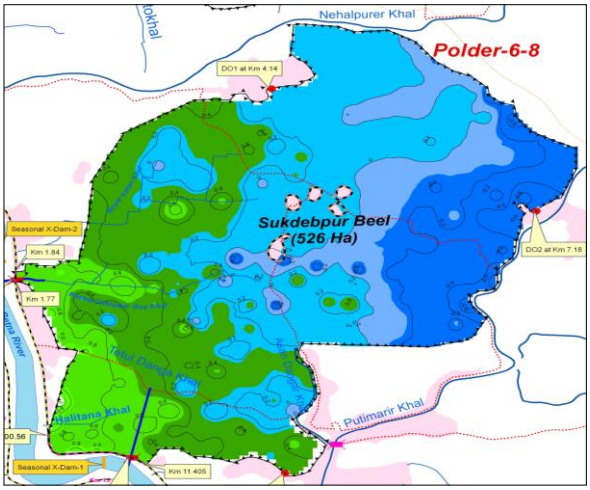
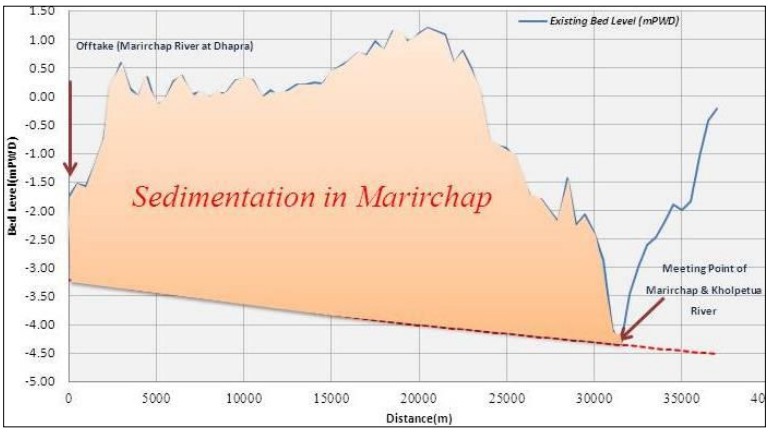
Government of the People's Republic of Bangladesh
Ministry of Water Resources

Bangladesh Water Development Board

Feasibility Study for Drainage Improvement of Polder 1, 2, 6-8 & 6-8 (Ext.) by Mathematical Modelling under the Satkhira District





FINAL REPORT

Main Report

March 2014

INSTITUTE OF WATER MODELLING

INSTITUTE OF WATER MODELLING

Government of the People's Republic of Bangladesh
Ministry of Water Resources

Bangladesh Water Development Board

Feasibility Study for Drainage Improvement of Polder 1, 2, 6-8 & 6-8 (Ext.) by Mathematical Modelling under the Satkhira District

FINAL REPORT

Main Report

March 2014

INSTITUTE OF WATER MODELLING

Institute of Water Modelling
House 496, Road 32
New DOHS, Mohakhali
Dhaka-1206, Bangladesh
Phone: 8824590, 8827902, 8822105
Fax : 8827901

Feasibility Study for Drainage Improvement of Polder 1, 2, 6-8 & 6-8 (Ext.) by Mathematical Modelling under the Satkhira District

Client: Bangladesh Water Development Board (BWDB)	**Client's contact:** Director Directorate of Planning -1 Bangladesh Water Development Board (BWDB) WAPDA Building, Motijheel C/A, Dhaka-1000.

Project Title	Feasibility Study for Drainage Improvement of Polder 1, 2, 6-8 & 6-8 (Ext.) by Mathematical Modelling under the Satkhira District	Project No. 51439

Division	Coast, Port & Estuary Management Division	Date	March 2014
Contributors	Md. Zahirul Haque Khan (ZHK) Md. Anwar Hossain Bhuiyan (AHB) Sheikh Nurul Ala (SNA) Mahendra Chandra Dey (MCD) Arjel Hossain Khan (ARK) Md. Shamsuddin (SMD) Mohammad Golam Rasul Nesar Uddin Mohammad Ziaur Rahman (ZIA) Md. Saiful Islam (MDS) Farhan Md. Zahir (FMZ) Md. Masum Billah (MML)	Passed for Submission: **Prof. Dr. M. Monowar Hossain** Executive Director	
Report Type	Final Report	Authors	Checked by
		ZIA SNA MCD SMD Md. Golam Rasul Nesar Uddin	ZHK
Key Words	Drainage Congestion, Drainage Modelling, Flood Control, Monitoring, Mathematical Modelling, Hydrodynamic, Morphology, Cross-section, Siltation, Erosion , Dredging, Topography ,Tidal Basin, Tidal Prism, Tidal River Management (TRM), EIA, SIA, Multi-criteria Analysis, Economic Analysis, Focus Group Discussion	Classification ☐ Open ☐ Internal √ Restricted within the parties concerned ☐ Confidential	

TABLE OF CONTENTS

List of Tables

List of Figures

List of Photographs

ACRONYMS AND ABBREVIATIONS

ADB:	Asian Development Bank
BCR:	Benefit Cost Ratio
Beel:	A natural depression, the bottom of which remains wet throughout the year
BWDB:	Bangladesh Water Development Board
CEP:	Coastal Embankment Project
DAE:	Department of Agricultural Extension
DGPS:	Differential Global Positioning System
DOE:	Department of Environment
DOF:	Department of Fisheries
DOL:	Department of Livestock
D/S :	Down stream
DHI:	Danish Hydraulic Institute (now DHI Water & Environment)
EIA:	Environmental Impact Assessment
EIRR:	Economic Internal Rate of Return
ENPV:	Economic Net Present Value
FAP:	Flood Action Plan
FD:	Forest Department
GoB:	Government of Bangladesh
GPS:	Global Positioning System
HD:	Hydrodynamic
HYMOS:	information system for water resources management
HYV:	High Yield Variety
IEC:	Important Environment Component
IRR:	Internal rate of Return
IWM:	Institute of Water Modelling (erstwhile SWMC)
LGI:	Local Government Institution
MCA:	Multi-criteria Analysis
MIKE 11:	River System Modelling Software Developed by DHI
MIKEF:	Flexible Mesh
mPWD:	Meter Public Works Datum
NAM:	Rainfall-Runoff Model
NPV:	Net Present Value
NWMP:	National Water Management Plan
O&M:	Operation and Maintenance
PPCCTF:	Project Proposal Format Bangladesh Climate Change Trust Fund
R.L:	Reduced Level
SIA:	Social Impact Assessment
SoB:	Survey of Bangladesh
SWMC:	Surface Water Modelling Centre (now renamed as IWM)
TB:	Tidal Basin
TBM:	Temporary Bench Mark
ToR:	Terms of Reference
TS:	Total Station
TP:	Tidal Prism
TRM:	Tidal River Management
TS:	Total Station
U/S:	Upstream
WMA:	Water Management Group

EXECUTIVE SUMMARY

E.1. Introduction

The study area is located in Kalaroa, Satkhira Sadar, Debhata, Assasuni and Tala Upazilas under the administrative jurisdiction of Satkhira district. It has been experiencing severe water-logging problem over the years because of high rate of siltation in the peripheral rivers and internal drainage khals. It severely affects the normal social and economic activities of the people of the project area. The drainage system of the project area is comprised of Ichamoti, Marirchap, Betna, Parulia Sapmara, Kholpetua and Kobadak Rivers and Satkhira Khal along with a vast network of internal drainage khals. At present the Marirchap River, Betna River and Parulia Sapmara Khal have lost their conveyance capacity significantly due to river bed siltation. As a result agricultural production mainly Boro cultivation has been significantly reduced and livelihood opportunities have also been deteriorated.

Institute of Water Modelling was entrusted to conduct the study titled "Feasibility Study for Drainage Improvement of Polder 1, 2, 6-8 & 6-8 (Ext.) by Mathematical Modelling under the Satkhira District." by Bangladesh Water Development Board (BWDB) through a formal contract agreement signed on 18th April 2012. The main objective of the study is to develop comprehensive water management plan for polder 1, 2, 6-8 and 6-8 (Ext.) and management of sediment for the restoration of Ichamoti, Marirchap, Betna and Kobadak Rivers and adjacent drainage khals through structural and non-structural interventions. The location of the study area is shown in the **Figure E1**.

E.2. Options for Sediment and Drainage Management

Considering the acute problems of sedimentation of rivers, removal of drainage congestion and reduction of flood risk, 2 (two) options have been devised in consultation with the local stakeholders elites and officials of Bangladesh Water Development Board. These options have been investigated integrating all the suggested measures applying hydraulic modelling technique. The major interventions for solution of drainage congestions are i) dredging/re-excavation of the Betna River, Marrichap River, Parulia-Sapmara Khal and Satkhira Khal, ii) excavation of all internal drainage khals, iii) construction of five new regulators, iv) replacement of Bhatshala 4-vent sluice by a Bridge across Parulia Sapmara Khal, v) remodelling of the 4-vent sluice at Shalkhali into a Bridge across Parulia-Sapmara Khal, vi) resectioning of embankment at different location of Polder-1, Polder-2, Polder-3, Polder-4 and Polder-6-8, vii) slope/river bank protective work at different location in Polder-2 and viii) sediment management by allowing natural tidal movement into embanked low-lying beels (TRM basins). The interventions of the proposed options are presented in the following **Table E1**.

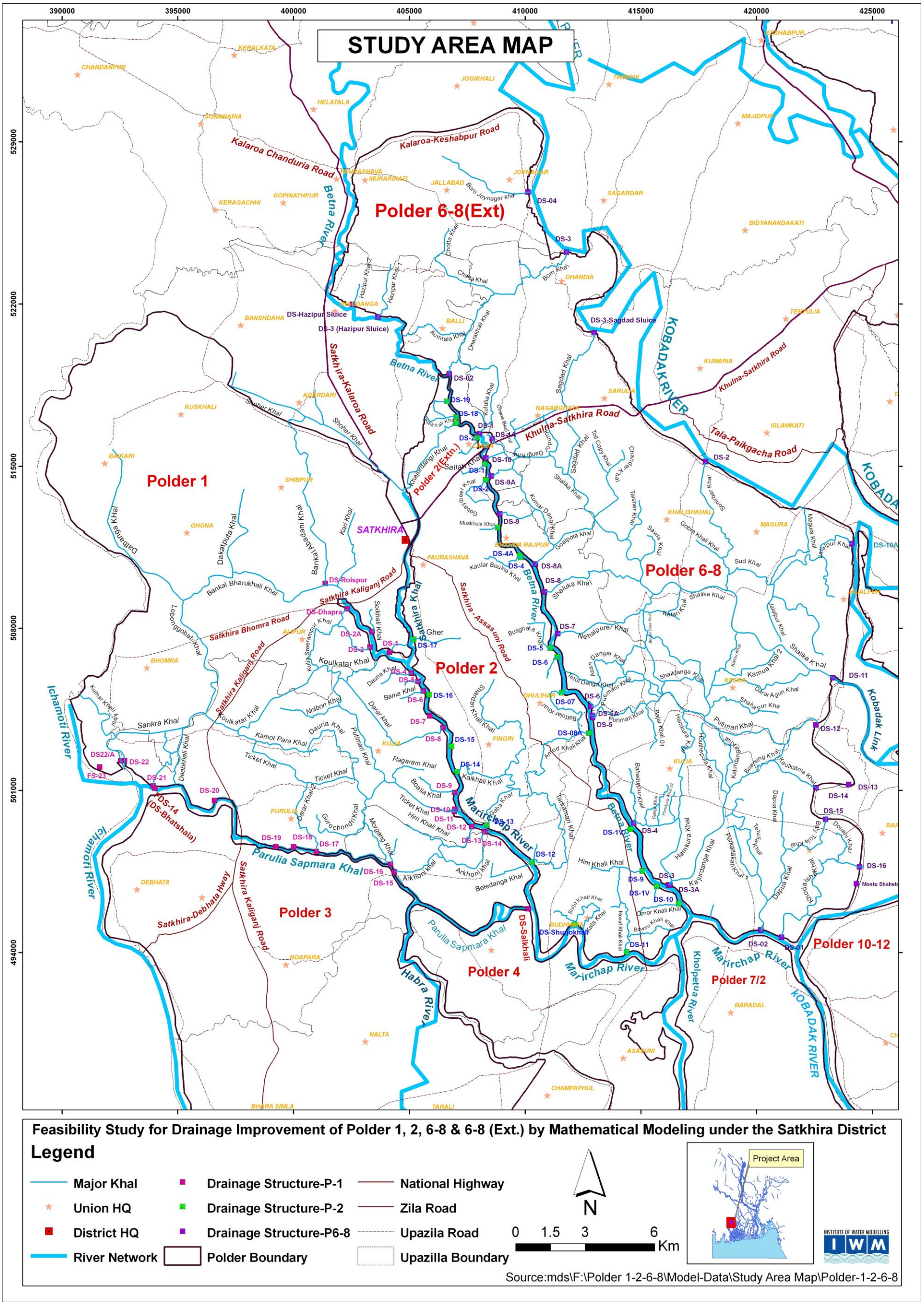


Figure E1: Map Showing the Study Area

Table E1: Drainage Improvement Options

SI	Proposed Interventions	Option-1	Option-2
A	***Dredging/Excavation of Rivers & Khals***		
A-1	Manual/Mechanical Excavation of Marirchap River (Km 0.00 to Km 37.00)	√	√
A-2	Dredging/Excavation of Betna River (Km 0.00 to Km 44.00)	√	√
A-3	Excavation of Parulia-Sapmara River (Km 0.00 to Km 23.50)	√	√
A-4	Excavation of Satkhira Khal (Km 0.00 to Km 8.00)	√	√
A-5	Excavation of Major and Minor Internal Khals (Length-357.00 km)	√	√
B	***Sequential operation of TRM at the proposed Tidal Basin for sediment management***		
Phase	1) TRM in Sukdebpur Beel (Betna Basin) +Ticket Beel (Marirchap Basin)	√	√
	2)TRM in Matiadanga Beel (Betna Basin)+ Jealmari Beel (Marirchap Basin)	√	√
	3)TRM in Sreeramkathi Beel (Betna Basin/Marirchap Basin) + Bugmara Beel (Marirchap Basin)	√	√
	4)TRM in Hazikhali- Amudkhali Beel (Betna Basin)+Gobindapur Beel (Marirchap Basin)	√	√
	5)TRM in Aumtoli Beel (Betna Basin)+Chapra Beel (Betna Basin)+Dorgahpur Beel (Marirchap Basin)	√	√
C	***Infrastructure***		
C-1	Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal	√	√
C-2	Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) in Polder-2 across Chumrikhali Khal	√	√
C-3	Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal	√	√
C-4	Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)	√	√
C-5	Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal	√	√
C-6	Repairing of existing structures(20 Nos)	√	√
C-7	Replacement of Bhatshala 4-vent sluice by a Bridge across Parulia-Sapmara khal	x	√
C-8	Remodeling of Shalkhali 4-vent sluice by a Bridge across Parulia-Sapmara khal	x	√
D	***Resectioning of Embankment at different location (41.50 km) in Polder-2, (44.42 km) in Polder-6-8, (21.00 km) in Polder 1, (14.00 km) in Polder 3 & (6.00 km) in Polder 4.***		
D-1	Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)	√	√
D-2	Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)	√	√
D-3	Resectioning of Embankment along the both banks of Paruluia Sapmara Khals from 28.00-49.00 (21.00 km) in Polder 1,from 23.00-37.00 (14.00 km) in Polder 3 & from 64.00-70.00 (6.00 km) in Polder 4	√	√
E	***Slope/River Bank Protective Work at different location (1.7 km) in Polder-2***		
E-1	Slope/River Bank Protective work along the Right banks of Betna River from 18.200 to 18.780; 19.753 to 20.193; 23.050 to 23.350;24.00 to 24.30 & 26.100 to 26.180 (1.70 km)	√	√

E.3. Effectiveness of Options

The effectiveness of the potential options has been assessed based on drainage improvement compared to present condition, backfilling rate in the dredged channel and usefulness of TRM and operations of regulators. Increase of conveyance capacity of the rivers/khals through dredging/excavation decreases the water level significantly in the rivers/khals compared to the present condition which reduces the existing drainage congestions. Total twenty (20) numbers water control structures have been proposed for repairing to provide full -functioning of existing structures and smooth drainage of the polders area. In order to operate TRM for sediment management and preventing re-siltation in the dredged channels 11 nos of potential beels have been identified. The effectiveness of these beels as TRM basin has been investigated using mathematical model.

Improvement of drainage condition in the proposed Option-1 and Option-2 are significant, compared to present drainage condition under average flood event. Flood free, F0 and F1 land become about 93 % in the Option-2 compared to 39% in the present condition in the polder 1. Similar results is also seen in the Option-1 but percentage of Flood free, F0 and F1 land is 89%. .

Both the Option-1 and Option-2 show considerable improvement of drainage condition of the study area under extreme flood event. The flood free, F0 and F1 land become about 89% in the polder-2 in comparison of 42% in the existing condition. The detail of drainage improvement is given in the main report.

The study results show decrease of about 0.75m water level for Ticket Khal in Polder-1 which is connected to the Marirchap River under the final option **(Option-2)** compared to the present condition. Water level decrease about 1.0 m for Himkhali khal in Polder-2 which is connected to the Betna River under the same option.

Tidal Basin for Sediment Management Utilizing Available Beels

Restoration of Betna River, Marrichap River and Parulia Sapmara Khal by dredging/excavation would not sustain since re-siltation rate is very high (almost 60-80%) during dry season without TRM. Virtually there is no upstream dry season flow to flush the huge incoming sediment into the rivers during high tide. Sediment management through TRM by allowing natural tidal movement in an embanked low-lying area is a proven and tested method for sediment management. Model result shows that these beels can generate tidal prism in the range of 6.20 to 14.00 Million-m3 individually, which is higher compared to the required tidal prism for maintaining the design/proper drainage capacity of the river. For the Marrichap River basin it is seen that Jealmari Beel, Ticket Beel, Gobindapur Beel, Bugmara Beel and Dorgahpur Beel are also effective as tidal basins for Tidal River Management (TRM).

It has been found that TRM can be successfully operated continuously in these two river basins using the selected beels for about 40 years for sediment and drainage management. Before implementation of TRM, location of link canal of TRM basin and cross-dam in the river needs to be finalized after detailed field investigation and in consultation with the local stakeholders. The operation combination and duration of operation of TRM basin are shown in **Table E2**.

Table E2: The sequence of potential TRM basins for Tidal River Management

Sequence of Operation	Beels	Area (ha)	Operation Period				
			2014-2021	2022-2029	2030-2037	2038-2045	2046-2053
Phase-1	Sukdebpur (Betna Basin) + Ticket (Marirchap Basin)	1071					
Phase-2	Matiadanga (Betna Basin) +Jealmari (Marirchap Basin)	1236					
Phase-3	Sreeram kathi (Betna/Marirchap Basin) + Bugmara (Marirchap Basin)	1164					
Phase-4	Hazikhali-Amudkhali (Betna Basin) +Gobindapur (Marirchap Basin)	955					
Phase-5	Aumtoli (Betna Basin) +Dorgahpur (Marirchap Basin)+Chapra (Betna Basin)	1309					

E.4. Environmental and Social Impact Assessments

Environmental assessment focussed on environmental baseline survey, screening, scoping, field investigation, selection of Important Environmental Components, impact assessment, impact evaluation and development of environmental management plan. The SIA study explored all the possible impacts of a proposed project and suggests mitigation measures and required actions before implementation of the project. The potential benefits of the project to agriculture, and property of people, infrastructure of the area are numerous and would positively impact on a very large number of beneficiaries in terms of reduced water logging, income generation, increased employment opportunities, health, sanitation and education facilities.

The EIA and SIA study show that the project is environment friendly and socially acceptable as long as all proposed mitigation, monitoring, management and enhancement programmes are in place as integral constituents of the project, with ensured people's participation in all stages of the project.

E.5. Project Cost and Economic Viability

Economic and financial analysis as have been carried out to assess the economic viability of potential options. The project impacts on economic welfare of the project stakeholders and on the economy as a whole were assessed by project evaluation along with all possible different alternatives.

All costs are presented in terms of present worth at year (zero) 0 of project life. It is assumed, for analytical purpose, that all project costs are to be incurred at the start of the year and all benefits to be accrued at the end of each year. The corresponding economic prices were worked out following

FAP Guidelines for Project Assessment.On the basis of above assumptions and procedures economic and financial analysis were computed and the results are summarized below:

Table E3: Analytical Results for All Options

Viability Indicator	**Option-1**		**Option-2**	
	Fin	**Eco**	**Fin**	**Eco**
Capital cost(Lakh Taka)	44435.75	31447.34	45317.95	32192.57
Annual O&M cost (Lakh Taka)	1633.48	1425.29	1657.78	1447.20
BCR @ 12%	1.90	2.61	1.98	2.74
NPV (Lakh Taka) @ 12%	(+) 38711.56	(+) 48409.51	(+) 42821.45	(+) 53477.57
IRR (%)	19.42	21.72	19.78	21.96

E.6. Recommendations

i. The study results show that the Option-2 is technically feasible, economically viable and socially acceptable solution. Thus this option is recommended for implementation as a log-term solution for drainage and sediment management in the project area. The recommended measures for restoration of drainage systems are as follows:

SI	**Proposed Interventions /Components**
1	Manual/Mechanical excavation (Km 0.00 to Km 37.00) of Marirchap River
2	Manual/Mechanical excavation (Km 0.00 to Km 23.50) and Mechanical Dredging (by dredger) (Km 23.50 to Km 44.00) of Betna River
3	Manual/Mechanical excavation of Parulia-Sapmara River (Km 0.00 to Km 23.50)
4	Manual excavation of Satkhira Khal (Km 0.00 to Km 8.00)
5	Manual excavation of Major and Minor Internal Khals (Approx. length-357.00 km)
6	Tidal River Management (TRM) utilizing beels (11 Nos)
7	Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal
8	Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) in Polder-2 across Chumrikhali Khal
9	Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal
10	Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)
11	Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal
12	Repairing of existing structures(20 Nos)
13	Replacement of Bhatshala 4-vent sluice by a Bridge across Parulia-Sapmara khal
14	Remodeling of Shalkhali 4-vent sluice by a Bridge across Parulia-Sapmara khal
15	Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)
16	Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)
17	Resectioning of Embankment along the both banks of Paruluia Sapmara Khals from 28.00-49.00 (21.00 km) in Polder 1, from 23.00-37.00 (14.00 km) in Polder 3 & from 64.00-70.00 (6.00 km) in Polder 4
18	Slope/River Bank Protective work along the Right banks of Betna River from 18.200 to 18.780; 19.753 to 20.193; 23.050 to 23.350;24.00 to 24.30 & 26.100 to 26.180 (1.70 km)

ii. It is suggested to develop Sukdebpur Beel for Betna River and Ticket Beel for Marirchap River as a first beel for tidal river management. Dredging of river would not be sustainable unless TRM operation is implemented along with the dredging activities. TRM needs to be operated at least 8 years or more in one beel depending on monitoring results;

iii. Remove all the illegal infrastructures and encroachment over the rivers/khals;

iv. Implementation of TRM should not be delayed. Delay in implementation of TRM will lead severe sedimentation at the downstream of the river, as a result prolong drainage congestion will prevail in the Sathkhira districts including study area;

v. Crop compensation to the land owners of the beels for TRM operation should be given for the whole period of operation;

vi. Monitoring of sedimentation, erosion, tide, drainage condition in the beel, khal and river is required to assess the effectiveness of implementation plan comparing it with the targets and identifying shortfalls;

vii. Involvement of local stakeholders and water management organizations working in the area is essential and useful during implementation of the recommended measures and operation & maintenance;

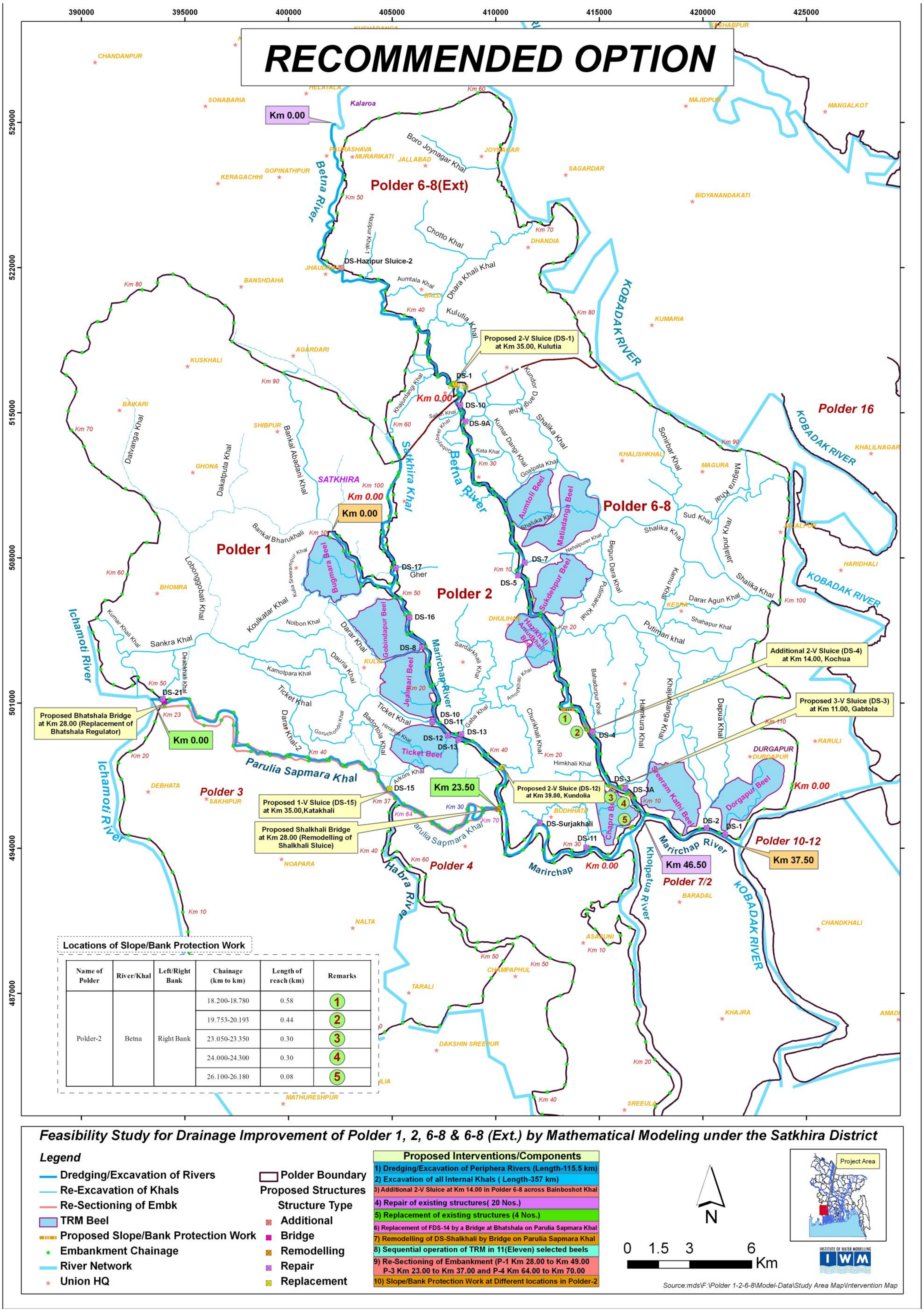


Figure E2: Proposed Interventions of the Recommended Option

CHAPTER ONE: INTRODUCTION

1.1 General

This Final Report (FR) has been prepared for the "Feasibility Study for Drainage Improvement of Polders 1, 2, 6 & 8(Ext.) under Satkhira Districts" in accordance with the Terms of Reference (ToR) and the Contract Agreement between BWDB and IWM on 18th April 2012. The Final Report contains the description of prevailing problems, best suited drainage improvement and sediment management plan, design of the drainage infrastructure, cost estimate and implementation schedule. The study has been carried out involving meaningful participation of local people and the stakeholders in identifying existing drainage problems and devising potential drainage improvement plan.

1.2 Background

The study area is located in the Southwest Coastal Part of Bangladesh. The entire southwest coastal part of Bangladesh has been experiencing river sedimentation and drainage congestions over the last few decades. This region is characterized by a vast network of morphologically active tidal creeks, which are the main drainage route for coastal polders and low lying beels. Thus, the natural drainage patterns of the area is predominantly characterised by the influence of the incoming tide from the sea. Tidal flow brings huge quantity of silt from the sea into the river systems of the coastal area. Before polderisation in early sixties and seventies, major parts of this incoming silt deposited naturally on the low-lying land (beels). On the other hand, there was significant amount of fresh water flow from the Ganges which helped to maintain a perennial tidal river in this part of Bangladesh. The continued fresh water flow from the Ganges helped to flush the incoming sediment with high tide from the sea and thus, the proper drainage capacity of these tidal creeks was maintained naturally. After polderisation and significant reduction of fresh water flow from the Ganges, this natural process seems to be hampered significantly. The presence of coastal polders prevents the spreading of the natural tidal flows and restricts sedimentation on the low lying lands. This leads to large scale river bed sedimentation in the peripheral rivers of polders and reduced the drainage capacity. Consequently polder areas were suffering from water logging and drainage congestion.

The study area (Polder 1, 2, 6-8) is drained towards the peripheral rivers the Ichamoti, Marirchap, Betna, Parulia-Sapmara, Kholpetua and Kobadak Rivers. There are many beels and low-lying area in the study area. The Roichpur beel situated in Satkhira Sadar, and beels and low lying area of Kulia, Bhomra Agardari, Shibpur, Baikari and Gona drain to the Ichamoti River. A large area of the Satkhira Sadar and Kulia Union used to drain through Balitha sluice to Marirchap River. The low lying areas of polder 2 and polder 6-8 and 6-8(Ext.) used to drain to Betna and Kobadak Rivers. These entire rivers have been severely silted up by the incoming silt from the sea with high tide and lost their drainage capacity severely which led to no or little drainage through the existing structures of the polders.As a result, the area has been suffering from acute drainage congestion for the last few years. In order to improve the prevailing drainage problem of the area there is a strong demand from the local stakeholders for dredging/excavation of the silted up rivers & khals.

In view of the above situation, BWDB undertooke this Feasibility Study program and engaged IWM to carry out the study for assessing the present problems and devising effective drainage improvement plan for removing the drainage congestions and sustainable water and sediment management in the study area.

1.3 Study Methodology

In order to identify prevailing problems and to devise potential solutions a comprehensive field survey, interaction meetings with local stakeholders at different locations in the study area, mathematical modelling and design of potential drainage improvement measures including EIA and economic analysis have been carried out. Focus Group Discussion involving the participation of local people, LGIs was conducted to identify the existing drainage problems and their potential solutions. Drainage model has been developed to investigate the adequacy and performance of the existing drainage structures and drainage systems and to select the best suited drainage improvement options for removal of drainage congestions in the study areas. The existing calibrated and validated Southwest Regional Model available at IWM has been used as the basis of drainage model for this study.

TRM Model has also been developed to assess the effectiveness of the selected beels for sustaining the drainage condition of the Betna and Marirchap Rivers by increasing the tidal prism and sedimentation inside the selected beels. Design and costing of drainage plans has been made to find the total project cost and economic analysis. Morphological model has been carried out to investigate the siltation patterns in the proposed tidal basins and also to quantify the re-siltation rate on the proposed dredged sections of the Betna and Marirchap, the main drainage route of the study area.

1.4 Objectives

The main objective of the study is to develop comprehensive water management plan for polder 1, 2, 6-8 and 6-8 (Ext.) and management of sediment for the restoration of Ichamoti, Marirchap, Betna and Kobadak Rivers and adjacent drainage khals through structural and non-structural options.

The specific objectives of the study

i. Preparation of comprehensive water management plan for polder 1, 2 6-8 and 6-8 (Ext.);

ii. Review of the existing drainage system and prepare improved plan of the drainage system;

iii. Assess the effectiveness of the dredging / excavation of rivers and khals;

iv. Study of long term sustainability of the sediment management of tidal rivers and khals;

v. Determine the size, location and number of drainage structures required;

1.5 Outputs and Scope of Works

The expected outputs of the study are as follows:

- Base line information of the existing project infrastructure like embankments, structures, river network, Benchmarks etc;
- Base line hydraulic and morphological condition in the perspective of drainage conditions;
- Preliminary alignment of the proposed embankment along the selected khals and location of the proposed drainage-structures;

- Design parameters for drainage structures including proposed embankments;
- Dredging location in the khals and rivers and required amount of dredging;
- Backfilling rate in the dredged channel of the river Betna and Marirchap rivers;
- Long-term plan and design of potential tidal basins and size of tidal basin for TRM along with technical specifications;
- Flood maps / inundation maps showing the area of different classes of land (F0, F1, F2 & F3) under the existing situation and proposed development option to indicate the extent or benefit and impact on surrounding area in respect of inundation pattern due to the implementation of the project and
- Design of regulators and embankment
- Spoil earth management plan
- Detailed component wise investment cost as per DPP requirement with year wise break-up;
- Economic and financial analysis;
- Workshop
- Reports.

Scope of works

The following activities has been carried out for fulfilling the objective of study:

- Collection and review of existing data, maps , information and past studies from secondary sources;
- Field visit, reconnaissance survey and consultation with local stakeholders;
- Field survey and data collection campaign to gather sufficient information on water level, discharge, river cross-sections, sediment concentration, river-bed sample and drainage regulation (structure operation);
- Establishment of baseline hydraulic and morphological characteristics based on model result and available data;
- Analysis of existing drainage condition of the study area based on primary and secondary data and in consultation with local stakeholders;
- Development of inundation maps using drainage model results and land level data from the updated Digital Elevation Model (DEM);
- Devising drainage improvement plans and assessment of their effectiveness
- Drainage modeling to determine the location, number and dimensions of drainage structures required for the improvement of the drainage system;
- Assessment of the dredging needs in the khals and peripheral rivers;
- Identification of dredging locations in the khals and rivers and determination of required dredging volume;
- Determination of the effectiveness of the proposed excavation of khals and rivers to remove the drainage congestion using drainage model and surveyed data;
- Assessing the effectiveness of proposed improvement plan;
- Preparation of dredging spoil removal plan;
- Sediment transport modelling to assess the backfilling rate at the dredged channel in the rivers;
- Optimization of design parameters of the proposed drainage structures;
- Sub-Soil Investigation of the proposed structures;
- Prepare detailed design of remodeled/proposed structures;
- Preparation of cost estimate of project works as per DPP format on the basis of recent actual schedule of rates, including annual expenditure schedules;

- Estimation of benefits: the benefits will include profits from extra agriculture production as a result from reduced flood damage and drainage congestion, higher cropping intensities and use of high yielding varieties based on the post project cropping patterns suggested by agronomist;
- Estimation for BCR, EIRR, NPV benefits and costs of improvement plan will be estimated based on the with and without project situation~
- Comprehensive studies to assess the benefits of the project including those accumulating to agriculture, navigation, fisheries and improvements to communities and human settlements
- Conducting EIA and SIA
- Dissemination of study results to all stakeholders by arranging workshop
- Reporting

1.6 Structure of the Report

This report describes Drainage Improvement plan of Polder 1, 2, 6-8 and 6-8 (Extn). The report contains twelve chapters and seven appendices. The contents of the chapters are as follows:

Chapter 1: It describes the background, the objectives of the study, brief study methodology and the output and scope of works;

Chapter 2: It describes the physical and social condition of the study area especially the location, river system & prevailing problems,tidal characteristics, climate, topography, agriculture and fisheries resources etc;

Chapter 3: This chapter presents the primary and secondary data collection and analysis;

Chapter 4: It deals with the identification of the existing problems of the study area;

Chapter 5: It describes the hydrological analysis and mathematical modelling of the study;

Chapter 6: It describes the drainage improvement options and their effectiveness;

Chapter 7: It presents the planning and design of the proposed drainage improvement structures;

Chapter 8: It describes the Agriculture and Fisheries at present & Future

Chapter 9: It describes Environmental Impact Assessment and Social Impact Assessment for the proposed interventions;

Chapter 10: It presents the cost estimate and implementation schedule for the proposed interventions;

Chapter 11: It describes the comparative analysis of suggested options both economically and financially;

Chapter 12: It describes conclusions and recommendations;

CHAPTER TWO: PHYSICAL AND SOCIO-ECONOMIC SETTING OF THE STUDY AREA

2.1 Location

The study area is located in Kalaroa, Satkhira Sadar, Debhata, Assasuni and Tala upazila under the administrative jurisdiction of Satkhira district in the Southwest Coastal Region of Bangladesh. The total study area is 75,790 ha of Polder No.1, Polder No.2 and Polder No.6-8 and 6-8 (Extension). The drainage system of the project area is composed of the rivers Betna, Marirchap, Parulia-Sapmara, Ichamoti, Kholpetua and Kobadak along with internal drainage khals. The study area is shown in **Figure 2.1.**

2.2 River System and Prevailing Problems

The project area is characterized by numerous morphologically active tidal rivers and creeks, which provide drainage network for a system of embanked hydrological units. The river systems in the study area are comprised of three distinct drainage systems:

- The Kobadak-Arpangasia river system
- The Betna-Marirchap-Kholpetua-Arpangasia river system
- The Ichamoti-Parulia Sapmara-Marirchap river system

The Kobadak River flows on the eastern side of the study area through Jessore, Satkhira and Khulna districts and the total length of this river is about 240 km (upper and lower) from Taherpur (at Chaugacha upazila in Jessore district) to Niamotkati (at Syamnagar upazila in Satkhira district). It is originated from Mathabhanga River (Adam Williams, 1919). Once upon a time it used to get upland fresh water discharge from the Ganges and flowed down to the Sundarban maintaining a perennial tidal river. More than hundred years ago, Kobadak lost its fresh water connection from river Mathabhanga (north of Taherpur) and became a simple seasonal river at north and a tidal river at the south. Consequently the flushing flow from upstream was reduced which enhanced the siltation process. As a result, many rivers/channels/khals in the area lost conveyance capacity significantly causing severe drainage congestion. The peripheral river of the study area Kobadak is one of the main sufferers of this process of siltation. One of the main drainage route, the Betna River flows through Jhenaidah and Jessore and Jessore and Shatkhira Districts in the south. Finally it meets the Marirchap River and Kholpetua River at Assasuni upazila. The lower part of the river is known as Kholpetua which meets the Kobadak River at west of Khulna which falls in to the Arpangasia River in downstream. The low lying area of polder 2 and polder 6-8 and 6-8(Ext.) drains to Betna and Kobadak Rivers. All these rivers have been silted up significantly and have lost their drainage capacity resulting no or little drainage through the existing sluices of these polders. Thus there is a crying need of dredging/excavation of the silted up riches of the rivers & Linkage khals and improvement of the whole drainage system. The Ichamoti River is a trans-boundary river which flows through India and Bangladesh and also forms the boundary between the two countries. Roichpur beel (situated in the Satkhira Sadar) and other beels and low lying areas of Kulia, Bhomra Agardari, Shibpur, Baikari and Gona drain to the Ichamoti River which have very negligible siltation meaning that hydrodynamic characteristics of the Ichamoti river governs the drainage of these areas. Due to the continuing process of sedimentation on the river bed, most of the other rivers/Channels/Khals in these areas have lost their conveyance capacity significantly. Thus drainage congestion in the project area for the last few years becomes the major natural hazards and threats.

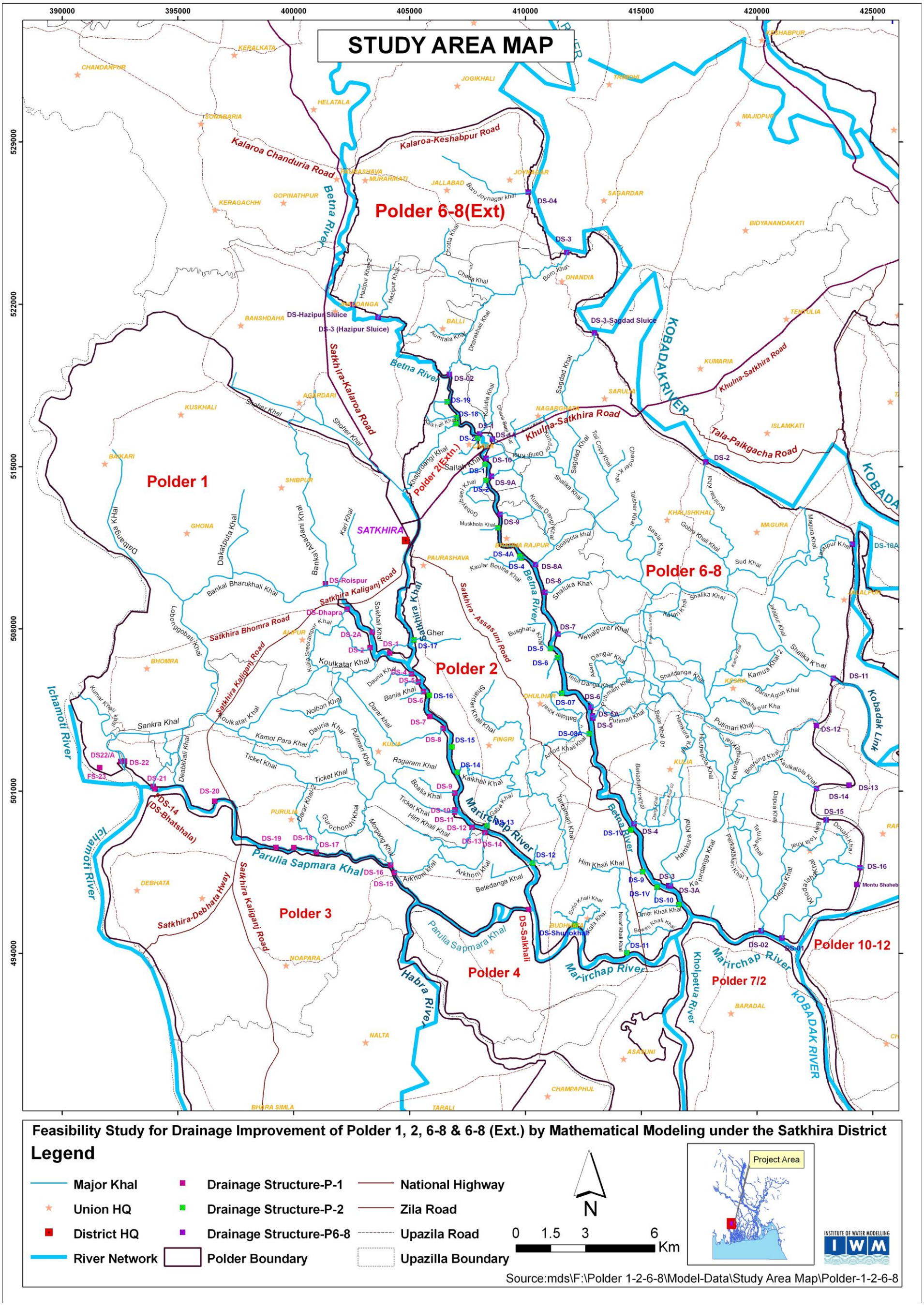


Figure 2.1: Map Showing the Study Area

2.3 Tidal Characteristics

Like most part of the coastal area in Bangladesh the study area is governed by the semidiurnal tide. Tide generated from the Bay of Bengal and propagates landward through the Malancha-Arpangasia River system. Tidal influence is the predominant factor of river sustainability of the study area due to absence of fresh water flow during the dry season. The usual range of fluctuation of water level is 0.7 m during neap tide and 3.0 m in spring tide at the downstream of the Malancha River.

Moving average of half hourly water level data is prepared to examine the seasonal variation of water level of Kobadak River, Betna River & Marirchap River. **Figure 2.2** shows the seasonal variation of Betna River (near Assasuni) and **Figure 2.3** shows the seasonal variation of the water level at the downstream reach of the Kobadak River (near Paikgacha). **Figure 2.4** shows the seasonal variation of the water level at the downstream reach of the Marirchap River (near Chapra). It is seen that seasonal variation is about 0.78 m for Kobadak River, 0.75 m for Betna River and 0.66 m for Marirchap River. **Table 2.1** shows the tidal characteristics of the study area.

Table 2.1: Tidal Characteristic of the Study Area

River Name	Seasonal Variation	Location	Tidal Range (Monsoon)	
			Spring Tide	Neap Tide
Kobadak River	0.78	Paikgacha Upazilla	4.40	1.50
Betna River	0.75	Assasuni Upazilla	4.50	1.55
Marirchap River	0.66	Near Chapra	3.1	1.10

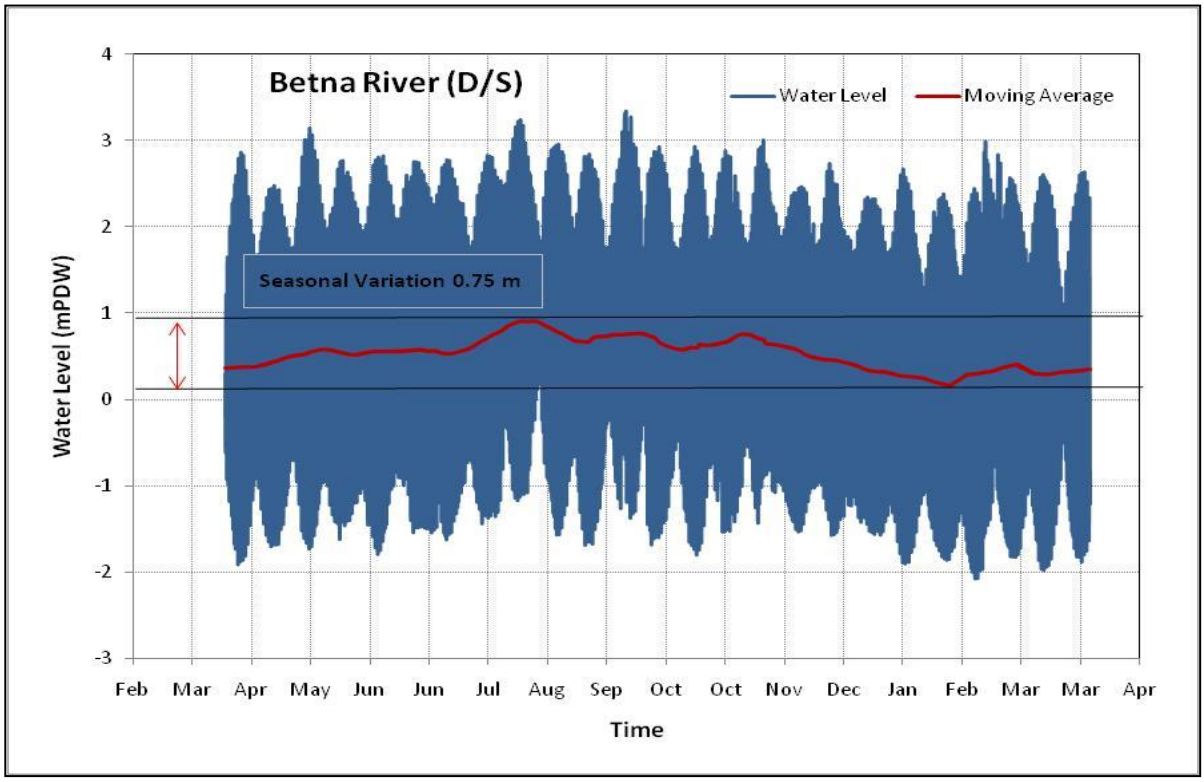


Figure 2.2: Typical Tidal Fluctuation and Seasonal Variation of Betna River

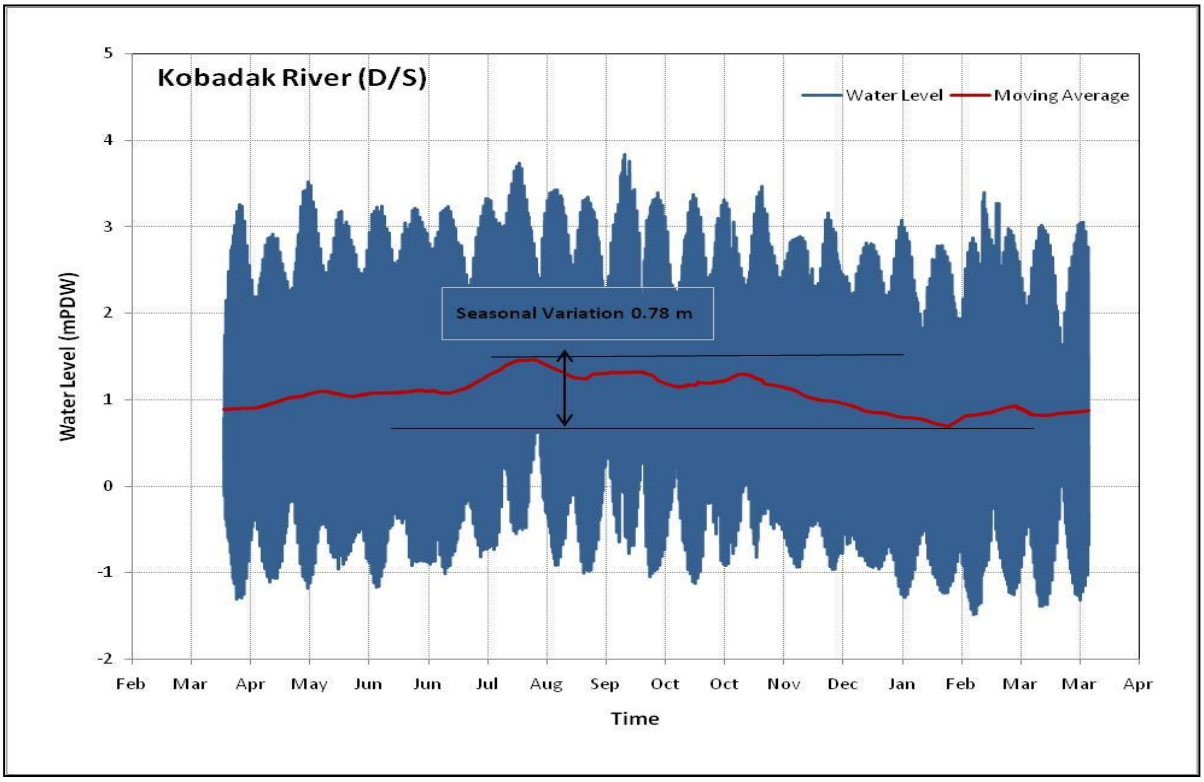


Figure 2.3: Typical Tidal Fluctuation and Seasonal Variation of Kobadak River

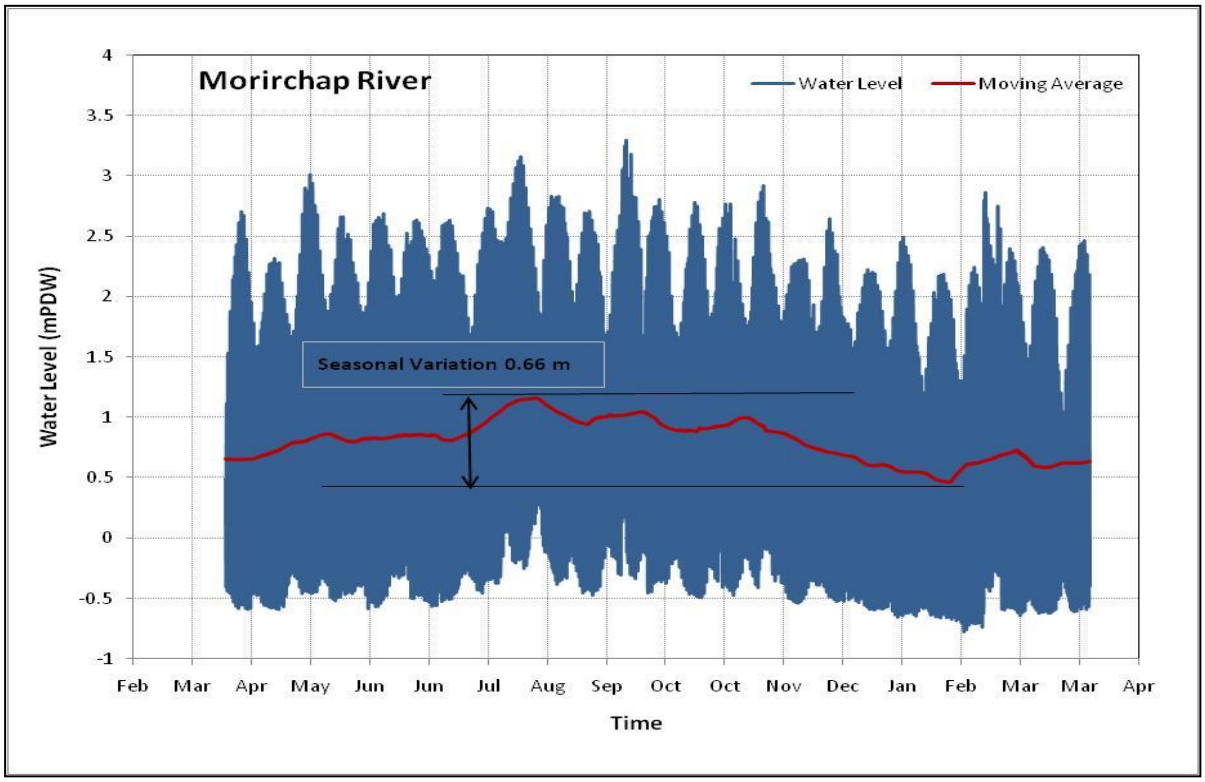


Figure 2.4: Typical Tidal Fluctuation and Seasonal Variation of Marirchap River

2.4 Climate

The study area has a typical monsoon climate with a hot and dry season from March to May followed by a rainy season from June to October and a cool period from November to February. Mean annual rainfall in the area is about 2,000 mm of which approximately 70% occurs during the monsoon season. Relative humidity of the area varies from about 70% in March to 90% in July. Mean annual temperature is 26°C with peaks of over 30°C in May. Temperature in winter may fall to 8°C in January.

2.5 Topography

The study consists of flat terrain and low-lying depressed areas (beels) and numerous tidal channels and creeks criss-crossing the area. The soils are mostly clayey and saline. The land elevations of the study area vary from 0.00 m PWD to 5.00 m PWD. The land level of Polder 1 varies from 0.00 m, PWD to 5.00 m, PWD. More than 50% area lies within the land level of 0.75 to 1.75 m, PWD. The land level of polder 2 varies from 0.00 m, PWD to 4.75 m, PWD of which more than 53% area of this polder is within land level of 0.75 m, PWD to 1.75 m, PWD. On the other hand, the minimum and maximum land level of Polder 6-8 is 0.25 m, PWD and 5.75 m, PWD respectively. More than 59% area of this polder is within the land elevation of 0.75 to 1.75 m, PWD. Elevation-wise distribution of area in different polders in the study area is given in **Table 2.2, 2.3 and 2.4**. The Area-Elevation Curves of these polders are given in **Figure 2.5, 2.6 and 2.7.**

Table 2.2: Area-Elevation Data of Polder 1

Elevation Range (m.PWD)	Area (sq km)	Cumulative Area (sq km)	% of Total Area
0.00-0.25	0.18	0.18	0.06
0.25-0.50	3.24	3.42	1.09
0.50-0.75	10.8	14.22	3.65
0.75-1.00	32.85	47.07	11.10
1.00-1.25	43.92	90.99	14.84
1.25-1.50	41.04	132.03	13.86
1.50-1.75	31.59	163.62	10.67
1.75-2.00	21.42	185.04	7.24
2.00-2.25	18.09	203.13	6.11
2.25-2.50	13.86	216.99	4.68
2.5-2.75	13.68	230.67	4.62
2.75-3.00	15.57	246.24	5.26
3.00-3.25	17.1	263.34	5.78
3.25-3.50	8.73	272.07	2.95
3.5-3.75	9.72	281.79	3.28
3.75-4.00	6.75	288.54	2.28
4.00-4.25	4.05	292.59	1.37
4.25-4.50	2.52	295.11	0.85
4.50-4.75	0.45	295.56	0.15
4.75-5.00	0.45	296.01	0.15

Table 2.3: Area-Elevation Data of Polder 2

Elevation Range (m_PWD)	Area (sq km)	Cumulative Area (sq km)	% of Total Area
0.25-0.50	0	0	0.00
0.50-0.75	1.08	1.08	0.90
0.75-1.00	10.98	12.06	9.11
1.0-1.25	19.62	31.68	16.28
1.25-1.50	16.47	48.15	13.67
1.50-1.75	17.37	65.52	14.41
1.75-2.00	11.25	76.77	9.34
2.00-2.25	7.47	84.24	6.20
2.25-2.50	6.57	90.81	5.45
2.50-2.75	7.74	98.55	6.42
2.75-3.00	6.48	105.03	5.38
3.00-3.25	7.38	112.41	6.12
3.25-3.50	3.06	115.47	2.54
3.50-3.75	2.43	117.9	2.02
3.75-4.00	1.35	119.25	1.12
4.00-4.25	0.54	119.79	0.45
4.25-4.50	0.45	120.24	0.37
4.50-4.75	0.27	120.51	0.22

Table 2.4: Area-Elevation Data of Polder 6-8

Elevation Range (m_PWD)	Area (sq km)	Cumulative Area (sq km)	% of Total Area
0.00-0.25	0	0	0.00
0.25-0.50	0.36	0.36	0.11
0.50-0.750	4.32	4.68	1.27
0.75-1.00	52.29	56.97	15.33
1.00-1.25	78.39	135.36	22.98
1.25-1.50	43.56	178.92	12.77
1.50-1.75	28.71	207.63	8.42
1.75-2.00	14.22	221.85	4.17
2.00-2.25	14.76	236.61	4.33
2.25-2.50	14.58	251.19	4.27
2.50-2.75	12.78	263.97	3.75
2.75-3.00	15.3	279.27	4.49
3.00-3.25	18.81	298.08	5.51
3.25-3.50	8.37	306.45	2.45
3.50-3.75	5.94	312.39	1.74
3.75-4.00	8.28	320.67	2.43
4.00-4.25	6.39	327.06	1.87
4.25-4.50	6.39	333.45	1.87
4.50-4.75	5.31	338.76	1.56
4.75-5.00	1.53	340.29	0.45
5.00-5.25	0.36	340.65	0.11
5.25-5.50	0.27	340.92	0.08
5.50-5.75	0.18	341.1	0.05

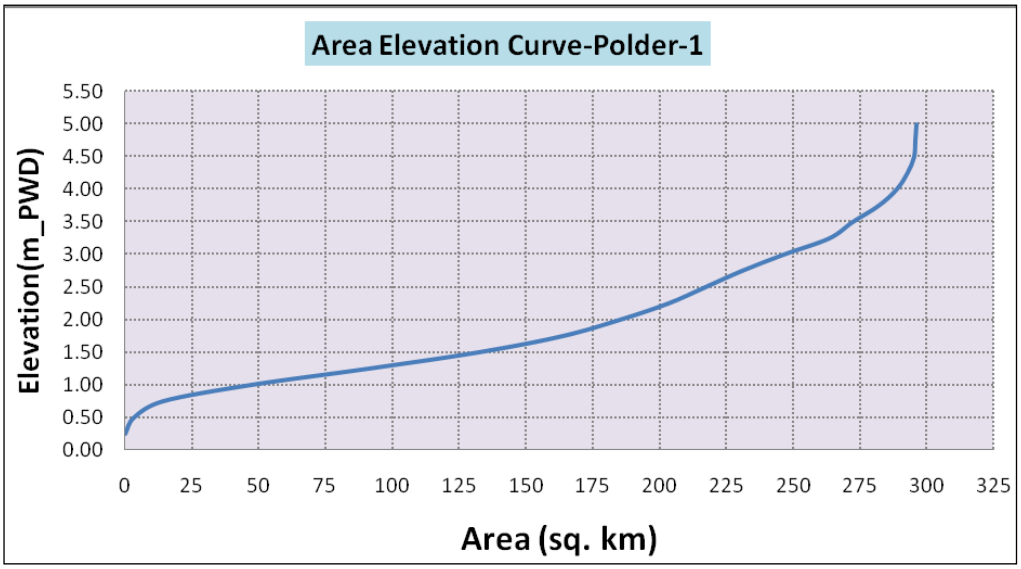


Figure 2.5: Area-Elevation Curve of Polder 1

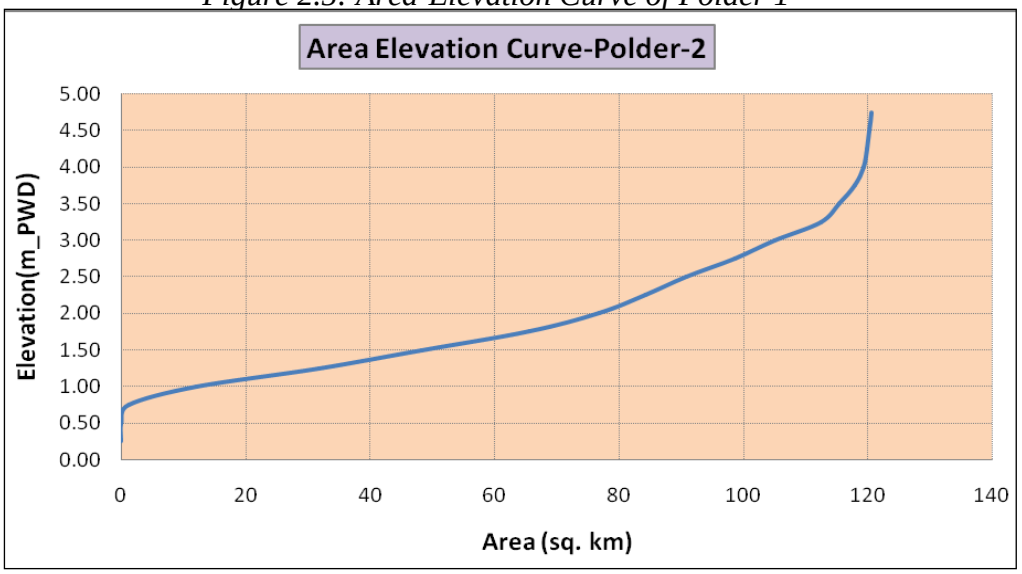


Figure 2.6: Area-Elevation Curve of Polder 2

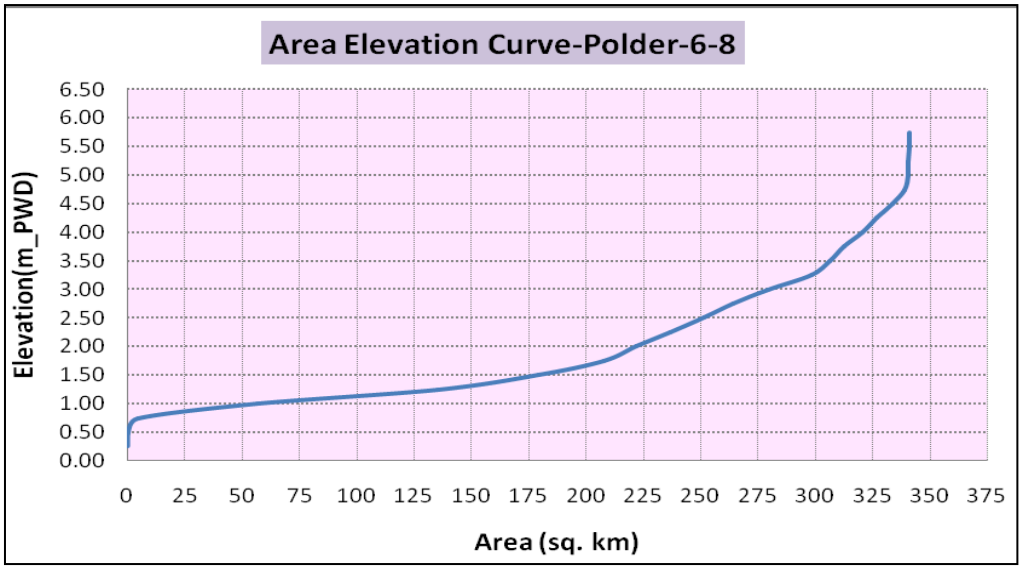


Figure 2.7: Area-Elevation Curve of Polder 6-8 & 6-8(Extn.)

2.6 Agriculture Resources

As part of a Land Resources Appraisal of Bangladesh for agricultural development, Bangladesh has been subdivided into 30 agro-ecological regions and 88 sub regions The study area lies under two Agro-ecological Zones: i) High Ganges River Floodplain (AEZ-11) and ii) Ganges Tidal Floodplain (AEZ-13). The soils are formed from alluvial sediments of the rivers crossing through the district. **Figure 2.8** shows the Agro-Ecological Zones of Bangladesh.They are seasonally flooded, poorly drained soils developed in medium textured to fine textured alluvial deposits. The areas under AEZ-11 are predominantly high land and medium high land with olive brown to dark grey silt loam to silty clay loam topsoil and silty clay to clay loam sub-soils. The soil pH ranges from 6.5-7.5 and salinity level ranges from 0-4 dS/m in the dry season. Soils of AEZ-13 have olive brown to dark grey silt loam to silty clay loam topsoil and silty clay to clay subsoil. Soils of southern part are mostly saline and non-calcareous. These soils become slightly and strongly saline at the surface during the dry season. The soils are moderately permeable with moderate moisture retention capacity in the dry season. In Rabi season, surface water from medium high land generally recedes early within mid November but some areas remain wet for most of the time of dry season. The soil pH ranges from 6.0 to 7.0. Soil salinity level ranges from 0-12 dS/m in the dry season. Water salinity becomes highest during March-June and lowest during August-October.

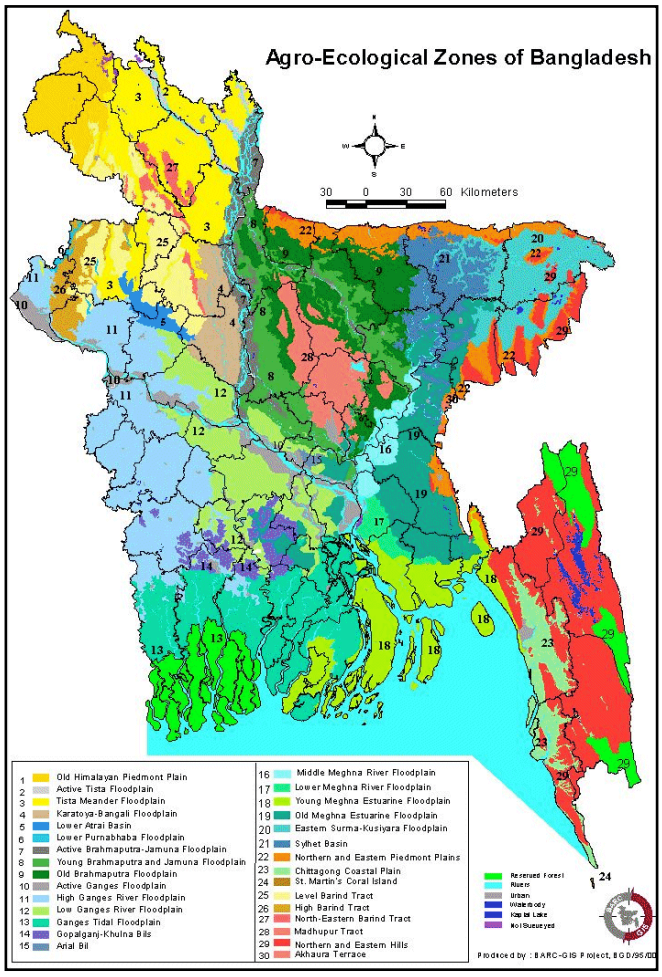


Figure 2.8: Agro-Ecological Zones of Bangladesh (Source: BRAC-GIS Project, BDG/95/00)

Present land use of the study area is dominated by crop production and shrimp culture. Production of mangoes and jujube is also important. Due to drainage congestion and salinity

increase a large part of medium high land and medium low land are being used for shrimp and fish culture.

Land use pattern of Kolaroa, Satkhira Sadar, Debhata, Assasuni and Tala upazilas of Satkhira district that total area of five upazilas of the study area is 1,53,160 hectares. About 21% of the total area is used for Homestead & Settlements and about 5.5% is water body. The rest 73.5% is used for Agriculture and Aquaculture (Fish/Prawn/Shrimp Culture). Nearly 77,423 hectares of land (50.5%) is used for crop production, 22262 hectares (14.5%) for Aquaculture (fish/shrimp/prawn culture) and 13145 hectares (8.5%) for mixed culture (Aquaculture+Agriculture). The lands used for mixed culture (Aquaculture+Agriculture) are basically wetlands and rice is grown along with or after harvesting fish or shrimp/prawn.

Intensity of Land Use of an area indicates the percentage of cultivable land against the total land of the area. Net Cropped Area shows the maximum coverage of crops in any cropping season of the year. Total Cropped Area is the sum total of crop coverage of all seasons in a particular year. It is calculated by the following formula: Total Cropped Area= Single Cropped Area+ 2 x Double Cropped Area+ 3 x Triple Cropped Area+ 4 x Four Cropped Area.

Total Area of five upazilas of the study area is 1,53,160 hectares and Net Cropped Area is 84,413 hectares. Total Single Cropped Area of the study area is 19,358 hectares (21% of NCA), Double Cropped Area is 49,670 hectares (53% of NCA), Triple Cropped Area is 23,806 hectares (25.6% of NCA) and Four Cropped Area is 325 hectares (0.4% of NCA). Total cropped area is 1,91,441 hectares and average Cropping Intensity is 205%. Cropping Intensity is highest (225%) in Kolaroa upazila and lowest (153%) in Assasuni upazila. Cropping Intensity of Satkhira Sadar upazila and Debhata upazila is almost similar to Kolaroa upazila. Average Intensity of Land Use for crop production is 61% which is similar to the country average. Intensity of Land Use is highest in Kolaroa upazila (74%) and lowest in Debhata upazila (39%).

Irrigation is the most important factor influencing the cropping pattern, crop varieties, crop yields and cultivation practices of an area. Most of the cultivated land of the study area has irrigation facilities. Irrigation is done by deep tube wells (DTW), shallow tube wells (STW) and low lift pumps (LLP). Practice of irrigation varies from upazila to upazila. Irrigated area of an upazila depends on the type and number of irrigation units.

Total number of irrigation units in the study area is 47,484 and total coverage in 2011-12 was 82,583 hectares which is nearly 87% of the Net Cropped Area. Total number of STWs is 46,404 which are about 98% of the total irrigation units. With the exception of Kalaroa upazila, the irrigation system of the study area depends mainly on shallow tube wells (STWs). Nearly 81% of the total irrigated area is covered by STWs. In Kalaroa number of DTWs is 469 which cover nearly 62% of the total irrigated area of the upazila. Per unit coverage of DTW is much higher as compared with STW and LLP. Average irrigated area under each DTW, STW and LLP is about 20 hectares, 1.5 hectares and 1.7 hectares respectively.

2.7 Fisheries Resources

Aquaculture is a major source of nutrition, income, employment and livelihood support to the local people of the study area. In the study area 48,925 hectares of land (32% of total land)

are wetlands of which 46,429 hectares are under aquaculture. Aquaculture of the study area is comprised of inland open water fisheries, fish culture in the homestead ponds and shrimp, prawn and commercial fish culture in the 'Ghers'. The source of open water fisheries are rivers, canals, 'beels' and flood plains. Low lying areas and single cropped paddy fields are generally used for making ghers which are used for shrimp (Bagda), prawn (Galda) and fish culture. A large portion of the wetlands is used for integrated culture in which rice is grown after harvesting fish, shrimp or prawn or as intercrop with fish, shrimp or prawn. Saline water is used for shrimp culture and fresh (non-saline) water for prawn culture.
The total wetlands in the study area are 48,925 hectares of which 37,221 hectares (76.2%) is under Ghers. About 28,798 hectares (59%) is under shrimp culture, 6054 (12.4%) hectares is under prawn culture and 2369 hectares (4.8%) is under commercial fish culture in the 'Ghers' and 1868 hectares (3.8%) under pond fish culture in the homestead ponds. Area under open water fisheries is 7,340 hectares (4.8%).

The total area under Ghers is 34,852 hectares of which 83% is used for Bagda culture and 17% is used for Galda culture. In recent years mixed culture of Galda and Bagda with other fishes have become popular in the study area. Native and exotic species like Rui (*Labeo rohita*), Katol (*Catla catla*), Mrigel (*Cirrhina mrigala*), Tilapia (*T. nilotica*), silver carp (*Hypopthalmichthys militia)*, Thai Sarputi, Bhetki, Parshae etc. are grown in Galda/Bagda ghers. Integrated culture of Galda/Bagda with rice is increasing day by day. At present about 37% of the Gher area is used for integrated culture. Integrated culture is more popular in upstream areas which are non-saline to mildly saline.

2.8 Livestock

Livestock is an important part of agriculture. Like other areas of the country, livestock is a major source of nutrition, income, employment and livelihood support to the people of Satkhira district. Trading of cattle is an important business in the district. A large number of bullocks/oxen are imported from India, traded and sent to other parts of the country. But local livestock production is not enough to meet the demand of the local people. Moreover, percentage of contribution of livestock sector to the local economy is reducing day by day.

Condition of livestock is directly dependent on agricultural condition. Cattle live mainly on grass and by-products of crops. With the expansion of aquaculture fallow lands and grazing lands have been reduced to almost nil in the study area. Due to drainage congestion about 32% of total land of the study area has turned into wetlands which do not produce grass. Salinity increase due expansion of shrimp culture has further aggravated the situation. Rice is grown in about 37% of Gher areas. So, there is acute scarcity of rice straw to feed the cattle. As a result, livestock production is in very bad condition in the study area.

CHAPTER THREE: DATA COLLECTION AND ANALYSIS

3.1 Establishment of Benchmark

The survey work for the entire project area has been conducted with reference to existing Survey of Bangladesh's (SOB) Bench Mark (BM) Pillar situated around Polder-01, Polder-02, Polder-6-8 and Polder-6-8 Ext in Satkhira District. BM Fly has been carried out along the embankment and existing road to establish a consistent datum in consideration of the surrounding areas and to facilitate the cross-section and topographic survey. BMs and TBMs have been kept by engraving on the permanent structures like regulator and sluices during the survey. Closing error has been checked to maintain the survey accuracy. The list of TBMs kept has been given in the **Table 3.1** and shown in **Figure 3.1**.

3.2 Primary Data Collection & Establishment of Benchmark

A comprehensive data collection programme was made to collect primary data such as bathymetry (cross-section), of rivers and khals, suspended sediment concentration, river bed sample, bottom topography of beels, water level and discharge etc within and around the project area. This data are duly processed and used to establish the existing condition of the physical processes (baseline hydrodynamic and morphological conditions). Relevant data are also used for development of Drainage, Morphological and TRM models. During cross-section survey campaign, the detail information (size and number of vent, type of structure and their invert level etc.) of existing hydraulic structures, which is very important for development of drainage model, are also collected. The specification of survey and data collection programs carried out in this study is given in **Table 3.2** and shown in **Figure 3.2.**

Table 3.1: Reference SOB Pillar List

Sl No	SOB BM	BM Description	BM Position		RL (mPWD)
			Easting (m)	Northing (m)	
1	SOB 1046	The pillar is situated south-east corner ofkapasdangabangabandhopeshabhittick secondary school field.It is about 10m north side of Kulna-satkhira main road. Vill: Kapasdanga, Upazila: Satkhira, District: Satkhira.	409678	516661	2.066
2	GTS-1051	The pillar is Situated NE corner of Kolaroa High School paly ground (Some partion of playground east side) including pillar portion used as russary, Kolaroa station.Vill: Kalaroa, Upazila: Kalaroa, District: Satkhira.	401988	528148	6.186
3	SoB-1050	The pillar is situated east side Gopinathpur primary School, it is east side wall school, Gapinathpur,Satkhira Sadar, District: Satkhira.	401809	524390	4.280
4	SoB-1047	The pillar is situated behind the Taltola Primary School & Ideal Secandary School building, it is about 15m north of Sathkhira-Khulna Road.Taltola, Satkhira.	406534	514324	3.075
5	SoB-1045	The pillar is situated 10m north from main road & curt from path south from Kumira Primary School, It is south west corner of school field, Vill: Kumira, Upazila: Tala, satkhira.	415396	517854	4.613
6	SoB-1048	The pillar is situated 16.8m north of Lafsa Primary School & 4m north side of a coconute tree on Satkhira, Kolaroa Road,Vill: Lakshaupazila: Satkhira, District: Satkhira.	403446	515401	4.176
7	GTS-106	The pillar is situated 6.5m north from latrine wich is near Bakal Primary School (old building), it is SW corner of school field, Vill: Bakal, Upazila: satkhira, District: Satkhira.	403402	509699	1.945
8	BTS-10A01	The pillar is situated at north-west corner of Parulia High School play ground, just behind the office of Parulia UP Chairman And est side of Satkhira-Kaliganj road. Upazila: Debhata, District: Satkhira	397587	500100	4.2616

Table 3.2: Specification of Primary Data Collection Activities

Item	Location and Nos.			Measurement and Specification	Time/period
Alignment survey	All the internal khals in the project area			Once	01/07/2012 to 01/09/2012
River Cross-section	Betna :48 km@500 m				
	Marirchap :38 km@500m				
	Parulia Sapmara :24 km@500m				
	Satkhira Khal :9.0 km@500m				
	Kholpetua :8.0 km@500m				
Khal Cross-section	Major and Minor Internal khals 520km@400m			Once	01/07/2012 to 01/09/2012
Discharge, Q	Notation	Location	Period	Half hourly measurement for 13 hours during spring & neap tide in wet season	01/08/2012 to 01/09/2012
	Q1	Betna	Wet season(Spring & Neap)		
	Q2	Kholpetua	Wet season(Spring & Neap)		
Suspended sediment, SS	Betna (One location)			Hourly measurement for 13 hours during spring tide in wet season	01/08/2012 to 01/09/2012
	Kholpetua (One location)				
	Total : 2 Locations				
Bed material (B)	Betna : 2 Locations			Once(Left bank, Right bank & Mid channel)	01/08/2012 to 01/09/2012
	Kholpetua : 2 Locations				
	Total 4 Loctions				
Water levels in rivers	Notation	Location	Period	Half-hourly measurement (17 hours daily)	01/08/2012 to 07/10/2012
	WL-1	Betna(Maskhola Kheya Ghat)	2 month in wet season		
	WL-2	Betna(Noapara)	2 month in wet season		
	WL-3	Marirchap(Ellarchar)	2 month in wet season		
	WL-4	Marirchap(Sararpur)	2 month in wet season		
Water level in khals	Notation	Location	Period	3-hourly WL measurement for 2 month and 7days during wet season in khals	01/08/2012 to 07/10/2012
	WL	Sankra Khal Ticket Khal Amod Khali Khal Novaf Khali Khal Kata khal Tetulia Khal	2 month in wet season		
Information of all existing water control structures	➢ Locations of the structures ➢ Opening and numbers of vents ➢ Sill/invert level of the srutures ➢ Opeing of all the important bridges and culverts			Polder 1, 2, 6-8 and 6-8(Extn)	01/07/2012 to 31/08/2012
Bottom Topography of beels	Hazikhali-Amudkhali Beel, Jealmari Beel, Matiadanga Beel,Ticket Beel, Aumtoli Beel, Gobindapur Beel, Sukdebpur Beel, Bugmara Beel,Sreeram katthi Beel, Himkhali Beel, Chapra Beel, Dorgahpur Beel			200x200m grid	January-2013

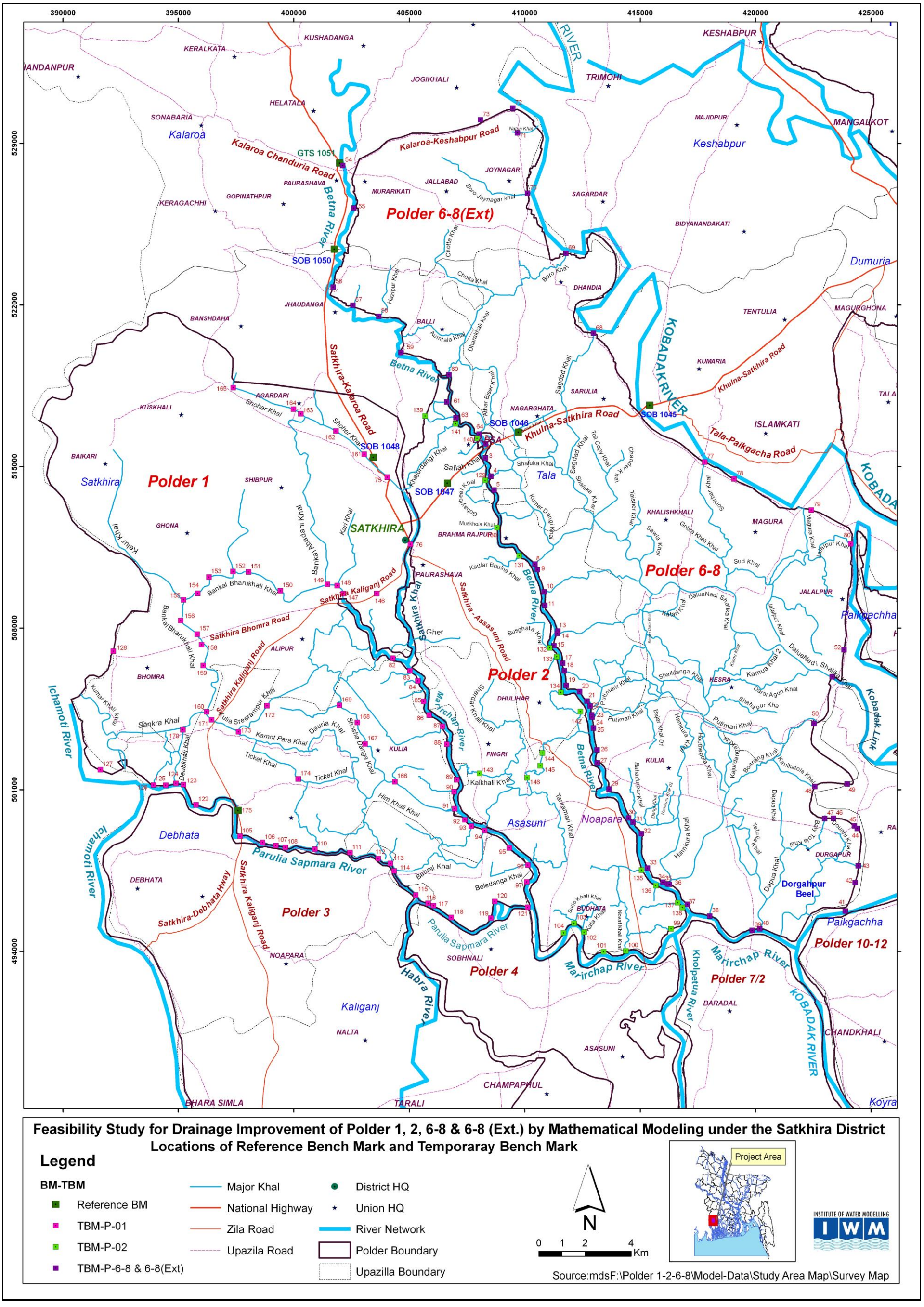


Figure 3.1 Reference Bench Mark and Temporary Bench Mark Map

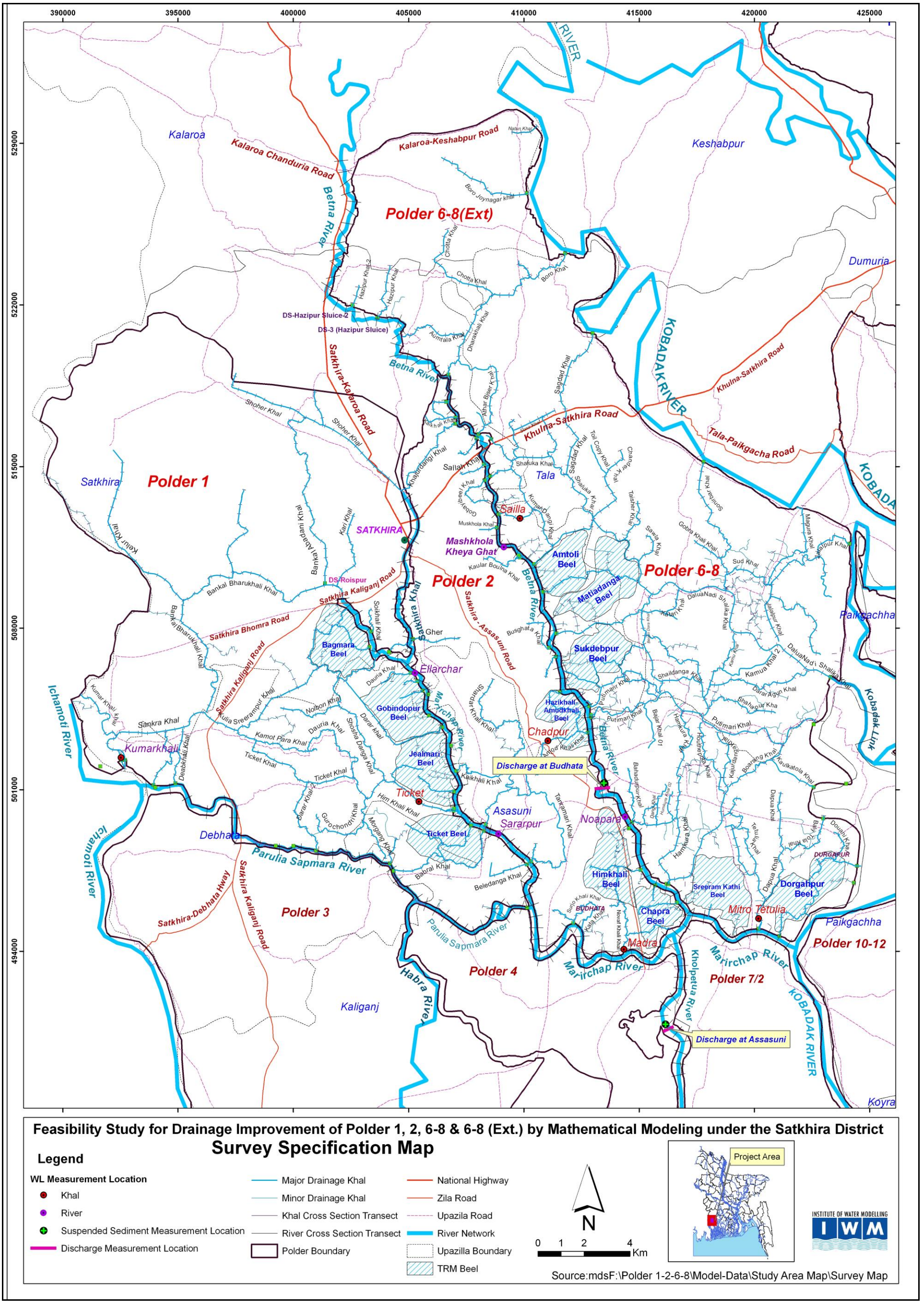


Figure 3.2 Survey Specification Map

3.2.1 Bathymetry/Cross-section Survey

Cross-section survey has been carried out for the river/khals to identify the critical silted-up reach, development of models for the study and also for assessment of dredging requiremet and drainage capacity of the existing river and drainage networks in the study area. The bathymetry/river cross section of Marirchap and Betna River and the interior drainage khals of Polder 1, 2, 6-8 and Polder 6-8 (Extn) have been surveyed in accordance with the specification stipulated in the ToR. The levelling machine has been used in the non-navigable drainage routes while Digital Echo sounder supported by DGPS and Laptop computer installed with HydroPRO survey software was used to survey the cross-section of rivers/khals. The Echo-sounder provides the depth while DGPS provides the position of the vessel in WGS 84 co-ordinate to the computer. Data is recorded automatically at an interval of one second in the computer in tabular format MS Access database during the survey. The Nav Edit module of the software compiles depth of water and position of sounding along with date and time. The depth data is then referred to the PWD datum using water level observed at the gauges within the survey area.

Cross section survey of internal drainage khals and rivers:

The bathymetry/river cross section in the Betna, Marirchap, Parulia-Sapmara and Kholpetua River and interior khals (Major & Minor) has been surveyed in accordance with the specification stipulated in the ToR The number of cross-sections survey are about 1546. The spacing of the cross-sections varied from 400m to 500m.The existing drainage model is updated with these surveyed cross sections of the drainage khals. Through this updated drainage model the problems of the project area was identified and verified through extensive field visits and interaction meeting with the stakeholders. It was also assessed the effectiveness of different potential options of long term solutions through this updated drainage model. This model was also used to assess the effectiveness of different beels as tidal basin. **Table 3.3** shows the list of surveyed khals. Three samples of surveyed sections for Betna River, Marirchap River and Satkhira Khal are shown in **Figure 3.3, Figure 3.4** and **Figure 3.5** respectively. The location of surveyed cross section is shown in the **Figure 3.6.**

Table 3.3: The List of Rivers and Khals Surveyed Cross Sections

SL	River/Khal	Nos of Surveyed Sections
1	Betna River	91
2	Marirchap River	75
3	Parulia Sapmara Khal	47
4	Kholpetua River	16
5	Satkhira Khal	17
6	All internal Khal(Polder-1)	400
7	All internal Khal(Polder-2)	180
8	All internal Khal(Polder-6-8 & 6-8(Extn))	720
	Total surveyed sections =	**1546**

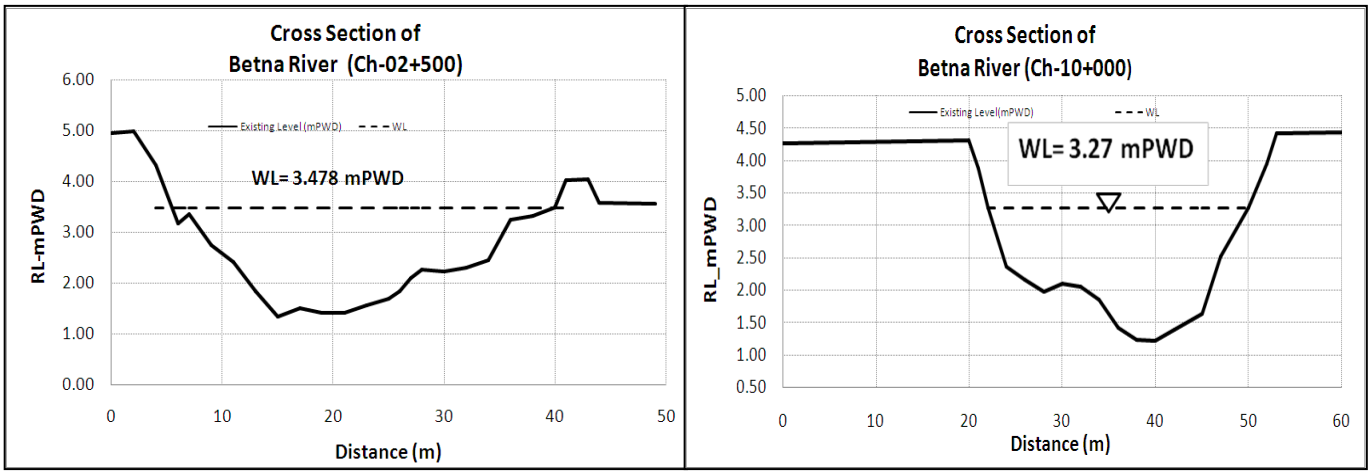


Figure 3.3: Sample Cross-Section of Betna River

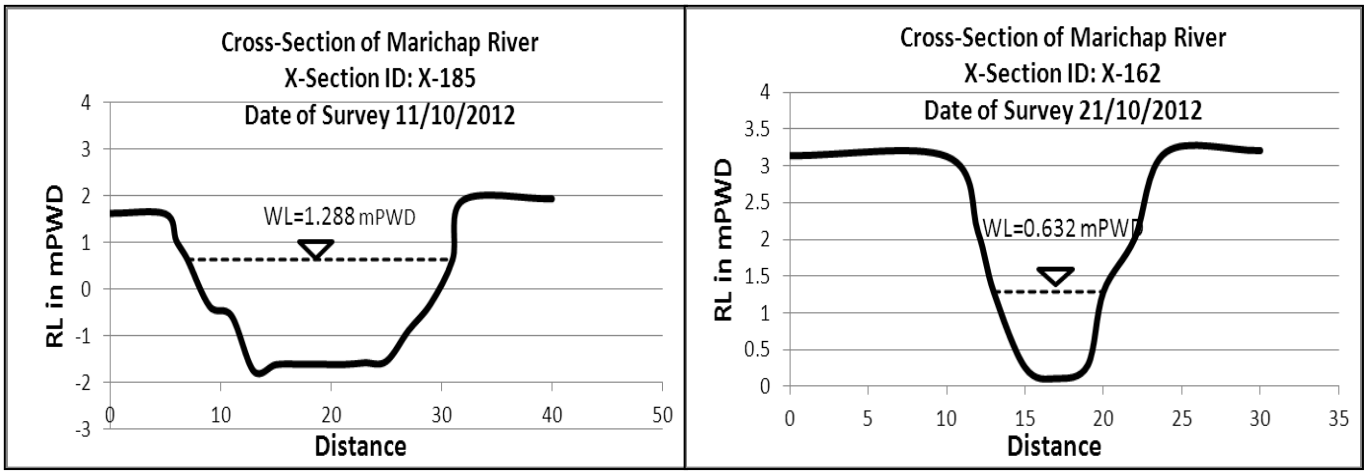


Figure 3.4: Sample Cross-Section of Marirchap River

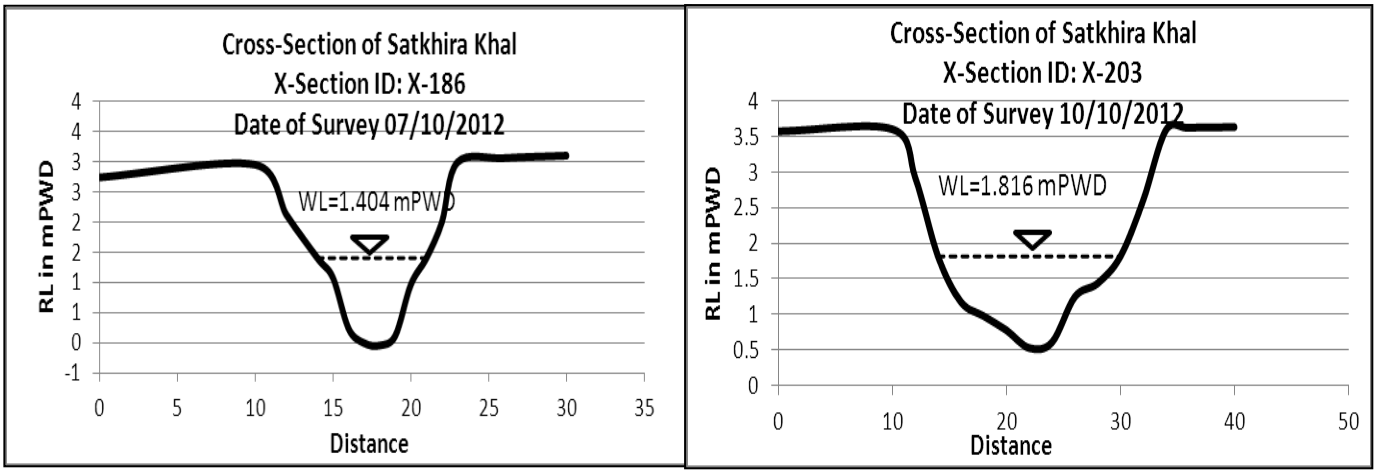


Figure 3.5: Sample Cross-Section of Satkhira khal

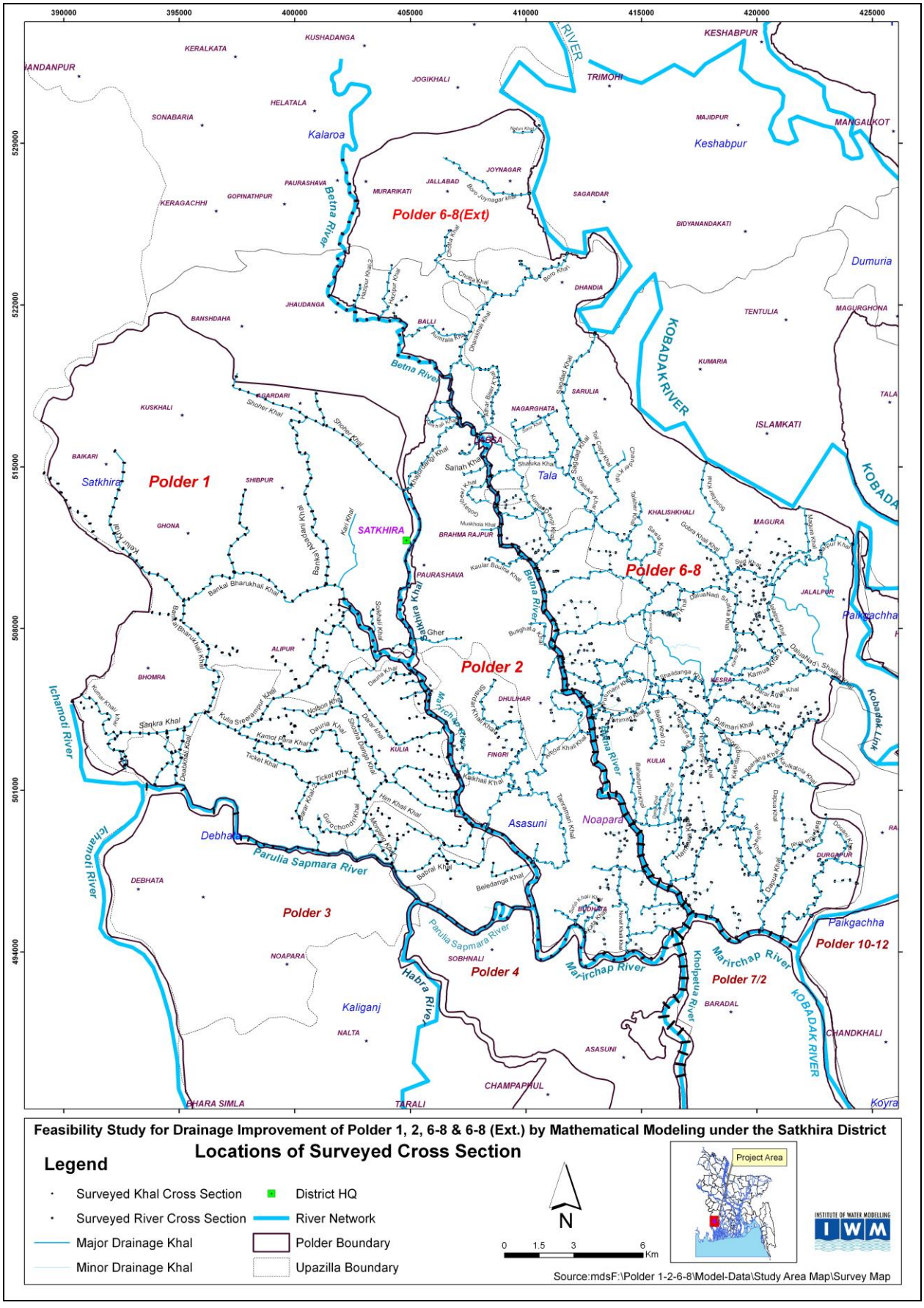


Figure 3.6: Map Showing the Completed Cross-sections Survey of the Internal Drainage Khals and River of the Project Area

3.2.2 Topographic Survey of Beels

Bottom topographic survey of the beels (Hazikhali-Amudkhali Beel, Jealmari Beel, Matiadanga Beel, Ticket Beel, Aumtoli Beel, Gobindapur Beel, Sukdebpur Beel, Bugmara Beel, Sreeram katthi Beel, Himkhali Beel, Chapra Beel and Dorgahpur Beel) for proposed TRM basin as mentioned in the ToR was carried out to generate baseline bottom topography of the tidal basin and also for development of TRM Modelling. Bottom topographic survey was carried out using Differential Global Positioning System (DGPS) and Total Station (TS) survey techniques. DGPS was used to establish a set of temporary bench-mark (TBM) required for bottom topography survey as reference locations for total station, while total station was used for collecting the position and spot level data. The spacing of the land level was kept at 100m to 200m. The height was taken with respect to the PWD datum. In addition to this, echo-sounding technique was applied in the area of greater water depths and in internal channels. Total 6306 ha low lying area has been covered under topographic survey. This bottom topographic data was used in updating the existig DEM (Digital Elevation Model) to calculate the present land type (i.e., FF, F0,F1,F2,F3 and F4 land type) and also to calculate the improvement after taking the mitigative measures for drainage improvement through drainage model technique .

3.2.3 Structural Inventory Survey

The Information of all existing water control structures of Polder 1, 2, 6-8 and Polder 6-8 (Extn) have been surveyed in accordance with the specification stipulated in the ToR.
The list of all drainage structures has been given in the **Table 3.4, 3.5 and 3.6** and **Figure 3.7, 3.8, 3.9** for Polder 1, Polder-2 and Polder 6-8 and 6-8 (Extn) respectively.

Table 3.4: The list of Drainage Structures (Polder-1)

SI	Khal Name	Structure Description	BTM_X	BTM_Y	Vent No	Vent Width (m)	Vent Height (m)	Pipe Dia(m)	Sill Level (mPWD)
1	Kultola Khal	DS-1(2V-0.90m dia)	404193.49	507040.89	2			0.9	-1.33
2	Kulia Sreerampur Khal	DS-2(3V-0.90m dia)	403304.00	507188.00	3			0.9	-0.97
3	Dauria Khal-1	DS-4(3V-0.9m dia)	405089.49	506062.26	3			0.9	-0.50
4	Char Balitha Khal	DS-5(1V-0.90X0.90)	405386.26	505706.19	1	0.9	0.9		-1.52
5	Bania Khal	DS-6 (2V-0.90m dia)	405609.41	505292.22	2			0.9	-1.60
6	Bania Khal-1	DS-7 (1V-0.90X0.90)	405609.41	505292.22	1	0.9	0.9		-1.22
7	Darar Khal	DS-8(3V-0.9m dia)	406458.00	503705.00	3			0.9	-0.50
8	Boailia Khal	DS-9 (3V-0.90m dia)	406961.00	500912.00	3			0.9	-1.00
9	Ticket Khal-Br	DS-10(2V-1.5X1.8)	406966.41	500180.89	2	1.5	1.8		-0.91
10	Ticket Khal	DS-11(5V-1.5X1.8)	406952.00	500088.00	5	1.5	1.8		-0.79
11	Sharafpur Khal	DS-12(4V-1.5X1.8)	407706.00	499430.00	4	1.5	1.8		-1.00
12	Arkoni Khal	DS-14(1V-1.5X1.8)	408267.00	499233.00	1	1.5	1.8		-1.25
14	Parulia Sapmara Khal	FDS-14 (4V-1.50X1.80)	394013.00	501093.00	4	1.5	1.8		-2.00
15	Arkoni Khal	DS-15(2V-0.9m dia)	404923.00	496817.00	2			0.9	-1.22
16	Badartola Khal	DS-16(4V-0.9m dia)	404190.00	497810.00	4			0.9	-1.00
17	Darar Khal-2	DS-17(1V-0.45m dia)	400979.52	498363.24	1			0.45	-1.00
18	-	DS-18 (1V-0.90X0.90)	400008.63	498558.83	1	0.9	0.9		0.40
19	-	DS-19 (1V-0.45m dia)	399234.70	498570.59	1			0.45	0.95
20	-	DS-20(1V-0.9m dia)	396564.29	500470.15	1			0.9	-0.50
21	Deabkhali Khal	DS-21(2V-0.9m dia)	393930.00	501203.00	2			0.9	-0.74
22	Sankra Khal	DS-22(15V-1.5X1.8)	392696.00	502287.00	15	1.5	1.8		-1.50
23	Sankra Khal-Br	DS-22/A(5V-1.5X1.8)	392540.00	502283.00	5	1.5	1.8		-1.22
24	Bankal Abadani Khal	DS-Roispur(3V-1.5X1.8)	401371.00	509937.00	3	1.5	1.8		-1.00
25	Parulia Sapmara Khal	DS-Salkhali(4V-1.50X1.80)	410142.00	495886.00	4	1.5	1.8		-2.17
26	Dhapra Khal	DS-Dhapra (1V-1.50X1.80)	402333.81	508841.23	1	1.5	1.8		-
27	-	DS-23(1V-0.9X0.9)	391512.73	501896.60	1	0.9	0.9		-0.30

Table 3.5: The list of Drainage Structures (Polder-2)

SI	Khal Name	Structure Description	BTM_X	BTM_Y	Vent No	Vent Width (m)	Vent Height (m)	Pipe Dia(m)	Sill Level (mPWD)
1	Sallah Kahl	DS-1 (1V-0.91m dia)	408269	515097	1			0.91	-1.11
2	Shailkar Beel Khal	DS-2-Shalika(1V-1.52X1.83)	407943	516222	1	1.52	1.83		-1.00
3	Gobayibeel Khal	DS-2 (1V-1.52X1.83)	408294	514402	1	1.52	1.83		-1.00
4	Muskhola Khal	DS-3 (1V-1.52X1.83)	408828	512355	1	1.52	1.83		-1.40
5	Kaular boulna Khal	DS-4 (3V-1.52X1.83)	409829	511058	3	1.52	1.83		-0.41
	Kaular boulna Khal-Br	DS-Kalur Boluna (1V-1.52V1.83)	409770.69	511137.38	1	1.52	1.83		-0.41
6	Busghata Khal	DS-5 (1V-1.52X1.83)	411088	507149	1	1.52	1.83		-1.38
7	Andharmanik Khal	DS-6 (2V-0.90 m dia)	411395	506763	2			0.90	-1.00
8	Battolar Khal	DS-7 (1V-0.90 m dia)	411580	505219	1			0.90	-1.45
9	Amod Khali Khal	DS-Amodkhali (3V-1.52X1.83)	412771.98	503475.07	3	1.52	1.83		-0.86
10	Noapara khal	DS-8 (1V-0.90 m dia)	414376.48	499264.27	1			0.90	-0.96
10	Him Khali Khal	DS-9 (3V-0.90 m dia)	415069	497519	3			0.90	-1.20
11	Omor Khali Khal	DS-10 (1V-0.90 m dia)	416635	496101	1			0.90	-1.57
12	Novaf Khali Khal	DS-11 (1V-1.52X1.83)	414386	494024	1	1.52	1.83		-1.88
13	Chumrikhali Khal	DS-12 (4V-0.90 m dia)	410325	497900	4			0.90	-1.00
14	Gaba Khal	DS-13 (2V-1.52X1.83)	408356	499499	2	1.52	1.83		-1.00
15	Kaikhali Khal	DS-14 (2V-0.90 m dia)	407070	501812	2			0.90	-1.00
16	Gosh Khali Khal	DS-15 (1V-0.90 m dia)	406831	502904	1			0.90	-0.45
17	Salmary Khal	DS-16 (2V-0.91m dia)	405853	505131	2			0.90	-0.44
18	Gher	DS-17 (1V-1.52X1.83)	405191	507522	1	1.52	1.83		-0.50
19	Kata Khal	DS-18 (2V-1.52X1.83)	407032	517120	2	1.52	1.83		-0.64
20	Rajnogor Khal	DS-19 (3V-1.52X1.83)	406629	517799	3	1.52	1.83		-0.70
21	Khajurdangi Khal	DS-Khajurdagi (6V-1.52X1.83)	407020	516854	6	1.52	1.83		-1.00
22	Labu Hagi Khal	DS-Labu Hagi (1V-1.52X1.83)	415695	496844	1	1.52	1.83		-0.35
23	Surjo Khali Khal	DS-Surjokhali (2V-1.52X1.83)	412147	495219	2	1.52	1.83		-1.00

Table 3.6: The list of Drainage Structures (Polder-6-8)

SI	Khal Name	Structure Description	BTM_X	BTM_Y	Vent No	Vent Width (m)	Vent Height (m)	Pipe Dia(m)	Sill Level (mPWD)
Polder-6-8									
1	Khodalsha Khal	DS-1 (1V-1.52X1.83)	421087	494660	1	1.52	1.83		-1.00
2	Tetulia Khal	DS-2 (1V-1.52X1.83)	420192	494973	1	1.52	1.83		-1.10
3	Sonibar Khal	DS-2-Bolorampur (1V-1.52X1.83)	417799	515200	1	1.52	1.83		0.27
4	Khajurdanga Khal-BR	DS-3 (2V-1.52X1.83)	416196	496919	2	1.52	1.83		-1.00
5	Kajurdanga Khal	DS-3A (3V-1.52X1.83)	416277	496901	3	1.52	1.83		-1.20
6	Sagdad Khal	DS-3-Sagdad (3V-1.52X1.83)	412987	520767	3	1.52	1.83		-0.78
7	Bainboshto Khal	DS-4 (1V-0.91X1.21)	414702	499595	1	0.91	1.21		-0.96
8	Putimari Khal	DS-5 (2V-1.52X1.83)	412920	504146	2	1.52	1.83		-1.35
9	Putimari Khal-Br	DS-5A (3V-1.52X1.83)	412904	504240	3	1.52	1.83		-1.35
10	Putimarir Khal	DS-6 (1V-1.52X1.83)	412839	504618	1	1.52	1.83		-0.76
11	Nehalpurer Khal	DS-7 (3V-1.52X1.83)	411414	507775	3	1.52	1.83		-1.32
12	Shaluka Khal	DS-8 (2V-1.52X1.83)	410849	509570	2	1.52	1.83		-1.38
13	Kumar Dangi Khal	DS-8A (5V-1.52X1.83)	410451	510771	5	1.52	1.83		-1.35
14	Kata Khal	DS-9 (2V-1.52X1.83)	408917	512941	2	1.52	1.83		-1.30
15	Kundor Dangi Khal	DS-9A (1V-1.52X1.83)	408544	514584	1	1.52	1.83		-1.00
16	Wapda Khal	DS-10 (2V-.90m dia)	408302	515371	2			0.90	-0.58
17	Jalalpur Khal	DS-10A (4V-1.83X1.21)	424130	511653	4	1.52	1.83		-1.00
18	Shalika Khal	DS-11 (15V-1.83X1.21)	423303	505870	15	1.52	1.83		-1.53
19	Putimarir Khal	DS-12 (1V-1.52X1.83)	422572	503836	1	1.52	1.83		-1.35
20	Puber Char	DS-13 (1V-0.91X1.21)	423980	501256	1	0.91	1.21		-0.59
21	Kaulkatola Khal	DS-14 (1V-1.52X1.83)	422570	501111	1	1.52	1.83		-0.53
22	Baly Tola Khal	DS-15 (1V-1.52X1.83)	422994	499750	1	1.52	1.83		-1.79
23	Sayed Khali Khal	DS-16 (1V-1.52X1.83)	424450	497696	1	1.52	1.83		-0.37
Polder-6-8 (Extn)									
1	Kulutia Khal	DS-1 (1V-1.52X1.83)	408035	516404	1	1.52	1.83		-0.50
2	Sree Jagul Khal	DS-1A (2V-1.52X1.83)	408588	516192	2	1.52	1.83		-0.73
3	Dharakhali Khal	DS-2 (4V-1.52X1.83)	406727	518983	4	1.52	1.83		-0.45
4	Hazipur Khal-2	DS-Hazipur (2V-1.52X.83)	402564	521988	2	1.52	1.83		-0.68
5	Hazipur Khal-1	DS-3 (2V-1.52X1.83)	403647	521447	2	1.52	1.83		-0.68
6	Boro Khal	DS-3-Boro Khal (3V-1.52X1.83)	411793	524244	3	1.52	1.83		-1.16
7	Boro Joynagar Khal	DS-4 (3V-1.52X1.83)	410131	526841	3	1.52	1.83		-1.00

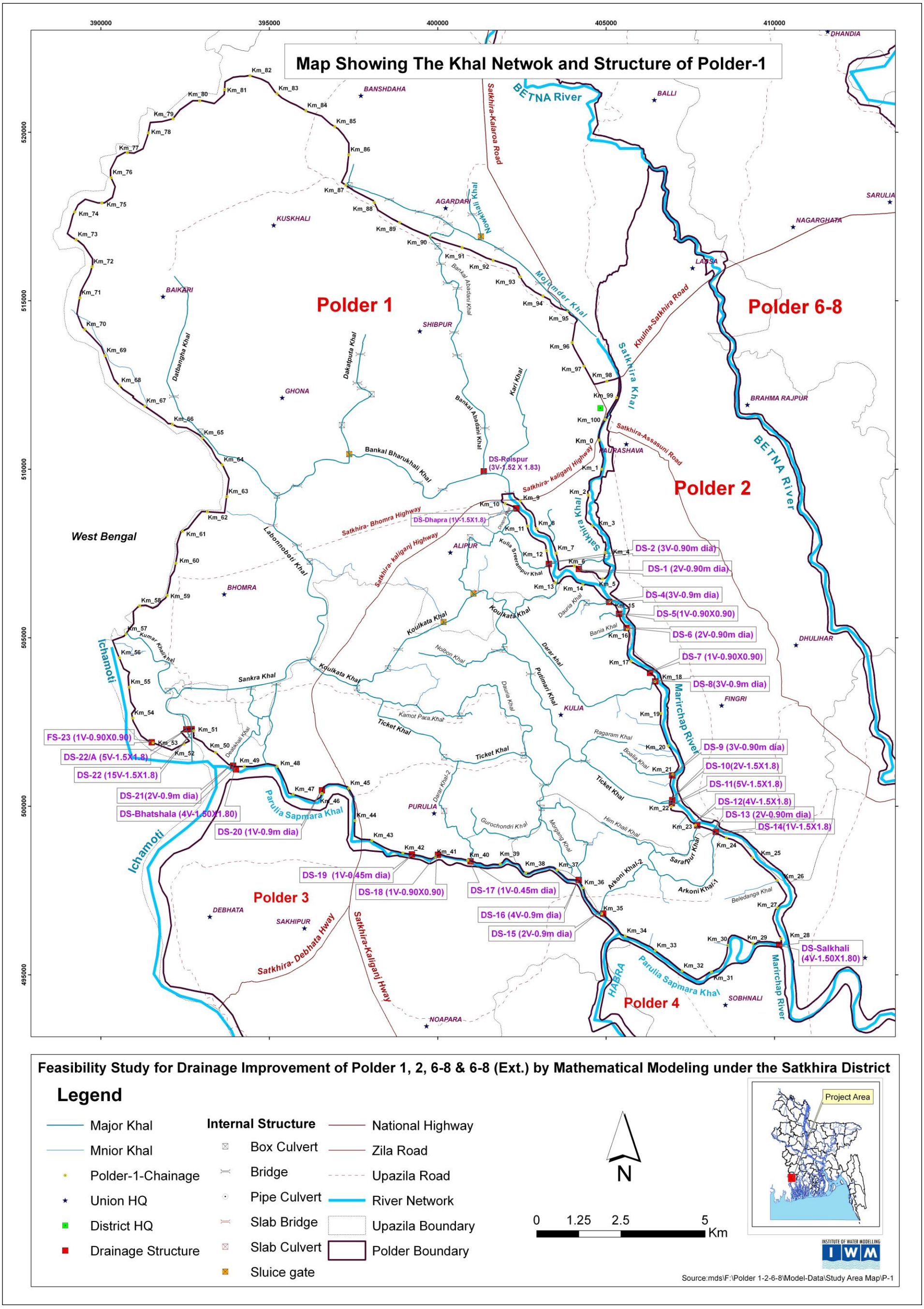


Figure 3.7: Water Control Structure of Polder-1

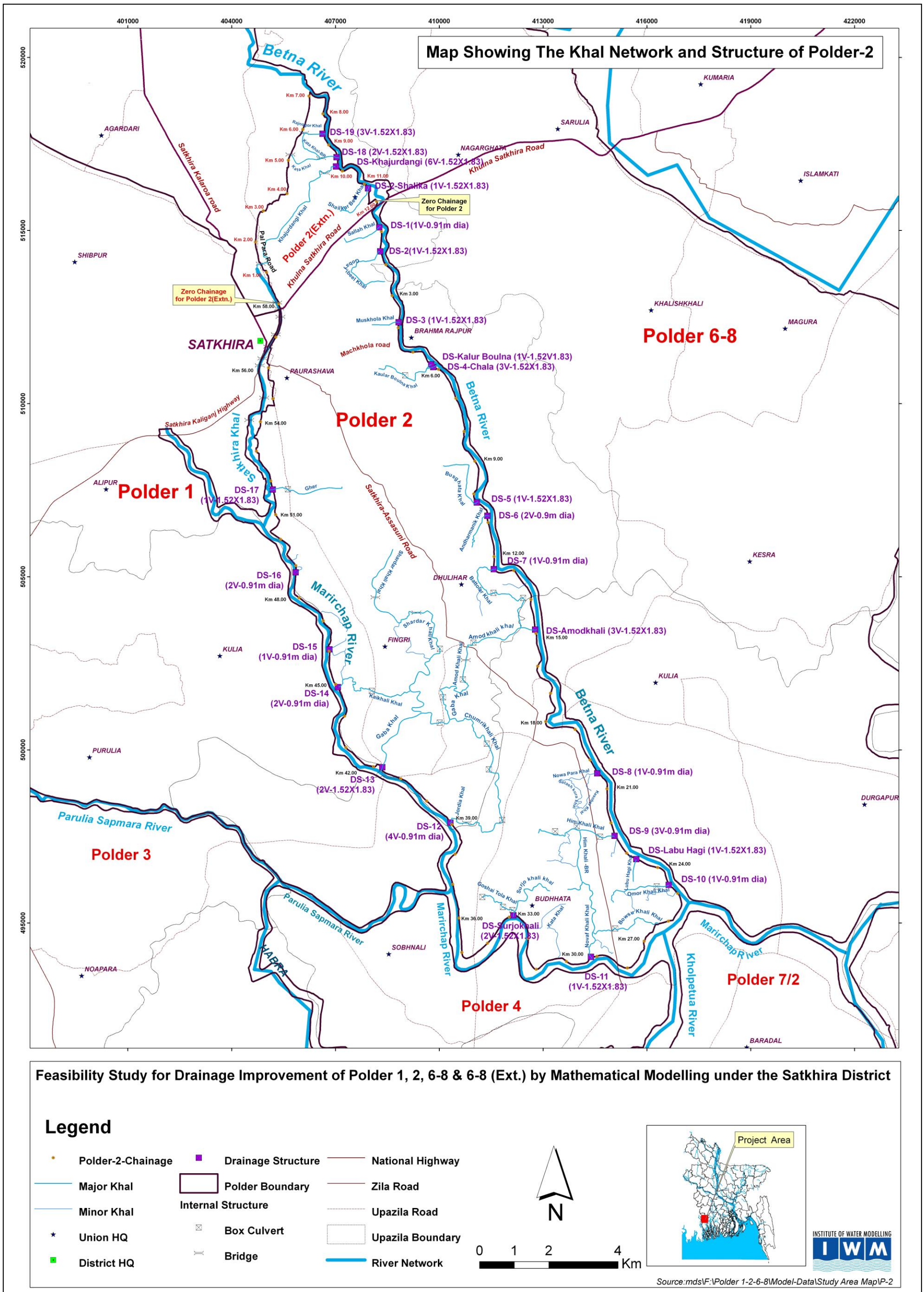


Figure 3.8: Water Control Structure of Polder-2

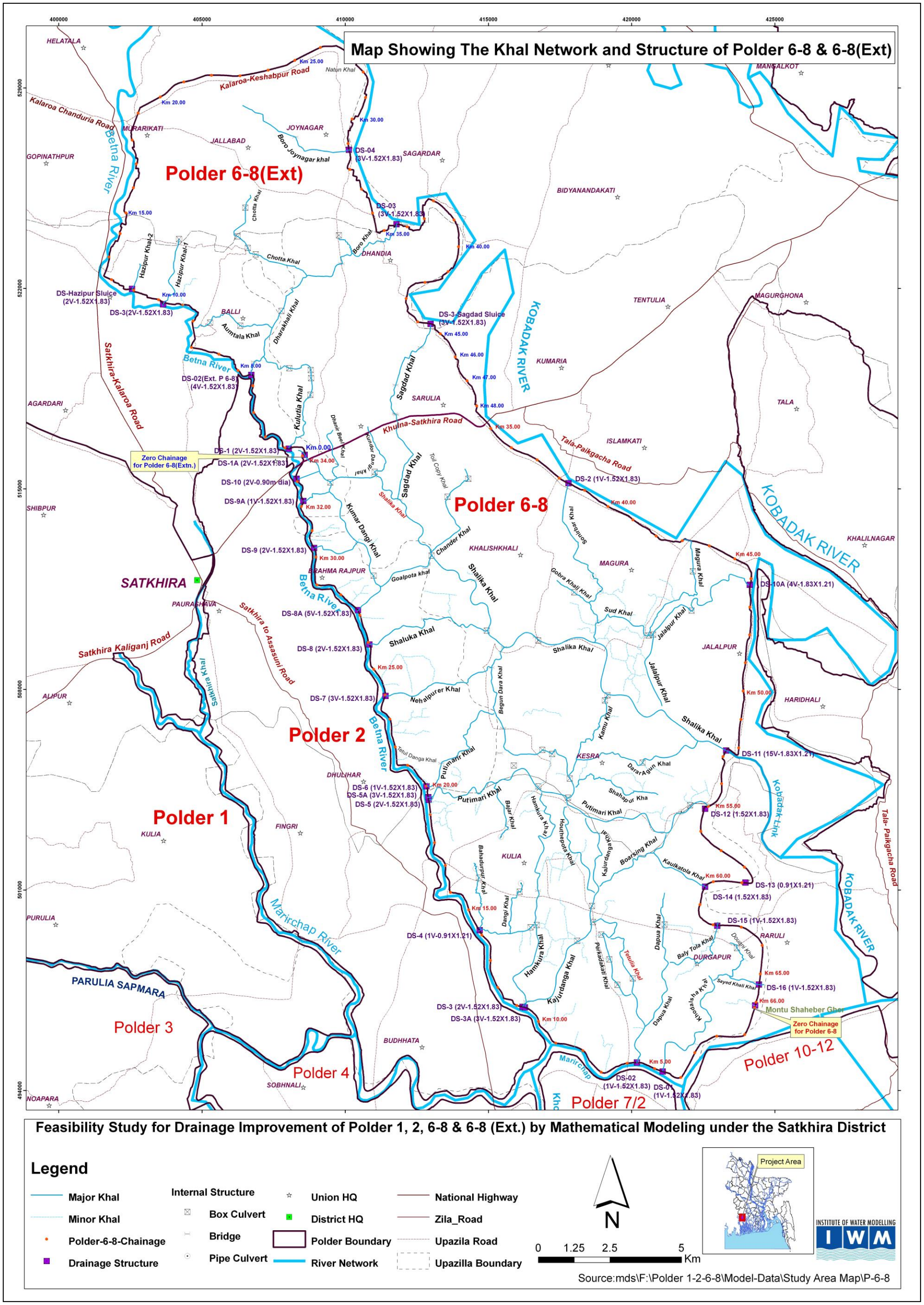


Figure 3.9: Water Control Structure of Polder-6-8 & 6-8 (Extn)

3.2.4 Water Level and Discharge Measurement

Water level data was collected to know the variation of water depth over the year, tidal characteristics and also to calibrate the water flow model. Water level observations were made at four locations, two in the Betna River and two in the Marirchap Rivr for 2 months. The water level data are collected at half hour interval. All water level data are referred to Public Works Datum (PWD). A sample water level variation of Betna and Marirchap River is shown in **Figure 3.10**. The Water Level collection locations are shown in survey specification map **(Figure 3.2).**

Discharge measurement was carried out for 13 hours with half hour interval at two locations both in spring and neap tide to know the water flow during flood tide and ebb tide, tidal prism and also to calibrate the model. Sample of the measured tidal discharge data at Betna River and Kholpetua River is shown in **Figure 3.11**. The water level and discharge collection locations are shown in survey specification map **(Figure 3.2).**

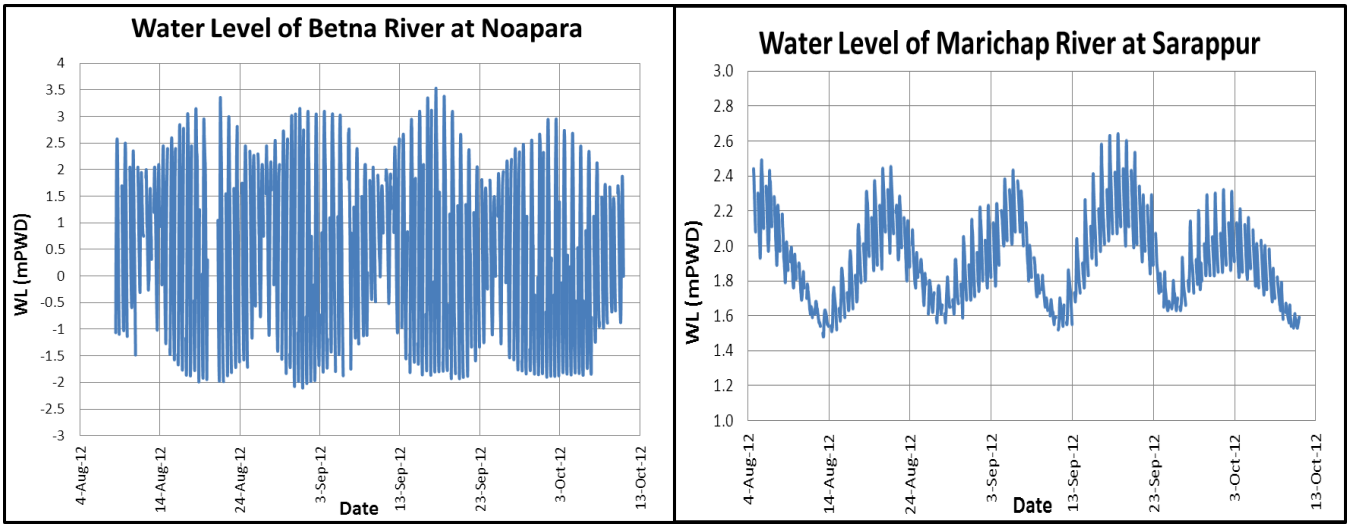


Figure 3.10: Water Level of Betna River and Marirchap River

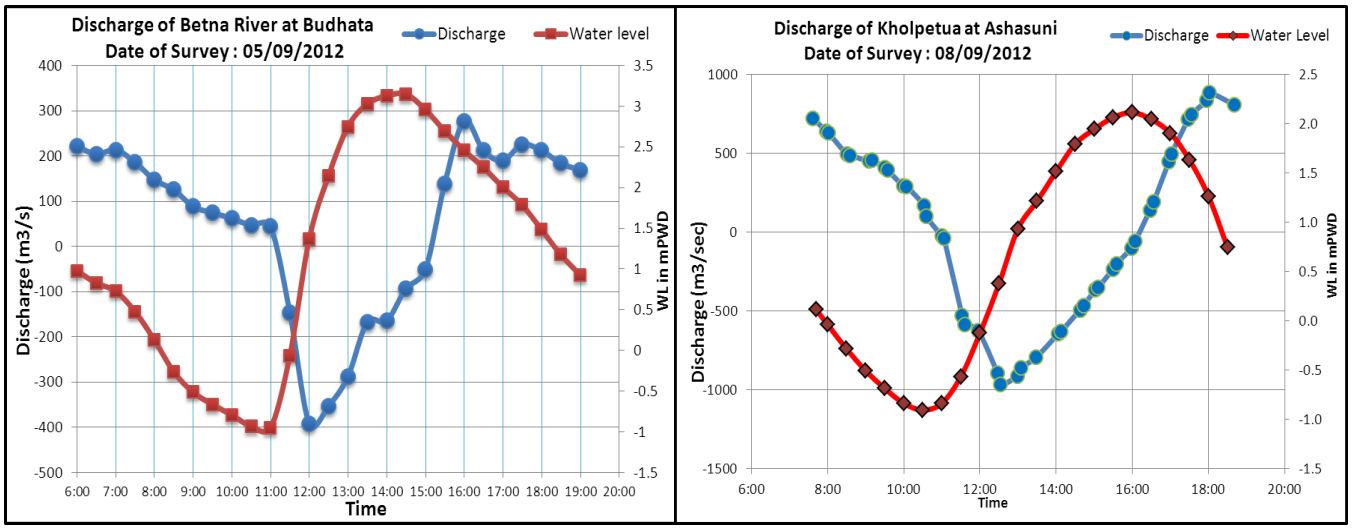


Figure 3.11: Discharge of Betna River at Budhata and Kholpetua River at Ashasuni

3.2.5 Sediment Measurements

Suspended Sediment Concentration

In order to know the suspended sediment characteristics, sediment transport rate and erosion-sedimentation pattern the suspended sediment concentration was measured at 2 locations during monsoon period covering spring tide at the time of discharge measurement. Position and depth of sampling locations have been recorded at each location. The samples have been taken every hour for the full tidal cycle of 12-13 hours. 3 samples are collected per location at 0.2, 0.6 and 0.8 depths to represent the sediment variation during the whole tide cycle.

Suspended sediment concentration is computed after laboratory analysis of suspended sediment samples collected during the flow measurement. The suspended sediment collection locations are shown in survey specification map (Figure 3.1). A sample of suspended sediment curve of Betna River is prepared and shown in **Figure 3.12.**

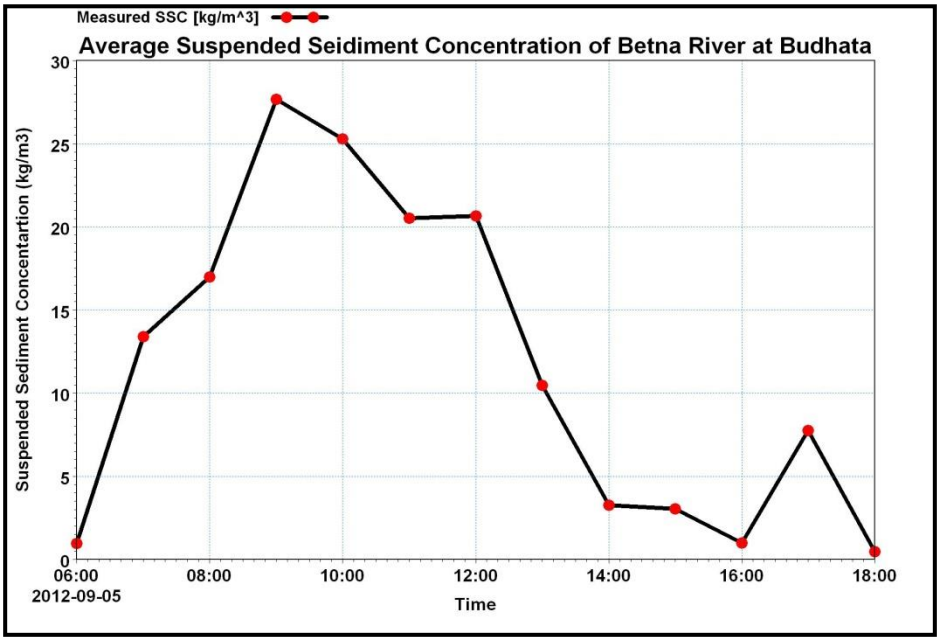


Figure 3.12: A sample of Depth Average Suspended Sediment Curve of Betna River at Budhata

Bed material

Bed material was collected at two locations in the Rivers Betna and Kholpetua. At a specific location three measurements were taken along the cross section i.e., at the left bank, right bank and middle of the river cross section, so total nine measurements were taken. This data was used in development and calibration of morphological model. The bed material collection locations are shown in survey specification map **(Figure 3.2)** and typical bed material characteristics are given in **Figure 3.13.**

IWM SEDIMENT LABORATORY

Determination of Grain Size Distribution

Analysis Type : Andreasens Tube & Wet Sieving

River: MARIRCHAP
Station:Eallaherchar_MIDDLE
Collection Date:
Collection Time:

Sample No: 11
Sample Type : Bed Sample
Position (m) (Easting) : 405277
Position (m) (Northing) : 506067
X-Section:

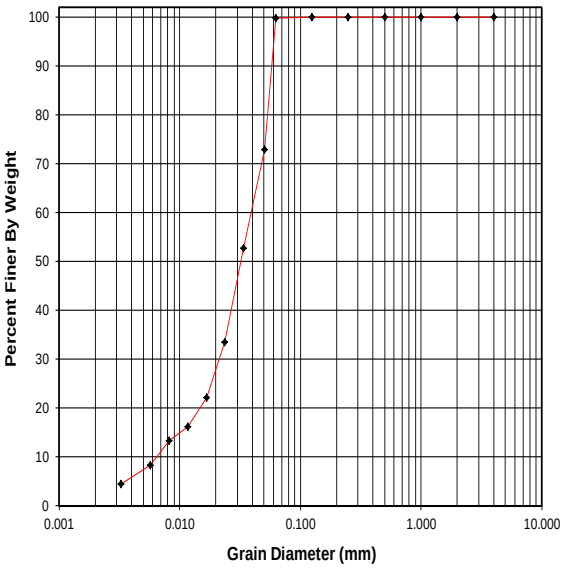
Temperature In °C. Initial : 20.0 Final : Factor, F: 0.01360

Time	Time (T) (min)	Height (H) (Initial)	SQRT. (H/T)	Volume (ml)	Filter Paper Wt.(g)	Filter Paper & Sample Wt.(g)	Concentration (mg/l)	Dia [D} (mm) [F*SQRT(H/T)]	Finer (%)	Adjusted Finer (%)
8:30	0	102.0		100.0	0.0743	0.4430	3687.00		100.00	99.753
8:31	1	100.0	10.000	100.0	0.0738	0.3970	3232.00	0.136	87.66	87.443
8:33	3	98.0	5.715	100.0	0.0746	0.3690	2944.00	0.078	79.85	79.651
8:37	7	96.0	3.703	100.0	0.0744	0.3440	2696.00	0.050	73.12	72.941
8:45	15	94.0	2.503	100.0	0.0747	0.2696	1949.00	0.034	52.86	52.731
9:00	30	92.0	1.751	100.0	0.0746	0.1988	1242.00	0.024	33.69	33.603
9:30	60	90.0	1.225	100.0	0.0745	0.1567	822.00	0.017	22.29	22.239
10:30	120	88.0	0.856	100.0	0.0745	0.1344	599.00	0.012	16.25	16.206
12:30	240	86.0	0.599	100.0	0.0744	0.1238	494.00	0.008	13.40	13.365
16:30	480	84.0	0.418	100.0	0.0746	0.1056	310.00	0.006	8.41	8.387
8:30	1440	82.0	0.239	100.0	0.0745	0.0910	165.00	0.003	4.48	4.464

B.Coarser Part (>63µm)

Sample Weight before Sieving (g): 50.5876
Sample (>63µm) Weight after Sieving (g): 0.1250
Sample (< 63µm) Weight after Sieving (g): 50.4626

Sieve Size (mm)	Weight Retained (g)	Weight Retained (%)	Cumulative Retained (%)	Finer (%)
4.000	0.0000	0.0000	0.0000	100.0000
2.000	0.0000	0.0000	0.0000	100.0000
1.000	0.0000	0.0000	0.0000	100.0000
0.500	0.0000	0.0000	0.0000	100.0000
0.250	0.0000	0.0000	0.0000	100.0000
0.125	0.0000	0.0000	0.0000	100.0000
0.063	0.1250	0.2471	0.2471	99.7529
Pan	0.0000	0.0000	0.2471	99.7529



C. Summary of Results :

Grain Diameter (mm)	4.000	2.000	1.000	0.500	0.250	0.125	0.063	0.050
Percent Finer	100.00	100.00	100.00	100.00	100.00	100.00	99.75	72.94
Grain Diameter (mm)	0.034	0.024	0.017	0.012	0.008	0.006	0.003	
Percent Finer	52.73	33.60	22.24	16.21	13.37	8.39	4.46	

D10 (mm)	D16 (mm)	D35 (mm)	D50 (mm)	D65 (mm)	D84 (mm)	D90 (mm)	Geometric Standard Deviation
0.006	0.011	0.024	0.032	0.043	0.055	0.058	2.314

Figure 3.13: Bed sample data analysis of Marirchap River at Eallaherchar.

3.3 Data Analysis

3.3.1 Water Level

After collection of water level data it has been duly analysed. The water level observation shows that the tidal range of Marirchap River at Sarappur varies from 0.1m to 0.6m. The tidal range in the Betna River at Noapara and Mashkhola varies from 1.0m to 5.4m and from 0.20m to 1.55m respectively during monsoon. The observed minimum and maximum water levels of Betna River at Noapara are -2.10 and 3.50 m PWD respectively. The observed maximum and minimum water level with tidal range at different locations of the Betna and Marirchap rivers is given **Table 3.7.**

Table 3.7: Maximum Tidal Range and Maximum, Minimum and Mean Water Level at Different Locations

SL No	Location	Name of River	Duration	Max WL (mPWD)	Min WL (mPWD)	Mean WL (mPWD)	Max Tidal Range (m)
1	Elalchar	Marirchap	08-08-2012 to 11-10-2012 (half hourly)	1.89	1.13	1.52	-
2	Sararpur	Marirchap	04-08-2012 to 10-10-2012 (half hourly)	2.64	1.48	1.91	0.60
3	Maskhola	Betna	05-08-2012 to 10-10-2012 (half hourly)	3.48	1.55	2.1	1.6
4	Noapara	Betna	08-08-2012 to 10-10-2012 (half hourly)	3.53	-2.10	0.52	5.4

3.3.2 Discharge

The observed maximum discharge of Betna River is about 277m3/sec and 392m3/sec during spring tide at the time of ebbing and flooding respectively. The maximum discharge at the two locations during flood and ebb tide are presented in the **Table 3.8.**

Table 3.8: Maximum Discharge during Flood and Ebb at Different Locations

Sl No	Location	Name of the River	Measurement Period	Type of Tide	Max Flow during Flood Tide (m3/sec)	Max Flow during Ebb Tide (m3/sec)
1	Budhata	Betna River	05-09-2012 (half hourly)	Spring	392	277
			08-09-2012 (half hourly)	Neap	173	175
2	Assasuni	Kholpetua River	08-09-2012 (half hourly)	Neap	967	886
			01-10-2012 (half hourly)	Spring	1607	1046

3.3.3 Sediment

The samples that have been collected during discharge measurement are duly analyzed at IWM Sediment laboratory Dhaka. After laboratory analysis of the sample, the total

concentration has been computed. The depth average maximum, minimum and average sediment concentrations are given in the **Table 3.9.**

Table 3.9: Depth average maximum, minimum and mean Suspended Sediment Concentration at Different Locations during Spring Tide

Name of the Location	Name of the River	Spring Tide Monsoon Period		
		Maximum(mg/l)	Minimum(mg/l)	Average(mg/l)
Budhata	Betna River	27660	455	11650
Ashasuni	Kholpetua River	1341	352	822

3.4 Collection of Secondary Data

Topographic (land level) data is very important for the assessment of inundation patterns during monsoon in the study area. Accurate topographic data is also needed for assessment of benefited areas with project conditions in terms of land classification coverage. The topographic data of the Polder area that has been used in this study were collected from the existing DEM of the southwest region of Bangladesh available with IWM. The rainfall data of the nearest rainfall stations in the study area has been collected from BWDB. BWDB rainfall stations collect daily rainfall records. Rainfall data forms the basic input to the Rainfall Runoff Model (NAM) which yields the run-off generated from the catchments.

CHAPTER FOUR: IDENTIFICATION OF PRESENT PROBLEMS

4.1 Interaction Meeting with Local People & Field Investigation to Identify Present Problems

In order to identify the problems of the study area a number of field visits were made by the Professional Teams of the study. During this field visit the team members made interaction meeting with the local peoples/stakeholders as well as extensive field investigation to identify the prevailing drainage congestion, number of affected unions & beels, total area affected, depth of inundation, condition of siltation in the main drainage rivers in the study area and other relevant problems. In the interaction meeting with the stakeholders attempt was made to extract people's view about the prevailing drainage congestion problems, causes and potential solution of the problems.

The problems those are preliminarily identified and raised by the local people are summarised as follows:

Problems of the project area

- Heavy siltation on the river bed of the Betna / Marirchap River and the main drainage routes of the proposed study area.
- At many places the river bed levels have been raised above the bed level of the internal drainage khals of the polders and caused drainage congestion in the area;
- Most of the water controls/drainage structures of polders have became non-functioning due to huge siltation at u/s and d/s of the structures in the drainage khals.
- Most of the internal khals (except few) are silted up.
- Condition of the most of the embankment of polders are not in good condition needsre-sectioning;
- Most of the peripheral rivers like Betna, Marirchap, Kobadak, Parulia-Sapmara were silted up and became dead due to lack of up land fresh water flow (flushing flow). Almost all the downstream channels of sluices/ regulators have also been silted up. Consequently the most of the areas are suffering from drainage congestion.
- Some land owners adjacent to khals & rivers illegally encroached from bank line toward the river bed by construction of earthen dwarf embankment to grab part of the rivers/ khals, for pisciculture/agriculture. As a result these enclosed area trapped silt more rapidly during flood tide;
- Leasing of land of the river by the district/local administration creates drainage congestion.
- No maintenance of excavation/dredging programmes carried out to excavate/dredge the silted up river/khals;

4.1.1 Field Visits

IWM study team visited almost entire area of Polder-1, Polder-2, Polder-6-8 and Polder-6-8 (Extn) during pre & post monsoon. The team visited different regulators and khals outfall to Betna & Marichap rivers and beel areas under polder-1,2,6-8& 6-8 (ext) at different locations to identify the existing problems, drainage route and explore the potential beels for TRM .During the visit the team discussed with the stakeholder on the existing problems, expected solution and their views at several locations.

Major problems were identified during field visit. These are: I) Siltation in the rivers & khals. II) Drainage congestion III) Most of the Water Controlling structures are inactive due to siltation, IV) Encroachment of River & Khals and V) Conflict between Agriculture & Aquaculture

4.1.2 Workshop

Local stakeholder consultation is important to understand the field problems and to identify preliminary options for solutions. Two workshop was arranged and held at the Conference Room of DC, Satkhira on 9th February 2013 & on 24th August 2013 in order to know problems & people's/participant's view of the study areas to asses the real causes of the problems and explore probable solutions through participatory approach involving the local stakeholders. Honourable District Commissioner (DC) of the study area, elected people's representatives of local government, as well as the local stakeholders, journalists and officials of BWDB, IWM attended the workshop. At the very beginning of the workshop, a power point presentation was shown by IWM to describe the problems of the project area and sufferings of the local people and also addressing the remedial measures of the existing problems and sufferings including the feasibility study.

Then an open discussion was held. Participants in the discussion meeting were of civil society members, vulnerable groups, women group, upazilla chairman & vice-chairman, union council chairmen & members, farmers, fisherman, journalist. Local people emphasized restoration of the Betna and Marirchap rivers by dredging and excavation of other silted up internal drainage khals of polders. Most of the participants demanded for rehabilitation of the existing structures of the polders, re-sectioning of the embankments of the different polders to prevent flooding and dredging/excavation of the silted up rivers/khals for proper drainage. They particularly demanded for immediate implementation of well-planned TRM in the potential beels for incoming sediment management in the Betna and Marirchap rivers for maintaining proper drainage capacity in these rivers. For the long term sediment management plan IWM has presented a sequential TRM operation Plan for the project area to the participants. **Photograph 4.2 to 4.4** shows the participants of the workshop at Satkhira held on 9 th February 2013 and on 24th August 2013.

4.2 Key Findings of Field Visits and Workshop

- Dredging/Excavation of the silted up rivers and internal drainage khals of polders;
- Steps to be taken for rehabilitation of the regulator/water control structures and embankment;
- Remove of all the illegal infrastructures and encroachment over the rivers/khals;
- Proper steps to be taken to stop/cancel all types of leasing the land/wetland inside the rivers zone immediately;
- Co-ordinated steps should be taken to stop unauthorised occupation of khas land within the study area before and after implementation of the project.
- TRM should be implemented comprehensively in the potential beels for maintaining proper drainage capacity of the Betna and Marirchap rivers;
- Effective steps should be taken to ensure proper compensation for the affected land owners of the beels before implementation of TRM;
- Extensive programme for creating public awareness should be created in favour of TRM operation;
- Drainage is hampering as almost all the R/S channels of the sluices silted up. These rivers/ internal major/ minor khals need re-excavation.

- To developed adequate drainage roots for removing drainage condition.
- For devising drainage improvement options, "Agro-Aquaculture" in the study area needs to be considered;
- Zoning of the Ghers and Agriculture inside the polders has to be done and unplanned gher needs to be removed;
- Majority participant opposed the proposal of constructing cross-dam with two additional drainage regulators over Betna River at Suparighat but MP, Satkhira-1 assured the house that there will be no future complication.
- IWM will examine its viability through modelling test and data analysis.
- TRM should be implemented in the Pakhimara beel immediately;

Photograph 4.1: Local people expressing their views

Photograph 4.2: Group Discussion in Workshop at DC office,Satkhira

Photograph 4.3: Presentation on Selection of Probable Solution and Potential Options at DC office, Satkhira

Photograph 4.4: Local people expressing their views in the Workshop at DC office, Satkhira

4.3 Problem Analysis

It is crucial to understand the proper causes of the prevailing water logging problems before devising/suggesting any potential solution of the problem. In order to understand the causes of the prevailing water logging, the identified problems are investigated based on the data and information gathered during field visit, Focus Group discussion/local stakeholder consultation, interaction with the officials of BWDB and LGIs, field survey and measurements etc. It is revealed that the major problems of the study area is acute drainage congestion due to the continuous sedimentation in the outfall rivers of the polders namely Betna, Marirchap, Kobadak over the years. **Figure 4.1, Figure 4.2 & Figure 4.3** shows the severity of sedimentation problem of Betna River, Marirchap River & Parulia Sapmara Khal.

Photograph 4.5: Consultation with BWDB official

It was observed that the rivers Ichamoti and Kholpetua are only live rivers with a better flowing condition. The accumulated rain water and water enters into the polders through the regulators/inlets during high tide could not drain out due to siltation on river/khals at the upstream and the downstream of structures and create water logging and drainage congestion inside the polders.

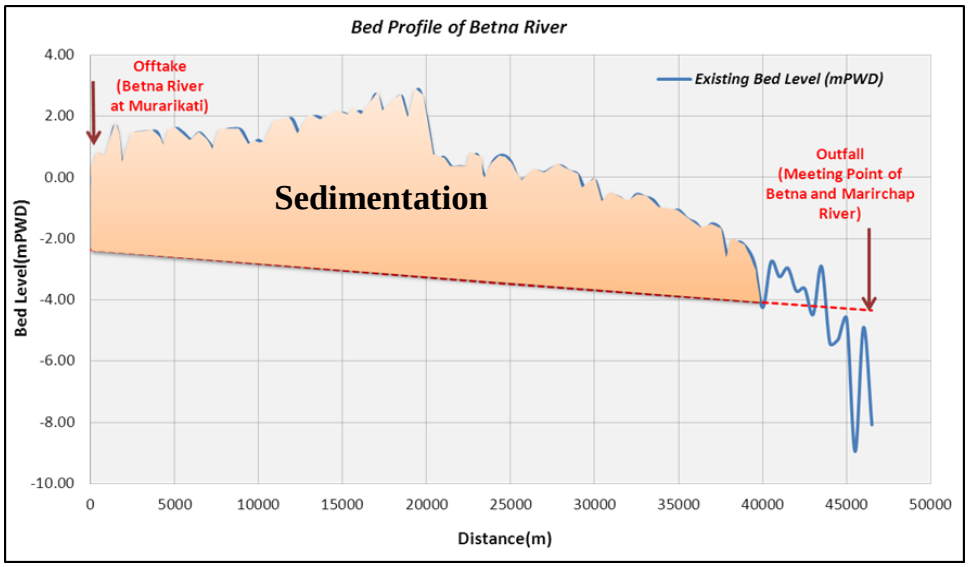


Figure 4.1: The Existing Bed Profile of Betna River

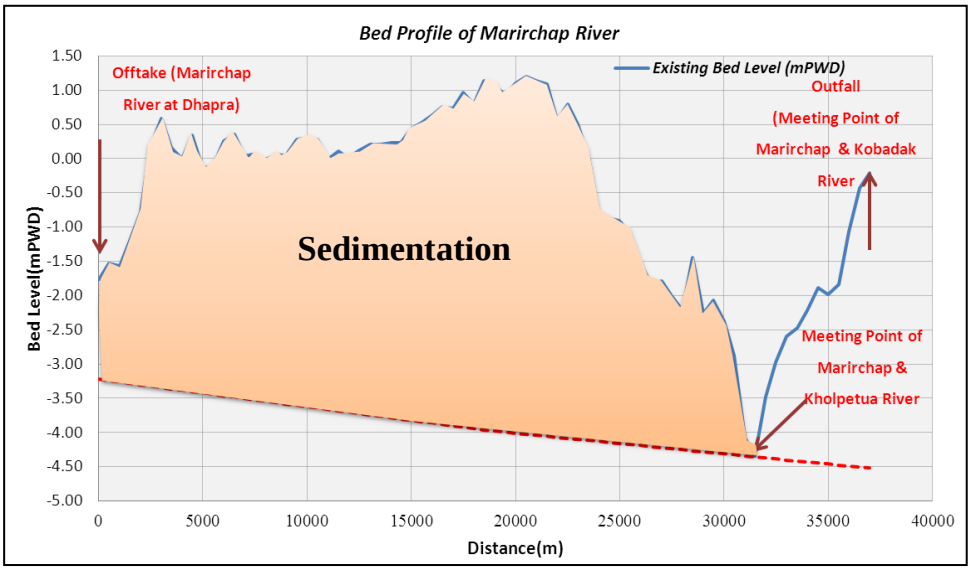


Figure 4.2: The Existing Bed Profile of Marirchap River

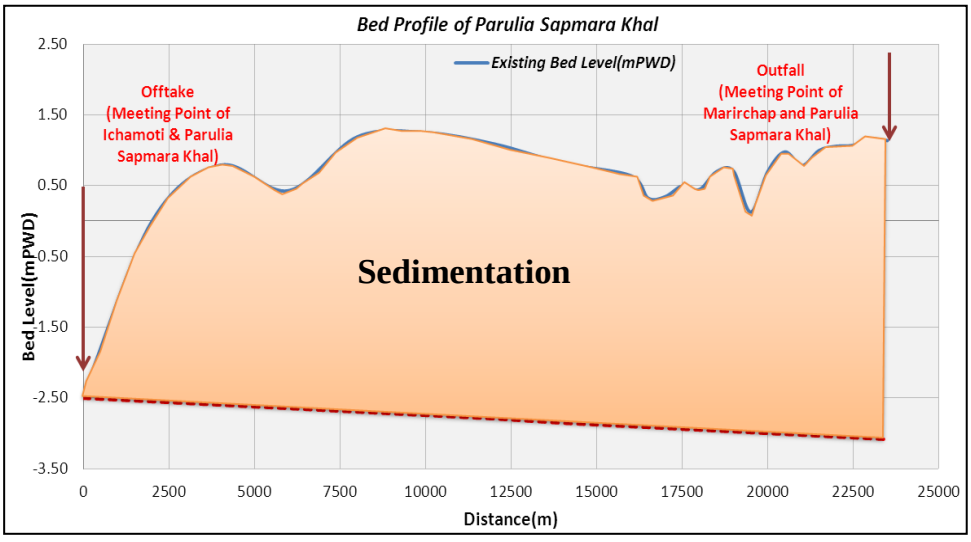


Figure 4.3: The Existing Bed Profile of Parulia Sapmar Khal

Photograph 4.6: Sedimentaion over River & Khals

As the bed level of the most internal major and minor khals have been raised due to continuous sedimentation drainage are delayed or completely stopped leading to drainage congestion. **Photograph 4.6** shows the sedimentation of major rivers and khals around the project area.

Un-planned activities carried out by the influential gher owner also accelerating create drainage and water logging problems.

It is also observed that due to inadequate drainage route and non-functioning of he existing structures/inlets/outlets and also due to continuous sedimentation on the bed of the outfall rivers/channels of the water control structures creates drainage congestion. **Photograph 4.7 and 4.8** shows the existing non-functioning drainage structures due to damaged launching aprons and U/S loose.

Photograph 4.7: Both Side Siltation over Nehalpur khal-Polder-6-8, DS-7 (3V-1.52X1.83)

Photograph 4.8: U/s Loose & Launching Aprons damageed in Novaf Khali Khal/ Madra Khal-Polder-2, DS-11 (1V-1.52X1.83)

The marginal and middle class farmers can not establish their opinion due to influential gher owner which creates conflicts of interest in the polder areas. The polder embankment is not in design section due to lack of routine maintenance can also creates water logging and drainage problem in the polder areas when the embankment breaches. The erosion of Ichamoti River is continuing and threatened the polder embankment and also the existing regulator.

The analysis has revealed that that water-logging problem is a result of a combination of many factors which includes excessive monsoon rainfalls, inadequate drainage, mis-management and lack of maintenance of embankments and water control structures, increased sediment inflow and siltation in the river bed over the years, restricted river flows due to dwarf embankments built for shrimp farming and decrease of upland flow due to withdrawl of water by construction of barrages in India, especially the Farakka Barrage. Several field visits, FGD/workshop, interaction with local people's representatives and stekholder have been made to ascertain the real problems and expected solution.

4.4 Identification of Problems using Model Results

In order to identify water-logged area, inundation depth map has been prepared for existing condition for different design flood events using drainage model results. The inundation depth maps have been made for 3-day duration for 1 in 20 year flood event. The inundation depth maps for the different polders are shown in Figure 4.1. Different land type area in

accordance to NWMP guide line is presented in **Table 4.1** for the existing morphological condition with 1 in 20 year flooding condition.

Table 4.1: Inundation Area for 3 days duration Flood inside Different Polders for the existing Condition

Flood-event	Inundated Area (ha)						
	Flood Free	F0 (inundation up to 0.3 m)	F1 (inundation 0.3))m to 0.9 m)	F2 (inundation 0.9 m) to 1.8 m)	F3 (inundation 1.8 m to 3.6 m)	F4 (inundation >3.6 m)	Total Deeply Flooded area
Polder 1	(11.0%)	(6.0%)	(14.6%)	(28.1%)	(40.4%)	(0.0%)	68.4%
Polder 2	(19.0%)	(7.1%)	(15.3%)	(28.3%)	(19.8%)	(10.5%)	58.6%
Polder 6-8 & Extn.	(9.2%)	(4.1%)	(25.4%)	(16.3%)	(16.5%)	(28.5%)	61.3%

It is evident from the above table that only 17.5% area remain flood free land (Flood Free+F0) for Polder P-1 under 1 in 20 year flood condition. The same value for polder 2 and 6-8& Extn are about 26.1% and 13.3% respectively. The total productive lands in terms of agriculture (Flood free+F_0+F_1 land) are 31.6%, 41.4% and 38.7% for polder 1, 2 and 6-8 respectively. Almost more than 60% area of these polders seems to be deeply flooded under existing field condition for 1 in 20 year flood event. Thus, the analysis revealed that all these polders are severely suffering in terms of drainage congestion under the present morphological condition and needs rehabilitation.

CHAPTER FIVE: HYDROLOGICAL ANALYSIS AND MODELLING

5.1 Hydrological Analysis and Selection of Design Flood Event

The drainage flow of the study area is exclusively generated from the catchment due to rainfall. As such, hydrological analysis on historical rainfall data in the study and surrounding areas has been carried out to identify the design flood event for the drainage study. In order to determine this flood event rainfall data are analyzed using the software HYMOS, a hydrological data management and processing tool developed by Delft Hydraulics.

According to the Theissen polygon analysis considering the four rainfall stations, Satkhira covers 51% project area where Benarpota and Paikgacha covers about 13% and 11% respectively the remaining 25% of the study area is covered by Islamkai, Kalaroa, Kaliganj and Kapilmuni. The **Figure 5.1** shows the area weightage influence of the stations in the project area. **Table 5.1** shows the available data of those stations.

Table 5.1: The Available Historical Rainfall Data for Different Stations

SL	Station Name	Station ID	Available Data		Available Years
			Starting Year	Ending Year	
1	Benarpota	R 502	1986	2011	24 years
2	Islamkati	R 505	1961	2011	45 years
3	Kalaroa	R 507	1987	2011	19 years
4	Satkhira	R 518	1987	2010	24 years
5	Paikgacha	R 515	1985	2012	23 years

Considering the influence and availability of data a Five days (05) cumulative historical rainfall data of Satkhira, Kalaroa, Islamkati, Benarpora, Kaliganj and Kapilmuni stations has been used for the analysis. The 5-day cumulative yearly maximum rainfall of Satkhira, Islamkati and Kalaroa station is shown **in Figure 5.2, Figure 5.3** and **Figure 5.4** respectively. For the statistical analysis, Gumbel, Log Normal and Log Pearson distribution method have been used. **Figure 5.5** shows the Log Normal distribution of Satkhira station. **Table 5.2** shows the 5-days cumulative rainfall for 20 years return period for different distribution .Frequency analysis shows 20 year return period rainfall is about 427 mm of Satkhira station in Log-Normal distribution. It is also found that year 1991 has the value of 434 mm for Satkhira station. Based on frequency analysis result of 5 rainfall stations in this area the hydrological year 1991 has been selected as design flood event and the Rainfall-Runoff model has been simulated for the year 1991 for assessing the drainage performance of the study area and effectiveness of the potential improvement options. Year 2005 has been selected as average flood event (2.33 year) for assessing the drainage performance for this year.

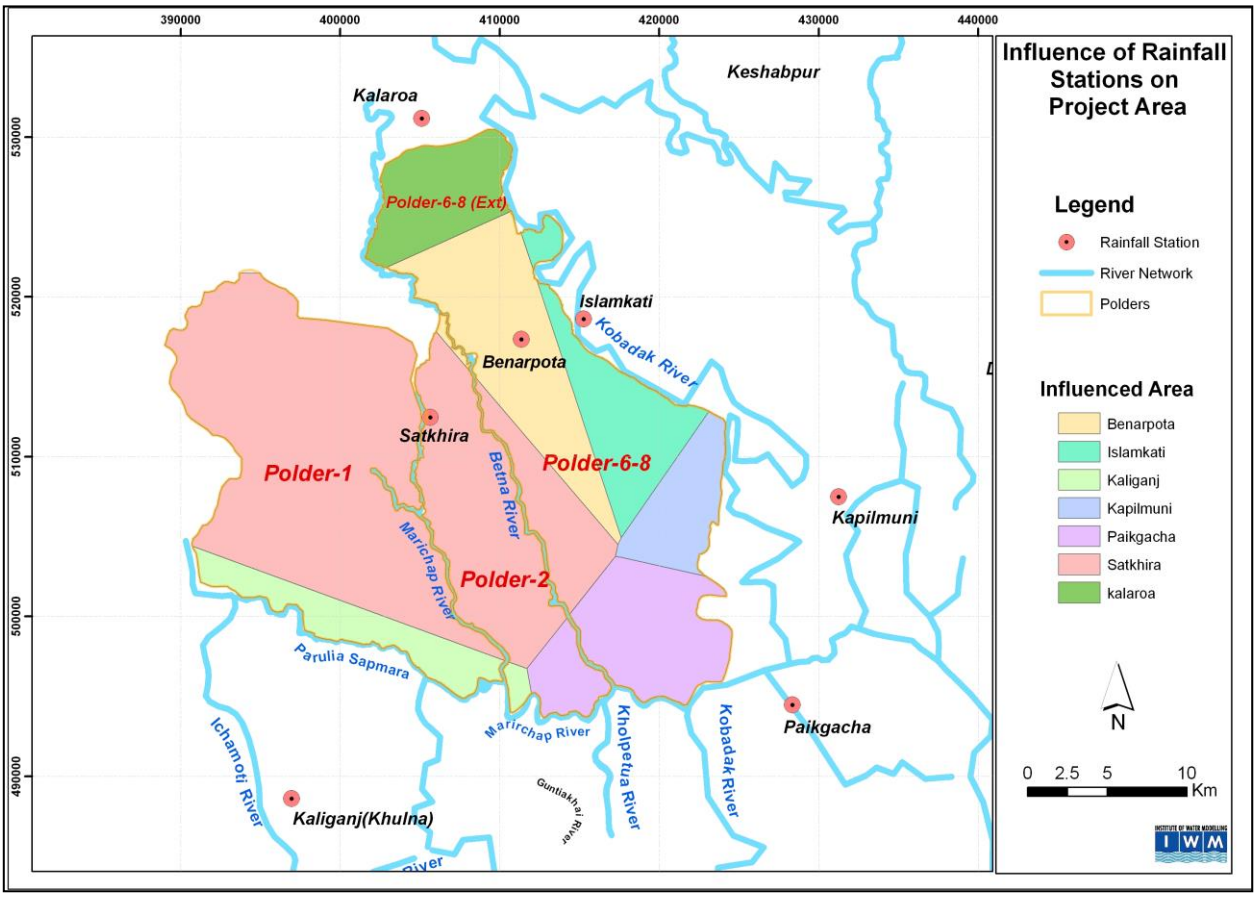


Figure 5.1: The Influence of Different Rainfall Stations within the Study Area.

Table 5.2: Twenty Years Return Period Rainfall for Different Distribution

SI	Station Name	Station ID	Distribution	5-day cumulative rainfall in mm for 20 year return period	Selected Year
1	Benarpota	R 502	Log-Normal	344	1988(347)
			Log-Pearson	364	
			Gumbel	355	
2	Islamkati	R 505	Log-Normal	388	1991(407)
			Log-Pearson	395	
			Gumbel	429	
3	Kalaroa	R 507	Log-Normal	416	1991(408)
			Log-Pearson	417	
			Gumbel	382	
4	Satkhira	R 518	Log-Normal	427	1991(434)
			Log-Pearson	460	
			Gumbel	435	
5	Paikgacha	R 515	Log-Normal	494	1986(387)
			Log-Pearson	470	
			Gumbel	487	

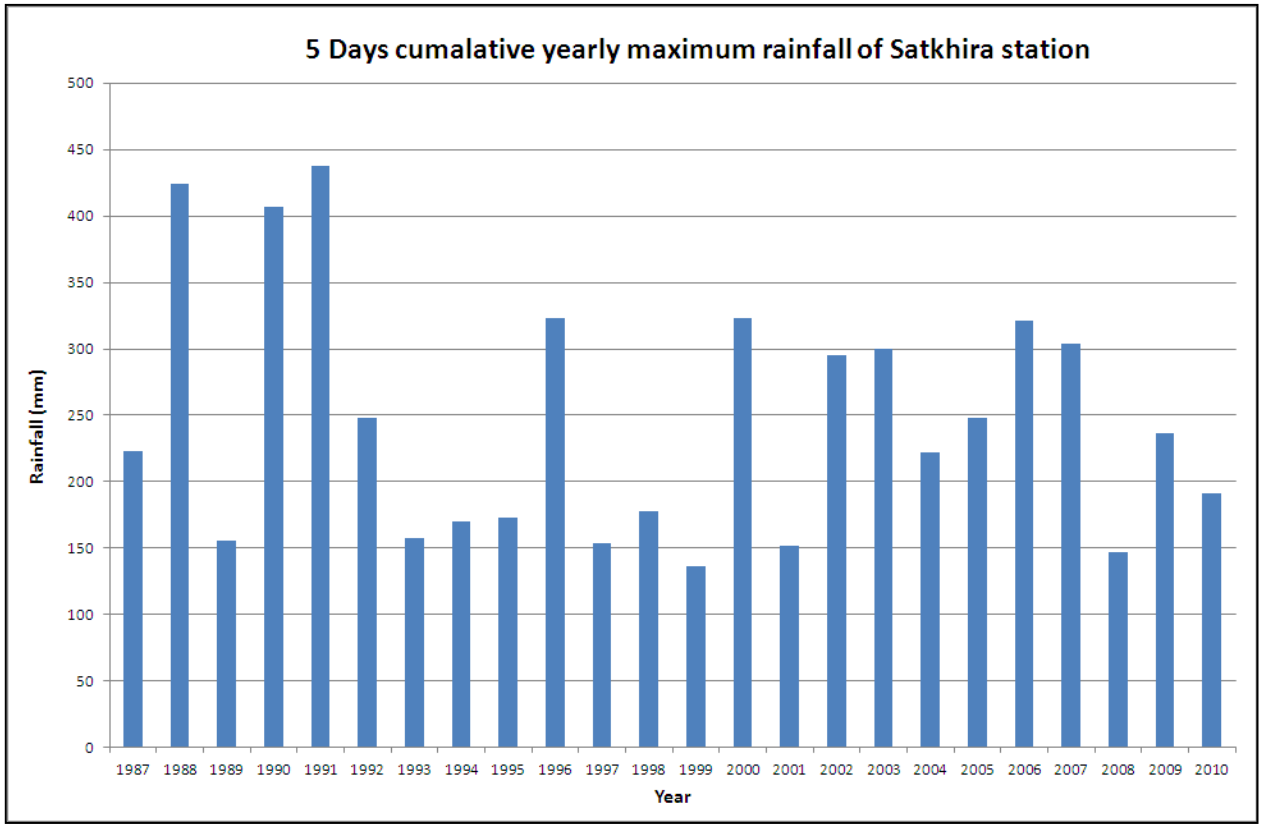


Figure 5.2: 5-Day Annual Maximum Rainfall of Satkhira Station.

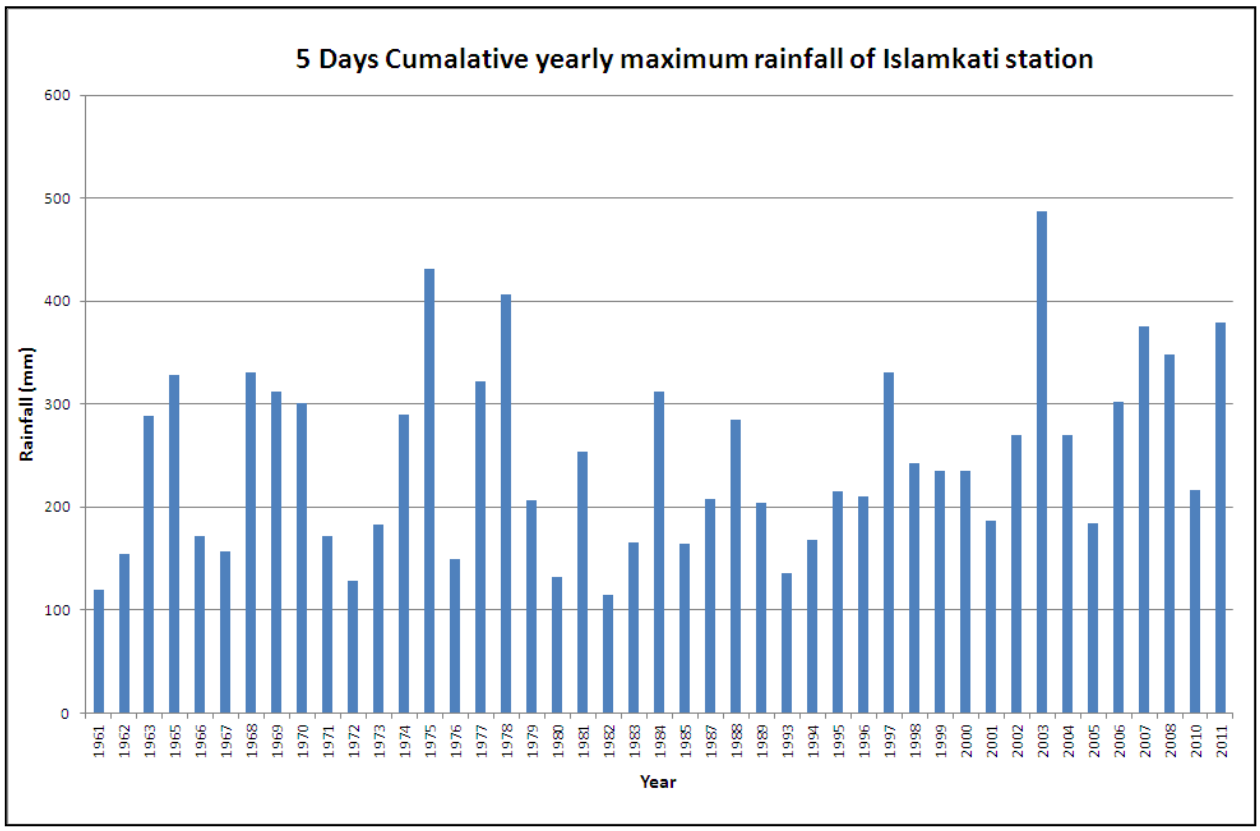


Figure 5.3: 5-Day Annual Maximum Rainfall of Islamkathi Station.

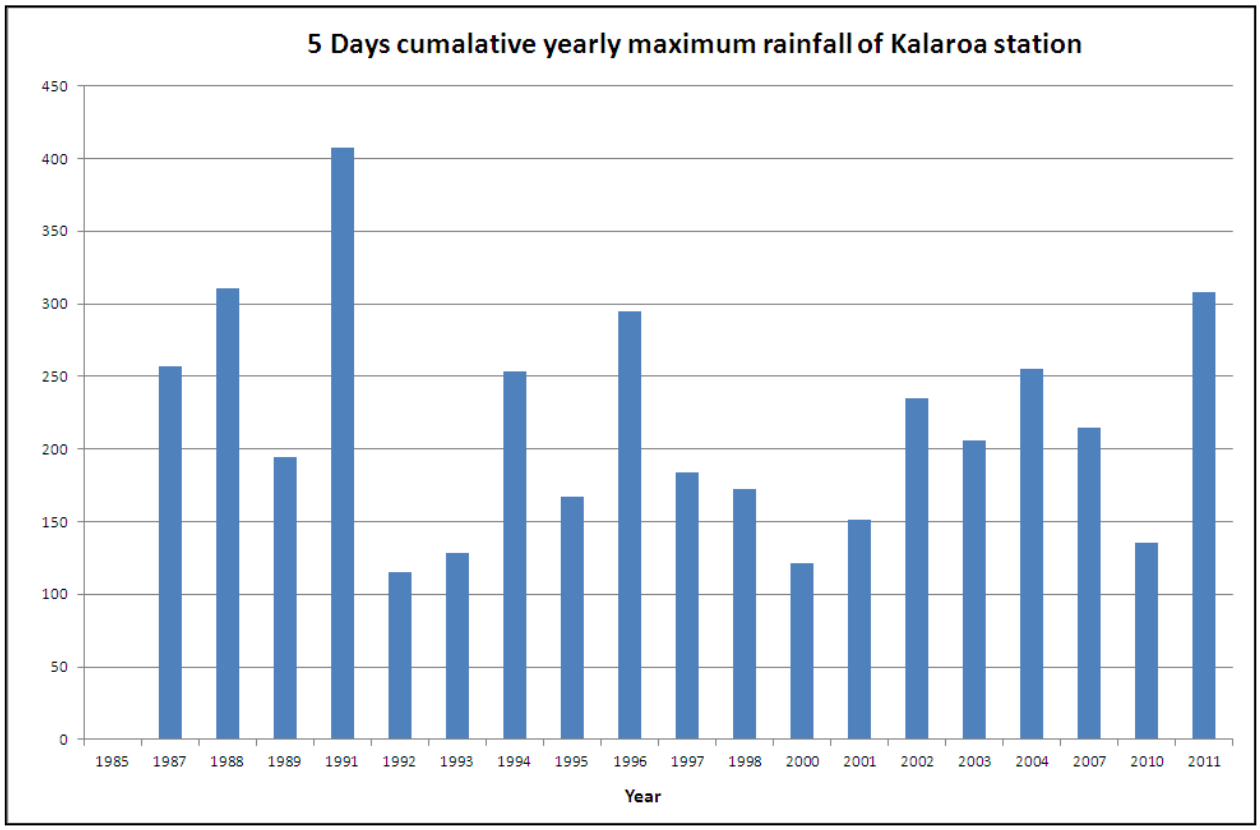


Figure 5.4: 5-Day Annual Maximum Rainfall of Kalaroa Station.

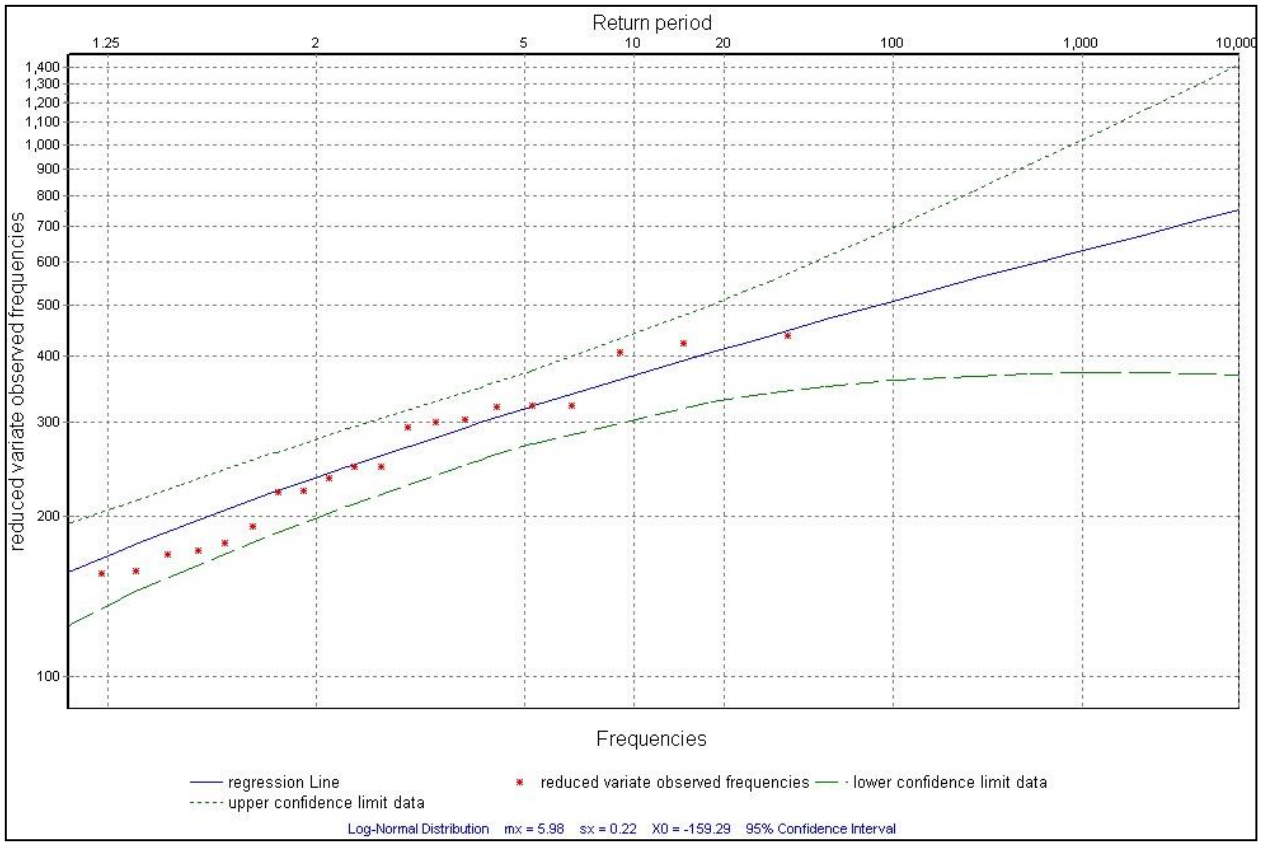


Figure 5.5: Frequency Analysis for 5-Day Annual Maximum Rainfall of Satkhira Station by Log-Normal Distribution

5.2 Development of Models

5.2.1 Hydrological (Rainfall-Runoff) Model

Rainfall Runoff Model is applied to estimate the runoff generated from rainfall occurring in the catchment. The model takes into consideration the basin characteristics including specific yield, initial soil moisture contents and initial ground water level and irrigation/abstraction from the surface or ground water sources. The catchments of the rainfall runoff model are delineated according to the topographic barriers/water shed boundaries, roads and river networks. The existing calibrated Southwest rainfall runoff model (NAM) contains 44 catchments. The catchment SW-27 represents the entire Sundarban area. Due to the absence of hydro-meteorological stations inside the Sundarbans, rainfall and evaporation data have been used from neighbouring stations for this catchment. However, input from NAM model for this catchment is ignored in HD model, since the runoff generated in SW-27 is insignificant compared to the volume of flow of the Sundarban river system. According to the findings of the hydrological analysis hydrological modelling has been carried out for the year 1991(1in 20 year) for extreme flood event study and 2005 has been considered as average (2.33year) flood event.

5.2.2 Drainage Model

Drainage model is a very effective tool for investigating the performance of potential drainage improvement plans and its possible impacts on the physical processes. It can also assist to establish the existing drainage patterns of a drainage basin and also helps to identify the future problem that can persist due to the implementation of the potential drainage improvement interventions. Drainage modelling has been carried out in order to investigate the adequacy and performance of the existing structures and drainage systems and providing design parameters for the potential drainage improvement interventions. The existing calibrated and validated Southwest Regional Model available at IWM has been used as the basis of development of drainage model for this study.The South West Region Model (SWRM) is one of the six regional models of Bangladesh developed at Institute of Water Modelling (IWM). It is basically a river network model, developed using two separate module of MIKE 11 modelling system; rainfall-runoff modelling (hydrological modelling, MIKE11-NAM) and hydrodynamic modelling (MIKE11-HD), which has been developed and continuously updated for some 20 years at IWM. This regional model covers the entire area lying to the south of the Ganges and west of the Meghna estuary.

The drainage model has been developed updating and incorporating the newly surveyed primary and secondary data as mentioned earlier into the Southwest Regional Model. In the original Southwest Regional Model polder information was not included. Hence, it is updated incorporating newly surveyed cross-section data of the internal drainage channels and existing water control structures within the polder area including detailed catchments distribution for the internal drainage channels and peripheral river systems for developing the drainage model. In the drainage model set up the polder drainage networks are connected to the peripheral river systems through water control structures. These structures have been entered properly with their dimensions and invert levels together with their operating rules i.e. if the outside water level is higher than that of polder water level the gates of the structure will automatically be closed and vice versa. Within the polder the runoff generated from the catchment is routed into the respective drainage khals in proportion to their respective drainage area which eventually drained towards the peripheral khals through the structures. The schematic diagram of the drainage model is shown in **Figure 5.6**.

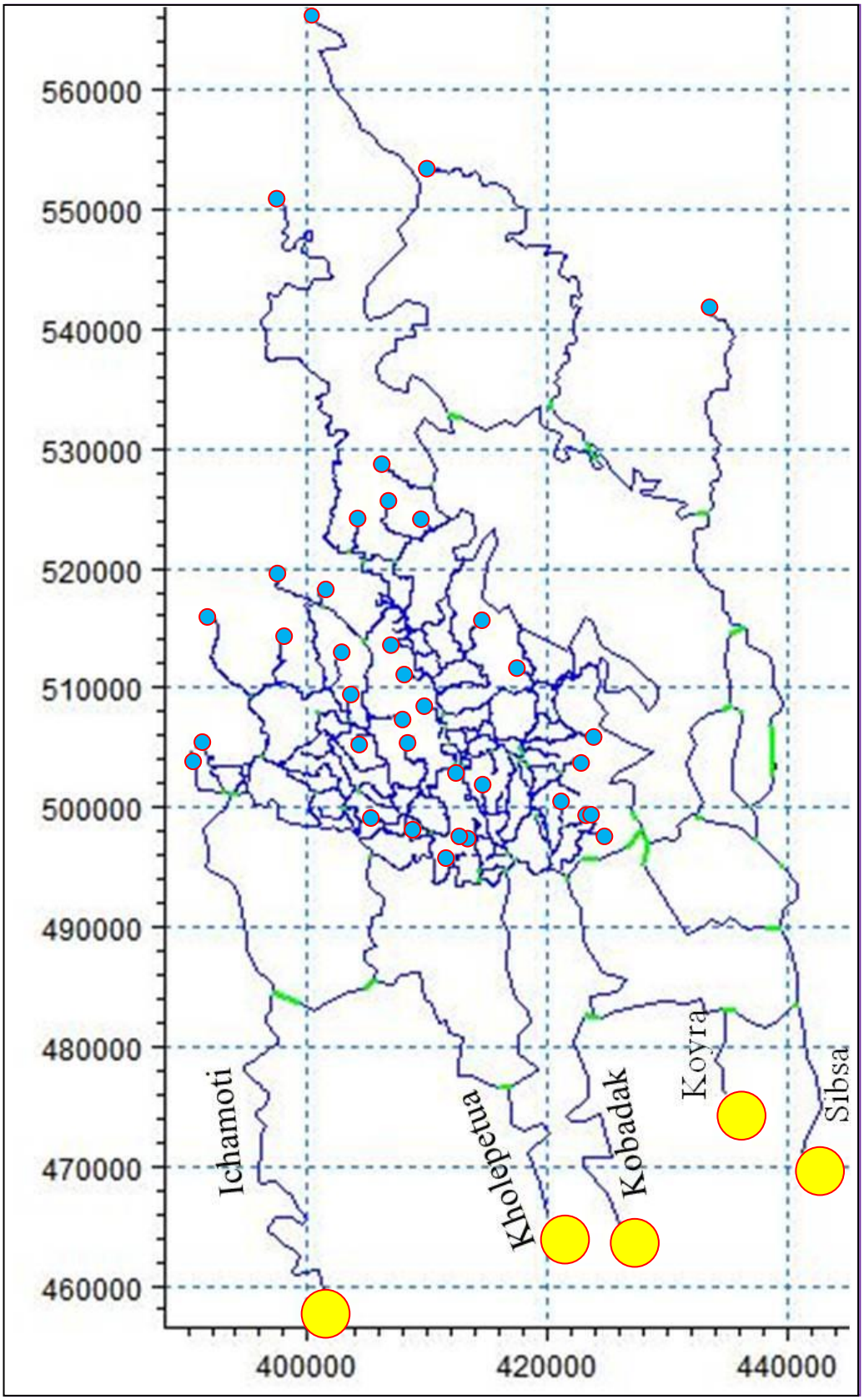


Figure 5.6: Schematic Diagram of River and Khals Network of Drainage Model

5.2.3 Hydrodynamic (HD) Model

In order to investigate the hydraulic characteristics such as water level fluctuations, variation river flow with tide, flow variation during dry and monsoon seasons a hydrodynamic model of the rivers and khals in the project area was developed. The model includes the rivers and internal drainage khals within the project boundary. The coverage of the numerical model is shown in **Figure 5.6**. A dedicated model was developed based on the existing South West Regional Model (SWRM), which was developed and updated by IWM under yearly validation program of southwest river network for flood forecasting purpose. The calibrated and validated model for hydrological year 2009-10 (April 2009 to March 2010) and 2012-13 was used to develop the model for this project. This hydrodynamic (water flow) model is updated using latest data and information collected from the field data collection program under the present study and including the internal khals of the project area. In order to represent the two-dimensional vectors of flow, a two-dimensional model has also been developed using MIKE 21 FM module system including the main river system of the project area.

The boundaries of the 2D model generated from the 1D model. The grid or mesh size decreases (or the resolution increases) towards narrow width rivers. The inter-tidal areas are flooded and dried during a tidal cycle, both in nature and in the model also.

Calibration

Calibration is an iterative procedure to make an adjustment between observed values and simulated values of a variable with a desired level of accuracy through adjusting certain parameters of model. Channel roughness (Manning's M is the inverse of Manning's n) is the controlling calibration parameter of hydrodynamic model. The calibration of the Drainage Model is done by comparing the simulated water level and discharge with observed values of Betna River. The calibration plot is shown in **Figure 5.7 and 5.8**. From the figure it is revealed that the simulated result matched well with the observed value for both water level and discharge.

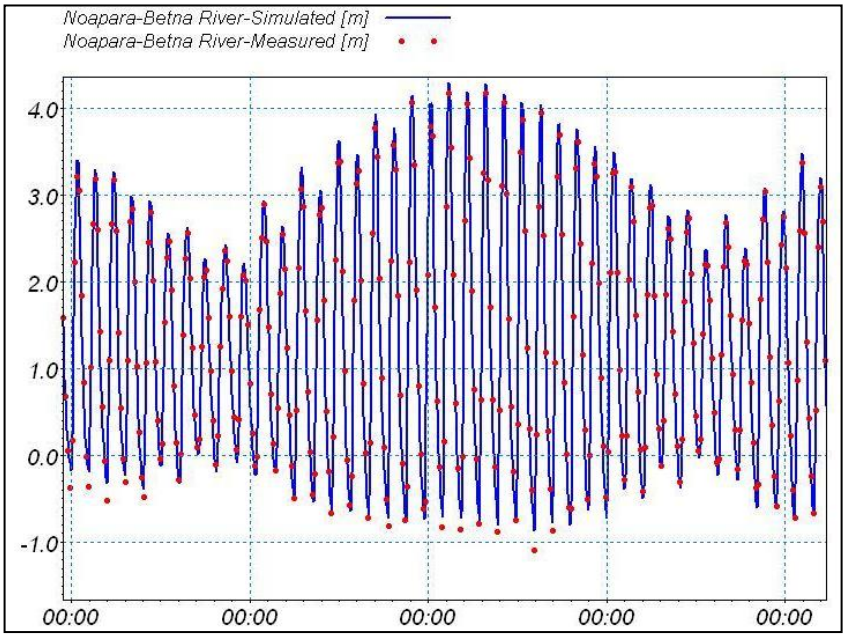


Figure 5.7: Comparison of Observed and Simulated Water Level of Betna River

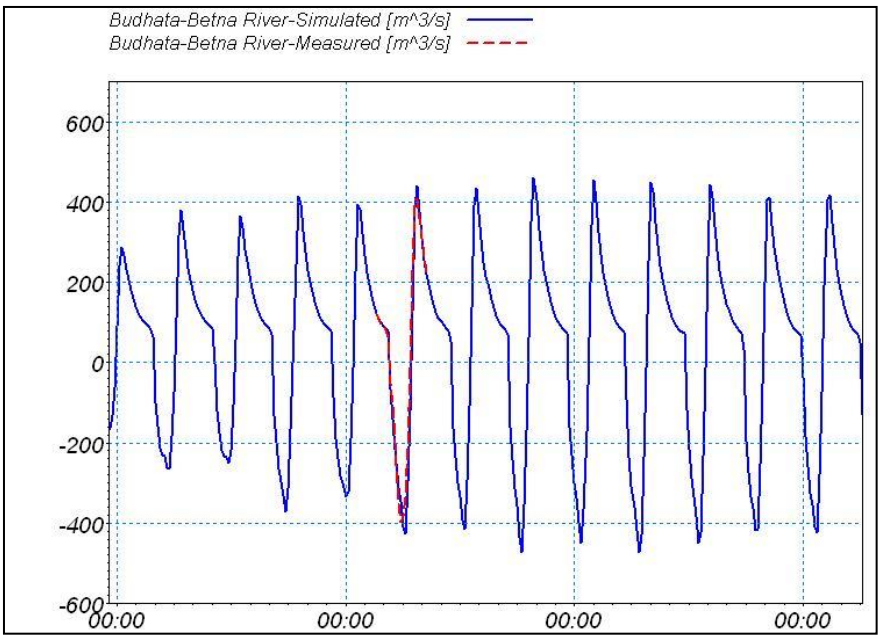


Figure 5.8: Comparison of Observed and Simulated Discharge of Betna River.

5.2.4 Morphological Model

Morphological model is an effective tool to assess the effectiveness and sustainability of dredged channels in terms of re-siltation/backfilling rate in the dredged section. In order to establish morphological characteristics of the Betna and Marirchap rivers, sediment transport/morphological model have been developed and applied it to quantify the backfilling rate of at the dredged sections of these rivers. As the sediments in these rivers are cohesive in nature, a cohesive sediment transport model is developed. The layer which has been recently relocated is considered as soft layer and used to describe the bed in the sediment transport model. The layer is assumed to form the bed surface consolidated for approximately one day to one week. The model has been development for 45 km River stretch for Betna River and 30 Km for Marirchap River. Mike21 FM module of DHI is used to develop the morphological model. The hydrodynamic model is coupled with sediment transport and bed changes modules. The hydrodynamic module solves either the 2-dimensional, depth-integrated equations for a fluid (Abbott et al, 1973), conservation of mass (continuity equation); and conservation of momentum equation (Newton's 2nd law expressed for a fluid).

The grid or mesh size decreases (or the resolution increases) towards narrow channel. Inter-tidal areas are flooded and dried during a tidal cycle, both in nature and in the model. Flexible mesh generated for the morphological model is shown in **Figure 5.9.**

Erosion and/deposition processes in a coastal river system is a very complex phenomena and it is particularly very complex for the coastal region of Bangladesh as there are lots of tidal and non-tidal rivers criss-cross forming large numbers of complex tidal meeting points. Sedimentation and erosion at a river reach depends on the net sediment transport at that specific reach of the river. Erosion rate is a function of stream energy whereas sedimentation rate is a function of suspended sediment concentration (SSC), settling velocity of particles, inundation time and local flow field. The higher the value of the first three factors the higher is the sedimentation rate and the lower the value of the local velocity below a certain level the higher is the sedimentation rate.

River bed morphology can be changed by erosion or deposition at bed. Erosion is calculated on the basis of information on bed shear stress from the hydrodynamic module and a critical shear strength for erosion and it is specified for each layer dependant on consolidation of the layer. Only if the bed shear stress is bigger than the critical shear stress for erosion then erosion of the bed layer takes place. Depositing material on river bed always enters the top bed layer. Deposition of weak or strong flocks is calculated on the basis of bed shear stress from the hydrodynamic module, critical shear strength for deposition and settling velocity of the suspended sediment. The settling velocity is related to the depth averaged concentration is also related to the concentration. Only if the bed shear stress is smaller than the critical shear stress for deposition then deposition of suspended sediment in the water column takes place.

Critical bed shear stresses and dispersion coefficients are calibration parameters for the sediment transport model and have been used as constant for temporally and spatially in the model set up. Dispersion in tidal river is expected to be higher than in non-tidal river. Empirical dispersion formulation is used where dispersion coefficient 5 m^2/s is applied depending on the current speed and water depth. Dispersion coefficient is given by

$$D = K_2 \cdot \Delta x.u$$

Where, D is the dispersion coefficient, Δx is the grid spacing, K2 is constant and u is the local current speed.

Settling velocity of sediment particle mainly depends on sediment sizes. It also depends on formation of flocks, which in turn depends on salinity and temperature. Usually flocculation occurs when salinity level is higher than 10ppt, as salinity level in most of the location is less than 10 ppt influence of salinity has been ignored.

Suspended sediment concentrations at the open boundaries have been generated based on the simulated water discharges from one-dimensional hydrodynamic model of the south west region through these boundaries. The generated sediment concentration compared with measured concentration close to the boundary and tuned to be used as boundary for two-dimensional cohesive sediment model. The calibrated sediment transport model has been used to assess the effectiveness of dredged channels based on capital dredging and backfilling rate. The bathymetry of the two dimensional morphological model is shown in **Figure 5.10.**

Figure 5.9: Mesh for 2D Morphological Model Betna River (Left) & Marirchap River (Right)

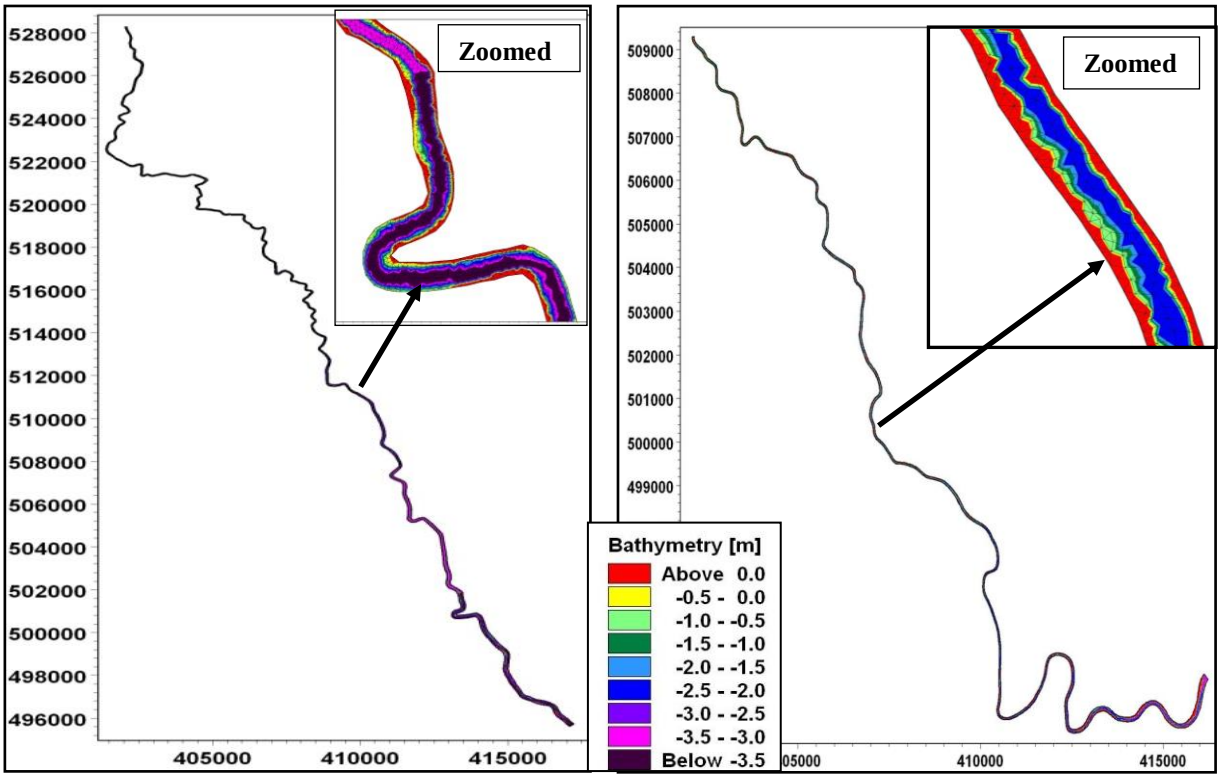


Figure 5.10: Bathymetry of Betna River (Left) & Marirchap River (Right)

The total bed thickness change in the Betna River based on the model result for six months during dry season is shown in **Figure 5.11**.

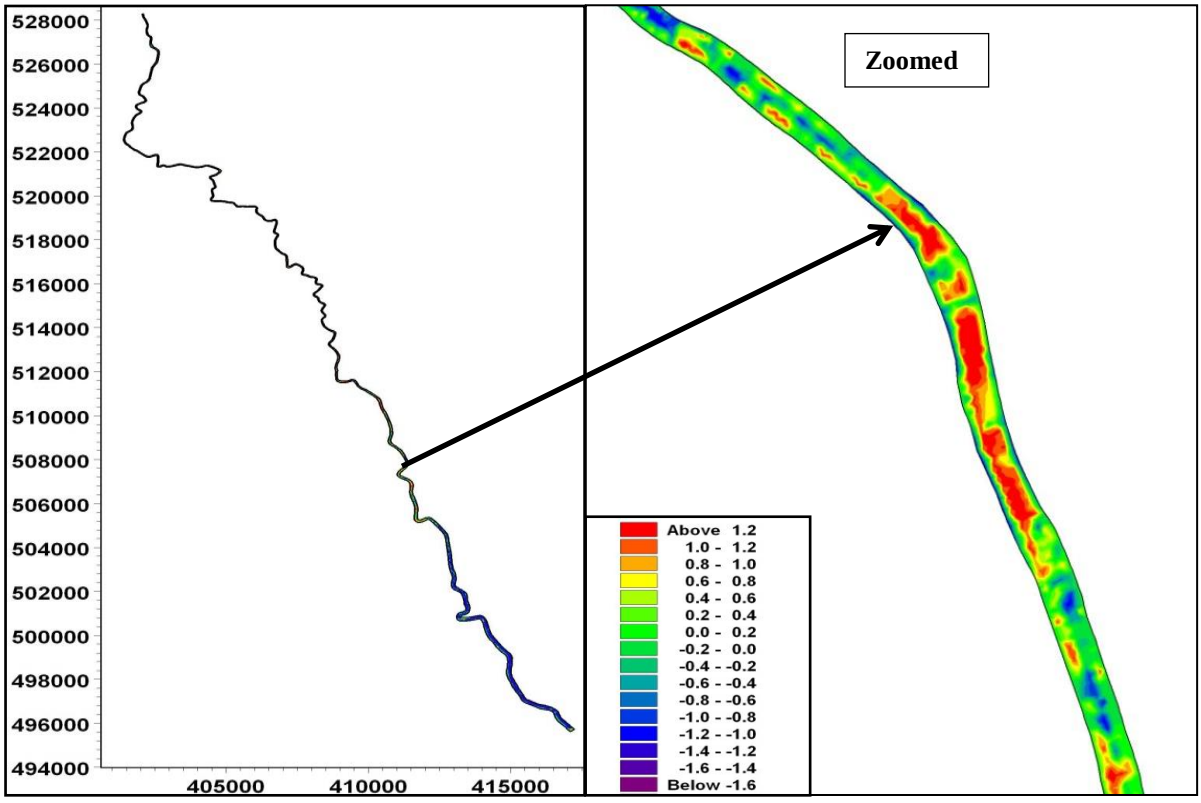


Figure 5.11: Total Bed Thickness change in Betna River during dry period

5.2.5 TRM Model

Basis of Tidal River Management (TRM)

A number of scientists opine that there is some relationship between the general dimensions of the entrance to a tidal estuary or tidal river in a sandy coast and volume of the tidal prism, but it appears that there was no previous attempt to achieve a definite correlation. Le Conte (1905) originated an equilibrium area concept for tidal inlets. O'Brien (1931, 1969) examined field data from tidal inlets through sandy barriers in the West Coast of the United States and determined a relationship between the minimum cross-sectional flow area of the entrance channel and the observed tidal prism and established an equation in the form:

$Ac = CPn$ ………………...………………..(1)

where, Ac is the minimum inlet cross-sectional area in the equilibrium condition, C is an empirically determined co-efficient, P is the tidal prism (typically during the spring tide/mean tide) and n is an exponent usually slightly less than unity. This type of analysis was carried out for the tidal rivers of southwest region in Bangladesh. Data of Kobadak River, Hari River, Pussur River and other rivers of this region has been used with a view to establishing a consistent relationship. In doing this, an excellent relationship was found between cross-sectional area & tidal prism expressed by the following equation:

$Ac = 43.42P^{0.9985}$ ………...……………..(2)

where, P = mean tidal prism (ebb + flood) in Mm3
Ac = cross-sectional area below mid tide level in m2

Figure 5.12 shows the relationship of x-sectional area and tidal prism (O'Brien Equilibrium relationship).

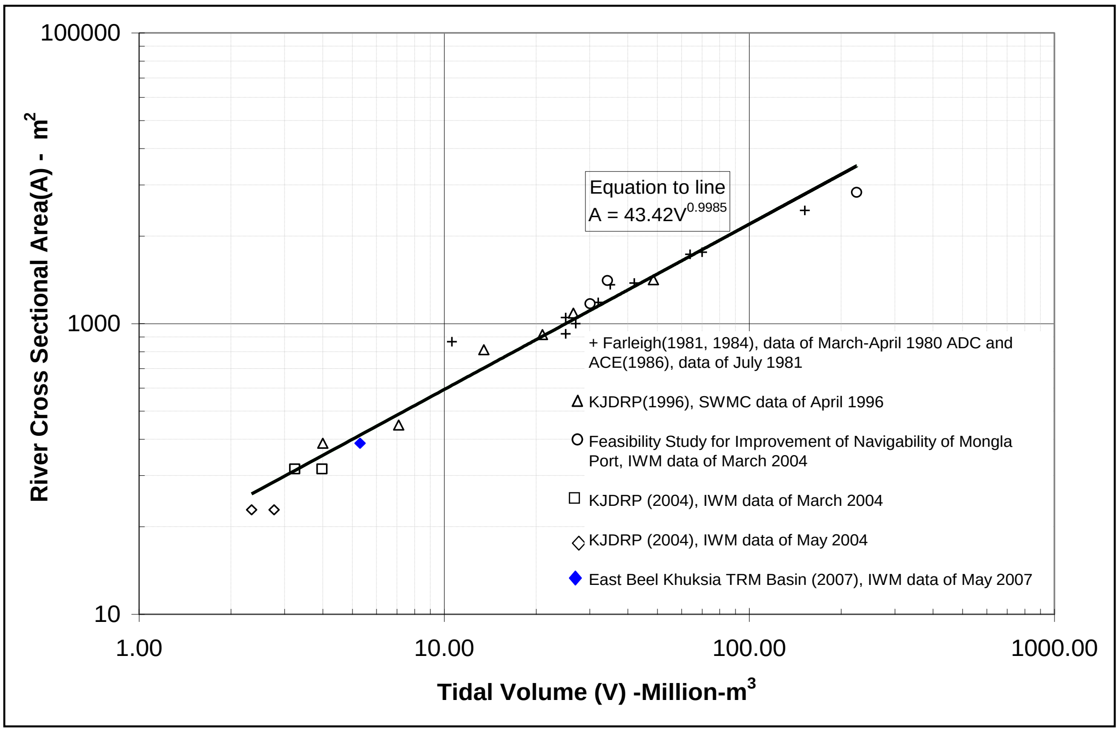


Figure 5.12: Relationship between Tidal Prism and Cross-sectional Area

Development of TRM Model

A physically based TRM model has been developed for the assessment of effectiveness of the selected beels as a tidal basin to maintain the required drainage capacity of the Betna and Marirchap rivers using MIKE11 one-dimensional river modelling system developed by DHI Water and Environment. In the model set up the downstream boundary is defined as tidal boundary providing half an hourly tidal water level time series for the dry season. The upstream boundary is defined as flow boundary or closed boundary depending on the upstream flow conditions. In the model set up the beel is connected to the main drainage route (rivers) with a link channel. The beel is schematized as a wide tidal basin based on its bottom topography and is allowed for natural free tidal movement.

After field investigations 11 nos of potential beels are identified for TRM operation. Depending on their location and size 5 different options are generated to operate TRM for which 5different TRM model set up were prepared for investigation. The potential beels are given in **Table 5.3**. Typical schematized river networks and beels of the TRM model is shown in **Figure 5.13.** Tidal prism (tidal volume in one tidal cycle) is considered as an important hydraulic parameter to assess the effectiveness of tidal basin since stability of a tidal river largely depends on it. The tidal prism, tidal range in the river and the beels have been calculated using the results of TRM model both for the spring and neap tide to examine the effectiveness of the proposed tidal basin (1 to 11) for tidal river management. The effectiveness of different beels for TRM operation under different options is described later in the following relevant sections.

Table 5.3: Potential Beels to be used as Tidal Basin with Sequence of Operation

SL No	Name of Beel	Sequence of Operation				
		Phase-1	Phase-2	Phase-3	Phase-4	Phase-5
1	Beel Hazikhali-Amudkhali	Sukdebpur Beel & Ticket Beel simultaneously for 8 years	Jealmari Beel & Matiadanga Beel simultaneously for 8 years	Sreeramkathi Beel & Bugmara Beel simultaneously for 8 years	Hazikhali-Amudkhali Beel & Gobindapur Beel simultaneously for 8 years	Aumtoli Beel ,Chapra Beel & Dorgahpur Beel simultaneously for 8 years
2	Beel Jealmari					
3	Beel Matiadanga					
4	Beel Ticket					
5	Beel Aumtoli					
6	Beel Gobindapur					
7	Beel Sukdebpur					
8	Bugmara Beel					
9	Beel Sreeram katthi					
10	Beel Chapra					
11	Beel Dorgahpur					

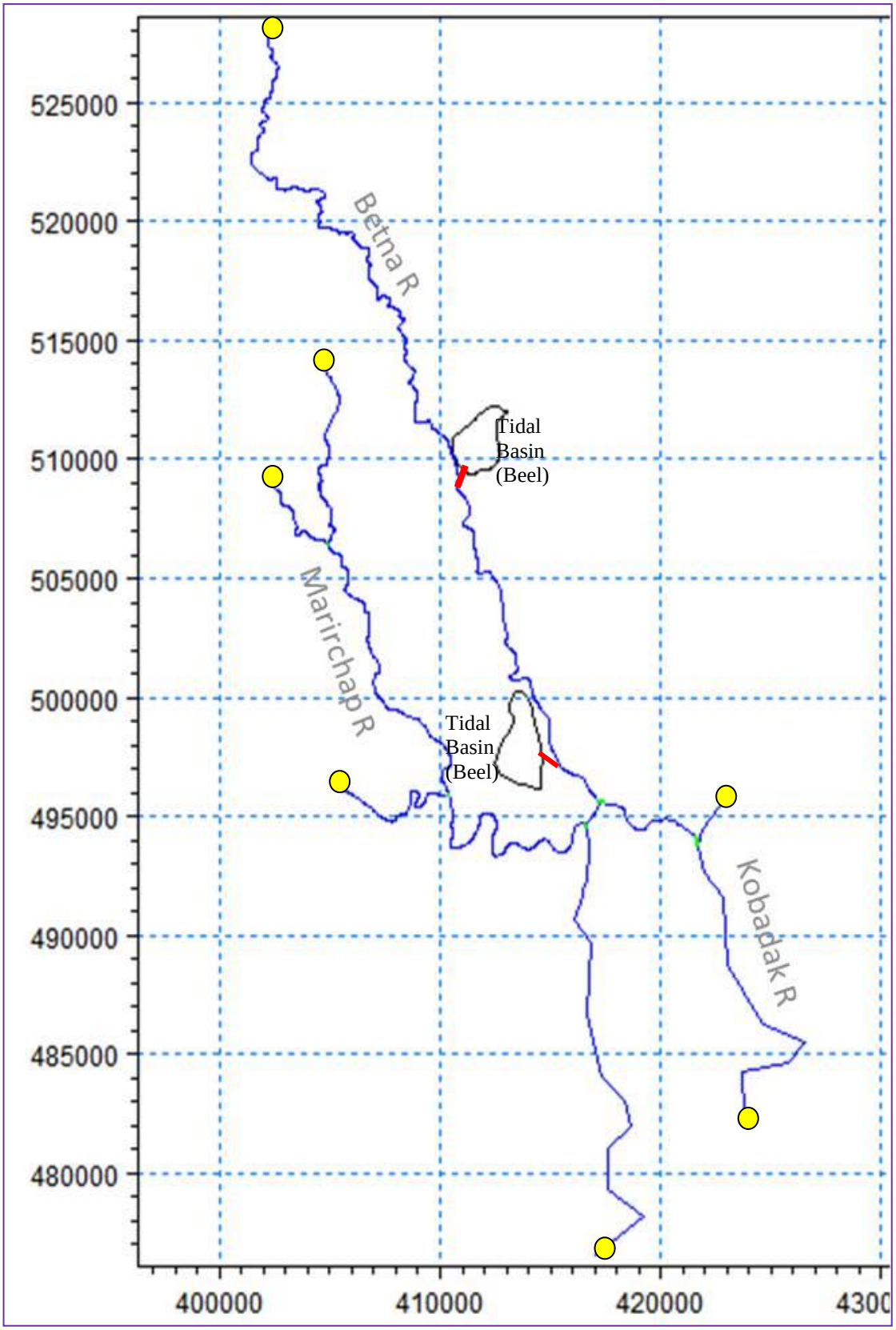


Figure 5.13: Typical Schematized River and TRM Basins of TRM Model Set up

CHAPTER SIX: DRAINAGE IMPROVEMENT OPTIONS AND EFFECTIVENESS

6.1 Potential Drainage Improvement Options

The study team made in-depth field investigation and interaction meeting with the local stakeholder in order to devise sustainable drainage improvement options. Two potential options have been formulated which are illustrated in the **Table 6.1.**

All the potential solutions are duly investigated using the mathematical model to assess their effectiveness in terms of decrease of inundation depth and extent and backfilling rate in the dredged channel. The details of Option-1 and Option-2 have been shown in the **Figure 6.1** and **Figure 6.2** respectively.

Table 6.1: Potential Drainage Improvement Options

SI	Proposed Interventions	Option-1	Option-2
A	***Dredging/Excavation of Rivers & Khals***		
A-1	Manual/Mechanical Excavation of Marirchap River (Km 0.00 to Km 37.00)	√	√
A-2	Dredging/Excavation of Betna River (Km 0.00 to Km 44.00)	√	√
A-3	Excavation of Parulia-Sapmara River (Km 0.00 to Km 23.50)	√	√
A-4	Excavation of Satkhira Khal (Km 0.00 to Km 8.00)	√	√
A-5	Excavation of Major and Minor Internal Khals (Length-357.00 km)	√	√
B	***Sequential operation of TRM at the proposed Tidal Basin for sediment management***		
Phase	1) TRM in Sukdebpur Beel (Betna Basin) +Ticket Beel (Marirchap Basin)	√	√
	2)TRM in Matiadanga Beel (Betna Basin)+ Jealmari Beel (Marirchap Basin)	√	√
	3)TRM in Sreeramkathi Beel (Betna Basin/Marirchap Basin) + Bugmara Beel (Marirchap Basin)	√	√
	4)TRM in Hazikhali- Amudkhali Beel (Betna Basin)+Gobindapur Beel (Marirchap Basin)	√	√
	5)TRM in Aumtoli Beel (Betna Basin)+Chapra Beel (Betna Basin)+Dorgahpur Beel (Marirchap Basin)	√	√
C	***Infrastructure***		
C-1	Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal	√	√
C-2	Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) in Polder-2 across Chumrikhali Khal	√	√
C-3	Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal	√	√
C-4	Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)	√	√
C-5	Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal	√	√
C-6	Repairing of existing structures(20 Nos)	√	√
C-7	Replacement of Bhatshala 4-vent sluice by a Bridge across Parulia-Sapmara khal	x	√
C-8	Remodeling of Shalkhali 4-vent sluice by a Bridge across Parulia-Sapmara khal	x	√
D	***Resectioning of Embankment at different location (41.50 km) in Polder-2, (44.42 km) in Polder-6-8, (21.00 km) in Polder 1, (14.00 km) in Polder 3 & (6.00 km) in Polder 4.***		
D-1	Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)	√	√
D-2	Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)	√	√
D-3	Resectioning of Embankment along the both banks of Paruluia Sapmara Khals from 28.00-49.00 (21.00 km) in Polder 1,from 23.00-37.00 (14.00 km) in Polder 3 & from 64.00-70.00 (6.00 km) in Polder 4	√	√
E	***Slole/River Bank Protective Work at different location (1.7 km) in Polder-2***		
E-1	Slope/River Bank Protective work along the Right banks of Betna River from 18.200 to 18.780; 19.753 to 20.193; 23.050 to 23.350;24.00 to 24.30 & 26.100 to 26.180 (1.70 km)	√	√

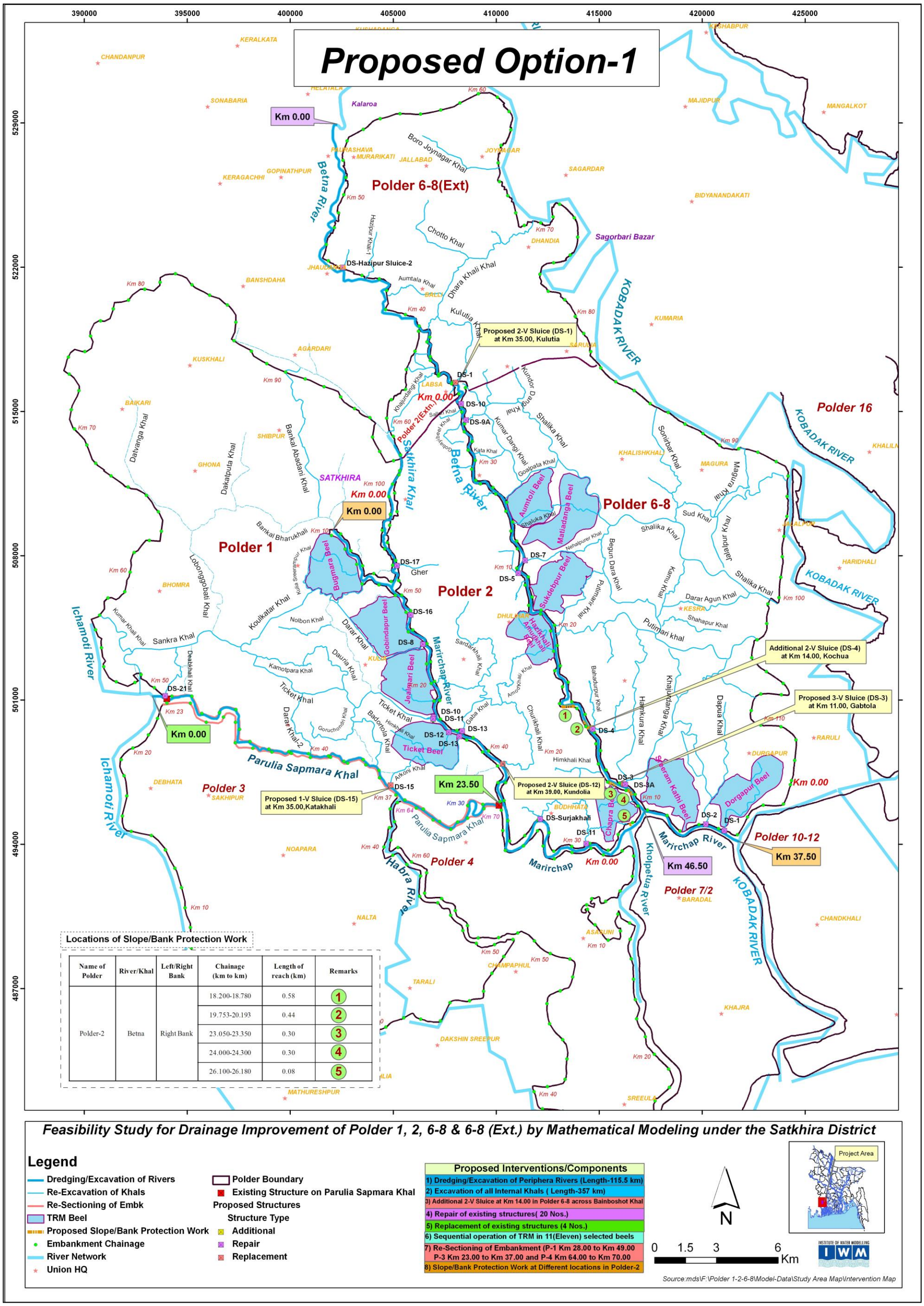


Figure 6.1: Potential Option-1

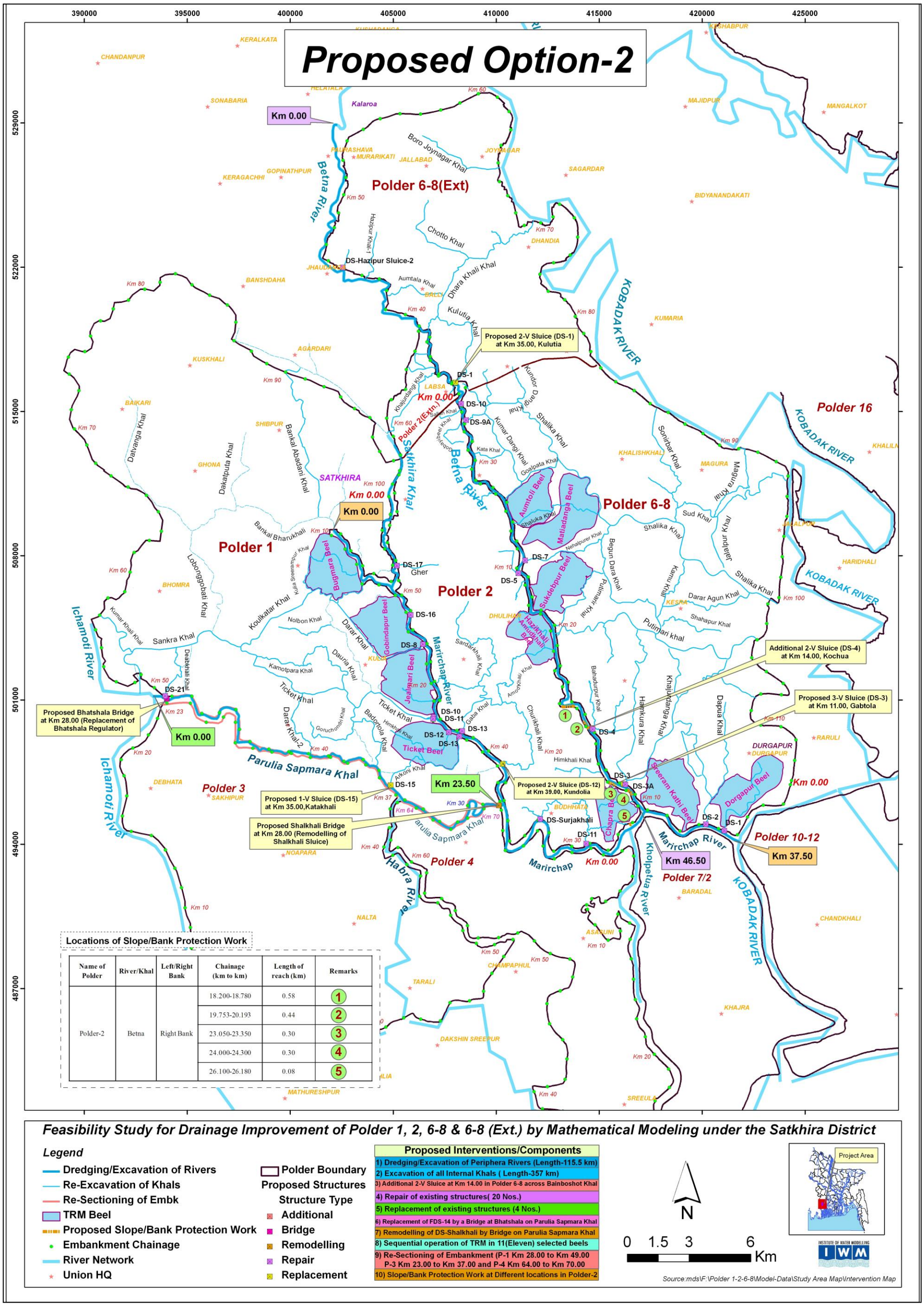


Figure 6.2: Potential Option-2

6.2 Drainage Improvement Interventions

The improvement of drainage congestion largely depends on the proper planning and implementation of best suited option. Considering the main objective and specific objectives, the study team found some critical problems and probable solutions. The necessities of the proposed interventions are given in the following sections.

6.2.1 Dredging/ Re-excavation of Peripheral Rivers/Khals

Dredging is an excavation activity or operation usually carried out at least partly underwater in rivers and shallow seas with the purpose of improvement of navigability through increasing the water depth. The critical silted up stretches of Betna River, Marirchap River Parulia-Sapmara Khal and Satkhira Khal need to be excavated to increase the drainage capacity. Drainage improvement measures by re-excavation of internal drainage khals, repair and rehabilitation of existing drainage structures, inclusion of new water control structures and TRM will not be effective unless the outfall rivers are made smoothly functional by dredging or excavation.

6.2.2 Re-excavation of Internal Drainage khals

Total 87 numbers of internal drainage channels have been identified for excavation in order to accelerate smooth drainage of the polder area. The channels are selectecd for excavation based on stakeholder discussions, field visits and model study results. Most of the khals have been silted up due to lack of re-excavation works under periodic maintenance. So, all the major and minor internal khals have been proposed for re-excavation to increase drainage and storage facility. The list of khals proposed for re-excavation in Polder-1, Polder-2 & Polder 6-8 have been furnished in **Table 7.1, Table 7.2** & **Table 7.3** respectively.

6.2.3 Construction of New or Additional Water Control Structures.

i) Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice in polder-1 across Arkoni (branch) Khal

This is a pipe sluice of two vent (each of 0.90m dia) (DS-15) was constructed during polder construction at the early 70.Flap gate of a pipe sluice do not last long because of it's non-monolithic & complicated gate hoisting system & also due to leakage at color joint between two pipes which can rarely be made 100% leak proof. The sluice has now become non-functional due to prolonged use & due to weather & salinity effect. A one vent box sluice of standard size have been proposed here as per drainage requirement & in concurrence with the BWDB & IWM's design team. Location of the structure will be at Easting: 404355 & Northing: 497481.

Photograph 5.1:The Existing 2-Vent (DS-15) Pipe Sluice is Under Soil across Arkoni Branch Khal (Polder-1)

ii) Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice in polder-2 across Chumrikhali Khal

This is another pipe sluice of four vent (each of 0.90m dia) was constructed during polder construction at the early 70. It was functioning more than its life time (i.e.30 years) .This has now become non-functional due to prolonged use & due to weather & salinity effect. A two vent box sluice of standard size has been proposed here as per drainage requirement & in concurrence with the BWDB & IWM's design team. Location of the structure will be at Easting: 410325 & Northing: 497900.

Photograph 5.2:The Existing 4-Vent (DS-12) Pipe Sluice is Under Soil across Chumrikhali Khal (Polder-2)

iii) Replacement of 2-vent sluice (DS-3) by 3-vent sluice in polder 6-8 across Khajurdanga khal

The DS-3 a 2-vent sluice in polder 6-8 was damaged long ago & became non functioning. It's openings have been closed by earthen x-bundh (barrier) to prevent washout of the structure breaching of embankment. Closing of the damaged sluice has exerted additional drainage load in the adjacent sluices. It was learnt from the local people that the sluice was under designed & was not capable to discharge from it's total catchment area. Based on their complain, as per demand of BWDB's field officials & as per drainage model a 3-vent sluice have been proposed here across the Khajurdanga khal as a replacement & in concurrence

with the BWDB & IWM's design team . Location of the new structure will be at Easting -416196, Northing-496919.

Photograph 5.3:The Existing Condition of Khajurdanga Sluice (DS-3) across Khajurdnaga Khal (Polder-6-8)

iv) Additional 2-vent sluice in polder 6-8 across Bainboshto Khal/Kochua Khal near (Ds-4)

The existing 1-vent (DS-4) sluice is functioning well but the velocity of flow is at an upper limit. BWDB field official informed that channel section & slope of Betna at this location is in is a favorable condition for drainage but due to inadequate number of vent, velocity has been increased endangering the stability of the structure & also causing delay in drainage to hamper transplantation of Boro crop as well. A two vent box sluice of standard size has been proposed here as per drainage requirement & in concurrence with the BWDB & IWM's design team. Location of the structure will be at Easting: 414680 & Northing: 499615.

Photograph 5.4:The Additional 2-Vent Regulator near Existing Kochua Sluice (DS-4) across Bainboshto Khal (Polder-6-8)

v) Replacement of 1 vent sluice (DS-1) by 2-vent sluice in polder 6-8 (Extn) across Kulutia khal

It was observed during field visit that the 1-vent (DS-1) sluice at Kulutia has became non functional long ago due to damage of it's vertical walls, gate& siltation up to box level. Due to blockage of inside drainage route water level has reached up to top level of embankment. Location of the structure being at the up-stream of Betna River, some sweet water will be available for irrigation in the month of October & November. BWDB field officials & the local people have a strong demand to replace it by a regulator of adequate opening. As per drainage model a 2-vent regulator have been proposed here in concurrence with the BWDB

& IWM's design team. The location of the proposed regulator will be at Easting-408035 & Northing-516404.

Photograph 5.5:The Existing Condition of Kulutia Sluice (DS-1) across Kulutia Khal (Polder-6-8-Extn)

6.2.4 Replacement of Bhatshala 4-Vent Sluice by a Bridge across Parulia-Sapmara Khal

Parulia- Sapmara khal originated from the Ichamati River at the downstream of Sankhra sluice & meets Marrischap River at the downstream of FDS-14 sluice. There are two sluices at the both ends of the khals. One is Bhatshala 4-vent sluice at the confluince of Ichamati & another is Sailkhali 4-vent sluice at the confluence of Marrischap. Parulia-Sapmara khal is the devider of polder -01 & polder -03.

FDS-14, a 4-vent sluice at Bhatshala across Parulia-Sapmara khal at the out fall of Ichamati was constructed to i) prevent intrusion of saline water during dry season in this khal ii) to prevent intrusion of flood water during extreme monsoon flooding & tidal surge. iii) to act the khal as a reservoir for supply water in the field/ghers when necessary. In addition the sluice is functioning as a bridge providing communication facilities like other sluices of the Coastal Embankment Project.

Photograph 5.6:The Existing 4-Vent (DS-Bhatshala) Sluice across Parulia Sapmara Khal

At present there is a demand from the local elites for a 8-vent regulator in place of FDS-14, 4-vent sluice at Bhatshala for quick drainage during monsoon & for supply of water during dry season for fish ghers. Drainage occurs from the up-stream of Polder -1 through Sankra

regulator. Drainage from a small area within the vicinity of the existing sluices occurs through Parulia-Sapmara khal into Ichamati River & Habra khal. Replacement of the 4-vent sluice by a 8-vent regulator as per demand of the local elites is not required from the point of drainage consideration. More ever removal of the sluice as per demand of the participants in the work-shop held in the conference room of the Deputy Commissioner, Satkhira is not possible by disrupting road communication. Replacement of the sluice by a new bridge would bring appropriate solution matching demands of all corners.

The main problem of the area is drainage congestion due to siltation in the rivers & khals. Reduction of upland flow is also an important factor for river siltation. In search of providing additional flow, it was explored that it can be done from the Ichamati River into Parulia-Sapmara khal through the existing 4-vent sluice at Bhatshala. In this case, the sluice need to be replaced by a bridge of adequate size to allow free flow & to restore communication. This will increase velocity, discharge and ultimately the tidal prism in the Parulia-Sapmara khal by widening & deepening of the section. The continuous flow during flow and ebb-tides will exert extra pressure along the wetted perimeter of the khal to widen & deepen the cross section by eroding bed material. More-ever Ichamati River get sweet water flow from Hoogly River through it's downstream distributories. This will reduce the salinity content in the down-stream channels of Parulia-Sapmara khal i.e.in Habra, Kobadak & Kholpetua.

6.2.5 Remodeling of Shalkhali 4-Vent Sluice by a Bridge across Parulia-Sapmara Khal

There is another 4-vent sluice at Shalkhali at the D/S of Parulia-Sapmara khal. This was constructed for drainage and to prevent intrusion of silt laden saline water in the khal. Participants expressed their demand in the workshop for free flow scenario without any structure. The demand was identical like Bhatshala sluice i.e removal of the sluice for uninterrupted free flow. Absolute removal of the sluice will solve the water related problem but will create social problem due to disruption of communication. To keep communication un-disturbed a bridge will be required. In this case total replacement of the sluice by a new culvert will not be necessary. During field visits it was observed that the sluice is in good condition & suitable for functioning as a bridge after remodeling. This can be done by i) breaking the vertical C/S & R/S head-walls, ii) breaking the slab at six feet height from the box floor, iii) raising the height of the piers and finally iv) casting the top slab at embankment level monolithically with top end of the both side abutment & the re-cast piers . Re-modeling of the structure will increase discharge in a free flow condition to create eroding velocity & reduce salinity in the adjacent down-stream rivers.

Photograph 5.7:The Existing 4-Vent (DS-Shalkhali) Sluice across Parulia Sapmara Khal

Like opening of the Bhatshala sluice, some people have suggestion to open the Sankra sluice permanently to allow free tidal movement through Kolkata & Ticket khal. The proposal is not at all feasible to allow tidal water into the polder area through a gigantic 15-vent sluice. In lieu of solving drainage problem, this will create further inundation rather can make havoc. More ever Scenario of Parulia-Sapmara khal with that of Kolkata-Ticket khal is not identical. Because Parulia- Sapmara khal is a divider of polder-1 and polder-3 and have embankments along it's both banks, which is not there along any bank of Kolkata or Ticket khals. But this can be done by dividing polder-1 into two sub-polders with construction of embankments along the both banks of Kolkata & ticket khals, and construction of sluices where necessary. But before that a detail feasibility study will be required. This can be done under the ensuing Coastal Embankment Rehabilitation Project or as a separate feasibility study project

The proposed water control structure for Replacement /Remodeling are given in the **Table 6.2.**

Table 6.2: Proposed Existing Water Control Structures for Replacement /Remodelling

SI	Polder	Outfall Khal Name	Easting (m)	Northing (m)	Structure Description	Proposed Interventions
1		Parulia Sapmara Khal	394013	501093	DS-14-Bhatshala (4V-1.52x1.83)	Replaced by Bridge
2		Parulia Sapmara Khal	410142	495886	DS-Shalkhali (4V-1.52x1.83)	Remodelling of existing water control structure by Culvert
3	P-1	Arkoni Khal	404355	497481	DS-15 (2V-0.90dia)	Replacement by 1-Vent (1.50X1.80) Regulator
4	P-2	Chumrikhali Khal	410325	497900	DS-12 (4V-0.90dia)	Replacement by 2-Vent (1.50X1.80) Regulator
5	P-6-8	Khajurdanga Khal-BR	416196	496919	DS-3 (2V-1.52X1.83)	Replacement by 3-Vent (1.50X1.80) Regulator
6	P-6-8(Extn.)	Athar Biser Khal/Kulutia Khal	408035	516404	DS-1 (1V-1.52X1.83)	Replacement by 2-Vent (1.50X1.80) Regulator
7	P-6-8(Extn.)	Bainboshtho Khal/Kochua	414680	499615	DS-4 (1V-1.52X1.83)	Additional 2Vent (1.50X1.80) Regulator

6.2.6 Reparing of existing Drainage Structures

Total twenty (20) numbers water control structure have been proposed for repairing to provide full -functioning of existing structures and smooth drainage of the polder area.The proposed water control structure for repairing are given in the **Table 6.3.**

Table 6.3: Proposed Existing Water Control Structures for Reparing

SI	Polder	Outfall Khal Name	BTM_X (m)	BTM_Y (m)	Structure Description	Proposed Interventions
1	P-1	Darar Khal	406458	503705	DS-8 (3V-0.90 dia)	**Repair :** • *Flap Gate replace* • *Vertical Gate replace* • *Reconstruction of Railing* • *Concrete repair* • *Pier and Abutment repair* • *C/S and R/S loose apron repair* • *Wing walls and return walls repair*
2	P-1	Ticket Khal-Br.	406966	500181	DS-10 (2V-1.50X1.80)	
3	P-1	Ticket Khal	406952	500088	DS-11 (5V-1.50X1.80)	
4	P-1	Ar Khoni Khal	407706	499430	DS-12 (4V-1.50X1.80)	
5	P-1	Deabkhali Khal	393930	501203	DS-21 (2V-0.90 dia)	
6	P-2	Arkoni Khal	408267	499233	DS-13 (1V-1.50X1.80)	
7	P-2	Busghata Khal	411088	507149	DS-5 (1V-1.52X1.83)	
8	P-2	Novaf Khali Khal	414386	494024	DS-11 (1V-1.52X1.83)	
9	P-2	Gaba Khal	408356	499499	DS-13 (2-1.52x1.83)	
10	P-2	Salmary Khal	405853	505131	DS-16 (2V-0.91dia)	
11	P-2	Gher	405191	507522	DS-17 (1V-1.52X1.83)	
12	P-2	Surjakhali Khal	412147	495219	DS-Surjakhali (2V-1.52x1.83)	
13	P-6-8	Khodalsha Khal	421087	494660	DS-1 (1V-1.52X1.83)	
14	P-6-8	Tetulia Khal	420192	494973	DS-2 (1V-1.52X1.83)	
15	P-6-8	Bainboshto Khal	414702	499595	DS-4 (1V-0.91X1.21)	
16	P-6-8	Nehalpurer Khal	411414	507775	DS-7 (3V-1.52X1.83)	
17	P-6-8	Kajurdanga Khal	416277	496901	DS-3A (3V-1.52X1.83)	
18	P-6-8	Shaluka Khal-Br	408544	514584	DS-9A (1V-1.52X1.83)	
19	P-6-8	Wapda Khal	408302	515371	DS-10 (2V-0.90dia)	
20	P-6-8(Ext.)	Hazipur Khal	402564	521988	DS-Hazipur Sluice-2 (2V-1.52X1.83)	

6.2.7 Re-sectioning of Embankment and Slope Protection Works:

There is a large network of embankment exists along the periphery of the rivers constructed during implementation of polders. It also provides road communication facilities to the villagers. The earthen embankment turns muddy & slippery during rainy seasons & there by become unusable as road communication. Under the annual routine and periodic maintenance works by food resource, BWDB implemented a lot of embankment-repair works from time to time in the decades of 80's & 90's. Since the decade of 2000 the food resource was not available as a result, embankment maintenance works were discontinued. Repair works of a limited length of badly damaged portion could be implemented within the provision of annual O & M budget. Due to lack of maintenance works, condition of embankment of the coastal

polders (i.e Slope, width & height of embankment) became vulnerable within the last decade. Condition of embankment as a whole is damaged by wind & rain action and human & cattle movement. Slope of embankment is mostly damaged by wave action, where as top of embankment is damaged due vehicular movement .More ever severe cyclonic storms like Sidr, Aila etc, occurred over the coastal area which deteriorated the condition of embankment seriously. The embankment frequently used as road, was up-grated as metalled pavement by LGED. This has reduced deterioration by weather affect but has created serious obstruction against re-sectioning works.

During the last field visit with a team of BWDB design, planning & field officials visited some vulnerable locations of embankment where some reaches need to be re-sectioned and some reaches need slope protection work. BWDB field officials expressed their demand to incorporate the most vulnerable reaches of slope protection & re-sectioning works in this study report. The proposal was supported by the other members of the team realized that without including the proposal full benefit may not be achieved if frequent breaches of embankment occur.Visualizing the constraint of time, the visiting IWM team agreed to incorporate the proposal in the study report without any detail design and subject to provision of the specific locations of the re-sectioning and slope protection works to IWM by the BWDB field officials. A list of the following reaches for re-sectioning of embankment and slope protection against wave action have been provided to IWM by the BWDB field officials are given in the **Table 6.4.**

Table 6.4: Reaches Requiring Resectioning of Embankment & Slope Protection works

Name of Polder	River/Khal	Left/Right Bank	Chainage (km to km)	Length of reach (km)	Remarks
Polder-1	Parulia Sapmara	Left Bank	28.00-49.00	21.00	*Re-sectioning of the Embankment (Polder 1, Polder 3 & Polder 4) along the both bank of Parulia Sapmara khal is required due to changed scenario.* ***(Total Length :41 km)***
Polder-3	Parulia Sapmara	Right Bank	23.00-37.00	14.00	
Polder-4	Parulia Sapmara	Right Bank	64.00-70.00	6.00	
Polder-2	Betna	Right Bank	1.00-17.50	16.50	*Re-sectioning of Embankment for Polder 2, Polder 2(Extn), Polder 6-8 & Polder 6-8 (Extn) have been proposed by the BWDB Satkhira field officials supported by the planning & design team.* ***(Total Length :85.92 km)***
			19.00-23.00	4.00	
			23.35-25.35	2.00	
	Marirchap	Left Bank	29.00-35.00	6.00	
			42.00-51.00	9.00	
Polder-2 (Extn)	Betna	Right Bank	2.00-6.00	4.00	
Polder-6-8	Kobadak	Right bank	1.10-5.00	3.90	
	Marirchap	Left bank	5.60-9.00	3.40	
	Betna	Left bank	9.00-11.00	2.00	
			11.5-12.00	0.50	
			12.60-20.00	7.40	
			20.00-33.50	13.50	
	Kobadak	Right bank	45.00-52.72	7.72	
Polder-6-8-(Extn)	Betna	Left bank	0.50-6.50	6.00	
Polder-2	Betna	Right Bank	18.200-18.780	0.58	*Slop/Bank Protection Work at different location.* ***(Total Length :1.70km)***
			19.753-20.193	0.44	
			23.050-23.350	0.30	
			24.000-24.300	0.30	
			26.100-26.180	0.08	

6.2.8 Tidal River Management

Drainage congestion in the study area attributes to the increase of sediment deposition on river bed. High tide brings huge sediment that deposits on river bed and ebb tide cannot erode that sediment. Gradually drainage capacity and tidal prism of the river decreases. TRM is the indigenous method of allowing tidal movement from the peripheral river into an embanked low-lying area through a link canal. It is a proven and tested method for sediment management where incoming silt will be deposited in the TRM basin instead of deposition in the canal bed on the other hand during ebb tide silt free water will pick silt from the river bed to reach in the equilibrium condition of sediment carrying capacity. After field investigations 11 nos of potential beels are identified for TRM operation. Beels along the left bank and Right bank of Betna and Marirchap river will be utilized as tidal basin for sediment deposition and increase of tidal prism and drainage capacity of the river.

6.3 Effectiveness of Drainage Improvement Options

6.3.1 Assessment of Effectiveness of Present Drainage System

The drainage performance/effectiveness of each option is evaluated in terms of decrease of flood, inundation area and depth of the polder area (land classification) compared to the existing condition. It is essential to examine the proposed drainage improvement plan to find out whether the project area can be drained within three days through the drainage system to save the agricultural crops and to avoid the prolong water-logging. This investigation is made by preparing flood inundation depth maps for 3-day duration maximum water level showing the area of different land classes (F0, F1, F2, F3 and F4) using model results and available Digital Elevation Model (DEM) of the study area. The analysis is carried out for both the average year flood and 1 in 20 year flood conditions. The results of inundation analysis are given in **Tables 6.5, 6.6 and 6.7** for 1 in 20 year flood event and in **Tables 6.8, 6.9 and 6.10** for average year flood event.The flood depth map is shown in **Figure 6.7 to 6.15.**

Table 6.5: Inundation area for 3 days duration Flood Level (1 in 20 year flood) of Polder 1

Existing Condition and Options	% Inundated Area						
	Flood Free	F_0 (inundation up to 0.3 m)	F_1 (inundation 0.3m to 0.9m)	F_2 (inundation 0.9 m to 1.8 m)	F_3 (inundation 1.8 m to 3.6 m)	F_4 (inundation >3.6 m)	Total (%) (FF,F0 & F1)
Existing Condition	11.06	5.99	14.56	28.05	40.35	0.00	31.60
Option -1	30.09	6.05	18.62	45.17	0.06	0.00	54.76
Option -2	31.82	6.38	24.05	37.74	0.01	0.00	62.25

Table 6.6: Inundation area for 3 days duration Flood Level (1 in 20 year flood) of Polder 2

Existing Condition and Options	% Inundated Area						
	Flood Free	F_0 (inundation up to 0.3 m)	F_1 (inundation 0.3 m to 0.9 m)	F_2 (inundation 0.9 m to 1.8 m)	F_3 (inundation 1.8 m to 3.6 m)	F_4 (inundation >3.6 m)	Total (%) (FF,F0 & F1)
Existing Condition	19.36	7.18	15.53	28.76	20.10	10.75	42.07
Option -1	46.41	15.14	27.93	10.51	0.00	0.00	89.49
Option -2	46.41	15.15	27.93	10.52	0.00	0.00	89.48

Table 6.7: Inundation area for 3 days duration Flood Level (1 in 20 year flood) of Polder 6-8 and 6-8 Extn.

Existing Condition and Options	% Inundated Area						
	Flood Free	F_0 (inundation up to 0.3 m)	F_1 (inundation 0.3 m to 0.9 m)	F_2 (inundation 0.9 m to 1.8 m)	F_3 (inundation 1.8 m to 3.6 m)	F_4 (inundation >3.6 m)	Total (%) (FF,F0 & F1)
Existing Condition	9.17	4.06	25.26	16.25	16.74	28.52	38.49
Option -1	23.69	7.82	46.62	20.10	1.78	0.00	78.13
Option -2	23.69	7.82	46.62	20.10	1.78	0.00	78.13

Table 6.8: Inundation Area for 3 Days Duration Flood Level (1 in 2.33 year flood) of Polder 1

Existing Condition and Options	% Inundated Area						
	Flood Free	F_0 (inundation up to 0.3 m)	F_1 (inundation 0.3 m to 0.9 m)	F_2 (inundation 0.9 m to 1.8 m)	F_3 (inundation 1.8 m to 3.6 m)	F_4 (inundation >3.6 m)	Total (%) (FF,F0 & F1)
Existing Condition	18.46	7.97	12.83	45.23	15.51	0.00	39.26
Option -1	40.93	8.96	39.15	10.96	0.00	0.00	89.04
Option -2	42.65	10.42	40.33	6.60	0.00	0.00	93.40

Table 6.9: Inundation Area for 3 Days Duration Flood Level (1 in 2.33 year flood) of Polder 2

Existing Condition and Options	% Inundated Area						
	Flood Free	F_0 (inundation up to 0.3 m)	F_1 (inundation 0.3 m to 0.9 m)	F_2 (inundation 0.9 m to 1.8 m)	F_3 (inundation 1.8 m to 3.6 m)	F_4 (inundation >3.6 m)	Total (%) (FF,F0 & F1)
Existing Condition	20.76	7.36	18.97	28.53	24.38	0.00	47.09
Option -1	56.99	16.61	24.04	2.37	0.00	0.00	97.63
Option -2	59.45	15.51	23.42	1.62	0.00	0.00	98.38

Table 6.10: Inundation Area for 3 Days Duration Flood Level (1 in 2.33 year flood) of Polder 6-8 and 6-8 Extn.

Existing Condition and Options	% Inundated Area						
	Flood Free	F_0 (inundation up to 0.3 m)	F_1 (inundation 0.3 m to 0.9 m)	F_2 (inundation 0.9 m to 1.8 m)	F_3 (inundation 1.8 m to 3.6 m)	F_4 (inundation >3.6 m)	Total (%) (FF,F0 & F1)
Existing Condition	12.42	9.73	23.46	15.00	39.39	0.00	45.62
Option -1	39.11	19.59	38.10	3.21	0.00	0.00	96.79
Option -2	39.37	19.93	37.77	2.94	0.00	0.00	97.06

The analysis indicates substantial improvement for all the polders under different options in terms of reduction of anticipated flood inundation for both the hydrological event (1 in 20 year flood and 1 in 2.33 year flood). Deeply inundated area has been decreased significantly under proposed options and consequently the productive agricultural land has been increased as well.

Polder 1:

In Option -1, about 36.14% area remains flood free (i.e., inundation up o .3 m depth of water) which is about 17.05% in pre-project condition. About 0.06% area remains under deeply inundation depth (depth>1.80m) which is more than 40% in present condition. Total inundation area (greater than F0) decreases from 83% in the pre -project condition to 63% in the proposed drainage improvement option-1. The total inundation area decreases to about 62% in option 2. The agricultural productive land increases from 31% to 55% and 62% in option 1and 2 respectively.

For average year flood event about 61% areas is likely to be flooded by more than 0.9 m depth under existing condition which seems to be reduced to only 11% and 6.6% under the proposed drainage improvement option 1 and 2 respectively.

Polder 2:

In Option-1 the analysis shows that about 61% area remains flood free which is about 26% in existing condition. The deeply inundated area decreases from 30.85% to 0.0% (depth>1.80m). The total inundated area decreases from 74% to 38% for drainage improvement option-1. Almost same amount of decrease is seen in option 2 for this polder. The agricultural productive land increases from 42% to 89.5% for option 1 and 2.

The analysis revealed that for average year flood event about 53% areas is likely to be flooded by more than 0.9 m depth under existing condition which seems to be reduced to only 2.37% and 1.62% under the proposed drainage improvement option 1 and 2 respectively meaning that substantial drainage improvement will be achieved by the proposed interventions.

Polder 6-8 & 6-8(Extn.):

In Option-1, 31.5% area remains flood free which is about 13% in pre-project condition. The deeply inundated area decreases from 45.26% to 0.0% (depth>1.80m). The total inundated area decreases from 86.8% to 68.5% for drainage improvement option-1. Almost same amount of decrease is found in option 2 for this polder. The agricultural productive land increases from 38% to 78% for this polder.

The analysis also shows that for average year flood event about 54% areas remains under inundation depth of more than 0.9 m for the existing condition which seems to be reduced to only 3.21% and 2.94% under the proposed drainage improvement option 1and 2 respectively. The study results show decrease of about 0.75m water level in Ticket Khal for Polder-1 which is connected to the Marirchap River under the final option **(Option-2)** compared to the present condition. Water level decrease about 1.0 m for Himkhali khal in Polder-2 which is connected to the Betna River under the same option. Water level decrease about 0.6 m for Tetulia khal in Polder-6-8 which is connected to the Betna River under the same option.The reduction of peak water level in the proposed plan implies the improvement of drainage

condition**. Figure 6.3, Figure 6.4 & Figure 6.5** shows the change of water level in Ticket Khal, Himkhali khal and Tetulia khal respectively. The effectiveness of proposed option for the average year flood is graphically presented in **Figure 6.3**

The analysis revealed that the productive agricultural land increases significantly in all the polders under proposed drainage improvement options. The improvement seems almost similar in the two selected options. Considering the technical, social and financial involvement, **option-2** may be proposed for implementation.

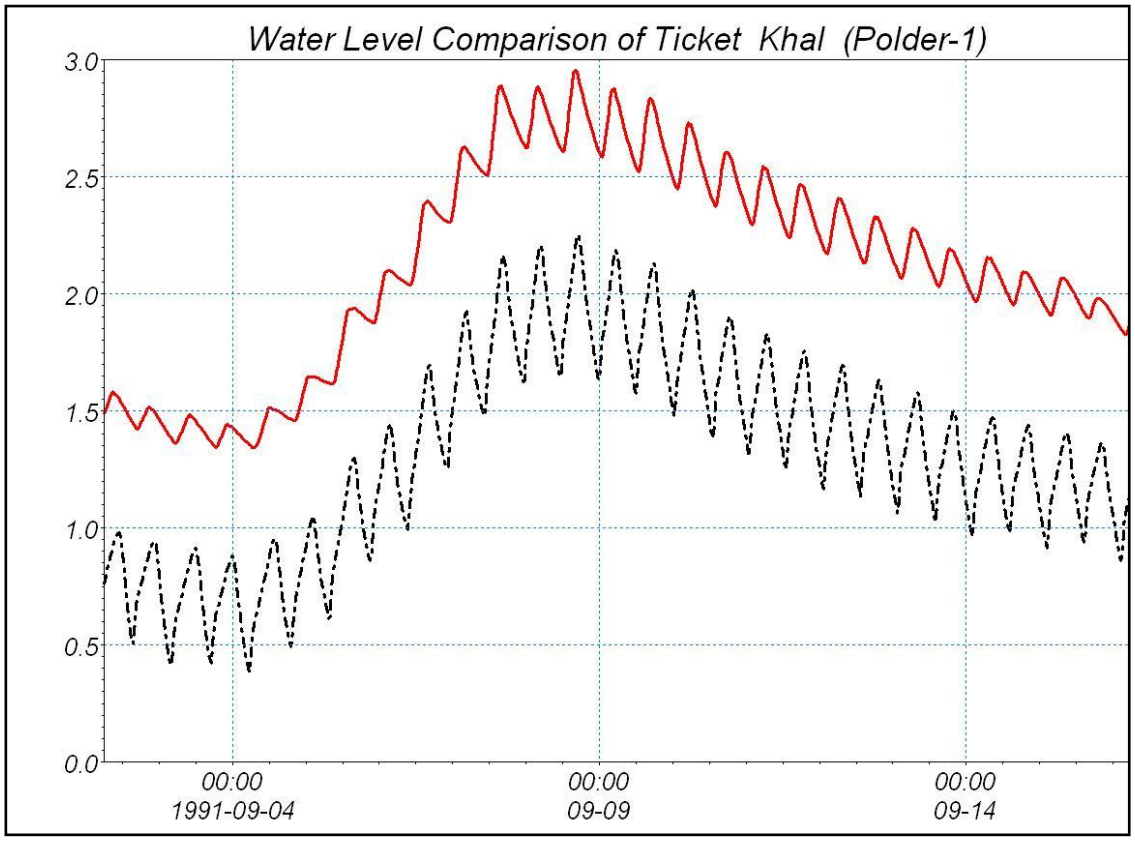


Figure 6.3: Water Level Comparison of Ticket khal in Existing Condition and in Option-2

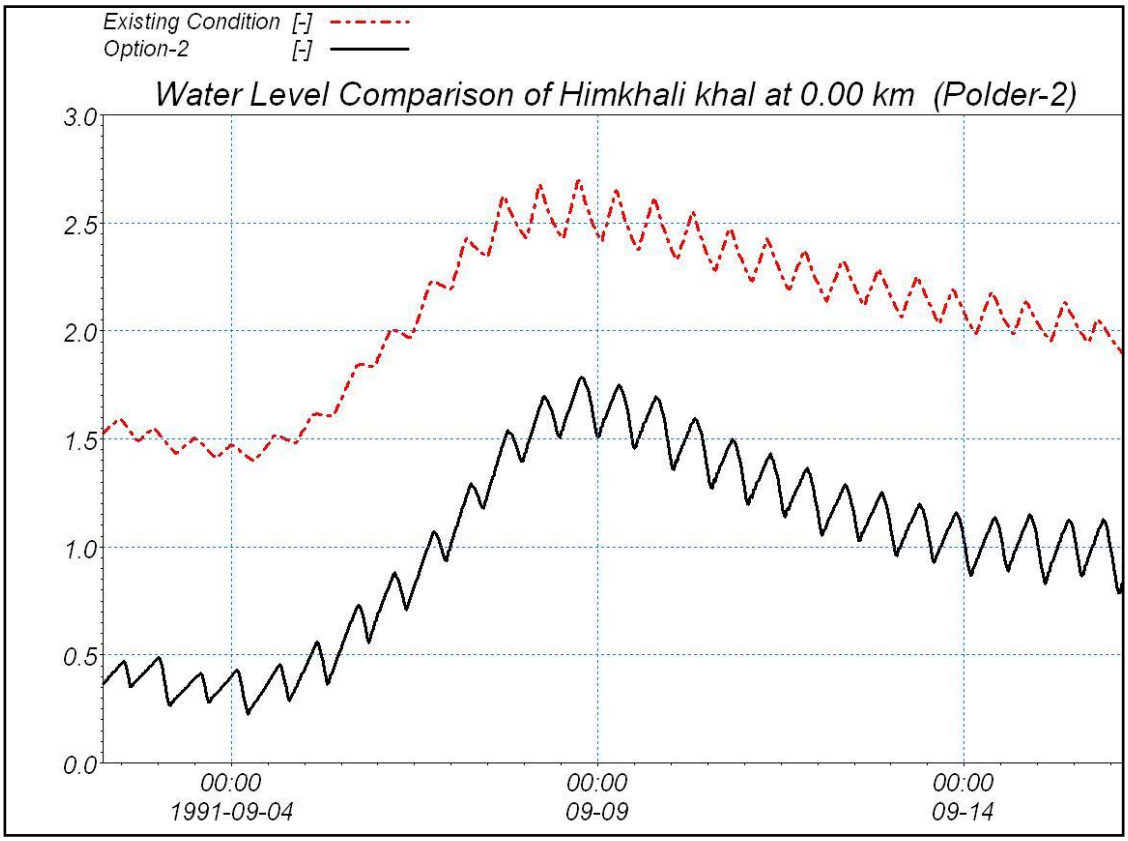


Figure 6.4: Water Level Comparison of Himkhali khal in Existing Condition and in option-2

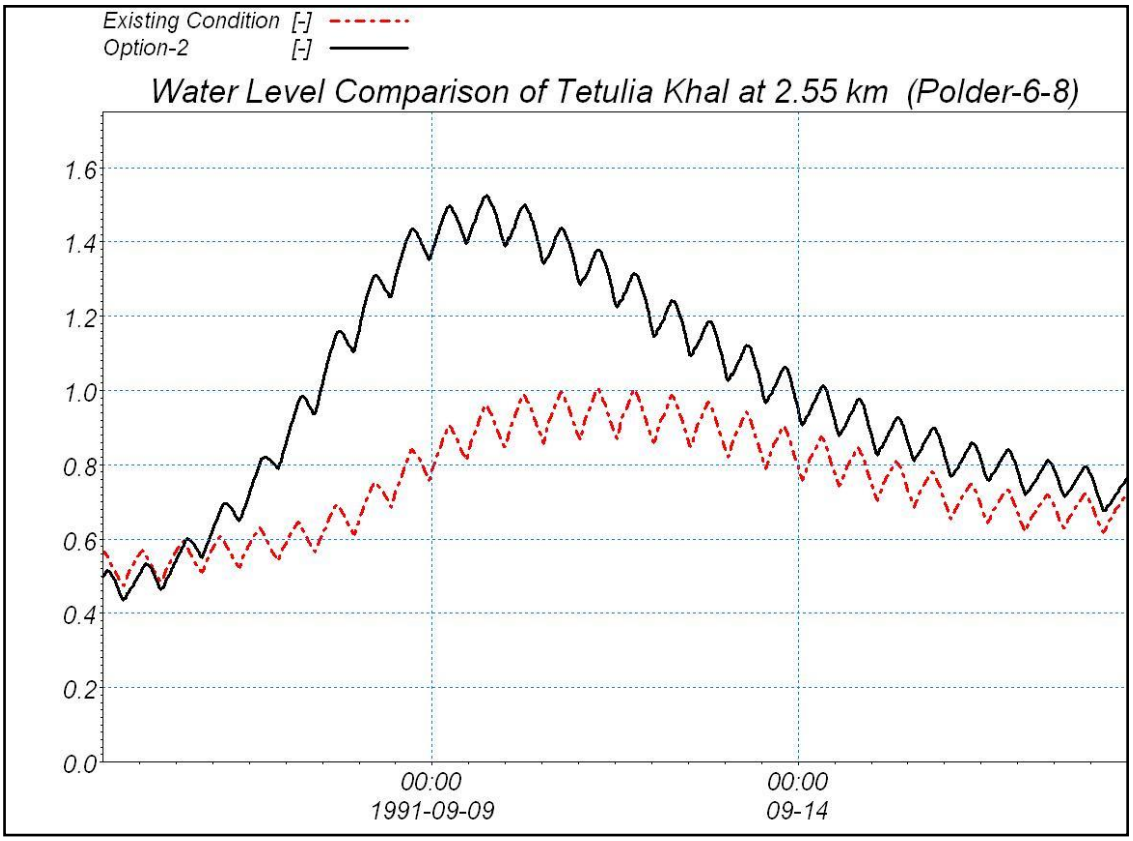


Figure 6.5: Water level comparison of Tetulia khal in Existing Condition and in option-2

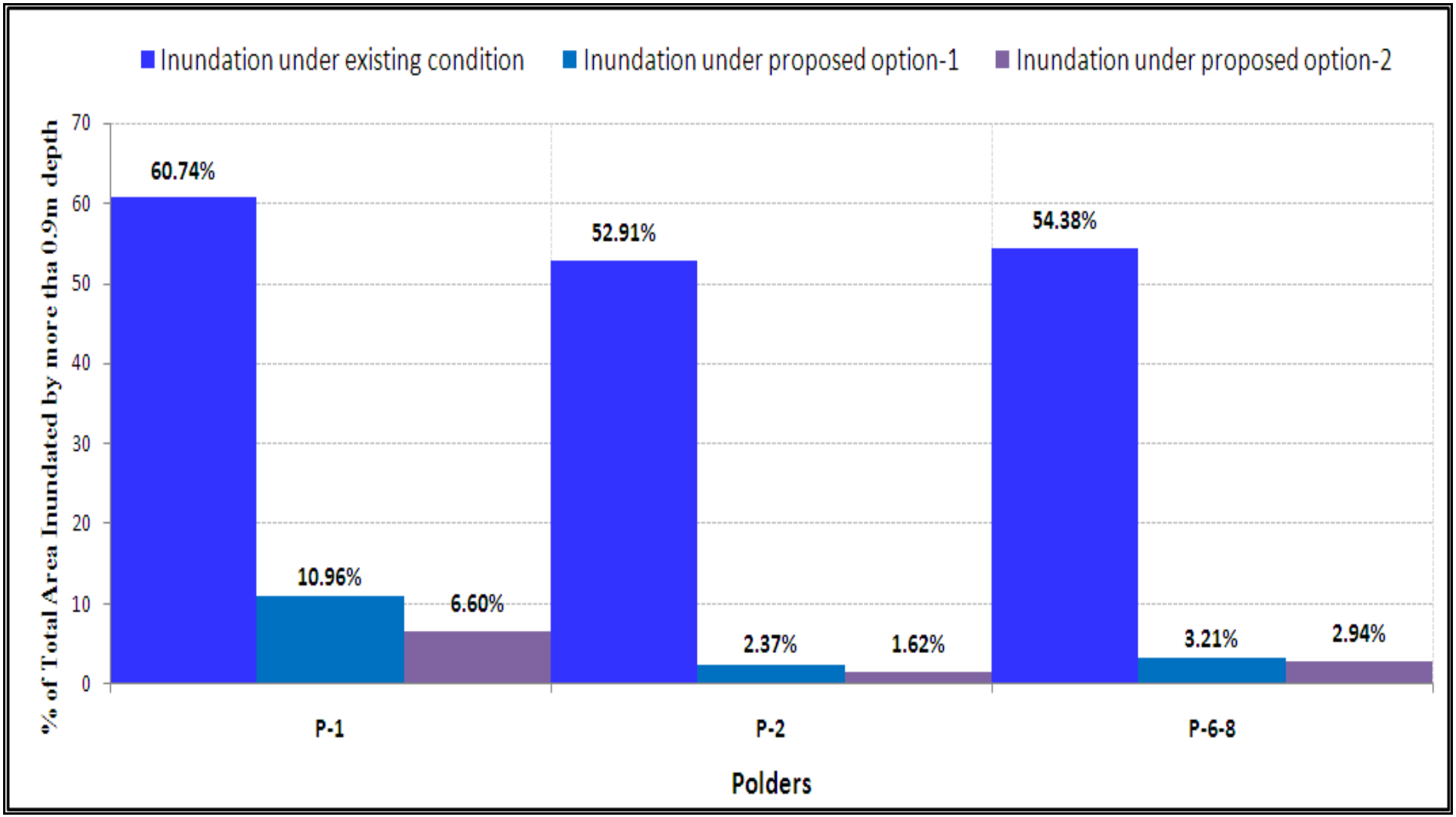


Figure 6.6: Effectiveness of Proposed Options for Average Year Flood (1 In 2.33year) for Individual Polders

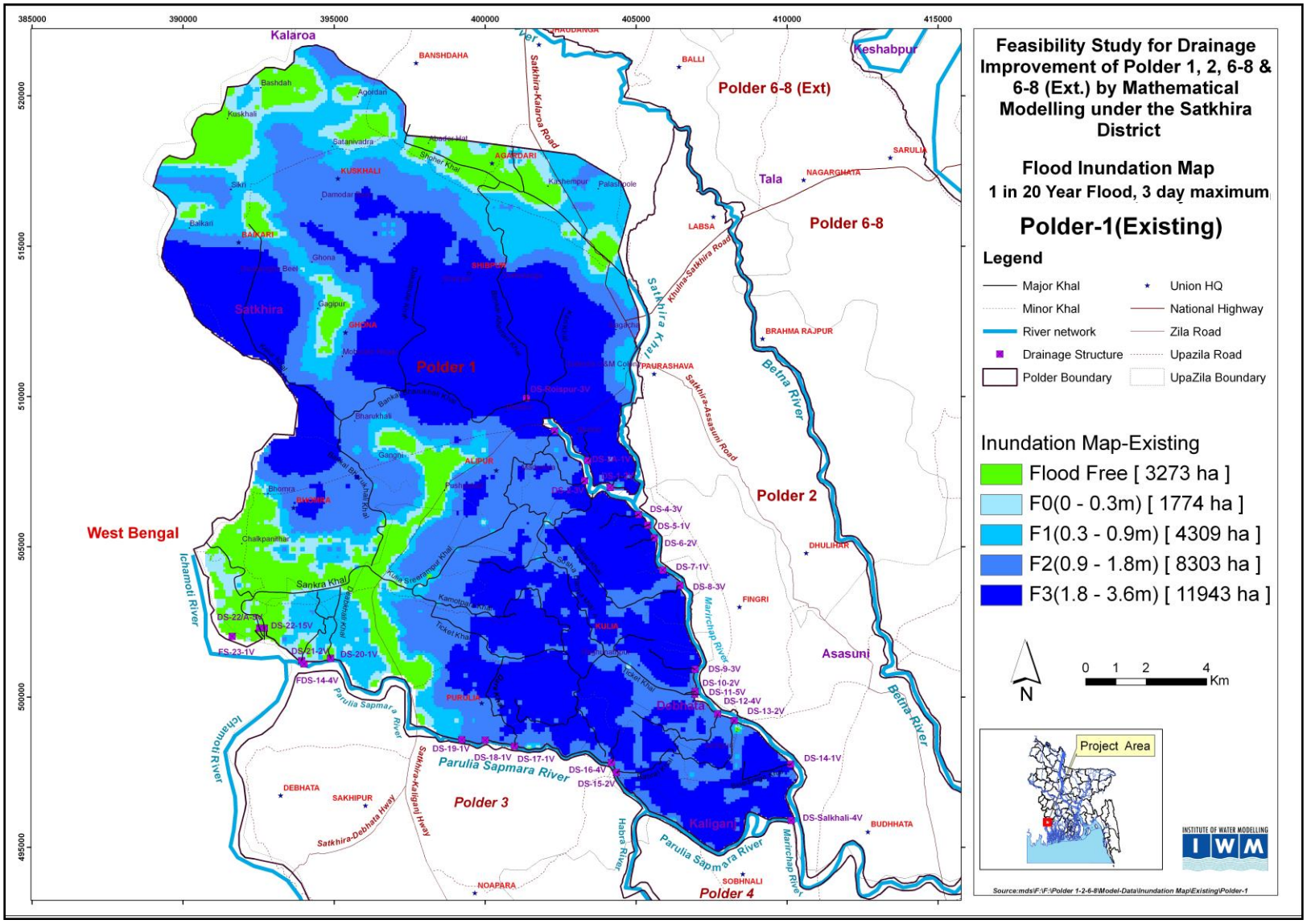


Figure 6.7: Inundation Depth for 3 Days Duration in the Present Condition for Extreme Flood Event. (Polde-1)

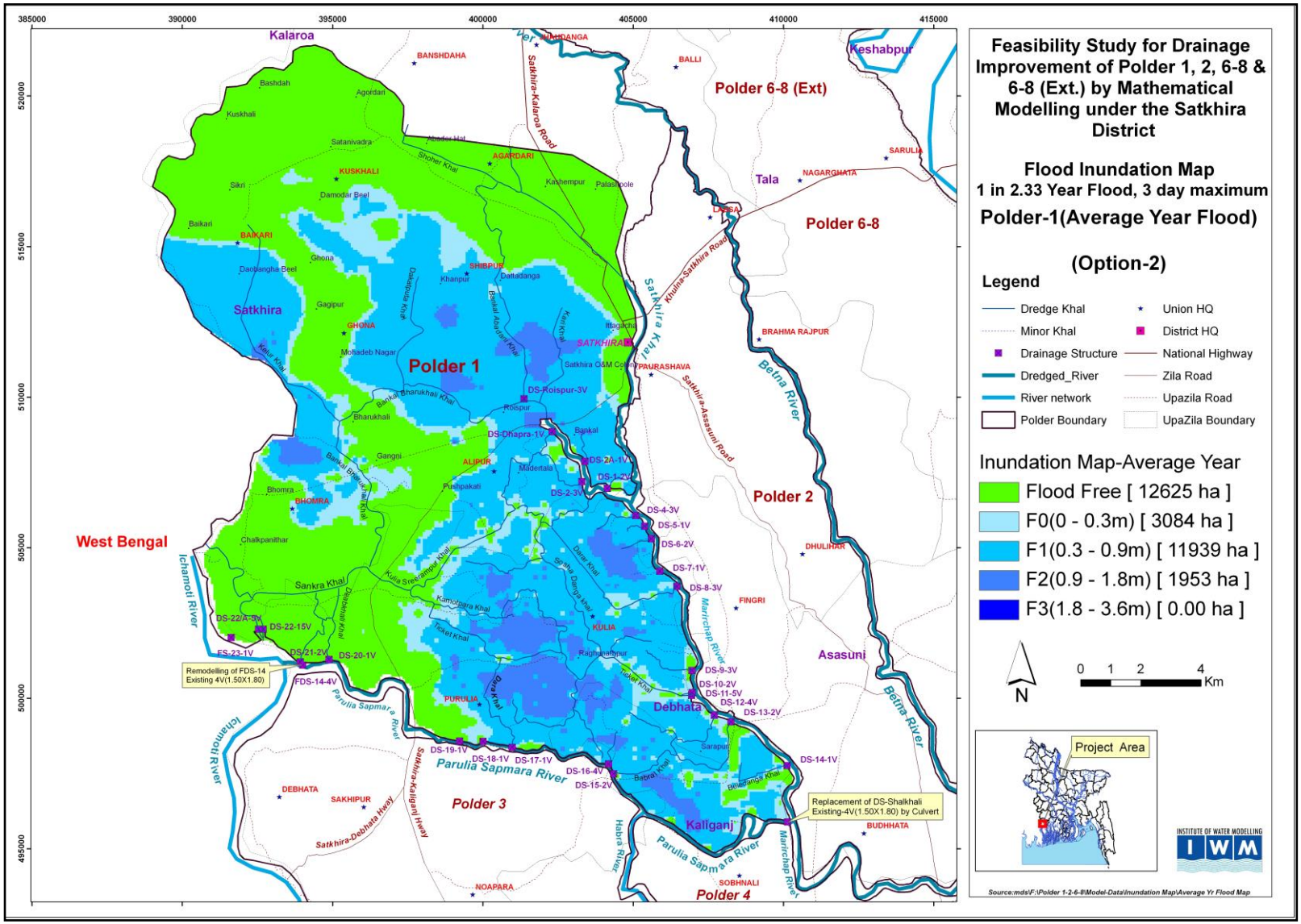


Figure 6.8: Inundation Depth for 3 Days Duration in the Post-Project Condition for Average Flood Event. (Polde-1)

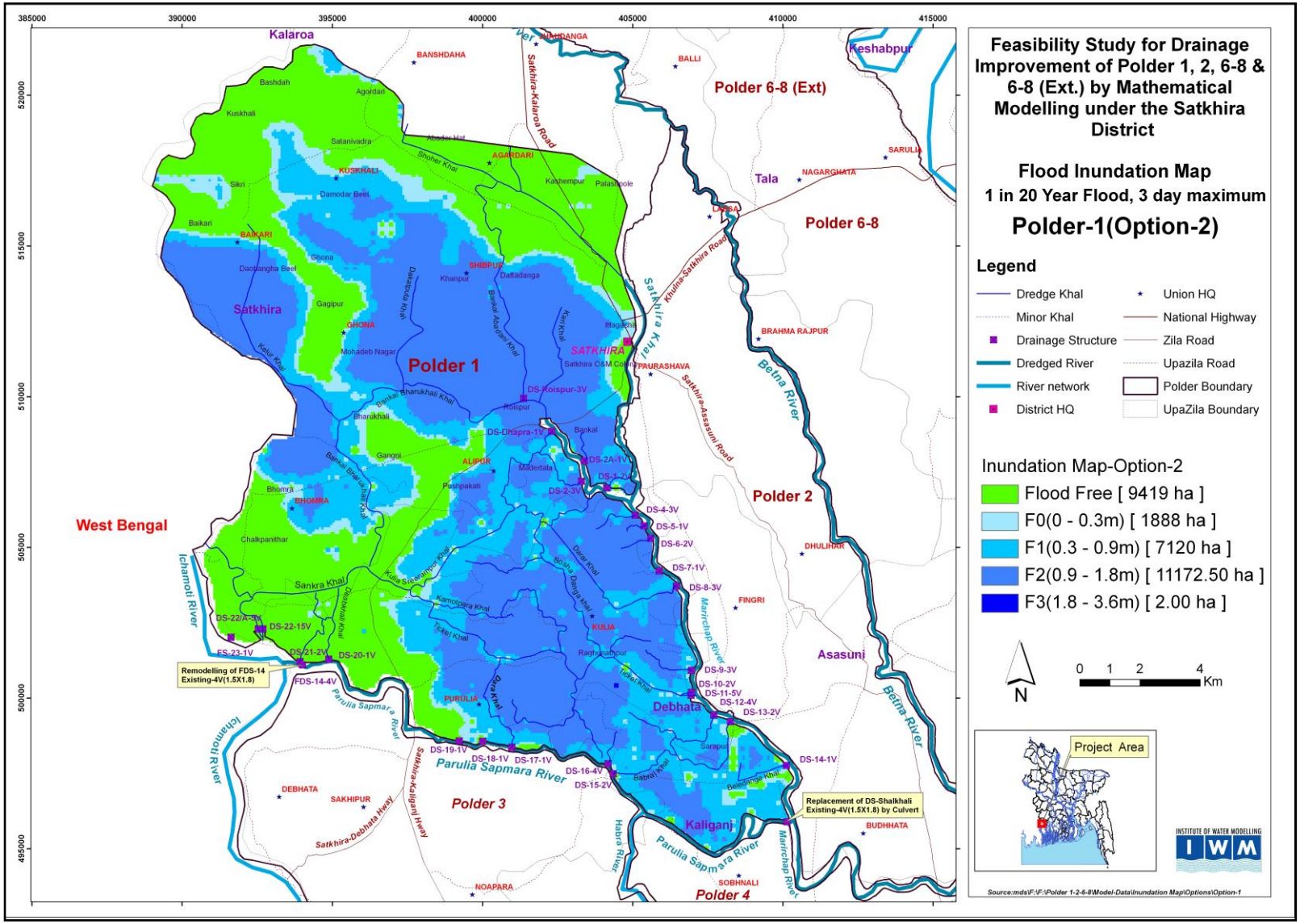


Figure 6.9: Inundation Depth for 3 Days Duration in the Post-Project Condition for Extreme Flood Event. (Polde-1)

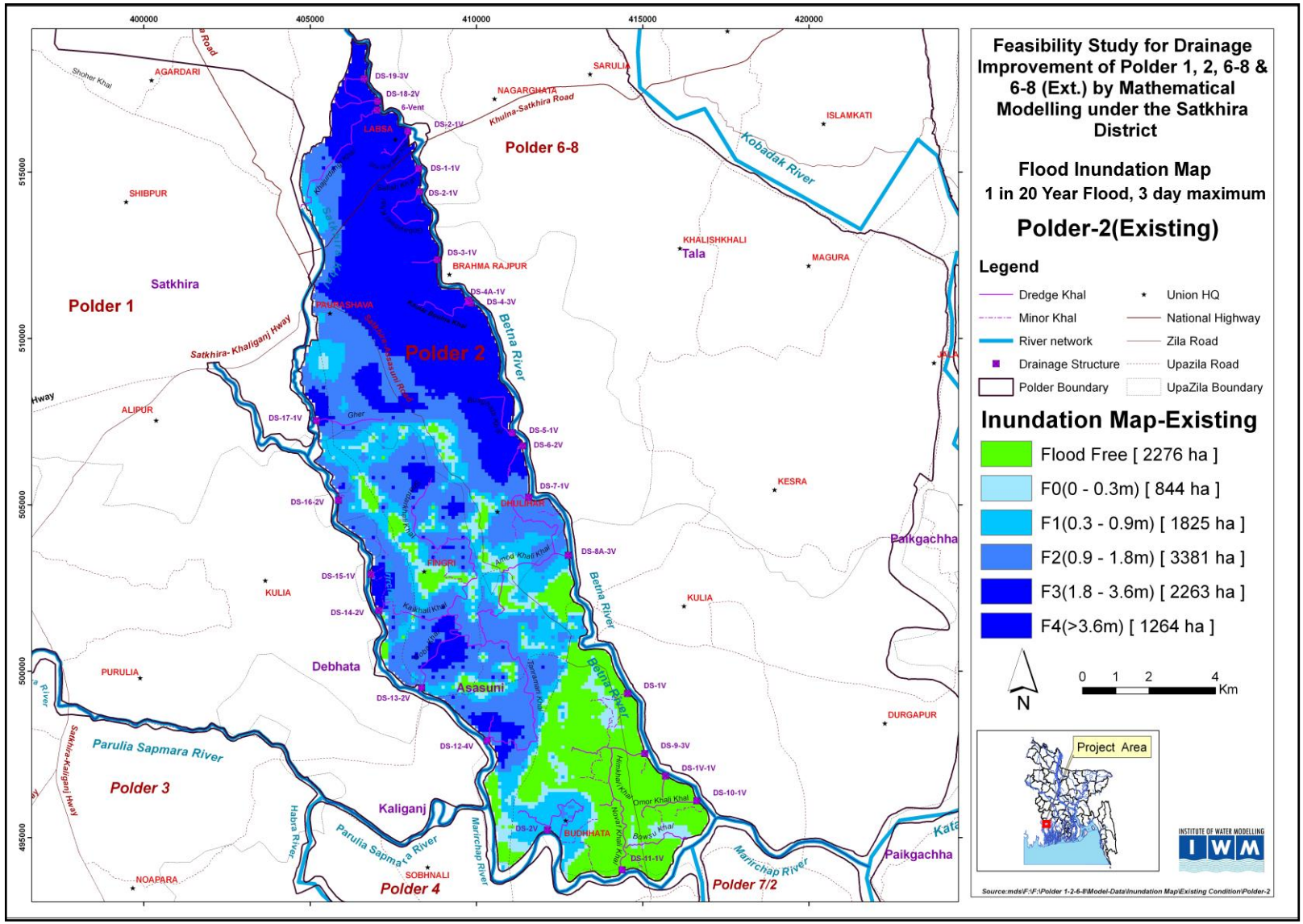


Figure 6.10: Inundation Depth for 3 Days Duration in the Present Condition for Extreme Flood Event. (Polde-2)

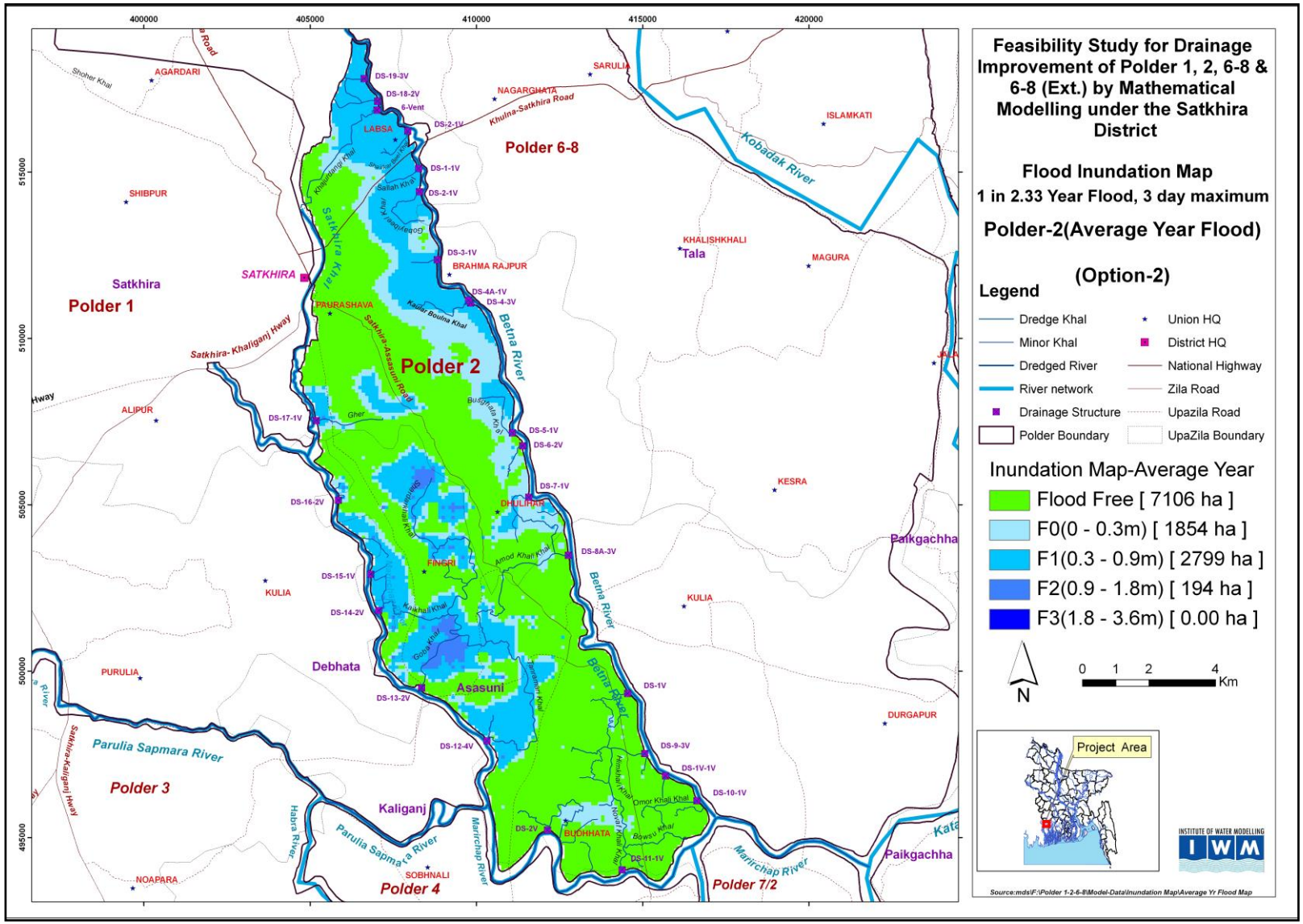


Figure 6.11: Inundation Depth for 3 Days Duration in the Post-Project Condition for Average Flood Event. (Polde-2)

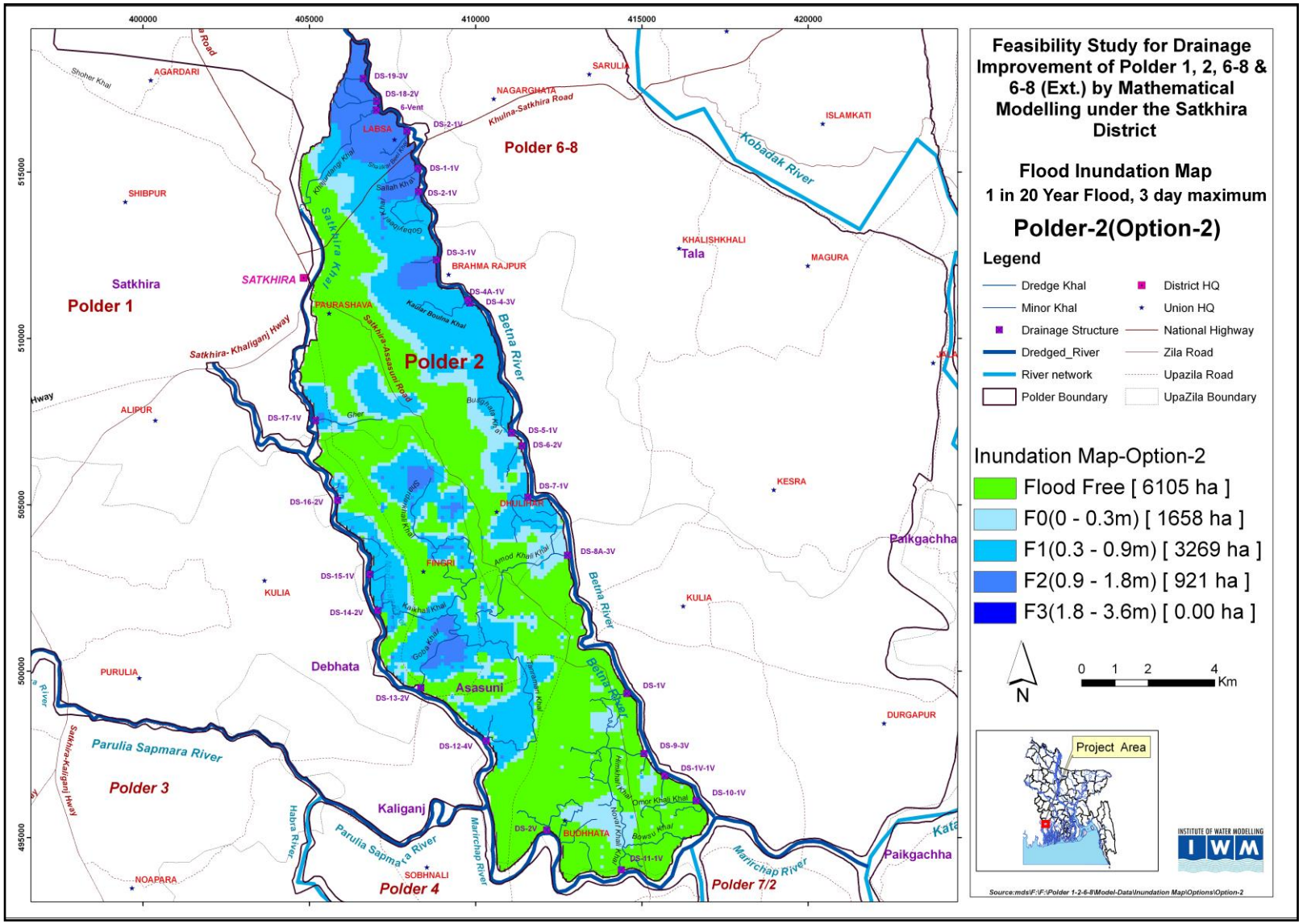


Figure 6.12: Inundation Depth for 3 Days Duration in the Post-Project Condition for Extreme Flood Event. (Polde-2)

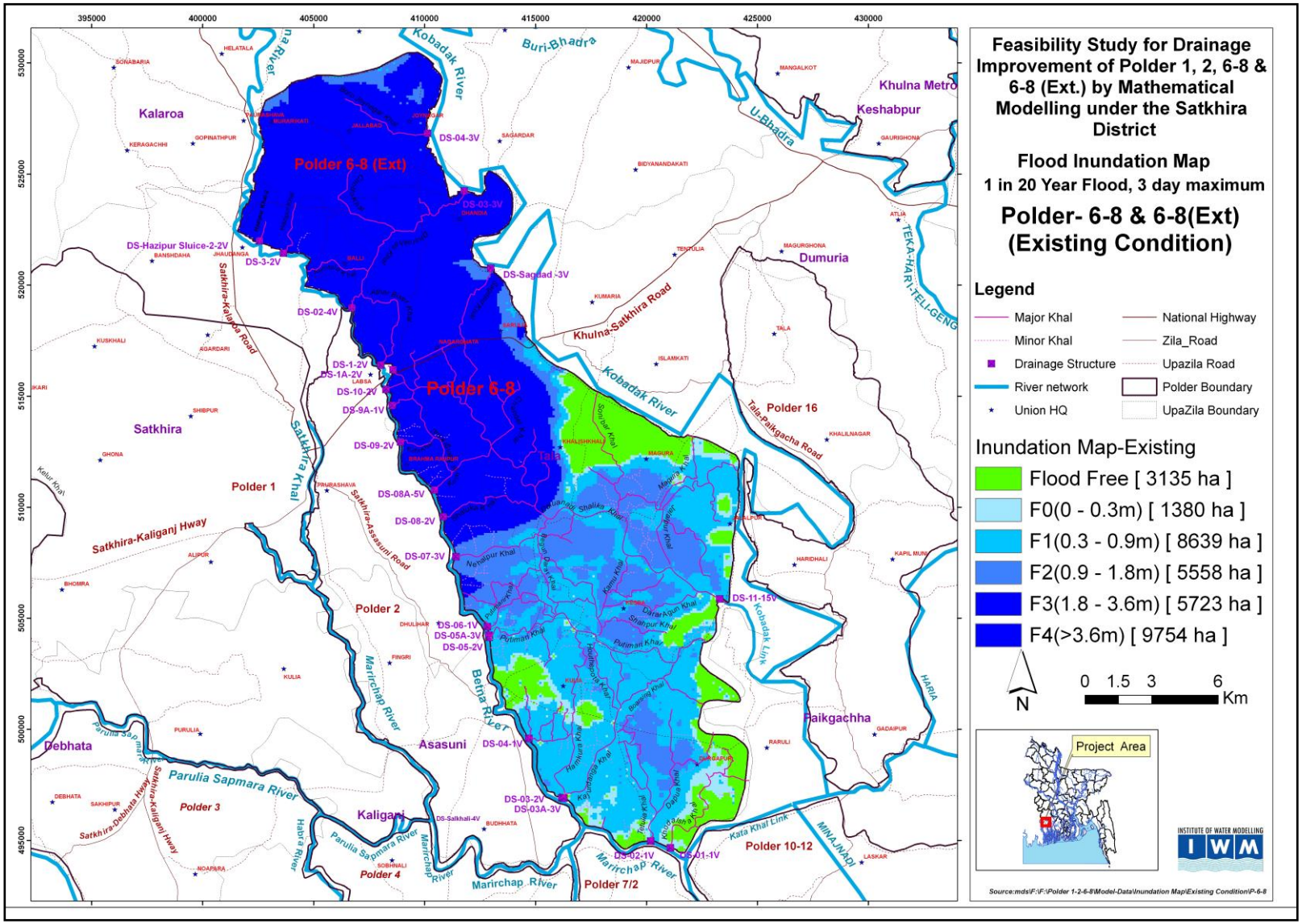


Figure 6.13: Inundation Depth for 3 Days Duration in the Present Condition for Extreme Flood Event. (Polde-6-8 & 6-8(Extn))

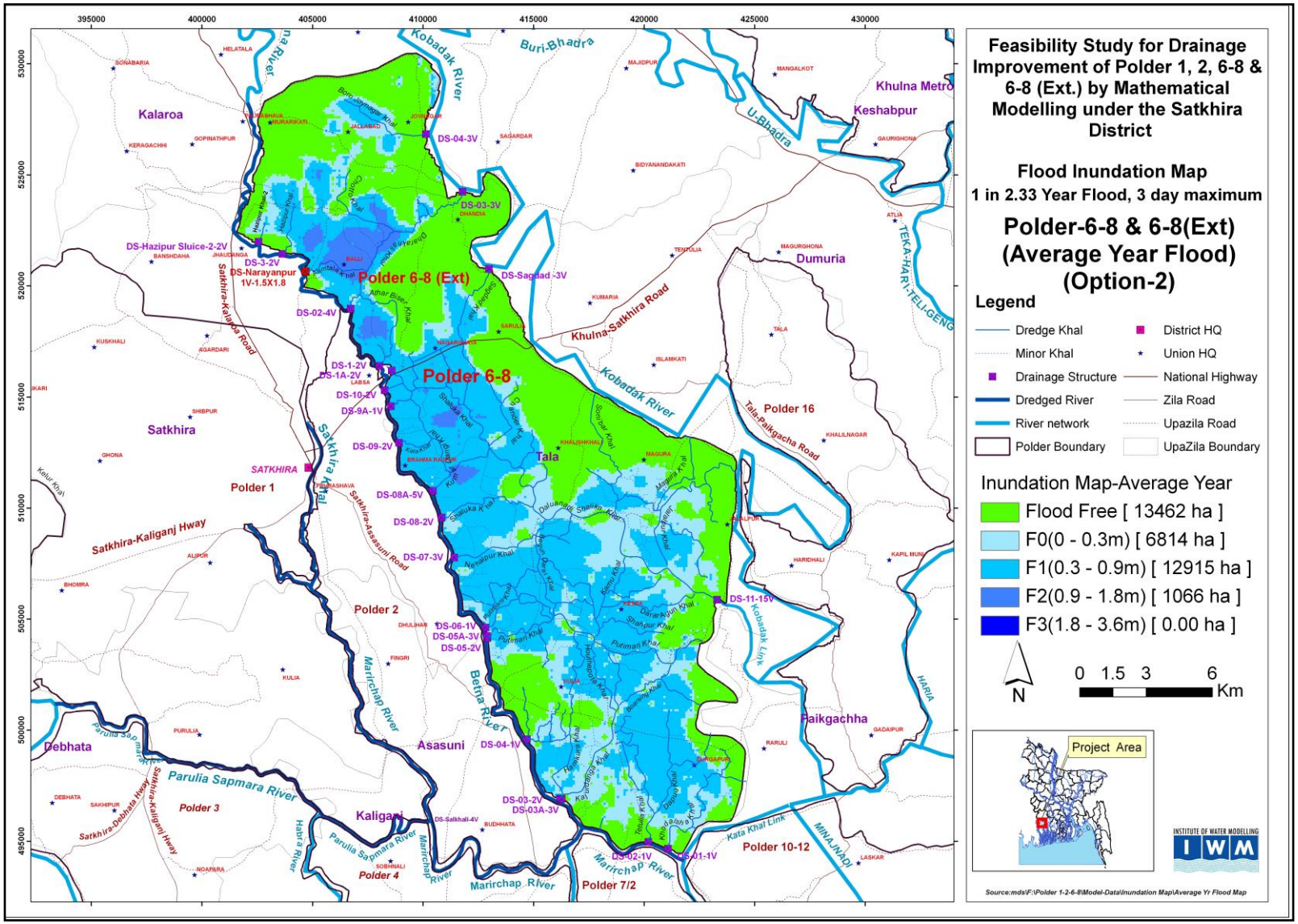


Figure 6.14: Inundation Depth for 3 Days Duration in the Post-Project Condition for Average Flood Event. (Polde-6-8 & 6-8(Extn))

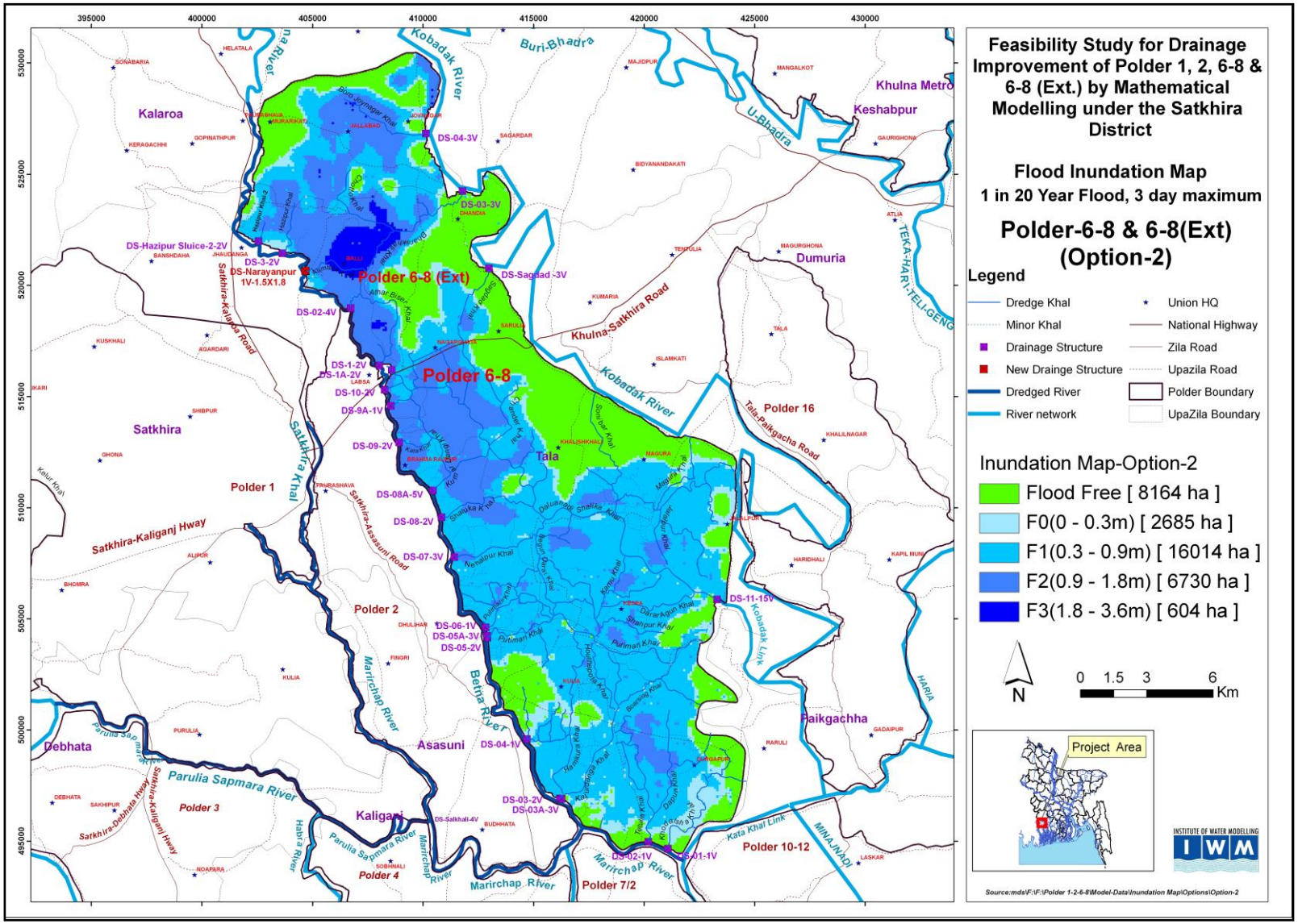


Figure 6.15: Inundation Depth for 3 Days Duration in The Post-Project Condition for Extreme Flood Event. (Polde-6-8 & 6-8(Extn))

6.3.2 Assessment of Capital Dredging and its Effectiveness

Dredging alignment has been ascertained considering the thalweg line, current speed, direction and backfilling rate. Based on existing river cross-section profile and design section capital dredging volume is ascertained. The bed width, dredged level and side slope of the proposed dredged channel are presented in the **Table 6.11, 6.12 & 6.13** for Betna River Marirchap River and Parulia Sapmara Khal respectively.

Table 6.11: Description of Design Bed Level, Side Slope and Width of the Dredged Section (Betna River)

Chainage (m)	Designed Dredged River Bed Level (m PWD)		Design Discharge(m^3/s)	Design Width (m)	Side Slope	Longitudinal Slope (cm/km)
0-2500	-2.36	-2.47	100	14	1:2	4.50
2500-5000	-2.47	-2.59	102	14		
5000-7500	-2.59	-2.70	106	15		
7500-10000	-2.70	-2.81	115	16		
10000-12000	-2.81	-2.90	118	16		
12000-15000	-2.90	-3.04	120	16		
15000-17500	-3.04	-3.15	143	20		
17500-19000	-3.15	-3.22	146	22		
19000-20000	-3.22	-3.26	150	23		
20000-24000	-3.26	-3.44	167	26		
24000-27000	-3.44	-3.56	212	36		4.00
27000-30000	-3.56	-3.72	235	39		
30000-35000	-3.72	-3.88	266	50		
35000-40000	-3.88	-4.08	300	58		
40000-46500	-4.08	-4.34	380	72		

Table 6.12: Description of Design Bed Level, Side Slope and Width of the Dredged Section (Marirchap River)

Chainage (m)	Designed Dredged River Bed Level (m PWD)		Design Discharge(m^3/s)	Design Width (m)	Side Slope	Longitudinal Slope (cm/km)
0-8000	-3.22	-3.54	39	8.00	1:2	4.00
8000-12000	-3.54	-3.7	48	9.00		
12000-13000	-3.7	-3.74	54	10.50		
13000-15000	-3.74	-3.82	74	12.00		
15000-18000	-3.82	-3.94	77	13.00		
18000-22000	-3.94	-4.07	127	26.00		3.00
22000-26000	-4.07	-4.19	130	28.00		
26000-30500	-4.19	-4.32	151	31.00		
30500-31500	-4.32	-4.35	380	89.00		
31500-37000	-4.35	-4.52	200	35.00		

Table 6.13: Description of Design Bed Level, Side Slope and Width of the Dredged Section (Parulia Sapmara Khal)

Chainage (m)	Designed Excavated Khal Bed Level (m PWD)		Design Discharge(m^3/s)	Design Width (m)	Side Slope	Longitudinal Slope (cm/km)
0-4000	-2.50	-2.60	82	10.00	1:2	2.50
4000-8000	-2.60	-2.70		10.00		
8000-12000	-2.70	-2.80		10.00		
12000-16000	-2.80	-2.90		10.00		
16000-20000	-2.90	-3.00		10.00		
20000-23500	-3.00	-3.0875		10.00		

The hydraulic parameters described in the table are used in assessing the capital dredging. The estimated capital dredging volume is about 6.83 million m^3 for Betna River, about 6.41 million m^3 for Marirchap River, about 2.28 million m^3 for Parulia Sapmara River, about 0.36 million m^3 for Satkhira Khal and the cumulative dredging volume of all internal drainage channels is about to 5.34 million m^3. Description of dredging of Peripheral River and Internal Drainage channels are shown in **Table 6.14.**

Table 6.14: Description of Capital dredging of Peripheral River and Internal Drainage Channels

SL No.	**River /Khal**	**Length(Km)**	**Dredging volume(Mm^3)**
1	Betna River	44	6.83
2	Marirchap River	37	6.41
3	Parulia Sapmar River	23.5	2.28
4	Satkhira khal	8	0.36
5	Internal Drainage channel (Polder-1)	94	1.94
6	Internal Drainage channel (Polder-2)	69	0.94
7	Internal Drainage channel (Polder-6-8 & 6-8 Ext)	194	2.46

The effectiveness of capital dredging is assessed in terms of backfilling rate in the dredged reach of the rivers. The net back filling rate in the 1st year is about 60 % to 80% of the capital dredging volume for Betna River & Marirchap River respectively without tidal river management (TRM). Re-siltation/backfilling is not evident in the dredged channel if TRM is in operation for sediment management.In order to achieve sustained drainage condition, TRM operation is essential.

6.3.3 Effectiveness of Beels for Tidal River Management

A low-lying area (beel) can be utilized as a tidal basin for trapping up the incoming sediment with tide for maintaining sustainable design dredged section of the silted up reaches of the rivers. There are 11 nos. of beels in the Betna and Marirchap river basin which are identified from field survey and investigation **(Figure 6.16).** It is important to assess the effectiveness of a beel for TRM before implementation since all beels may not be effective to generate required volume of tidal prism for sustaining the drainage capacity of the river and sedimentation inside the basin. The performance of TRM basin varies depending on the location, area and bottom topography of the beel, length and location of the connecting channel and also the river bathymetry.Combination of Beels for TRM operation has been

shown in **Table 6.15**. The effectiveness of all the selected beels under different combinations for TRM operation has been investigated using numerical modelling technique. The integrating one beel with the Betna and one beel with the Marirchap River has been simulated for dry seasons to obtain tidal volume in a tidal cycle, which is the indicator for the stability of a tidal river as mentioned earlier. Model provides required land area for tidal basin, location of the link canal and tidal fluctuation inside the beel.

The findings of the TRM model studies are given in **Table 6.16**. Model result indicates that downstream beels are more effective as tidal basin than the upstream beels. The selected tidal basin for the Betna River is more effective and can generate more tidal prism than required tidal volume. On the other hand the selected beels for Marirchap River can generate a tidal prism which is slightly greater than the required tidal prism and can be considered as potential basin for maintaining the required drainage capacity of the river. The tidal range in the selected beels varies from 23cm to 196 cm depending on the topography and location of the beels. The required and generated tidal volume is shown in **Figure 6.17.**

Table 6.15: Combination of Beels for TRM Operation

Operation Combination	Name of Beels	River Basin under Consideration	Proposed Duration of Operation
Phase-1	Sukdebpur Beel	Betna Basin	8 years
	Ticket Beel	Marirchap Basin	8 years
Phase-2	Matiadanga Beel	Betna Basin	8 years
	Jhelmari Beel	Marirchap Basin	8 years
Phase-3	Sreeram katthi Beel	Betna/Marirchap Basin	8 years
	Bagmara Beel	Marirchap Basin	8 years
Phase-4	Hazikhali-Amudkhali	Betna Basin	8 years
	Gobindapur Beel	Marirchap Basin	8 years
Phase-5	Aumtoli Beel	Betna Basin	8 years
	Dorgahpur Beel	Marirchap Basin	8 years
	Chapra Beel	Betna Basin	8 years

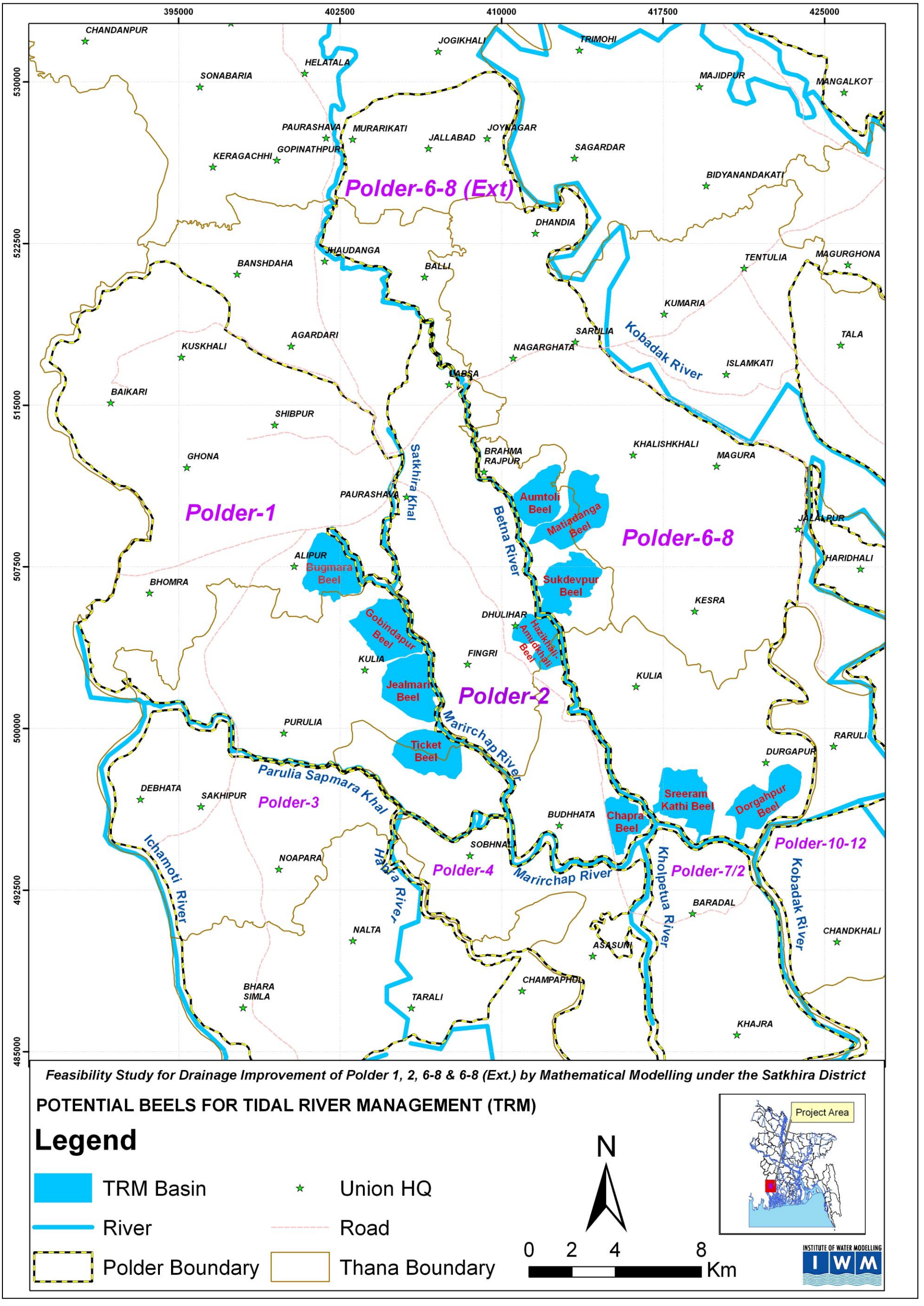


Figure 6.16: Potential Tidal Basin

Table 6.16: Effectiveness of Beels as Tidal River Management (TRM) Basin

Operation Combination	Name of Beels	Maximum Tidal Range (m) inside the proposed Tidal Basin	Generated Tidal Volume (Million-m^3)	Required Tidal Volume (Million-m^3)	Remarks
Phase-1	Sukdebpur Beel	1.34	11.10	6.00	Effective
	Ticket Beel	0.40	3.50	3.15	Effective
Phase-2	Matiadanga Beel	0.65	9.62	6.00	Effective
	Jealmari Beel	0.34	4.20	3.15	Effective
Phase-3	Sreeram katthi Beel	1.96	8.11	5.50	Effective
	Bugmara Beel	0.23	2.90	3.15	Marginal
Phase-4	Hazikhali-Amudkhali	1.79	14.00	9.00	Effective
	Gobindapur Beel	0.22	3.33	3.15	Effective
Phase-5	Aumtoli Beel	1.16	9.20	6.00	Effective
	Dorgahpur Beel	0.96	6.20	5.60	Effective
	Chapra Beel	1.10	6.20	5.60	Effective

N.B. Tidal volume is estimated in the Betna and Marirchap rivers at the downstream reaches of the location of the proposed Tidal Basins.

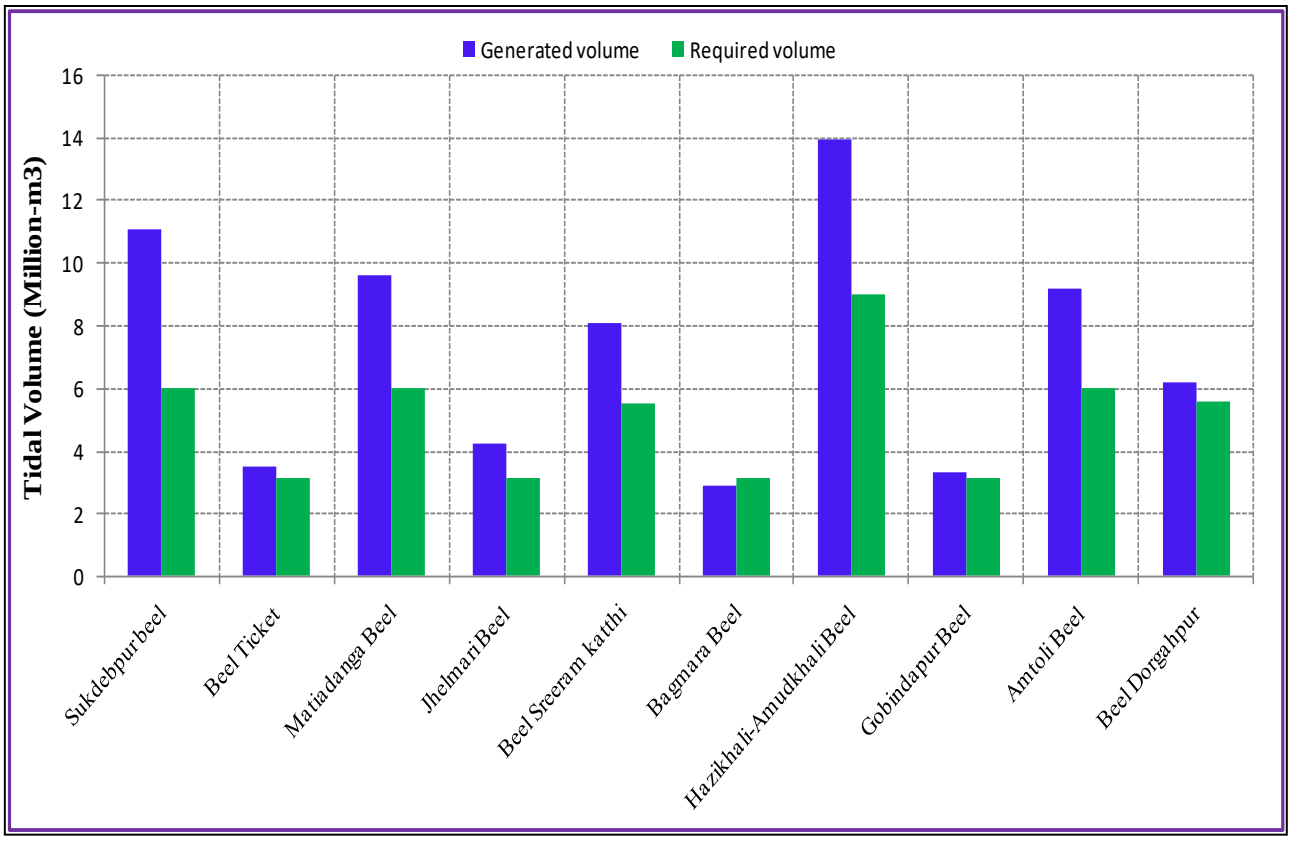


Figure 6.17: Comparison of Required and Generated Tidal Volume for Different Beels (as Tidal Basin)

Effectiveness of Matiadanga Beel and Jealmari Beel as a TRM basin (Phase-2)

In case of Matiadanga beel one link canal and for Jealmari beel two link canals were considered. For Matiadanga beel the link canal will be connected with Betna River at 24.5 km chainage. In case of Jealmari beel the link canal will be connected with Marirchap River at 21.00 Km Chainage (1st Link Canal) and at 22.00 Km Chainage (2nd Link Canal).

For Matiadanga beel, the model results show that tidal prism is 9.62 Mm^3 which is sufficient enough to maintain the required drainage capacity of the Betna River for smooth drainage. In case of Jealmari Beel tidal prism is 4.20 Mm^3 which is effective to maintain the required drainage capacity of the Marirchap River for smooth drainage.The tidal range in the Matiadanga beel is in the range 30 to 40 cm during neap tide and 60 to 65 cm in the spring tide during dry season. The tidal range in the Jealmari beel is in the range 20 to 25 cm during neap tide and 30 to 35 cm in the spring tide during dry season. Tidal fluctuation during spring tide in Matiadanga beel and Jealmari beel has been shown in the **Figure 6.18** and **Figure 6.19** respectively.

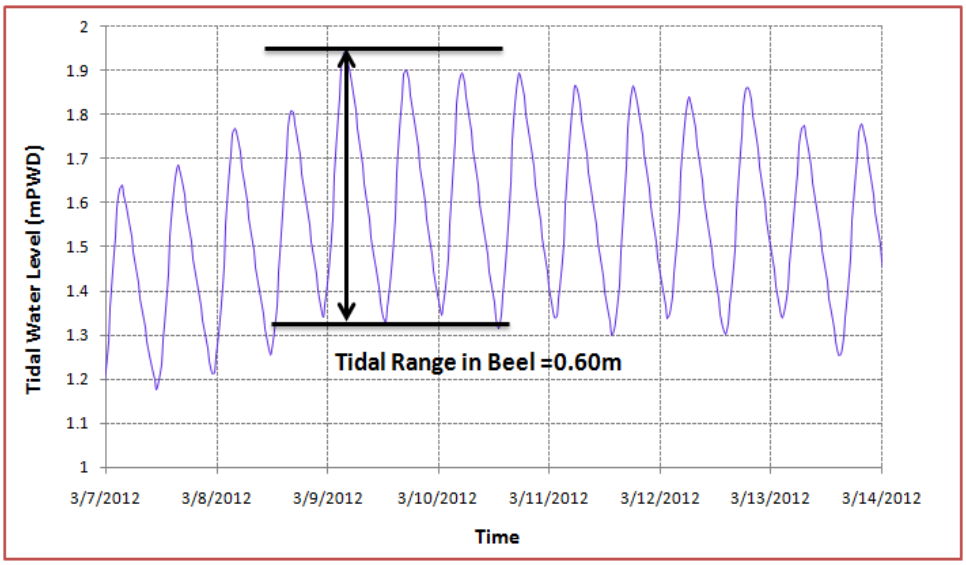


Figure 6.18: Tidal Fluctuation in Matiadanga Beel

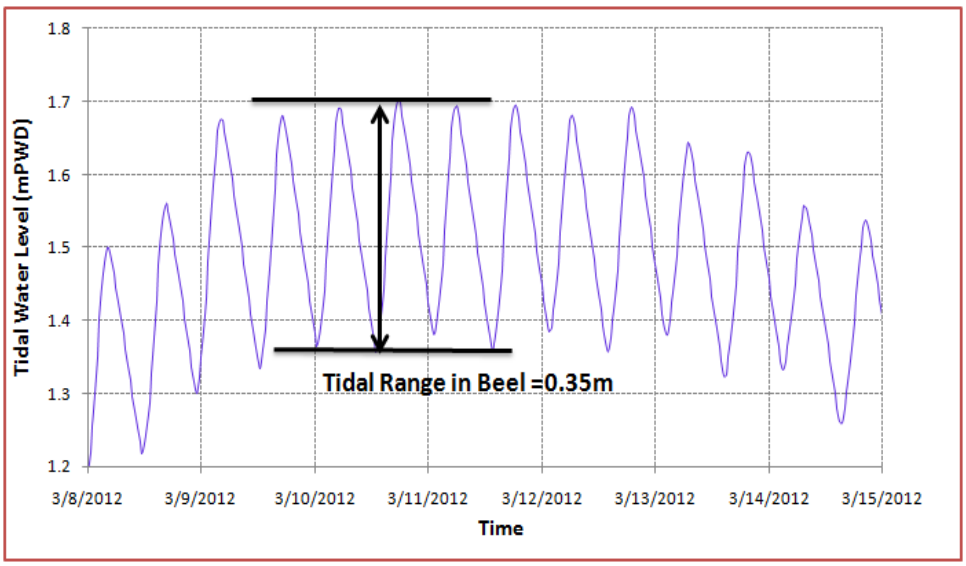


Figure 6.19: Tidal Fluctuation in Jealmari Beel

6.3.4 Sequential Operation of TRM for Sustainable Sediment Drainage Management

Huge quantity of sediment enters continuously into the tidal rivers/creeks of the study area from the sea with high tide, especially, during the dry season. Thus, it becomes a great challenge to manage this incoming sediment for implementation of sustainable drainage improvement plans. From the lesson learnt in the previous study, it is evident that continuous operation of TRM basins for trapping up the incoming sediments inside the basin is an effective way of maintaining sustainable drainage capacity of the sediment dominated tidal rivers. Thus, it appears that continuous operation of TRM is a must for sustainable drainage management.

For sediment and drainage management of Betna and Marirchap River basin some potential beels to be used as tidal basins for TRM operation has been identified under this study through field investigation and local stakeholder consultations. Effectiveness of these beels as tidal basin has been assessed using TRM model as described earlier. It has been found that TRM can be successfully operated in these two river basins using the selected beels for about 45 years for sediment and drainage management. All these beels are effective in terms of maintaining required tidal volume in the river. Before implementation of TRM, location of link canal of TRM basin and cross-dam in the river needs to be finalized after detailed field investigation and in consultation with the local stakeholders. Sequential operation of these TRM basins is given in **Table 6.17**.

Table 6.17: The Sequence of Potential TRM Basins for Tidal River Management

Sequence of Operation	Beels	Effective Area (ha)	Operation Period					
			2014-2021	2022-2029	2030-2037	2038-2045	2046-2053	
Phase-1	Sukdebpur Beel (Betna Basin) + Ticket Beel (Marirchap Basin)	1071						
Phase-2	Matiadanga Beel (Betna Basin) + Jealmari Beel (Marirchap Basin)	1236						
Phase-3	Sreeramkathi Beel (Betna/Marirchap Basin) + Bugmara Beel (Marirchap Basin)	1164						
Phase-4	Hazikhali-Amudkhali Beel(Betna Basin) +Gobindapur Beel (Marirchap Basin)	955						
Phase-5	Aumtoli Beel (Betna Basin) + Dorgahpur Beel Marirchap Basin)+Chapra Beel (Betna Basin)	1309						

CHAPTER SEVEN: PLANNING AND DESIGN

7.1 Restoration of Peripheral Rivers

The Polder 1, Polder 2, Polder 6-8 & 6-8(Ext) surrounded by the Betna River, Marirchap River, Parulia Sapmara River and Satkhira Khal. The stated rivers need to be dredged or excavated on priority to remove the drainage congestion of the polder area and for restoration of navigability. Betna River is the common peripheral drainage route of polder 6-8 & 6-8(Ext) and Polder-2. Marirchap River is the common peripheral drainage route of polder 1 and Polder-2. The design parameters have been finalized in accordance with the result of drainage model, field visit and discussion meeting with the design and field offices of BWDB.

Design Considerations:

The following considerations have been taken into account for designing the section of rivers for re-excavation:

- The section should be adequate for passage of flood discharge of 20 year return period so as to lower down the present water level;
- Design section of peripheral rivers has been fixed in such a way that improvements of drainage and irrigation purpose are meet satisfactorily;
- The critical reach of river requiring re-excavation has been determined from existing bed profiles;
- The adequate bed width, bed level and bed slope have been derived by using hydrodynamic modelling after trial of few bed widths, bed levels and bed slope; and
- The design section has been accommodated within the river banks as far as possible to avoid land acquisition.

Determination of Design Discharge:

The whole procedure for determination of the design discharge consists of two steps, the catchment delineation and quantification of runoff for design hydrologic event. As the flow of different river/Khals are generated exclusively from the catchments, it is very important to properly delineate the respective catchments of each reaches of river/khals. Thus, efforts are made to accurately delineate the catchments based on the available topographic data, field investigation and Google Earth Image. For quantification of runoff, Rainfall-Runoff Model (Hydrological Model) available at IWM has been used. Frequency Analysis of long time series rainfall data of the representative stations for the study area has been carried out to select the design hydrologic event. 1 in 20 year hydrologic flood event is considered as design flood event. From Frequency Analysis of rainfall data, 1991 year hydrologic event has been found as 1 in 20 year flood event. The available calibrated and validated Rainfall-Runoff Model of South West Region has been simulated for the hydrological year of 1991 to generate runoff from the catchments. There are 44 catchments in the Southwest Regional Rainfall Runoff Model set up. The Southwest catchments SW-18, SW-21 and SW-22 mainly cover the study area. Hence, runoff found from the rainfall runoff model for these catchments has been used to determine the design discharge for rivers and Khals. As the rainfall runoff model is a Lumph Model, each catchment yields a single output for the respective southwest catchments and thus, the design discharge for each river/Khals reaches are determined proportionately according to the amount of their respective delineated catchment area.

Design of Dredging/Excavation Section of Peripheral Rivers:

Based on the design discharge for each river as mentioned above, the designed section is determined. Design bed width and depth is assumed initially from the field survey data and flow area is evaluated considering 1:1.5 side slope of the design section. Then the assumed depth and width is duly checked for the design discharge using Manning's Equation. Wetted perimeter and hydraulic radius is calculated using the flow area. The design discharge and allowable velocity is then checked by Manning's Equation. The roughness of the Manning's Equation is considered as 0.025 and 0.04 for rivers and Khals respectively. The maximum allowable velocity in the channel is taken as 1.00 m/sec. The longitudinal slope of the river is selected from the analysis of long profile generated from field survey data.The typical Longitudinal dredged design profile has been shown in **Figure 7.1, 7.3, 7.5** and **7.7** for Betna River, Marirchap River, Parulia Sapmara Khal and Satkhira Khal respectively.The typical dredged design cross section has been shown in **Figure 7.2, 7.4, 7.6** and **7.8** for Betna River, Marirchap River, Parulia Sapmara River and Satkhira Khal respectively.

Design Parameters:

The following parameters have been checked from hydrodynamic modelling:

- bed width: 14 m (in upstream) to 72 m (in downstream) for Betna River
- bed width: 8 m (in upstream) to 35 m (in downstream) for Marirchap River
- bed width: 10 m (in upstream and in downstream) for Parulia Sapmara Khal
- bed width: 3 m (in upstream and in downstream) for Satkhira Khal
- bed level: -2.36m PWD to -4.34 m PWD for Betna River
- bed level: -3.22m PWD to -4.52 m PWD for Marirchap River
- bed level: -2.50m PWD to -3.09 m PWD for Parulia Sapmara River
- bed level: -3.06m PWD to -3.38 m PWD for Satkhira Khal
- Side Slope: (1:1.5)
- Longitudinal Slope:
    - 4.5 (cm/km) to 4.0 (cm/km) for Betna River,
    - 4.0 (cm/km) to 3.0 (cm/km) for Marirchap River
    - 2.5 (cm/km) for Parulia Sapmara Khal &
    - 4.0 (cm/km) for Satkhira Khal

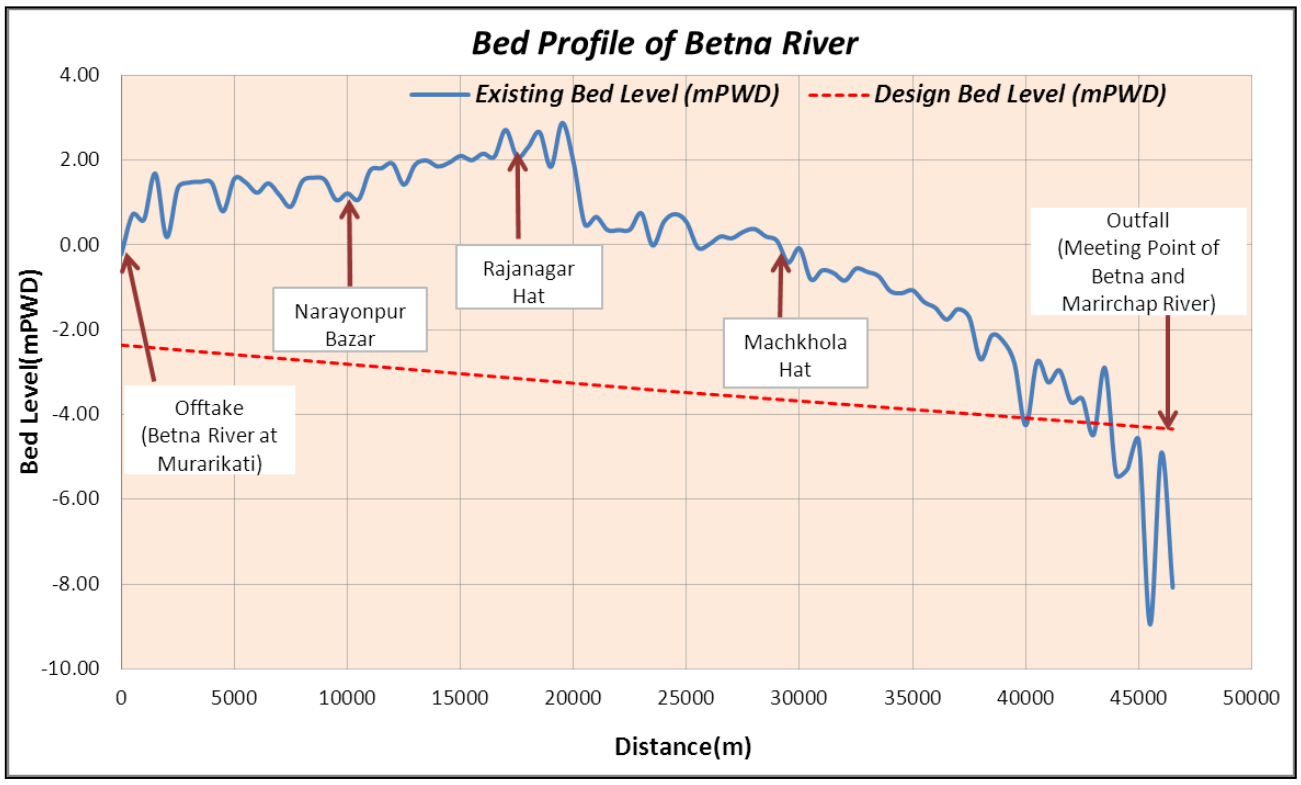


Figure 7.1: The Existing and Design Bed Profile of Betna River

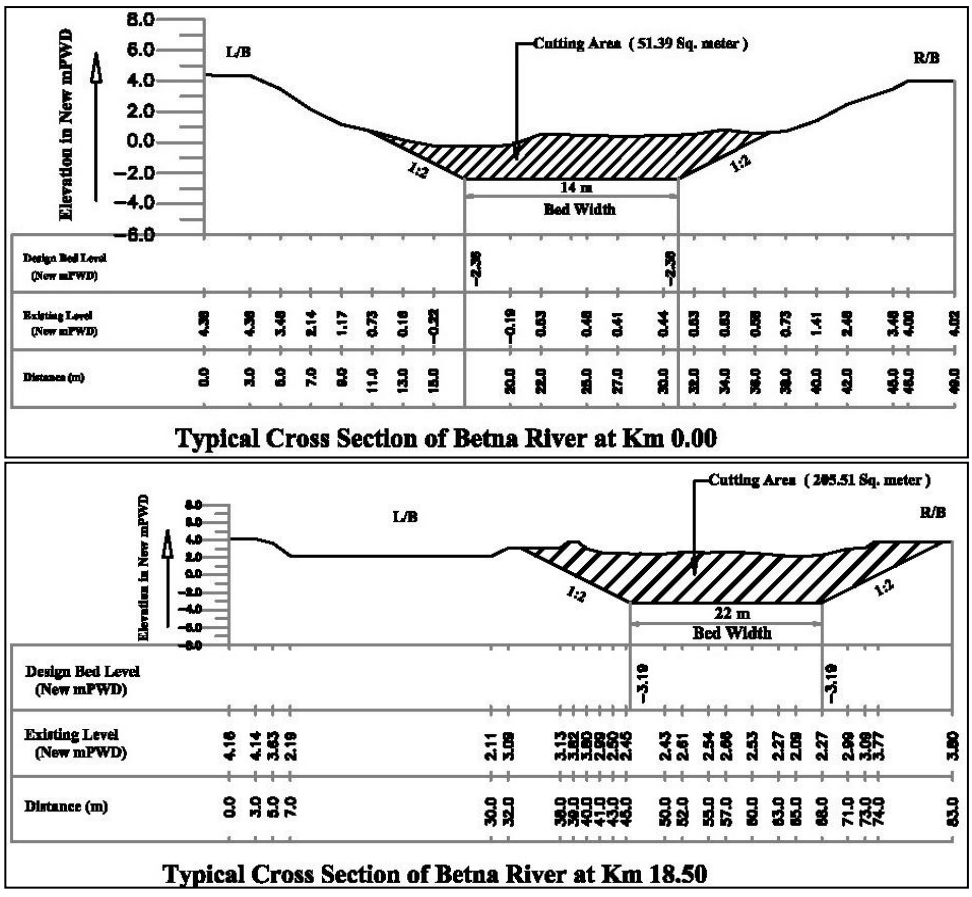


Figure 7.2: Design Bed Width at Different Locations of Betna River

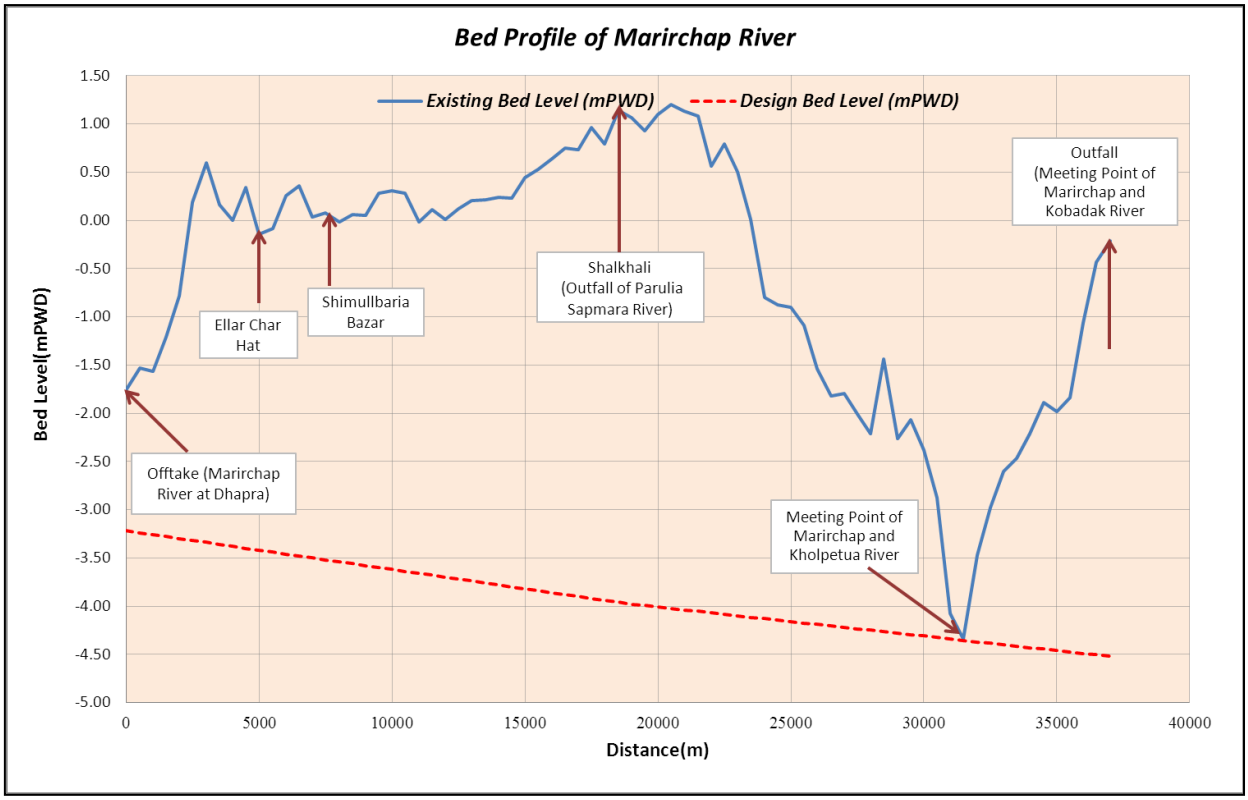


Figure 7.3: The Existing and Design Bed Profile of Marirchap River

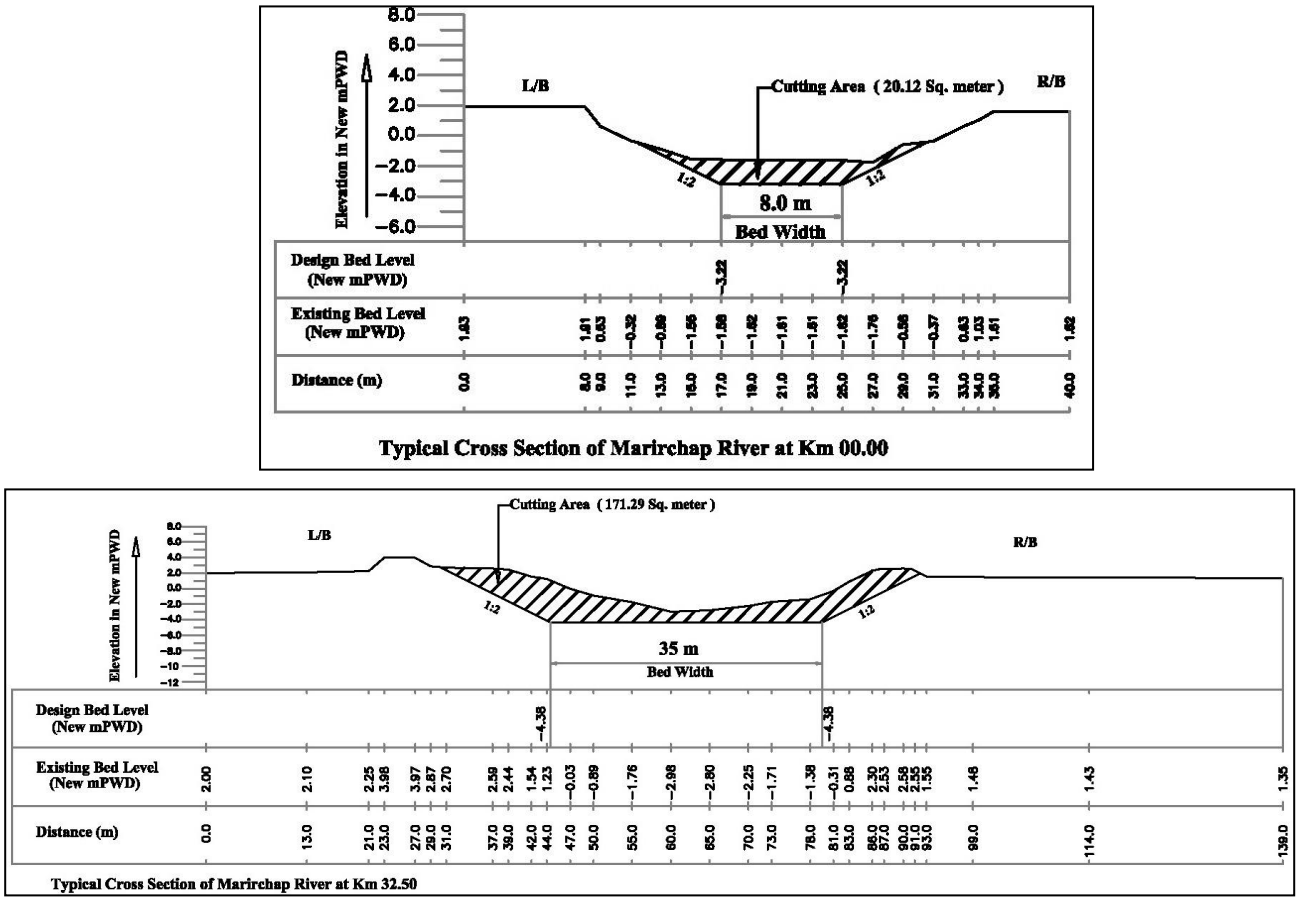


Figure 7.4: Design Bed Width at Different Locations of Marirchap River

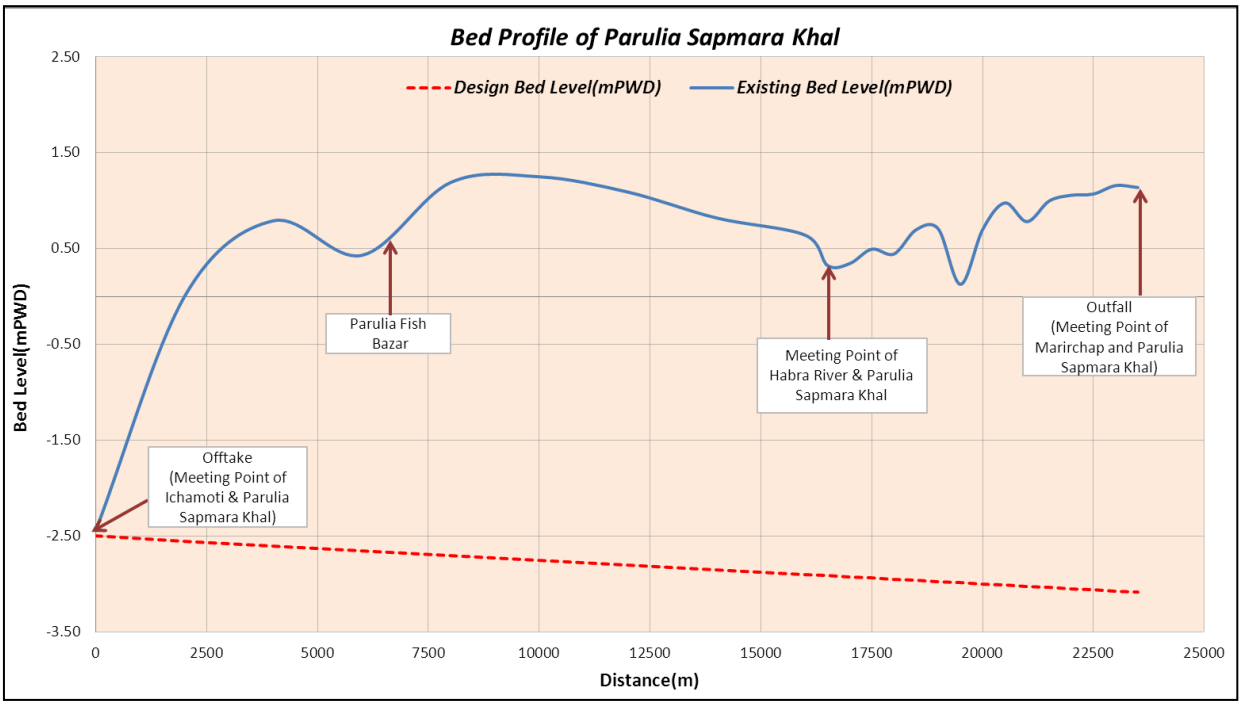


Figure 7.5: The Existing and Design Bed Profile of Parulia Sapmara Khal

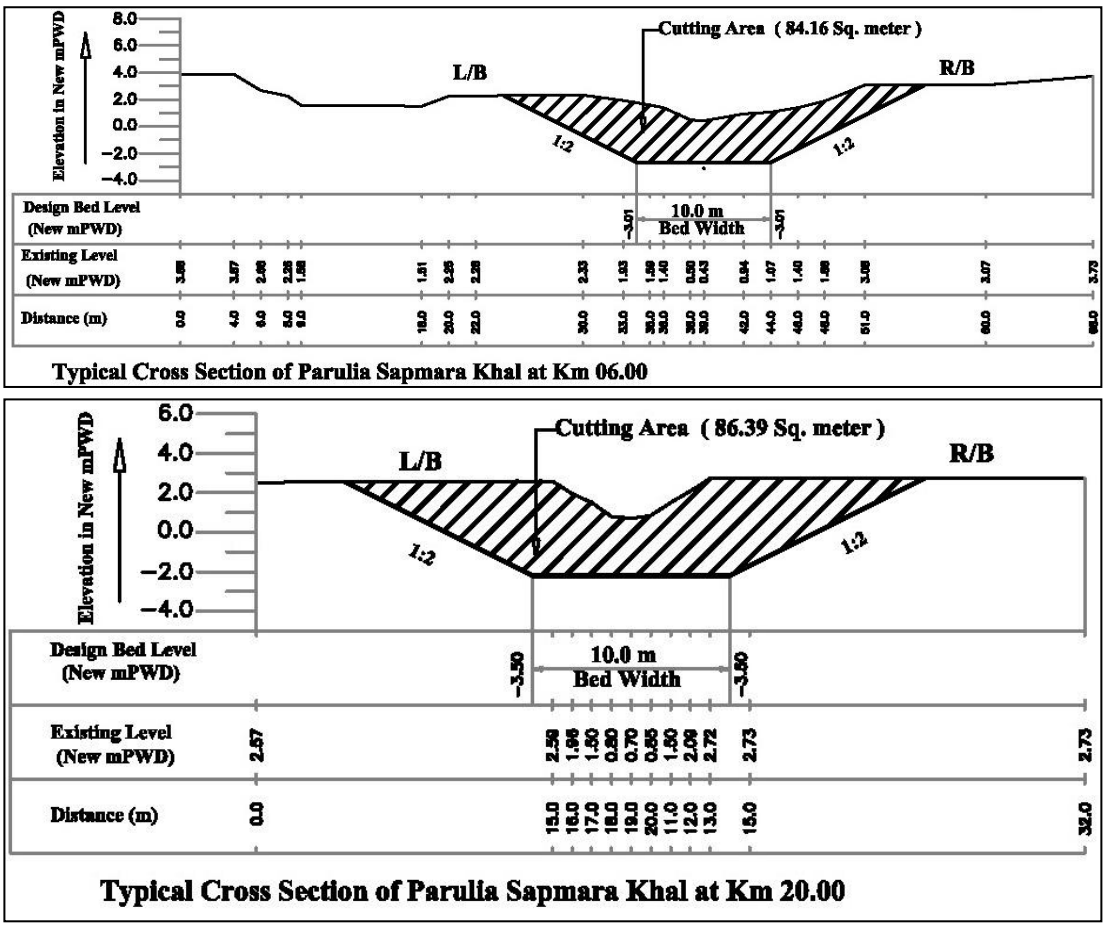


Figure 7.6: Design Bed Width at Different Locations of Parulia Sapmara River

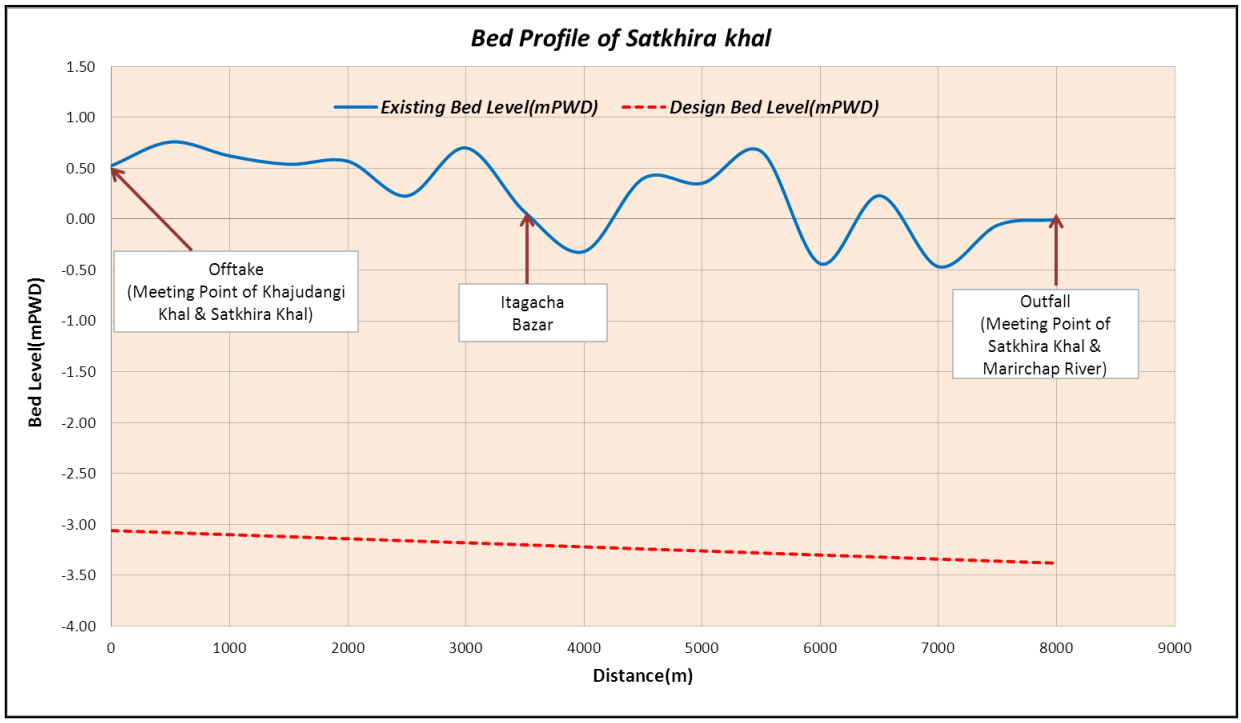


Figure 7.7: The Existing and Design Bed Profile of Satkhira Khal

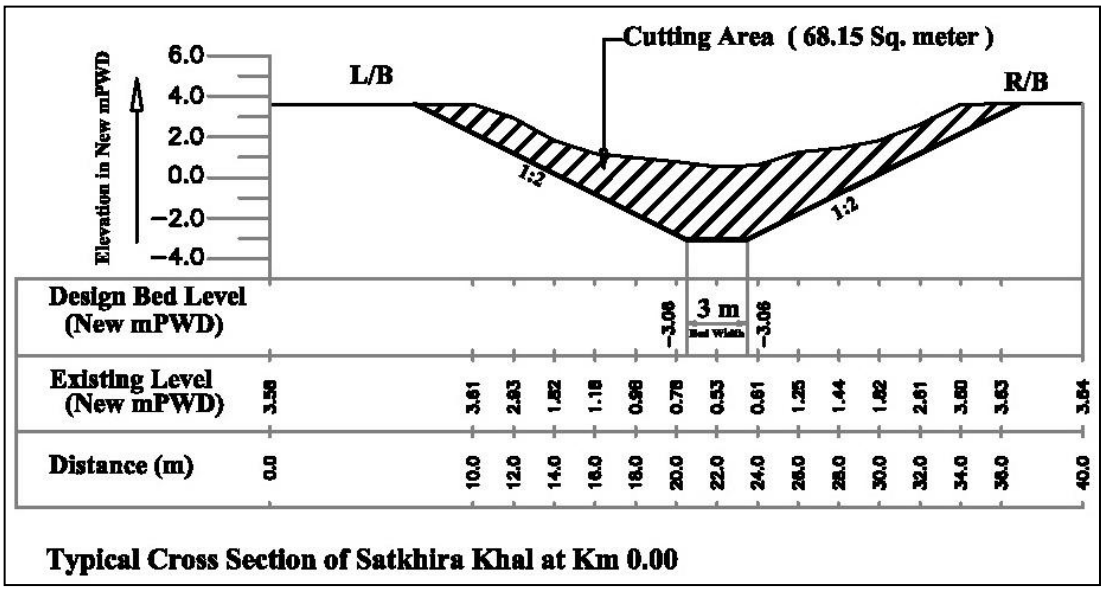


Figure 7.8: Design Bed Width at Different Locations of Satkhira Khal

7.2 Design for Excavation of Internal Drainage Channels

Total 87 numbers of internal drainage channels have been identified for re-excavation in order to accelerate smooth drainage of the polder area of Polder-1, Polder-2, Polder-6-8 & 6-8 (Extn). The channels are excavation based on stakeholder discussions, field visits and model study results. The design bed level, bed width for different Khals are given in **Table 7.1,7.2** and **7.3** for Polder-1, Polder-2, Polder 6-8 & 6-8(Extn) respectively.The typical

longitudinal dredged design profile and dredged design cross section has been shown in **Figure 7.9 Figure 7.10** respectively for Nehalpuer Khal (Polder-6-8).

Design Parameters:

The following parameters have been derived from hydrodynamic modelling:

- bed width: varies from Khal to Khal
- side slope: 1:1.5
- bed slope: varies from Khal to Khal
- bed level: varies from Khal to Khal.

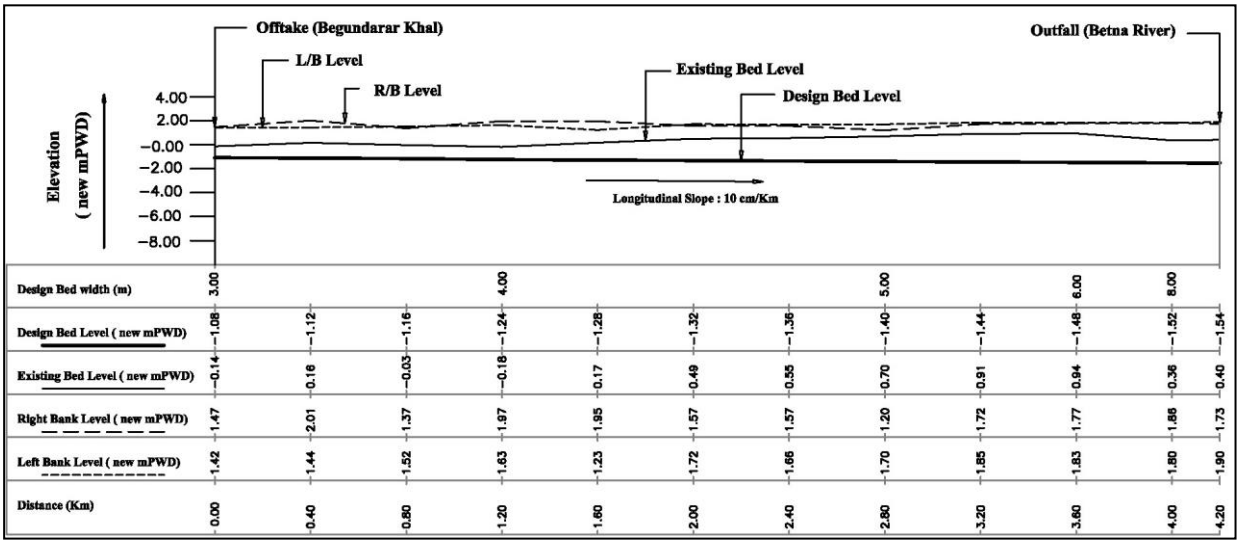


Figure 7.9 The L/B, R/B, Existing and Design Bed Profile of Nehalpurer Khal (Polder-6-8)

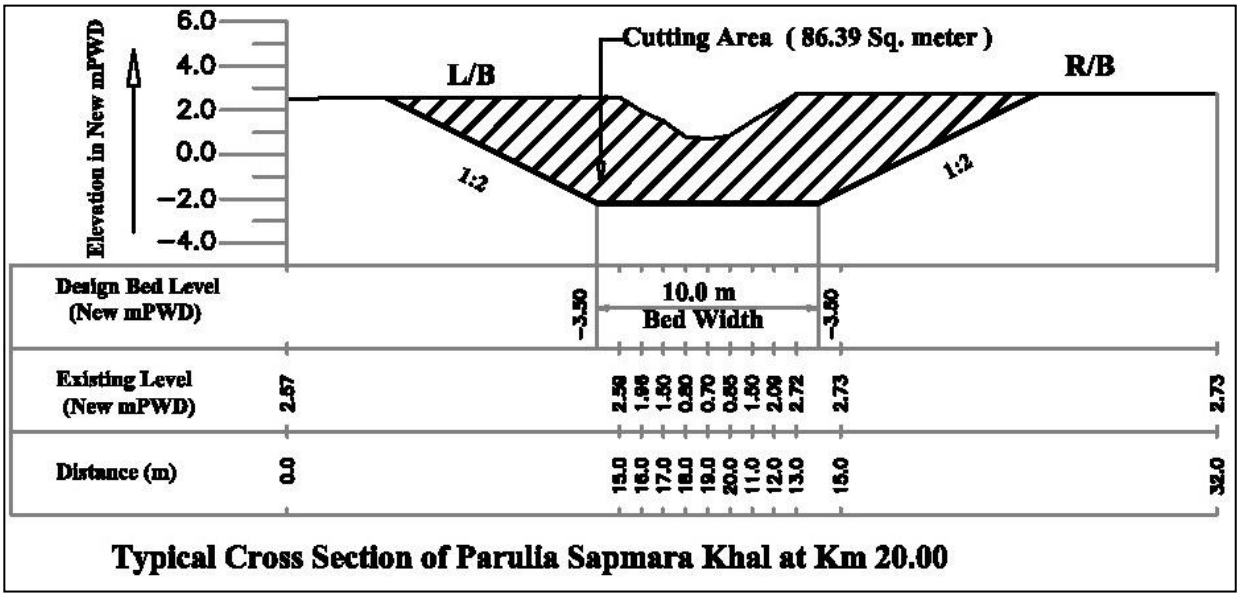


Figure 7.10: Design Bed Width at Different Locations of Of Nehalpurer Khal (Polder-6-8)

Table 7.1: List of Selected Drainage River and Khals of Polder-1 need to be Re-excavated

SL No.	Khal Name	Length (m)	Estimated volume (m3)	Design Section						Longitudinal slope (cm/km)	Side slope	Remarks/Structure (At outfall)
				At Offtake			At Outfall					
				Bed width (m)	Bed level (m PWD)	Name of Offtake Khal	Bed Width (m)	Bed Level (mPWD)	Name of Outfall Khal/River			
1	ArKhoni Khal	6200	123962	4	-1.11	Meeting point of ArKhoni khal and Sharafpur Khal	6	-1.55/ -1.29	Parulia Sapmara Khal/ Marirchap River	10	1:1.50	DS-14 1Vent Regulator/ Proposed 1Vent Regulator ; Detailed Drawing
2	Badartola Khal	4500	126000	3	-1.10	Gurochondri Khal	8	-1.55	Parulia Sapmara Khal	10	1:1.50	DS-16 4 Vent Pipe Sluice
3	Bankal Abadani Khal	9200	84694	3	-0.49	Closed by Embankment at Km 90.00	10	-1.42	Bankal Bharukhali Khal	10	1:1.50	Detailed Drawing
4	Boailia Khal	2050	58080	3	-1.30	Not connected by other sources	6	-1.50	Marirchap River	10	1:1.50	DS-9 3 Vent Pipe Sluice
5	Darar Khal	6050	131600	3	-0.52	Koulkatar Khal	7	-1.00	Marirchap River	8	1:1.50	DS-8 3 Vent Pipe Sluice
6	Darar Khal -2	4000	40960	3	-1.19	Ticket Khal	4	-1.59	Parulia Sapmara Khal	10	1:1.50	DS-17 1 Vent Pipe Sluice
7	Dauria Khal	4800	59750	3	-1.00	Ticket Khal	6	-1.38	Kamotpara khal	8	1:1.50	---
8	Deabkhali Khal	3400	33272	4	-0.10	Sankra Khal	6	-1.34	Parulia Sapmara Khal	10	1:1.50	DS-21 2 Vent Pipe Sluice, Detailed Drawing
9	Gurochondri Khal	4400	16400	3	-0.71	Not connected by other sources	4	-1.15	Ticket Khal	10	1:1.50	---

SL No.	Khal Name	Length (m)	Estimated volume (m3)	Design Section						Longitudinal slope (cm/km)	Side slope	Remarks/Structure (At outfall)
				At Offtake			At Outfall					
				Bed width (m)	Bed level (m PWD)	Name of Offtake Khal	Bed Width (m)	Bed Level (mPWD)	Name of Outfall Khal/River			
10	Him Khali Khal	2000	26200	3	-1.00	Not connected by other sources	4	-1.2	Sharafpur Khal	10	1:1.50	---
11	Kamotpara khal	2800	40900	6	-1.27	Dauria khal	7	-1.55	Ticket Khal	10	1:1.50	---
12	Koulkatar Khal	10000	225250	5	-1.00	Open by a Bridge; Marirchap River	20	-1.75	Sankra Khal	7.5	1:1.50	Detailed Drawing
13	Kulia Sreerampur Khal	5670	104770	5	-1.08	Koulkatar Khal	7	-1.50	Marirchap River	5	1:1.50	DS-2 3 Vent Pipe Sluice; Detailed Drawing
14	Kumra Khali Khal	3600	89800	5	-1.04	Closed by Embankment at Km 57.00	7	-1.40	Sankra Khal	10	1:1.50	---
15	Nolbon Khal	2800	24500	3	-0.22	Not connected by other sources	4	-0.50	Putimari Khal	10	1:1.50	---
16	Sankra Khal	6800	269180	30	-1.75	Koulkatar Khal	36	-2.43	Ichamoti River	10	1:1.50	DS-22 Sankra-15 vent Regulator; Detailed Drawing
17	Sharafpur Khal	2880	137678	6	-1.29	ArKhoni Khal	12	-1.51	Marirchap River	8	1:1.50	DS-12 4 vent Regulator; Detailed Drawing
18	Ticket Khal	12600	343962	10	-0.79	Meeting Point at Ticket Khal and Putimari Khal	15/13	-1.65/ -1.31	Koulkata Khal /Marirchap River	10	1:1.50	DS-11 Ticket-5 vent Regulator, Detailed Drawing
19	Ticket Khal-Br	400	3300	7	-1.14	Ticket Khal	8	-1.20	Marirchap River	18	1:1.50	DS-10 Ticket-2 vent Regulator

Table 7.2: List of Selected Drainage River and Khals of Polder-2 need to be Re-excavated

SL No.	Khal Name	Length (m)	Estimated volume (m3)	Design Section								Remarks/Structure (At outfall)
				At Offtake			At Outfall			Longitudinal Slope (cm/km)	Side slope	
				Bed width (m)	Bed level (m PWD)	Name of Offtake Khal	Bed Width (m)	Bed Level (mPWD)	Name of Outfall Khal/River			
1	Amod Khali Khal	4200	58494	5	-1.20	Gaba Khal	10	-1.62	Betna River	10	1:1.50	DS-Amod khali 3 Vent Regulator; Detailed Drawing
2	Andharmanik Khal	1200	8500	3	-1.60	Not connected by others	4	-1.66	Betna River	5	1:1.50	DS-6 2 Vent Pipe Sluice
3	Battolar Khal	3600	38000	3	-1.59	Amod khali Khal	3	-1.95	Betna River	10	1:1.50	DS-7 1 Vent Pipe Sluice
4	Bowsu Khali Khal	2400	28000	3	-2.06	Closed by Embankment at Km 26.50	4	-2.30	Novab Khali Khal	10	1:1.50	---
5	Busghata Khal	2000	38200	3	-2.18	Not connected by others	4	-2.28	Betna River	5	1:1.50	DS-5 1 Vent Regulator
6	Chumri Khali Khal	6800	108319	3	-1.41	Gaba Khal	6	-1.75	Marirchap River	5	1:1.50	DS-12 Proposed 2 Vent Regulator; Detailed Drawing
7	Gaba Khal	5700	61886	5	-1.20	Amod khali Khal	7	-1.77	Marirchap River	10	1:1.50	DS-13 2 Vent Box Regulator; Detailed Drawing
8	Gher	2400	32759	3	-1.02	Not connected by others	4	-1.26	Satkhira Khal	10	1:1.50	DS-17 1 Vent Regulator
9	Gobayibeel Khal	2080	32000	3	-1.40	Not connected by others	4	-1.61	Betna River	10	1:1.50	DS-2 1 Vent Regulator
10	Goshai Tola Khal	1200	15000	3	-1.30	Not connected by others	4	-1.42	Surjo Khali Khal	10	1:1.50	---
11	Him Khali Khal	2490	16600	3	-1.45	Not connected by others	6	-1.70	Betna River	10	1:1.50	DS-9 3 Vent Pipe Sluice

12	Him Khali-BR Khal	1600	7032	3	-1.41	Closed by Road	5	-1.57	Him Khali Khal	10	1:1.50	---
13	Kaikhali Khal	2900	32000	3	-1.34	Shardar Khali Khal	4	-1.63	Marirchap River	10	1:1.50	DS-14 2 Vent Pipe Sluice
14	Kata Khal	1600	23000	4	-1.18	Start at Bridge at km 63.20	6	-1.34	Betna River	10	1:1.50	DS-18 2 Vent Regulator
15	Kata Khal BR	800	19000	4	-1.21	Closed by Embankment at Km 63.90	4	-1.29	Kata Khal	10	1:1.50	---
16	Kaular Boulna Khal	2400	46000	3	-0.63	Not connected by others	8	-0.92	Betna River	10	1:1.50	DS-4 3 Vent Regulator
17	Kaular Boulna Khal BR	200	4000	3	-0.80	Kaular Boulna Khal	4	-0.92	Betna River	10	1:1.50	DS-Kalur Boluna 1Vent Regulator
18	Khajurdangi Khal	4870	127214	4	-1.24	Satkhira Khal	8	-1.73	Betna River	10	1:1.50	---
19	Labu Hagi Khal	600	2880	3	-0.57	Not connected by others	4	-0.65	Betna River	10	1:1.50	DS-Labu Hagi 1Vent Regulator
20	Muskhola Khal	390	27000	3	-1.84	Not connected by others	4	-1.90	Betna River	10	1:1.50	DS-3 1 Vent Box Regulator
21	Novab Khali Khal	3280	58888	4	-2.06	Not connected by others	5	-2.39	Marirchap River	10	1:1.50	DS-11 1 Vent Regulator; Detailed Drawing
22	Omor Khali Khal	2080	17000	3	-1.87	Not connected by others	3	-2.07	Betna River	10	1:1.50	DS-10 1 Vent Pipe Sluice
23	Rajnogor Khal	800	9849	4	-1.22	Kata Khal BR	8	-1.30	Betna River	10	1:1.50	DS-19 3 Vent Regulator
24	Sallah Khal	1200	14700	3	-1.49	Not connected by others	4	-1.61	Betna River	10	1:1.50	DS-1 1 Vent Pipe Sluice
25	Shailkar Beel Khal	1600	40000	3	-1.34	Not connected by others	3	-1.50	Betna River	10	1:1.50	DS-2-Shalika 1 Vent Regulator
26	Shardar Khali Khal	8800	42132	5	-0.83	Not connected by others	6	-1.45	Gaba Khal	7	1:1.50	Detailed Drawing
27	Surjo Khali Khal	2000	29680	3	-1.30	Not connected by others	6	-1.50	Marirchap River	10	1:1.50	DS- Surjo Khali 2 Vent Regulator

Table 7.3: List of Selected Drainage River and Khals of Polder-6-8 & 6-8(Extn) need to be Re-excavated

SL No.	Khal Name	Length (m)	Estimated volume (m3)	Design Section								Remarks/Structure (At outfall)
				At Offtake			At Outfall			Longitudinal slope (cm/km)	Side slope	
				Bed width (m)	Bed level (m PWD)	Name of Offtake Khal	Bed Width (m)	Bed Level (mPWD)	Name of Outfall Khal/River			
1	Aumtala Khal	3200	22000	3	-0.43	---	5	-0.75	Dharakhali Khal	10	1:1.50	Closed by Embankment at Km 41.80
2	Bahadurpur Khal	2800	28000	3	-1.51	---	4	-1.79	Bainboshto Khal	10	1:1.50	Not connected by other Khal
3	Bainboshto Khal	2400	13200	3	-1.66	Hamkura Khal	4	-1.86	Betna River	10	1:1.50	DS-4 1 Vent Pipe Sluice
4	Bajar Khal	2000	22000	3	-1.75	---	4	-1.95	Putimari Khal	10	1:1.50	Not connected by other Khal
5	Begun Darar Khal	8000	20000	3	-1.40	Shalika Khal	4	-1.80	Putimari Khal	5	1:1.50	---
6	Boarsing Khal	3600	11000	3	-1.32	Putimari Khal	3	-1.50	Khajurdanga Khal	10	1:1.50	---
7	Boro Joynagar Khal	4477	106000	3	-1.16	---	8	-1.61	Kobadak River	10	1:1.50	DS-4 (Polder-6-8-Extn) 3 Vent Regulator
8	Boro Khal	2400	12500	3	-0.01	Closed by Embankment at Km 69.50	3	-0.25	Dharakhali Khal	10	1:1.50	---
9	Chotta Khal	4800	40000	3	0.08	Not connected by other Khal	4	-0.40	Dharakhali Khal	10	1:1.50	---
10	Dangi Khal	2000	21700	3	-1.59	Not connected by other Khal	3	-1.79	Bainboshto Khal	10	1:1.50	---
11	Dapua Khal	5200	56500	3	-1.38	Not connected by other Khal	3	-1.90	Tetulia Khal	10	1:1.50	---
12	Darar Agun Khal	5200	25000	3	-1.48	Shalika Khal	3	-2.00	Kamu Khal	10	1:1.50	---
13	Dhanir Beel Khal	2000	14600	3	-0.96	Not connected by other Khal	3	-1.20	Kundor Dangi Khal	10	1:1.50	---
14	Dharakhali Khal	7640	73640	4	-0.19	Boro Khal	10	-0.95	Betna River	10	1:1.50	DS-2 (Polder-6-8-Extn) 3 Vent Regulator; *Detailed Drawings Included*
15	Goalpata Khal	2400	22000	3	-1.46	Shalika Khal	3	-1.70	Kumar Dangi Khal	10	1:1.50	---
16	Gobra Khali Khal	2800	16240	3	-1.34	Not connected by other Khal	3	-1.62	Shalika Khal	10	1:1.50	---

SL No.	Khal Name	Length (m)	Estimated volume (m3)	Design Section						Longitudinal slope (cm/km)	Side slope	Remarks/Structure (At outfall)
				At Offtake			At Outfall					
				Bed width (m)	Bed level (m PWD)	Name of Offtake Khal	Bed Width (m)	Bed Level (mPWD)	Name of Outfall Khal/River			
17	Hamkura Khal	9200	65208	6	-1.34	Putimari Khal	8	-1.80	Kajurdanga Khal	5	1:1.50	*Detailed Drawings Included*
18	Hazipur Khal-1	2860	75000	3	-1.00	Not connected by other Khal	6	-1.29	Betna River	10	1:1.50	DS-3 (Polder-6-8-Extn) 2 Vent Regulator
19	Hazipur Khal-2	1000	35000	3	-1.19	Not connected by other Khal	6	-1.29	Betna River	10	1:1.50	DS-Hazipur (Polder-6-8-Extn) 2 Vent Regulator
20	Jalalpur Khal	8465	67242	4	-1.74	Mid Point of Shalika Khal	10	-1.92/ -1.90	Shalika Khal/ Kobadak River	4	1:1.50	DS-10A 4 Vent Regulator, *Detailed Drawings Included*
21	Kamu Khal	3600	11500	3	-1.34	Shalika Khal	3	-1.70	Begun Dara Khal	10	1:1.50	---
22	Kata Khal	2050	49000	3	-1.62	Goalpota khal	6	-1.85	Betna River	10	1:1.50	DS-9 2 Vent Regulator
23	Kaulkatola Khal	2400	8000	3	-0.60	Closed by Road	4	-0.84	Boarsing Khal	10	1:1.50	---
24	Khajurdanga Khal	8400	74954	8	-1.63	Putimari Khal	14	-2.05	Betna River	5	1:1.50	Proposed DS-3 DS-3(2V-1.50X1.80); DS-3A(3V-1.52X1.83); *Detailed Drawings Included*
25	Khodalsha Khal	5670	42000	3	-1.04	Sayed Khali Khal	4	-1.61	Marirchap River	10	1:1.50	DS-1 1 Vent Regulator
26	KulutiaKhal	5070	53000	3	-0.85	Dharakhali Khal	6	-1.10	Marirchap River	5	1:1.50	DS-1 (Kulutia) Proposed 2 Vent Regulator
27	Kumar Dangi Khal	5300	116000	3	-1.43	Kundor Dangi Khal	10	-1.96	Betna River	10	1:1.50	DS-8A 5 Vent Regulator
28	Kundor Dangi Khal	5300	74000	3	-0.98	Not connected by other Khal	4	-1.51	Betna River	10	1:1.50	DS-9A 1 Vent Regulator
29	MaguraKhal	4400	31000	3	-1.26	Closed By Embankment at Km 91.00	3	-1.70	Sud Khal	10	1:1.50	---
30	Nehalpur Khal	4200	100616	8	-1.42	Begun Darar Khal	10	-1.84	Betna River	10	1:1.50	DS-7 3 Vent Regulator; *Detailed Drawings*

SL No.	Khal Name	Length (m)	Estimated volume (m3)	Design Section						Longitudinal slope (cm/km)	Side slope	Remarks/Structure (At outfall)
				At Offtake			At Outfall					
				Bed width (m)	Bed level (m PWD)	Name of Offtake Khal	Bed Width (m)	Bed Level (mPWD)	Name of Outfall Khal/River			
												Included
31	Perkadakati Khal	4400	40000	3	-1.82	Khajurdanga Khal	3	-1.84	Tetulia Khal	5	1:1.50	---
32	Putimari Khal	12870	175000	7	-1.25	Closed By Embankment at Km 103.00	12	-2.15	Betna River	7	1:1.50	DS-5 2 Vent Regulator; *Detailed Drawings Included*
33	Putimari Khal-Br	215	3800	8	-2.04	Putimari Khal	8	-2.05	Betna River	10	1:1.50	DS-5A 3 Vent Regulator
34	Putimarir Khal	4425	20000	3	-1.51	Closed by Road	4	-1.95	Betna River	10	1:1.50	DS-6 1 Vent Regulator
35	Shahapur Khal	3600	26000	3	-1.39	Not connected by other Khal	3	-1.75	Begun Darar Khal	10	1:1.50	---
36	Shalika Khal	20100	536770	10	-0.93	Kundor Dangi Khal	32	-2.14	Link Channel-Kobadak River	6	1:1.50	DS-11 15 Vent Regulator; *Detailed Drawings Included*
37	Shaluka Khal	5050	146466	3	-1.48	Shalika Khal	7	-1.95	Betna River	10	1:1.50	DS-8 2 Vent Regulator; *Detailed Drawings Included*
38	Sonirbar Khal	5200	112000	3	-0.98	Not connected by other Khal	3	-1.50	Gobra Khali Khal	10	1:1.50	---
39	SreeJagul Khal	1500	17000	3	-1.16	Kundor Dangi Khal	6	-1.24	Betna River	5	1:1.50	DS-1A 2 Vent Regulator
40	Sud Khal	2400	18000	3	-1.50	Gobra Khali Khal	3	-1.74	JalalpurKhal	10	1:1.50	---
41	Tetulia Khal	5380	57522	4	-1.74	Perkadakati Khal	5	-2.00	Marirchap River	5	1:1.50	*Detailed Drawings Included*

7.3 Design of Drainage Structures/Bridges

In addition to repairing and reviving the existing sluices, five new drainage structures have been proposed. The purpose of the new sluice is to control salinity intrusion during flood tide & expedite drainage during ebb tide and maintain water regime within the polder area by improving drainage situation

Design parameters for five new regulators, one bridge & one box culvert are tabulated in **Table 7.4** and **Table 7.5** respectively. The detail designs have been carried out after consultation with relevant design office.The detailed drawings heve been furnished in the **Volume I.**

Table 7.4: Design Parameter at Regulators Site

Sl	Polder	Khal Name	ID	Revised no of vents & size (m)	Sill Level (mPWD)	Design Discharge (m^3/s)	Remarks
1	1	Arkoni Khal	DS-15	1(1.50mx1.80m)	-0.90	5.50	Replaced
2	2	Chumrikhali Khal	DS-12	2(1.50mx1.80m)	-1.00	8.00	Replaced
3	6-8	Khajurdanga Khal	DS-3	3(1.50mx1.80m)	-1.00	21.00	Replaced
4	6-8	Bainbhosot Khal	DS-4	2(1.50mx1.80m)	-0.90	11.50	New Structure
5	6-8(Ext)	Kulutia Khal	DS-1	2(1.5m0x1.80m)	-0.50	14.00	Replaced

Table 7.5: Salient Design Parameter Bridges

Sl	Polder	River/Khal Name	Flow area (sqm)	Sill Level (mPWD)	Design Discharge (m^3/s)	Remarks
1	Polder-1	Parulia-Sapmara Khal (At Bhatshala Sluice)	74.5 (Velocity 1.10m/s)	-2.0	82	Replacement of existing Bhatshala Sluice by Bridge
2	Polder-1	Parulia-Sapmara Khal (At Shalkhali Sluice)	122 (Velocity 0.57 m/s)	-2.17	70	Remodelling of existing Shalkhali Sluice by Bridge

7.4 Fixation of Design Crest Level

There are four water level measurement stations found around the study area to fix the Highest Water Level (HWL). The station wise frequency analysis result has been done and given in **Table 7.6** and accordingly the design crest level has been fixed considering 0.90 m free boad and 0.30 m for sea level rise due to climate change. The **Figure 7.11** shows the Highest Water Level (HWL) at different structures locations of Polder 1, Polder-2, Polder 6-8 & Polder 6-8 (Extn).

Table 7.6: The List of Water level stations with 20 years Return Period HWL

Sl No	Station ID (BWDB)	Station Name	River Name/Khal	Available data years	HWL for 20 years return period
1	SW24	Benarpota	Betna	41	4.05m PWD
2	SW25	Chapra	Marirchap	40	3.90m PWD
3	SW164	Chandkhali	Kobadak	32	3.60m PWD
4	SW 128	Sankra	Sankra	41	4.60m PWD

The following consideration has been made to fixup the design crest level of of Embankment:

i) Free Board = 0.90 m
ii) Climate Change Effect = 0.30 m (As per Model Study)

Gauge Station (Betna River) at Benarpota (km 35.5, Polder 6-8) HWL for 25 yrs return period is = 4.05 m PWD
Gauge Station (Kobadak River) 37 km down (from Benarpota) at Chandkhali HWL for 25 yrs return period is = 3.60 m PWD
Gauge Station (Betna River) at Benarpota (km 35.5, Polder 6-8) HWL for 20 yrs return period is = 4.05 m PWD

20 years HWL at Km 35 (Polder 6-8 Extn.), Kulutia (0.5 km down from Benarpota Gauge station) = 4.05 - 0.012 x 0.5 =4.04 ≈ 4.05 m PWD

Therefore, Design Crest Level of Embankment at Km35 (Polder 6-8 Ext.)
= (4.05 + 0.90 + 0.30) m PWD = 5.25 m PWD

20 years HWL at Km 14 (Polder 6-8), Kochua (21.5 km down from Benarpota Gauge station) = 4.05 - 0.012 x 21.5 = 3.79 ≈ 3.80 m PWD

Therefore, Design Crest Level of Embankment at Km 14.0 (Polder 6-8)
= (3.80 + 0.90 + 0.30) m PWD = 5.00 m PWD

20 years HWL at Km 11.00 (Polder 6-8), Gabtola (24.5 km down from Benarpota Gauge station) = 4.05 - 0.012 x 24.5 = 3.76 ≈ 3.80 m PWD

Therefore, Design Crest Level of Embankment at Km11.00 (Polder 6-8)
= (3.80 + 0.90 + 0.30) m PWD = 5.00 m PWD

Gauge Station (Marirchap River) at Km 28.00(Polder 2) at Chapra, HWL for 20 yrs return period is =3.90 m PWD

20 years HWL at Km 39.00(Polder 2), Kundolia (11.00 km up from Chapra Gauge station) = 3.90 + 0.012 x 11 = 4.03 ≈ 4.05 m PWD

Therefore, Design Crest Level of Embankment at Km 39.00 (Polder-2)
= (4.05 + 0.90 + 0.30) m PWD = 5.25 m PWD

20 years HWL at Km 37.00 (Polder-2), meeting point of of Parulia Sapmara Khal and Marirchap (9.0 km up from Chapra Gauge station) = 3.90 + 0.012 x9 = 4.00 ≈ 4.00 m PWD

Therefore, Design Crest Level of Embankment at Km 37.00 (Polder-2)
= (4.00 + 0.90 + 0.30) m PWD = 5.20 m PWD

20 years HWL at Km 35(Polder-1), (at Katakhali 7.00 km up from meeting point of of Parulia Sapmara Khal and Marirchap) = 4.00 + 0.02 x 7.00 = 4.14 ≈ 4.15 m PWD

Therefore, Design Crest Level of Embankment at Km 35.00 (Polder-1)
= (4.15 + 0.90 + 0.30) m PWD = 5.35 m PWD

20 years HWL at Km 49.00 (Polder-1), (at Bhatshala 21.00 km up from meeting point of of Parulia Sapmara Khal and Marirchap) = 4.0 + 0.02 x 21.00 = 4.42 ≈ 4.45 m PWD

Therefore, Design Crest Level of Embankment at Km 49.00 (Polder-1)
= (4.5 + 0.90 + 0.30) m PWD= 5.65 m PWD

Say, 1) water way slope for Betna River = 0.012 m / Km
2) Water way slope for Marirchap River = 0.012 m / km
3) Water way slope for Parulia Sapmara Khal = 0.022 m / Km

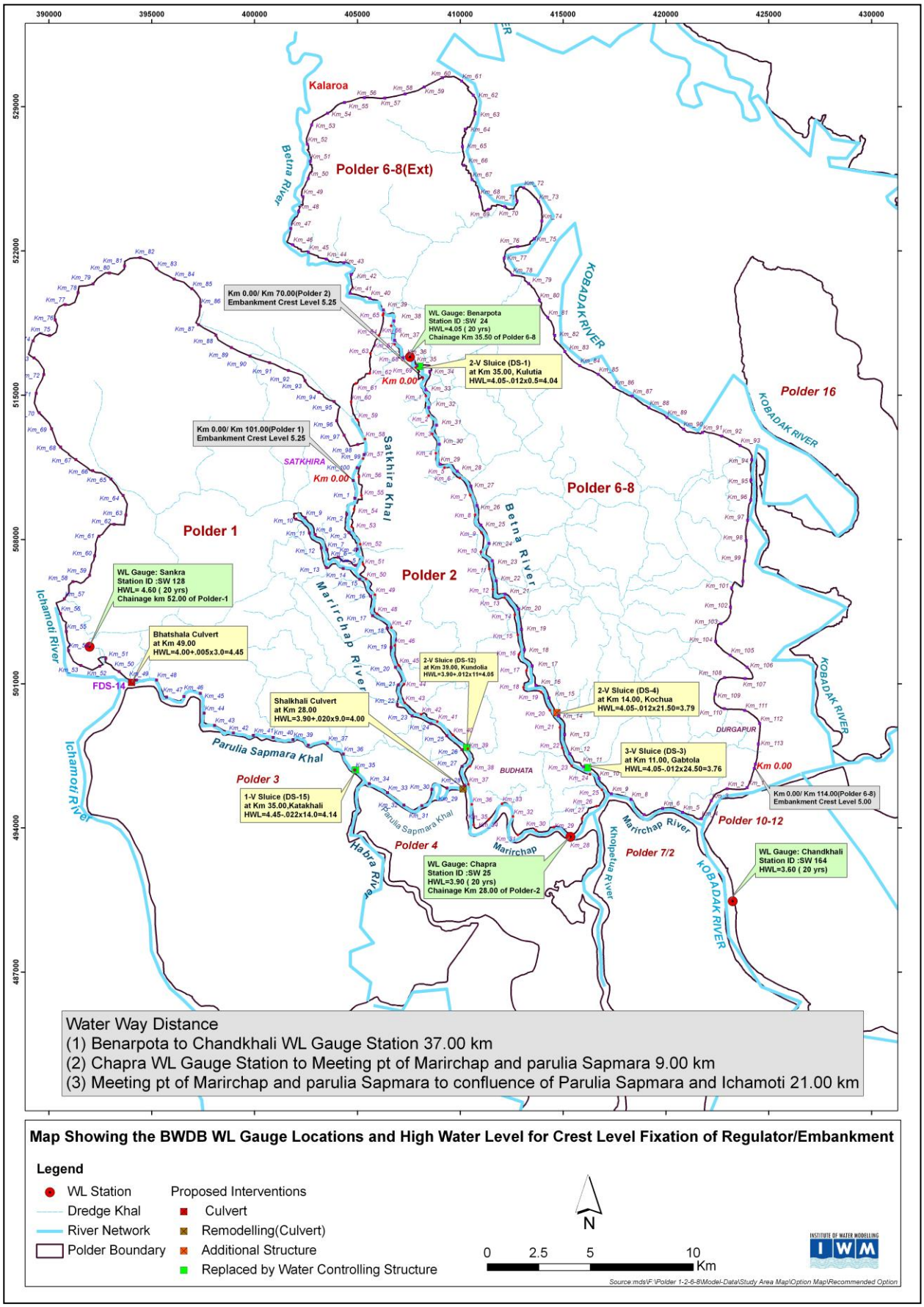


Figure 7.11: Highest Water Level (HWL) at Different Structures Locations and Water-way Distance

7.5 Design of Embankment

Reaches Requiring Construction of Embankment:

Due to replacement of Bhatshala sluice into bridge the hydraulic characteristics of Parulia Sapmara River have been change.So, Re-design of the embankment (Polder 1, Polder 3 & Polder 4) along the both bank of Parulia Sapmara khal is required due to changed scenario. The reaches of such areas have been identified by comparing the longitudinal river bank levels and water level profile of 25 year return period. Re-sectioning of embankment for Polder 2, Polder 2(Extn), Polder 6-8 & Polder 6-8 (Extn) have been proposed by the BWDB Satkhira field officials supported by the planning & design team. The reaches requiring construction of embankment are shown in **Table 7.7.**

Table 7.7: Reaches Requiring Construction of Embankment

Name of Polder	River/Khal	Left/Right Bank	Chainage (km to km)	Length of reach (km)	Remarks
Polder-1	Parulia Sapmara	Left Bank	28.00-49.00	21.00	Re-design of the Embankment (Polder 1, Polder 3 & Polder 4) along the both bank of Parulia Sapmara khal is required due to changed scenario. **(Total Length :41 km)**
Polder-3	Parulia Sapmara	Right Bank	23.00-37.00	14.00	
Polder-4	Parulia Sapmara	Right Bank	64.00-70.00	6.00	
Polder-2	Betna	Right Bank	1.00-17.50	16.50	Re-sectioning of Embankment for Polder 2, Polder 2(Extn), Polder 6-8 & Polder 6-8 (Extn) have been proposed by the BWDB Satkhira field officials supported by the planning & design team. **(Total Length :85.92 km)**
			19.00-23.00	4.00	
			23.35-25.35	2.00	
	Marirchap	Left Bank	29.00-35.00	6.00	
			42.00-51.00	9.00	
Polder-2 (Extn)	Betna	Right Bank	2.00-6.00	4.00	
Polder-6-8	Kobadak	Right bank	1.10-5.00	3.90	
	Marirchap	Left bank	5.60-9.00	3.40	
	Betna	Left bank	9.00-11.00	2.00	
			11.5-12.00	0.50	
			12.60-20.00	7.40	
			20.00-33.50	13.50	
	Kobadak	Right bank	45.00-52.72	7.72	
Polder-6-8-(Extn)	Betna	Left bank	0.50-6.50	6.00	

Design Water Level:

For selecting the crest level of embankment a design water level corresponding to 25 year peak flood level has been computed by frequency analysis of annual peak river water level data.

Crest Level of Embankment:

The design crest level has been fixed adding freeboard and future impact of climate change above deign water level. Minimum free board of 0.9 m as practiced in BWDB is used here. For the project area the future climate change impact has been considered as 0.3 m for thirty years period.

Design crest level = Design water level + free board (0.90m) + Climate Change (0.30m)

Crest width of Embankment:

A crest width of 4.3 m is used following the criteria of BWDB's Design Manual.

Side Slope of Embankment:

The C/S side slope and R/S side slopes are taken 1:3 and 1:2 respectively.

Design Section of Embankment:

Typical cross section of proposed embankment is shown in **Figure 7.12.**

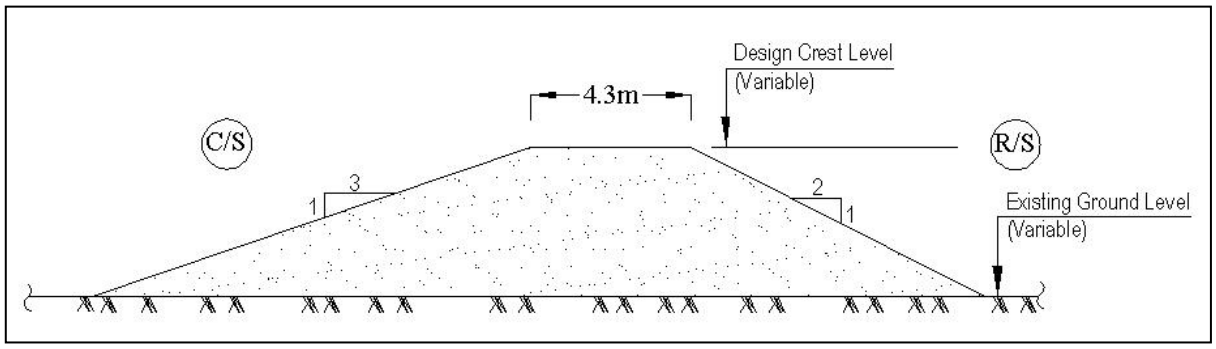


Figure 7.12: Typical Design Section of Embankment

7.6 Design of TRM Infrastructure

Selection of design parameters is important for successful and effective operation of beels as tidal basin. Detail design of TRM Basin in Jealmari Beel, Ticket Beel, Gobindapur Beel, Bugmara Beel, Sreeram katthi Beel, and Dorgahpur Beel for Marirchap River. Hazikhali-Amudkhali Beel, Matiadanga Beel, Aumtoli Beel, Sukdebpur beel, Chapra Beel for Betna River has been devised in this section. Following are the parameters that have been considered in design stages:

- The area of the Tidal basin and its suitability to act as an effective basin
- The location of the link channel that will connect the basin to the adjacent river.
- The alignment of the peripheral embankment encircled the basin
- The location and size of the outlet structures to ensure the drainage of the area hinders by the construction of peripheral embankment
- The provision of other additional structures requires for TRM operation.

A comprehensive plan for sequential TRM basin has also been formulated in this report. This will allow maintaining the sustainable and improved drainage condition for the coming decades. The area of the tidal basin are given in **Table 7.8.**

Table 7.8: Area (size) of the Tidal Basin

Sequential operation	TRM Combination	Beel Name	Effective Area (ha)
Phase-1	Sukdebpur Beel & Ticket Beel	Sukdebpur Beel	526
		Ticket Beel	545
Phase-2	Jealmari Beel & Matiadanga Beel	Jealmari Beel	586
		Matiadanga Beel	650
Phase-3	Sreeram kathi Beel & Bugmara Beel	Sreeram kathi Beel	590
		Bugmara Beel	574
Phase-4	Hazikhali- Amudkhali Beel & Gobindapur Beel	Hazikhali- Amudkhali Beel	364
		Gobindapur Beel	591
Phase-5	Aumtoli Beel , Chapra Beel & Dorgahpur Beel	Aumtoli Beel	433
		Chapra Beel	318
		Dorgahpur Beel	558

7.6.1 Hydraulic Design Parameters of Link Canal of TRM

Location of the Link channel:

In order to select the potential location of link channel, a team of professionals of IWM comprising Planning and Design Specialist and Hydraulic Engineer visited the site in association with the local stakeholders, BWDB field officials and members of LGIs. The team made extensive field visit and consultation with local people and land owners and identified potential locations of the link canal to investigate their effectiveness in terms of natural tidal movement and sediment deposition. Typical design section of the Link Channel is shown in **Figure 7.13.** Locations of link channel of 11 beels are shown in **Figure 7.17** to **Figure 7.27.**

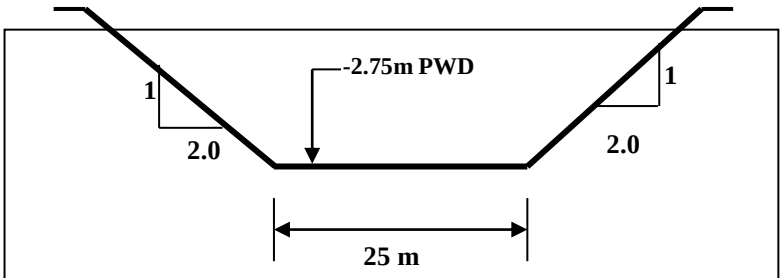


Figure 7.13: Typical Section of Link channel

7.6.2 Selection of alignment and design of peripheral embankment of TRM

Peripheral Embankment

The alignment of peripheral embankment of the proposed tidal basin has been fixed based on the field visit and interaction meeting with the local stakeholders and TRM model. From the findings of the field visit and interaction meeting with local stakeholders it is evident that the proposed peripheral embankment needs to be constructed partly by upgrading the existing embankment, partly by construction of new embankment in the beel and partly along the cluster of village.

Design of Peripheral Embankment

Design of the embankment has been carried out using the results of the TRM and Drainage modelling.

Design Crest Level:

The crest level of embankment has been shown in **Table 7.7** to **Table 7.18**.The crest level considering a design water level inside the beel and 0.90 m free board without the future impact of climate change.

Design Cross Section:

The design section of embankment shall have crest width of 3.0 m and side slopes of 1:3 in the basin side and 1:2 on the country side.

Slope Protection:

The embankment slope needs to be protected from rain damage by providing close grass sod turfing.Typical design section of the peripheral embankment, marginal dyke & pheripheral dyke of cluster village is shown in **Figure 7.14, 7.15 & 7.16** respectively**.**

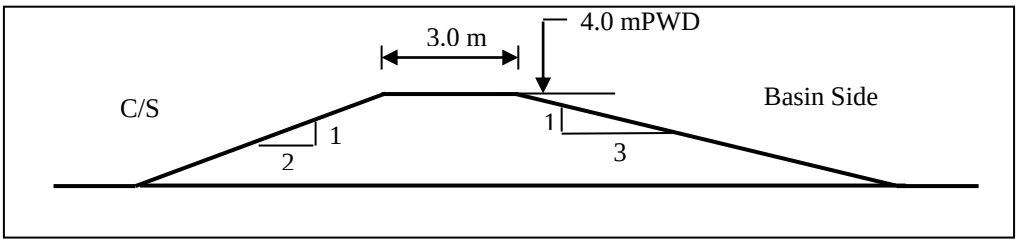


Figure 7.14: Typical Design Section of Peripheral Embankment

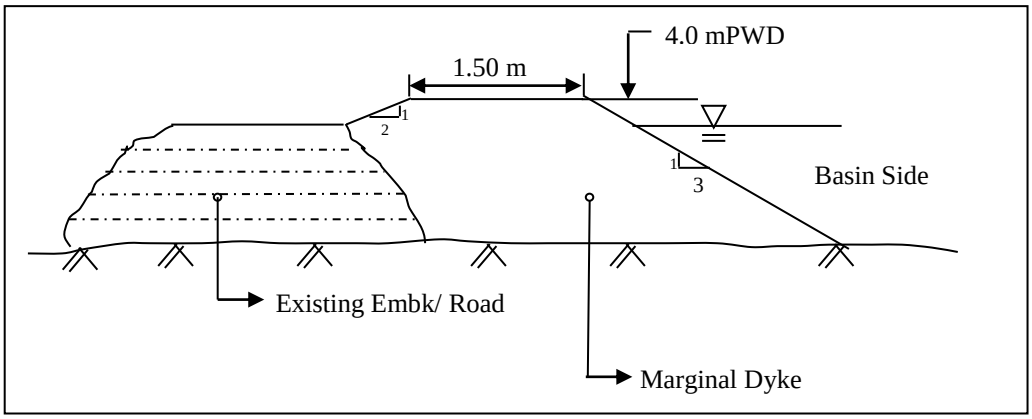


Figure 7.15: Typical Design Section of Marginal Dyke

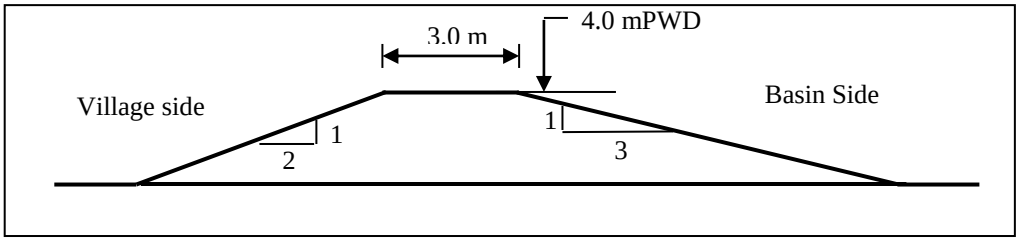


Figure 7.16: Typical Design Section of Peripheral Dyke of Cluster Village

7.6.3 Detailed list of Civil Works for Implementation of TRM

The detailed list of activities to implement the 11 Beel as TRM basin is presented in **Table 7.9** to **Table 7.19.** Details of TRM Basin of 11 beels are shown in **Figure 7.17** to **Figure 7.27**.

Table 7.9: List of Civil Works to be constructed for Proposed Tidal Basin at Sukdebpur Beel (Phase-1)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Sukdebpur Beel	
B.	Effective area for TRM	526 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.17** Total Length : 11.505 km • New peripheral embankment in the beel : 10.78 km • Marginal dyke length along existing embankment: 00.72 km • New peripheral dyke of cluster village : 1.68 km Design Section: Crest level : 4.0 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 536 m (approx.) Design Section: Top width : 40 m Bottom width : 28 m Bottom level : -2.25 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 235 m (approx.) Design Section: Top width : 40 m Bottom width : 28 m Bottom level : -2.25 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.17** No & Size: Drainage RCC Pipe Outlet : : 3 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.17**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.10: List of Civil Works to be constructed for Proposed Tidal Basin at Ticket Beel (Phase-1)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Ticket Beel	
B.	Effective area for TRM	545 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.18** Total Length : 9320 m • New peripheral embankment in the beel : 7.98 km • Marginal dyke length along existing embankment: 1.34 km Design Section: Crest level : 4.00 mPWD Top width : 3.0 m Side slopes :1:2.5 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 240 m (approx.) Design Section: Top width : 30 m Bottom width : 12 m Bottom level : -1.75 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 300 m (approx.) Design Section: Top width : 30 m Bottom width : 12 m Bottom level : -1.75 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Not Required	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 30.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.18**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.11: List of Civil Works to be constructed for Proposed Tidal Basin at Jealmari Beel (Phase-2)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Jealmari Beel	
B.	Effective area for TRM	586 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.19** Total Length : 10490 m • New peripheral embankment in the beel : 7.66 km • Marginal dyke length along existing embankment: 2.83 km Design Section: Crest level : 4.00 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 224 m (approx.) Design Section: Top width : 35 m Bottom width : 20 m Bottom level : -1.8 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 150 m (approx.) Design Section: Top width : 35 m Bottom width : 20 m Bottom level : -1.8 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.19** No & Size: Drainage RCC Pipe Outlet : : 4 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m (Two spans @ 30m each)	
G.	Seasonal Cross Dam	Location shown in **Figure 7.19**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.12: List of Civil Works to be constructed for Proposed Tidal Basin at Matiadanga Beel (Phase-2)

Item	Features	Quantity and Design Parameters
A.	Name of Beel	Matiadanga Beel
B.	Effective area for TRM	650 ha
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.20** Total Length : 12690 m • New peripheral embankment in the beel : 12.69 km Design Section: Crest level : 4.0 mPWD Top width : 3.0 m Side slopes :1:2.5 for R/S (Beel side) :1:2 for C/S (Land Side)
D.	Link Channal	Length : 850 m (approx.) Design Section: Top width : 40 m Bottom width : 28 m Bottom level : -2.00 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.20** No & Size: Drainage RCC Pipe Outlet : : 1 No. each 1-Vent, 0.9 m diameter RCC pipe
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m
G.	Seasonal Cross Dam	Location shown in **Figure 7.20**
Km 0 starts at link channel and increases in clockwise direction		

Table 7.13: List of Civil works to be constructed for Proposed Tidal Basin at Sreeram Kathi Beel (Phase-3)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Sreeram Kathi Beel	
B.	Effective area for TRM	592 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.21** Total Length : 12110 m • New peripheral embankment in the beel : 11.87 km • Marginal dyke length along existing embankment: 0.24 km Design Section: Crest level : 4.0 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 620 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.9 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 615 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.90 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.21** No & Size: Drainage RCC Pipe Outlet : : 5 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.21**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.14: List of Civil works to be constructed for Proposed Tidal Basin at Bugmara Beel (Phase-3)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Bugmara Beel	
B.	Effective area for TRM	574 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.22** Total Length : 10100 m • New peripheral embankment in the beel : 7.02 km • Marginal dyke length along existing embankment: 3.08 km Design Section: Crest level : 3.50 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 250 m (approx.) Design Section: Top width : 30 m Bottom width : 12 m Bottom level : -1.6 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 273 m (approx.) Design Section: Top width : 30 m Bottom width : 12 m Bottom level : -1.60 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.22** No & Size: Drainage RCC Pipe Outlet : : 2 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 30.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.22**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.15: List of civil works to be constructed for Proposed Tidal Basin at Hazikhali-Amudkhali Beel (Phase-4)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Hazikhali- Amudkhali Beel	
B.	Effective area for TRM	364 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.23** Total Length : 8910 m • New peripheral embankment in the beel : 5.98 km • Marginal dyke length along existing embankment: 2.93 km Design Section: Crest level : 4.0 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 324 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.75 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 367 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.75 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.23** No & Size: Drainage RCC Pipe Outlet : : 7 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m (Two spans @ 30m each)	
G.	Seasonal Cross Dam	Location shown in **Figure 7.23**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.16: List of civil works to be constructed for Proposed Tidal Basin at Gobindapur Beel (Phase-4)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Gobindapur Beel	
B.	Effective area for TRM	591 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.24** Total Length : 10450 m • New peripheral embankment in the beel : 7.70 km • Marginal dyke length along existing embankment: 2.75 km Design Section: Crest level : 3.50 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 133 m (approx.) Design Section: Top width : 30 m Bottom width : 12 m Bottom level : -1.75 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 285 m (approx.) Design Section: Top width : 30 m Bottom width : 12 m Bottom level : -1.75 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.24** No & Size: Drainage RCC Pipe Outlet : : 5 Nos. each 1-Vent, 0.6 m diameter RCC Pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 30.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.24**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.17: List of Civil works to be constructed for Proposed Tidal Basin at Aumtoli Beel (Phase-5)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Aumtoli Beel	
B.	Effective area for TRM	433 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.25** Total Length : 8600 m • New peripheral embankment in the beel : 7.81 km • Marginal dyke length along existing embankment: 0.79 km Design Section: Crest level : 4.0 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 280 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -1.5 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 155 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -1.5 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.25** No & Size: Drainage RCC Pipe Outlet : : 4 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.25**	
Km 0 starts at link channel and increases in clockwise direction			

Table 7.18: List of Civil works to be constructed for Proposed Tidal Basin at Chapra Beel (Phase-5)

Item	Features	Quantity and Design Parameters
A.	Name of Beel	Chapra Beel
B.	Effective area for TRM	318 ha
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.26** Total Length : 8420 m • New peripheral embankment in the beel : 8.42 km Design Section: Crest level : 4.0 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)
D.	Link Channal	Length : 353 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.9 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.26** No & Size: Drainage RCC Pipe Outlet : : 8 Nos. each 1-Vent, 0.9 m diameter RCC Pipe
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m
G.	Seasonal Cross Dam	Location shown in **Figure 7.26**
Km 0 starts at link channel and increases in clockwise direction		

Table 7.19: List of Civil works to be constructed for Proposed Tidal Basin at Dorgahpur Beel (Phase-5)

Item	Features	Quantity and Design Parameters	
A.	Name of Beel	Dorgahpur Beel	
B.	Effective area for TRM	558 ha	
C.	Peripheral Embankment	Alignment : Shown in **Figure 7.27** Total Length : 11830 m • New peripheral embankment in the beel : 11.83 km Design Section: Crest level : 4.00 mPWD Top width : 3.0 m Side slopes :1:3 for R/S (Beel side) :1:2 for C/S (Land Side)	
D.	Link Channal	1st Link Channel Length : 336 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.5 mPWD Side slope : 1:2 (Both sides)	2nd Link Channel Length : 311 m (approx.) Design Section: Top width : 40 m Bottom width : 25 m Bottom level : -2.5 mPWD Side slope : 1:2 (Both sides)
E.	Drainage Outlet	Location: Shown in **Figure 7.27** No & Size: Drainage RCC Pipe Outlet : : 4 No. each 1-Vent, 0.9 m diameter RCC pipe	
F.	Baily Bridge	Location : at crossing of link canal and existing road Length : 40.0 m	
G.	Seasonal Cross Dam	Location shown in **Figure 7.27**	
Km 0 starts at link channel and increases in clockwise direction			

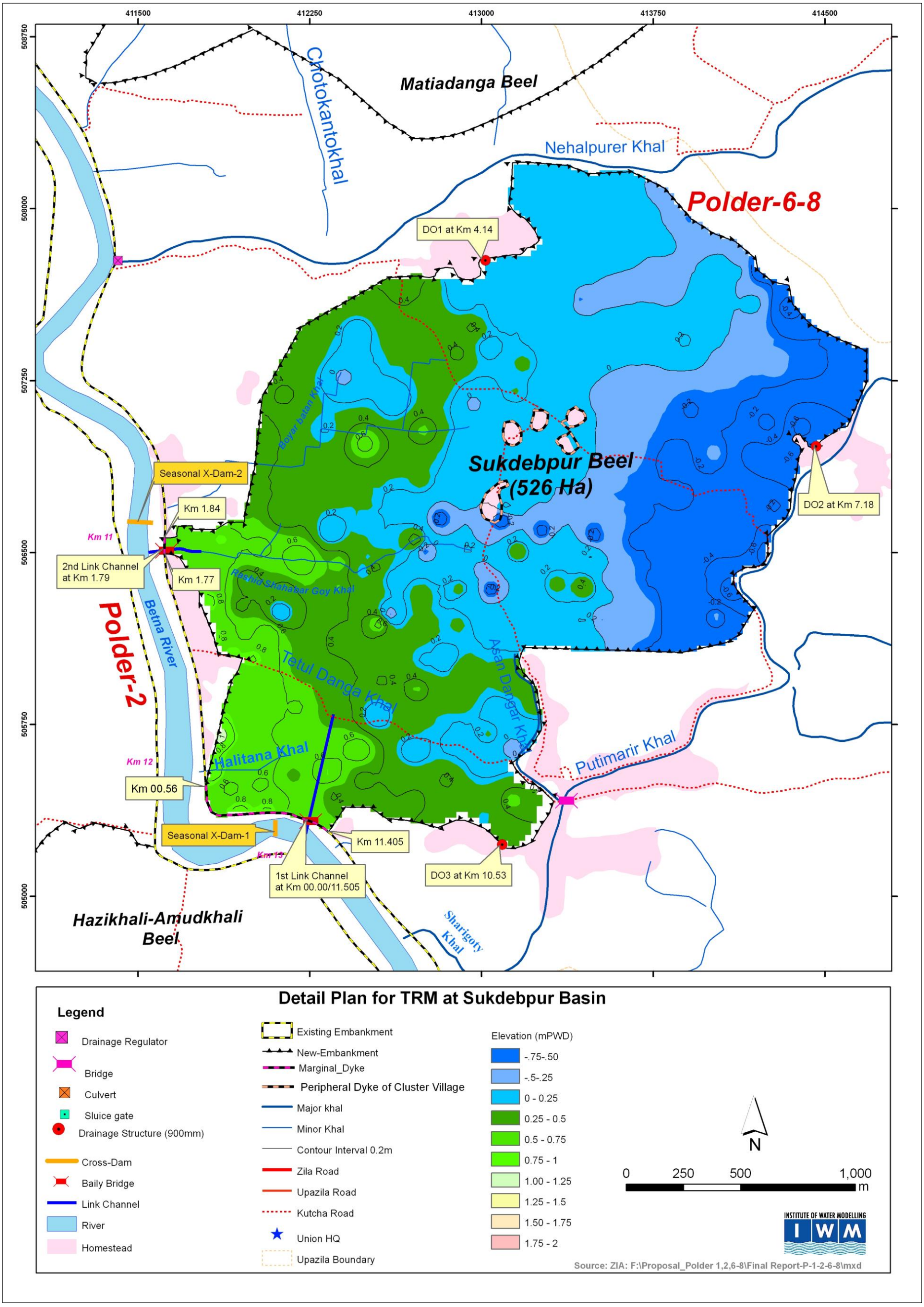


Figure 7.17: Details of Sukdebpur TRM Basin (Sequince-1)

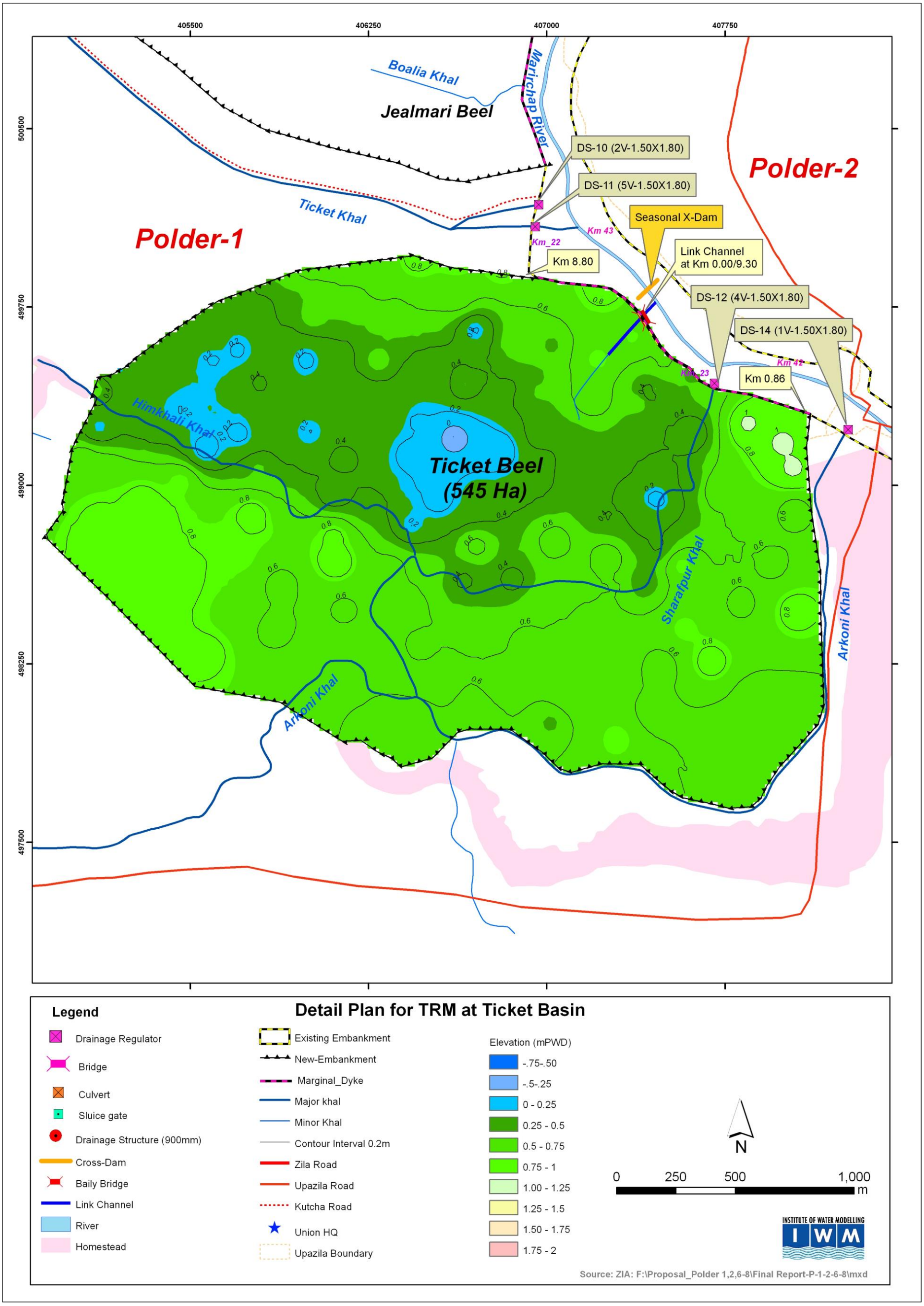


Figure 7.18: Details of Ticket TRM Basin (Sequince-1)

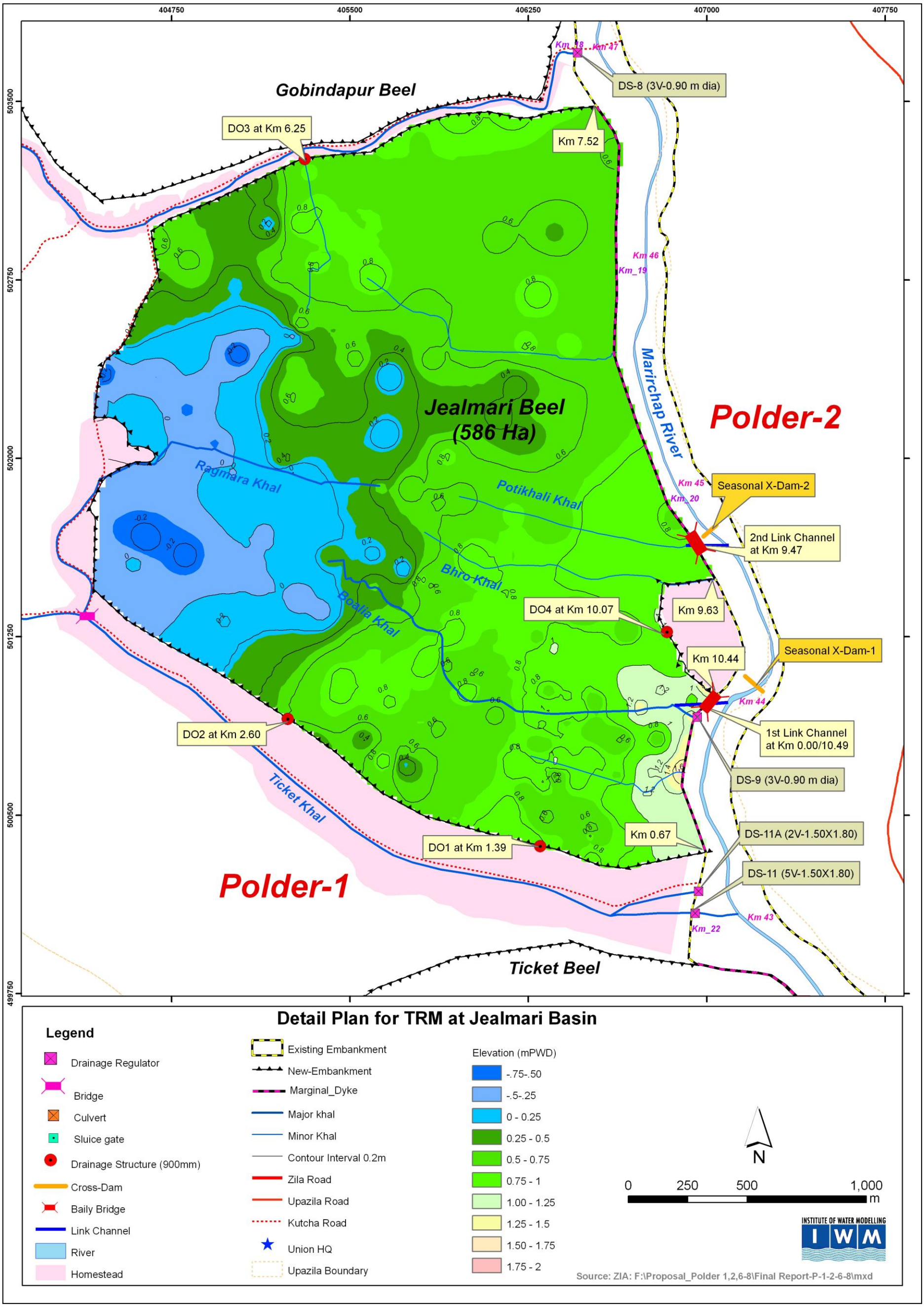


Figure 7.19: Details of Jealmari TRM Basin (Sequince-2)

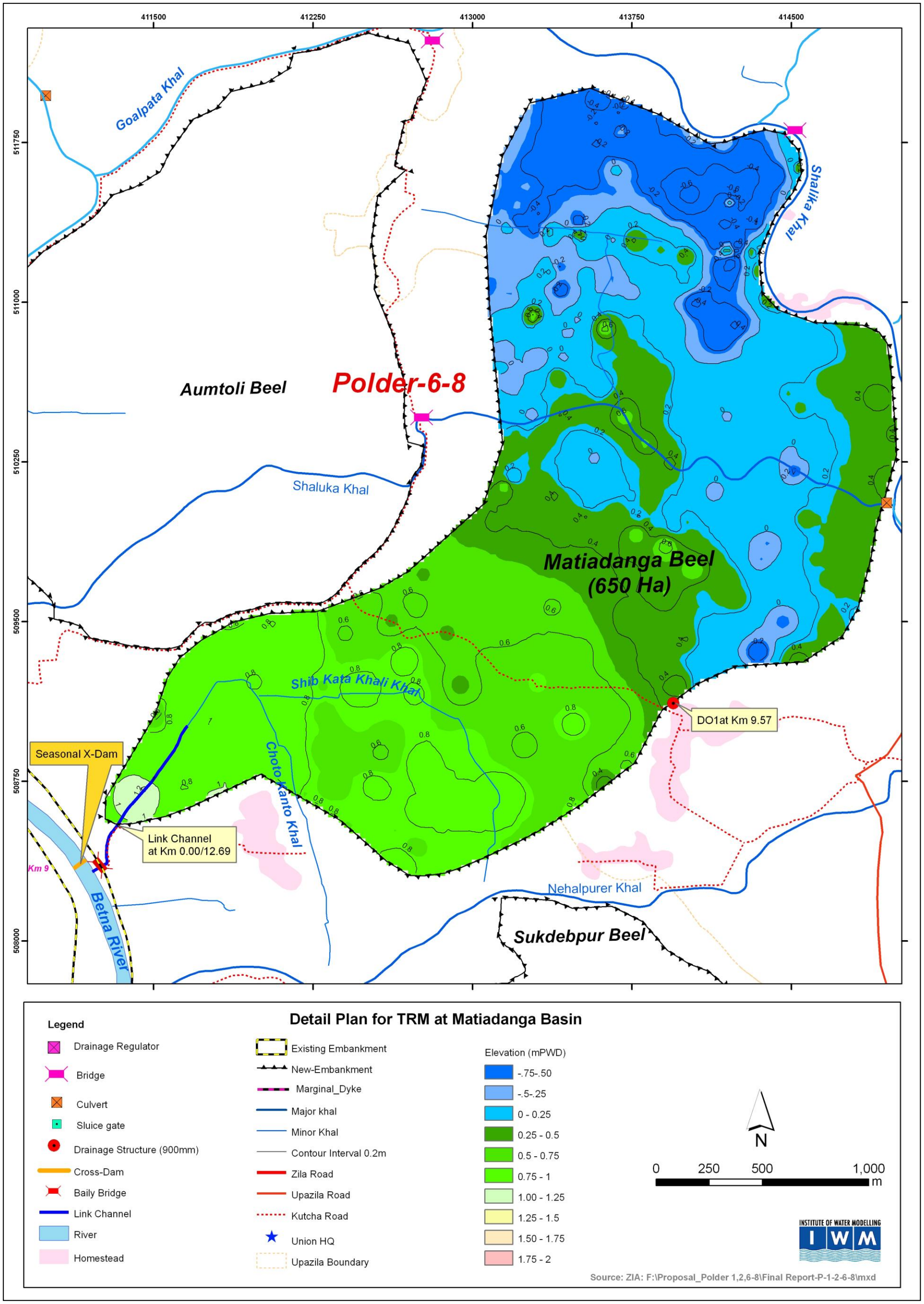


Figure 7.20: Details of Matiadanga TRM Basin (Sequince-2)

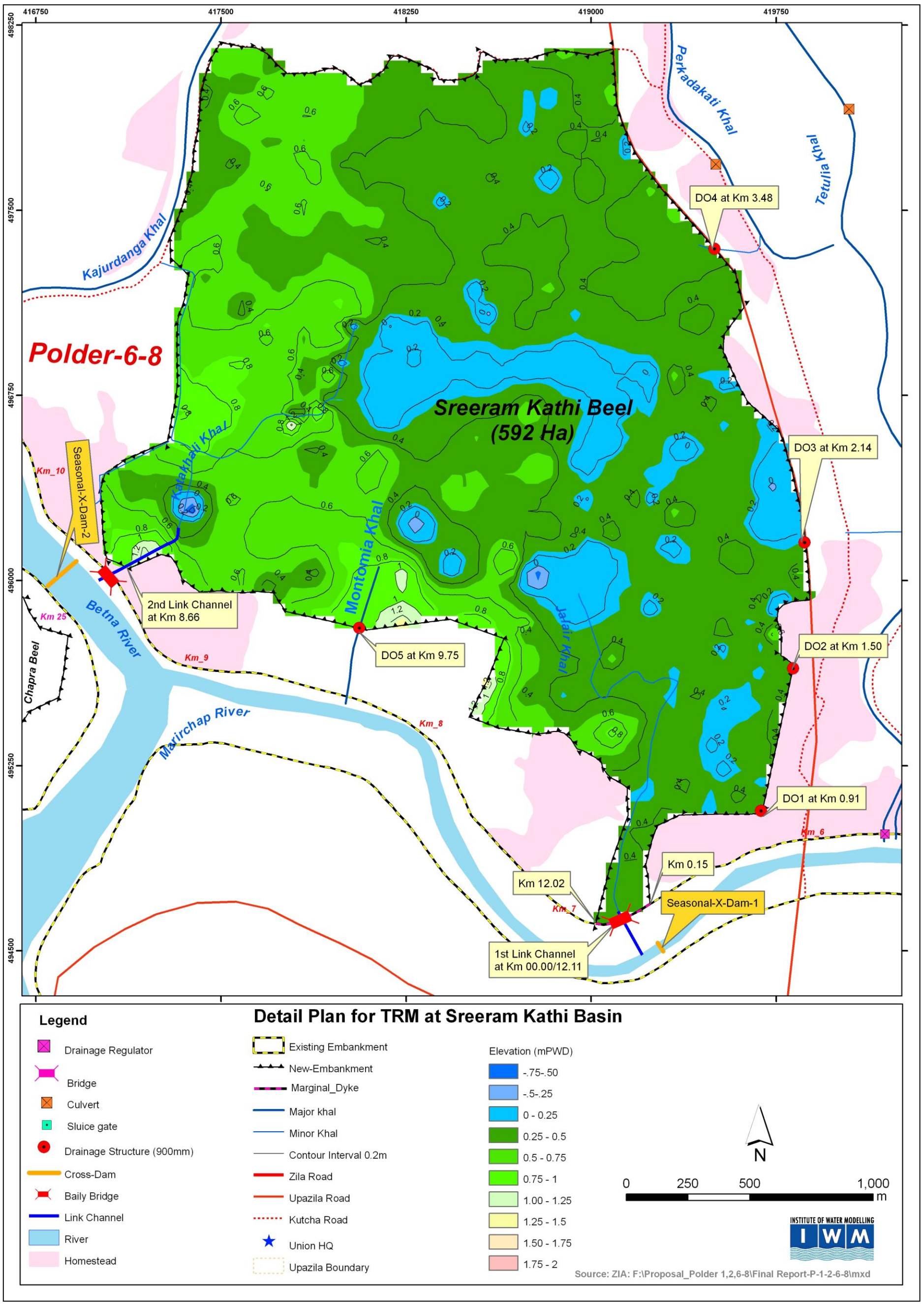


Figure 7.21: Details of Sreeram Kathi TRM Basin (Sequince-3)

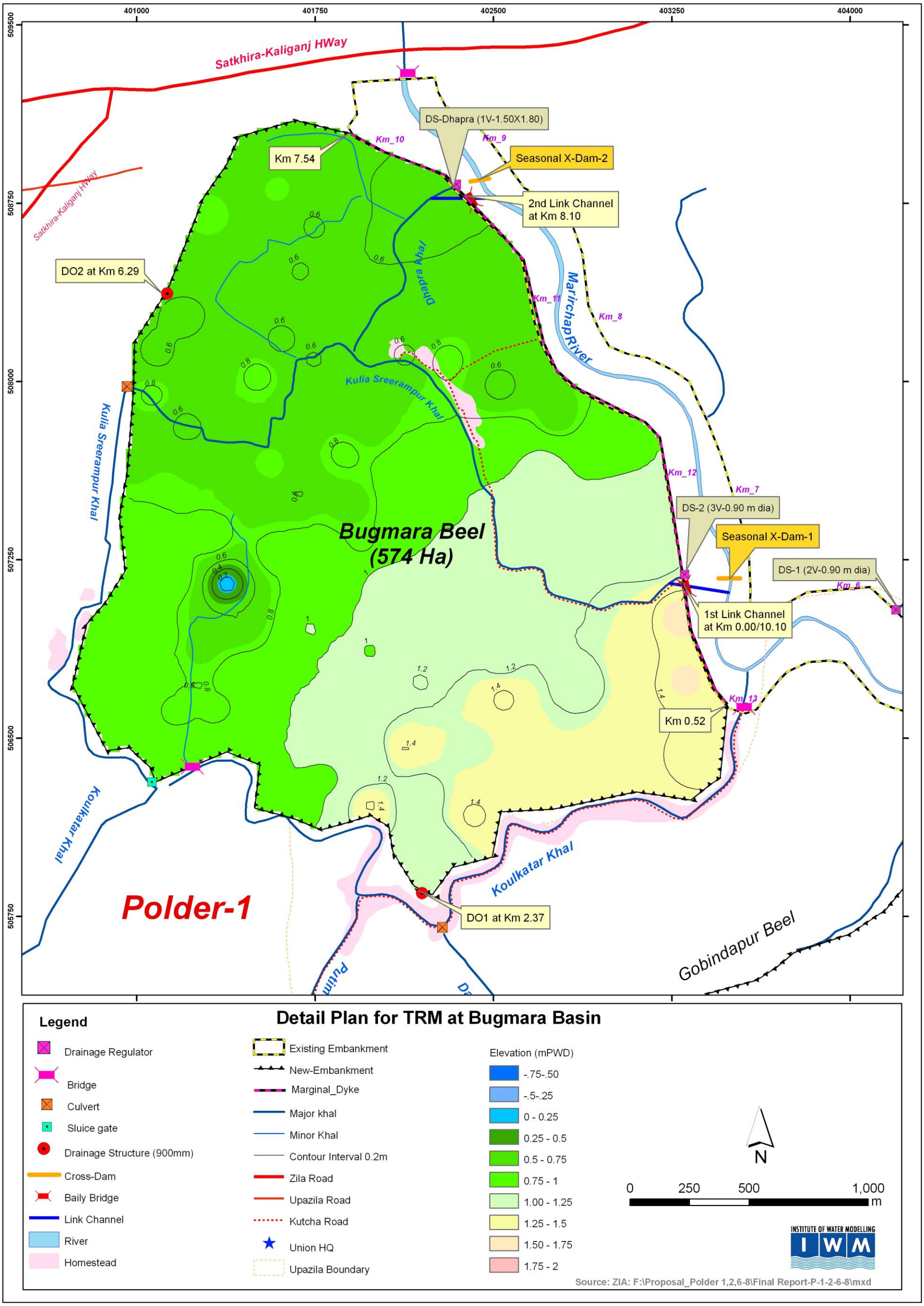


Figure 7.22: Details of Bugmara TRM Basin (Sequince-3)

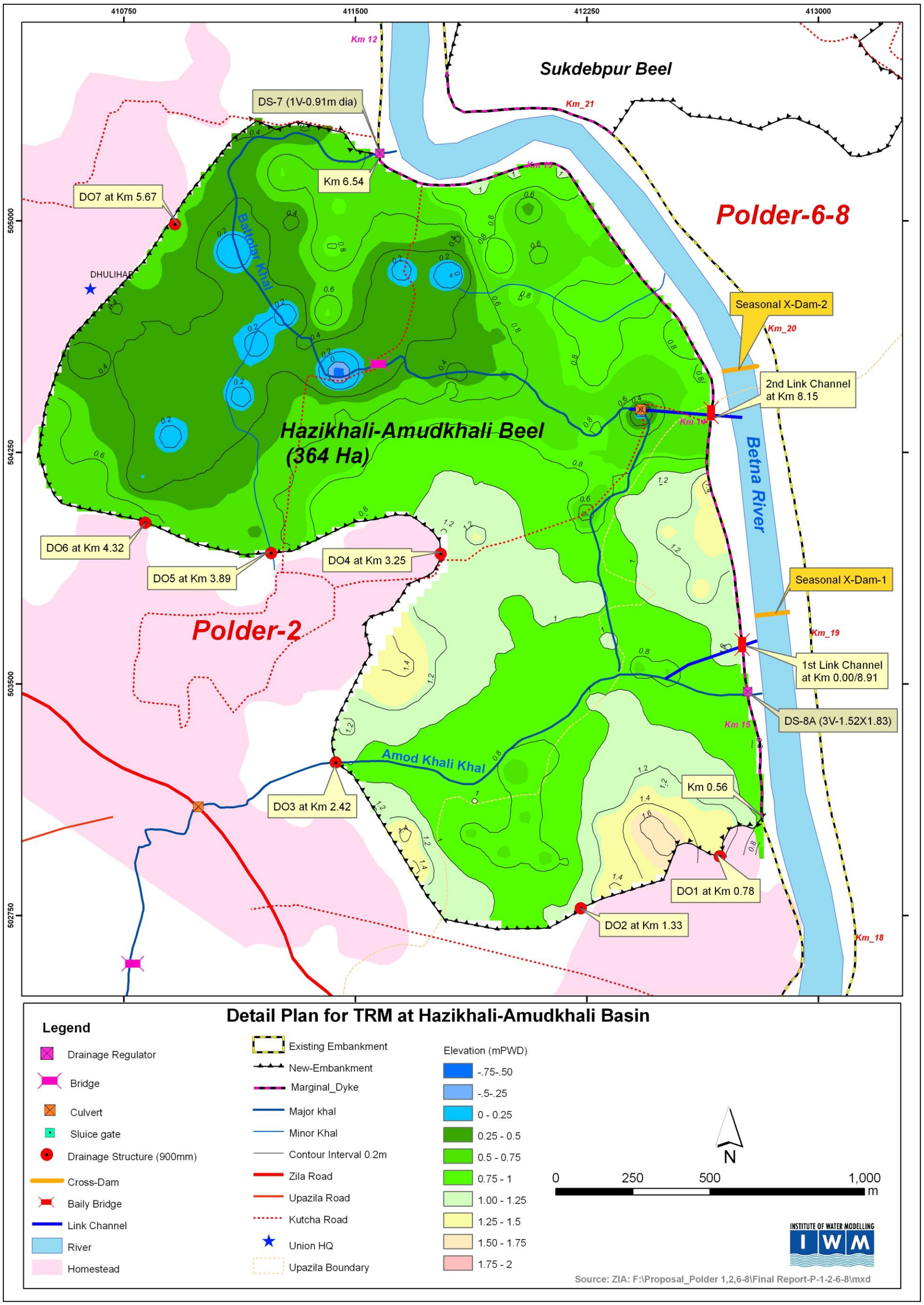


Figure 7.23: Details of Hazikhali-Amudkhali TRM Basin (Sequince-4)

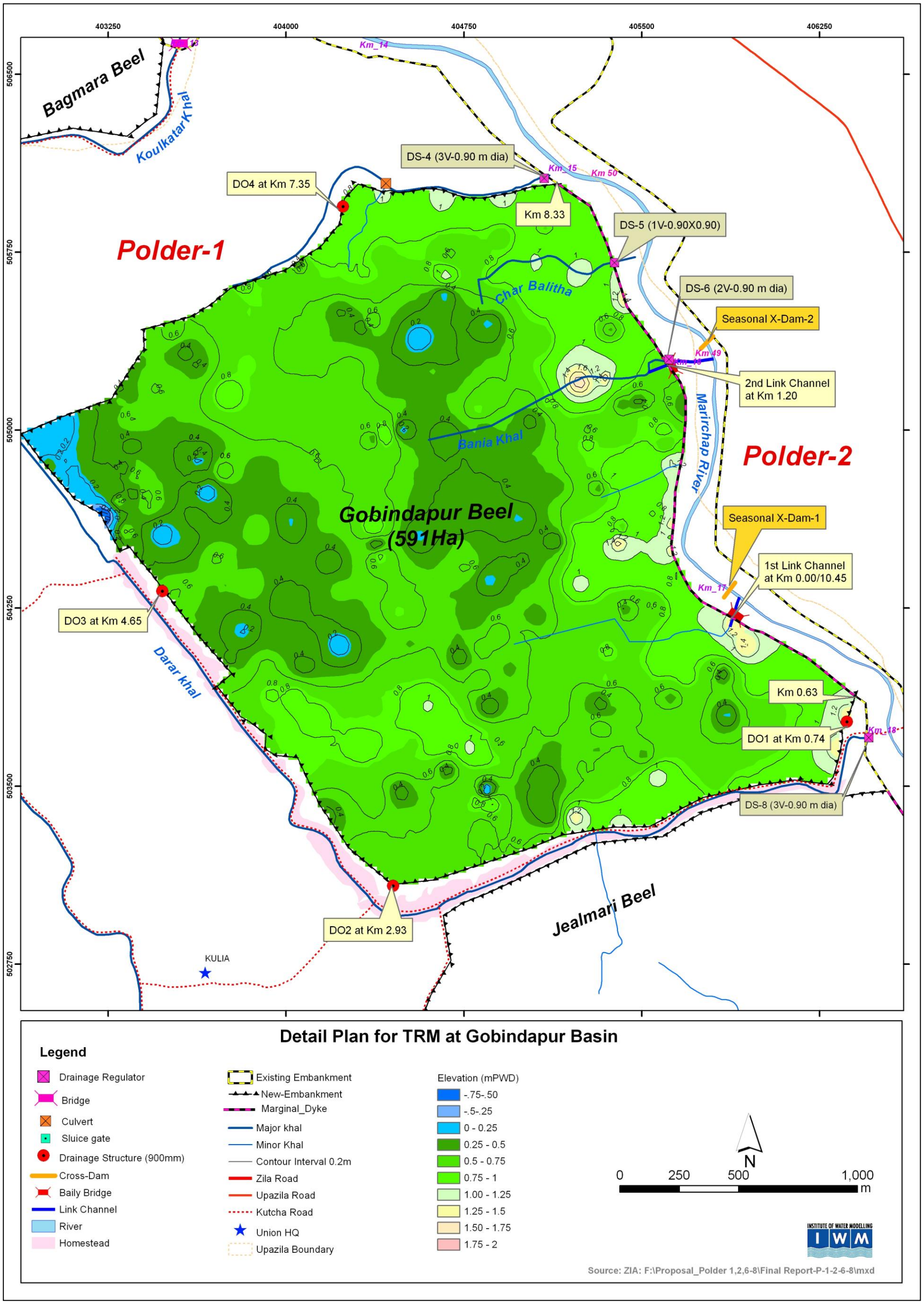


Figure 7.24: Details of Gobindapur TRM Basin (Sequince-4)

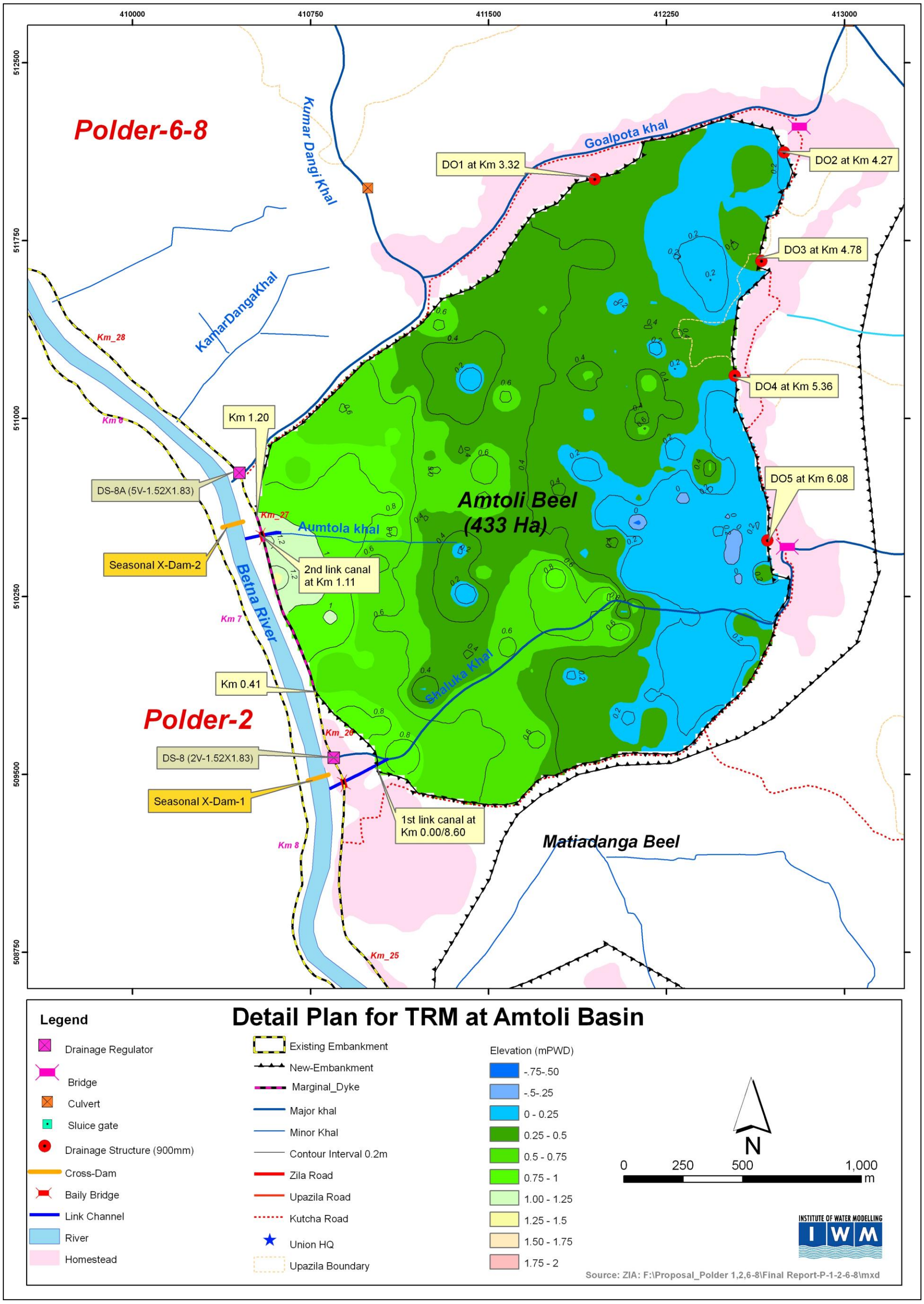


Figure 7.25: Details of Aumtoli TRM Basin (Sequince-5)

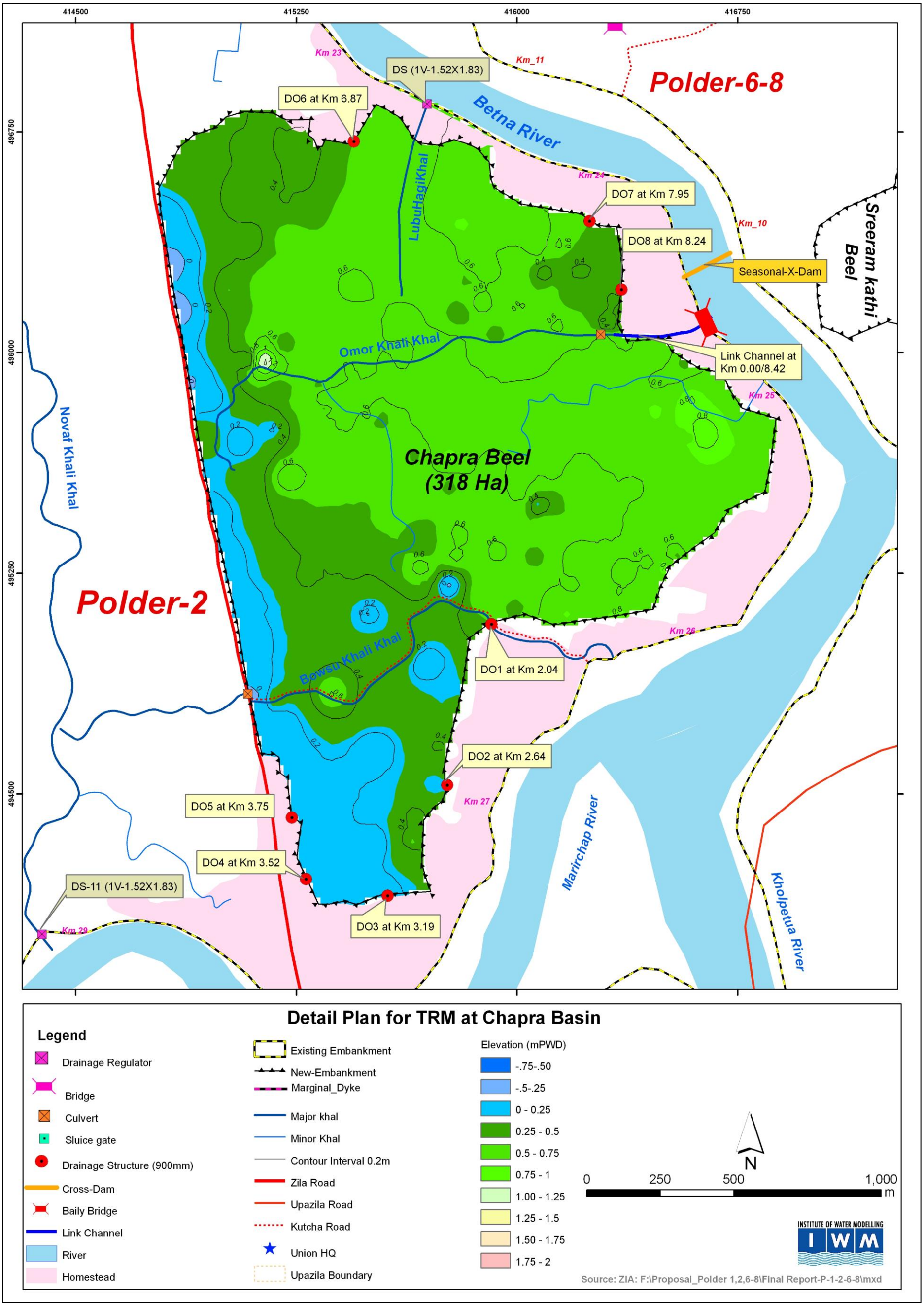


Figure 7.26: Details of Chapra TRM Basin (Sequince-5)

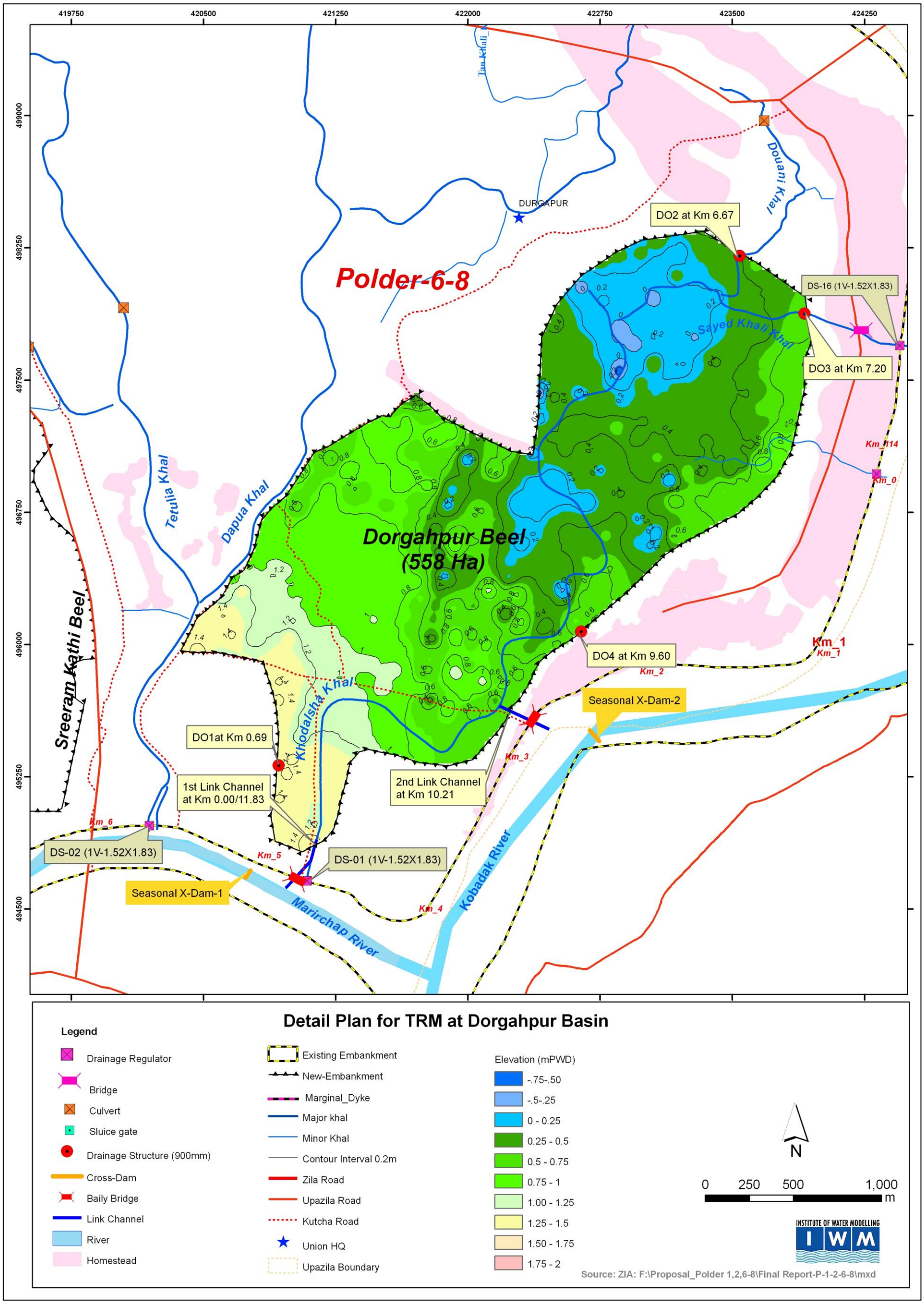


Figure 7.27: Details of Dorgahpur TRM Basin (Sequince-5)

7.7 Establishment of Dredging and River Alignment on Mouza Map

It has been always a very difficult to implement the dredging plan in the field due to change in river alignment over the years compared to Mouza map and also encroachment of river by local community. It is of immense important to establish existing river and proposed dredging alignment on the Mouza map to facilitate the execution of dredging and consultation process with the local community. Digitizing and geo-referencing of Mouza map are the integral part of preparing maps showing the present river and dredging alignment and adjacent plots of land.

Geo-referencing is a process by which different sources of geographic data can be referenced to the Earth's surface. The concept of geo-referencing of satellite images involves establishing relationships between each point of the land and its corresponding representation on the image through the assignment of coordinates linked to the land and related features to a spatial reference system. To get the actual and dredging alignment of river, IWM has been collected mouza map from Department of Land Records & Survey (DLRS). There are 73 numbers of mouza (157 numbers of sheets). Initially geo-referencing of all maps with some known established points was carried out. After geo-referring, all maps has been joined each other. After joining each sheet/map, actual river bank alignment has been digitized on mouza map. Dredged alignment are also superimposed on this mouza map. Detailed are describe below.

- **Collecting Ground Control Points (GCP) through Field Survey**

Ground Control Points are highly accurate control points or layer such as road-network or any layer on earth surface of known location (i.e. fixed within an established coordinate system) that contains coordinates used as control reference to geo-reference image data sources especially satellite images or scanned Mouza Maps. GPSs were collected through RTK-GPS survey from the field for known locations which were identified both on satellite imagery and on earth surface. At least, four GCPs for each satellite imagery surveyed which were spread throughout the image. GCPs were taken in WGS 84 Coordinate System and transformed into Bangladesh Transverse Mercator (BTM) with Everest Bangladesh 1937 Datum following standard procedure, as the projection system for all spatial data for the project is BTM. Beyond GCPs, Others available archive spatial data such as river network, road network, etc. were used as reference layer.

- **Geo processing and Geo referencing Satellite Imageries using GCPs**

Archived Satellite imageries were processed to enhance colour, tone, rearranging band combination, etc. for better visualization. Imageries were further geo-rectified using several (not less than four) GCPs or highly accurate control layer. This geo-referencing process has been done using tools available ArcGIS 10.1 Software. Satellite imageries of best possible resolution for different year were made available for the project area from IWM achieves. Mostly, Quick Bird Satellite imageries of different years were used for this project. RMS (Root Mean Square) Error were kept minimum while georeferencing images for maintaining higher accuracy.

- **Geo referencing Mouza Maps using Geo referenced Satellite Imageries**

Mouza Maps collected from DLRS (Total 73) were scanned first with a standard resolution (preferably 300 dpi). Mouza map were georeferenced using ArcGIS 10.1 software identifying known locations such as plot corner, built structure, etc. both on the image and map. Affine Method (First Order Polynomial) were used and RMS Error were kept minimum for maintaining higher accuracy.More control points preferably 10-15 control points were taken to kept RMS error minimum.

- **Mouza Map Digitizing and Database Building**

Georeferenced Mouza Maps were further processed for better visualization in order to digitizing plot boundaries on the Mouza Map. All features/plot are digitized in line shape file for each Mouza Map. After digitization, all plot lines for each Mouza sheet were mosaicked through edge matching. Later polyline features were transformed into polygon features and was made a single feature dataset. All plots were attributed with its respective plot number, mouza name, mouza sheet no. Jurisdiction Limit (JL) number, district and upazila name. Finally, a comprehensive GIS database was developed with adding required information and actual river bank alignment has been found from this geo-referred mouza map.

- **Superimposing Dredge Alignment and Dredge Earth Management locations with Mouza Map**

Finally proposed dredged alignment and dredged spoil locations were superimposed with digitized mouza maps in order to show the spatially the dredged areas and to know whether the alignment was compliance with the existing river alignment or not. In case of noncompliance of proposed dredged alignment with existing river alignment on mouza map, existing plots and its respective areas which are crossed by the existing river were identified. **Figure 7.28** shows the river alignment; dredge alignment locations on digitizing mouza map. All are include in **Volume II** Sheet no. 1 to 37.

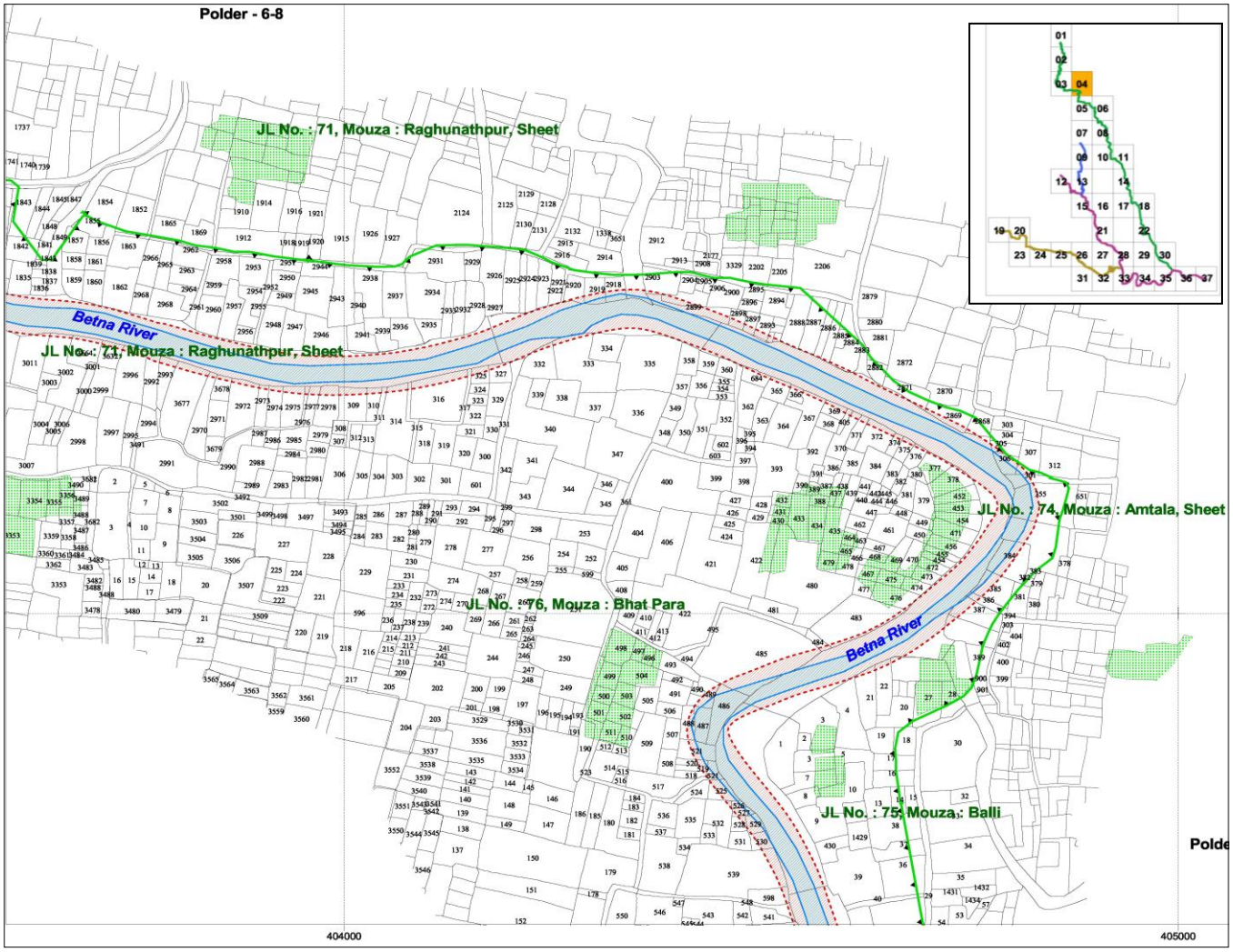


Figure 7.28: River and Dredge Alignment with Mouza Map

7.8 Planning of Disposal of Dredged Material

One of the main challenges of dredging and excavating (By mechanical/manual) program is disposal of dredged/excavated material, which requires technical, environmental and social considerations. The dredged/excavated spoil earth is, in principle, disposed on the locations where natural sedimentation may not be expected and there is no scope of resuspension of dredged/excavated spoil into the dredged channel. These locations are the inner bends, adjacent low-pocket areas and abandoned channels.

In the present study location of the dredged/excavated spoil disposal has been assessed by several field visits and using the recent mouza maps and satellite images, surveyed data on river cross-section profile with adjacent physical features and local stake holder opinion along the river stretch. The total dredged/excavated length of the river are 37.00 km (Ch:00.00km to 37.00km) for Marirchap, 44.00 km (Ch:00.00km to 44.00km) for Betna & 23.50 (Ch:00.00km to 23.50km) km for Parulia Sapmara out of which only 20.50 km (Ch:23.50km to 44.00km) from Bak Khali to kata Khali will be dredged by dredger and the rest of the length will be excavated manually excavation or mechanical excavaor.The available location near the dredging/excavating site examined to use as the location of the dredged/excavated spoil disposal on the basis of hydraulic conditions and environmental conditions. There are plenty of lands available for spoil earth

management to avoid future complications. In few places spoil management cause problems like Parulia Sapmara khal where the dredged/excavated spoil earth can be used to build resectioning of embankment (Polder-1, Polder-3 & Polder-4) along the river where it is required. Existing roads can also be widen with this dredged/excavated material and some amount of spoil earth also be used in Brick fields beside the river. All maps for spoil earth management have been provided in A1 size with mouza map and incorporated in the Volume II.

7.9 Challenges & Strategy for Implementation of TRM in the Polders

7.9.1 Background

Due to construction of embankment along the banks of main rivers for implementation of coastal polders, movement of tide remained confined within both banks of the rivers. In the post project condition during dry season, deposition of silt occurs twice a day (24 hours) within the territory of the rivers (in between the both banks) which was usually being deposited in the beels (poldered area) in the pre-project condition. Deposition starts from the dead end of upcoming silt laden saline water at the time of flow tide. This siltation process was accelerated due to reduction of upland flow after commissioning & operation of Farraka Barrage in the year 1972. After poldering the area within the embankment remained in same elevation as it was before, because entrance of tide was totally obstructed. In course of time, river bed became silted-up above the ground level obstructing natural drainage. This situation prevailed in the rivers Betna, Marichchap, Hamkura, Hari, Kobadak, Bhadra, Gangrail in the South-West Region of Bangladesh to create water logging in several beels. Earlier BWDB tried to solve the water logging problem merely by excavation of channels, but within one or a couple of years the excavated channels became silted up fully as it was before excavation. Excavation/ dredging for years together was not possible due lack of fund & shortage of adequate number of dredgers. Availability of adequate land for disposal of spoil/dredged earth for years together is also a very acute problem. Manual excavation of a flowing tidal river at a specific /entire length by construction of cross-bundh at the both end across the channel effects adversely accelerating siltation from the end of downstream cross-bundh to obstruct drainage as a whole.

7.9.2 Previous Remedial Projects

Khunna-Jessore Drainage Rehabilitation Project (KJDRP) funded by ADB was started in the year 1994-95 to solve the drainage congestion in beel Dakatia of Khulna district, and beel Kedaria, beel Bakr, beel Jhikra & other beels of Jessore district.

Water logging from beel Dakatia was removed by canal re-networking & construction of two new regulators ,one at Ramdia & other at Soilmari where lower Soilmari is the out fall river to drain out eventually through lower Salta river. Kazibacha, lower Soilmari & lower Salta rivers are inter-connected to have a semi-circular tidal flow as a result the rate of siltation at the out fall of Ramdia & Soilmari sluices is not significant.

Water logging problem of beel Kedaria & other adjacent beels of Jessore district was planned to solve by construction of a gigantic regulator at Madhukhali at the down-stream of Hari River. But this could not be implemented due to vehement oppose from the local people organized by NGO's & LGI's, who believed to be the Bhabodah regulator was the main cause of drainage congestion in the beels of Jessore area. They did not want to create another 'Big Bhabodah' at the downstream.

7.9.3 Concept of TRM

When the affect of devastating flood in the year 1998 was added with water logging & water could not be drained out in any way & became stagnant, local people of Keshabpur U.Z. had cut flood embankment at beel Bhaina to get rid of marooned situation. Due to having a high magnitude of head difference between C/S & R/S water levels, rapid drainage & recession of water took place. But after few days, tide started to enter in the beel as a natural phenomenon to create tidal flooding. *To & fro* (incoming & outgoing) tidal flow formed a wide channel which was beyond the capacity of the local people to close it when they desired.

At the end of dry season the local people surprisingly noticed that land level of beel Bhaina had been raised significantly & the depth of Hari River had been increased. They correlated the phenomenon of deepening of the river & siltation in the beel to be the function of tidal movement to & from the beel. Actually the beel was brought under pre-project condition by cutting the embankment. After maturity of siltation in the year 2001 & closing of the channel developed at the cut point, value of the land of beel Bhaina was approximately tripled. The local people became inclined & interested in this process & urged the KJDRP Consulting Team to apply the process sequentially in all the low lying beels along the both banks of Hari River in the project area. This was accepted by the KJDRP Consulting Team giving a new title as Tidal River Management (TRM) being this natural process environmental friendly, cost effective & socially acceptable.

7.9.4 TRM in other Beels

After recognizing TRM as a solution of water logging problem in the KJDRP area, beel Kedaria was selected as the next TRM basin. Beel Kedaria was linked with Hari River through the Bhabodah regulator after construction of peripheral embankment to keep the incoming tidal water confined within the basin. TRM in beel Kedaria was operated from 2002 to 2004.

As TRM in beel Kedaria was operated through the Bhabodah regulator, deposition of silt was not as per expectation of the local people & also silt was not uniformly deposited throughout the beel. This made the people discouraged to spare their land to be inundated twice a day by tidal flooding for operation of TRM in a third basin. More ever where land was developed in the front line of beel Kedaria, local people transplanted Boro crop & closed all the gates of Bhabodah regulator to prevent intrusion of saline water in their paddy field .This led to severe siltation in Hari river at about 17 KM of stretch resulting water logging in 18300 ha of land in 193 villages of 21 unions & 2 municipalities under Abhaynagar, Monirampur & Keshabpur U.Z. Local people then realized that there is no alternative solution to get rid of water logging except operation of TRM.

In a meeting held in the conference room of the Deputy Commissioner, Jessore, local people & their representatives supported to start TRM in East beel Khuksia immediately having a positive study result from IWM, except the Chairman of Sufalakathi U.P under which the beel Khuksia was situated.

Under the circumstances BWDB engaged CEGIS to find out an acceptable & standard rate of crop compensation per ha per year payable to the landowners of TRM basin, for the period of TRM operation. Simultaneously BWDB started construction of peripheral embankment around east beel Khukshia in association with LGI, WMA & contractors. CEGIS submitted a

report proposing Taka 60(sixty) per decimal per year as the rate of crop compensation. However, payment could not be made in time due to various reasons.

Beel Khukshia was linked on 30-11-2006 with Hari River to start TRM. Operation of TRM in east beel Khukshia was initially scheduled for three years i.e. Up to 2010 but it continued up to 2013 due to failure of starting TRM in a fourth TRM basin i.e. in beel Kapalia.

7.9.5 Failure to Start TRM in Beel Kapalia

Program for construction of peripheral embankment in beel Kapalia was taken well ahead in the year 2009, but local people demanded compensation in advance & obstructed BWDB's contractors to implement their works. When payment of crop compensation was agreed on principle by the BWDB, the demand was enhanced incorporating compensation of fish also. Ultimately BWDB agreed to pay compensation of both crop & fish at a total rate of Taka 480/per decimal per year.

Even this handsome rate of compensation could not make BWDB enable to start construction of embankment in beel Kapalia along the periphery by the contractors. Farmers of beel Kapalia started to transplant Boro crop in their land in the dry season. After harvesting Boro crop, the Gher owners and the dependent workers in their Ghers who felt eventually to lose their business & job respectively, joined in anti-TRM movement in beel Kapalia along with those land owners who did not possess valid ownership document of their land & the surrounding villagers under NGOs' umbrella who will not be benefited out of TRM in any way. They actively played role against operation of TRM in beel Kapalia & burst together when the M.P of Jessore-6 constituency launched a program to start construction of embankment on 2nd June 2012. They attacked with the local traditional weapons & injured at least 30 people including U.Z. Chairman, Abhaynagar, Executive Engineer, BWDB, Jessore, ASP, and Jessore & APS of the M.P. The angry mob set fire on three official Jeeps & at least four motor cycles. Due to sufferings & unnecessary delay in receiving compensation from the L.A office, the land owners who were in favour of implementation of TRM also turned to the opposite group. Since then all attempt to start TRM in beel Kapalia remained stop. This incident created a negative impact & shock on implementation of TRM keeping the total area under threat to long term water logging.

7.9.6 Learning from the Past

These are the extracts from the past incidents for future guidance.

Implementation of TRM in the other beels could be easier & smooth if TRM in beel Kapalia could be started smoothly. TRM in beel Kapalia could be started easily if:

- In beel Kapalia motivational work & campaign could be conducted at the initial stage.
- Crop compensation could be paid to the landowners of east beel Khuksia in time which could inspire the land owners of beel Kapalia.
- Before starting of earthwork in beel Kapalia, compensation could be paid to the majority (more than 50%) of the land owners in advance & in a hassle free & easier process.
- LGI & WMA could be engaged to construct peripheral embankment in beel Kapalia.
- Construction of embankment could be started before transplanting Boro crops. This allowed them 4 months extra time to be organized against TRM.
- Mass people those are directly benefitted out of TRM operation could be invited & gathered in the inaugural event of embankment construction.

- Mechanical excavator could be used to achieve rapid initial progress.

7.9.7 Implementation of TRM in the Beels of Polder 1-2, 6-8 & 6-8 Extension

The following potential beels have been identified along the banks of mostly silted-up Betna & Marrichap River suitable for operation of TRM.

Sl. No	Name of River	Name of potential beels for TRM operation in the polders			
		Left bank	Polder	Right bank	Polder
01	Betna	Aumtoli, Matiadanga, Sukdebpur	Polder 6-8	Hazikhali-Amud Khali, Chapra	Polder-2
02	Marrichap	Sreeramkathi, Dorgahpur	Polder 6-8	Bugmara, Gobindapur, Jealmari, Ticket	Polder-1

A social survey was conducted to know the people's perceptions about operation of TRM in the above beels. Local people understand that TRM is a two way solution to solve the water logging problem in the coastal area by natural process, where incoming silt will be deposited in the TRM basin to raise the land instead of being deposited in the river bed. But some mixed opinions are there about operation of TRM among the local people.

- Landowners of Sukdevpur & Ticket beels are in favour of operation of TRM in their beels.
- Landowners of Matidanga, Dorgapur & Sreemantakathi beels are not against TRM operation.
- Landowners of Chapra, Himkhali & Hazikhali-Amodkhali beels are not in favour of TRM.
- Small farmers will abide by the decision of owners of large plots and Ghers.
- Large plot owners taking lease of land from small farmers make a large 'Gher' & invest capital to construct internal dykes, inlet structures and other ancillary works for a permanent Gher . They will not support TRM to lose their business permanently by raising their land & will try with all their efforts to resist TRM in their beel.
- Owner of individual Ghers of smaller size are scared about their means to subsist for the time of TRM operation after losing their business.
- Some people are scared about uncertainty of getting compensation.
- Some farmers are concern about the agricultural productivity of their land due to increased soil-salinity at the end of 3 to 4 years operation of TRM by saline water intrusion twice a day.
- All are concerned about future water logging in this region in a greater area with higher depth of water grabbing them gradually. But at present they cannot indulge their family to starve.

7.9.8 Suggestions for Future

It is not wise to indulge the area in a permanent water logging scenario when there will be no solution to return from it, except to migrate from that area. It will not be possible to prepare a

TRM basin by constructing embankment & inlet / outlet structures if the total area is inundated. TRM under this scenario cannot be operated in any beel, even the land owners invite BWDB & agree to spare their land without any payment of compensation for TRM operation. It is established that TRM is the only solution & a two way solution (raising of land & deepening the river). So it is to find out a solution by implementation of TRM before it is too late.

- At present, it is not possible to implement TRM in any beel without paying compensation of crop & fish to the land owners.
- Before operation of TRM in any beel there should be a motivational program to be conducted jointly by selected NGO, LGI & WMA in & around the TRM basin keeping record of proceedings as official document.
- Compensation of fish should be provided to the Gher owners if they have taken lease of the land from the land owner(s) with valid documents .Or they will have the right to capture open water fishes from the TRM basin coming in during flood tide.
- List of workers dependant on the land/ gher of the proposed TRM basin should be prepared well ahead during motivational works to compensate lose of job either by providing VGF cards or by other means for their subsistence for the period of TRM operation.
- More than 50% (preferably 60%) of the land owners should get compensation before starting construction of peripheral embankment.
- Payment should be made at Union level Land Office (Tahseel Office) instead of district level office to save time & money of the land owners.
- Procedure for payment of compensation should be made easier and hassle free. (This is now under progress).
- LCS (Labor Contracting Society) through LGI & WMA should be engaged in embankment construction (for earth works). Contractors may be engaged for construction of inlet/outlet structures bailey bridges/other earth works etc.
- Mud/slushy earth should not be used in embankment construction which may cause frequent breach of embankment.
- TRM should not be operated through the opening of a regulator.
- Subject to availability, TRM should be operated through more than a single cut point (link canal) at an equal time interval for uniform siltation in the TRM basin.

Taking account of the above issues & addressing properly, TRM in Sukdevpur & Ticket the first two beels should be started at first stage as a pilot project with adequate motivational works. There should not be any chance of failure. Videos of sufferings of the Bhabodah area in the year 2005 & 2006, how TRM was started in beel Khuksia by link canal, what was the post project situation in the year 2008 & after wards, how silt deposition was there, how agricultural activities are going on & was there any impact of salinity or not should be shown to the people of the project area particularly to the people of Chapra, Himkhali & Hazikhali-Amodkhali beels those are not in favour of TRM.

Guidelines for payment of compensation to the land owners as well as to the share holding farmers in an easier method has been developed by the MoWR and is under process of approval. This will minimize harassment & un-necessary delay in the traditional payment process. If the local people can see the benefits of TRM in the first two pilot TRM basins & get compensation easily & in time then it will be easier for BWDB to operate TRM in the next TRM basins. Success of TRM in the previous beels will make the process easier in the subsequent beels of the study area.

CHAPTER EIGHT: AGRICULTURE AND FISHERIES AT PRESENT & FUTURE

8.1 Introduction

The study area is located in the southwest region of Bangladesh within Satkhira district. It includes Kalaroa, Satkhira Sadar, Tala, Debhata and Assasuni upazilas. It is comprised of Polder No.1, Polder No.2 and Polder No.6-8 and 6-8 (Extension) of Bangladesh Water Development Board. Total area of the five upazilas is 153,160 hectares and total area under the Polder No.1, 2, 6-8 and 6-8 (Extension) is 75,790 hectares. About 49.48% of total area of the five upazilas is under the polders. Nearly 18% area of Kalaroa, 81% area of Satkhira Sadar, 47% area of Tala, 46% area of Debhata and 38% area of Assasuni Upazila are under the polders (details shown in **Aneex-VI and Annexure-VI-1**).

The study area lies under two Agro-ecological Zones: i) High Ganges River Floodplain (AEZ-11) and ii) Ganges Tidal Floodplain (AEZ-13).The soils are formed from alluvial sediments of the rivers crossing through the district. The rivers and canals of the area face severe siltation causing serious drainage congestion resulting to crop damage in the rainy season almost every year. The rivers get no fresh water flow from the upstream during the dry season. They are influenced by tidal action at the downstream only. River beds are so badly raised that rain water and runoff water of the catchment area remain stagnant on a large part of medium high lands and medium low lands even after the end of rainy season limiting intensive cultivation of rabi crops.

Shrimp culture is an important source of income in the study area. Soils of most of the unions of the study area are moderately to strongly saline. Soil salinity in the area is increasing due to intrusion of saline water for shrimp culture. It is creating environmental hazards and degradation of soil productivity. As a result, the farmers of a large area are not able to grow crops round the year. The effect of salinity increase has not only restricted the cultivation of necessary crops but also seriously affected livestock production and overall environment of the area.

For the purpose of the study information regarding present socio-economic and agricultural condition to assess the baseline situation was collected through household survey. The consultants conducted a number of Focus Group Discussions (FGD) at village level. Consultations were made with the public representatives, local elites, farmers, gher owners, land owners, fishermen, day laborers and other stake holders. Upazila and district level officers of Department of Agriculture Extension (DAE), Department of Fisheries and Department of Livestock Service were interviewed. Detailed information regarding present agricultural condition of the study area was collected from the offices of the concerned Upazila Agriculture Officers and Deputy Director, DAE, Satkhira which is the important basis of this report.

8.2 Land Types of the Study Area

Selection of crops and cultivation practices of an area largely depend on the topographic position of land in relation to seasonal inundation depth and its duration. Based on the depth and duration of seasonal inundation, lands of the study area are of four types. Nearly 40,787 hectares (27.6% of the total area) is High Land, 88,150 hectares (57.6%) is Medium High Land, 23,404 hectares (15.3%) is Medium Low Land and 818 hectares (0.5%) is Low Land.

High lands are above normal inundation level and provide opportunities for growing both perennial and year round dry-land crops. High lands are not only used for crop production but also for homesteads and settlements, commercial, industrial and many other purposes. Medium High Lands and Medium Low Lands are suitable for production of a wide range of crops throughout the year. Due to severe drainage congestion and increase of salinity a large portion of these of lands is being used for aquaculture especially for shrimp culture. Upazila wise area under different land types of the study area is shown in **Aneex-VI** and **Annexure-VI-2.**

8.3 Soil Types of the Study Area

The study area lies under two Agro-ecological Zones. So, the soil characteristics differ from place to place. The soils of northern part are non-saline to moderately saline and calcareous while the soils of southern part are mostly saline and non-calcareous. In Rabi season, surface water from medium high lands generally recedes early within mid November but some areas remain wet for most of the time of dry season. Soil salinity level ranges from 0-12 dS/m in the dry season. Soil pH ranges from 6.5 to 7.5. The study area has six types of soil. Areas under different soil types are: Clay (46%), Clay Loam (16%), Silty Clay (19.5%), Silty Clay Loam (2.5%), Silty Loam (10%) and Sandy Loam (5%). Upazila wise area under different soil types of the study area is shown in **Aneex-VI (details shown in Annexure-VI-2)**

8.4 Land Use Pattern of the Study Area

Depending on the drainage condition lands of Satkhira district can be divided into**:** i) Arable Lands and ii) Wetlands. Total arable lands in the study area are 104,173 hectares (68% of total area) and wetlands are 48,987 hectares (32% of total area). Arable lands are used for homesteads & settlements and crop production. About 31,690 hectares (21% of total area) is used for homesteads & settlements and 72,483 hectares (47% of total area) for agriculture. Homesteads & settlements include dwelling houses, homestead forests, orchards, educational institutions, markets, roads etc. Wetlands are mainly used for aquaculture (shrimp/prawn and fish culture). Due to drainage congestion a large part of medium high lands and medium low lands have turned into wetlands. About 42,779 hectares (87% of wetlands) is under 'Ghers' of which. 24,919 hectares (58% of Gher area) are used for shrimp/prawn culture and commercial fish culture and 14,860 hectares (42% of Gher area) for integrated culture. For integrated culture rice is grown along with or after harvesting fish or shrimp/prawn. Upazila wise land use pattern of the study area is shown in **Aneex-VI.**

8.5 Upazila wise Intensity of Cropping in the Study Area

Intensity of Land Use of an area indicates the percentage of cultivable land against the total land of the area. Net Cropped Area shows the maximum coverage of crops in any cropping season of the year. Total Cropped Area is the sum total of crop coverage of all seasons in a particular year. It is calculated by the following formula: Total Cropped Area= Single Cropped Area+ 2 x Double Cropped Area+ 3 x Triple Cropped Area+ 4 x Four Cropped Area. Cropping Intensity is the percentage of Total Cropped Area against the Net Cropped Area. Intensity of Cropping of the study area are shown in **Table No. 8.1**.

Table 8.1: Upazila wise Intensity of Cropping of the Study Area

Description	Intensity of Land Use and Cropping Intensity					
	Kalaroa	Satkhira Sadar	Debhata	Assasuni	Tala	Total/ Average
1. Total Area (ha)	23,830	40,808	17,307	37,660	33,555	**153,160**
2. Net Cropped Area (ha)	17,594	26,890	6,800	11,840	21,289	**84,413**
-Single Cropped Area	1,900	2,833	625	4,890	5,025	**15,273**
-Double Cropped Area	9,500	15,451	4,000	5,915	13,600	**48,466**
-Triple Cropped Area	6,044	8,411	2,000	1010	5,730	**23,195**
-Four Cropped Area	150	195	175	25	0	**545**
3. Total Cropped Area (ha)	39,632	59,738	15,325	19,850	49,415	**183,960**
4. Intensity of Cropping	**225%**	**222%**	**225%**	**168%**	**202%**	**218%**

Source: District and Upazila Offices of DAE

Data shows that Total Area of five upazilas of the study area is 1,53,160 hectares and Net Cropped Area is 84,413 hectares. Total Single Cropped Area of the study area is 19,358 hectares (21% of NCA), Double Cropped Area is 49,670 hectares (53% of NCA), Triple Cropped Area is 23,806 hectares (25.6% of NCA) and Four Cropped Area is 325 hectares (0.4% of NCA). Total cropped area is 1,83,960 hectares and average Cropping Intensity is 218%. Cropping Intensity is highest (225%) in Kolaroa upazila and lowest (168%) in Assasuni upazila. Cropping Intensity of Satkhira Sadar upazila and Debhata upazila is almost similar to Kolaroa upazila.

8.6 Mode Wise Irrigation Practice of the Study Area

Irrigation is the most important factor influencing the cropping pattern, crop varieties, crop yields and cultivation practices of an area. Most of the cultivated land of the study area has irrigation facilities. Irrigation is done by deep tube wells (DTW), shallow tube wells (STW) and low lift pumps (LLP). Practice of irrigation varies from upazila to upazila. Upazila wise type and number of irrigation units and coverage for the year 2011-12 are shown in **Table No.8.2**.

Table 8.2: Upazila wise Number of Irrigation Units and their Coverage in 2011-12

Upazilla	Number of Running Irrigation Units				Area under the Irrigation Units (ha)			
	DTW	STW	LLP	Total	DTW	STW	LLP	Total
Kolaroa	469	4,050	27	4546	9075	5,483	67	14642
Satkhira Sadar	247	16,800	151	17,198	5345	26,000	190	31,535
Debhata	3	4,554	50	4,607	50	6,750	125	6,975
Assasuni	0	4,900	112	5,012	0	7,305	210	7,515
Tala	19	16,100	2	16,121	315	21,600	1	21,916
Total	**738**	**46,404**	**342**	**47,484**	**14785**	**67,283**	**593**	**82,583**

Source: District office of DAE

Above table shows that total number of irrigation units in the study area is 47,484 and total coverage in 2011-12 was 82,583 hectares which is nearly 98% of the Net Cropped Area. With the exception of Kalaroa upazila, irrigation system of the study area depends mainly on shallow tube wells (STWs). Nearly 81% of the total irrigated area is covered by STWs. In Kalaroa number of DTWs is 469 which cover nearly 62% of the total irrigated area of the upazila. Per unit coverage of DTW is much higher as compared with STW and LLP. Average command area under each DTW, STW and LLP is about 20 hectares, 1.5 hectares and 1.7 hectares respectively.

8.7 Area, Yield and Production of Major Crops in the Study Area

Farmers of the study area grow a large number of crops including Local Aus, Transplanted Aus (HYV), Broadcast Aman (Local), Transplanted Aman (HYV), Boro (HYV), jute, vegetables, wheat, lentil, khesari, mustard, sesame, potato, onion, garlic, chili, sweet potato, turmeric, sugarcane, betel leaf etc. Boro (HYV) is the most important crop which is followed by T.Aman (HYV), Rabi vegetables, T.Aus (HYV), mustard, Kharif vegetables, potato, spices etc. Total area under major crops, their yields and production of Kolaroa, Satkhira Sadar, Debhata, Assasuni and Tala upazilas of Satkhira district are shown in **Table 8.3**.

HYV Boro is the main crop of the project area. Total area under HYV Boro is 66,680 hectares (72% of NCA) and total production is 2, 63,454 metric tons (clean rice). Other major crops in terms of cultivated area and percentage of Net Cropped Area are: T.Aman-61,150 hectares (66%), jute-10,850 hectares (12%), T.Aus-9,180 hectares (10%), Mustard-7,280 hectares (8%), Rabi Vegetables-6,308 hectares (7%), Kharif Vegetables-4,455 hectares (5%), Potato-2,410 hectares (2.6%) and lentil-1,009 hectares (1.1%).

Table 8.3: Area, Yield and Production of Major Crops in 5 Upazilas of the Study Area

Name of Crops	Rainfed Crop			Irrigated Crop			Total/Average		
	Area (ha)	Yield (Ton/ ha)	Prduction (Ton)	Area (ha)	Yield (Ton/ ha)	Prduction (Ton)	Area (ha)	Yield (Ton/ ha)	Prduction (Ton)
T.Aus (HYV)	0	0	0	9,180	4.92	45,165	**9,180**	**4.92**	**45,165**
T.Aman (local)	1,890	1.78	3,364	0	0	0	**1,890**	**1.78**	**3,364**
T.Aman (HYV)	54,760	4.54	248,610	4,500	4.8	21,615	**59,260**	**4.56**	**270,225**
Boro (HYV)	0	0	0	66,680	5.93	3,95,412	**66,680**	**5.93**	**395,412**
Jute	9,350	1.93	18,045	1,500	2.22	3,330	**10,850**	**1.97**	**21,375**
Kharif Vegetables	244	10.93	2,668	4,211	14.95	62,954	**4,455**	**14.73**	**65,622**
Rabi Vegetables	300	16.0	4,800	6,008	19.21	115,430	**6,308**	**19.06**	**120,230**
Wheat	0	0	0	954	2.93	2,795	**954**	**2.93**	**2,795**
Mustard	460	0.86	396	6,910	1.08	7394	**7,280**	**1.07**	**7,790**
Lentil	1,009	1.01	1,019	0	0	0	**1,009**	**1.01**	**1,019**
Potato	0	0	0	2,410	20.81	50,152	**2,410**	**20.81**	**50,152**
Sesame	236	1.06	250	0	0	0	**236**	**1.06**	**250**
Summer Mug	129	1.06	137	0	0	0	**129**	**1.06**	**137**
Onion	25	6.5	163	700	10.49	7,340	**725**	**10.35**	**7,503**
Chili	105	1.2	126	573	4.45	2,547	**678**	**3.94**	**2,673**
Khesari	569	1.2	639	0	0	0	**569**	**1.2**	**639**
Garlic	10	5	50	483	8.21	3,967	**493**	**8.15**	**4,017**

Source: District and Upazila Offices of DAE

8.8 Major Cropping Patterns of the Study Area

Cropping Pattern is the sequential cultivation of crops on a piece of land in a year. Depending on land and climatic conditions cropping patterns varies from place to place. Selection of crops depends on soil texture, temperature, rainfall, drainage conditions, mode of irrigation etc. There are more than 40 different cropping patterns in the study area. Fifteen of them may be considered as important. Major Cropping Patterns of four upazilas of the study area are shown in **Table 8.4**.

The most prominent cropping pattern of the project area is Fallow-T.Aman-Boro which covers more than 46% of the Net Cropped Area. Other important cropping patterns are: Fallow-Fallow-Boro (8.65%), T.Aus (HYV)-T.Aman-Boro (8.26%), Fallow-T.Aman-

Mustard+Boro (6.18%), Fallow-T.Aman-Mustard (5.62%), Fallow-T.Aman-Fallow (5.8%), Vegetables-Vegetables-Vegetables (5.2%) and Jute-T.Aman-Potato (3.1%).

Table 8.4: Major Cropping Patterns of the Study Area

Major cropping Patterns			**Area (ha)**	**% of NCA**
Kharif-1	**Kharif-2**	**Rabi**		
Fallow	T.Aman	Boro (HYV)	39,223	46.47%
Fallow	Fallow	Boro (HYV)	7,301	8.65%
T.Aus (HYV)	T.Aman	Boro (HYV)	6,975	8.26%
Fallow	T.Aman	Mustard+Boro	5,217	6.18%
Fallow	T.Aman	Mustard	4,746	5.62%
Fallow	T.Aman	Fallow	4,935	5.85%
Vegetables	Vegetables	Vegetables	4,390	5.2%
Jute	T,Aman	potato	2,614	3.1%
Jute	Pulse	Boro (HYV)	1,064	1.26%
Jute	T.Aman	Boro (HYV)	1,058	1.26%
T.Aus (HYV)	T.Aman	Mustard+Boro	1,166	1.38%
Jute	T.Aman	Wheat	1,000	1.18%
Jute	Vegetables	Boro (HYV)	850	1.01%
Vegetables	T.Aman	Vegetables	575	0.68%
Prawn	T.Aman	Boro (HYV)	450	0.53%
Others			2,849	3.37%
Total			**84,413**	**100%**

Source: District and Upazila Offices of DAE

8.9 Aquaculture Situation of the Study Area

Aquaculture is a major source of nutrition, income, employment and livelihood support to the local people of the study area. In the study area 48,925 hectares of land (32% of total land) are wetlands of which 46,429 hectares are under aquaculture. Aquaculture of the study area is comprised of inland open water fisheries, fish culture in the homestead ponds and shrimp, prawn and commercial fish culture in the 'Ghers'. The source of open water fisheries are rivers, canals, 'beels' and flood plains. Low lying areas and single cropped paddy fields are generally used for making ghers which are used for shrimp (Bagda), prawn (Galda) and fish culture. A large portion of the wetlands is used for integrated culture in which rice is grown after harvesting fish, shrimp or prawn or as intercrop with fish, shrimp or prawn. Saline water is used for shrimp culture and fresh (non-saline) water for prawn culture. Number of Ghers and areas under Ghers and their use are shown in the **Table No.8.5**.

Table 8.5: Upazila wise No. of Ghers, Area and their Utilization (Year-2012)

Upazila	**Total Area (ha)**	**No. of Ghers**			**Area under Ghers (ha)**			**Paddy within Ghers**	
		Bagda	**Galda**	**Total**	**Bagda**	**Galda**	**Total**	**Paddy Area (ha)**	**% of Gher Area**
Kolaroa	23,830	0	475	475	0	631	631	600	95%
Satkhira Sadar	40,808	2120	3058	5178	4,065	3,413	7,478	5,600	75%
Debhata	17,307	2829	525	3354	8,875	365	9,240	2,495	27%
Assasuni	37,660	13469	764	14233	13,590	526	14,116	2,126	15%
Tala	33,555	1295	4545	5840	2,268	1,119	3,387	1,863	55%
Total (% of Total Area)	**153,160**	**19713**	**9367**	**29080**	**28,798** (19%)	**6,054** (4%)	**34,852** (23%)	**12,684** (8.3%)	**37%**

Source: District Fishery Officer, Satkhira

The above table shows that total area under Ghers is 34,852 hectares of which 83% is used for Bagda culture and 17% is used for Galda culture. In recent years mixed culture of Galda

and Bagda with other fishes have become popular in the study area. Native and exotic species like Rui (*Labeo rohita*), Katol (*Catla catla*), Mrigel (*Cirrhina mrigala*), Tilapia (*T. nilotica*), silver carp (*Hypopthalmichthys militia)*, Thai Sarputi, Bhetki, Parshae etc. are grown in Galda/Bagda ghers. Integrated culture of Galda/Bagda with rice is increasing day by day. At present about 37% of the gher area is used for integrated culture. Integrated culture is more popular in upstream areas which are non-saline to mildly saline.

8.10 Area, Yield and Production of Bagda and Galda

About 23% of land in the study area is under Galda and Bagda culture. But the yield and production is low due to unavailability of water, drainage congestions, lack of quality post larvae (PL), viral and non-viral diseases and poor management. Upazila wise area, yield and production of Bagda and Galda are shown in **Table 8.6** below (details shown in **Aneex-VI**)

Table 8.6: Upazila wise Area, Yield and Production of Bagda and Galda (Year-2012)

Upazila	Area (ha)			Yield (Kg/ha)			Production (M. Ton)		
	Bagda	Galda	Total	Bagda	Galda	Average	Bagda	Galda	Total
Kolaroa	0	631	631	0	500	500	0	316	316
Satkhira Sadar	4,065	3,413	7,478	234	498	354	950	1,700	2,650
Debhata	8,875	365	9,240	234	493	244	2,079	180	2,259
Assasuni	13,590	526	14,116	328	599	338	4,456	315	4,771
Tala	2,268	1,119	3,387	401	508	442	910	586	1,496
Total	**28,798**	**6,054**	**34,852**	**292**	**512**	**330**	**8,395**	**3,097**	**11,492**

Source: District Fishery Officer, Satkhira

The above table shows that total area under Galda and Bagda culture is are 34,852 hectares. Average yield is 330 kg/ha and total production is 11,492 metric tons. The yield of Galda is much higher than that of Bagda. Per hectare average yield of Galda is 522 kg which is about 75% higher than Bagda. Moreover, the yield varies from place to place.

8.11 Livestock Situation of the Study Area

Livestock is an important part of agriculture. Like other areas of the country, livestock is a major source of nutrition, income, employment and livelihood support to the people of Satkhira district. Trading of cattle is an important business in the district. A large number of bullocks/oxen are imported from India, traded and sent to other parts of the country. But local livestock production is not enough to meet the demand of the local people. Moreover, percentage of contribution of livestock sector to the local economy is reducing day by day. Present livestock situation of the study area is shown in **Table 8.7**.

Condition of livestock is directly dependent on agricultural condition. Cattle live mainly on grass and by-products of crops. With the expansion of aquaculture fallow lands and grazing lands have been reduced to almost nil in the study area. Due to drainage congestion about 32% of total land of the study area has turned into wetlands which do not produce grass. Salinity increase due expansion of shrimp culture has further aggravated the situation. Rice is grown in about 37% of Gher areas. So, there is acute scarcity of rice straw to feed the cattle. As a result, livestock production is in very bad condition in the study area.

Table 8.7: No. of Livestock and Production of Meat, Milk and Egg in the Study Area

Items	Kolaroa	Satkhira Sadar	Debhata	Assasuni	Tala	Total
1. No. of Livestock						
1.1 Cattles						
-Cow	27,240	31,740	13,240	21,750	41,200	135,170
-Bullock/Ox	23,010	38,430	25,382	5,002	7,951	99,775
Subtotal	50,250	70,170	38,622	26,752	49,151	234,945
1.2 Buffalos	0	0	0	225	0	225
1.3 Goat	58,912	65,872	24,196	35,334	38,250	222,564
1.4 Sheep	174	3,308	210	10,172	1,520	15,384
1.5 Poultry	998,595	1,388,000	601,198	184,325	1,033,000	4,205,118
1.6 Ducks	99,850	24,410	10,380	72,351	75,200	282,191
Total	**1,207,781**	**1,551,760**	**674,606**	**329,159**	**1,197,121**	**4,960,427**
2. Production						
2.1 Meat (M.Ton)	1,092	1,256	37	94	184	2,583
2.2 Milk (Kg)	314,000	711,850	199,100	609,700	5,503,170	7,337,820
2.3 Egg (Nos.)	391,700	987,450	261,115	128,000	1,027,540	2,795,805
3. No. of Farms						
3.1 Dairy	260	295	152	165	292	1164
3.2 Poultry	0	0	0	0	0	0
-Broiler	92	496	30	24	47	689
-Egg	7	45	180	92	127	451
Subtotal	99	541	210	116	174	1140
3.3 Goat	5	42	29	29	2	107
3.4 Sheep	0	0	16	42	22	80
3.5 Ducks	0	0	0	1	5	6
Total	**463**	**1419**	**617**	**469**	**669**	**3637**

Source: District Livestock Officer, Satkhira

8.12 Agriculture Related Problems of the Study Area and Suggested Measures

A large number of agriculture related problems were identified during the field visits and consultations with the different stakeholders of the study area. Major Problems and their impacts on crop production and their probable solutions as suggested by the stakeholders are discussed in the following paragraphs.

8.12.1 Major Problems and their Impacts on Crop Production

The following major issues were identified which are responsible for the degradation of land resources and sufferings of human lives and livelihoods:

● Valuable agricultural land is decreasing rapidly due to unplanned development of fisheries projects (especially shrimp ghers), housing and settlements, markets, industries, brickfields, roads and different other development infrastructures.

● The rivers and canals of the area face severe siltation causing serious drainage congestion resulting to crop damage in the rainy season almost every year. River beds are so badly raised that rain water and runoff water of the catchment area remains stagnant on medium high lands and medium low lands even long after the end of rainy season limiting intensive cultivation of rabi crops. Soils of low lying areas remain wet even in the dry season. Most of the old canals have been closed due to unplanned human interventions like constructions of

houses, markets and other infrastructures creating barriers to natural flow of water contributing to severe drainage congestion in the area.

● Trans-boundary River Ichhamati is the only live river in the study area. The rivers like Betna, Kobadak and Marichap are influenced by tidal action at the downstream only. They get no fresh water flow from the upstream during the dry season. These rivers look like drainage canals in the upstream. The rivers like Basadah and Bansana are severely silted up and occupied by illegal occupiers in such a way that their existence can hardly be recognized at many places.

● Soil salinity is increasing in the area due to drainage congestion and intrusion of saline water for shrimp culture. Saline water that enters at the time of high tide does not go out at the time of low tide due to badly raised riverbeds. Gher owners bring saline water in the ghers for shrimp culture which is kept there until the end of the season. Soils of most of the unions have turned into moderate to strongly saline.

● Increasing salinity is creating environmental hazards and degradation of soil productivity. It is reducing interest of the land owners and farmers to grow different types of agricultural crops in the area. As a result shrimp culture using agricultural land is increasing. But the small and marginal farmers need to continue their agricultural practices as they have no alternative livelihood.

● Comparative economic advantage of shrimp culture over crop production tempted the landlords and big farmers to go for shrimp culture. Most of the land owners have made ghers themselves or leased out their lands to the commercial gher entrepreneurs. Sometimes the medium and small farmers are compelled to lease out their lands for shrimp culture. But the concerns of the small and marginal farmers are increasing for saving valuable agricultural lands from degradation and misuses.

● Shifting to aquaculture from agriculture has reduced employment opportunities in the rural areas. Most of the share croppers, marginal farmers and farm laborers are either unemployed or had to change their profession which has created social problems in the area.

● Occupation of Khas khals and open water bodies by the influential persons and gher entrepreneurs has sharply reduced the scope of capture fishing by the fishermen. As a result, fishermen are forced to change their profession.

● Natural vegetation, homestead fruit/forest trees and orchards are much less in saline and shrimp culture areas than non-saline areas. Farmers of those areas are unable to rear livestock due to shortage of grazing land, green grass and fodder. These have significant negative impact on the economy, human health and environment of the area.

● Scarcity of surface water for irrigation is a major problem for intensive irrigation in the area. Water of most of the rivers and canals is saline and unsuitable for irrigation during the dry season. Salinity intrusion is highest in the months of March to June which causes severe problem to grow Boro or Transplanted Aus paddy using surface water. So, the farmers have to depend on sub-surface water for irrigation.

8.12.2 Suggested Measures

During consultations the stakeholders of the study area put forward their suggestions regarding probable solutions of the problems. Following recommendations are made by incorporating their views.

● Dredging or re-excavation of the rivers and linked canals is essential for the improvement of drainage congestion of the area. All kinds of drainage impediments are to be removed. The rivers and old canals are to be made free form illegal occupation. New drainage canals are to be excavated and connected with the rivers wherever necessary.

● Appropriate flood control measures like construction and repair of embankments and sluice gates are necessary to mitigate crop damages due floods. Construction of drainage structures like culverts, bridges and regulators should be considered as adaptation measures for facilitating drainage and reduce flood related vulnerability of the area.

● Pumping out water to remove water logging which has already been practiced in Tala upazila may be considered as an effective adaption option for future drainage improvement program.

● Intrusion of saline water can be prevented by constructing of new embankments and regulatory structures or modifications of the existing ones.

● Fisheries projects, especially shrimp culture has made drainage congestion and salinity problems more severe. So, appropriate physical measures along with motivation and awareness building programs should be taken up immediately to control unplanned shrimp culture

● Indiscriminate use of valuable agricultural lands for shrimp culture, fisheries, housing and settlement, industrial and commercial purposes should be prevented by enacting law. Nobody will be allowed to change land classification and to use agricultural land for non-agricultural purposes.

● Zoning of land considering the present uses, physical and chemical characteristics and potentialities may be a tool to control land degradation and proper land use. Land zoning should be implemented to assign the land to its best possible and proper uses like-agriculture, fisheries, shrimp culture, forestry, industrial and commercial development in order to get maximum benefits from the lands resolving conflicts of interest.

● Degradation of land can be prevented by prohibiting unplanned shrimp culture and intrusion of saline water in the ghers. Shrimp culture should be allowed only on medium low lands and low lands in aquaculture zone. It will not be allowed in other zones and on high lands and medium high lands even in shrimp culture zone.

● Special research programs should be taken up to develop saline tolerant crop varieties and appropriate production technologies for the saline areas of the country Agriculture extension services should be strengthened to ensure dissemination of modern crop production technologies and training of famers on modern cultivation practices. Saline and drought tolerant crop varieties should be made available to the farmers. Special programs are to be taken up to increase soil productivity and for adoption of environment friendly Integrated Pest Management (IPM) and Integrated Crop Management (ICM) practices by the farmers. Use of pesticides should be discouraged and if essential bio-pesticides may be encouraged.

● Dependence on subsurface water for irrigation should be reduced. A viable irrigation system needs to be developed combining surface and subsurface irrigation.

●Easy access of the marginal and landless farmers to financial supports and land resource management process should be ensured.

● TRM is one of the best options for improvement of drainage congestions and land development in the low lying areas (beels). But people's participation is essential for

successful implementation of the TRM program. Extensive motivation and awareness building programs should be taken up before starting the program.

8.13 Recommended Land Zones in the Study Area

The National Land Use Policy 2001 of Ministry of Land highlights the need, importance and modalities of land zoning for integrated planning and management of land resources of the country. Ministry of Land conducted a detailed study in all the upazilas of Satkhira district for land zoning and prepared upazila wise Land Zoning Reports in 2011. According to the Land Zoning Reports land use classes identified in Satkhira district are-homestead and settlements, agriculture, shrimp culture, fishery, urban, commercial etc. Ministry of Land has recommended seven land zones in the study area. The recommended land zones are- a) Agriculture Zone, b) Agro-Aquaculture Zone, c) Shrimp Culture Zone, d) Agro-Urban and Commercial Zone, e) Urban and Commercial Zone, f) Urban and Agro-aquaculture Zone and g) Urban Commercial and Shrimp Zone. Upazilawise area under recommended zones is shown in the **Table 8.8**.

Table 8.8: Upazilawise Area under Recommended Land Zones of the Study Area

Recommended Land Zones	Upazilawise Total Area under the Zones (hectares)					
	Kolaroa	Satkhira Sadar	Debhata	Assasuni	Tala	Total
Agriculture Zone	22,35	21,913	0	6,839	14,531	65,658
Agro Aqua-culture Zone	0	15,250	15,182	12,344	19,938	62,714
Shrimp Culture Zone	0	0	0	11,742	0	11,742
Agro-Urban and Commercial Zone	1,455	0	0	0	2,476	3,931
Urban and Commercial Zone	0	3,645	0	0	0	3,645
Urban and Agro-aquaculture Zone	0	0	2,125	0	0	2,125
Urban Commercial & Shrimp	0	0	0	3,345	0	3,345
TOTAL	**23,830**	**40,808**	**17,307**	**34,270**	**36,945**	**1,53,160**

It can be seen from the above table that about 43% of the total area is under recommended Agriculture Zone, 41% is under Agro Aqua-culture Zone, 8% is under Shrimp Culture Zone, 2.6% is under Agro-Urban and Commercial Zone, 2.4% is under Urban and Commercial Zone, 1.4% is under Urban and Agro-aquaculture Zone and 2.2% is under Urban Commercial and Shrimp Zone. Unions under Recommended Land Zoning and area are shown in **Annexure-VI-4.**

So far the land based production is concerned recommended land zones are of three principal types. They are-i) Agriculture Zone, ii) Agro-Aquaculture Zone and iii) Shrimp Zone. For the purpose of production Agro-Urban & Commercial Zone and Urban & Commercial Zone may be included in Agriculture Zone and Urban Commercial & Shrimp Zone in Shrimp Zone. At present there is no such zoning for land use. Land owners of the area use their lands either for crop production, shrimp culture or integrated culture irrespective of the recommended zoning. Present land use depends mainly on land type, soil salinity, water salinity, duration and depth of inundation, water availability and above all comparative economic advantages of agriculture and aquaculture. Details are shown in **Aneex-VI.**

Zoning of land may be a tool to control land degradation and proper land use. Land zoning should be implemented to assign the land to its best possible and proper uses like–homestead & settlements, agriculture, fisheries, shrimp culture, forestry, industrial and commercial purposes in order to get maximum benefits from the lands resolving conflicts of interest.

Shrimp culture must not be allowed in agriculture zone. It should be restricted only in Shrimp Culture Zone and in low lands and medium low lands of Agro-aquaculture Zone. Besides, water bodies should be left open for capture fishery.

If land zoning program is implemented after implementation of the project, the land use pattern of the study area will be changed. Shrimp culture area will be decreased and more area will come under crop production. High lands will be used for both agricultural and nonagricultural purposes including forestry, orchards, homestead and settlements, urban, commercial and many other purposes. It is expected that there will be no shrimp culture in Agriculture Zones. Most of the medium high lands and a large portion of medium low lands in Agro-aquaculture Zone and Shrimp Culture Zone will come under crop production. Proposed land use is shown in **Aneex-VI.**

8.14 Probable Benefit by Project Activities

Implementation of the project will help to reduce drainage congestion and salinity in the area. As a result the cropping pattern of the study area will be changed. Triple and double cropped will be increased. With the decrease of salinity and improvement of irrigation facilities cropping area, especially in the kharif-1 season will increase significantly. Orchards like mango and jujube may be increased considerably. Cropping patterns like T.Aus (HYV)-T.Aman (HYV)-Boro (HYV), Fallow-T.Aman (HYV)-Mustard+Boro, T.Aus (HYV)-T.Aman (HYV)-Mustard, Jute-T.Aman (HYV)-Mustard, T.Aus (HYV)-T.Aman (HYV)-Mustard, Jute-T,Aman (HYV)-potato, Jute-T,Aman (HYV)-Vegetables, Vegetables-Vegetables-Vegetables and Vegetables-T.Aman (HYV) -Vegetables may become more popular. Expected area, yield and production of major crops in the post project situation may be as shown in the **Table 8.9**. Details are shown in **Aneex-VI.**

Table 8.9: Present and Expected Area and Yields of Major Crops in the Study Area

Name of Crops	Present Area, Yield and Production			Expected Area,Yield and Production		
	Area (ha)	Yield (Ton/ha)	Production (Ton)	Area (ha)	Yield (Ton/ha)	Production (Ton)
T.Aus (HYV)	9,180	4.92	45,165	25,000	5.0	125,000
T.Aman (HYV)	59,260	4.56	270,225	65,000	5.0	325,000
Boro (HYV)	66,680	5.93	395,412	70,000	6.0	420,000
Jute	10,850	1.97	21,375	12,500	2.0	25,000
Kharif Vegetables	4,455	14.73	65,622	7,000	16.0	112,000
Rabi Vegetables	6,308	19.06	120,230	7,000	22.0	154,000
Wheat	954	2.93	2,795	1,500	3.5	5,250
Mustard	7,280	1.07	7,790	10,000	1.2	12,000
Lentil	1,009	1.01	1,019	1,500	1.2	1,800
Potato	2,410	20.81	50,152	3,000	25.0	75,000
Summer Mug	129	1.06	137	2,000	1.25	2,500
Kharif Maize	0	0	0	1,000	10.0	10,000
Kharif Sessame	236	1.06	250	500	1.2	600

Implementation of the project will not only benefit the agriculture sector but also livestock and fisheries sectors. With the development of agriculture, availability of fodder will increase and livestock production will be increased. With the improvement of drainage condition and availability of water, future cost of fish and shrimp production will be reduced and production may be increased by 20-30 percent. Moreover, the project will have a tremendous positive impact on overall environmental and social conditions of the area.

CHAPTER NINE: ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

9.1 Introduction

The areas of polder 1, 2, 6-8 and 6-8(extension) has been suffering from water logging and drainage congestion for long periods, which, in turn caused large scale environmental, social and economical degradation. In view of the above, Environmental Impact Assessment (EIA) and Social Impact Assessment was conducted. Environmental Impact Assessment (EIA) aims to ensure that project options under consideration are environmentally sound and sustainable. The purpose of SIA is to define the present socio-economic conditions of the people of the project area which will provide sound reference and assess probable socio-economic impact of the proposed interventions. This will enable us to compare the changes and impacts of the project interventions in future.

9.2 Environmental Impact Assessment

9.2.1 Environmental Study

The EIA study has been taken up as per regulatory requirement of the Department of Environment (DOE) and to comply with the requirement of Terms of Reference (TOR) signed between IWM and BWDB. In the preparation of the report the DOE's Guidelines and Guidelines for Environmental Assessment of Flood Control Drainage and Irrigation (FCDI) Projects by Water Resources Planning Organization (February, 2005) were followed. Guidelines and Manual of FPCO were also consulted.

9.2.2 Assessment Methodology

A multidisciplinary team consisting environmentalist and other specialists conducted the study. Environmental assessment process included environmental baseline survey, screening, scoping, field investigation, impact assessment, impact evaluation and development of environmental management plan. Data collection, field investigation started from beginning of the project and consultation with the stakeholders continued throughout the study period.
Environmental assessment began with the establishment of scenario 'future without project' assuming that the past trend will continue in future and this was followed by the scenario 'future with project' after implementation of study findings. The impact was predicted by assuming the difference between the scenarios. A 21 point rating scale ranging from -1 to -10 for negative impacts and + 1 to + 10 for positive impacts while 0 for no impacts was used for environmental impact assessment matrix.

9.2.3 Legal and Policy Considerations

Development interventions are governed by some legal and institutional requirements. The policy, strategy and regulatory issues are extremely important for any project proponent. It is expected that BWDB is well aware of these requirements and will comply with the provisions while implementing the intervention recommended by the study. Relevant policies, rules and regulations are described in **Annex-V-2.**

9.2.4 Baseline Environmental Settings

Baseline data on environment are important as it forms the basis to analyze the probable impacts of the proposed study interventions for potential use of water resources on the

existing important environmental components of the study area. Baseline data were collected on physical, biological, human and socio-economic environment and depicted precisely in Appendix-C, Volume IV.

9.2.5 Screening and Scoping

Screening was carried out to identify environmental category of the proposed intervention. The screening exercise was accomplished based on field visits, public consultations meetings with the key stakeholders. Scoping was conducted to identify the important environmental issues to arise from the project interventions and the important environmental components (IECs). These have been evaluated in terms of distribution, quantity, quality and seasonality, socio-economic and ecological importance. The scoping was based on relevant study reports, field reconnaissance survey, meetings with key stakeholders and information gathered through interviews and focus group discussions.

9.2.6 Identification of Impacts

Environmental impacts can broadly be classified as those taking place during pre-construction, construction and operation stages. Impacts during pre-construction stage are those related to site selection, survey and design activities and are generally insignificant in terms of its duration, severity and magnitude. The environmental impacts during construction are highly dependent on (i) the incorporation of the mitigating measures identified in the EIA or EMP into bid documents and specifications (ii) the contractor's work habits, especially those related to storage of construction materials, clearance of the site, cleanliness of the work sites; (iii) Health safety to workers and (iv) project management's strict enforcement of the standard construction practices and norms.

Impacts could be of short duration (i.e. nuisance due to dust emission during construction period) and of long duration. The magnitude of impact can be categorized as low, medium and high depending on scale of magnitude on the important environmental components. Impacts can also be categorized broadly as direct impact and indirect impact. For example direct impact of earth work/re-excavation may be dust nuisance, change of topography and land requirement for safe disposal of excavated earth while indirect impact may be negative impact on health, loss of scenic value, socio-economic loss, etc. **Table 9.1** presents impact identification matrix. From the table it is evident that in most cases there will be positive impact due to the project implementation.

9.2.7 Environmental Management Plan

The environmental management plan (EMP) aims at reducing or offsetting potential negative impacts and enhancing positive impact on important environmental components (IECs) due to proposed project intervention. EMP includes compensation plan, mitigation plan, enhancement plan, monitoring plan, institutional arrangement and people's participation. EMP should be fully integrated with the project design and implementation, since many features depend closely on this. In addition, institutional arrangement shall be in place ensuring the participation of relevant agencies such as the BWDB, Department of Agricultural Extension (DAE), Department of Fisheries (DOF), Department of Environment (DOE), Department of Livestock (DOL) and Forest Department (FD). Tentative cost for environmental training, monitoring, etc. is Taka10 lacs, which will require revision during detail design phase.

Table 9.1: Environmental Impact Assessment Matrix for the Proposed Project

Important Environmental Components (IECs)	Future Without Project	Future With Project	EMP	Total Project Impacts
A. Physical Environment				
Air:				
a) Air quality	-1	-2	M	-1
Climate:				
a) Temperature	-1	-1		-1
b) Rainfall	-1	+1		+1
c) Risks	-3	+1	M. Mt	+2
Land:				
a) Topography	-1	+2	M	+3
b) Land use	-2	+2	E	+3
Soil:				
a) Soil Productivity	-2	+2	M	+3
b) Soil salinity	-2	+3	Mt	+3
c) Soil accretion	-2	+3	M	+5
Water Resources:				
a) Water bodies	-2	+2	M, Mt	+3
b) Water level variation	-1	+1	Mt	+2
c) Siltation & water-logging	-7	+3	Mt. M	+5
d) Drainage	-7	+3	Mt	+5
e) Surface water pollution	-4	-3	Mt., M	-2
f) Ground water pollution	-2	+1	Mt.,M	+2
B. Biological Environment				
a) Flora	-4	+2	E. M	+3
b) Fauna	-4	+1	E. M	+2
c) Forestry	0	+1	E	+2
C. Human Environment				
a) Agricultural land type & use	-1	+2	E,M	+2
b) Cropping pattern & intensity	0	+3	E.M	+4
c) Crop yield & Production	0	+3	E,M	+4
d) Crop Damage	-2	+3	M	+4
e) Homestead Agriculture	+1	+3	E	+4
f) Input Use	+1	+3	M	+3
Livestock:				
a) Population	0	+2	M	+4
b) Income & Expenditure	0	+2	M	+4
c) Constraints	-1	+3	M	+4
Fisheries:				
a) Aquatic resources	0	-1	M	+1
b) Capture fisheries	-1	+ 2	Mt/M	+3
c) Culture fisheries	+3	+1	E	+2
D. Social Environment				
a) Demographic characteristics	+4	+6	M	+7
b) Land ownership	+1	+1		+1
c) Land tenancy	-1	+ 1		+1
d) Occupation	-1	+2	E	+3
e) Water supply and Sanitation	+ 1	+2	E, M	+3
f) Human Diseases	-1	+2	M, Mt	+3
g) Women & Development	-1	+2	E	+4
E. Economic Environment				
a) Income & Expenditure	+2	+3	M,E	+4
b) Land value	+2	+4		+4
c) Education	+4	+5	E	+6
d) Transportation	+4	+5	M	+6
e) Safety of life & Property	+2	+3	E, M	+4

Note: E = Enhancement; M = Mitigation and Mt = Monitoring

9.3 Social Impact Assessment

9.3.1 Problems and Affect on Livelihood due to present situation of river/canal

Water logging is the major concern of the project area followed by decrease of fertility of land, River bank and bed silted up. Other mentionable problems are intrusion of saline water in lands, decreasing level of sweet water and fishes being flushed away with tidal waves. Based on present problems, the majority of the respondent blamed water logging affecting their livelihood resulting land remains uncultivated followed by influencing on their economic condition, Other notable factors were decreased crop production, lack of income generating sources, brought up scarcity of drinking water, disruption of communication.

9.3.2 Rationale for Selection of Important Social Components (ISCs)

The SIA study tries to explore all the possible impacts of a proposed project in advance and suggests mitigation measures and required actions before implementation of the project. Accordingly, it collects baseline or benchmark data on Important Social Components (ISCs). The present study, therefore, selects some ISCs likely to be impacted by the project interventions. Any development is directed for the well being of the people. The interventions, in addition to meeting basic human requirement, also work for the improvement of the quality of life. So, the ISCs are selected according to food, accommodation, education and clothing and health. Here, improving quality of life largely means availability of drinking water, sanitation, employment opportunity and income.

Table 9.2: Component wise Logic of Selection of Important Social Components (ISCs)

Component	Rationale for selection
Income	Without increasing income, people cannot maintain livelihood smoothly. Even to ensure standard livelihood, it is impossible without increasing of income.
Food	Decreasing of crop, vegetables and fruits production resulted in food intake in this area. The poor and landless people are more vulnerable in this matter.
Accommodation	There are number of environmentally unsecured dwelling houses exist.
Clothing	After meeting food demand, people intend to spend on non-food item i.e. clothing, housing, education, health care, etc. The poor are not adequately clothed.
Health	The improvement of health condition is the major indicator of standard livelihood.
Education	Higher education are considered to be the basis of educational achievement.
Drinking water	Availability of safe water can improve health as well as quality of life.
Sanitation	Proper sanitation keeps water borne diseases away. This also have influence on overall disease situation.
Employment opportunity	The employment opportunity is a one of the determinants of income and consequently, quality of life.
Recreation	With improvement of quality of life, demand for recreational opportunity is likely to rise.
Gender Situation	Gender disparity occurs in payment, opportunities education etc.

9.3.3 Impact on Important Social Components

a). **Household income:** The project will impact positively on the household income of the project area. According to the survey, most of the respondent (73.9%) opined that household income will be increased. They think that facility to cultivate the land will be increased, crop cultivation will be easier. The production of agriculture will increase.

Due to water congestion of the area, a huge amount of land either remain uncultivated round the year or only one crop is cultivate instead of two or more. So they can cultivate two or three times in the area if there is no water congestion.

If TRM implemented then more land would be under crop cultivation, which will help to involve more people in the cultivation process. The crop cultivation also insists to explore other income generation activities e.g. livestock and poultry rearing. The by product of crops production would be fodder for the livestock and poultry. So there will be the scope to involve more people in these works. The scope of employment will increase. Facility in aquaculture will increase and more benefit would be generated. At present, due to scarcity of saline water many people stopped shrimp cultivation. However, if excavation of river/canal completed, the availability of saline water will be increased and that way, aquaculture will be increased. Due to lack of scope of employment especially for the landless and marginal people in this area, they are forced to migrate (seasonal/frequent) throughout the country. During earthwork and construction work, they have scope to work which help to increase household income as well as play role to alleviate poverty. The project will enhance the scope of investment in agriculture, fishery, small industry, trade and business.

b) **Food**: The survey data indicate the low calorie intake by the family members. The major reasons behind low intake calories are that majority household doesn't have ability to purchase vegetable, meat and pulses as per their need. The production of different food items by the household members has been decreased. By removing water congestions, people will get adequate time and land for crop and agriculture production, which may help to increase food intake of the household members. In addition, they may export surplus crops and vegetables throughout the country. The direct employment in earthwork and construction work will increase the income as well as their food intake.
It is also expected that the local people would be able to enhance their agricultural products in diversified ways such as cash crops, cultured fisheries and open water fisheries due to mitigation of drainage congestion and water logging. They believe that through implementation of the project, the plantation in this area will be increased significantly. In that case, fresh reforestation activities like homestead, agro-forest, embankment side reforestation, especially the plantation of fruit trees, and medicinal plants would help the local people not only for sustaining their livelihood, but also protect the ecology, environment and climate.

c). **Accommodation:** A number of environmentally insecure dwelling houses still exist. The increase in employment opportunity and income as envisaged will improve the housing status of the people of the area. People will naturally go for better house.

d). **Clothing:** The expenditure of clothing for the household member is very low; it takes about 6% of the total household yearly expenditure. If the family income increased then the expenditure for clothing may increase, especially for the poor and marginal income household of the project area.

e). Health: Health care accounts only seven percent of the total household expenditure. According to FGD participants, the scarcity of safe drinking water in the remote area is the main cause of diseases. They also face communication problems to take patient to the hospitals. Due to low income, people have no ability to consult with qualified physicians or hospitals having qualified physicians. With better income more physicians will be

available in the rural area and more people will consult with them. Thus health aspect is likely to be improved by the project.

f). Education: Expenditure on education accounts for 13% of total expenditure. The income from the project through increased crop production and higher employment opportunity is likely to help the higher educational attainment of the people of the area.

g). Drinking water: Most of the people (80.8 percent) of the rural area drink tube well water. But people of the southern area of the polders opined that they have to collect safe water far from the residence, even people of Subnali UP, mentioned that they buy water drum from deep water plant. The people of the Noapara collect safe drinking water from Budhata costing 15 taka per 30 litre. They are not much aware about arsenic. So, safe water scarcity exists in the project area.

h). Employment opportunity: Implementation of the project will generate some direct employment in the project which include earthwork and construction work. Indirect employment will be in agriculture, navigation, fisheries and it is related to other sectors. In case of shrimp farm only five persons is required for 3300 dcm but in case of crop production about 300 persons are required for cultivation of 3300 dcm. So it is a social problem that people of the shrimp farming area loosing employment opportunity. The population is increasing on the one side; the scope of employment is reducing on the other side. Therefore, there is a need to enhance agriculture production. The people of the area especially those who have small or medium land holder, want to get back to agriculture production. The project interventions especially TRM, can play role to enhance agriculture. Both men and women will get the opportunity of employment

i). Recreation: Five percent of the total family expenditure spends for recreation. 31 percent people have Television in the house. With increased income and consequent saving number of recreational gadgets will increase. With higher income people will go for visits to other places. There will be more options for recreations.

j). Gender: Higher income will encourage people to send girls to schools, colleges and universities. Higher agricultural production will require additional processing where women play the main role. With higher demand of labor, the payment discrimination will come down. Thus income of women will be improved. With the continuing support for female education by the government, the educational status of women will be improved. The gender situation will be improved as well.

9.3.4 Matrix of Probable Impact of ISCs

The impact of the project is shown in the matrix below. Impacts of the proposed intervention on ISCs have been estimated for 5 to 10 years after implementation of the project in two broad situations: (i) future without project situation (FWOP), and (ii) future with project situation (FWIP). The difference between these two situations is considered as the impact of the project interventions. The impacts have been assessed qualitatively. The qualitatively assessed impacts have been evaluated in a matrix with following scale: much improve = (+++), improve = (++), somewhat improve = (+), no change = (+), inferior = (-). Scoring Matrix for Impact Assessment on Important Social Components at a Glance has been shown in **Table 9.3.**

Table 9.3: Scoring Matrix for Impact Assessment on Important Social Components at a Glance

ISCs (Unit)	Baseline	Future-without-project	Future-with-project
Household income	a) The minimum yearly HH income of the household is 11600 tk. Average is Tk. 130715.7. b) 36 percent household income level is below $750 (national per capita income)	a) Somewhat improve (+) due to other interventions b) Somewhat improved = (+)	a) Improve. (++) b) Improve (++)
Food	a) 38.0% household have has adequate food only for the next 7 days in the house. b) The average expenditure of HH for food is 54076 taka per year	a) No change (±) b) Somewhat improve (+)	a) improve (++) b) Improve (++)
Clothing	a) People of the area spend about 6% of non-food expenditure.	a) No change (±)	a) increase (++)
Dwelling house	a) The number of *kancha* is worth mentioning.	a) No change (±)	improve (++)
Health	a) Still large number people have no ability for better treatment	a) Likely to improve (+)	a) Improve (++)
Education	a) Literacy rate among seven years is 72.4 percent in the study area. b) 12.1 percent at higher secondary level and 10.1 percent at graduation and above	a) Somewhat improve (+) b) Somewhat improve (+)	a) Improve (++) b) Improve (++)
Suffering from water	a) 46.8 percent has been suffering from water logging.	a) Inferior (-)	a) Much improve (+++)
Sanitation	a) 52.2 percent household use unsafe latrine	a) Improve (++)	a) Improve (++)
Employment	a) 26% household head work as a day labor	a) inferior (-)	a) Improve(+++)
Gender situation	a). Female literacy rate is less than male b) Only 2 percent women engaged in income earning outside of household	a) Improve + b) Improve +	a) Improve (++) b) Improve (++)
Recreational Opportunity	5 percent of the total family expenditure spend for recreation.	Somewhat improve (+)	More income will create scope to spend more (++)

9.3.5 Stakeholder Consultation

In order to carry out SIA, local stakeholder consultation was conducted to assess opinion of local people who will be directly affected due to the implementation of proposed interventions. The major findings of stakeholder consultation are given below:

9.3.6 The Salient Feature of the Project Area

- Water logging is the major concern, which has hampered people's life and livelihood.
- Saline water intrusion and availability of access of saline water has privileged the people to shift the land from agriculture to aquaculture.

- A huge number of landless people live on the bank and silted up river site. Therefore it would be difficult to excavate the river/canals.
- At the starting period of the shrimp culture, the size of the shrimp farm was big. At present, a huge number of small sizes shrimp farms are in the project area. These small shapes of structure of shrimp farms may one of the causes of water logging.
- Shifting from the agriculture to aquaculture has decreased the engagement of people to the land. That is why a huge number of people either has no work or has migrated (seasonally/frequently) to other places to seek work. The middle class are silent victims due to changing land use pattern.
- The dredging conducted by the fund of Climate Change Fund is not as high quality. The spoil is deposited in the bank of the canal; as a result the width of the canal is reducing.
- Due to saline water intrusion and inundation, normal fertility of the land is lost for crop production.
- The elements of environment have been changed. The trees, birds and wild life have endangered. It is happened more, where saline water permitted to enter in to field for shrimp farming.
- Now the average bed level of all rivers has become so high that it cannot contain the huge volume of tidal water as before. As a result, the mean tidal level has crossed the danger level.
- Consequently tidal water has started overtoppling embankment in many places during monsoon, threatening embankment and the standing crop.
- Water carrying huge amount of silt comes from Marirchap River and comparably less amount of silt with water of Ichamati River.
- Increasing of the height of the entire embankments are not done immediately, catastrophic damage will occur within the next few years resulting irreparable damage in many places in the coastal belt.
- Due to scarcity of saline water, shrimp aquaculture owners have been cultivating white fish. The rate of white fish is good at present. The cultivation of prone and white fish would be environment friendly for the project area.
- On the one hand water is not available for shrimp cultivation and on the other hand crop production is not possible. However, scarcity of water is a problem for both agriculture and aquaculture.
- The tidal time of these are different from others for Marirchap River and Ichamati River and it is about 2:00 hour to 2:30 hours.
- Generally, small shrimp farm owners (less than 10 bighas) cultivate rice in the same land. But medium and large shrimp farm organizer culture fish round the year.
- Majority of the people understood that TRM is better technique to solve water logging situation but they have not much knowledge about TRM.

9.3.7 Social Action Plan

Social action plan are designed for the different stages of the project for smooth implementation and for positive impact of the people of the project area. Following are possible social action plan:

Stage	Plan of Action	Strategy
Planning Stage/pre implementation stage	• Detail Discussion before designing the project some key issues like TRM and resettle of both bank side residence of Marirchap and Shapmara Rivers. • For TRM a series of discussion need especially with land owner, dependent of those lands, residence of the surrounding area. • Motivate and make people aware of what benefit they may gain~~ed~~ if TRM is implemented • Form committee with the participation of the dependent people for TRM.	• Discussion in every ward/village, ensure participation of all dependent people. • Can be engaged NGO, UP, samiti to aware people
Implementation Stage	• Ensure local day labor participation for earthwork. • Proper spoil management: developing embankment of the river side, filling low lying land, and develop residence to resettle the residents living at both sides of the bank. • Land use for excavation and TRM is an important task. Maximum canals, bank of the river encroach by the people. So, negotiation with the people may be needed for smooth implementation. However, in that line, it is needed to ensure providing lease money on time and resettle "project affected people".	• Use labor force instead of cutter machine • A project office can be set up to implement and monitor this activities or NGO can help in the above matter.
Post project period/long time sustainability	• Regular monitoring of the project intervention to gain maximum benefit from the project. • For long time sustainability, more small and big remedial measures like TRM are required. • It is mentionable that establishing brick fields on the river bank could be useful to sediment management. • Ensure Proper Management of the Sluice Gate	• Employ manpower and monitoring from the project office.

9.4 Recommendations and Suggestions

For successful implementation of the project with sustainability the following recommendations are made:

- All canals should have to be opened, no leasing out by the government.
- Building barriers must be stopped (bandh) within canal and rivers.
- No alternative of excavation of river and canal.
- All free flowing rivers should be connected. Even better if it is possible to open the sluice gate of Shakra. The tidal flow of Ichamati will go to south through Marirchap River.

- Ensure people participation in project implementation stage. Should involve poor people/daily labors in excavation and other activities.
- Restore the Marirchap River to its earlier form.
- Depth and width of river should be increased.
- Based on the gravity of present condition, TRM can be given the good result at present.
- TRM is possible where khals/government land available.
- For proper implementation of TRM, a committee ensuring the participation of all classes of the society should form without involving any political leaders.
- Resettle illegal residents of both banks of Rivers before implementation of the project interventions.
- The sluice gates should be repaired and rebuilt and ensure proper operation of its.
- Formulate policy for land use zoning for fish and paddy cultivation practice and must be implemented it.
- Developing a practical technology to overcome the siltation problem.
- New culverts, bridges (if required), short connecting canals, be constructed. This way, rain water gets easy passage and fishes can move around naturally.
- Social forestation of bank side of Rivers, plant mangrove varieties and saline viable on the both side of the embankment.
- Conditional lease out the bank of the Betna River for establish Brickfield to use silt.
- Initiate and permission to silt/sand transfer from the river with agreement with the government, if it has no negative impact for River.
- Brick field can be set up both bank sides to silt management. Already a number of brickfields have been using silt as raw material of brick.
- The women groups must be involved in every step of the project such as planning, construction, social forestry and O&M;
- The services of NGOs, UAO, DAE etc. must be coordinated by the PC (Project Committee);
- Compliance with the National Environment and Water Policies and compliance with the Environment conservation Act and Rules will have to be ensured.

CHAPTER TEN: COST ESTIMATE AND IMPLEMENTATION SCHEDULE

10.1 Basis of Cost Estimation

The cost estimation of the study is required to i) find out the total cost of the project and ii) to calculate the Benefit Cost Ratio (BCR) of the project and Internal Rate of Return (IRR). The project implementation period is limited to be five years. Implementation schedule is prepared according to sequence of priority and having linkage with previous and next item of work in the sequential chain of implementation. For example when operation of TRM is going to be started in a basin in the year 'n' then its preparatory works should have to be completed in the year (n-1).

The objective of cost estimate in feasibility level is to derive total cost of the project which will be the basis of financial and economic analysis. The project works include construction of new dyke, re-excavation of rivers and khals, construction of regulators, construction of peripheral embankment, inlet structures, construction of baily bridge and crop compensation for which detail assessment was made through field survey.

All individual items of works were taken from the BWDB's approved schedule of rates of Khulna O & M Circle, BWDB, Khulna. The rate of crop compensation is taken from the report of "Engineering Survey, Morphological and Hydrological Study with Mathematical Modelling for Rehabilitation of Bhutiar Beel and Barnal-Salimpur-Kolabashukhali Flood Control & Drainage project in Khulna District".. The rates are already authenticated by BWDB. These rates are applicable here due to having more or less identical scenario and being within the vicinity of the southwest region.

The quantity estimate has been prepared on outline drawings. The unit cost has been taken from different sources. **Table 10.1** shows the unit cost for different items of the project and respective sources. The rates which are not included in current 'Schedule of Rates' of Khulna O & M Circle, BWDB, Khulna effective from 2012- 2013, should have to be vetted by the competent authority of BWDB.

Table 10.1: Unit Cost of Different Items

Item	Unit	Unit Cost (Taka)	Sources/Item Code
Manual Excavation for Khals & River	cum.	113.76	Standard Schedule of Rates Manual, Khulna O&M Circle, BWDB, Khulna (2012-13) (*Code:16-130)*
Manual Excavation of Link Channel for TRM	cum.	113.76	Standard Schedule of Rates Manual, Khulna O&M Circle, BWDB, Khulna (2012-13) (*Code:16-13)0*
Mechanical Dredging	cum.	250.00	Dredger Division Khulna (*Code:16-130)*
Construction of Embankment	cum.	150.04	Standard Schedule of Rates Manual, Khulna O&M Circle, BWDB, Khulna (2012-13) (*Code:16-140-10)*
Crop compensation	ha/yr	5,92,800.00	Agricultural Extension Office, Jessore
Outlet structure (900 mm dia RCC pipe)	nos.	8,00,000.00	Followed the rate used in Kapalia Beel
Baily bridge (40m length)	nos.	1,60,00,000.00	Chittagong Dockyard
Re-sectioning of Embankment	LS	----------	Standard Schedule of Rates Manual, Khulna O&M Circle, BWDB, Khulna (2012-13)
River Bank Protection	LS	----------	Standard Schedule of Rates Manual, Khulna O&M Circle, BWDB, Khulna (2012-13)

10.2 Cost of Project Works

The cost has been calculated for Option-1 and Option-2. The estimated total cost for the project with option-1 is Tk. 44,435.75 Lakh and that of option-2 is Tk. 45,317.95 Lakh. Summary of detailed calculation has been furnished in the **Table 10.2 and Table 10.3** for option-1 and option-2 respectively.

10.3 Implementation Schedule

Five years ideal time is scheduled as implementation period of the project as usual. Item of work selected for the implementation according to priority and to follow the relevant linkage with the previous or next item of works. A mostly realistic sequence is followed in order of priority and to follow the implementation chain of works. The year-wise cost breakup with the five years period of implementation for option-1 is 45.04%, 29.98%, 8.98%, 10.21% & 5.80% for the 1st, 2nd, 3rd, 4th and 5th year respectively and for option-2 44.16%, 30.57%, 9.57%, 10.01% & 5.69% for the 1st, 2nd, 3rd, 4th and 5th year respectively. Item-wise cost estimation and implementation plan has been furnished in the **Table 10.4** and **Table 10.5** for Option-1 and Option-2 respectively.

It is proposed to complete all the project works within 5 years based on priority basis. An implementation schedule has been finalized in discussion with BWDB officials for Option-1, and Option-2**. Table 10.6** and **Table 10.7** shows the implementation schedule for Option-1, and Option-2 respectively.

Table 10.2: Summary of Detail Cost Estimation and Year-Wise Breakdown for Option-1

Sl. No.	Items	Total Cost (Lakh Tk.)	Year-wise break down (Lakh Tk.)				
			Year-1	Year-2	Year-3	Year-4	Year-5
A	**Dredging/Excavation/Re-excavation of Rivers/Khals :**						
1	Re-excavation/Dredging of Marirchap River :	7,293.08	3,646.54	3,646.54	0.00	0.00	0.00
2	Re-excavation/Dredging of Betna River :	12,108.68	6,054.34	6,054.34	0.00	0.00	0.00
3	Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal including Resectioning of Embankment :	1,829.94	914.97	914.97	0.00	0.00	0.00
4	Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal :	1,211.62	605.81	605.81	0.00	0.00	0.00
5	Re-excavation/Dredging of Satkhira khal for removal of deposited silt :	405.53	0.00	202.76	202.76	0.00	0.00
6	Re-excavation of 87 Internal drainage Khals (manually) :	6,076.45	0.00	0.00	2,430.58	2,430.58	1,215.29
	Sub-Total of A:	**28,925.30**	**11,221.66**	**11,424.42**	**2,633.35**	**2,430.58**	**1,215.29**
B	**Excavation work for TRM :**	107.38	80.11	0.00	0.00	27.27	0.00
C	**Construction of peripheral embankment and Closure Dam For TRM :**	1,553.33	1,313.33	60.00	60.00	60.00	60.00
D	**Crop Compensation/ Land Acqusition :**	6,348.89	6,348.89		0.00	0.00	0.00
E	**Construction and Shifting of Baily Bridge For TRM :**	325.00	320.00	0.00	0.00	5.00	0.00
F	**Reconstruction/Construction of new structures :**	1,315.00	312.50	877.50	125.00	0.00	0.00
G	**Construction of Structures For TRM :**	24.00	24.00	0.00	0.00	0.00	0.00
H	**Repair of existing regulators/Sluices :**	350.00	0.00	0.00	140.00	105.00	105.00
I	**Resectioning of Embankment at different location (41.50 km) in Polder-2, 44.42 Km in Polder 6-8 & 6-8 (Extn) :**	1,288.80	0.00	0.00	0.00	644.40	644.40
J	**Slope/River Bank Protective Work at different location (1.7 km) in Polder-2 :**	1,033.05	0.00	0.00	516.53	516.53	0.00
K	**Implemantation of Environmental Management Plan (EMP) Including formation and bi-annual updating of Gate operation :**	50.00		12.50	12.50	12.50	12.50
L	**Monitoring of Sedimentation,Sailinity, Tide and Flood in river system & TRM basin :**	300.00	0.00	75.00	75.00	75.00	75.00
	Grand-Total (A to L):	**41,620.75**	**19,620.48**	**12,449.42**	**3,562.37**	**3,876.28**	**2,112.19**
M	**Physical contingency (2%) :**	**832.41**	**392.41**	**248.99**	**71.25**	**77.53**	**42.24**
N	**Price contingency (5%) :**	**1,982.59**		**622.47**	**356.24**	**581.44**	**422.44**
	Grand-Total (A to N):	**44,435.75**	**20,012.89**	**13,320.88**	**3,989.86**	**4,535.24**	**2,576.87**

Table 10.3: Summary of Detail Cost Estimation and Year-Wise Breakdown for Option-2

Sl. No.	Items	Total Cost (Lakh Tk.)	Year-wise break down (Lakh Tk.)				
			Year-1	Year-2	Year-3	Year-4	Year-5
A	**Dredging/Excavation/Re-excavation of Rivers/Khals :**						
1	Re-excavation/Dredging of Marirchap River :	7,293.08	3,646.54	3,646.54	0.00	0.00	0.00
2	Re-excavation/Dredging of Betna River :	12,108.68	6,054.34	6,054.34	0.00	0.00	0.00
3	Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal including Resectioning of Embankment :	1,829.94	914.97	914.97	0.00	0.00	0.00
4	Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal :	1,211.62	605.81	605.81	0.00	0.00	0.00
5	Re-excavation/Dredging of Satkhira khal for removal of deposited silt :	405.53	0.00	202.76	202.76	0.00	0.00
6	Re-excavation of 87 Internal drainage Khals (manually) :	6,076.45	0.00	0.00	2,430.58	2,430.58	1,215.29
	Sub-Total of A:	**28,925.30**	**11,221.66**	**11,424.42**	**2,633.35**	**2,430.58**	**1,215.29**
B	**Excavation work for TRM :**	107.38	80.11	0.00	0.00	27.27	0.00
C	**Construction of peripheral embankment and Closure Dam For TRM :**	1,553.33	1,313.33	60.00	60.00	60.00	60.00
D	**Crop Compensation/ Land Acqusition :**	6,348.89	6,348.89		0.00	0.00	0.00
E	**Construction and Shifting of Baily Bridge For TRM :**	325.00	320.00	0.00	0.00	5.00	0.00
F	**Reconstruction/Construction of new structures :**	1,925.00	312.50	1,177.50	435.00	0.00	0.00
G	**Construction of Structures For TRM :**	24.00	24.00	0.00	0.00	0.00	0.00
H	**Repair and Remodelling of existing regulators/Sluices :**	550.00	0.00	200.00	140.00	105.00	105.00
I	**Resectioning of Embankment at different location (41.50 km) in Polder-2, 44.42 Km in Polder 6-8 & 6-8 (Extn) :**	1,288.80	0.00	0.00	0.00	644.40	644.40
J	**Slope/River Bank Protective Work at different location (1.7 km) in Polder-2 :**	1,033.05	0.00	0.00	516.53	516.53	0.00
K	**Implemantation of Environmental Management Plan (EMP) Including formation and bi-annual updating of Gate operation :**	50.00		12.50	12.50	12.50	12.50
L	**Monitoring of Sedimentation,Sailinity, Tide and Flood in river system & TRM basin :**	300.00	0.00	75.00	75.00	75.00	75.00
	Grand-Total (A to L):	**42,430.75**	**19,620.48**	**12,949.42**	**3,872.37**	**3,876.28**	**2,112.19**
M	**Physical contingency (2%) :**	**848.61**	**392.41**	**258.99**	**77.45**	**77.53**	**42.24**
N	**Price contingency (5%) :**	**2,038.59**		**647.47**	**387.24**	**581.44**	**422.44**
	Grand-Total (A to N):	**45,317.95**	**20,012.89**	**13,855.88**	**4,337.06**	**4,535.24**	**2,576.87**

Table 10.4: Item-Wise Detail Cost Estimation and Year-Wise Breakdown for Option-1

Sl. No.	Items	Unit	Quantity	Unit Cost (Tk.)	Total Cost (Lakh Tk.)	Year-wise break down				
						Year-1	Year-2	Year-3	Year-4	Year-5
A	**Dredging/Excavation/Re-excavation of Rivers/Khals :**									
1	**Re-excavation/Dredging of Marirchap River :**									
	i) Manual/Mechanical excavation (00.00-30.50 km.)	cum.	4,944,837.88	113.76	5,625.25	2,812.62	2,812.62			
	ii) Manual/Mechanical excavation (31.50-37.00 km.)	cum.	1,466,093.65	113.76	1,667.83	833.91	833.91			
2	**Re-excavation/Dredging of Betna River :**									
	i) Manual/Mechanical excavation (00.00-23.50 km.)	cum.	3,637,038.98	113.76	4,137.50	2,068.75	2,068.75			
	ii) Mechanical Dredging (23.50-44.00 km.) (by dredger)	cum.	3,188,474.90	250.00	7,971.19	3,985.59	3,985.59			
3	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal including Resectioning of Embankment :**									
	i) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 28.00-49.00 (21.00 km) in Polder-1	cum.	495,985.40	150.04	744.18	372.09	372.09			
	ii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 23.00-37.00 (14.00 km) in Polder-3 (Bhatshala to Confluence of Habra)	cum.	497,815.30	150.04	746.92	373.46	373.46			
	iii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 64.00-70.00 (6.00 km) in Polder-4 (Confluence of Habra to Shailkhali)	cum.	225,835.50	150.04	338.84	169.42	169.42			
4	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal :**									
	i) Manual/Mechanical excavation (00.00-23.50 km.)	cum.	1,065,063.80	113.76	1,211.62	605.81	605.81			
5	**Re-excavation/Dredging of Satkhira khal for removal of deposited silt :**									
	i)Manual/Mechanical excavation (8 km.)	cum.	356,477.60	113.76	405.53		202.76	202.76		
6	**Internal drainage Khals re-excavation :**									
	i) All listed ineternal khals re-excavation (Approx. length 357 km) (manually)	cum.	5,341,466.00	113.76	6,076.45			2,430.58	2,430.58	1,215.29
Sub-Total of A:		**cum.**	**21,219,089.00**		**28,925.30**	**11,221.66**	**11,424.42**	**2,633.35**	**2,430.58**	**1,215.29**
B	**Excavation work for TRM :**									
	i) Excavation of 1st Link Canal for TRM at Sukdebpur beel by Manual way (536 m)	cum.	54,672.00	113.76	62.19	62.19				
	ii) Excavation of 2nd Link Canal for TRM at Sukdebpur beel by Manual way (235m)	cum.	23,970.00	113.76	27.27				27.27	
	iii) Excavation of 1st Link Canal for TRM at Ticket by Manual way (300m)	cum.	15,750.00	113.76	17.92	17.92				
	Sub-Total of B:	**cum.**	**94,392.00**		**107.38**	**80.11**	**0.00**	**0.00**	**27.27**	**0.00**
C	**Construction of peripheral embankment and Closure Dam For TRM :**									
	i) Construction of new peripheral embankment for TRM at Sukdebpur Beel (10.78 km)	cum.	500,260.00	131.54	658.04	658.04				
	ii) Construction of new peripheral embankment for TRM at Ticket Beel (7.98 km)	cum.	312,135.00	131.54	410.58	410.58				
	iii) Construction of marginal dyke for TRM at Sukdebpur Beel (00.72 km)	cum.	2,520.00	131.54	3.31	3.31				
	iv) Construction of marginal dyke for TRM at Ticket Beel (1.34 km)	cum.	50,535.00	131.54	66.47	66.47				
	v) Construction of peripheral dyke of cluster village for TRM at Sukdebpur Beel (1.68 km)	cum.	87,360.00	131.54	114.91	114.91				
	vi) Construction and removal of closure dam of 85m long (at 4.00 mPWD crest level) for TRM at Sukdebpur beel for 5 Years	No	5.00	4,000,000.00	200.00	40.00	40.00	40.00	40.00	40.00
	vii) Constructionand removal of closure dam of 15m long (at 4.00 mPWD crest level) for TRM at Ticket beel for 5 Years	No	5.00	2,000,000.00	100.00	20.00	20.00	20.00	20.00	20.00
Sub-Total of C:		**-**	**-**	**-**	**1,553.33**	**1,313.33**	**60.00**	**60.00**	**60.00**	**60.00**
D	**Crop Compensation/ Land Acqusition :**									
	i) Crop Compensation for TRM at Sukdebpur Beel (For 5 years) (526 ha area) 480 Tk/yr/deci	ha.	526.00	592,800.00	3,118.13	3118.13				
	ii) Crop Compensation for TRM at Ticket Beel (For 5 years) (545 ha area) 480 Tk/yr/deci	ha.	545.00	592,800.00	3,230.76	3230.76				
Sub-Total of D:		**ha.**	**1,071.00**	**-**	**6,348.89**	**6,348.89**	**0.00**	**0.00**	**0.00**	**0.00**
E	**Construction and Shifting of Baily Bridge For TRM :**									
	i) Construction of Baily bridge over 1st Link channel for TRM at Sukdebpur beel (2 span@20m)	nos.	1.00	16,000,000.00	160.00	160.00				
	ii) Construction of Baily bridge over Link channel for TRM at Ticket beel (2 span@20m)	nos.	1.00	16,000,000.00	160.00	160.00				
	iii) Cost of shifting of Baily bridge at 1st Link Channel for TRM at Sukdebpur beel	nos.	1.00	500,000.00	5.00				5.00	
Sub-Total of E:		**-**	**-**	**-**	**325.00**	**320.00**	**0.00**	**0.00**	**5.00**	**0.00**

Sl. No.	Items	Unit	Quantity	Unit Cost (Tk.)	Total Cost (Lakh Tk.)	Year-wise break down				
						Year-1	Year-2	Year-3	Year-4	Year-5
F	**Reconstruction/Construction of new structures :**									
	i) Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal	nos.	1.00	19,000,000.00	190.00		190.00			
	ii) Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) inPolder-2 across Chumrikhali Khal	nos.	1.00	25,000,000.00	250.00		125.00	125.00		
	iii) Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal	nos.	1.00	37,500,000.00	375.00	187.50	187.50			
	iv) Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)	nos.	1.00	25,000,000.00	250.00	125.00	125.00			
	v) Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal	nos.	1.00	25,000,000.00	250.00		250.00			
	Sub-Total of F:				**1,315.00**	**312.50**	**877.50**	**125.00**	**0.00**	**0.00**
G	**Construction of Structures For TRM :**									
	i) Construction of pipe sluice of 900mm dia for TRM Operation in Sukdebpur Beel	nos.	3.00	800,000.00	24.00	24.00				
Sub-Total of G:		**-**	**-**	**-**	**24.00**	**24.00**	**0.00**	**0.00**	**0.00**	**0.00**
H	**Repair of existing regulators/Sluices :**									
	i) Repair of existing drainage regulator (20 Nos)	nos.	20.00		350.00			140.00	105.00	105.00
	Sub-Total of H:				**350.00**	**0.00**	**0.00**	**140.00**	**105.00**	**105.00**
I	**Resectioning of Embankment at different location (41.50 km) in Polder-2, 44.42 Km in Polder 6-8 & 6-8 (Extn) :**									
	i) Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)	km	41.50	1,500,000.00	622.50				311.25	311.25
	ii) Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)	km	44.42	1,500,000.00	666.30				333.15	333.15
Sub-Total of I:		**-**	**-**	**-**	**1,288.80**	**0.00**	**0.00**	**0.00**	**644.40**	**644.40**
J	**Slope/River Bank Protective Work at different location (1.7 km) in Polder-2 :**									
	i) Slope/River Bank Protection work of Betna River at Budhata Bazar from 18.200 to 18.780 (Total Length 580 m at right bank)	**m**	580.00	60,767.86	352.45			176.23	176.23	
	ii) Slope/River Bank Protection work of Betna River at Noapara from 19.753 to 20.193 (Total Length 440 m at right bank)	**m**	440.00	60,767.86	267.38			133.69	133.69	
	iii) Slope/River Bank Protection work of Betna River at Chanditola from 23.050 to 23.350 (Total Length 300 m at right bank)	**m**	300.00	60,767.86	182.30			91.15	91.15	
	iv) Slope/River Bank Protection work of Betna River from 24.000 to 24.300 (Total Length 300 m at right bank)	**m**	300.00	60,767.86	182.30			91.15	91.15	
	v) Slope/River Bank Protection work of Betna River at Maddha Chapra from 26.100 to 26.180 (Total Length 80 m at right bank)	**m**	80.00	60,767.86	48.61			24.31	24.31	
Sub-Total of J:					**1,033.05**	**0.00**	**0.00**	**516.53**	**516.53**	**0.00**
K	**Implemantation of Environmental Management Plan (EMP) Including formation and bi-annual updating of Gate operation :**	No.	LS	5,000,000.00	**50.00**	**0.00**	**12.50**	**12.50**	**12.50**	**12.50**
L	**Monitoring of Sedimentation,Sailinity, Tide and Flood in river system & TRM basin:**	No.	1.00	30,000,000.00	**300.00**	**0.00**	**75.00**	**75.00**	**75.00**	**75.00**
Grand-Total (A to L):			**-**	**-**	**41,620.75**	**19,620.48**	**12,449.42**	**3,562.37**	**3,876.28**	**2,112.19**
M	**Physical contingency (2%) :**	No.	1.00	LS	**832.41**	**392.41**	**248.99**	**71.25**	**77.53**	**42.24**
N	**Price contingency (5%) :**	No.	1.00	LS	**1,982.59**		**622.47**	**356.24**	**581.44**	**422.44**
Grand-Total (A to N):					**44,435.75**	**20,012.89**	**13,320.88**	**3,989.86**	**4,535.24**	**2,576.87**

Table 10.5: Item-Wise Detail Cost Estimation and Year-Wise Breakdown for Option-2

Sl. No.	Items	Unit	Quantity	Unit Cost (Tk.)	Total Cost (Lakh Tk.)	Year-wise break down				
						Year-1	Year-2	Year-3	Year-4	Year-5
A	**Dredging/Excavation/Re-excavation of Rivers/Khals :**									
1	**Re-excavation/Dredging of Marirchap River :**									
	i) Manual/Mechanical excavation (00.00-30.50 km.)	cum.	4,944,837.88	113.76	5,625.25	2,812.62	2,812.62			
	ii) Manual/Mechanical excavation (31.50-37.00 km.)	cum.	1,466,093.65	113.76	1,667.83	833.91	833.91			
2	**Re-excavation/Dredging of Betna River :**									
	i) Manual/Mechanical excavation (00.00-23.50 km.)	cum.	3,637,038.98	113.76	4,137.50	2,068.75	2,068.75			
	ii) Mechanical Dredging (23.50-44.00 km.) (by dredger)	cum.	3,188,474.90	250.00	7,971.19	3,985.59	3,985.59			
3	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal including Resectioning of Embankment :**									
	i) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 28.00-49.00 (21.00 km) in Polder-1	cum.	495,985.40	150.04	744.18	372.09	372.09			
	ii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 23.00-37.00 (14.00 km) in Polder-3 (Bhatshala to Confluence of Habra)	cum.	497,815.30	150.04	746.92	373.46	373.46			
	iii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 64.00-70.00 (6.00 km) in Polder-4 (Confluence of Habra to Shailkhali)	cum.	225,835.50	150.04	338.84	169.42	169.42			
4	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal :**									
	i) Manual/Mechanical excavation (00.00-23.50 km.)	cum.	1,065,063.80	113.76	1,211.62	605.81	605.81			
5	**Re-excavation/Dredging of Satkhira khal for removal of deposited silt :**									
	i)Manual/Mechanical excavation (8 km.)	cum.	356,477.60	113.76	405.53		202.76	202.76		
6	**Internal drainage Khals re-excavation :**									
	i) All listed ineternal khals re-excavation (Approx. length 357 km) (manually)	cum.	5,341,466.00	113.76	6,076.45			2,430.58	2,430.58	1,215.29
Sub-Total of A:		**cum.**	**21,219,089.00**	**-**	**28,925.30**	**11,221.66**	**11,424.42**	**2,633.35**	**2,430.58**	**1,215.29**
B	**Excavation work for TRM :**									
	i) Excavation of 1st Link Canal for TRM at Sukdebpur beel by Manual way (536 m)	cum.	54,672.00	113.76	62.19	62.19				
	ii) Excavation of 2nd Link Canal for TRM at Sukdebpur beel by Manual way (235m)	cum.	23,970.00	113.76	27.27				27.27	
	iii) Excavation of 1st Link Canal for TRM at Ticket by Manual way (300m)	cum.	15,750.00	113.76	17.92	17.92				
	Sub-Total of B:	**cum.**	**94,392.00**		**107.38**	**80.11**	**0.00**	**0.00**	**27.27**	**0.00**
C	**Construction of peripheral embankment and Closure Dam For TRM :**									
	i) Construction of new peripheral embankment for TRM at Sukdebpur Beel (10.78 km)	cum.	500,260.00	131.96	660.14	660.14				
	ii) Construction of new peripheral embankment for TRM at Ticket Beel (7.98 km)	cum.	312,135.00	131.96	411.89	411.89				
	iii) Construction of marginal dyke for TRM at Sukdebpur Beel (00.72 km)	cum.	2,520.00	131.96	3.33	3.33				
	iv) Construction of marginal dyke for TRM at Ticket Beel (1.34 km)	cum.	50,535.00	131.96	66.69	66.69				
	v) Construction of peripheral dyke of cluster village for TRM at Sukdebpur Beel (1.68 km)	cum.	87,360.00	131.96	115.28	115.28				
	vi) Construction and removal of closure dam of 85m long (at 4.00 mPWD crest level) for TRM at Sukdebpur beel for 5 Years	No	5.00	4,000,000.00	200.00	40.00	40.00	40.00	40.00	40.00
	vii) Constructionand removal of closure dam of 15m long (at 4.00 mPWD crest level) for TRM at Ticket beel for 5 Years	No	5.00	2,000,000.00	100.00	20.00	20.00	20.00	20.00	20.00
Sub-Total of C:		**-**	**-**	**-**	**1,557.33**	**1,317.33**	**60.00**	**60.00**	**60.00**	**60.00**
D	**Crop Compensation/ Land Acqusition :**									
	i) Crop Compensation for TRM at Sukdebpur Beel (For 5 years) (526 ha area) 480 Tk/yr/deci	ha.	526.00	592,800.00	3,118.13	3118.13				
	ii) Crop Compensation for TRM at Ticket Beel (For 5 years) (545 ha area) 480 Tk/yr/deci	ha.	545.00	592,800.00	3,230.76	3230.76				
Sub-Total of D:		**ha.**	**1,071.00**	**-**	**6,348.89**	**6,348.89**	**0.00**	**0.00**	**0.00**	**0.00**
E	**Construction and Shifting of Baily Bridge For TRM :**									
	i) Construction of Baily bridge over 1st Link channel for TRM at Sukdebpur beel(2 span@20m)	nos.	1.00	16,000,000.00	160.00	160.00				
	ii) Construction of Baily bridge over Link channel for TRM at Ticket beel (2 span@20m)	nos.	1.00	16,000,000.00	160.00	160.00				
	iii) Cost of shifting of Baily bridge at 1st Link Channel for TRM at Sukdebpur beel	nos.	1.00	500,000.00	5.00				5.00	
Sub-Total of E:		**-**	**-**	**-**	**325.00**	**320.00**	**0.00**	**0.00**	**5.00**	**0.00**

Sl. No.	Items	Unit	Quantity	Unit Cost (Tk.)	Total Cost (Lakh Tk.)	Year-wise break down				
						Year-1	Year-2	Year-3	Year-4	Year-5
F	**Reconstruction/Construction of new structures :**									
	i) Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal	nos.	1.00	19,000,000.00	190.00		190.00			
	ii) Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) inPolder-2 across Chumrikhali Khal	nos.	1.00	25,000,000.00	250.00		125.00	125.00		
	iii) Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal	nos.	1.00	37,500,000.00	375.00	187.50	187.50			
	iv) Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)	nos.	1.00	25,000,000.00	250.00	125.00	125.00			
	v) Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal	nos.	1.00	25,000,000.00	250.00		250.00			
	vi) Replacement of Bhatshala 4-vent sluice by a Bridge across Parulia-Sapmara khal	nos.	1.00	60,000,000.00	600.00		300.00	300.00		
	vii) Dismantling of Bhatshala Sluice (4V-1.52mx1.83m)	nos.	1.00	LS	10.00			10.00		
	Sub-Total of F:				**1,925.00**	**312.50**	**1,177.50**	**435.00**	**0.00**	**0.00**
G	**Construction of Structures For TRM :**									
	i) Construction of pipe sluice of 900mm dia for TRM Operation in Sukdebpur Beel	nos.	3.00	800,000.00	24.00	24.00				
Sub-Total of G:		**-**	**-**	**-**	**24.00**	**24.00**	**0.00**	**0.00**	**0.00**	**0.00**
H	**Repair and Remodelling of existing regulators/Sluices :**									
	i) Repair of existing drainage regulator (20 Nos)	nos.	20.00		350.00			140.00	105.00	105.00
	ii) Remodeling of the 4-vent sluice at Shalkhali into a culvert across Parulia-Sapmara khal including Sub Soil Investigation	nos.	1.00	LS	200.00		200.00			
	Sub-Total of H:				**550.00**	**0.00**	**200.00**	**140.00**	**105.00**	**105.00**
I	**Resectioning of Embankment at different location (41.50 km) in Polder-2, 44.42 Km in Polder 6-8 & 6-8 (Extn) :**									
	i) Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)	km	41.50	1,500,000.00	622.50				311.25	311.25
	ii) Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)	km	44.42	1,500,000.00	666.30				333.15	333.15
Sub-Total of I:		**-**	**-**	**-**	**1,288.80**	**0.00**	**0.00**	**0.00**	**644.40**	**644.40**
J	**Slope/River Bank Protective Work at different location (1.7 km) in Polder-2 :**									
	i) Slope/River Bank Protection work of Betna River at Budhata Bazar from 18.200 to 18.780 (Total Length 580 m at right bank)	**m**	580.00	60,767.86	352.45			176.23	176.23	
	ii) Slope/River Bank Protection work of Betna River at Noapara from 19.753 to 20.193 (Total Length 440 m at right bank)	**m**	440.00	60,767.86	267.38			133.69	133.69	
	iii) Slope/River Bank Protection work of Betna River at Chanditola from 23.050 to 23.350 (Total Length 300 m at right bank)	**m**	300.00	60,767.86	182.30			91.15	91.15	
	iv) Slope/River Bank Protection work of Betna River from 24.000 to 24.300 (Total Length 300 m at right bank)	**m**	300.00	60,767.86	182.30			91.15	91.15	
	v) Slope/River Bank Protection work of Betna River at Maddha Chapra from 26.100 to 26.180 (Total Length 80 m at right bank)	**m**	80.00	60,767.86	48.61			24.31	24.31	
Sub-Total of J:					**1,033.05**	**0.00**	**0.00**	**516.53**	**516.53**	**0.00**
K	**Implemantation of Environmental Management Plan (EMP) Including formation and bi-annual updating of Gate operation :**	No.	LS	5,000,000.00	**50.00**	**0.00**	**12.50**	**12.50**	**12.50**	**12.50**
L	**Monitoring of Sedimentation,Sailinity, Tide and Flood in river system & TRM basin:**	No.	1.00	30,000,000.00	**300.00**	**0.00**	**75.00**	**75.00**	**75.00**	**75.00**
Grand-Total (A to L):			**-**	**-**	**42,430.75**	**19,620.48**	**12,949.42**	**3,872.37**	**3,876.28**	**2,112.19**
M	**Physical contingency (2%) :**	No.	1.00	LS	**848.61**	**392.41**	**258.99**	**77.45**	**77.53**	**42.24**
N	**Price contingency (5%) :**	No.	1.00	LS	**2,038.59**		**647.47**	**387.24**	**581.44**	**422.44**
Grand-Total (A to N):					**45,317.95**	**20,012.89**	**13,855.88**	**4,337.06**	**4,535.24**	**2,576.87**

Table 10.6: Year Wise Implementation Schedule for Option-1

Sl. No.	Items	Year-wise break down				
		Year-1	Year-2	Year-3	Year-4	Year-5
A	**Dredging/Excavation/Re-excavation of Rivers/Khals :**					
1	**Re-excavation/Dredging of Marirchap River :**					
	i) Manual/Mechanical excavation (00.00-30.50 km.)	50%	50%	0%	0%	0%
	ii) Manual/Mechanical excavation (31.50-37.00 km.)	50%	50%	0%	0%	0%
2	**Re-excavation/Dredging of Betna River :**					
	i) Manual/Mechanical excavation (00.00-23.50 km.)	50%	50%	0%	0%	0%
	ii) Mechanical Dredging (23.50-44.00 km.) (by dredger)	50%	50%	0%	0%	0%
3	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal including Resectioning of Embankment :**					
	i) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 28.00-49.00 (21.00 km) in Polder-1	50%	50%	0%	0%	0%
	ii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 23.00-37.00 (14.00 km) in Polder-3 (Bhatshala to Confluence of Habra)	50%	50%	0%	0%	0%
	iii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 64.00-70.00 (6.00 km) in Polder-4 (Confluence of Habra to Shailkhali)	50%	50%	0%	0%	0%
4	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal :**					
	i) Manual/Mechanical excavation (00.00-23.50 km.)	50%	50%	0%	0%	0%
5	**Re-excavation/Dredging of Satkhira khal for removal of deposited silt :**					
	i)Manual/Mechanical excavation (8 km.)	0%	50%	50%	0%	0%
6	**Internal drainage Khals re-excavation :**					
	i) All listed ineternal khals re-excavation (Approx. length 357 km) (manually)	0%	0%	40%	40%	20%
B	**Excavation work for TRM :**					
	i) Excavation of 1st Link Canal for TRM at Sukdebpur beel by Manual way (536 m)	100%	0%	0%	0%	0%
	ii) Excavation of 2nd Link Canal for TRM at Sukdebpur beel by Manual way (235m)	0%	0%	0%	100%	0%
	iii) Excavation of 1st Link Canal for TRM at Ticket by Manual way (300m)	100%	0%	0%	0%	0%
C	**Construction of peripheral embankment and Closure Dam For TRM :**					
	i) Construction of new peripheral embankment for TRM at Sukdebpur Beel (10.78 km)	100%	0%	0%	0%	0%
	ii) Construction of new peripheral embankment for TRM at Ticket Beel (7.98 km)	100%	0%	0%	0%	0%
	iii) Construction of marginal dyke for TRM at Sukdebpur Beel (00.72 km)	100%	0%	0%	0%	0%
	iv) Construction of marginal dyke for TRM at Ticket Beel (1.34 km)	100%	0%	0%	0%	0%
	v) Construction of peripheral dyke of cluster village for TRM at Sukdebpur Beel (1.68 km)	100%	0%	0%	0%	0%
	vi) Construction and removal of closure dam of 85m long (at 4.0mPWD crest level) for TRM at Sukdebpur beel for 5 Years	20%	20%	20%	20%	20%
	vii) Constructionand removal of closure dam of 15m long (at 4mPWD crest level) for TRM at Ticket beel for 5 Years	20%	20%	20%	20%	20%
D	**Crop Compensation/ Land Acqusition :**					
	i) Crop Compensation for TRM at Sukdebpur Beel (For 5 years) (526 ha area) 480 Tk/yr/deci	100%	0%	0%	0%	0%
	ii) Crop Compensation for TRM at Ticket Beel (For 5 years) (545 ha area) 480 Tk/yr/deci	100%	0%	0%	0%	0%
E	**Construction and Shifting of Baily Bridge For TRM :**					
	i) Construction of Baily bridge over 1st Link channel for TRM at Sukdebpur beel (2 span@20m length)	100%	0%	0%	0%	0%
	ii) Construction of Baily bridge over Link channel for TRM at Ticket beel (2 span@20m length)	100%	0%	0%	0%	0%
	iii) Cost of shifting of Baily bridge at 1st Link Channel for TRM at Sukdebpur beel				100%	
F	**Reconstruction/Construction of new structures :**					
	i) Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal	0%	100%	0%	0%	0%
	ii) Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) inPolder-2 across Chumrikhali Khal	0%	50%	50%	0%	0%
	iii) Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal	50%	50%	0%	0%	0%
	iv) Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)	50%	50%	0%	0%	0%
	v) Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal	0%	100%	0%	0%	0%
G	**Construction of Structures For TRM :**					
	i) Construction of pipe sluice of 900mm dia for TRM Operation in Sukdebpur Beel	100%	0%	0%	0%	0%
H	**Repair of existing regulators/Sluices :**					
	i) Repair of existing drainage regulator (20 Nos)	0%	0%	40%	30%	30%
I	**Resectioning of Embankment at different location (41.50 km) in Polder-2, 44.42 Km in Polder 6-8 & 6-8 (Extn) :**					
	i) Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)	0%	0%	0%	50%	50%
	ii) Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)	0%	0%	0%	50%	50%
J	**Slope/River Bank Protective Work at different location (1.7 km) in Polder-2 :**					
	i) Slope/River Bank Protection work of Betna River at Budhata Bazar from 18.200 to 18.780 (Total Length 580 m at right bank)	0%	0%	50%	50%	0%
	ii) Slope/River Bank Protection work of Betna River at Noapara from 19.753 to 20.193 (Total Length 440 m at right bank)	0%	0%	50%	50%	0%
	iii)Slope/ River Bank Protection work of Betna River at Chanditola from 23.050 to 23.350 (Total Length 300 m at right bank)	0%	0%	50%	50%	0%
	iv) Slope/River Bank Protection work of Betna River 24.000 to 24.300 (Total Length 300 m at right bank)	0%	0%	50%	50%	0%
	v) Slope/River Bank Protection work of Betna River at Maddha Chapra from 26.100 to 26.180 (Total Length 80 m at right bank)	0%	0%	50%	50%	0%
K	**Implemantation of Environmental Management Plan (EMP) Including formation and bi-annual updating of Gate operation :**	0%	25%	25%	25%	25%
L	**Monitoring of Sedimentation,Sailinity, Tide and Flood in river system & TRM basin :**	0%	25%	25%	25%	25%
M	**Physical contingency (2%) :**	47.1%	29.9%	8.6%	9.3%	5.1%
N	**Price contingency (5%) :**	0.0%	31.4%	18.0%	29.3%	21.3%

Table 10.7: Year Wise Implementation Schedule for Option-2

Sl. No.	Items	Year-wise break down				
		Year-1	Year-2	Year-3	Year-4	Year-5
A	**Dredging/Excavation/Re-excavation of Rivers/Khals :**					
1	**Re-excavation/Dredging of Marirchap River :**					
	i) Manual/Mechanical excavation (00.00-30.50 km.)	50%	50%	0%	0%	0%
	ii) Manual/Mechanical excavation (31.50-37.00 km.)	50%	50%	0%	0%	0%
2	**Re-excavation/Dredging of Betna River :**					
	i) Manual/Mechanical excavation (00.00-23.50 km.)	50%	50%	0%	0%	0%
	ii) Mechanical Dredging (23.50-44.00 km.) (by dredger)	50%	50%	0%	0%	0%
3	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal including Resectioning of Embankment :**					
	i) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 28.00-49.00 (21.00 km) in Polder-1	50%	50%	0%	0%	0%
	ii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 23.00-37.00 (14.00 km) in Polder-3 (Bhatshala to Confluence of Habra)	50%	50%	0%	0%	0%
	iii) Manua/Mechanical excavation of Parulia Sapmara Khal & Resectioning of Embankment from 64.00-70.00 (6.00 km) in Polder-4 (Confluence of Habra to Shailkhali)	50%	50%	0%	0%	0%
4	**Re-excavation (Manual/Mechanical Excavation) of Parulia-Sapmara Khal :**					
	i) Manual/Mechanical excavation (00.00-23.50 km.)	50%	50%	0%	0%	0%
5	**Re-excavation/Dredging of Satkhira khal for removal of deposited silt :**					
	i)Manual/Mechanical excavation (9 km.)	0%	50%	50%	0%	0%
6	**Internal drainage Khals re-excavation :**					
	i) All listed ineternal khals re-excavation (Approx. length 357 km) (manually)	0%	0%	40%	40%	20%
B	**Excavation work for TRM :**					
	i) Excavation of 1st Link Canal for TRM at Sukdebpur beel by Manual way (536 m)	100%	0%	0%	0%	0%
	ii) Excavation of 2nd Link Canal for TRM at Sukdebpur beel by Manual way (235m)	0%	0%	0%	100%	0%
	iii) Excavation of 1st Link Canal for TRM at Ticket by Manual way (300m)	100%	0%	0%	0%	0%
C	**Construction of peripheral embankment and Closure Dam For TRM :**					
	i) Construction of new peripheral embankment for TRM at Sukdebpur Beel (10.78 km)	100%	0%	0%	0%	0%
	ii) Construction of new peripheral embankment for TRM at Ticket Beel (7.98 km)	100%	0%	0%	0%	0%
	iii) Construction of marginal dyke for TRM at Sukdebpur Beel (00.72 km)	100%	0%	0%	0%	0%
	iv) Construction of marginal dyke for TRM at Ticket Beel (1.34 km)	100%	0%	0%	0%	0%
	v) Construction of peripheral dyke of cluster village for TRM at Sukdebpur Beel (1.68 km)	100%	0%	0%	0%	0%
	vi) Construction and removal of closure dam of 85m long (at 4.0mPWD crest level) for TRM at Sukdebpur beel for 5 Years	20%	20%	20%	20%	20%
	vii) Constructionand removal of closure dam of 15m long (at 4mPWD crest level) for TRM at Ticket beel for 5 Years	20%	20%	20%	20%	20%
D	**Crop Compensation/ Land Acqusition :**					
	i) Crop Compensation for TRM at Sukdebpur Beel (For 5 years) (526 ha area) 480 Tk/yr/deci	100%	0%	0%	0%	0%
	ii) Crop Compensation for TRM at Ticket Beel (For 5 years) (545 ha area) 480 Tk/yr/deci	100%	0%	0%	0%	0%
E	**Construction and Shifting of Baily Bridge For TRM :**					
	i) Construction of Baily bridge over 1st Link channel for TRM at Sukdebpur beel (2 span@20m length)	100%	0%	0%	0%	0%
	ii) Construction of Baily bridge over Link channel for TRM at Ticket beel (2 span@20m length)	100%	0%	0%	0%	0%
	iii) Cost of shifting of Baily bridge at 1st Link Channel for TRM at Sukdebpur beel				100%	
F	**Reconstruction/Construction of new structures :**					
	i) Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal	0%	100%	0%	0%	0%
	ii) Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) inPolder-2 across Chumrikhali Khal	0%	50%	50%	0%	0%
	iii) Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal	50%	50%	0%	0%	0%
	iv) Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)	50%	50%	0%	0%	0%
	v) Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal	0%	100%	0%	0%	0%
	vi) Replacement of Bhatshala 4-vent sluice by a Bridge across Parulia-Sapmara khal	0%	50%	50%	0%	0%
	vii) Dismantling of Bhatshala Sluice (4V-1.52mx1.83m)	0%	0%	100%	0%	0%
G	**Construction of Structures For TRM :**					
	i) Construction of pipe sluice of 900mm dia for TRM Operation in Sukdebpur Beel	100%	0%	0%	0%	0%
H	**Repair and Remodelling of existing regulators/Sluices :**					
	i) Repair of existing drainage regulator (20 Nos)	0%	0%	40%	30%	30%
	ii) Remodeling of the 4-vent sluice at Shalkhali into a culvert across Parulia-Sapmara khal including Sub Soil Investigation	0%	100%	0%	0%	0%
I	**Resectioning of Embankment at different location (41.50 km) in Polder-2, 44.42 Km in Polder 6-8 & 6-8 (Extn) :**					
	i) Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)	0%	0%	0%	50%	50%
	ii) Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)	0%	0%	0%	50%	50%
J	**Slope/River Bank Protective Work at different location (1.7 km) in Polder-2 :**					
	i) Slope/River Bank Protection work of Betna River at Budhata Bazar from 18.200 to 18.780 (Total Length 580 m at right bank)	0%	0%	50%	50%	0%
	ii) Slope/River Bank Protection work of Betna River at Noapara from 19.753 to 20.193 (Total Length 440 m at right bank)	0%	0%	50%	50%	0%
	iii)Slope/ River Bank Protection work of Betna River at Chanditola from 23.050 to 23.350 (Total Length 300 m at right bank)	0%	0%	50%	50%	0%
	iv) Slope/River Bank Protection work of Betna River 24.000 to 24.300 (Total Length 300 m at right bank)	0%	0%	50%	50%	0%
	v) Slope/River Bank Protection work of Betna River at Maddha Chapra from 26.100 to 26.180 (Total Length 80 m at right bank)	0%	0%	50%	50%	0%
K	**Implemantation of Environmental Management Plan (EMP) Including formation and bi-annual updating of Gate operation :**	0%	25%	25%	25%	25%
L	**Monitoring of Sedimentation,Sailinity, Tide and Flood in river system & TRM basin :**	0%	25%	25%	25%	25%
M	**Physical contingency (2%) :**	46.2%	30.5%	9.1%	9.1%	5.0%
N	**Price contingency (5%) :**	0.0%	31.8%	19.0%	28.5%	20.7%

10.4 Linkage with the Current DPP

The drainage congestion and sedimentation have been major issues over the years in the kobadak river basin area. Kobadak River has been experiencing huge siltation over a long stretch area that reduces the drainagecapability of the river &causes huge prolong drainage congestion &water logging in the river basin. That causes public suffering of local people & ultimately affect the total economy of that area.

In response of the acute drainage congestion and huge water logging of kobadak river basin resulting inhuman people suffering. BWDB has to take plan to reduces the calamity & awarded IWM for carrying consultancy services on July/2009 for devising a sustainable drainage & flood management plan. The kobadak River flows through Jessore, Satkhira, Khulna districts and the total length of the river is about 240 km. The catchment area of the kobadak river system is about 102000 ha &the study area from Taherpur to katakhali is about 75000ha. More than hundred years ago, River Kobadak lost its freash water connection from Mathabhanga north of Taherpur and become a mere seasonal river.

Under this study a comprehensive field survey, focus group discussion at different locations in the study area, Mathematical modelling, economic analysis , Environmental impact have been carried out in order to identify prevailing problems and devise measures for rejuvenating the kobadok river system. Drainage model has been developed and caliberated on the field survey data to investigate the drainage problems &to select the best suited drainage plan to removal of drainage congestions. TRM model has also been developed to asses the effectiveness of beels for sustaining the drainage condition of the kobadak river system.

After implementation of the drainage plan, removal of water logging, water conservation, agriculture productivity, enhancement of economic activity, navigation facilities, establishment of economic balance & enhancement of employment opportunity will be achieved. Objective, Output of the project, Structural report have been included in the final report.In the final report IWM formulate a drainage & sediment management, highlighting the capital dredging & tidal river management. An integrated planning has also been included for the restoration of Mathabhanga-Hisna including Bhairab & Kobadak River was also emphasized considering the future implementation of Ganges Barrage Project.

CHAPTER ELEVEN: ECONOMIC AND FINANCIAL ANALYSIS

11.1 Introduction

Economic analyses govern the main criteria in the decision making process for acceptability and feasibility of the formulated project. The main objective is to evaluate and compare the project cost with the multi-sectoral benefits from the project. Financial cost and benefits are considered as the primary indicators of the feasibility, though some benefits could not be quantified, which are included in the multi-criteria analysis. The most important indicator is the Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV), which dictates the feasibility of the project. However, sensitivity analysis and evaluation of Net Present Value (NPV) were also considered as important indicator in the decision making process.

Basically, the Flood Action Plan (FAP) Guidelines for Project Assessment (1992) have been followed in the economic analysis of this project. The guidelines have been used in conformity with the methodology followed by different donor agencies.

11.2 Assumptions

The economic life of the project has been assumed for 30 years from the start of project construction. Individual project components may have a lifetime either higher or lower than the analytical lifetime. But it is assumed that economic life of overall project facilities will be sustained for 30 years subject to periodic annual maintenance works. However, the cumulative project impacts beyond 30 years were considered in Multi–Criteria Analysis.

Implementation period of the project is assumed to be 5 financial years. The full benefits are assumed to be achieved after three years of the completion of the proposed investment programme. This is consistent with FAP recommendations. But it is assumed that partial benefits will start from the 1st year of the project completion. To estimate benefit-build-up based on practical experience; a curvilinear trend is considered and presented in **Table 11.1.**

Table 11.1: Curvilinear Trend of Benefit-Built-Up

Years	Investment (%)	Benefit-Built-Up (%)
1	39	-
	14	-
3	19	-
4	16	
5	12	
6		20
7	-	40
8	-	60
9	-	80
10	-	90
11	-	100
…	-	…

11.3 Economic Parameters

Discount rate of 12% is used for computation of BCR & NPV following the "Guidelines for Project Assessment" of FAP, May 1992 and updated later on. Following factors on market prices and shadow prices have been used in the analysis.

- In pricing inputs and outputs, 2013 farm-gate prices collected by the study team were used and average of the prices during peak and lean seasons considered to assess financial costs and benefits.
- Economic benefits and costs of the project have been worked out based on the shadow conversion factors furnished in updated "Guidelines for Project Assessment" of FAP, May 1992.
- Shadow conversion factors used for unskilled labour in agriculture is 0.65 and that for skilled labour in construction work is 0.902. All these were used to remove the market distortions, un-employment / under-employment, low productivity, inefficiency and lack of even distribution of labour force, etc.
- A standard conversion factor (SCF) of 0.902 was used to convert the price of non-traded goods into international equivalence.

The analysis is based on projected future benefits and costs. Sunk costs i.e. investments made in the project prior to appraisal and its impacts were not included.

11.4 Benefits And Costs

Project benefits have been identified for the following sectors:

- Increased cropping intensity and yields
- Saving due to droughts

Net benefits on agriculture were considered for analysis. Other direct and indirect benefits of the project were ignored and not accounted for analysis although such sectors would enhance potential tangible benefits as a direct impact of the project.

Costs considered are capital and operation and maintenance (For Option-1: Annex-VII: Table-A.1 and for Option-2: Annex-VII: Table-B.1). Capital cost includes pre-construction, construction, engineering & administration costs. Annual O&M cost is considered after project completion. All costs are presented in terms of present worth at year 0 of project life. It is assumed, for analytical purpose, that all project costs are to be incurred at the start of the year and all benefits to be accrued at the end of each year. The corresponding economic prices were worked out following FAP Guidelines for Project Assessment.

The estimated gross product of crops in normal and average years at market & economic price is given in Annex-VII (Table-A.2 and A.3) for Option-1, Annex-VII (Table-B.2 and B.3) for Option-2.

Cultivation costs include labour, power tillar, seeds, fertilizers, pesticides etc. The cost of cultivation relating to the pre-project and post-project conditions (full development stage) including financial & economic unit rate of inputs with conversion factors is shown in Annex-VII (Table-A.4 and A.5) for Option-1 and Annex-VII (Table-B.4 and B.5) for Option-2.

The net benefit derived from the difference between the gross product and the production cost. Net Incremental Benefit, which represent the surplus of the net benefit in post-project condition over that of pre-project condition are shown in Annex-VII (Table-A.6) for Option-1 and Annex-VII (Table-B.6) for Option-2.

11.5 Analytical Results

The benefit and cost stream are presented in Annex-VII (Table- A.7, A.8, A.9 and A.10) for Option-1 and Annex-VII (Table- B.7, B.8, B.9 and B.10) Option-2. Computations of NPV & BCR both financial and economic are shown in Annex-VII (Table- A.7 and A.9) for Option-1 and Annex-VII (Table- B.7 and B.9) for Option-2. Computation of IRR is shown in Annex-VII (Table- A.8 and A.10) for Option-1 and Annex-VII (Table- B.8 and B.10) for Option-2. Summary of the analytical results are shown in the **Table 11.2** below.

Table 11.2: Summary of the Analytical Results of Benefit and Cost Analysis

Viability Indicator	**Option-1**		**Option-2**	
	Fin	**Eco**	**Fin**	**Eco**
Capital cost(Lakh Taka)	44435.75	31447.34	45317.95	32192.57
Annual O&M cost (Lakh Taka)	1633.48	1425.29	1657.78	1447.20
BCR @ 12%	1.90	2.61	1.98	2.74
NPV (Lakh Taka) @ 12%	(+) 38711.56	(+) 48409.51	(+) 42821.45	(+) 53477.57
IRR (%)	19.42	21.72	19.78	21.96

11.6 Sensitivity Analysis

Sensitivity analysis for the proposed project has been carried out to test the effects of changes in the following critical variables:

- If investment and O&M cost increase by 40%;
- If costs increase by 20% and benefits decrease by 20%;
- If only benefits decrease by 40%;
- If only investment cost & O&M cost increase by 50%;
- If project implementation period delayed by 3 years.

All the analyses under these sensitivity tests are presented in Annex-VII. The summary of the analytical results are shown in the following **Table 11.3.**

Table 11.3: Summary of the Analytical Results of Sensitivity Analysis

Critical Variables	**EIRR (%)**	
	Option-1	**Option-2**
Base case	21.72	21.96
Investment cost and O&M cost increase by 40%	19.48	19.91
Costs increase by 20% and benefits decrease by 20%	18.80	19.28
Only benefits decrease by 40%	16.16	16.42
Investment cost and O&M cost increased by 50%	18.80	19.28
Implementation period delayed by 3 years	20.77	21.07

11.7 Multi Criteria Analysis

The purpose of multi-criteria analysis (MCA) is to compare the quantitative and qualitative criteria in their performances in alternative or complementary development scenarios. Criteria are chosen to give decision makers the necessary elements on the major impacts. The principle of a MCA is to draw up an assessment of water resources management strategies not only on the basis of financial and economic analysis of benefits and costs but also taking into account institutional, social and environmental effects.The MCA matrix, recommended in FAP Guidelines (1992) presented following criteria:

a) Economic : EIRR, NPV.

b) Quantitative :

i. Increase of agricultural production;
ii. Increase of fish production;
iii. Increase of navigational facility;
iv. Health and diseases;
v. Increase of employment & income;
vi. Tree plantation.

c) Qualitative :

i. Socio-economic impacts;
ii. Environmental improvement;
iii. Balanced development;
iv. Organizations / Institutions; and
v. Poverty alleviation.

d) Financial :

Costs	Option-1	Option-2
Investment cost (Lakh Taka)	44435.75	45317.95
Gross Benefited Area (Hectare)	75,790	75,790
Net Benefited Area (Hectare)	42,207	42,207
Cost \ ha. (Tk.)	58,630	59,794
Annual O&M cost (Lakh Taka)	1633.48	1657.78

A summary of project results focusing the salient scenarios is presented in MCA Matrix in Annex-VII (Table- A.16) for Option-1 and Annex-VII (Table- B.16) for Option-2.

11.8 Indirect / Macro Economic Impacts

The project impacts were considered upon following significant Indirect / Macro economic parameters:

11.8.1 Poverty Alleviation

The project will directly increase agricultural production in the area. Thus the hard line poverty will be alleviated by virtue of both increase in income and employment. The most affected groups, being daily laborers, will be directly benefited from enhanced employment in construction works, other related works as well as expanding agricultural sector. As wages

increase, consumption of daily food and other necessities by poor households will also increase, thereby reducing the extent of poverty line in the project area.

11.8.2 Risks and Uncertainty

The project risks may arise due to the following reasons:

- Delay in project implementation due to lack of fund.
- Lack of O&M after project implementation.

The above project risks are crucial to derive targeted benefit of the project. If the project implementation is delayed years after years, the rivers will be silted up. The O&M of any project is the corner stone of total investment cost. The full benefit of the project will be accrued after implementation and if the provision of annual O&M is not kept later on, the benefit of the project will whither away yielding negative EIRR. This will lead project investment to a meaningless exercise. Therefore the planners and policy makers must ensure O&M activities before the project implementation takes off.

11.9 Conclusion

The project area offers an excellent opportunity for water management. The project is cost-effective and of short-gestation, and satisfies the current strategy of agricultural planning to contribute to the attainment of food-grain self-sufficiency at the earliest. Evaluation results and sensitivity analysis indicate that the proposed project is economically viable. The project is thus recommended for early implementation.

CHAPTER TWELVE: CONCLUSIONS AND RECOMMENDATIONS

12.1 Conclusions

The study has been carried out for devising sustainable drainage and sediment management plan to solve the long standing drainage congestion problem in the Polder 1, 2, 6-8 and 6-8 extension under Kalaroa, Satkhira Sadar, Debhata, Assasuni and Tala upazila Upzillas in the Satkhira district. A comprehensive field survey and investigation, focus group discussions at different locations in the study area, mathematical modelling and field level workshop have been carried out in order to identify the causes of the prevailing problems and to devise interventions for solving existing problems.

Considering the issue of sedimentation of the rivers, removal of drainage congestion and improvement of socio-economic conditions two (2) options have been devised for sediment and drainage management and duly tested for their effectiveness. The major interventions considered in the options for removing drainage congestion are dredging/excavation of rivers, additional drainage and flushing regulators, tidal river management by allowing natural tidal movement into embanked low-lying beel for sediment management, excavation of khals etc.

The volume of dredged earth for different river and drainage khals is presented in the following table:

SL No.	River /Khal	Length(Km)	Dredging volume(Mm^3)
1	Betna River	44.00	6.83
2	Marirchap River	37.00	6.41
3	Parulia Sapmar Khal	23.50	2.28
4	Satkhira khal	8.00	0.36
5	Internal Drainage channel (Polder-1)	94.00	1.94
6	Internal Drainage channel (Polder-2)	69.00	0.94
7	Internal Drainage channel (Polder-6-8 & 6-8 Ext)	194.00	2.46

The proposed interventions have been found very effective in terms of removing the existing water-logging problems. At present about 61% area of the Polder-1 experiences water-logging and in the proposed condition about 7 to 11% areas is likely to be inundated, which implies about 93% area become productive land under average flood event.

The flood free, F0 and F1, which are productive land, become about 98% and 97% in the Polder-2, Polder 6-8, 6-8 (ext.) in the proposed drainage improvement plan under average flood event.

In the extreme flood event, about 70% of the study area experiences drainage congestions. Model results shows that about 62%, 89% and 78% of polder-1, polder-2 and polder 6-8 become flood free in the proposed drainage improvement plan.
The study results show decrease of about 0.75m water level in Deabkhali khal and Ticket Khal in Polder-1 which is connected to the Parulia-Sapmara River and Marirchap River respectively under the final option compared to the present condition. Water level decreases about 1.0 m for Himkhali khal in Polder-2 which is connected to the Betna River. Water level decreases about 0.6 m for Tetulia khal in Polder-6-8 which drains to the Betna River. The

decrease of peak water level in the proposed plan implies the improvement of drainage condition**.**

Restoration of Betna River, Marirchap River and Parulia-Sapmara khal by dredging/excavation alone would not sustain since re-siltation rate is almost 60-80% during dry season as virtually there is no upstream fresh water flow to flush the huge incoming sediment into the rivers with high tide. Thus, in addition to dredging/excavation, implementation of TRM, using operation of potential tidal basins is required to trap up the incoming sediment inside the basins for sustainable sediment and drainage management. Continuous TRM operation of all the potential beels along the Betna and Marirchap river basin would be effective. TRM basins for sediment management to increase tidal prism, which will result in increasing the drainage capacity of the rivers. The study indicates that Hazikhali-Amudkhali Beel, Matiadanga Beel, Aumtoli Beel, Sukdebpur beel, Sreeramkathi Beel, Chapra Beel for Betna River basin are effective as tidal basins in terms of generating required tidal prism for Tidal River Management. Model results shows that these beels generate tidal prism in the range of 6.20 to 14.00 Mm^3 individually, which is higher, compared to the required tidal prism for maintaining the design/proper drainage capacity of the river. In case of Marirchap River basin, it is seen that the selected Jealmari Beel, Ticket Beel, Gobindapur Beel, Bugmara Beel and Dorgahpur Beel are also effective for tidal basin for Tidal River Management.

TRM can be successfully and continuously operated in these two river basins using the selected beels for about 40 years or so. However, before implementation of TRM, location of link canal of TRM basin and cross-dam in the river needs to be finalized after detailed field investigation's and in consultation with the local stakeholders.

Dredged earth would be deposited in the adjacent low lying area, borrow pit of roads, ponds, unproductive land and in the area to be raised by the local people willingly. Benefit of the project depends mostly on the implementation standard and accuracy. A strong monitoring and supervision during project implementation is quite necessary.

The present project is cost-effective and satisfies the current strategy of agricultural planning to contribute to the attainment of food self-sufficiency at the earliest as well as savings of govt. and private properties including additional expenditure due to drainage improvement in the areas. Analysis shows that the proposed project is economically viable. The suggested drainage and flood management plan is environment friendly and socially acceptable. The SIA and EIA study also show that the proposed drainage improvement plan is socially acceptable and environmental friendly.

The EIA and SIA study show that the project is environment friendly and socially acceptable as long as all proposed mitigation, monitoring, management and enhancement programmes are in place as integral constituents of the project, with ensured people's participation in all stages of the project.

12.2 Recommendations

i. The study results show that the Option-2 is technically feasible, economically viable and socially acceptable solution. Thus this option is recommended for implementation as a log-term solution for drainage and sediment management in the project area. The recommended measures for restoration of drainage systems are as follows:

SI	Proposed Interventions /Components
1	Manual/Mechanical excavation (Km 0.00 to Km 37.00) of Marirchap River
2	Manual/Mechanical excavation (Km 0.00 to Km 23.50) and Mechanical Dredging (by dredger) (Km 23.50 to Km 44.00) of Betna River
3	Manual/Mechanical excavation of Parulia-Sapmara River (Km 0.00 to Km 23.50)
4	Manual excavation of Satkhira Khal (Km 0.00 to Km 8.00)
5	Manual excavation of Major and Minor Internal Khals (Approx. length-357.00 km)
6	Tidal River Management (TRM) utilizing beels (11 Nos)
7	Replacement of 2-vent (DS-15) pipe sluice by 1-vent sluice (1.50x1.80) in Polder-1 across Arkoni (Branch) Khal
8	Replacement of 4-vent (DS-12) pipe sluice by 2-vent sluice (1.50x1.80) inPolder-2 acros Chumrikhali Khal
9	Replacement of 2-vent sluice (DS-3) by 3-vent (1.50x1.80) sluice in Polder 6-8 across Khajurdanga khal
10	Additional 2-vent sluice (1.50x1.80) in Polder 6-8 across Bainboshto Khal near (Ds-4)
11	Replacement of 1 vent sluice (DS-1) by 2-vent sluice (1.50x1.80) in Polder 6-8 (Extn) across Kulutia khal
12	Repairing of existing structures(20 Nos)
13	Replacement of Bhatshala 4-vent sluice by a Bridge across Parulia Sapmara khal
14	Remodeling of Shalkhali 4-vent sluice by a Bridge across Parulia-Sapmara khal
15	Resectioning of Embankment from 1.00-17.50; 19.00-23.00; 23.350-25.350; 29.00-35.00; 29.00-35.00 & 42.00-51.00 (37.50 km) in Polder 2 & from 2.00 to 6.00 (4.00 km) in Polder 2 (Extn)
16	Resectioning of Embankment from 1.10 -5.00; 5.60-9.00; 9.00-11.00; 11.5-12.00;12.60-20.00;20.00-33.50 & 45.00-52.72 (38.42 km) in Polder 6-8 & from 0.50 to 6.50 (6.00 km) in Polder 6-8 (Extn)
17	Resectioning of Embankment along the both banks of Paruluia Sapmara Khals from 28.00-49.00 (21.00 km) in Polder 1, from 23.00-37.00 (14.00 km) in Polder 3 & from 64.00-70.00 (6.00 km) in Polder 4
18	Slope/River Bank Protective work along the Right banks of Betna River from 18.200 to 18.780; 19.753 to 20.193; 23.050 to 23.350;24.00 to 24.30 & 26.100 to 26.180 (1.70 km)

ii. It is suggested to develop Sukdebpur Beel for Betna River and Ticket Beel for Marirchap River as a first beel for tidal river management. Dredging of river would not be sustainable unless TRM operation is implemented along with the dredging activities. TRM needs to be operated at least 8 years or more in one beel depending on monitoring results;

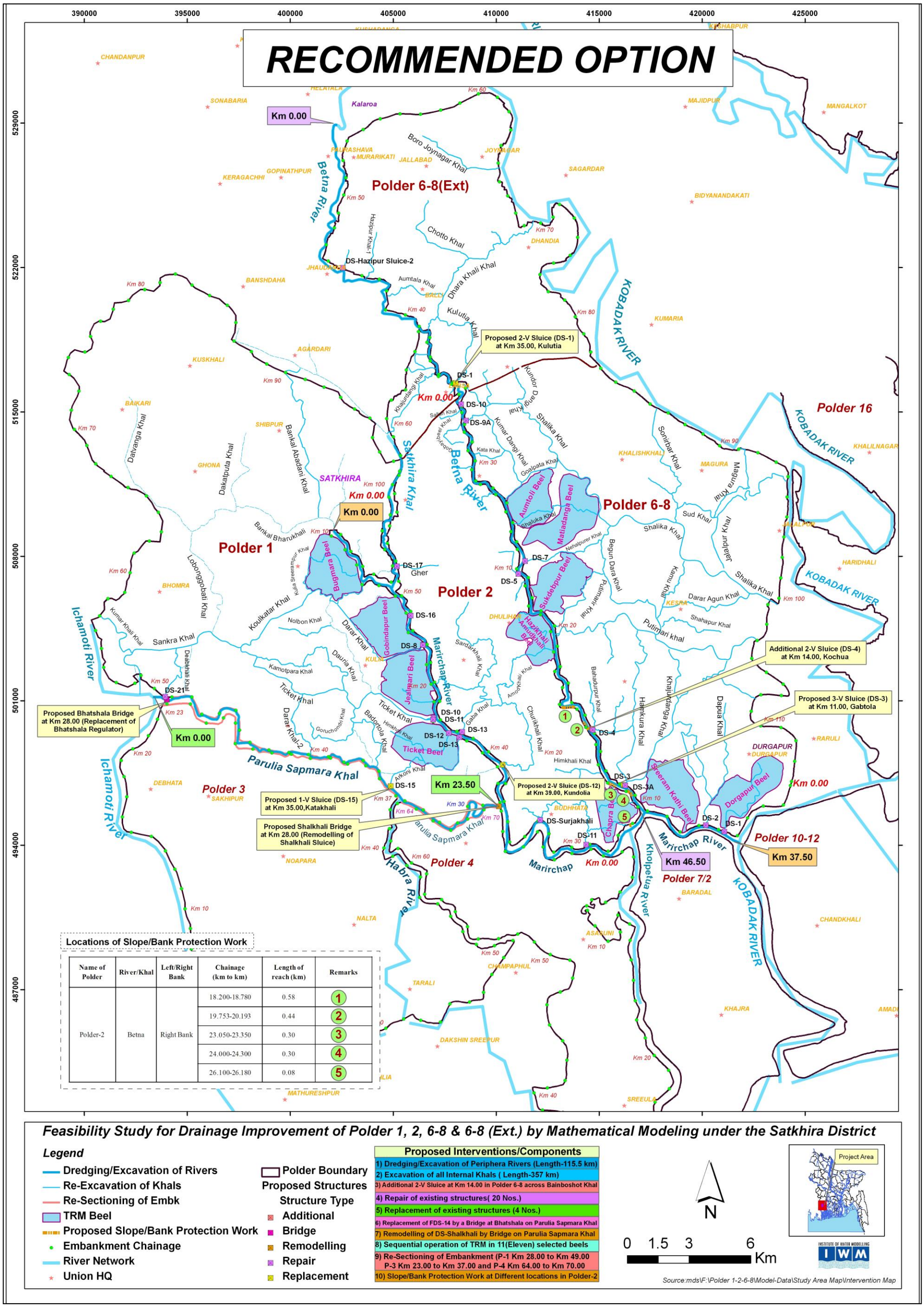
iii. Remove all the illegal infrastructures and encroachment over the rivers/khals;

iv. Implementation of TRM should not be delayed. Delay in implementation of TRM will lead severe sedimentation at the downstream of the river, as a result prolong drainage congestion will prevail in the Sathkhira districts including study area.

v. Crop compensation to the land owners of the beels for TRM operation should be given for the whole period of operation;

vi. Monitoring of sedimentation, erosion, tide, drainage condition in the beel, khal and river is required to assess the effectiveness of implementation plan comparing it with the targets and identifying shortfalls.

vii. Involvement of local stakeholders and water management organizations working in the area is essential and useful during implementation of the recommended measures and operation & maintenance.



Name of Polder	River/Khal	Left/Right Bank	Chainage (km to km)	Length of reach (km)	Remarks
Polder-2	Betna	Right Bank	18.200-18.780	0.58	1
			19.753-20.193	0.44	2
			23.050-23.350	0.30	3
			24.000-24.300	0.30	4
			26.100-26.180	0.08	5

Figure 12.1: Proposed Interventions of the Recommended Option

REFERENCES

C. ADAMS WILLIAMS (1919), History of the Rivers in the Gangetic Delta, Bengal Secretariat Press, Calcuta.

DHI Water and Environment (2007), MIKE 21 FLOW MODULE (User Guide; Mud Transport Module), Danish Hydraulic Institute.

EGIS, 1999, Environmental Impact Assessment and Social Impact Assessment of Khulna-Jessore Drainage Rehabilitation Project, Final Report, Dhaka, Water Resources Planning Organisation

Environmental and Social Impact Assessment of Gorai River Restoration Project, Main Report, October 2001, Environmental and GIS Support Project for Water Sector Planning (EGIS).+

EPWPDA, 1968, Coastal Embankment Project (CEP).

IWM, 2012, Final Report, Main Report, Engineering Survey, Morphological and Hydrological Study with Mathematical Modelling for Rehabilitation of Bhutiar Beel and Barnal-Salimpur-Kolabashukhali Flood Control & Drainage project in Khulna District.

IWM, 2010, Final Report, Main Report, Feasibility Study and Detailed engineering Design for Long Term Solution of Drainage Problems in the Bhabodah Area, Bangladesh Water Development Board.

IWM, 2010, Final Report, Main Report, Feasibility Study for sustainable drainage and flood management of Kobadak river basin under Jessore and Satkhira districts, Bangladesh Water Development Board.

IWM (2009), Final Report, Mathematical Modelling Study for Planning and Design of Beel Kapalia Tidal Basin, Bangladesh Water Development Board.

IWM, 2008, Final Report, Main Report, Sub-Regional Hydro-morphological Study of Peripheral Rivers of Polders 22, 23, 29, 30, 31 & 32, Bangladesh Water Development Board.

IWM, 2007, Final Report, Main Report, Monitoring the Performance of East Beel Khuksia and Dredging of Hari River for Drainage Improvement of Bhabodah area.

IWM (2006), Monitoring the Performance of Beel Kedaria TRM and Baseline Study for Beel Khuksia, Final Report, Bangladesh Water Development Board.

SMEC, 1998, Khulna-Jessore Drainage Rehabilitation Project, Feasibility Study Report for new Drainage Plan, Dhaka, Bangladesh Water Development Board.

SMEC, 2002, Khulna-Jessore Drainage Rehabilitation Project (KJDRP), Project Completion Report (Final), December, Dhaka, Bangladesh Water Development Board.

HASKONING, 1993, Second Coastal Embankment Rehabilitation Project (Main Report).
Halcorw, 1993, Southwest Area Water Resources Management Project (FAP 4).