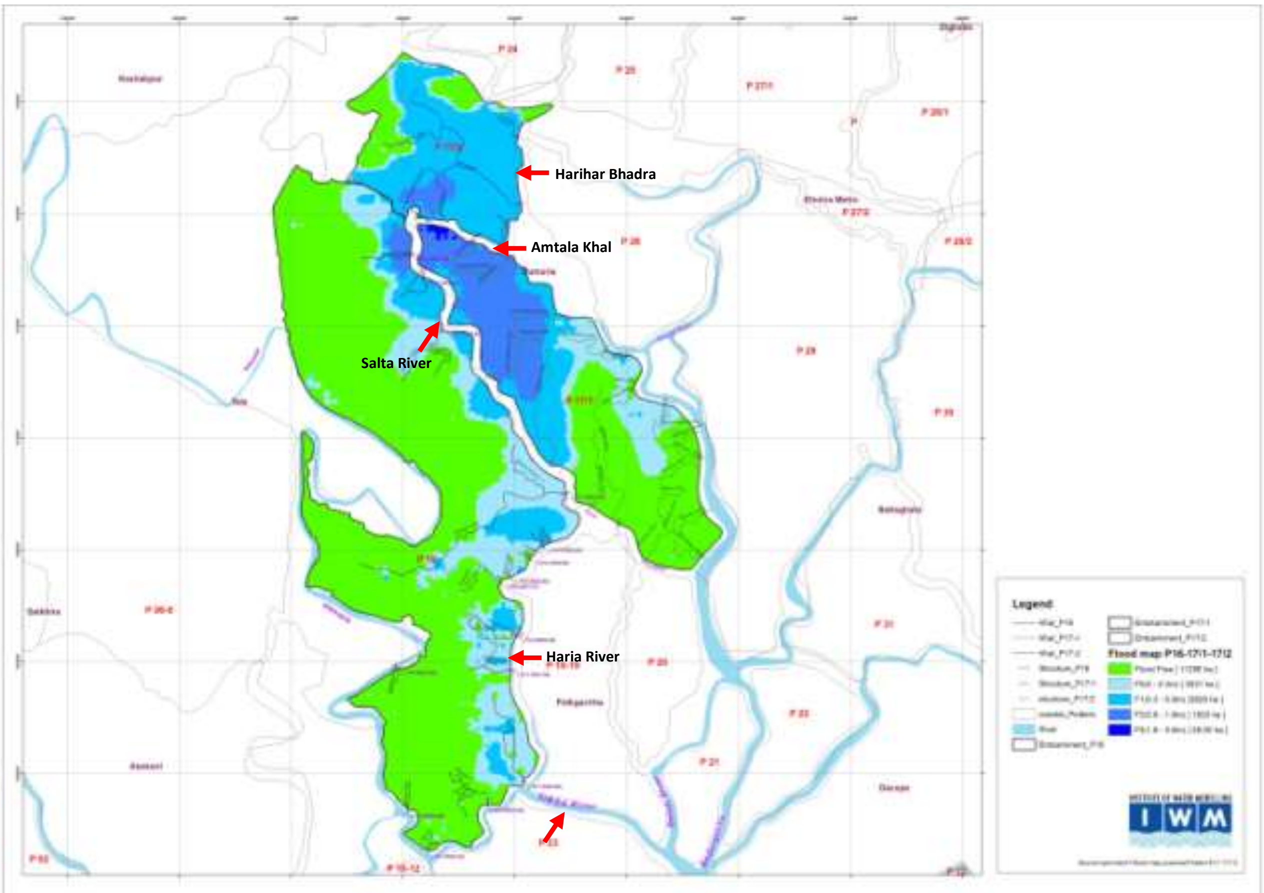


Figure 8.3: 3 Day Inundation Duration Map showing Polders 16, 17/1 and 17/2 (present condition – with Climate Change)

Figure 8.3 illustrates the drainage difficulties encountered in the cluster of polders (16, 17/1 and 17/2) due to the severe siltation problems in the river Salta and Amtala Khal. The siltation problems here are endemic and due to the reduction of tidal volumes due the the overall effect of polder construction and the more local effect of a cross-dam being built across the upper reaches of Salta River. The siltation is so severe that any attempt to excavate could be neutralised by further siltation within one season. Any sustainable improvement in the conveyance of the Salta River and Amtala Khal requires a more comprehensive solution which will address the root causes of siltation in these two rivers.

There is a TRM solution for this problem. Until this solution is implemented the problems of siltation affecting the northern reached on Polders 17/1 and 16 cannot be addressed except very temporarily. The problems in 17/2 could however be addressed separately and solved to a great extent by re-directing the drainage eastwards towards the Harihar/Bhadra River which has a healthy tidal regime.

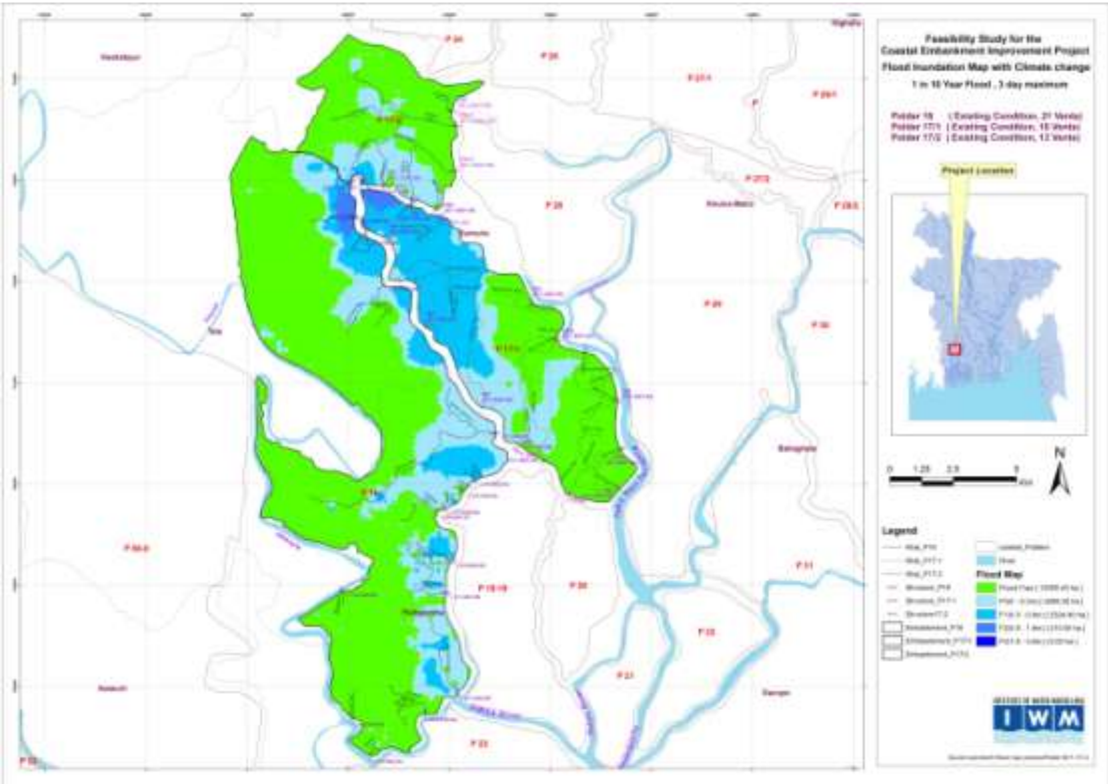


Figure 8.4: 3 Day Inundation Duration Map showing Polders 16, 17/1 and 17/2 (with interventions and Climate Change)

Drainage Congestion caused by Peripheral Rivers Siltation in other polders

There are a few other polders coming with CEIP-1 that are affected or are beginning to be affected by a moderate amount of silt build up in a peripheral river or khal. As the problem is not one of rapid siltation it would be appropriate to propose the following:

a) The first alternative would be to examine the possiblity of re-directing the drainage path towards a more active peripheral river.

b) If the re-direction of the drainage water away from the waterlogged area is not feasible then the only alternative is to excavate the khal – not to solve an immediate problem but to postpone it for a period of time. This type of solution requires that the siltation rate is monitored by regular (annual) surveys.

The polders of interest are shown in Table 8.2

Table 8.2 Rivers/Khals to be Excavated

Polder	Khal/River to be Excavated	Remarks
35/3	Putimari River	Excavate and Monitor
34/3	Putimari River	Excavate and Monitor
40/2	Badurtala-Tengra Khal	Excavate and Monitor
48	Mohipur Khal	Excavate and Monitor

9.0 INSTITUTIONAL ARRANGEMENTS FOR SUSTAINABILITY

9.1 Introduction

The CEIP is intended to improve the performance of the polders from the point of view of safety and effectiveness in providing for the water management needs of the polder population over the entire intended lifetime of the project (30 years) and longer, without significant negative social and environmental impacts. Very good design and execution is not sufficient to ensure this. The continued good performance of the 'hardware" (i.e., the drainage system, the flushing inlets and the embankment) does depend on excellent operation and maintenance. Excellent operation and maintenance does not happen automatically; *it needs resources and an effective institutional arrangement* to make good use of resources. This too is not sufficient. It is even more important that the users of the variety of services provided in the polder are able to avail themselves of those services amicably and without conflict. Thus it is possible to say that even the best engineering designs will need to be supported by an effective institutional arrangement to provide the "software" to sustain the project over a long period.

9.2 Operation and Maintenance[14]

There is no denying the fact that the Operation and Maintenance (O&M) of large scale water resources projects in Bangladesh are chronically under-financed. BWDB field offices have a common complaint that they are always provided with insufficient funds to cover the exact requirement of major preventive maintenance works; but also in most cases the funds are so small that it is not possible to undertake even minor maintenance work. Thus for the years together vital works of preventive maintenance are deferred and eventually pushed downstream to the point where expensive rehabilitation measures would have to be undertaken. Several studies for O&M of BWDB sub-projects and polders have addressed this issue in depth and many suggestions have been put forward. The most relevant to the current assignment i.e., "Guidelines for O&M Planning and Budgeting, August 2001; CERP-II" have been consulted very carefully. Moreover the Consultants discussed all the pros and cons of polder-O&M issues with BWDB's field staff and local stakeholders to suggest this approach for polder O&M planning.

The consultant's experience while studying the effectiveness of the existing drainage networks prior to renovation has shown that most (if not all) of the drainage difficulties experienced in the polders are a result of defective or damaged structure and much of this could have been avoided had there been adequate maintenance. Thus the importance of operation and maintenance cannot be over emphasised. In fact the massive investment being made by CEIP to improve the polders would be lost within a decade unless resources and institutional support is made available on a continuing and sustainable basis throughout the life of the project.

Past experiences show that preventive maintenance of polders (embankments, structures, canals and foreshore) through community participation is a successful strategy. This has been the most effective O&M strategy due to its organisational simplicity, robustness in nature and cost effectiveness. Success however depends on the active participation of the local stakeholders. To make participation worth and meaningful, stakeholders should be allowed to express their ideas freely right from the planning process to actual implementation stages.

[14]These observations are based on the O & M report reproduced as Volume X of this report of this report.

The prioritization of maintenance works when there is a shortage of funds; interaction with local government, NGOs etc. in organising a sustainable maintenance regime is discussed in detail in Volume X of this report.

9.3 Community Participation

Although in Bangladesh the experience of community participation in polders' O&M is not very old, it gives much valuable insight to further adoption in future maintenance. Community participation in maintenance is best rewarded by the provision of common amenities such as tube wells and other material benefits and facilities rather than by direct payments. Secondly, the settlers and /or the functional groups should be clearly told at the beginning that the contracts are not perpetual rather performance based and will be renewed after certain period.

The Embankment Settlers and the functional groups with the responsibilities of preventive maintenance may be allowed a particular reach of embankment, borrow pit, or foreshore lands as the case may be with the condition that they will live (preferably by erecting suitable houses at the country side toe at their own) here and/or enjoy the usufructuary rights of plantation in lieu of effective preventive maintenance of the infrastructure only. So the groups would have the understanding and belief at the very initial stage of settlement that whatever assistances are being allowed to them are only for the sake of preventive maintenance of the embankment, structures, canals and foreshore and for nothing else.The success however depends on the active participation of the local stakeholders. To make participation worth and meaningful, stakeholders should be consulted right from the planning process to actual implementation.

There should have some accountability on the part of the community based organizations (CBO) involved in the O&M activities. This obviously needs a fair assessment of the preventive maintenance activities they actually accomplished over a certain period of time. The assessment needs to be done twice in a year; once at the beginning when the polders will be jointly supervised to record the actual conditions of the infrastructures i.e., more specifically the requirement of probable preventive works will be listed and finally at the end of the year another joint verification will be made to ascertain the real accomplishment of the maintenance jobs by the ESs and/or functional groups (EPG, FFG, CMG &EMG).. Continuous guidance and monitoring the performance of CBOs by BWDB Field staffs may make the CBOs more accountable and preventive maintenance program will also become successful. In the process of this joint verification and assessment, the Local Government Institutions (LGIs) i.e. Union Parishad leaders/representatives (Ward Members) should be involved for active support and cooperation.

9.4 Institutional Arrangements

Participation

The need for sound institutional arrangements and and communitiy participation in maintenance has already been discussed above. A multi-user facility like a polder system requires to be operated efficiently and without conflict. This can be done only through community participation. Participation by the local community and other stakeholders can occur at four broad levels; Information sharing, Consultation, Decision-making and Implementation. A real participation of local communities in a development process means effective involvement of the primary beneficiaries in all these levels without undermining their knowledge and expertise. Much of the relative strength of rural people's knowledge lies in what can be observed locally and over a sustained period, and in what touches directly their lives and livelihoods. Most obviously, this applies to their knowledge of customs and practices. Descriptive and conceptual terms also provide points of departure for scientific investigation which may be more practical and useful than the externally determined categories of outsiders' knowledge.

The paricipation of the community and other stakeholders is best actuated through the formation of several bodies such as Polder Development Committee (PDC), Water Management Organisation (WMO). Proposals for constituting these bodies have been given in the Institutional Report (Volume X of this report).

Institutional Basis to Promote Community Participation

Within the Guidelines for Participatory Water Management (GPWM) provision has been made to develop Water Management Organizations (WMOs) involving the concerned local people. The structure and composition of WMOs depend on the nature and objective of the development project. From the consultation held with local people and considering the objectives of CEIP it seems that at the bottom level Water Management Organizations can be developed on the basis of Hydrological units to be constructed within the framework of this project. This refers to the fact that a Water Management Organization will be formed for each hydrological unit involving different classes of people including poor and women living within the benefitted area of that particular unit.

To make these WMOs more beneficial to local communities, efforts need to be made to include different conflicting classes of people in this water management organization like farmers and fishermen always have their different position on the issue of water management for crop and fish cultivation. In principle this WMO will be the real user/ owner of the infrastructure by providing their services for day-to-day operation and maintenance of the structures to be developed. These WMOs can be registered within the framework of the Cooperative Societies Act in order to provide them a legal basis. Considering the area available within the each polder and the WRS required to be constructed in each polder, it would be more realistic to form a Polder Development Committee (PDC) for each polder comprising the representatives from each WMO formed within the polder area. Local Government Institutions, in this case the concerned Union Parisad can play a vital role in activating this PDC as focal point for overall polder development. Representatives from Bangladesh Water Development Board as well as from other service provider agencies (like DAE, DOF, DOL and DOC) can be included in the PDC. Representatives from the NGOs operating in the area can also be included in the PDC. (a detailed TOR for both WMO and PDC are presented in the following section) It will be worthwhile to mention here that under no circumstances the community representation will be under representation. In order to focus the community interests on top and also to make it more workable for the local communities, concerned Local Government Institution can lead this PDC. The main role of this PDC will be among others to ensure the availability of required cooperation/ services of BWDB including other service providers and to guide and monitor the day-to-day performance of WMOs in discharging their assigned tasks and responsibilities

10.0 ECONOMIC AND FINANCIAL ANALYSIS

10.1 Description of the Study Polders

10.1.1 General

Out of 139 polders, 17 polders have been considered for feasibility study of which five polders are considered for detailed design under the first year programme package. Out of the 17 Polders, 35/1 14/1, 15, 40/2, 41/1, 43/2c, 47/2, 48 and 39(2c) are considered as storm surge affected polders and polders nos. 35/3, 16, 17/1, 17/2, 23 and 34/3 are diagnosed as flood affected polders. Polders 32 and 33 are affected nearly equally by both storm surges and floods. In other words, out of seventeen polders selected for study, nine polders are classified as storm surge affected polders and remaining 8 polders are considered as flood affected polders The design of the polders (embankment, protection works and drainage system) were based on the need to resist both storm surge and flood impacts, each of return period 25 years. The benefits that would accrue from project interventions included the benefits of avoiding damages due to either storm surge or floods and not from both. Therefore the estimate of this type of benefit is conservative. Polders 32 and 33 were taken as flood affected polders for this purpose. The salient features of the seventeen polders are given in Table10.1.

Table 10.1: Summarized Main Features for Seventeen Selected Polders under CEIP-I

S.No.	Polder No.	Location	Length of Emb'kment (km)	No. of Drainage Sluice	No. of Flushing Inlets	Drainage Channel (km)	Polder Population	Avg. HH Size	No. of HH
1	14/1	Koyara	30.50	3	4	13.00	20,578	4.57	4,468
2	15	Shyamnagar	30.78	4	8	14.24	31,788	5.35	5,755
3	16	Pailgacha, Tala	45	12	20	26.88	1,18,616	4.62	19,472
4	17/1	Dumuria	38.50	11	0	30.23	23,919	4.35	5,461
5	17/2	Dumuria	11	4	0	11.85	34,070	4.51	7,554
6	23	Paikgacha	37	11	25	20.15	23,888	4.26	5,605
7	32	Dacope	49.50	8	23	17.50	38,397	4.51	9,700
8	33	Dacope	52.50	12	17	63.21	62,305	4.34	14,354
9	34/3	Bagerhat	16.75	3	6	9	65,399	4.75	13,652
10	35/1	Sharankhola	62.50	17	20	70.50	99,182	5.63	17,783
11	35/3	Rampal/ Bagerhat Sadar	40.00	4	10	23.50	31,075	4.39	6,747
12	39/2C	Matbaria	61.50	13	12	57.23	84,853	4.59	18,486
13	40/2	Patharghata	35.58	12	13	36.70	41,317	3.94	10,360
14	41/1	Barguna Sadar	33.81	6	24	31	41,051	4.36	9,301
15	43/2C	Galachipa	25.70	6	18	24.55	14,851	4.13	3,596
16	47/2	Kalapara	17.55	4	6	7.25	5,411	4.21	1,285
17	48	Kalapara	37.88	8	3	31	26,260	4.13	644

These Polders were conceived in the year of 1960 under Coastal Embankment Project (CEP). Construction of the Polder was started in 1961 and completed in different years. Different types of additions such as drainage sluices, flushing inlets and flushing cum drainage sluices as well as re-excavation of canals, construction of a closure dam etc. were carried out after wards. The original concept of construction of these polders was only to protect the agricultural lands from salinity intrusion caused due to tidal inundation from the sea and river. In the present context, the polder embankments are under heavier threat of storm surge, flood, wave attack and increasing risks brought about by climate change.

10.1.2 Project Activities

Many segments of the embankment in different places have been damaged during SIDR and to a lesser extent by AILA mostly through overtopping of embankment, severe wave action and river erosion. All the existing drainage sluices are in a very deplorable condition and have become almost non-functional. All these structures were constructed in early 1970 and the concrete surfaces are severely affected by salinity. The upstream and downstream aprons of the sluices have been damaged. The loose aprons have also either been damaged or washed away. The gates of many sluices are either damaged or missing or non-functional. The embankment so far damaged have to be rebuilt based on surge height and sea level rise due to climate change scenarios. In some places alternative structures are to be constructed as per the outcome of the mathematical modeling study. The internal drainage channels have become silted up which needs to be re-excavated for smooth drainage.

In order to make comprehensive rehabilitation of the polder the consultants have identified the major activities as per actual field condition which are: i) Re-sectioning of embankment, ii) Backing of embankment towards C/S, iii) Retirement of embankment, iv) Slope protection work, v) Bank protection work, vi) Afforestation on the foreshore area, vii) Repair of existing sluice (if repairable), viii) Replacement of existing sluice, ix) Construction of alternative structures, x) Construction of additional structure (if required), xi) Construction of cross dam and xii) Land acquisition etc.[15]

10.2 Methodology

10.2.1 General

Economic analysis of environmental impacts is important in project preparation to determine whether the net benefits of undertaking the project are greater than the alternatives, including the non-project scenario. Project alternatives often vary in their economic contribution and environmental impacts. Economic assessment of different alternatives in the early stages of project planning should provide important inputs to improve the quality of decision-making. The economic analysis of the environmental impacts of the selected project will allow for a more complete assessment of the project's costs and benefits.

The steps followed for undertaking the economic and financial analysis of environmental impacts are: i) identification of environmental impacts and their relationships to the project, ii) quantification of environmental impacts and ordering them according to importance, iii) assessment of appropriate monetary values for economic and financial analysis of environmental impacts identified; and iv) deciding appropriate time frame and perform the extended benefit-cost analysis.

[15] Source: For details, please refer to CEIP-I engineering report for selected polders.

10.2.2 Basic Assumptions

The primary benefits from the planned improvement program for embankments are:

i) Benefits in the form of damages avoided due to less frequent overtopping;

ii) Benefits in avoidance of water logging within the polders; and

iii) Benefits from the foreshore afforestation program.

The first category of benefits will be the result of raising and strengthening the embankment; the second category of benefits emanate from restoring and improving the drainage systems of the polders in order to ensure adequate drainage capacity even under future adverse conditions induced by climate change (to eliminate water logging) better regulate water flow into and out of the polders to serve the present and future needs of the community. The foreshore afforestation, where sufficient land is available for planting, dissipates wave energy and partially or fully protects the embankments from slope erosion as well as reducing overtopping due to wave run-up. There are other economic benefits that follow from managing the plantations through a social forestry initiative.

Overtopping and Inundation

In the cases of polders threatened by storm surge, it has been assumed that once an existing embankment is overtopped, it is highly likely that the embankment will be breached. The principal underlying reasons behind this assumed scenario are: most of the embankments were built almost forty years ago, and have now spent their designed life span; suffer from poor maintenance; have been weakened by unauthorized installation of flushing inlets, and were manually compacted instead of being mechanically compacted. When an embankment is breached, the water depth reaches a minimum of 1.5 to 1.75 meters. The depth of the saline water, along with the speed with which it flows, causes the damage. However, the water starts to recede within a few hours. On the other hand the breached embankment could open the polder to flooding at every high tide making agricultural activity impossible until the breached are repaired and the saline water evacuated through the drainage system (where it is still functioning).

On the other hand, for the polders threatened by river severe flooding, when and once the water overtops the embankment, it continues to flow in for a few days at a stretch. This results in complete inundation of the whole polder.

Reduction of Probability of Overtopping

In order to estimate the benefits from the incremental height of an embankment, it is essential to first estimate the reduction in the risk or probability of overtopping and inundation[16]. The reduction in the probability of overtopping is then to be multiplied by the mean damages inflicted by a storm surge/river flood to arrive at the expected damages in the absence of the CEIP-I.

Method of Damage Estimation

In order to estimate the damages from a storm surge, we have two choices of measurement. One involves predictions of the depth of water by area in the polder concerned. However, analyzing of possible such scenarios requires a huge amount of time

[16] Refer Annex1.0 Table 1.0 for a better description and assumption of the concept.

and resources to obtain reliable and accurate estimates. For this study, due to constraints of time and resources, this option was not feasible.

Another way of obtaining estimates for future damage scenarios, is to get estimates from a past storm surge and then deduce the probable damage estimates for other storm surges, which may be stronger or weaker than the past one. Perhaps this route for estimating damages is a better option, in the sense that it is based on actual experience, rather than solely based on theoretical constructs of such scenarios. The study has followed the second alternative route.

With regard to the estimation of damage due to river flood, the fundamental assumption here is that the whole polder will remain inundated for at least 5 to 7 days. In low lying areas, the inundated period will be even longer. In the cases of river flood induced overtopping, we have assumed different parameters of damages for different sectors. These parameters were arrived at after extensive consultation with the relevant experts, as well as after taking into account the uniqueness of the flooding mechanism in the coastal polders.

Return Period

IWM has estimated that the return period of the existing embankment of storm surge polders is only 6 years, whereas the storm surge “Sidr” had a return period of 35 years for some of the storm surge polders directly affected. As a result, the embankment was overtopped. However, when the newly designed embankments are in place, the return period of the newly erected embankment will be 55 years, mainly because sea level rise, subsidence, and an increment in wind speed will take place only in the future (the design will resist a 25 years return period storm occurring 30 years in the future). The storm surge level caused by Sidr, with a 35 year return period, was well below the height of the planned embankment.

Obviously, the damages caused by a weaker storm surge, say one that has a return period of slightly more than 6 years, will cause less damage than Sidr on the existing polders. On the other hand, a storm surge, perhaps of a 55 year return period, will cause more damage to the polders than Sidr. The implicit assumption here is that the damages and the storm surge water levels are positively correlated. We have assumed that the relationship between storm surge water levels and damages is linear, which, in reality, may not be accurate. For example, one can easily imagine that after the devastation of a Sidr-like storm surge, there will be fewer things to damage. However the coverage of area will increase.

In order to remain on the conservative side, it is assumed that the damages caused by a 55 year return period storm surge will cause only 1.25 times the damages that Sidr has caused. On the other hand, even after breaching the embankment, the storm surge that has a return period of slightly more than 6 years, is assumed to cause only 25% of damages caused by Sidr. Hence, on average, a storm surge that has a return period between 6 and 55 years, with its accompanying storm surge level, will cause only 75% (0.25+1.25=1.5/2=0.75) of the damages caused by Sidr.

With climate change, due to eustatic sea level rise and other factors of relative sea level rise – such as subsidence – (and the intensification of storm cyclones) the return period of the existing embankment may get reduced, say from 10 years to 2 years. Similarly, the return period of the planned or newly installed embankment may go down from 55 to 25 years (Table 2).

With regard to the cases of river flood induced over topping, with climate change, due to ecstatic sea level rise and other factors of relative sea level rise – such as subsidence – the return period of the existing embankment may get reduced, say from 10 years to 1.5 years. Similarly, the return period of the planned or newly installed embankment may go down from 87 to 25 years. The return periods of the embankments of these polders are assumed to be the means of the return periods of the embankments of the polders 32, 33, and 35/3 (Table 10.2).

Table 10. 2 Return Period of Seventeen Polders

Particular	Probability of Overtopping		Return Period in Years	
	2010	2040	2010	2040
	Eight Storm Surge Polders			
1.Existing Embankment	0.167	0.500	6	2
2. New Embankment	0.018	0.040	55	25
1-2	0.148	0.460		
	Five Flood Affected Polders			
1.Existing Embankment	0.100	0.667	10	1.5
2. New Embankment	0.012	0.040	87	25
1-2	0.088	0.627		
	Polder No. 35/1			
1.Existing Embankment	0.167	0.500	6	2
2. New Embankment	0.018	0.04	55	25
1-2	0.148	0.46		
	Polder No. 32			
1.Existing Embankment	0.100	0.670	10	1.5
2. New Embankment	0.010	0.040	100	25
1-2	0.090	0.627		
	Polder No. 33			
1.Existing Embankment	0.100	0.667	10	1.5
2. New Embankment	0.014	0.040	70	25
1-2	0.086	0.627		
	Polder No. 35/3			
1.Existing Embankment	0.100	0.667	10	1.5
2. New Embankment	0.011	0.040	90	25
1-2	0.089	0.627		

10.3 Prices

All costs and benefits are adjusted to market prices of 2011. Parity prices of major traded commodities are calculated based on World Bank Commodity Price Projections (See Volume VI). Financial prices of agricultural inputs and outputs used for farm budget analysis are collected from respective Upazilla/Union Parishads (U/P) Agricultural Offices, Upazilla Statistical Offices, from field visits by interviewing the local farmers. The discount rate is taken as 12% which is the standard practice in Bangladesh. For the purpose of economic analysis, assumptions are made as per FAP Guidelines for Project Assessment (GPA).[17]

[17] Details of both financial and economic prices of inputs and outputs are shown in the annexes to the individual polder analyses in Volume VI.

10.4 Conversion Factor (CF) and Shadow Wage Rate Factor (SWRF)

Individual Conversion Factors are derived for all major items of works for the project and it has been adopted for the purpose of analysis. In addition, a Standard Conversion Factor (SCF) of 0.902 has also been derived for Bangladesh as a whole. A shadow wage rate factor (SWRF) 0.75 has also been derived and used for local unskilled labour, so that it cannot create any harmful effects on the labour market through unemployment and efficiency. No residual value was assumed at the end of the project life. The detailed calculations of CF, SWRF and estimates of conversion factors for local cost component of capital cost items and estimates of conversion factor for local cost component of O & M cost items and Standard Conversion Factor are given in Table 10.3a, 10.3b and 10.3c [18].

Table 10.3a: Estimates of Conversion Factor for Local Cost Component of Capital Cost Items

Item	Skilled Labour		Unskilled Labour		Materials		Taxes & Duties		F.E.C		Transportation		Total	
	%	CF	%	CF	%	CF	%	CF	%	CF	%	CF	%	CF
Embankment	6.375	0.902	78.625	0.75		0.902	15	0		1		0.902	100	64.72
Re-excavation of Drainage Channel	6.375	0.902	78.625	0.75		0.902	15	0		1	0	0.902	100	64.72
Protective work	17	0.902	17	0.75	25	0.902	15	0	20	1	6	0.902	100	76.046
Drainage Structure	17	0.902	17	0.75	25	0.902	15	0	20	1	6	0.902	100	76.046
Dismantling of structure	20	0.902	55	0.75	10	0.902	15	0	0	1	0	0.902	100	68.31

Table 10.3b: Estimates of Conversion Factor for Local Cost Component of O & M Cost Items

Item	Skilled Labour		Unskilled Labour		Materials		Taxes & Duties		F.E.C		Transportation		Total	
	%	CF	%	CF	%	CF	%	CF	%	CF	%	CF	%	CF
Embankment	6.38	0.9	78.6	0.75		0.902	15	0		1		0.9	100	64.72
Re-excavation of Drainage Channel	6.38	0.9	78.6	0.75		0.902	15	0		1	0	0.9	100	64.72
Protective work	10	0.9	55	0.75	15	0.902	15	0	5	1	0	0.9	100	68.8
Drainage Structure	10	0.9	60	0.75	10	0.902	15	0	5	1		0.9	100	68.04

[18] For details, Pl. sees individual polders detailed Financial and Economic analysis in Volume VI.

Table 10.3c: Estimation of Shadow Wage Rate Conversion Factor for Unskilled labour

Peak Season			
a	Market wage	200	BDT/pd
b	Estimated marginal product of labour	160	BDT/pd
c	Marginal value product in peak season (abs)/2	180	BDT/pd
Lean Season			
d	Food for works wage rate (amount of wheat)	7	Kg
e	Leakage	10 per cent	
f	Discrepancy - market wage in lean season & FFW wage	20 per cent	
g	Marginal product of labour in lean season(amount of wheat)[d(1-e)(1-f)]	5.04	Kg
h	Average price of wheat(2005/06-2009/2010) adjusted 2011	18	BDT/kg
i	Marginal product in peak season (gxh)	90.7	BDT/pd
Unemployment & under employment			
j	Un/under employment in a whole year	20 percent	
k	Un/under employment in months (jx12)	2.4	month
l	Total lean months	6	month
m	Employment in lean season in month (l-k)	3.6	month
n	Employment in lean season as percent of total lean season [(m/l)x100]	60 percent	
o	Marginal product of labour in lean season adjusted for un/under employment (ixn)	54.43	BDT/pd
Marginal product of labour			
p	Marginal product in peak season (c)	180	BDT/pd
q	Marginal product in lean season (o)	54.43	BDT/pd
r	Months in peak season	6	month
s	Months in lean season	6	month
t	Marginal product: weighted average of peak & lean season [{(pxr)+(qxs)}/12]	117.22	BDT/pd
Marginal product in border price			
u	Share of rice in food grain consumption	85 per cent	
v	Share of wheat in food grain consumption	15 per cent	
w	Conversion factor of rice	1.0024	
x	Conversion factor of wheat	1.0005	
y	Conversion factor in food grain consumption{(uxw)+(vxx)}	1.0021	
z	Marginal product of labour expressed in border prices (txy)	117.46	
Social cost of consumption			
aa	Marginal product of capital (MPK)	15.5 per cent	
ab	Savings rate (s)	11 per cent	
ac	Consumption rate of interest (CRI)	12 per cent	
ad	Social value of investment relative to consumption (v) [{aax(1-ab)}/{ac-(aaxab)}]	1.34	
ae	Border to domestic price ratio for labor's consumption	1.06	
af	Social cost of consumption: 2nd term in Shadow wage rate (SWR) expression [(a-t)x(1-1/ad)xae}	22.26	BDT

Peak Season			
Shadow wage rate			
ag	Shadow wage rate for unskilled labour in project construction (z+af)	139.73	BDT/pd
ah	Shadow wage rate for unskilled labour in crop cultivation([{bx(1-j)+af}]	150.26	BDT/pd
Shadow wage conversion factor for unskilled labour.			
ai	Market wage (a)	200	BDT/pd
aj	Conversion factor for unskilled labour in project construction (ag/ai)	0.70	
ak	Conversion factor for unskilled labour .in crop cultivation (ah/ai)	0.751	

10.5 Project Cost

10.5.1 Investment Cost

The engineering cost estimates were taken as the starting point. These costs include taxes. The schedule of works considered as one that reflects the priorities for implementing the structures/equipment in conjunction with the annual envisaged investment flows. The project cost is based on constant 2011 prices, including direct and indirect charges and are expressed in foreign currency (US$) and local currency (BDT). The total project cost includes physical contingencies @ 5 percent and design, supervision & administrative charges @ 5 percent. Economic costs exclude resettlement cost, tax & duties and price contingencies. The exchange rate assumed for the project is US$1 = BDT 82. The proposed total financial investment cost estimated for the project amounts to BDT 25996.42 million or US$ 317.03 million (Table 10.4). The proposed total economic investment estimated for the project amounts to BDT 18947.28 million or US$ 231.06 million in 2011 prices (Table 10.5).

Table 10.4: Summary of Project Costs (Financial) for Seventeen Polders

I. Investment Costs	Polder 32	Polder 33	Polder 35/1	Polder35/3	* Strom surge(8 Polder)	* * Flood Affected(5 Polder)	Total
A. Civil Works							
1. General Mobilization	8.46	10.79	24.57	6.92	58.35	22.00	131.08
2. Embankment					-	-	-
New/Retired Embankment	387.80	310.33	742.13	364.53	2,425.88	940.36	5,171.04
3. Khal					-	-	-
Re-excavation of Drainage Channel	16.83	137.22	127.70	120.98	122.68	66.04	591.45
4. Structure					-	-	-
Drainage Structure (new)	190.79	342.63	406.01	98.23	1,396.06	862.75	3,296.47
Drainage Structure (repair)	-	-	13.24	-	16.90	28.58	58.72
Flushing Inlet (new)	24.67	146.86	219.38	123.33	1,000.72	432.56	1,947.51
Flushing Inlet (repair)	56.84	12.59	7.61	-	27.12	34.95	139.11
Protective work (slope protection)	126.64	224.98	1,605.63	13.34	1,776.50	198.07	3,945.16
Protective work (bank protection)	257.02	277.97	199.52	220.64	1,426.99	59.81	2,441.94
Dismantling of Road/Structure	37.46	57.60	59.37	32.10	161.97	156.32	504.81
Closure	105.52	-	-	-	55.00	-	160.52
Day Work	1.64	2.09	4.77	1.34	11.03	4.13	25.01
Subtotal	800.57	1,064.72	2,515.53	488.97	5,872.28	1,777.17	12,519.25
5. O & M during construction /**a**	30.34	38.08	85.25	24.53	211.98	70.14	460.32

I. Investment Costs	Polder 32	Polder 33	Polder 35/1	Polder35/3	* Strom surge(8 Polder)	* * Flood Affected(5 Polder)	Total
Subtotal	1,244.00	1,561.15	3,495.17	1,005.93	8,691.18	2,875.71	18,873.14
B. FS & ESS					-	-	-
Afforestation	1.89	2.35	0.72	0.85	5.62	3.32	14.74
Resettlement	174.40	188.28	174.40	79.21	1,186.79	472.50	2,275.58
Subtotal	176.29	190.62	175.12	80.06	1,192.41	475.82	2,290.32
C. Land Acquisition	80.40	30.00	75.00	18.00	403.15	98.10	704.65
D. EMP	27.26	47.94	24.06	30.40	199.34	69.00	398.00
E. Consultancy Service for supervisions and monitoring	52.59	67.10	152.73	43.00	318.63	124.20	758.25
F. O&M Training for staffs and beneficiaries	0.80	0.85	1.00	0.75	5.08	3.25	11.73
G. Engineering and Administration /**b**	31.10	39.03	87.38	25.15	217.28	71.89	471.83
H. Provisional Sum /**c**	31.10	39.03	87.38	25.15	217.28	71.89	471.83
Total Base line Cost	1,643.55	1,975.72	4,097.84	1,228.45	11,244.34	3,789.86	23,979.75
Physical Contingencies	82.18	98.79	204.89	61.42	562.22	189.49	1,198.99
Price Contingencies					-	-	-
Inflation					-	-	-
Local	55.06	67.87	142.27	42.25	380.90	129.33	817.68
Foreign	-	-	-	-	-	-	-
Subtotal Inflation	55.06	67.87	142.27	42.25	380.90	129.33	817.68
Devaluation	-	-	-	-	-	-	-
Subtotal Price Contingencies	55.06	67.87	142.27	42.25	380.90	129.33	817.68
Total Project Cost	1,780.78	2,142.38	4,445.00	1,332.11	12,187.46	4,108.68	25,996.42

a/2.5% of Civil works

b/2.5% of Civil works

c/2.5% of Civil works

* Storm surge (8 polders) = Polder 39/2C, 14/1, 15, 40/2, 41/1, 43/2C, 47/2 & 48
* * Flood affected (5 polders) = Polder 16, 17/1, 17/2, 23 & 34/3

Table 10.5: Summary Project Economic Costs (BDT Million)

Particulars	Polder 32	Polder 33	Polder 35/1	Polder35/3	Strom surge(8 Polder)	Flood Affected(5 Polder)	Total
I. Investment Costs							
A. Civil Works							
1. General Mobilization	6.49	8.27	18.83	5.30	44.74	16.87	100.50
2. Embankment					-	-	-
New/Retired Embankment	250.98	200.85	480.31	235.92	1,570.03	608.60	3,346.70
3. Khal					-	-	-
Re-excavation of Drainage Channel	10.89	88.81	82.65	78.30	79.40	42.74	382.79
4. Structure					-	-	-
Drainage Structure (new)	145.07	260.54	308.73	74.69	1,061.56	656.03	2,506.63
Drainage Structure (repair)	-	-	10.06	-	12.85	21.73	44.65
Flushing Inlet (new)	18.76	111.67	166.82	93.78	760.94	328.92	1,480.88
Flushing Inlet (repair)	43.22	9.58	5.78	-	20.62	26.58	105.78
Protective work (slope protection)	96.30	171.08	1,220.92	10.14	1,350.85	150.61	2,999.90
Protective work (bank protection)	195.44	211.37	151.72	167.77	1,085.08	45.48	1,856.85
Dismantling of Road/Structure	28.72	44.16	45.52	24.61	124.18	119.85	387.04
Closure	80.91	-	-	-	42.17	-	123.07
Day Work	1.26	1.61	3.66	1.03	8.46	3.16	19.17
Subtotal	609.67	809.99	1,913.21	372.03	4,466.72	1,352.37	9,523.99
5. O & M during construction /a	30.34	38.08	85.25	24.53	211.98	70.14	460.32
Subtotal	908.37	1,146.00	2,580.25	716.09	6,372.87	2,090.72	13,814.29
B. FS & ESS					-	-	-
Afforestation	1.45	1.80	0.55	0.65	4.31	2.54	11.30
Resettlement	133.71	144.35	133.71	60.73	909.91	362.27	1,744.69
Subtotal	135.16	146.15	134.26	61.38	914.22	364.81	1,755.99
C. Land Acquisition	72.52	27.06	67.65	16.24	363.64	88.49	635.59
D. EMP	20.90	36.76	18.45	23.31	152.83	52.90	305.15
E. Consultancy Service for supervisions and monitoring	40.32	51.44	117.10	32.97	244.29	95.22	581.35
F. O&M Training for staffs and beneficiaries	0.61	0.65	0.77	0.58	3.89	2.49	8.99
G. Engineering and Administration /b	31.10	39.03	87.38	25.15	217.28	71.89	471.83
H. Provisional Sum /c	31.10	39.03	87.38	25.15	217.28	71.89	471.83
Total Baseline Costs	1,240.09	1,486.13	3,093.23	900.86	8,486.31	2,838.42	18,045.02
Physical Contingencies	62.00	74.31	154.66	45.04	424.32	141.92	902.25
Price Contingencies					-	-	-
Inflation					-	-	-
Local	-	-	-	-	-	-	-
Foreign	-	-	-	-	-	-	-
Subtotal Inflation	-	-	-	-	-	-	-
Devaluation	-	-	-	-	-	-	-
Subtotal Price Contingencies	-	-	-	-	-	-	-
Total Project Costs	1,302.09	1,560.43	3,247.89	945.90	8,910.62	2,980.34	18,947.28

10.5.2 Reconstruction Costs of Dismantled Roads

In the process of improving on the existing embankments, a number of kilometers of bituminous carpeting and HBB roads have to be dismantled. In order to account for the damages and losses caused by this, we have assumed 20% of the reconstruction costs of the dismantled roads as losses per year until the roads are back in operation. In the year following the construction of the embankments, the roads are expected to be rebuilt. The cost of reconstructing the roads is assumed to be a part of the capital cost occurring in the year following the last year of construction. Per kilometer construction costs of similar quality bituminous carpeting and HBB roads were collected from the LGED[19]. Table 10.6 present the cost of dismantling of roads of 17 polders. It is estimated that about 66.08km of HBB road and 101.69 km of carpeting road would be dismantled at a total cost of about BDT 815.27 million or US$ 9.94 million and the economic cost of dismantling works out to be BDT 737.37 million or US$ 8.97 million.

Table 10.6: Dismantling of Roads of 17 Polders

Sl. No.	Name of Polder	Dismantling Road		Cost(Million BDT)	
		HBB Road*	Carpeting Road**	HBB	Carpeting
		in Km	in KM	in Km	in KM
1	Polder - 14/1	0.7	-	2.1	0
2	Polder - 15	1.7	-	5.1	0
3	Polder - 16	3.55	3	11.55	15
4	Polder - 17/1	5	7	24	42
5	Polder - 17/2	4	5	12	30
6	Polder - 23	6.5	1.75	19.5	10.5
7	Polder- 32	9.3	0	27.9	0
8	Polder- 33	25.5	0	76.5	0
9	Polder - 34/3	1.2	0.54	3.6	3.24
10	Polder - 35/1	1	12	3	72
11	Polder- 35/3	4.4	0.3	13.2	1.8
12	Polder - 39/2C	3.23	8.21	9.68	49.26
13	Polder - 40/2	-	13.28	0	79.68
14	Polder - 41/1	-	29.11	0	174.66
15	Polder - 43/2C	-	4	0	24
16	Polder - 47/2	-	-	0	0
17	Polder - 48	-	17.5	0	105
Total		66.08	101.69	208.13	607.14

10.5.3 Operation and Maintenance Cost

Estimated Operation & Maintenance (O&M) cost has been worked out according to BWDB standard practice. The O&M costs include the estimated expenditures for the maintenance of embankments, khal, structures and protective works, afforestation etc. No replacement cost is included as it is considered as part of the O&M cost. The financial recurrent cost of O&M has been estimated at 589.3 million or US$ 7.19 million. per annum for the seventeen polders as a whole. The economic cost of annual O&M and replacement for different goods and services for these polders is derived from financial O&M and replacement costs statements by using the weighted economic conversion factor. The economic O&M cost

[19] Cost of constructing HBB road (BDT 3 million/km) and cost of construction of carpeting road (BDT 6 million/km).

works out to be BDT 421.9 million or US$ 5.15 million per annum. The O&M costs starts from 4th year of the project's life cycle. The O&M cost is given in Table 10.7.

Table 10.7: Summary of O&M Cost of Seventeen Polders (BDT million)

Item of Works	Investment Costs	% of O&M Cost	Financial O&M Cost	CF	Economic O&M Cost
1. Embankment	5171	3.0%	155.1	0.647	100.4
2. Khal	591	3.0%	17.7	0.647	11.5
3. Structure	6132	2.0%	122.6	0.688	84.4
4. Protective work	6130	3.0%	183.9	0.688	126.5
5. Physical Contingencies	1374	3.0%	41.2	0.902	37.2
FS & ESS	2290	3.0%	68.7	0.902	62.0
Total	21688	0	589.3	4	421.9

10.6 Project Benefits

10.6.1 Assessment of Avoided Damages and Loss

At the outset, we acknowledge enormous difficulties and limitations in assessing damages and losses. Given the large uncertainties about the magnitude and timing of the added risks from climate change, it is essential to identify the potential damage and losses caused to agriculture and allied sectors production and loss, properties, assets and other infrastructure due to a cyclone of the magnitude of Sidr. Embankments will protect all polders both from storm surges as well as river floods. For the purpose of our analysis, we have considered either storm surge or river flood impact whichever has the major dominant cause with respect to a particular polder.

Potential damages and losses in each of the major economic sectors resulting from cyclones or river floods are computed. They are determined by applying sector-specific damage and loss functions to the affected assets and activities in the sector assessed. Those sector specific damage and loss functions are either derived from the Sidr experience or have been arrived at after consultation with relevant experts. The major economic impacts on different sectors are likely to be the same in terms of magnitude and scale as that of those which incurred damages and losses during cyclone Sidr in 2007.

Damages include complete or partial destruction inflicted on assets. Losses refer to the goods and services that are not produced or rendered ineffective due to a disaster. Losses also include increases in disaster-induced cost being incurred in continuing and maintaining essential services. Data about damages and losses caused due to SIDR was obtained from *Upazilla* office of respective storms and flood affected polders. For the purpose of economic analysis, we extrapolated the average percentage of damages and losses for polder no. 35/1 for different major economic sectors to arrive at figures, as close as possible, for the storm surge affected polders. The extrapolated values so obtained for different specific economic sectors were used for assessing damages and losses for storm surge polders.

For river flood affected polders, we have assumed different parameters of damages for different sectors. Those parameters were arrived at after extensive consultation with the relevant experts, and after taking into account the uniqueness of the flooding mechanism in the coastal polders. We extrapolated the average percentage of damages and losses of polder nos. 32, 33, and 35/3 for different major economic sectors to arrive at figures for the remaining flood affected polders.

Expected changes in the Bangladesh economy, including growth in population and income, and structural shifts in the economy, are applied uniformly to assess the expected assets and activities for seventeen polders over the next thirty years. The current spatial distribution of assets and activities provides the starting point for identifying the assets and activities that will be exposed to inundation risks for the next thirty years. The avoided damages/benefits identified and assessed are:

- Avoidance of Storm Surge/Flood to Crop Damage,
- Estimation of Water Logging damage to Agricultural Output
- Livestock Benefit,
- Fishery Benefit,
- Afforestation Benefit
- Housing Damage(Property) Benefit
- Road Damage Benefit
- Human lives Benefit and
- Commercial Benefit

Avoidance of Storm Surge/Flood to Crop Damage

Crop losses accounted for nearly 90-95 percent of agriculture sector damages and losses during cyclone Sidr. Damages and losses to fisheries and livestock were much smaller. Crop losses from a specific storm surge may vary based on the season during which it strikes. Historical records show that Bangladesh is about twice as likely to be hit by a tropical storm surge in the post-monsoon season as in the pre-monsoon season (67 per cent and 33 per cent). The expected crop damages caused by a storm surge are the probability-weighted crop damages.

The cropping calendar (planting/harvesting dates) of the major rice crops, Aman, Aus, and Boro, are different. Aus is grown in the pre-monsoon season (Kharif-I: March-June), Aman is grown in the monsoon season (Kharif-II: July-October), and Boro is grown in the post-monsoon season (Rabi: Nov-Feb.). If a storm surge occurs in a given year, the probability of it striking during the Kharif season is assumed to be 67%, and the probability for Rabi and the other seasons is assumed to be 33%. The percentage of crop-land affected, based on Sidr data, is assumed to be 64% for all seasons. On average, 65% of the standing crop will be lost for any storm stricken piece of cultivated land. This figure is based on field assessment. The agricultural output is likely to decline in such a situation. The agricultural output is likely to be affected by such extreme events. Table 10.8 gives the assumed probability of storm surge and damage factors used for computing agricultural production damages for storm surge polders.

Table 10.8 Assumed Probability of Storm Surge and Damage

Sl. No.	Particulars	Percentage
1.	Probability of a storm surge striking during Kharif season	67%
2.	Probability of a storm surge striking during Rabi and other season	33%
3.	Percent of affected cropped land	65%
4.	Percent of crop damage	64%

Inundation risk exposure in an area is characterized by the maximum potential inundation depth that may occur for any storm surge under a given scenario. Storm-surge related risk is expected to increase from this level due to climate change. Future storms tracks cannot be predicted with any degree of precision. SIDR and AILA have hit the polders in the year 2007 and 2009 and damaged about 55-65% crops and washed away food storages and personal stockpiles, and destroyed fruit trees. The rice crop was the hardest hit among many affected central crops including pulses, vegetables (an important source of income and nutrition), and bananas.

Regarding river flood polders, it is assumed that only Aus and Aman will be impacted. The damage parameters have been arrived at after consultation with project experts and others. The assumptions for percentage damages to the crops are: 25% damage to crops in F0 land, 50% to crops in F1 land and 60% for other lands. The rising proportion of crop damages is due to the fact that water tends to recede more slowly as the land category goes down. The cultivated areas of the seventeen polders got extensively damaged through different means and amount of losses that occurred during 2007-2011 are given in agricultural report[20] for these polder. The highest crop damage (50-80%) occurred in the year 2007 and 2009 by natural calamities like SIDR and AILA.

Crop losses resulting from a cyclone are determined in detail for all major crops both under storm surge and flood conditions. By 2042-43, the agriculture sector is expected to grow at an annual average growth rate of 2.4 percent, largely through increases in yields (Yu et al. 2010). As a result, by 2042-43, yields for Aman, Aus, Boro and other crops are expected to rise. The net estimated financial values of avoided agricultural damages and loss through implementation of CEIP-1 works out to be about BDT 1095.46 million or US$ 13.36 million annually and given in Table 10.9. The net estimated economic values of avoided agricultural damages and loss through implementation of CEIP-1 work out to be about BDT 1075.10 million or US$ million annually.

[20] For detail pl. refers CEIP-I Agricultural reports for all seventeen polders as well as economic analysis reports of all these polders.

Table 10.9 Total Incremental Benefit

(Million BDT)

Project Benefits	Items	Polder 32		Polder 33		Polder 35/1		Polder35/3		Strom surge(8		Flood Affected(5		Total	
		Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.	Fin.	Eco.
Avoided damage	Value of Life lost	0	0	0	0	2952	2662.7	0	0	1320.4	1191	0	0	4272.4	3853.7
	Property Damage	214.5	193.5	216	194.8	584	526.7	101.5	91.6	1590	1434.2	798	719.8	3504.0	3160.6
	Road Damage	427.6	385.7	967.3	872.5	206	185.8	897.5	809.6	1419.2	1280.1	2246.3	2026.2	6163.9	5559.8
	Crop Damage*	78.3	78.5	59.9	60	219.3	211.9	59.8	59.9	487.9	474.1	190.3	190.7	1095.5	1075.1
	Livestock	1.9	1.8	2.9	2.6	75.6	68.2	6.5	5.8	128.8	116.2	7.4	6.7	223.2	201.4
	Fisheries	14.4	13	35.9	32.4	148.4	133.9	307.4	277.3	863.9	779.3	219.1	197.6	1589.2	1433.5
	Non-agricultural Productive Sectors**	29	26.5	50.5	45.8	164.9	149.3	54.1	49	229	207.9	136.4	123.8	663.9	602.3
	Total avoided damage	765.8	698.9	1332.5	1208.1	4350.2	3938.5	1426.9	1293.2	6039.2	5482.8	3597.5	3264.8	17512.0	15886.3
	Reduction of overtopping probability	14.10%	14.10%	14.10%	14.10%	17.80%	17.80%	14.10%	14.10%	17.80%	17.80%	14.10%	14.10%		
	Ratio of average storm damage over Sidr damage	100%	100%	100%	100%	75%	75%	100%	100%	75%	75%	100%	100%	5.5	5.5
	Expected annual value of damage	**107.7**	**98.3**	**187.3**	**169.9**	**579.7**	**524.9**	**200.6**	**181.8**	**804.8**	**730.7**	**505.8**	**459**	**2386.0**	**2164.5**
Additnl'l annual Benefit	ESS & FS	3.4	3	2.8	2.5	1.3	1.2	1.5	1.3	10.2	9.2	6.2	5.6	25.3	22.8
	Water logging	148.3	117.1	163	152.1	235	205.2	117	96.8	963.5	934.1	958.8	923.9	2585.6	2429.1
Total Benefits		**259.3**	**218.4**	**353.1**	**324.4**	**816**	**731.2**	**319.2**	**280**	**1778.6**	**1674**	**1470.8**	**1388.5**	**4996.9**	**4616.5**

Avoidance of Loss from Water Logging

Regarding the water logging benefits, it has been assumed that in absence of the project, 30% of land from one land category will deteriorate to the next lower land category. For example, 30% of F_0 category land will be relegated to the F_1 category, and 30% of F_1 will move to the F_2 category, and so on and so forth. This will change the existing cropping pattern. The change in production will work through changes in yield per hectare and reduced cropping intensity. The most impacted crops, Aus and Aman, are considered in the exercise.

According, to IWM estimates, the water logging situation will even improve over the current situation if the project is implemented. For example, F0 land in seventeen polders currently constitutes about 59.61% of total land, but decreases to 42.27 % under a without-project situation. With the project, however, (even after climate change), un-inundated area or F0 land is expected to increase to 97.68%. Similarly, F1 land currently constitutes about 36.26% of total land. However, under a with-project situation, F1 land reduces to only 2.12 % of total land. After consultation with the relevant experts, it has been estimated that, in the absence of the regular stop gap measures that are currently being undertaken, water logging will arrive within the first five years if the project is not implemented(Table 10.10).

Table 10.10: Areas under Different Types of Land under 17 Polders

Land type & flood depth	Present situation	Without project situation	With project situation
F0	51493	36517	84376
%	59.61%	42.27%	97.68%
F1	31320.5	37078	1831
%	36.26%	42.92%	2.12%
F2	3539	11754.5	174.5
%	4.10%	13.61%	0.20%
F3	29	1032	0
%	0.034%	1.195%	0.000%
F4	0	0	0
%	0	0	0
Total	86381.5	86381.5	86381.5

The adequate availability of irrigation water/facilities, removing of drainage congestion and arresting intrusion of saline water by repairing of sluice gates, the polder will receive protection from tidal and monsoon flooding and will prevent salinity intrusion. In dry season the embankment will check inflow of saline water. In monsoon, cultivated area would be protected from inundation by tides. The regulators will be used for intake of water during drought and preserve sweet water in the Khals for irrigation to Rabi crops. In other words, with the modernization and renovation of embankment, i.e. under with project situation (climate change), entire cultivable area would be free from water logging and salinity which can sustain agricultural production ecology and environment. The net estimated economic values of agriculture benefit (Water logging) through implemetation of CEIP-I works out to be about BDT 2429.10 million annually and given in Table 10.9.

Crops, Cropping Pattern and Cropping Intensity

Under the present situation, single cropping is the main practice covering approximately 58.04 per cent of the net cultivated land followed by double cropping 36.31 percent and triple cropping 5.65 percent. On an average, the present cropping intensity is observed to be about 147.61 per cent. Under the without project situation, it is assumed that situation would deteriorate further and area under single cropping would increase (70.54%), double cropping and triple cropping would reduce progressively over a period to 25.62 % and 3.84 % respectively in that order. On the other hand with the implementation of project, area under single cropping would reduce significantly (19.42 %) and area under double cropping would increase to 50.39 % and triple cropping to 30.19 %. (Table 10.11) as the entire cultivable land becomes un-inundated and available for cultivation as explained above. The cropping intensity would increase to 210.77 % from 147.61%.

Table 10.11: Types of Land Used Under Seventeen Polders

Particulars	Present situation	Without project situation	With project situation
Single Crop	50134.5	60933.5	16774.5
%	58.04%	70.54%	19.42%
Double crop	31369	22131	43530
%	36.31%	25.62%	50.39%
Triple crop	4878	3317	26077
%	5.65%	3.84%	30.19%
Total	86381.5	86381.5	86381.5
%	100.0%	100.0%	100.0%
Cropping Intensity	147.61%	133.30%	210.77%

Livestock[21]

The proportion of livestock which perished during Sidr has been applied to current and estimated future livestock numbers to predict future livestock deaths. Secular growth rates of livestock for the country over the years were applied to arrive at livestock deaths in the future. The net estimated financial values of avoided livestock damages and loss through implementation of CEIP-1 works out to be about BDT 223.24 million or US$ 2.72 million annually and given in Table 10.9. The net estimated economic values of avoided livestock damages and loss through implementation of CEIP-1 work out to be about BDT 201.36 million or US$ 2.45 million annually.

Fisheries[22]

The damages and losses that Sidr caused consist of damages to the fisheries infrastructure such as ponds, *dighis*, and *ghers*; damages to private fishing equipment such as boats and nets; damages to public infrastructure such as boundary walls, roofs, and electric lines in fisheries-related public buildings; and losses in catch or production. Many boats were reported lost, mostly small boats washed away by the surge.

We have ignored other damages and attempted to account for the value of lost fish output only. The percentage of fish output that would be lost when a Sidr like storm strikes is estimated to be 90%. However, we have assumed that only 50% of the yearly fish output would be in the water when the storm/flood occurs. Hence, only 45% of the yearly fish output is expected to be lost in a Sidr like storm, or if the polder is completely inundated by a river flood. The net estimated financial values of avoided fishery damages and loss through implementation of CEIP-I works out to be about BDT 1589.21 million or US$ 19.38 million annually and given in Table 10.9. The net estimated economic values of avoided fishery damages and loss through implementation of CEIP-I work out to be about BDT 1433.47 million or US$ 17.48 million annually.

[21] For detail pl. refers CEIP-I Livestock reports for all seventeen polders as well as economic analysis reports for all these polders.
[22] For detail pl. refers CEIP-I Fisheries reports for all seventeen polders as well as economic analysis reports for all these polders

Afforestation Benefits

As for foreshore afforestation benefits, its main contribution to the benefit stream is the protection it provides to the polders. However, as the improvement program is a composite one encompassing the embankment and afforestation programs, the afforestation benefits are not separately considered in order to avoid double counting. However, income stream from the forest in the forms of wood and other products are estimated and found to be small, in monetary terms, compared to other benefits. The net estimated financial values of afforestation benefits through implementation of CEIP-I works out to be about BDT 25.32 million or US$ 0.31 million annually and given in Table 10.9. The net estimated economic values of avoided fishery damages and loss through implementation of CEIP-1 work out to be about BDT 22.84 million or US$ 0.28 million annually.

Housing Damages[23]

In the past, the housing sector has accounted for a significant portion of storm surge damages. For example, in 2007, it accounted for half of the economic damage caused by storm surge Sidr (GOB 2008). The types of houses damaged were predominantly semi-*pucca* and *kutcha* houses. The same is true for river flood related damages. The damages inflicted consist of two types: i) structural damages and ii) damages to household goods. Obviously, wealthier households will suffer greater damages, in strictly monetary terms, to household goods. However, in terms of structural damages, it is the poorer households, who live in *kutcha* houses that suffer greater damages to the structures of their houses.

For the purpose of predicting housing damages in the future, we need to have some idea of what sort of houses people will live in in the future. Clearly, in the context of Bangladesh, as households cross a certain threshold of family income, they tend to move from *kutcha* houses to semi-*pucca* houses, and then on to *pucca* houses as their family incomes cross the next threshold.

Analysis of Bangladesh's 2005 Household Income and Expenditure Survey (HIES) data indicates that only 3.65 percent of rural households with a monthly per capita income of BDT 3500 or higher could afford *pucca houses*[24], 9.94 percent with a monthly per capita income of BDT 2000 or higher could afford to live in semi-*pucca*[25] houses, and about 86.41 percent of households with a monthly per capita income lower than BDT 2000 lived in *kutcha* houses[26]. Table 10.12 gives the distribution of households according to per capita Income groups in BDT at 2005 and 2011prices.

[23] For details, pl. refer CEIP-I individual polders economic analysis report for housing damage estimation.
[24] *Pucca* house :a brick house with a concrete roof
[25] Typical characteristics of semi-pucca housing are: foundation made of earthen plinth or brick and concrete, walls made of bamboo mats, CI sheet and roof made of CI sheet with timber framing.
[26] Typical characteristics of kutcha housing are: foundation made from earthen plinth with bamboo, walls made of organic materials, and roof thatched made of straw, split bamboo etc.

Table 10.12 Distribution of Households According to Per Capita Income Groups (in BDT)

Monthly per capita income groups(In BDT) at 2005 prices (5.20*)	% of Households	Annual per capita income groups (In BDT) at 2005 prices	Monthly per capita income groups (In BDT) at 2011 prices	Annual per capita income groups (In BDT) at 2011 prices
< 200	1.43	< 2400	< 344	<4128
200-249	1.20	2400-2988	344-428	4129-5136
250-299	2.12	2989-3588	429-515	5137-6180
300-349	2.58	3589-4188	516-600	6181-7200
350-399	2.83	4189-4788	601-686	7201-8232
400-449	3.59	4789-5388	687-772	8233-9264
450-499	4.16	5389-5988	773-859	9265-10308
500-599	8.76	5989-7188	860-1030	10309-12360
600-699	8.98	7189-8388	1031-1202	12361-14424
700-799	8.01	8389-9588	1203-1374	14425-16488
800-899	7.45	9589-10788	1375-1546	16489-18552
900-999	5.48	10789-11988	1547-1718	18553-20616
1000-1249	12.14	11989-14988	1719-2148	20617-25776
1250-1499	7.69	14989-17988	2149-2578	25777-30936
1500-1999	9.74	17989-23988	2579-3438	30937-41256
200-2499	4.53	23989-29988	3439-4298	41257-51576
2500-2999	3.25	2289-35988	4299-5158	51577-61896
3000-3499	1.9	35989-41988	5159-6019	61897-72228
3500+	4.16	42000+	6200+	74400+
Total	100			

Analysis of the 2010-11 population of seventeen polders indicates that households increasingly will move to "*pucca*" houses as their incomes rise. The projected increase in per capita incomes by next thirty years (2042-43) is expected to alter the mix of housing types of Polders. Nevertheless, it is expected that, by 2042-43, the vast majority (about 73.33 %) of households will live in pucca houses, suggesting a significant reduction in housing damage but a substantial rise in household asset damage from storm surges over a period. Table 10.13 gives the projected distribution of households according to per capita income groups in BDT along with GDP growth rate from 2005-6 to 2010-11 at 2011 prices.

Table 10.13: Distribution of Projected Households According to Per Capita Income Groups in BDT

Annual per capita income groups at 2011) prices with GDP growth rate*	% of Kutcha households	% of Semi Pucca households	% of Pucca house holds
< 21479	0.0143		
21480-26724	0.012		
26725-32156	0.0212		
32157-37463	0.0258		
37464-42833	0.0283		
42834-48203		0.0359	
48204-64312		0.0416	
64313-75052		0.0876	
75053-85792			0.0898
85793-96531			0.0801
96532-107271			0.0745
107271-134120			0.0548
134121-160969			0.1214
160970-214667			0.0769
214668-268365			0.0974
268366-322063			0.0453
322064-375824			0.0325
375825-387125			0.019
387126+			0.0416
	0.1016	16.51%	73.33%

*Source: Statistical Year Book of Bangladesh 2006, National Income Section, BBS

In the future, with rising per capita income, the distribution of houses among the *kutcha*, semi-*pucca* and *pucca* categories will keep changing. The Monetary value of damages inflicted on the housing sector due to storm surge or river flooding will also keep changing due to rising population and the changes in the distribution of houses among different categories.

In the exercise, we have projected future population growth, and the distribution of houses by category. On the basis of the projected numbers of households and houses by category, we have estimated the potential damages to the housing sector for both storm surge and river flood cases. We have assumed that *pucca* and semi-*pucca* houses can't be fully damaged. On the other hand, *kutcha* houses can suffer full damages, requiring complete reconstruction of the house. The damages to household goods have also been accounted for, keeping in mind that the distribution of houses by category will change in the future.

Population growth rate of Bangladesh for 2010-11 is reported to be 1.40. Average population growth rate of polders for 2010-11 is observed to be 1.30. According to Bangladesh Census 2011, projected growth rate of population of Bangladesh up to 2021 would be 1.15. This study estimated the population of seventeen polders for 2007 during Sidr from the present level of population of the polder in a reverse order by adding the estimated number of deaths that took place in all the polders due to Sidr.

According to the final estimate of Bangladesh Bureau of Statistics (BBS) the country had achieved GDP growth of 5.74 percent in FY 2008-09 amid unprecedented global financial crisis. BBS revised the provisional estimate of GDP growth at 5.83 percent for fiscal year 2009-10. However, based on updated trend of macroeconomic indicators, the Medium Term Macroeconomic Framework (MTMF) projected 6.0 percent GDP growth for the same period. The MTMF considered positive trend in export earning, increased production of Aman and Boro crops, growth of agricultural and industrial credit and the growth of imports of capital machinery and industrial raw materials for the projection of GDP growth. Moreover, the MTMF envisaged that the growth of GDP for the fiscal year 2010-11 will be 6.7 percent which will gradually increase to 7.2 percent and 7.6 percent in the fiscal year 2011-12 and 2012-13 respectively. As per vision 2021, the government will try to achieve 8 percent growth of GDP in 2013 and 10 percent in 2017.

Per capita GDP growth rate are estimated to be 4.9%, 4.85%, 4.42%, 4.46%, 5.60% and 5.29 for 2005-06, 2006-07, 2007-08, 2008-09 and 2010-11 respectively. Combined growth rate of GDP from 2005-6 through 2010-11 works out to be 1.33. For the purpose of analysis, this study projected GDP for next thirty years (2042-43) from 2010-11 onwards. It is assumed that GDP would grow at 6.5 per cent per annum for next thirty years. As such, per capita GDP at 2010-11 observed to be BDT 26023 and it is projected to increase to a level of BDT 135407 in 2042-43. In other words, Per Capita GDP would be 5.20 times higher in 2042-43 than GDP in 2010-11(Table 10.14).

Table 10.14: per Capita GDP

Project Year	Calendar Year	GDP at constant market price(Million BDT)	GDP Growth rate	Per capita GDP	Bangladesh Population (Million)
1	2010-11	38,48,850	0.067	26023	147.90
2	2011-12	4099025	0.065	27400	149.60
3	2012-13	4365462	0.065	28849	151.32
4	2013-14	4649217	0.065	30375	153.06
5	2014-15	4951416	0.065	31981	154.82
6	2015-16	5273258	0.065	33673	156.60
7	2016-17	5616020	0.065	35454	158.40
8	2017-18	5981061	0.065	37329	160.22
9	2018-19	6369830	0.065	39304	162.07
10	2019-20	6783869	0.065	41382	163.93
11	2020-21	7224821	0.065	43571	165.82
12	2021-22	7694434	0.065	45876	167.72
13	2022-23	8194572	0.065	48302	169.65
14	2023-24	8727219	0.065	50857	171.60
15	2024-25	9294489	0.065	53547	173.58
16	2025-26	9898630	0.065	56379	175.57
17	2026-27	10542041	0.065	59361	177.59
18	2027-28	11227274	0.065	62501	179.63
19	2028-29	11957047	0.065	65807	181.70
20	2029-30	12734255	0.065	69287	183.79
21	2030-31	13561981	0.065	72952	185.90
22	2031-32	14443510	0.065	76811	188.04
23	2032-33	15382338	0.065	80873	190.20
24	2033-34	16382190	0.065	85151	192.39
25	2034-35	17447033	0.065	89655	194.60
26	2035-36	18581090	0.065	94396	196.84

Project Year	Calendar Year	GDP at constant market price(Million BDT)	GDP Growth rate	Per capita GDP	Bangladesh Population (Million)
27	2036-37	19788861	0.065	99389	199.10
28	2037-38	21075136	0.065	104646	201.39
29	2038-39	22445020	0.065	110181	203.71
30	2039-40	23903947	0.065	116009	206.05
31	2040-41	25457703	0.065	122145	208.42
32	2041-42	27112454	0.065	128605	210.82
33	2042-43	28874763	0.065	135407	213.24

The types of houses damaged were predominantly semi-*Pucca* and *kutcha* houses. A storm surge/flood, with a larger extent of inundated area, would be expected to damage more number of houses in 2042-43. The net financial value of property protection estimated to be about BDT 3503.95 million or about US$ 42.73 million. The net of property protection estimated to be about BDT 3160.57 million or about US$ 38.54 million (Table 10.9).

Road Damages[27]

We have assumed that the number of kilometers of road will have increased by 22%. The estimate is based on past World Bank publications. In addition, the currently existing *kutcha* roads will be converted into paved roads by the end of the project period. Hence, as the years go by, the number of kilo meters of *kutcha* road will steadily decline and that of paved roads will increase.

In the case of storm surge polders, the damages to roads, whether partial or total, are basically updated estimates of Sidr damages. Regarding river flood related polders, all roads whether *pucca* or *kutcha* would be inundated and have been assumed to suffer partial damages. The repair cost of these roads is considered as direct damages to the road sector.

Economic losses due to the closure of roads during the reconstruction period and the cost of alternative but less efficient systems were assumed to be about 22 percent of the total damages to the road infrastructure when Sidr damages were estimated. We have used the same percentage figure. Again, based on Sidr experience, the repair cost of damaged bridges and culverts on the damaged roads was assumed to be almost equal to the damages and losses incurred by the roads themselves. Roads are highly sensitive to inundation, become partially damaged with inundation of less than 1 meter, and are fully damaged when inundation exceeds 1 meter. Total financial value would be about BDT 6163.85 million[28] or US$ 75.17 million. Total economic value would be about BDT 5559.79 million[29] or US$ 67.80 million (Table 10.9).

[27] For details, pl. refers to CEIP economic analysis reports for all seventeen polders.

[28] Repair rates are taken as BDT 2 million per km for pucca road; BDT 1 million per km for partially damaged pucca road; BDT 0.4 million per km for fully damaged kutcha road and BDT 0.16 million per km for partially damaged kutcha road.

[29] Repair rates are taken as BDT 2 million per km for pucca road; BDT 1 million per km for partially damaged pucca road; BDT 0.4 million per km for fully damaged kutcha road and BDT 0.16 million per km for partially damaged kutcha road.

Human Lives and VSL[30]

This study estimates the economic value of lives lost due to Sidr for the polders affected by storm surge. It has been measured using the Value of Statistical Life (VSL) method. Fatality rates have been developed from the deaths resulting from Sidr. We have then calculated the VSL for an average Bangladeshi. For the river flood affected polders, the economic value of human lives lost is not estimated, as the death rates are too low to have any impact on the estimates. We have considered fatalities only, ignoring injuries as the economic valuation of injuries turned out to be insignificant in the case of Sidr.

Because few empirical estimates of VSL are available for developing countries, the method commonly used is to transfer estimates – "benefits transfer" – of the VSL from developed to developing countries. The most common approach to benefits transfer assumes that the ratio of the VSL to per capita income is constant among countries. This is equivalent to assuming that the income elasticity of the VSL = 1. This may overstate the VSL in developing countries. Indeed, preliminary analysis suggests the ratio is much lower for middle income countries. Pending additional studies in low and middle-income countries, M. L. Cropper and S. Sahin (2009) have suggested using an income elasticity of the VSL larger than 1.0 in place of an income elasticity of 1.0 for middle and low-income countries. We have assumed a value of 1.5 for the elasticity.

This study estimates the economic value of lives lost due to Sidr for the polders affected by storm surge. It has been measured using the Value of Statistical Life (VSL) method. Fatality rates have been developed from the deaths resulting from Sidr. It is reasonable to assume that, due to the rising number of newly built pucca houses that will be available for use as emergency shelters, death rates would drop. It has been assumed that for every percentage point increment in pucca dwellings, death rates will fall by an additional one percent.

This analysis derived a VSL estimate of BDT 5.06 million (about US$0.065 million) for Bangladesh. This estimate was computed by updating the central estimate of the VSL for the United States (US$ 7.4 million in 2006 dollars) available from the US Environmental Protection Agency with a price adjustment of the US 2007 inflation rate, the foreign exchange rate of BDT for 2007, the inflation rate of Bangladesh from 2007 to 2011 and the per capita GDP growth rate of Bangladesh from 2007 to 2011.

Cyclone shelters have protected human lives and livestock in the coastal region of Bangladesh during past cyclones, including Cyclone SIDR, when 15 percent of the affected population took refuge in shelters (GoB 2008). Many studies on cyclone-affected areas revealed that willingness to use shelters during an emergency would largely increase if shelters are having (i) easy accessibility, (ii) located closer to affected people's homes, (iii) less crowded, (iv) provision for separate facilities for women, (v) facilities for people with disabilities, (vi) sanitation facilities above the ground floor, and (vii) facilities to protect livestock.

The number of cyclone shelters needed in an area depends on the population and housing characteristics of the area. While pucca houses can structurally withstand most of the wind damages from the average severe cyclone, they provide no remedy for inundation from storm surges. Pucca houses can effectively substitute for cyclone shelters in areas with inundation depth of less than 1 meter. In contrast, cyclone shelters are necessary to

[30] For details, pl. refers to CEIP-I different economic analysis reports done for seventeen polders.

protect inhabitants living in single story dwellings that can potentially be exposed to inundation depths in excess of 3 meters.

This study estimates the economic value of lives lost due to Sidr for the polders affected by storm surge. It has been measured using the Value of Statistical Life (VSL) method. Fatality rates have been developed from the deaths resulting from Sidr. It is reasonable to assume that, due to the rising number of newly built pucca houses that will be available for use as emergency shelters, death rates would drop. It has been assumed that for every percentage point increment in pucca dwellings, death rates will fall by an additional one percent.

Data on number of death were obtained from *upazilla* offices of respective polders as explained earlier. Multiplying this figure by the expected value of the increased number of lives at risk from a storm surge in a changing climate results in BDT 4272.38 million or US$ 52.10 million in year of additional financial damage from greater fatality risk (1 US$=BDT 82). The economic value is estimated to be about BDT 3853.69 million or US$ 47 million.

The benefits of disaster risk mitigation projects are stated in terms of the expected number of deaths avoided. Since at the time a project is considered it is unknown whose lives the project would save, the expected deaths avoided represent a reduction in the risk of dying that is spread over the population exposed to the disaster risk. By reducing the probability that an individual dies, conditional on a storm occurring, the project will save a number of statistical lives, equal to the sum of reductions in risk of death over the relevant population. The Value of a Statistical Life (VSL) is the sum of what individuals would pay for risk reductions that, together, sum to one statistical life. Avoided deaths are an important component of the benefits of disaster risk reduction projects, especially for projects to reduce losses from storms. To monetize these benefits requires first that the expected number of deaths avoided be quantified (Table 10.9).

Non-Agricultural Productive Sectors[31]

Any storm surge/flood will cause damages and losses to the non-agricultural productive sectors (small & medium enterprises, local trade and business). It is assumed that damages and losses would be to the extent of 3.70 percent of total damages and losses, as a whole, for all seventeen polders. The figure is based on 2007 Cyclone Sidr experience. It is also assumed that the percentage will remain fixed during the life time of the project, which may actually be an underestimation. Non-Agricultural Productive Sectors also contribute to GDP. Structural shifts in Bangladesh economy associated with rising income levels in next thirty years are expected to increase the contribution of these sectors to the economy of all seventeen polders by 2042-43. Higher GDP levels combined with increased shares of the non-agricultural productive sectors in the economy in 2042-43 would result in total financial damages and losses of BDT 663.90 million or US$ 8.10 million for all seventeen polders in 2042-43. The total economic damages and losses estimated to be about BDT 602.27 million or US$ 7.34 million for all seventeen polders in 2042-43 (Table 10.9).

[31] For details, pl. refers to CEIP-I economic analysis reports for all seventeen polders.

10.7 Costs-Benefit Analysis[32]

To test the viability of the project, the Economic Internal Rate of Return (EIRR) and Financial Internal Rate of Return (FIRR) have been calculated based on a comparison of incremental cost and benefit streams. A time horizon of 30 years has been used for evaluating the project from the end of the project's construction period. Project implementation period has been assumed as three years, considering availability of BWDB fund and timely land acquisition, if any. In other words accruing of project full benefits are assumed to be achieved from the fourth year of project life i.e. after completion of the investment program. Individual components of the project may have a lifetime lower or higher than the analytical life assumed for the project. The sunk costs have not been considered for economic analysis. The B/C ratios and the Internal Rate of Return for the proposed investment on retired embankments, re-sectioning of embankments, drainage structures, drainage channels, protective works, afforestation and environmental mitigation for all seventeen polders is given in Table 10.15.

Table 10.15: IRR, NPV and B-C Ratio

Particulars	Criteria	IRR (%)		NPV (BDT Million)		B/C Ratio	
		FIRR	EIRR	Fin.	Eco.	Fin.	Eco.
Eight Storm Surge Polders	Base case	14.73%	17.85%	3352.7	5648.4	1.28	1.66
Five Flood Affected Polders	Base case	29.50%	34.59%	10257.3	10359.5	3.55	4.51
Polder no.32	Base case	17.57%	19.51%	1191.5	1258.4	1.71	2.01
Polder no. 33	Base case	19.00%	21.95%	1892.7	2109.4	1.91	2.37
Polder no.35/3	Base case	25.50%	28.32	2555.0	2457.8	3.01	3.60
Polder no.35/1	Base case	17.47%	20.48%	2343.4	2823.2	1.55	1.90

10.7.1 Sensitivity Tests and Switching Values[33]

Project benefit-cost analysis is based on forecasts of quantifiable variables such as costs and benefits. The values of these variables are estimated based on the most probable forecasts, which cover a long period. A great number of factors may influence the values of these variables for the most probable outcome scenario, and the actual values may differ considerably from the estimated values, depending on future developments. It is therefore useful to consider the effects of likely changes in the key variables on the viability (EIRR) of a project. Performing sensitivity analysis does this. In order to allow for various uncertainties and unforeseen circumstances, sensitivity analysis has been carried out to test the soundness of economic results.

However, sensitivity tests are not without problems. Correlations among the variables often pose serious difficulties. The usual technique of varying one variable at a time, keeping the others constant at their expected values, is justified only if the variables concerned are not significantly correlated; otherwise, the related variables must be varied jointly. Furthermore, sensitivity analysis may not identify any variable that, by itself, significantly affects the

[32] For details, pl. refers to CEIP-I economic analysis reports for all seventeen polders.
[33] For details, pl. refers to CEIP-I economic analysis reports for all seventeen polders.

overall result, even though many variables are tested here. This does not necessarily mean that the project concerned is not risky as it ignores the effects of possible joint variations. For such cases, the sensitivity of the outcome to changes in several combinations of variables that are expected to vary together has been explored. However, it should be noted that the greater the degree of aggregation, the less useful is the information provided by the tests.

A Sensitivity Indicator (SI) summarizing the effect of changes in the variables on the project NPV are also calculated. SI is calculated as ratio of the percentage change in the NPV to the percentage in a variable analysed. A high value for the indicator(s) indicates project sensitivity to the variable(s). For variables where percentages are less significant, the percentage changes in the NPV are also stated along with the changes in the variables.

The Switching Values (SV) is also calculated. Where the base case shows a positive NPV, the SV shows the percentage increase in a cost item (decline in a benefit item) required for NPV to become zero (which is the same as the EIRR reducing to the cut off level of twelve percent). SV is itself a percentage, percentage change in a variable for the project decision to change. It may be compared to the variation shown in the post-evaluation studies or in price forecasts. For variables where the SVs are high, implies a very substantial change in the variable before the project decision is affected. For variables where SV are relatively low, indicates there may be a significant risk in the project outcome.

10.8 Conclusions

The overall purpose of the project is to improve or further strengthen disaster risk reduction and climate change adaptation capacities for sustainable livelihood and food security including livestock, fisheries and forestry and other key factors for rural livelihoods in the project area. Agricultural production, lives and livelihoods are constantly threatened by natural and human induced hazards such as floods, storm surges, droughts, tidal surges, tornados, earthquakes, river erosions, water logging, water and soil salinity and high arsenic content in ground water.

Since natural disaster occupies such a prominent spot in the Bangladesh economic burden, it is important to gauge the economic loss from natural storms like SIDR. Information on the economic loss from SIDR can help in setting priorities for policy-making, and type of interventions required. Interventions should be concentrated where burden is relatively high and the potential for cost-effective reduction of burden is greatest. Assessing current and projected future economic loss from natural disaster may encourage government to implement storms surveillance, prevention and control measures as well as fund preventive measures at both national and sub-national levels.

As stated earlier, project benefits identified for the projects are (i) agricultural benefits, (ii) livestock benefits, (iii) fishery benefit, and (iv) afforestation, (v) property (vi) roads and (vi) human lives. Project is economically viable. Any adverse circumstances in the form of increase in investment cost by 20% and decrease in net return by 20% will keep the project viable but effort should be made to strictly adhere to implementation schedule for completion of the projects and starting of production activities in time. However, in addition to the viability of the project, the Government will have to take into account the total magnitude of net return, employment and other non-quantifiable secondary and indirect benefits.

Many of the households have complex livelihoods, combining several overlapping activities, and thus some were simultaneously affected by losses in crops, livestock, fisheries or wage employment. The most vulnerable groups include landless laborers, and marginal farmers with very little land and no other sustainable source of income. These households are using various coping mechanisms in reaction to storm surge/flood damage.

Project stakeholders or communities have adapted to some of the natural hazards as part of their coping mechanisms. However, some hazards are very large in scale and easily exhaust community capabilities to cope. Climate change is seen to increase the severity and frequency of these large-scale hazards, which will further augment community risk and vulnerability. The project risks may arise due to (i) delay in project implementation, (ii) lack of maintenance during execution, (iii) lack of O& M after project implementation. These risks are crucial to achieve identified direct and indirect benefits from the project. As such, planners and policy makers must ensure O&M activities before the project implementation takes off.

This study is largely focused on the impacts of climate risks (both climate variability and climate change) on vulnerability of coastal population and infrastructures as well as food security in Bangladesh. The risks from climate change include higher temperatures and changing precipitation patterns, increased flood intensity and frequency, droughts and sea level rise effects on agriculture production. The models and methods used here are among the best alternative methods available of the physical and economic responses to these exogenous climate changes. However, like all methods and modeling approaches, uncertainty exists as parameters may not be known with precision and functional forms may not be fully accurate. Thus, careful sensitivity analysis and an understanding and appreciation of the limitations of these models and methods are required. Further collection and analysis of critical input and output observations (e.g. climate data, farm-level practices and irrigation constraints) will enhance this integrated framework methodology and future climate impact assessments.

The conclusions of the assessment were discussed with different experts. It is emphasized, however, that present assessment is based on the information available at the moment of completion of the reports. Understanding of the effects of the storm surge/floods can be expected to evolve as more information becomes available.

11.0 PROJECT IMPLEMENTATION

11.1 Introduction

This report documents the Feasibility Study of 17 Polders included in CEIP-1. However, there has been another component of CEIP-1 running in parallel which addresses the detailed design of 5 of these 17 polders up to and including the following:

- *Preparation of detailed designs and bidding documents for the first contract covering works of about US$50-75 million in value, preparation of the corresponding full resettlement action plan (RAP) and environmental management plan (EMP)for these works along with cost estimates, and institutional and implementation arrangements;*
- *Support in procurement of works, bidding procedures, pre-qualification of and constructors if necessary evaluation of tender and preparation of the bid evaluation report;*

The above activities are also complete and will be reported through another series of reports submitted under the title **"Detailed Designs for 5 Polders".** The RAP and EMP will be included in this series of reports. Five Environmental Impact Assessments have also been carried out in order to obtain environmental clearance from the Department of the Environment.

The implementation of the construction phase was to be awarded as single contract package. Any difficulties arising out of the fat that the 5 polders fall within the jurisdictions of three Executive Engineers working under two Superintending Engineers was to be overcome by bringing all 5 polders under the direct control of the Project Director and his staff.

11.2 Reporting Schedule

This work of this project has been delayed due to various setbacks that were experienced in 2011. The project period was extended until the end of September 2012 by mutual agreement between the Client, the Donor and the Consultant. The following milestones are anticipated:

Draft Final Report

Submission Milestone	Scheduled Date
Draft Final Report (Volume I)	Mid-September 2012
Strategic Plan (Volume II)	Mid-October 2012
Modelling & Survey Report (Volume III) Parts A, B, C, D	Mid-September 2012 onwards
Land Use Reports (Volume IV) 2 parts	Mid-September 2012
Economic & Financial Analysis Report (Volume V)	Mid-October 2012
Feasibility Level Design Report (Volume VI)	Mid-September 2012
Social and Environmental Reports (Volume VII)	Mid-September 2012
IEE Reports 17 Polders (Volume IX) Parts A,B,C,D,E, F	Mid-September 2012
Institutional Reports (Volume X)	Mid-September 2012

Detailed Design Report and Other Documents

Submission Milestone	Scheduled Date
Volume I: Design Report for Detailed Design of 5 Polders	Mid-September 2012
Volume II: Design Drawings	Mid-October 2012
Volume III: Environmental Impact Assessment For 5 Polders	End-September 2012
Volume IV: EMP and RAP	Mid-September 2012
Contract Documents	End October 2012

11.3 Project Implementation Schedule

The probable schedule for the formal steps that have to be taken to initiate the project is given in Table 11.1

Table 11.1 Project Implementation Sequence

	Milestone	Probable Date
1	Appraisal of the Feasibility Study Report by the Pre-Appraisal Mission of World Bank.	03 Oct 2012
2	Approval of the Feasibility Report by the competent authority of BWDB.	13 Nov 2012
3	Commncement of Land Acquisition process	15 Nov 2013
4	Preparation of Draft Development Project Proposal (DPP) by the Project Director, CEIP	01 Jan 2013
5	Review & Recommendation of the Draft DPP by BWDB & sending to the MOWR.	12 Mar 2013
6	Review & Recommendation of the Draft DPP by the Rationalization Committee in the Ministry of Water Resources (MOWR)	27 Mar 2013
7	DPP Sending to Planning Commission	10 Apr 2013
8	Review & Recommendation of the Draft DPP in the Pre-Pre-ECNEC meeting in the Planning Commission & sending to the Pre-ECNEC meeting.	15 May 2013
9	Review & Recommendation of the Draft DPP by the Pre-ECNEC & sending to the ECNEC	30 May 2013
10	Approval of the Draft DPP by ECNEC.	15 June 2013
11	Preparation and approval of estimate of the physical works by the competent authority of BWDB,	15 July 2013
12	Finalisation of Bidding Documents	31 July 2013
13	Pre- qualification of contractor by the competent authority of BWDB.	20 Sep 2013
14	Floating of Tender among the pre-qualified contractors.	25 Sep 2013
15	Pre-bid meeting	25 Oct 2013
16	Receive Tenders	15 Nov 2013
17	Evaluation of Tender by the standing Evaluation Committee,	05 Dec 2013
18	Approval of contract by Cabinet Committee for Govt. Purchase (CEGP)	31 Dec 2013
19	Award of contract,	07 Jan 2014
20	Signing of Contract	15 Jan 2014
21	Commencement of Implementation of physical works.	21 Jan 2014
22	Completion of Contract	20 Jan 2018
23	Defect Liabilities & Finalization of Reimbursement Claims etc.	19 Jan 2019

12.0 CONCLUSIONS AND RECOMMENDATIONS

12.1 Feasibility of CEIP-1

This report documents the Feasibility Study of 17 Polders included in CEIP-1. The study concludes that proposed project to improve 17 polders is technically, financially and economically feasible. However, it should be re-iterated that the performance levels anticipated in the economic analyses will be reached if a proper institutional arrangement is put in place with the agreement of all stakeholder groups.

The implementation of the construction phase is to be awarded as single contract package with the expectation of bringing in an experienced and reputed International Contractor. Any difficulties arising out of the fact that the 5 polders fall within the jurisdictions of three Executive Engineers working, under two Superintending Engineers, is to be overcome by bringing all 5 polders under the direct control of the Project Director and his staff.

12.2 Constraints and Uncertainties

Constraints

The difficulties experienced during the unusually long inception phase were finally overcome with sub-contracts being awarded to CEGIS and IWM to carry out environmental and mathematical model studies respectively. IWM also undertook the topographic and bathymetric surveys necessary for the work. Some of these tasks over-ran their schedules partly for unforeseen reasons.

The difficulty of establishing a relationship between the surveys carried out by IWM using the new SoB level benchmarks and the old Sob bench marks used in the original surveys that were used for polder construction in the 1960s and 1970s became immediately apparent. The same bench marks – many of which had subsided in the intervening period, were used for subsequent repairs and/or replacement of these structures, causing many difficulties in executing the model studies. It was necessary to harmonise the datum used in all variables present in the hydraulic model studies (water levels, ground and embankment levels, structure levels). This required some corrections to be made and for models to be re-run several times.

The observation that there was significant ground subsidence of in the coastal zone *and that the rate of subsidence varied from place to place* had to be taken into account. As there was still no general agreement on the actual rate of subsidence, the project had to allow for an assumed uniform rate of subsidence for its lifetime. The rate of 10mm per year was selected based on the GPS studies carried out by the University of Dhaka, and the embankment crest levels were adjusted accordingly to compensate for this. This is not ideal. It is necessary to begin and continue a ground level monitoring programme extending the current work of Dhaka University Department of Geology. It is necessary to monitor a selected number of level bench marks *in perpetuity*.

Uncertainties

The problem of subsidence would remain as a project uncertainty until the rates of subsidence at key points in the Coastal Zone are determined and the SoB primary level grid is updated at regular intervals. It is unlikely that BWDB would revise its entire water level database – in fact there is no possibility of accounting for errors of datum (which have been affected by subsidence) that would be present in time series of water levels stretching over 50 years or more. It is however necessary to tie all future level measurements to the new national level datum.

The IPCC's predictions of sea level rise due to climate change are also updated at regular intervals. The present study is based on IPCC estimates (IPCC AR4, 2007). It is necessary to review these assumptions against new sea level rise estimates announced by IPCC at regular intervals in the future. The ability to monitor ground subsidence will soon make it possible to directly measure the objective rise in sea level in the Bangladesh coastal zone with respect to GPS observations.

The embankments have not been tested against the impacts of earthquake induced accelerations. This is because the probability of the occurrence of an earthquake coinciding with the occurrence of a storm surge is very remote. The subducting tectonic fault line which gave rise to the 2004 tsunami runs through Bangladesh. It is also widely believed that the possibility of a tsunami being generated by slippage at this fault is very low. However, in 1762 such a mega-thrust earthquake did occur. Cummins (2007) postulates that this earthquake was responsible for changing the Chittagong to Cox's Bazar coastline and that it also generated a Tsunami. The polder system cannot withstand such an event. The tsunami would then coincide with earthquake damage to some embankments as well. On the other hand a recent evaluation by IWM (2010) does not place the tsunami risk at a high level.

Design of Coastal Revetments

It has been apparent that wave overtopping is an important consideration that determines the amount of freeboard required when setting embankment crest levels and the large area of land must also be set aside for the mild slope necessary to restrict run up. There is a case for spending some resources in optimizing the designs of revetments that face the open sea.

In future phases of CEIP there would be very large lengths of sea facing embankments requiring protection on both the south east coast and the offshore islands. These embankments face a wave climate that has not yet been measured systematically. ***Designs could be made more economic if real wave data was available and the tools for optimizing the revetment design.***

There is a case for initiating a long term wave recording programme at two or three offshore stations to generate data for establishing the wave climate. This would not only serve the needs of thousands of kilometres of CEIP embankment design but also the needs of breakwater designs for a future deep water port. Problems of beach erosion on the Chittagong coast and protection where necessary of the coastal highway will be served by the existence of a wave climate database.

Testing and optimising revetment designs using wave flume testing is a long established practice. The River Research Institute in Faridpur is a place that could easily be provided the facilities and trained staff to carry out flume tests on sea facing revetments – for the foreseeable future. Such a flume testing facility could be sustained for a long period with just the flume testing requirements of CEIP designs. There is in-country expertise in coastal engineering and hydraulics already available – though not necessarily at RRI. It would be a worthwhile enterprise – amply justified by the needs of one project.

12.3 Long Term Outlook

The long term outlook (2100 and beyond) will be dependent on both global and local (Ganges-Brahmaputra Basin) phenomena. Global phenomena are related to climate change – sea level rise and changes in precipitation.

The most important changes (other than precipitation and ice melt) that could change in the basis are sediment discharges related to earthworks, landslides and changes in land use. Changes in sediment inflows would result in immediate changes in wash load reaching the delta – but the bed levels changes could take centuries to be propagated downstream. This also means that there could have been recent events in the far catchment have not yet propagated downstream as far as Bangladesh. The presence of embankments (it is likely that the major rivers will become increasingly channelized despite a strong negative environmental outlook for this kind of development) would reduce the diversion of sediments into the flood plains – resulting in slow subsidence of the flood plains and an additional sediment load staying in the river. This classic river response has not yet become a major factor in river planning in Bangladesh.

The construction of large hydroelectric dams in all the upper riparian countries will create more regulation of flow and a reduction of sediment loads reaching and flowing through Bangladesh. Sea level rise would reduce the discharge of sediments into the Bay of Bengal causing river bed levels to rise. These phenomena will not all act in one direction and the morphological response of the river system would be complex and the time scales of these responses are not known. The continuous land subsidence in parts of the delta that have been protected from being flooded by sediment-bearing flood water add another dimension to this problem.

For these reasons it is necessary to undertake a major detailed study of the morphological development of the river and estuarine system and the flood plains in Bangladesh in the face of natural and man-made changes. The sedimentation processes in the bay and in the estuaries are quite complex and it will be necessary to adapt and further develop the modelling tools we have now (however powerful they are) before they could be applied to this problem. The projections with respect to morphology being made in Volume II of this report are only qualitative and provide some indicators. Strategies for dealing with the less favourable outlook for polder drainage in the face of subsidence combined with sea level rise are also discussed in Volume II. Further work has to be done to predict long term morphological impacts of sea level rise and other changes that are taking place upstream.

12.4 Conclusions & Recommendations

- The project has developed a viable methodology for designing polder improvements to protect the polders from storm surges and to correct drainage problems within polders. The designs proposed by the project are tailored not only for the present conditions but also to cater to future climate change scenarios.
- The project has identified some areas of uncertainty that could be removed before the next phases of CEIP are put into action. The current design has left sufficient margin to allow for the designs to be safe despite these uncertainties.
- The existing embankment system in the polders under consideration for CEIP-1 has a level of protection of approximately 10 years return period. The present condition of the embankments make it likely that an overtopping event can lead to disastrous breaches in the embankment at existing weak points – a seen after Sidr and Aila

- The new design will ensure that the embankment would be protected against events of 25 years return period for climate change conditions that would exist in 2050. Additional safety factors have also been built in by allowing for the higher estimates of subsidence and sea level rise.
- The actual level of protection soon after project completion (say 2015) would be more than a 50 year return period.
- The design specifies the re-construction of the entire length of embankment in all 17 polders under CEIP-1 to a stringent specification – thus eliminating weak points.
- The embankment crest levels have been raised to provide sufficient freeboard to severely limit overtopping by waves during extreme events as well.
- The project has identified the need to monitor land subsidence at selected stations all over the coastal zone.
- The first phase (Assignment A) was to serve as a pilot programme to show the way for future stages
- The project has emphasised the need for quality control in all construction activities and most importantly in the resistance of embankments to overtopping erosion and the need for excellent mechanical compaction.
- The project recognised that even the best and most effective physical interventions cannot be sustained without a viable plan for maintenance a sound institutional arrangement for efficient operation of the system without conflict between users.
- Conflicts among fisheries, agriculture and other users of the available land must be resolved in the management of water within each polder.
- Sustainable longer term operations and maintenance of the facilities provided by the project should be ensured with a suitable institutional/consultative arrangement.
- Replacement of the existing sluices constructed in 1960-1970 is essential providing long lasting structures compatible with project objective keeping provision for flushing cum-drainage.
- Strong design with high quality construction materials are to be used for all construction works.
- Damaged structures are to be re-constructed and where needed new structures to be constructed. New structures should be constructed to facilitate drainage in the rainy season and control fresh water in winter season so that farmers can save T. Aman crops from water logging and cultivate winter crops.
- Drainage / Irrigation channels should be re-excavated and new drainage channels may be excavated as per demand of the local people to provide storage of sufficient water for winter irrigation.
- Arrangements are to be made with the beneficiaries (through formation of WMOs) to control and facilitate smooth operation of structures as necessary.
- It should also be confirmed that the Gher owners cannot cut the embankment to take in saline water in to the polders for culture of shrimp under any circumstance.
- DAE may be involved for advising the farmers for better crops production activities and switching over to high value crops resulting economic benefit of the farmers.
- The improvement to the drainage system could be demonstrated by showing the flood depth classification of the 86.382ha of land in the 17 project polders under the present situation, in 30 years if there is no intervention (without project) and in 30 years (with

project – including climate change) after drainage improvement as shown in the table 12.1 shown below:

Table 12.1: Post Project Drainage Improvement

Land type & flood depth	Present situation (ha)	%	Without project situation (ha)	%	With project situation (ha)	%
F0	51,493	59.6%	36,517	42.3%	84,376	97.7%
F1	31,321	36.3%	37,078	42.9%	1,831	2.1%
F2	3,539	4.1%	11,755	13.6%	175	0.2%
F3	29	0.0%	1,032	1.2%	-	0.0%
F4	-	0.0%	-	0.0%	-	0.0%
Total	86,382	100.0%	86,382	100.0%	86,382	100.0%

12.5 Recommendations for Follow up Action for Future CEIP use

The following actions are recommended as necessary to ensure better quality designs and elimination of uncertainties for improving future CEIP designs:

- Set up a GPS based land subsidence monitoring programme as a continued long term programme to support all planning and design activities in the coastal zone, including Clime Change Adaptation. The project could be appended to the present GPS monitoring programme of the Dhaka University Earth Observatory (DUEO) and coordinated by a Steering Committee with representatives from SoB, BIWTA, Bangladesh Geological Survey, BWDB, IWM and CEGIS. Survey of Bangladesh has acquired the capability of using ground penetrating radar to measure local land subsidence. Such technologies could supplement the monitoring programme.
- Set up a Wave Flume Testing Facility in River Research Institute in Faridpur and train engineers and laboratory staff to carry out flume tests, data processing and analysis initially for servicing CEIP needs.
- Set up a directional wave measurement and recording programme at two or three carefully selected location offshore in the Bay of Bengal within the control of an organisation (such as Chittagong Ports Authority) with the marine deployment and recovery capabilities. The ownership of the data to be shared between CPA, BWDB and RRI who will maintain separate databases.