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MINISTRY OF WATER RESOURCES
BANGLADESH WATER DEVELOPMENT BOARD

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MEGHNA ESTUARY STUDY

Volume - 2

INCEPTION REPORT

(ANNEX 01 - 04)

APRIL 1996

DHV CONSULTANTS BV

in association with

KAMPSAX INTERNATIONAL
DANISH HYDRAULIC INSTITUTE
RESOURCE ANALYSIS

DEVELOPMENT DESIGN CONSULTANTS
SURFACE WATER MODELLING CENTRE
AQUA CONSULTANTS AND ASS. LTD.

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ANNEX 01

LOGICAL FRAMEWORK

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1 INTRODUCTION

The logical framework matrix prepared for MES in the project document(s) appears to be somewhat in-consistent and incomplete.

The MES Team has used the logical framework approach to project design and the log frame from the TOR as a vehicle to stimulate the team building exercise and generating the necessary internal debate on project objectives, internal structures, responsibilities and external assumptions.

Furthermore, all technical groups within MES have been asked to design their own framework on the basis of the discussions they had to guide management and their own work planning.

Finally, all the technical specific contributions to the logical framework have been put together in a comprehensive framework for MES.

2 THE PURPOSE AND LIMITATIONS OF THE SUMMARY SHEET

The summary sheet is an "aid to thinking". It is a useful device to test the consistency of project design. It enables the formulator to check the internal logic of the design, e.g. whether a specified group of activities are likely to generate a targetted output, or whether the immediate objective is over-ambitious and therefore unattainable, given the planned outputs. The summary sheet is objective - oriented, it does not describe in detail the schedules or activities which transform inputs into outputs. Specific work plans are needed.

In multi-component projects as MES the association between elements of the various levels in the Narrative Summary column may not come out clearly enough. Separate summary sheets for the different components of the project have been prepared to increase transparency.

3 THE INTERNAL FRAMEWORK: PROJECT MANAGEMENT

The project design gives a clear indication of the management structure for project implementation. In our work planning the MES Team has made it a point to specify the following issues:

- (i) who is the ultimate authority in managing the project and who does the project manager report to?
- (ii) who is responsible for what part of the work plan?
- (iii) how are the activities of the work plan organized between expatriate and national staff (role and responsibilities)?
- (iv) what mechanisms are to be employed in the organization , supervision and coordination of the work plans to the various project units?
- (v) what is the machinery for consultation among expatriate and national staff as well as the various project experts?
- (vi) what is the mechanism for implementation monitoring?
- (vii) to which parties are the project results reported and for what purpose?
- (viii) what are the structure, role and responsibilities of any Coordinating Committee set up for the project?

4 IMPLEMENTABILITY ASSESSED USING A WORKPLAN

Work plans enable the project manager to see if, with the planned resources, it is possible to complete all the project activities and procedure outputs in the time allocated. A work plan will draw attention to any problem with scheduling, for example:

- too many activities at one time and not enough at others,
- coordination of activities with monsoon seasons,
- whether outputs required before other activities can take place, will be available in time.

The work plan also provides a basis on which to monitor the overall progress of the project.

The work plan shows for each significant activity and its output:

- the time frame;
- who will be responsible for the activity;
- who will carry out the activity and other major inputs required;
- any preconditions for activities including the production of another output.

In preparing the MES work plans the Team has specifically been careful to:

- break down the large activities into tasks that fall within one functional sector, within the management responsibility of an individual and directed towards the achievement of a single objective.
- sequence the activities so that they are in logical chronology.
- locate the main activities in the timescale of the project so that resource requirements can be budgeted on a yearly or monthly basis.
- assign indicators of activity completion or achievement and denominate milestones of progress for monitoring.
- note any outputs from other activities necessary to complete each activity or other constraints such as completion of one activity before manpower is available for another.

5 MES LOG FRAME MATRICES

On the following pages to the MES Log Frames will be presented as follows:

- Project Log Frame
- Institutional Development
- Hydraulical and Morphological Studies
- Land Reclamation and Civil Engineering Works
- Water Management and Drainage
- Rural Development
- Agriculture
- Environmental Aspects
- Socio-economic Aspects
- Economic Aspects
- Remote Sensing and GIS

Figure A01.01 indicates the relation between the Project Log Frame and the Log Frame of the different components of the Project.

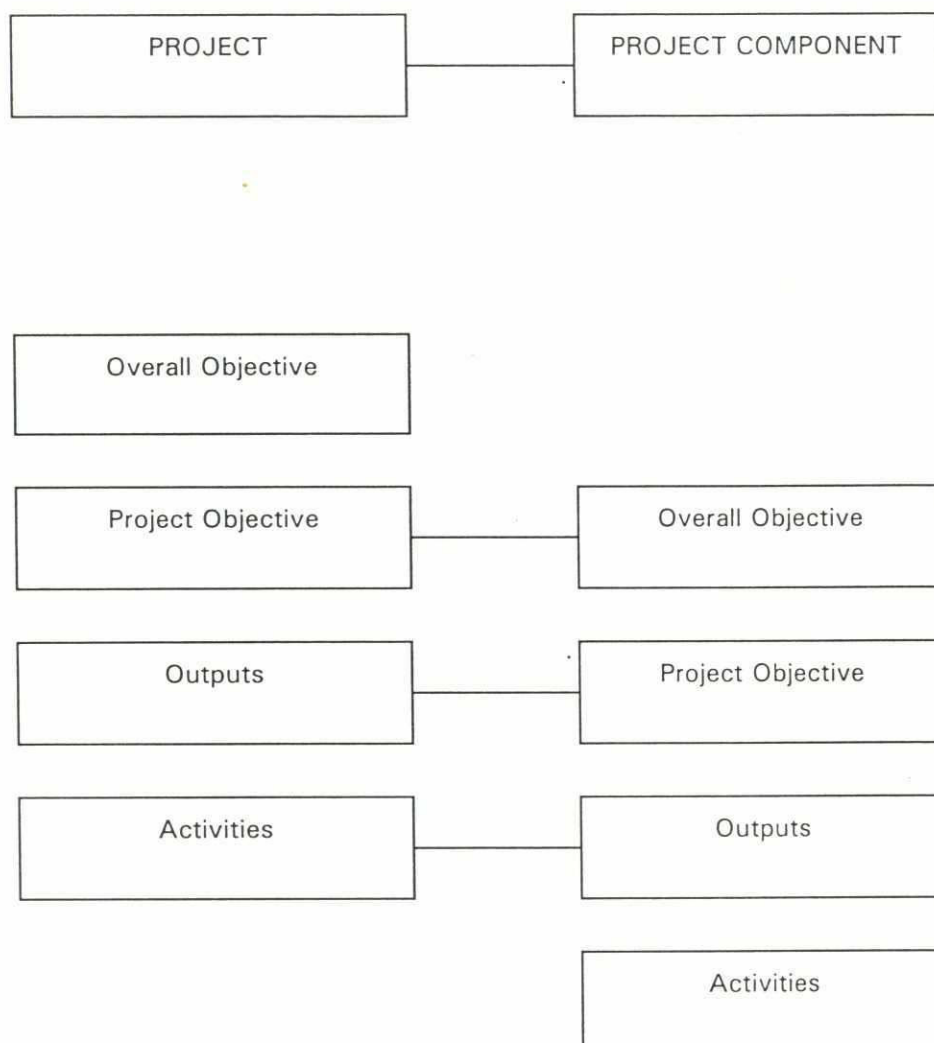


Figure A01.01 Relation between the Project Log Frame and Log Frame different components of the Project.

MEGHNA ESTUARY STUDY
Overall Logical Framework

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Development objectives	Increased physical and social security for the population in the coastal areas and on the islands	Less casualties among the population and less damaged properties during floods and cyclones, compared to similar storms in the past	Flood damage reports and statistics of the MWR and GoB after completion of implementation of priority projects	
Immediate objectives	Enhanced operational knowledge of hydraulic and morphological processes in the Meghna Estuary established and institutional capacity to maintain and update the same knowledge (surveys and studies) strengthened Suitable land reclamation methods identified and increased capacity of BWDB to reclaim new land Priority projects and programmes for flood protection, agricultural and socio-economic development prepared for early implementation	Programme of necessary surveys and studies and continuation of surveys and studies to maintain and update established databases and hydraulic models completed Suitable land reclamation methods described in Land Development Report Project/Programme Report prepared	MES Progress Reports Development Plan Report Project/Programme Report	Continued GOB commitment to coastal area protection and to addressing land distribution issues, including ownership of landless to new Khas land Availability of donor and GoB financing for larger scale reclamation projects such as Sandwip and Hatia cross dam projects
Outputs	1. Capacity and institution building 1.1 Project implementation plan 1.2 Strengthened BWDB Survey and Study Division, Chittagong	Project Implementation Plan completed and periodically updated Approved training programme implemented	Inception Report and Annual Progress Reports MES Progress Report	Attractive career opportunities in Chittagong Surveys and Studies Division Continued availability of BWDB staff seconded to

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
1.3 Recommendations regarding (institutional arrangements for) an effective continuation of surveys and study programme of the Meghna Estuary aimed at sustained and coordinated actions to update and progressively implement a long term master plan 1.4 Enhanced qualitative and quantitative knowledge of the hydraulic and morphological processes that shape the area and impact of human interventions on these processes 2. Master Plan 2.1 Proposals for and implementation of small scale interventions using locally available facilities 2.2 A Master Plan for the physical development of the estuary aimed at a net sustainable gain in land and at enhancing the physical security of the population in the area	Necessary institutional arrangements defined, approved and implemented by BWDB Hydraulic and morphological data base up-dated and completed Hydraulic numerical model operational Morphological assessment completed and interventions analysed in hydraulic models At least one proposals prepared for such an intervention Interim and Master Plan Reports completed	MES report with recommendations on this issue MWR and BWDB board decisions LAED Progress Reports MES Progress Reports Established MES data bases Operational hydraulic models Submittance of proposals Interim Master Plan Report Master Plan Report	the project Stable allocation of funds by MWR in future ADPs to BWDB Directorate of Land and Estuary Development including the Chittagong Survey and Studies Division External funding available for priority projects and programmes

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
1.1.3 Prepare final Project Implementation Plan as an integral part of the Inception Report	First draft of Project Implementation Plan completed	MES Inception Report	
1.2.1 Establish a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES	Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS	MES Progress Reports	
1.2.2 Upgrading existing hydrographic network as required and carry out a comprehensive programme of hydrographic measurements and bathymetric surveys on a regular basis.	Completion of 4 surveys by Anwasha in the period 1996 - 1998 Hydraulic model set-up and calibration completed for regional and local hydraulic impact analysis	MES Progress Reports Operational hydraulic model of the Megna Estuary	
1.2.3 Carry out on-the-job training and more formal training activities to ensure effective technology transfer on survey techniques, equipment O&M, data analysis and mathematic modelling	Implementation of training programme on schedule and SSD staff involved in all necessary surveys and studies	MES Progress Report MESS report on proposed training programme Approval of training programme	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	1.3.1 Based on an assessment of present institutional capabilities prepare proposals for continuation of the survey programme beyond MES and on a permanent basis including required facilities, equipment and staffing and associated costs (investment and annual costs) 1.4.1 Survey existing primary and secondary protection systems to establish extent and causes of flooding and coastal erosion and assess requirements for protection of the population and property and for sustained agriculture-based development 1.4.2 Assess the morphological changes in the area, on a regular basis to identify areas of apparent rapid siltation and erosion, using results from the surveys and relevant information from other sources such as aerial photos, satellite imageries etc.	Assessment concerning institutional capabilities completed Recommendations to adjust institutional arrangements for surveys and studies prepared Inventory of protection systems and their status for project area completed Strategy and priorities for protection works assessed Inventory and preparation of present data completed Field survey data of 4 field surveys processed and analysed Morphological evolution and potential land reclamation and erosion areas assessed	MES Progress Report MES proposal on institutional arrangements to continue surveys and studies beyond the duration of MES Institutional arrangements approved MES Progress Reports MES Progress Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	1.4.3 Based on the existing mathematical models for the area (developed under LRP and at the SWMC) and survey results, prepare an up-dated 1-D model for the study area to simulate the hydraulic and morphological processes and to predict the effects of interventions Master Plan 2.1.1 Develop low cost measures for accelerated accretion, reduced erosion and rapid reclamation using indigenous materials and labour intensive methods 2.1.2 Locate and design works for small scale interventions using (such) local technologies, advice BWDB during construction and monitor the effectiveness of such interventions 2.2.1 Prepare an Interim Master Plan report for the physical development of the estuary, which will present potential measures for land protection and reclamation and associated planning criteria. These will be essential for priority and short term development	Model set-up, calibration and production of hydraulic and wave conditions completed for model Inventory and study of low cost measures for enhancing accretion, reducing erosion and rapid reclamation completed Identification and design of 3 small scale interventions completed BWDB advised during implementation and effectiveness monitored Interim Master Plan Report prepared	MES Progress Reports MES Progress Report MES Progress Report Interim Master Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	3.1.3 Prepare an Interim Development Plan Report with identification of projects and preliminary priorities for primary and secondary protection systems, development of protected areas and non-structural systems including a provisional assessment of institutional requirements, economic and financial viability, social and environmental impacts and recommendations for priority projects and programmes that may proceed to feasibility stage immediately 3.1.4 Prepare a Development Plan Report based on review and discussions with concerned agencies, including; a) updating, modifications and elaborations as a result of continued surveys and studies, notably FAP 7 Cyclone Protection Project and other relevant FAP projects, the Char Development and Settlement Project and priority projects and programmes identified above, b) confirmation or revision of the components of the Interim Development Plan, c) prefeasibility level economic, social and environmental impact analyses, d) preparation of the Development Plan with phasing, identification of first stage projects, financial requirements and institutional recommendations, e) draft project formulations and terms of reference of such first stage projects	Interim Development Plan Report prepared Development Plan Report prepared	Interim Development Plan Report Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	3.2.1 Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment and including an reassessment of the Nijum Dwip feasibility study 3.2.2 Carry out programme preparation for non-structural measures (flood/cyclone forecasting, disaster preparedness and management, flood proofing etc.) to be implemented in advance of, or parallel with, any structural interventions 3.2.3 Prepare a project/programme report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Preparation of priority projects completed Nijum Dwip feasibility study reassessed Preparation of programme preparation for non-structural measures completed Project /Programme Report completed	MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report Project/Programme Report	
Input	TA funds from DGIS and Danida for a) 154 expat man months, b) 490 local man months, c) survey instruments, d) office equipment, e) transport, f) training, g) operation costs FA fund from DGIS and Danida for the implementation of small scale interventions	Budget of USD 5.655 million Budget of USD 500,000	Expenditures made and approved by BWDB and DGIS/Danida. Expenditures made and approved by BWDB and DGIS/Danida.	Deputation to MES study team of GoB staff presently attached to the survey and study component of the LRP project from project start Deputation, not later than half way through the study, of full team of government staff as required for the

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Contribution of GoB for a) payroll cost and office accommodation of seconded GoB staff, b) cost of data to be collected from various GoB agencies, c) any land acquisition costs required	Estimated budget of USD 1.1 million	Expenditures made and approved by BWDB	permanent continuation of surveys and studies beyond the MES Equipment from LRP project available, for the duration of the study, and operational

MEGHNA ESTUARY STUDY Logframe for Morphology and Hydraulics

Outputs	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Check quality of existing survey equipment and determine need of additional equipment 3. Prepare final Project Implementation Plan as an integral part of the Inception Report 4. Establish a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES	Collection of LRP and FAP reports in a project library and consultation of these documents during the study Existing survey equipment checked and procurement of additional survey equipment assessed First draft of Project Implementation Plan completed Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS	MES Inception Report MES Progress Reports Report on assessment of existing and required survey equipment MES (interim) Inception Report MES Inception Report MES Progress Reports	Permanence of BWDB staff seconded from previous LRP project Weather conditions favourable for surveys during the study period Collaboration between CDSP and MES institutionalised and efficient

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
5. Upgrading existing hydrographic network as required and carry out a comprehensive programme of hydrographic measurements and bathymetric surveys on a regular basis.	Completion of 4 surveys by Anwasha in the period 1996 - 1998 Hydraulic model set-up and calibration completed for regional and local hydraulic impact analysis	MES Progress Reports Operational hydraulic model of the Megna Estuary	
6. Carry out on-the-job training and more formal training activities to ensure effective technology transfer on survey techniques, equipment O&M, data analysis and mathematic modelling	Implementation of training programme on schedule and SSD staff involved in all necessary surveys and studies	MES Progress Report MESS report on proposed training programme Approval of training programme	
7. Assist in an assessment of present institutional capabilities and in the preparation of proposals for continuation of the survey programme beyond MES and on a permanent basis including required facilities, equipment and staffing and associated costs (investment and annual costs)	Assessment concerning institutional capabilities completed Recommendations to adjust institutional arrangements for surveys and studies prepared	MES Progress Report MES proposal on institutional arrangements to continue surveys and studies beyond the duration of MES Institutional arrangements approved	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	8. Assess the morphological changes in the area, on a regular basis to identify areas of apparent rapid siltation and erosion, using results from the surveys and relevant information from other sources such as aerial photos, satellite imageries etc. 9. Based on the existing mathematical models for the area (developed under LRP and at the SWMC) and survey results, prepare an up-dated 1-D model for the study area to simulate the hydraulic and morphological processes and to predict the effects of interventions Master Plan 10. Prepare an Interim Master Plan report for the physical development of the estuary, which will present potential measures for land protection and reclamation and associated planning criteria. These will be essential for priority and short term development	Inventory and preparation of present data completed Field survey data of 4 field surveys processed and analysed Morphological evolution and potential land reclamation and erosion areas assessed Model set-up, calibration and production of hydraulic and wave conditions completed for model Interim Master Plan Report prepared	MES Progress Report MES Progress Reports Interim Master Plan Report	

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
11. Prepare a full Master Plan Report for the physical development of the estuary, which will contain the following a) description of the process of accretion and erosion, b) hydrological and hydraulic criteria for planning and designing protection systems, c) assessment of methods and potential for land reclamation, d) provisional long term plan for the estuary, taking as far as possible upstream development into account	Master Plan Report prepared	- Master Plan Report	
Development Plan			
12. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for flood/cyclone protection, reclamation and the development of protected areas	Development strategies formulated Development options defined at prefeasibility level for at least six areas	MES Progress Report Interim Development Plan Report	
13. Prepare an Interim Development Plan Report with identification of projects and preliminary priorities for primary and secondary protection systems, development of protected areas and non-structural systems including a provisional assessment of institutional requirements, economic and financial viability, social and environmental impacts and recommendations for priority projects and programmes that may proceed to feasibility stage immediately	Interim Development Plan Report prepared	Interim Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	14. Prepare a Development Plan Report based on review and discussions with concerned agencies, including; a) updating, modifications and elaborations as a result of continued surveys and studies, notably FAP 7 Cyclone Protection Project and other relevant FAP projects, the Char Development and Settlement Project and priority projects and programmes identified above, b) confirmation or revision of the components of the Interim Development Plan, c) prefeasibility level economic, social and environmental impact analyses 15. Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment and including an reassessment of the Nijum Dwip feasibility study 16. Prepare a project/programme report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Development Plan Report prepared Preparation of priority projects completed Nijum Dwip. feasibility study reassessed Project /Programme Report completed	Development Plan Report MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report	
Activities	Capacity and institution building 1.1 Inventory and preparation of present data such as bathymetric maps, shoreline data and morphological reports on the MES area	Data inventory report completed	Data inventory report	

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
1.2 Review of existing hydraulic data, assessment of states and processes and selection of baseline conditions	Initial hydraulic model up-dated and operational	MES progress reports	
2.1 Need assessment of required survey equipment	Need assessment completed	MES progress reports	
2.2 Check of existing equipment and procurement of additional survey equipment	Check completed and assessment of equipment to be procured prepared	MES progress reports	
2.3 Installation of survey equipment	Survey equipment installed	MES progress reports	
3.1 Detailed planning of work programme including surveys	Work programme prepared	Inception Report	
4.1 Set-up of a reliable database system for hydraulic and morphological data	Initial set-up of database completed	MES progress reports	
4.2 Periodical up-date of the database	Two up-dates, in 1997 and 1998, completed	MES progress reports	
5.1 Implementation of 4 field surveys in 4 season for 2 years	Four field surveys completed	MES progress reports	
5.2 Implementation of land based surveys	Land based survey completed	MES progress reports	
5.3 Implementation of waves and water level surveys	Wave and water level survey completed	MES progress reports	
5.4 Numerical modelling on a regional scale	Regional numerical model prepared	MES progress reports	

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
5.5 Numerical modelling on a local scale	Three local numerical models prepared	MES progress reports	
6.1 Provide on-the-job training and assist in formal training activities on survey techniques, equipment O&M, data analysis and mathematical modelling	On-the-job training implemented and assistance provided for formal training activities	MES progress reports	
7.1 Assist institutional development specialists in an assessment of present institutional capabilities and proposals for improvement	Assistance provided to institutional specialists	MES progress reports	
8.1 Data processing and analysis of hydrological and morphological data of existing data and data collected from 4 field surveys	Data processing and analysis of hydrological and morphological data completed	MES progress reports	
8.2 Assessment of empirical input/output relationships and morphological adaptation process	Assessment of relationships completed	MES progress reports	
8.3 Periodical up-date of empirical input/output relationships	Two up-dates of empirical i/o relationships prepared	MES progress reports	
8.4 Processing and analysis of digitised maps and shorelines of previous years	Digitised bathymetric maps and shoreline maps prepared	MES progress reports	
8.5 Assessment of morphological evolution and potential land reclamation in the MES area	Assessment made	Master Plan Reports	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Master Plan 9.1 Development of regional and local models for the MES area by SWMC, including the production of hydraulic and waves conditions 9.2 Analysis of model results in simulating hydraulic and morphological processes and effects of interventions 10.1 Contribute to the preparation of an Interim Master Plan Report 11.1 Contribute to the preparation of a full Master Plan Report Development Plan 12.1 Presentation of an initial assessment of the overall morphological development and a prediction of regional and local morphological processes 12.2 Contribute to the development and assessment of strategies and options for flood/cyclone protection and reclamation 13.1 Contribute to the preparation of an Interim Development Plan Report 14.1 Contribute to the preparation of a Development Plan Report	Regional and local models developed and operational Analysis completed and described Contribution to Interim Master Plan report prepared Contribution to Master Plan report prepared Presentation prepared Identification and assessment of potential land reclamation prepared Contribution to Interim Development Plan Report prepared Contribution to the Development Plan Report completed	MES progress reports Master Plan Reports Interim Master Plan Report Master Plan Report Morphological Report MES progress reports Interim Development Plan Report Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	15.1 Contribute to the preparation of priority projects and the Nijum Dwip feasibility study	Identification and assessment of morphological development and processes in feasibility studies prepared	Feasibility Studies	
	16.1 Contribute to a Project/Programme Report	Contribution to the Project/Programme Report completed	Project/Programme Report	

MEGHNA ESTUARY STUDY

Logframe for Civil Engineering and Reclamation

Outputs	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report 3. Contribute to the establishment of a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES 4. Survey existing primary and secondary protection systems to establish extent and causes of flooding and coastal erosion and assess requirements for protection of the population and property and for sustained agriculture-based development	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS Inventory of protection systems and their status for project area completed Strategy and priorities for protection works assessed	MES Inception Report MES Progress Reports MES Inception Report MES Progress Reports - MES Progress Reports	Permanence of BWDB staff seconded from previous LRP project Weather conditions favourable for surveys during the study period Collaboration between CDSP and MES institutionalised and efficient

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Master Plan 5. Develop low cost measures for accelerated accretion, reduced erosion and rapid reclamation using indigenous materials and labour intensive methods 6. Locate and design works for small scale interventions using (such) local technologies, advice BWDB during construction and monitor the effectiveness of such interventions 7. Contribute to the preparation of an Interim Master Plan report for the physical development of the estuary, which will present potential measures for land protection and reclamation and associated planning criteria. These will be essential for priority and short term development 8. Contribute to the preparation of a full Master Plan Report for the physical development of the estuary, which will contain among others a) hydrological and hydraulic criteria for planning and designing protection systems, b) assessment of methods and potential for land reclamation, c) provisional long term plan for the estuary, taking as far as possible upstream development into account	Inventory and study of low cost measures for enhancing accretion, reducing erosion and rapid reclamation completed Identification and design of 3 small scale interventions completed BWDB advised during implementation and effectiveness monitored Contribution to the Interim Master Plan Report prepared Contribution to the Master Plan Report prepared	MES Progress Report MES Progress Report Interim Master Plan Report Master Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Development Plan 9. Collect data and carry out surveys to establish the existing state of development on the estuarine islands and new char lands as required for preparation of a comprehensive land and water development plan including associated infrastructure developments 10. Contribute to the development and assessment of alternative strategies and subsequent options (at prefeasibility level) for flood/cyclone protection, reclamation and the development of protected areas considering structural as well as non-structural elements 11. Contribute to the preparation of an Interim Development Plan Report with identification of projects and preliminary priorities for primary and secondary protection systems, development of protected areas and non-structural systems and recommendations for priority projects and programmes that may proceed to feasibility stage immediately	Data collected, investigations and surveys completed by the various project components for an assessment of the present state of development within the project area Development strategies formulated Development options defined at prefeasibility level for at least six areas Contribution to the Interim Development Plan Report prepared	MES Progress Report MES Progress Report Interim Development Plan Report Interim Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	15. Contribute to the preparation of a project/programme report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Project /Programme Report completed	Project/Programme Report	
Activities	Capacity and institution building			
	1.1 Review and assess existing reports, data etc. from LRP and FAP	Review and assessment completed	MES Progress Reports	
	1.2 Study relevant ongoing and previous activities in MES area	Activities in MES area visited	MES Progress Reports	
	2.1 Prepare a Project Implementation Plan for civil engineering and reclamation aspects	Work programme prepared	Inception Report	
	3.1 Integrate collected data in an overall project database.	Database established	MES Progress Reports	
	4.1 Survey existing protection systems by field visits and by the use of satellite imagery	Survey completed and satellite images studied	MES Progress Reports	
	4.2 Assess requirements for protection of population, property and sustained agricultural development	Assessment completed	MES Progress Reports	
	Master Plan			
	5.1 Develop low cost measures enhancing accretion	Low cost measures enhancing accretion studied and adapted	MES Progress Reports	

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
5.2 Develop low cost measures to reduce or check erosion	Low cost measures to reduce or check erosion studied and adapted	MES Progress Reports	
6.1 Locate, design and assist with the implementation of accretion enhancing works	Accretion enhancing works designed and BWDB advised	MES Progress Reports	
6.2 Locate, design and assist with the implementation of erosion protection works	Erosion protection works designed and BWDB advised	MES Progress Reports	
6.3 Intervention to save Sonagazi Polder embankment	Intervention designed, BWDB advised and implementation monitored	MES Progress Reports	
7.1 Contribute to Interim Master Plan with potential measures for land protection, reclamation and planning criteria	Contribution to Interim Master Plan prepared	Interim Master Plan Report	
8.1 Contribute to the preparation of a full Master Plan Report on hydraulic criteria for planning protection systems, methods and potentials for land reclamation and a long term plan.	Contribution to Master Plan Report prepared	Master Plan report	
Development Plan			
9.1 Collect data and carry out surveys to establish the existing state of development on islands	Surveys and data collection completed	MES Progress Reports	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	10.1 Assess various strategies and options for flood/cyclone protection, reclamation and development of protected areas 11.1 Identification of projects and preliminary priorities for protection systems including non-structural systems 11.2 Contribute to a provisional assessment of the economic and financial viability and social and environmental impact 12.1 Contribute to the Development Plan 13.1 Contribute to feasibility studies of priority projects 13.2 Contribute to reassessment of Nijum Dwip and Sandwip cross dam feasibility studies 14.1 Carry out programme preparation for non-structural measures 15.1 Contribute to preparation of draft concept papers and project proformas 15.2 Incorporate recommendations of Review Committee	Strategies assessed Projects and priorities for protection systems identified Provisional assessment completed Contribution to development plan prepared Contribution to feasibility studies completed LRP cross dam feasibility studies reassessed Programme preparation for non-structural measures carried out Preparation of draft concept papers and PPs completed Recommendations incorporated	MES Progress Reports Interim Development Plan Report Interim Development Plan Report Development Plan Report Project\Programme Report Project\Programme Report Project\Programme Report Project\Programme Report Project\Programme Report	

MEGHNA ESTUARY STUDY Logframe for Water Management and Drainage

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Outputs	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report 3. Contribute to the establishment of a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES 4. Survey existing protected areas to establish status and causes of water management and drainage problems	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS Inventory of protection systems and their status for project area completed Strategy and priorities for protection works assessed	MES Inception Report MES Progress Reports MES Inception Report MES Progress Reports MES Progress Reports	Permanence of BWDB staff seconded from previous LRP project Collaboration between CDSP and MES institutionalised and efficient

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Master Plan 5. Contribute to the Interim Master Plan Report 6. Contribute to draft Master Plan Report Development Plan 7. Collect data and carry out surveys to establish the existing state of development on the estuarine islands and new char lands as required for preparation of a comprehensive land and water development plan including associated infrastructure developments for water management and drainage aspects 8. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for the development of protected areas considering structural as well as non-structural elements related to water management and drainage aspects	Contribution completed Contribution completed Data collected, investigations and surveys completed by the water management and drainage component for an assessment of the present state of development within the project area Development strategies formulated Development options for water management and drainage defined at prefeasibility level for at least six areas	Interim Master Plan Report Draft Master Plan Report MES Progress Report MES Progress Report Interim Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	9. Prepare an Interim Development Plan Report with identification of projects and preliminary priorities for development of protected areas and non-structural systems including a provisional assessment of institutional requirements and recommendations for priority projects and programmes that may proceed to feasibility stage immediately 10. Prepare a Development Plan Report based on review and discussions with concerned agencies, including water management and drainage aspects 11. Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment. and including an reassessment of the Nijum Dwip feasibility study for water management and drainage aspects 12. Prepare water management and drainage contributions for a project/programme report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Water management and drainage aspects for Interim Development Plan Report prepared Water management aspects for Development Plan Report prepared Preparation of priority projects completed for water management and drainage aspects Nijum Dwip feasibility study reassessed for water management and drainage Contributions to project /Programme Report completed	Interim Development Plan Report Development Plan Report MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report	

Activities	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Capacity and institution building			
	1.1 Review and assess existing reports, data etc. from LRP and FAP	Review and assessment completed	MES Progress Reports	Data exist and are made available in time to the project
	1.2 Study relevant ongoing and previous water management interventions in MES area	Water management interventions in MES area visited	MES Progress Reports	Accessibility of the selected area regarding weather, transport and security situation
	2.1 Prepare a Project Implementation Plan for water management and drainage aspects	Work programme prepared	Inception Report	Availability of most relevant project and study documents
	3.1 Integrate collected data in an overall project database	Database established	MES Progress Reports	
	4.1 Visit CPP, SRP and CDSP sites	Field visits completed	MES Progress Reports	
	4.2 Study documents of relevant completed and on-going projects and studies	Study completed	MES Progress Reports	
	4.3 Visit potential protected and unprotected locations in MES area	Areas visited	MES Progress Reports	
	Master Plan			
	5.1 Contribute water management and drainage chapters to the Interim Master Plan Report	Contribution prepared	Interim Master Plan Report	

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
6.1 Contribute to draft Master Plan Report	Contribution completed	Draft Master Plan Report	
Development Plan			
7.1. Collect existing data of the study area relevant to water management and drainage	Data available at project level	Project data base	
7.2 Implement field investigations and studies of selected protected and unprotected areas	Field visits of three selected areas in estuary completed	Technical notes with findings of field visits	
8.1 Review of relevant water management and drainage projects and studies	Field visits of at least 3 on-going projects done and studies of approximately 8 previous and on-going projects completed	Technical notes with findings of studied projects	
8.2 Assess alternative strategies for development of protected areas for water management and drainage aspects	Strategies developed for water management and drainage	Technical report on strategies including water management and drainage aspects MES Progress Reports	
9.1 Water management and drainage contribution to the development and assessment of models for protected areas	Contribution for models developed regarding water management and drainage		
10.1 Contribute for water management and drainage to the Development Plan Report	Water management and drainage aspects for development plan completed	Development Plan Report	

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	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	11.1 Contribute for water management and drainage to project preparation of priority projects 12.1 Carry out feasibility study activities on water management and drainage aspects 12.2 Contribute on water management and drainage aspects to Project and Program Preparation Report	Water management and drainage aspects for project preparation of priority projects completed Water management and drainage aspects for feasibility studies completed Water management and drainage aspects for Project and Program Preparation Report completed	Project Preparation Report Feasibility study reports Project and Program Preparation Report	

MEGHNA ESTUARY STUDY Logframe for Economic Aspects

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Outputs	Capacity and institution building 1. Prepare final Project Implementation Plan as an integral part of the Inception Report for the Economic aspects 2. Based on an assessment of present institutional capabilities prepare a training programme for counterpart staff on economic project planning and evaluation methodology Master Plan 3. Prepare an Interim Master Plan report for the physical development of the estuary, aimed at a net sustainable gain in land and at enhancing the physical security of the population 4. Prepare a full Master Plan Report for the physical development of the estuary	First draft economic chapters of Project Implementation Plan completed Workshop teaching material Staff attended Economic chapters for Interim Master Plan Report prepared Economic chapters Master Plan Report prepared	MES Inception Report MES Progress Report MES workshop report Interim Master Plan Report Master Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Development Plan 5. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for flood/cyclone protection, reclamation and the development of protected areas considering structural as well as non-structural elements 6. Prepare a contribution to an Interim Development Plan Report with identification of projects and preliminary priorities for primary and secondary protection systems, development of protected areas and non-structural systems including a provisional assessment of economic and financial viability and recommendations for priority projects and programmes that may proceed to feasibility stage immediately 7. Prepare contribution to Development Plan Report based on review and discussions with concerned agencies, including; a) updating, modifications and elaborations, as a result of continued surveys and studies, b) prefeasibility level economic, social and environmental impact analyses, c) preparation of the Development Plan with phasing, identification of first stage projects and financial requirements	Economic aspects for development strategies formulated Development options defined at prefeasibility level for at least six areas Interim Development Plan Report prepared Economic chapters of Development Plan Report prepared	MES Progress Report Interim Development Plan Report Interim Development Plan Report Development Plan Report	

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	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	8. Contribution to project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment and including an reassessment of the Nijum Dwip feasibility study 9. Prepare a contribution to a project/programme report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Preparation of priority projects with economic study inputs completed Nijum Dwip economic feasibility study reassessed Economic aspects for Project /Programme Report completed	MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report	
Activities	Capacity and institution building 1.1 Prepare a work programme for the economic aspects 1.2 Train counterpart staff in economic project planning and evaluation methodology (micro and macro level) and prepare curriculum and conduct workshop Master Plan 3.1 Ranking of possible projects listed in the Interim Master Plan from an economic point of view	Work programme prepared Workshop materials prepared Workshop conducted Ranking prepared	MES progress reports MES progress reports MES progress reports	Appropriate staff identified and interested Cooperation from FPCO and FAP economists

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
4.1 Ranking of possible projects listed in the Master Plan from an economic point of view	Ranking prepared	MES progress reports	
Development Plan			
5.1 Develop the project assessment models	Models being developed	MES progress reports	
6.1 Develop operative screening models	Models being developed	MES progress reports	
6.2 Study the FCPO and other guidelines and relevant FAP projects	FCPO guidelines and FAP reports available	MES progress reports	
7.1 Contact and discuss with FCPO economists and policy makers and colleagues on other FAP projects experiences - positive and negative	Regular communication established Meetings held	MES progress reports	
7.2 Recommend on an update the FCPO guideline information	Guidelines updated	MES progress reports	
7.3 Prepare the MES project assessment guideline	Guidelines being prepared	MES progress reports	
8.1 Prepare proposals for impact data reporting	Proposals being developed	MES progress reports	
8.2 Develop a format for presenting the multi-criteria analysis	Formats being developed	MES progress reports	
9.1 Assess and rank alternative project proposals in terms of their scoring under the multi-criteria assessment	Assessment and ranking completed	MES progress reports	

MEGHNA ESTUARY STUDY
Logframe for Rural Development and Socio-Economic Aspects

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Outputs	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report 3. Establish a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES Master Plan 4. Prepare an Interim Master Plan Report 5. Prepare a full Master Plan Report for the physical development of the estuary	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS Interim Master Plan Report prepared Master Plan Report prepared	MES Inception Report MES Progress Reports MES Inception Report MES Progress Reports Interim Master Plan Report - Master Plan Report	Permanence of BWDB staff seconded from previous LRP project Collaboration between CDSP and MES institutionalised and efficient

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Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Development Plan 6. Collect data and carry out surveys to establish the existing state of development on the estuarine islands and new char lands as required for preparation of a comprehensive land and water development plan including associated infrastructure developments 7. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for reclamation and the development of protected areas considering structural as well as non-structural elements 8. Prepare an Interim Development Plan Report with identification of projects and preliminary priorities for primary and secondary protection systems, development of protected areas and non-structural systems including a provisional assessment of institutional requirements, economic and financial viability, social impact and recommendations for priority projects and programmes that may proceed to feasibility stage immediately	Data collected, investigations and surveys completed by the various project components for an assessment of the present state of development within the project area Development strategies formulated Development options defined at prefeasibility level for at least six areas Interim Development Plan Report prepared	MES Progress Report MES Progress Report Interim Development Plan Report Interim Development Plan Report	

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	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	9. Prepare a Development Plan Report based on review and discussions with concerned agencies, including: a) updating, modifications and elaborations as a result of continued surveys and studies, the Char Development and Settlement Project and priority projects and programmes identified above, b) confirmation or revision of the components of the Interim Development Plan, c) prefeasibility level economic and social impact analyses, 10. Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment and including an reassessment of the Nijum.Dwip feasibility study 11. Carry out programme preparation for non-structural measures (flood/cyclone forecasting, disaster preparedness and management, flood proofing etc.) to be implemented in advance of, or parallel with, any structural interventions 12. Prepare a project/programme report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Development Plan Report prepared Preparation of priority projects completed Nijum Dwip feasibility study reassessed Preparation of programme preparation for non-structural measures completed Project /Programme Report completed	- Development Plan Report MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report Project/Programme Report	

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Activities	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Capacity and institution building 1.1 Review LRP and recent CDSP and FAP reports on rural development issues 2.1 Prepare a work programme to be included in the Inception Report 3.1 Prepare a database for storage of collected data Master Plan 4.1 Contribute to the preparation of an Interim Master Plan Report 5.1 Contribute to the preparation of a Master Plan Report Development Plan. 6.1 Prepare questionnaires for a socio-economic survey 6.2 Implement preliminary field investigations 6.3 Implement finalised field investigations and survey	Review of existing reports completed Work programme prepared Database established Contribution to Interim Master Plan Report prepared Contribution completed Questionnaires prepared Preliminary field investigations completed Field investigations and surveys completed	MES progress reports Inception Report MES progress reports Interim Master Plan Report Master Plan Report MES progress reports MES progress reports MES progress reports	

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
7.1 Contribute to alternative strategies and options for land reclamation and development from a rural development point of view	Strategies formulated	MES progress reports	
8.1 Contribute to the preparation of an Interim Development Plan Report	Contribution to Interim Development Plan prepared	Interim Development report	
9.1 Contribute to the preparation of a Development Plan report	Contribution completed	Development Plan report	
10.1 Contribute to the preparation of priority projects and feasibility studies	Contribution to priority projects and feasibility studies completed	Feasibility study reports	
11.1 Contribute to the preparation of a programme to carry out non-structural measures	Contribution prepared	MES progress reports	
12.1 Contribute to the preparation of a Project/Programme Report	Contribution completed	Project/Programme Report	

MEGHNA ESTUARY STUDY
Logframe for Agricultural Aspects

Outputs	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report Master Plan	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed	MES Inception Report MES Progress Reports MES Inception Report	Permanence of BWDB staff seconded from previous LRP project Collaboration between CDSP and MES institutionalised and efficient
	3. Prepare an Interim Master Plan Report that includes an assessment of agricultural aspects 4. Prepare a full Master Plan Report for the physical development of the estuary Development Plan	Interim Master Plan Report prepared Master Plan Report prepared	Interim Master Plan Report Master Plan Report	
	5. Collect data and carry out surveys to establish the existing state of agricultural development on the estuarine islands and new char lands and the scope for further agricultural development	Data collected, investigations and surveys completed	MES Progress Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	6. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for flood/cyclone protection, reclamation and the development of protected areas based on an initial environmental impact assessment 7. Prepare an Interim Development Plan Report including a provisional assessment of environmental impacts 8. Prepare a Development Plan Report 9. Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment including a reassessment of the Nijum Dwip feasibility study 10. Prepare a project/programme report containing recommendations of regarding agricultural aspects	Development strategies formulated Development options defined at prefeasibility level for at least six areas Interim Development Plan Report prepared Development Plan Report prepared Preparation of priority projects completed Nijum Dwip feasibility study reassessed Project /Programme Report completed	MES Progress Report Interim Development Plan Report Interim Development Plan Report Development Plan Report MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report	
Activities	Capacity and institution building 1.1 Review LRP findings on agricultural issues and make an inventory of FAP contributions on agricultural aspects	Review completed and inventory made	MES progress reports	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	2.1 Prepare a work programme for agricultural aspects Master Plan 3.1 Contribute to the preparation of an Interim Master Plan Report regarding agricultural aspects 4.1 Contribute to the preparation of a Master Plan Report Development Plan 5.1 Prepare questionnaires for an agricultural survey 5.2 Implement preliminary field investigations 5.3 Implement finalised field investigations and survey 6.1 Screen strategies with different agricultural options for the implementation of flood/cyclone protection, reclamation and development of protected areas 7.1 Contribute to the preparation of an Interim Development Plan Report regarding agricultural aspects	Work programme prepared Contribution on agricultural aspects prepared Contribution prepared Questionnaires prepared Preliminary field investigations completed Field investigations and surveys completed Alternative strategies on agricultural aspects screened Chapters on agricultural aspects completed	Inception Report Interim Master Plan Report Master Plan Report MES progress reports MES progress reports MES progress reports MES progress reports Interim Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	8.1 Contribute to the preparation of a Development Plan Report	Contribution prepared	Development Plan Report	
	9.1 Contribute to the preparation of priority projects and reassessment of feasibility studies regarding agricultural aspects	Agricultural aspects incorporated in priority projects and studies	MES progress reports Feasibility Studies	
	10.1 Contribute to the preparation of a Project Programme Report	Contribution completed	Project Programme Report	

MEGHNA ESTUARY STUDY
Logframe for Environmental Aspects

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Outputs	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report Master Plan 3. Prepare an Interim Master Plan Report that includes an assessment of possible environmental impacts 4. Prepare a full Master Plan Report for the physical development of the estuary, that will contain an initial environmental evaluation, covering the effects on navigation, fisheries and other environmental aspects	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed Interim Master Plan Report prepared Master Plan Report prepared	MES Inception Report MES Progress Reports MES Inception Report Interim Master Plan Report Master Plan Report	Permanence of BWDB staff seconded from previous LRP project institutionalised and efficient

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Development Plan 5. Collect data and carry out surveys to establish the existing state of development on the estuarine islands and new char lands and the impact of these developments on the environment 6. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for flood/cyclone protection, reclamation and the development of protected areas based on an initial environmental impact assessment 7. Prepare an Interim Development Plan Report including a provisional assessment of environmental impacts 8. Prepare a Development Plan Report 9. Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Environmental Impact Assessment including a reassessment of the Nijum Dwip feasibility study	Data collected, investigations and surveys completed by the various project components for an assessment of the present environmental impact of developments within the project area Development strategies formulated Development options defined at prefeasibility level for at least six areas Interim Development Plan Report prepared Development Plan Report prepared Preparation of priority projects completed Nijum Dwip feasibility study reassessed	MES Progress Report MES Progress Report Interim Development Plan Report Interim Development Plan Report Development Plan Report MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	10. Prepare a project/programme report containing recommendations of regarding environmental aspects	Project /Programme Report completed	Project/Programme Report	
Activities	Capacity and institution building			
	1.1 Review LRP findings on environmental issues and make an inventory of FAP contributions on environmental aspects	Review completed and inventory made	MES progress reports	
	2.1 Prepare a work programme for environmental aspects	Work programme prepared	Inception Report	
	Master Plan			
	3.1 Contribute to the preparation of an Interim Master Plan Report regarding environmental aspects	Contribution on environmental aspects prepared	Interim Master Plan Report	
	4.1 Contribute to the preparation of a Master Plan Report	Contribution prepared	Master Plan Report	
	Development Plan			
	5.1 Implementation of field visits in the MES area to assess current environmental impacts resulting from land accretion, reclamation and protection interventions in the past	Identification and data collected on relevant institutes finished	MES progress reports	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	6.1 Screen strategies with different environmental impacts for the implementation of flood/cyclone protection, reclamation and development of protected areas	Alternative strategies on environmental aspects screened	MES progress reports	
	7.1 Contribute to the preparation of an Interim Development Plan Report regarding environmental aspects	Chapters on environmental aspects completed	Interim Development Plan Report	
	8.1 Contribute to the preparation of a Development Plan Report	Contribution prepared	Development Plan Report	
	9.1 Contribute to the preparation of priority projects and reassessment of feasibility studies regarding environmental aspects in line with FAP guidelines	Environmental aspects incorporated in priority projects and studies	MES progress reports Feasibility Studies	
	10.1 Contribute to the preparation of a Project Programme Report	Contribution completed	Project Programme Report	

MEGHNA ESTUARY STUDY Logframe for Institutional Development

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Outputs	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report 3. Establish a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES 4. Carry out on-the-job training and more formal training activities to ensure effective technology transfer on survey techniques, equipment O&M, data analysis and mathematic modelling	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS Implementation of training programme on schedule and SSD staff involved in all necessary surveys and studies	MES Inception Report MES Progress Reports MES Inception Report MES Progress Reports MES Progress Report MES report on proposed training programme Approval of training programme	Permanence of BWDB staff seconded from previous LRP project Collaboration between CDSP and MES institutionalised and efficient

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	5. Based on an assessment of present institutional capabilities prepare proposals for continuation of the survey programme beyond MES and on a permanent basis including required facilities, equipment and staffing and associated costs (investment and annual costs) Master Plan 6. Prepare an Interim Master Plan Report for the physical development of the estuary 7. Prepare a full Master Plan Report for the physical development of the estuary Development Plan 8. Collect data and carry out surveys to establish the existing state of development on the estuarine islands and new char lands as required for preparation of a comprehensive land and water development plan including associated infrastructure developments	Assessment concerning institutional capabilities completed Recommendations to adjust institutional arrangements for surveys and studies prepared Interim Master Plan Report prepared Master Plan Report prepared Data collected, investigations and surveys completed by the various project components for an assessment of the present state of development within the project area	MES Progress Report MES proposal on institutional arrangements to continue surveys and studies beyond the duration of MES Institutional arrangements approved Interim Master Plan Report Master Plan Report MES Progress Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	9. Develop and assess alternative strategies and subsequent options (at prefeasibility level) for flood/cyclone protection, reclamation and the development of protected areas considering structural as well as non-structural elements 10. Prepare an Interim Development Plan Report with identification of projects and preliminary priorities for non-structural systems 11. Prepare a Development Plan Report based on review and discussions with concerned agencies, including; a) updating, modifications and elaborations as a result of continued surveys and studies, notably FAP 7 Cyclone Protection Project and other relevant FAP projects, the Char Development and Settlement Project and priority projects and programmes identified above, b) confirmation or revision of the components of the Interim Development Plan, c) institutional recommendations, d) draft project formulations and terms of reference of such first stage projects	Development strategies formulated Development options defined at prefeasibility level for at least six areas Interim Development Plan Report prepared Development Plan Report prepared	MES Progress Report Interim Development Plan Report Interim Development Plan Report Development Plan Report	

	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	12. Carry out project preparation of priority projects as agreed with FAP Review Committee and Technical Committee and in accordance with the FAP guidelines for Project Assessment and including an reassessment of the Nijum Dwip feasibility study 13. Carry out programme preparation for non-structural measures (flood/cyclone forecasting, disaster preparedness and management, flood proofing etc.) to be implemented in advance of, or parallel with, any structural interventions 14. Prepare a Project/Programme Report containing the recommendations of the activities and including draft Concept Papers and Project Proforma's (PP's)	Preparation of priority projects completed Nijum Dwip feasibility study reassessed Preparation of programme preparation for non-structural measures completed Project /Programme Report completed	MES Progress Reports Project/Programme Report Nijum Dwip Feasibility Study report Project/Programme Report Project/Programme Report	
Activities	Capacity and institution building 1.1 Study LRP activities and findings on strengthening the institutional capacity within BWDB 2.1 Preparation of a work programme on Institutional Development 3.1 Contribute to the project data base on institutional aspects	Review on institutional aspects under LRP completed Work programme completed Collected data processed and stored in project data base	MES progress reports Inception report MES progress reports	Permanance of trained BWDB staff

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
4.1 Implement a training need assessment of institutions involved in MES and in particular SSD	Training need assessment prepared	MES progress reports	
5.1 Review past, current and future tasks of SSD	Review of SSD completed	MES progress reports	
5.2 Assess the existing institutional capabilities regarding hydraulic and morphological surveys, data processing and analysis	Assessment done	MES progress reports	
5.3 Assess the present institutional set-up in relation to MES activities	Present institutional set-up worked out	MES progress reports	
5.4 Recommend on alternative institutional arrangements to sustain surveys and studies	Recommendations formulated	Report on recommendations to adjust institutional arrangements for surveys and studies	
Master Plan			
6.1 Contribute to the preparation of an Interim Master Plan Report regarding institutional aspects of macro planning	Contribution on institutional aspects prepared	Interim Master Plan Report	
7.1 Contribute to the preparation of a Master Plan Report	Contribution prepared	Master Plan Report	

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
Development Plan 8.1 Identify and collect data on institutions involved in the implementation of relevant infrastructural interventions in the estuary 9.1 Develop strategies for alternative institutional arrangements for the implementation of flood/cyclone protection, reclamation and development of protected areas in close collaboration with rural development and water management specialists 10.1 Contribute to the preparation of an Interim Development Plan Report regarding institutional aspects of micro planning 11.1 Contribute to the preparation of a Development Plan Report 12.1 Contribute to the preparation of priority projects and reassessment of feasibility studies regarding institutional aspects 13.1 Contribute to the programme preparation for non-structural measures about institutional arrangements 14.1 Contribute to the preparation of a Project Programme Report	Identification and data collected on relevant institutes finished Alternative strategies for institutional arrangements developed Chapters on institutional aspects completed Contribution prepared Institutional aspects incorporated in priority projects and studies Contribution made Contribution completed	MES progress reports MES progress reports Interim Development Plan Report Development Plan Report MES progress reports Feasibility Studies MES progress reports Project Programme Report	

MEGHNA ESTUARY STUDY
Logframe for Remote Sensing and GIS

Outputs	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	Capacity and institution building 1. Collect and review LRP reports and data, establish liaison with relevant FAP activities and other activities in the study area 2. Prepare final Project Implementation Plan as an integral part of the Inception Report 3. Establish a proper database and management system for easy access to all existing field data of the LRP project as well as data being collected under MES 4. Survey existing primary and secondary protection systems to establish extent and causes of flooding and coastal erosion and assess requirements for protection of the population and property and for sustained agriculture-based development	Collection of LRP and FAP reports in a project library and consultation of these documents during the study First draft of Project Implementation Plan completed Inventory, review and preparation of existing data and data collected by project components completed and stored, where appropriate, in computerised data bases readily available for modelling, GIS or MIS Inventory of protection systems and their status for project area completed Strategy and priorities for protection works assessed	MES Inception Report MES Progress Reports MES Inception Report MES Progress Reports MES Progress Reports	Permanence of BWDB staff seconded from previous LRP project Collaboration between CDSP and MES institutionalised and efficient

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
5. Assess the morphological changes in the area, on a regular basis to identify areas of apparent rapid siltation and erosion, using results from the surveys and relevant information from other sources such as aerial photos, satellite imageries etc. Master Plan 6. Prepare an Interim Master Plan Report 7. Prepare a full Master Plan Report for the physical development of the estuary Development Plan 8. Collect data and carry out surveys to establish the existing state of development on the estuarine islands and new char lands as required for preparation of a comprehensive land and water development plan including associated infrastructure developments 9. Prepare an Interim Development Plan Report 10. Prepare a Development Plan Report	Inventory and preparation of present data completed Field survey data of 4 field surveys processed and analysed Morphological evolution and potential land reclamation and erosion areas assessed Interim Master Plan Report prepared Master Plan Report prepared Data collected, investigations and surveys completed by the various project components for an assessment of the present state of development within the project area Interim Development Plan Report prepared Development Plan Report prepared	MES Progress Report Interim Master Plan Report Master Plan Report MES Progress Report Interim Development Plan Report Development Plan Report	

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	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	11. Prepare a Project/Programme Report	Project /Programme Report completed	Project/Programme Report	
Activities	Capacity and institution building			
	1.1 Review LRP activities regarding remote sensing, aerial photography and mapping	Review completed	Inception Report	
	1.2 Assessment of need for support on satellite imagery, aerial photographs, topographical and bathymetric maps and GIS data bases	Assessment completed	MES progress reports	
	1.3 Preparation of an inventory on available satellite images, aerial photographs, maps and relevant digitised and GIS databases in Bangladesh	Inventory prepared and up-dated	Inception Report	
	2.1 Preparation of a remote sensing and GIS work plan	Work plan prepared	Inception Report	
	3. 1 Coordinate and assist in the establishment of a digitised data bases for all disciplines within MES project for existing LRP data as well as data collected under MES	Data bases established and maintained	MES progress reports	
	3.2 Collection and storage of reports, satellite images, aerial photographs and maps collected from various institutes	Initial collection completed	MES progress reports MES library	

Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
4.1 Assist MES studies with the preparation of digitised base maps and thematic maps	Maps prepared	MES progress reports	
5.1 Digitisation of existing maps and images	Digitisation completed	MES progress reports	
5.2 Preparation of coastline GIS maps, in particular for the period 1973 - 1996	Coastline maps prepared	MES progress reports	
Master Plan			
6.1 Assist in the preparation of base maps and thematic maps for the Interim Master Plan Report	Supporting maps prepared	Interim Master Plan Report	
7.1 Assist in up-dating existing maps and preparation of new maps for the Master Plan Report	Supporting maps prepared and up-dated	Master Plan Report	
Development Plan			
8.1 Coordinate and assist in processing and storage of collected data in appropriate data bases of MES	MES data processed and stored	MES progress reports	
9.1 Assist in the preparation of base maps and thematic maps for the Interim Development Plan Report	Maps prepared	Interim Development Plan Report	
10.1 Assist in up-dating existing maps and preparation of new maps for the Development Plan Report	Maps updated and prepared	Development Plan report	

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	Intervention Logic	Verifiable Indicators	Sources of verification	Assumptions
	11.1 Assist in the preparation of supporting maps for the Project/Programme Report	Maps prepared	Project/Programme Report	

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ANNEX 02

GUIDELINES FOR EXECUTION OF ESTUARINE SURVEYS

12

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1 INTRODUCTION

The present Guidelines cover a part of the field programme of the Meghna Estuary Study, namely the vessel surveys by Anwasha. The Guidelines are intended for internal use. Their objective is to ensure a transparent and well documented data production. Well-defined routines are required for maintaining the inter-project consistency, and as a basis for quality management. Also, it is noted that the work takes place in a dynamic collaboration between staff members from different organisations, so it is particularly important to maintain an effective exchange of information within the project.

Another aim of the Guidelines is to provide a reference for the training activities to be carried out in connection with the work.

Suggestions on updates are encouraged and should be given to the Team Leader.

2 GENERAL INFORMATION ABOUT THE MEGHNA ESTUARY

2.1 Tide

The BIWTA Tide Tables cover the area well. The tidal range increases in the direction from SW (around 4 m range at S Bhola) towards NE (around 7 m range at Sandwip).

There is a pronounced seasonal sea level variation. The sea level is highest during the SW monsoon and lowest in the winter. The range of the seasonal variation is about 0.2 m in the southern part of the survey area and several m in the northern part of the area.

2.2 Charts

The area is characterised by rapid morphological changes. These changes take place mainly in the monsoon season. Therefore, in general, the depths (and even the coast contours) indicated on nautical charts become unreliable one monsoon season after the survey took place. The hydrographic surveys in the area concentrate on the main navigation channels, while other areas are surveyed less frequently.

Recent information about coast contours is found on maps based on LANDSAT images produced by MES in the course of the project. Downloading of satellite scanning data for the purpose was done in February 1996.

2.3 Weather

The worst weather (frequent and unpredictable storms) is expected in the period from mid April to end of June, at the onset of the SW monsoon. According to LRP experience, operation should be avoided in this period, and particularly in June. Strong winds and high waves occur during the SW monsoon, for which reason operation should be confined. However, this is also the time of the peak flow in the Meghna River (in July-August-September). Therefore, a confined programme of flow measurements should be aimed at.

The best operation conditions are expected in BIWTA's period of '*fair weather towage*', which is from November 15 to February 15. In this period, the sea is generally calm. In January and February, fog in the morning hours is expected to be the main nuisance.

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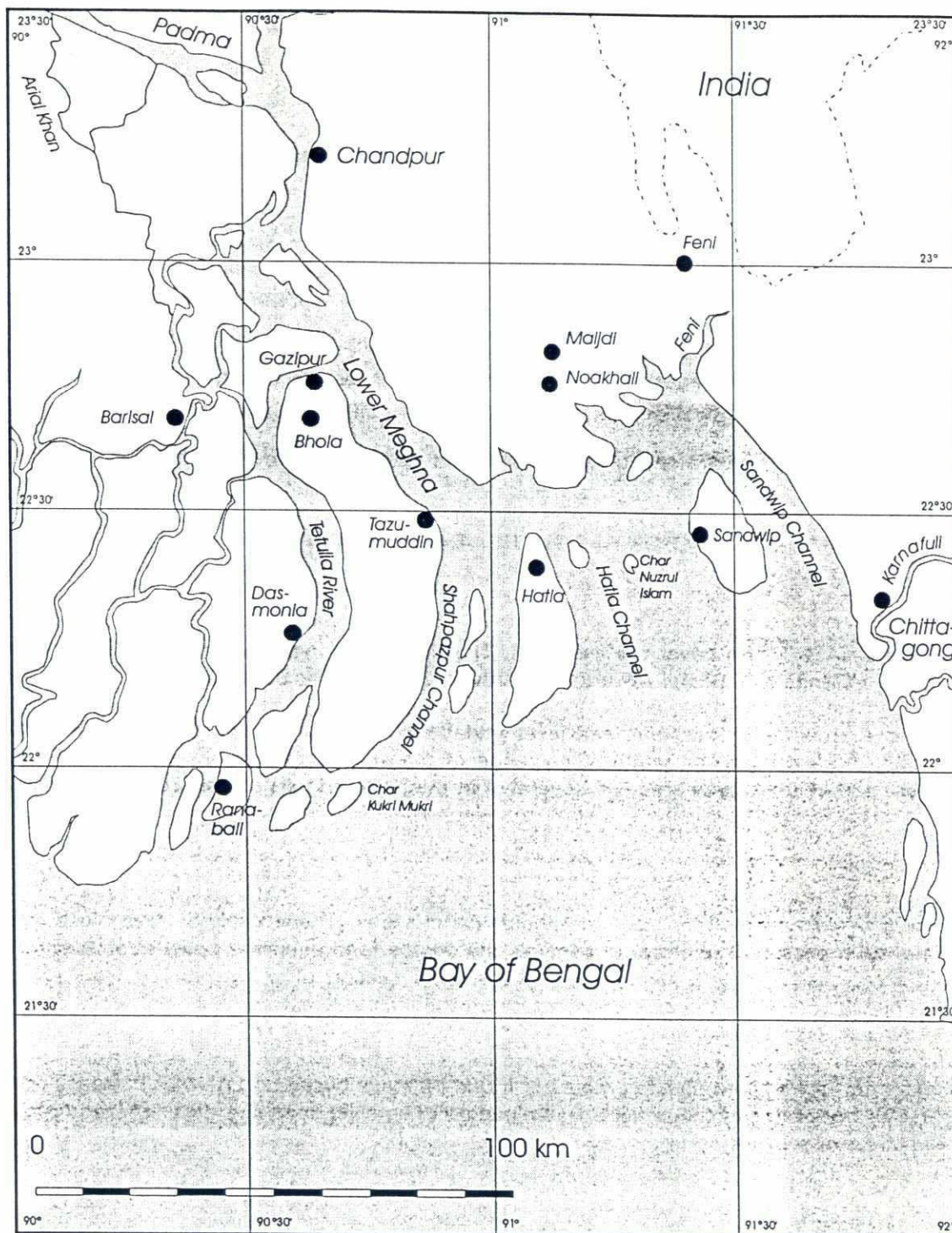


Figure A02-2.1: Location map

Month	Monsoon	Cyclone risk	River flow	Operating conditions
J		low		good
F		low		good
M		low		medium
A		medium		medium
M		high		adverse
J	SW	high		bad
J	SW	medium	high	adverse
A	SW	medium	highest	adverse
S	SW	medium	high	adverse
O	SW	high		medium
N		high		medium
D		medium		good

Note: Information is indicative

Table A02-2.1: General operating conditions in the Meghna Estuary

2.4 Cyclones and storms

Cyclones can occur all year. They are more frequent in May, October, and November, and less frequent in January through March. A 'cyclone' is defined by a wind speed of at least 62 km/hour, while a 'severe cyclone' has a wind speed of at least 89 km/hour. Extreme cyclones can have wind speeds of 200 km/hour (or even more), and a storm surge of 6-10 m. On an average, 0.7 cyclones occur per year. Among these, 0.25 are severe.

These figures do not include ordinary depressions, which are much more frequent. For example, around 6 ordinary monsoon depressions occur per year in the period from June through September. Such depressions give strong winds and extreme rainfalls.

Thunderstorms are particularly frequent in March, April, May and October (30-40 occurrences per year in this period). They can give strong winds. Nor'westers, locally called *Kal Baisakhi*, occur from March to May, with wind speeds of 75-150 km/hour. Unlike cyclones and other storms related to moving depressions, they nor'westers come suddenly and are difficult to predict.

2.5 Other navigational hazards

The estuary is a tricky area, also apart from the weather implications. During the LRP operation of Anwasha, the following hazards were encountered:

- *Grounding*, during ebb tide, or caused by tidal bores or storm surge, with consequential structural damage
- Damage to propeller shafts, gear and bearings due to entangling with *fishing nets*

According to LRP reports, the vessel had to go to the dockyard 8 times in 5 years (1986-91) for repair of damage caused by these two reasons. In 1990, an appraisal mission made the following observations:

- Local currents are sometimes dangerous
- Unpredictable and dangerous tidal bores occur in the area. On one occasion, a tidal bore caused the loss of one vessel

3 ANWESHA

The estuarine surveys will be carried out by 'Anwasha', which was the main survey vessel of the LRP, and which is stationed in Chittagong. Today, the vessel is operated by BWDB/SSD.

Built (Akerboom, Leiden, Holland):	1980
Length:	32 m
Beam:	7 m
Draft (summer mark):	1.9 m
Speed	(maximum): 10 knots
	(steaming): 8 knots
Tank capacity,	freshwater: 22,000 l
	fuel: 36,000 l
Power supply (2x85 kW + 20 kW):	440/220 V AC
2 tender boats,	length: 7 m
	draft: 1 m
	speed: 20 knots

Source: 'Holland Shipbuilding', May 1980, pp. 36 - 37

Table A02-3.1: Key specifications of 'Anwasha'

From May 1980 to 1991, 'Anwasha' was in operation for some 50 percent of the time, the remaining time being spent on bunkering, scheduled and unscheduled repair and maintenance, weather downtime, holidays, and unrelated activities. The vessel was docked once per year for routine inspection and maintenance, and also, on several occasions, for major repairs due to accidental damage to the hull or to the propulsion system. Typical reasons for such damage was hitting the seabed, and getting the propeller entangled with fishing nets (to which the vessel is reportedly particularly sensitive).

4 OUTLINE OF THE FIELD PROGRAMME

4.1 General

The MES estuarine surveys comprise the following components:

- Establishment of a geodetic grid for reference stations
- Installation and operation of water level gauges and wave recorders
- Routine measurements from Anwasha: Bathymetric surveys, flow transects, sediment sampling, and S/T profiles
- Data processing and reporting

The present Guidelines describe the routine measurements from Anwasha.

4.2 Routine measurements from Anwasha

Following the initial mobilisation, this work is composed of five campaigns:

- 1 pilot survey (selection of runlines, flow, sediment sampling, and S/T profiles)
- 2 monsoon season campaigns (flow, sediment sampling, and S/T profiles)
- 2 dry season campaigns (bathymetry, flow, sediment sampling, and S/T profiles)

Year	1996	1997	1998
Dry season survey	pilot □	2 □	4 □
SW monsoon survey	1 □	3 □	

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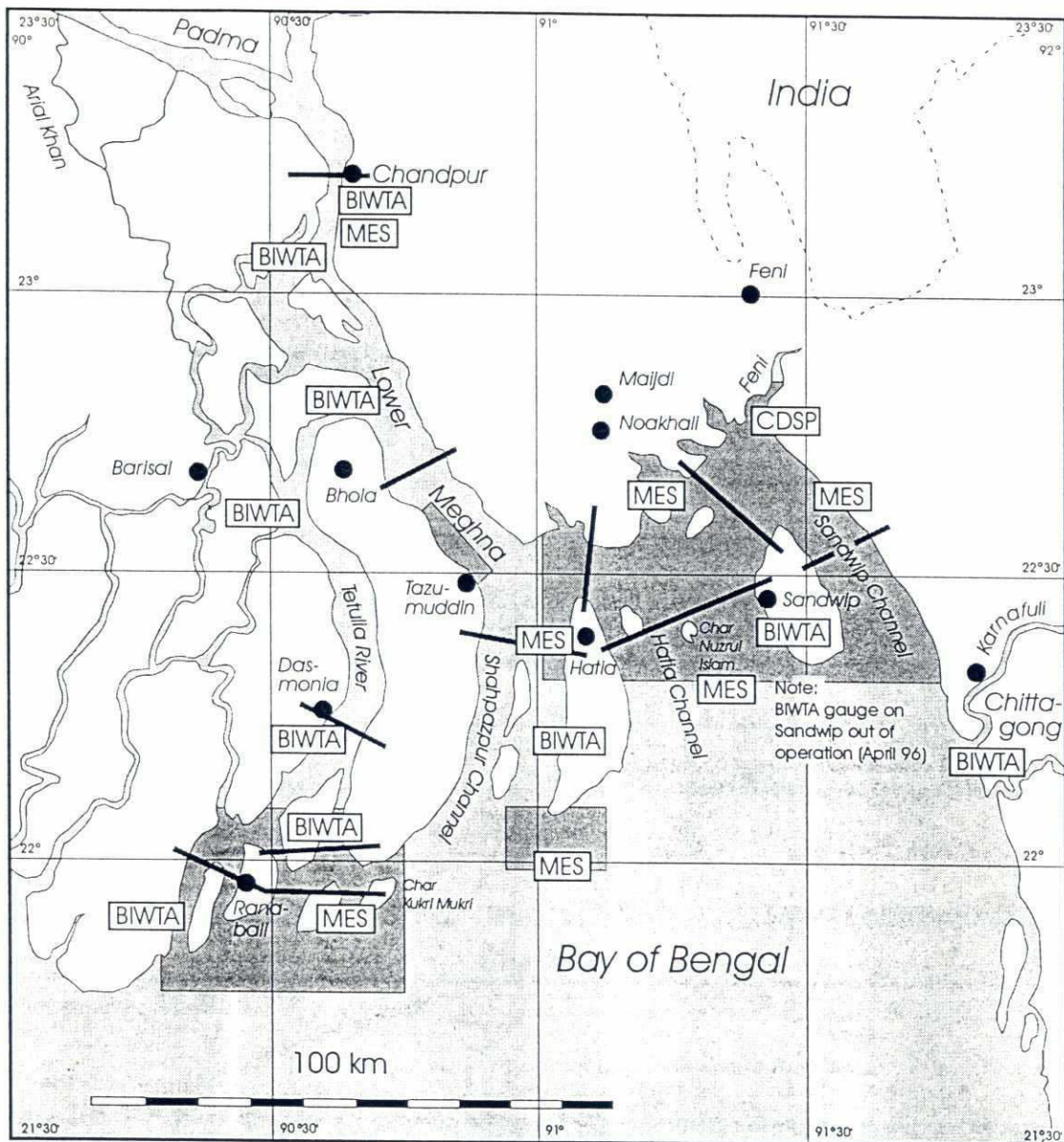
Figure A02-4.1 : Survey campaigns

The tentative programmes for different categories of campaigns are indicated in Table A02-4.1.

Activity	Pilot survey	Monsoon survey	Dry season survey
Bathymetry			+
Cross-section geometry and flow transects	+	+	+
Salinity/temperature profiles	+	+	+
Suspended sediment samples	+	+	+
Sea bed samples	+	+	+
Deployment and servicing of instruments	+	+	+
Transfer and stand-by	+	+	+

Table A02-4.1: Outline of survey activities

The bathymetry and flow transects as well as the priority study and bathymetry areas are indicated on Figure A02-4.2.



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-  MES bathymetry and flow gauging transect
-  MES priority study area and bathymetry area
-  BIWTA water level gauge - location shown in BIWTA Tide Tables
-  MES wave and water level gauge, to be established
-  CDSP wave and water level gauge, to be established

Figure A02-4.2 Location of survey areas

4.3 Instrumentation and data flow

The survey instrumentation and facilities are listed in Enclosure C.

In brief, the self-recording data collection system consists of three integrated components:

- A positioning and navigation system (by DGPS)
- A depth-recording system (by echo sounder)
- A flow profile recording system (by ADCP)

The data flow from the two former components is managed by the HYDRO system, while the data flow from all three components are managed by the ACQ system via the HYDRO system and a separate ADCP system.

An outline of the on-line data flow is given in Figure A02-4.3

The separate systems for sediment sampling and S/T profiling are not self-recording.

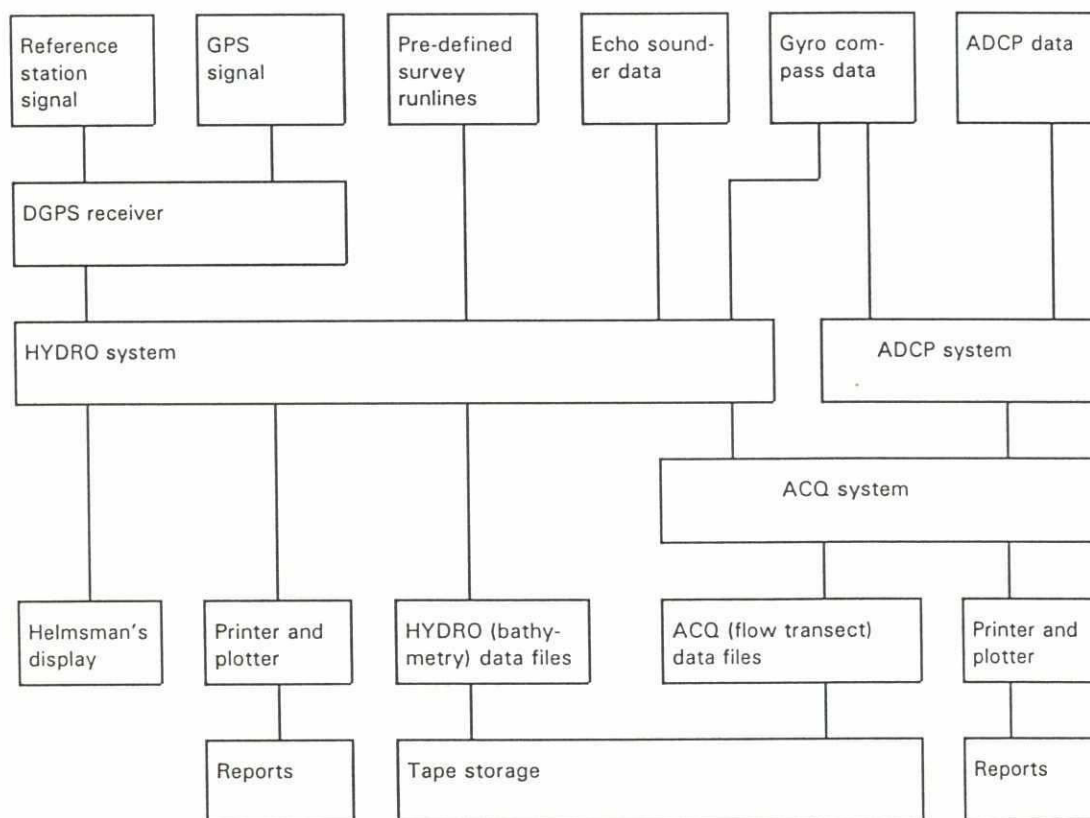


Figure A02-4.3: On-line data flow



5 ORGANISATION

5.1 The Master of Anwasha

The Master of Anwasha is responsible for all matters relating to navigation, navigational safety, and operation of the vessel.

The Master is responsible for paying due consideration to navigational hazards, such as grounding, or precautions in case of anticipated bad weather. In case of conflicts of interest between navigational considerations and the survey work, the former take priority. The decision on whether, when and where to relocate the vessel, including discontinuation of survey activities if deemed appropriate, remains with the Master.

5.2 The Party Chief

At any time during the field work, there will be a Party Chief onboard. The Party Chief is responsible to the Team Leader for the execution of the field measurements and has the following duties:

- Any required decisions on execution of the survey work
- Liaison with the Master of the vessel about its day-to-day operation
- Liaison with the Project Office
- Reporting
- Data back-up
- Registration of staff arrivals and departures
- Maintenance of inventory of instruments, software and manuals onboard
- Photo documentation

Also, the Party Chief is responsible for updating the present Guidelines upon completion of the first campaign, and in general as required.

5.3 Surveyors

Several routine activities may be assigned to specific surveyors, so that there is no doubt about who is doing what. This may be the case with the daily wind and weather log (Section 6.6) and the coastline classification (Section 7.3).

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6 DAILY ROUTINE

6.1 Summary

The daily routine comprises a combination of some of the following activities:

- Check of weather forecast (3 times every day)
- Relocation from place to place (depending on programme)
- Installation or withdrawal of reference stations (depending on programme)
- Measurements (depending on programme)
- Maintenance, repairs, field tests (depending on programme)
- Photo documentation (depending on programme)
- Bunkering of fuel/water (as required)
- Data back-up (every evening)
- Daily reporting (every evening)

6.2 Weather forecast

An official weather forecast is transmitted by the national (medium wave) radio daily as follows:

at 7:00, 13:00 and 18:00 hours (in Bangla)

at 8:00, 13:00 and 19:00 hours (in English)

6.3 Daily reporting

This reporting comprises routine reporting of the general progress. The reporting comprises

- Daily journal
- Position and weather log
- Daily SAFECOM update

6.4 Daily journal

General

The daily journal must be prepared *every evening during the entire campaign*, also if there seems to be 'no news', for example during weather stand-by.

It should be short, and should contain the following information:

1. Date, time, initials 1)
 2. Evening position and course (if sailing) 1)
 3. Place: Morning, waypoints, evening 1)
 4. Activities of the day 1)
 5. Staff arrivals or departures 2)
 6. Anything else 2)
 7. Engine hours readings 3)
- 1): Every evening
 2): As appropriate
 3): Engine hours to be given at least (1) at the start of each campaign, (2) at discontinuations of the campaign, (3) when bunkering, (4) at the end of each campaign

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'Position' is the 'exact' easting and northing (or longitude and latitude). 'Place' is the location described in words, e.g. 'Hatia Channel'.

Form A-1 can be used for the purpose. Form A-2 is available for additional information, if required.

6.5 Tidal bores and storm surge

Some uncertainty exists about how frequent these phenomena occur, and additional information is desired. Storm surge and tidal bores can look alike, only they are generated by different mechanisms. They can be confused with a surf zone of ordinary waves breaking over a sand bar (but such surf does not propagate).

Whenever observing a tidal bore or storm surge, the following information should be entered in the daily journal:

- Time and position
- Wave direction towards
- Estimated height and propagation speed

6.6 Wind and wave log

This log serves several purposes, one being to compile systematic information about the wave conditions in the area. Waves are measured at a very few locations only, and even on these locations, only the height and the period are registered, not the direction. By regular observations of wind and waves, results of the wave recordings can be generalised.

Wind speed and direction is registered by a Venturi meter on the roof of Anwasha, which is mounted at a fixed level.

Wind and wave observations are made *6 times per day during the entire campaign*, also when the weather is calm (as this may not be the case in the entire estuary). These observations can be the responsibility of an assigned junior surveyor. Use Form A-3 for the purpose.

6.7 Daily SAFECOM update

This update must be sent to the MES office in Dhaka *every evening during the entire campaign*. It must be sent also if there seems to be 'no news', for example during weather stand-by.

It should be short, and should be sent as a separate document. It should contain the following information:

- a. Header, with date, time and sequential number
- b.
 1. Position, place and course
 2. Today's activities
 3. Near-future programme
 4. Staff arrivals or departures
 5. Actions (as relevant)
 6. Anything else (if required)
- c. Signature

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Daily SAFECOM update, example

From: Anwasha
To: MES, Dhaka
Time: March 22, 1996, 19:30 hours
Subject: Daily update no. 17

1. Position: 91 deg 35 min E 22 deg 30 min N (Sandwip Channel, cruising SSE towards CTG)
2. Today: Flow transect no. 7 (Sandwip Channel). Withdrawal of S4. Withdrawal of reference station. Suspended sediment sampling and bed sampling.
3. Tomorrow: Bunkering at CTG, transfer to area S of Bhola, ETD 10:00 hours
4. Staff arr./dept.: None
5. Pls. ask SSD to pick up data tapes and sediment samples tomorrow morning at Anwasha Berth, CTG

Bst rgds, Md. Kamal, JRS

6.8 Photo documentation

Occasional photos should be taken for the following purposes:

- General documentation of the work
- Character of the coastline: Eroding or accreting reaches, tidal flats and sand bars, etc., particularly in the priority areas
- Cross-reference for satellite photo interpretation
- Appearance of coastal structures: Regulators, embankments, WL gauges, etc.

Try to get pictures covering all survey activities. Try to make a person appear on the photo. Remove unrelated mess from the photo angle, such as cables, rope, plastic bags, newspapers, etc. Avoid dark shadows or sharp light contrasts within the key part of the picture.

The most interesting photos should be listed in a photo log (Form F). When self-explanatory, just write the date, number sequence, and 'field work'. For photos of coastlines, coastal structures, etc., please indicate the place (or even the exact position), and the photo angle. Wherever the sea level is of interest to the interpretation, e.g. for tidal flats and sand bars, indicate also date and time (some cameras can do this automatically).

7 BATHYMETRY AND COASTLINES

7.1 Objectives

The bathymetric surveys are not intended for producing navigation charts. They are made for the following reasons:

- To supply data to be used directly for the morphological studies
- To supply data and information to support interpretation of satellite photos and old data, also mainly for the sake of the morphological analysis
- To provide part of the design basis for land development schemes
- To provide input data to the hydrodynamic models

This implies that

- In general, shallow areas are of a particular interest
- Also, the coastline is of a particular interest
- The measurements should allow for a direct comparison from year to year

In turn, this means that much of the work will take place in areas where navigation is limited by the draft, and that the day-to-day planning must be made with due consideration to the tide.

Note: The MES echo sounder recordings can possibly supply some indicative information about the degree of consolidation of the sea bed by either registering the strength of the reflected signal, and/or by comparing the two signals from the dual frequency echo sounder.

7.2 Horizontal and vertical control

Positioning of Anwesha and the tender boats will be done by RTK-DGPS relative to a network of reference benchmarks, which was established by MES for the purpose in March/April 1996.

Horizontal coordinates	: BTM (Bangladesh Transverse Mercator) grid
Vertical levels	: PWD (Public Works Department) datum

Table A02-7.1: Coordinate system for positioning during estuarine surveys

The coordinates are produced as follows:

- a. The coordinates of the reference benchmark are regarded as 'correct'
- b. The DGPS reference station measures the coordinates of the reference benchmark. These coordinates are compared with the 'correct' ones, and the pseudo range corrections for each satellite are calculated and transmitted by UHF radio to Anwesha

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- c. The DGPS receiver onboard Anwasha measures the coordinates of its position. The pseudo range corrections received from the reference station are applied to obtain the 'correct' coordinates
 - d. Coordinates are converted from WGS84 (applied by the GPS satellites) to BTM grid and PWD datum (applied by MES)

The position is given for the GPS antenna. During the measurements, the coordinate differences (or the off-set) between the antenna and each instrument must be taken into account in order to obtain the correct position of the instrument. This is particularly important for the bathymetric surveys and for the ADCP measurements.

While the antenna and the instruments are fixed relative to each other, the coordinate off-set depends on the orientation of the vessel, which changes all the time. A gyro compass is used for monitoring the orientation of the vessel, so that the correct eastings and northings can be obtained.

These corrections are made by the HYDRO on-line data processing system.

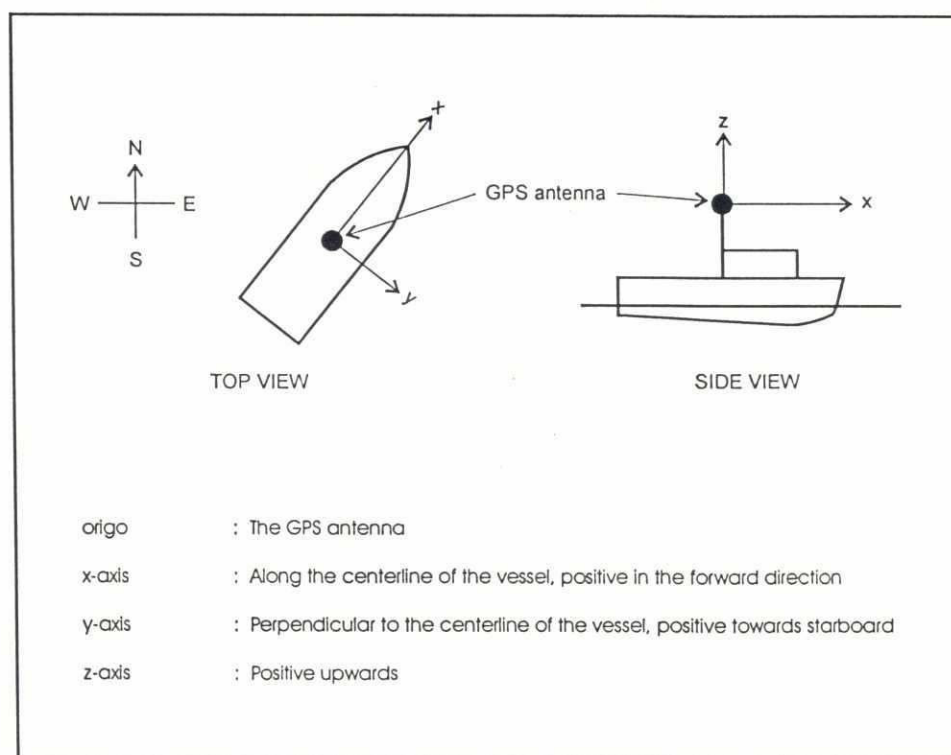


Figure A02-7.1 : The ship's coordinate system

Also, the sea level can vary relative to the GPS antenna, depending on the draft of the vessel. When using RTK-DGPS, this is not so important for the bathymetric surveys, but it can have some significance during the flow measurements.

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If, for some reason, the GPS antenna be moved, even by a few cm, the data processing routines must be modified accordingly.

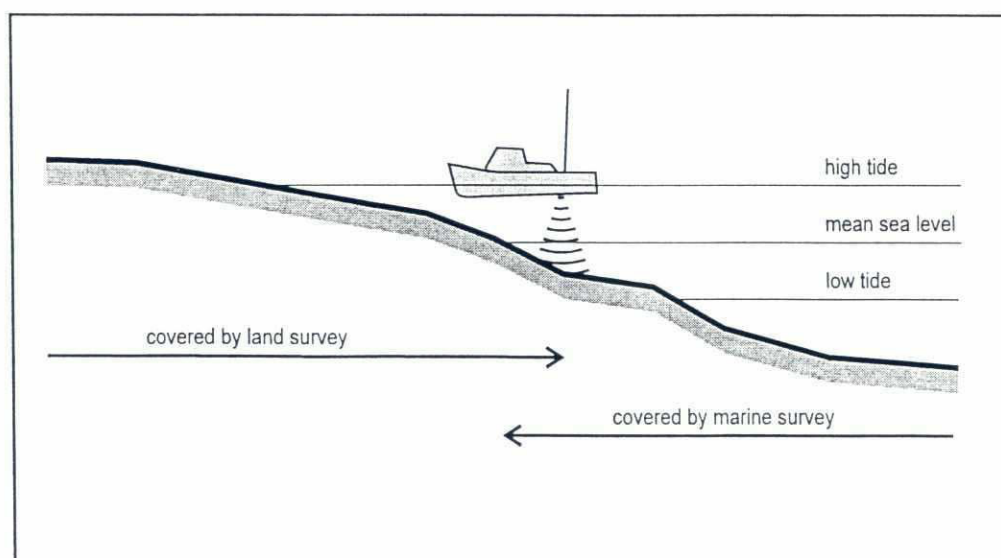
	x	y	z
GPS antenna	0.00 m	0.00 m	0.00 m
Echo sounder transducer			
ADCP transducer			
Sea level	-	-	

Table A02-7.2 : Location of instruments relative to the ship's coordinate system

7.3 Coastlines

The coastline contours will be established by LANDSAT satellite mapping. One aspect in this regard is that the LANDSAT image is taken 'once and for all', at a certain sea level (which cannot be determined beforehand). Therefore, it can be required to adjust its location in connection with the post-processing. Also, a number of old satellite images exist, which require coastline adjustment for comparison in connection with the morphological studies.

For these purposes, the coastline *gradient* (rather than its delineation) must be registered during the surveys, which should, for this reason, cover the area near the coastline at high tide. (Additional work can then be made by geodetic surveying at low tide, where required, see Figure A02-7.2).



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Figure A02-7.2: Overlap between cross-shore survey lines

- Accreting: Low gradient, wide sand bars without vegetation, or with thin, juvenile vegetation (typically grass), no trees or coastal structures near the coastline
- Stable: Mean gradient, ordinary vegetation (possibly including trees) extends to the high water line (or even beyond), no sign of erosion, coastal structures are in their proper place
- Eroding: Steep gradient, steep eroding bank, vegetation extends to the edge of the bank, coastal structures may be damaged
- Tidal bar: Area submerged at high tide, without any vegetation
- Low char: Area submerged at high tide, with vegetation

Table A02-7.3: Coastline categories

In order to generalize the results, the coastline must be classified into categories, by observations supported by photos. These observations serve the additional purpose of providing a reference for interpretation of the satellite photos: By comparing the satellite signals with observations in the field, routines can be developed for an automatic mapping of the morphological development. This mapping may be less accurate, but is important, because it can cover the entire area both today and in the past.

The coastline classification should be made by making notes on a chart. This activity should be carried out whenever possible, aiming at covering the entire area in the course of the programme. A junior surveyor may be assigned for the purpose.

Since the transfer of coastlines from satellite data must be regarded as a non-routine exercise, the distance to the coast from the end of the survey line is registered as a fall-back measure (see Form C-3, Bathymetry Log Sheet).

7.4 Sound velocity adjustment

The sound velocity varies within the survey area, because of the temperature and salinity variations. The variations can occur over short distances and short periods of time, and it is not practical to adjust the sound velocity during the bathymetric surveying.

Therefore, a constant sound velocity of 1506 m/s is applied for the entire programme. Required adjustments will be made during the post-processing.

Regular S/T profiles must be made for several purposes, one being the monitoring of the sound velocity. As seen from Table 8.4, the anticipated variation can incur significant deviations, particularly when making year-to-year comparisons.

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	0 PPT	15 PPT	30 PPT
15 °C	1458 m/s	1479 m/s	1500 m/s
25 °C	1485 m/s	1506 m/s	1526 m/s
35 °C	1501 m/s	1522 m/s	1543 m/s

	0 PPT	15 PPT	30 PPT
15 °C	- 3.2 %	- 1.8 %	- 0.4 %
25 °C	- 1.4 %	100 %	+ 1.3 %
35 °C	- 0.3 %	+ 1.1 %	+ 2.5 %

Table A02-7.4: Velocity of sound in sea water

7.5 Check of echo sounders

Checking of the echo sounders must be done for the following reasons:

- To maintain a good accuracy
- To maintain a good consistency between the 3 vessels operating together
- To describe the effect of seabed vegetation

The checks take place for each vessel on each day with bathymetry work. This is not because the echo sounders change from day to day, but because, if they change, it is important to know when it happened.

In addition, the draft of the vessel varies with the sea water density (which again depends on the temperature and salinity). Although, in theory, the draft variation is not critical when using RTK-DGPS positioning, information about it can still prove useful.

The checks are made as comparative lead line soundings, whenever possible at places with a flat, regular, hard sea bed. The lead line is cast from the starboard draft mark.

Indicate the draft of the vessel, and the sea state. Also, if possible, the sea bed vegetation should be observed, and categorised into 'none', 'thin', or 'dense'. Indicate species, if known. Form C-2 may be used for the purpose.

Day-to-day deviations, if any, should not be incorporated in the on-line processing. Required corrections will be made during the post-processing.

7.6 Runlines

A set of runlines must be defined during the first survey on each location.

This can be done either on the HYDRO computer, or by hand, or by a combination. In any case, the runline coordinates must be preserved for later use. Form B may be used for the purpose.

Easterly/westerly runlines are oriented *from west towards east* (which is the opposite of what is done in the Bangladeshi river system).

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7.7 Daily routine

The daily routine comprises:

- Check of echo sounders and S/T profiles
- Reconnaissance lines, as appropriate
- Measurements as per work plan
- Longshore lines at high tide
- Coastline observations
- Sediment samples, if these can be conveniently incorporated in the work programme (i.e. without detaining the bathymetric measurements)
- Occasional photo documentation

Depth range:	0 - ## m
Depth resolution:	#.## m
Sampling frequency:	1 per s
Maximum operational speed:	4 knots (2 m/s)

This gives a sounding for appr. every 2 m.

Table A02-7.5 : Echo sounder performance and operational speed

Lines are made in the direction of the runline (normally from W towards E).

One among other purposes of the measurements is to compare measurements from different years. Therefore, ideally, the lines should be sailed between identical waypoints (to be established 'once and for all' during the first campaign). In practice, this is expected to be more difficult than it might appear, due to newly created sand banks, fishing nets, etc. However, the largest possible overlap of identical lap should be aimed at, in order to enhance the value of the data.

Organize the daywork according to the tide tables, so that shallow areas, such as banks and nearshore areas, are mapped around high tide. These areas are particularly important for the purpose of MES.

Use small sketches or photos to show features that are not recorded, such as sand banks.

(Instrument and computer start-up, navigation, monitoring, and shut-down)

(To be prepared during the first survey)

Table A02-7.6 : Check list for bathymetric measurements

8 FLOW TRANSECTS

8.1 Objective

Flow transects of tidal streams will take place in the dry season, while measurements of high river discharges (of water and sediments) will take place as a part of the monsoon season programme.

The objective of this exercise is to produce a general picture of the flow in the estuary, to serve the following applications:

- as a baseline description of present conditions
- as a reference and data basis for hydrodynamic and morphological impact analyses
- supply of calibration data for the hydraulic models

8.2 Rationale

The desired general knowledge of the current pattern is produced by a series of 'instantaneous' flow transect measurements, and by relating the results to the tidal variation and the water level slopes in the area.

Each flow transect will be recorded by a combination of a continuous (S4) current recording, at one single point, and an ADCP flow transect, covering the entire cross-section. The following procedure will be applied:

- 1 deployment of the current meter
- 2 measuring the cross-sectional flow transect by ADCP
(to be carried out at least twice)
- 3 withdrawal of the current meter
- 4 calculating the time variation of the cross-sectional flow over the entire tidal cycle, assuming a direct proportionality between the current meter velocity and the simultaneous ADCP velocity

It is expected that a general correlation exists (and can be established by the dry season field programme) between tidal streams and tidal elevations, as registered by the sea level gauges. Such correlation will consist of a phase lag and a amplitude proportionality. In the monsoon season, the relationship will be blurred by wind-generated currents and by the discharge of the Meghna, but these flow-generating mechanisms, although more complex, are of no less interest to the subsequent impact evaluation.

8.3 Preparatory work

Certain preparatory activities must be carried out 'once and for all' prior to the first measurements at each transect. This work comprises

- a reconnaissance of depth contours
- definition of runlines
- selection of S4 current meter location

To the extent that the choice is open, the following preferences should be observed when selecting the exact cross-section location:

- prefer an orientation perpendicular to the flow direction
- prefer locations in long, straight, regular channels
- prefer cross-sections with an adequate navigation depth all the way across
- avoid locations near shallow bars and reefs
- avoid locations near channel bends, width contractions or expansions, and confluences or bifurcations

At least 3 runlines should be defined: One for the transect itself, and one on either side of the transect, at a distance of 100 m.

Although not critically important, the same lines should be applied for each survey, whenever possible. If, for some reason, the line is relocated (due to fishing nets, sand banks or similar), the new line coordinates must be registered. Form B can be used for the purpose.

8.4 Validation of the ADCP

A validation of the ADCP should be carried out three times during each campaign.

The validation comprises a comparative measurement with an Ott current meter, at 3 different depths. The applied current meter should have either a factory calibration or some other suitable calibration, and should be in a good state of maintenance.

Select a straight, regular tidal channel for the purpose. The depth should be at least 10 m. The current should be at least 1 m/s.

The vessel must be anchored during this activity.

At each measuring depth, the validation is carried out by doing 3 successive ADCP recordings (of 20 s each) and comparing the mean speed with an Ott registration averaged over 60 s. Hereby, the flow direction is disregarded.

Measuring depths should be around 20 %, 40 %, and 70 % of the total depth.

No matter what the outcome of the validation is, no on-line data processing corrections (of deviations or trends) should be implemented in the course of the campaign.

8.5 Gauging routine

The gauging routine comprises

- Deployment of S4 current meter
- Draft registration and S/T profile
- First ADCP flow transect
- Suspended sediment sampling and an S/T profile
- Second ADCP flow transect
- S/T profile
- Recovery of S4 current meter

The standard ADCP instrument settings listed in Table A02-8.1 are applied.

Bin height (depth resolution):	1 m
Sampling frequency:	1 per s
Frequency of ADCP signal:	600 kHz
Current velocity range:	0 - ### m/s
Current velocity resolution:	### m/s
Averaging period:	25 s
Maximum operational speed:	4 knots (2 m/s)

This gives a profile for appr. every 50 m.

Table A02-8.1: Standard ADCP settings and operational speed

The S4 current meter is deployed in order to measure the tidal stream. It should be located in the same flow channel as the transect, and as close as possible to it. For 'composite' transects (that are in fact several transects in the same area), the S4 should be located in the main flow channel. It can be installed 4 m above the sea bed at a location with a water depth of at least 8 m at low tide, or, if not possible, 3 m above the bed at a place with a water depth of 5-6 m at low tide.

The actual draft variation during operation is not known beforehand, but the draft may well be of some significance because the transects will cover shallow areas. Therefore, a draft registration should be made relative to 4 draft marks established for the purpose. This should be done while sailing.

In order to cover the full tidal cycle, and with a little overlap, the S4 should be deployed for at least 30 hours at each location. For single day transects, this means for example from the evening before till the morning after the day of the flow measurements. For transects that take several days, the S4 current meter can simply be deployed just before the start of the work, and can be recovered upon its completion.

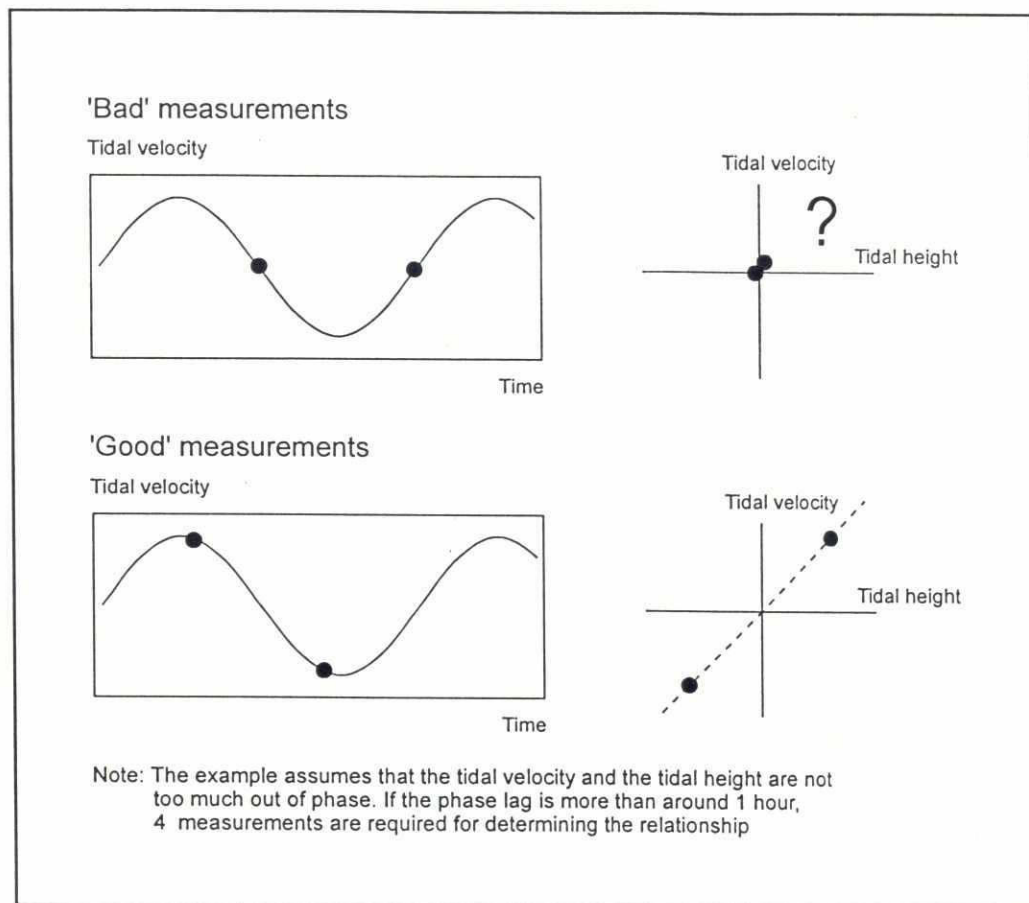
For 'composite' transects, the S4 should remain at the same position during the entire exercise.

Current speed range:	0 - ### m/s
Current speed resolution:	### m/s
Temperature range:	## - ## °C
Temperature resolution:	### °C
Sampling frequency:	2 per s
Sampling duration:	5 minutes
Sampling interval:	15 minutes
Data storage capacity:	## days

Table A02-8.2: Standard S4 settings

It is important to try to cover the entire cross-section, from bank to bank.

The cross-section should be covered by two good transect scanings, without indications of errors or irregularities.



file mes-a04.cdr

Figure A02-8.1 : Validity of tidal stream measurements

Ideally, there should be an interval of 6 hours (half a tidal period) between the scannings. This is no imperative requirement, but for scannings that take a few hours only, an interval of another few hours between each scanning will enhance the validity of the recordings. As a rule of thumb,

- avoid measuring at the same place along the transect within less than 2 hours, or at the same stage of the next tidal cycle (after 10-15 hours, or after 22-27 hours).

As far as possible, the scannings should take place at peak tidal flow, which is expected somewhere halfway between high tide and low tide. If both the two scannings are dominated by slack water, one more must be made. Because of the tidal variation, it should not be expected that the recorded flow is the same for the two scannings.

In case of a significant phase lag between tidal height and tidal stream velocity, the number of flow transects must be increased from 2 to 4. If so, the 4 transects should be made with an interval of around 3 hours. A 'significant' phase lag is 'more than around 1 hour'.

A simplified illustration of 'bad' and 'good' measurements is given in Figure A02-9.1.

(Instrument and computer start-up, navigation, monitoring, and shut-down)

(To be prepared during the first survey)

Table A02-8.3: Check list for flow transect measurements

9 SEDIMENT SAMPLES AND S/T PROFILES

9.1 Objective

These activities aim at producing data for the morphological and environmental baseline description and impact analysis.

9.2 Suspended sediment samples

Suspended sediment samples are taken

- 1 in order to characterise the sediment with respect to settling velocity and other properties
- 2 to estimate the sediment transport rate at the location

The samples are taken as vertical profiles. They are always accompanied by an ADCP current profile and by an S/T profile.

The sampling profiles should be located on a flow transect runline if there is one in the area. Samples should be made whenever a flow transect gauging is made (and on other occasions as well, depending on the work programme).

Anchoring during the sampling is an advantage, but can be omitted if not practical. In case that anchoring is decided against, a light marker buoy may be temporarily deployed as a guideline for keeping the position.

Positioning is made by DGPS for profiles that are located in a flow transect, or anywhere within range of an active reference station, and by GPS elsewhere.

Pump capacity:		## l/minute
Sampling height above seabed (for near-bed samples):		0.# m
Flushing of umbilical:		# minutes
Sample depths:	5 (surface, 3 over the water column, 1 near-bed)	
Sample volume,	standard:	0.5 l
	heavy sediment contents	0.25 l
	settling tube samples:	10 l
Sampling duration,	standard	30 s
	settling tube samples:	## s

Table A02-9.1: Suspended sediment sampling

Bottles should always remain filled with a little water, in order to prevent adhesion of clay or salt.

For samples that contain large amounts of sediments, the sample volume should be reduced to half, as indicated in Table A02-9.1. (This is to prevent a need of reducing the sample volume prior to its analysis, which can result in a sorting of the sample).

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The samples should cover the entire water column, because both the concentration and the settling characteristics will vary over the vertical. This is the case in general, and particularly when the current and S/T profiles indicate two-layer flow and/or density stratification. Sample depths are indicated in Table A02-9.2.

Form E-1 may be applied for this activity.

Depth	Suspended sediment concentration	Settling tube tests
1 m below surface	+	+
2 intermediate depths	+	
1 m above seabed	+	+
0.3 m above sea bed	+	
Total per vertical	5	2

Table A02-9.2: Depths of suspended sediment samples

9.3 Sea bed samples

Sea bed samples are collected in connection with bathymetric surveying or flow transects.

When practical, the samples should be taken along a runline across a flow channel. If so, they should cover the entire channel between the two high water lines, i. e. not only at sea, but also on the shore. The samples taken from the vessel should be distributed evenly across the channel, and should include its deepest part. Between 10 and 15 samples should be collected along such a transect, approximately as indicated on Figure A02-9.1.

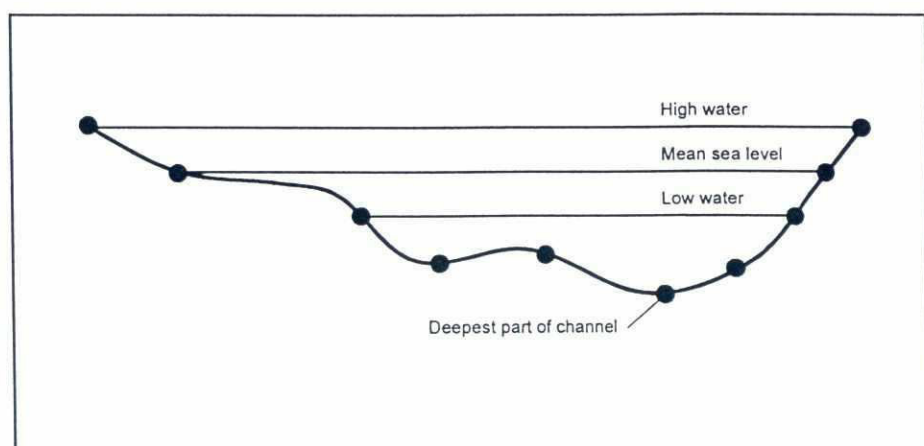


Figure A02-9.1: Location of sea bed samples (File mes-a05.cdr)

Positioning is done by DGPS from the vessel, and by GPS on land.

In connection with their collection, the samples are visually classified as indicated in Table A02-9.3. The colour should be established by comparison with a standard colour sheet. Form E-2 may be applied for this activity.

Hard/soft
 Fine/coarse/medium ... sand/silt/clay
 Colour
 Shells

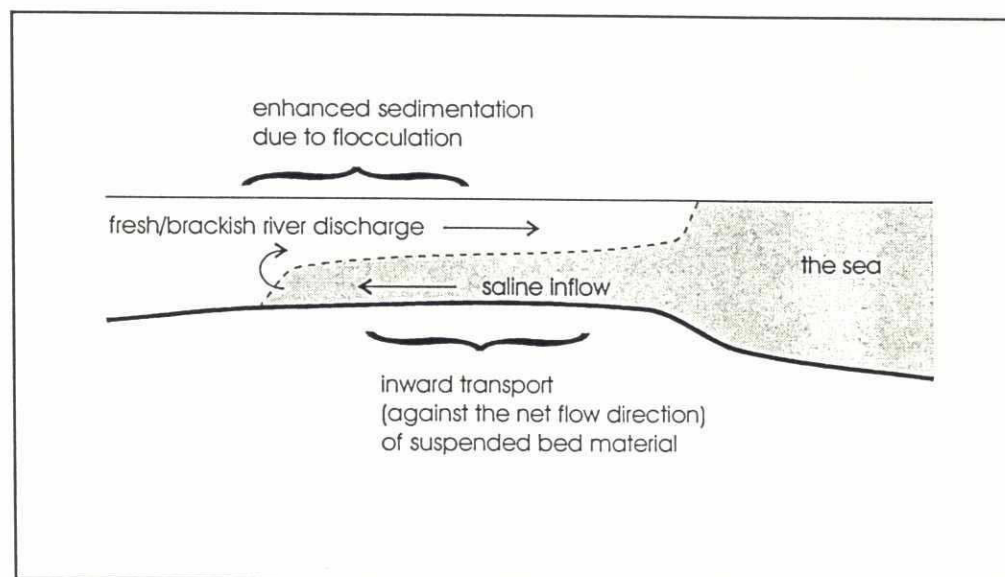
Table A02-9.3: Classification of sea bed samples

9.4 S/T profiles

The Meghna Estuary is a zone of transition between the fresh-water river discharge and the saline sea water of the Bay of Bengal. Mapping of the S/T distribution in the estuary is of a considerable importance, for the following reasons:

- The salinity and temperature are expected to vary significantly both in time and space. This can affect the echosoundings, and thereby the comparison of depth contours measured on different occasions
- Salinity gradients can generate density-driven flows, for example a flow near the sea bed in the opposite direction of the net current. Such a reverse near-bed flow can highly influence the mode of sediment transport, because high concentrations of coarse sediments occur near the sea bed
- An enhanced sedimentation can occur in zones of mixing between fresh and saline water, due to flocculation of fine river sediments

These effects are illustrated in Figure A02-9.2.



file mes-a08.cdr

Figure A02-9 .2: Significance of S/T mapping

In addition, the salinity is an important water quality determinant, as even a slightly increased salinity can render a water resource unsuitable for irrigation and industrial consumption.

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During the estuarine surveys, S/T profiles are always taken

- 1 before and after each daywork of bathymetry
- 2 before and after each flow transect
- 3 whenever a suspended sediment sampling profile is done
- 4 whenever an S4 current meter is deployed or recovered (for the sake of intercalibration)

In addition, as a separate activity, some profiles must be taken while cruising, particularly some N/S oriented lines. Along the lines, profiles are measured with an interval of around 1 km. This can be done by a detached survey unit, either one of the tender boats, or a country boat hired for the purpose, while Anwasha is occupied by other work.

The measurements are registered for every m depth, and are always done from the surface towards the seabed.

The probe must be held at a given depth for 5 seconds before the measurement is taken (allowing for adjustment of the temperature sensor).

Anchoring is not required, and positioning by non-differential GPS is fully adequate for these profiles. Form E-3 may be applied for the data collection.

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A ADDRESSES

To be completed later

B CREW AND SURVEY STAFF

To be completed later

C INVENTORY OF FACILITIES

To be completed later

D LOCATION OF GAUGES, TRANSECTS, AND SURVEY AREAS

(map and table with coordinates)

(BIWTA gauges, MES WL and wave gauges, transects, bathymetry areas)

(to be prepared later)

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E NAME CONVENTIONS AND LOCATION CODES

Name convention for field data files

Format: SYMDVCNN.[ext]

S : Site location code (A - Z) (see below)
Y : Year no. (1996 = 6, 1997 = 7, etc.)
M : Month no. (January = 1, October = A, etc.)
D : Day no. (1 - 9, A - V)
V : Vessel code (1 = Anwasha, 3 = Tender 3, 4 = Tender 4)
C : Survey category code: T = transect, B = bathymetry
NN : Series no. (00-99)

[ext] : ACQ : Data acquisition file from ACQ computer
HOD : HYDRO data file from HYDRO computer (ASCII)
HSB : HYDRO data file from HYDRO computer (binary)
RAW : ADCP raw data file from ADCP computer
S4 : S4 raw data file
INF : S4 info file

Name convention for sediment samples

Format: SYMMDDVC-NN

S : Site location code (A - Z) (see below)
Y : Year no. (1996 = 6, 1997 = 7, etc.)
MM : Month no. (January = 1, etc.)
DD : Day no. (1 - 31)
V : Vessel code (A = Anwasha, 3 = Tender 3, 4 = Tender 4)
C : Category of measurement:
1 = suspended sediments, 2 = settling tube sample, 3 = bed sample
NN : Series no. (1 - 99)

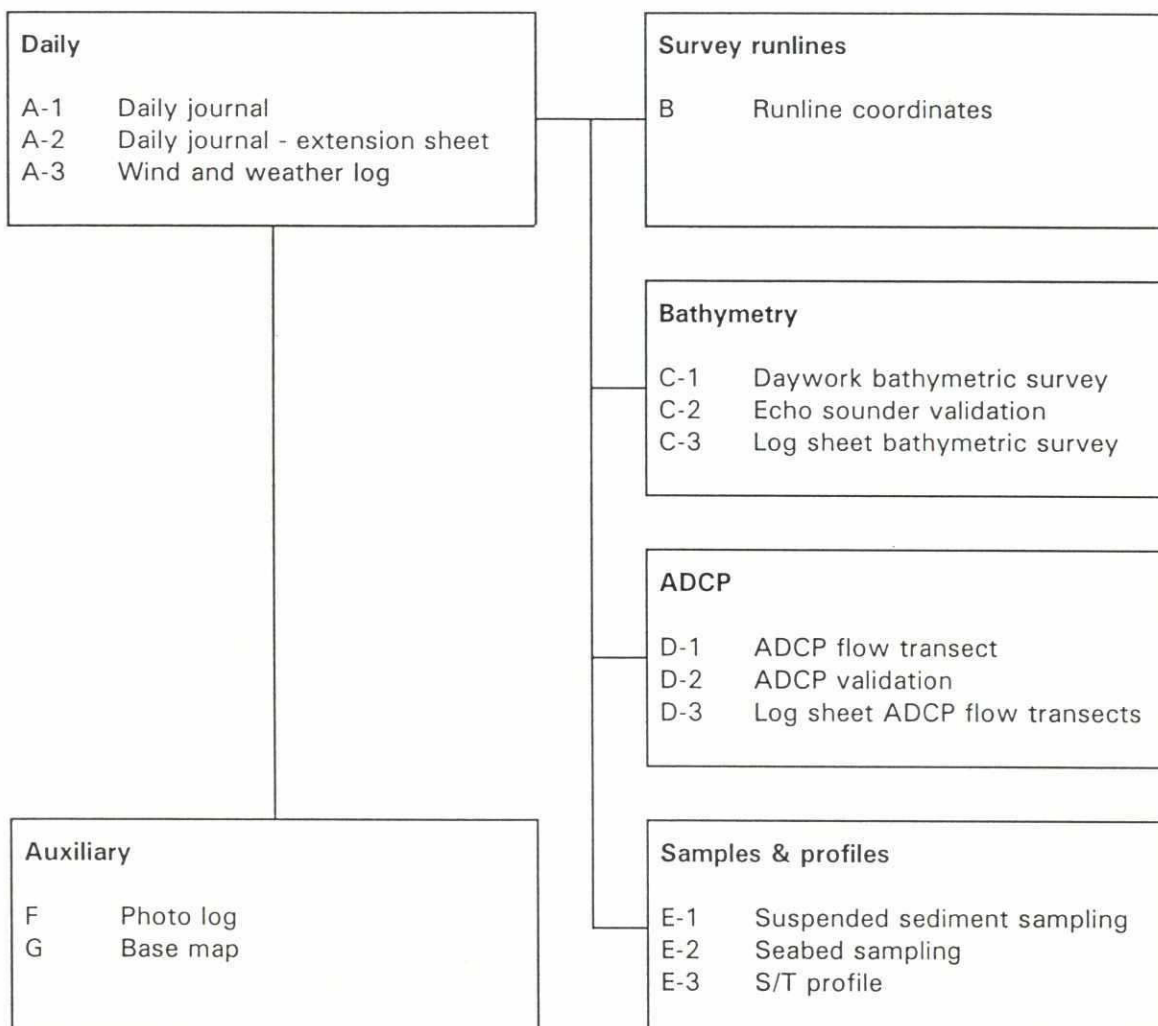
Name convention for survey runlines

Format: SCGTNN

S : Site location code (A - Z) (see below)
C : Survey category code: T = transect, B = bathymetry
G : Runline group no. (0-9)
T : Type of runline: X = transverse, Y = longitudinal
NN : Series no. (00-99)

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F DATA REGISTRATION FORMS



ANNEX 03

HYDRAULIC AND MORPHOLOGICAL STUDIES

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1 RATIONALE

The hydraulic and morphological studies aim at predicting the impact of the different land development schemes to be considered in the course of the planning process.

Hereby, an impact is identified as the difference between two future sets of hydraulic, morphological, or environmental conditions. One set of conditions is without a given land development scheme, and one set is with this scheme.

The analysis requires (i) a set of prediction tools (which in turn requires knowledge about states and governing processes), and (ii) a reference for the comparison.

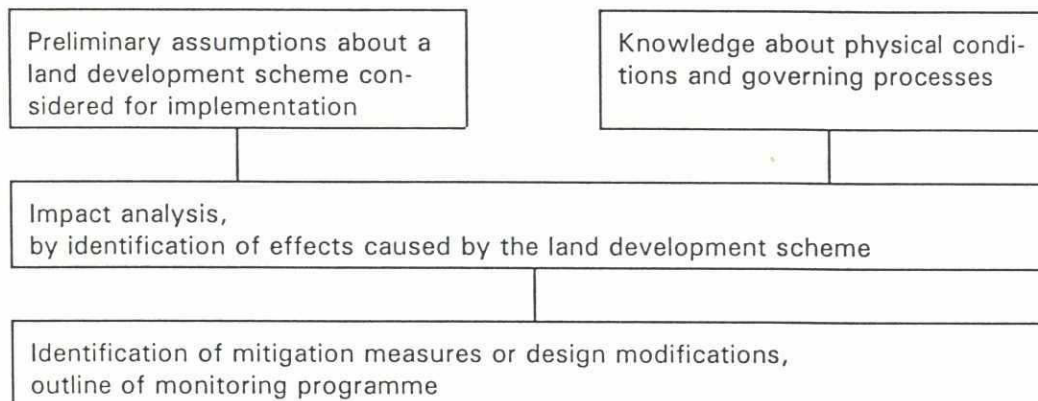


Figure A03-1.1 : Rationale of hydraulic and morphological studies

In the Meghna Estuary, the comparison might consider the coastline (which varies from year to year), meteorological, hydrographic, and morphological conditions, and independent man-made changes of the physical environment (for example by CERP, adjacent FAP projects, and others). Such aspects can be defined by a baseline situation (or present state) and by a development scenario (of governing processes). For practical reasons and in order to maintain a suitable data consistency, the comparison will comprise a set of simplified, but well-defined impact calculation periods, describing normal dry season and monsoon season conditions.

2 DATA BASIS

Data will be taken from three sources:

- Historic data (from BIWTA, LRP, and others)
- Ongoing monitoring programmes (BIWTA, Meteorological Department, and others)
- MES surveys and satellite mapping

The historic data are indispensable as the only source of information about normal conditions, seasonal variation, and long-term trends. The ongoing monitoring programmes are important for several reasons, one being their consistency with data from the past, whereby they serve as a reference for the more detailed surveys carried out by MES.

The surveys and mapping carried out by MES provide a dedicated supplement to this information, providing a more detailed information about selected processes that are important to the hydraulic and morphological analysis.

There are a number of interventions in the rivers of Bangladesh, either planned or recently taken up for implementation, which have in some way or another, linkages with the Meghna Estuary Study. This applies in particular for activities which come under the Flood Action Plan (FAP).

3 ESTUARINE SURVEYS

3.1 Objective

The surveys aim at the following objectives:

- Upgrading of the survey spread of M/S Anwasha
- Establishment of a grid of geodetic reference points covering the project area, serving as a basis for all measurements, including ongoing water level monitoring
- Generation of competence within BWDB/SSD and SWMC to utilise the supplied data collection and data processing facilities
- Provision of hydraulic data, to serve as a part of the basis for design and impact evaluation within the project

The planned upgrading of the survey spread of M/S Anwasha and its tender boats comprises accurate positioning, state-of-the art survey instruments for bathymetry, flow and S/T measurements and sediment sampling, and computer hardware and software for high-capacity on-line data processing. Hereby, the vessel will have facilities that compare favourably with the best survey units in operation in Bangladesh today. With respect to positioning, which is crucial for the morphological monitoring, the vessel will be equipped with advanced so-called RTK-DGPS 3-dimensional satellite positioning.

As a basis for the surveys, a grid of geodetic reference points is required. Most of the country is already covered by a geodetic grid recently established by Survey of Bangladesh, but this grid does not cover the MES area. Therefore, a grid will be established for the purpose. At the same time, the grid will supply a link with the reference levels of the ongoing water level registrations, and the reference levels of the LRP bathymetry mapping, so that past, present and future data from different sources can be directly compared. The results of the activity will comprise the network itself, as established in the field, together with its BTM coordinates and PWD levels. Also, information will be provided about conversion from WGS84 coordinates.

The survey work will be carried out by BWDB/SSD. Since the scope and facilities are highly extended as compared with for example the LRP, a comprehensive capability upgrading is required for the purpose. This process will take place gradually in the course of the Study. Initially, the field work will be done under supervision and with full-time active participation by expatriate project staff, whereas later on, the work can be done by BWDB/SSD staff with some occasional assistance (backstopping and trouble-shooting) by the foreign specialists. At the end of the project, it is intended that BWDB/SSD can plan and execute estuarine surveys (of the type in question) by own means.

3.2 Approach

Summary of scope

The field measurements can be divided into categories as follows:

- Water level registration by self-recording gauges and by staff gauges
- Wave recordings by self-recording gauges
- Bathymetric surveys
- Current and S/T recordings by electromagnetic self-recording instrument
- Measurements of flow transects, flow profiles, and S/T profiles

- Collection of suspended sediment samples for determination of sediment concentration and settling velocity
- Collection of sea bed samples

Outline of the field programme

The MES estuarine surveys comprise the following components:

- Establishment of a geodetic grid for reference stations
- Installation and operation of water level gauges and wave recorders
- Routine measurements from Anwasha: Bathymetric surveys, flow transects, sediment sampling, and S/T profiles
- Data processing and reporting

Survey procedures

Please refer to Annex 2 for an outline of the survey procedures.

Data processing

The data processing is a stagewise exercise, comprising (i) on-line processing, (ii) routine post-processing, and (iii) non-routine post-processing.

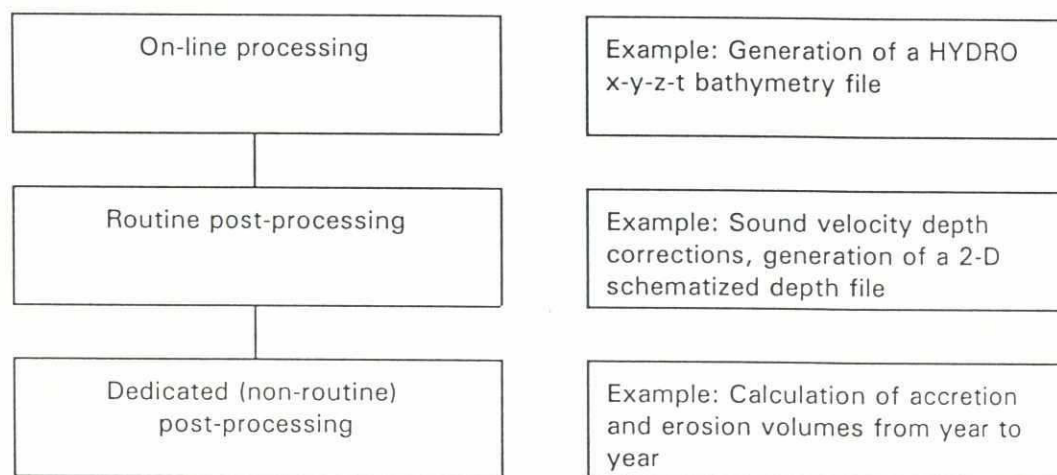


Figure A03-3.1: Categories of data processing

The routine processing will produce (i) data tables and (ii) graphic presentations. There will be three types of data tables:

- x-y data files, for example a vertical current profile
- time series, for example of water level
- schematized arrays of x-y-z data, for example of sea bed levels

Data flow summaries

Data flows for different categories of measurements are presented in the following figures.

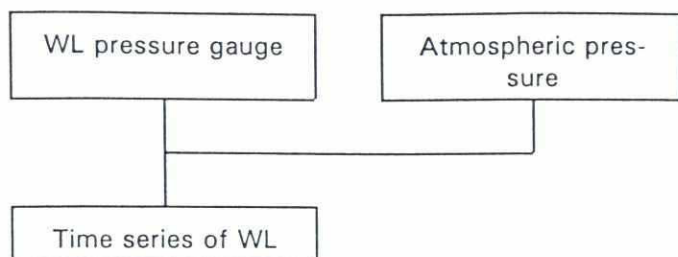


Figure A03-3.2: Data flow, water level from pressure gauges



Figure A03-3.3 : Data flow, wind and waves

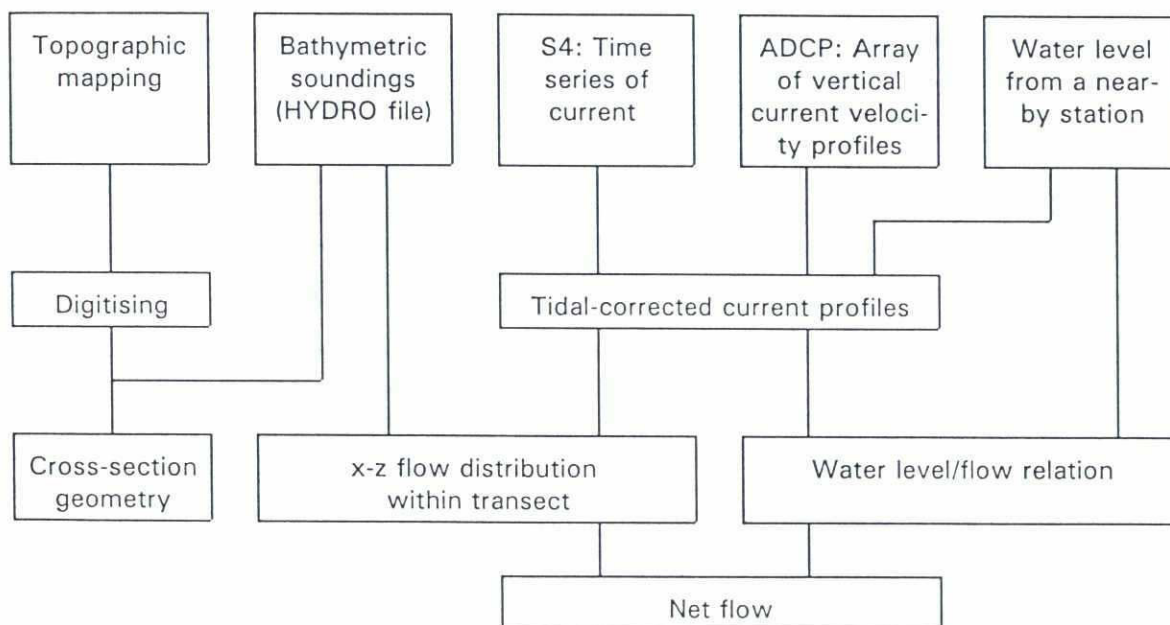


Figure A03-3.4 : Data flow, transect gauging

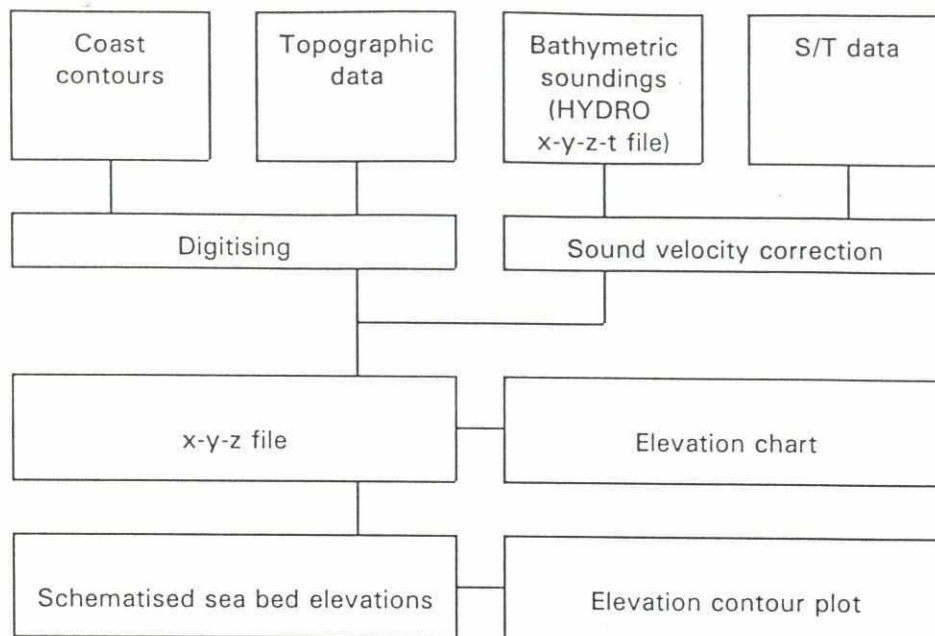


Figure A03-3.5 : Data flow, bathymetric surveys

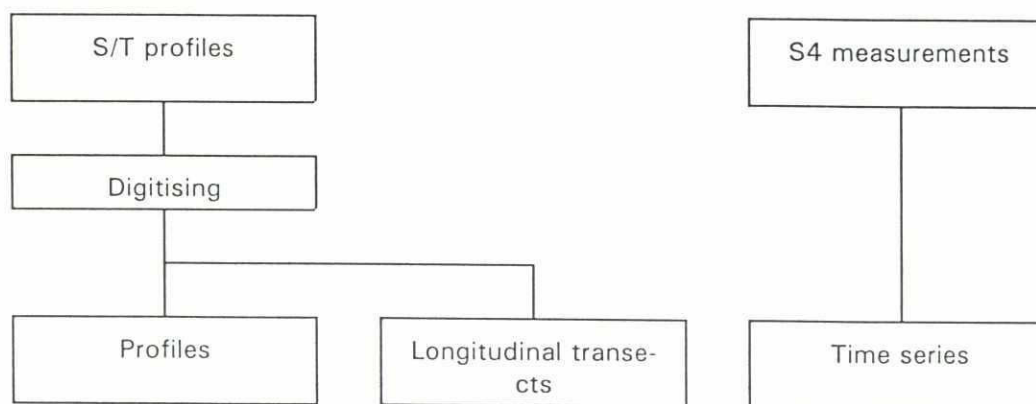


Figure A03-3.6 : Data flow, S/T measurements

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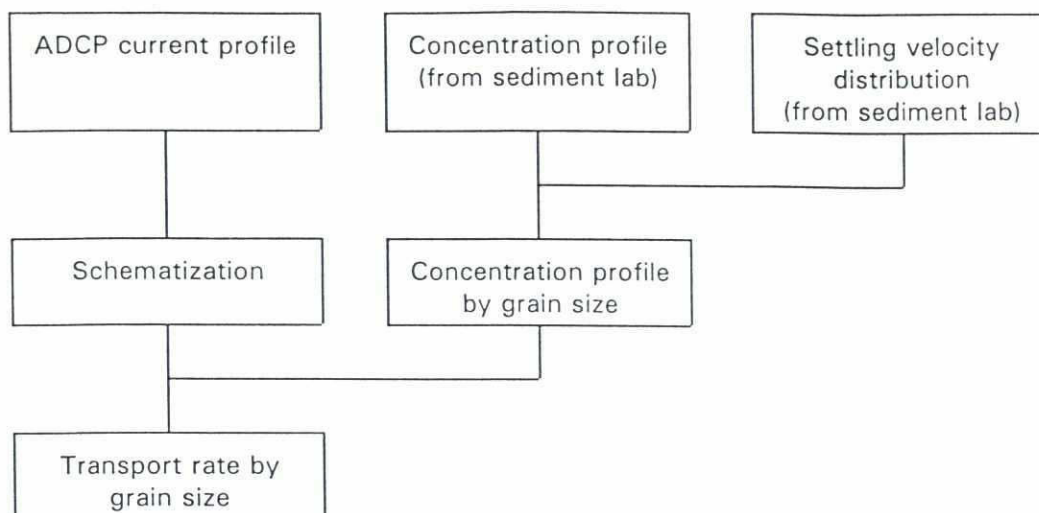


Figure A03-3.7 : Data flow, sediment transport

Data administration

The data administration comprises the following routine operations:

- Preparation of data tables (= processed data files)
- Data catalogue entries
- Preparation of plot files
- Data reporting
- Data storage

Data tables

All processed data are presented in data tables, which are prepared as shown in Table 1.

x-y data:	ASCII and/or Quattro Pro (?) spreadsheet format
Time series:	ASCII and/or Quattro Pro (?) spreadsheet format
Schematized arrays of x-y-z data:	ASCII and/or MIKE21 format

Table A03-3.1 : Data tables, categories and file format

One single data catalogue will be maintained with a complete inventory of

- all raw data files
- all processed data files

The catalogue is a listing of

- (1) file name
- (2) measurement type (code)

- mb
- (3) location (code)
 - (4) date/time of the measurement
 - (5) data storage tape identification

Data reporting

All processed data are summarised in MES data reports.

These data reports come as a series. Each report presents one category of measurements for a given period of time. The categories have letters from A and upwards. Within each category, the data reports are numbered from 1 and upwards.

The categories of measurements are

- A Water level recordings
- B Wind and wave recordings
- C Transect measurements (depth profiles and flow)
- D Bathymetric mapping
- E S/T profiles
- F Sediment transport and sediment characteristics
- G Miscellaneous

It is expected that preparation of around 2 reports per category per year will be convenient to both data producers and data users.

Each report contains

- (a) A front page
- (b) A location map, showing where the measurements have taken place
- (c) A data collection summary table, which is also the list of contents:
Dates, positions, file names, and drawing (= page) references
- (d) Drawings (which includes tables) with standard summary data presentations

Data storage

All field sheets, and all raw and processed data files will be stored on data tapes in 2 copies, one being kept at the MES office, and one at the SWMC.

Data processing routines

The data processing routines are laid down in the '*MES Guidelines for data processing, estuarine surveys*', which have, by end of February, been prepared as a first draft only.

The Guidelines is a living document, which will be updated and supplemented in order to include a complete description of how the data collection is done.

3.3 Results

The anticipated results of the surveys comprise

- A geodetic reference grid of the area
- Zero level validation of water level gauges in operation
- Information about tidal flows and net flows in the dry and the monsoon season
- Information about sediment transport and properties
- Information about waves and water levels
- Information about dry season and monsoon season salinity distributions

- Information about accretion and erosion in selected parts of the estuary

Data produced by the estuarine surveys are summarised in Table A03-2.

Item	Data table	Plot
Water level, wind and waves		
• Time series of water level at a given measuring position	x	x
• Time series of wind speed and -direction	x	x
• Monthly wind speed-direction frequency distribution	x	
• Time series of Hs and Ts (or Tz)	x	x
• Monthly frequency distribution of Hs and Ts (or Tz)	x	
Depth contour/flow transects		
• Schematized sea bed level	x	x
• Cross-sectional flow distribution	x	x
• Cross-section area/water level relationship	x	
• Total flow/water level relationship	x	x
• Time series of total flow	x	x
• Ebb and flood flow volume, and net flow	x	
Bathymetry		
• x-y-z sounding/topographic data files	x	
• x-y-z sounding/topographic charts		x
• Schematized sea bed and land levels	x	
• Bed/land level contour plots		x
S/T profiles		
• S/T/depth data tables	x	
• Vertical salinity profiles		x
• Longitudinal salinity transects	x	x
• Time series of S4 salinity registrations	x	x
Sediment profiles		
• Schematized vertical current profile	x	x
• Settling velocity distribution	x	x
• Grain size distribution	x	x
• Concentration profile by grain size category	x	x
• Sediment transport profile by grain size	x	x

Table A03-3.2 : Results of estuarine surveys

4 HYDRAULIC MODELLING

4.1 Objective

The hydraulic modelling aims at

- serving as a tool for the hydraulic impact analysis
- supplying part of the basis for the morphological impact analysis

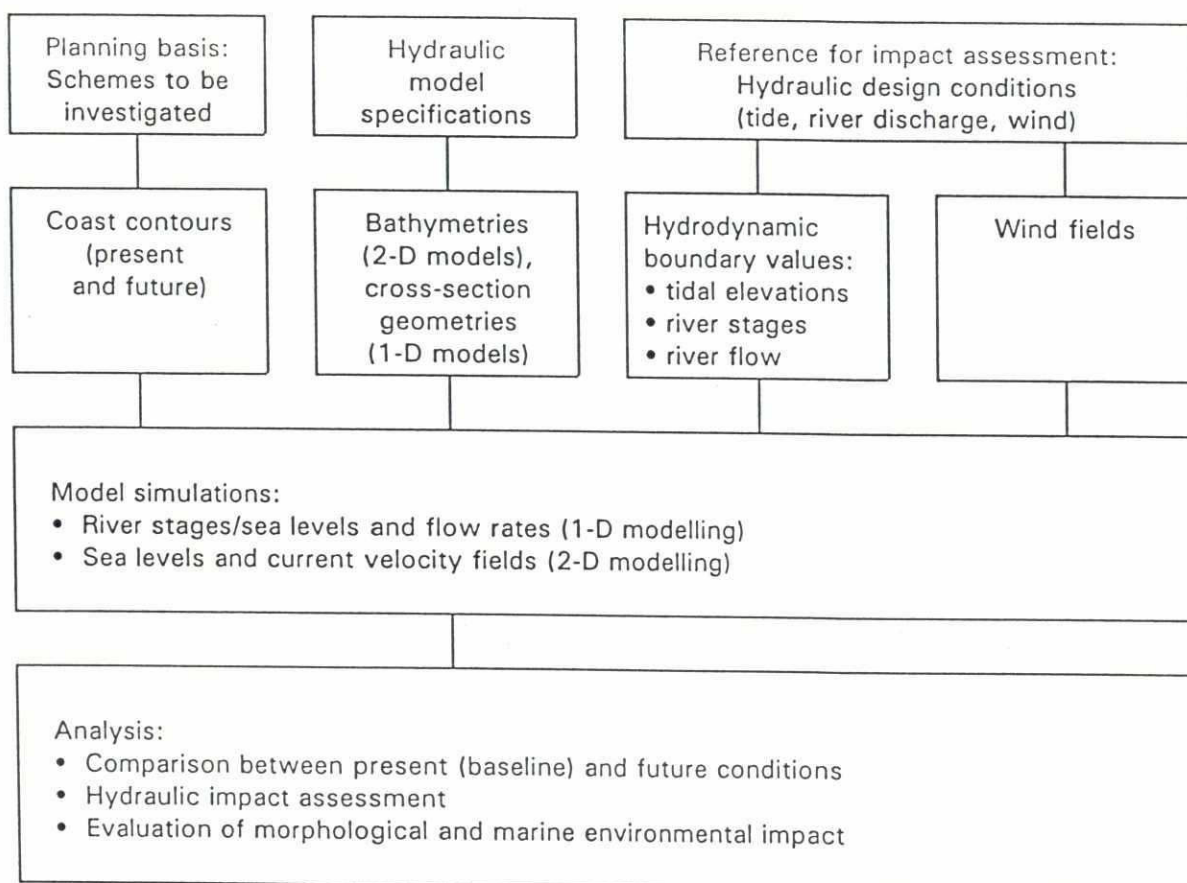


Figure A03-4.1 : Context of hydraulic modelling

4.2 Approach

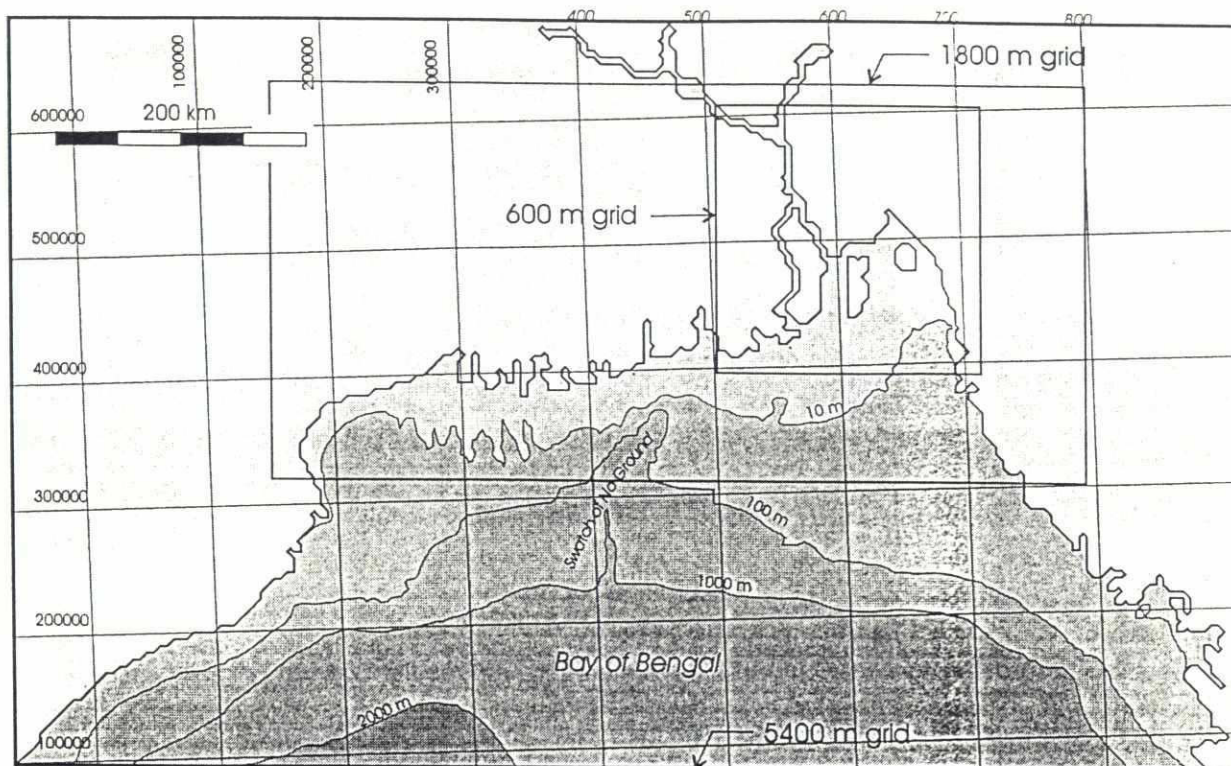
The hydraulic modelling will be made by a set of separate models for hydrodynamics and waves.

The 2-D model will be a development of previous models applied by SWMC in the MES area. The model will be of the nested grid type, with grid sizes ranging from 5400 m to 200 m, as outlined in Table A03-4.1 and shown in Figure A03-4.2.

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5400 m grid Bay of Bengal model					
easting BTM	northing BTM	Area	Water area	Time step	CPU time per simulation day 1)
-50 - 800 (850 km)	100 - 700 (600 km)	510,000 km ²	40 percent	60 s	3 min
1800 m grid intermediate model					
easting BTM	northing BTM	Area	Water area	Time step	CPU time per simulation day 1)
180 - 750 (570 km)	300 - 620 (320 km)	182,000 km ²	37 percent	60 s	7 min
600 m grid Meghna Estuary model					
easting BTM	northing BTM	Area	Water area	Time step	CPU time per simulation day 1)
500 - 720 (220 km)	360 - 600 (240 km)	53,000 km ²	43-70 percent 2)	60 s	31 min
The above 3 models when combined as one nested grid model					
				Time step	CPU time per simulation day 1)
				60 s	38 min
200 m grid local sub-model for detailed analysis					
		Area	Water area	Time step	CPU time per simulation day 1)
		100,000 km ²	50 percent	60 s	63 min
All 4 models when combined as one nested grid model					
				Time step	CPU time per simulation day
				60 s	114 min
1): The CPU time depends on the computer capacity. Values in the table are given for SWMC's DEC-Alfa 250 4/266 work station 2): This area includes land area exposed to occasional flooding					

Table A03-4.1 : Specifications for hydrodynamic model



mes-m54.cdr

Figure A03-4.2 : Hydrodynamic model areas

Input data to the model comprise coast contours and the bathymetry of the area. The coast contours can be the present ones, or the ones after implementation of a scheme considered in the planning. Boundary values will be given as calculated tidal elevations along the open boundary of the 5400 m grid model.

The river discharge and a wind field will be specified as appropriate. The sea bed roughness will be estimated during the calibration.

The model will initially be calibrated against BIWTA water level recordings, and will subsequently be validated against results of the field survey.

Each basic simulation will have a duration of 14 days, illustrating an average-spring-average-neap-average fortnightly tidal cycle. Two different simulation periods will serve as a reference for comparison between baseline conditions and the planning scenarios:

- A dry season period, with astronomical tide, no wind, and low river discharge
- A monsoon season period, with astronomical tide, monsoon wind, and high river discharge

The anticipated extent of simulations is indicated in Table 4. As noted in the table, the actual number and duration of the impact simulations may be adjusted in the course of the study.

In case that a hydraulic impact is found to extend upstream of the northern model boundary (which is just upstream of the Padma/Meghna confluence), a 1-D hydrodynamic model will be applied as a supplementary tool. This model (which is already established at SWMC) covers the entire main river system of Bangladesh.

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Calibration and validation	4 simulations
Baseline description	2 simulations (dry season and monsoon season)
Impact analysis	8 x 2 simulations
A duration of each simulation of 14 days has been assumed	
The extent indicated is preliminary. The simulations for impact analysis may be organised as a larger number of simulations with a shorter duration, or a combination	

Table A03-4.2 : Extent of hydrodynamic model simulations

4.3 Results

Depending on the scope of each particular simulation, the results can comprise for example

- Fields of calculated, characteristic instantaneous current velocities
- Fields of calculated, characteristic neap and spring tidal ranges and tidal stream velocity amplitudes
- Fields of calculated speed differences between 'present' (baseline) and 'future' situation, as well as time series at selected locations
- Fields of calculated sea level set-up by comparison between 'present' (baseline) and 'future' situation, as well as time series at selected locations
- Longitudinal transects of calculated set-up (as applicable), by comparison between 'present' (baseline) and 'future' situation, as well as time series at selected locations

All 2-D model data (input and output) will be given or produced in the same fixed grid as the one used for the bathymetric and topographic mapping.

Model bathymetries and key model results will be stored in the GIS.

5 HYDRAULIC IMPACT ANALYSIS

5.1 Objective

The objective of the hydraulic impact analysis is to identify, gauge and evaluate hydraulic effects of the different land development schemes that are considered in the course of the planning process.

From case to case, such effects can comprise

- changed flow resistance, resulting in changed water level
- re-distribution of flow, resulting in changed tidal flow and current velocity distribution
- changed wave climate
- changed salinity distribution
- changed erosive capacity (due to changed wave and current energy)

Further, the hydraulic impact analysis form a part of the basis for the morphological impact analysis.

5.2 Approach

The analysis will largely be carried out by numerical model simulations, which will compare 'present' (baseline) and alternative, potential 'future' development scenarios.

The comparison will be made for the entire simulation periods. In some cases, simulations of a shorter duration can be made for a preliminary hydraulic optimisation of the schemes, or for the purpose of sensitivity analysis. The comparison is illustrated in Table A03-5.1.

Basis for comparison: Hydraulic conditions	Baseline: 'Present' land contours	Planning scenario: 'Future' land contours	Impact: Calculated difference with respect to distribution of water level, current, salinity, waves, etc.
Dry season: Tide	Simulation	Simulation	Comparison of results
Monsoon season: Tide, wind, river discharge	Simulation	Simulation	Comparison of results

Table A03-5.1 : Model simulations for hydraulic impact analysis

In this approach, a good validity is pursued by selecting different sets of normal meteorological and oceanographic conditions with respect to astronomical tide, wind, and river discharge. These are the main governing hydraulic forces in the estuary, and each of them is well known. The tide is fully regular, and its main variation takes place within a period of a fortnight. The wind varies on a seasonal basis, as well as the river discharge. These forces are fairly well described by two different periods, one dry season period, and one monsoon period.

5.3 Results

The primary results are calculated differences with respect to each hydraulic parameter, for example the water level or the current speed. These results will be presented as

- time series at selected locations
- longitudinal transects of instantaneous values, for example across a channel
- 2-dimensional fields of instantaneous or average values, covering the entire study area or a part of this area

Part of these results (selected 2-dimensional presentations) will be transferred to the GIS for storage and further analysis in the GIS.

Based on the primary results, the potential for design adjustments will be evaluated. In case that an adverse impact has been predicted, it will be considered whether some suitable mitigation measure can be identified. Further, where relevant, an outline will be made of a monitoring of the predicted impact after implementation of the scheme.

6 MORPHOLOGICAL IMPACT ANALYSIS

6.1 Objectives

In accordance with the aims of the project, the morphological studies and activities should cover a range of levels of concreteness and detail. In the morphological studies, the same as in most of the other elements of MES, three levels of detail and concreteness can be distinguished: 1) master plan level, 2) development plan level and 3) feasibility level. The morphological studies at each of these levels are interlinked in an iterative manner.

At the master plan level as well as the development plan level, the morphological studies are specifically focused on the general understanding of the actual physical processes and mechanisms which shape the morphology of the estuary system. Based upon this knowledge criteria and priorities will be formulated to identify potential land reclamation areas and potential land reclamation projects from a morphological point of view.

At the project pre-feasibility and feasibility level, detailed morphological studies at site specific projects will be executed. Results of FAP and LRP projects, in particular CDSP "Muhuri feasibility study", will be taken into account in the morphological studies, see Figure A03-6.1.

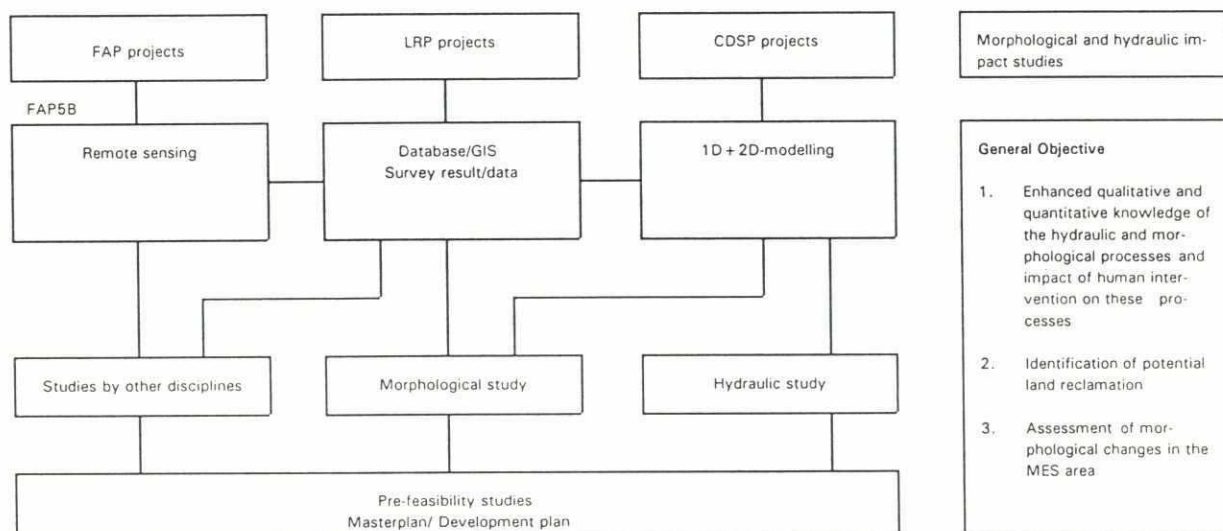


Figure A03-6.1 : Approach Morphological Impact assessment

The objectives of the morphological impact studies are:

- To increase the knowledge of morphological processes in the Meghna estuary based upon a combined analysis of bathymetric data and process data as well as results from empirical and numerical process models,
- To provide morphological criteria to identify potential land reclamation areas, to select potential land reclamation areas from a morphological point of view, and to set priorities,
- To improve understanding of the morphological effects of human interventions at site specific project areas.

6.2 Approach

A crucial element in the development of long-term plans for human interference in estuarine or coastal waters is the prediction of the impact on the bottom topography and coastlines. In recent years, substantial effort has been put into the numerical modelling of hydraulic and morphological changes in complex situations in the fluvial and coastal areas of Bangladesh.

For estuaries and coastal waters, however, this has not yet resulted into sufficiently reliable predictions at mid- and long-term. On the other hand, statistical and empirical techniques applied to field data are useful to extrapolate existing trends, but they are hardly suited as sole predictor if these trends are changing (e.g. due to human interference, sea level rise). To increase the reliability of the predictions at mid- and long-term, it is necessary to combine two approaches: numerical modelling approach and phenomenological approach.

Numerical modelling approach

The dominant hydraulic and morphological conditions and processes that shape the morphology in the study area can be studied through regional and detailed local 1D- and 2D-models. To determine the dynamic behaviour of the entire estuary system or in site specific areas, computations can be carried out under different hydrodynamic conditions: neap tide, average tide and spring tide. Current velocity and sediment transport patterns and wave conditions can be assessed, whereby the consequences of the different impacts can be quantified and compared.

The results of these computations give qualitative and quantitative information about the spatial and temporal (short-term) variation of the water level, current velocity, discharge and could as well give sediment transport and the rate of sedimentation and erosion.

Calculations of the residual current velocities and residual sediment transport give a qualitative indication of the hydraulic and morphological processes and circulations patterns in the Meghna estuary.

Phenomenological approach

Phenomenological approach uses statistical/empirical techniques and physical interpretation to identify trends and empirical input/output relationships from field datafiles and observations. This approach requires extensive and reliable data sets at the input-side (hydrodynamics, sedimentology, meteorological conditions) as well as at the output-side (morphological changes).

Based upon a selection of field data a great number of relevant morphometric and hydraulic parameters can be derived such as:

- size of the tidal basin or parts of it, channel area and tidal flat area,
- characteristics of tidal levels and ranges
- shoreline and channel stability
- flow areas (below PWD or MHW-level) and profiles of selected channel cross sections in the basin, tidal prism
- mean and maximum channel depths below reference level and channel width
- tidal volumes passing selected cross sections
- maximum and mean tidal flow velocities and shear stress velocities

If sufficient data are available, the morphological response to various input conditions or to human interventions can be assessed using a selection of suitable relationships.

The results give an indication of the physical processes at work, and thus the mechanisms underlying the morphological evolution. In this respect observations in comparable situations, if available, can also be of help. Once the input conditions and the I/O relationships have been established, the expected (large-scale) morphological changes can be assessed.

See Figure A03-12.

6.3 Activities and Results

The phenomenological and numerical modelling activities can be divided in five phases (Figure A03-6.2) :

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- A. Inventory and preparation of relevant data
- B. Data processing and analysis of relevant hydraulic data and morphological data
- C. Empirical I/O relationships and morphological adaptation process
- D. Numerical modelling on regional and local scale
- E. Morphological evolution and potential land reclamation areas; integration of results from the phenomenological research and numerical modelling (optional).

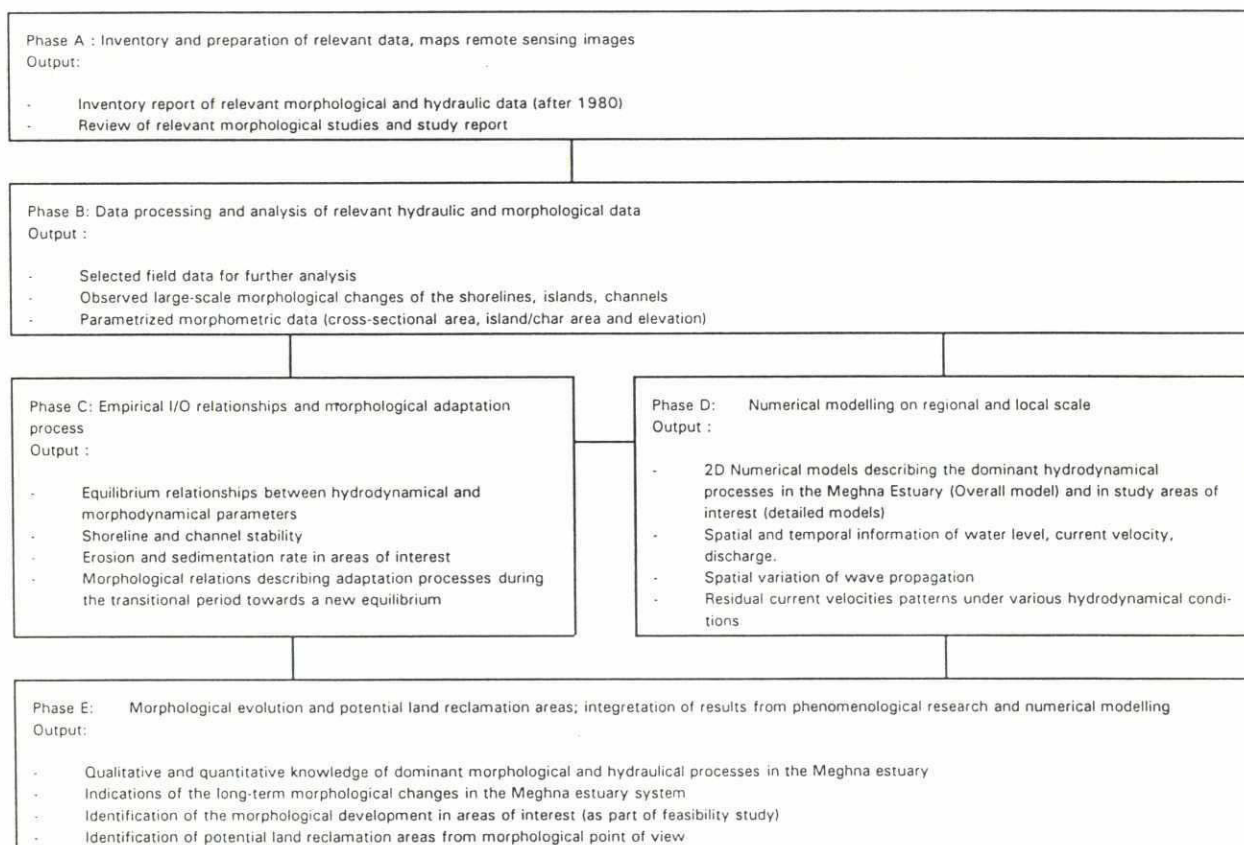


Figure A03-6.2 : Phasing of modelling activities

PHASE A Inventory and preparation of relevant data

- A.1 Inventory of available and relevant hydraulic data (water levels, discharges, current velocities, salinities) and morphological data (coastline data, bathymetric data, cross-sectional profiles, sediment transport, grain sizes). This inventory will mainly be based upon data gathered during the monitoring surveys by LRP and relevant other project surveys (see appendix D). Furthermore an inventory of relevant and available remote sensing images as well as aerial photos will be made,
- A.2 Review of relevant morphological studies and study reports (see appendix A),
- A.3 Digitization of relevant bathymetric maps and leveling data as well as of shoreline information derived from remote sensing images (1973, 1980, 1988, 1996) and aerial photos,
- A.4 Set-up of a reliable standard data-base system containing the relevant hydraulic and morphological information. If available, the LOTUS database system developed during LRP will be incorporated and updated.

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PHASE B Data processing and analysis of relevant hydraulic and morphological data

- B.1 Selection and processing of field data for further analysis
- B.2 Analysis of the large-scale morphological changes of the shoreline
- B.3 Analysis and parametrisation of relevant morphometric data (cross-sectional area, leveling data), sediment transport and hydraulic data (discharge, current velocity) and external conditions
- B.4 If available, analyse and parametrisation of relevant morphological and hydraulic data at site specific areas as part of the detailed studies

PHASE C Empirical I/O relationships and morphological adaptation process

- C.1 Investigation and determination of equilibrium relationships between hydrodynamic (e.g discharge, tidal prism etc.) and morphometric parameters (e.g cross sectional area of the channel etc.) representative for the Meghna estuary system. These relationships enable us to forecast morphological adjustments if changes occur in the Meghna estuary system or channels, whether caused by human intervention or by natural processes. In this respect results from LRP will be incorporated and updated.
- C.2 Investigation and determination of the shoreline and channel stability as well as the rate of erosion and sedimentation in areas of interest (in terms of accreted and eroded area, shoreline shifts, channel migration)
- C.3 Investigation and determination of the morphological response to input-conditions (in terms of e.g. time scale of adaptation process, trends of accretion and erosion)

PHASE D Numerical modelling on regional and local scale

- D.1 Preliminary analysis of the relevant physical processes
- D.2 Selection and composition of the model components, schematization (geometry, bottom topography, computational grids, physical input parameters, natural conditions).
- D.3 Validation of components (calibration and verification with field data). The field data needed for this operation are drawn from available information, like bathymetric maps, hydrodynamical data (water level data, discharge measurements, current velocities etc.), sedimentological data and, if necessary, additional field surveys,
- D.4 Production of hydraulic and morphological computations in terms of maximum velocity during flood or ebb conditions, water level, discharge, wave propagation (wave height and period, dissipation of wave energy), residual current velocity, sediment transport, rate of sedimentation and erosion, residual sediment transport.
- D.5 Analysis of the model results in terms of physical processes and morphological effects

PHASE E Morphological evolution and potential land reclamation areas

- E.1 Identification of the long-term morphological changes and dominant physical processes in the Meghna estuary system based upon combined analysis of results from phenomenological research and numerical modelling of hydraulic and morphological processes.
- E.2 Identification and classification of potential land reclamation areas based upon criteria from a morphological (and hydraulic) point of view.
- E.3 Identification of the morphological changes and dominant physical processes in the framework of (pre-)feasibility studies (such as Nijhumdip, South Hatia, South Bhola, Sandwip and Muhuri accretion area)
- E.4 Interpretation of morphological changes and (indicative) prediction of future changes based upon results of phases C and D.

The following results of the morphological study should be aimed at:

1. An inventory of available and relevant morphological and hydraulic data.
2. A reliable data system containing available and relevant morphological and hydraulic data using standard spreadsheet software and GIS-facilities. This data system has to be updated regularly.
3. An initial assessment of the overall (long term and large scale) morphological development of the Meghna Estuary area, as a result of the present governing hydromorphological conditions and as a result of possible changes in these conditions due to various natural processes.
4. Identification of the morphological development and processes at site specific areas in the framework of (pre-)feasibility studies
5. Identification and priority ranking of potential land reclamation areas from a morphological point of view based upon morphological and hydraulic criteria.

7 PROGRESS BY END OF MARCH 1996

7.1 Data collection

- A screening has been made of the data and information available from LRP, and a part of the data have been copied to the MES office. The information includes a large number of study reports, which are listed in Enclosure A
- Bathymetry charts from BIWTA have been compiled, and water level data have been ordered. Meteorological data have been ordered from the Meteorological Department
- A LANDSAT mapping of the entire MES area was made on 09 and 18 February 1996. Data have been received via EGIS, who is presently undertaking geo-correction and digitising of land contours

Further, a screening has been initiated of a number of other marine investigations or study components have been carried out or are in progress in the estuary, such as for example

- 2nd Coastal Embankment Rehabilitation Project (CERP II) (BWDB) (1988-91)
- Pussur-Sibsa River and Karnafuli Entrance (Ministry of Shipping, GoB) (comprising marine field surveys, numerical hydraulic modelling) (1989-92)
- Cyclone Protection Project II (BWDB) (comprising topographic field surveys, and numerical hydraulic modelling) (1990-91)
- SW Area Water Resources Management Project (FAP4) (FPCO) (comprising numerical hydraulic modelling) (1991-93)
- Cyclone Shelter Preparatory Study (Local Government Engineering Department) (comprising topographic and marine field surveys, numerical hydraulic modelling) (in progress, November 1995 - August 96)

As indicated, some of these investigations have comprised small or comprehensive field surveys, and numerical hydraulic simulation.

Geographically adjoining FAP projects are FAP4 (SW Area Regional Study), FAP5A (SE Area Regional Study), FAP5C (S Area Regional Study) (not yet initiated), and FAP9B (Meghna Left Bank Strengthening). The River Survey Project (FAP24) does not cover the Lower Meghna.

FAP18 (The topographic mapping project within the FAP programme) is expected to be in possession of a substantial amount of data of interest to MES. An inquiry is pending on the availability of these data.

A new phase of the Coastal Embankment Rehabilitation Project (CERP) is scheduled for implementation in 1996. This project may produce data of interest to MES (and may in turn have an interest in the data produced by MES).

7.2 Field reconnaissance and geodetic survey

The following activities were initiated or completed:

- A field reconnaissance of reference points for DGPS positioning and BIWTA water level bench marks was carried out from January 19 to February 12, 1996. The geodetic survey, establishing the coordinates of the MES reference points and bench marks, started on February 20, 1996. This activity was delayed by the period of political unrest so that, by end of March, about one third of the work had been completed. The work was resumed on April 6, 1996

- MES Survey Guidelines and MES Data Processing Guidelines have been drafted in an initial edition, intended for internal review between the data producers and the data users within the MES project organisation. The draft Survey Guidelines is included as Annex 02 to the present Inception Report

7.3 Hydraulic model set-up

The following activities were initiated or completed:

- the over-all approach, as briefly outlined in the TOR and in the Technical Proposal, was reviewed against the needs of the different applications within the project. On this basis, the approach was outlined in more detail, as presented in the Interim Inception Report
- A model of the MES study area has been established on the basis of models already available with SWMC, but in a new (600 m) grid schematization, and on a new bathymetric basis (Figure 03-7.1)

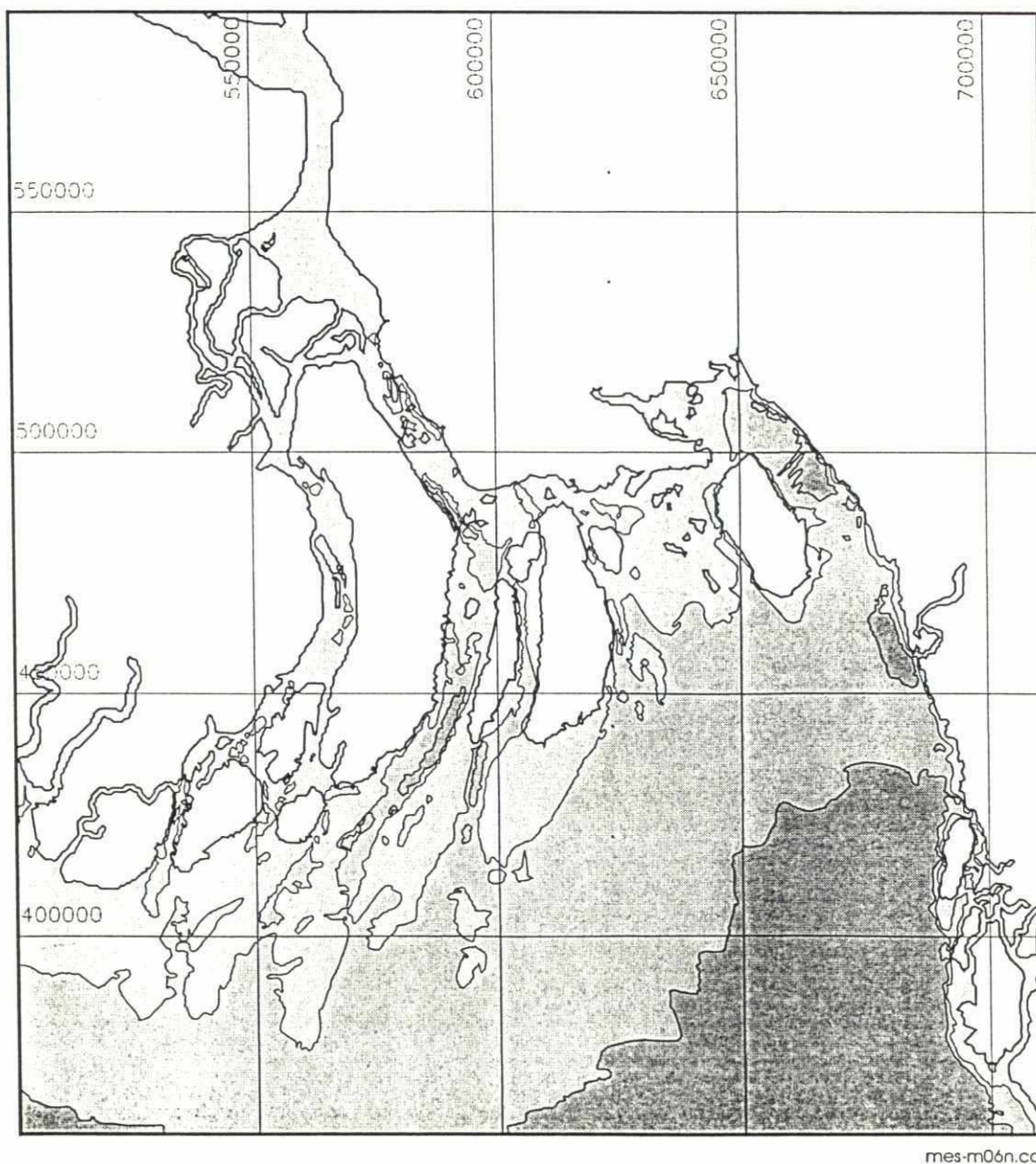


Figure A03-7.1 : Hydrodynamic model (600 m grid)

7.4 Staffing and instrumentation

The following activities were initiated or completed:

- The over-all approach, as briefly outlined in the TOR and in the Technical Proposal, was reviewed against the needs of the different applications within the project. On this basis, the approach was outlined in more detail, as presented in the Interim Inception Report
- the instrumentation of Anwesha was planned and has subsequently been discussed and agreed with BWDB. Instruments have been identified, procured, delivered and tested (in Europe). Shipment and installation will take place after completion of import clearance formalities
- the required upgrading of 'Anwesha' (comprising a tubewell for the ADCP instrument, installation of new echo sounder transducers, and upgrading of the navigation system) has been completed

ANNEX 04

LAND RECLAMATION AND CIVIL ENGINEERING WORKS

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1 INTRODUCTION

1.1 The Land Reclamation Project

In the period December 1977 - June 1991, the Land Reclamation Project (LRP) executed a considerable number of studies, and several (pilot) projects were implemented. Moreover, trials were carried out to support the studies.

The original objectives of LRP were defined as follows (quote from LRP Final Report, Section 1.2):

1. to set up an organization within the Bangladesh Water Development Board (BWDB) to carry out surveys and studies in order to develop a longterm policy for land accretion works in the south-eastern coastal area of Bangladesh;
2. to try out various methods to accelerate the accretion of land, in order to define those methods that are feasible in Bangladesh;
3. to implement an experimental test scheme with the purpose to promote a quicker and more effective use of newly gained land, so that food production is increased and conditions are viable for poor farmers.

The initial project period (until the end of 1980) was extended a number of times since it was recognized by the Netherlands as well as the Bangladesh government that planning and implementation of land reclamation works are matters of many years.

As, in the course of the project, it was felt that LRP should pay more attention to project-related feasibility studies and the implementation of specific land reclamation projects, the original objectives were slightly modified (September 1984). Since then, LRP carried out a number of (pre-)feasibility studies, in particular dealing with major works enhancing land accretion, and with land reclamation. The very high cost of effective erosion protection made that no special (pre-)feasibility studies were dedicated to this subject; erosion protection was, however, taken into account in the accretion studies.

During a DGIS appraisal mission in the end of 1990, the two governments agreed to continue LRP up to 1 July 1991 as it had been functioning till then, and to split it after that date into two components: the Char Development and Settlement Project (CDSP) and the Meghna Estuary Study (MES), together forming the Land Reclamation and Settlement Project (LRSP).

These projects should have been a continuation of LRP; but unfortunately, due to various reasons, it was not until 1 September 1994 that CDSP could start whereas the official MES starting date was 1 November 1995.

Due to lack of funds also the surveys of the Estuary by SSD came to a stop in 1991, and virtually nothing was done with the collected data.

The MES morphologists visited the BWDB/SSD Chittagong on 4 and 5 March 1996 to scrutinise the Meghna Estuary data files available there, and to collect the ones required for the MES.

Their first conclusions are as follows:

1. In the BWDB/SSD office in Chittagong a lot of valuable data and information are available, but these should be taken better care of, in particular the data on floppy disk. Until now it is unclear whether all computerized data are readable or not. A quick scan of the diskettes indicates that about 60% is readable; if this appears true, 40% of the precious data is lost.

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2. Two of the three computers were found not to function properly: one computer has a defect drive, another has harddisk problems. All diskettes and probably all three computers were heavily infected by computer viruses.
 3. No back-ups of data files are available.
 4. The available software needs updating.
 5. All bathymetric maps and coastline maps are available; bathymetric data and coastline maps are not available in Chittagong in digitized form.
 6. No computer operator is available at the BWDB/SSD office who takes care of the valuable data.
 7. Data collection has stopped in 1991.

1.2 The Flood Action Plan

Under the Flood Action Plan (FAP), some reports of a number of projects may be of interest for the land reclamation and civil engineering aspects of MES. These projects are:

- FAP-7 : Cyclone Protection Project Phase I
- FAP-8A: Greater Dhaka Protection Project
- FAP-8B: Dhaka Integrated Flood Protection Project
- FAP-9A: Secondary Town Integrated Protection Project
- FAP-9B: Meghna River Bank Protection Project
- FAP-21/22: Bank Protection, River Training and AFPM Pilot Project

It appeared impossible to get hold of all of the relevant FAP reports before the end of March 1996, the due date of the Inception Report. We think, however, that with the reports of FAP-7 and 21/22 we have had most of the FAP information relevant for MES.

1.3 General Civil Engineering Aspects; Review of LRP and FAP reports

Chapter 2 of this Annex 4 describes the general aspects of the civil engineering works that may be planned in the Meghna Estuary. These general aspects are applicable to all 18 potential priority projects mentioned in the Terms of Reference of MES.

Chapter 3 deals with most of these projects, elaborates their backgrounds, history, status, and gives a summary of the results, findings, conclusions and recommendations from a number of LRP and other reports available to MES during the preparation of the Inception Report.

2. POSSIBLE CIVIL ENGINEERING WORKS IN THE MES AREA

2.1 Introduction

Civil engineering under the Meghna Estuary Study relates to the following main groups of works, or a combination of two or all of them:

1. Erosion protection and prevention
2. Accretion of new lands
3. Empoldering, land reclamation

Most important of the civil engineering works and other interventions in this context are:

- 1a Installation of bank and toe protections
- 1b Installation of devices to reduce wave impact
- 1c Construction of groynes
- 1d Installation of flow and sediment diversion devices
- 1e Construction of cross-dams

- 2a Installation of devices to enhance settlement of sediment
- 2b Plantation of mangroves
- 2c Construction of cross-dams

- 3a Construction of embankments
- 3b Plantation of mangroves
- 3c Construction of drainage outlet sluices
- 3d Excavation of drainage channels; construction of bridges
- 3e Implementation of other infrastructural works
- 3f Construction of cyclone shelters

In the following sections these subjects will be briefly dealt with. First the three main subjects in Section 2.2, then in Section 2.3 the various civil engineering works and other interventions.

The conclusions and recommendations of this chapter will then be applied to the 18 projects specifically mentioned in various LRP reports and in the Interim Inception Report of the MES project.

2.2 The three main groups of civil engineering works

2.2.1 Erosion protection and prevention

Erosion of coasts and river banks is caused by a number of phenomena; most important are high velocity flow, waves, rapid drop of water level, non-cohesive soils, human interference.

Erosion can be prevented in a passive way, viz. by protecting the embankment by means of revetment: filter material covered with graded stones or concrete blocks sufficiently heavy to remain stable in the current and under wave attack, preventing washing out of the embankment material. Also protection of the toe of the embankment is essential to prevent bed erosion in front of the embankment and its undermining.

Erosion can also be checked indirectly, by dealing with the phenomena. Most of these can be influenced in such way that erosion stops or is slowed down. For instance:

- flow can be diverted from the bank by means of diversion structures such as groynes, by bottom or surface vanes, or by the construction of cross-dams;
- waves can be broken by mangrove plantations, by a wide shallow foreland, by parallel dams off the coast;
- human interference, such as closure of channels causing increase of flow velocity and thus erosion elsewhere, can be stopped;
- non-cohesive soils can be made cohesive by grouting (theoretical solution), or by a well-chosen vegetation with strongly developed root system binding the soil.

Rapid drop of water level due to tides cannot be prevented. It causes excess pressure in the soil and instability of the bank leading to slides or sloughing.

Measures to counter or prevent erosion are technically possible but in general the costs are so high that they are prohibitive if the land to be protected does not have a high economic value justifying the cost. In other words: the benefit/cost ratio is insufficient.

However, the social impact of erosion in the Meghna Estuary is dramatic. Large areas of good agricultural land are being lost in particular at the northern coasts of the main islands: Bhola, Hatia, Sandwip, and also of smaller islands and inhabited chars. Every year, thousands of people lose their lands and become landless. They try to resettle, on the outer slopes of embankments, on chars that are not protected from cyclones, high water and salt intrusion, or have to leave the area.

It would make sense, instead of using the Economic Internal Rate of Return (EIRR), a Socio-Economic IRR (SEIRR) could be taken into account so that erosion protection would become feasible and the loss of valuable agricultural lands and homesteads could be prevented. Refer to Main Report Section 4.5.

2.2.2 Accretion of new lands

Whereas heavy erosion occurs along the coast of the northern parts of the islands and along the mainland, substantial accretion occurs to the south of the islands and along the Noakhali coast. The Terms of Reference for FAP 5B, Meghna Estuary Study dated 9 November 1992, states the following:

"While there appear to be potentials to gain new land in the estuary of the Meghna (.....) the natural increase during the last two centuries has been almost negligible. This is shown by comparing the Rennell map of 1779 with the present situation (.....). Even if some net accretion appears to have taken place over the last few years, this may represent a temporary stage of an essentially oscillating phenomenon.

In the absence of any convincing evidence to the contrary, it must be assumed that, if the area is left unattended, the dynamic processes of erosion and accretion will continue without any net gain in land, that tidal waves and cyclones will continue to claim their regular toll and that the environment will be full of risks for human settlement and unattractive for investments which could induce economic growth" (ToR Section 3.2).

If this is true, then the conclusion must be that land accretion has to be promoted, and the land once accreted should be preserved.

Accretion may occur in areas with low flow velocities and a certain sediment content in the water. For settlement of sediment there should be a decrease in sediment gradient: ds/dx must be negative.

By reducing the velocity of the flow sufficiently, the sediment transport capacity will decrease exponentially and the sediment may settle.

Flow velocities can be reduced by means of small scale interventions: the installation of screens or the plantation of mangroves on chars falling dry during low tide. This may also be achieved by the implementation of major interventions: the construction of cross-dams through tidal channels to stop the through-flow; only tidal flows filling and emptying the channel up to the dam remain.

Tests have confirmed what was known already: that only there where natural accretion is ongoing small scale interventions can be successful. Mangroves and screens help accretion of new lands but do not prevent erosion of old lands.

Planting of mangroves on young chars is in general done by the Forest Department and has proven very successful. However, unless there are good reasons why the (interested) population should not carry out such afforestation themselves, possibly with the help and under supervision of this Department, this should be stimulated. Also the installation of sediment settlement promoting devices should preferably be done by the people of the area.

The environmental report of the South Hatia Cross-dams Feasibility Study (June 1990, Dr. A. Atiq Rahman and Dr. Saleemul Huq) gives an interesting description of **char land formation**, applicable to the entire Meghna Estuary. Below, we condense Chapter 4 of the report.

There is a generally consistent pattern of char land formation in this area which occurs naturally as well as with human interaction. This interaction may be formal (Forest Dept.) and informal (people).

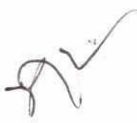
The local names for such chars reflect the stage of formation. When a char rises above low tide water level it is called "Kak Char" (Crows' Land), implying that crows (and seagulls) hover over it to catch the fish and small aquatic animals trapped on the land at low tide.

Once the land becomes somewhat consolidated, a salt tolerant variety of grass Cynodon dactylon or "Dubla" starts to grow, followed by another grass, related to rice: Oryza coarctata or "Urir dhan". The char is then called "Urir char". People will come to cut the grass and use it as fodder, thatching or fuel. This vegetation binds the soil to its roots and being very fibrous it acts as a consolidating factor in soil formation, and adds to the organic content of the soil.

If the Forest Department does not take possession, the people will bring their livestock to graze on the Urir dhan in daytime. This has opposite effects on the soil consolidation. On the one hand trampling loosens the soil so that it will be washed away by the high tide more easily. On the other hand, the grass is trampled and integrated into the soil, what enhances soil consolidation.

When the land is considered to be fully formed it is settled officially by the Ministry of Land and is often named after the name of the District Commissioner at the time of settlement. However, the Forest Department takes possession of the island when the island is considered suitable for growing salt resistant mangroves, e.g. Sonnerata apetala or "Keora" and Avicenna officinalis or "Gewa". These are grown on the island in nurseries protected by small bunds; the saplings are planted systematically over the island. The forest is thinned every five years.

The above is particularly interesting if we use remote sensing techniques to get an insight into the development of the chars over the years. Especially when a char has attained a certain level, survey by ship is not possible. Moreover, a survey now does not say anything about the development in the past. But, by comparing aerial photographs and satellite imagery taken at different points of time over a period of for instance 20 years, we can see how a char has developed and we can assess the level of the char in relation to the sea level (low, high or high high tide) at the time of the photo by studying the vegetation. Of course, a land survey is necessary for "calibration" of the features of the photographs and satellite images. It will be possible to distinguish between chars without vegetation at all, with first vegetation (dubla and urir dhan), mangroves, agriculture, settlement, etc.



Remote sensing techniques, in combination with study of bathymetric data around the char over a number of years will give us a clear idea whether reclamation of the char or group of chars is already feasible or better can wait for some time, or is not feasible at all because of progressing erosion. It will show us whether charland is still being flooded frequently, sufficiently high for grazing or already occupied either by settlers or by the Forest Department. In the context of MES, the grazing stage is the most interesting. Once the Forest Department has started afforestation it will be late for human settlement.

2.2.3 Empoldering, land reclamation

Generally speaking, a polder is a (low-lying) area, surrounded by an embankment, where the water level is more or less controlled. If the water level outside (sea) is continuously higher than inside the embankment (polder) the only way to drain the water from the polder is by pumping. This is the case in more than half of the area of the Netherlands. Pumping is, however, expensive and should if possible be avoided. In Bangladesh, empoldering is postponed until the area is high enough to allow gravity drainage.

Once a char in the Meghna Estuary has attained a certain level, in general some 2.0-2.5 m above mean sea level it can be considered ripe for empoldering. Already amply before that stage, the char will be occupied by landless people.

If the water levels outside a polder are fluctuating frequently, as is the case in the Meghna Estuary due to tides, it is possible to drain the water from the polder during low water stages under gravity, without pumping. The drainage channel then has to be provided with a gated outlet sluice that closes at high tide and thus will keep the sea water out, and opens automatically at low tide when the outside water level falls below the water level inside the polder.

Summarising, the objectives of polder construction are:

- protection of the land and the crops against saline water intrusion and thus improvement and increase of crop yields;
- protection of people, animals, crops, infrastructure (housing, godowns, roads, electricity and water supply, etc.) against floods;
- possibility to introduce and maintain a good water management, including storage of fresh water for households, animals, leaching and irrigation.

However, 100% safety especially in case of cyclone, is not possible. Each design water level and each design wave height corresponds to a certain frequency of occurrence: the higher the embankment the lower the frequency of exceedance overtopping so the better the protection - but higher the construction cost. The choice of the design frequency of exceedance is a highly subjective matter; moreover, it is virtually impossible to carry out a frequency analysis of the level of surge due to cyclones because of lack of relevant and reliable data.

Boundary conditions for the design of the polder embankment, drainage facilities and other infrastructure include high and low water levels, wave heights, wind velocities and directions, soil characteristics, availability of local construction materials, rainfall and evaporation.

Due to so-called "unavoidable circumstances" the planned visits to BWDB and other authorities to investigate the design criteria for sea embankments could not be made. At a later stage these criteria and other relevant data will be collected. Section 2.3.8 further elaborates the construction of embankments.

2.3 Various civil engineering works and other human interventions

2.3.1 Bank and toe protections

The installation of bank and toe protections are the most direct way to combat erosion. A good bank protection consists of a revetment:

- that prevents the flow from washing out bank material;
- that remains stable under the most unfavourable conditions, i.e. a combination of strong current, heavy wave attack, rapid pressure fluctuations, settlement and liquefaction of the material under the revetment; and
- that resists destructive actions of men, animals, vegetation and elements (e.g. UV radiation).

In an area like the Meghna Estuary, where the banks of mainland and islands are exposed to the forces from the open ocean and the soils in general are unstable, an effective bank protection is difficult to design and install, and very costly.

Construction of a bank protection without protecting the adjacent river/sea bed against scour is money spoilt. However, a good bed protection is generally speaking even more difficult to make than the revetment of the bank. Except under very special circumstances, the bed protection has to be installed under water, and often the work is handicapped by high waves and strong current. In particular the installation of the filter, be it gravel/stones, fascine mattress or geotextile, is not easy; dumping of stones or concrete blocks without underlying filter is useless. A bed protection has to be flexible and sufficiently long: it must follow the bed erosion along its outer edge down to the bottom of the scour hole. It is obvious that an effective bank/bed protection, especially under the conditions in the Meghna Estuary, cannot be low cost. To the contrary, such a protection is extremely expensive.

This is confirmed by the tests under FAP-21/22. These tests are located in and along the Jamuna River. They are being implemented with various slope and toe protections. The provisional conclusion of these tests is that the cost of a good slope and toe protections is excessive, and the annual maintenance also is very costly.

The protection of the toe and the under-water-slope of an embankment serve to withstand scour and wave action. However, also the part of the slope above high water level may need protection: against waves and against erosion by rain and wind if the embankment material is non-cohesive and unstable. The same goes for the inner slope. A good slope protection above high water can be provided by grass sowing or, better, by turfing. If this is not possible for instance because the grass does not grow, concrete tiles may be required.

2.3.2 Measures to reduce wave impact

The enormous energy of high waves exerts very strong forces on the revetment of an embankment. It is therefore important to take measures to have the wave energy absorbed as much as possible before the embankment is reached.

A very good method of breaking wave energy is afforestation with mangroves on a sufficiently wide strip of char off the bank or embankment. Planting mangroves serves other purposes, too; please refer to Section 2.3.7.

Wave heights can also be reduced by a sufficiently high foreland outside the embankment: the waves will brake at a certain distance from the embankment and lose most of their energy.

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Wave run-up can be limited by means of a well-chosen revetment of the embankment. Lower wave run-up may make it possible to reduce the crest level of the embankment.

An effective and very expensive method to protect a coast or embankment against direct wave attack is the construction of a "detached breakwater": an off-shore dam parallel to the coast. In the case of MES this is probably a theoretical option, because very expensive.

2.3.3 Groynes

Groynes are dams more or less perpendicular to the bank, protruding into a channel. Installation of groynes is a method to keep the erosive flow in the channel at a distance from the bank or embankment, and thus to prevent erosion. Construction of a number of groynes along for instance the outer curve of a channel may be less expensive than the installation of a full bank and bed protection over the same length as where the groynes are built. In general, groynes will not make the revetment of the embankment and the bed protection superfluous, but less expensive.

The construction cost of the groynes themselves is most considerable, not in the last place because of the bottom protection around the head of the groyne required to protect the groyne against heavy scour and undermining. A good design can reduce the scour depth very considerably; very effective is to make the groyne permeable over its full length or part of it. Even with this knowledge, it is not easy to make a good design for a groyne and a groyne system.

The design of groynes should be done with caution. Experience acquired in other projects has to be taken into account, all relevant characteristics of the construction site have to be collected, and possibly mathematical and/or physical models have to be built to avoid bad surprises as much as possible.

FAP-21/22 designed, on the basis of ample surveys and model testing, different types of test-groynes and constructed a group of them along the Jamuna River. The experience with these groynes was very instructive. Serious erosion took place at unexpected locations and heavy damage was the result. The tests showed also that the river behaved differently than expected after model tests; the embankment in between the groynes was significantly attacked.

2.3.4 Low-cost flow diversion devices

If it is possible to control the direction of the flow of water and of sediment into a wanted direction, it is possible to check or reduce erosion by diverting the aggressive flow away from the river bank, and to initiate or enhance the settlement of sediments by diverting the flow of bedload towards it.

Relatively low-cost systems of flow diversion, the so-called bottom vanes, are being used successfully in various countries. However, although the theory is simple, it is not sure that under certain conditions the systems will work.

DHV Consultants designed bottom vanes for a major hydraulic system in Nepal, for the diversion of bed load sediment. They have been installed and function satisfactorily and in accordance with the calculations. In various places in the USA bottom vanes are being used to check erosion.

FAP-21/22 proposed (floating) surface vanes to divert the river flow and thus facilitate the closure of river channels. However, these vanes were not installed and tested in practice. Test of bottom as well as surface vanes is planned under the MES programme of small scale interventions; please refer to Chapter 4.3 of this Annex.

2.3.5 Cross-dams

LRP carried out feasibility studies for the construction of cross-dams in two locations: Sandwip-Noakhali mainland and South Hatia-Nijhum Dwip/South Hatia-Damar Char, and reportedly initiated investigations into the feasibility of cross-dams between South Bhola and the southerly chars; however, no evidence could be found of such investigations.

In spite of the major advantages of cross-dams: enhancement of accretion, check of erosion, facilitation of communication, improvement of safety, the conclusion was that the construction of the N.Sandwip and S.Hatia dams was economically not justified at that moment (1986 and 1990, respectively). The donor, the Netherlands Government, informed the Bangladesh Government in 1988 that they and other donors were still interested in principle in financing the Sandwip Cross-dam, but that a number of actions had to be taken before a new appraisal mission would be sent. With regard to South Hatia Cross-dam, there was no follow-up in that time since LRP came to an end' mid 1991.

Cross-dams are again included in the MES programme, and the main objective of the construction and running of three local 2-D hydrodynamic models is to forecast the development of the actual situation in the sea areas around North Sandwip, South Hatia and South Bhola. If the results are promising, and if it appears from surveys that the accretion of the chars in those areas has sufficiently progressed so that the construction of the cross-dams has become less complicated/expensive, then the implementation of one or more of the dams may become economically feasible. Therefore, the old feasibility studies for Sandwip and South Hatia Cross-dams will be reviewed and updated, and a pre-feasibility study for South Bhola may be carried out.

We refer also to Sections 3.3, 3.8 and 3.15.

2.3.6 Devices enhancing accretion

In areas where natural accretion already takes place, the char formation may be speeded up by the installation of devices that promote sediment settlement.

LRP carried out accretion enhancing tests along the coast north of Chittagong. Later, it appeared that the choice of the locations had been wrong. The entire coast concerned is subject to a cycle of erosion and accretion; areas of accretion alternate with areas of regression, and these areas move over the years in northerly direction.

Sedimentation fields have been and still are an important tool in reclaiming land from the sea. For instance along the German and the Netherlands north coasts, the Schleswig-Holstein (SH) method has been used during centuries and still is being used, and many thousands of hectares of new land have accreted and could be empoldered. Condition for success is that there is a substantial sediment content in the water, and that natural accretion, even very slow, takes place. Trying to reclaim land from the sea in eroding areas, by installation of accretion promoting devices, is useless.

In various areas in the Meghna Estuary accretion is taking place, sometimes at a very high rate: this is the case along the coast of Noakhali mainland, and in the char areas south of Bhola, South of Hatia and north-west of Sandwip.

We intend to implement the accretion enhancement tests include in the MES Terms of Reference, in one or more of the above areas. Please refer to Section 4.2 of this Annex where the accretion tests are further elaborated.

For completeness' sake, we mention here planting of mangroves as an effective way to promote accretion. Refer further to Section 2.3.7 below.

2.3.7 Afforestation with mangroves

The Forestry Department is planting mangroves on developing chars as soon as their surface level is so high that they emerge part or most of the time from the water. Mangrove forests have a multiple function:

- promotion of land accretion;
- protection against wave attack and consequent erosion;
- protection of crops against salt water spray during storm;
- provision of firewood and construction material.

Contrary to what is stated in some reports, mangrove forests do **not** protect against storm surge and tidal bore. Neither can mangroves check erosion other than caused by wave attack.

It seems that in places where afforestation has taken place, settlement of people or cultivation is impossible, until the time that the forest is cut down entirely - if this ever happens. If mangrove plantations would be restricted to the edges of the chars, settlement of more people would be facilitated. However, this issue has to be studied and discussed with the authorities concerned: in the first place Forest Department and Thana Administration.

In the LRP feasibility report on South Hatia/Nijhum Dwip Cross-dam project, mangroves are seen as the vegetation preceding the development of the soil into agricultural land: mangroves are cut, stumps and roots are removed and the lands are prepared for the first (salt resistant) crops. However, according to some foreign and national biologists, lands on which mangroves have grown would for several decades be unsuitable for any form of agriculture, due to the extreme acidity of the soil and the changed soil structure. This statement will have to be checked thoroughly since, if found true, will completely change the outcome of the LRP feasibility analysis.

2.3.8 Embankments

Embankment construction is, after land accretion, the next step to empoldering and reclamation of new land. The primary functions of a sea embankment are:

- keeping salt water out of the polder;
- keeping high water (flood, surge, bore, waves) out of the polder;
- keeping sweet water reserves inside the polder.

The positive results of adequate embankment construction are:

- it provides a certain degree of protection against flooding to the people, animals, crops and infrastructure (100% is impossible: refer to Section 2.2.3 of this Annex);
- it makes good water management inside the polder possible;
- it protects the sweet water resources inside the polder from contamination with saline water and sediment;
- it encourages investments in the polder.

The negative result of embankment construction is that the natural accretion stops. However, as empoldering should wait until the char level has become sufficiently high so that inundation and thus accretion, takes place only a few times a year, this negative effect is very limited, and is amply outweighed by the advantages.

The design criteria for embankment construction will be discussed with the BWDB and other authorities as soon as possible. As far as we can see it now, the assessment of the crest levels of embankments in the Meghna Estuary will be based on rather high frequencies of occurrence, for instance once in 20 or 50 years, because of practical and economic considerations.

In consequence, cyclone shelters will have to be included in the empoldering and reclamation works of charlands.

A vast experience has been built up with the construction of polder embankments and land reclamation in the Meghna Estuary. MES will review this experience and apply it where appropriate. This means that, for instance, we will review the method applied to assess crest levels. Instead of using the purely empirical way by taking over embankment design and level from nearby existing embankments, we will check whether for existing embankments calculations have been made on the basis of measured data, frequency analysis and theory. The results will be compared with what has been constructed in the area. Where deemed necessary, we will formulate recommendations for strengthening or raising the existing embankments. Where new embankments are to be made the designs will be made on the same basis.

Plantation of mangroves on a sufficiently wide strip of land off the (future) embankment, at the windward side, will help to protect the embankment against wave attack, and the crops against salt water spray during storm. With mangroves on the fore-shore, the wave run-up will be lower and the slope gradient can, probably, be somewhat steeper than usual for these highly incoherent soils. Moreover, the mangrove wood has a high economic value as fuel wood and building material.

2.3.9 Drainage channels and outlets; other infrastructural works

Drainage of the polder area is a crucial aspect of the water management: not only should saline water be kept out, but it is also necessary to drain off the surplus water inside the polder. Often, the natural drainage channels and gullies of the pre-polder time can be used after some reprofiling. Additional channels can be made to improve drainage. Crossings (culverts or bridges) have to be considered as part of the drainage network. It is important to allow cattle, sheep and other domestic animals to cross channels at certain locations prepared for that, and to prevent them to destroy the already unstable banks of the drains by crossing at random places.

The drainage water has to be removed from the polder during low stages of the tide outside. BWDB has implemented many drainage outlets, open or as culverts, with flap gates that open automatically when the sea water level falls below the polder water level. Slide gates may be applied at the polder side of the outlet for storage of sweet water. We will review the BWDB designs and where necessary adapt them to the local situation.

Experience shows that a point of concern with outfall structures in the Meghna Estuary (and not only there) is constituted by the rapid siltation of the outside channels. We noticed several such structures that could not operate anymore due to huge amounts of sediment deposited in front of the automatic gates and obstructing their operation.

According to Section 3.3 (Rationale) of the Terms of Reference one of the main components of MES is

The preparation of a comprehensive plan for flood protection and (for) the improvement of the internal water management of the coastal islands included in the study area; (.....). In principle all inhabited islands in the area are included, notably Sandwip, Hatia. However Bhola is excluded from considerations of internal area development (.....).

Many more infrastructural works are required for full polder development. Without going into detail we mention:

- feeder and rural roads;
- water and electricity supply, and telephone networks; sewerage systems;
- public buildings, such as cyclone shelters (see Section 2.3.10), mosques, community centres, schools, godowns,
- private buildings and utilities: houses, sheds, workshops, shops,

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These aspects will be dealt with in the studies concerning the development of empoldered areas, which will be part of the (pre-)feasibility studies to be carried out.

2.3.10 Cyclone shelters

A reason to mention cyclone shelters specifically in a separate section of this Annex, is that

their importance even in a polder is not to be under-estimated. As discussed in Section 2.3.8, it will not be possible to construct embankments to such level that the polder is safeguarded from flooding due to cyclones. The same as on Noakhali mainland, in areas behind embankments, cyclone shelters will have to be provided to the people who will settle in the newly reclaimed areas.

2.4 Reports dealing with civil engineering & land reclamation - References

This Section 2.4 gives an overview of the following categories of reports and other data relevant for the civil engineering and land reclamation aspects of the Meghna Estuary Study.

1. LRP and other studies dealing with the 18 initially identified Priority Projects;
2. LRP and other studies dealing with specific civil engineering and land reclamation subjects;
3. Several FAP reports.

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No.	Name Scheme	Reports relating to study			
		numbers in 3rd column refer to LRP Final Report Reference List and list reports collected at CDSP office Noakhali [() = not available yet]			
1.	Six Polder Scheme				(not included in MES)
2.	Urir Char Polder				Recent morphological developments in Urir Char area (Mar'86)
3.	Sandwip X-dam	1.	LRP	49	TR 18: Recomm. to measures to protect to protect Sandwip and Hatia against erosion - feas. stude (Apr'84)
		2.	LRP	139	Draft proposal EC/DHL for feas. study on construction of X-dam Sandwip -Noakhali (Jul'84)
		3.	LRP	31/140	TR S1; Feas. study Constr. X-dam; proposal geotechn.invedtings; visit De Wit (Oct'84)
		4.	LRP		Report on frasibility of geotech. investigations; Delft Lab. of Soil Mechanics (Oct'84)
		5.	LRP	141	TR 19: Tidal comp. for pre-feas. study on measures to protect Sanwip & Hatia islands against erosion (Dec'84)
		6.	LRP		Hydro-sediment. field survey Pre-monsoon 1985; Part I-data collection, recommendations; DHL R1331, draft (?1985)
		7.	LRP	(142)	Risk analysis first stage; Rijkswaterstaat, Dir. Sluizen en Stuwen (Jan'85)
		8.	LRP	144	Inception Report feasib. study (May'85)
		9.	LRP	33/143	TR S2: Resources for and execution of construction (May'85)
		10.	LRP	150	Stabililty of clay-filled gunny bags, Invest. report R11331-40 Delft Hydraulics (May'85)
		11.	LRP		Interim report feasibility study (Jun'85)
		12.			Hydr. conditions of closure gaps; report on computations; DHL R1331-30 (Oct'85)
		13.			Geulsluitingen; grondmech. en hydraulische grenstoestanden; RWS, S&S (Dec'85)
		14.	LRP		Economics and social studies, Bangladesh consultants team (Dec'85)

Table A04-2.1 : Summary of existing LRP and other studies relevant for MES

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No.	Name Scheme	Reports relating to study			
		<i>numbers in 3rd column refer to LRP Final Report Reference List and list reports collected at CDSP office Noakhali [] = not available yet</i>			
3.	Sandwip X-dam	15.	LRP	151	Preogess report Feas. study (Jan'86)
		16.			Results of revised Netflow computations DHL; revised (Jan'86)
		17.			Hydraulic and morphological investigations (Jan'86)
		18.	LRP	149	Soiltech Int. Report on geotechn. investigations in connection with Sandwip-noakhali X-dam BWDB (Jan'86)
		19.	LRP	152	Progress not on design of closure dams (Feb'86)
		20.	LRP		Geotech. and hydrodynamic design considerations - Presentation by BUET Dhaka (Mar'86)
		21.	LRP	153	Review and comments on draft Final Report of Feas. Study of June'86 (Sep'86)
		22.			Preliminary comments on draft Final Report (20 Sep'86)
		22a.	LRP		Comments on draft Final Report of June 1986 (23 Nov'86)
		23.	LRP	56	TR 25, 25A-F: Topogt, bathymetr. and hydro-sedimentological surveys in period end 1984 to mid 1986 (Jan'87)
		24.			Tidal propagation in Sanwip Channel; paper Barua/Koch (Jan'87)
		25.	LRP		Final Report, feas. study on Sanwip X-dam devt. scheme; executive summary and 4 volumes (May'87)
		26.	LRP		Comments on Final Report (Oct'87)
		27.	LRP	155	Report of Review Panel (Jul'88)
		28.	LRP		Draft report on Visit to Delft Laboratory to study possible effects of proposed Sanwip X-dam (Jan'88)
		29.			Issues for preparation and implementation (Mar'88)
4.	S-E Sandwip Polder				

Table A04-2.1 : Summary of existing LRP and other studies relevant for MES (cont.)

952

No.	Name Scheme	Reports relating to study			
		numbers in 3rd column refer to LRP Final Report Reference List and list reports collected at CDSP office Noakhali [() = not available yet]			
5.	Feni Polder				(not included in MES, but support to be given to CDSP if required)
6.	Char Boya X-dam		CDSP	24	CDSP 24 Preliminary report on Remgati Boyer Char X-dam (Feb'88)
7.	Char Nurul Islam				
8.	S.Hatia/Nijhum Dwip X-dam	1.	CDSP	10	Inception report on Hatia-Nijum Dwip X-dam (Oct'87)
		2.	CDSP	18	Nijhum Dwip & South Hatia X-dam, Pre-feasib. study report (Apr'88)
		3.	CDSP	14	Nijhum Dwip/S.Hatia X-dam; construction aspects - tour report Te Slaa (May'88)
		4.	LRP	(120)	Nizumdwp X-dam feas. study, results of surveys and hydraulic/morph. studies (Aug'88)
		5.	CDSP	9	Feas. study, prop. for Nijhum Dwip X-dam, Pl.&Mon. Cell, Off. Superint. Eng, Estuar.Survey; 1st draft (Apr'89)
		6.	LRP	124	Feas. study, prop. for Nijhum Dwip X-dam, Pl.&Mon. Cell, Off. Superint. Eng, Estuar.Survey; 1st draft (Apr'89)
		7.			Nijhum Dwip X-dam and S.Hatia development; workplan & cost est. for feas. study in 1989/90 (Nov'89)
		8.	LRP	(83)	TR 52: Soil & land use on S.Hatia/Nijhum Dwip; supplement to Feas. study (Feb'90)
		9.	CDSP	17	Nijhum Dwip & Damarchar X-dams, draft tender documents LRP Estuarine Circle BWDB Dhaka (Mar'90)
		10.	LRP	?	Feas. study on S.Hatia X-dams, Draft (Apr'90)
		11.	LRP	78	TR 47: Feas. study on S.Hatia X-dams; environmental report (Jun'90)
		12.	LRP	136	Feas. study on S.Hatia X-dams, Final (Dec'90)

Table A04-2.1 : Summary of existing LRP and other studies relevant for MES (cont.)

20

No.	Name Scheme	Reports relating to study			
		numbers in 3rd column refer to LRP Final Report Reference List and list reports collected at CDSP office Noakhali () = not available yet			
9.	Hatia Bank Protection	1.	LRP	49	RT 18: Recommendations to measures to protect Sandwip and Hatia Islands against erosion; feas. study (Apr'84)
		2.	LRP	50/14 1	TR 19: Tidal comput. for pre-feas. study on measures to protect Sandwip and Hatia Islands against erosion (Dec'84)
		3.	LRP	139	TR139: Recomm. measures to protect Sanwip, Hatia against erosion; pre-feas. study; prop. for feas. study (Jul'84)
10.	N.W.Hatia X-dam		LRP	115	Report on hydrographic surveys, erosion Hatia North; LRP Survey & Study Division (Jan'87)
11.	Manpura Polder				
12.	Gazaria Polder				
13.	N-E Bhola Bank		LRP	68	TR 37: Estuary development information system, hydraulic and morphological estuarine conditions; draft (May'90)
14.	West Bhola Bank Protection	1.	LRP	68	TR 37: Estuary development information system, hydraulic and morphological estuarine conditions; draft (May'90)
		2.	CDSP	30	Report of National Committee on erosion of Bhola; IWDFC (Apr'88)
15.	South Bhola X-dams	1.	LRP	68	TR 37: Estuary development information system, hydraulic and morphological estuarine conditions; draft (May'90)
		2.	LRP	131	South Bhola development schemes, reconnaissance survey; Planning Cell (May'90)
16.	Ramgate polder				(Not included in MES)
17.	Sudharam Drainage				(Not included in MES)
18.	Ramdaspur X-dam				

Table A04-2.1 : Summary of existing LRP and other studies relevant for MES (cont.)

26

FAP no.	Title of FAP Report	Subjects of Relevance to MES with Reference
FAP 4	Southwest Area Water Resources Management Project, Final Report Aug-1993	Volume 2 Hydraulic studies Hydraulic modelling studies: overall modelling strategy and detailed description of data, development, calibration, application of hydrodynamic model. Volume 4 Coastal studies Volume 7 Forestry and Navigation Volume 8 Engineering : Integrated water management, flood control drainage and irrigation.
FAP 7	Cyclone Protection Project II - FAP 7, Feasibility and Design Studies , Final Project Preparation Report, May 1992	Volume 2 Annex II - Engineering Analysis General information about hydrological and hydraulic aspects, design of embankment and hydraulic structures. Volume 3 Annex XII - Polder Data Data on engineering inventory of the already existing projects in different polders. Appendix A - Hydraulic Studies Data collection of water levels and wave heights and their statistical analyses. Preliminary mathematical model study of cyclonic surges. Volume 1 Main Report Embankment, protective works, hydraulic structures, afforestation.
FAP 9A	Secondary Towns Integrated Flood Protection, Final Report, April 1992	Main Report - Volume 1A General description on flood protection, river bank erosion, drainage, river erosion protection works.

Table A04-2.2 : Summary of existing FAP reports of interest for MES

206

FAP no.	Title of FAP Report	Subjects of Relevance to MES with Reference
FAP 9B	Meghna River Bank Protection, Short Term Study, February 1992	Volume 1 Main Report (Final Report) General description on the river training, bank protection works and associated investigations, studies, design and construction methods Volume II to V - Annexes Hydrology, river morphology and geomorphology, geotechnical investigations, scale model studies, mathematical model studies, river bank protection
FAP 21/22	Bank Protection and River Training (AFPM) Pilot Project FAP 21/22 , Draft Final Report Planning Study, December 1992, January 1993	Volume 1A - Main Report on Bank Protection FAP 21 Discussion on bank protection methods, type of structure, construction methods and materials, design methods, design of bank protection works, study of alternative design methods. Volume 1B - Main Report on River Training (AFPM) FAP 22 General information about hydrologic, hydraulic and morphological aspects and the river training. Volume VII - Annexes 15 to 21 Scour investigations near groynes in outer bends, design of cover layer and filter layer of revetments, dimensioning of groynes; constructional materials, methods and equipment used mainly in groynes and revetment works; and study of alternative design solution.

Table A04-2.2 : Summary of existing FAP reports of interest for MES (cont.)

207

Technical Subject	Reports Relating to Technical Subject
Erosion, Erosion Control	Coastal Erosion West-Africa, Inventory of Coastal Problems Based on Nedeco's Project Experience in the Region. Report Prepared for UNESCO WACAF/3 Project, March 84
	National Committee on Erosion of Bhola, April 88
	Recommendations on Measures to Project Sandwip Island and Hatiya Island Against Erosion. Report on a Pre-feasibility Study by E. Stamuis and J.J van Wijngaarden, April 84
	Report of the National Committee on Erosion of Bhola, April 88
	Report on Hydrographic Surveys Erosion Hatiya North, June 87
	TR-18, Recommendations on Measures to Protect Sandwip Island and Hatiya Island Against Erosion, Report on a Pre-feasibility Study by E.Stamuis and N.J. van Wijngaarden, April 84
	TR-19, Tidal Computations on Behalf of a Pre-feasibility Study on Measures to Protect Sandwip Island and Hatiya Island Against Erosion. Report on Computations by C. Flokstra, Dec 84
Bank Protection Revetment Toe Protection	TR-18, Recommendations on Measures to Protect Sandwip Island and Hatiya Island Against Erosion. Report on a Pre-feasibility Study by E.Stamuis and N.J. van Wijngaarden, April 84
	TR-19, Tidal Computations on Behalf of a Pre-feasibility Study on Measures to Protect Sandwip Island and Hatiya Island Against Erosion. Report on Computations by C. Flokstra, Dec 84
River Training Groynes	Volume 1B - Main Report on River Training (AFPM) FAP 22 General information about hydrologic, hydraulic and morphological aspects and the river training. Volume VII - Annexes 15 to 21 Scour investigations near groynes in outer bends, design of cover layer and filter layer of revetments, dimensioning of groynes; constructional materials, methods and equipment used mainly in groynes and revetment works; and study of alternative design solution.
Land Accretion, Reclamation	Bangladesh Training Programme in the Processing of Landsat Digital Data for Land Accretion, Boro rice Inventory and Forestry Applications. Bangladesh Landsat Programme; Aug-79
	Hydrology and Accretion in the Area of Char Batir Tek, Martin Bos, Practice Report, Bangladesh, July 1986
	Land Reclamation and Estuary Control in Bangladesh, Proforma for Survey of Development Project Jan-81
	Land Reclamation and Estuary Control in Bangladesh. Proforma for Survey of Development Project, Dec-77
	Land Reclamation and Shore Protection Project, Mar-86
	Land Reclamation Project Sandwip Cross-dam, Geulsluiting, grondmechanische en hydraulische grenstoestanden

Table A04-2.3 : Summary of existing LRP and FAP studies on general technical subjects

207

Technical Subject	Reports Relating to Technical Subject
Land Accretion, Reclamation	Land Reclamation Project Sandwip Cross-dam, Risk analysis, First Stage Jan-85
	Measurement of Land Accretion in the Coastal Zone of Bangladesh by the Analysis of Landsat Digital Data. Final Report , Jul-81
	Muhuri Accretion Reconnaissance Identification Study Land Reclamation Project, Executive Engineer Planning & Monitoring cell, Estuarine Survey, BWDB Dhaka, Jun - 90
	Nijhum Dwip & Damarchar Cross-dam , Land Reclamation Project Tender Documents , Tour report of Mr. G. Te Slaa Mar-90
	Report on a Practical Period Spent at the Land Reclamation Project, Bangladesh from September 1986 to May 1987 by Herman Bergama Sep-86
	Study of Aspects of Land Accretion in the coastal areas , Md. Matiur Rahman, Md. Hedayet Hossain Mar-87
	TR-12, Land Reclamation on Char Baggar Dona Research Plot Activities 1981/82 Aug-83
	TR-13, Land Reclamation on Char Baggar Dona Soil Salinity Investigations 1979 - 1982 , Report on a Visit by Dr. L.K. Smedema Oct-83
	TR-15, Basic Considerations on the Morphology and Land Accretion Potentials in the Estuary of the Lower Meghna River. Report on a Study by W.D. Eysink Dec-83
	TR-17, Basic Considerations on the Morphology and Land Accretion Potentials in the Estuary of the Lower Meghna River, Dec-83
	TR-20, Proposal for a Long - Term Plan on Land Reclamation and Estuary Control, Dec-84
	TR-23, Evaluation of Accretion Trails (Sedimentation Fields) Along the Chittagong Coast in Bangladesh. Report on a Study by A.E.R. Beeker, Jun-85
	TR-3, Land Accretion Trials Along the Coast of the Chittagong District and the Reclamation Research Plot on Char Baggar Dona (Noakhali District). Report on a Site Visit by IR. R.J.De Glopper, Nov-80
Cross Dams	A Cross-dam in the Coastal Region of Bangladesh. Geotechnical and Hydrodynamic Design Considerations by Muhammed Humayun Kabir, Muhammed Monowar Hossain, Presented at the 30th Annual Convention of the Institution of Engineers, Mar-86
	Comments of the Final Report of the Feasibility Study on Sandwip Cross-dam Development Scheme, Oct-87
	Comments on the Draft Final Report of the Feasibility Study on Sandwip Cross- dam Development Scheme, June 1986, Nov-86

Table A04-2.3 : Summary of existing LRP and FAP studies on general technical subjects (cont.)

289

Technical Subject	Reports Relating to Technical Subject
Cross Dams	Feasibility Study on Construction of a Cross dam between Sandwip Island and Noakhali Mainland. Progress Note on the Design of the Closure Dams, Feb-86
	Feasibility Study on Construction of a Cross-dam Between Sandwip Island and Noakhali Mainland. Draft Proposal, Jul-84
	Feasibility Study on Construction of Cross-Dam between Sandwip Island and Noakhali Mainland. Hydraulic and Morphologic Investigations, Jan-86
	Feasibility Study on Construction of a Cross-dam Between Sandwip Island and Noakhali Mainland, Inception Report, Mar-85
	Feasibility Study on Construction of a Crossdam Between Sandwip Island and Noakhali Mainland, Draft Proposal, Jul-84
	Feasibility Study on Construction of a Sandwip-Noakhali Cross-dam in Bangladesh. Results of Revised Net-flow Computations (Modification of Draft Report of January 1986), Jan-86
	Feasibility Study on Construction of a Sandwip-Noakhali Cross-dam in Bangladesh , Results of WAQUA Computations I, Jan-86
	Feasibility Study on Construction of a Sandwip-Noakhali Cross-dam in Bangladesh , Results of WAQUA Computations II, Jan-86
	Feasibility Study on Construction of Cross-dam Between Sandwip Island and Noakhali Mainland , Progress Report Jan-86
	Feasibility Study on Construction of Cross-dam, Between Sandwip Island and Noakhali Mainland, Jan-87
	Feasibility Study on Sandwip-Noakhali Cross-dam, Economic and Social Studies, Dec-85
	Feasibility Study on South Hatia Cross-dam, Environmental Report, Dr. A. Atiq Rahman , Dr. Saleemul huq, Jun-90
	Feasibility Study on South Hatia Cross-dams, Dec-90
	Feasibility Study on South Hatia Cross-dams, Apr-90
	Feasibility Study on the Sandwip Cross-dam Development Scheme, Executive Summary, Final Report, Mar-87
	Feasibility Study on the Sandwip Cross-dam Development Scheme, Vol - II, Final Report, Mar-87
	Feasibility Study on the Sandwip Cross-dam Development Scheme, Vol. - I, Main Report, Final Report, Mar-87
	Feasibility Study on the Sandwip Cross-dam Development Scheme, Vol. -III, Final Report, Mar-87
	Feasibility Study on the Sandwip Cross-dam Deveopmnet Scheme, Vol -IV, Final Report, Mar-87

Table A04-2.3 : Summary of existing LRP and FAP studies on general technical subjects (cont.)

MM

Technical Subject	Reports Relating to Technical Subject
Cross Dams	Feasibility Study of Sandwip Cross-dam, Stability of clay-filled Gunny Bags, Report on Investigations, Dec-85
	Feasibility Study of South Hatia Cross-dam, Feb-90
	Feni River Closure dam (Part of Muhuri Irrigation Project), Final Design Report, Sep-83
	Nijhum Dwip / South Hatia Cross- dam, Construction Aspects, May-88
	Nijhum Dwip Cross-dam and South Hatia Development, Workplan and Cost Estimate for a Feasibility Study in 89/90, Nov-89
	Nijhum Dwip Hatia Cross-dam, a Report on Reconnaissance Survey, Mohiuddin Ahmed, Mar-87
	Nijhum Dwip and South Hatia Cross-dam, Pre-feasibility Study, Apr-88
	Nijhum Dwip Cross-dam and South Hatia Development, Workplan and Cost Estimate '89/90, Nov-89
	Nijhum Dwip Cross-dam Feasibility Study, Results of Surveys and Hydraulic/morphological Studies, Second Draft, (Including Revised Chapters 3.3, 4 and 5 of Mr. te Slaa's Report on the Construction Aspects), Aug-88
	Pre-Feasibility Study of Nijhum Dwip and South Hatia Cross-dam, Apr-88
	Preliminary Comments on the Draft Final Report of the Feasibility Study on Sandwip Cross-dam Development Scheme, June 86
	Preliminary Report on Ramgati Boyer Char Cross-dam, by Abdul Khaleque & ATM Khorshed Alam (Draft, 17.9.87), Sep-86
	Report of the Review Panel Sandwip Cross-dam Development Scheme, Jul-88
	Report on the Construction of the Feni River Closure-dam Aug-86
	Review and Comments on the Draft Final Report of the Feasibility Study on Sandwip Cross-dam Development Scheme Sep-86
	Sandwip Cross-dam, Report on the Feasibility of Geotechnical Investigations, Oct-84
	Sandwip Cross-dam Development Scheme, Issue for Preparation Implementation, Mar-88
	TR-25, Feasibility Study on Construction of a Cross-dam Between Sandwip Island and Noakhali Mainland, Topographic, Bathymetric and Hydro-sedimentological surveys in the Period end 1984 to mid 1986 , Jan-87
	TR-47, Feasibility Study on Hatia Cross-dam, Environmental Report, by Dr. A. Atiq Rahman & Dr. Saleemul Huq, Jun-90

Table A04-2.3: Summary of existing LRP and FAP studies on general technical subjects (cont.)

Technical Subject	Reports Relating to Technical Subject
Cross Dams	TR-S1, Feasibility study on Construction of a Cross-dam Between Sandwip Island and Noakhali Mainland, Bangladesh. Proposal for Geotechnical Investigations by J.M.de Wit, Oct-84
	TR-S2, Feasibility Study on Construction of a Cross-dam Between Sandwip Island and Noakhali Mainland, Bangladesh. Resources for Execution of Construction, May-85
	Visit to Delft Laboratory, Holand, to Study the Possible Effect of Proposed Sandwip Cross-dam, Draft Report
Hydraulic Structures	TR-42, Review of the Hydraulic Design of Drainage Sluices , Dec-89

Table A04-2.3 : Summary of existing LRP and FAP studies on general technical subjects (cont.)

3 THE 18 POTENTIAL PRIORITY PROJECTS IN A NUTSHELL

3.1 Introduction

The Terms of Reference for the Meghna Estuary Study mention a number of potential priority projects that should be considered in MES. These projects were selected by LRP in 1988. Some of them were studied in detail, up to feasibility level; others were not studied but just identified.

This chapter deals with most of the 18 projects, elaborates their backgrounds, history, status, and gives a summary of the results, findings, conclusions and recommendations from a number of LRP and other reports available to MES during the preparation of the Inception Report.

The 18 projects are the following; Figure A04-3.1 gives an overview of their location.

- 1 Six Polder Scheme
- 2 Urir Char Polder
- 3 Sandwip Cross-dam
- 4 South-east Sandwip Polder
- 5 Feni Polder / Muhuri Accretion
- 6 Char Boya Cross-dam
- 7 Char Nurul Islam Polder
- 8 South Hatia/Nijhum Dwip Cross-dam
- 9 Hatia Bank Protection
- 10 North-west Hatia Cross-dam
- 11 Manpura Polder
- 12 Gazaria Polder
- 13 North-east Bhola Bank Protection
- 14 West Bhola Bank Protection
- 15 South Bhola Cross-dams
- 16 Ramgati Polder
- 17 Sudharam Drainage
- 18 Ramdaspur Cross-dam

The following potential projects are considered to be situated outside the project boundary, and are therefore not included in the Meghna Estuary Project:

- 1 Six Polder Scheme
- 16 Ramgati Polder
- 17 Sudharam Drainage

The other 15 potential priority projects will be dealt with below one by one.

For easy reference the sections dealing with these 15 projects have the numbers of the projects; this means that there are no Sections 3.16 and 3.17, whereas the Projects 13 and 14 have been combined in Section 3.13.

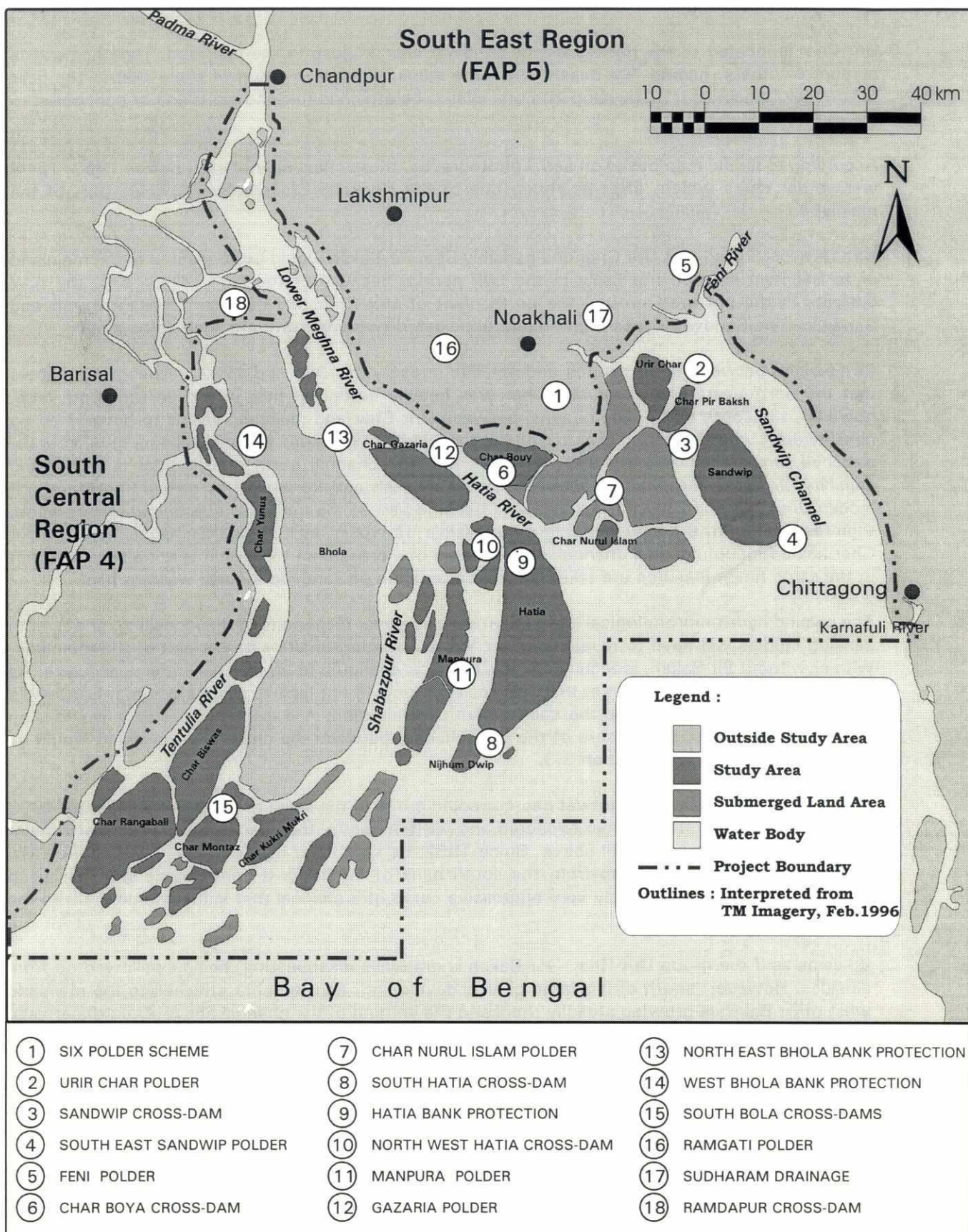
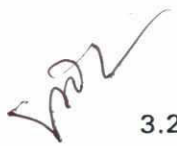


Figure A04-3.1 : Location plan of LRP priority projects



3.2 Urir Char Polder

Urir Char is located to the north-west of Sandwip Island, close to the mainland. Together with a number of others, named "Pir-Baksh" on some maps, it forms a group of chars that in the near future may remain as it is, develop into one island, be attached to Sandwip Island or connected to the mainland.

According to an old map based on aerial photographs, these chars did not exist before 1967. There were other chars which, after accretion due to the Noakhali Cross-dams, now are part of the mainland.

Natural accretion so that Urir Char and possibly Char Pir-Baksh would be connected to the mainland or to Sandwip seemed not likely in the LRP period, because of the high velocities of the tidal currents in the channels around the north point of Urir Char and between Char Pir-Baksh and Sandwip. The Sandwip Cross-dam project anticipated two important channels to be closed.

Comparison between aerial photos and satellite imagery of 1984 and 1992, respectively, shows that the north-eastern bank of Urir Char was heavily eroded in that period. In the same time, however, the south end of the channel between Urir Char and mainland seems to have silted up considerably, whereas a long char in 1984 in the middle of the same channel appears to be virtually attached to the mainland in 1992. It seems that the channel north of Urir Char is fast losing capacity, whereas the channel between Char Pir-Baksh and Sandwip has gained importance. If indeed Urir Char and Char Pir-Baksh would become part of the mainland due to natural accretion, then reclamation of the new land might be feasible. However, as long as the channel north of Urir Char has a function as tidal channel, construction of a cross-dam through it is not advisable if not in the same time measures are taken to prevent erosion of Sandwip's north-western bank.

The coming hydro-morphological and bathymetric surveys, the results of the modelling, and remote sensing studies will have to reveal whether the reclamation of Urir Char as part of the mainland, with or without Pir-Baksh, is technically feasible or is expected to be feasible in the near future. As said earlier, the first condition is that this reclamation will not lead to more erosion at Sandwip's north-west coast than will be the case without reclamation. A Sandwip Cross-dam would stop further erosion there, but closure of the tidal channel between the chars and the island would be a major undertaking; see Section 3.3.

On 21 March 1996 the first, not yet geo-corrected prints of the satellite images of 9 February 1996 became available. Different than expected and written above, the channel around the north point of Urir Char appears to be still active. Since 1992, its south end has formed a curve to the east, at the cost of Pir-Baksh. Also from the south bank of Pir Baksh a considerable strip has been scoured away by an apparently very aggressive curve of a channel that shifted some 6 km to the north over the last 12 years.

It seems as if the group Urir Char - Pir Baksh is gradually disappearing, being swallowed up from all sides. However, south of it a large char is developing, and the char attached to the mainland west of Pir Baksh is growing steadily thanks to the shifting of the channel above. Even the erosion at Sandwip's north coast has stopped and a char is developing there.

Conclusion

As far as we can see it now, reclamation of Urir Char - Pir Baksh seems not attractive any more; it still might be considered in the wider context of a Sandwip Cross-dam; refer to Section 3.3. However, the chars around Char Lakhi west of Pir Baksh seem to develop fast and to be stable at this moment. We propose, therefore, to give preference to a study of the possibilities of promoting accretion and eventually reclaim the char in front of Char Lakhi.

3.3 Sandwip Cross-dam Project

A pre-feasibility study on the Construction of a Cross-dam From Sandwip Island to Noakhali Mainland (December 1983) concluded that there was a clear scope for such dam: it would stop the serious erosion of the north-west coast of Sandwip.

It would lead to the accretion of some 22,000 ha of new land, good for the settlement of some 25,000 landless peasants with their families. During a mid-term review meeting in September 1984, the Bangladesh and the Netherlands government decided to engage into a full feasibility study. The tentative picture of accretion of new land 10 - 15 years after the completion of Sandwip cross-dam is shown in Figure A04-3.2. (Source LRP)

The objectives of the feasibility study were, in short:

- to study the technical viability of a cross-dam between Sandwip Island and Noakhali mainland, and to prepare a design and cost estimate;
- to evaluate various construction methods and select the most cost-effective one(s);
- to study the morphological effects of the cross-dam: positive effects (accretion) as well as negative (erosion, drainage, navigation);
- to study the environmental impact;
- to study the technical viability of land reclamation and development of new land, assuming that this land will be allotted to really landless peasants, and to prepare designs and cost estimates;
- to evaluate the financial, economic and social feasibility of this development scheme.

The LRP consultants and other institutions carried out several studies at feasibility level, and produced a considerable number of reports on the Sandwip Cross-dam Development Scheme; see reference list on the next page. Other, more general studies, in particular surveys and modelling, contributed to the knowledge of the physical processes of the Meghna Estuary as a whole and of the area between Sandwip and the main land in particular. The Draft Final Feasibility Study Report was issued in June 1986.

The Ministry of Foreign Affairs, Directorate General of International Cooperation (DGIS) of the Netherlands convened a meeting between representatives of the prospective donors and of the Government of Bangladesh in the Hague (25-26 September 1986) to discuss the Final Report. In order to formulate provisional comments on the draft report, MIWDFC organised on 20 September 1986 an interministerial meeting in which various ministries, authorities and institutes participated. The final version of the Comments, dated 23 November 1986, comprises a considerable number of observations of the various ministries participating in the meeting. The definitive Final Feasibility Report of March 1987 takes these comments into account. Beside a number of positive findings, a crucial conclusion of the Final Report is:

(.....) that from an economic point of view the project would not be attractive because of the high cost involved in the construction of the cross-dam. (.....) Even when the social benefits of the project are taken into account quantitatively, the Internal Rate of Return is still not very high. Yet, the project is attractive from a social point of view because it offers the opportunity to continue on a large scale a unique process of land development (.....) which may have a great positive impact on the landless people in the project area.

(Main Report, Section 2.3, last paragraph).

In view of the conclusion that the economic feasibility of the project was not promising, the Netherlands government in concurrence with other potential donors decided that an independent Review Panel should study, evaluate and review the Sandwip Cross-dam project proposal as laid down in the Final Report, so as to provide interested donors with an objective and well-founded analysis of the project.

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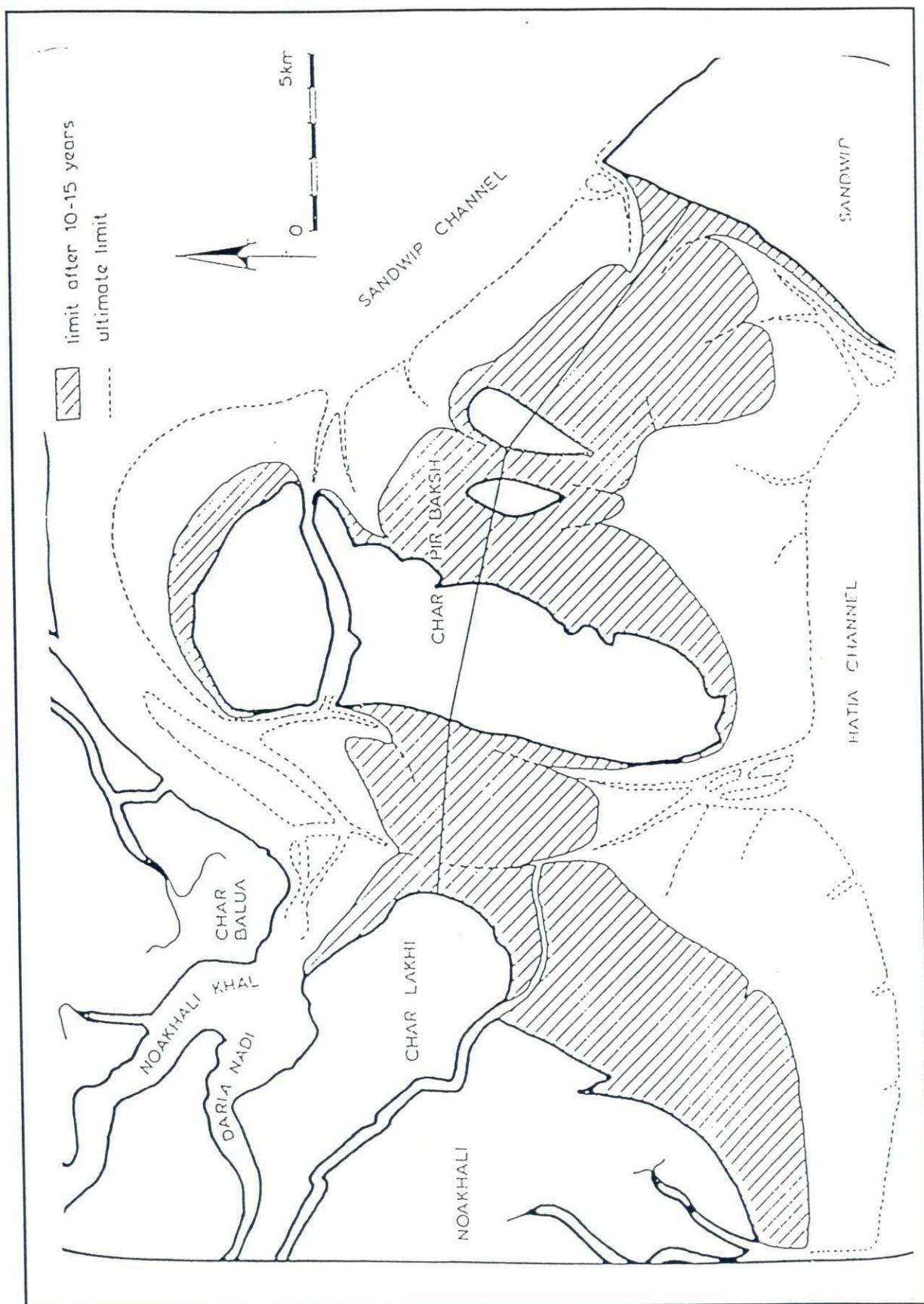


Figure A04-3.2 : Possible accretion after construction of Sandwip cross-dam (acc. to LRP)

The Review Panel Report was issued in July 1988, and the Netherlands Embassy Dhaka sent it to MIWDFC by letter No.4953 dated 6 September 1988 with, among other, the following comments:

(.....) As can be seen from the report, the recommendations of the mission are, especially as regards the project for Cross Dam construction and reclamation settlement, not positive. The cost-benefit ratio as well as the morphological situation do not justify an early start of the project; a number of issues are still to be sorted out and, last but not least, it can be concluded from the report that the equitable distribution of newly accreted land among the landless in the project - the most important issue to the donors - is not adequately assured. (.....)

If the donors who were interested before the start of the panel mission are still prepared to follow up the project, an appraisal will have to be postponed and can only take place after a number of issues have been sorted out.

In the opinion of some or most of the donors a number of reasons play a role in postponing the appraisal:

- 1. possible morphological changes resulting in decreasing water depths which in medium term might facilitate dam construction considerably and might reduce the construction costs substantially (.....) This requires improvement of the hydrological and morphological database;*
- 2. promising land reform procedures still have to be tested in practice;*
- 3. the position of the Ministry of Land vis a vis the project needs to be clarified, especially on the matter of assurances concerning land distribution. The Ministry's commitment to implementation of the new policy is still to be demonstrated. There should be a manual for land allocation and this particular point has to be agreed upon by GoB and donors;*
- 4. different settlement methods have to be tried out in newly reclaimed polders before settlement on the large scale foreseen in the cross dam project is started;*
- 5. the role of the upazilla in reclaimed and settled polders and in the cross dam project needs to be clarified and elaborated;*
- 6. the issue of the size of the land holdings needs to be clarified. There are discrepancies between the regulations and the practice in the pilot polder on Char Baggar Dona; the Government prescribed 0.8 ha plots fail to meet subsistence requirements of the average family in Bangladesh;*
- 7. there is a need for clarification of the responsible agency for agricultural extension;*
- 8. the desalination rates need a more precise estimation;*
- 9. the lack of adequate credit programmes and of a component covering off-farm employment;*
- 10. the roles of the lead agency have to be clarified;*
- 11. the roles of the various NGOs to be involved in the project need to be clarified;*
- 12. an independent evaluation of the present land reclamation project has to be carried out.*

It was clear from the consultations that some donors feel more strongly on one of the above issues, while others have more reservations on other points. E.g. the high technical construction risk was stressed. Also the insufficient clarity provided by the Government as regards its commitment to the project in general and land distribution in particular was cited. Besides, some issues not covered by the report (e.g. an environmental impact assessment and construction costs) might need to be clarified for some donors. In view of these opinions, the very low rate of return of the project, and the above cited 12 reasons preclude the possibility of an early start of the appraisal. (.....)

The clarification needed, summarized in the points cited above will require quite some effort. As you are aware the Land Reclamation Project (LRP) is continuing its activities until the end of 1989. The present Plan of Operations for the project is sufficiently flexible to allow work on at least part of the issues mentioned in these points. However, it will make quite some demands on the Bangladesh authorities involved and on the Netherlands as donor in LRP.

Despite the rather pessimistic undertones of the above paragraphs several donors remain interested in the project.

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However, if the Government of Bangladesh feels that earlier financing or another arrangement for financing the project is needed, it should pursue other financing arrangements as none of the donors involved in the panel mission can indicate willingness at this stage to finance the project(s) in the future.

All of them feel that at least two donors should be involved in such a complex undertaking. (.....)

As far as could be found out, hardly any actions have since been undertaken to meet (part of) the requirements of the donors as expressed in the report of the Review Panel, summarised in the above-cited letter of the Netherlands Embassy. The technically most important suggestion: that improvement of the hydrological and morphological database is required to assess the morphological changes, has not been taken up. Actually, the marine surveys continued for some time but the results were not processed. In 1991, at the end of LRP, the surveys came to a virtual stop.

Actually, the report of the Review Panel makes the following statement:

Little information can be found in the Feasibility Study about calibration of the mathematical models. However, a lot of difficulties have been mentioned in the Study and this gives rise to doubts over accuracy, since no comparison between measurements in the field and calculations has been included.

*The panel is fully aware that it is seemingly impossible to get full insight into the hydraulic conditions of the estuary. Despite the comprehensive field investigations which have been carried out and which are still ongoing, **the data base has to be assessed as extremely weak.***

Inconsistencies still exist regarding simultaneous measurements of tidal elevations, tidal velocities and discharge conditions and, in addition, bathymetry and chart datum.

(.....) it is self-evident that a model can only be as accurate as its data inputs, and these are still incomplete. (Section 3.3.2 of the Review Panel Report)

Taking into account the timing of the survey and modelling activities during the Meghna Estuary Study (MES), an assessment whether the morphological and hydraulic situation has changed sufficiently to justify a new study of the technical and economic feasibility of the Sandwip cross-dam development scheme will not be possible before May 1997. In the meantime, we will carefully review the available hydro-morphological data (of 1991 and before) and the results of the model studies, and assess their quality and usefulness.

Apart from these technical considerations, there are many other issues dealt with in the Review Panel Report and summarised in the Embassy letter of 6 September 1988. In the time that the existing hydro-morphological data and calculations are reviewed, and new surveys are carried out, the issues regarding agriculture, land distribution and social aspects, policy, institutional framework and social planning, economic and financial aspects, will have to be dealt with.

As said in Section 3.2, the satellite images of February 1996 show that the area to the north-west and west of Sandwip is changing rather dramatically. It is questionable whether a cross-dam had between Sandwip and the mainland (Char Lakhi) would have stopped the development of the channel south of Char Pir Baksh, since 1984 some six kilometres shifted northward.

It is obvious that without modelling forecasting of the developments in this most dynamic environment is impossible; even with a good model the results will have to be considered as an indication rather than as the answer.

Conclusion

The 1987 Sandwip Cross-dam feasibility study should be updated taking into account the morphological development that has taken place since the study, and with a critical review of the (socio-) economic analysis.

3.4 South-east Sandwip Polder

Reportedly, along the south-east coast of Sandwip Island, chars are being formed. The main tidal channel is obviously situated more to the east. Whether this is a situation that will remain stable is hard to say with certainty; however, as far as we can see now there are no reasons to expect major changes in this situation for the first decades from now, provided that no human interference disturbs the situation.

On the other hand, the Accretion and Erosion Map (See Figure A04-3.3) shows some erosion that has taken place along the north-east bank in the period 1972-1991; erosion of the entire west bank in the same period was more serious: some 1.5 km.

Land accretion downstream of Feni Closure Dam (Muhuri accretion) and a possible reclamation of Urir Char and Char Pir-Baksh (PP-2) are not likely to have any influence on the natural development of the south-east coast of Sandwip. On the other hand, the construction of the Sandwip Cross-dam by which the important tidal channel between Sandwip and Char Pir-Baksh would be closed, may result in (enhanced) erosion of the island's east coast due to the increased tidal volume passing through Sandwip Channel.

Hydro-morphological and bathymetric surveys, and the results of running the 2-D hydrodynamic models will have to provide clearness in the various options: no interference at all, reclamation of Urir Char, reclamation of Urir Char and Char Pir-Baksh, or construction of the Sandwip Cross-dam.

Conclusion

It seems unlikely now that South-east Sandwip polder will be included in the list of Priority Projects for which further studies will be made. Certainty about this view will be obtained after the hydrodynamic models have made their first runs.

3.5 Feni Polder / Muhuri Accretion

This project concerns rather the large area accreted since the closure of the Feni River, than the Feni Polder situated at the mouth of the Little Feni River.

The Muhuri area is already occupied by settlers and being cultivated to some extent. The Char Development and Settlement Project (CDSP) is studying the feasibility of empoldering and reclaiming the higher areas of the chars.

Conclusion

In March 1996, MES has given support to CDSP regarding the morphological aspects of this project during the preparation of the pre-feasibility report. MES will give further assistance as needed in the feasibility phase.

3.6 Char Boya Cross-dam

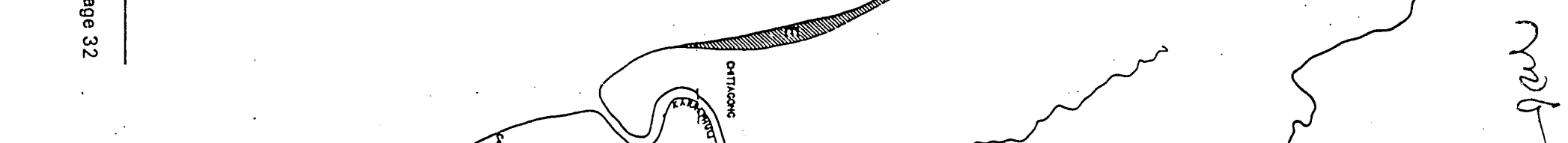
Char Boya is situated close to the Noakhali mainland, opposite Char Majid, Char Bagardona and Char Bamja. The second char and part of the first one have been empoldered and reclaimed after the accretion had reached a sufficient level, whereas the last one, according to the Accretion and Erosion Map 1972-91 (see Figure A04-3.3) is subject to erosion.

Char Boya was not there in 1972 but has developed in the 20 years since to a char of about 4,500 ha. How the development has been in the period 1991-96 will have to be investigated.

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From visual inspection on the spot, early February 1996, it appeared that the channel between the mainland and Char Boya has become almost non-existent. Standing at the end of the road over the western embankment of Char Majid, we observed people wading through the channel, some 20 metres wide there, with the water reaching to their knees. However, this was during ebb; how the situation is during high tide has to be found out yet.

A first look at a print of the February 1996 satellite images, on which a part of Char Boya can be seen, suggests that the accretion has continued. Mangrove(?) plantations seem to have been extended. It is also seen that the char land east of Char Boya and Char Boya itself are only separated by a relatively narrow channel. This char land is also shifting in the direction of Hatia.

The construction of a cross-dam between Char Boya and the mainland would without doubt bring about rapid accretion resulting in Char Boya becoming part of the mainland in the near future. It depends on the flow through the tidal channel between the mainland and the char what will be the effect of a cross-dam on the flow through the Hatia Channel north of Hatia. If closure would result in a considerable increase of the flow and thus in a considerable increase in flow velocities, the erosion of Hatia's northern bank would worsen, too.

Therefore, the results from the hydrodynamic models (the general one and the one of the North-Hatia area) will have to be known before recommendations can be made as to the desirability and feasibility of a cross-dam between Char Boya and Noakhali mainland.

Conclusion

The construction of a cross-dam connecting Char Boya to the mainland seems an interesting project possibility. Morphological investigations and modelling will have to give the answer to the question whether such a project would have any negative consequences, in particular with regard to the erosion of Hatia's coast.

If modelling and investigations show that the construction of the dam will not induce negative effects elsewhere this project could be included in the list of Priority Projects for which a pre-feasibility study should be made.

3.7 Char Nurul Islam

Char Nurul Islam is located in between Hatia and Sandwip Islands. It is situated almost halfway the cross section line No.1, surveyed during the period 1979-81 for the purpose of calibrating the WAQUA model. This cross section runs from the north-east of Hatia to the mid-west of Sandwip passing via Char Shahebani and the north side of Char Nurul Islam.

No specific report or publication is available to provide any definite information about the present condition of Char Nurul Islam, though the location and existence of the char is shown in many reports, in general dealing with the surveys, plans of operation, morphological and other studies in the Meghna Estuary area.

Figure 4.1 of the Report of the National Committee on Erosion on Bhola of April 1988 and Figure 4 of the LRP Final Report of August 1991, indicate that Char Nurul Islam is still developing and that its surface is at low water level, like other chars developing in the area south and south-west of Hatia.

Extensive bathymetric survey of the area, as well as data collection and research of the morphological condition, trend of sedimentation, environmental, hydraulic and hydrologic studies are necessary to analyse and assess the present condition and find out what are the possibilities of reclamation. Possible development of Char Nurul Islam, and of other chars like Shahebani, may be included in the long term planning schedule of the MES project.

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It may be considered to implement at Nurul Islam and other chars accretion promoting works: either as small scale intervention or later. The disadvantage of carrying out accretion tests at these chars is the fact that they are difficult to reach, so the tests would be difficult to monitor.

Conclusion

Further study of the viability of empoldering Char Nurul Islam can, in this stage of MES, not be recommended. In the future, depending on the results of investigations, implementation of accretion works could be considered.

3.8 South Hatia/Nijhum Dwip Cross-dams project

South of Hatia Island, there are two smaller islands viz. Nijhum Dwip and Damar Char. According to the Accretion and Erosion Map 1972-1991 (figure A04-3.3), Damar Char did not exist yet in 1972 but was in 1991 already attached to Hatia. The construction of cross-dams between Hatia and the two other islands would stop the (minor) erosion of Hatia's south point and enhance the already very rapid accretion.

By 1988, the area outside the existing embankment amounted to 10,800 ha above a level of PWD+1.5m. viz. 6,600 ha of mangroves and 4,200 ha at PWD+2.2m. with agriculture, inhabited by 3,750 households. Some 5,200 households who lost their land at North Hatia because of erosion were then living on the South Hatia embankment.

In the same year, LRP carried out a pre-feasibility study into the possibilities of a cross-dam between Hatia and Nijhum Dwip (dam 1). This was followed in 1989 by a feasibility study including the option of another cross-dam, to Damar Char (dam 2).

The initial feasibility study was restricted to the assessment of the cost of dam construction and the estimate of the increase of agricultural production and benefits on the newly accreted lands.

The feasibility report states that the construction of the dams would be technically rather simple, and possible in two consecutive years by local contractors with a high input of local labour. The channel between Damar Char and Hatia was shallow, at low tide 0.5 - 1.0m deep, but tended to deepen locally. The channel between Nijhum Dwip and Hatia was much deeper, some 4.0m, and also tended to deepen.

Construction was planned to start at the end of 1989, but was postponed due to lack of funds. Moreover, the EIRR appeared to be low: 4-8% depending on the valuation of the newly accreted lands, an estimated 4,800 ha. Still, the Bangladesh and the Netherlands governments remained interested in the project. They decided that the feasibility study should be reviewed: additional data would be collected and the scope of the study would be widened by consideration of various options of land use off the South Hatia coast.

LRP issued the draft version of the "Feasibility Report on South Hatia Cross-dams" in April 1990, and the final version in December 1990. An Environmental Report was published in June 1990. The report states that the economic feasibility of the project is found to be low; one of the main causes is the fact that the benefits (agricultural production) will be generated only decades after the costs (construction of dams, reclamation) have been made. In this respect the Feasibility Report states the following:

(.....) Decisions on the construction of these cross-dams should be taken on other criteria than economic feasibility as well. Such other criteria may include social criteria, for example related to the availability of new land to accommodate families whose homesteads disappeared due to erosion in other parts of Hatia, and political criteria with respect to the possibilities newly accreted lands offer to allocate land to landless people.

Recognition of the above general characteristics of land reclamation projects in Bangladesh creates at least two specific problems a bilateral decision by the Government of Bangladesh and The Netherlands is confronted with and which should be taken into account in this feasibility study. (.....)

(.....) most of the benefits in addition to an increased agricultural production are difficult to express in economic terms or to quantify. (Feasibility Report Section 2.1)

The Feasibility Report concentrates on technical and economic analyses, but takes also other criteria into account in an effort to broaden the scope of the study.

Various development strategies are dealt with based on variations of three components:

- the construction of one or two cross-dams;
- the empoldering schemes;
- forestry options.

These components, in a number of variations, result in several strategies that are worked out, priced and compared.

On the other hand, several categories of impact have been taken into account, from national economic development, distribution of benefits and employment to fisheries, environment and people's perception.

After study of three dam construction options: only dam 1, only dam 2, or dams 1 + 2, the conclusion is that only the option with two dams has to be taken into account.

The report elaborates three different land development strategies :

1. Maximum forest. All newly accreted land used for forestry, no forest cleared for agriculture; no polders.
2. Minimum forest. All newly accreted land under forest, but clearance for agriculture when accretion level PWD + 2.0m. has been reached; no polders.
3. Polders. As 2., plus empoldering when level PWD + 2.2m has been reached.

These strategies are compared with the zero-option: no development, under the assumption that accretion and erosion will remain in balance, and not more land will become available for forest and/or agriculture.

Some of the other conclusions of the Feasibility Report are, summarised:

- The project contributes to the realisation of the National Development Goals with regard to economic growth, food production, employment and equity. Essential condition is a change in forest policy and proper land allocation procedures.
- Commercial forestry is not justified; a change from commercial to social forestry is recommended.
- The environmental impact of dam construction with regard to navigation/inland communication and natural hazards is expected to be positive, to bird life negligible, to provision of building material negative and to employment of fishermen "probably not detrimental" in view of the fact that the fishing grounds are already changing.
- Public response is overwhelmingly positive.
- Proper measures have to be taken to ensure that most of the newly reclaimed lands are allocated to the landless peasant families.

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The financial cost (in early 1990 prices) of construction of the two cross-dams has been assessed at (rounded) Tk 280 million: an investment of Tk 70,000/ha for an accretion due to the cross-dams of 4,000 ha. The economic cost would be about Tk 220 million.

Development of a "standard" polder of 2,000 ha would cost Tk 100.0 million financially, Tk 80 million economically, with annual O&M cost and social development both assessed at some Tk 1.5 million over the first six years and then decreasing to 0 in year 11.

The report calculates the economic costs and returns for various cropping patterns on the existing land, on new land and in polders taking into account the influence of periodical flooding, for forestry and for homestead production.

The economic analysis results in the following EIRRs:

Maximum forest:	negative;
Minimum forest:	7.3% ;
Polders:	8.9% .

It is certain that in the period of six years elapsed since early 1990, the morphological situation of the area south of Hatia has changed. How much, can only be assessed by survey: partly from a survey vessel, partly from land. Comparison of the latest and previous satellite and other data in a GIS will also help to get an insight in the development of the area. First study of the satellite images of early February 1996 gives the impression that Damar Char has grown somewhat; the area planted with mangroves has been extended substantially.

Update of the information obtained during the feasibility study from interviews with the people of South Hatia and Nijhum Dwip, is very important, too. The 2-D hydrodynamic models to be developed (one general model, one local model for the Nijhum Dwip area) will have to give a reliable insight into the hydro-morphological processes during and after the construction of cross-dams 1 and 2, respectively.

On this basis, MES will re-assess the feasibility of the cross-dam construction and polder development in the South Hatia/Nijhum Dwip area. See Figure A04-3.3 for the potential accretion in case cross-dams are constructed. (source LRP)

Conclusion

As per the Terms of Reference for MES, and in view of the fact that cross-dams connecting the two chars Nijhum Dwip and Damar Char with Hatia might appear to be an economically feasible option with very positive effects on the land accretion in the area south of Hatia, the South Hatia / Nijhum Dwip Cross-dam project will be one of the Priority Projects for which MES will carry out a (pre-)feasibility study or review an existing feasibility report.

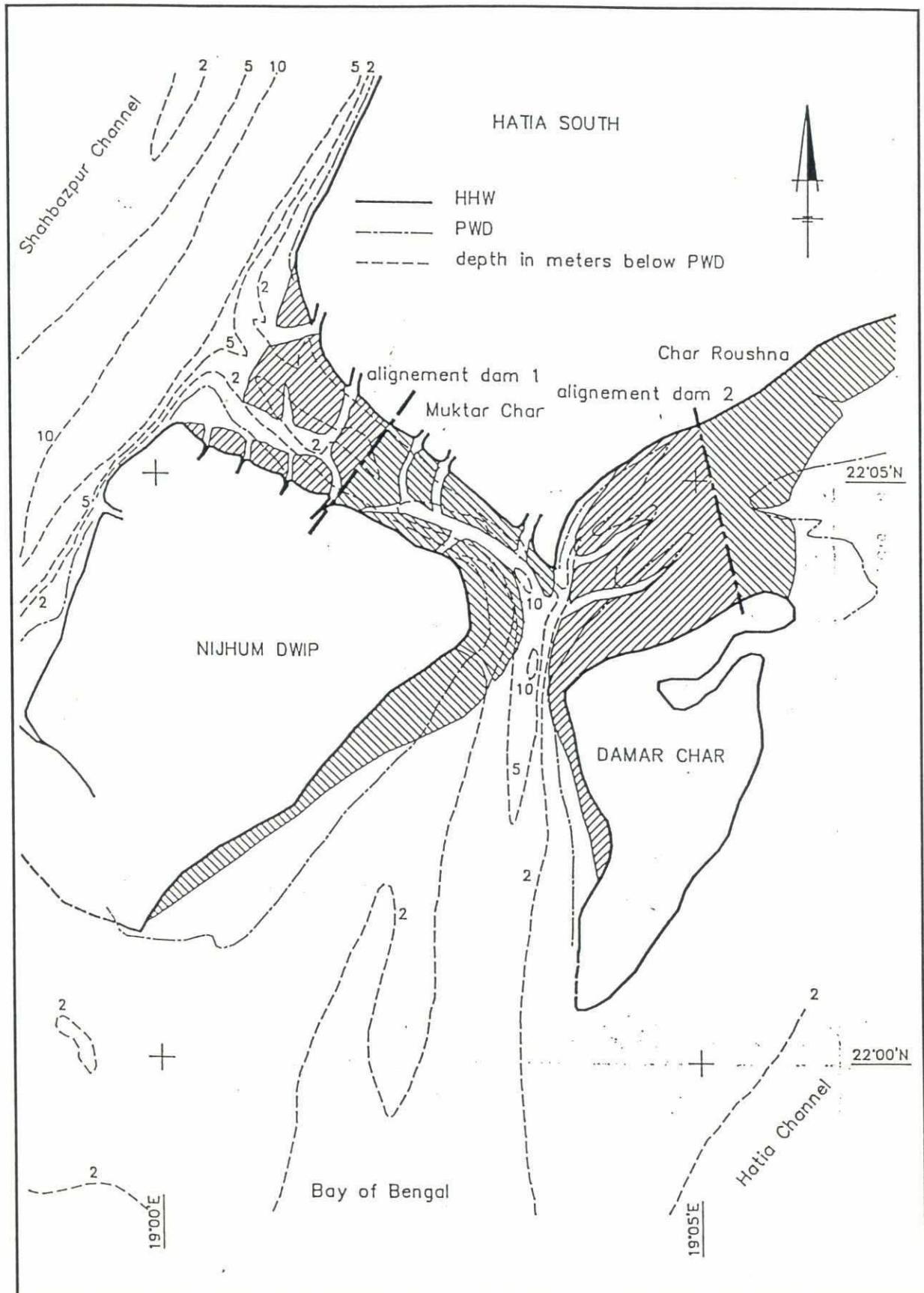


Figure A04-3.4 : Possible accretion after construction of Nijhum Dwip cross-dams (acc. to LRP)

3.9 Hatia Bank Protection

Hatia is the second largest island of Bangladesh located in the Meghna Estuary south of Noakhali mainland. The island is protected by a coastal embankment. The northern coast of the island suffers a great deal from erosion due to a complex flow pattern prevailing in the Meghna Estuary, owing to river flow from the lower Meghna as well as the strong tidal flow from the Bay of Bengal. A Report on a "Pre-feasibility Study on Measures to Protect Sandwip Island and Hatia Island Against Erosion" was prepared following an order of the Netherlands Ministry of Foreign affairs to Delft Hydraulics Laboratory in August 1982 and subsequent approval of the Government of Bangladesh in February 1983. The study report was submitted in April 1984.

The following paragraphs are a brief summary of the most important findings and recommendations of that report.

1. The general objective of the study was to search for technical solutions to stop the process of erosion on Sandwip and Hatia Islands which should fit within the framework of development of the region (Meghna Estuary) as a whole. This delta of Ganges-Brahmaputra-Meghna Rivers covering a large area of Bangladesh is highly unprotected and suffers from large morphological changes. These morphological changes are characterized by a considerable erosion at the banks of the tidal channels, whereas at the same time accretion is found in the inner bends of these channels, and the lee sides of the islands and chars. Due to this process, valuable agricultural lands, homesteads and other infrastructure are lost causing a tremendous impact on the socio-economic condition of the people.
2. It is seen from review of various maps and reports that in the period between 1963 to 1983, about 6 km of land has been scoured away from the north point of Hatia, resulting in the loss of about 46 sq.km of land.
3. In 1940 the lower Meghna River still bifurcated just north of Bhola Island. The branch of the river going towards the east discharged into Sandwip and Hatia Channels at that time, whereas the other branch was heading south and mainly discharged into Shahbazpur Channel with a secondary connection north of Hatia Island into Hatia Channel. Then and after that, the eastern branch of the Lower Meghna silted up and finally lost its function completely after the construction of the first Meghna cross-dam in 1957, which speeded up the natural siltation process in this river branch. As a result of this the other branch of the lower Meghna that is the northern reach of the Shahbazpur River has developed as the main branch. When comparing the 1940 and the 1963 situation, the major change that happened was a considerable migration of the river branch towards the west. In that period, however, the western branch of the Shahbazpur Channel and the section of the Hatia Channel north of Hatia Island widened significantly.
4. As indicated in the pre-feasibility study, the erosion of Hatia is probably caused by a widening of the bend of the tidal channel, resulting in erosion at the outer bend and sedimentation in the inner bend. Because of the decrease of the tidal amplitude in the Bay of Bengal along the southern boundary going from the east to the west, it could be expected that the discharge of the Lower Meghna would keep flowing through Hatia Channel. Therefore, the erosion at the northern coast of Hatia might continue for a long series of years, if no remedial measure is taken.
5. Bank protection would be the only way to stop the erosion. This would cost a great effort, because of high flow velocities and great depths along the coast. The pre-feasibility study report recommends the protection to be done by groynes. These groynes would have to be constructed at intervals of about 500 m along the coast over a distance of about 5,000 m and should have a length perpendicular to the coast of 100m (200m in case of sensitivity for liquefaction). The report provides figures (Fig.48 and 49) which give preliminary designs of a closed and an open groyne, respectively.

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6. The report also recommends systematic data collection during a long period, to enable the design of remedial measures to stop erosion and to increase the rate of accretion. For the erosion of Sandwip and Hatia, this means regular observations of the morphological changes in the area from Tetulia River in the west up to Sandwip Channel in the east.

The report considers the existence of a measuring service in Chittagong with the survey vessel Anwesha, in combination with the development of a mathematical model of the area, of high value and indispensable. Because the ever-changing situation has to be updated, measurements and computations should be continued; otherwise no remedial measures on any scale to improve the situation can be taken.

7. The report states that, for a good design of the technical measures to stop the erosion of Hatia, it is necessary to investigate the subsoil of the submarine bank. Undisturbed samples and laboratory tests for the research of the density properties of this soil can give a decisive answer to the question if there exists a sensitivity for liquefaction. If this sensitivity is low a technical solution is much cheaper than in case the probability for loss of stability by liquefaction is high. It is therefore recommended to do this research first. But, according to the LRP Final Report of August 1991, the recommended geotechnical subsoil investigation was not done.
8. The choice between open or closed groynes would depend on the results of laboratory research. It was recommended to start with this research as soon as possible in order to be able to design the most favourable structure. After the determination of the dimensions, the pile driving equipment could be selected and one groyne of 100 m could be constructed as a pilot project.

As mentioned in the LRP Final Report of August 1991 [reference LRP Report on Hydrographic Surveys, Erosion Hatia North LRP/SSB, January 1987] the following surveys were carried out at Hatia North:

- bathymetric and coastline surveys;
- sounding of standard cross section No.2 between Hatia North and Char Jabbar; and
- velocity and sediment content measurements in one or more verticals of that cross section.

Figure 6 of the Hydrographic Surveys Report of January 1987 shows standard cross section No.2 during the period 1983 - 1989. According to the same report, the erosion at Hatia North advanced annually some 200 to 300 metres in then recent years.

Conclusion

It is certain that the prevention of erosion along the coast of Hatia with the conventional means, viz. bank/ bed protection, and groynes, will be extremely costly. Even though valuable agricultural lands are being lost, the benefit/cost ratio is expected to be low.

3.10 North-west Hatia Cross-dam

About five kilometres of Hatia's north end, as well as a strip 15 km long and 1 km wide, disappeared in the period 1992-91 due to erosion.

To the west of north-Hatia and to the north-east of Manpura Island, a number of chars are developing. Moulovin Char and Dhal Char, the most to the north, existed already in 1972. Since, they have eroded at the north-east side and accreted towards the south. The others, between the two islands, arose later. In total the chars covered in 1991, according to the Accretion and Erosion Map (see Figure A04-3.3), an area of about 5,000-6,000 ha.

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Whereas new chars originated at a few kilometres off the west coast of Hatia, the west coast itself opposite the chars and the east coast of Char Moulovin were subject to erosion.

It is obvious that any interference in such a dynamic environment, where erosion and accretion are occurring so closely together, could bring about dramatic changes. A serious increase of the erosion rate of west Hatia's and/or east Manpura's old land might be the result.

Study of maps and satellite images of the area show that it is unlikely that a cross-dam between north Hatia and one or more of the chars would stop the problem of the erosion of Hatia's north: such a dam would not change the course of the channel between the island and the mainland.

Running of the general and the Hatia regional hydrodynamic models may give an answer whether a north-west Hatia cross-dam is worth being studied further or not.

Conclusion

As far as we can judge now, without the support of recent surveys and modelling, the North-west Hatia Cross-dam is probably not a feasible project. It contains the considerable risk of introducing erosion or other unwanted effects elsewhere. Moreover, the Cross-dam is expected to be very expensive and to have a very low EIRR.

For the time being, the results of the running of the hydrodynamic models will be awaited before a decision can be taken whether or not to include the North-west Hatia Cross-dam in the group of projects to be studied.

3.11 Manpura Polder

Manpura Island, situated between South Bhola and Hatia, has a long-stretched shape. In the length, in north-south direction, it measures about 30 km; the average width is 4-5 km. The island consists of three parts: the northern part is called Manpura, the central part Goalia or Char Sakuchi, the southern part Char Pathila. In the following we will speak about the three parts together as "Greater Manpura".

The three parts are separated by narrow channels. The population of the island tried to close the channel between Manpura and Goalia in a traditional way but reportedly failed. We will make an investigation whether this is true and, if so, why the closure did not succeed.

On the Accretion and Erosion Map (see Figure A04-3.3) it can be seen that in the period 1975-1990 the regression of the north-west coast of the northern part due to erosion amounted to some 800 metres. Five kilometres off the west coast, a double char developed in the same period; its surface area is approximately the same as that of the strip lost by erosion.

Char Pathila is, according to a Landsat image of March 1992 planted with a mangrove forest of some 1,500 ha. Over the same period, its south-west coast eroded heavily: a strip with a width of half to one kilometre was lost. Close to the coast a small char with a diameter of about 1.0 km developed.

To the south-south-west of Char Pathila, at two kilometres distance lies a small char, intersected by a channel of a few hundred metres wide and with an acreage of some 200 ha. It seems completely covered by mangroves. According to the Accretion and Erosion Map (Figure A04-3.3) the char did not exist yet in 1975.

Farther to the south-south-west, there are two more chars: a very small one, named Char Nizam, 12 km from Pathila's southpoint, of about 200 ha partly covered by mangroves and probably inhabited; surprisingly, one kilometre of its south point disappeared in the period 1975-1992, and a strip of some 500 metres accreted at its east side.

A larger char named Char Dhal lies 10 km farther away, separated from Kukri Mukri by a deep channel of 7 km width. It was in 1975 still a small circular char, with a diameter of 3 km. Due to accretion it is now 8 km long and 3 km wide, and covers about 2,500 ha. At some 4 km east of Char Dhal a new char is apparently being born.

It is clear that Greater Manpura as well as the chars south of it are continuously moving; erosion claims strips of land, and elsewhere new chars develop and grow fast. In the case of Greater Manpura the situation is not favourable. Over 70 per cent of its west bank it has lost a strip of about 800 metres, whereas no accretion took place at its east coast. The Shabazpur River is widening its bed: also the opposite coast of Bhola is eroding seriously. Why in the same time new chars are being formed in the middle of the river is not clear. And where the river widens fast accretion takes place, along Bhola's south-east coast and against the existing chars.

Conclusion

Under these circumstances it does not seem very logical to spend funds on Manpura polder. Strengthening of the eastern embankments, where no erosion occurs, is possible; but construction of new embankments along the west coast to replace the ones that disappeared might just be loss of money.

It is to be feared that the erosion will continue. Erosion prevention is expensive, and probably too expensive for the protection of such a relatively narrow strip of land. In our opinion, this project does not have much chance to be included in the final list of Priority Projects; this will, however, be verified by the running of the 2-D models.

3.12 Gazaria Polder

Char Gazaria, at the northern extremity and in the middle of Shahbazpur Channel, has in the course of a few decades developed from two chars of about 5,000 ha into a main char of 7,500 ha and a few adjacent chars; in total some 10,000 ha. This development has taken place simultaneously with the erosion of lands at the opposite sides of the channel branches: a 1-2 km wide strip along the mainland (Char Bamja) and a 2-3 km wide strip of Bhola Island. Also some 1,000 ha disappeared at the north side of Gazaria. An obvious but not confirmed conclusion is that the chars could develop thanks to the erosion across the Shahbazpur channels. In the period 1979-87 Gazaria shifted almost 3km to the west.

This situation is certainly not stable: Gazaria will change further, be eroded at the one and accrete at the other side, walk in the direction of the sea - as is the case in many places in the estuary. It depends of course on the net result and speed of accretion and erosion whether in the coming decades Gazaria will continue to grow, keep the same size or shrink and gradually disappear.

The river, under the influence of flow and floods from upstream and of strong tidal currents is continuously shaping and reshaping its bed. In spite of the increased knowledge of the behaviour of river flows, it is still impossible to forecast the developments of a young river bed on the longer run. This is demonstrated in the Meghna Estuary: coasts which a few decades ago were accreting, may now be subject to heavy erosion. Chars appear and disappear.

In view of the above, empoldering of Gazaria as part of the MES project would not be a justifiable undertaking. Erosion protection in that most dynamic environment would be very costly and would not have more than a dubious result.

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Whereas erosion protection is not feasible, protection against flooding is. Whether there are sea embankments on Gazaria, and if so what is their condition, is unknown at the moment of writing this report (March 1996). After collection of the latest available data it should be discussed whether to include Gazaria in the list of priority projects or not.

Whatever will be the outcome of the discussion, it is clear that the situation is unstable and that an embankment built now may be scoured away in five or ten years. The inhabitants of the island have to be (made) aware that, most probably, an intervention for flood protection will be a temporary solution.

Conclusion

Inclusion of Gazaria Polder in the list of Priority Projects can only be decided upon after running the hydrodynamic models. Erosion protection would be desirable but is probably too expensive. If less expensive methods can be developed for erosion protection their application at Gazaria could be considered.

3.13 North-east Bhola and West Bhola Bank Protection

A committee termed as 'National Committee on Erosion of Bhola' was constituted by the Government of Bangladesh on 10 February 1988 and entrusted with the responsibility of investigating into the causes of continuous erosion around Bhola district and suggesting appropriate measures to that effect. Terms of Reference of the committee were as follows:

- a) *To investigate and determine the nature, process and causes of erosion at different parts of the district;*
- b) *To evaluate, on an overall basis, the consequences of erosion on the socio-economic life of the district; and*
- c) *To recommend, on the basis of findings as to the causes of erosion and in the context of socio-economic conditions obtaining in the country, measures for combating the menace of erosion*

The Committee submitted their study report in April 1988. A summary is given in the following sections.

Other technical and survey studies were also conducted to identify the technical possibilities of erosion protection at Bhola and for the reconnaissance purpose to assist in formulating and layout of appropriate measures to combat erosion hazard. There are also other survey, technical, morphological studies of general nature either covering the Meghna Estuary as a whole, or part thereof covering the areas around Bhola Island. The reports of these studies also contribute to having data and information regarding morphology, hydrology and hydraulics, fluvial current and wave erosion, sediment concentration and flow pattern around Bhola.

Bhola is the largest offshore island of Bangladesh about 80 km. long in north-south direction and about 16 km. east-west covering about 125,000 ha of which about 80,000 ha arable. The population is above 1.5 million; vast majority of the people depend on agriculture for their livelihood.

It is located in the mouth of the lower Meghna River and is flanked by Shahabazpur Channel on the east and the Tetulia River on the west. The entire island is criss-crossed by numerous small and large tidal creeks.

The water of the Shahabazpur Channel along the eastern boundary remains saline during most of the dry season. To save the area along the eastern boundary from intrusion of saline water BWDB maintains a closed embankment along the entire east coast. The khals are closed by sluice regulators with dual function: drainage and check of saline water entry into the polder.

In the Tetulia River along the western boundary of Bhola the tide as well as the floods from the Meghna are reduced, while in winter the water is mostly fresh and suitable for access into innumerable tidal creeks which are being used as the arterial system for irrigation.

In 1986, BWDB started implementing the Bhola Irrigation Project with assistance from the Asian Development Bank (ADB) constituting development of drainage, flood protection, irrigation opportunities, improvement of road communications and market development of three out of six thanas of mainland Bhola (Bhola, Borhanuddin, Lalmohon) which was completed in 1991. Another similar project was taken up for implementation in the remaining three thanas (Daulatkhan, Tazamuddin, and Charfesson) in April 1994 under the Second Bhola Irrigation Project (BHIP-2). The project BHIP-2 has been designed to provide flood control, drainage and irrigation facilities, development of markets (Growth Centers) and road communications. The project is expected to complete by the end of 1997.

The tidal wave from the Indian Ocean travels rather fast through the deep Bay of Bengal and approaches the coast of Bangladesh from the south. The extensive shallow area in front of the large delta causes some refraction and distortion of the tidal wave contributing to the increase of the tidal amplitude. Due to the deformation of the front of the tidal wave, under certain circumstances a bore can occur in the Shahabazpur Channel below Noakhali district. Tidal amplitudes at the entrance of Sandwip, Hatia, Shahabazpur and Tetulia Channels lie between 1.5 and 3.5 meter in the spring-neap cycle. Such high tidal fluctuations give way to bank sloughing. The maximum ebb velocities in the estuaries vary from 1.75 to 3.5 m/sec and the maximum flood velocities vary from 1.5 to 3.8 m/sec. Such velocities are too high for the river banks, composed of silty clay and fine sand.

In the course of time, the Shahabazpur Channel has doubled in width and the Tetulia River has undergone an increase in width of one-fourth of its former size. Total westward movement of the east bank of Bhola is large compared to that of the west bank. As a result, the width of Bhola decreased along the east-west direction and this decrease in width is more prominent in the northern part of the island. During 1940 to 1963, a considerable widening of the Shahabazpur Channel took place due to migration of the west bank towards the west. The width of the Tetulia River remained practically unchanged.

The north-eastern coast of Bhola from Tazamuddin upto Ilshaghat along the Shahabazpur channel and the western coast along the Tetulia River at and north of Gangapur are subject to erosion. Daulatkhan is the worst-hit thana owing to bank erosion hazard. The study of bank movement and erosion in the period 1940 - 1963 as performed in six sections in Shahabazpur Channel in the eastern boundary of Bhola district clearly demonstrates the extent of erosion in the north-east.

Erosion at Gangapur in Bhola Sadar Thana, along the east bank of the Tetulia River started about 1983. A cross section survey of the Tetulia River along the line Gangapur-Dhalia in August 1982 and October 1986 clearly indicated that the river bank migrated about 200 metres inside Gangapur in four years. As per report the bank erosion there has increased in recent years. Similarly the studies of cross section surveys of the Shahabazpur Channel were undertaken in two different places along the north-eastern boundary of Bhola: the one along the line Daulatkhan-Chittalkhali in November 1979 and October 1987 and the other along the line Tazamuddin-Ramgati on the same dates. The results of these surveys also indicate erosion at the north-eastern side of Bhola.

Bank erosion occurs mainly during the monsoon season. The Committee after review of available reports, preliminary analysis of available data and observation during field visits suggested that there were possibly four factors which were mainly responsible for causing erosion of Bhola Island. The factors were:

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- emergence of the Shahabazpur Channel as the main carrying channel of the fluvial flows brought by the Ganges-Brahmaputra-Meghna river system;
 - large accretion of land in the area south of Noakhali mainland;
 - formation and movement of chars in the river; and
 - changes in tidal characteristics of the Shahabazpur Channel.

The Committee also further emphasized that their observation on the cause of erosion should be treated as very preliminary and finally remarked in their report that complete determination of the specific causes of erosion was not possible without a clear understanding of the dynamics of flow in such a complex situation. A detailed survey and investigation supported by model studies would be necessary to identify the causes of erosion of Bhola Island and to find appropriate solutions for the problems.

The impact of erosion of Bhola from 1940 to 1985 is such that an area of only 77.0 sq.km in total was accreted as against a total area of 303.6 sq.km eroded: a net loss of 226.6 sq.km in 45 years. Socio-economic condition of the people who lost their land due to erosion is utterly miserable.

A summary of the socio-economic conditions of the affected people, recorded for about 15 years from 1972 to 1987 is presented below.

- From 1972 to 1987 more than 50 percent of the mouzas in the district were affected involving a loss of about 48,000 ha of land. Most severely affected were the Daulatkhan and Tazamuddin thanas where erosion claimed 66.58 and 61.21 per cent of the lands, respectively;
- Approximately 240,000 people were displaced in the district over these 15 years, and about 20,000 infrastructural items consisting of houses, schools, mosques, madrashas, hats and bazars were destroyed.

The report of the Committee says that the above data are very tentative and rough and need to be supplemented by extensive research as per assessment of the Committee. Other than these there are other socio-economic aspects which need further survey and research.

LRP Technical Report No. 20 (December 1984) on a study made by W.D. Eysink, included the protection of Bhola Island in the tentative long term planning schedule, and suggested measures for protection by fixing the coastline by means of groynes and / or longshore protection. According to the report, the closure of the deep channel between Bhola Island and Char Medua near Shantirhat or Daulatkhan could be another possibility. By closing the channel, the current would be diverted off the coast towards the main river east of Char Medua. And this char would then, for the time being, act as an erosion buffer, whereas at the same time new land ultimately might arise in the closed channel, which then could be reclaimed in the scope of LRP.

Conclusion

The benefit/cost ratio of the construction of erosion protection is very low. A less expensive solution might be found in the installation of surface/bottom vanes; MES proposes to test their effectiveness in the Meghna Estuary under the Small Scale Intervention programme. Refer to Section 4.3.

If the vanes appear to be effective and the benefit/cost ratio is acceptable, then their installation along the eroding coast of Bhola (and in other eroding locations) may be considered. This will, however, not be possible before the test results are known, i.e. by or after the end of the MES (mid 1998).

The results of the tests with surface/bottom vanes will have to make clear whether erosion protection by means of such vanes could be feasible or not.

From a social point of view, however, the implementation of erosion protection structures, which would prevent that thousands of people become landless, would be of the greatest importance.

3.14 Void

3.15 South Bhola Cross-dams

The same as with all islands in the Meghna Estuary, a number of chars are situated south of Bhola Island. Although their shape changes in the course of time and the channels shift, get larger and deeper or silt up, the presence of chars seems permanent.

In particular in view of the problem of erosion due to which large areas are lost every year along Bhola's north-east and west bank, reclamation of the chars in the south would be very interesting. However, the channels separating the chars from each other and from Bhola Island are all at least a few hundred metres wide, some of them two or three kilometres or more.

On the other hand, the Accretion and Erosion Map (Figure A04-3.3) shows that a considerable accretion has taken place along the banks of the large chars south

of Bhola, and also along Bhola's south-east coast in the period 1975-1992. Two chars at Bhola's south-west point have become part of its mainland. Several smaller chars are growing together and form now a few large chars: Kukri Mukri, Rangabali/Maudubi, Char Agasti.

Only the south banks of the most southerly chars have been eroded significantly.

Even in the Tetulia River along the southern half of Bhola, a number of large islands/chars, about 10 km in length, appear to have developed in the course of not yet two decades.

The surface area of the chars is very considerable; the largest ones measure some 10 to 30 thousand hectares. Rangabali/Moudubi Char, for instance, has about the same surface area as Sandwip Island. A channel or creek still intersects it but appears to have silted up completely in the north.

The large chars and several of the smaller ones are inhabited. The Forest Department planted mangroves on most of them even on very small ones, clearly to enhance natural accretion.

Priority projects in this area may range from rather modest interventions to massive works. Small scale works could consist of construction of minor dams through small creeks or channels with only some local effect, viz. accretion of some tens or hundreds of hectares, and without risk of adverse effects in other places. Such works may be carried out with traditional techniques, in particular using porcupines and gunny bags. Construction of embankments to protect the (inhabited) chars against frequent flooding would be possible under the Food for Work programme.

However, embankments that are flood-free even during storm and cyclones would be far more costly, and a detailed study would be required to assess their design crest levels and other specifications such as slope gradients, toe and slope protection, etc.

Other major work to be considered is the construction of cross-dams through one or more of the tidal channels. These would probably have a favourable effect on the already fast accretion of new land between the chars and between char(s) and Bhola mainland. But the closure of a channel will also lead to an increased flow through one or more other channels, with as result higher flow velocities, giving rise to (aggravating) scour.

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Construction of major cross-dams would be very costly and have a considerable impact on the hydro-morphological development of the char area. A thorough hydro-morphological study based on surveys and hydrodynamic modelling will be required to assess the effects of such interventions in the area south of Bhola; a study at pre-feasibility level will have to give an answer to the question whether they are technically and economically feasible or not. But in view of the very limited economic value of the existing and the accreted lands concerned, and with the outcome of the LRP Sandwip Cross-dam Feasibility Study in mind, the prospects of cross-dam construction south of Bhola do not seem bright.

From a socio-economic viewpoint, however, the accretion and reclamation of lands south of the island is important to relocate the people who lost their land in North-Bhola, and for settlement of landless people.

It will be essential to monitor how the area develops in the coming years. If the tendency of natural accretion lasts, construction of cross-dams may become feasible in the narrowing and shallowing channels, so as to speed up the natural accretion.

This area seems also very suitable for the implementation of accretion trials in sedimentation fields. The tests should be conducted with a maximum participation of the population; they can, in the future, also be involved in the construction of (small) cross-dams if the accretion continues.

Conclusion

The prospects of one or more medium or large size cross-dams in the area south of Bhola are not bright. Technically, it is expected to be a complicated project and the cost will be very high. As is the case with, for instance, Sandwip Cross-dam, the EIRR is likely to be very low due to the high cost and the delayed benefits. Moreover, the value of agricultural land is relatively low, as compared with the cost of the interventions.

From a socio-economic point of view, however, the project would be very interesting. We therefore suggest that the South Bhola Cross-dams is considered for inclusion in the list of Priority Projects, and that a pre-feasibility study is undertaken.

3.16 Void

3.17 Void

3.18 Ramdashpur Cross-dam

Ramdashpur is a large island north of Bhola. A map produced by FAP-19 (GIS) for FAP-4 (South-west regional study), based on a 1973 and 1989 satellite images, shows the development of (among others) North Bhola and Ramdashpur. A channel, some 1-2 km wide, separates the two islands. It shifted in 16 years more than one kilometre to the north-west, at the cost of Ramdashpur, whereas considerable accretion occurred at north-west Bhola. The satellite image of February 1996 shows that this tendency continued.

The channel between Bhola and Ramdashpur (in this context called B-R Channel) is one of the main tributaries of the Tetulia River. The construction of a cross-dam between the two islands is likely to lead to an increase of the flow through the other tributaries and to (increased) erosion there. There will be no through-flow in the B-R Channel any more, and only tidal flow filling and emptying the channel on both sides of the dam will remain. The erosion of south-east Ramdashpur will stop. The channel may silt up, but this is not certain.

The many channels to the north-west of Bhola and Ramdashpur form a hydraulically very complicated network. Detailed hydrodynamic modelling of the North-Bhola region is not planned in the MES programme, and foretelling what would happen in that area when a cross-dam is constructed without detailed model investigations would rather be a prophecy.

Conclusion

Further study of a Bhola-Ramdashpur cross-dam under MES must be seriously reconsidered.

4 IMPLEMENTATION OF SMALL SCALE INTERVENTIONS

4.1 Introduction

One of the planned outputs of MES is: "Proposals for and implementation of small scale interventions using locally available facilities" (TOR 4.2.5). The Consultant will locate and design the works and monitor their effectiveness. Construction and monitoring will be the responsibility of BWDB (TOR 5.3.10). A certain part of the project budget is reserved for implementation of these projects. A list of interventions supported by outline designs and cost estimates will be provided by month 8 of the study.

The implementation of these small scale interventions should, according to the ToR, have the following objectives:

- Projects should be aimed at land reclamation and/or erosion protection.
- Emphasis is on low costs construction methods within the capability of local contractors and with maximum participation of the population.
- Projects should be selected, implemented and evaluated within the project period.
- Monitoring these projects will supply the project with information on:
 - . effectiveness of the interventions;
 - . construction methods;
 - . construction cost.

Section 4.2 of this chapter focusses on the implementation of small scale interventions with the aim to reclaim land. Interventions aiming at erosion prevention are dealt with in Section 4.3. Section 4.4 elaborates the proposal for a special small scale intervention, viz. a low-cost method to prevent the imminent breaching of an embankment of Sonagazi polder.

In Section 4.5 the construction of cross dams is considered briefly as a small scale intervention.

4.2 Land accretion

4.2.1 Approach and planning

The methodology for selecting accretion trial areas will be as follows:

- a. Review existing studies on land reclamation;
- b. Review implemented land reclamation projects;
- c. Set-up overview of accretion promoting techniques applicable in the Meghna Estuary;
- d. Select potential locations for accretion trials;
- e. Evaluate combinations of locations and techniques and define two or three trials;
- f. Design accretion devices (construction of accretion and/or protection works by BWDB);
- g. Supervise construction;
- h. Set up monitoring programme of trial (monitoring by BWDB);
- j. Evaluate results of trials.

A substantial percentage of the budget available for the trials should be reserved for extension of the various techniques to the population. This amount should be available to pay incentives to BWDB staff explaining the techniques, supervising the works, monitoring the effects, selecting and training future trainers /supervisors.

A list of interventions, with outline designs and cost estimates, will be provided in month 8 of the study (June 1996). Installation of the most promising trial devices should be completed before December 1996. The monitoring programme has to start directly after completion of the works and monitoring will have to continue after the end of the project.

4.2.2 Review of existing techniques

Tidal flows transport huge volumes of sediment within the Meghna Estuary. Sedimentation creates and gradually enlarges chars; reclamation techniques can be applied to accelerate this natural accretion process. They should be carefully planned so that accretion at one side of a char does not induce erosion at another place in the vicinity.

Over the years various coastal areas in Bangladesh have been reclaimed using various techniques. In 1977 the Land Reclamation Project (LRP) started. One of the objectives of the project was to try out various methods to accelerate the accretion of land and to define methods that are feasible in Bangladesh. On the basis of these studies and additional literature, MES will prepare an overview presenting criteria for successful implementation of the most promising techniques.

Various reclamation projects have been implemented using various techniques, on a large scale as well as on small scales. In most cases the applied techniques consisted of the closure of tidal channels or river mouths. Examples of such projects are:

- Meghna cross-dams 1 & 2 (large scale);
- Manpura Island cross-dam (small scale, constructed by local initiative);
- Daria Nadi cross-dam (small scale, as part of LRP).

LRP carried out sedimentation field tests as part of their research programme. The results of these test have been evaluated and reported.

The Forest Department has undertaken and still is implementing a large number of coastal afforestation projects by planting mangroves. These projects not only aim at the production of fuel wood, but also enhance land accretion in areas prone to silting-up, and protect the coast against wave attack.

Sometimes accretion of land occurs as "side effect" of a project. An example of such projects is the closure of the Feni River which caused a large and rapid accretion at the seaside of the dam (Muhuri accretion).

MES will prepare a document presenting an overview of land accretion techniques over the years applied and tested in the Meghna Estuary. This document can be used as a guideline to select suitable techniques for potential land reclamation areas in the Meghna Estuary.

4.2.3 Selection of locations for the intervention

The selection of suitable locations for accretion tests is very important. Not only should such location technically facilitate a rapid accretion, but organisational and socio-economic aspects are also important for a successful implementation of the test.

People should be willing to settle on the newly reclaimed land and the land should be suitable for use for agricultural or otherwise profitable activities. This is especially important to guarantee a successful follow-up of the project, which will depend largely on the initiative and incentive of settlers.

As the interventions will be monitored during the course of the Meghna Estuary Study, the location should preferably be in the vicinity of a BWDB local office and be easily accessible for supervision and monitoring staff.

Selection criteria for reclamation locations

The location of the interventions should fulfil the following technical criteria to facilitate a rapid accretion:

- accretion already takes place;
- current velocity is low and can be reduced by intervention;
- sediment content in the water is high.

The scope of the MES poses the following criteria on the selection of the locations of the tests. The interventions have to be:

- small scale;
- low cost;
- implemented in short period;
- carried out with local assets (material, labour);
- serve as an example to other projects.

It has to be decided whether the accretion tests should be planned in areas exposed to wave attack or in areas without wave attack; or maybe in both.

With respect to the effects of the intervention, the following criteria should apply:

- substantial positive effect on land accretion;
- no erosion elsewhere resulting from intervention;
- no or minor negative effect on navigation;
- minimum negative effect on drainage of already cultivated areas, unless cheap solution for the additional drainage problems is possible.

Criteria from an operational point of view are:

- easily accessible from existing land;
- preferably in the vicinity of BWDB or SSD office;
- potential labour nearby;
- willingness of population to contribute their labour to implementation activities.

Potential reclamation locations

The Land Reclamation Project studied the Meghna Estuary for potential and suitable land reclamation locations. Screening these locations in the light of the MES scope, and comparison of old and recent satellite images result in the preliminary selection of the following areas where the implementation of accretion trials seems promising:

- South Bhola;
- South Hatia and Nijhum Dwip;
- South-east Sandwip;
- Little Feni River;
- Char Boya.

Selection process

- 1 Collect basic environmental data of potential reclamation areas (bathymetry, coast line development, tides, currents, sediment content).
- 2 Select potential locations for small scale interventions based on technical criteria.
- 3 Determine most suitable accretion enhancing technique for each location.
- 4 Select interventions which match the MES scope.
- 5 Estimate potential effects of interventions and their cost.
- 6 Select optimal intervention(s) taking into account operational criteria.

4.2.4 Design of the intervention

Once the selection of locations of the small scale interventions is complete, their designs will be taken up. In general, they will consist of measures to reduce currents and/or retain sediments. The design process will consist of:

- detailed data collection;
- set-up of design criteria;
- structural design;
- method statement for construction;
- estimation of accretion rate and future coastline development.

Data relevant for the design of the interventions are:

- reports on previous studies in the area;
- bathymetric and topographic maps;
- data on tides, current, waves and sediment concentration;
- geotechnical data;
- data regarding availability of construction material;
- unit costs of local labour and material.

The structural elements of the intervention will be designed according to certain criteria, such as:

Life expectancy:

After a certain period of time accretion will change the local conditions at the structure such that the structure loses its main function of reducing currents and/or retaining sediments. The structural elements should be designed such that they will function as long as they are needed, and not much longer (with a view to saving money).

Construction materials:

The design of the devices should include use of materials which can locally be acquired and can be easily handled by local labour. Emphasis should be on low cost construction techniques and materials.

Safety:

The intervention should in no way endanger lives and properties of people living in the vicinity and/or working in the construction sites.

The structural design of the intervention depends on what reclamation technique will be applied. A description of the design methodology for each reclamation technique will form part of the review.

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The construction drawings will be presented with design notes and a summary report stating objective, design criteria and cost breakdown.

Once the design is ready a brief statement will be prepared describing the methodology of installing the structural elements. As much as possible the already successfully implemented methods will be the basis of this methodology. Only construction aids available for and manageable by local labour will be used.

The method statement will give the sequence of construction, temporary works, safety requirements, work restrictions (tides) and other aspects required for an efficient and safe implementation.

4.2.5 Monitoring programme

After implementation of the small scale interventions their effects on the accretion process will be monitored, in accordance with a monitoring programme to be set up. This programme will aim at keeping record of the accretion process at the intervention site and of basic prevailing environmental conditions.

At the end of the construction works, the necessary tools for the monitoring programme will be installed. These tools consist of reference points, gauges and other facilities required to ensure an accurate and efficient monitoring process. A technical note will describe the requirements for these facilities, and indicate on drawings the locations of reference points and facilitating tools.

A concise guideline will describe, both in English and Bangali, the monitoring methodology. This guideline will deal with:

- type of data to be collected;
- measurement methodology;
- number and location of measuring points;
- frequency of measurements;
- conditions in which measurements should be taken.

The guideline will also include standard monitoring forms to note down measured data.

4.2.6 Evaluation of the intervention

At the end of the MES project, all aspects of the project will be analysed and an evaluation report will be prepared. The evaluation report will describe the experiences gained and the effects of the interventions on the surroundings.

The report will analyse and evaluate the whole process of implementing the small scale interventions. Important recommendations in this evaluation will concern:

- organisational aspects (relation between BBEDB and population);
- materials and construction methods to be used;
- further investigations.

The report will also include the results of the monitoring programme, which will be processed, analysed and evaluated. Interviews with the local people will permit to collect their experience with the interventions. Effects of the interventions to be analysed concern:

- land accretion;
- erosion elsewhere;
- navigation and other environmental aspects;
- drainage of cultivated areas.

4.3 Bank erosion protection

Bank protection methods have been extensively described in the Planning Study of Bank Protection prepared for FAP 21, Main Report, June 1993. The following measures have been discussed:

- revetment of slopes
- retaining structures
- bank heads
- impermeable groynes
- permeable groynes
- guide banks
- training walls
- sills
- closure dams
- dredging

In the Planning Study on River Training/Active Flood Plain Management prepared for FAP 22, Main Report, December 1992, the following recurrent measures are mentioned for river training:

- dredging
- revetment
- permeable groynes
- bottom vanes
- surface vanes
- jacks
- bend cut-off

For the Jamuna river training works, bottom vanes are not selected because of the fast changing bed shapes. However a row of bottom vanes along the bank for protection is preliminarily selected for further study.

Surface vanes or screens are considered as probably effective because of the fine non-cohesive bed materials. This conclusion is based on the successful application of bandals (a local type of surface vanes) for so many years in the Jamuna and such kind of rivers.

Since under the Jamuna conditions surface screens are considered the most promising, that recurrent measure is recommended in the report on FAP 22 to be investigated in more detail in order to achieve a quantitative assessment of their effectiveness.

In the executive summary of the Final Report Planning Study the following is concluded: "Floating surface vanes as recurrent measures in the Jamuna River are very attractive with respect to their technical capabilities, their flexibility and relatively low costs".

However so far more detailed investigations of bottom or surface vanes have not been included in the FAP 21/22.

In the meantime considerable favorable experience has been obtained with installations of bottom vanes as bank protection as well as for other purposes in the United States of America (in particular designs by Iowa State University), Japan, New Zealand and most recently also in Nepal.

A major objective of the Meghna Estuary Study is to create new land and to make sure that landless people will occupy this new land. Many of these landless people have lost their land due to erosion of the river bank. Therefore effective, flexible and relatively low cost bank protection measures preventing loss of valuable existing land as well as more landless people would be very desirable.

Therefore the Consultant proposes to pursue investigations of the possibilities of using screens or vanes for river bank protection, river training and closure of river channels.

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Part of the financial aid, included in the project budget of the Meghna Estuary Study, will be earmarked for installation of a vane field along the bank of the lower Meghna, in case more detailed study of the possible effect of vanes result in a positive advice for further action.

An basic outline design has been prepared of a surface/bottom vane (SBV).
A SBV consist of the following components:

- three circular steel or concrete piles that are water jetted into the river bed
- steel or concrete beams to connect the top of the concrete piles for stability
- screens of geotextile sewn around a steel pipe that hangs on the outside of two concrete piles. The screens are kept in a vertical position by the weight of coarse sand/fine gravel sewn as a sausage into the lower end of the screen
- fixtures to support the screens

The screens can be fixed at different levels and directions between the water surface and the river bed. In this way a SBV provides "double action" and could be very effective in diverting the bed load towards the river bank thus preventing further erosion of the bank. The SBV's shall be installed in a field as indicated in Figures A04-4.1 and A04-4.2.

A number of SBV fields could provide bank protection over considerable distances, see Figure A04-4.3.

As a first step on the way to application of the SBV, specialist advice will be obtained from Prof. A.J. Odgaard of Iowa State University, USA, who has extensive experience in the application of vanes, both in laboratory conditions as in prototype. In particular the tidal movements within the project area and the very fine bed material have to be taken into account when evaluating the potential effectiveness of the SBV in the Meghna Estuary.

It is expected that the SBV's will be effective along the lower Meghna and Tetulia River. Protection of the North coast of Hatia and other problem areas with strong tidal currents and a high amplitude of the tide most likely will not be possible.

A second step would be to design and install a SBV field somewhere along the lower Meghna where the system is expected to be effective. Construction of the protection should be done early 1997 and the performance should be monitored during the remainder of MES.

After the flood season of 1997 an intermediate evaluation will be done. Provided that the results are positive, the technical and economic feasibility could be assessed in detail.

This study shall include the design of a self-propelled vessel that is equipped with all facilities to install the SBV, to adjust the position of the screen and to dismantle SBV completely in case the SBV has lost its functionality.

Such a flexible SBV system may be very well suited to provide adequate protection over considerable distances of presently eroding banks of the lower Meghna, Tetulia and possibly elsewhere.

A third step would be implementation of SBV protection along stretches of river bank where erosion occurs and SBV's have proven to be effective.

Further investigations into the effectiveness of SBV fields for training of the rivers with the magnitude of the Lower Meghna could be taken up a later stage provided the SBV has proven to be effective as bank protection as well as durable under conditions prevailing in the project area.

See also Figures A04-4.1 and A04-4.2.

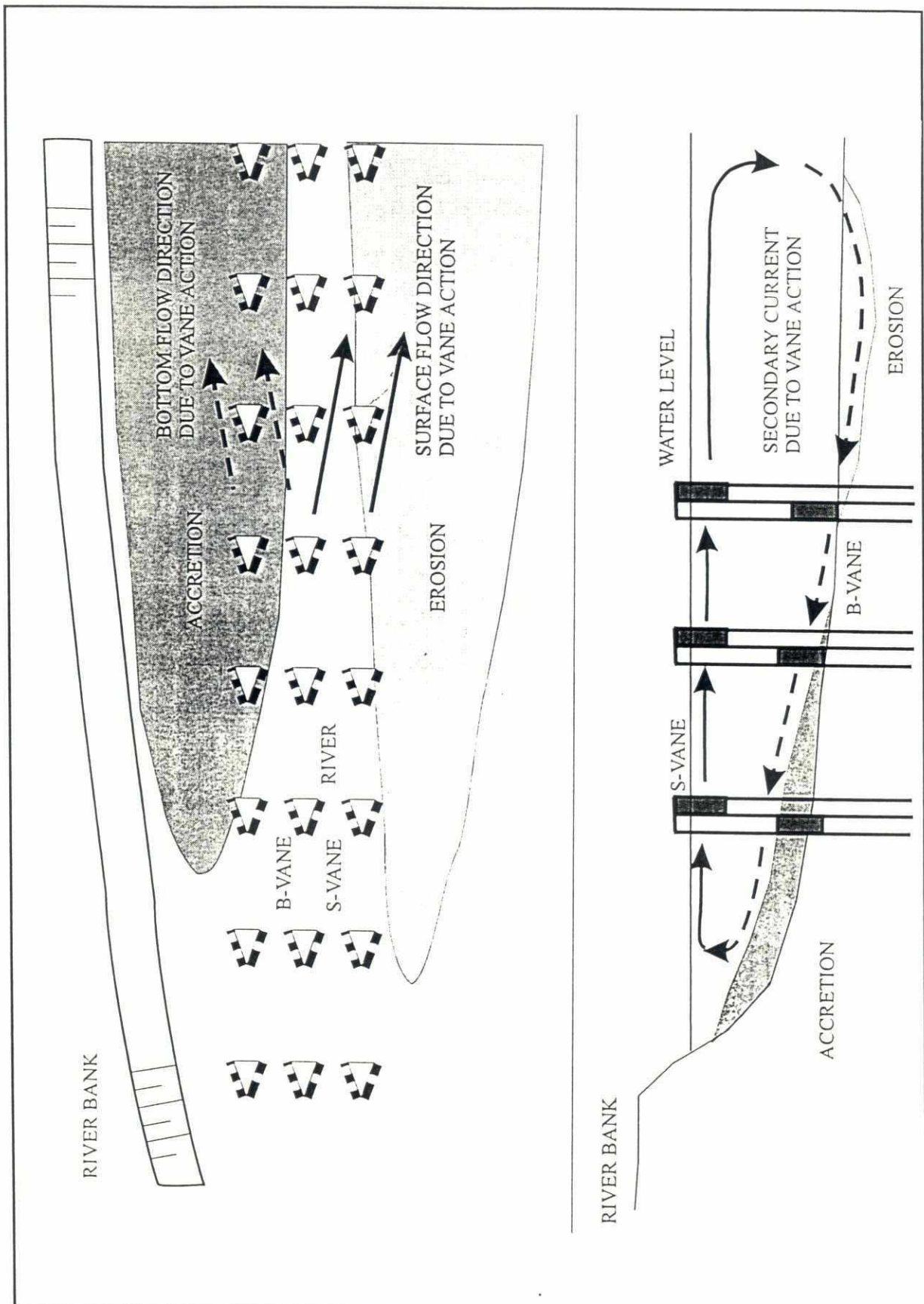


Figure A04-4.1 : Plan of a SBV field for bank protection

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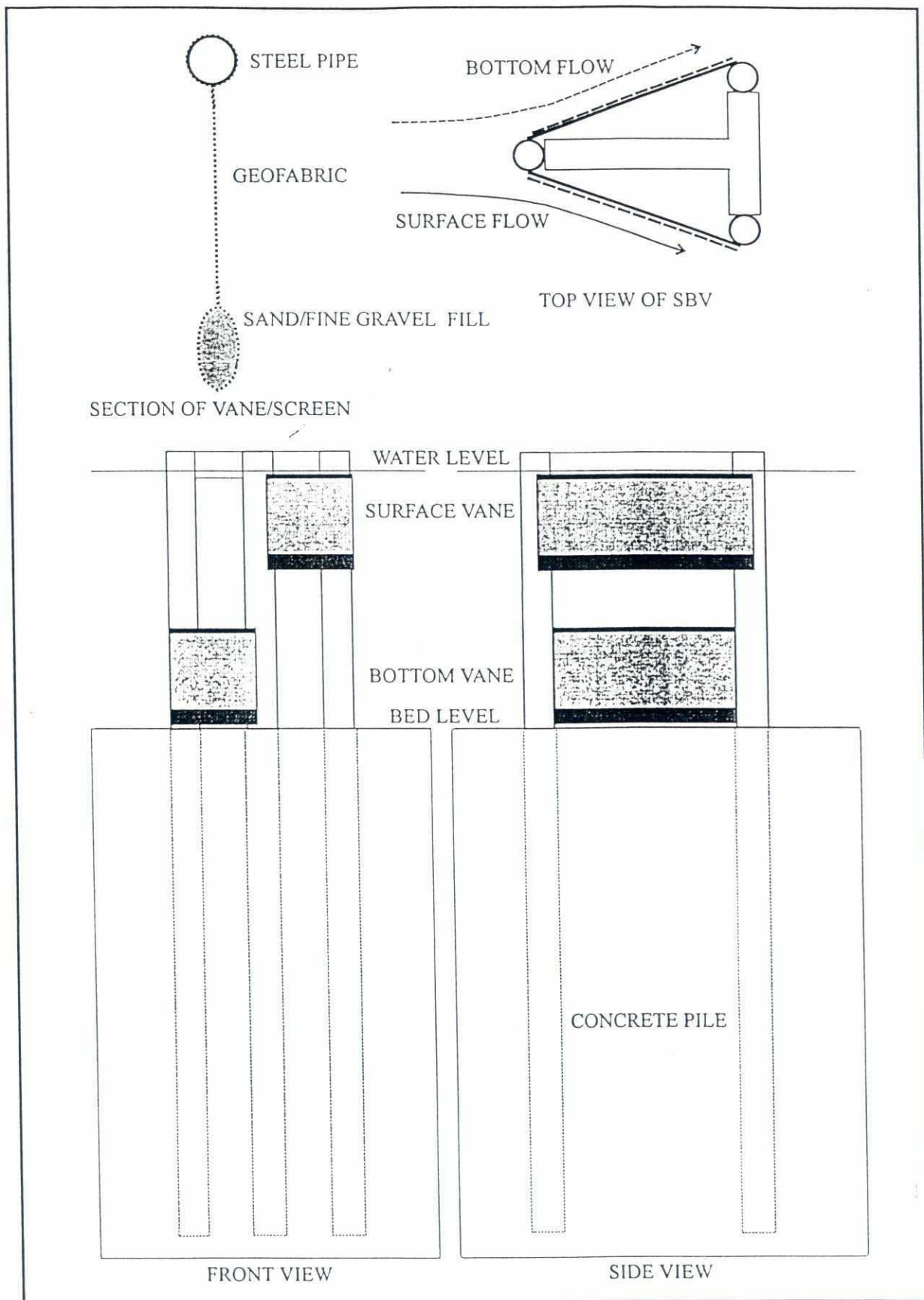


Figure A04-4.2 : Preliminary design of a SBV

4.4 Protection of Sonagazi Polder Embankment

The bank of the Feni river, downstream of the Feni regulator has been eroded over a considerable distance. The embankment, that prevents inundation of the adjacent polder, may be washed away in the very near future.

Because of the very urgent nature of taking preventive measures, the consultant proposes to use part of the budget for small scale interventions to take remedial measures and prevent loss of valuable land.

Usually bank protection works are very expensive and hardly justifiable from an economic point of view. However in this case special circumstances may be conducive to an effective and low cost solution of the problem.

Since the construction of the Feni closure dam, the area on the seaside of the dam has completely silted up and the new land is already under cultivation. At present the possibilities for further development including empoldering of the area (Muhuri accretion under CDSP) is to be studied at feasibility level.

Even without such development the concrete block protection on the seaward slope of Feni dam can be considered as completely redundant because the wave attack on the dam during cyclones would be very much reduced by the presence of the foreland.

Moreover the embankment, that is present under attack by the and even the embankment joining the Feni dam on the east side, is much more vulnerable to breaching than the Feni dam without concrete block protection.

It is proposed to removed the concrete blocks above the high water line, back fill with clay and provide grass sodding on slopes where blocks have been removed. The concrete blocks can be transported to the endangered site by local, low cost means and be used as bank protection. If this proposal is acceptable, the consultant will prepare a design and cost estimate. The protection should be installed before the 1997 monsoon season.

4.5 Small cross dams

The implementation of (small) cross dams is to be considered as proven technology in Bangladesh. Therefore construction of such a dam would not have a pilot function but would merely be expected to accelerate accretion in a certain area. Spin-off in terms of improved technology would not be an objective.

Consultants propose not to include construction of a cross dam in the programme for small scale interventions because of this lack of enhancement of knowledge. The construction cost of even a small cross dam would be considerable and might be well beyond the total budget provision.

5. OVERVIEW RECLAMATION TECHNIQUES

5.1 Introduction

5.1.1 Background

One of the targets of the Meghna Estuary Study is to indicate measures for promotion of land reclamation/accretion if and where possible. Circumstances and phenomena are not uniform over the project area; different places require different measures. This chapter deals with different accretion techniques practiced in project area and their success or failure and their future recommendation.

This chapter gives an overview of reclamation techniques which over the years have been applied and tested in the Meghna estuary. It can be used as a guideline to select suitable land reclamation techniques for potential reclamation areas in the Meghna estuary.

5.1.2 Natural accretion process

Coastal waters contain a certain amount of suspended sediments. The sediments are kept in suspension due to turbulence of water movement initiated by coastal currents. These currents can be induced by tidal movement, upland discharges, wind action or others. Apart from the sediment characteristics, the concentration of sediments depends largely on the velocity of the current. Currents with a high flow velocity have a higher capacity to transport sediments than currents with lower velocities.

In coastal areas currents are usually dominated by tidal movements. During high water, water mainly moves inland through tidal channels. Because of the rising water level, the water is spread out over the shallow areas. At the turning of the tide, the tidal current slows down and comes to a standstill. During this period suspended sediments partly settle because of the reduced capacity to transport sediments.

As the tide drops, the current velocity will increase again (in reversed direction) and part of the freshly deposited sediments are taken into suspension again. Due to preliminary consolidation of the sediments at the bottom, slightly higher velocities are required for bringing sediments back in suspension, than during sedimentation.

In some areas, the water level will drop below soil level during low tide resulting in a period in which the deposited sediments can dry. By drying, the fluvial material consolidates even quicker and many times more cohesive. During the next tide the material may be retained, even though waves or currents may be less favourable.

This situation may lead to a gradual natural accretion. Many times though this process is disturbed by irregular currents and waves due to climatic conditions.

5.1.3 Available techniques for accelerating accretion

Natural accretion can be stimulated by eliminating the effects of irregular waves and currents. Other options to stimulated natural accretion is to conduct measures which locally lower the current velocity and/or enhance retainment of sediments.

The following land reclamation techniques have been applied and tested in the Meghna Estuary:

- Sedimentation fields
- Cross-dams closing tidal channels
- Sills in tidal channels
- Afforestation

5.1.4 General accretion aspects for land reclamation

Sedimentation rate

The sedimentation rate is logarithmic; as land elevation rises by continued siltation, the frequency of inundation reduces. As a result the siltation process slows down. As the sedimentation process depends on water depositing sediments on the char, the maximum sedimentation level depends on the maximum water level to occur at a certain location. For practical reasons the maximum water level is taken to be Mean High Water Spring (MHWS), even though water levels may occasionally exceed this level during exceptional conditions.

During the Sandwip cross-dam study a sedimentation rate equation has been derived at to estimate the sedimentation rate in time : $h_t = h_0 \exp[-q (t-t_0)]$

where:

h_t	= depth of water with relation to MHWS after a period t [m]
h_0	= initial depth of water with relation to MHWS before intervention
t	= time [year]
t_0	= time of constructing intervention
q	= coefficient (characteristic for location)

The coefficient "q" can be derived by regression analysis of accretion measurements over a certain number of years. If no accretion data is available in a certain area, "q" can be analytically be estimated [Barua 1990, Ref.]. Former investigations show that "q" is directly proportional to the settling velocity of particles and the SSC. An example of "q" for some areas in the Meghna Estuary is given below:

Feni dam area	$q = 0.78$
Nijhum dwip area	$q = 0.43$
South-Bhola area	$q = 0.023$

Empoldering level

Once the siltation has reached a level that the emerged land will only be inundated during high tides, people will consider to start cultivating the land. To ensure safe habitation, the land should be empoldered. Empoldering of the land is executed by constructing dikes and water control structures; hydrologically isolating the area from surrounding areas.

A study has been carried out on the selection of empoldering levels in the south-eastern deltaic region of Bangladesh [Ref.]. This study suggests that the coastal area of Bangladesh should be divided into separate zones, each zone with a characteristic empoldering level. The following empoldering levels have been recommend by the study:

Feni dam area	MHW + 1.0 m (3.8 m + PD)
Nijhum dwip area	MHW + 0.6 m (2.2 m + PD)
South-Bhola area	(accretion promotion measures are not encouraged)

In general the level at which empoldering can be started depends on the following aspects:

- sedimentation rate
- drainage environment
- wave exposure
- top soil characteristics
- rate of subsidence
- tidal characteristics
- socio-economic factors

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A more elaborate description of these aspects is described in the report "Some considerations on the selection of height of empoldering level in the newly accreted south-eastern deltaic region of Bangladesh"

Salinity

The salinization of the chars is brought about by two processes. The first one relates to the inundation of char land during periods that the water of the Gulf of Bengal is saline (pre-monsoon and post-monsoon periods). The second one relates to the saline groundwater that occurs at various depths below the land surface.

The most common way to remove the salts that have accumulated in the soil profile is by creating a downward flow of fresh water through the soil. Salts will dissolve in this water and will be transported to the ground water. This process is called leaching.

Important for the effectiveness of leaching are the hydraulic conductivity of the soil (permeability) and the intake (infiltration) rate. The higher the hydraulic conductivity and the intake rate of the saline soil profile the sooner this saline soil can be reclaimed.

Once the char has been de-salinized, re-salinization may occur due to inundation of seawater and capillary rise of saline groundwater. In the first phase of the development of the newly reclaimed land the char will be unprotected from the sea and inundation by sea water (and corresponding re-salinization) will occur frequently. Once the char has been protected, the presence of saline groundwater (especially at the end of the dry season) will be the main cause of re-salinization.

To minimize the effect of salinization the following aspects should be taken into account during the design of a land reclamation project:

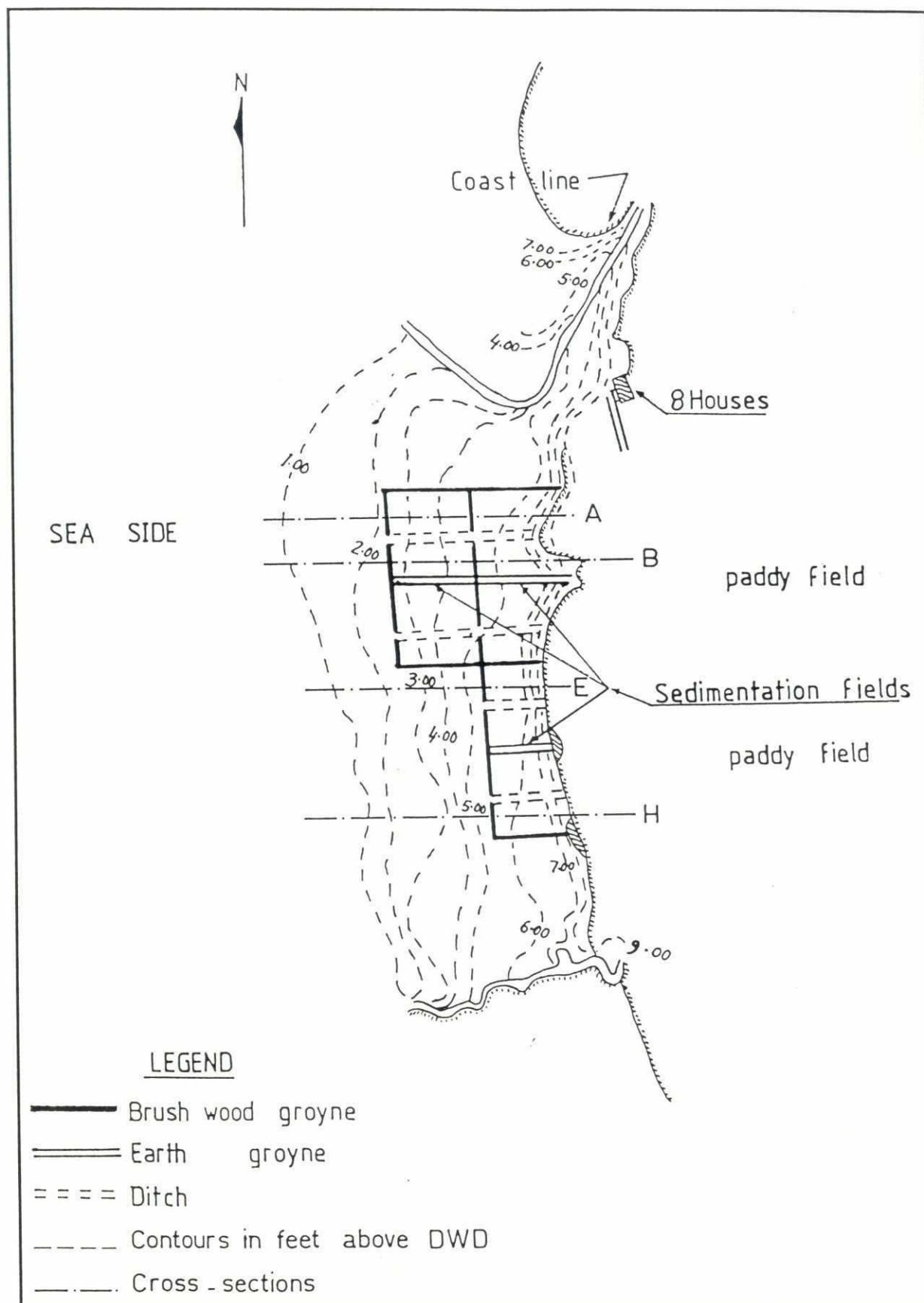
- Construct a dike around the reclaimed land to prevent inundations
- Accomplish an accretion level which is as high as possible
- Create a deep drainage system to assure fresh water to infiltrate deeply during the wet season

5.2 Sedimentation fields

5.2.1 Description of physical process :

One of the objectives of the land reclamation project was to try out various methods to accelerate the accretion of land in order to define those methods that are feasible in Bangladesh. As such the construction of sedimentation fields were tried out along the Chittagong coast at two locations. A similar construction will be used in the proposed MES project, the description of which is stated below in brief.

The sedimentation field is constructed generally measuring 240 m x 120 m area with provision of ditches and brushwood groynes as shown in Figure A04-5.1. To determine the influence, the extension of fields seaward one single and one double field have to be constructed. Sometimes irregular shape of the embankment resulted in unequal size of fields. As soon as possible, the brushwood groyne, with its limited durability as a result of deterioration; will be replaced by an earth groyne. The land ward earth groyne is strengthened by polyethylene bags filled with broken bricks. The main purpose is to prevent scour under the bamboo groynes.



Ditches

It is clear that drainage of the tidal water to the sea is very important; quick drainage means a longer dry period, so ultimately more sedimentation.

This is the reason for digging canals across the sedimentation fields, while the sea is receding, water concentrates in the canals and from there it is quickly removed. To which details a drainage pattern should be applied by digging cross-canals and ditches, depends of the local situation. A second benefit of digging canals is that the tidal water moves more concentrated and with a higher velocity to the fields, so that sediments that normally might have settled already in the deeper area, are carried to the fields and settle there.

Vegetation

Grasses as well as higher vegetation may play an important role in the process of settlement and establishment of new soils. First of all the vegetation abstracts the current, causing less sediments to go back into suspension condition for this process is that the vegetation can follow the rise of the bottom. Secondly the roots of the vegetation can play an important role in stabilization of the new soil. In the coast of Bangladesh the natural grass (uri) is common, they definitely play an important role in the sedimentation / erosion processes.

5.2.2 Evaluation of reference projects

Construction of sedimentation fields were tried at two locations; one at Sitakunda and another at North -Kattalia and following are the conclusions and recommendations.

Morphology

- The accretion trial near Sittakunda was already abandoned after one year due to disturbance by mangrove vegetation and the construction of an embankment through the fields. No further use is made of results obtained from this trial.
- The trial near North-Kattali was strongly disturbed by external morphological processes. During the first two years of the trial the annual siltation rate was 0.18 m of which approximately 0.06 m was a direct result of the sedimentation fields while the remaining 0.12 m was caused by external morphological processes.
- After two years the natural accretion overshadowed the effect of the fields. No further data concerning the effect of the fields could be gained.
- Sedimentation fields cannot control the morphological processes along the Chittagong coast. Their influence is subordinate to the stronger effect of the natural morphological processes.
- Sedimentation fields along the Chittagong coast are less beneficial as they were along the Waddensea coast due to essential differences in environmental factors.

Siltation caused by sedimentation fields

- Siltation predominantly depends on the duration of flooding of the fields. The longer the period the higher the siltation to be expected. This is the reason why during moonson siltation is more because the MSL is 1.0 m higher than in winter.
- Vegetation was expected to have a positive influence on siltation, however this could not be supported by measurement.

- Siltation as result of flocculation of clay particles by saline seawater is negligible due to low clay content, and the limited period of the seawater being saline.
- Significant increase of siltation due to gripdigging was not observed.

Aspects of design and materials

- The local thick-walled bamboo proved to be more durable than the thinwalled bamboo originating from the Hill - Tracts. There are no differences in prices so the use of the local type is to be preferred. Durability of the local type ranges from 3 to 4 years and for the Hill - Tract type 2 to 3 years. The bamboo more than 0.3 m below ground level proved to be in very good condition and can be re-used for other purpose. High salinity of the subsoil is likely to conserve the bamboo.
- The locally obtained galvinised iron wire ($\phi = 2-3$ mm) proved to be of bad quality. Savings can be attained by using better quality iron wire or plastified iron wire.
- Kancha reeds as groyne filling served their purpose insufficiently. Low durability resulting in shrinkage caused high maintenance cost. Also the bundles of reeds formed impermeable unities not able to dissipate wave-energy and causing current concentration between the bundles, resulting in local scour.
- No suitable materials could be found to replace the bamboo and kancha reeds.

Economic aspects

- Sedimentation fields are only feasible economically if many constraints are met and construction cost can be reduced with 50%. Then an Internal Rate of Return of 15.8% will be reached, being 0.8% higher than the Accounting Rate of Interest which is stated to for Bangladesh. The most important requirements to be met are:
 - Reclamation of the sedimentation fields can take place 3 years after implementation of the fields.
 - average rice yields on the newly reclaimed land are 4500 kg/ hectare.
 - No damage to crops as result of flooding or salinity will occur. It is expected that these and other requirements cannot possibly be met.

5.2.3 Design aspects and costs

The best construction of the groins appeared to be two rows of bamboo piles (2.1 m into the soil, 1.2 m above the soil), the rows being 0.3 m apart and the piles in the row also 0.3 m apart. In between the two rows brushwood is placed from 0.3 m below the soil surface to about 0.9 m above the surface. For the brushwood filling, brushwood from the Kancha tree is used in bundles kept together by wire. On top of the groyne brushwood is kept in place by tightened wire, fixed to the bamboo piles by bolts (Figure A04-5.2).

From the above design, the total amount of materials can be found out and from the BWDB's schedule of rates of the locality, the total cost of the sedimentation fields can be found out.

5.2.4 Conditions for successful applications

Following are the recommendation for future successful applications of sedimentation fields.

- Locations most suited to construct sedimentation fields are found along the coasts of Noakhali Mainland just opposite of Char Pir Baksh, west of the Feni river mouth and on both sides of the mouth of the Noakhali Khal. Here minor longshore tidal currents are found and tidal flats will extend seaward but morphological processes will overshadow the artificial accretion.
- Although better location might be found it is not expected that sedimentation fields offer technically and economically feasible solutions in the Lower Meghna estuary, neither concerning the protection of embankment against wave - attack nor concerning the accretion and reclamation of new land.
- Intensive and regular maintenance proved to be necessary during the first monsoon after each rough weather period. If no proper maintenance is carried out then carefully obtained accretion over a long period can be washed away within one rough weather period. Both financing and organisation of maintenance can cause problems.

5.3 Cross-dams

5.3.1 Description of physical process

The construction of a cross-dam in a tidal channel will stimulate the accretion of new land. As a consequence of the cross-dam, the flow through the closed channel is blocked and some areas with very weak currents to both sides of the dams are created. Silt laden water penetrating in those areas cannot longer hold the suspended sediments in suspension resulting in settlement of silt in those areas. Thus siltation of too wide channel profiles will occur and accretion of new land will start along the dam and the banks of the closed channels. This on its turn reduces the tidal storage area, yielding further flow reductions and hence further siltation of channels, shoaling of tidal flats and accretion of new land. This process continues until a new equilibrium between morphology and hydraulic conditions are achieved.

5.3.2 Evaluation of reference projects

- Meghna cross-dams 1 and 2

The history of land reclamation in the south eastern delta of Bangladesh starts from 1959 when the Meghna cross-dam-1 was constructed. In 1962, this was followed by the construction of the Meghna cross-dam-2. Together, this cross-dams, that were constructed without any foreign assistance, stimulated and accelerated the already naturally occurring accretion in the area. About 155,000 hectares of new land were reclaimed (Figure A04-5.3).

- Feni cross-dam

The Feni river closure dam was constructed in 1985 as a part of Muhuri Irrigation project. After construction of the dam, the morphological-process at the Feni river mouth (U/S of the Sandwip Channel) were completely changed. Rapid accretion started D/S of the dam, raising the estuary bed. Survey showed very encouraging development around 4 meters vertical raising of an area of about 1760 ha has occurred which indicates possibility of empoldering the area for further development.

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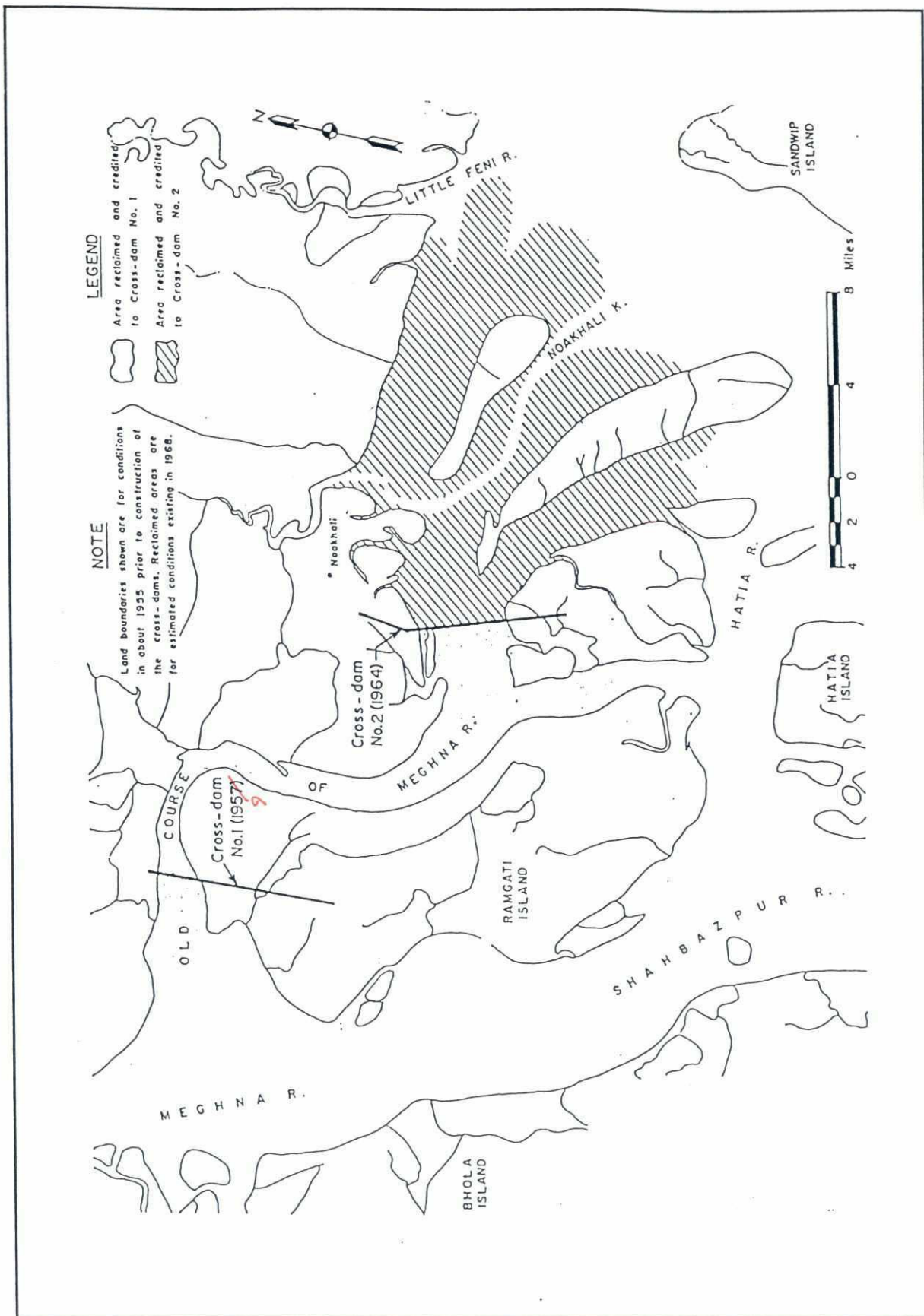


Figure A04-5.3 : Reclaimed area in the old course of the lower Meghna River (acc. to LRP)

- Daria Nadi cross-dam

The experimental Daria - Nadi closure was executed by constructing a cross-dam in 1982 on the Daria Nadi at the North-east of Char Lakhmi. A drainage channel was also excavated to link U/S of Daria Nadi with Noakhali Khal. A water control structure was then constructed at the outfall of the excavated channel to facilitate drainage, water retention and protection against saline intrusion. A link road-cum-dyke was built linking closure dam and water control structure to protect the area to the north east of link road from saline water.

After construction an area of about 1800 hectares of land has been accreted on the D/S of Daria Nadi and further accretion is going on (Figure A04-5.4).

5.3.3 Design aspects and costs

From the past experiences of construction of the previous cross-dams, the design of the proposed cross-dam can be made (Figure A04-5.5).

Basically two approaches are possible for construction of cross-dams.

- approach with local equipment, local labour, and local materials,
- approach introducing foreign equipment, labour and materials in execution of works.

Which of these approaches will be preferable depends on the results of the studies mainly till to be carried out for the respective location.

Following additional data to be collected :

- bathymetric survey to obtain the recent channel configuration and cross-section;
- soil survey to assess the availability of suitable soil for the construction of dams;
- geotechnical survey to verify the bearing capacity of the sub-soil.

The cost to be involved can be found out from the design of materials and the unit cost prepared by BWDB for that locality.

5.3.4 Conditions for successful application

After collecting all the required data, a prefeasibility and feasibility study to be done extensively for the project and if found successful, the project of cross-dam may be taken up for execution.

5.4 Sill

5.4.1 Description of physical process

Another possibility to reduce local tidal volumes, is the construction of 'Sill' in channels falling dry at 'low-water'. By constructing submerged sills, preventing part of the water to go out at low tide, would accordingly result in less currents at flood tide. Due to stagnation of the silt - containing water, the submerged sills will not only reduce currents at the sea side, but also promote accelerated siltation upstream.

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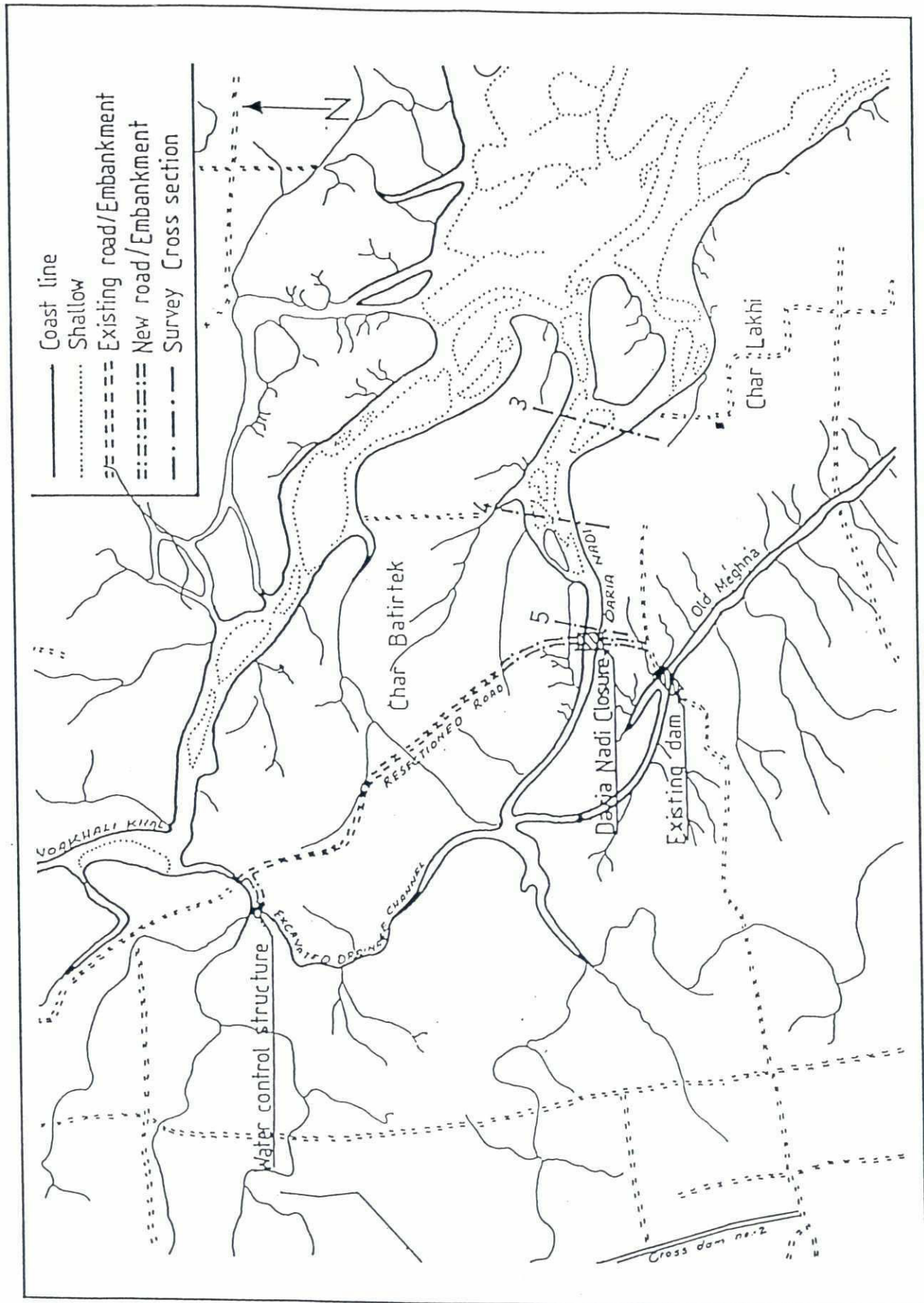


Figure A04-5.4 : Daria Nadi Closure and related works (acc. to LRP)

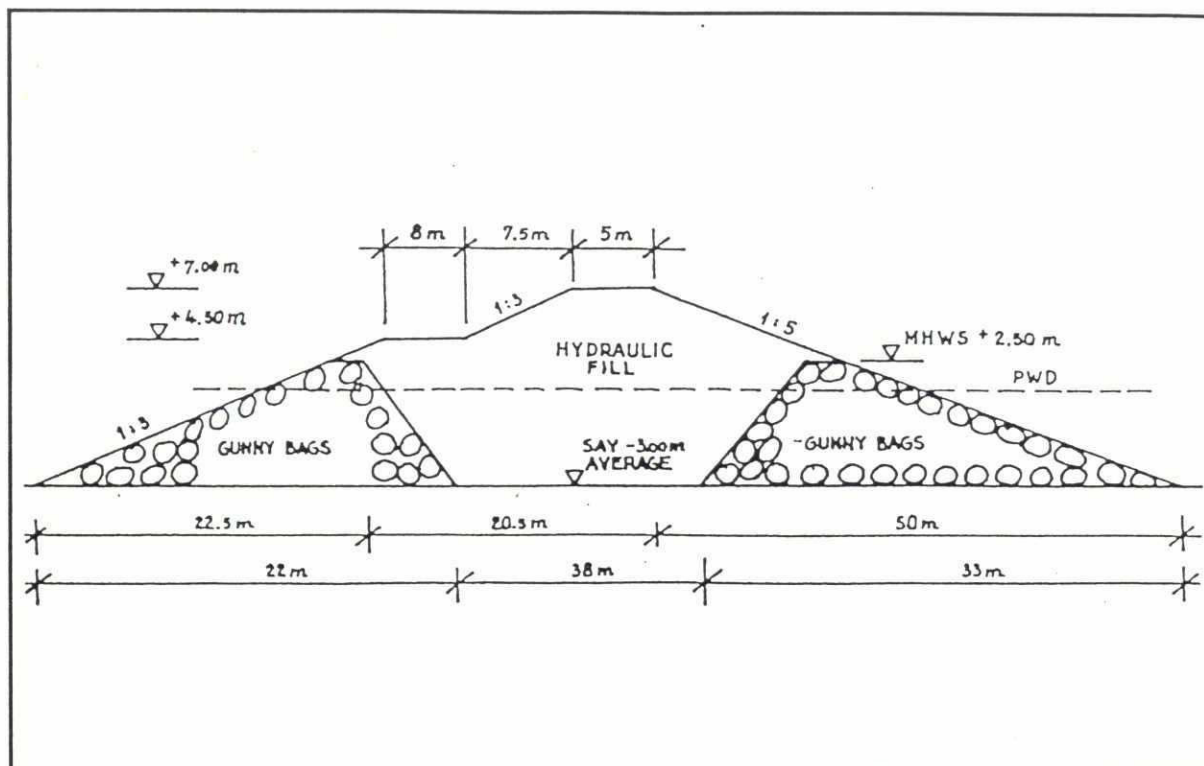


Figure A04-5.5 : Section of a cross-dam (acc. to LRP)

5.4.2 Evaluation of reference project

Realising such a sill in cross-sections as shown in Figure A04-5.6, the total tidal discharge passing this cross section would be reduced with 20% to 85% in mid-winter, respectively during spring tide and neap tide. In summer these figures would be 6% and 25%. Apart from the reduced discharge, more depth during the initial stage of flood tide will lower the velocities. Another possibility would be to construct more than one sill. The advantage is that more water is stored in this way, resulting in less discharge over the down stream sill, which means more safety or scope for a higher crest. Constructing a sill of 1.5 m height near the cross-section would give reductions of 70% and 100% in winter, 25% and 100% in summer for cross-section no. 5 and 20%, 40%, and 5% and 25% respectively for cross-section no. 3. Different possibilities in this respect and construction methods for the sub-merged sills will be investigated.

Of course, other consequences of the sills need careful consideration such as drainage problems and problems concerning possible disadvantages for the people living along the channel e.g. for the fishermen. Allocation of land e.g. for borrow pits, may have to be realised.

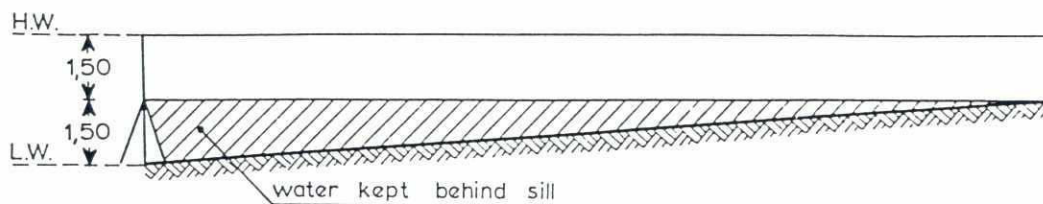
5.4.3 Design aspects and coast

After collecting all the required data, the design of 'Sills' (Fig-8) may be made based on previous experiences at different locations. The cost involves can be worked out according to the design of materials and labour and the unit cost calculated by BWDB for different locations.

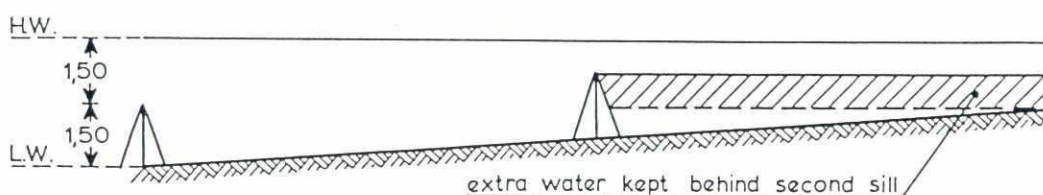
5.4.4 Conditions for Successful Application

All the required data to be collected and the possibilities of constructing sills at suitable locations have to be studied extensively and if comes out successful, the project may be taken up.

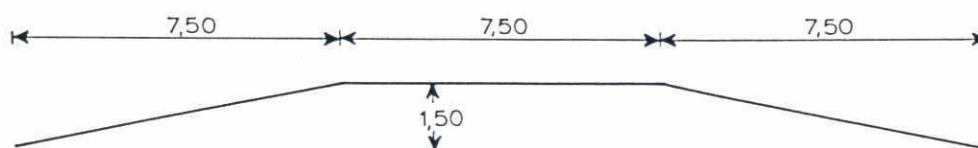
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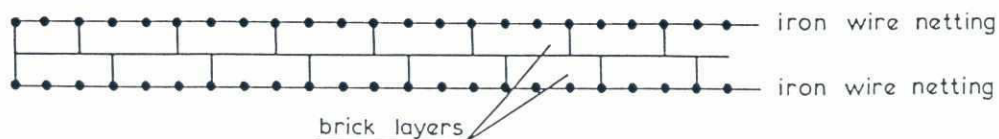
EFFECT OF A SUBMERGED SILL ON FLOOD VOLUMES



EFFECT OF A COMBINATION OF TWO SILLS ON FLOOD VOLUMES



POSSIBLE CROSS-SECTION OF SILLS SCALE 1:150



TOP COVER FOR SILLS SCALE 1:20

Figure A04-5.6 : Preliminary sketches of submerged sills (acc. to LRP)

5.5 Afforestation

5.5.1 Description of Physical Process

Mangrove plantations offer good possibilities for protecting the embankment bordering agricultural areas against erosion as a result of short waves and bores. Vegetation itself will smooth out turbulence and reduce current. As a result accretion rates are promising thus providing a high foreland which acts as a break water. Annual accretion rates to be expected are estimated to 0.15 to 0.25 m though no monitoring ever took place.

5.5.2 Evaluation of Reference Projects

Coastal afforestation projects were undertaken by the Bangladesh Forestry Department. The aim of afforestation was two fold.

- protecting the embankment from wind and waves
- promoting accretion of land for agricultural use in future.

The emphasis was put to the first aim which demanded for a belt of mangrove forest which should not be discontinuous and not too narrow.

Standards about requested dimensions of the belt and information on effects of the mangrove on wind and waves were not available. So, if and when the second aim can be served without affecting the first aim is very uncertain.

5.5.3 Design Aspect and Cost

In the beginning afforestation carried out by seeding the tidal flats but results were marginal due to washing away of the seeds. Later on seeding was replaced by planting of 1 year old seedlings with a height of about 0.4 m which was much more successful.

The cost of the seedling will be found out from the local forestry department and total cost per Hectare may be found out.

5.5.4 Conditions for Successful Application

Conditions for successful plantations are

- Availability of a 0.25 - 0.30 m thick mud layer
- Ground level above mean low neap tide during plantation.
- Availability of 2.5 hours of sun-shine a day

After plantation 50% to 70% of the seedlings may be washed away due to wave activity, so for 3 years the washed out seedlings to be replaced by new ones. Once a protective belt is formed, the forest will stabilize and is expected to extend itself in a natural way.

