Ministry of Water Resources

Bangladesh Water Development Board

Coastal Embankment Improvement Project, Phase-I (CEIP-I)

Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics)

QUARTERLY PROGRESS REPORT-2

April 2019

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ACRONYMS AND ABBREVIATIONS

ADCP- Acoustic Doppler Current Profiler

BDP2100- Bangladesh Delta Plan 2100

BIWTA- Bangladesh Inland Water Transport Authority

BMD- Bangladesh Meteorological Department

BoB- Bay of Bengal

BWDB- Bangladesh Water Development Board

CBA- Coast Benefit Analysis

CCP- Chittagong Coastal Plain

CDMP-Comprehensive Disaster Management Program

CDSP- Char Development Settlement Project

CEA- Cost Effectiveness Analysis

CEGIS- Centre for Environmental and Geographic Information Services

CEIP- Coastal Embankment Improvement Project

CEP- Coastal Embankment Project

CERP-Coastal Embankment Rehabilitation Project

CPA- Chittagong Port Authority

CPP-Cyclone Protection Project

CSPS-Cyclone Shelter Preparatory Study

DDM- Department of Disaster Management

DEM- Digital Elevation Model

DOE- Department of Environment

EDP- Estuary Development Program

FAP- Flood Action Plan

FM- Flexible Mesh

GBM- Ganges Brahmaputra Meghna

GCM- General Circulation Model

GIS- Geographical Information System

GNSS- Global Navigation Satellite System

GPS- Global Positioning System

GTPE- Ganges Tidal Plain East

GTPW- Ganges Tidal Plain West

HD- Hydrodynamic

InSAR- Interferometric Synthetic Aperture Radar

IPCC- Intergovernmental Panel for Climate Change

IPSWAM- Integrated Planning for Sustainable Water Management

IWM- Institute of Water Modelling

LCC- Life Cycle Costs

LGED- Local Government Engineering Department

LGI- local Government Institute

LRP- Land Reclamation Project

MCA- Multi Criteria Analysis

MES- Meghna Estuary Study

MoWR- Ministry of Water Resources

MPA- Mongla Port Authority

NAM - Nedbor Afstromnings Model

PPMM- Participatory Polder Management Model

RCP- Representative Concentration Pathways

RSET-MH- Rod surface elevation table – marker horizon

RTK- Real-Time Kinematic

SET-MH- Surface Elevation Tables – Marker Horizons

SLR- Sea Level Rise

SOB- Survey of Bangladesh

SSC- Suspended Sediment Concentration

SWRM- South West Region Model

TBM- Temporary Bench Mark

ToR- Terms of Reference

WARPO- Water Resources Planning Organization

WL - Water Level

1 INTRODUCTION

The coastal zone of Bangladesh spans over 710 km of coastline and is subject to multiple threats. Sixty- two percent of the coastal land has an elevation less than 3 meters above mean see level. The coastal lands, being subject to regular flooding by saline water during high tides, could not be used for normal agricultural production in a country with a very high demand for land. The Coastal Embankment Project)CEP(was initiated in the 1950s and 1960s to build polders surrounded by embankments preventing the spilling of saline water onto the land at high tides. These embankments were built along the larger rivers and across the smaller rivers and creeks which then formed the drainage system within each polder and connected to the peripheral rivers via appropriately sized flap gate regulators, that open at low tide to let the drainage water out.

The Coastal Embankment Project made possible the reclamation of large tracts of land for agriculture from 1960 onwards. Polder building proceeded continuously until today. We now have 1.2 million hectares reclaimed in 139 active polders in the coastal zone of Bangladesh.

In over half century of its existence, a number of challenges have surfaced that threaten the long-term safety and even the very existence of the polder system as a viable and sustainable resource. These are:

- The interference with natural tidal regime created severe siltation problems in some rivers resulting in severe drainage congestion in some polders.
- Sea level rise and changes in precipitation and water discharge due to climate change
- Threats of damming and diversion to the delivery of river sediments from upstream
- Subsidence of lands)except where it has been allowed to be rebuilt by tidal flooding(and structures founded on existing land
- Increasing vulnerability to cyclones and storm surges

The damage caused by Cyclones Sidr and Aila in 2007 and 2009 led to a major new investment of World Bank funds called the Coastal Embankment Improvement Project through which the coastal embankment system was to be improved and made much more climate resilient, over several phases of construction. After the feasibility study of the first phase CEIP-1, it was recommended that certain gaps in our knowledge of the delta should be addressed by the research study which was to be known as the **Long-Term Monitoring, Research and Analysis of Bangladesh Coastal Zone.**

After a very long gestation period, the study was initiated on 15 October 2018 and the Inception Phase was completed in January 2019. The Inception Report was treated as the first Quarterly Progress Report (QPR-1). This report QPR-2 is to cover the period 1 January 2019 to 31 March 2019.

1.1 Full Project

The Inception Report (DHI, 2019) gives a detailed description of the work to be carried out by this project. It is not necessary go into further detail except for the activities expected to be carried out for ***Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone,*** in the 2nd Quarter.

1.2 Activity Schedule of the Full Project

Table 1.1 shows the full schedule of activities to be carried out during the 30 months of the project. The second quarter is completed on 31 March 2019. The Inception Report took the place of the First Quarterly Progress Report.

Table 1-1: Full Activity Schedule

Activity Schedule

Component	Component NAME	Sub Activity	2018			2019												2020												2121			
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
C-1	Inception	**Inception Report & Workshop**																															
C-2	Literature Review and Lessons Learned	**Detailed Leterature Review**							X																		X						
		Lessons learnt							X																								
C-3	Develop Datasets for model input	**Data Coverage and Collection**																															
		National Polder Database											X																				
Component - 4	Modelling Long-term Processes in the Coastal Zone	**Macro-scale Modelling**																						D			X						
		Meso-scale Modelling																						D			X						
		Micro-scale Modelling																						D			X						
		Subsidence																					1	1			2						2
		Meteorology																															
		Salinity, Water Levels, Storm Surges																						D			X						
C-5	Polder Reconstruction Programme	**Phased Zonal Programme**																						D						F			
		Coherence & Delta Overview																									F						
C-6	Design Parameters Construction, Management & and Monitoring	**Updating Parameters and Specifications**								P																							F
		Polder management, stakeholder participation								P																							F
		Performance Monitoring System								P																							P
C-7	Investment Plan for Entire CEIP	**Plan Preparation**																															F
C-8	Capacity Building	**In-houseTraining Programmes**																															
		External Training Programmes																															
C-9	Transparency & Accountability	**Outreach Programme**																															
		Communication Activities																															
		Communication Activities																															

- X: Reporting (usually final)
- F: Reporting (Final)
- D: Reporting (Draft)
- 1: First
- 2: Second

quarterly progress | quarterly progress | quarterly progress | quarterly progress | quarterly progress | quarterly progress | quarterly progress | quarterly progress | quarterly progress

1.3 Activities of this Quarter

Component No 2 (Literature Review) is the first activity listed for the post inception period. This activity is described in sufficient detail in Chapter 3

The major activities undertaken during the current quarter are Data Collection as inputs for Modelling (Component 3) and Component 4 which included a very substantial amount of advanced modelling of delta processes at several scales, as seen in Table 1.2

Table 1-2: Detailed Activity Schedule for Components 3 and 4

Component			2018			2019											
		Sub Activity	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Month No		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C-3	Input Datasets for Modelling	Prepare Data full Inventory & QA															
		Project Data Collection Programmes															
		Supplementart Surveys in BoB															
		National Polder Database															
Component - 4	Macro-scale Modelling	GBM Basin-wide Sediment Studies															
		Detailed River Models															
		Flood Plain Sedimentation															
		Subsidence Studies															
	Meso-scale Modelling	BoB, Cyclone and Storm Surge Modelling															
		Wave Propagation Modelling															
		Estuary Modelling 1															
		Estuary Modelling Salinity															
		Bank Erosion Modelling															
	Micro-scale Modelling	Sediment Management															
		Polder Drainage Modelling															
		Polder Operational Studies															
	Meteorology																

1.4 Deliverables due at the end of 2nd Quarter

A large number of outputs have been listed as deliverables during the 30 months duration of this project. Table 10.3 lists only those outputs than are to be either partially or completely delivered within the second quarter.

Table 1-3: Deliverables

Delivery	Description	Output/Report	Scheduled (Month)	Delivery
D-1	Inception	Inception Workshop	0-3	Delivered
		Inception Report (Workplan etc		
D-2	Literature	Literature Inventory & Annotated Review	0 - 6	Scheduled 15 April
D-3	Data	Data Report , Inventory, quality checks etc	03 to 09	On going
		Database Design Report	03 to 09	Ready
		GIS based maps	03 to 09	under preparation
		Supply of model boundary data (various)	03 to 09	under preparation
D-5A	Polder Development Plan	Draft Report on initial 4 polders	0 TO 21	under discussion
D-6.1	Updated Parameters	Detailed Delivery plan	6	Delayed
D-6.2	Polder Management	Detailed Delivery plan	6	Delayed
D-8		Action Plan for Capacity Building	6	Under preparation
		In-country on-the-job technical training	0 - 24	On going
D-9.1	Outreach programme	Workshops		Delivered 2 workshop to date

2 DATA ACQUISITION

2.1 Collecting Existing Data

IWM already has a very comprehensive database comprising hydrometric, meteorological and morphological and environmental data collected over many decades all over the territory of Bangladesh and the adjacent ocean. These data have the advantage of having been used many times over in a large model studies which have also established the quality of the data through repeated verification.

The present study requires the addition of socio-economic data and its subdivision in to a polder-wise demarcated body of data. The availability of data is described in the Inception Report and is too large to be included in this progress report. The reader is directed to the Inception report for an outline of availability. Appendix A gives a list of available data.

2.2 Field Surveys carried out by IWM

2.2.1 Mobilization

The survey team has been mobilized to the site on 05 February 2019. A team of 12 personnel comprising the IWM survey Expert, experienced hydrographic surveyor and land surveyors has been deployed for conducting the planned data collection campaign as per specification. Two camp offices have been set up at Khulna and Kalapara.

2.2.2 Summary of Field Survey Activities

The whole survey team has been spilt into four groups. Out of these two groups comprising specialised hydrographic surveyors and land surveyors for conducting bathymetry survey, monitoring section, discharge observation and other hydrological observation. Whereas, other two groups comprising experience in BM Fly and salinity data collection has been engaged for water level gauge installation and Salinity data collection.

The progress of survey activities is shown in Table 2-1.

Table 2-1: Progress of Bathymetric Survey.

SL	River Name	Description/Specification	Duration of survey	Unit	Target		Achieved as on 31th Mar, 2019	Remarks
					TOR	Modified		
1	Shibsa	From Haborkhali to Akrampoint 70 Km length(out of this 50 km @ 1000m interval & 20km @ 500 m interval	18-23/03/2019	Km	0	168	168	As per inception report and also subsequent consultation, bathymetry survey is being done at Sibsha, Pusur, Baleswar, Bishkhali and Lower Meghna at 500m and 1000m interval
2	Pussur	From Rupsha to Outerbar of 133 km length @ 1000m interval	12-24/03/2019	Km	0	353	353	
3	Baleswar	From Hularhat to outfall of 82 km length @ 1000m Interval	1-10/03/2019	Km	0	196	196	
4	Bishkhali	From Gabkhan khal to Badurtala of 92 Km length @ 1000m interval	Will be done in April, 2019	Km	0	113		
5	Lower Meghna	From Chandpur to Tajumuddin of 100 km @ 1000m interval	On going	Km	1306	1306		
6	Sangu River	95Km @ 500m interval		Nos.	141	141		

Table 2-2: Progress of discharge and Sediment Sampling

SL no.	Location/ River Name	Position in UTM		Taget (Number)		Achieved as on 31st Mar, 2019	Remarks
		Easting (m)	Northing (m)	TOR	Modified		
1	Bahadurabad, Brahmaputra			18	48		As per post inception consultation (Twice a months for 2 years)
2	Hardinge Bridge, Ganges			18	48		
3	Bhairab Bazar, Upper Meghna	295749	2660683	18	48	2	
4	Chandpur, Lower Meghna			3	5		As per inception, 3 nos. (2 spring+ 1 neap during monsoon) and 2 nos. (1 Spring +1 Neap for dry season)
5	Dasmina, Tetulia			0	2		Add as per post inception consultation (June-Oct, 19, 1 Spring+ 1 Neap) to investigate the distribution of sediments.
6	Kakchira, Bishkhali	193530	2454366	0	3	1	
7	Polder-17/2, Gangril	129242	2517741	44	8	2	As per post inception consultation 40 nos. observation in these 5 locations (Each location for 8 measurement- 1 spring in every two months and -1 neap in every six months for the perios of one year).
8	U/S of Mongla port, Pusur	146811	2496031		8	2	
9	Nalian, Shibsha	131298	2483991		8	2	
10	Charduani, Baleswar	176355	2464492		8	2	
11	Bhandaria, Baleswar	185038	2483342		8	2	

Table 2-3: Progress of water level data collection

SL. No.	Name of Location/River	Postion in UTM		Installation Date	Taget as per TOR/ Inception report (stat^n-month)	Achieved as on 31st Mar, 2019	Remarks
		UTM_X	UTM_Y				
1	Outfall of Rabnabad Channel	216528	2421048	18-Feb-19	21	1	
2	Outfall of Biskhali /Baleswar/Buriswar	193946	2426687	17-Feb-19	21	1	
3	Kaikhali	713469	2456684	15-Feb-19	21	1	
4	Chandpur, Lower Meghna	258997	2570810	1-Feb-19	4	1	
5	Dasmina, Tetulia				4		Will be installed in April 2019
6	Digraj, Pusur	771508	2474265	14-Mar-19	4		
7	Nalian, Shibsha	750574	2485746	15-Mar-19	4		
8	Charduani, Baleswar				4		Will be installed in April 2019

Table 2-4: Progress of Monitoring Sections

SL no.	River name	Position in UTM		Survey Date	Taget as per TOR/ Inception report (event)	Achieved as on 31th Mar, 2019	Remarks
		Easting (m)	Northing (m)				
1	Pusur	762273	2501059	21/02/2019	4	1	
		765884	2494718				
2	Sibsha	751161	2487806	20/02/2019	4	1	
		751557	2482153				
3	Kobadak	734559	2474997	17/02/2019	4	1	
		735522	2468624				
4	Chunkuri	759390	2500705	23/02/2019	4	1	
		758092	2498287				
5	Badurgacha	753417	2504229	22/02/2019	4	1	
		749232	2499644				
6	Dhaki	755788	2498307	23/02/2019	4	1	
		751834	2493821				
7	Gangril	739773	2522911	19/02/2019	4	1	
		746214	2515543				
8	Gashikhali	772383	2496263	25/02/2019	4	1	
		769190	2489629				
9	Andharmanik	206871	2432616	2/3/2019	4	1	
		214473	2433381				
10	Galachipa	233074	2451448	3/3/2019	4	1	
		232892	2462016				
11	Baleswar	808406	2488650	28/02/2019	4	1	
		796650	2467005				
12	Lower Meghna	259138	2565429	26/02/2019	4	1	
		261237	2543677				
13	Shangu				4		

2.2.3 Survey Methodology

Establishment of Bench Marks

Control point arrangement is very essential to conduct any survey activities. Survey of Bangladesh has established Bench Marks across the whole country for Horizontal Control (Latitude, Longitude) and Vertical Control (Reduce Level). Nearest available Survey of Bangladesh (SOB) existing BM along the study area will be used as reference. BM ties will be carried out by using optical level and RTK GPS as per requirement. BMs and TBMs will be kept by engraving on the permanent structures such as bridges, regulators and sluices during the survey. After the resurvey of the benchmarks, later in the project, the elevations will be corrected for subsidence since the establishment of the benchmarks.

Figure 2-1: SOB Benchmark at Kapilmuni (Sundarbans) used for Bathymetry

Water Level Observation

As per TOR, it was planned that water level data would be recorded in two locations- one is Rabnabad outfall for 40 months and the other one is at Hiron point for 12 months. However, as per inception and subsequent consultation, it is planned that water level data would be recorded at 3 locations (Rabnabad Outfall, Biskhali outfall & Kaikhali) for 18 months. In addition, 5 nos. water level gauges would be installed at Lower Meghna (Chandpur), Tetulia (Dasmina), Pusur (Digraj), Sibsha (Nalian) and Baleswar (Charduani) for 4 months (2 months in monsoon and two months in dry season). Accordingly, data collection has been started since mid of February, 2019. The data is being collected at 15 minutes interval by installing pressure cell as well as by installing staff gauges for cross checking. The gauge reading is being taken by gauge readers and as well as automatic recoded by pressure cell. The gauges are connected from a nearest TBM connected from the existing SOB Benchmark by the RTK survey and level flying. The sensor readings are downloaded time to time as well during the data collection period.

Bathymetry Survey

As per TOR, it was planned that a total of 1306Km bathymetry survey would be conducted at Lower Meghna at 1.0 Km interval for 100 Km length starting from Chandpur to Tajumuddin and 141 nos. section would be conducted at Sangu @ 500m interval over the 70Km length starting from Lama to Outfal. However, during the inception and consecutive consultation, it is planned that additional 830 km bathymetry survey also conducted at Baleswar (from Hularhat to outfall of 82 km length @ 1000m Interval), at Pusur (From Rupsha to Outerbar of 133 km length @ 1000m interval), at Sibsha (From Haborkhali to Akrampoint 70 Km length(out of this 50 km @ 1000m interval & 20km @ 500 m interval) and at Bishkhali (From Gabkhan khal to Badurtala of 92 Km length @ 1000m interval). In the meantime, bathymetry has been already completed at Shibsha, Pusur and Baleswar starting from 01/03/2019 to 23/03/2019. Survey has been done by using Digital Echo-sounder and DGPS.

Figure 2-2: Installation Pressure sensor for water level recording during bathy survey at inside Sundarbans

Figure 2-3: Bathymetric survey at Pusur inside the Sundarbans

Yearly Monitoring survey

As per inception and subsequent consultation, yearly monitoring cross section survey would be done at 12 rivers (Pusur, Sibsha, Kobadak, Chunkuri, Badurgacha, Dhaki, Gangril, Gashiakhali, Andharmanik, Galachipa, Baleswar, Lower Meghna and Sangu). The section is being conducted in two locations for each river and for each location 3 nos. cross sections at 50m in interval. As such, a total of 6 nos. cross section has been carried out for each river. Data would be taken twice in year (January & May) and accordingly 4 nos. session would be conducted in two years. In the meantime, one session data collection has been completed in February, 2019.

Discharge observation and sediment sampling

As per TOR, it was planned to conduct a total of 54 nos. discharge measurement including sediment sampling and turbidity measurement at 3 locations (Bahadurabad, Hardinge Bridge and Bairab Bazar) once in month for 1.5 years. However, as per post inception consultation, it is planned that a total of 144 nos. observation would be made in these 3 locations twice in a month for the two years for the better understanding of the sediment rating curve. In case of Lower Meghna at Chandpur, it was planned to conduct a total of 3 measurements once in six months for 1.5 years as per original TOR. However, now it is rescheduled to take a total of 5 measurements at Chandpur of which 3 nos. during monsoon (2 spring+ 1 neap) and 2 nos. during dry season (1 Spring +1 Neap) as per revised . However, in case of discharge including sediment observation for the 5 tidal location (Gangril, Pusur, Shibsha, two locations in Baleswar), a total of 44 nos. observation was planned during 1.5 years as per original TOR. Now, as per post inception consultation 40 nos. observation in these 5 locations (each location for 8 measurement- 1 spring in every two months and -1 neap in every six months for the periods of one year). In addition, another 5 observations would be made at Bishkhali (3 nos. 1 spring in dry season and 1-Neap+1-Spring for monsoon) and Tetulia (2 nos-1 spring & I neap during monsoon).

2.3 Field Surveys to be carried out by US University Teams

2.3.1 Planned GPS and SET-MH Field Work

Upcoming field plans include the installations and upgrades of GNSS/GPS and SET-MH networks at the several locations (Figure 1) [note: GPS refers to the U.S. satellite navigation system and GNSS to the larger constellation including Russian, European and Chinese systems]. This will take place in two parts planned for the summer (July-Aug) 2019 and the fall-winter of 2019. The subcontract between DHI and the U.S universities were signed too late to conduct the survey in April, 2019

In the summer, likely starting in mid-July, M. Steckler, C. Wilson, C. Small and J. Galetzka, an engineer from UNAVCO, will conduct the joint installations of GNSS and RSET-MH. Access to most of the sites will be by boat, the M/V Bawali. At Site #4 (Polder 35/1), we will also install 2 new SET-MH, one inside the polder of interest (Polder 43), and one outside on the non-embanked river terrace. We will also deploy two new GNSS (Septentrio PolaRx5): one will be installed on the roof of a reinforced concrete building, likely a school, similar to our other GPS for consistency. The other will be mounted on a stainless steel rod driven to refusal to match the SET-MH installation and provide a direct comparison and provide a measurement of subsidence beneath the depth to refusal.

Two other sites will be established at Polder 16 or 17/1 (Site #1), and Polder 14/1 or 15 (Site #2). At each of these locations, 1 new GPS and 2 new SET-MH will be installed (within the polder and outside on the embanked terrace). An additional SET-MH will be installed within the Sundarbans near an existing GPS location (Hiron Point, HRNP) to record sedimentation within the natural tidal delta plain for comparison. We will replace the batteries and nonworking modem there with a new one. We will also stop at Katka Beach to collect data from an existing RSET-MH and piezometer. We will also visit Polder 32 (PD32) to replace the batteries and install a cellular antenna for better telemetry. We will disembark from the boat at Khulna

At Khulna, they will collect the final data from KHUL at Khulna University, another obsolete GPS receiver, and add a modem to KHL2, its replacement. The collection of overlapping data from KHUL (installed 2003) and KHL2 (installed 2014) will enable the time series to be combined. Finally, we will visit KHLC, the fiber-optic strainmeter well nest installed in 2011 at Bhanderkote, but non-operational since 2015. We will bring a replacement computer and new connectors for the EDM (electronic distance meter) to enable measurements to begin again. If it can be fixed an the site was not compromised by dredging of the river at the site, we will restart the weekly measurements made by the local host family. We will visit the site yearly to collect the data and conduct optical levelling between the 6 wells (20, 40, 60, 80, 100, 300 m depth.

C. Wilson will then continue to the land sites (PUST, KHEP) with the existing GPS. At PUST, she will also install 2 new SET-MH, one inside the polder of interest (Polder 43), and one outside on the non-embanked river terrace. At KHEP, she will also install two new SET-MH in the vicinity of the GNSS.

In the fall 2019, M. Steckler and J. Galezka, will repair and upgrade existing GPS receivers at two existing sites. The antennas for these sites are installed on the roofs of reinforced concrete buildings. They will also add cellular modems so the data can be remotely downloaded and replace the aging backup batteries. They will be accompanied by C. Small, who will ground truth remote sensing data. At Patuakhali, we will upgrade the antenna and receiver at the Patuakhaki Science and Technology University (PUST), replacing the obsolete Trimble 4000ssi receiver and antenna (vintage 1992) with a repaired Trimble NetR9 previously purchased. We will also reinstall a repaired Trimble NetR9 and modem at the Khepupara Meteorological Dept. Radar Station (KHEP).

During the fall/winter trip, Steckler and Galezka will work with a Bangladeshi team on reoccupying SOB benchmarks. The benchmarks in the field area were mainly installed in 2001-2003. Thus, they have experienced up to 10 cm or more of subsidence and seasonal elevation changes since that time. They will deploy 4 campaign GPS installing one antenna on a tripod at a benchmark each day. We would then leapfrog one receiver each day. In this manner, each site gets at least 3 full days of occupation for maximum accuracy (2 mm horizontal, 6 mm vertical). Our local GPS network will contribute to the accuracy of the resurvey. With this plan, it will take ~2 months to complete the survey of the ~60 benchmarks in the field area.

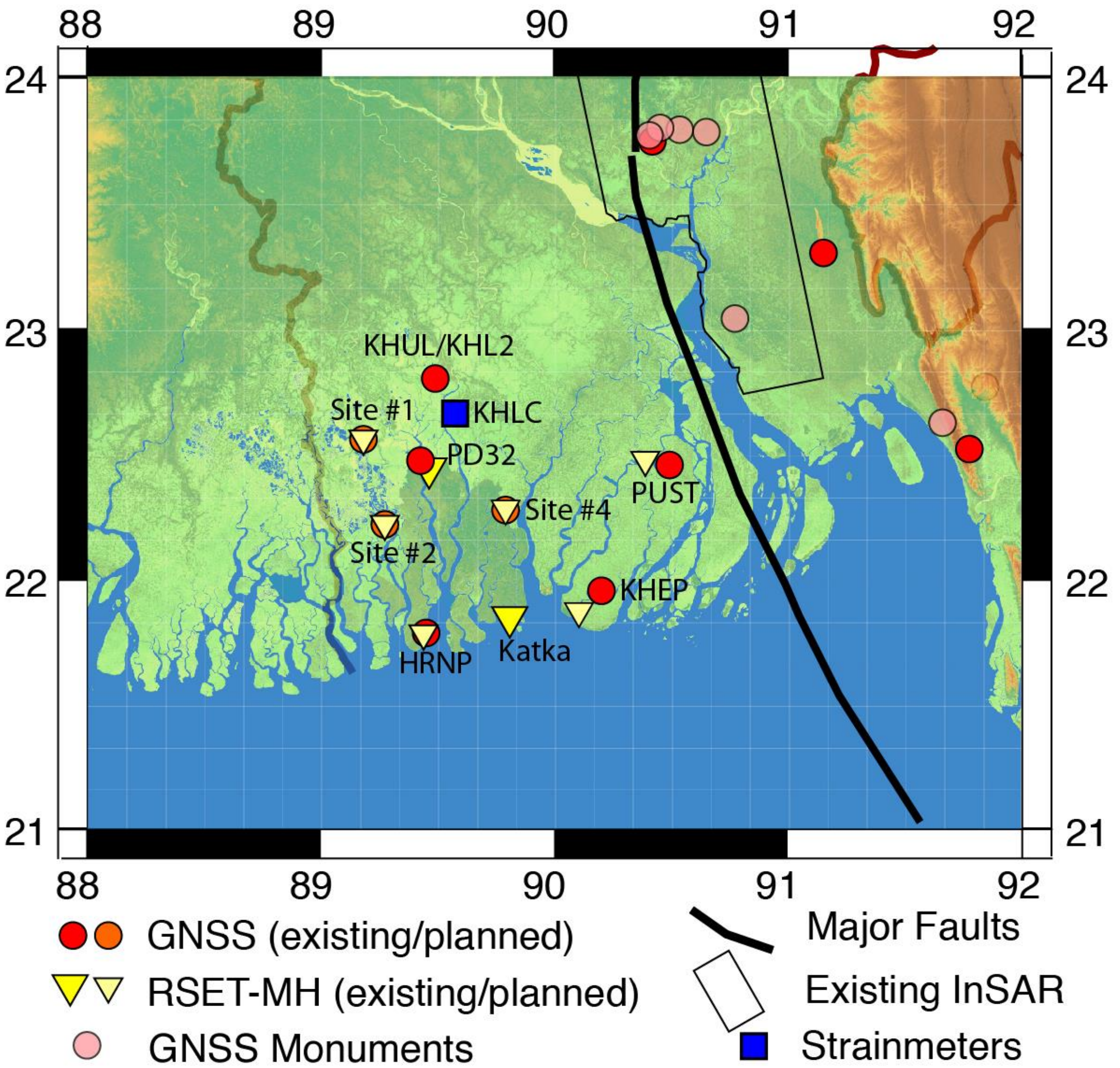

Figure 2-4: Locations of existing and planned GNSS and RSET-MH equipment in SW Bangladesh.

2.3.2 Planned Coring Field Work

The coring locations area planned and presented in the Figure 2-5.

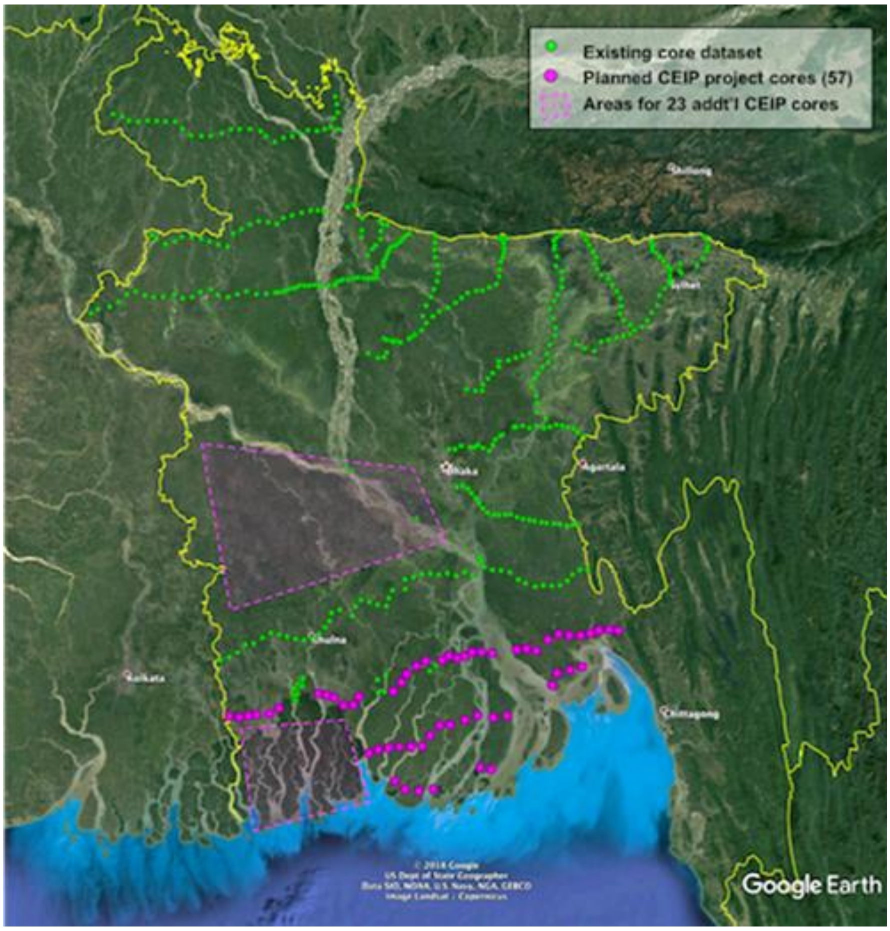

Figure 2-5: Coring Locations

2.4 Development of an Interactive Database for the Coastal Zone

2.4.1 Introduction

Significant progress was made during this Quarter in developing an Interactive Geo-Database for Coastal Zone. The objectives and the strategy for carrying out this work were described in detail in the Inception Report (2019).

Preliminary consultations were carried out with project stakeholders about the requirements of the current and future users of the database. As the database was to be transferred and installed at the BWDB at the closure of the study, close consultations were carried out with the database administrators at the BWDB to ensure that there was software and structural compatibility between databases.

In the light of the objectives of the project, the database will cover environmental and socio-economic aspects of Bangladesh Coastal Zone, which will be one of the important and lasting legacies of the project

2.4.2 Review Related Systems in BWDB

There are several systems and database are running in BWDB central server**.** The following similar systems are reviewed and analyzed in order to develop the proposed Polder database.

Scheme Information management (SiMS)

A web GIS based Scheme Information Management System (SiMS) has been developed under the Water Management Improvement Project (WMIP) in late 2014 for managing and maintaining of BWDB completed and ongoing Projects. Detailed inventory of ongoing and completed projects has been developed for Southeastern Zone of Chittagong. The SiMS database is now available on the web centralized at the BWDB central database server. General information of each project having details infrastructural information such as Polders, Embankment, Canal and Hydraulic Structures are found in the database which are georeferenced and visualized in web GIS environment. The SiMS is running with a backend Oracle based Geo-database where all the geo-spatial data are stored and accordingly several GIS map and feature services are running in an ArcGIS Server which are also held in BWDB central GIS Server hosted at BWDB Headquarter. In order to design and develop the Coastal Polder database, SiMS database has been reviewed rigorously to apply the data concept, database structuring and designing and database designing wherever it was applicable.

BWDB Hydrological Database

BWDB Hydrological Circle maintains a hydrological database for over the country. There is a hydrological established network system around the country from which BWDB Hydrological Circle collects hydrological time series and discrete data.

2.4.3 Installation of the Software Hardware Platform

The required software and hardware platforms have been already installed and properly configured using IWM resources at IWM Office.

Software:
ArcGIS Server
Oracle Database
Required Web developer's tools and scripts

Hardware:
Web Server
Database Server
GIS Server

2.4.4 Prototype Software Development

After installation of Software and Hardware platforms, and following the completion of database development (ongoing) several test datasets have been uploaded in the database and started to develop a prototype version of different modules for the proposed Web GIS based Polder database application according to the high-level architecture as shown in the following Figure.

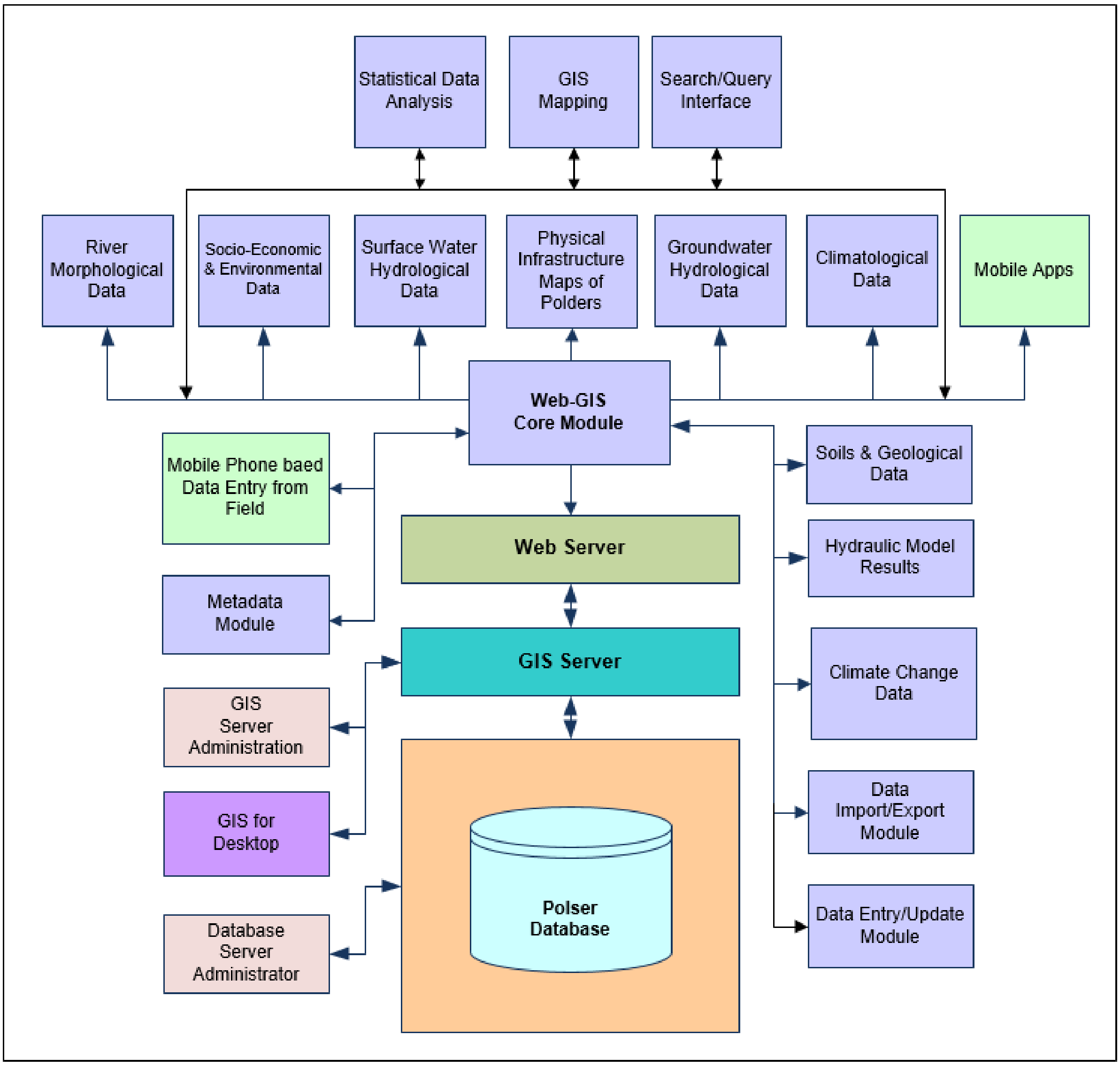

Figure 2-6: High-level System Architecture

2.4.5 Progress at a Glance

The following table presents the targets and current achievements of the database and Web GIS based application development till to date and also illustrates the target of the work for the next quarter.

Table 2-5: Targets and the current achievement of Polder database Development

Sl No	Activity/Task	Progress Target (%)	Progress Achievement (%)	Target Next Quarter (%)
1	Mobilization	100	100	-
2	Review Existing Systems	100	100	-
3	Consultation with Project Team	100	100	100
4	Consultation with Project Client	100	100	100
5	Requirement Analysis	100	100	-
6	Data Requirements	100	100	-
7	Conceptual System Architecture	100	100	-
8	Inception Report	100	100	-
9	Identification of Data Sources	100	100	-
10	Data Collection	40	20	100
11	Data Review, Validation & data Processing	40	20	90
12	Preparation of SRS & SDD Report	100	50	100
13	Installation of Software Development Platform	100	100	-
14	Database Design & Development	50	40	100
15	Database Implementation	-	-	30
16	Prototype Development	30	10	100
17	Full Version Development			30
20	Testing & Debugging	-	-	10
21	Final Development	-	-	-
22	Fully operational version of IGDCZ commissioned	-	-	-
23	Training & Technology Transfer	-	-	-

3 LITERATURE SURVEY

3.1 Progress

Literature review is an important task of the project as it helps the consultants providing insights of the study area including climate, ideas on coastal dynamics, information on site specific driving parameters for changing morphology, etc. All these help the project professionals and experts to correctly dragonize the problems to deal with the study and come out with the best solution.

With a view to that identification and collection of relevant documents and papers for literature review is in progress. The gathered documents (reports) are mostly in hardcopies which are being converted into softcopies in PDF format. Till preparation of the progress report for the 2nd quarter, photocopies of 50 reports have been made of which 27 are scanned to convert into PDF format. Other than the reports, relevant papers are being obtained from internet websites. The obtained materials are in the process of reviewing which are categorized into different disciplines. For each category, overall synopsis of the reviewed materials has been planned to be included in the literature review report. In addition, the report will include separate briefs of at least 30% of the reviewed materials in specific format containing summary, methodology and key findings & knowledge gaps.

The project has set up an online folder where any individual professional of the project, sitting in different countries, can upload reference materials on literature review. This will ease sharing of information among project professionals.

3.2 Review Report

Review of literature for different categories are in progress. For the “Geology, Subsidence and Delta building” category, 71 international publications on the Ganges-Brahmaputra-Meghna (GBMD) have been reviewed till the 2nd quarter of the project. Of which 34 provide state-of-the-art knowledge on the tectonic and earthquake vulnerability of the GBMD. The remaining numbers of reviewed references on subsidence and delta building are 17 and 20 respectively. Synopsises of the reviewed literature altogether for the subsidence and delta building have been made. Separate briefs of at least 30% of the reviewed papers are in progress.

For the morphology category, overall synopsis of the review of 9 papers have been made where summarized information on characteristics, concentration and distribution, composition and mineralogy of the suspended and bed load materials of GBMD are provided.

In the climate change and sea level rise category, 26 papers have been reviewed. Based on the review, a synopsis has been prepared where the effects of climate change on Sea level, Cyclone Intensity and Frequency, Rainfall, River discharge and Temperature in the basin are described.

Review of 8 individual papers on 3 different categories (2 papers on Salinity, 4 papers on Climate Change and 2 papers on Environmental and Social) have so far been completed and synopsis of all individual papers into specific format containing summary, methodology, and key findings & research gap have been made.

4 MORPHOLOGICAL MODEL DEVELOPMENT

4.1 Macro Scale Models: GBM Basinwide Applications

These macroscale modelling runs focus on the complex interaction of fluvial-tidal processes and sediment transport across the Ganges-Brahmaputra-Meghna Delta (GBMD) in Bangladesh. The control of these processes on delta morphology is well understood: in the southernmost region of the delta, mesotidal processes dominate, creating large tidal channels throughout the Sundarbans mangrove forests, whereas the northern portion of the delta located upstream of the backwater zone is actively reworked by the Ganges River and its distributaries, where thin riverine networks to avulse across the landscape. This work focuses how sediment transport patterns change along the transition of hydrodynamic processes in the GBMD. Using a numerical modelling approach, with the Delft3D modelling suite, we address the following questions:

• How do sedimentation patterns change across the fluvial, tidal and mixed regimes?

• Are there lateral changes in grain size distribution in the different process zones?

• At the macroscale, can rates of sedimentation compete with rates of sea level rise?

To explore these ideas, machine learning techniques are used to create new “process zones”, grouping different portions of the delta together based on local geometric properties of individual islands and channels. From three of the major new process zones (poldered mixed fluvio-tidal plains, purely tidal shoals and inactive fluvial), characteristic islands are selected. The Delft3D modelling suite is used to simulate flow across characteristic islands using the appropriate boundary condition processes. Where available, field data are used to set model parameters. If no further bathymetry is available for many of the distributary channels, hydraulic relationships are used to estimate depth given satellite-derived channel widths.

For the three test cases, one modelled year of monsoonal discharge and/or tidal fluxes are used to drive sediment transport and deposition of clay, fine silt, medium silt and coarse silt grains. At cross-sections placed near the boundary, and set distances from the boundary (~1, 5, and 10 km), grain size distributions and rates of sedimentation are calculated. In sites with tidal forcings, changes in sediment thickness and grain size prevalence through time are also plotted to determine how sediment composition changes with the shift from ebb to flood.

Preliminary results indicate that in the fluvial zone, overbanking of monsoonal floods leads to the formation of levees at a rate between 2.4 – 4.7 cm/yr. In the mixed fluvio-tidal and purely tidal cases, sedimentation occurred more laterally or uniformly across the floodplain. Modelled rates of sedimentation in these zones ranged from 2.3 – 4.2 cm/yr and 4.4 – 5.3 cm/yr, respectively. These rates are comparable to, but still exceed, field estimates of monsoon-driven deposition of 1 – 3 cm/yr. The high rates of sedimentation are likely due to the fact that sediment distribution in the model is based on floodplain observations and not in situ measurements from channels, which would be finer grained. Still, model results suggest sedimentation in all zones would exceed predicted rates of sea level rise for the GBMD (0.8 - 1.8 cm/yr, Syvitski et al., 2009). Further testing, and validation using planned field measurements, are needed to more accurately estimate sediment rates driven by fluvial and tidal accretion across the GBMD.

4.2 Macro Scale Models: Large Rivers System

A Macro Scale Model is being developed covering all the major river systems of Bangladesh. The river network selected for Macro Scale Modelling is presented in the Figure 4.1. Simulation of different scenarios is feasible with this model to examine the impact of river linking project, land use and climate change. This model will provide data on, water level, water flow and sediment, which is eventually essential to define the boundary conditions of Meso and micro scale modelling.

Figure 4-1: The river network selected for Macro Scale Modelling

4.3 Meso Scale Models for Long Term Morphology

The main objective of this modelling is to address the morphodynamical behaviour of river branches around the polder area and to estimate future changes under different scenarios. In addition, the meso scale is suitable for addressing local 3D effects such as density-driven flows on sediment transport pathways. Apart from reproducing current conditions for model validation, the time span involved concerns conditions after 25, 50 and 100 years.

Meso scale model domains have already selected based on available previous data, erosion history and the peripheral rivers around the polders that covers the whole coastal area. CEIP officials also agreed the selected zones for this modelling. The selected meso scale modelling groups are following (Figure 4.2):

Pussur – Sibsa River system (Polder 32 & 33)

Baleswar – Bishkhali River system (Polder 35/1, 39/1, 39/2, 40/1, 40/2, 41 & 42)

Lower Meghna- Tentulia River system (Polder 56/57,55/1,55/2, 55/3 & 59/2)

Sangu River system (Polder 63/1a, 63/1b & 64/1b)

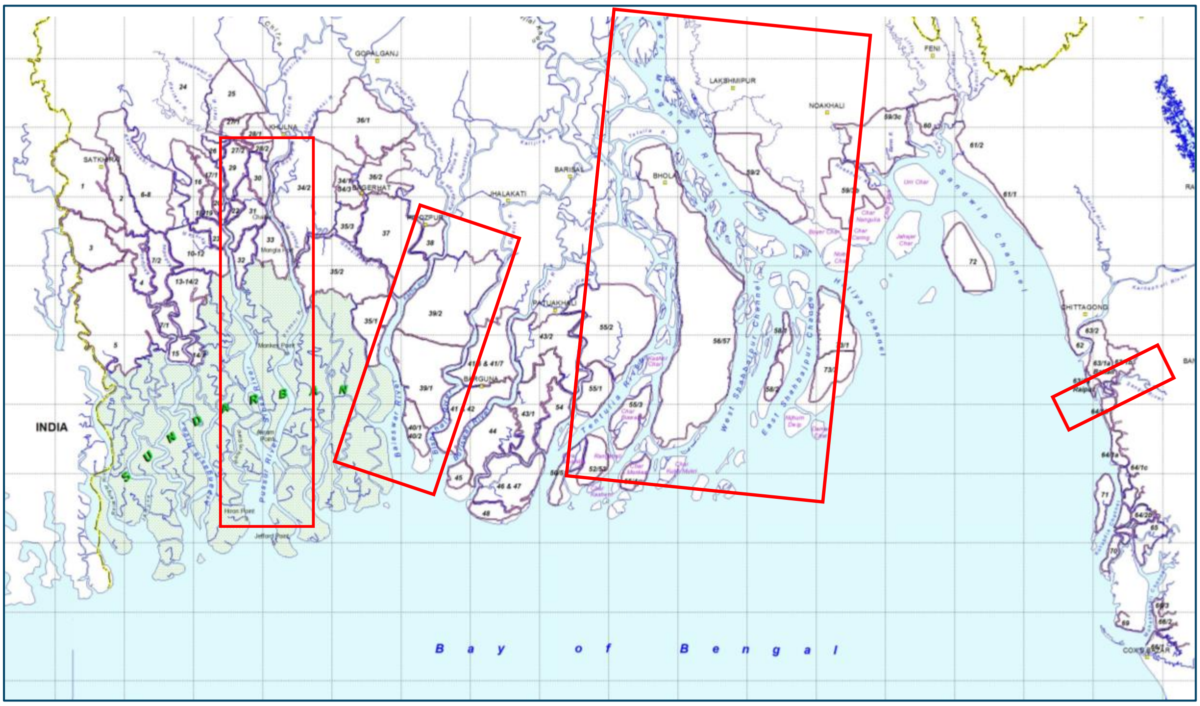

Figure 4-2: Map of meso scale modelling groups for long term morphology

4.3.1 Pussur-Sibsa River system for meso scale modelling for long term morphology

From the previous studies, it observed that both rivers have different sediment size in the bed materials: Pussur seems cohesive sediment characteristics whereas Sibsa is non-cohesive sediment characteristics. The secondary data for Pussur-Sibsa rivers are available for 2011, and the primary data collection is going on for 2019 in the same area coverage like the year 2011. The modelling activities for the river system are the following:

- Setup and Calibration – Setup, calibrate and validate the model with field measurements and remote sensing data.
- Morphological hindcast – reproduce the morphology from 2011 to 2019.
- Scenario runs - Study future changes in the morphological processes based on possible scenarios.
- Output - Geospatial datasets of erosion and sedimentation in the Pussur-Sibsa river system at present for various seasons and for possible scenarios 25, 50 and 100 years from now, for various seasons and circumstances.

The long term meso scale model development has already started by Delft3D FM modelling system. Figure 4.3 shows the computational grid and interpolated bathymetry for 2011. The Pussur-Sibsa model has two upstream boundaries and one downstream boundary. Upstream boundaries were collected from calibrated and validated South West Regional Model and measured water level of Hiron Point was used as downstream boundary.

The Delft3D FM sediment transport model calculates transport rates on a flexible mesh (unstructured grid) covering the area of interest on the basis of the hydrodynamic data obtained from a simulation with the Hydrodynamic Module (HD) together with information about the characteristics of the bed material. That is why a well calibrated and validated hydrodynamic model is needed to develop a reliable sediment transport model. Hydrodynamic model calibration and validation are going on for the Pussur-Sibsa river system.

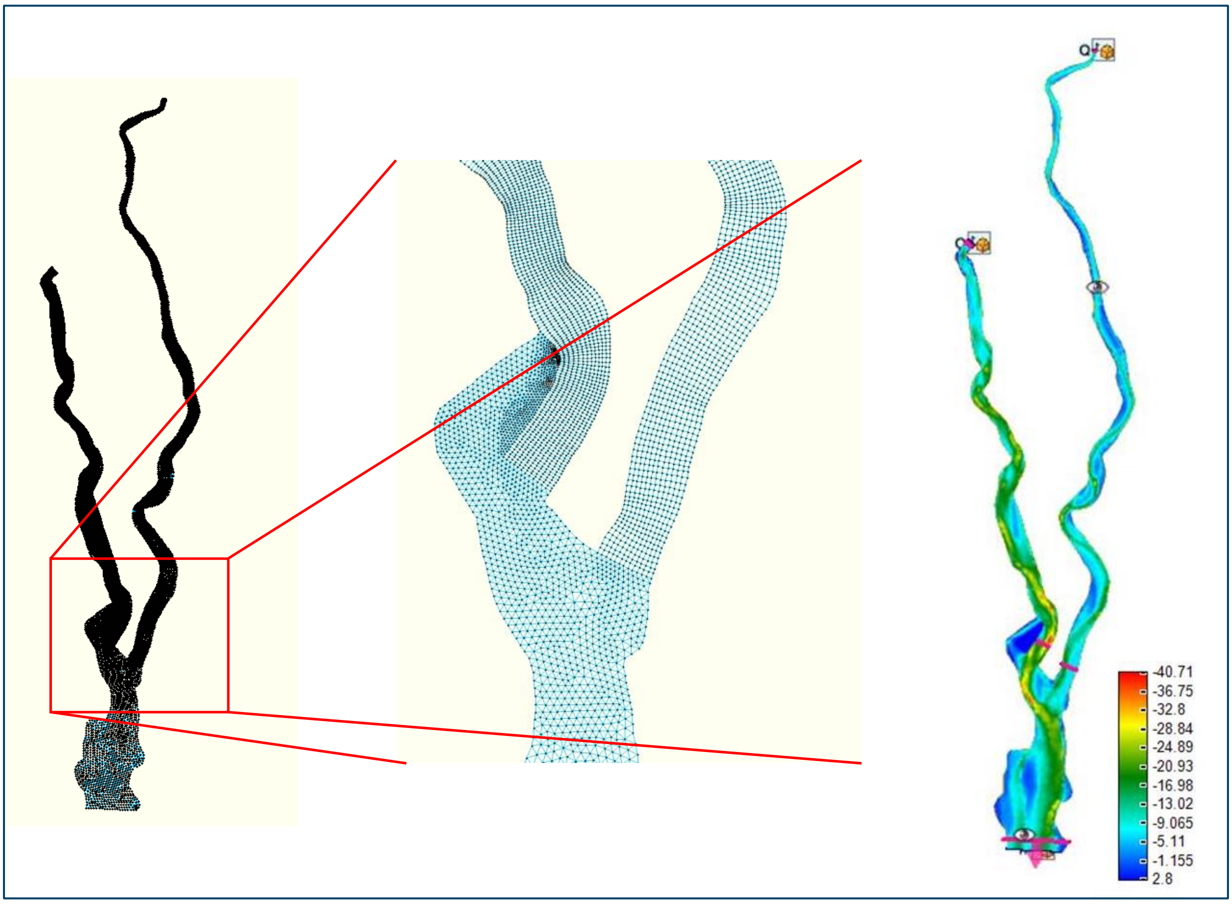

Figure 4-3: Computational mesh/grid for Pussur-Sibsa river system and interpolated bathymetry for 2011.

4.3.2 Baleswar River system for meso scale modelling for long term morphology

According to previous knowledge, Baleswar river has cohesive sediment characteristics. The secondary data for this river is available for 2011, and the primary data collection is going on for 2019 in the same area extent like 2011. The modelling activities for the river system is similar to the Pussur- Sibsa river modelling system.

The long term meso scale model development has already started by Delft3D FM modelling system. Figure 4.4 shows the computational grid and interpolated bathymetry for 2011. Baleswar river system has one upstream boundary which was collected from calibrated and validated Southwest Regional Model and one downstream boundary which was collected from measured data at Haringhata.

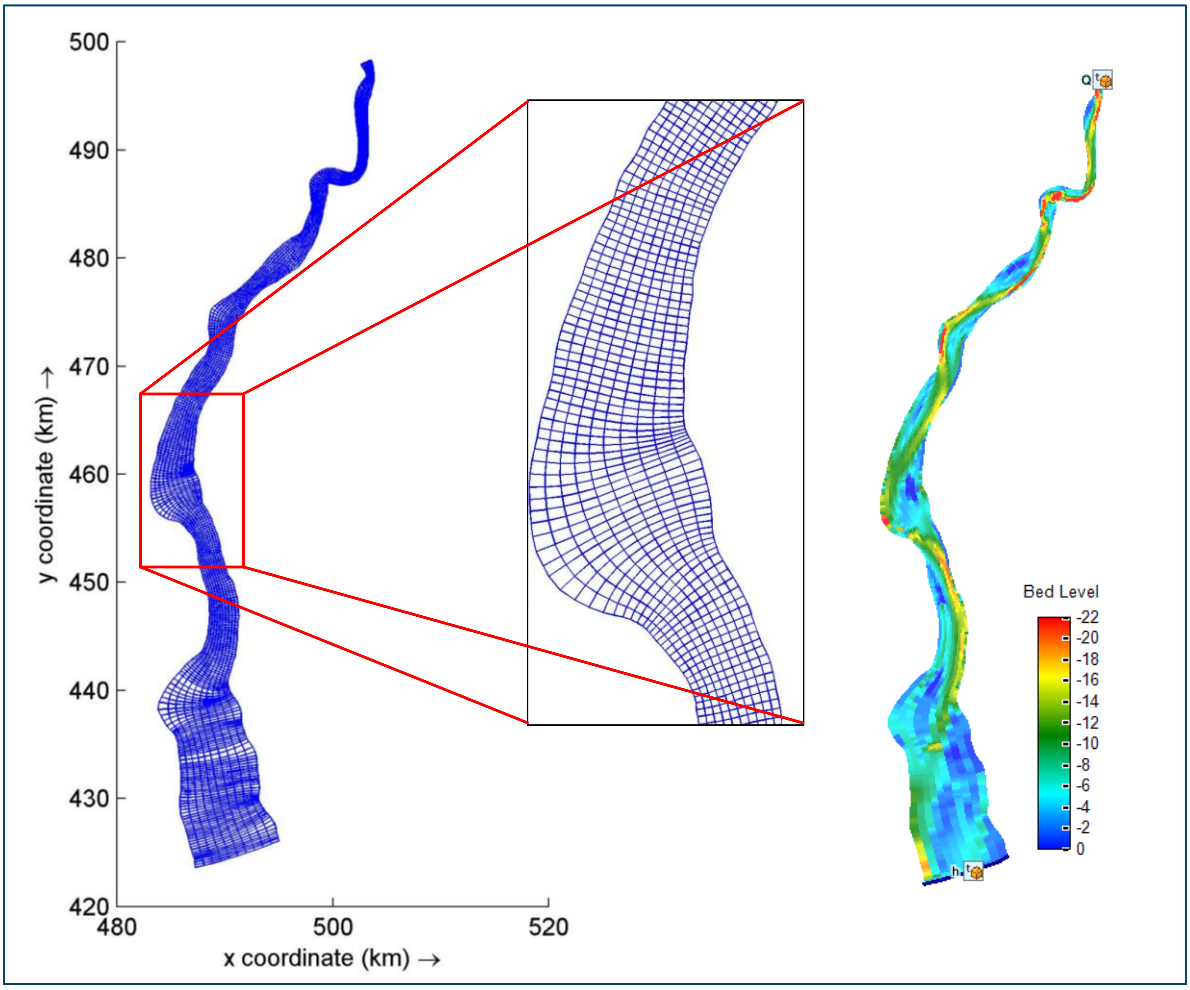

Figure 4-4: Computational mesh/grid for Baleswar river system and interpolated bathymetry for 2011.

Hydrodynamic model calibration and validation are going on for this river system.

4.4 Meso Scale Models for Bank Erosion

The development of the meso scale bank erosion models was initiated in February 2019 with the following key activities:

- Select river for pilot bank erosion model study
- Identify areas to be studied using a bank erosion model
- Augment the IWM survey program to include data collection needed for the bank erosion models
- Preliminary study of historical bank erosion in the larger tidal rivers by using satellite imagery
- Digitization of historical bank lines (Landsat) for the Baleswar and Pussur-Sibsa rivers
- Review of publications related to bank erosion with emphasis of identifying the most suited bank erosion description for the tidal rivers in Bangladesh

The prediction of bank erosion hinges on the already complicated prediction of bathymetry in a river, with strong feedback between the planform and bathymetry. This makes bank erosion complex, and to make matters worse, the complexity is increased compared to the complexity associated with predicting the bathymetry development.

However, we find encouragement when studying the historical bank erosion development from satellite imagery. Contrary to e.g. Jamuna River where bank erosion can be awfully complicated to predict more than a few years into the future due to degrees of freedom in a braided river, the locked channel morphology in the tidal rivers investigated gives rise to optimism when it comes to predicting bank erosion.

4.4.1 Selection of Baleswar River for pilot bank erosion model study

We selected Baleswar River for the following reasons:

- Baleswar is one of the largest tidal rivers with clearly defined curvature over decades
- Data collection has taken place on the river, i.e. data already exists
- A very detailed bathymetry survey was conducted in 2011 (GRRP)
- Bathymetry surveys were conducted 2009, 2011, 2015, with 2011 (GRRP) being very detailed
- Classic bathymetry with deep ebb channels (bend scours) and shallow flow channels through point bars
- Significant bank erosion problems currently being mitigated by the CEIP
- Inspection of the erosion during the past 32 years (1984-2016) showed that the erosion over time has been consistent
- The magnitude of erosion during the past 32 years has not been excessive or dramatically altered the river planform, so the erosion appears reasonably predictable compared to a case where the planform changes significantly (see e.g. Sangu River south of Chittagong).
- Dominantly outer riverbank erosion driven by curvature, but also extremely deep (40 m) channel along the bank, which could also be curvature driven; in other words the bank erosion and bathymetry developments are linked (meaning predictability)

Figure 4-5: Bank erosion along the Baleswar river, photo from field conducted 10 February 2019.

Baleswar was also visited by the Team Leader and IK-6 in February 2019 to visually inspect the ongoing bank erosion problems. Typical bank erosion is seen in Figure 4.5.

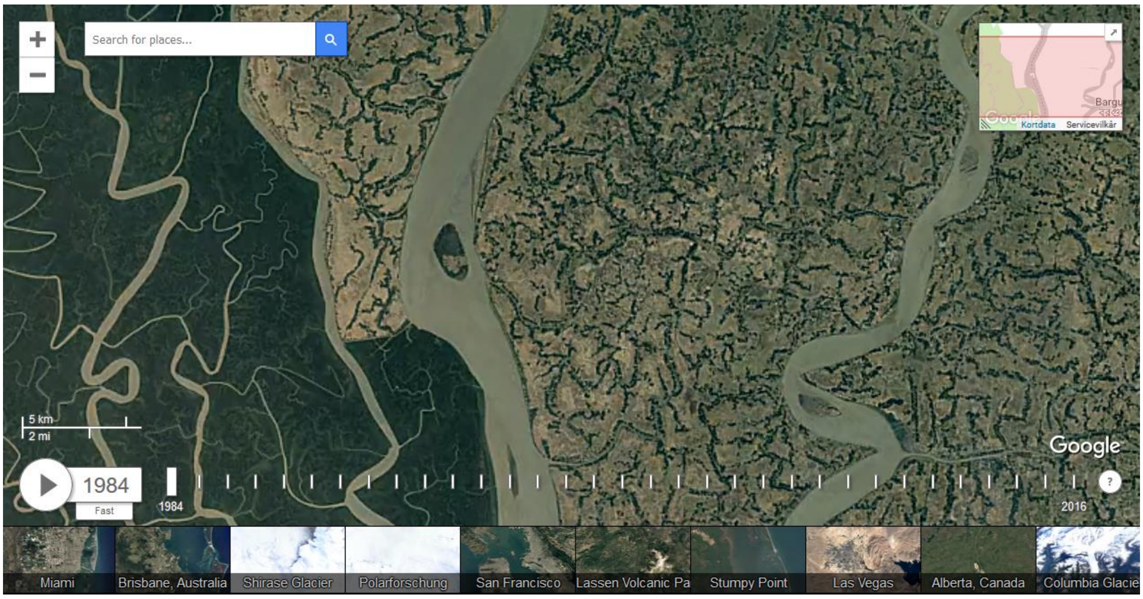

Figure 4-6: The website https://earthengine.google.com is extremely useful for animating and understanding bank erosion, here using the URL: https://earthengine.google.com/timelapse/#v=22.24371,89.91704,10.149,latLng&t=0.63

The animations available via the website https://earthengine.google.com (see Figure 4.6) are not enough for working with the bank erosion development digitally. Therefore, IWM engineers digitized the bank lines 1988 to 2019, typically every 5 years, to have the data available for the model study.

We have also looked at bank erosion publications in order to initially investigate the best suited bank erosion description.

4.4.2 Selected rivers for data collected by IWM

IWM has already identified 6 rivers for the forthcoming survey campaign:

- Pussur
- Sibsa
- Baleswar
- Bishkali
- Tentulia
- Sangu

These rivers are a sensible choice for the data collection programme.

Tentulia is a braided river, which we know we can describe using 2D models, but bank erosion predictability usually has a short time-scale in braided rivers (still depending on the activity).

Based on https://earthengine.google.com, Sangu is the most active and complex river, which will be challenging for bank erosion modelling. Sangu is also the only river in the southeast and was clearly selected over Karnafuli because the latter does not exhibit much planform activity.

4.4.3 Augmented data collection programme

The tidal rivers flowing past polders transport both cohesive and sandy material. Traditionally data collection by IWM includes any particle size distributions for the bed samples, but currently we only have such samples available for the dry season. The samples almost all show purely clay to silt sizes, but we know that sand is arriving to the tidal rivers from upstream. We also know that tidal pumping takes place in the rivers during the dry season, making the rivers import a blanket of cohesive sediment from the Bay of Bengal.

IWM informed DHI that monsoon bathymetry collection is impractical due to the strong currents in the rivers during the monsoon.

The main augmentation to the data collection programme, to be included for each river:

- Monsoon bed samples to be subjected to sieve analysis to determine particle size distribution; this is a standard analysis conducted by IWM, but extended to both dry season and monsoon
- Dry season and monsoon suspended sediment samples to be subjected to particle size distribution; this is not a standard analysis and requires special techniques due to the small sample sizes obtained from suspended samples.
- ADCP data will be collected in two selected bends on the Baleswar in order to be able to use the ADCP data not just for discharge, but also to possibly (can be difficult) evaluate the secondary flow and obtain a flow distribution between the ebb and floods channels, which is very useful calibration data.

4.5 Morphological Models for TRM (Micro Scale)

Reports on tidal river management (TRM) have been studied, and Polder 24 has been identified as a good case for a pilot model. IWM collected a lot of data at Polder 24 including:

- River cross-sections, several datasets were collected
- Floodplain elevations, including levees (very important for the hydraulics)
- Discharges and water levels (tidal cycle)
- Sediment particle size distribution data
- Sediment concentrations during the tidal cycle

The available data for Polder 24 is extremely suited for morphological modelling because it allows determination of sedimentation and erosion over time, which is not normally available for modelling studies. IWM also deliberately collected bathymetry data associated with specific interventions, which also calls for the use of modelling to understand the processes, which has a lot of potential value for conducting TRM.

In other words, the data offers opportunities that we do not normally get in modelling. The first step in the study should be to reproduce the developments documented in the IWM data and reports, i.e. hindcasting, which is normally not possible at this level of detail.

5 OTHER STUDIES

5.1 Subsidence and Delta Building

Subsidence Mapping with Differential InSAR (D-InSAR) remote-sensing data

Subsidence is a key process to be quantified, and remote-sensing techniqes, notably Differential INSAR data analysis does show some promise to arrive at spatially-distributed maps of subsidence. D-InSAR use the repeat passes of radar instruments on satellite and analyzes the phase change, Λϕ, of the returned radar signal between different passes.

$$\Delta\phi = \Delta\phi_g + \Delta\phi_a + \Delta\phi_t + \Delta\phi_d + \Delta\phi_n + \Delta\phi_o$$

In deltaic regions, phase changes may be due to ground deformation, atmospheric beam delay, topography change, decorrelation, thermal noise or orbital drift. Our analysis corrects for all of these factors, but for monsoonal regions dry season acquisitions turn out the most reliable (Higgins et al., 2014).

Another key part of the D-InSAR analysis, is that even when phase change can be accurately quantified, that is not to be interpreted as absolute surface change, and thus calibration with in-situ GPS records is imperative. The existing Columbia-Dhaka University GPS network and soon to be installed new GNSS units will provide calibration.

Figure 5-1: JAXA-ALOS 1 coverage of the GBM system.

This data provides coverage from 2006-2011 and is now discontinued.

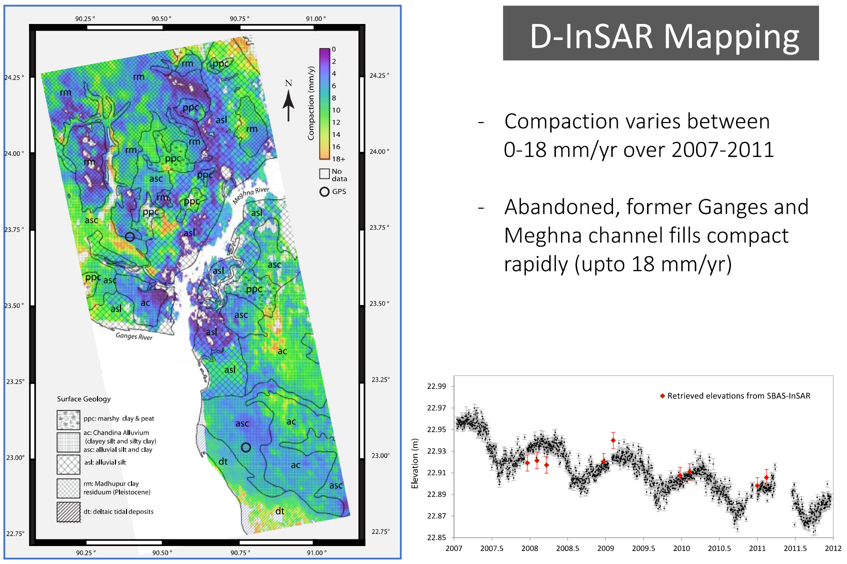

Figure 5-2: A) Previous subsidence map of Dhaka and Meghna-GB confluence shows subsidence rates are between 0-18 mm/year. B) Comparison of local ALOS derived subsidence data (in red triangles) compared to continuous GPS record (after Higgins et al., 2014).

Over January 2019-April 2019, the team at the University of Boulder has been established to be Dr. Irina Overeem, Prof. Kristi Tiampo and her research assistant Clay Woods (to replace Dr. Stephanie Higgins).

The University of Colorado team has organized three meetings for project overview briefing, planning and design of work. The team has coordinated plans with Dr. Mike Steckler (Columbia University) to ensure smooth cooperation on using GPS data for ground-truthing.

Our plan is over April 2019 – June 2019, we will revisit earlier analysis of the JAXA ALOS 1 data. Processing software for this purpose is free and open-source, but the newer version (as compared to earlier analysis) takes a time investment to be up and running. This is being done in the next reporting period. Once completed, we plan to expand the spatial coverage of the analysis provided by Higgins et al 2014 to additional mappings of the Khulna, Barisal, Barguna districts.

JAXA ALOS 1 satelite is dead in orbit since 2011, and JAXA ALOS -2 is not easily available to the scientific community. The project team has started the scoping of the use of ESA –Sentinal 1 SAR data - an imaging radar mission providing continuous all-weather, day-and-night imagery at C-radar band, to expand the ALOS time series. This will require a comparison of Sentinal data with earlier maps and in-situ GPS data of Steckler. The team also investigates whether new techniques developed since 2014, may improve both the atmospheric correction and topographic correction (see Eq 1) and can be done better nowadays as compared to earlier analysis.

5.2 Climate Change, Sea Level Rise, Cyclones/ Storm Surges

The work undertaken during this quarter focussed on:

a) Collecting and analysing relevant information from open available **global datasets**, with downscaled information for Bangladesh

b) Collect relevant **local measured data** to be analysed in the following months

The analysis will be used as a basis to derive the scenarios for the long-term simulations.

5.2.1 Analysis based on global datasets

5.2.1.1 Sea level rise

Sea level rise data for Bangladesh were analyzed based on Vousdoukas et al. (2018). Probabilistic projections of Extreme Sea Levels (ESL) for the present century were estimated, taking into consideration changes in mean sea level, tides, wind-waves and storm surges.

Between the year 2000 and 2100 the authors projected a very likely increase (5–95th percentile) of the global average 100-year ESL of 34–76 cm under a moderate-emission-mitigation-policy scenario and of 58–172 cm under a business as usual scenario on the global scale. For South East Asia, a very likely increase in the 100-year ESL was estimated equal to 37-79 cm under RCP 4.5 and 62-188 cm under RCP 8.5. The contribution due to sea level rise was estimate equal to a median value of 57 cm (very likely range 26 – 93 cm) for RCP 4.5 and 91 cm (very likely range 52-214 cm) for RCP 8.5.

Figure 5.3 shows the estimated contribution due to sea level rise only for time horizons 2010, 2015 and 2100 under RCP scenarios 4.5 and 8.5. The figure shows relatively small variations along the coast when considering the sea level rise component alone. Spatial sea level rise variations are for example of much smaller entity than local difference in subsidence rates.

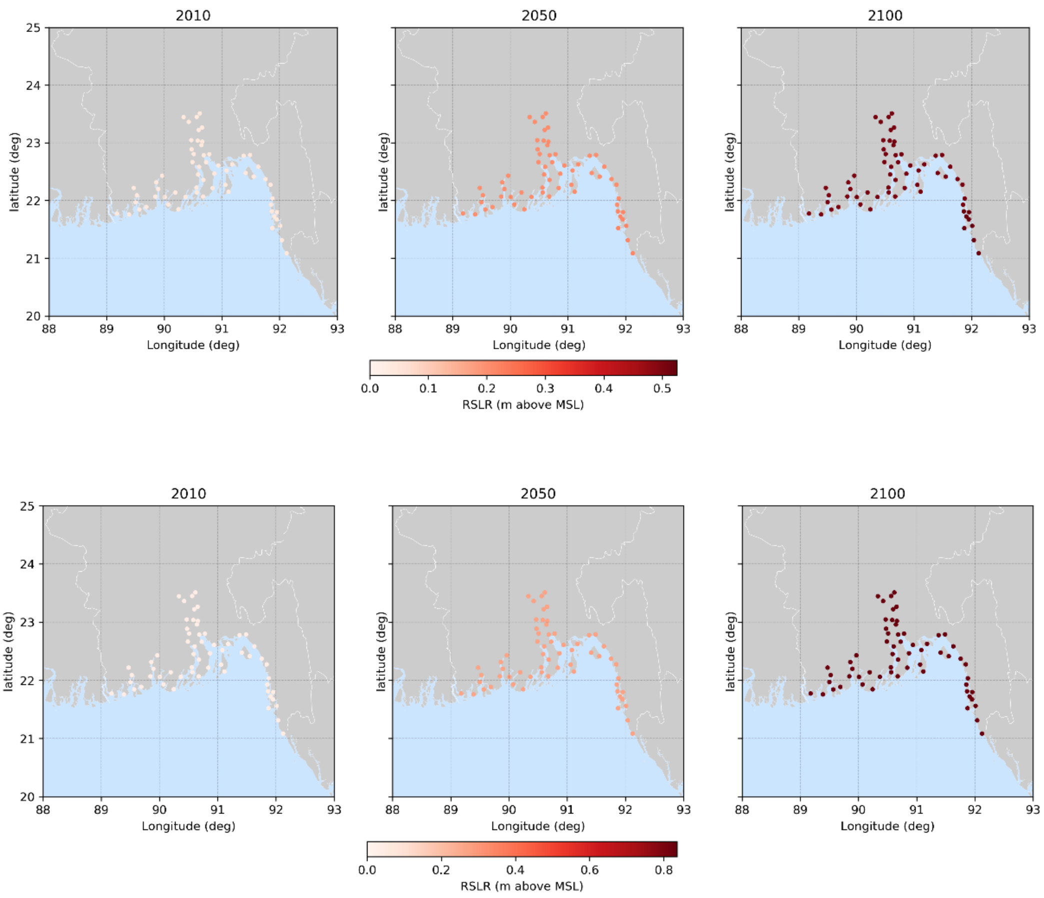

Figure 5-3: Predicted mean sea level rise rates according to Vousdoukas et al. (2018) for Bangladesh, respectively for RCP 4.5 (panel above) and RCP 8.5 (panel below) for 2010, 2050 and 2100.

Figure 5.3 indicates the changes in total water levels (including changes in mean sea level, tides, wind-waves, and storm surges) along the Bangladesh coast for time horizons 2010, 2050 and 2100 for RCP scenarios 4.5 and 8.5.

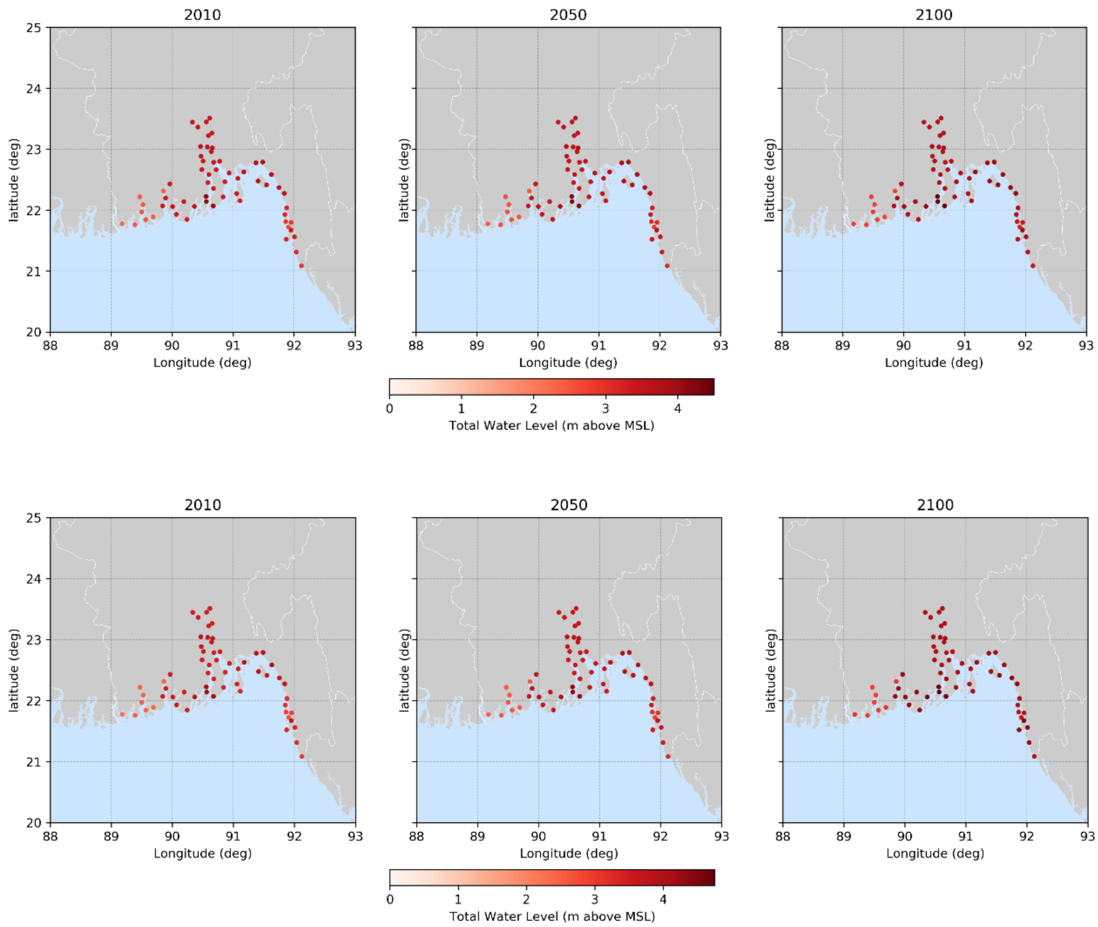

Figure 5-4: Predicted extreme sea level rise rates (including changes in mean sea level, tides, wind-waves, and storm surges) according to Vousdoukas et al. (2018) for Bangladesh, respectively for RCP 4.5 (panel above) and RCP 8.5 (panel below), for 2010, 2050 and 2100. Waves and storm surges refer to a 1/100 year extreme event.

5.2.1.2 Changes in cyclone intensity and frequency

Bangladesh is a global hotspot for tropical cyclones and it adverse impacts on society (Dasgupta et al., 2016). For example, between 1960-2004 more than half a million inhabitants of Bangladesh died as a consequence of TCs, primarily due to storm surge (Schultz et al., 2005).

In the current situation, generally-speaking, tropical cyclones (TC) generate in the Bay of Bengal, propagate northwards and make landfall in a southwest / northeast direction at Bangladesh (see Figure 5-5). Once on land, the intensity of the TC decreases due to lack of warm water supply and increased land roughness. Generation occurs both during the early summer time period (April, May, June, July) as in the late rainy season period (September, October, November, December; see for more information Dasgupta et al., 2016).

In 45 years of time, the Joint Typhoon Warning Center (JTWC) for the Indian Ocean (IO) basin, reported 45 TCs with wind speeds higher than 20 m/s. This means there is, on average, every year a TC that makes landfall in Bangladesh. When only focusing on the most intense TCs (maximum wind speeds higher than 50 m/s; denoted as extremely severe cyclone storm and super cyclone storm) the probability decreases with 80%. This means that, on average, every 5 or 6 years such a heavy TC makes landfall in Bangladesh.

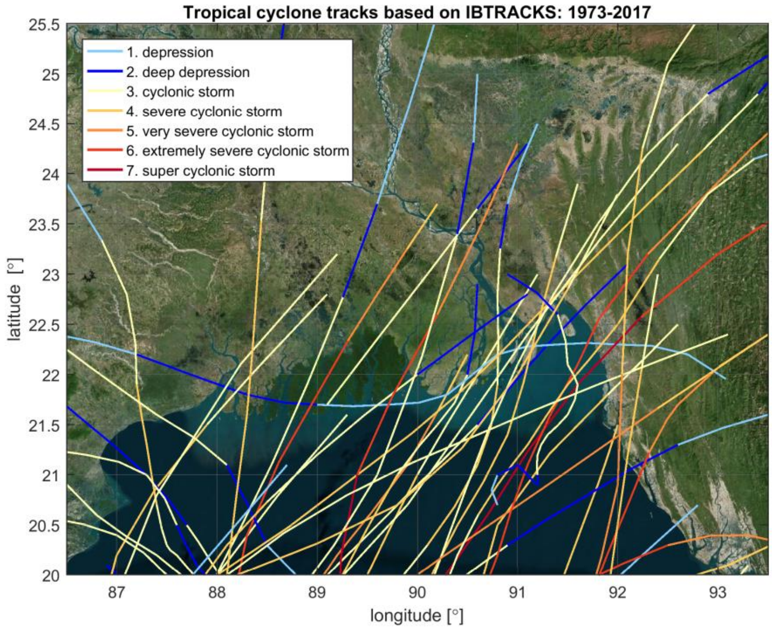

Figure 5-5: Tropical Cyclone (TC) tracks and intensity based on the IB TRACKS database. Here the joint typhoon warning center for the Indian Ocean (IO) was used as data source. The tracks are colored-coded based on the India Meteorological Department (IMD).

Future situation

For the future situation it is challenging to detect any change in tropical cyclone activity based on data. When observing the data from the Joint Typhoon Warning Centre, this suggests a larger number of TCs for the time period 1980 – 2000 with respect to the years before/after. The same can be said for the number of the most extreme TCs only. Six out of the eight TCs with wind speeds larger than 50 m/s occurred in the ten-year time period 1988 – 1997, while only one event occurred after 2000 (i.e. TC Sidr, 2007 with a maximum reported wind speed of 67 m/s). Therefore, the data seems to suggest a decreasing trend in the number of (strong) TCs. However, due to relatively short data record, one need to assume that these perceived trends are based on randomness.

Knutson et al. (2015) carried out a numerical modally study to assess projection in TC frequency and intensity for different oceanic basins. CMIP5 multimodel ensembles were used to compare conditions under RCP 4.5 for the late twenty-first century to the period 1982-2005. For the North Indian Ocean, an average increase of 19.5% in the frequency of TCs of all different intensities was found, with a peak in increase for TCs with stronger intensities (category 4-5). This was also accompanied by an increase in duration maximum wind speed (3%) and precipitation rate (10-20%).

5.2.2 Analysis based on measured data

The following datasets have been collected and will be analyzed statistically in order to derive possible long-term trends:

- Water level data

- Cyclone tracks and intensity

- Rainfall data

- River discharges

- Temperature data

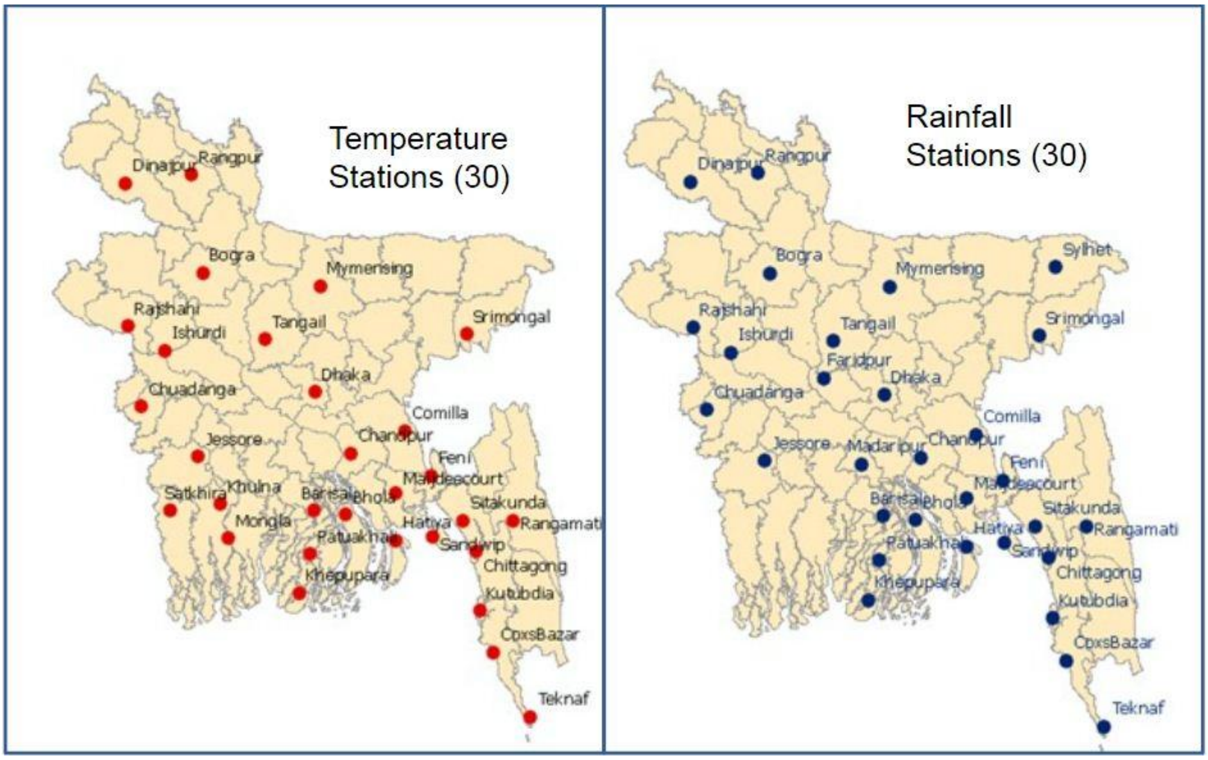

Figure 5-6: Temperature and rainfall stations across Bangladesh.

6 POLDER RECONSTRUCTION PROGRAMME

Available reports data and information are being collected. Detailed activities are planned for commencement in the next quarter.

7 DESIGN PARAMETERS CONSTRUCTION MANAGEMENT & MONITORING

No Activity this quarter

8 INVESTMENT PLAN FOR ENTIRE CEIP

Reports of Bangladesh Delta Plan 2100 and other past studies were collected to set the context for developing the proposed investment plan.

9 CAPACITY BUILDING

9.1 On the Job Training

The national consultants engaged in the project have received on the job training while working with several visiting experts. The subjects covered during this Quarter are:

Long Term Morphological Modelling in Rivers & Estuaries

Modelling Bank Erosion Mechanisms in Tidal Estuaries

Macro scale modelling for the major river systems of Bangladesh for future scenario simulations

9.2 Expert Lectures and Training Sessions in-house

The following visiting experts conducted the following training sessions:

Name Expert	Topic for Lecture or Seminar
Prof. Zheng Bing Wang	Long-term morphodynamic modelling for tidal regions
Dr Mick van der Wegen	Estuarine morphodynamics under sea level rise : do we drown or not?
Prof Dano Roelvink	Approaches to modelling coastal evolution in the context of global change
Dr Soren Tjerry	Morphological Modelling of Braided Rivers

9.3 Training Courses and Study Tours

No special Training Courses or Study Tours were arranged during the Second Quarter.

10 TRANSPARENCY AND ACCOUNTABILITY

10.1 Workshops

The Inception Workshop which was held 9 January has already been reviewed and acted upon by the entire water resources community in Bangladesh. The Final Inception Report, containing responses to several rounds of comments was finally published on 20 February 2019.

There are two workshops scheduled to be held during this quarter. However, there have been delays in organising these and only the first Consultative Workshop for Stakeholders was conducted this quarter, in Barisal, under the patronage of the State Minister of Water Resources, the World Bank and the BWDB on 30th of March 2019. The views of stakeholders from a multitude of backgrounds were sought and a fruitful discussion resulted. Few photos of the regional stakeholder consultation workshop at Barisal are presented in Figure 10.1. Two more such workshops are planned to be held in Khulna and Chittagong. The findings of these workshops will be collated and published as a report. These findings will also be taken into account when devising improved planning and design methodologies which would be the basis for making an investment plan for the coastal zone.

Several other consultative meetings were held with other projects active in this field. Such as, Blue Gold Project and CEIP project team.

Figure 10-1: Photos of Regional Stakeholder Consultation Workshop at Barisal

More photographs of regional stakeholder consultations workshop are shown in Appendix-B.

11 CONCLUSION

This report describes the extent of work done in the second quarter of this project from 1 January to 31 March 2019. The work done during the previous Quarter is included in the Inception Report that was submitted in January 2019. The Inception Workshop which was held 9 January has already been reviewed and acted upon by the entire water resources community in Bangladesh. The Final Inception Report, containing responses to several rounds of comments was finally published on 20 February 2019.

Only the outline of the work is described in this report because of the fact that the technical/scientific results of the work are being published in a separate series of reports published by the project.

Some difficulties have been experienced by the fact that the contract does budget does not cover some expenditure that are unavoidable. Among these are the payment of the domestic air travel costs for project staff and the payment of customs duties and taxes that arise when goods and equipment are imported to be handed over to the BWDB after they are deployed for field work. It will be necessary to apply to the Project Director to obtain additional budget to cover these costs.

12 References

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Knutson, T. R., Sirutis, J. J., Zhao, M., Tuleya, R. E., Bender, M., Vecchi, G. A., Villarini, G., and Chavas, D. (2015). Global projections of intense tropical cyclone activity for the late twenty-first century from dynamical downscaling of CMIP5/RCP4.5 scenarios. Journal of Climate, 28(18), 7203–7224. http://doi.org/10.1175/JCLI-D-15-0129.1.

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Vousdoukas, M., Mentaschi, L., Voukouvalas, E., Verlaan, M., Jevrejeva, S., Jackson, L.P., Feyen, L., 2018. Global probabilistic projections of extreme sea levels show intensification of coastal flood hazards. Nature Communications.

APPENDIX A – INVENTORY OF EXISTING DATA

A Inventory of Existing Data

Table A- 1: List of Bathymetric Data Available in IWM

Sl. No	Name of the River	Length River Stretch (km)	Interval (m)	No of Cross-section	Remark
1	Haringhata	16	500	32	GRRP-II/2011
2	Pussur	100	1000	100	
3	Sibsa	70	1000	70	
4	Aura Sibsa	20	1000	20	
5	Dhaki	20	1000	20	
6	Sutakhali	30	1000	30	
7	Baleswar	55	1000	55	
8	Kocha	15	500	30	
9	Sarupkathi	15	1000	15	
10	Kaliganga and Madhumati	90	2000	45	
11	Nabaganga, Atai and Rupsa	60	2000	30	
12	Gorai	30	500	60	
13	Betna	48	500	96	IWM/2012
14	Marirchap	38	500	76	
15	Parulia Sapmara	24	500	48	
16	Kholpetua	8	500	16	
17	Jamuna	50	2000	25	GBS/2010-11
18	Padma	128	2000	64	
19	Meghna	26	2000	13	
20	Afrakhal	40	5000	8	
21	Agarpur	15	5000	3	
22	Amanatganj	30	5000	6	
23	Arialkhan	75	5000	15	
24	Badugacha	20	5000	4	
25	Baleshwar	85	5000	17	
26	Bansana	15	5000	3	

Sl. No	Name of the River	Length River Stretch (km)	Interval (m)	No of Cross-section	Remark
27	Betna	105	5000	21	
28	Bhadra	30	5000	6	
29	Bhairab Lower	15	5000	3	
30	Bishnu	30	5000	6	
31	Chitra	45	5000	9	
32	Daudkhali	25	5000	5	
33	Deluti	25	5000	5	
34	Ghagor	30	5000	6	
35	Gobra	10	5000	2	
36	Gashiakhali	30	5000	6	
37	Gunkhali	15	5000	3	
38	Katakhali	5	5000	1	
39	Kazibacha	20	5000	4	
40	Kobadak	70	5000	14	
41	Kaliganga-SW	10	5000	2	
42	Kumar Nadi	45	5000	9	
43	Kumarkhali	15	5000	3	
44	Kumar River	45	5000	9	
45	MBR	35	5000	7	
46	M.G.Canal	10	5000	2	
47	Mongla-Nulia	20	5000	4	
48	Marirchap	30	5000	6	
49	Nalua-Nullah	10	5000	2	
50	Naria	15	5000	3	
51	Nabaganga-M	35	5000	7	
52	Old Pussur	30	5000	6	
53	Otra River	20	5000	4	
54	Palong	35	5000	7	
55	Polyhara	35	5000	7	
56	Pussur	40	5000	8	
57	Rupsa	35	5000	7	
61	Salta-W	10	5000	2	
62	Ganges	60	500	121	2011

Sl. No	Name of the River	Length River Stretch (km)	Interval (m)	No of Cross-section	Remark
63	Gorai	30	50	600	2011
64	Pussur	100	200	440	MP/2011
65	Mongla nala	30	200	150	MP/2011
66	BishKhali	70	2500	28	FFWC/2009
67	Burishwar	55	5000	11	
68	Lohalia	36	2000	18	
69	Baleswar	90	5000	18	
70	Kobadak				IWM/2008-09
71	Tetulia				2017
72	Meghna (Kamal Nagar to Ramgati)	Total length 1260 km	250-500		Ramgati/2012
73	Sandwip-Noakhali-urir char area				IWM/2012-2014-2015
74	Cox's Bazar to Inani	24		228	IWM-Marine Drive/2012-13
75	Karnaphuli River				CPA/2012-14
76	Brahmaputra-Jamuna	240		500	IWM-SRM/2011
77	Ganges-Padma	225		1000	
78	Meghna	50		1000	
79	Old Brahmaputra	265		500	
80	Atrai	245		250	
81	Karnaphuli	50		500	

Table A- 2: Inventory of Discharge Observation and Sediment Sampling

SL no.	Location Name	River name	Date	Project
1	Amtoli	Payra	15-Aug-15	CEIP
2	Amtoli	Payra	21-Aug-15	CEIP
3	Bagerhat	Daratana	18-Aug-15	CEIP
4	Bagerhat	Daratana	25-Aug-15	CEIP
5	Bhola	Hilsha	9-May-16	CEIP
6	Bhola	Hilsha	11-May-16	CEIP
7	Charkhali	Baleswar	17-Aug-15	CEIP
8	Charkhali	Baleswar	24-Aug-15	CEIP
9	Dacope	Dhaki	8-Sep-15	CEIP
10	Dacope	Sutarkhali	10-Sep-15	CEIP
11	Dacope	Sutarkhali	10-Sep-15	CEIP
12	Fulbunia	Sonatala	14-Aug-15	CEIP
13	Fuljuri	Bishkhali	7-Apr-16	CEIP
14	Fuljuri	Bishkhali	18-Apr-16	CEIP
15	Gabura	Arpangasia	4-Sep-15	CEIP
16	Gabura	Kobadak	19-Mar-16	CEIP
17	Gabura	Kobadak	21-Mar-16	CEIP
18	Galachipa	Lohalia	4-May-16	CEIP
19	Golachipa	Lohalia	13-Aug-15	CEIP
20	Golachipa	Lohalia	20-Aug-15	CEIP
21	Golachipa	Lohalia	6-May-16	CEIP
22	Ichakhali	Modhumoti	24-Mar-16	CEIP
23	Ichakhali	Nobagonga	24-Mar-16	CEIP
24	Ichakhali	Modhumoti	3-Apr-16	CEIP
25	Ichakhali	Nobagonga	3-Apr-16	CEIP
26	Kachubunia	Haria	31-Aug-15	CEIP
27	Kanchan Mohol	Bhadra	30-Aug-15	CEIP
28	Kobadak	Kobadak	2-Sep-15	CEIP
29	Kobadak	Arpangasia	2-Sep-15	CEIP
30	Kobadak	Kobadak	4-Sep-15	CEIP
31	Kobadak	Arpangasia	4-Sep-15	CEIP
32	Mongla	Mongla nala	5-Mar-16	CEIP
33	Mongla	Pussur	6-Mar-16	CEIP
34	Mongla	Mongla nala	13-Mar-16	CEIP
35	Mongla	Pussur	14-Mar-16	CEIP
36	Nalion	Sibsa	4-Mar-16	CEIP

SL no.	Location Name	River name	Date	Project
37	Nalion	Sibsa	9-Mar-16	CEIP
38	Patuakhali	Payra	6-Apr-16	CEIP
39	Patuakhali	Payra	19-Apr-16	CEIP
40	Rayanda	Baleswar	28-Mar-16	CEIP
41	Rayanda	Gosiakhali	29-Mar-16	CEIP
42	Rayanda	Gosiakhali	31-Mar-16	CEIP
43	Rayanda	Baleswar	16-Apr-16	CEIP
44	Rupsa bridge	Rupsa	23-Mar-16	CEIP
45	Rupsa bridge	Rupsa	2-Apr-16	CEIP
46	Sibsa	Sibsa	6-Sep-15	CEIP
47	Sundor Mohol	Bhadra	7-Sep-15	CEIP
48	Dharla Outfal	Jamuna	7-Apr-12	SRMP
49	Dharla Outfal	Jamuna	24-Jul-12	SRMP
50	Dharla Outfal	Jamuna	9-Aug-12	SRMP
51	Panka Narayanpur	Ganges	24-Jun-12	SRMP
52	Panka Narayanpur	Ganges	5-Jul-12	SRMP
53	Panka Narayanpur	Ganges	22-Jul-12	SRMP
54	Panka Narayanpur	Ganges	7-Aug-12	SRMP
55	Dewanganj	Old Bputra	9-Jul-12	SRMP
56	Dewanganj	Old Bputra	24-Jul-12	SRMP
57	Dewanganj	Old Bputra	8-Aug-12	SRMP
58	Atrai Rly Bridge	Atrai	30-Jul-12	SRMP
59	Atrai Rly Bridge	Atrai	13-Aug-12	SRMP
60	Kachikata	Atrai	28-Jul-12	SRMP
61	Kachikata	Atrai	14-Aug-12	SRMP
62	Rangunia	Karaphuli	21-Jul-12	SRMP
63	Rangunia	Karaphuli	11-Aug-12	SRMP
64	Kalurghat	Karaphuli	19-Jul-12	SRMP
65	Kalurghat	Karaphuli	10-Aug-12	SRMP
66	KAFCO	Karaphuli	22-Jul-12	SRMP
67	KAFCO	Karaphuli	13-Aug-12	SRMP
68	klaspur	Meghna	30-Jul-12	SRMP
69	klaspur	Meghna	8-Aug-12	SRMP
70	Chandpur	Meghna	1-Aug-12	SRMP
71	Chandpur	Meghna	6-Aug-12	SRMP

SL no.	Location Name	River name	Date	Project
72	Kaliganj	Meghna	3-Aug-12	SRMP
73	Kaliganj	Meghna	4-Aug-12	SRMP
74	Amtoli	Buriswar	23-Jan-11	GRRP
75	Bordia	Modhumoti	9-Jan-11	GRRP
76	Bordia	Modhumoti	21-Feb-11	GRRP
77	Bordia	Modhumoti	24-Jan-11	GRRP
78	Bordia	Modhumoti	27-Feb-11	GRRP
79	Chapail Ghat	Modhumoti	13-Jan-11	GRRP
80	Char Doani	Baleswar	9-Jan-11	GRRP
81	Char Doani	Baleswar	15-Jan-11	GRRP
82	Dirga, Nazirpur	Kaligagna	6-Jan-11	GRRP
83	Dirga, Nazirpur	Kaligagna	13-Jan-11	GRRP
84	Mollarhat	Modhumoti	7-Jan-11	GRRP
85	Mollarhat	Modhumoti	15-Jan-11	GRRP
86	Mongla	Pusur	6-Mar-11	GRRP
87	Mongla	Pusur	9-Feb-11	GRRP
88	Mongla	Pusur	14-Feb-11	GRRP
89	Mongla	Pusur	3-Mar-11	GRRP
90	Mongla	Pusur	30-Mar-11	GRRP
91	Akram-point	Pusur	6-Feb-11	GRRP
92	Akram-point	Pusur	12-Feb-11	GRRP
93	Akram-point	Pusur	13-Mar-11	GRRP
94	Akram-point	Pusur	21-Mar-11	GRRP
95	Rupsha	Pusur	16-Jan-11	GRRP
96	Rupsha	Pusur	6-Jan-11	GRRP
97	Akram-point	shibsa	7-Feb-11	GRRP
98	Akram-point	shibsa	11-Feb-11	GRRP
99	Akram-point	shibsa	14-Mar-11	GRRP
100	Akram-point	shibsa	20-Mar-11	GRRP
101	Gangril	Gangril	8-Mar-11	DANIDA/DPHE
102	Gangril	Gangril	14-Mar-11	DANIDA/DPHE
103	Baithaghata	Kazibacha	11-Mar-11	DANIDA/DPHE
104	Baithaghata	Kazibacha	5-Mar-11	DANIDA/DPHE
105	Kobadok	Kobadok	13-Mar-11	DANIDA/DPHE
106	Kobadok	Kobadok	7-Mar-11	DANIDA/DPHE
107	Rupsha	Pusur	1-Mar-11	DANIDA/DPHE
108	Rupsha	Pusur	13-Feb-11	DANIDA/DPHE
109	Monglanala	Monglanala	6-Mar-11	DANIDA/DPHE

SL no.	Location Name	River name	Date	Project
110	Mongla	Pususr	6-Mar-11	DANIDA/DPHE
111	Mollarhat	Modhumoti	20-Feb-11	DANIDA/DPHE
112	Mollarhat	Modhumoti	26-Feb-11	DANIDA/DPHE

Table A- 3: Inventory of Water Level measurement Station available in IWM

SL No.	Project/ Source	Station Name	River Name	Position		Frequency	From	To
				Easting	Northing			
1	CEIP-1	Uttar Kamarkhola	Shibsha	448518	495367	10 minutes	May-15	Oct-15
2	CEIP-1	Nalian	Shibsha	442209	483440	10 minutes	May-15	Oct-15
3	CEIP-1	Joynagor	Pusur	443435	492161	10 minutes	May-15	Oct-15
4	CEIP-1	Baniasanta	Pusur	457520	483393	10 minutes	May-15	Oct-15
5	CEIP-1	Sannasi Bazer	Katakhali River	476639	493987	10 minutes	May-15	Oct-15
6	CEIP-1	Khegraghat	Binshu River	471164	497887	10 minutes	May-15	Oct-15
7	CEIP-1	Sonatala	Bhola River	479753	459977	10 minutes	May-15	Oct-15
8	CEIP-1	Tafalbari Lanchghat	Baleswar River	483653	461700	10 minutes	May-15	Oct-15
9	CEIP-1	South Shialkhati	Pona River	506103	485919	10 minutes	May-15	Oct-15
10	CEIP-1	Tele Khali Bazar	Baleswar River	497126	479454	10 minutes	May-15	Oct-15
11	CEIP-1	Haridebpur Ferry ghat	Galachipa Rivr	542275	452350	10 minutes	May-15	Oct-15
12	CEIP-1	Golkhali	Musir khal	538678	448673	10 minutes	May-15	Oct-15
13	CEIP-1	Patuakhali	Paiyra	523368	469538	10 minutes	May-15	Oct-15
14	CEIP-1	Barguna	Paiyra	521696	448197	10 minutes	May-15	Oct-15
15	CEIP-1	Pathar ghata	Bishkhali	497281	435318	10 minutes	May-15	Oct-15
16	CEIP-1	Fulbunia	Andharmanik	518214	422277	10 minutes	May-15	Oct-15
17	CEIP-1	Maherpur	Chaitabunia	517219	419029	10 minutes	May-15	Oct-15
18	CEIP-1	Fakir ghat ,Taltali	Outfall of Paiyra	503709	421110	10 minutes	May-15	Apr-18
19	CEIP-1	Kawar Char, Kuakata	Outfall of Rabnabad	524699	414764	10 minutes	May-15	Apr-18
20	CEIP-1	Khajura, Kuakata	Outfall of Andharmanik	510674	416952	10 minutes	May-15	Oct-15
21	CEIP-1	Kalapara	Andharmanik	523890	430373	10 minutes	May-15	Apr-18
22	MPA	Mongla	Pusur	458270	485533	10 minutes	11-Mar-11	31-Mar-11

SL No.	Project/ Source	Station Name	River Name	Position		Frequency	From	To
				Easting	Northing			
23	MPA	Joymoni	Pusur	462810	471712	10 minutes	11-Mar-11	31-Mar-11
24	MPA	Akrampoint	Pusur	454364	432328	10 minutes	11-Mar-11	31-Mar-11
25	MPA	Hironpoint	Pusur	454364	432328	10 minutes	11-Mar-11	31-Mar-11

Table A- 4: List of bathymetric data surveyed under EDP (2009-10) & MES-II (1999-2000)

Sl. No.	Description of data	Period		Cruise Number/Data Source	
		From	To		
1	Bay near Sandwip Channel,Lower Meghna	07/04/2009	22/04/2009	EDP-1	MES-II (1999-2000)
2	East Shahabazpur Channel, East of Hatiya	06/05/2009	20/05/2009	EDP-2	
3	Lower Meghna	16/06/2009	25/06/2009	EDP-3	
4	Channel between Sandwip & Jahazer Char	01/07/2009	27/07/2009	EDP-4	
5	Tentulia River	02/10/2009	17/10/2009	EDP-6	
6	West Shahabazpur Channel	08/01/2010	07/02/2010	EDP-7	
7	West Shahabazpur Channel, near Nijhum Dwip	15/02/2010	06/03/2010	EDP-8	
8	Mainka Channel	Oct-09		IWM	
9	Montaz Channel				
10	Bangla Channel				
11	Tentulia-Ilisha Channel	Jan-Feb 2010		IWM	

Table A- 5: Data used for DEM in the coastal area

Sl. No.	Description of data	Period	Data Source
1	All over coastal areas	1991	FINNMAP Land Survey
2	KJDRP area except Beel Kapalia and Beel Khuksia	1997	Khulna Jessore Drainage Rehabilitation Project (KJDRP), surveyed by IWM
3	Beel Kapalia (inside KJDRP)	March 2008	Beel Kapalia, surveyed by IWM
4	Beel Khuksia (inside KJDRP)	February 2004	Beel Khuksia, surveyed by IWM

Table A- 6: Inventory of Historical Water level measurement Stations

SI	Station Name	River Name	Station ID	Source	Frequency	From	To
1	Abupur	Narayanganj	323	BWDB	3 hr	01-Apr-90	30-Mar-16
2	Afraghat	Bhairab	30	BWDB	3 hr	01-Apr-90	30-Mar-16
3	Amtali	Buriswar	20	BWDB	3 hr	01-Apr-90	30-Mar-16
4	Arpara	Behabati	21	BWDB	3 hr	01-Apr-90	30-Mar-16
5	Athabanki	Maddhumati	105	BWDB	3 hr	01-Apr-90	30-Mar-16
6	Babuganj	Babuganj	316	BWDB	3 hr	01-Apr-90	30-Sep-14
7	Bagerhat	Doratana	1	BWDB	1 hr	07-Apr-90	30-Mar-16
8	Bakerganj	Barisal-Buriswar	18.1	BWDB	3 hr	01-Apr-90	30-Mar-16
9	Bamna	Bishkhali	38	BWDB	3 hr	01-Apr-90	30-Mar-16
10	Barguna	Bishkhali	38.1	BWDB	3 hr	01-Apr-90	30-Sep-15
11	Barisal	Barisal-Buriswar	18	BWDB	3 hr	01-Apr-90	30-Mar-16
12	Baruria Transit	Padma	91.9L	BWDB	3 hr	01-Jan-85	30-Mar-16
13	Basantapur	Ichamati	129	BWDB	1 hr	01-Apr-90	30-Mar-16
14	Benarpota	Betna	24	BWDB	1 hr	03-Apr-90	30-Mar-15
15	Betagi	Bishkhali	37.5	BWDB	3 hr	01-Apr-90	30-Mar-16
16	Bhanga	Kumar	170	BWDB	3 hr	01-Apr-90	30-Mar-16
17	Bhatiapara			BWDB	3 hr	01-Apr-90	30-Dec-08
18	Bhola Kheya ghat			BWDB	3 hr	01-Jan-04	30-Dec-08
19	Bhairab Bazar	Upper Meghna	273	BWDB	3 hr	01-Apr-90	30-Mar-16
20	Chalna	Rupsa-Pasur	243	BWDB	1 hr	01-Apr-90	30-Mar-16
21	Chandpur	Dakatia	IW277	BIWTA	0.5 hr	01-Nov-06	31-Dec-16
22	Chapra	Betna Khal	25	BWDB	3 hr	01-Apr-93	30-Mar-16
23	Chhoto-Bagi			BWDB	1 hr	17-Dec-90	31-Mar-93
24	Chuadanga	Mathabhanga	207	BWDB	1 hr	01-Jan-06	30-Mar-16

SI	Station Name	River Name	Station ID	Source	Frequency	From	To
25	Chowdhury Char (Chowdhurihat)			BIWTA	1 hr	07-Dec-90	31-Mar-94
26	Daulatkhan	Surma-Meghna	278	BWDB	3 hr	01-Apr-92	30-Sep-14
27	Dumuria	Bhadra	28	BWDB	3 hr	01-Apr-93	30-Mar-16
28	Elarchar	Satkhira Khal	254.5	BWDB	2 hr	01-Apr-04	30-May-14
29	Faridpur	Kumar	168	BWDB	3 hr	01-Apr-90	30-Mar-16
30	Garaganj	Kumar	171	BWDB	3 hr	01-Jan-06	30-Mar-16
31	Gazirhat	Nabaganga	219	BWDB	3 hr	01-Apr-90	28-Aug-08
32	Gournadi	Torki	300	BWDB	3 hr	01-Dec-90	30-Mar-16
33	Haridaspur	MB Route	198	BWDB	3 hr	01-Apr-90	30-Mar-16
34	Hatbolia	Mathabhanga	206	BWDB	3 hr	01-Jan-06	30-Mar-16
35	Hizla	Dharmaganj	320	BWDB	3 hr	01-Apr-90	30-Mar-16
36	Insafnagar	Mathabhanga	205.A	BWDB	3 hr	01-Jan-06	30-Mar-16
37	Jhalokati	Bishkhali	37	BWDB	3 hr	01-Jul-98	30-Mar-16
38	Jhikargacha	Kobadak	162	BWDB	3 hr	01-Apr-90	30-Mar-16
39	Jhinaidaha	Nagabganga U	215	BWDB	3 hr	01-Jan-06	30-Mar-16
40	Kabirajpur	Madaripur Beel	193	BWDB	3 hr	01-Apr-90	30-Mar-16
41	Kaikhali	Ichamoti	130	BIWTA	1 hr	01-Apr-90	30-Mar-16
42	Kaitpara	Lohalia	183	BWDB	3 hr	01-Apr-90	31-Mar-03
43	Kala Chandpur	Nabaganga	217	BWDB	3 hr	01-Apr-90	30-May-14
44	Kalaroa	Betna	23	BWDB	3 hr	01-Apr-93	30-May-14
45	Kamarkhali	Gorai	101.5	BWDB	3 hr	01-Jan-06	30-Mar-16
46	Kamarkhali Tran	Gorai	101	BWDB	3 hr	01-Jan-06	30-Mar-16
47	Khathuli	Bhairab Upper	32	BWDB	3 hr	01-Jan-06	30-Mar-16
48	Kazipur	Mathabhanga	205	BWDB	3 hr	01-Jan-06	30-Mar-16
49	Keshabpur	Bhadra	27	BWDB	3 hr	01-Apr-90	30-Mar-16
50	Khatur Magura	Chitra	55	BWDB	3 hr	01-Apr-90	30-Mar-16

Sl	Station Name	River Name	Station ID	Source	Frequency	From	To
51	Khulna	Rupsha	241	BWDB	1 hr	08-Apr-90	30-Mar-16
52	Kobadak Forest Office	Kobadak	165	BWDB	1 hr	01-Apr-90	30-Mar-16
53	Lohagara	Nabaganha U	217 A	BWDB	3 hr	01-Apr-90	30-Mar-16
54	Madaripur	Arialkhan	5	BWDB	3 hr	01-Apr-90	30-Mar-16
55	Mirzaganj	Buriswar	19	BWDB	3 hr	01-Apr-90	30-Apr-10
56	Magura	Nabaganga	216	BWDB	3 hr	01-Jan-06	30-Mar-16
57	Magura Divr	Nabaganga U	216 A	BWDB	3 hr	01-Jan-06	30-Mar-16
58	Mongla	Pussur		(BIWTA MPA GAUGE)	1 hr	01-Apr-90	30-Mar-16
59	Mostafapur	Kumar	190	BWDB	3 hr	01-Apr-90	30-Mar-16
60	Muzurdia	Kumar	169	BWDB	3 hr	01-Jan-06	30-Mar-16
61	Nalianala	Sibsha	259	BWDB	1 hr	01-Apr-90	30-Mar-16
62	Narail	Chitra	56.1	BWDB	3 hr	01-Apr-90	30-Mar-16
63	Nazirpur	Baleswar	107	BWDB	1 hr	01-Apr-91	29-Dec-01
64	Nilkamal			BWDB	3 hr	01-Jan-04	31-Oct-08
65	Paikgacha	Haria	258	BWDB	3 hr	01-Apr-93	30-May-14
66	Patharghata	Bishkhali	39	BWDB	3 hr	01-Apr-91	30-May-14
67	Pirojpur	Baleswar	107	BWDB	3 hr	01-Jan-04	30-Mar-16
68	Protapnagar	Kholpetua	26	BWDB	1 hr	01-Apr-90	30-Mar-16
69	Ratandanga	Chitra	55.1	BWDB	3 hr	01-Apr-90	30-Mar-16
70	Rayenda	Baleswar	107.2	BWDB	3 hr	01-Jan-04	30-Mar-16
71	Shakra	Ichamoti	128	BWDB	1 hr	01-Apr-90	30-Mar-16
72	Sureswar			BWDB	3 hr	01-May-02	30-Dec-08
73	Sutarkhali_Forest Office	Sutarkhali	29	BWDB	3 hr	01-Apr-90	30-Mar-16
74	Swarupkati			BWDB	3 hr	01-Jun-04	30-Dec-08
75	Tajumuddin			BWDB	3 hr	01-Feb-01	31-Mar-02

SI	Station Name	River Name	Station ID	Source	Frequency	From	To
76	Tala Magura	Kobadak	163	BWDB	3 hr	01-Apr-90	30-Mar-16
77	Tongibari	Rangamatia	288.3	BWDB	3 hr	18-Mar-04	30-May-14
78	Umedpur	Baleswar	136.1	BWDB	3 hr	24-Aug-04	30-Mar-16
79	Uzirpur	Swarupkhati	SW 253A	BWDB	3 hr	01-Apr-90	30-Jul-14
80	Dashmina			BWDB	30 min	01-Nov-06	07-Oct-13
81	Galachipa		710	BIWTA	30 min	01-Apr-90	31-Dec-16
82	Bardia		2410	BIWTA	30 min	01-Apr-90	30-Jun-14
83	Chardoani		410	BIWTA	30 min	01-Apr-90	30-Jun-14
84	Chitalkhali		1610	BIWTA	30 min	01-Apr-93	30-Jun-14
85	Khepupara		610	BIWTA	1 hr	01-Jan-88	31-Dec-16
86	Dhulia		820	BIWTA	30 min	01-Apr-90	30-Jun-14
87	Pussur		Pussur		30 min	01-Apr-90	30-Jun-14
88	Hiron Point		IW110		1 hr	01-Jan-77	31-Dec-16
89	Gorai Railway Bridge	Gorai	99	BWDB	3 hr	01-Nov-09	31-Jul-11
90	Tahirpur	Kobadak	161	BWDB	3 hr	01-Nov-09	30-Mar-16
91	Nawhata		261	BWDB	3 hr	01-Nov-09	30-Apr-11
92	Bandarban	Sangu	SW247	BWDB		1965	2016
93	Dohazari	Sangu	SW248	BWDB		1996	2016
94	Banigram	Sangu	SW250	BWDB		1996	2016
95	Lama	Matamuhuri	SW203	BWDB		1996	2016
96	Chiringa	Matamuhuri	SW204	BWDB		1996	2016

Table A- 7: Inventory of Historical Flow measurement Stations

Sl	Station Name	River Name	Frequency	From	To
1	Baruria	Padma	Daily	01-Jan-1985	31-Dec-16
2	Gorai Railway Bridge	Gorai	14 days	01-Jan-1985	31-Dec-16
3	Bhairab Bazar	Upped Meghna	Daily	01-Apr-1985	31-Dec-16
4	Kamarkhali	Gorai	14 days	12-Jan-2006	31-Dec-13

Table A- 8: Inventory of Wind & Rainfall measurement Stations of BMD

Sl	Station Name	From	To	From	To
		Wind		Rainfall	
1	Dhaka	1953	2018	1966	2018
2	Mymensingh	1948	2018	1966	2018
3	Tangail	1987	2018	1966	2018
4	Faridpur	1948	2018	1966	2018
5	Madaripur	1977	2018	1966	2018
6	Chittagong	1949	2018	1966	2018
7	Sandwip	1966	2018	1966	2018
8	Sitakunda	1977	2018	1966	2018
9	Rangamati	1957	2018	1966	2018
10	Comilla	1948	2018	1966	2018
11	Chandpur	1964	2018	1966	2018
12	M_Court	1951	2018	1966	2018
13	Feni	1973	2018	1966	2018
14	Hatiya	1966	2018	1966	2018
15	Cox's_Bazar	1948	2018	1966	2018
16	Kutubdia	1977	2018	1966	2018
17	Teknaf	1977	2018	1966	2018
18	Sylhet	1956	2018	1966	2018
19	Srimangal	1948	2018	1966	2018
20	Rajshahi	1964	2018	1966	2018
21	Ishurdi	1961	2018	1966	2018
22	Bogra	1948	2018	1966	2018
23	Rangpur	1954	2018	1966	2018
24	Dinajpur	1948	2018	1966	2018
25	Sayedpur	1991	2018	1966	2018

SI	Station Name	From	To	From	To
		Wind		Rainfall	
26	Khulna	1948	2018	1966	2018
27	Mongla	1989	2018	1966	2018
28	Satkhira	1948	2018	1966	2018
29	Jessore	1948	2018	1966	2018
30	Chuadanga	1989	2018	1966	2018
31	Barisal	1949	2018	1966	2018
32	Patuakhali	1973	2018	1966	2018
33	Khepupara	1974	2018	1966	2018
34	Bhola	1966	2018	1966	2018

APPENDIX B – PHOTOGRAPHS OF STAKEHOLDER CONSULTATIONS WORKSHOP

B Photographs of Stakeholder Consultations Workshop

B.1 Photographs of Inaugural Session

B.2 Photographs of Plenary Session