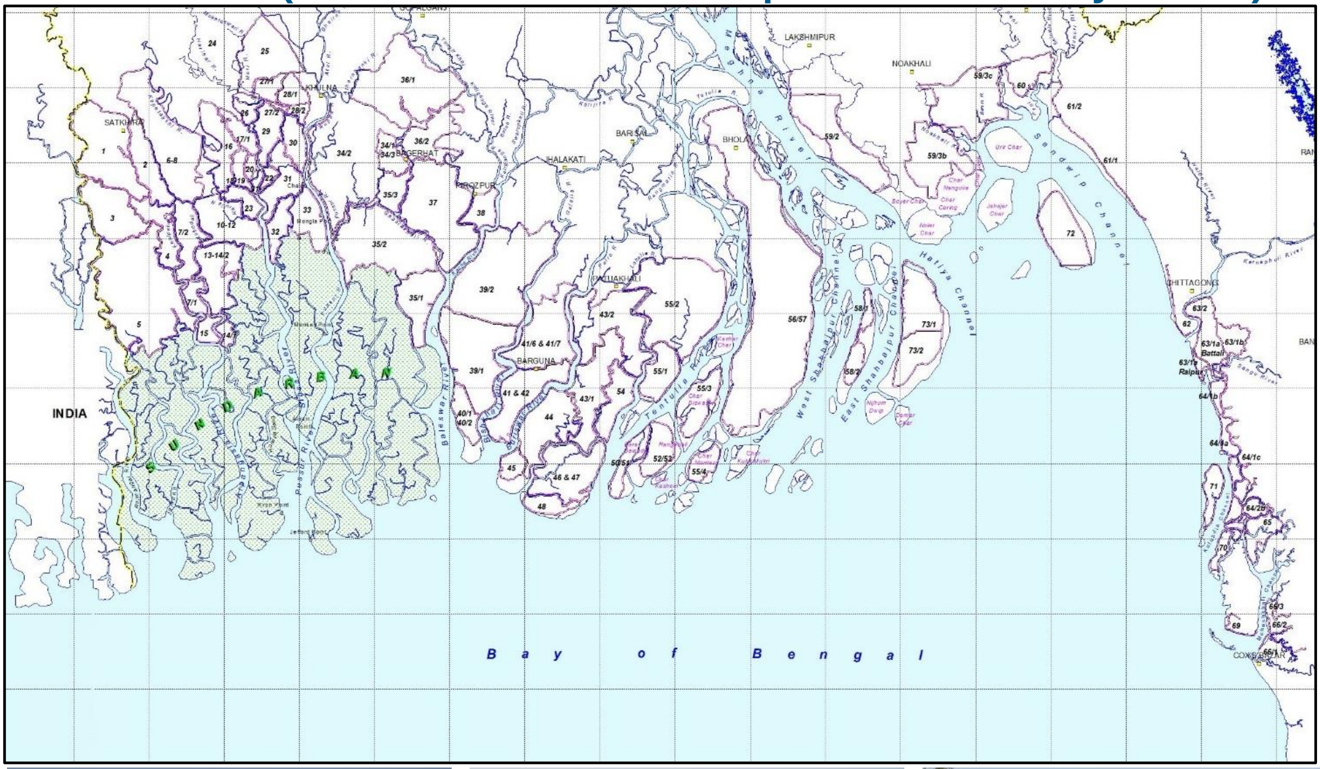
**Ministry of Water Resources**

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-3

July 2019

The expert in **WATER ENVIRONMENTS**

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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). The Second Quarterly Progress Report which was submitted in April 2019 covered the period 1 January 2019 to 31 March 2019. This Third Quarterly Progress Report (QPR-3) covers the period 1 April 2019 to 30 June 2019.

## 1.1 Work Plan

The Inception Report (DHI, 2019) gave a detailed description of the work to be carried out by this project. Table 1.1 shows the full schedule of activities to be carried out during the 30 months of the project. It is not necessary go into further detail except for the activities which were expected to be carried out for ***Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone,*** in the during the 3rd Quarter (1 April to 30 June 2019).

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

## 1.2 List of Project Milestones and Deliverables

A large number of outputs have been listed in the ToR as deliverables during the 30 months duration of this project. In order to rationalise the work programme, we have subdivided the activities into intermediate activities. Table 1.2 lists these intermediate activities as well as the officially mandated deliverables.

Table 1-2: Milestones and Deliverables

| Output No | Description | Output/Report | Scheduled (Month) | Status |
|---|---|---|---|---|
| D-1 | Inception | Inception Workshop | 3 | Delivered |
| | | Inception Report (Workplan etc | | |
| D-2 | Literature | Literature Inventory & Interim Review 1 | 6 | Delivered |
| | | Literature Inventory & Interim Review 2 + Lessons Learned Version 1 | 14 (Dec 2019) | receiving contributions |
| | | Literature Review & Lessons Learnt | 24 | |
| D-3 | Data Collection, Analysis and Documentation | Data Report , Inventory, quality checks etc (Data Inventory from Database, Quality Check Report) | Late 2019 + every quarter | On going |
| | | Database Design Report (Draft) | 9 | Delivered |
| | | Field Measurement Programmes IWM (plus reclamation phase field work) | 5 - 20+ | Major Ongoing |
| | | Prelim Field Measurement Prog US Luminscence | report inlcuded below | preliminary |
| | | Field Measurement Programmes US Data monitoring and recovery in several stages | 9 + + | |
| | | Database Report Final Presentation | 24 | at Workshop |
| | | GIS based maps (from Database) on request | 9 ++ | |
| | | Supply of model boundary data (various) | Continuous | ongoing |
| D-4 | Mathmeatical Modelling | Complex programme of modelling, with multiple models each of macro, meso and micro scales PI see Table 1-3 | PI see separate description in Chapter 4 | PI see Chapter 4 |
| D-5 | Polder Development Plan | Analysis, Classification and Prioritisation | 14 (Dec 2019) | planned |
| | | Draft Polder Plan, Consultation Workshop | 14 (Dec 2019) | W/S 1st week December |
| | | Pilot programme for 3-5 polders | 10 - | selection |
| | | Strategic Consideration of Polder Development Approach | Jan-00 | |
| | | Cost Benefit Analysis | | |
| D-6.1 | Updated Parameters | Updated Design Parameters & specifications | 12 | Delayed |
| D-6.2 | Polder Management | Beneficary/Stakeholder Participation | 12 | Delayed |
| | | Performance Monitoring Mechanisms | | |
| D-7 | Investment Plan and Fund Raising | Phased Investment and Management Plan for Entire CEIP and Road Map | 14 (Dec 2019) | Under preparation |
| | | Fund raising and Technical Collaboration with the International Community | 0 - 24 | On-going |
| D-8 | Capacity Building and Technical Sustainability | Action Plan for Capacity Building | 12 | Under preparation |
| | | In-country on-the-job technical training | 0 - 24 | On going |
| D-9.1 | Outreach programme | Workshops | | 2 workshop to date |

The original lists of deliverables in the Inception Report and in QPR-2 were based on the TOR. However, on detailed consideration (during the second quarter) of the issues and processes to be studied and understood, using the different types of models applied simultaneously by the DHI, Deltares and American groups, it was realized that the tasks (and deliverables) in the TOR were over-simplified and could not be made to fit easily into the specified categories and schedule stated there. The models being developed by the different groups have to compatible despite their diversity. It was therefore necessary to refine and re-categorise the deliverables and to reorganise their schedule. A new and longer list of deliverables that could together address the demands of the TOR while satisfying the objectives of the study is given in Table 1.2.

The deliverables connected to Chapter 4 (Modelling Tasks) are shown in Table 1.3.

Table 1-3: Modelling Outputs & Deliverables

| Output No | | Description |
|---|---|---|
| 4A-1 | Macro Scale Morphology | Sediment Dynamics of the GBM Delta |
| | | Macro Scale Sediment Balances |
| | | Long Term Morphology of River Network |
| | | Climate Change Scenarios |
| 4A-2 | Meso Scale Morpohology | Fluvial Dominated river morphodynamcs |
| | | Tidal Dominated river morphodynamcs |
| | | River Bank Erosion Prediction |
| 4A-3 | Micro Scale Modelling of Drainage, and Morphological Management | Drainage and Waterlogging |
| | | Polder Water Management |
| | | Polder Ground Level Management TRM |
| | | Stakeholder Consultation |
| 4B | Subsidence and Relative Sea Level Rise | Nature of Subsidence in the Coastal Zone |
| | | Geospatial analysis of field Observations |
| | | Predictions forspecific polders |
| 4C | Meteorology | Analysis of Current Trends incl Cyclone Activity |
| | | Prediction of Future Scenarios |
| | | Creation of Synthetic Cyclones and Analysis |

## 1.3 First Activities of the Third Quarter (Components 2 and 3)

Component No 1 (Inception Phase) has been completed during the first Quarter. The Work Plan proposed and approved in the Inception Report will provided broad guidance for the later activities. The final Inception Report has been accepted by the Project Authority.

Component No 2 (Literature Review) is the first activity listed for the post inception period. Much progress was achieved in this activity, keeping in mind the need to keep up with the outputs from new field campaigns, other related studies and projects, which will continue to provide additional knowledge and insights. The first Interim Literature Review was published in the month of April 2019. Table of contents of this report is published as Appendix A of this report.

It is anticipated that the next interim Review will be prepared in December 2019. It is intended that a section on "Lessons Learnt" will be included in the Second Interim Literature Review and in subsequent reports.

The major activities undertaken during the previous and current quarter are Data Collection as inputs for Modelling (Component 3). This is described in Chapter 2.

The data collection efforts on several fronts have already begun to culminate in the development of a major Database designed for use in managing the Coastal Zone of Bangladesh. This is described in Chapter 3.

# 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 of the Second Quarter Progress Review Report gave a list of available data at the end of the second quarter.

## 2.2 Field Surveys carried out by IWM

### 2.2.1 Mobilization

The survey team was mobilized 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.

### 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.

The survey methodology employed by IWM survey teams is described in detail in the Second Quarterly Progress Report

Table 2-1: Progress of Bathymetric Survey.

| Progress of bathymetric survey | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SL | River Name | Description/Specification | Duration of survey | Unit | Target | | Achieved as on 31$^{st}$ March, 2019 | Cumulative achieved as on 30$^{th}$ June, 2019 | Achieved in between 01/04/19 to | 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 | 168 | 0 | As per inception report and also subsequent consultation, bathymetry survey has been 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 | 353 | 0 | |
| 3 | Baleswar | From Hularhat to outfall of 82 km length @ 1000m Interval | 1-10/03/2019 | Km | 0 | 196 | 196 | 196 | 0 | |
| 4 | Bishkhali | From Gabkhan khal to Badurtala of 92 Km length @ 1000m interval | 28-31/03/2019 | Km | 0 | 97 | 0 | 97 | 97 | |
| 5 | Lower Meghna | From Chandpur to Tajumuddin of 100 km @ 1000m interval | 26/03/19-09/04/19 | Km | 1306 | 1068 | 0 | 1068 | 1068 | |
| **Total** | | | | **Km** | **1306** | **1882** | **717** | **1882** | **1165** | |
| SL | River Name | Description/Specification | Duration of survey | Unit | Target | | Achieved as on 25$^{th}$ June, 2019 | Cumulative achieved as on 30$^{th}$ | Achieved in between 01/04/19 | Remarks |
| | | | | | TOR | Modified | | | | |
| 1 | Sangu River | 95Km @ 500m interval | | Nos. | 141 | 141 | 0 | | | At 500m interval for 70 km, a total of 141 transects |

## Table 2-2: Progress of discharge and Sediment Sampling

| Progress of Suspended Sediment Sampling | | | | | |
|---|---|---|---|---|---|
| SL no. | Location/ River Name | Survey Date | No. of Sampl | Description | Total nos. of |
| 1 | Bahadurabad, Brahmaputra | 12-Apr-19 | 16 | 4 verticle @ 4 sample per Verticle | 340 |
| | | 29-Apr-19 | 24 | 6 verticle @ 4 sample per Verticle | |
| | | 25-May-19 | 16 | 4 verticle @ 4 sample per Verticle | |
| | | 17-Jun-19 | 34 | 4 verticle @ 4 sample per Verticle | |
| | | 18-Jun-19 | 18 | 9 verticle @ 2 sample per Verticle together with BWDB | |
| 2 | Hardinge Bridge, Ganges | 13-Apr-19 | 8 | 2 verticle @ 4 sample per verticle | |
| | | 29-Apr-19 | 6 | 2 verticle @ 3 sample per verticle | |
| | | 23-May-19 | 8 | 2 verticle @ 4 sample per verticle | |
| | | 11-Jun-19 | 8 | 3 verticle @ 4 sample per verticle | |
| 3 | Bhairab Bazar, Upper Meghna | 15-Feb-19 | 15 | 5 verticle @ 3 sample per verticle | |
| | | 8-Mar-19 | | No sample was taken | |
| | | 3-Apr-19 | 20 | Hourly at 1-verticle @ 4 sample for 5hrs | |
| | | 28-Apr-19 | 48 | Hourly at 2-verticles 4 sample in each verticle for 6hr | |
| | | 21-May-19 | 72 | 3 verticle @ 4 sample per verticle 6hr | |
| | | 19-Jun-19 | 47 | Hourly in 3 verticle 2 samples in each verticle for 2 hr and 4 sample per verticle for3 hr | |
| 4 | Chandpur, Lower Meghna | 30-Mar-19 | 36 | Hourly at 1 verticle 4 samples for 12hrs | 95 |
| | | 5-Apr-19 | 59 | Hourly at 1 verticle 3 samples for 5hrs + at 1 verticle 4 samples for 11hrs | |
| Sediment sampling at Gangril,Pusur, Shibsha, Baleswar and Bishkhali | | | | | |
| 5 | Dasmina, Tetulia | | | Will be done during June-Oct, 19 at time of discharge observation. | 863 |
| 6 | Polder-17/2, Gangril | 19-Feb-19 | 36 | 1 verticle @ 3 sample per verticle fo | |
| | | 26-Feb-19 | 33 | 1 verticle @ 3 sample per verticle fo | |
| | | 6-May-19 | 52 | 1 verticle @ 4 sample per verticle fo | |
| 7 | U/S of Mongla port, Pusur | 22-Feb-19 | 39 | 1 verticle @ 3 sample per verticle fo | |
| | | 1-Mar-19 | 30 | 1verticle @ 3 sample per verticle for | |
| | | 20-Mar-19 | 32 | 1verticle @ 4 sample per verticle for | |
| | | 21-May-19 | 52 | 1verticle @ 4 sample per verticle for | |
| 8 | Nalian, Shibsha | 20-Feb-19 | 36 | 1 verticle @ 3 sample per verticle fo | |
| | | 28-Feb-19 | 30 | 1 verticle @ 3 sample per verticle fo | |
| | | 19-Mar-19 | 44 | 1verticle @ 4 sample per verticle for | |
| | | 8-May-19 | 52 | Hourly at verticle-1 @4 sample for 4hrs + verticle-2 @ 4 sample for 9 hrs | |
| 9 | Charduani, Baleswar | 3-Mar-19 | 48 | Hourly at verticle-1 @3 sample for 9hr + verticle2 @ 3 sample for 7 hr | |
| | | 8-Mar-19 | 60 | Hourly at verticle1 @3 sample for 7hrs + verticle2 @ 3 sample for 13 hrs | |
| | | 19-May-19 | 84 | Hourly atverticle1 @4 sample 10hrs + verticle2 @ 4 sample for 11 hr | |
| 10 | Bhandaria, Baleswar | 2-Mar-19 | 33 | Hourly at 1 verticle @ 3 sample per verticle 11hr | |
| | | 7-Mar-19 | 51 | Hourly at verticle1 @3 sample per verticle 9hr + verticle2 @ 3 sample per verticle 8 hr | |
| | | 18-May-19 | 100 | Hourly at verticle1 @4 sample per verticle 12hr + verticle2 @ 4 sample per verticle 13 hr | |
| 11 | Kakchira, Bishkhali | 10-Mar-19 | 51 | Hourly at verticle1 @3 sample per verticle 9hr + verticle2 @ 3 sample per verticle 8 hr | |

Table 2-3: Progress of water level data collection

| SL. No. | Name of Location/River | Postion in UTM | | Installation Date | Target as per TOR/ Inception report (stat$^{n}$-month) | Achieved as on 31$^{st}$ March, 2019 (statn-month) | Cumilative achieved as on 30$^{th}$ June, 2019 (statn-month) | Achieved in between 01/04/19 to 30/06/19 (statn- |
|---|---|---|---|---|---|---|---|---|
| | | UTM_X | UTM_Y | | | | | |
| 1 | Outfall of Rabnabad Channel | 216528 | 2421048 | 18-Feb-19 | 12 | 1 | 4 | 3 |
| 2 | Outfall of Biskhali /Baleswar/Buriswa r | 193946 | 2426687 | 17-Feb-19 | 12 | 1.5 | 4 | 2.5 |
| 3 | Kaikhali | 713469 | 2456684 | 15-Feb-19 | 12 | 1.5 | 4 | 2.5 |
| 4 | Chandpur, Lower Meghna | 258997 | 2570810 | 1-Feb-19 | 4 | 2 | 4.5 | 2.5 |
| 5 | Dasmina(Hajir hat), Tetulia | 252198 | 2465785 | 8-Apr-19 | 4 | | 2.5 | 2.5 |
| 6 | Joymuni, Pusur | 771508 | 2474265 | 14-Mar-19 | 4 | | 3 | 3 |
| 7 | Nalian, Shibsha | 750574 | 2485746 | 15-Mar-19 | 4 | | 3 | 3 |
| 8 | Charduani, Baleswar | 800698 | 2449693 | 31-Mar-19 | 4 | | 2 | 2 |
| Total | | | | | 56 | 6 | 27 | 21 |

Table 2-4: Progress of Monitoring Sections

| SL no. | River name | Position in UTM | | Survey Date (1st cycle) | Survey Date (2nd cycle) | Target as per TOR/ Inception report | Achieved as on 30th March, 2019 | Achieved as on 30th June, 2019 | Cumulative achieved upto June, | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Easting (m | Northing (m | | | | | | | |
| 1 | Pusur | 762273 | 2501059 | 21-Feb-19 | 10-May-19 | 4 | 1 | 1 | 2 | |
| | | 765884 | 2494718 | | | | | | | |
| 2 | Sibsha | 751161 | 2487806 | 20-Feb-19 | 7-May-19 | 4 | 1 | 1 | 2 | |
| | | 751557 | 2482153 | | 8-May-19 | | | | | |
| 3 | Kobadak | 734559 | 2474997 | 17-Feb-19 | 22-May-19 | 4 | 1 | 1 | 2 | |
| | | 735522 | 2468624 | | | | | | | |
| 4 | Chunkuri | 759390 | 2500705 | 23-Feb-19 | 9-May-19 | 4 | 1 | 1 | 2 | |
| | | 758092 | 2498287 | | | | | | | |
| 5 | Badurgacha | 753417 | 2504229 | 22-Feb-19 | 5-May-19 | 4 | 1 | 1 | 2 | |
| | | 749232 | 2499644 | | 7-May-19 | | | | | |
| 6 | Dhaki | 755788 | 2498307 | 13-Feb-19 | 9-May-19 | 4 | 1 | 1 | 2 | |
| | | 751834 | 2493821 | | | | | | | |
| 7 | Gangril | 739773 | 2522911 | 19-Feb-19 | 6-May-19 | 4 | 1 | 1 | 2 | |
| | | 746214 | 2515543 | | 7-May-19 | | | | | |
| 8 | Gashikhali | 772383 | 2496263 | 25-Feb-19 | 11-May-19 | 4 | 1 | 1 | 2 | |
| | | 769190 | 2489629 | | | | | | | |
| 9 | Andharmanik | 206871 | 2432616 | 3-Feb-19 | 15-May-19 | 4 | 1 | 1 | 2 | |
| | | 214473 | 2433381 | | | | | | | |
| 10 | Galachipa | 233074 | 2451448 | 3-Mar-19 | 14-May-19 | 4 | 1 | 1 | 2 | |
| | | 232892 | 2462016 | | | | | | | |
| 11 | Baleswar | 808406 | 2488650 | 28-Feb-19 | 17-May-19 | 4 | 1 | 1 | 2 | |
| | | 796650 | 2467005 | | | | | | | |
| 12 | Lower Meghna | 259138 | 2565429 | 26-Feb-19 | 9-May-19 | 4 | 1 | 1 | 2 | |
| | | 261237 | 2543677 | 28-Feb-19 | | | | | | |
| 13 | Shangu | | | | 28-May-19 | 4 | 0 | 1 | 1 | |
| | | | | | 29-May-19 | | | | | |
| Total | | | | | | 52 | 12 | 13 | 25 | |

## 2.3 Field Surveys to be carried out by US University Teams

### 2.3.1 Using geochronology to reconstruct channel dynamics of the macroscale Ganges-Brahmaputra Delta

The rates and patterns of landscape evolution can be measured with through geochronologic and instrumental tools, such as radiocarbon dating, luminescence dating, short-lived radioisotopic markers,  archaeological records, satellite and geodetic measurements, and others (Chamberlain et al., in press). Of these, luminescence dating (Huntley et al., 1985) is particularly useful for "rating and dating" of delta deposits because it directly measures a signal captured in mineral (quartz or silt) grains, the most common material in the stratigraphic record of many deltas including the GBMD (Chamberlain et al., in press). Luminescence dating has previously been shown to be a viable option for obtaining geochronology of Holocene-aged deposits of the GBMD (Chamberlain et al., 2017).

In 2019, our team, including postdoc Chamberlain and two Research Assistants (Nahian & Rahman) from Dhaka University, executed a field campaign in the western delta plain. This region of the GBMD was constructed by past pathways of the braided Ganges mainstem channel (Allison et al., 2003) and is veneered by shallow (1-5 m deep) deposits sourced to smaller meandering channels. The deposits of the meandering channels form a scrollplain of point bar deposits in the upper reaches, and the paleochannels associated with the deposits appear to lock in place as they approach the present-day coast.

Using a hand auger and Van der Horst sediment sampler (Figure 1), our team obtained 25 sediment samples for luminescence dating. Samples were selected from point bar deposits which capture the timing of small meandering channel activities (Figure 2). We anticipate that the results of this initiative will yield new information about the rates of lateral channel migration and sediment aggradation accomplished by these small yet numerous channels. This information will be a key component to understanding the dynamics of the macroscale GBMD.

Figure 2-1: Research assistants Nahian and Rahman (left) working with postdoc Chamberlain to obtain shallow stratigraphic information and sediment samples for luminescence dating.

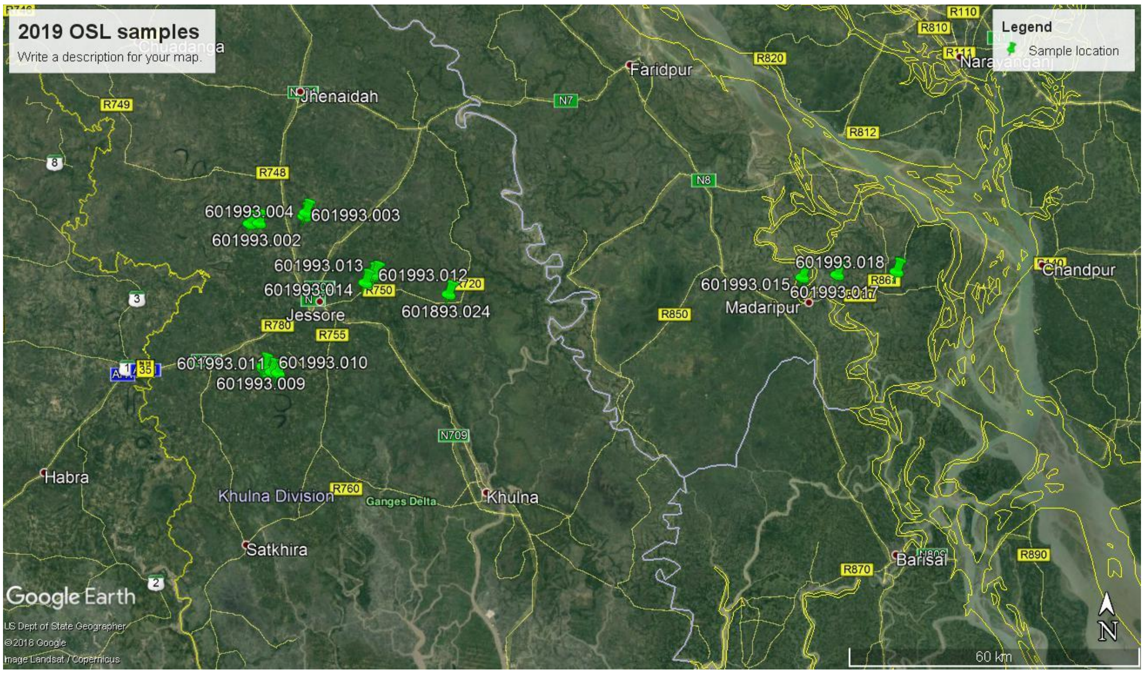


Figure 2-2: Locations of sediment samples obtained in March 2019 for luminescence dating.


Allison, M. A., Khan, S. R., Goodbred, S. L., and Kuehl, S. A., 2003, Stratigraphic evolution of the late Holocene Ganges-Brahmaputra lower delta plain: Sedimentary Geology, v. 155, p. 317-342.

Chamberlain, E. L., Goodbred, S. L., Hale, R., Steckler, M. S., Wallinga, J., and Wilson, C., in press, Integrating geochronologic and instrumental approaches across the Bengal Basin: Earth Surface Processes and Landforms.

Chamberlain, E. L., Wallinga, J., Reimann, T., Goodbred, S. L., Steckler, M., Shen, Z., and Sincavage, R., 2017, Luminescence dating of delta sediments: novel approaches explored for the Ganges-Brahmaputra-Meghna Delta: Quaternary Geochronology, v. 41, p. 97-111.
Huntley, D. J., Godfrey-Smith, D. I., and Thewalt, M. L. W., 1985, Optical dating of sediments: Nature, v. 313, p. 105-107.

### 2.3.2 Planned GPS and SET-MH Field Work (rescheduled start 17 July 2019)

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. Galetzka, 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 Patuakhali 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.

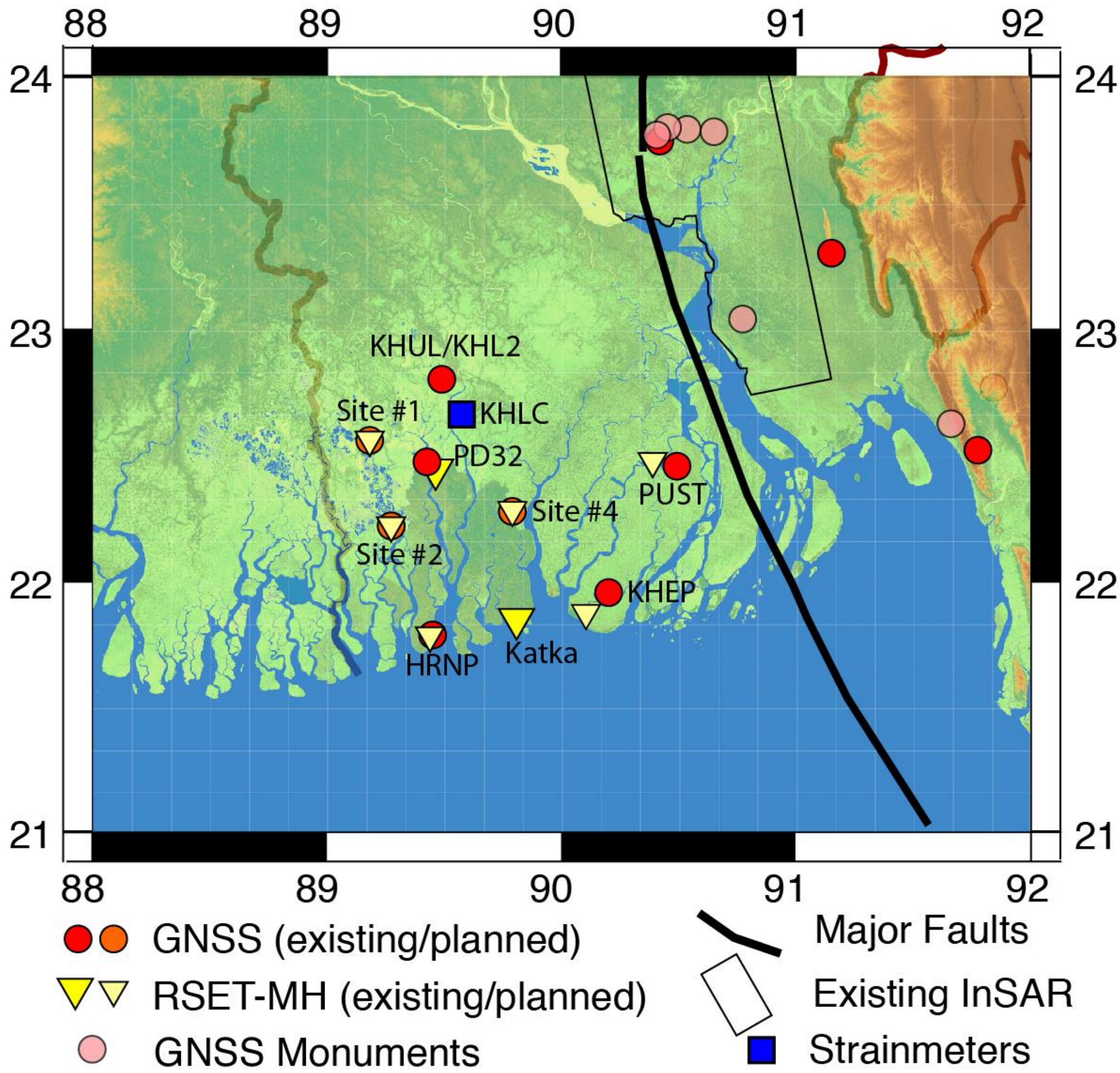


Figure 2-3: Locations of existing and planned GNSS and RSET-MH equipment in SW Bangladesh.

### Planned Coring Field Work

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

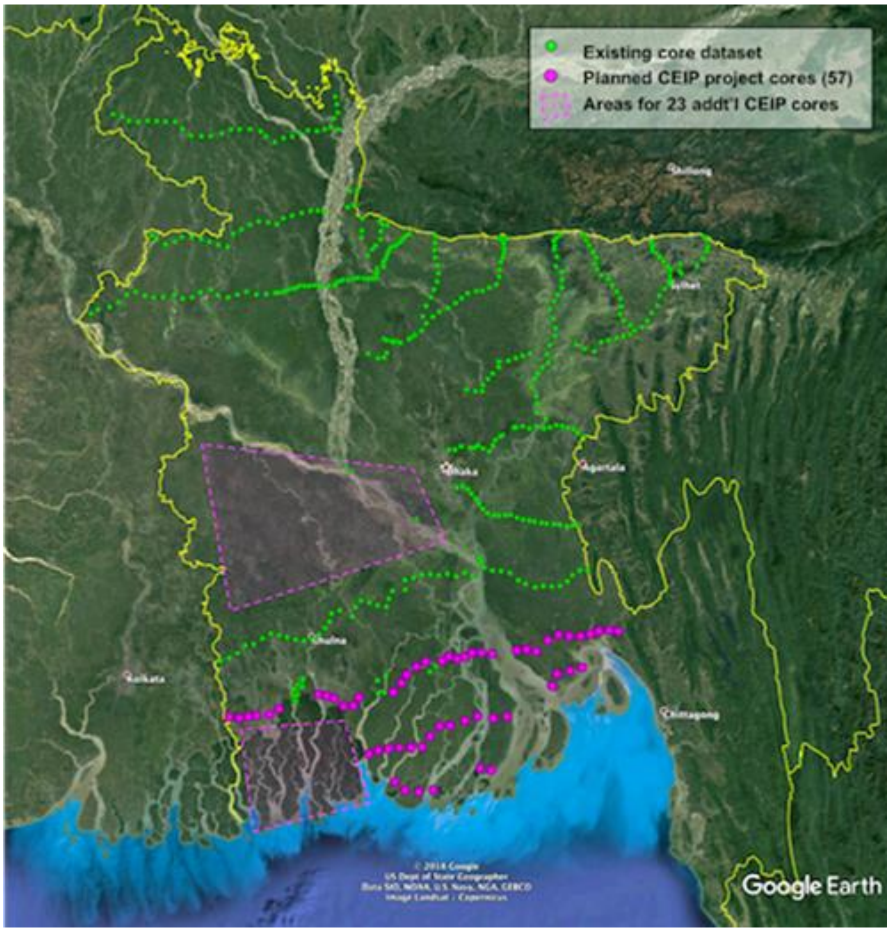


Figure 2-4: Coring Locations

### 2.3.3 Report from the Field Campaign carried out from 16 July 2019 to 5 August 2019.

This field programme will be successfully completed on schedule in early August 2019.  A fullt report of the work carried out, together with a map showing the locations of activities performed will be carried in the Fourth Quarterly Progress Report that will be published on 30 September 2019.

# 3. DATABASE FOR THE COASTAL ZONE

## 3.1 Introduction

Significant progress was made during this Quarter in developing an Interactive Geo-Database for Coastal Zone.

Several consultations have been carried out with project stakeholders to determine 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.

A Committee has been appointed by the Director General of BWDB to ensure that the database would satisfy all the software and licencing requirements in the BWDB, and in the longer term be able to satisfy the relevant standards promulgated by the Government of Bangladesh.

## 3.2 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. The application was developed as standalone program which run only on desktop.

***SiMS-Smart***

To upgrade the SiMS from stand alone mode to web with additional functionalities another project was taken in 2016. This version was named SiMS-Smart as it incorporated smart technologies like IP-Camera, Skype, Mobile App, Real-time Water Level data visualization from Sensor based gauges and other advanced web technologies.

Under this project detailed inventory of ongoing and completed projects has been developed for Southeastern Zone of Chittagong. The SiMS-Smart 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-Smart 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-Smart 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. From some of the water level stations data are being collected through sensors and are being stored in database automatically at certain interval.

**BWDB Hydraulic Structure Database**

BWDB has prepared a Hydraulic structure status database covering entire Bangladesh through physical survey with questionnaire. All the data along with geolocations, photograph, video and physical information with operational status are collected for about 18000 hydraulic structures. The database has been stored in Oracle database and front end has been developed in ASP.NET.

**State of Water Resource Database:**

WARPO has developed a database on state of water resources of entire Bangladesh. The database is developed in MS SQL Server. Its main contents are surface ground water and meteorological data.

All above database.

All of the above databases are reviewed before preparing the data structure for this project. Specially, to make the database compatible with BWDB central database, in depth review of SiMS-Smart has been done suggestion from BWDB relevant officials have been considered.

***Database and Software Platforms:***

SiMS-Smart Database has been developed on Oracle, ArcGIS Server for Windows, ASP.NET. BWDB Hydraulic Structure Database has been developed on MS-SQL Server, ASP.NET, ArcGIS Server on Windows. Later on database was migrated to Oracle.

### 3.2.1 Database and Software Delopment Platform

After several meetings following platforms are selected for database and software and software development platform.

Database: Oracle – This can be installed on Linux/Windows

Software Development Framework: Laravel – this can be hosted both on Linux and Windows platform

GIS Server: ArcGIS Server for Windows.

### 3.2.2 Database Design and Development

The database has been designed considering the review, the ToR, and feed backs from project review meetings.

Initially the data items and sources have been identified and grouping has been made on rational basis and presented before the progress review meeting. The identified data and sources are shown in figure below.

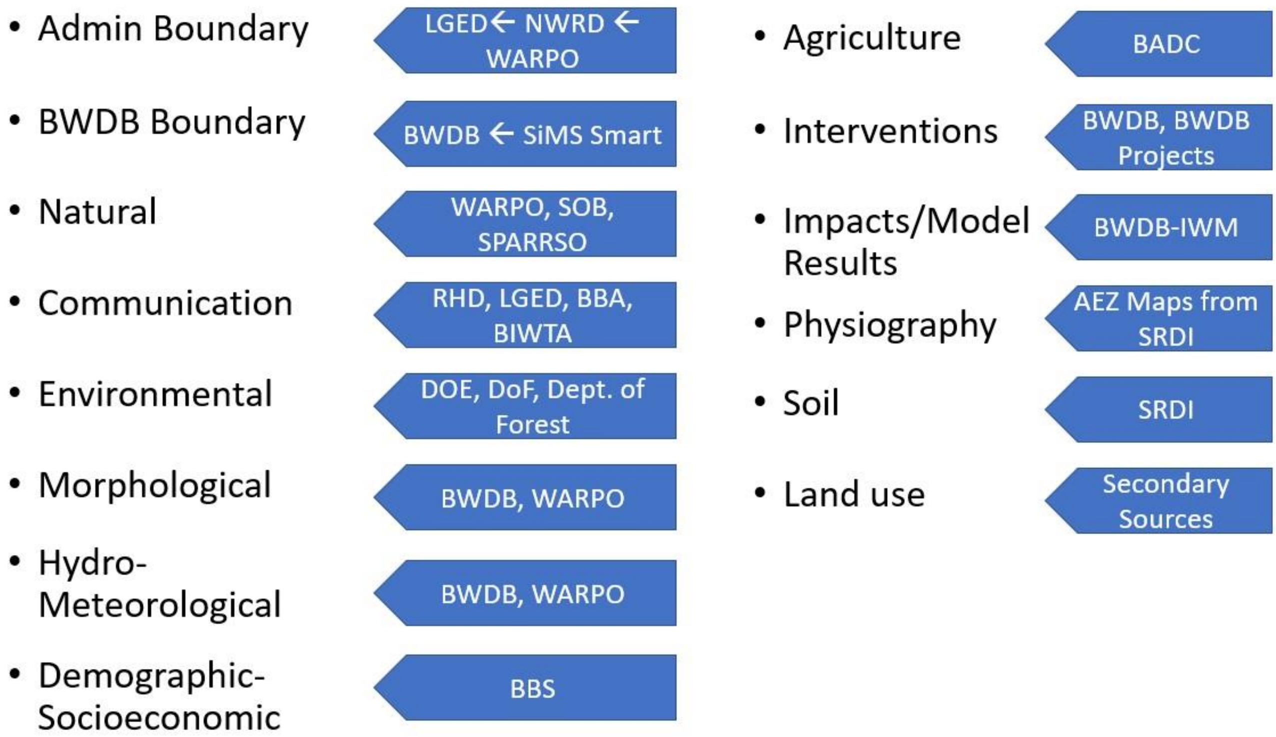


Figure 3-1: Data Sources

The contents under different data categories are defined on logical basis as shown in Figure below.

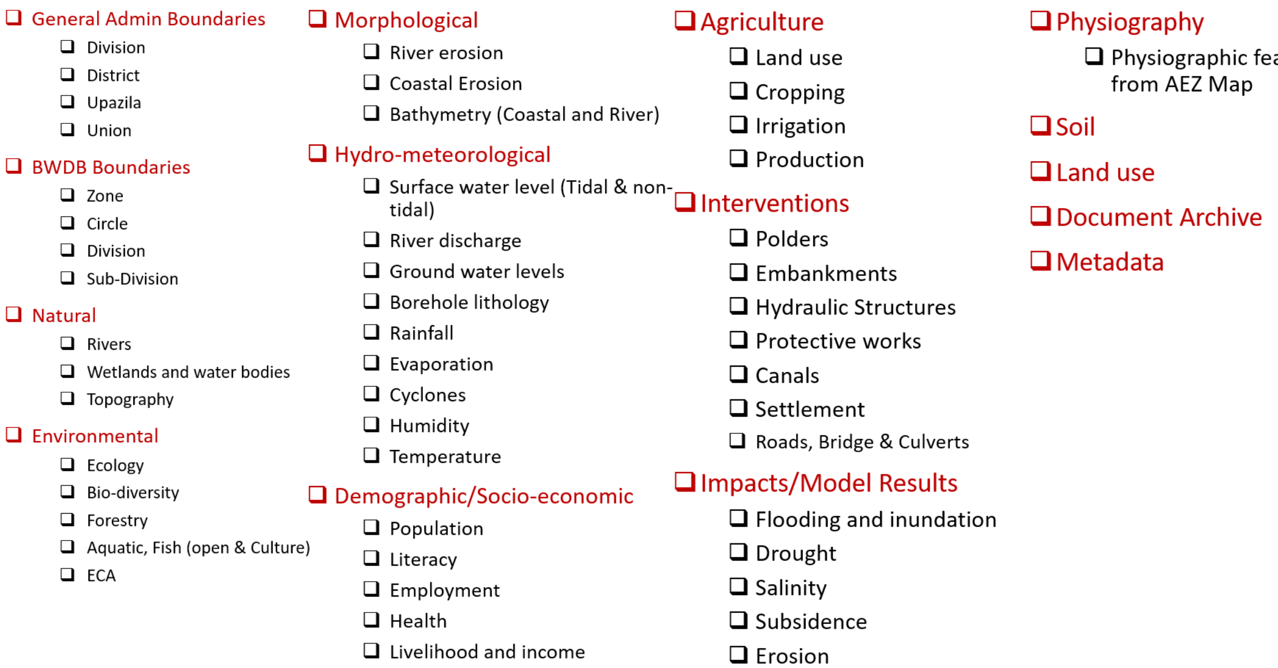


Figure 3-2: Data contents under each category

After investigation of the data, review of existing databases, compatibilities and uses data structure is being prepared. A part of the data structure is shown in Figure below.

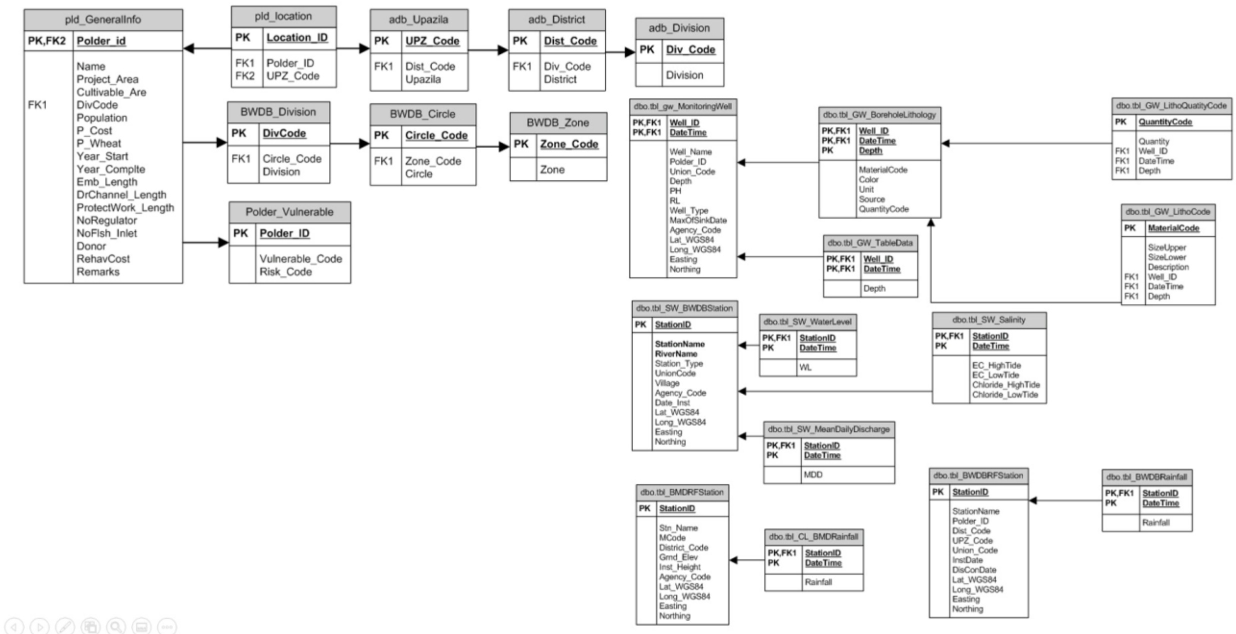


Figure 3-3: Data Structure

## 3.3 Web-GIS based Application Development

Conceptual Architecture of IGDCZ

Based on the ToR, Review and expected deliverable a conceptual architecture of the system has been depicted as prsented in Figure below. It shows modules, database and connection between them. This will guide to develop database and software modules.

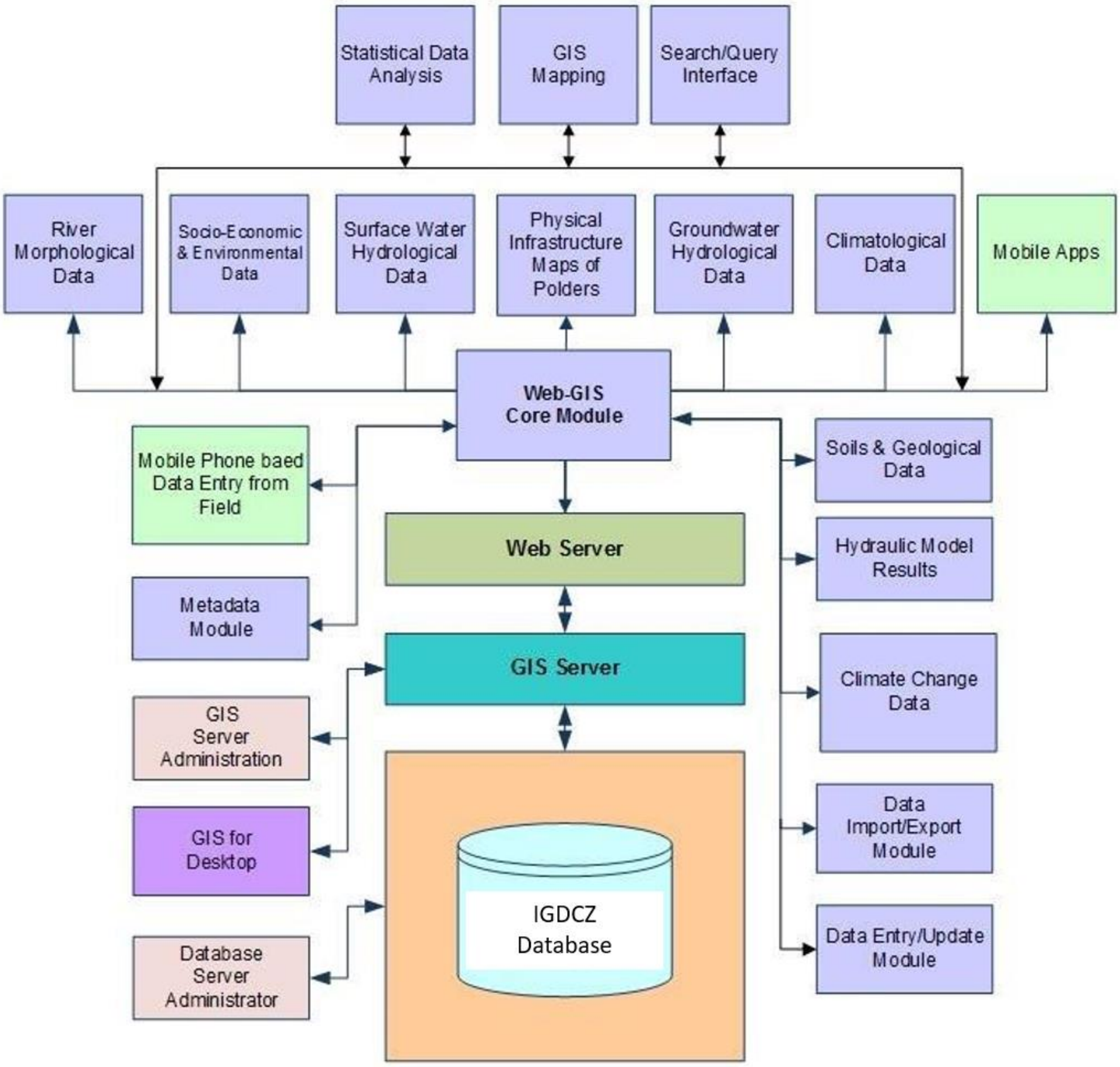


Figure 3-4: High Level System Architecture

The development of IGDCZ considered in two major steps: (i) Prototype Development, and (ii) Full Scall Development. These two steps are described below.

### 3.3.1 Prototype Software Development

A prototype is a physical representation used to illustrate and verify aspects of a conceptual design as part of the development process for a new product or technology. Essentially, it brings an idea into being. A prototype used to help explain a new notion to users or investors, to a highly detailed, fully operational representation of how an intricate design concept of IGDCZ will look, feel and work in the real world.

To develop prototype small set of real or realistic data is required. With these idea in mind a prototype is being developed, most of the parts with realistic features are developed and presented before the client. A snapshot of the prototype is presented in Figure below.

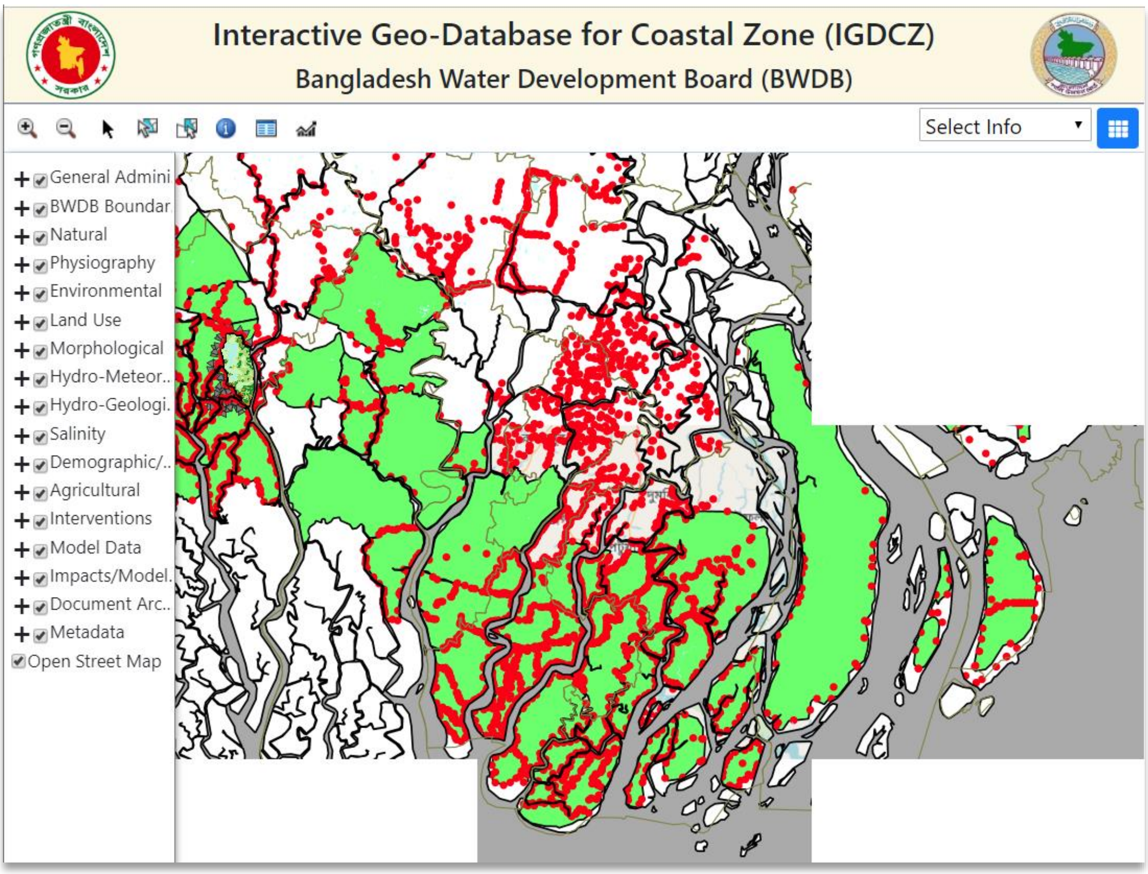


Figure 3-5: Snapshot of the Prototype IGDCZ

The components of prototype is being prepared module by module. The main data categories are accessible by left panel of the frontend interface as shown in Figure above. Information of each entity can be viewed interactively on web-GIS map.

### 3.3.2 Full Scale IGDCZ

Step by step, module-by-module successful development of the prototype will eventually lead to towards the full scale IGDCZ development by uploading the real data in each table.

### 3.3.3 Progress at a Glance

***Data collection:*** The data collection so far is presented below in Table 3.1.

Table 3-1: Data collection status

| Sl No | Broad Category | Type | Source | Status of Collection |
|---|---|---|---|---|
| 1 | **General Admin Boundaries** | | | |
| | Division | Spatial | BBS | 100 |
| | District | Spatial | BBS | 100 |
| | Upazila | Spatial | BBS | 100 |
| | Union | Spatial | BBS | 100 |
| 2 | **BWDB Office** | | | |
| | Zone | Spatial | BWDB | 100 |
| | Circle | Spatial | BWDB | 100 |
| | Division | Spatial | BWDB | 100 |
| | Sub-Division | Tabular | BWDB | 100 |
| 3 | **Ntural** | | | |
| | Rivers | | WARPO | 100 |
| | Wetlands and water bodies | | WARPO | 100 |
| | Topography (spot elevaion) | | IDMS Project, SOB | 100 |
| 4 | **Hydro-meteorological** | | | |
| | Surface water level (Tidal & non-tidal) | Tabular | BWDB | 100 |
| | River discharge | Tabular | BWDB | 100 |
| | Ground water Table | Tabular | BWDB | 100 |
| | Borehole lithology | Tabular | BWDB | 100 |
| | Rainfall | Tabular | BWDB | 100 |
| | Surface Water Salinity | Tabular | BWDB | 100 |
| | GW Salinity | Tabular | BWDB | |
| 5 | **Interventions** | | | |
| | Polders | Spatial & Tabular | BWDB | All |
| | Embankments | Spatial & Tabular | BWDB | Chittagong (spatial) |
| | Hydraulic Structures | Spatial & Tabular | BWDB | Chittagong (spatial) |
| | Protective works | Spatial & Tabular | BWDB | Chittagong (spatial) |
| | Canals | Spatial & Tabular | BWDB | Chittagong (spatial) |
| | Settlement | Spatial | LGED | |
| | Roads, Bridge & Culverts | Spatial | RHD & LGED | 60 |
| **Sl No** | **Broad Category** | **Type** | **Source** | **Status of Collection** |
| 6 | **Demographic/Socio-economic** | | | |
| | Population | Tabular | BBS | 100 |
| | Literacy | Tabular | | 100 |
| | Employment | Tabular | Project/BBS | - |
| | Health | | Project/BBS | - |
| | Livelihood and income | | Project/BBS | - |
| 7 | **Environmental** | | | |

| Sl No | Broad Category | Type | Source | Status of Collection |
|---|---|---|---|---|
| | Ecology | Spatial | DoE | - |
| | Bio-diversity | Spatial | DoE | - |
| | Forestry | Spatial | | |
| | Aquatic, Fish (open & Culture) | Spatial | DoE | - |
| | ECA | Spatial | | |
| 8 | **Agriculture** | | | |
| | Land use | Spatial | Satellite Image | - |
| | Cropping | Spatial/Tabular | Project/DAE | - |
| | Irrigation | | Project/DAE | - |
| | Production | | Project/DAE | - |
| 9 | **Soil Distribution** | Spatial | BARC/GSB | 100 (BARC) |
| 10 | **Geological maps** | Spatial | GSB | |
| 11 | **River/Canal Cross Sections** | Spatial/Tabular | IWM | 20 |
| 12 | **Sediment** | Spatial | Project | 60 |
| 6013 | **Erosion & Accresion** | Spatial | Project | |
| 14 | **Cyclone Intensity** | Tabular | Project | 100 |

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

Table 3-2: 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 | - |

| Sl No | Activity/Task | Progress Target (%) | Progress Achievement (%) | Target Next Quarter (%) |
|---|---|---|---|---|
| 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 | - | - | - |

# 4. MODELLING LONG TERM PROCESSESS

## 4.1 Introduction

A very large proportion of the work carried out by the consultant on this project comprises the development and application of many types of mathematical models for predicting the long-term processes (evolution) of the conditions in the Bengal Delta. The evolution of the Bengal Delta under the disturbances imposed upon it by natural processes and by human interventions occur at many different length and time scales.

## 4.2 Macro Scale Models: GBM Basin wide Applications

Table 4-1: Macro Scale Modelling

| | | |
|---|---|---|
| D-4A-1 | | **Modelling of the long-term physical processes; Morphology on a macro scale** |
| | **1a** | Basin scale modelling (HydroTrend)<br>Products: HydroTrend model, report, data upstream boundary conditions |
| | **1b** | MIKE Basin Model of GBM Basin<br>Products: Upstream Boundary Conditions for multiple Scenarios |
| | **1c** | Macro scale river modelling (Reinier, Wang)<br>Products: Delft3D-FM 1D model, report, data water/sediment budget |
| | **1d** | Macro scale coastal modelling (Dano)<br>Products: Delft3D-FM 2D model, report, data long-term erosion/sedimentation |
| | **2** | **Geospatial datasets of main sources and deposits of sediment at present (reference modelling results), including full meta-data restored and archived in Database of BWDB** |
| | **3** | **Geospatial datasets of main sources and deposits of sediment for 100 years from present (scenario modelling results), including full meta-data are published on archived in Database of BWDB** |
| | **4** | **Technical Report (one report for 4A-1 and 4A-2)** [2)+C44] |

### 4.2.1 The Hydrotrend model

The Hydrotrend model is a model applied to the entire GBM Basin. (see Figure 4.1) This is the key that controls all the inputs to the GBM Delta.

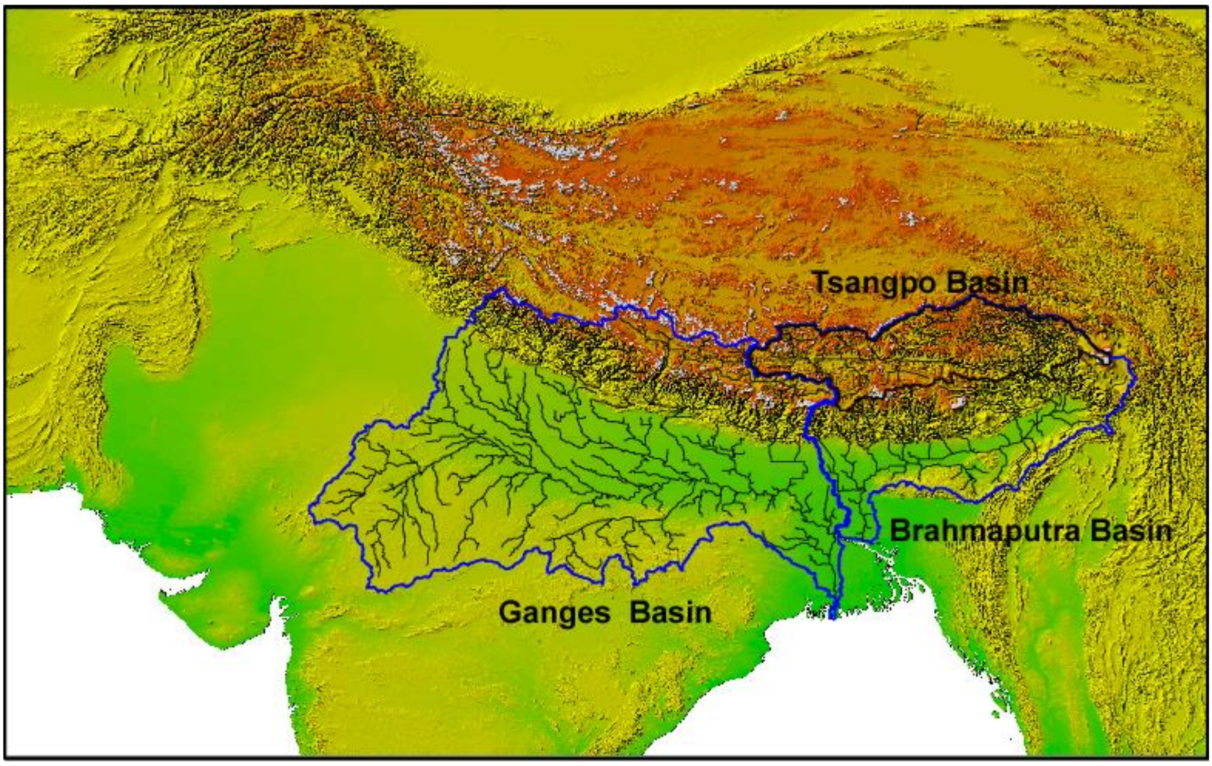


Figure 4-1: Map showing the Ganges and Brahmaputra basins

A list of input data types such as terrain (eg DEM), landuse, precipitation, erosion properties etc.

The main input file (HYDRO.IN) which contains: project title, input–output directory, simulation length, yearly and monthly climate statistics (such as precipitation observed in the basin, average temperature at downstream of the basin, lapse rate etc.), glacier parameters, groundwater parameters and parameters that describe the possible river distributaries;

Hypsometric Input file (HYDRO0.HYPS) which is analysis of the Digital Elevation Model (DEM) of the basin;

Another optional input file (HYDRO.CLIMATE) can be used which contains sequential climate input instead of the statistical realizations of the climate otherwise defined in HYDRO.IN. The sequential climate input minimum–maximum time step ranges from 1-hour to 1-day.

**Scenarios we plan to use in the model**

- Future with climate change;
- Future with implementation of Indian River Linking Project (IRLP);
- Future with both climate change and implementation of IRLP

Model outputs (eg water and sediment at Hardinge, Bahadurabad etc)

- The outfall of the model domain is at Farakka (not Hardinge bridge) in the Ganges and Bahadurabad in the Brahmaputra River. The model will provide the following outputs for base and future scenarios:
- Water discharge, discharge velocity, width and depth at the river mouth;
- Bed load and the suspended sediment concentrations for each grain size.

### 4.2.2 Macro Scale Models: Large Rivers System

The macro-scale models will be developed for the major river systems of Bangladesh. These models are divided into two modelling approaches:

1) River branch modelling approach (1D)

- To derive a sediment budget for the Bangladesh Ganges-Brahmaputra-Meghna (GBM) delta
- To assess the effects of changing boundary conditions (climate change, upstream damming) on the sediment budget
- To derive boundary conditions for smaller scale (i.e. meso scale) sub-models

2) Coastal modelling approach (2D)

- Large-scale tidal propagation and flow distribution
- To study coastal hydrodynamics and sediment transport pathways
- Sand and fine sediment distribution
- Pathways for fine sediment
- Morphology of major channels on decadal scales
- To forecast long-term morphological changes for different scenarios
- To derive boundary conditions for meso-scale models

Both the River branch (1D) modelling and Coastal modelling (2D) will be developed using Delft3DFM modelling system. The preliminary 1D river network was selected for this model which is shown in Figure 4.2.

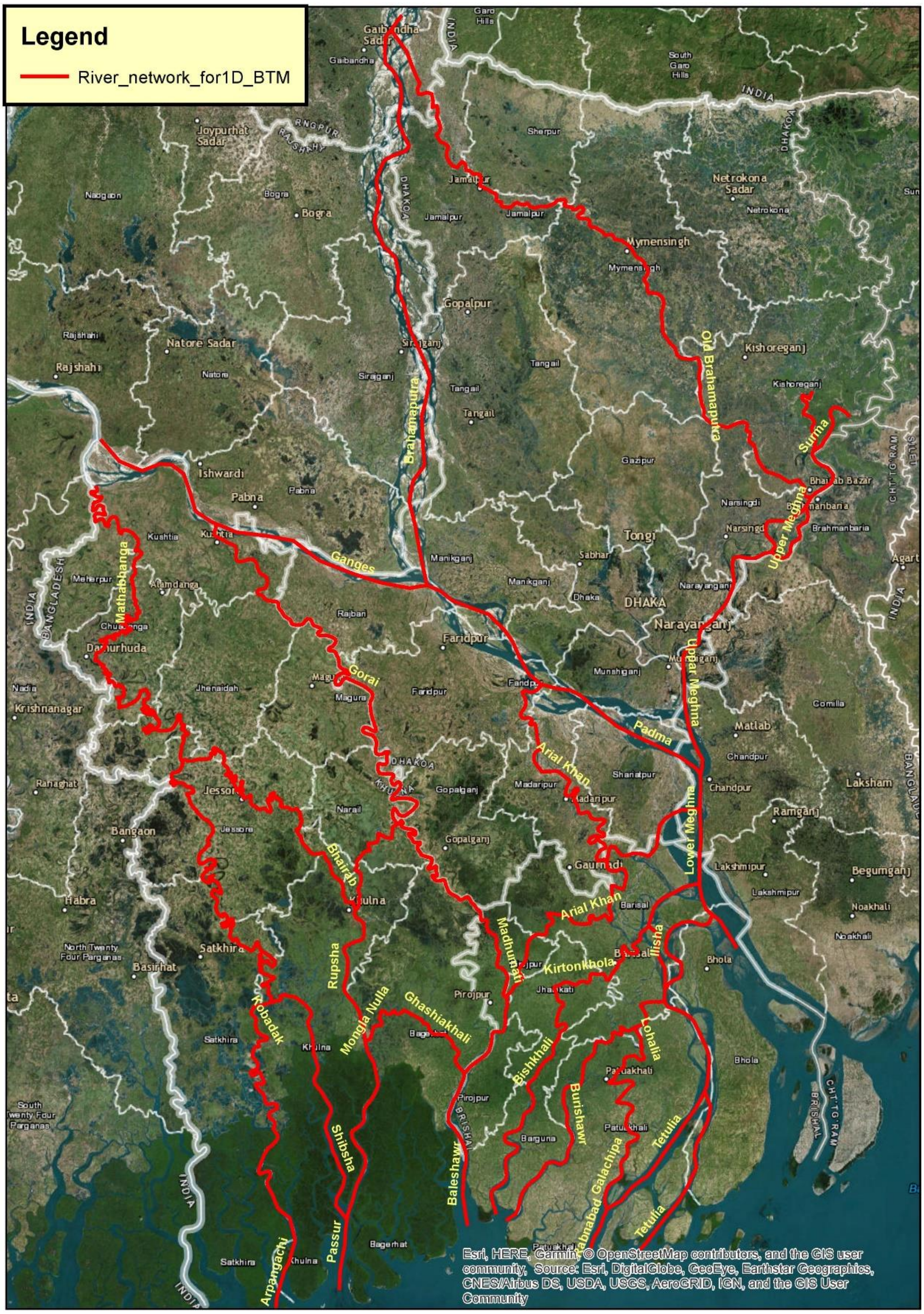


Figure 4-2: River network for 1D River branch modelling

The 2D coastal model domain will cover the whole coastal area including the river and land area. The resolution varies from 8km to 500m. Figure 4.3 shows the model domain.

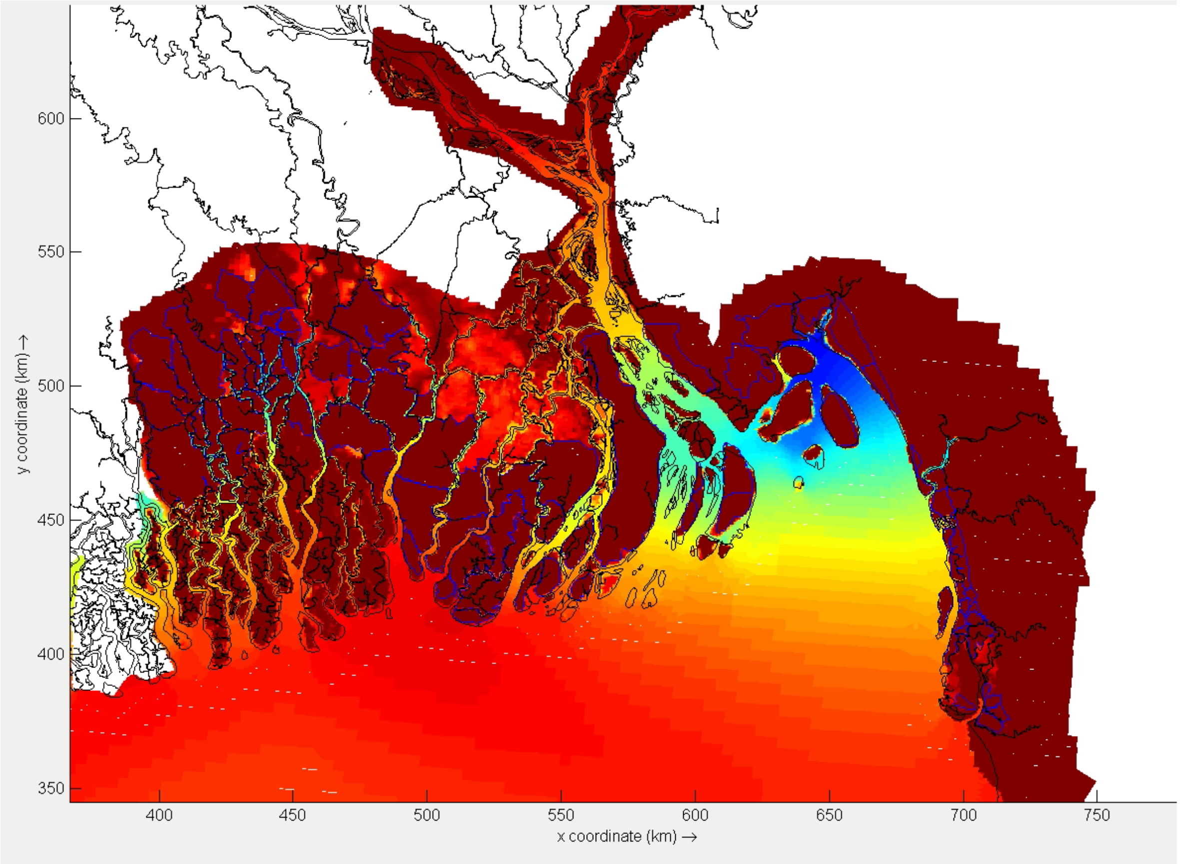


Figure 4-3: Two-dimensional coastal model domain for the coastal area of Bangladesh

## 4.3 Meso Scale Models for Long Term Morphology

Table 4-2: Meso Scale Modelling for Long Term Morphology

| | | |
|---|---|---|
| D-4A-2 | | **Modelling of the long-term physical processes; Morphology on a meso scale** |
| | 1a | Pussur-Sibsa (Delft3D-FM & Delft3D 4) |
| | 1b | Baleshwar (Delft3D-FM) |
| | 1c | Lower Meghna (Delft3D-FM) |
| | 1d | Chittagong (Delft3D-FM) |
| | 2 | Geospatial datasets of erosion and sedimentation in the coastal zone stored and archived in Data base |
| | 3 | Geospatial datasets of erosion and sedimentation in the coastal zone for possible scenarios 25, 50 and 100 years from now stored and archived in Data base |
| | 4 | Technical Report (one report for 4A-1 and 4A-2) |

The main objective of this modelling is to develop morphological models for the selected rivers around the polder areas and estimate future long-term morphological changes under different scenarios. The selected meso scale modelling groups are following (Figure 4.4):

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)

The general approach for this modelling is the following:

- Preliminary study of historical morphological changes in the larger tidal rivers by using available bathymetry data
- Setup and Calibration – Setup, calibrate and validate the model with field measurements and remote sensing data.
- Morphological hindcast – reproduce the morphology from previous different periods.
- Scenario runs - Study future changes in the morphodynamic processes based on possible scenarios.
- Output - Geospatial datasets of erosion and sedimentation in the river system at present for various seasons and for possible scenarios 25, 50 and 100 years from now, for various seasons and circumstances.

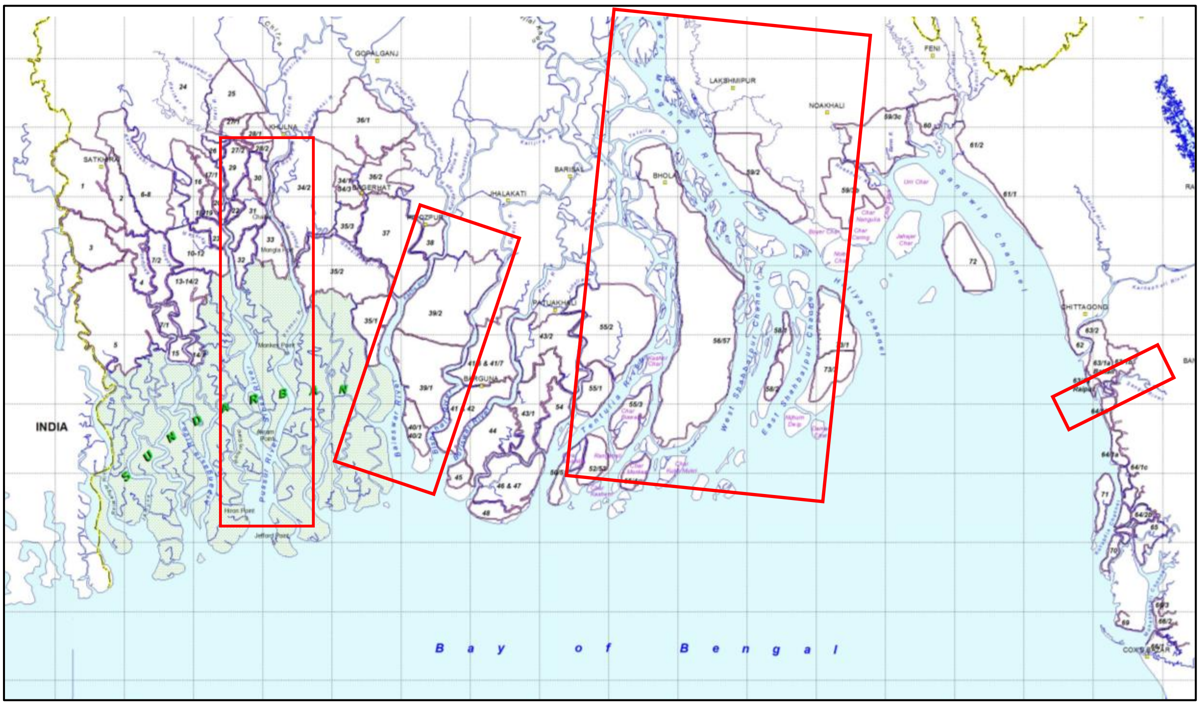


Figure 4-4: Map of meso scale modelling groups for long term morphology

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

From the previous studies, the secondary bathymetry data for Pussur-Sibsa rivers are available for 2011, and the primary data collection for 2019 has already collected for the present study with the same area coverage as the year 2011. The changes of bed level changes were estimated from 2011 to 2019. The Sibsa river seems more erosion in the river bed than the Pussur river during the eight-year period. Figure 4.5 shows the bathymetry of 2011 and 2019, and changes of bed level from 2011 to 2019.

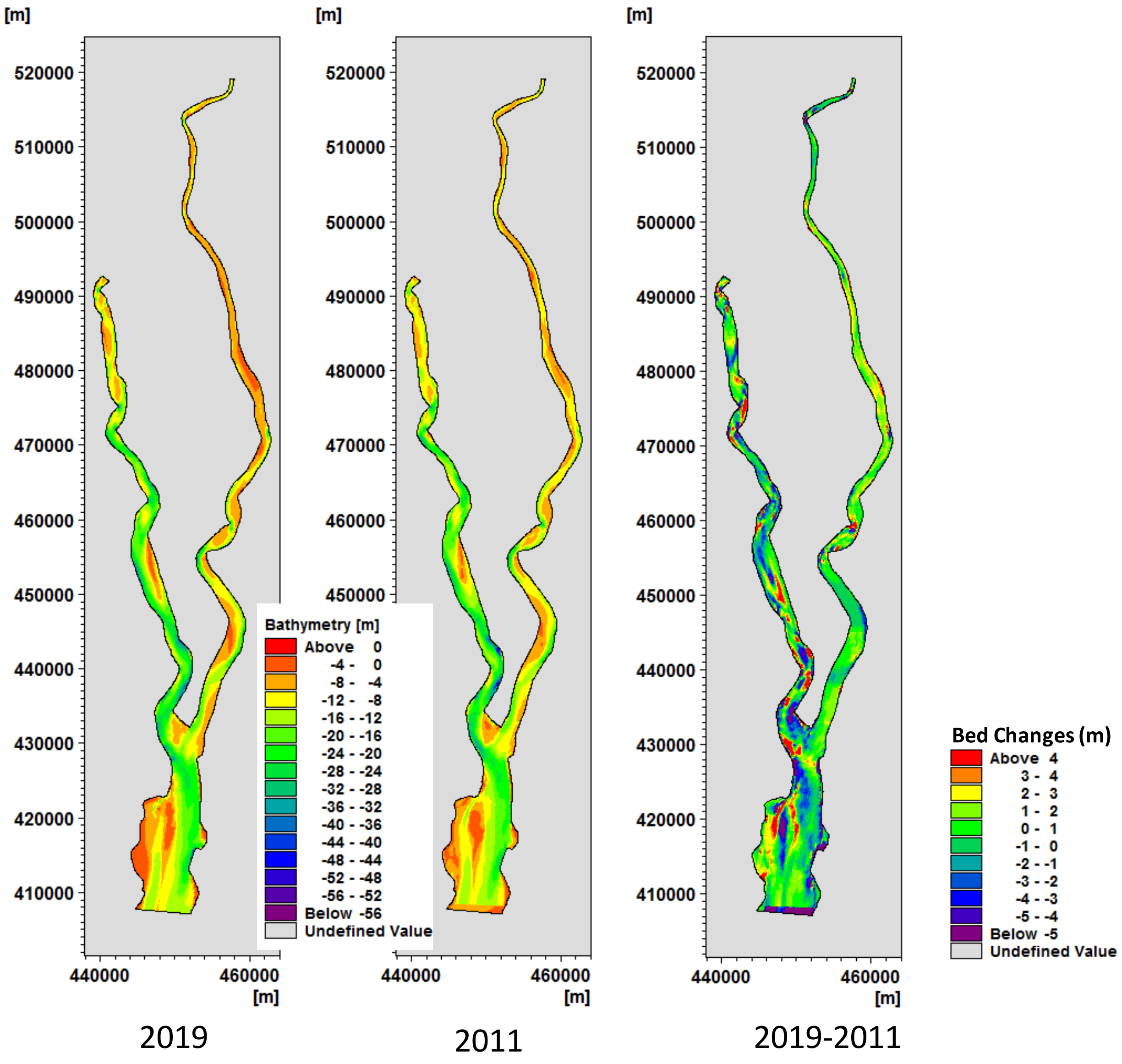


Figure 4-5: Bed level during 2019 and 2011. Bed level Changes from 2011 to 2019 (right panel).

The long term meso scale model development has already started by Delft3D FM modelling system. The Pussur-Sibsa river system is modelled in one numerical grid, combining both river systems in a single model. The river system is influenced by interaction with the adjacent floodplains (e.g., Mangrove forest and outside the polder area) as the bed level is relatively low around this area and flooding occurs. Therefore, the floodplain was incorporated on both sides of the rivers in the numerical grid. The available 2011 bathymetry data for the main river channel was interpolated on the unstructured curvilinear grid system. Figure 4.6 shows the grid and bathymetry for the Pussur-Sibsa river system.

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.

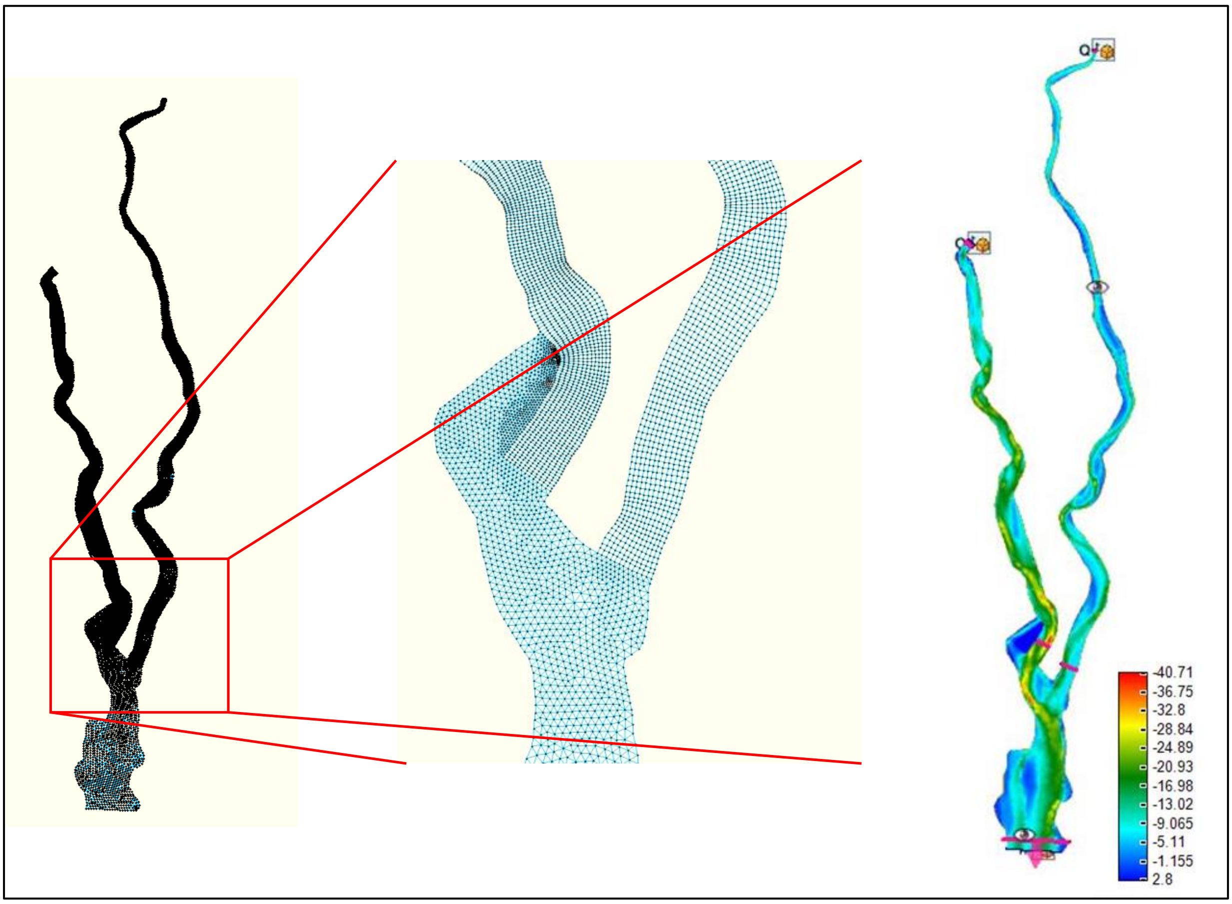


Figure 4-6: Computational mesh/grid for Pussur-Sibsa river system and interpolated bathymetry for 2011.

### 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 has already been collected for this study in 2019 in the same area extent as year 2011. The changes of bed level changes were assessed from 2011 to 2019. The Baleswar river seems erosive near out bank of river bend during the last eight-year. However, there was formation of island inside the river. Figure 4.6 shows the bathymetry of the Baleswar river for 2011 and 2019, and changes of bed level from 2011 to 2019.

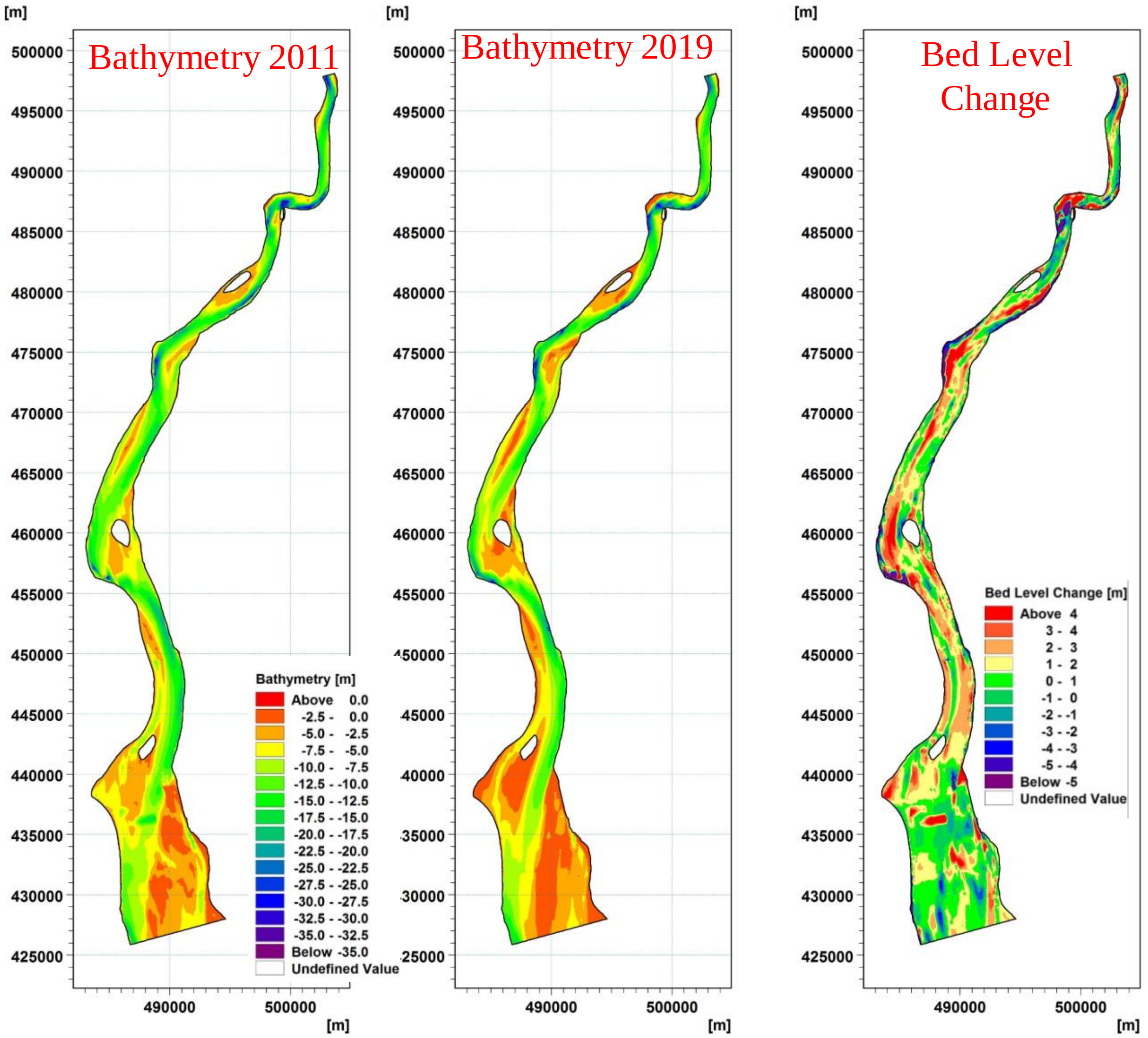


Figure 4-7: Bed level during 2019 and 2011. Bed level Changes from 2011 to 2019 (right panel).

The long term meso scale model development has already started by Delft3D FM modelling system. Figure 4.8 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.

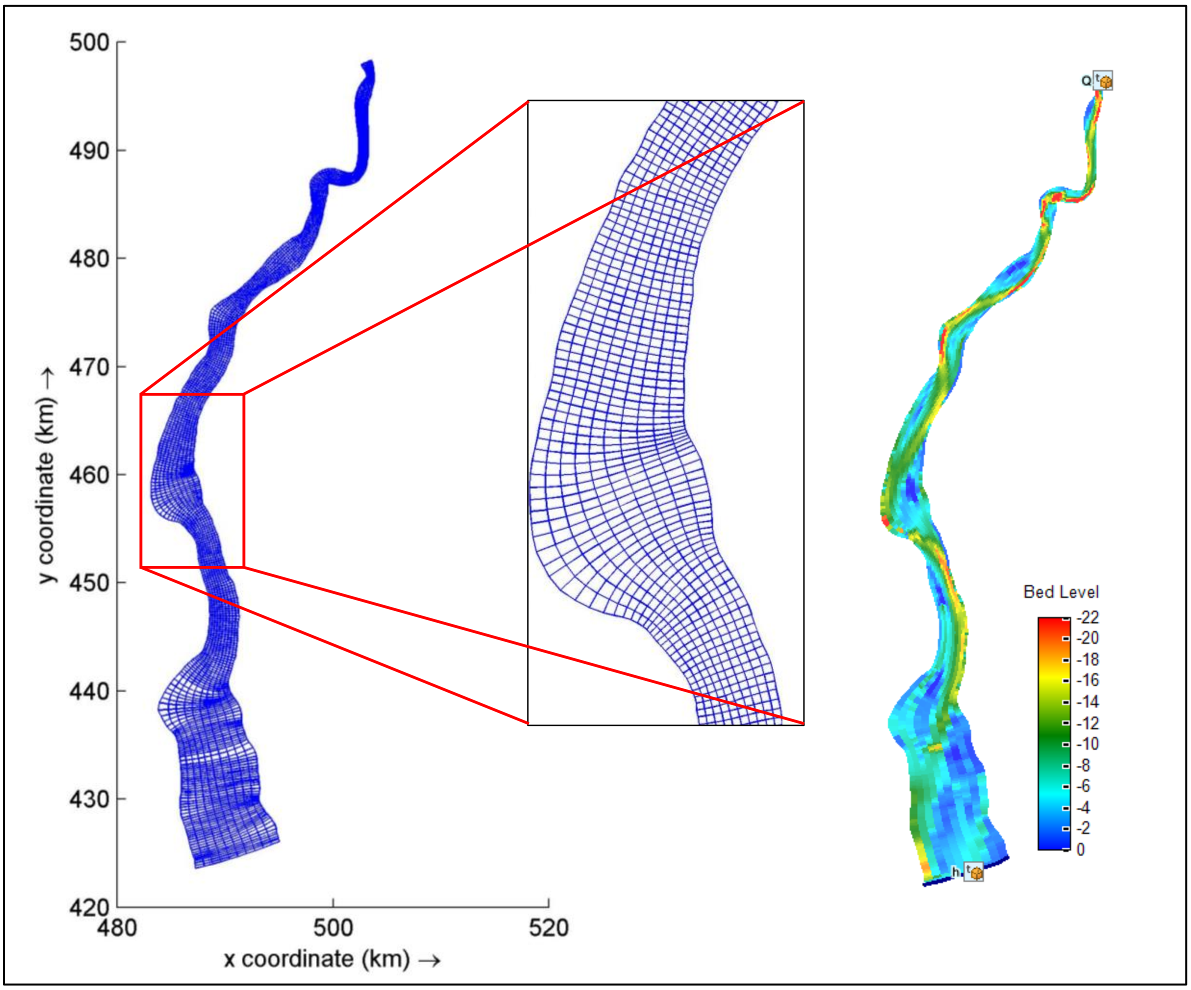


Figure 4-8: Computational mesh/grid for Baleswar river system and interpolated bathymetry for 2011.

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

## 4.4 Meso Scale Models for Bank Erosion

Table 4-3: Meso Scale Modelling for Bank Erosion Prediction

| | | |
|---|---|---|
| D-4A-3 | | **Modelling of Bank Erosion Processes; Morphology on a Meso scale** |
| | 1 | Several models setup & developed to study bank erosion processes - to model recent occurrences and to hindcast erosion of a medium term time scale. Identify three or four key vulnerable sites A, B, C for detailed study |
| | 2a | Site A: Tagetted field investigations, model schematisation & set up, simulations for hindcasting and forecasting & risk assessemt, testing preventive measures and other proactive interventions |
| | 2b | Site B: Tagetted field investigations, model schematisation & set up, simulations for hindcasting and forecasting & risk assessemt, testing preventive measures and other proactive interventions |
| | 2c | Site C: casting and forecasting & risk assessemt, testing preventive measures and other proactive interventions |
| | ¨3 | Report on Erosion Guidelines and Recommendations, early warning methodology & Erosion Management Strategy |

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 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.

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

### 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)

For the inspection of erosion, Landsat imagery were acquired for the period of 1988-2019. IWM engineers digitized the bank lines 1988 to 2019, typically every 5 years, to have the data available for the model study. Figure 4.8 presents all the extracted banklines for the Baleswar river. The large erosion was observed at polder 35/1 and polder 37 along the right bank of Baleswar River.

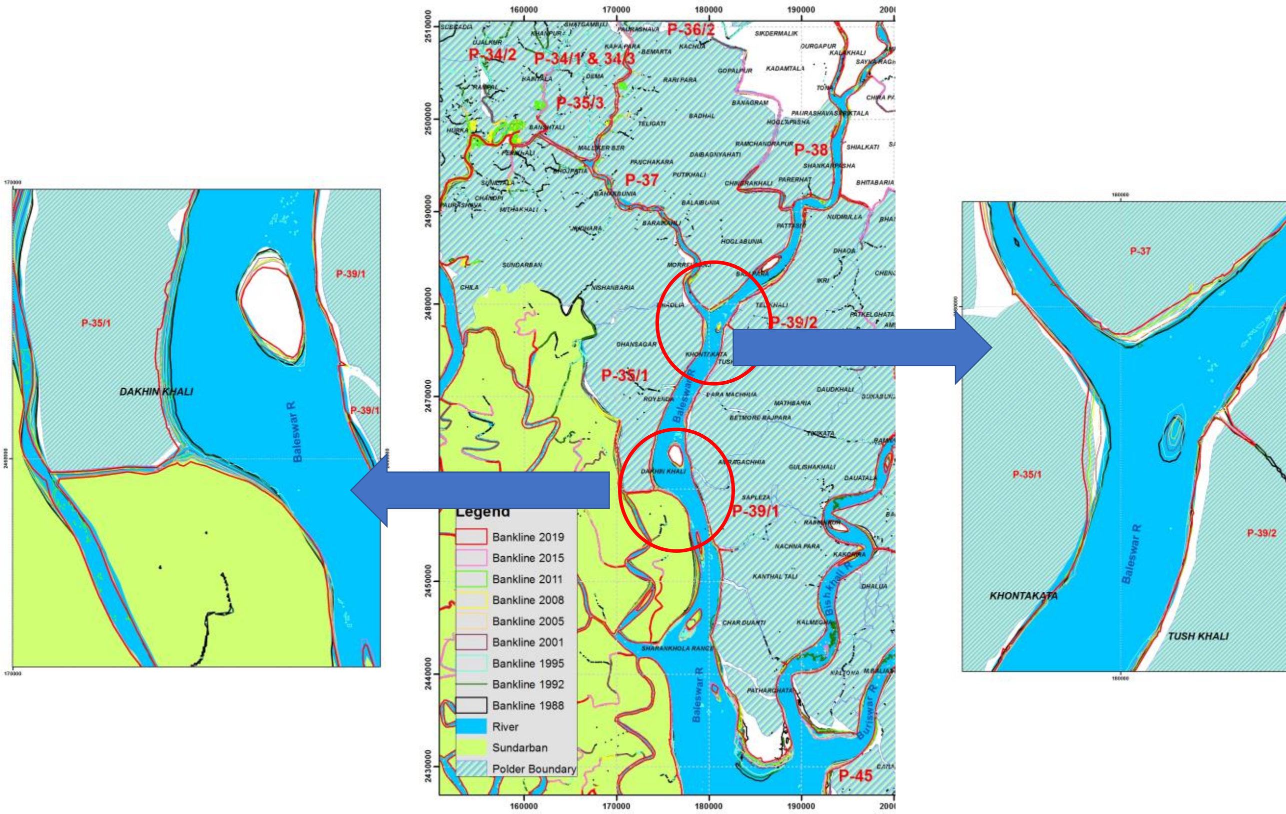


Figure 4-9: Bankline shifting from 1988 to 2019 for the Baleswar river

The preliminary model has been developing by MIKE21C modelling system. The computational curvilinear grid and interpolated bathymetry for the Baleswar river is presented in the Figure 4.9. The hydrodynamic model is still going on for 2011.

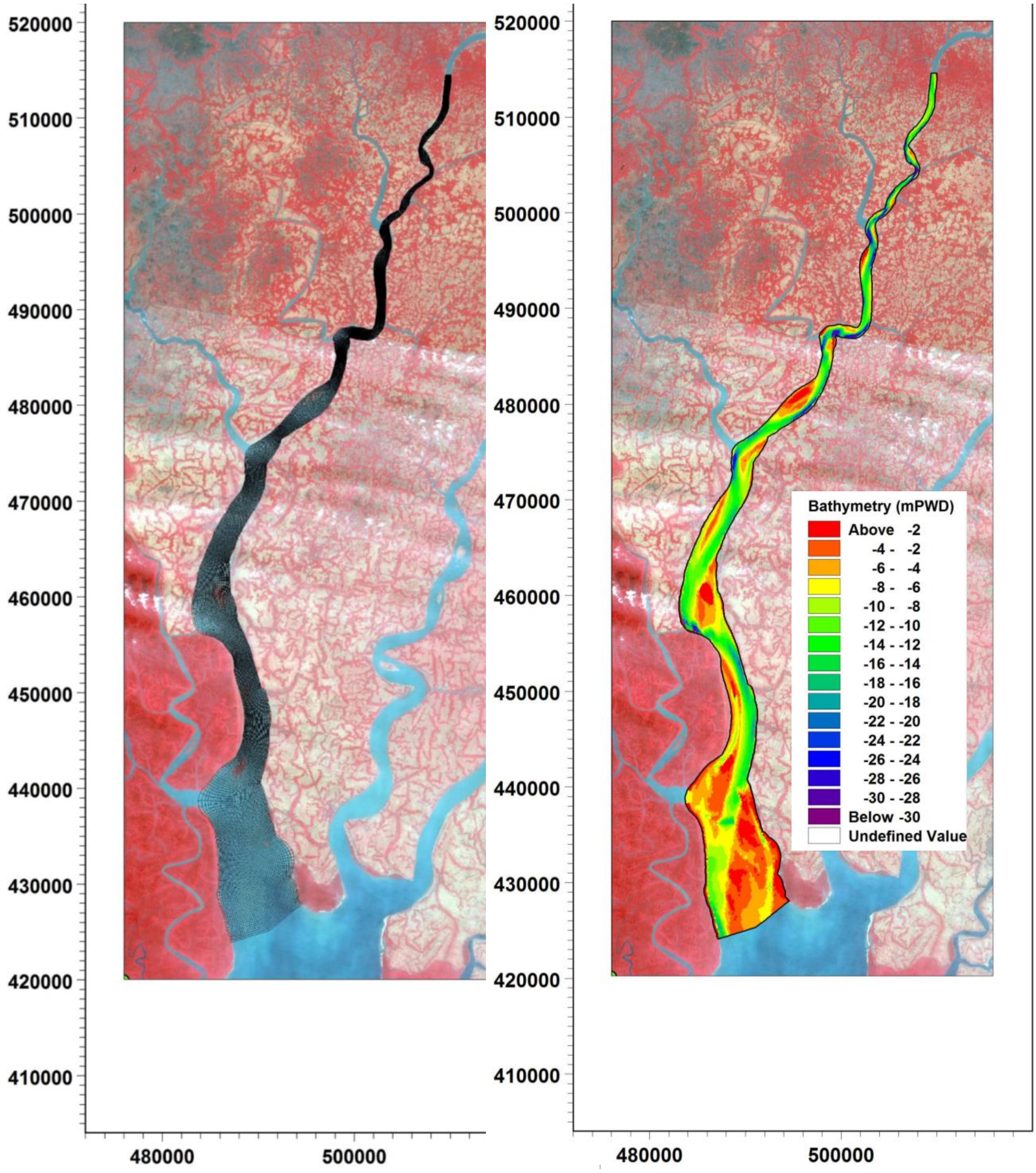


Figure 4-10: Computational curvilinear grid and interpolated bathymetry for the Baleswar river

### 4.4.2 Pussur-Sibsa River system for bank erosion model study

In the study area, erosion behaviour of past events was observed from the bank line from Landsat images from 1988-2019. All the extracted river bank lines from images are presented in Figure 4.10 for the Pussur-Sibsa system.

Erosion was observed along the Polder 30 in Pussur River where both erosion and deposition patterns were found along the Polder 33 from 1988 to 2019. Bankline shifting in downstream of Pussur River was balanced by erosion and accretion which is may be due to the flood channel and ebb channel flow. Sibsa River exhibits an erosional pattern on both banks. Polder 32 was largely affected along the left bank of Sibsa River due to erosion during this time period.

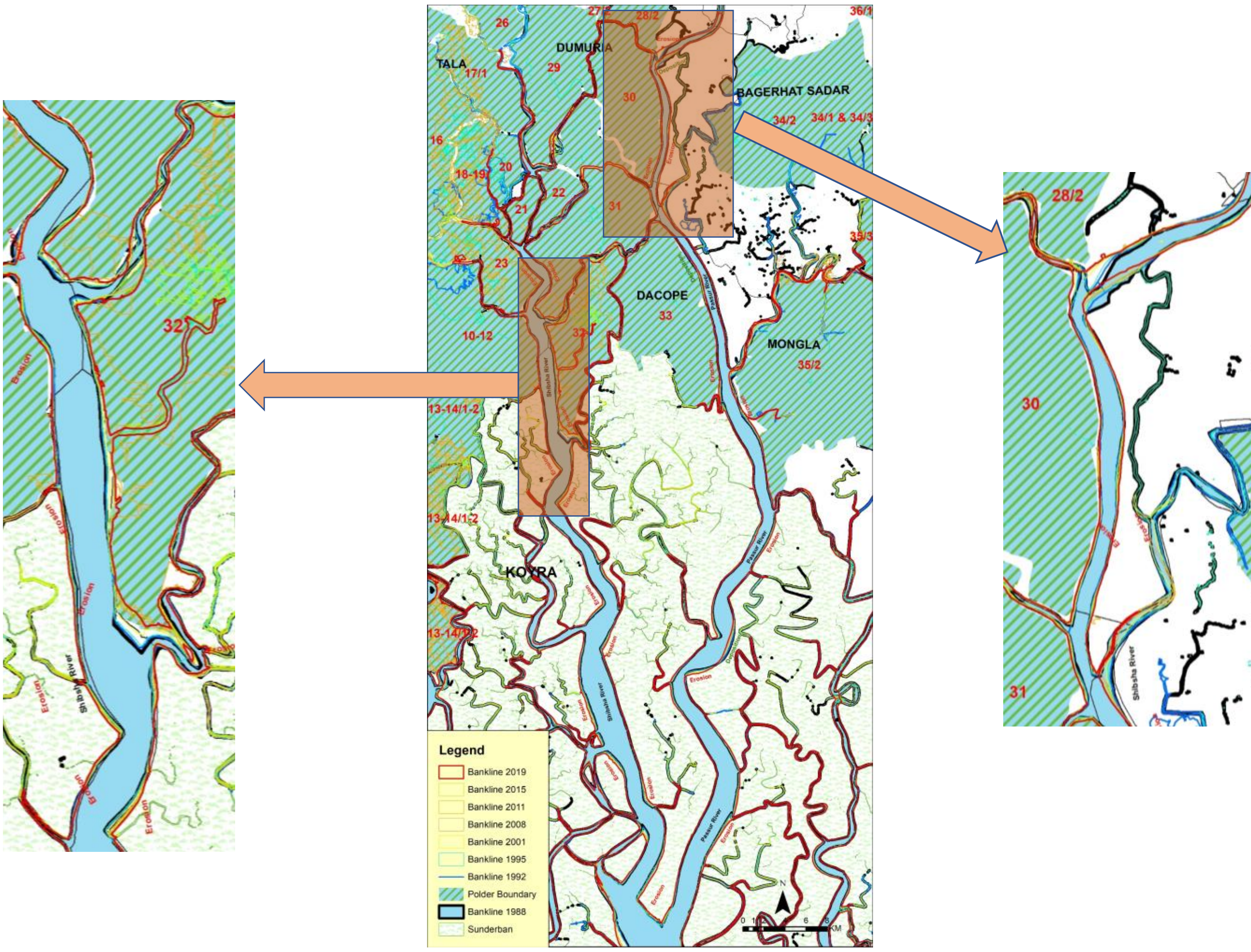


Figure 4-11: Bankline shifting from 1988 to 2019 for the Pussur-Sibsa river systems

Preliminary model for the two rivers has been developing by using MIKE21C modelling system. The river system has some influence from floodplain (e.g. mangrove forest and outside the polder areas), which was identified from the available DEM elevations. Therefore, the floodplain was incorporated with the river in the MIKE 21C modelling system. The available 2011 bathymetry data for the main river channel and floodplain data from IWM DEM (FinMap 1993-94) were interpolated in the curvilinear grid system. Figure 4.11 shows the model curvilinear grid and interpolated bathymetry for 2011.

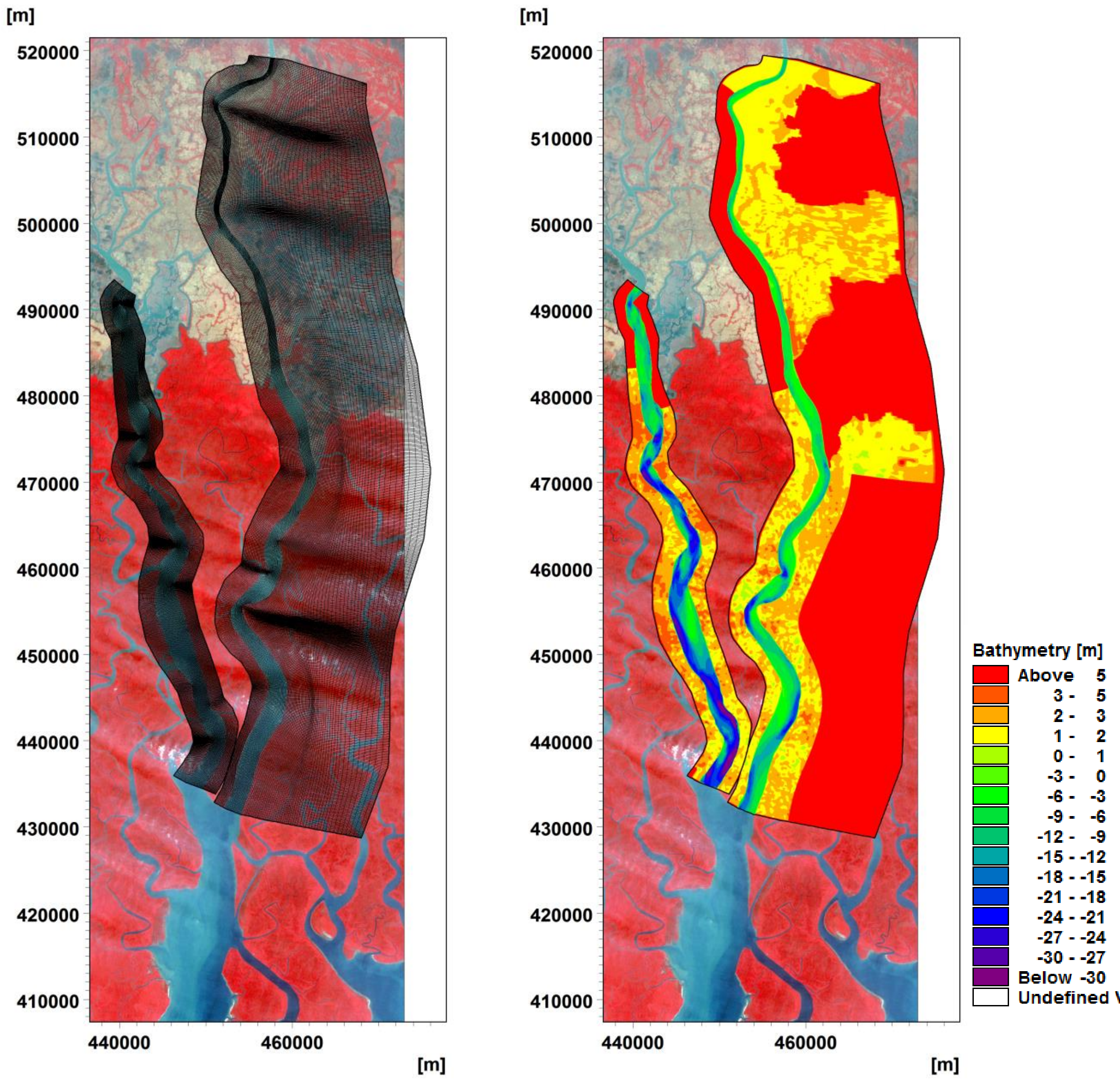


Figure 4-12: Computational curvilinear grid and interpolated bathymetry for the Pussur-Sibsa river system

### 4.4.3 River 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.

### 4.4.4 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)

Table 4-4: Morphological Modelling on Micro-scale

| | | |
|---|---|---|
| D-4A-4 | | **Modelling of the long-term physical processes; Morphology on a micro scale** |
| | | Identify a number of polders requiring especially detailed study (beyond the crest levels and standard drainage designs practiced in the most recent CEIP-1 ) to investigate operational and management alternatives for sustainably overcoming waterlogging and drainage congestion |
| | | 2) A report that describes the pros and cons of the different methodologies to prevent water-logging within the polder and sedimentation of tidal river system including polder subsidence. The report will include meta-data on the models used and measurements, recommendations for polder design including drainage and long term management plan, and recommendations for pilot area/polder to implement the ideas, such as but not limited to location, methods and measurements |
| | | Recommend plans to manage sediment at the downstream stretch of the tidal river and in the polder |

Tidal River Management has been implemented in some of the polders (polder 6-8 and Polder 24) in south western region. After detailed studying reports on tidal river management (TRM) Polder 24 has been identified as a good case for a pilot model. IWM collected a lot of data at Polder 24 before and after the implementation of the TRM. The available data 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

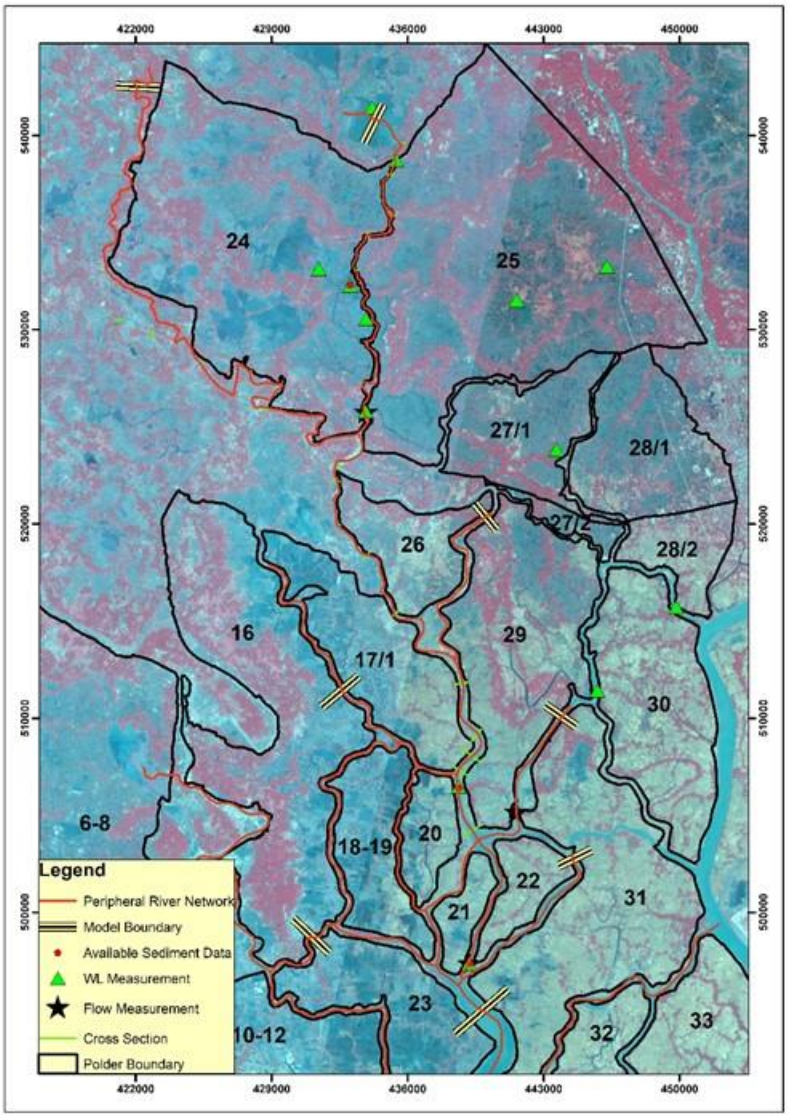


Figure 4-13: River Network for Mike 11 Model Extracted from SWRM

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.

For the initial model development for the TRM, existing data is being reviewed and currently in progress of identifying the peripheral river hydrodynamics using Mike 11 model. The Mike 11 hydrodynamic model is under process of extracting and hydrodynamic analysis of river network for the TRM location from the existing SWRM model. After this following step would be performed:

- Create local MIKE 11 model to be combined with the MIKE 21 model
- Verify that the MIKE 11 model behaves as the SWRM model
- Include a sediment transport formulation into the MIKE 11 model
- Calibrate the sediment transport model
- Cut the local MIKE 11 model into branches to be connected to the MIKE 21 model
- Combine the M11 branches and the M21 model to create a MIKE FLOOD model for pre and post TRM conditions
- Investigate different TRM strategies using short term simulations (neap-spring cycle)
- Morphological modelling of the transition processes in the peripheral rivers and the beel

# 5. OTHER STUDIES

## 5.1 Subsidence and Delta Building

The approach to studying subsidence and delta building has been described in detail in the Second Quarterly Progress Report (QPR-2). The field work proposed was postponed because of an administrative difficulty and the rescheduled programme is to commence on 15 July 2019.

Subsidence is a key process to be quantified, and remote-sensing techniques, 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 analyses 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.

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) Collection of historical timeseries data on rainfall, temperature and river discharge and water level

c) Statistical analysis of rainfall, temperature, river discharge and water level data to examine the trend of the variables

d) Carryout Pearson's t-test (PS), Spearman's rank test (SM), Mann-Kendall test (MK) and Wilcoxon-Mann-Whitney test (WMW) to examine the trend of variables

e) Future projection of temperature and precipitations will be carried out based on literature review, model results from Colorado university and model outputs from five IPCC approved climate models

The climate change projections for different RCP scenarios will be used for long-term simulations.

### 5.2.1 Analysis based on global datasets

#### 5.2.1.1 Sea level rise

To examine the trend of tidal water level, the time series water level at Hironpoint (MPA gauge), Khepupara (BIWTA gauge) and Rangadia (SoB gauge) were analysed. Analysis suggests increasing trend of sea level rise.

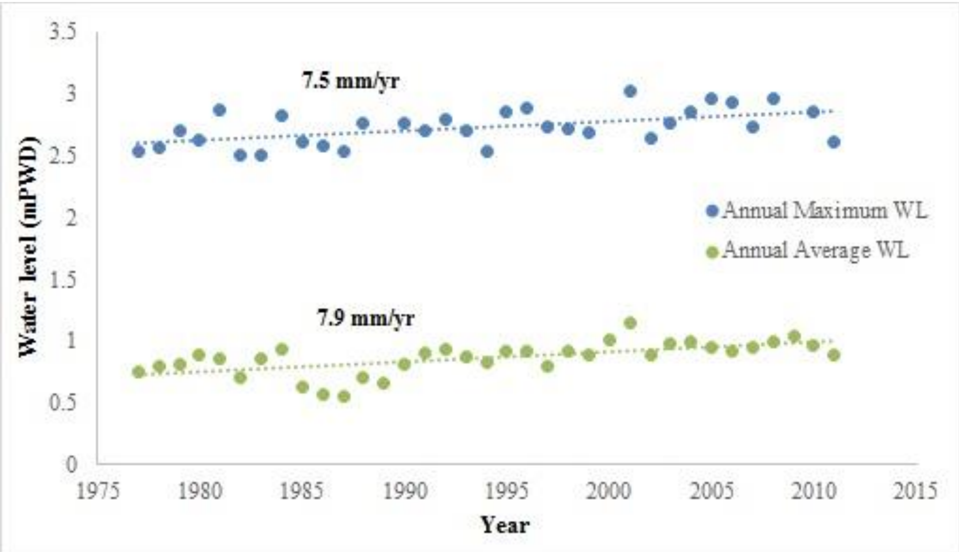


Figure 5-1: Trend of tidal water level at Hironpoint

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.

However, along the coast of Bangladesh absolute sea level rise is not same. For assessment of impact, relative mean sea level rise is required. Relative sea level rise will also be different along the coast due to varied subsidence rate.

Figure 5.2 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 ~zcoast 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.

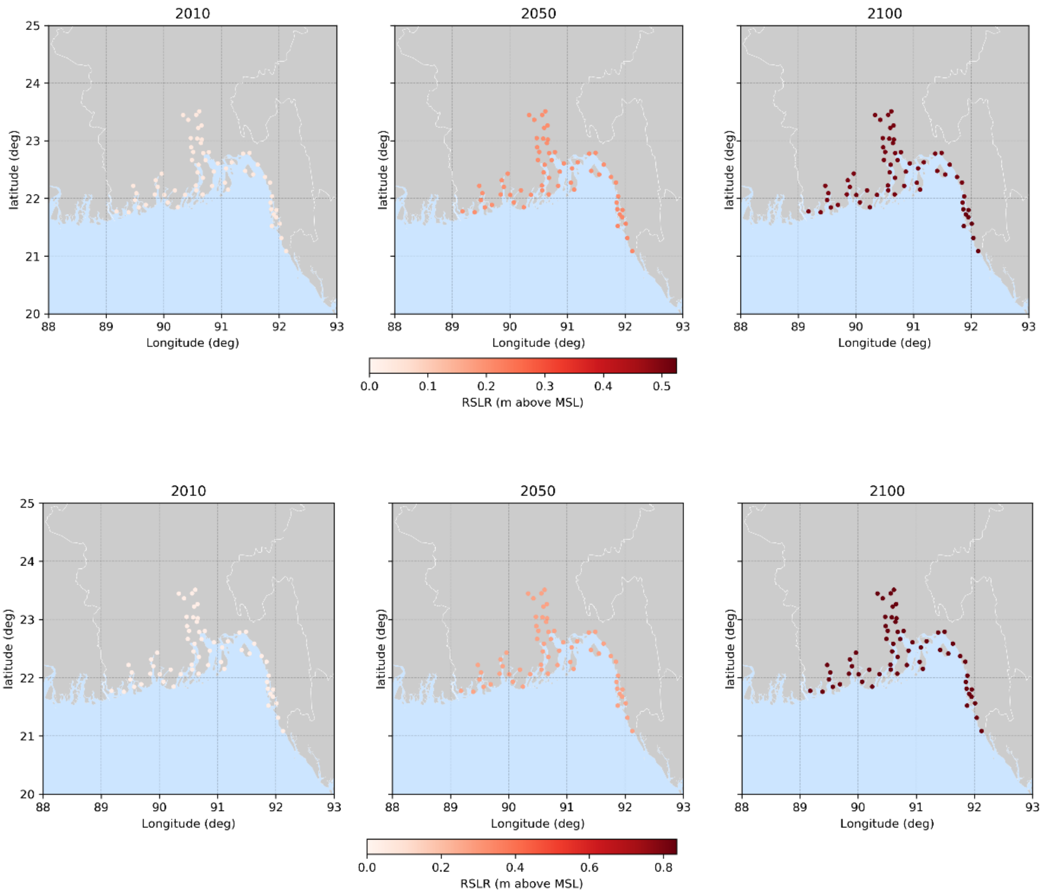


Figure 5-2: Predicted mean sea level rise rates according to Vousdoukas et al. (2018) for Bangladesh, respectively for RCP 4.5 (panel above) and RCP 8.5 (panel below) for 2010, 2050 and 2100.

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.

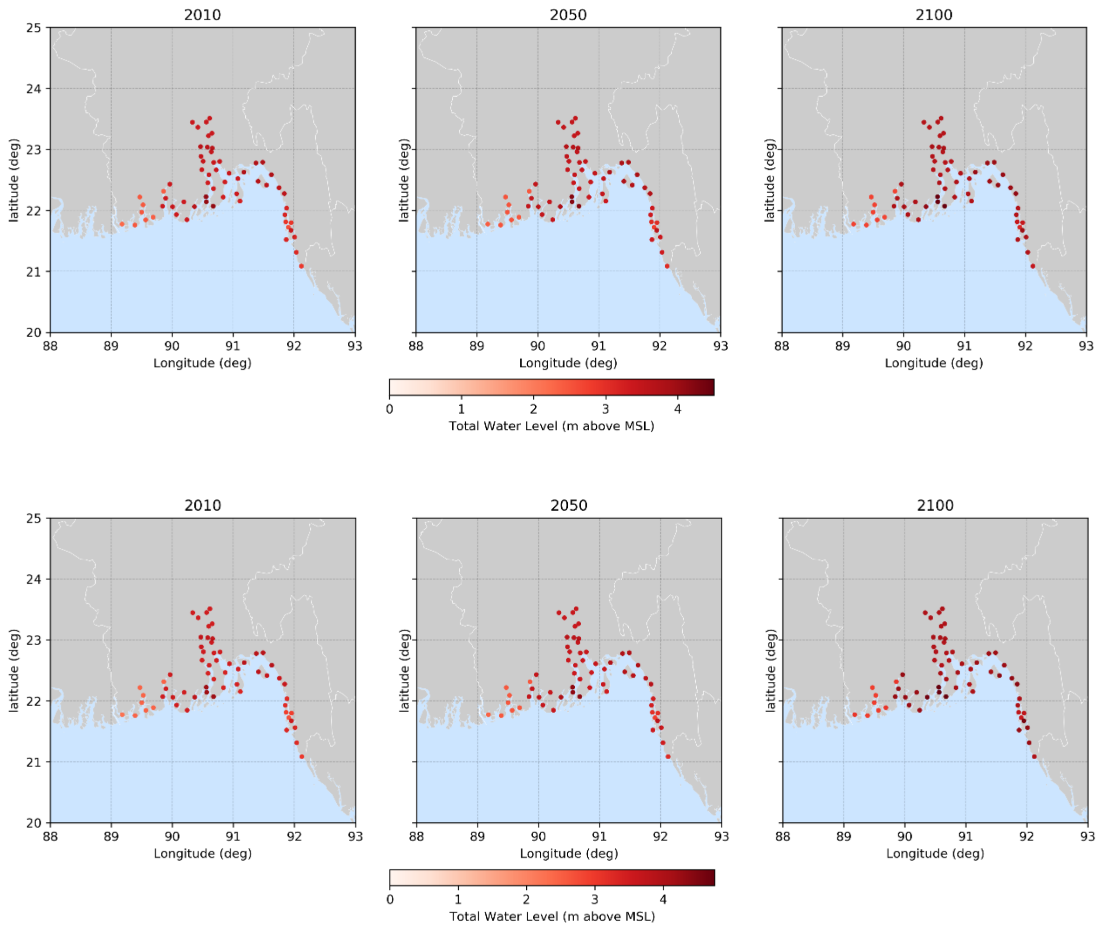


Figure 5-3: Predicted extreme sea level rise rates (including changes in mean sea level, tides, wind-waves, and storm surges) according to Vousdoukas et al. (2018) for Bangladesh, respectively for RCP 4.5 (panel above) and RCP 8.5 (panel below), for 2010, 2050 and 2100. Waves and storm surges refer to 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 pre-monsoon (April, May, June) as in the late rainy season period (September, October, November, December; see for more information Dasgupta et al., 2016).

About 23 number of severe cyclone hit the coast of Bangladesh from 1960-2016. Figure 5-4 shows the occurrence of cyclone in pre-monsoon and post-monsoon. The increase of wind speed due to climate change about 5-11% in accordance with 5$^{th}$ IPCC report. Increase of cyclonic wind speed causes increase of storm surge height.

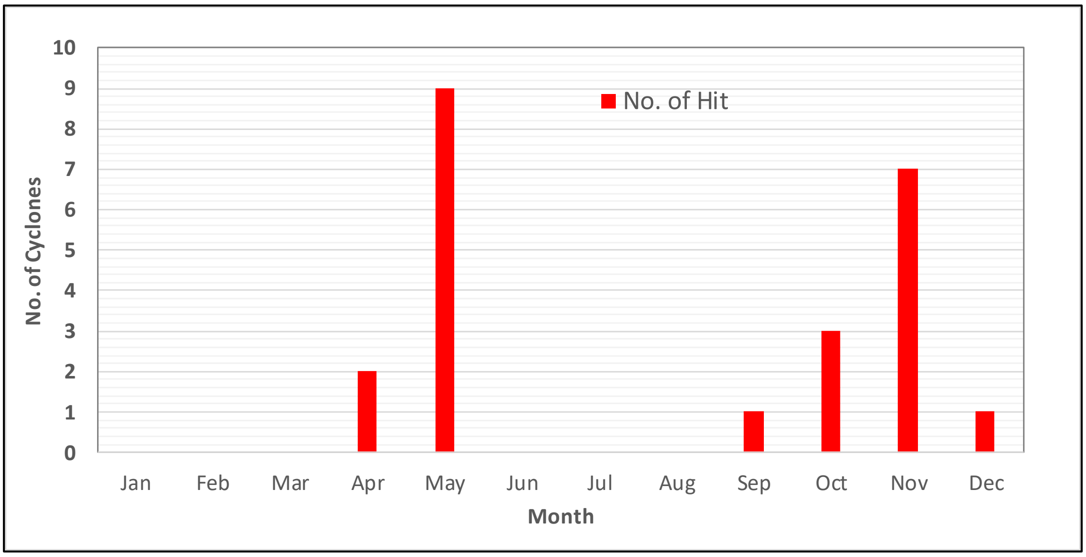


Figure 5-4: The occurrence of cyclone in pre-monsoon and post-monsoon season in Bangladesh coast during 1960-2016.

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.

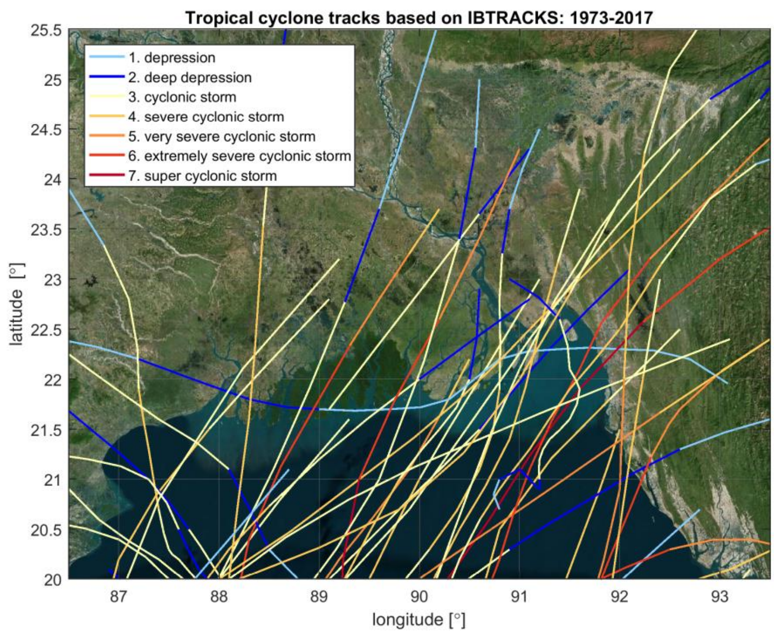


Figure 5-5: Tropical Cyclone (TC) tracks and intensity based on the IB TRACKS database. Here the joint typhoon warning center for the Indian Ocean (IO) was used as data source. The tracks are colored-coded based on the India Meteorological Department (IMD).

**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%).

### 5.2.3 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

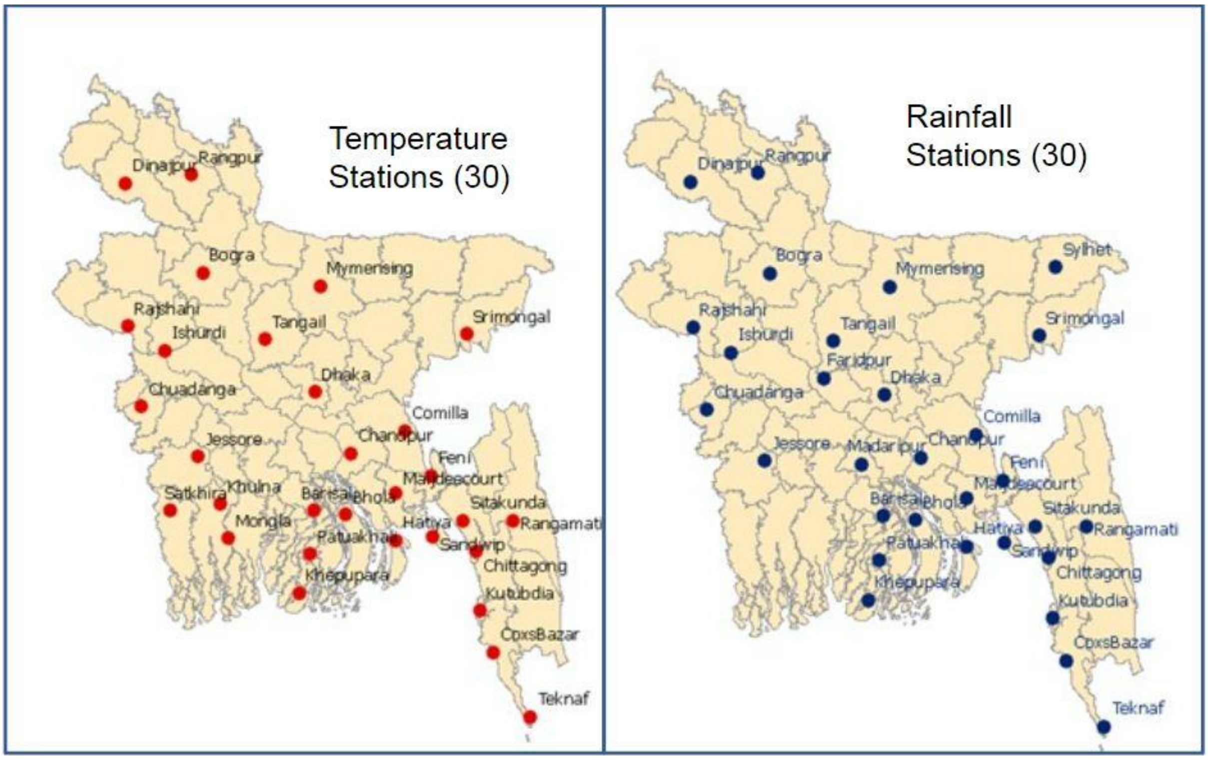


Figure 5-6: Temperature and rainfall stations across Bangladesh.

# 6. POLDER RECONSTRUCTION PROGRAMME

Devising a polder reconstruction programme must be based on agreement on a set of clearly enunciated objectives. There is much literature available as project reports on solving problems associated with the Coastal Embankment System over the past 60 years. These reports cover areas of water resources and flood protection, drainage, operation and maintenance of systems, environment, agriculture, socio-economics etc. In more recent times questions of sustainability have begun to play a larger role in design and planning of new systems.

The Coastal Embankment Improvement Programme was initiated in August 2010 as a phased programme of improving the Coastal Embankment System, which had already been in existence for 50 years, to improve its resilience to Climate Change in the face of two major cyclones, in 2007 and 2009, which caused damage in excess of USD 2 Billion. At that time there were 139 polders protecting the loverhoods of 28 million people occupying 1.2 million hectares of land which was once subject to tidal inundation. While it was necessary to protect the embankment system from storm surges originating in the Bay of Bengal which was now recognised as subject to sea level rise driven by climate change, It was clear that the polders would need to be classified in terms of their vulnerability so that a phases improvement programme could be devised to take up the gradual strengthening of the embankment system to resist the impact of climate change

17 polders were selected for CEIP-I as the first stage of this project. The selection was done on the basis of a multi-criteria analysis of all 139 polders. The selection criteria were based on the actual physical attributes of the polder an hydraulic structures and the vulnerability assessment of the respective BWDB Engineers responsible for and possessing intimate knowledge of each polder. The selection of groups of polders for intervention was also influenced by the need to keep the selected polders in groups within close proximity for convenience of access and for determining the design parameters and model boundary conditions.

The original selection of 17 polders for CEIP-1 was based on a multi-criteria analysis of the 139 polders. It is necessary to revisit this analysis and make revisions based on our current understanding of phenomena, which have evolved based on new knowledge of matters such as land subsidence, climate change and changes in the catchments in the upper delta. The original selection was based on the data available in the year 2011. The second group of 10 polders selected (but not finalised) for CEIP-2 was also selected in 2012 based mainly on the same dataset.

There probably has been a tendency to concentrate more on technical solutions and engineering and give less considerations to the operational and management aspects that are also essential to ensure longer term sustainability. There have, in recent times, been efforts to give emphasis to the views of stakeholders – in particular, polder communities – who are direct beneficiaries of the systems under consideration. (cf Blue-Gold reference?)

In order to broaden the view of the project teams studying the coastal embankment system with a view to creating more sustainable systems, , the project has conducted several Stakeholder Consultation Workshops (please see Chapter 9 of this report) to give additional guidance to the teams planning and designing the polder reconstruction programme.

It is necessary to take advantage of the Polder Database being set up and populated under this project (see Chapter 3) and use it as the principle tool for analysing the properties of the polders into categories suitable for deciding on a strategy for polder reconstruction. The new database would need to be expanded to include much more information in demographic, administrative, socio-economic, environmental and other characteristics in order to make it suitable as a tool for devising a reconstruction strategy.

# 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

The national consultants engaged in the project were able to interact closely with visiting experts and jointly carry out the tasks necessary to analyse data and develop and set up numerical models. The national consultants have received on the job training while working intensively with several visiting experts. The subjects covered during this Quarter are:

| **Name** | **Speciality** | **Expertise Transferred** |
|---|---|---|
| Dr. Bo Brahtz Christensen | Coastal and Estuarine Morphologist | TRM model review for Micro-scale modelling |
| Prof. Zheng Wang | River and Estuarine Morphologist | Data analysis technics for river bathymetry |
| Prof. Dano Roelvink | River and Coastal & Estuarine Morphological Modeler | Delft3DFM modelling for the meso-scale and macro-scale modelling |
| Mr. Henrik Rene Jensen | Storm Surge and Wave Specialist | Storm Surge and Wave Propagation modelling |
| Dr. Kim Wium Olesen | River Morphologist | Micro-scale Morphology modelling |
| Dr. Alessio Giardino | Climate Change Risk Assessment and Adaptation | Climate Scenarios |
| Dr. Bas van Maren | Fine sediment Modelling | Analysis the morphodynamic characteristics based on the previous study data for the south-west region |
| Dr. Ferdinand Diermanse | Statistical Analysis of Meteorological Data | Trend analysis for rainfall and temperature based on historical data |
| Mr. Reinier Schrijvershof | Morphodynamics Modelling Expert | Preliminary setup for 1D morphological model (Macro Model) |

The modelling work continues uninterrupted, with regular consultation over skype and emails, after the visiting experts return to their home offices, the modelling work. The following experts who did not visit the field during this quarter, were nevertheless able to interact effectively to perform their training function.

| | | |
|---|---|---|
| Dr.Soren Tjerry | Tidal River & Sediment Management Specialist | MIKE21C modelling technics for river bank erosion modelling (Meso-scale model) |
| Dr Irina Overemm | Macro-Scale Delta Morphologist | Preliminary setup for Hydrotrend Model (Macro-Basin Model) |
| Dr Jordan Adams | Post Doctoral Fellow | Technical support on Hydrotrend Model |

IWM has vast experience on water management modelling on coastal polder, cyclonic storm surge modelling. A program for on job training of BWDB engineer on polder water management, storm surge and salinity modelling will be developed in the next quarter. This training is planned to commence from November 2019.

## 9.1 Training Courses and Study Tours

No special Training Courses or Study Tours were arranged during the Second Quarter.
Selection of candidates from among BWDB professionals to follow Masters Programmes at IHE, Delft was carried out at the end of the quarter.

# 10. TRANSPARENCY AND ACCOUNTABILITY

## 10.1 Stakeholder 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 and accepted by the Client.

There were two Stakeholder Consultation Workshops; first to be held in Barisal on 30 March 2019, and the second to be held in Khulna. The second Workshop was eventually held on 27 April 2019. The Workshops were held under the patronage of the State Minister of Water Resource, the Secretary of the Ministry and other senior officials. There was a wide cross-section of participants from a range of stakeholder organisations with lively discussions and exchanges of views. Almost the entire proceedings, which were conducted in Bangla has been documented. The reports await translation into English pending submission officially to the Client and the World Bank.

A third workshop is scheduled to be held in Chittagong in the next quarter.

Photos from the Barisal Workshop

## Photos from the Khulna Workshop

# 11. CONCLUSION

This report describes the extent of work done in the Third Quarter of this project from 1 April to 30 June 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 technical reports published by the project.

Some difficulties have been experienced by the fact that the contract 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.

# APPENDIX A – LITERATURE REVIEW REPORT

# A TABLE OF CONTENTS OF THE LITERATURE REVIEW REPORT

Table of Contents for the Literature Review report are given below


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8.1 Introduction and Synopsis
8.2 List of Publications Reviewed
8.3 Summary of Selected Papers