People's Republic of Bangladesh
Ministry of Irrigation, Water Development
and Flood Control

Flood Plan Coordination Organisation

Southwest Area Water Resources Management Project

United Nations Development Programme
(BGD/88/038)

Asian Development Bank
(TA No 1498-BAN)

FAP 4

FINAL REPORT

Volume 1

Main Report

August 1993

Sir William Halcrow & Partners Ltd.

in association with
Danish Hydraulic Institute
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SOUTHWEST AREA WATER RESOURCES MANAGEMENT PROJECT (FAP-4)

FINAL REPORT - VOLUME 1

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AEZ	Agro-Ecological Zones
Aman	Main Monsoon Paddy
AST	Agricultural Sector Team
Aus	Late dry season/early monsoon Paddy
BADC	Bangladesh Agriculture Development Corporation
B.Aman	Broadcast Aman
Baor	Ox-bow lake
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BFDC	Bangladesh Fisheries Development Corporation
BFRI	Bangladesh Forest Research Institute
BIWTA	Bangladesh Inland Water Transport Authority
BIWTC	Bangladesh Inland Water Transport Corporation
BIWTMAS	Bangladesh Inland Water Transport Master Plan
BKB	Bangladesh Krishi Bank
BLRI	Bangladesh Livestock Research Institute
BMD	Bangladesh Meteorological Department
Boro	Winter (dry) season Paddy
BRAC	Bangladesh Rural Advancement Committee (NGO)
BRDB	Bangladesh Rural Development Board
BRRI	Bangladesh Rice Research Institute
BSS	Bhumiheen Samabay Samity (Landless Cooperative Society)
BWDB	Bangladesh Water Development Board
CARE	Cooperative for American Relief Everywhere (NGO)
CEP	Coastal Embankment Project
CERP II	Second Coastal Embankment Rehabilitation Project
CH	Chainage (1 Chain = 100 feet)
CIDA	Canadian International Development Agency
DAE	Department of Agricultural Extension
DANIDA	Danish International Development Agency
DHI	Danish Hydraulic Institute
DOF	Department of Fisheries
DPHE	Directorate of Public Health Engineering
DSSTW	Deep Set Shallow Tube Well
DTW	Deep Tube Well
EIRR	Economic Internal Rate of Return
FAO	Food and Agriculture Organisation of the United Nations
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FCD/I	Flood Control, Drainage and Irrigation
FFYP	Fourth Five Year Plan
FPCO	Flood Plan Coordination Organisation
GB	Grameen Bank
GIS	Geographical Information System
G-K	Ganges - Kobadak
GOB	Government of Bangladesh
HYV	High Yielding Variety
IDA	International Development Agency (World Bank)

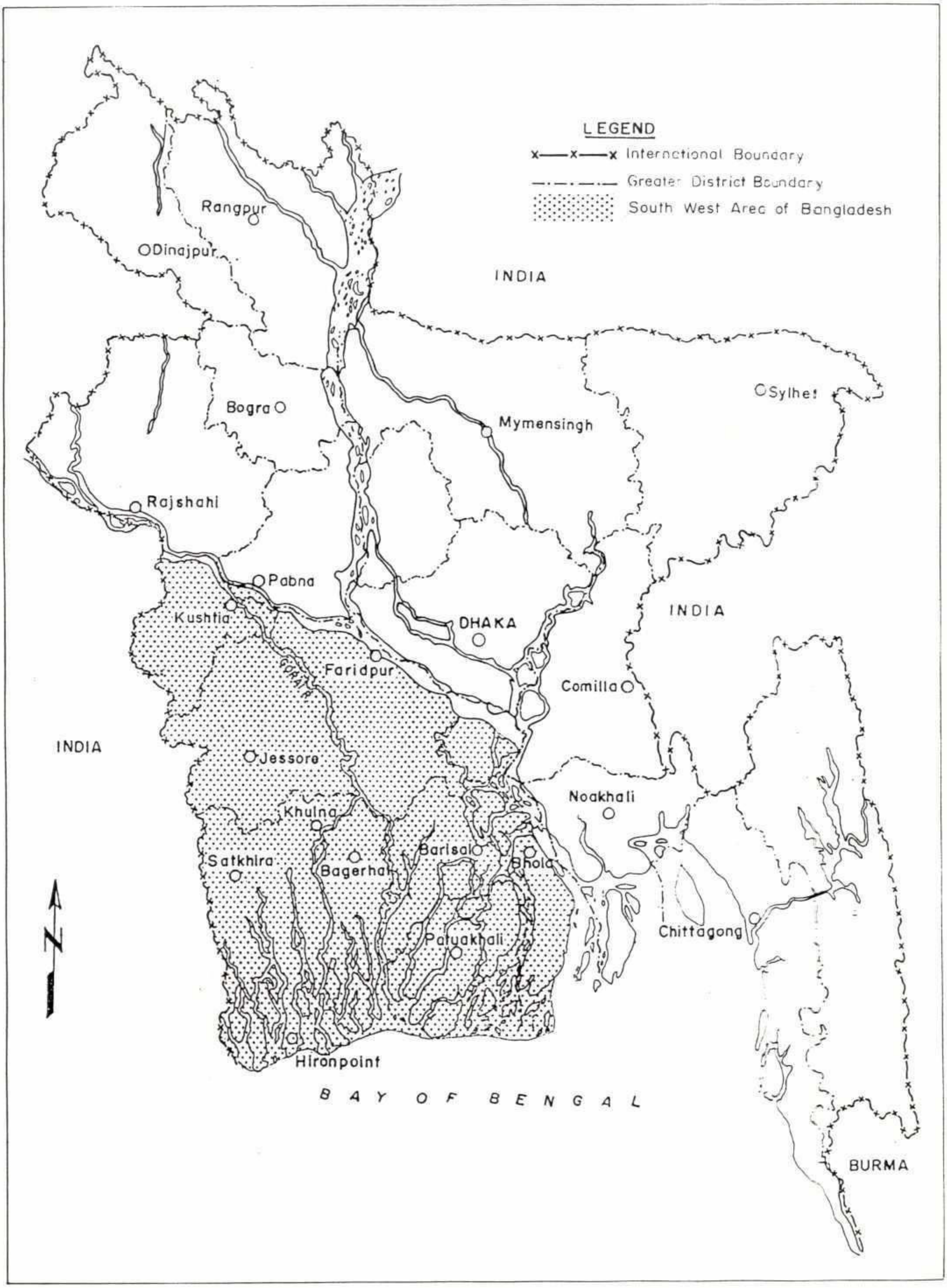
IECO	International Engineering Company Inc
IFAD	International Fund for Agricultural Development
Khariff	Summer, monsoon cropping season
KSS	Krishi Samabya Samity (Farmers' Cooperative Society)
LAD	Least Available Depth
LLP	Low Lift Pump
LGEB	Local Government Engineering Bureau
MBR	Madaripur Beel Route
MLGRDC	Ministry of Local Government, Rural Development and Cooperatives
MP	Muriate of Potash
MPO	Master Plan Organisation
MS	Ministry of Shipping
MSY	Maximum Sustainable Yield
NAM	Rainfall Runoff Model
NFC	National Flood Council
NFMP	New Fisheries Management Policy
NGO	Non - Government Organisation
NWC	National Water Council
O & M	Operation and Maintenance
ODA	Overseas Development Administration (U.K)
PDB	Power Development Board
PDEU	Population Development and Evaluation Unit
PEP	Production Employment Programme
PET	Potential Evapotranspiration
PU	Planning Unit
PWD	Public Works Department
Rabi	Winter (dry) season crop
RAOM	Resource Allocation and Optimisation Model
RB	Right Bank
R & H	Roads and Highways
SC	South Central
SCR	South Central Region
SCRM	South Central Regional Model
STW	Shallow Tube Well
SW	South West
SWA	South West Area
SWAM	South West Area Model
SWRM	South West Regional Model
SWMC	Surface Water Modelling Centre
SWR	South West Region
T. Aman	Transplanted Aman
TOR	Terms of Reference
TSP	Triple Super Phosphate
UCCA	Upazila Central Cooperative Association
UNDP	United Nations Development Programme
UNO	Upazila Nirbahi Officer
Upazila (Now Thana)	Administrative Unit above Union and below Zila
WFP	World Food Programme
WARPO	Water Resources Planning Organisation
WSS	Women's Cooperative Society

PART I

Regional Water Resources

Management Plan

Figure 1.1



South West Area Location Map

1 INTRODUCTION

1.1 Background

The Southwest Area Water Resources Management Project forms a component of the Bangladesh Flood Action Plan (FAP) formulated in 1989 as the first stage of a systematic long-term programme to implement a countrywide flood control strategy. The Flood Action Plan, conceived in the wake of disastrous floods in 1987 and 1988, provides the basis to implement a comprehensive system of flood control and drainage works consistent with the country's long-term development strategy. The objectives of the Flood Action Plan are contained in the Eleven Guiding Principles which are reproduced in Table 1.1. These provide the framework for the development planning to be undertaken.

The project which was financed by the United Nations Development Programme (UNDP) and the Asian Development Bank (ADB) with ADB acting as executing agency commenced on 20 October 1991 with a 19 month study period.

The location of the project is shown in Figure 1.1.

1.2 The Flood Action Plan

1.2.1 Action Plan

After the unprecedented floods of 1987 and 1988, the Government of Bangladesh (GOB) undertook a comprehensive review of flood control and drainage policy. Soon after the 1988 flood, work began on a Flood Policy Study and Flood Preparedness Study, both financed by UNDP, and completed in early 1989. In addition, in 1988, a 'Prefeasibility Study of Flood Control' initiated by Government of France and carried out directly by experts from Bangladesh and France, the 'Eastern Waters Study' sponsored by USAID and a study supported by the Japanese Government were also carried out. An 'Action Plan for Flood Control' was prepared by the World Bank in July 1989 in consultation with the Government of Bangladesh. The Action Plan covering the five year period 1990-1995 is the first of several stages in the development of a comprehensive system of flood control and drainage works designed to meet the Government's long-term objectives.

The main components of the Flood Action Plan (FAP) are given below:

MAIN COMPONENTS

FAP 1	Brahmaputra Right Bank Embankment Strengthening
FAP 2	North West Regional Study
FAP 3	North Central Regional Study
FAP 3.1	Jamalpur Priority Project
FAP 4	South West Area Water Resources Management Study
FAP 5	South East Regional Study
FAP 6	North East Regional Study
FAP 7	Cyclone Protection Project
FAP 8A	Greater Dhaka Protection Project
FAP 8B	Dhaka Integrated Town Protection Project
FAP 9A	Five Towns Protection Project
FAP 9B	Meghna Left Bank Protection Project
FAP 10	Flood Forecasting and Early warning
FAP 11	Disaster Preparedness

TABLE 1.1

THE ELEVEN GUIDING PRINCIPLES

1. Phased implementation of comprehensive Flood Plan aimed at:

   - protection of urban, rural, commercial, industrial and public utility centres and communication networks;

   - controlled flooding, wherever possible and appropriate, to meet the needs of agriculture, fisheries, navigation, urban flushing,soil productivity and recharging the surface water/groundwater resource with minimum dislocation of the environment.

2. Effective land and water management of protected and unprotected areas, involving compartmentalisation, drainage, irrigation, drainage decongestion, land use, cropping patterns, environment, ecology, erosion/sedimentation control etc.

3. Strengthening and equipping the disaster management machinery including building infrastructure for quick and effective communication and transmission during disasters.

4. Improvement of the flood forecasting system and establishment of a reliable and comprehensive flood warning system with adequate lead times and at the same time evolving techniques for dissemination.

5. Safe conveyance of the large cross-boundary flow to the Bay of Bengal by channeling it through the major rivers with the help of embankments on both sides.

6. Effective river training works for the protection of embankments,infrastructure and population centres, linked wherever possible with the reclamation of land in the active river flood plain.

7. Reduction of distribution of load on the main rivers through diversion of flows into major distributaries or interception of local runoff/local rivers by channeling through major tributaries or special diversions.

8. Improvement of the conveyance capacity of the river networks to ensure efficient drainage through appropriate channel improvements and ancillary structures to provide regulation and conservation.

9. Development of flood plain zoning as a flexible instrument to accommodate necessary engineering measures and allocate space for habitation patterns, economic activities and environmental assets.

10. Coordinated planning and construction of all rural roads, highways and railway embankments with provision for unimpeded drainage.

11. Encouraging maximum possible popular participation by beneficiaries in the planning, implementation, operation and maintenance of flood protection infrastructure and facilities.

In addition to the above, there are fifteen (15) supporting components as detailed below:

FAP 12	FCD/I Agricultural Review
FAP 13	O & M Study
FAP 14	Flood Response Study
FAP 15	Land Acquisition and Resettlement Study
FAP 16	Environmental Study
FAP 17	Fisheries Study and Pilot Project
FAP 18	Topographic Mapping
FAP 19	Geographic Information System
FAP 20	Compartmentalisation Pilot Project
FAP 21/22	Bank Protection, River Training & AFPM Pilot Project
FAP 23	Flood Proofing Pilot Project
FAP 24	River Survey Programme
FAP 25	Flood Modelling/Management Project
FAP 26	Institutional Development Programme

All the main components except one (FAP-11) and the supporting studies except FAP-26 have commenced and some of the studies are completed.

1.2.2 Flood Plan Coordination Organisation

A National Flood Council and an Implementation Committee for the Action Plan were established in September 1989 by the Government. The council meets periodically to review progress on the Action Plan and formulate policies needed to ensure timely implementation. The Implementation Committee is headed by the Minister of Irrigation, Water Development and Flood Control (MOIW&FC) and has the responsibility and authority to review and approve the recommendations of the Technical Committee. The Technical Committee's main responsibility during the study phase of the Action Plan will be to work with the various bilateral and multilateral agencies in the design, financing and supervision of studies and pilot projects. The Technical Committee will be assisted by an Expert Panel composed of local and foreign experts in the fields of engineering, agriculture, economics, social and environmental sciences etc.

The World Bank, as requested by the GOB, will assist in coordinating the Action Plan on behalf of the Donors.

In order to provide support directly to the MOIW&FC the Flood Plan Coordination Organisation (FPCO) was created to assist in the planning, project preparation, monitoring and evaluation functions of the Action Plan. FPCO is headed by a Chief Engineer who is assisted by 6 Superintending Engineers, 11 Executive Engineers and other technical and administrative staff.

FPCO is the implementing agency for the Southwest Area Water Resources Management Project (FAP-4).

1.2.3 Interaction with other FAPs

The Terms of Reference recognises the need for the study to interact closely with related FAP components to ensure that the study is consistent with the overall strategy of FAP and it is acknowledged that the relevant proposals and results of some of the components will have a direct impact on the Southwest Area.

The FAP programme is now well advanced and into its third year of Plan. All except one of the main components and one of the supporting activities have commenced. Some of the studies have already been completed and others in advance stages of completion.

The expected interactions between the Southwest Area Study and other related FAP studies are summarised in Table 1.2.

Contacts have been made with all the relevant FAP study teams and discussions held. Close coordination was also maintained with the ADB financed Coastal Embankment Rehabilitation Project II (CERP II) which was completed recently.

1.3 Study Objectives and Terms of Reference

The Government's main sector development objective under the current Fourth Five-Year Plan (FY 1990/91-1994/95) and the National Water Plan (NWP) is to increase agriculture production with the aim of achieving food grain sufficiency through more efficient and balanced use of natural resources. The main objective of the study is to assist the Government in formulating a comprehensive regional water resources development and management plan for the Southwest Area, thereby helping the Government to achieve its long-term goal for sustained growth through the balanced, systematic development and management of the region's land and water resources. Within this broad objective, the study is intended to provide an understanding of the region's complex land and water regimes and to develop a capacity to forecast the impact of development activities on the delicate resources setting of the region. These measures would be primarily aimed at sustained agricultural growth within a well defined environmental management framework for the Area, encompassing multi-sectoral activities such as agriculture, fisheries, forestry, navigation etc.

In formulating the regional water resources management plan, the Study would identify a number of medium to long-term water resources management projects.

The Study would be implemented in a number of phases to provide the following outputs:

- a phased, long term, land and water resources management plan
- a framework that will allow the Government to identify and evaluate in a systematic way justifiable development options and to formulate first priority projects
- a portfolio of priority projects identified on a preliminary basis

Detail Terms of Reference (TOR) are given in Appendix 1.

TABLE 1.2

RELATED FAPS AND RELEVANCE TO FAP 4

FAP No	Study	Relevance to FAP 4
1	BRE Strengthening	(a) Downstream impact of river training
2	NW Regional Study	(a) Downstream impact of drainage and flood control (b) Downstream impact of flood control on Ganges RB (c) Downstream impact of irrigation abstraction from Ganges
3	NC Regional Study	(a) Downstream impact of flood control embankments on LB of Brahmaputra
5B	Meghna Estuary Study	(a) Defining conditions and planning development along the common L. Megna - Tetulia River boundary.
7	Cyclone Protection Project	(a) Proposals for improving and rehabilitating coastal embankments/polders. (b) Priority schemes (c) Design standards
9A	Secondary Towns Integrated Project	(a) Selected towns including Flood Protection of Khulna (b) Environmental standards for secondary towns (c) Flood protection and river training standards for towns
10	Flood Forecasting and Early Warning	(a) Flood forecasting for the Ganges (b) Cyclone warning for Southwest Region
11	Disaster Preparedness	(a) Infrastructure for flood and cyclone preparedness (b) Establishing strategic food reserves
12	FCD/I Agricultural Study	(a) Assess impact of flooding, flood control and drainage (FCD) and flood control, drainage and irrigation (FCDI) on agriculture (b) Review existing FCD and FCDI schemes and assess agricultural, economic, social and environmental impact. (c) Prepare guidelines for future FCD/I including methodology for FAP feasibility and evaluation studies
13	Operation & Maintenance Study	(a) Review Operation and Maintenance(O&M) of existing schemes (b) Formulate proposals for future O&M of FAP schemes
14	Flood Response Study	(a) Assess likely impacts of embankments and compartments on flood response activities
15	Land Acquisition	(a) Review of existing land acquisition procedures including compensation levels and method of payment (b) Preparation of recommendations for improving and streamlining land acquisition procedures to lessen impact on affected households under FAP.
16	Environmental Study	(a) Identify environmental implications of flood control development (b) Prepare EIA guidelines for FAP
17	Riverain and Floodplain Fisheries Study & Pilot Project	(a) Study of fish and shrimp production in floodplain water resource systems to be affected by activities of Action Plan (b) Determination of social and economic benefits for the fishery and fishing sector in floodplain areas.
18	Topographic Mapping and Related Activities	(a) Aerial photography of riverain areas of all major rivers (b) Preparation of LANDSAT and SPOT photo maps for Bangladesh (c) Establishing GPS Network of primary and secondary stations.
19	Geographic Information Systems	(a) Preparation of national Geographic Information System incorporating SPARRSO, MPO, Bureau of Statistics, DAE, BARC and BIDS information.
20	Compartmentalisation Pilot Project	(a) Guidelines on water management beneficiaries participation and institutional aspects
21 & 22	Bank Protection and River Pilot Project	(a) Design and construction standards for river training (b) Review of land reclamation methods and identification of social/institutional issues.
23	Flood Proofing Pilot Project	(a) Development of new, high productivity cropping strategies which take account of differing water regimes (b) Developing opportunities for and benefit of flood proofing
24	River Survey Programme	(a) Collect hydrological, morphological and hydrographic data at key locations on the main rivers (b) Undertake special studies on the behaviour of the river systems
25	Flood Modelling and Management	(a) Establishment of hydrological standards for hydraulic studies (b) Mathematical modelling for floodplain, management
26	Institutional Development Programme	(a) Review of institutional capability for project planning, implementation, maintenance and operation (b) Identification of problems facing BWDB in the implementation of projects (c) Formulation of proposals for project implementation under FAP

1.4 Scope of Report

The Terms of Reference require a number of Reports to be submitted at specific periods. An Inception Report detailing the approach to the study, methodology, work plan and staffing schedule is to be submitted at the end of month three. This was submitted on 20 January 1992 as required and was reviewed at a Tripartite meeting held on 8 March 1992.

An Interim Report on the progress of the hydraulic and morphological studies was submitted at the end of month eight on 20 June 1992. Comments on the Report were received on 3 September 1992 and replies were sent on 15 September 1992. Annexes on Hydrology and Hydrogeology were provided with this Report.

A Second Interim Report was submitted at the end of month twelve, (November 1992) which included an Interim Water Resources Management Plan and a preliminary list of portfolio of projects. Comments on the Report were received in January 1993 and replies were sent in April 1993.

TOR require the Draft Final Report to be submitted at the end of month 18. the Draft Final Report will include the regional water resources management plan including the results of the hydraulic and morphological studies.

The TOR also require a feasibility report of the selected early implementation priority project to be submitted with the Draft Final Report. However during the technical meeting between the ADB, FPCO and the Consultant on 15 November 1992 to discuss the Second Interim Report it was decided that the Consultants,

- complete the regional water resources management plan by May 1993
- study the Gorai Augmentation Scheme to pre-feasibility level by May 1993
- review the list of priority projects recommended in the Second Interim Report and submit a new list of priority projects to ADB and FPCO by 17 December 1992 so that priority project(s) could be selected for feasibility study
- prepare a revised work programme and staffing schedule to incorporate the above by 15 January 1993.

A new list of priority projects with recommendation for feasibility study together with revised work programme and staffing were sent to ADB and FPCO on 15 December 1992 but no decision was taken on the selection of project for feasibility study. Since there was limited time available for the completion of the Draft Final Report by May 1993 it was decided in addition to completing the regional water resources management plan and the pre-feasibility study of the Gorai Augmentation Scheme some additional work is to be carried out on a selected project (Chenchuri Beel Rehabilitation Project) and reported.

Copies of Notes on the meetings with FPCO and ADB are appended with the TOR in Appendix 1.

The Draft Final Report was submitted in 13 Volumes in May 1993 and the comments on the Report were received from the FPCO, ADB and other organisations in June/July 1993. Replies to the comments were sent in August 1993 which were discussed at the Review Committee meeting on 24 August 1993. Final Report is then produced taking into account these agreed comments.

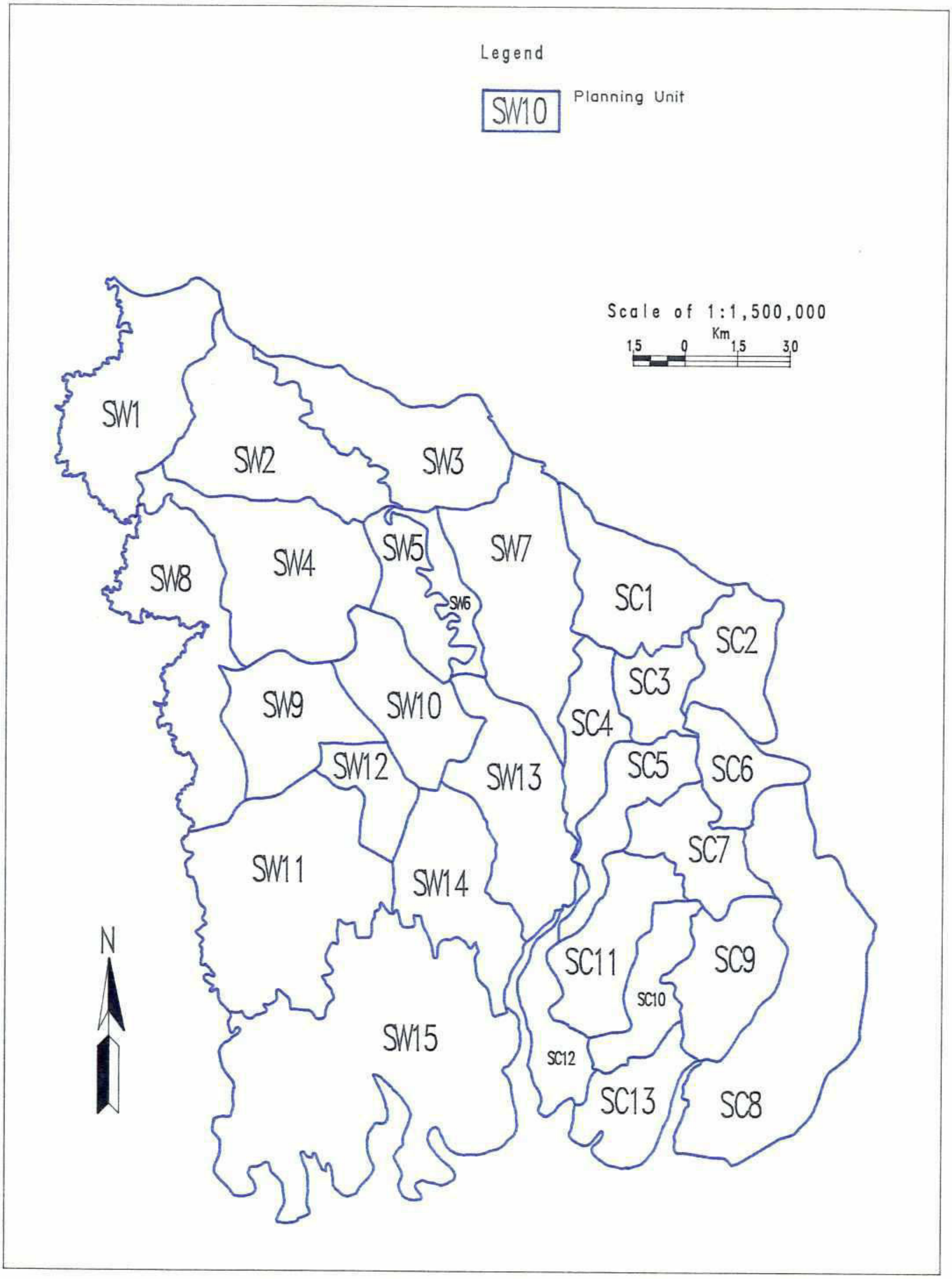
1.5 Structure of Report

The Final Report is produced in 13 volumes. Volume 1 is the Main Report which consists of three parts: Part I summarises the present situation, the needs, issues and constraints, the development choices leading to the Regional Water Resources Management Plan. Part II describes in detail the Water Resources Management Options including for the three 'burning issues' and in Part III other sectoral policy options are discussed. The other volumes include supporting Annexes, results of the hydraulic and morphological studies, pre-feasibility of the Gorai Augmentation Project and other selected schemes.

The full list of the Final Report is given below:

Vol 1 Main Report
Vol 2 Hydraulic Studies
Vol 3 Morphological Studies
Vol 4 Coastal Studies
Vol 5 Hydrology, Hydrogeology and RAOM
Vol 6 Land Resources, Agriculture and Fisheries
Vol 7 Forestry and Navigation
Vol 8 Engineering
Vol 9 Impact Studies
Vol 10 Economics
Vol 11 Regional Data
Vol 12 Pre-feasibility study of the Gorai Augmentation Project
Vol 13 Pre-feasibility studies of selected Projects

Figure 2.1



Planning Units

2 REGIONAL OVERVIEW

2.1 General Description of the Area

2.1.1 Location and Topography

The Southwest Area (SWA), which includes the Southwest and South Central Regions, comes under the jurisdiction of the greater districts of Kushtia, Jessore, Faridpur, Khulna, Barisal, and Patuakhali which includes 16 Zilas of Khulna Administrative Division, 5 Zilas of the Dhaka Administrative Division and Haimchar Thana in the Chandpur zila of the Chittagong Administrative Division. The SWA comprises an area of approximately 40,450 sq km or 27 percent of Bangladesh's total area. The Area is bounded by the Indian border to the west, by the Ganges-Padma and Lower Meghna rivers to the north and east, by the Bay of Bengal to the south. 62 percent of the Area is cultivated, about 10 percent or 4,000 sq km is covered with a coastal mangrove forest known as 'Sundarbans' and about 13 percent is surface water areas including rivers and natural land depressions known as 'beels'.

The northern part of the area upto Jessore-Kamarkhali-Faridpur is comparatively high to medium high land with a rolling topography : drops from an elevation of + 14 m PWD to + 6 m at an average slope of 1 in 7500. Further south of Jessore-Fardipur, the topography starts off as gently sloping but soon becomes very flat. This southern part has a large number of beels and low lying areas. In addition, the coastal areas, which includes the Sundarbans, are criss-crossed by a number of tidal rivers and creeks.

For the purposes of planning the SWA has been divided into 27 Planning Units (PU), 14 in SWR and 13 in SCR. The derivation of PUs is described in Volume 5 and Figure 2.1 shows their locations.

2.1.2 Climate

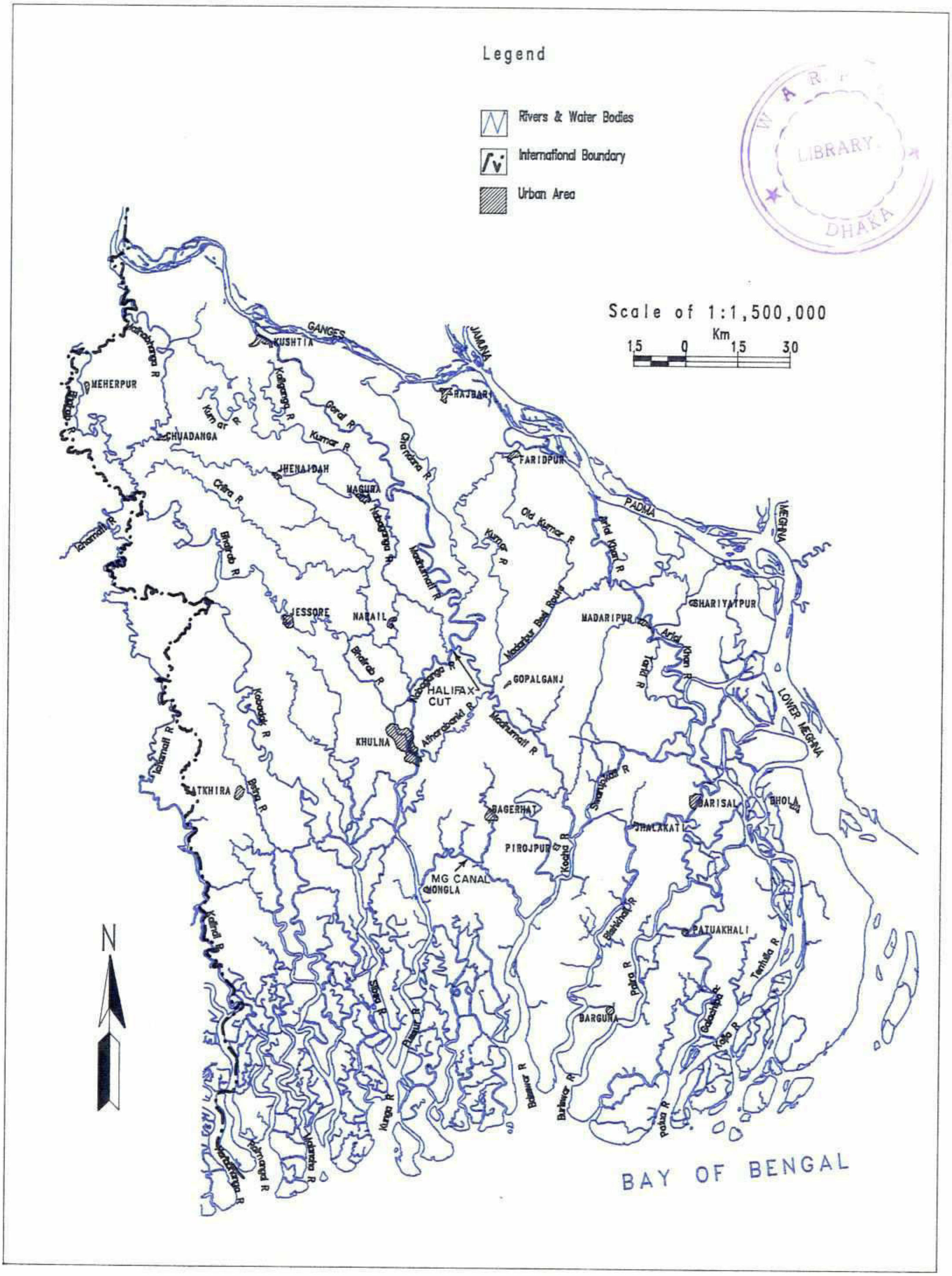
The study area has a typical monsoon climate with a warm and dry season from March to May followed by a rainy season from June to October and a cool period from November to February. The mean annual rainfall in the Area is 2000 mm of which approximately 70% occurs during the monsoon season. Rainfall in the Area generally varies in a north-west to south-easterly direction, increasing from a mean annual rainfall of 1500 mm in the north-east to 2900 mm in the south-eastern corner of the Area. Potential evapotranspiration rates are of the order of 1500 mm and exceed the rainfall rates from November to May. The Area has high relative humidity which varies from 70% in March to 89% in July.

The study area experiences moderate to high duration of sunshine hours across the Area and durations in excess of 8.5 hours outside the monsoon season are not uncommon. The mean annual temperature is 26°C with peaks of over 30°C in May. Temperature in winter can fall to 19°C in January.

The southern region of the study area and in particular the south-eastern coastline is vulnerable to cyclones during the monsoon season when storm surges can cause dramatic increases in water level of up to 4 m above tide and seasonal levels. The south-west coastline is protected to some extent by the dampening effects of the Sundarbans although surges do progress up the major rivers.

The climate is in general favourable for agriculture across the Area throughout the year.

Figure 2.2



Major River Network

2.1.3 River Systems

The Southwest Area is demarcated by the courses of the major rivers bounding the area, the Ganges, Padma and Lower Meghna together with the Bay of Bengal to the south. The boundary rivers spill into several major distributaries which cross the Area giving access to fresh water and maintaining internal drainage channels. The regional distributary rivers receive additional drainage flows during the monsoon season from inland rivers which mostly follow the course of former regional rivers. More than half of the area is tidally influenced and the major regional rivers of the south central area are dependent on tidal effects as is much of the drainage of the southern part of the Area. The importance of the dynamics of the river system in forming and sustaining the landscape cannot be overstated and detailed studies of all regionally significant rivers including the boundary rivers have been undertaken. The results and implications of these studies are summarised in this report and further details are given in Volumes 2 to 5.

The major rivers of the Area are shown in Figure 2.2 and characteristics of selected regional rivers are given in Table 2.1.

TABLE 2.1

Characteristics of Main Regional Rivers

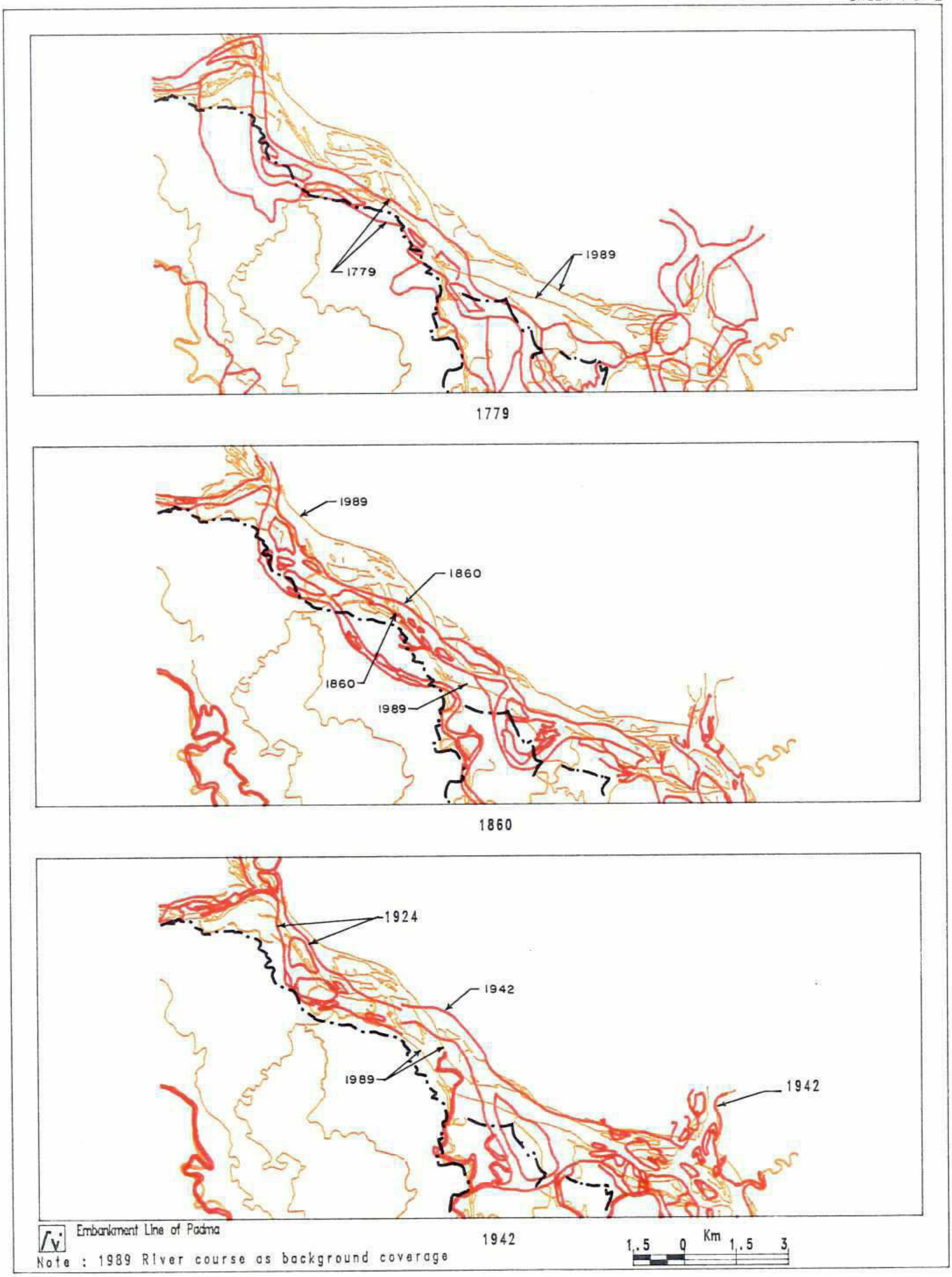
River Name	Tidal/Non-Tidal	Dominant Discharge (m^3/s)	Peak Tidal Flow (m^3/s)		Net Flow (m^3/s)		Width (m)
			August	April	August	April	
Gorai	N	4250	-	-	-	-	500
Madhumati	N/T	-	4490	1300	5010	93	600
Lower Madhumati	N/T	-	400	31	320	2	250
Arial Khan	N/T	2000	2900	300	2120	150	400
Swarupkati	T	-	16880	7120	3500	770	400
Buriswar	T	-	19340	9150	3070	620	1250
Biskhali	T	-	10990	8920	2400	360	1600
Tentulia	T	-	9020	4820	4380	1108	4000

Notes: (1) Tidal Flow given for spring tide 1991 from model simulation.
(2) Net Flow derived from mean monthly flow of 25 year tidal simulation using current cross sections.
(3) Width at section for which flows given.
(4) Flows for Madhumati given just above Halifax cut, Lower Madhumati values given just below.

The border with India leaves the Ganges downstream of Rajshahi around the offtake of the Matabhanga river. The Ganges follows a meandering pattern in the approach to the Hardinge Railway Bridge at which the river is constrained and contracted by extensive training works. The bridge marks a point of particular interest as it is the main gauging site for the Ganges and is also the only point at which a major river has been trained in Bangladesh. The site is a natural constriction at a harder clay outcrop on the left bank. The Intake to the G-K irrigation project is just downstream of the bridge and the Gorai offtake at Talbaria some 17 Km downstream.

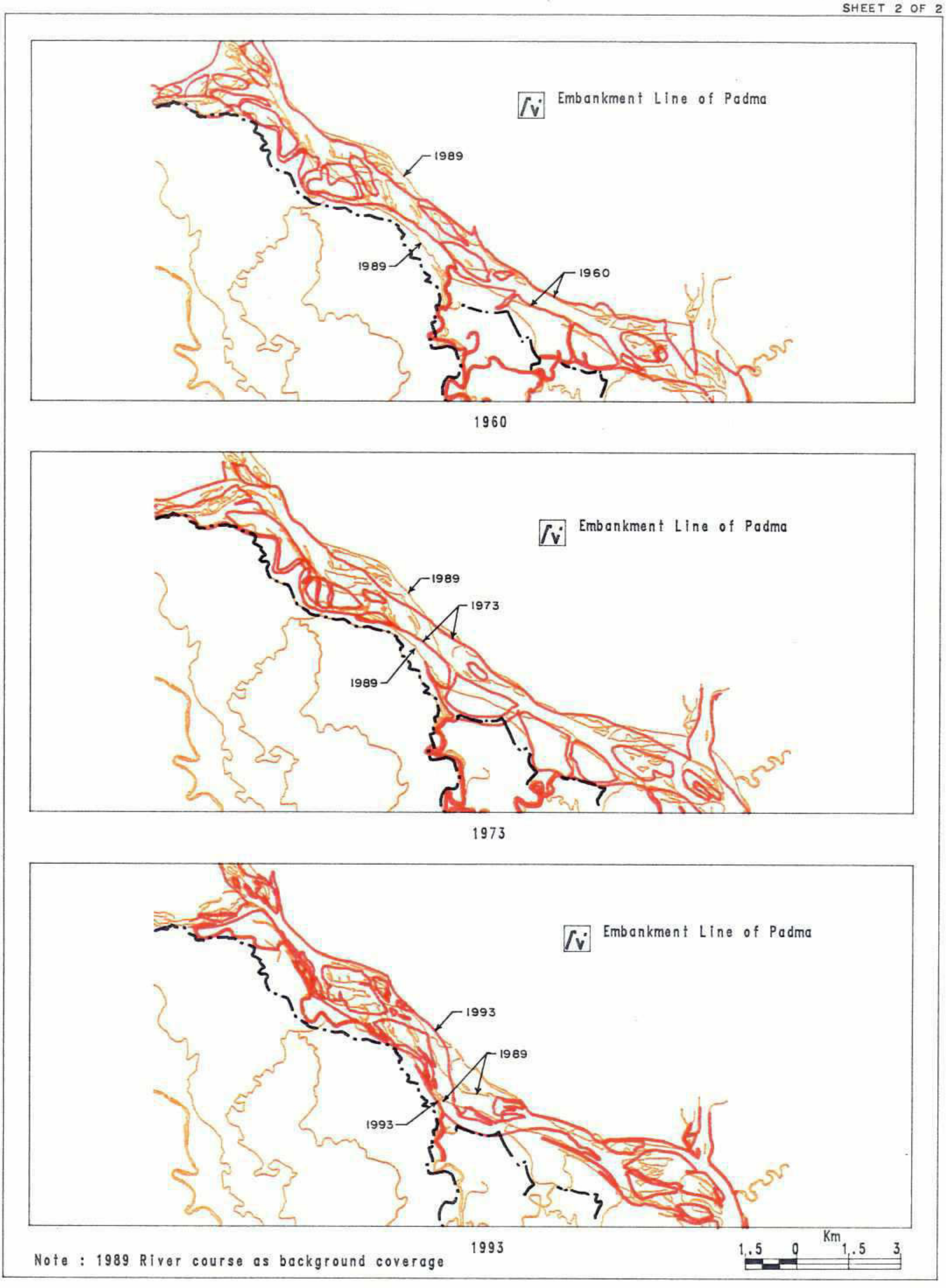
Downstream of the Gorai the Ganges adopts more braided characteristics and major chars and anabranches are apparent. The river is characterised by a wandering pattern of movement within former courses with a periodicity of 40-50 years. In the 100Km reach to the confluence with the Jamuna near Rajbari, two formerly major channels, the Chandana and Kumar rivers receive spill only during high levels in the Ganges. Both these rivers are now controlled by intake gates. The confluence of the Ganges with the Jamuna marks the transition to the Padma which has significantly greater dry season flows than the Ganges and is geologically much younger and more active than the Ganges.

Figure 2.3
SHEET 1 OF 2



BANKLINE MOVEMENTS OF PADMA 1779–1942

Figure 2.3
SHEET 2 OF 2



BANKLINE MOVEMENT OF PADMA 1960 – 1993

The upper part of the Padma has a single channel and carries a dominant bankfull flow of about 70,000 m3/s and conveys an annual sediment load of 0.5 x 10^9 tons. The movement of the banks of the Padma can be extremely fast as illustrated in Figure 2.3. This results in the favouring or cutting off the various spill channels. The upper part of the Padma has tended to move in a North easterly direction on average over the last century allowing embankments to be constructed on the right bank in the Faridpur area. Further south towards the Meghna the channel becomes tide affected and is also constrained by geological features upstream of which the greatest channel movements take place. Towards the confluence with the Meghna shifting chars are present possibly due to the constricting effect of the large bend into the Lower Meghna. The spill channels from the Padma are the Kumar at Faridpur and the three channels feeding the Arial Khan, the dominant one at present is the upstream channel though for navigation purposes the middle channel the Dubaldia is the favoured route. The upper Meghna joins the Padma providing only a relatively small additional freshwater flow.

The Meghna is tidal throughout with a mean tidal range of less than 1m at the Chandpur to over 2.5m at the Bay of Bengal. The influence of the tide varies between the monsoon period and the dry season. During high monsoon flows tidal influence is decreased as well as saline intrusion into the estuary and into the regional rivers as shown in Figure 2.4. The Meghna is the main active delta building river and significant changes to the patterns of erosion and accretion can be seen over relatively short time spans including a general trend for accretion on the right bank.

The main regional rivers are the Gorai Madhumati, the Arial Khan and the tidal rivers of the South Central region which feed into the Baleswar, Bishkhali, Buriswar, Lohalia and Tentulia channels. These regional rivers play a key role in maintaining the health and vitality of the Area and detrimental changes must be guarded against.

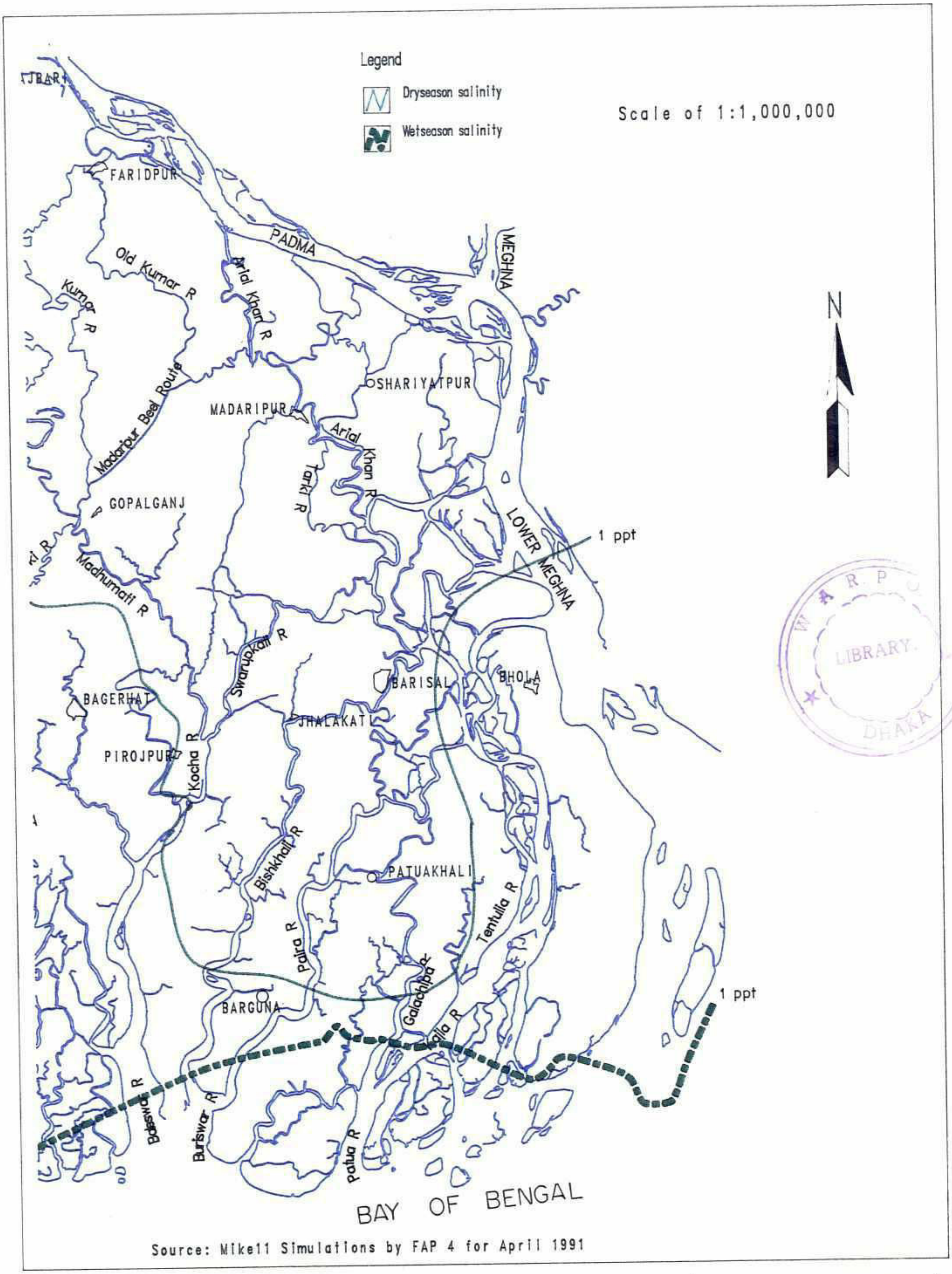
The Gorai river is the only remaining major spill channel from the Ganges. The Gorai is important as it fulfills a number of functions such as salinity control, maintenance of a large tidal volume at the head of the Pussur Sibsa system, and influencing the siltation rates in the tidal zone. The gradual decline of the Gorai that may be expected is thus of concern and is discussed further in Section 9.

The tidal areas of the Southwest are characterised by large estuaries such as the Pussur, Sibsa, Malancha and Raimangal/Hariabhanga (marking the border with India) which are interlinked by numerous smaller channels and are sustained by tidal spill, fresh water flows and differences in the time of tidal propagation which causes net flow from one estuary to another. The western part of the area is saline even during the monsoon season, whereas the central Pussur Sibsa is fresh during the monsoon and increasingly saline at other times. The eastern rivers are fresh due to high net flow from the Meghna though there is limited saline intrusion at the coast. The Tetulia channel to the west of Bhola Island is dependant on the position of the saline front in the Meghna and can become more saline than desirable if the front moves above the top of the Island.

Notable inland rivers such as the Nabaganga, Chandana, Chitra, Kumar, Kobadak and Bhairab serve as essential drainage channels that are generally at a lower level than the regional rivers.

The complexity of the river network in the Southwest area has been appreciated in the study through field visits and surveys, analysis of mapping and satellite imagery, analysis of hydrological data and numerical modelling of rivers to supply additional data where field results were not readily available.

Figure 2.4



Source: Mike11 Simulations by FAP 4 for April 1991

MEGHNA ESTUARY SALINITY LEVEL(WET & DRY SEASON)

2.1.4 The Coastal Zone

The coastal zone of the Area comprises the extensive, flat, coastal and deltaic land of the Ganges Delta which is crossed by large tidal rivers discharging into the Bay of Bengal. The south western coastal zone is in a state of transition from an actively developing delta of the Ganges to a semi moribund delta partially sustained by 'local' rivers. Of these 'local' rivers only the Gorai receives significant fresh water flows from the Ganges.

The south central coastal zone is part of the active Meghna delta and as such is not showing moribund tendencies.

The coastal area is subjected to coastal processes which include tides causing periodic variations in water levels and currents, consequential saline intrusion, wave attack on the coastal fringe, surges and extreme wave attack due to cyclone and possible long term sea level rise due to global warming.As a consequence of the flat topography coastal processes have a major impact on the freshwater resources of the area.

The average tidal range in the area varies from approximately 3.0 m on the coast at Hiron Point to 0.5 m 275 km inland. The time difference between high water at Hiron Point and high water at Narail is approximately 7 hours. In addition to daily tidal fluctuations there are half yearly increases in sea level of 600 mm in the northern part of the Bay of Bengal due to the onset of the wet season and the NE Monsoon. These fluctuations combine with seasonal changes in river level caused by changes in freshwater flows. These reversals are experienced up to 225 km inland in the wet season and 325 km inland in the dry season as shown on Figure 2.5.

Tidal propagation into the delta system carry saline water inland which mixes with the fresh water to create different levels of salinity in the river system, depending on the upland freshwater discharges.A level of average saline intrusion likely to have an adverse effect on agriculture, 1 ppt (2000 mmhos), is experienced through 10% (4000 sq km) of the Area in the wet season and throughout 40% (16200 sq km) in the dry season as shown on Figure 2.4. In both seasons the extent of intrusion is greater in the southwest than the south central where intrusion is prevented by the fresh water flows entering the south central area from the Lower Meghna via the Arial Khan. In the southwest the 1 ppt isohaline is 75 km and 150 km inland in the wet and dry seasons respectively. In the south central the corresponding figures are 25 km and 45 km.

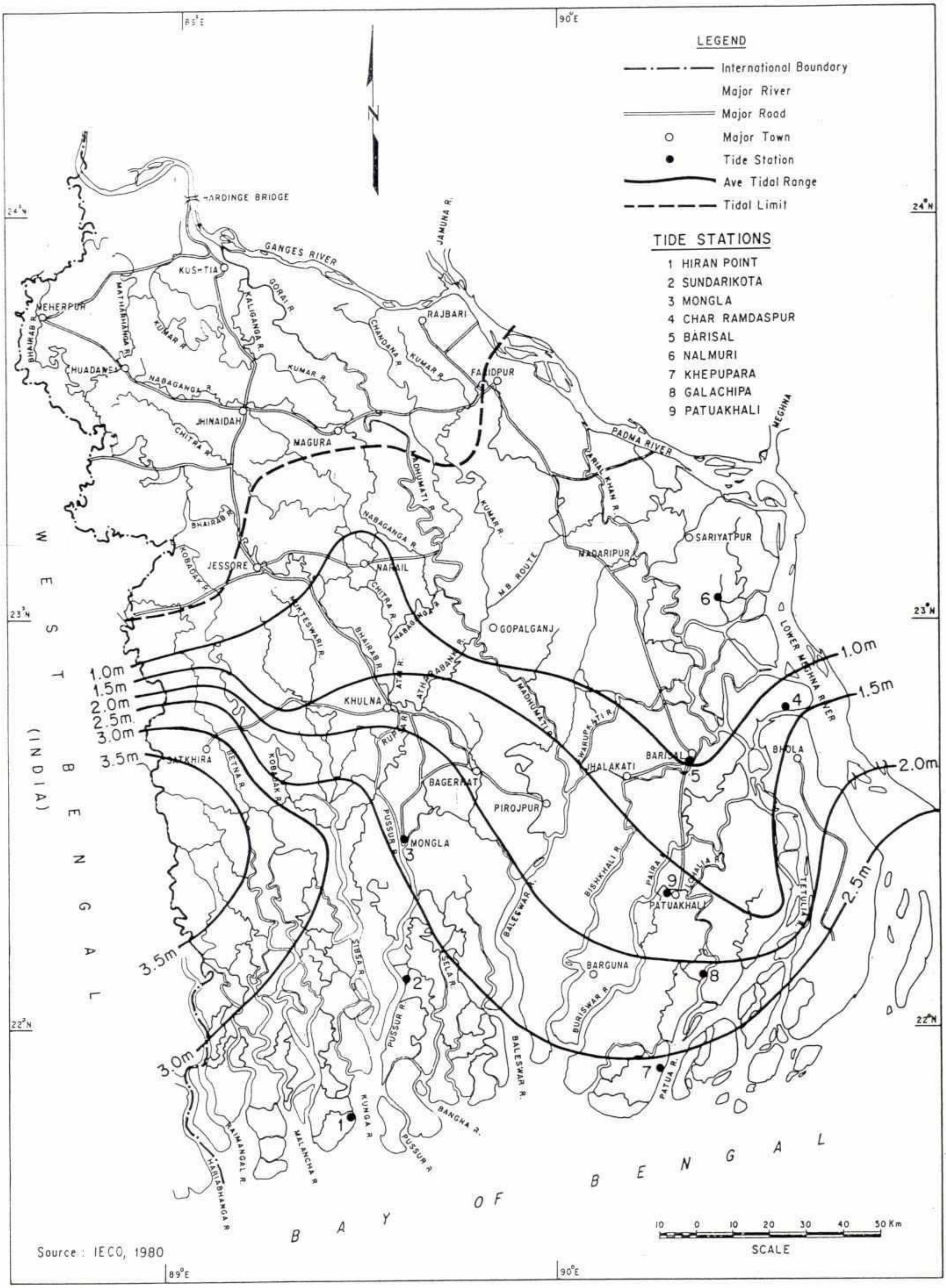
Currents in the coastal zone carry sediments to and from the tidal rivers and influence the shape of accretion and erosion of the coastal boundary. However, except for large scale accretion at the mouth of the Meghna, there have been no significant changes over the last two hundred years to the shape of the coastline. Fine sediment is also transported by tidal currents into the inland areas. It is probable that the sediment originates from the Meghna discharge during the wet season and is carried westwards by near shore currents created by the SW monsoon in the period July to November. Sediment is also carried into the Area by the freshwater rivers.

Cyclones originating in the Bay of Bengal can cause storm surges and waves which have a devastating impact on the coastal region. Although the predominant passage of cyclones is to the east of the Meghna the Area coastal boundary has suffered from storm surge attack. The main areas of vulnerability are the sea facing coastal embankment areas in the south-central and the lands adjacent to the main rivers. The Sundarbans forest dampens the impact of surges in the south west but surges have propagated up the main rivers.

2.1.5 Surface Water Resources

Surface water resources fall into two main categories. The first is that which is associated with flows across the Regional boundaries and the second is runoff which is a consequence of rainfall falling within the Regions. These amounts have been estimated from available data and the Consultants own analysis of rainfall/runoff relationships and of records (amplified by simulation techniques) of rivers flows into the Regions. The results of these analyses are summarised in Table 2.2.

Figure 2.5



Average Tidal Range and Stations

Table 2.2
Surface Water Resources
(MCM/Year)

Runoff - Southwest

PU Code	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	Total
Mean	471	968	124	1,165	485	344	1,721	1,191	712	735	2,072	501	1,602	1,687	13,779
80% Dep	235	537	70	626	294	202	1,080	579	380	384	1,246	282	991	1,052	7,958

Runoff - South Central

PU Code	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6	SC 7	SC 8	SC 9	SC 10	SC 11	SC 12	SC 13	Total
Mean	1,229	582	584	731	896	1,009	950	950	1,276	1,188	147	488	1,556	11,586
80% Dep	754	363	355	456	577	687	571	571	866	856	91	374	1,152	7,672

Regional Inflows - Southwest

Location	G-K pumps w1	Gorai w2	Chandana w3	Kumar w4	M B route w5	Baleswar w6	Mathabhang w7	Bhairab w8	Betna w9	Ichamati w10	Total
Mean	1,180	43,567	0	717	4,087	54,082	157	0	0	0	103,789

Regional Inflows - South Central

Location	Arial Khan c1	Arial Khan_L c2	Naria Khal c3	pumped c4	Joyanti 1 Joyanti 2 c7	S Meghna Ilsha c8	Total
Mean	21,523	4,925	484	0	75,676	123,653	226,260

Notes : Runoff estimates are of amounts available before deductions are made for existing irrigation.
Regional inflows are based on values determined from 25 year simulation run results.

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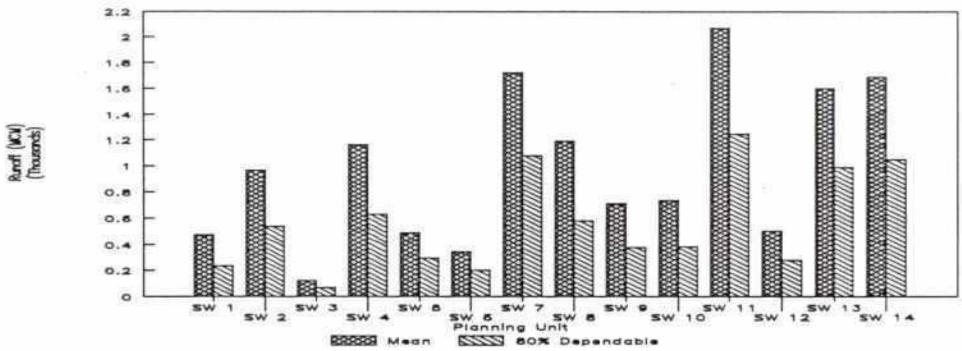
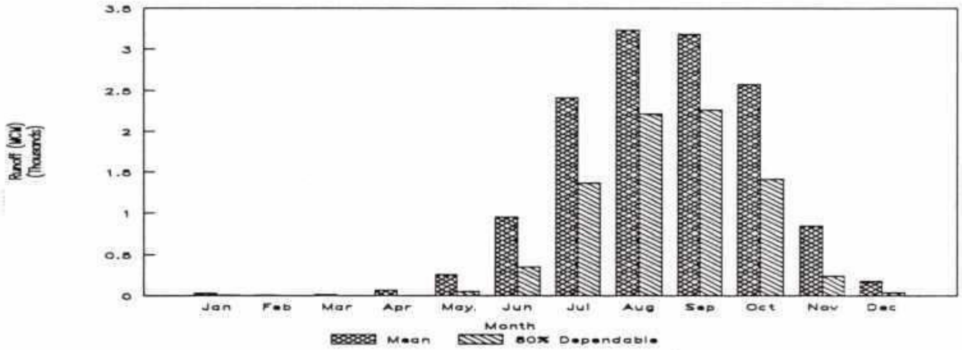
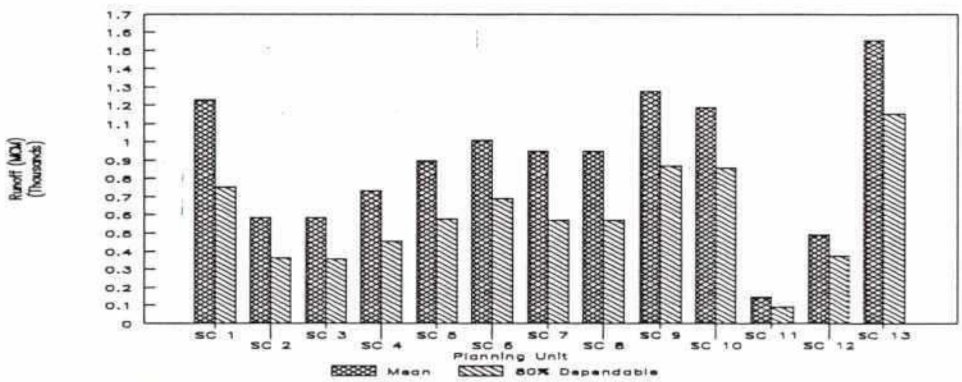
Figure 2.6

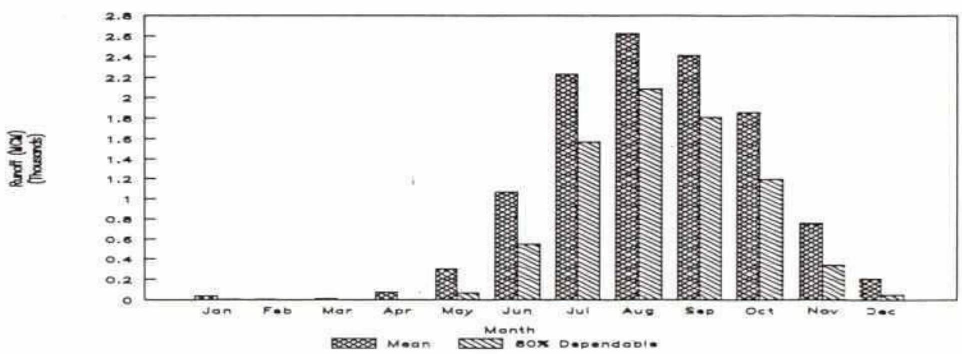
Southwest Region





South Central Region





Regional Runoff

The rainfall is seasonal and catchment runoff naturally follows a similar pattern. Figure 2.6 illustrates the monthly mean and monthly 80% dependable runoffs aggregated for the Southwest and South Central Regions. As may be seen runoff during the months of January - April is negligible. Figure 2.7 illustrates the Regional inflows which again exhibit strong seasonality. The South Central Region nevertheless enjoys a base inflow of around 5000 mcm/month (1930 cumec) throughout the year as a result of its proximity to the Padma and Lower Meghna rivers. The SW Region, however, suffers from the lower flows in Ganges during the dry season attributed to upstream abstractions at Farakka.

At a macro-level the surface water system contains very little storage that significantly lags gross outflows behind gross inflows. Such attenuation as does occur as a result of flooding and filling of natural depressions creates a marginally increased outflow during November through to January but which does not extend significantly into March and April when peak water requirements for winter season crops occurs. At a macro level the potential for increasing storage appears to be negligible. This broad overview does not reflect however the value of even small amounts of storage at a local level. The use of beels as a source of water for irrigation is widespread and there appears scope, in engineering and resource terms, to increase the volumes of storage available. Other possibilities, such as making use of river cut-offs at looped bends, may be beneficial also.

The quality of surface water outside of the areas of saline intrusion is understood to be generally good with no significant limitation upon use for irrigation. The critical issue is the extent of saline intrusion.

Water is used for a variety of means within the Southwest Area including irrigation, potable and industrial water supply, navigation, agriculture etc.

In some instances and mainly in the irrigation and water supply sectors, water is consumed, in others, for instance navigation, water is not consumed but its presence is required. For aquaculture and forestry notably within the Sundarbans, the quality of the water rather than quantity is the key issue. The ability of the rivers to transport sediment in a favourable manner is also a vital issue which has impact upon the overall allocation of water.

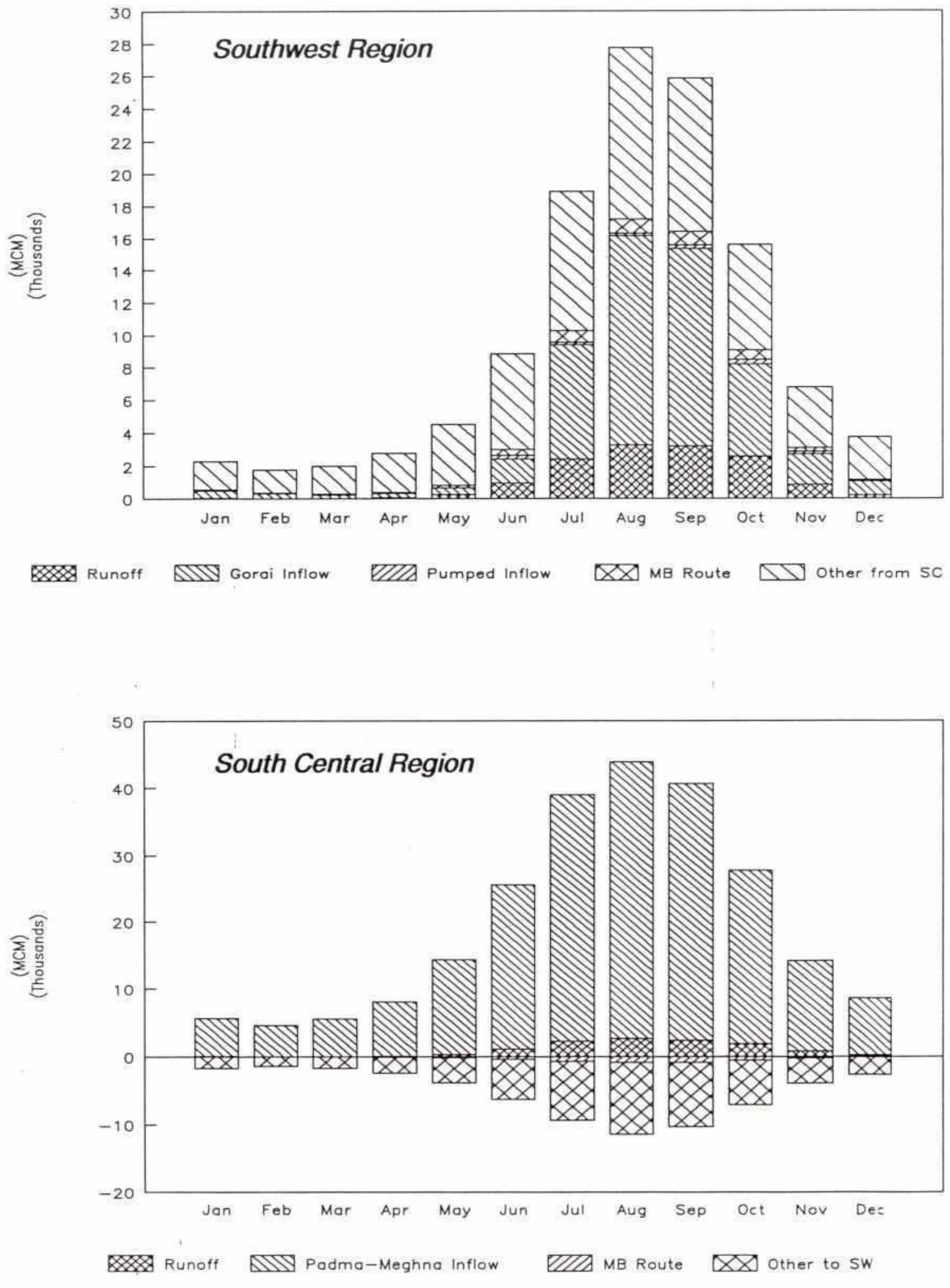
For the main consumptive sectors of irrigation and water supply the critical factors are the availability of water in the dry season both within the rivers and the groundwater table, given that generally no constraints exist within the monsoon season. Dry season surface flows also have a major impact upon the maximum extent to which the saline front moves inland each year and upon the depths of channels for navigation purposes. Whilst these constraints are in place and have to be acknowledged in the South Central Region, they are most felt in the Southwest Region.

In the wet season, whilst it is true to a large extent that the problem is too much water, it needs to be recognised equally that wet season fresh water flows are important from two main standpoints. Firstly, the high river flows flush out the saline front virtually to the coast each year, thus counterbalancing the net inward movement each year during the dry season. Secondly these peak flows contribute to the maintenance of channel sizes, thus keeping the surface water conveyance system in place in the non-tidal areas. This is of course not the case in the tidal areas where cubature is the dominant effect.

Estimates have been made of current irrigation water requirements and domestic and industrial water supply requirements by Planning Unit. The resulting figures compare very closely with MPO's own estimates across the two Regions and enable a structured evaluation of the impact upon water requirements of FCD. Assumptions made with regard to domestic and industrial demands have been updated to accommodate the latest available population statistics.

An overall water balance for the two Regions for the period November - April is set out in Table 2.3.

Figure 2.7



Expressed as mean values derived from 25 years simulation run results.

Regional Inflows

Table 2.3

Dry Season Water Balance

Mean Values (MCM for Nov-Apr)

Southwest Region

Boundary Inflows		Resources		Potential Demands		Balance Resources - Demands	
G-K pumps	614	Total Groundwater	2,347	Domestic	131	Groundwater	943
Gorai	3,971	Additional Groundwate	586	Industrial	4	Surface water	(8,201)
Kumar	26	Total Runoff	1,160	Groundwater Irrigation	1,480	Boundary Inflows	18,278
M B route	544			GW to Conjunctive use	375	Less Gorai (unreliable flows)	(3,971)
Baleswar	12,938			Surface water Irrigation	9,361	Less Baleswar (mostly unuseable	(12,938)
Mathabhanga	148						
Betna	37						
Total	18,278		4,094		11,352	*Net Regional Balance*	*(5,889)*

South Central Region

Boundary Inflows		Resources		Potential Demands		Balance Resources - Demands	
Arial Khan	2,420	Total Groundwater	850	Domestic	67	Groundwater	635
Arial Khan_L	410	Additional Groundwate	203	Industrial	1.2	Surface water	(5,628)
Naria Khal	66	Total Runoff	1,086	Groundwater Irrigation	76	Boundary Inflows	45,601
Joyanti 1, Joyanti 2	15,718			GW to Conjunctive use	273		
S Meghna, Ilsha	26,987			Surface water Irrigation	6,714		
Total	45,601		2,139		7,131	*Net Regional Balance*	*40,609*

Notes : Total Groundwater – Calculated GW potential from MPO data
Additional Groundwater – Actually used now over and above the calculated potential
Potential water supply demands for 2017

W_B_POT.wk1

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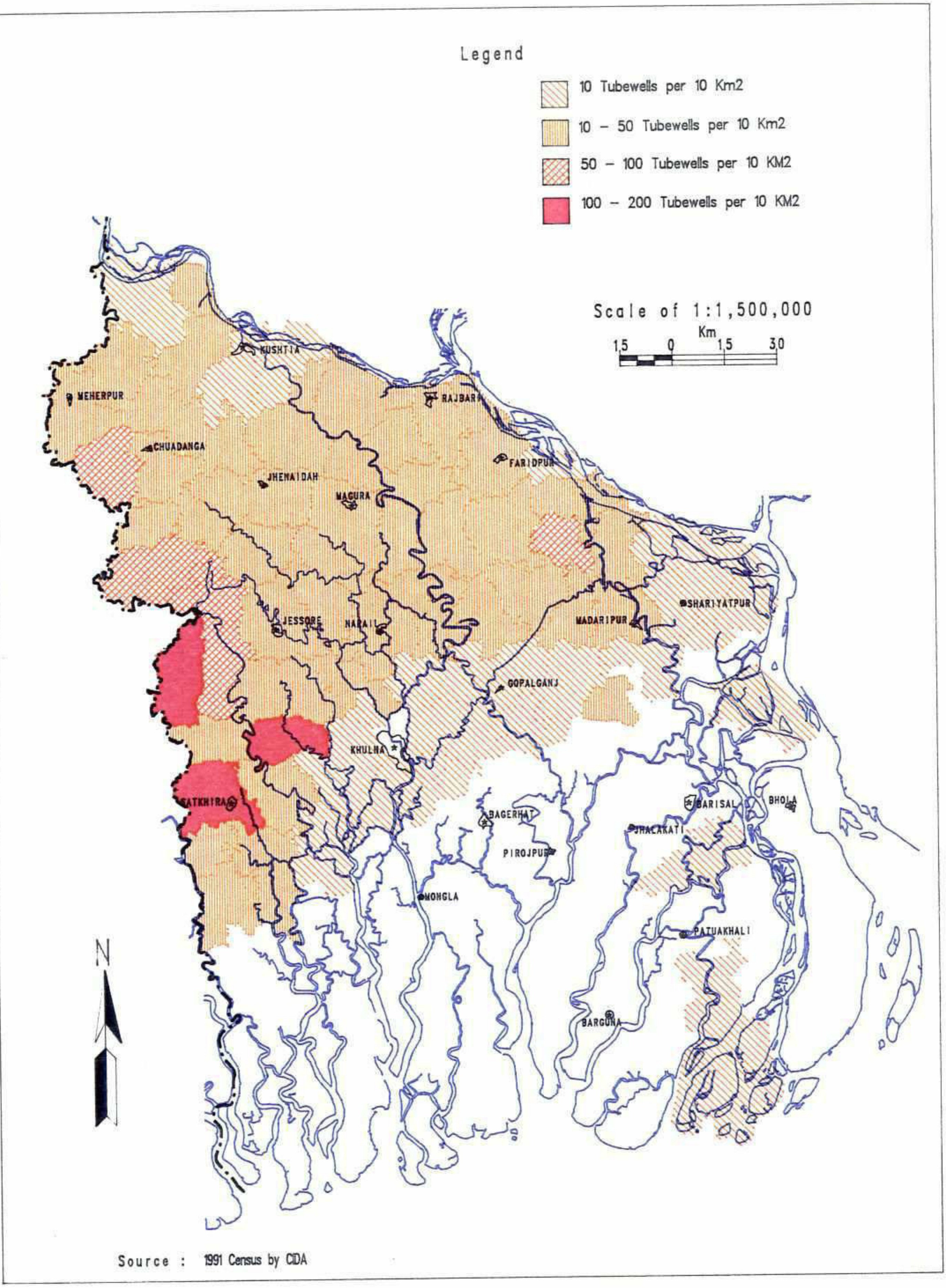
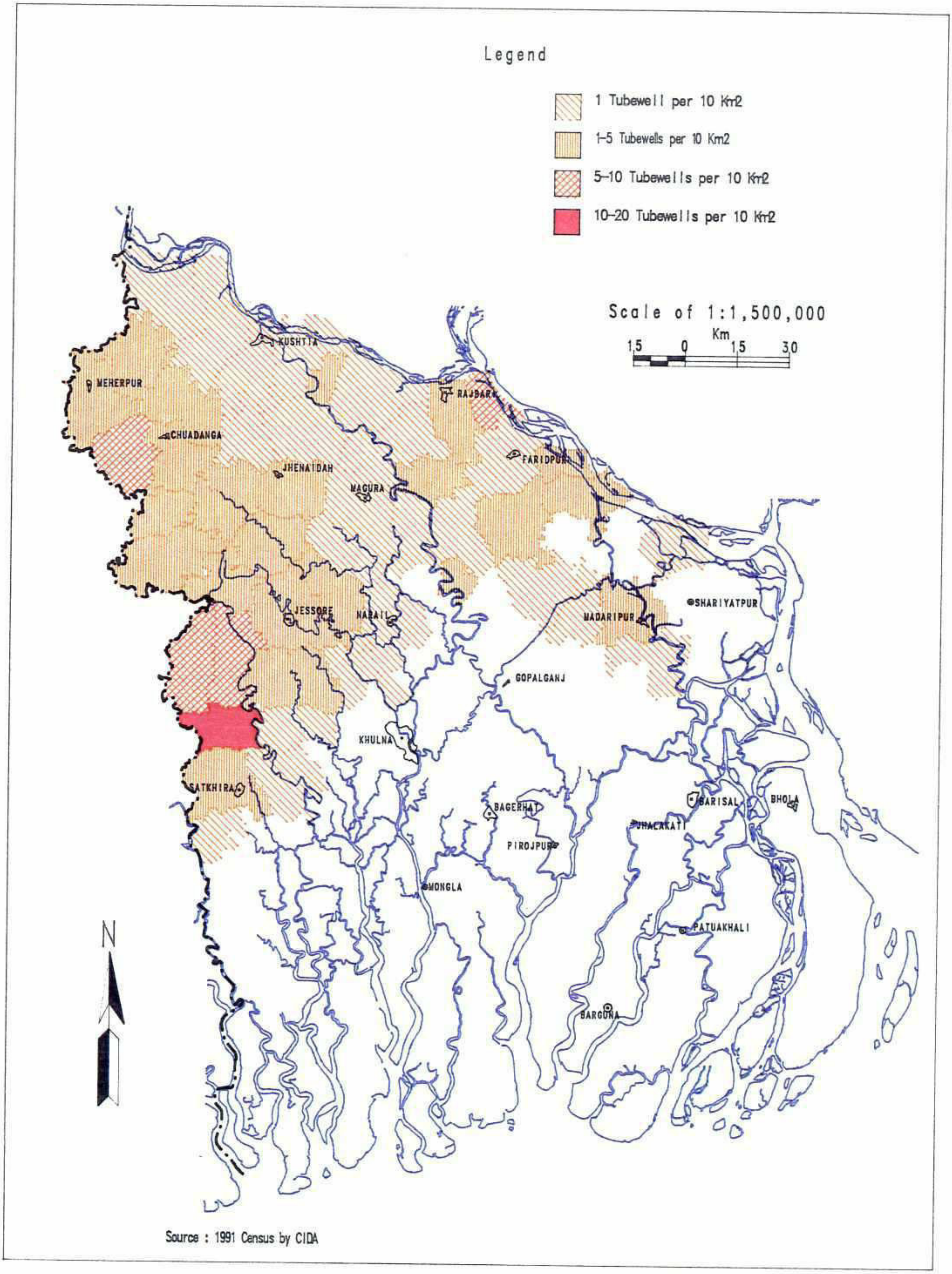
Figure 2.8



Source : 1991 Census by CIDA

Density of Shallow Tubewells

Figure 2.9



Density of Deep Tubewells

2.1.6 Groundwater

The project area is underlain by alluvial sediments of the Bengal Basin, laid down by the Ganges - Brahmaputra - Meghna river system. The sediments become progressively older with depth and lithologically they range from clay and silt, to fine, medium and coarse sand. All are unconsolidated or, at the most, lightly compacted, and the geometry of individual units is inevitably complex. Only those sediments down to 300m depth are of interest hydrogeologically in project terms, and there are no faults or folds within the sediments of hydrogeological significance.

Within this sequence, an aquifer system can be identified which closely relates to the lithological sequence. The main units are:

- an upper clay and silt layer;
- an intermediate layer of clay and fine sand (composite aquifer);
- a layer of fine-coarse sand which is separated by clay from the intermediate layer (main aquifer);

The upper clay and silt layer has poor aquifer properties and is so thick in some parts of the project area as to preclude significant groundwater development for irrigation. The intermediate layer has moderate to good aquifer properties and can provide water to HTW, MOSTI, and sometimes STW. However the lower unit, the Main Aquifer, is the most important source of groundwater for irrigation. The distribution of these units is such that the most favourable conditions for groundwater development are in the northern part of the project area.

Groundwater quality is generally good but because the area includes the coast, there is a saline-freshwater interface. There is always a risk in such circumstances that groundwater development will cause movement of the saline front inland. There is evidence of this process occurring in the water supply wells at Khulna.

Most groundwater movement within the system is vertical. In the dry season water is lost by capillary rise, evaporation, and in areas of groundwater irrigation by well abstraction. This depletion in storage is replaced by recharge during the wet season, during which, field capacity is always reached. Although there are some baseflow losses, and regional groundwater flow patterns can be identified, hydraulic gradients are low, so because the permeability of the surface layers is also low, the lateral volumetric transfer of water is comparatively small.

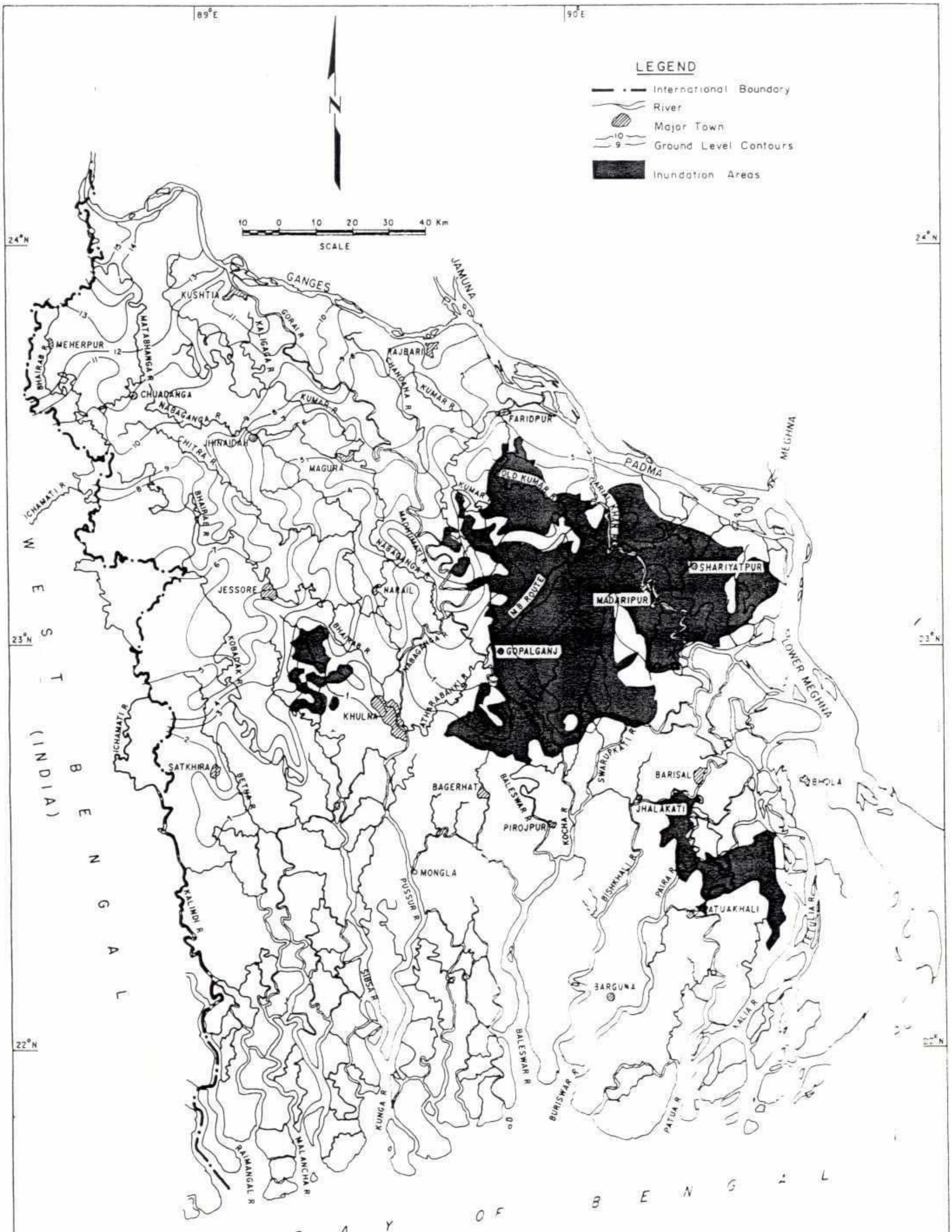
Present distribution of Shallow and Deep Tubewells are shown in Figures 2.8 and 2.9 respectively.

2.1.7 Flooding and Inundation

The mechanisms of flooding and inundation are inter-related. Flooding is taken as an extreme event caused principally from overbank spill due to high river discharges whereas inundation is representative of the depth and duration of water in an "average" condition caused primarily by local run-off and impeded drainage. Thus, inundation is generally taken as that which will dictate land use patterns whereas flooding is more a measure of occasional damage and economic losses.

The MPO derived land categories relating to inundation depths (duration of five or more days) are:- F0 : Less than 30 cm; F1:30 to 70 cm; F2:90 to 180 cm and F3; F4-greater than 180 cm.

Figure 2



Indicative Inundation Areas

Large scale inundation in the Southwest Area occurred in 1987 and 1988 due to the combined effects of drainage congestion and overbank spills from the three major rivers (Ganges, Padma and Lower Meghna) and their main distributaries. The principal cause of inundation in 1987 was drainage congestion, while in 1988 it was overbank spilling. An examination of AVHRR scenes obtained by NOAA-SPARRSO (Figure 2.10.) during the 1988 flood shows a large extent (about 6,500 km^2) in the northeast of the study area inundated. Considering the limited available information on routes, flow segregations and watershed boundaries it would be impossible to demarcate the areas that are inundated predominantly due to internal drainage congestion and overbank spilling.

According to information collected from Coastal Embankment Polder areas about 3300 km^2 of a total poldered area of about 8000 km^2 would be suffering from drainage congestion. The ongoing morphological changes in the coastal rivers and tidal flow into some of the polders due to overtopping, breaches or public cutting have aggravated the drainage congestion.

Data from BBS show that between 1971 and 1989 the average annual value to the economy of flood damage to crops in SWA was just over two percent of the total annual value of all crops. This was equivalent to about Tk 443M each year.

2.1.8 Population

Preliminary data from the 1991 Population census found the SWA population to be 26.1 M, almost one quarter of the country's total 109.9 M. Selected indicators are set out in Table 2.4.

Sixty four percent of the population were found in SWR. In 1991, population density in SWA was 702 pp/km^2 compared with 820 pp/km^2 for Bangladesh as a whole. If the sparsely populated Sundarbans are excluded, overall density rises to 774 pp/km^2. There were significant variations in density within SWA. Planning Unit SW12, which includes most of Khulna municipality, has the highest density, 1625 pp/km^2, SC13 the lowest, 408 pp/km^2 except for SW15, the Sundarbans Forest Reserve which has a small, supposedly transient population of woodcutters and fishermen and a density of about 100 pp/km^2.

About 91% of SWA's people live in the rural areas. The rural population is lower in the SWR (89%), in which the city of Khulna is situated than, in the less urbanised SCR (95%).

Final adjusted age group figures from the 1991 Census were not available for all SWA at the time of writing. Final 1991 data for five southern districts, however show that 30% (range 28-32%) are under 10 years of age a further 59% (55-61%) between 10 and 49 years and 11% (10-13%) over 49 years.

The literacy rate of the over five year old population varies from 17% in Kushtia to 33% in Barisal according to the latest published BBS figures. Typically women have a much lower literacy rate than men, 11-27% compared to 22-40%.

The 4.72 M households in the study area have an average size of 5.5 persons and there is little difference between the size of rural and urban households. The division of households between the various major population groups is also shown in Table 2.4. The size of the full time fishing community is uncertain and the proportions given in the table are approximate.

TABLE 2.4

Selected Population Indicators (1991)

Indicator	Unit	Region		South West Area
		South West	South Central	
Population	#m	16.72	9.39	26.11
urban	%	11	5	9
rural	%	89	95	91
Male/female	ratio	1.06	1.03	1.05
Households	#m	2.97	1.75	4.72
urban		0.34	0.07	0.41
rural		2.63	1.68	4.31
Household size	pp	5.64	5.35	5.53
urban		5.45	5.99	5.55
rural		5.66	5.32	5.53
Literacy	%	na	na	24.8
Density	pers/km²			
Total				
+ Sundarbans		674	757	702
- Sundarbans		784	757	774
Rural				
+ Sundarbans		599	722	640
- Sundarbans		695	722	705
Dependency ratio (1)		2.54	2.35	2.41
Households	#m	2.97	1.75	4.72
landless	%	15	16	15
farming				
marginal	%	21	22	21
small	%	24	23	24
medium	%	24	21	23
large	%	9	6	8
fishing (2)	%	7	12	9

Source: 1991 Statistical Yearbook of Bangladesh, BBS.
Supplement No 1 Preliminary Report on Population Census 1991, June 1992, BBS.

(1) Dependents = 0.9 and 55+ years of age

(2) Data for fishing households uncertain. Estimate taken from BBS data for landless households.

2.1.9 Land Ownership

The latest (1983/84) BBS data showed that one quarter of households in SWA were landless; with less than 0.2 ha; and 76% owned land with an average net cultivable area of 0.88 ha, which by 1991 had fallen to about 0.7 ha. Sixty percent of farm households had less than 0.5 ha and only 10% had more than two hectares. The BBS data showed farm holding to be grouped as shown in Table 2.5.

TABLE 2.5

Farm Holding Size

	Marginal (0.21-0.50 ha)		Small (0.51-1.00 ha)	Medium (1.01-2.00 ha)		Large (>2.00 ha)		All Holdings
SWR %	27		31	31		11		
Av NCA ha		0.32			1.59		4.35	1.00
SCR %	31		32	28		9		
Av NCA ha		0.30			1.54		4.43	0.78
SWA %	28		32	30		10		
Av NCA ha		0.31			1.57		4.39	0.88
National %	70		25			5		
Av NCA ha		0.38			1.67		4.71	0.92

Three categories of rural land tenure are recognised; owner operators, tenants and owners-cum-tenants. National figures show 63% of holdings to be owner operated, one percent tenanted and 36% farmed by owner-cum-tenants. In SWA the division between the categories was: owner operator 59-70%, owner-cum-tenants 29-41% and tenants only exceeded one percent in Kushtia District.

Most tenancies are under a share cropping system. Government regulations covering tenancy conditions set out the division of output as: 33% to the landowner, 33% to the share cropper who provides labour and draught power and the balance to whoever provides the other production inputs. In practice local customary arrangements often apply and may be altered at short notice even though legislation provides that unless good reason can be shown agreements should not change for a period of five years. In SWA two main share cropping arrangements are found:

	Labour Draught power %	Other Inputs %	Output %
(1) Owner	-	50	50
Sharecropper	100	50	50
(2) Owner	-	-	33
Sharecropper	100	100	67

Seasonal or annual cash rents also occur but on a small scale and mainly in the Southernmost parts of SWA.

2.1.10 Health and Nutrition

Over 80% of disease in Bangladesh is associated with water. Malaria, dengue fever, dysentery, cholera and many other diseases and parasites are widespread, and cause significant damage to the national economy and the more immediate quality of rural and urban life.

Most health problems result from poor sanitation, personal and communal hygiene. The use of open waters brings people into contact with waste from poorly sited latrines and a wide range of substances washed from adjacent land.

Health hazards are increased where water supplies depend on hand pumps and the level of the aquifer has fallen below suction height. This occurs with increasing frequency in the dry season where shallow tubewells are installed and used without regulation for irrigation.

Still surface water found in borrow pits, ponds, low velocity canals and drains is associated with a range of serious vector borne diseases and the increasing infestation of such areas with aquatic weeds improve insect breeding conditions and the related risk of disease.

Data for Bangladesh show the lowering of food intake and its nutritional value in the recent past. From 1962/64 to 1981/82; more recent data are sparse; the decline has been significant as illustrated in the table below.

Consumption per person/day		1962/64	1975/76	1981/82	Reduction 1962/64-1981-82
Energy	Kcal	2300	2094	1943	-15.5
Carbohydrate	gm	482	439	412	-14.5
Protein	gm	57.9	58.5	48.4	-16.4
Fat	gm	15.8	12.2	9.8	-38.0

Source : INFS University of Dhaka, Nutrition survey of Bangladesh 1981/82

Contributions from livestock, fish and non cereal crops, pulses and oilseeds in particular, have with as a result of increasing pressure on land, the spread of rice cropping in the rabi season under irrigation and deteriorating conditions for capture fisheries. These commodities have become increasingly more expensive and beyond the reach of the poorer sections of the community.

In 1991 the gross production of the major nutrition components from SWA cropping was:

Per person/day	Energy Kcal	Carbohydrate gm	Protein gm	Fat gm
Southwest Region	2092	422	47.7	9.8
South Central Region	2142	444	46.7	11.2

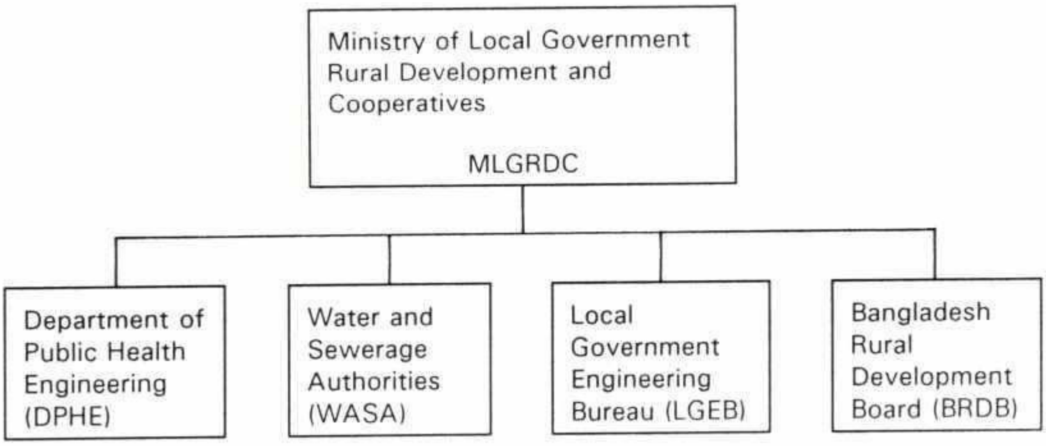
Actual consumption, after losses of perhaps 12 to 15% (for rice) are lower. The figures compare with the accepted minimum daily requirement of 2275 Kcal energy and 45.3 gm protein each person.

The nutritional deficits and poor health conditions can both be improved, in part, by the better distribution, utilisation and management of water resources proposed in the SWA study.

2.1.11 Public Administration

The SWA proposals for water resource management will affect whole communities. To realise maximum benefits to the proposed SWA schemes requires the involvement of each of the individual groups within the community at all stages; from the approval of the initial proposals through design and construction to long term operation and maintenance. Individual groups will benefit to varying degrees and some may be disadvantaged so it is clearly preferable that all groups are kept aware of developments and given the opportunity to influence and participate in the development and operation of the schemes. There are a wide range of organisations; including non-government organisations (NGO), traditional community structures, government and private sector organisations; which each target a particular section of the community and their interests differ and may be opposed. In addition a number of government and non government bodies are likely to be directly involved in the schemes. Local government has the potential and the duty to play a key role in bringing together all sections of the community and coordinating the implementing agencies.

The Ministry of Local Government, Rural Development and Cooperatives (MLGRDC) is responsible for local government administration. The structure for public administration in the urban and rural areas of SWA is illustrated in Figure 2.11. The MLGRDC is also responsible for a number of other activities through the structure set out below:

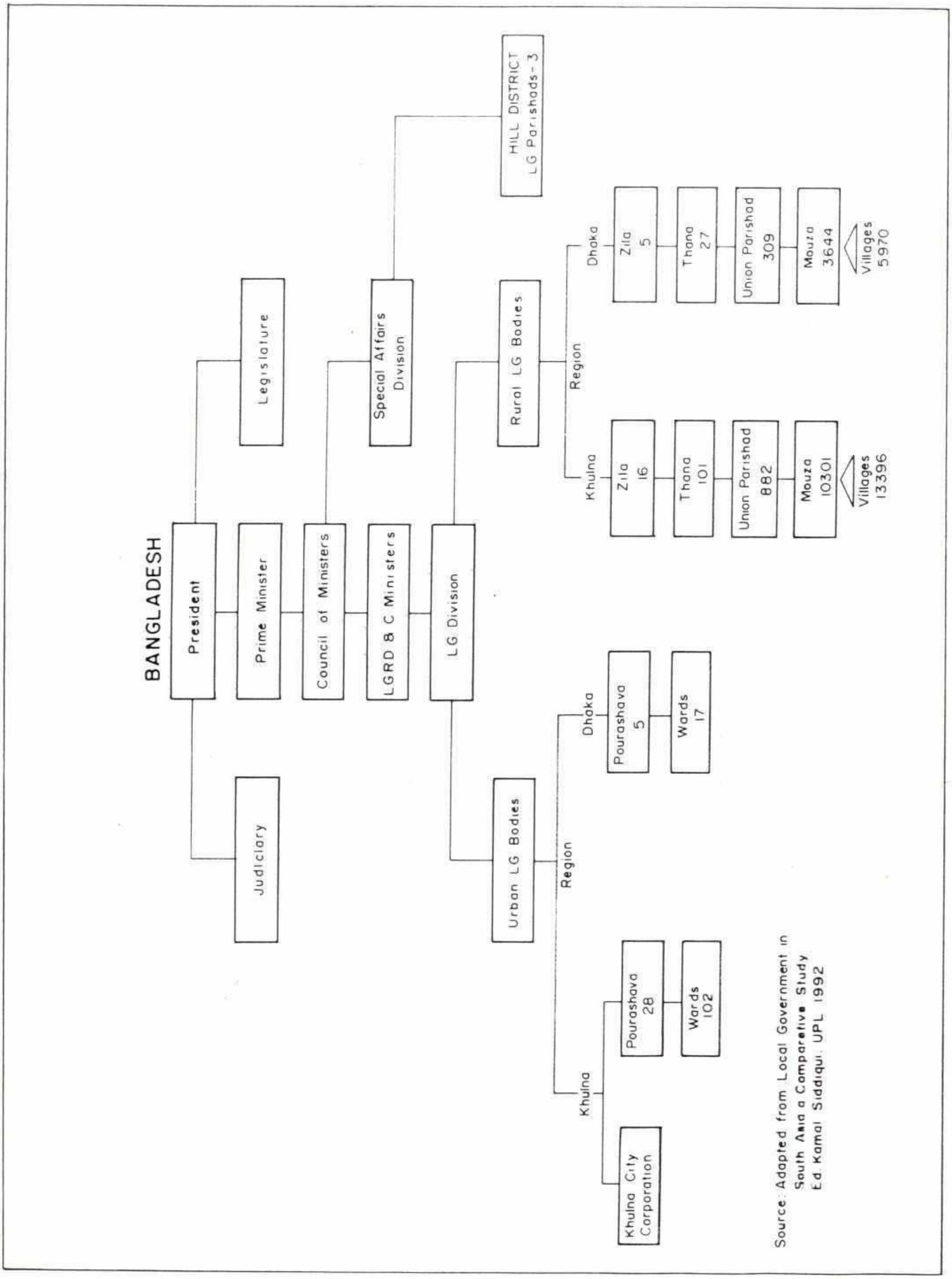


The SWA falls within two administrative regions, Khulna and Dhaka. Public affairs are regulated in the area by one metropolitan city corporation, Khulna, 28 municipalities (Pourashava), and 29 rural districts known as zillas. The main burden of administration falls on the urban wards (119 in SWA) and the 128 Thanas (formerly upazillas) in the rural areas. The Thana is the principal block in local administration. In SWA each Thana serves a population of about 18,300 grouped into about six Union Parishads with an average but very variable area of 260 km². The basic social unit, the village, has no legal standing in the country's administration system. However each Union Parishad is divided into a number of mauzas typically 8 to 16. The mauza has no physical centre but is the smallest legally recognised unit for administration within the public administration. The area of a mauza varies and may cover a part of a village or up to three villages, usually one to two villages, covering 200 - 300 ha.

The Thana is headed by a civil servant, the Thana Nirbahi Officer (TNO), who is appointed directly by government. It is the prime unit to plan and implement government development initiatives at the local level. The TNO coordinates officers of various line agencies in a wide range of development activities.

The Bangladesh Rural Development Board (BRDB) which is an arm of MLGRDC has the potential for involvement in the distribution of development funds and involving entire

Figure 2.11



Local Government Structure

communities. Its activities are under review by the National Committee for Administrative Reorganisation and the resulting recommendations may enable the Board and the Thana level administration to more effectively and equitably pursue their development responsibilities.

2.1.12 Land Resources

The SWA has been divided into 7 agroecological regions based on a combination of physiography, soils and climate. The regions are described in Table 2.6.

TABLE 2.6

Agroecological Regions and their characteristics

Agroecological Region	Major Characteristics and constraints
Active Ganges River Floodplain	Active charlands; irregular relief; active erosion and deposition
High Ganges River Floodplain	Relatively high lying area of complex ridges and clay basins; deep flooding (F2+) occur over 20% of the area shallow flooding (FO) over 45%
Low Ganges River Floodplain	Meander floodplain of broad ridges and basins; 15% of the land is above normal flood levels (FO), 55% is moderately deeply flooded (F2); soil permeability is generally low
Ganges Tidal Floodplain	Area of tidal rivers separated by basin topography; tidal flooding occurs in unprotected areas; surface water salinity in dry season, less so in monsoon; heavy clay soils, some saline.
	Bhola and adjacent islands, silty unstable soils; some dry season salinity; active bank erosion.
Young Meghna Estuarine Floodplain	Deeply and moderately deeply flooded basins; slow drainage
Old Meghna Estuarine Floodplain Gopalganj-Khulna Beels	Low lying basins on the Ganges Flood plain; mainly deeply flooded by fresh and sometimes saline water, layers of peat and muck stratified with alluvium.

The SWA is a complex agroecological region, subject to a number of influences. The incidence of normal inundation is shown in Table 2.7.

TABLE 2.7

Distribution of Land Types by Planning Unit (percentage of nca)

P.U.	F0	F1	F2	F3	F4
SW1	42	41	16	1	0
SW2	39	43	15	3	0
SW3	23	47	24	6	0
SW4	49	35	12	4	0
SW5	26	43	24	7	
SW6	23	46	24	6	<1
SW7	10	27	35	22	6
SW8	49	38	10	3	0
SW9	43	32	19	6	0
SW10	19	24	43	14	0
SW11	15	81	4	<1	0
SW12	19	71	9	1	0
SW13	10	50	25	12	3
SW14	15	80	5	<1	0
SC1	14	40	39	7	<1
SC2	14	54	27	5	0
SC3	10	43	33	11	3
SC4	9	35	33	17	6
SC5	23	57	14	5	1
SC6	16	57	21	5	1
SC7	29	71	<1	0	0
SC8	21	75	4	<1	0
SC9	19	78	3	0	0
SC10	16	83	1	0	0
SC11	20	80	0	0	0
SC12	19	80	1	0	0
SC13	21	75	4	0	0
Average	24	53	17	5	1

Over the SWA as a whole, land type F1 (30-90cm) is most common covering 53 percent of the area. The F2 land type (90-180cm) occurs over only 17 percent and very deep flooding (F3 + F4) is of limited occurrence.

The soils of the region represent a complex pattern of textural variation reflecting their alluvial origin. For the purposes of the study five soil characteristics have been considered as exerting the most influence on crop production over the area. These are, salinity, organic soils, potential acid sulphate conditions, texture and permeability.

The saline soils are defined as those with an electrical conductivity of 4mmhos/cm or greater as measured in the saturation extract. They are found predominantly in the Ganges Tidal floodplain region and to a lesser extent the Young Meghna Estuarine Floodplain. In total they occupy about 32.9 sq km of the SWA, mainly in the South West Region. In many areas, polders have been constructed to stop the daily tidal inundation of the land but dry season cropping is still limited by soil salinity and saline surface and ground waters.

2.1.13 Agriculture

The net cropped are in the SWA is estimated at 25,090 sq km. The major crops grown in the SWA and area for the year 1990-91 is shown in Table 2.8 Rice is grown on 2.9m hectares or 72 percent of the area.

TABLE 2.8

Major Crops Grown in the SWA, 1990-91

Season	Crops	Area (ha) ('000's)	% of NCA
Kharif	Broadcast Aus	636	25
	Hyv Aus	122	5
	Broadcast Aman	359	14
	Local Transplanted Aman	919	37
	Hyv Aman	422	17
	Jute	119	5
Rabi	Local Boro	35	1
	Hyv Boro	407	16
	Hyv Wheat	154	6
	Potato	30	1
	Pulses (1)	355	14
	Oilseeds (2)	239	10
	Spices (3)	47	2
	Minor crops (4)	76	3
	Orchards (4)	30	1
Perennial	Sugarcane	52	2
	Total Cropped Area	4002	159
	Total Rice Area	2900	

Source: MPO (1989/90) and BBS unpublished data for 1990-91

Notes :
(1) Lathyrus, lentil & chickpea
(2) Mustard and rape
(3) Onion, garlic, chilli
(4) MPO estimate

The crop production by district is shown in Table 2.9. As elsewhere in Bangladesh, the area under high yielding varieties has increased in all districts, whereas local aus and b.aman have declined. There is a general move to rice production being concentrated in the aman and boro crops. Pulse production has increased in the SWA as a whole but there are marked regional differences. In the northern districts of Faridpur and Kushtia production has declined but in all other districts it has increased.

TABLE 2.9

Area, Production and percent change of Major Crops, SWA 1983-84, 1990-91

Area in '000 hectares; Production in '000 tons

Crop	Faridpur						Jessore						Kushtia					
	1983 - 84		1990 - 91		% change	% change	1983 - 84		1990 - 91		% change	% change	1983 - 84		1990 - 91		% change	% change
	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod
Aus (L)	218	158	199	133	-9	-16	183	124	113	113	-38	-9	101	83	100	125	-1	51
Aus (M)	2	5	3	6	50	20	15	24	19	38	27	58	24	56	20	42	-17	-25
B. Aman	242	176	183	164	-24	-7	119	124	57	57	-52	-54	26	23	22	22	-15	-4
T. Aman (L)	27	25	77	84	185	236	113	143	42	61	-63	-57	8	9	2	3	-75	-67
T. Aman (M)	3	4	10	20	233	400	30	76	190	410	533	439	24	50	71	160	196	220
Boro (L)	7	10	30	38	329	280	1	2	1	1	0	-50	1	1	1	1	0	0
Boro (M)	32	81	90	311	181	284	29	61	111	355	283	482	3	6	22	60	633	900
Total Rice	531	459	592	756	11	65	490	554	533	1035	9	87	187	228	238	413	27	81
Wheat	41	100	46	68	12	-32	25	59	43	74	72	25	53	132	45	72	-15	-45
Jute	74	106	69	105	0.7	0.9	94	103	54	104	-43	1	33	53	36	72	9	36
Sugarcane	19	813	23	904	21	11	11	479	12	506	9	6	18	887	12	506	-33	-43
Lathyrus	42	22	33	30	-21	36	13	8	14	11	8	38	5	3	5	4	0	33
Lentil	55	38	50	38	-9	0	49	30	34	31	-31	3	29	24	31	26	7	8
Chickpea	31	27	27	17	-13	-37	35	21	30	24	-14	14	12	13	7	8	-42	-38
Total Pulses	128	87	110	85	-14	-2	97	59	78	66	-20	12	46	40	43	38	-7	-5
Mustard	32	18	81	60	153.1	233.3	35	20	71	55	103	175	12	9	14	12	17	33
Tobacco	3	2	2	2	-33.3	0.0	2	2	2	1	0	-50	8	8	6	4	-25	-50
Onion	7	25	7	30	0.0	20.0	2	13	3	15	50	15	1	6	2	8	100	33
Garlic	3	6	3	9	0.0	50.0	1	3	1	3	0	0	1	2	1	2	0	0
Chilli	6	3	6	3	0.0	0.0	2	1	2	2	0	100	1	0.4	1	0.4	0	0
Banana	2	32	2	35	0.0	9.4	2	30	1	22	-50	-27	1	12	1	14	0	17

Source : BBS. Statistical year book 1990-91 and unpublished reports, 1992.

cland/tab2-9

Note : These comparative data are from BBS and differ from the MPO data for 1990/91 which were forecast from 1986/87 BBS data.

TABLE 2.9 (Continued)

Area, Production and percent change of Major Crops, SWA 1983-84, 1990-91

Area in '000 hectares; Production in '000 tons

Crop	Khulna						Barisal						Patuakhali					
	1983 - 84		1990 - 91		% change	% change	1983 - 84		1990 - 91		% change	% change	1983 - 84		1990 - 91		% change	% change
	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod
Aus (L)	20	42	46	100	130	138	148	125	168	163	14	30	67	66	66	58	-1	-12
Aus (M)	5	9	6	14	20	56	29	50	10	19	-66	-62	3	4	13	23	333	475
B. Aman	40	47	35	30	-13	-36	89	78	35	30	-61	-62	0	0	0	0	0	0
T. Aman (L)	321	394	288	397	-10	1	274	317	315	439	15	38	270	345	303	321	12	-7
T. Aman (M)	30	62	72	176	140	184	33	65	22	41	-33	-37	12	26	72	108	500	315
Boro (L)	6	8	11	15	83	88	4	4	4	6	0	50	6	5	0.4	1	-93	-80
Boro (M)	14	34	35	85	150	150	28	71	59	240	111	238	4	8	2	3	-50	-63
Total Rice	436	596	493	817	13	37	605	710	613	938	1	32	362	454	456	514	26	13
Wheat	2	5	3	5	50	0	2	2	4	5	100	150	0.0	0.0	0.22	0.2	584	567
Jute	13	22	11	22	-15	0	3	2	2	3	-33	50	0.4	0.3	0.4	0.3	0	0
Sugarcane	4	152	4	245	0	61	3	119	4	117	33	-2	1	16	0.4	13	-60	-19
Lathyrus	5	3	2	1	-60	-67	42	34	50	36	19	6	19	10	33	20	74	100
Lentil	6	4	6	26	0	550	9	5	6	4	-33	-20	2	1	1	0.2	-50	-80
Chickpea	14	19	29	21	107	11	5	3	4	2	-20	-33	1	1	2	1	100	0
Total Pulses	25	26	37	48	48	85	56	42	60	42	7	0	22	12	36	21	64	77
Mustard	0.8	5	11	15	1275	200	4	3	39	14	875	367	0.3	0.1		6	-100	5900
Tobacco	0.3	0.2	0.1	0.04	-67	-80	1	1	0.4	0.2	-60	-80	1	0.3	7	0.05	600	-83
Onion	1	4	1	2	0	-50	1	2	1	1	0	-50	0.1	0.4	0.3	1	200	150
Garlic	0.3	2	0.3	1	0	-50	1	2	0.4	1	-60	-50	0.2	0.3	0.3	0.4	50	33
Chilli	1	1	1	1	0	0	7	4	7	5	0	25	6	3	7	4	17	33
Banana	3	43	0.2	17	-93	-60	7	127	6	95	-14	-25	2	32	2	36	0	13

Source : BBS. Statistical year book 1990-91 and unpublished reports, 1992.

cland/tab2.9

Note : These comparative data are from BBS and differ from the MPO data for 1990/91 which were forecast from 1986/87 BBS data.

The overall cropping intensity in the SWA is 160 percent. The intensity of use on irrigated land averages 199 percent and for non-irrigated land is 146 percent. The overall cropping intensity for the SWR and SCR is shown in Table 2.10.

TABLE 2.10

Summary of Cropping Intensity, SW and SC Regions

Region	Irrigated	Non-Irrigated	Overall
SW	199	140	156
SC	200	155	165

The rabi season cropping intensity for the SWR and SCR are shown in Table 2.11.

TABLE 2.11

Rabi Season Cropping Intensity, SW and SC Regions

Region	Rabi Season CI	Irrigation as % of Rabi Season CI
SWR	56	50
SCR	53	47

The area of organic soils is found mainly in the Gopalganj-Khulna Beels but may occur locally elsewhere. They are sometimes deep peats exposed at the surface but more commonly, are found interstratified with clay or mixed to form a muck. They are seasonally flooded and perennially wet. In the less deeply flooded areas they may support a crop of mixed b.aus/b.aman or b.aman. Where flooding is deeper, they are uncultivated. In the dry season they can support local or HYV boro, pulses, oilseeds and vegetables. The area of such organic soils is estimated at some 1418 sq km.

The area of potential acid sulphate soils is about 112 sq km in the SWR in Planning Units SW11, 12, 13 and 14. The presence of buried horizons containing appreciable amounts of sulphides limit the use of such soils as, when drained, extensive acidity will develop limiting crop growth.

Soil texture and permeability exert an influence over the choice of crops that can be grown. Generally, higher lying more permeable soils are less suitable for rice but, more importantly, they have high potential for the production of pulses, oilseeds, other cereals particularly wheat and cash crops such as tobacco and cotton. The distribution of such soils is important as a guide to crop selection and irrigation suitability.

The rabi season cropping intensities are low throughout the area with only some 50-60 percent of the land cultivated at that period. Of the land that is cultivated only about 50 percent receives irrigation (Table 2.11).

The major cropping patterns are shown in Table 2.12.

The importance of livestock in Bangladesh agriculture cannot be over emphasised and the case is no different in the SWA. The most important livestock is cattle which provide the necessary draught power for ploughing, road and farm transport, threshing and oilseed and sugarcane crushing. In addition, cattle and other livestock provide animal protein through milk, meat and eggs, and a cash income through the sale of live animals, hides and skins, meat, milk and eggs as well as through the hiring out of draught animals. Livestock also provide fuel in the form of dry cowdung for rural households and manures. On a national level this provides about 14% of total energy requirements in the form of cowdung and urine as well as poultry dropping for fields and homestead plots. Hides, skin and leather goods are important items of export.

The salient points in livestock production in the SWA are:

- numbers of bovines are decreasing; sheep, goats and poultry are increasing,
- feeds and fodder have declined due to a decrease in grazing land, introduction of HYV's and reduction in area of pulses,
- shortage of draught power, and
- decline in per capita meat and milk consumption.

TABLE 2.12

Major Cropping Patterns in the Southwest Area

AEZ	Predominant Textures	Land Type	Rainfed	Irrigated
Active Ganges Floodplain	Sands, loamy Sands and Sandy loam	F0	1. B.Aus/Jute-W/P/V/O/S 2. B.Aus/Jute-LT Aman(1)	-
		F1	1. B.Aus/Jute-L.T. Aman 2. B.Aus/Jute-W/P/V/O/S	1.T.Aman (L/M)(2)-HYV Boro*
		F2	1. Mixed B.Aus and B.Aman-Rabi crops	1.DWT T.Aman-HYV* Boro
High Ganges River Floodplain	Loams to clay	F0	1. B.Aus - W/P/V/O/S 2. B.Aus - T.Aman(L/M) 3. Sugarcane 4. B.Aus - Cotton	1.HYV* T.Aus-HYV *T.Aman-Rabi crops 2.Sugarcane*
		F1	1. B.Aus - T.Aman(L/M) 2. B.Aus-T.Aman(L/M)-Rabi 3. B.Aus-Tobacco/W/P/V/O/S	1.HYV* T.Aman-HYV Boro* 2.HYV* T.Aus-HYV T.Aman*
		F2 F3	1. Mixed B.Aus and B.Aman-Kheshari 2. B.Aman-Kheshari/fallow	1.Mixed B.Aus and B.Aman-HYV Boro* 2.HYV Boro*- Fallow
Low Ganges River Floodplain	Silty clay loam to clay	F0	1. B.Aus/Jute-T.Aman(L/M) 2. B.Aus-T.Aman-Rabi	1.HYV T.Aman - HYV Boro*
		F1	1. B.Aus/Jute-T.Aman(L/M) 2. B.Aus/Jute-T.Aman-Rabi	1.HYV T.Aman - HYV Boro*
		F2 F3	1. Mixed B.Aus and B.Aman-kheshari 2. B.Aman-kheshari/Fallow	1.HYV*Boro-Fallow 2.DWT Aman-HYV Boro*
Ganges Tidal Floodplain	Silty clay loam to silty clay(3)	F0	1. T.Aman (L/M)-Fallow 2. Hyv Aus- T.Aman	1.HYV T.Aman - HYV Boro*
		F1	1. T.Aman(L/M)-Fallow 2. T.Aus(L) - T.Aman(L/M) 3. B.Aus - T.Aman (L/M) 4. Shrimp - T.Aman (L)	1.HYV T.Aman - HYV Boro*
Young Meghna Estuarine Floodplain	Silt loam to silty clay loam(3)	F0	1. B.Aus - T.Aman(L/M) 2. B.Aus - P/S/V 3. D.Aus - T.Aman (L)	1.HYV T.Aman - HYV Boro*
		F1	1. T.Aman(L/M) - Fallow 2. B.Aus/Jute-T.Aman(L) 3. T.Aus(L)-T.Aman(L/M) 4. T.Aman(L/M)-P/V/S	1.HYV T.Aman - HYV Boro*
Old Meghna Estuarine Floodplain	Silt loam to silty clay	F0	1. B.Aus/Jute-T.Aman(L/M) 2. B.Aus/Jute-W/P/V/O/S	1.HYV T.Aman - HYV Boro*
		F1	1. B.Aus/Jute-T.Aman(L/M) 2. B.Aus/Jute-W/P/V/O/S 3. B.Aus/Jute-T.Aman(L/M)-Rabi	1.HYV T.Aman - HYV Boro*
		F2	1. Mixed B.Aus and B.Aman-pulses/oilseeds 2. B.Aman-Pulses/Oilseeds/Wheat 3. B.Aus/Jute - T.Aman(L)	1.Mixed B.Aus and B.Aman - HYV Boro* 2.HYV* Boro-Fallow
Peat Basin	Peat + clay + muck	F2 & F3	1. B.Aman - Fallow 2. Mixed B.Aus and B.Aman rabi/fallow 3. Boro(L) - Fallow	-

Sources: Compiled from AEZ Reports (FAO, 1988), MPO (1989-90) and DAE (1992)

Notes:
(1) L.T. Aman refers to Local varieties of transplanted Aman
(2) (L/M) refers to local and HYV respectively
(3) D. Aus refers to dibbled Aus
(4) W= Wheat; P= Pulses; V= Vegetables; O= Oilseeds; S= Spices
* Irrigated or partially irrigated
(5) DWT Aman - Deep Water Transplanted Aman

2.1.14 Fisheries

The fisheries sector contributes 3% of Bangladesh's GDP, about 8% of gross value added of agriculture product, more than 11% of export earnings and nearly 80% of national animal protein intake.

The fisheries of SWA comprises capture fisheries, culture fisheries and brackish water shrimp farming. The open water capture fisheries in SWA comprise the river system, beels and seasonally inundated floodplain. Although culture fisheries in freshwater ponds in SWA has increased in recent years the yields per hectare are still relatively low, averaging about 1230 kg/ha/yr overall. Yields of over 4000 kg/ha/yr are feasible.

Table 2.13 summarises the area and production of both capture and culture fisheries in the SWA.

TABLE 2.13

SW Area Fish Production by Sub-sectors, 1983/84 - 1989/90
(Rounded to nearest 100 Metric tons)

Fishery	Water Bodies SWA Total Area (ha)	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
A. Capture Fishery								
1. Rivers and Estuaries	743000	105700	116000	103500	88600	81600	72500	na
2. Beels	9600	4300	2100	2000	2100	3100	2600	2400
3. Flood Lands	667000	59600	70300	47600	47400	43000	44000	39600
Total Capture Fish	1419600	169600	188400	153100	138100	127700	119100	-
B. Culture Fisheries								
5. Pond Fish	38500	32200	32300	34100	39400	41400	43800	47700
6. Baors	5500	900	1000	1000	1200	1300	1300	1400
7. Shrimp Farms	81000							
- shrimp		2500	5000	12100	11400	13600	15200	15400
- fish		2400	2000	4400	6000	6100	7000	7000
Total Culture Fish	125000	38000	40300	51600	58000	62400	67300	71500
Overall Total	1544600	207600	228700	204700	196100	190100	186400	-

Source: DOF Fish Catch Statistics of Bangladesh 1984/1990

Note: There was a further increase in shrimp farm output during 1990/91 to 16,900 tons of shrimp and 7600 tons of fish. No other fish production data is yet available for 1990/91.

As can be seen from the Table, overall annual capture fishery catch fell by 30%, beel and floodplain catches were down by 40% and 26% respectively and the combined river and estuarine catch fell by 31%. In contrast the culture fisheries has increased by 48% in the same period. Brackish water shrimp farming has expanded rapidly in recent years mostly in the Khulna District.

The decline in capture fisheries may be partly attributed to the expansion of FCD schemes in the area (FAP12) and partly due to recent spread of disease epidemic. Over exploitation is also another cause for decline.

Although shrimp farming has expanded with the welcome foreign exchange it has brought in, it is not without problems. Social conflicts have arisen between rice farmers and shrimp farmers because some small land owners or share croppers have been forced by more powerful interests to surrender the use of their land for the shrimp season (December to May) to be incorporated into large salt water shrimp "ghers", in exchange for cash compensation.

It is estimated that there are a further 89,000 ha of land in Satkhira, Khulna and Bagerhat districts of SWA which are suitable for development as shrimp farms and that it should be possible to increase yields to at least 300 kg/ha from the present average of 190 kg/ha.

The effects on the population, nutrition, employment etc are discussed in Section 2.3.9.

2.1.15 Forestry

Forest resources in the SWA consists mainly of

- natural mangrove forest (Sundarbans) - 0.40m ha
- plantation mangrove - 0.04m ha
- village groves - 0.10m ha

The Sundarbans are a unique and valuable ecosystem mangrove forests, that show a continuing, dynamic and changing mosaic of plant communities. The Sundarbans is under considerable threat and this may be attributed to the reduction in freshwater flushing action caused by upstream abstractions notably at Farakka and poldering, over exploitation of wood resources, increased agriculture and increased silt deposition. The Sundarbans are essential to the survival of the shrimp culture industry in the SWA, which relies on the capture of past-larval shrimp found in the mangroves.

Dominant trees in the Sundarbans that have commercial value include the Sundri (*Heriteria fomes)* and Gewa (*Excoecaria agallocha*). The Sundri is under threat from the phenomenon of 'top dying', the cause of which is unknown, although increased salinity is thought to be one of the causes.

The Sundarbans apart from supporting a number of other forest products also supports many species of mammals and reptiles.

Coastal mangrove plantations, established since the 1960s on the newly accreted mud flats along the Bay of Bengal have been successful. To date about 0.1m ha have been established of which 0.04m ha are in the SWA.

Homestead wood is essentially a product of trees planted along field borders and around village homesteads. These homestead groves account for 90% of the fuelwood source in rural Bangladesh as well as providing about 80% of valuable sawlog timber.

The plantation mangrove areas and the Sundarbans have proved to be very useful for dampening local wind effects and storm surges. After the experience of the 1990 devastating cyclone, their value in the island areas of the SW Region have been recognised and consideration is being given to retain these plantations for forestry.

2.1.16 Water Supplies

The major source of domestic and industrial water supplies in the Southwest Area is groundwater. Water for domestic supply in the rural areas is usually abstracted by hand tubewells (HTW) while deep tubewells (DTW) are used to supply in the urban areas including industries. Though the quality of water is good in the northern areas, salinity is a special problem faced by areas around Khulna and further south. In the coastal areas and southern areas of the south central region DTWs are not widely used because of the problem of salinity. Available data indicate that there are about 207,200 HTW in the 122 Thanas that cover the Study Area. The limitations of HTW to shallow water table render their operation during the dry season, particularly during March/April, ineffective.

For most of the district headquarters in the Study Area there are formalised water supply systems including distribution systems. Further expansion of urban water supply would continue, as the population expands, based on DTW technology.

Khulna is the third largest city in Bangladesh and already suffer from salinity intrusion in the aquifer during the dry season. The industries located around Khulna use surface water for their use also suffer from increase in salinity in the rivers during the driest months and resort to importing fresh water from further upstream in barges.

Further expansion of groundwater for water supply to Khulna and its surround is highly improbable and other means need to be explored.

The current water supply requirements for domestic and industrial use in SWA are about 288 mcm/yr which will rise to about 423 mcm/yr by the year 2020. The corresponding increase for the SWR and SCR are from 192 to 282 mcm/yr and 96 to 141 mcm/yr respectively.

2.1.17 Industry

Industry in the Southwest Area mainly comprises of small industrial units (10-20 persons employed). Only in the larger towns, and especially in Khulna, there are large manufacturing operations. The region provides about 13% of industrial output for Bangladesh (1988-89 BBS). The main industrial centres are Khulna, Kushtia, Jessore, Barisal and Patuakhali.

The industries in the Area includes 4 Sugar mills, 21 Jute mills, 1 Newsprint mill, 1 Hardboard mill, 1 Shipyard, 6 Textile/Garment factories, 4 Steel re-rolling mill, 38 Fish processing units, 2 Match factories, 2 Tanneries, 3 Tobacco factories, 17 Pharmaceutical factories and a number of rice mills, ice factories etc. In addition to this handloom sub-sector plays a vital role in the Area's economy, particularly in providing employment. There are more than 212,400 units consisting of nearly 515,000 looms which employ about 1.54 million people.

At present the industrial demand for water is a problem mainly in Khulna, where the northward ingress of the saline wedge has reduced the ability for certain industries to use river water for cooling during parts of the dry season.

Of more concern is the discharge of industrial effluent without any form of treatment. The lack of a water quality monitoring programme has meant that the makeup, concentrations and impacts of industrial effluent in the region's surface waters are unknown.

2.1.18 Infrastructure

Roads

Most parts of Southwest Area are served by a reasonable network of roads. The Roads and Highways (R and H) Department maintains approximately 3000 km of roads of different categories of which about 600 km are National Highways, and 390 km are regional highways. The National Highways link the main district headquarters of the area to the major ferry ghats (Khulna, Hardinge Bridge, Daulatdia, etc) for onward connection to other Regions of Bangladesh. However, the islands in the South Central Region are not linked by road with other parts of the Area.

Railways

There are about 400 km of broad gauge railway line in the Southwest Area. The main line runs from Khulna towards the north via the Hardinge Bridge. Another line (Faridpur/Goalanda) connects this main line at Poradah (Kushtia District). A new line from Faridpur to Bhanga (15 km) is under construction. There is also a proposal to connect Mongla Port with Khulna.

Airport

The Southwest Area presently has an air link between Jessore and Dhaka. There is a proposal to construct another airport at Barisal.

Ports

Mongla Port, the second largest seaport of Bangladesh, is located in the study area on the Pussur River. In addition, there are river ports at Barisal, Khulna, Patuakhali and Bhola. There are 89 boat terminals, including ferry and launch ghats in the Area. The river routes connecting these ghats are important to the Area's economy.

Power

SWA power distribution network is linked to the national grid of the Power Development Board (PDB) Electricity is also locally generated by PDB using various types of power plants and is connected to the national grid. There are 13 generating sets in four different areas (Khulna, Bheramara, Barisal and Bhola) with an estimated installed capacity of 366 MW. However, the generated capacity of 1990/91 as reported by the PDB was only about 30% of the installed capacity.

2.1.19 Navigation

Bangladesh is a riverine deltaic country. It is criss-crossed by three major rivers (Ganges-Padma, Brahmaputra and Lower Meghna) and numerous small rivers and this physical condition has enabled inland water transport to become a natural and relatively cheap means of transport. In certain parts of the SWA inland water transport is the principal mode of transport. There are about 290 km of Class I, 260 km of Class II and over 1500 km of Class III and other minor routes in the SWA.

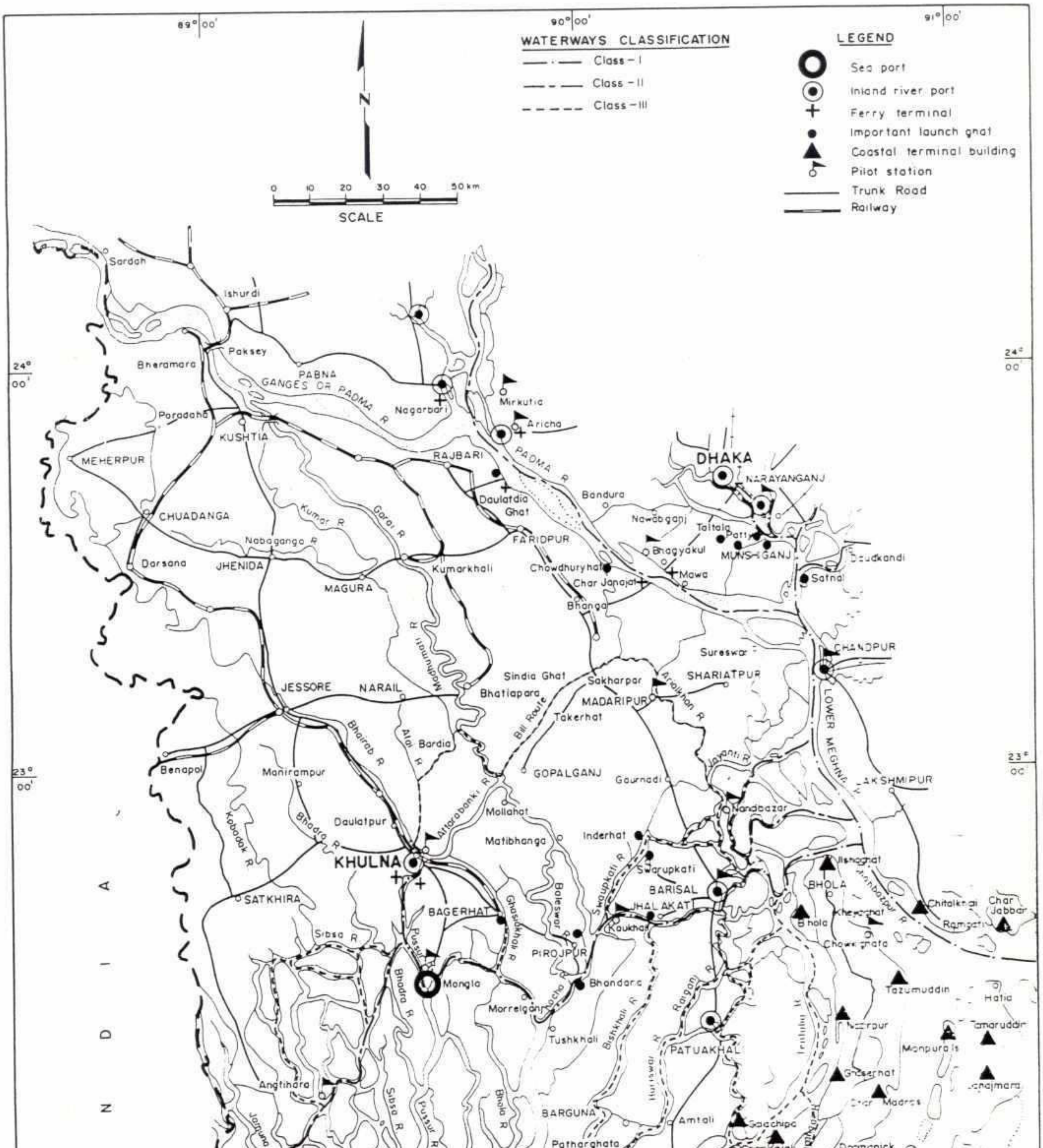
Mongla, the second largest seaport of Bangladesh is located in the study area on the Pussur river. In addition there are river ports at Barisal, Khulna, Patuakhali and Bhola. There are 89 terminals, ferry, launch ghats in the Area. The river routes connecting these ghats are important to the Area's economy.

Figure 2.12 shows the principal transport routes in the SWA.

The cargo and passenger transport volumes for 1985 are about 1600m Ton. km and 7m Pass. km respectively and is expected to grow higher than the rail transport.

Country boats play an important part in the field of navigation in the SWA and in Bangladesh as a whole. The role of country boats to the economy is underestimated. It is

Figure 2.12



Principal Transport Routes

estimated that country boats annually carry around 15 million tons of cargo throughout Bangladesh which is not an insignificant figure.

2.1.20 Environmental Base

The Southwest Area is a complex of inter-linked ecosystems, defined by the delta of the Ganges-Bramhaputra-Meghna rivers and by a number of unique environmental factors.

The landscapes and ecosystems of the Study Area include: the agricultural lands with freshwater supplies in the north and northeast of the area; the transitional lands within the coastal polders; the Sundarbans; and the coast. In the agricultural lands the availability of groundwater and/or surface water for irrigation, and groundwater from shallow, hand-pumped tubewells (HTWs) ensure production and secure livelihoods. In the coastal polders water supplies are less secure, and saline intrusion limits much to the land to rainfed agriculture. The Sundarbans are a unique mangrove forest, with a complex mosaic of community structures, the dynamics of which are not completely understood. The remaining coastal areas are given over to agriculture behind polders, except where coastal afforestation is proceeding to assist in cyclone protection.

The major environmental issues relate to the effect of certain past interventions and events, which have caused changes in some or all of the Study Area. Of these factors, the single most important is the reduction in dry season flows in the Ganges river and distributaries feeding the South West Region. This denial of water has led to inland movement of river salinity with a commensurate fall-off in production dependent on surface water irrigation. Groundwater is not necessarily available as a replacement water source. Rural potable supplies can be put at risk if groundwater is extensively required for irrigation, so forcing rural populations to use surface water for potable supplies, greatly increasing the risk and incidence of water borne disease.

The loss of dry season flows allows further tidal ingress resulting in greater sedimentation in some rivers. This, in turn, has led to drainage congestion by impeding tidal drainage patterns, and loss of productive land by inundation. Such flooding affects the food availability and diet of local populations which, together with the higher risk and incidence of water-related disease and the lowering of hygiene standards due to poor water supplies, adversely affects the health of the rural populations in the polder areas. The impoverishment in diet is further compounded by restriction in fishing due to the drying up of river channels.

The Sundarbans are less affected by the changes in salinity, but the complex dynamics of the forest's hydrology and species compositions are more likely to alter significantly due to changes in channel flows due to sedimentation.

The Sundarbans represent a major natural ecosystem as well as the single largest area of natural resources in the Southwest, whose importance cannot be over-emphasized. This forest is not simply the primary timber production area of the paper and pulp industries in Khulna, but also the major nursery and growing area for the shrimp and coastal fisheries of the deltaic coast of Bangladesh; as well as being a repository for other forest products, wildlife and biodiversity. The forest also provides protection from storms to the polder lands inland.

Deforestation is a major issue in this part of Bangladesh. The demand for timber from the Sundarbans is reported to be in excess of the sustainable yield, and is compounded by illegal felling. The use of timber in brick making has been another major source for deforestation, coupled with the need for domestic fuel in the villages. Field observations in Kushtia, Jessore, Khulna and Barisal districts in March 1993 indicate that the prohibition on the use of timber for brick making is widely disregarded in this industry.

The protection against major storm damage afforded to the South West Region by the Sundarbans is not available in the South Central Region where little natural forest remains. This part of the Study Area is most frequently affected by major storms and cyclones.There is relatively little accretion along this part of the Bangladesh coast where some afforestation is being practiced, though forest depth will need to be extended for protection to be significant over the coast of this region.

FCD interventions in the past, have caused major alterations in the riverine ecosystem. Little is known of the river fish populations in the Study Area, but anecdotal evidence from fishermen indicate a fall-off in production over the years. This is particularly the case in beel and baors areas dependent on floodplain recruitment. Embankment problems are not confined to FCD schemes, as the infrastructure of the Study Area (roads, railways and control structures) have added to the impact on floodplain recruitment (as assessed from fishermen livelihoods).

2.2 The Impact of Past Interventions

2.2.1 Works on the Brahmaputra (Jamuna), Ganges, Padma, Meghna and other rivers

Engineering works have been constructed on the main river systems with the broad aims of flood control, channel stabilisation and communications.

Brahmaputra (Jamuna)

On the Jamuna, engineering works have concentrated on flood protection and bankline stabilization along the right bank e.g. the Brahmaputra Right Embankment (BRE). However, erosion of the right bank has removed the berm between the BRE and the river in many locations and the points protecting these vulnerable areas are relatively widely spaced along the river and they have mostly had only local impacts. Only the heavy protection required at Sirajganj appears to have any impact at reach scale, but there is no evidence of significant bankline changes further than about 20km downstream.

The present flood embankments do not effectively constrict the flow and consequently have no impact on flow levels. Bank protection works have only local or reach scale impacts and have not materially altered the channel approach to the Ganges confluence. It can be concluded that embanking has produced no measurable impact on channel morphology in the boundary rivers of SWA nor will they even with full embanking.

Ganges

Major engineering works on the Ganges include the embankments on the left and right banks, groynes at Rajshahi, the guide bunds at the Hardinge Bridge and dredging associated with the G-K Project.

The Rajshahi groynes have been successful in preventing retreat of the bank line at that location. Morphologically, the Rajshahi groynes are acting as a constraint to channel movement and distort the pattern of migrating bends locally, but it is unlikely that any regional impacts will be observed.

The guide bunds at the Hardinge Bridge constrict the channel width down to 1.5km, compared with a regime width at formative flow of about 4km. There is no doubt that this constriction has marked hydraulic effects at high flow and some morphological responses are apparent. Its primary morphological impact has been to fix the location of the channel at the bridge by preventing lateral shifting, although the river came close to out flanking the bridge at the bend upstream in the 1930s and only stringent efforts prevented disaster.

The second morphological impact of the bridge has been to act as a pivot point in the planform, when flow at Sara, some 4 km upstream of the bridge on the left bank, follows the curve of the outer bank. This produces a crossing at the Gorai mouth and a bar partly, or completely, blocks the mouth. However, when the bend at Sara is cut-off, the meander pattern is shifted downstream by half a wavelength which ensures a supply of water to the mouth. Thus, the bridge polarises conditions for spill flow as being either very favourable or very unfavourable, but not intermediate.

There has been capital and maintenance dredging of the Ganges next to the intake for the G-K irrigation scheme, but its impact is not discernable.

Padma

Significant engineering works on the Padma are limited to a discontinuous embankment along the right bank. The alignment of the embankment was set out under a plan conceived in the 1960s, but construction has been implemented under a series of schemes. At the moment the embankment does not constrict the flow or prevent high flow spillage to the distributaries and flood plain to the south. Under these circumstances, when completed, it will have no significant impact on the regional morphology of the channel.

Lower Meghna

Engineering works on the Lower Meghna include right bank polders and land reclamation and bank protection schemes on the other side.

The delta is criss-crossed by numerous distributary channels and it is not feasible to have a right bank embankment, only local, polders. These polders do not appear to have any impact on the river's morphology.

Land reclamation together with stabilisation of the left bank at Chandpur, has reduced the tendency of the Lower Meghna to migrate eastwards and have disrupted the sinuous planform of the river. They may be expected to trigger further planform developments as the river attempts to regain the morphological adjustment of channel formed by the fluvial and tidal processes.

It may be concluded that past interventions on the Lower Meghna have had significant impacts on its geomorphic form and processes, which affect the South Central Region.

Other Structures

There have be a number of other man-made interventions whose local impacts can be summarised as follows :

Teesta Barrage	:	only just completed
Gorai Rail Bridge	:	constriction and local upstream changes
Kamarkhali Bridge	:	minor scour and accretion
Halifax Cut	:	led to a diversion of the Madhumati's flows and the development of the Nabaganga
M B Route	:	transfer of water to the SW, morphological changes at Gopalganj
M G Canal	:	lateral transfer of saline water, control required
Groynes on the Gorai	:	local scour and changes in the planform of the river.

Two other interventions, which have had a very significant impact in the SWA, are the polders and, in the past, the destruction of part of the Sundarbans. These are dealt with in Section 2.3.3.

2.2.2 Farakka Barrage

Farakka Barrage is located on the Ganges in India, a few kilometres upstream of the border. It was completed in 1975 and, during the dry season, augments flows in the Bhagirathi-Hoogly system and to support irrigation in West Bengal. Its success in these functions is reported to have been limited (Basu, 1992).

Under the India-Bangladesh Agreement of 1977, abstraction during the driest 10 day period of 21st to 30th April was limited to 20,500 cusecs (580 cumecs), with Bangladesh receiving the remainder and a guaranteed minimum of 75% of the dependable flow calculated from 1948 to 1973, even if the actual flow fell short in any year. Hence, initially the impact of Farakka on dry season flows was limited. However, in 1988 the Agreement expired and it has not yet been renewed or replaced. As a result, dry season flows entering Bangladesh have decreased even more markedly since 1989, although the period of record (4 years) is too short to statistically evaluate the reduction.

Early signs are that the flow changes may have induced measurable impacts on the river systems of the Southwest Region. Many of these impacts are difficult to distinguish from natural changes, but it is apparent that the operation of Farakka has :

- Reduced dry season flows in the Ganges to record low levels.
- Closed the Ganges-Kobadak Irrigation Scheme during the dry season.
- Reduced of minimum dry season flows in the Gorai to zero for long periods.
- Led to a deterioration of the condition Gorai's mouth through siltation, that may be irreversible without major intervention.
- Accelerated flow recession during the months of September, October and November.
- Reduced duration of spill flows into the Gorai in the autumn due to accelerated flow recession and associated morphological adjustment of the channels.
- Reduced flows to the Southwest Region from the Gorai-Madhumati system during seven months ie from October to April.
- Produced morphological changes during the accelerated falling stage and hence to siltation and early abandonment of the link between the Gorai and Ganges low flow channels as early as November.
- Adverse impacts on in-stream and riparian habitats resulting from accelerated flow recession and low dry season water levels.
- Increased salinity concentrations in the Madhumati and in the Khulna area for most of the dry season.
- Adversely affected environmental, commercial and agricultural interests associated with reduced dry season inputs of fresh water.

- Accelerated the possible permanent abandonment of the Gorai as a Ganges distributary if the morphological changes are allowed to continue without human intervention. Thus, even wet seasons spills will be limited or even terminated.

- Accelerated the change of the Gorai from a distributary to an inland river, with extensive morphological and environmental impacts, including channel shrinkage and heavy siltation, leading to drainage congestion.

2.2.3 The Coastal Embankment Project

In the Southwest Area initial cultivation commenced in the fertile river plain to the north of the beels but as the demand grew for more land, attention was focussed on protecting low-lying areas from tidal inundation by the construction of small scale bunds. The bunds were controlled so that in the wet season the land was protected from tidal inflow and rice could be grown. This system was largely managed by the zamindars (landlords) until Partition after which the system fell into disrepair and crop failures due to flooding or saline incursion became a frequent occurrence. To remedy this situation the former East Pakistan Water and Power Development Authority (EPWAPDA) embarked, in the early 1960s, on a huge programme of polder construction known as the Coastal Embankment Project (CEP).

Construction of the CEP continued through the 1970's and to the present day and has created a poldered area in the tidal zone of the Southwest Area of approximately 8600 km^2. This area is now subdivided into approximately 80 polders. The general ground level in the area lies below high tide. Without the embankments the land would have been flooded at high tide which would have allowed sediment in suspension to be deposited over the low lying areas. This would have gradually raised the ground level. On the ebb tide the flooded areas would have drained through the tidal rivers providing a flushing action helping to maintain these rivers in equilibrium. Prior to the CEP most of the area was enclosed by dwarf bunds which had only a small impact on tidal flooding and flushing. Although the CEP has been successful initially and large areas have been benefitted over the years, recently there have been problems due to drainage congestion partly caused by the reduction in upland flows.

To provide an indication of the scale of the impact of the CEP the present total tidal volume now entering the Area on a spring tide, $2\text{-}3\times10^9$ m^3 may be compared with the flooding volume "lost" as a consequence of the CEP, 2×10^9 m^3 (on the assumption that the depth of spring tide flooding would have been 0.25m). From this comparison it is clear that the size of CEP is sufficient to have a significant impact on the morphology of the tidal zone.

The effect of this impact is three fold:

- the reduction of tidal volume has reduced the peak discharge velocities and the tidally dominated channels have ceased to be in equilibrium. Siltation in the channels has occurred and will continue until a new equilibrium is achieved;

- land inside the polders will remain at the pre-polder levels;

- as a consequence of closure of minor channels and removal of over spill areas by poldering, the tidal flow is constrained to the channels between polders resulting in a raising of tidal levels in these channels.

In addition to the impact of the CEP there have also been reductions in dry season fresh water flows to the area following the completion of the Farakka Barrage in 1975. As the dry season tidal flows are flood tide dominated, resulting in net movements of sediment inland, it is possible that this reduction in fresh water flow has resulted in some increases in the extent and quantity of dry season siltation. However, in practice it is difficult to distinguish in any meaningful manner the component effect of Farrakka from the contemporary impacts resulting from the CEP. However, it can be deduced that should the Gorai become closed to both wet and dry season flows, deterioration would accelerate in the Southwest Region. At the same time flood protection on the Padma and Lower Meghna would not have negative impacts as long as the flows in the spill rivers are maintained.

The combined effect of these impacts however is clearly drainage congestion observed in the CEP area. Immediately after polder construction drainage was not a problem and, as a consequence of protecting crops from salinity and flooding, yields increased in places by 200 to 300 percent. However, as siltation progressed in the tidally dominated channels, the channel bed and tide levels have risen relative to the land levels inside the polder thereby obstructing drainage and preventing polders performing as expected. In some areas the situation is worse than before the CEP was implemented.

2.2.4 Existing FCD and I Projects

There are more than 140 comprehensive flood control, drainage and irrigation projects (FC/D/I) covering a total gross area of about 14,500 km² located in the Southwest Area, almost all of them implemented by BWDB. The main objective of these projects, except the Ganges-Kobadak (GK), the Barisal Irrigation (BIP), Bhola Irrigation and the Chenchuri Irrigation Projects, is to provide flood control to some selected areas prone to severe flooding. In the Irrigation Projects, the provision of formalised irrigation systems was one of the main objectives. In most of the FCD projects, farmers practise some form of minor irrigation either individually or in small groups, utilising groundwater/surface water (STW, DTW, LLP, etc.).

FCD/I projects of major significance in view of either their productive potential or their impact on the hydro-morphological processes of the river network are the GK Project, Barisal Irrigation Project, Bhola Irrigation Project Phase-I, Madhumati-Nabaganga FCD/I Project (FCD III Project).

Though most of these were completed during the 1960s and 1970s, the expected increase in agricultural productivity is yet to be realised. In general, there is lack of any integrated approach for water management within FCD/I projects. The Barisal Irrigation Project which started operation in the early 1980s cannot be considered a success yet, as only less than about 23% of the area is currently under irrigated agriculture, which is mainly due to socio-economic reasons. The G-K Irrigation Project, the first phase of which became operational in the early 1970s, could soon be expected to achieve cost effectiveness in its operation after the completion of the ongoing water management and rehabilitation programme. However, considering that the managing authority (BWDB) of the G-K Project was able to collect only about 2% of the pump station operating cost from the participating farmers during the last financial year, the BWDB might have to reassess its policy on collection of water rates in order to ensure that the Project generates its operation fund from within. The current policy of not pumping during much of the dry season when water is at its most valuable also should be reviewed. However in recent years the G-K Project suffers from low levels in the Ganges during the months of March/April due to upstream abstractions at Farakka.

One of the most striking aspects of the FCD/I projects is the lack of any preventive maintenance programmes. Also, the farmers' participation in the maintenance work has been minimal. Another short-coming of these projects is the under-utilisation of the pumps associated with minor irrigation : on an average, each pump operates only for about 10 hours per day during the peak water demand periods.

2.2.5 Groundwater Development

Existing groundwater development has taken place mainly in north western districts, which reflects the better aquifer conditions which exist in those areas. Groundwater is abstracted by a mix of STW and DTW but the incidence of DTW is higher in some Thanas than others, because aquifer conditions vary and DTW are needed because of higher well drawdown in poorer areas.

In much of the area however, there is no groundwater development for irrigation at all, either because of very poor aquifer conditions or the presence of saline water. In these areas groundwater is capable of providing small yields to HTW for domestic purposes only.

In those areas where groundwater is used for irrigation there are no reports of adverse effects, even though in some cases the current MPO estimates of recharge are being exceeded. However it has been shown elsewhere in Bangladesh that the MPO recharge estimates are very conservative and it presumably applies here, that is, available recharge may be considerably in excess of the MPO estimates. One source of additional recharge which is prevalent here is the number of LLP, whose residual contribution becomes a significant net gain to groundwater storage.

The only groundwater problem of significance is at Khulna city, where the quality of groundwater abstracted for domestic/industrial purposes is deteriorating due to increased salinity. Records show that there are many deep wells and HTW in operation whose output and siting are not controlled. The total abstraction is clearly too large so saline intrusion is occurring. The present situation is difficult but tolerable and is becoming progressively worse. Given the large population of Khulna it is a matter which requires immediate attention.

2.3 Changing Resource Setting

2.3.1 Introduction

The resource setting of the SWA is described in Section 2.1. Major evolutionary changes are taking place in the rivers in the Southwest Area of which perhaps the most significant are the channel planform changes occurring in the main boundary rivers which is affecting both banklines and spillage with the area through the right bank distributaries. These distributaries play a vital role in sedimentation transport, salinity control, flooding, land drainage and surface water supplies for irrigation, domestic and industrial use.

Of similar importance are the coastal processes involved which have a major impact on the generally low-lying topography. Tidal action and saline intrusion, which are felt 275 km and 150 km inland respectively have great inference on the manner in which the river and surrounding land may be developed.

Whilst accurate predictions of the future behaviour of such complex systems is difficult, there are good indicators which point to the direction in which these processes are evolving. Any water resources management development strategy must take account of this changing resource setting.

2.3.2 River Systems

Major evolutionary changes that are taking place in the rivers of the SWA have important implications for its resources and thus it is vital to understand the dynamics of the local and regional fluvial systems. The issue of greatest significance is perhaps that of channel planform change in the major boundary rivers, which affect both their banklines and flood plains and the spillage into the Area through right bank distributaries. These distributaries are themselves large regional rivers that play fundamental roles in sedimentation, salinity control, flooding, land drainage and surface water supply for irrigation and commercial and domestic use.

The Boundary Rivers, which formed the SW Area and control the present flows into it, can be categorised by their age and from this, their behaviour. While all the rivers are subject to dynamic change because of the deposits through which they pass and their own flows and sediment loads, the Ganges, which is the oldest, appears more understandable and thus easier to predict and control. The Padma, which was only formed about 200 years ago and has already had one major avulsion, to join the Lower Meghna, is far less stable and is subject to bankline changes of up to 1 km in a season. The Lower Meghna was only formed about 150 years ago, lies in a zone of significant crustal movement, is tidal throughout and is the least stable of all. The contribution of the Regional Rivers which spring from them, in terms of fresh water supply to the SWA, is inversely proportional to the stability of the Boundary River. The Gorai, which is the only remaining spill river on the Ganges, appears to be dying in a similar way to the older ones like the Mathabanga and the Chandana. The Arial Khan on the Padma is a dynamic river in its own right with a wide river corridor and has a number of tributaries at its head. The Lower Meghna contains a number of more major spill rivers such as the Tentulia, Jayanti and Ilisha, which are also subject to change. In their lower reaches Regional Rivers exhibit their strong tidal characteristics.

The Inland Rivers represent the remaining channels of old spill or Regional Rivers, which have lost their connection to the oldest Boundary river, the Ganges. Their channel is usually oversized and they simply transport run-off and occasionally flood spill from the boundary river. The Chandana, Kumar, Nabaganga and Kobadak are good examples of such rivers as is the Mathabanga although, being one of the last to be disconnected, it still receives Ganges water during peak flows.

The Inland and Regional rivers run into tidal rivers or estuaries whose influence extends over 60% of the SWA. In the west, because the freshwater discharges are low, the coastal rivers or estuaries are mainly saline, especially in the dry season. In the east, though tidal, they remain mainly freshwater, being fed by spill from the Lower Meghna.

The flow regimes are driven by high, variable, sediment laden flows to produce a 'wandering' planform for the rivers, which exhibit elements of both meandering and braided patterns. Their local alignment and configuration vary in time and space and frequent channel shifting and re-alignment within the active corridor results in changing conditions at distributary offtakes at the corridor margin. Thus, a particular distributary may be located adjacent to a deep, fast flowing channel in the parent river, or behind a wide bar.

Superimposed on the continuous planform adjustments that create and maintain the active corridor, there may be channel migration across the flood plain. Distributaries on the eroding side will generally grow as their courses are shortened and their offtake mouths kept clear by channel erosion. The opposite is true for the other bank.

Consequently, the morphological impacts of each boundary river depend on the combined result of corridor widening and progressive migration.

The Ganges follows a course adopted prior to the sixteenth century when regional tectonics led to the river migrating eastwards and abandoning former spill channels at the western end of the present delta. Although diminution of the right bank distributaries such as the Baghirathi-Hoogly, has continued, the channel of the Ganges has been in its present location for at least four hundred years. This has given sufficient time for the gross features of the channel geometry to adjust to the river regime and for the active corridor to widen sufficiently to contain both meander sweeps and braided reaches. There is evidence that the river may still be migrating slowly northeast due to regional tectonics.

The morphologically less mature Padma, is still adjusting to the avulsion of the Brahmaputra River at the end of the eighteenth century and its later avulsion and confluence with the Lower Meghna. The width of the active corridor has not yet stabilised and there is evidence that erosion resistant boundary materials, particularly along the left bank, may be limiting the northerly development of the channel. Hence, further activity may be expected along the right margin of the active corridor. Morphologically the present rather straight alignment of the river could change at any time to produce stronger meandering or braiding and attack the flood plain behind the corridor margin, especially along the right bank.

The morphologically younger Lower Meghna is also a tidal estuary and receives a vast sediment load annually, most of which it conveys to the Bay of Bengal. It has not yet fully adjusted either to the avulsion of the Brahmaputra or its confluence with the Padma. Its active corridor is poorly defined, but potentially encompasses the entire active delta, any sector of which could be re-worked with little prior warning. However, its marked propensity to migrate eastwards, is currently being delayed by heavy intervention at Chandpur. Its right bank distributaries are located in the active corridor and are therefore themselves highly dynamic, but in the long term will diminish if eastward migration occurs.

Predictions of the future development of highly dynamic river systems like those in the SWA are difficult. However using engineering and geomorphic judgement based on field observations, historical records and together with a sound understanding of the fluvial system the following trends can be predicted:

- the Ganges is broadly in a state of dynamic equilibrium and its channel lies within its active corridor, but serious channel instability outside the active corridor is not expected.
- embankments along the right margin of the active corridor of the Ganges are in general safe.
- detrimental impacts of the accelerated post-monsoon recession and reduced dry season flows on in-stream and riparian habitats and on distributary channels will continue.
- embankments along the right margin of the active corridor of the Padma are more likely to be attacked through embayment and meander loop development associated with on-going widening. However, likely locations and rates of attack are broadly predictable.
- polders on the right bank of the Lower Meghna are much more prone to erosive attack as all lie within the active corridor. Likely rates and locations of erosion are broadly predictable, but stabilisation of the left bank may trigger new and unpredictable right bank erosion.
- the Gorai spill flows are likely to continue to vary widely as the Ganges alters the position and orientation of its low flow channel(s). Over longer time-scales, both wet and dry season flows in the Gorai (and other right bank distributaries) will diminish due to net north-easterly migration of the Ganges.
- deterioration of the Gorai off-take mouth will continue with the underlying trend to its permanent abandonment as a Ganges spill channel. Conversion of the Gorai to an inland river reliant on local rainfall will occur sometime in future, unless actions are taken to prevent this.

- flows through the Arial Khan and its distributaries will vary due to channel shifting in the Padma. Over the longer term the Arial Khan should continue to receive spill flows.

- inflows to the Tetulia and other right bank distributaries of the Lower Meghna will vary with the relatively rapid channel changes of alignment of the parent river. In the long term they will diminish due to eastward migration of the Lower Meghna, but stabilisation of the left bank could alter radically spill flow quantities in either direction.

- any reduction in spill flows, especially from the Ganges, will increase the penetration of saline water into the Area and, in the long term, to siltation in the smaller tidal rivers.

2.3.3 The Coastal Zone

The coastal area is subjected to coastal processes which include tides causing periodic variations in water levels and currents, consequential saline intrusion, wave attack on the coastal fringe, surges and extreme wave attack due to cyclone and possible long term sea level rise due to global warming.As a consequence of the flat topography coastal processes have a major impact on the freshwater resources of the area.

The southwestern coastal zone is in a state of transition from an actively developing delta of the Ganges to a semi-moribund delta, partially sustained by 'local' rivers. Of these 'local' rivers only the Gorai receives significant freshwater flows from the Ganges.

The South Central coastal zone is part of the active Meghna delta and as such is not showing moribund tendencies.

The transitional processes is the south western zone have been accelerated by the CEP and reduced fresh water flows as a result of the construction of the Farakka Barrage. These processes have resulted in increasing rates of siltation and salinity intrusion which become progressively worse moving from east to west. The most conspicuous impact of the processes is drainage congestion in the CEP with its consequent impact on farming, fishing homesteads and navigation. Without major interventions this situation will deteriorate further until eventually equilibrium is reached in the coastal zone. This main to be hundreds rather than tens of years. Clearly measures are needed to alleviate the current problems arising from drainage congestion.

In the south central coastal zone drainage congestion and salinity intrusion are of less significance providing the Meghna flows are sustained.

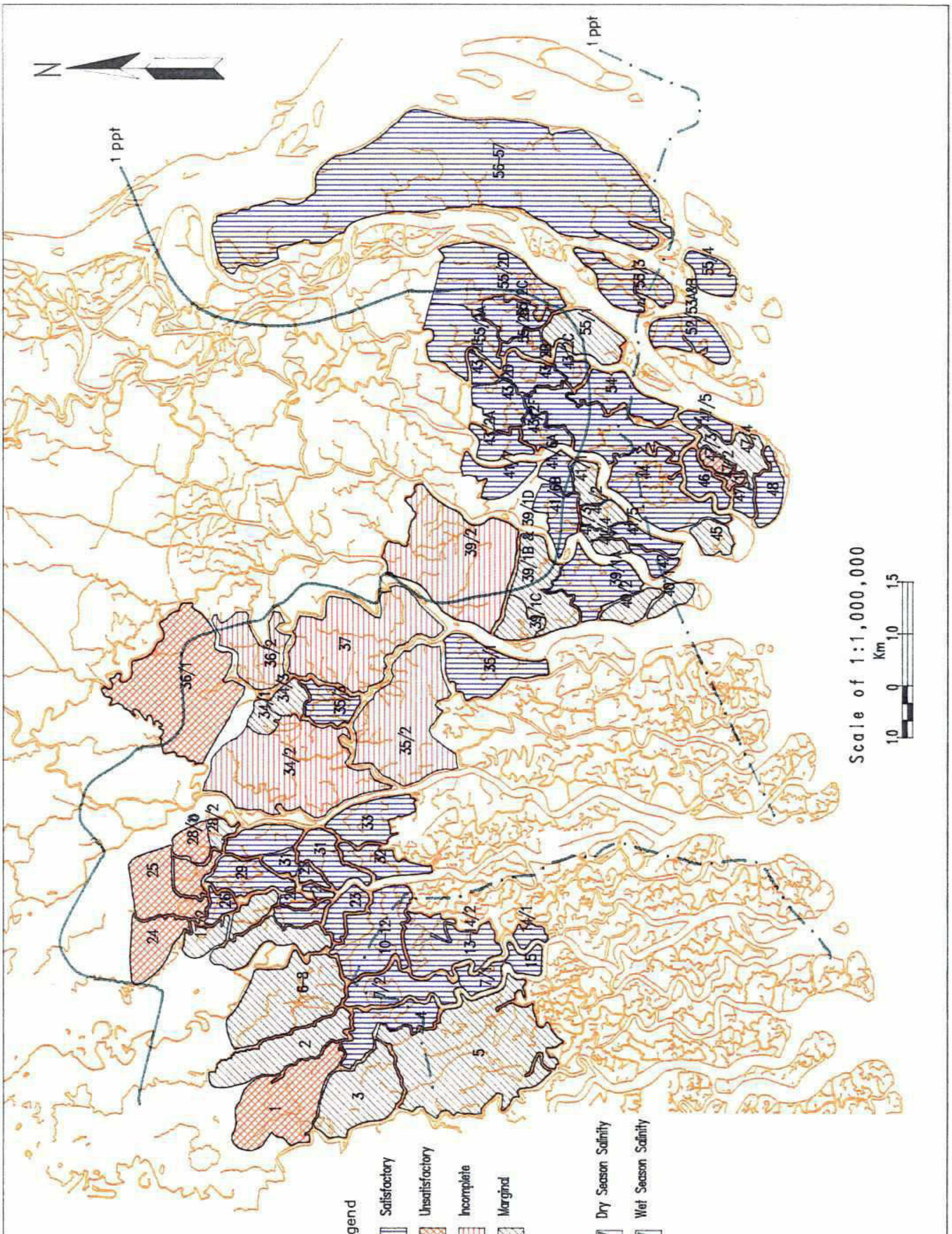
To provide a method of estimating the extent that polder performance is related to drainage congestion an examination was made of all the outfall sluices in each polder. The area of sluices outfalling into each perimeter river was determined and the proportion of sluice area outfalling into silting rivers calculated.

In general the polder performance has been assessed as follows:

(i) a satisfactory condition exists when the drainage congestion affects less than 30% of the total area of outfall sluices;

(ii) a marginal condition exists when the area affected is between 30% and 60% of the total area; and

Figure 2.13



POLDER PERFORMANCE PRESENT SITUATION

(iii) an unsatisfactory condition exists when the area affected is in excess of 60% of the gross area

The choice of these percentages is subjective and relates primarily to polder drainage performance. They could be reviewed when specific data on actual and potential crop yields are available. However, if the polder is failing to produce its potential crop yield there could be a number of factors involved and it would be necessary to separate problems caused by drainage congestion from other causes.

The appraisal was checked against field information supplied by the BWDB; the Consultants' field visits; past reports, and SPOT imagery for 1989-90 and modified where necessary. The results are shown on Figure 2.13.

Because the coastal area is in a state of transition an estimate of the future drainage condition is as important as the assessment of the present condition. This has been carried out by first assessing the future condition of rivers followed by a corresponding reassessment of polder drainage based on the future river conditions.

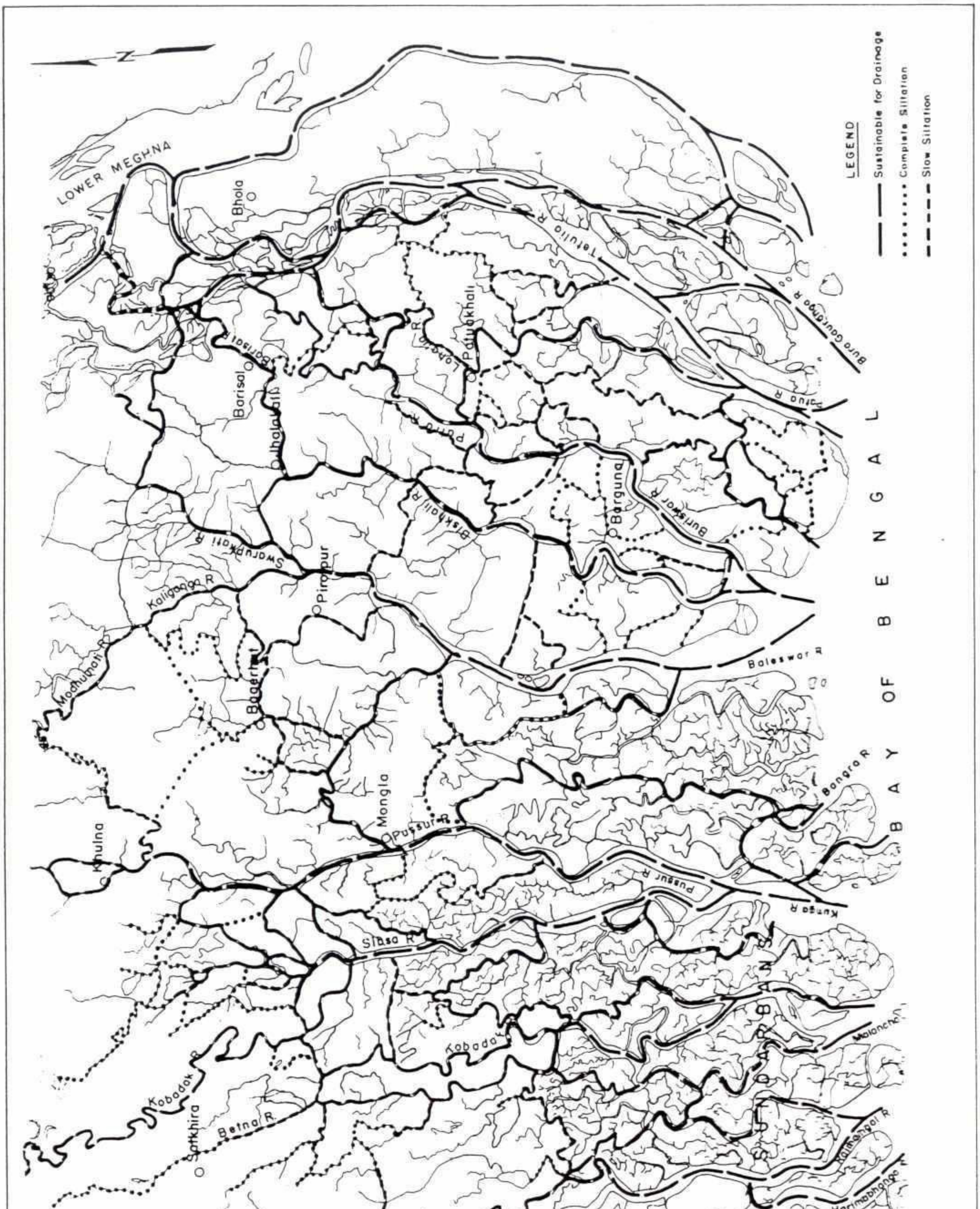
The results of the future river and polder classifications are shown on Figures 2.14 and 2.15 respectively.

Further corroboration has been sought by carrying out an analysis of the drainage characteristics of each individual polder. This has been based on the flood elevation curves set against the rate of gravity drainage as a function of the water levels inside and outside the polder as predicted by the mathematical model. The percentage areas of land within each polder and each flood depth category has been determined for the existing drainage capability and for situations in which the ventage both decreases and increases. The changes in the proportion of land in each flood depth category then indicates which polders are under performing with their existing drainage capability, and which would become most inefficient should diffent levels of ventage reduction occur. The results corresponded very well with the polder classification based on present day and projected future river conditions. Furthermore, those polders that would not materially benefit even if the vetage were to be increased by a substantial amount indicate where pumped drainage might be considered. This alternative analysis also assists in prioritising improvement measures.

The rivers show a continuing process of siltation progressing generally from the NW toward the SE and the polders show a deteriorating trend in the same direction. The main exception is the South Central Region where siltation of the main rivers is not anticipated but deterioration of the polder system will occur as a consequence of siltation in the cross rivers and drainage congestion within the polders. Due to the limitations of the predictive methods available it is not possible to place an accurate time estimate for the transition from the present to the future condition but it will probably be in the time scale of 10 - 30 years.

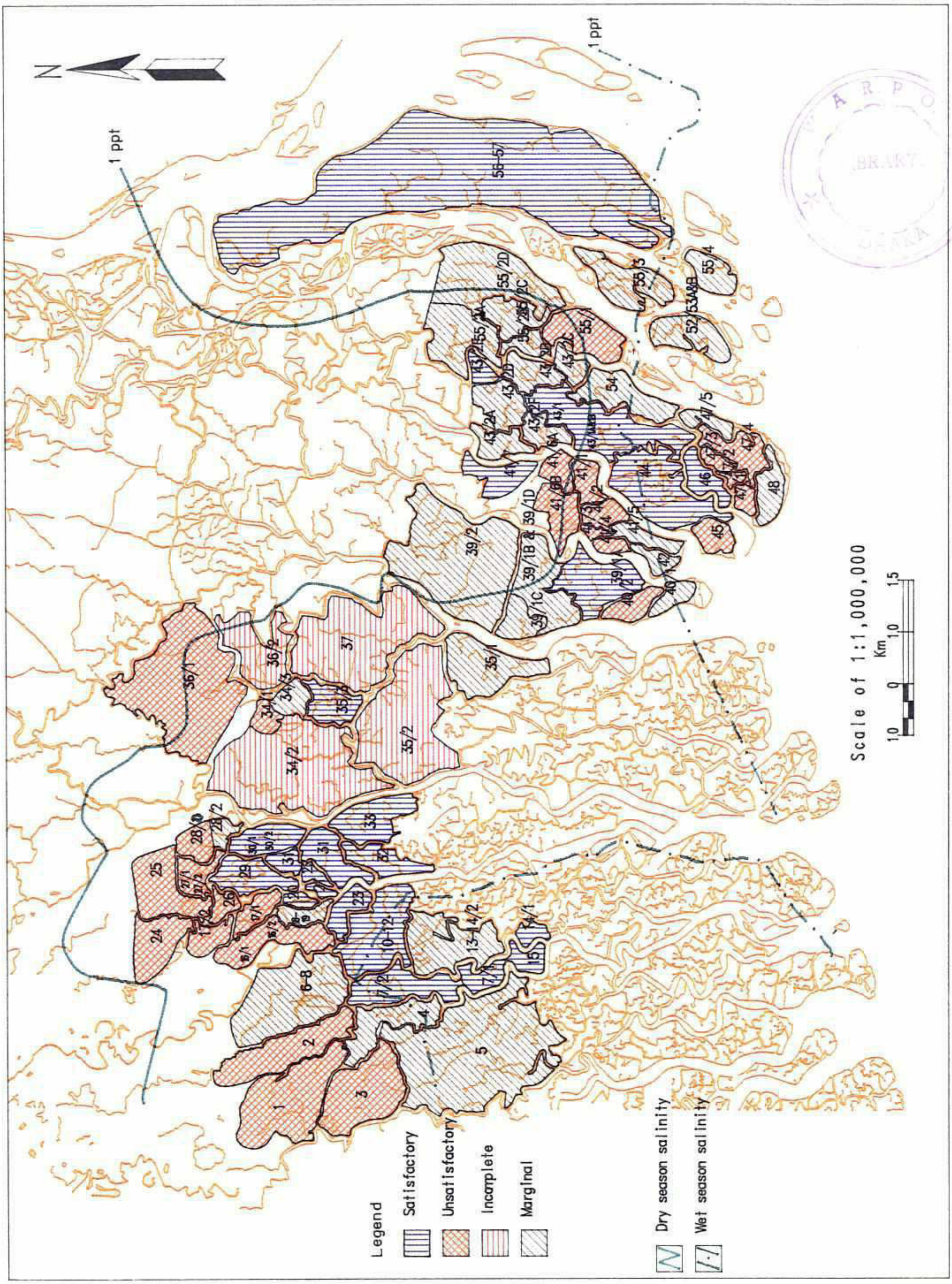
The regional deterioration of the CEP is summarised in Table 2.14.

Figure 2.14



Tidal River Characteristics – Future "Do Nothing" Situation

Figure 2.15



POLDER PERFORMANCE FUTURE SITUATION

TABLE 2.14

Present and future polder performance

	CEP net area (%) (total = 622,00 Ha)		
	Satisfactory	Marginal	Unsatisfactory
Present situation	59	24	17
Future "do nothing" situation	33	38	29

The resource implications based on an interpretation of these changing conditions are:

- the south western coastal zone in a state of transition from an actively developing delta to a semi-moribund delta. This transition has not yet reach equilibrium with present day conditions.
- the construction of the CEP project and consequential siltation of the inland tidal rivers has caused drainage congestion to the extent that 40% of the CEP investment is not performing satisfactorily.
- interventions are strategically essential to prevent further deterioration that could result in non performance increasing to 70% within the next 10 - 30 years.
- saline intrusion has increased due to increased tidal penetration and reductions in freshwater flows. Any further reduction in freshwater inflows will increase the penetration of saline water into the area and, in the long term, to siltation in the smaller rivers.
- primary navigation routes within the Area and to the Country's second largest Port at Mongla has been deteriorating and any intervention measures must seek to minimise any further deterioration.
- the Sundarbans forest relies on a delicate balance of environmental conditions and would be damaged if these were to change in any significant way.
- the possibility of future sea level rise due to global warming coupled with potential land subsidence poses a threat to the long term viability of maintaining effective gravity drainage in some of the poldered areas.

2.3.4 Population Trends

The 1981 - 1991 intercensal population annual growth rate in SWA was 1.89%, lower than the national rate of 2.01% pa. Provisional figures indicate that the rural urban drift was lower in the 1980s than during the previous two decades. In SWA the urban population grew at 4.2% pa between 1981 and 1991 compared to 1.58% pa in the rural areas. The national and SWA figures show there to be positive success in curbing population growth through the countrywide family planning campaign promoted actively by government during the past decades.

The Population Development and Evaluation Unit (PDEU) of the Planning Commission forecast continued progress and expect the growth rate to fall to one percent by 2009. The

PDEU's forecasts and the lower than expected 1981-1991 growth rate result in the following, possibly optimistic, projections for SWA which indicate that the population will be one third higher by 2010 (Table 2.15).

TABLE 2.15

Population Trends (in million)

Area	1991	1995	2000	2005	2010
SWA	26.11	28.28	30.77	32.98	34.66
SWR	16.72	18.12	19.71	21.13	22.20
SCR	9.39	10.17	11.06	11.86	12.46
Density pp/km^2	702	760	885	885	930

The forecasts are based on the official BBS national rate of 2.01% pa during the first five year period rather than the lower but unofficial SWA figure of 1.89% and in the absence also of officially released growth rates 2.01% has been applied to both the rural and urban 1991 populations.

The projections show that population densities in SWA can be expected to rise from 702 pp/km^2 in 1991 to 930 in 2010. Even if the proportion of farming households remains unaltered at 76% the effect on the farming community be drastic unless migration to urban centres or out of SWA occurs or, as is most likely the proportion of landless within the rural areas increases very substantially. To retain the same amount of land for each farming household the proportion of landless households (including fishermen) would have to increase from about one quarter in 1991 to 36% in 2000 and 43% in 2010.

The present and future estimated figures shown in Table 2.16 below illustrate the effect of expected population growth in rural SWA.

TABLE 2.16

Present and Future Population Growth in Rural SWA

Year	1991	1995	2000	2005	2010
Rural Density (1) pp/km^2	705	765	830	890	935
Cultivable Land Ha/hh (2)	0.699	0.646	0.593	0.554	0.527

(1) excluding the Sundarbans

(2) Based on a total net cultivable area of 25090 km^2 and 5.53 persons per each household.

Section 2.3.9 clearly shows the implications for food production and nutrition if no significant developments take place in SWA even at the low growth rates forecast and assumed in the Study analyses.

2.3.5 Land Use

The land use in Bangladesh has undergone changes in the past 15-20 years reflecting trends in agricultural production. The national changes are shown in Table 2.17.

TABLE 2.17

Annual Trends in Crop Production (%) (Year 1979-80 to 1987-88)

Crop	Yield Trend	Area Trend	Production Trend
Rice	1.97	0.20	2.17
Wheat	Recently	Negative	
Pulses	1.86	-4.53	-2.67
Sugarcane	-0.21	1.40	1.19
Vegetables	-0.79	1.50	0.71
Fruits	-0.76	1.41	0.65
Oilseeds	1.67	-0.07	1.60
Jute	1.93	0.23	2.16

Source: Crop Agriculture Development Programme for the Fourth Five Year Plan, Ministry of Agriculture, 1991.

At a national level, the production of all crops except pulses have increased albeit at levels less than the population has risen.

Similar trends have been calculated for the SWA based on ten years data from BBS, the results are shown in Table 2.18.

TABLE 2.18

Annual Trends in Crop Production, 1980-81 to 1990-91

Crop	Yield Trend	Area Trend	Production Trend
L. aus	3.81	1.86	5.67
HYV aus	-1.46	-2.85	-4.31
B. aman	1.42	-2.57	-1.15
L.T. aman	2.28	0.91	3.19
HYV aman	0.25	11.87	12.12
L. boro	0.56	5.71	6.27
HYV boro	1.70	11.12	12.82
Wheat	-6.48	1.21	-5.27
Jute	4.51	-6.62	-2.10
Lathyrus	0.73	0.80	1.53
Lentil	0.6	-0.80	-0.2
Mustard & Rape	0.02	0.01	0.04

The overriding trend is the decrease in the area of HYV aus, b.aman and Jute and to a lesser extent lentil. This has been offset by the increase in area of HYV aman and HYV boro.

On the assumption that irrigation and FCD continue, there is no reason to suppose that such trends will not continue although at what rate it is difficult to forecast.

2.3.6 Agriculture

The future situation without any further interventions will reflect the continuation of present trends excluding those that are brought about as a result of FCD.

The expansion of the area under boro will continue due to the continued increase in the number of low lift pumps and shallow tube wells purchased privately by farmers. This will continue, particularly in the north and centre of the SWR and in the SCR where water quality allows. The Consultants have not tried to set an upper limit on this expansion but would draw attention to some of the negative consequences of such a trend. Although the trend data only shows a slight decrease in the production of pulses in the SWA it is highly likely that a further increase in the area of boro will lead to a decline in pulse production with detriment to nutrition. Pulses are not the only crop likely to decline in output, oilseeds and vegetables are likely to be reduced as well. The increase in boro may likewise lead to a decrease in Keshari, a pulse used as an animal feed. This will have a continued negative affect on livestock nutrition, a situation that has been reported by FAP-12.

It is almost certain that without further intervention, crop production will not keep pace with the continued increase in population. The expansion of the area under boro, although impressive cannot produce sufficient rice for the population. Further FCD will be needed to lessen the risks to the aman rice crop and produce further, substantial increases in production.

2.3.7 Fisheries

The capture fishery catch has been falling in recent years and with the expansion of agriculture by FCD schemes will only accelerate this fall in production. Although culture fisheries has expanded in the same period it cannot be reasonably considered to replace the shortfall. The yields of culture fisheries as practiced now are still low and unless a concerted effort is made to increase these yields the shortfall between the capture and culture fisheries is bound to widen.

Shrimp farming has expanded in areas south of Khulna within the last ten years or so but the yields are only about half of that achieved elsewhere in Southeast Asia. If the present method of production are allowed to continue, the yields will further go down due to shortage of post-larvae which are threatened by offshore trawled catch.

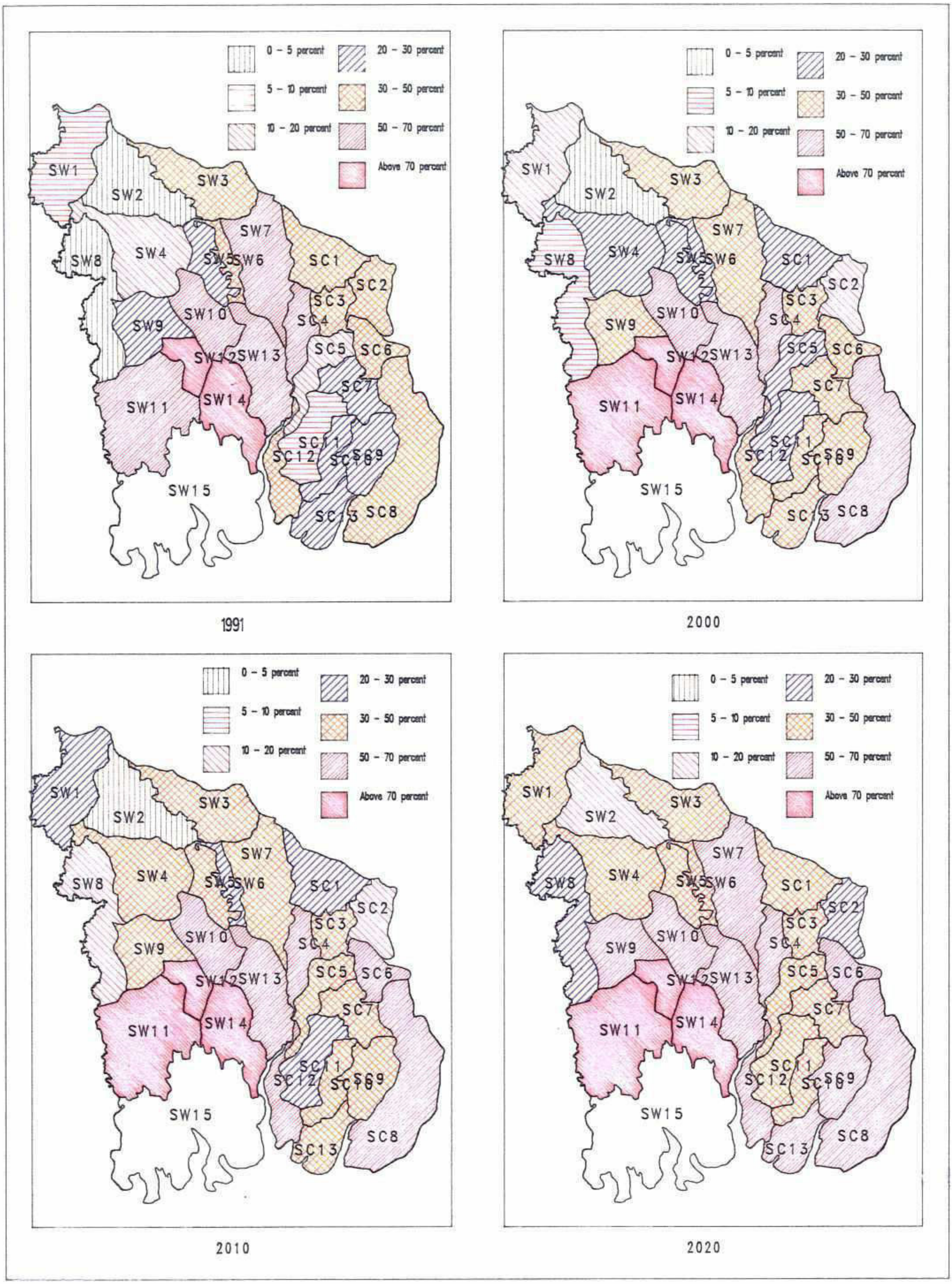
The lack of access to institutional sources of low-cost credit has been a constraint to fisheries development. Unless easy credit facilities are made available expansion of fisheries sector, culture fisheries in particular, cannot be reasonably expected.

2.3.8 Forestry

As stated in the earlier sections forestry resources are declining and unless measures are taken to arrest this situation, the prospects for the increasing population of SWA is not very bright.

In Sundarbans if no interventions are made, the decline of the commercial timber will continue to such an extent that the 'disappearance' of this species in Sundarbans is a distinct possibility. Coupled with this, already existing regulations should be strictly enforced to stop overexploitation.

Figure 2.16



Food Energy Shortage (No Development)

2.3.9 Nutrition, Employment and Health

The SWA population is forecast, conservatively, to grow by a third by 2010 from an already broad age group base. By 2010 the overall density including the lightly inhabited Sundarbans will rise to 930 pers/km^2 from 702 pers/km^2 in 1991.

Opportunities for emigration will remain very limited and the Area's resources will come under very considerable pressure.

Estimates of food energy requirements and gross production show that only two Planning Units (SW2, SW8) with only 11% of the population had surpluses in 1991. With no development other than from groundwater all areas will be in deficit by 2010 as illustrated in Figure 2.16.

Underemployment and unemployment already occur on a considerable scale in SWA and the landless and marginal farmers (with under 0.5 ha) already accounted for 45% of all the Area's households in 1983/84.

Nutritional standards can be expected to fall, especially in communities unable to purchase additional food. This in turn will affect public health, by a general lowering of the disease resistance of individuals.

To purchase food, particularly in the south of the Study Area, new forms of income generation will be necessary. At present the lack of forward planning and institutional structures, suggests that these initiatives are unlikely in the short term.

As land holdings decrease in size, rural employment opportunities will fall. However industry is expanding and the linear urban development between Khulna - Jessore and possible smaller scale expansion in Barisal and Patuakhali may provide some alternative employment opportunities for the rural population. Nevertheless without increased investment in rural development, including water resources management the forecast pressures on resources can only lead to wider food and fuel energy deficits. This coupled with an increase in the already high proportion of the population with very limited means of support and unpredictable but adverse social and cultural changes placing an increasing strain on the SWA and national economies.

2.3.10 Environment

The Southwest Area is presently facing a trend of general degradation in a predominately agricultural area. Three main factors can be identified that dominate the present trend in the changing environment of the Southwest Area:

- the diminution of dry season flows through the Ganges distributaries to the Southwest Region

- the tidal dominance in the delta

- the growing human population

Diminution of dry season flows will have inevitable, long-term consequences, although a timetable for these situations cannot be suggested on present data:

(i) the dying of the distributary streams from the Ganges as sediment bars increases at the offtakes;

(ii) the northward movement of the saline wedge, as tidal movements meet less and less resistance from dominant freshwater flows;

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(iii) increased sedimentation;

(iv) increased monsoon flooding from inundation and poor drainage in sedimented channels.

As a result of the lack of Gangetic dry season flow, there will be difficulty in providing (and in extending) surface water irrigation from existing schemes in the Southwest Area. Agricultural production will inevitably suffer.

Groundwater development alone will not provide for the water supply and irrigation needs of the Southwest Area. Even if groundwater is allowed to fully develop (assumed completely developed by year 2000) the benefits of improved food production will be lost by 2020 as the population increases in all areas.

The northward movement of the saline wedge and increased sedimentation are dominated by the tidal movements in the delta. Tidal dominance and sedimentation reduce the ability to drain land behind flood embankments resulting in further drainage congestion.

If sedimentation rates increase, at the northern end of the Sundarbans there will be degradation of the forest as flushing regimes are lost. Lagooning and salt pan development will destroy the trees, resulting in bare, salt-grass areas with minimal productivity.

The shrimp fishery in the Southwest Region is likely to peak, dependent as it is on the capture of post-larval shrimp from rivers. This industry may decline if adult and larval stocks are over-fished, or if the northern Sundarbans become further degraded.

The major impact on the sustainability of the Sundarbans is felling, including the over-exploitation of timber for the Khulna paper, pulp and hardboard industries, and illegal felling.

Changes in the Sundarbans, brought about by a combination of over-felling, sedimentation and dynamic community change, will alter the resource value of the forest. It is probable that sensitive, though valuable, species such as Sundri (*Heriteria formes*) are likely to be reduced in number. Salinity stress will result in more stunted, less commercially attractive, growth.

The demand for fuelwood is expected to increase with an increasing population. As a result felling within village groves will continue. This may result in severe deforestation, unless there is a commensurate increase in social forestry. In the short-term there is likely to be a depletion of timber stocks, until new plantings mature; and it is difficult to predict the long-term situation in this sector.

The pressure that will be placed on food sustainability, to meet a growing population, may cause social and cultural changes. Nutritional standards can be expected to fall, especially in communities unable to purchase additional food. This in turn will affect public health, by a general lowering of the disease resistance of individuals.

If conditions become too severe, there may be a steady migration out of parts of the region, to other parts of the country (which also have severe population pressures). Such patterns of movement may be accelerated by catastrophic damage due to cyclone and flood, particularly in the absence of mitigation measures.

Village homestead groves are on the decline due to pressures on fuelwood, particularly from the brick fields, although timber firing is banned for brick production. If no action is taken the village homestead groves will diminish with consequence environmental impacts.

The available land in the coastal areas in the SWA for coastal plantations is limited. New plantations should be considered on degraded coastal land if this is to be expanded.

3 DEVELOPMENT OBJECTIVES

3.1 Introduction

Future development of the Southwest and South Central Regions' water resources should be with clear objectives in mind. These objectives fall into principally four categories:

- Conformity with Government policy and FAP Guidelines
- Satisfaction of socio-economic needs of the people of the Regions
- Sustainable development, recognising and harmonising with the natural and physical changes occurring within the Regions
- Ensuring that best use of resources is made in support of the goals above

The studies undertaken indicate that, whilst these goals are in fact substantially complimentary, they nevertheless place individual constraints upon the choices now and in the future and create trade-offs between the fulfillment of the different aims.

3.2 Government Policy and the FAP Guidelines

Government policy is embodied within the current Fourth Five Year Plan (1990-95) which sets objectives for development within the water resources sector. The central strategy of this policy, as reflected in the National Water Plan, is to make use of irrigation and water control for the purposes of improving agricultural productivity and employment. Emphasis is given in the plan to minor irrigation and to flood control and drainage (FCD) as the principal means by which to achieve these goals. Priorities are established relating to maximising the benefits from existing facilities and where new projects are required, selecting those which have a short gestation period. Allied to these priorities are strengthened operation and maintenance and water management capabilities as well as involvement of the private sector in developing new areas and in providing support services to existing schemes. Other strategies are also recognised as being important. These include augmentation of surface water resources from the main rivers and basin-wide integrated development of both surface and groundwater resources.

These policies are reinforced in the Flood Policy Study and the National Water Plan and these documents broadly state how the nation's water resources are to be developed and the goals which are to be aimed at. It is pertinent to note also that given the specific problems of the Southwest Area, in which water resource development is as much a central issue as flood control and drainage, the National Water Plan is of even more relevance than might otherwise have been the case.

The Flood Action Plan (FAP) provides additional focus on the central objectives for water management development planning. The FAP policy defines Eleven Guiding Principles for implementation of a comprehensive system of flood control and drainage for the entire country. These principles reproduced in Table 1.1 of this Report have the twin aims of:

- protection of urban, rural, commercial, industrial and public utility centres and communication networks.
- controlled flooding, wherever possible and appropriate, to meet the needs of agriculture, fisheries, navigation, urban flushing, soil productivity and recharging the surface water/ground water resource with minimum dislocation of the environment.

The Principles stress the need for effective land and water management through a variety of measures which include engineering interventions, coordinated planning of other infrastructure developments, flood forecasting and warning systems, an enhanced disaster management capability and beneficiary participation in all phases of planning, implementation and subsequent operation and maintenance. Within this overall framework it is nevertheless essential to define a sub-set of objectives by which the relative impact of policy options may be assessed. These definitions require an appreciation of the specific needs of the people in the Southwest Area (SWA) and of the overall environmental considerations when devising the means by which to best satisfy these needs.

3.3 Socio-Economic Needs

The 1991 estimate of total population of the Southwest Area is 26.1 million of whom about 91% are living in rural communities and about 70% are considered below the poverty line. Employment offered by agriculture creates about 2 million person-years of work per year (at 220 days per year). Given that agriculture is the main source of employment it is self-evident security of income is of major importance.

Estimates of food sufficiency indicate that overall food production falls some 33% below overall requirements for the Area and that, with development only of groundwater resources, by the year 2020 this will have increased to about 48% given the expected population increases. Self-sufficiency is presently achieved only in areas where widespread irrigation is practiced, either by existing surface schemes such as the G-K project or where groundwater is heavily utilised. Nevertheless by 2020 even these areas are forecast to go into deficit. Similar deficiencies are experienced in fuel energy and fodder whereas overall protein levels are generally adequate at present except in the lower producing areas in the southern half of the Southwest Region. However, even overall protein levels are expected to go into deficit by 2020 except in one or two areas.

Fishing is an important source of protein to the area as well as income. Capture fisheries as practiced in the rivers and flood plains is vital to the livelihood of many, particularly those amongst the most disadvantaged groups. Measures counterproductive to capture fishing would severely affect such groups. Culture fishing and shrimp farming where appropriate are high value uses of land which bring benefit directly to those concerned. These are worthy of encouragement especially in a manner where the benefits may be fed directly back into the community.

Domestic water supplies are almost exclusively drawn from groundwater resources, most of which is by hand-operated tubewells. The expected continuing rapid increase in groundwater development by both shallow and deep tubewells poses a threat to domestic supplies, both from the perspective of lowered water tables and, where relevant, increased risk of saline intrusion. Security of potable water supplies is thus of paramount importance.

Diarrhoea and water-associated insect vector diseases represent a major health problem, which are aggravated by unsafe water supplies, poor sanitation and hygiene. The impact of flooding can be particularly severe causing severe health problems within the affected communities. Additionally cyclone/flood protection shelters in areas of high risk and improved FCD will reduce considerably the health risks associated with flooding.

The role of women in the economy needs further investigation, including the needs of female-headed households. Preliminary studies show this group (together with landless household heads) identifying security of employment and opportunity for income generation as major concerns. The expansion of on-farm labour requirements brought about by FCD/I projects, as well as associated non-agricultural sector developments, thus become important areas in promoting opportunities for women's participation.

Transportation is an important community need both for maintaining communications as well as major and minor trading links. The Southwest Area, whilst modestly well served by road and rail links is considered to be substantially dependent upon river transport. Maintenance and improvement where possible of the waterways for both formal and informal river craft is important to the Area.

Thus, in the context of this study, the needs of the people within the Area, and especially the majority in the rural areas, require the development of agricultural productivity with the aims of growing more food and producing more protein and of generating more employment with higher incomes. Allied to this are requirements to secure potable water supplies and facilitate public health and to maintain and promote fisheries and transportation facilities. To these general needs may also be added the concern for equitable distribution of benefits within the community as a whole.

3.4 Sustainability of Development

A clear objective of any natural resource development programme is sustainability. For the Southwest Area this is not a question of just ensuring that estimates of useable land and water resources are not exceeded. The dynamic situation of the evolution of the topography and of the rivers within the Area requires special attention to ensure that current, and indeed future, resource levels are maintainable. In the event of no further development, deterioration of resources can be expected even if the absolute rate of decline is difficult to predict, as is the case in many instances. Positive steps are required to counteract this deterioration and the measures employed have to be in a form which can be sustained either through harmonisation with the long term physical changes in the area and/or through the availability of sufficient financial resources to maintain whatever is done.

The measures introduced also must themselves generate adequate funds, either through the public or private sectors, to ensure that maintenance is possible. The choice of whether to promote development through either of these sectors hinges on the abilities of each to not only fund but also to operate and maintain works. Whereas the burden has often fallen in the past on Government, it is increasingly appreciated that with prudent planning the private sector can potentially undertake this work better for themselves in many instances.

Sustainability has of course much wider connotations than ensuring physical works can be operated and maintained, vital as these are. Development within the Area as a whole should bring benefits which will be available for future generations to come, and should not, without widespread public consent, create irreversible disbenefits which in the long term will deny opportunities for those in the future.

Sustainability demands that developments proceed in sympathy with environmental requirements. The present institutional framework, based on mainly sectoral and sub-sectoral interests, is not well-placed to ensure the coordinated use of all natural resources in a manner which is sustainable. Interactions exist between water management measures and a wide variety of other important sectors. For instance, embankment design needs to take account of flood plain fisheries as well as address the issues of resettlement, flood refuges and the limited areas available for forestry. Both structural and non-structural interventions have to be mindful of how they fit into the changing resource setting and the linkage that exist between the many processes at play. Sustainability is more likely to be achieved if these interventions harmonise with these processes rather than oppose them.

The Sundarbans is an important multisectoral resource of the Southwest Region and of the nation as a whole. Given the current limited knowledge of how its ecosystem works and should be best managed, it remains essential that flow conditions at its boundary are tampered with as little as possible until such time as the potential impacts are properly understood.

In a broader context sustainability also requires that the quality of life be at least maintained in the future. The Area's flora and fauna and historical sites are assets which should not be adversely affected without reasoned justification. Similarly, existing levels of satisfaction of human needs effort should be given to maintaining and where possible achieving improvements in a manner which can be sustained in the long term. Given the expected population increases this is a major undertaking which will require the continued commitment and coordination of the many agencies concerned, directly or indirectly, with human needs.

4 DEVELOPMENT NEEDS, CHOICES AND LINKAGES

4.1 Introduction

The needs of the Southwest Area are many and diverse. They relate principally to the underlying social needs which are recognised by Government policy as outlined in Section 3.1 above.

These needs are bounded by the recognition that development should proceed in an environmentally sustainable manner, which includes acceptance of resource limitations as well as giving importance to ensuring a reasonable quality of life to all the inhabitants now and for future generations.

A holistic approach to development is clearly necessary by which all of the Area's resources and natural advantages are utilised to the benefit of the population. Whilst for Bangladesh and for the Southwest Area in particular, water management is self-evidently a central issue, it must be acknowledged that it is far from being the only issue. Great opportunities exist to develop the sectors of agriculture, fisheries, forestry and rural and urban industries as well as to enhance social welfare and economic activities through water supply and sanitation programmes, cyclone and flood protection, improved transportation and energy supplies, housing and education. This Report, whilst primarily directed at the opportunities in the water sector, endeavours to address those other issues which directly or indirectly impact upon the choices for water management options.

In the context above the key components to the development of the Area as a whole are increases in agricultural and aquacultural productivity in a manner which increases and equitably distributes rural wealth; provision of secure rural and urban water supplies; reduction in loss of life; physical and economic damage and opportunity costs caused by cyclones and flooding; promotion of forestry as both a source of local income as well as timber, pulpwood and fuel; maintenance of an adequate transportation network and strengthening of public and private institutional capability to plan implement and manage these activities in a constructive and coordinated manner that takes full account of the public's needs.

In the southern parts of SWR interlinked with increasing agricultural productivity and providing secure potable water supplies is reducing the salinity intrusion from the coast due to reduction in upland flows during the dry season. This will also have direct link to improved health in the areas concerned.

Development choices necessarily have to be set in the context of and be responsive to the changing resource setting within the Area. Strong linkages exist between the problems that are faced in different parts of the Area, such that actions in one place may have either positive or negative impacts in another. Recognition of these linkages is vital to appreciating how best to develop the Area as a whole and in a sustainable manner.

4.2 The Main Problems

The main problems that face the Southwest Area from a water management point of view have been correctly identified within the Terms of Reference. These are augmentation of the dry season flows in the Gorai River, drainage improvement in the Coastal Embankment Project area and flood control on the right bank of the Ganges - Padma right embankment. These have become to be known as the three "burning issues" of the Southwest Area. Whilst of fundamental importance, these are of course not the only issues. A broader perspective of the main problems facing the Area in water management terms is as follows:

(i) Acute shortages of dry season surface water flows in the Southwest Region which severely limit the prospects of irrigation development, which is substantially the key to raising agricultural production

(ii) The high risk that the Gorai mouth will be permanently closed by siltation in the short to medium term future and the severe consequences that this would have on salinity intrusion and channel stability in the coastal areas as well as the loss of opportunities for irrigation development

(iii) The progressive siltation of channels within the coastal polder areas reducing the effectiveness of the drainage and consequently the productivity of the polders themselves

(iv) Widespread flooding in the areas adjacent to the Padma and Lower Meghna areas causing damage to physical assets and crops as well as inhibiting investment in these areas

(v) The limited potential of further groundwater development in the context of meeting the Area's future needs and the risks associated with saline intrusion if exploitation is allowed to continue unchecked in certain areas

(vi) The supply of freshwater to Khulna city given its size and importance and that both surface and groundwater resources are critically placed with respect to saline intrusion

(vii) The currently unsatisfied demand for water given the marginal degree of food sufficiency and the expected growth in demand with population increasing nearly 50% by the year 2020

(viii) General concerns over the management and social impacts of shrimp farming, the importance of capture fisheries particularly to low income groups if flood protection closes fish migration routes.

There are of course many other problems which the Area faces. These include the concerns expressed over the changing river flows affecting the ecological balances within the Sundarbans area, maintenance of adequate waterways for Mongla Port and navigation routes generally, the impact of saline intrusion upon agricultural communities, and the concerns for maintaining adequate base flows in the Lower Meghna to ensure the right bank spill rivers stay clear of saline intrusion. As may be seen however, many of these problems fundamentally relate to the key issues enumerated above. In addition a further major problem is that of cyclones which periodically cause devastation and widespread loss of life. This particular issue is being separately addressed by the ongoing Cyclone Protection Project (FAP-7) which is directed at the strengthening of coastal embankments and provision of shelters as places of refuges during cyclones. Whilst consideration has been given to the linkages between these works and proposals set out in this report, the measures and investments necessary for cyclone protection are not incorporated in detail within the Regional Plans set out herein.

4.3 The Main Development Options

The main water management development options that have been identified to address these key issues are as follows:

- Securing the Gorai mouth as a priority measure and related to this progressive augmentation of the surface water resources of the Southwest Region to meet future demands

- Reducing the salinity intrusion in areas south of Khulna in the dry season by augmentation or other means

- Improvement of drainage within the coastal polders for which a range of alternative measures have been investigated from which a policy focussed on a controlled transition to tidal equilibrium is preferred

- Strengthening and extension of embankments protecting the Area from the main boundary rivers and provision of upgraded and new flood control and drainage facilities where appropriate within the Area

- Development of irrigation within the area through exploitation of both surface and groundwater resources to the extent that may be permitted with or without augmentation

- Measures to support the largely private sector development of groundwater and improved monitoring and assessment of groundwater utilisation and resource assessment, measures to encourage and/or enforce the institution of a buffer zone to control saline intrusion and measures to mitigate against adverse effects of groundwater development on potable supplies

- Strengthening overall of management and monitoring capabilities related to water resource development and usage.

Accompanying these principal measures are a range of ongoing and proposed interventions in sectors directly related to water management. These include : strengthening of the agricultural sector with an emphasis on improved productivity and crop diversification facilitated by better input and credit supply, research, extension and marketing; expansion of fisheries production through similar measures including support for artisanal shrimp farming, growth of culture fish ponds and efforts to support dwindling capture fishing; support for the forestry sector to encourage the growth of homestead groves (social forestry), to manage the Sundarbans as a complete ecosystem from which sustainable exploitation of forest products (as well as fish resources, wildlife and tourism) would be possible and to continue development of coastal plantations as a means of cyclone protection and as a source of timber; and further support and investment in the transportation sectors, particularly the navigation sub-sector and the maintenance of navigable access to Mongla Port.

4.4 Development Choices and Linkages

The Southwest Area is a complex area in water resource management terms. Great care has to be taken to ensure that interventions perform in the way intended and do not adversely affect other parts of the Area. Careful consideration has been given to this point in formulating an overall strategy for development of the two Regions. The consequences of the individual interventions has been discussed in part 2 of this Report and a regional perspective is given below.

4.4.1 Overall Requirements

In response to the perceived needs of the area and Government's general development policy, the water resource development options are focussed primarily on facilitating growth of agricultural production and rural incomes in the context of a socially equitable and environmentally sound approach. Further key issues relate to securing potable water supplies, particularly for rural households and for Khulna city, the latter being judged to being critically vulnerable to saline intrusion. The opportunities for significantly improving water-borne transport are generally restricted to securing existing routes through more stable rivers and discharges and further dredging.

The further development of agriculture requires better management of the water resources whereby water is available for crop growth but not in excessive quantities which cause damage. Thus the key components are flood control, adequate drainage and access to irrigation.

Figures 4.1 and 4.2 show diagrammatically the main issues and the linkages respectively.

4.4.2 Groundwater Development

Since 1985 groundwater development has been substantially in the hands of the private sector and large increases have been observed in the numbers of shallow tubewells for irrigation as a result. Estimates of future development potential of groundwater are known to be conservative, but prudently so. Nevertheless there is clearly a limit which, in relation to the estimates made, has been reached in a number of areas, particularly in the north western part of the Area. In the southern half of the Area aquifer conditions are less favourable and salinity risks are high. In the areas to the east and west of Khulna, conditions are in transition from those favourable for groundwater to the north and less favourable to the south. It may be anticipated that with growing demands from agriculture further exploitation of groundwater in this transition zone will occur. This is not desirable given the risks of drawing the saline interface further north and it is considered necessary that a buffer zone be established to minimise the likelihood of this happening. Monitoring of groundwater in the buffer zone over a number of years would provide data to establish whether it should become a permanent feature. Enforcement of a buffer zone in a de-regulated situation is likely to be difficult, but which would be much less of a problem if alternative surface water resources were made available, especially since at a local level these are likely to be less expensive for the farmers to develop. At present however, other than in certain part of the South Central Region there is virtually no potential for further development of dry season irrigation in the Area.

Nevertheless, opportunities do exist for further groundwater development, primarily in areas to the east of the Gorai and to the north and east of Gopalganj in the South Central Region. These areas are however subject to widespread flooding from the Ganges/Padma, Lower Meghna and Arial Khan systems and flood protection in these areas would greatly enhance the value of tubewell irrigation.

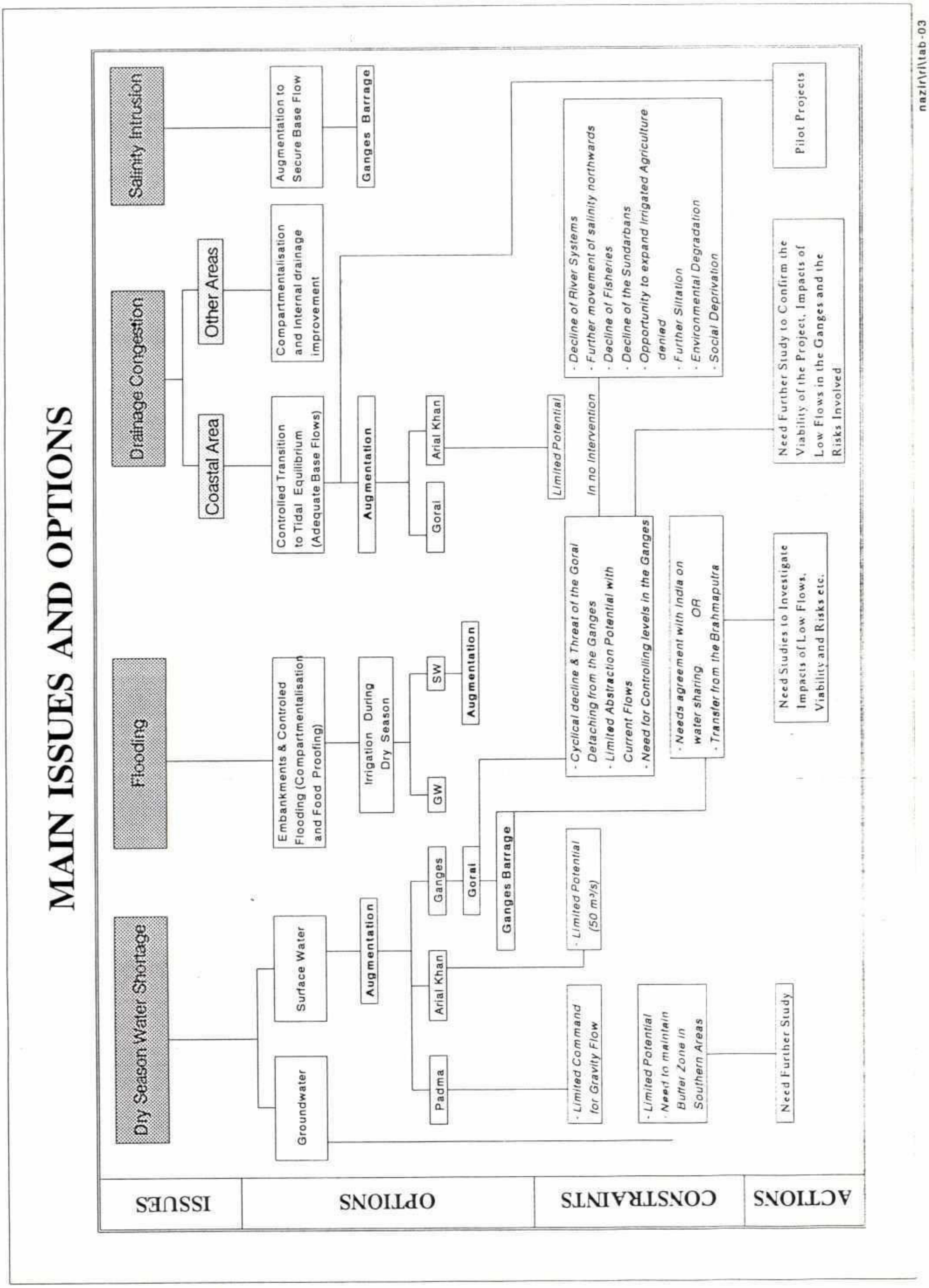
Overall, as has been indicated, groundwater irrigation alone will not meet the long term needs of the area and other parallel developments are required.

4.4.3 Flood Control, Drainage and Irrigation

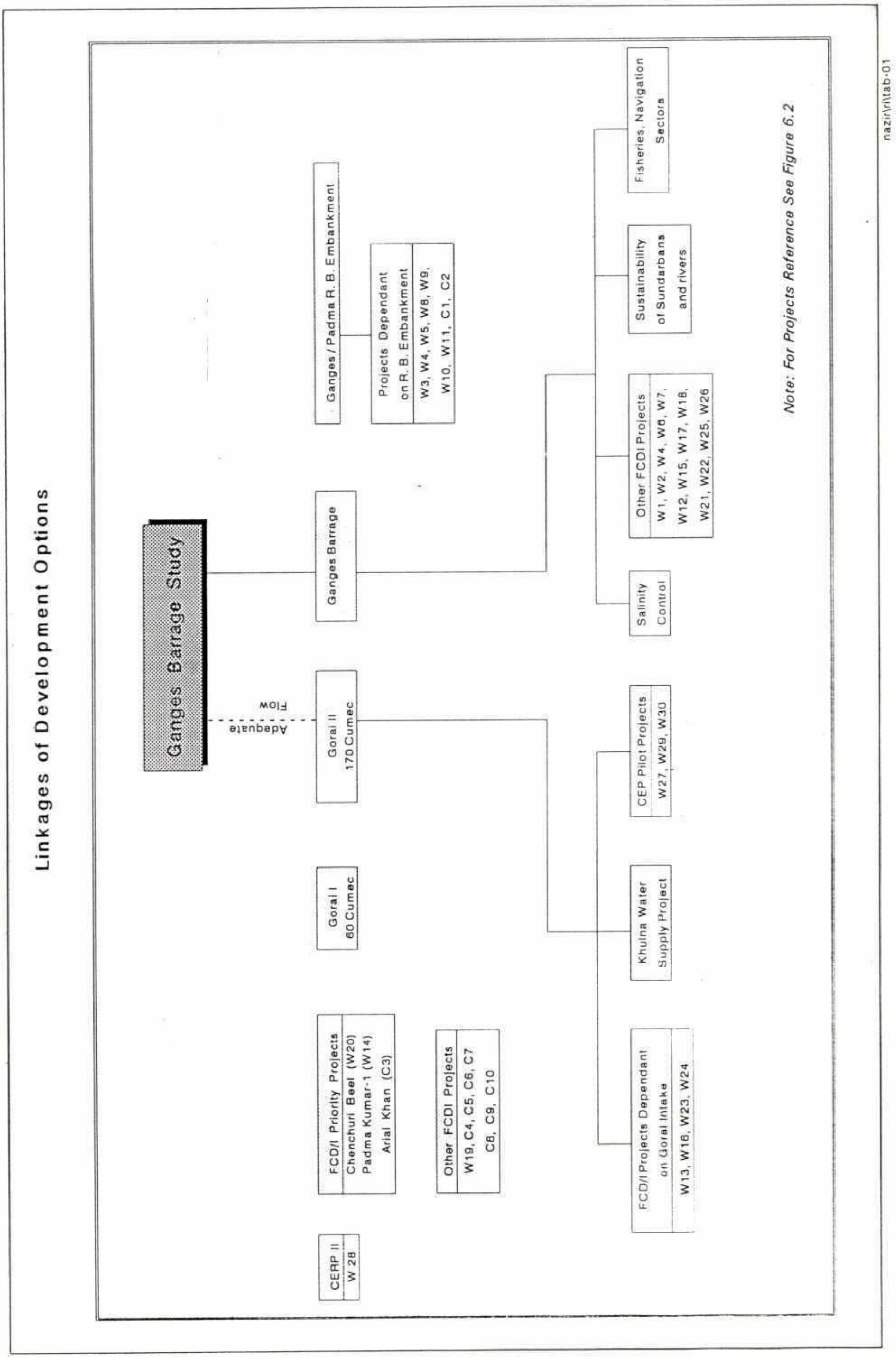
In general, flood control and drainage (FCD) without corresponding irrigation development would result in only a marginal benefit to the area. This benefit in some cases would only offset the consequent loss in capture fisheries in the area. However, the value of FCD without an irrigation component depends on how badly an area is presently inundated and what improvements in internal water management could be achieved through compartmentalisation.

Given that drainage depends on favourable river levels at outfall locations, and they in turn are influenced by the flows and levels in the main inland rivers which in certain river reaches are also subjected to tidal influences, there is a case for reducing high flows brought into the area by the main distributaries of the Ganges and Padma. However, the

Figure 4.1



Main Issues and Options



Linkages of Development Options

consequences of high flow suppression on salinity intrusion and sediment transport need to be looked into.

Irrigation generally is a highly beneficial use of water. The potential for increased irrigated agriculture is evident from the comparatively low agricultural productivity mainly during the rabi/boro season. The groundwater potential for large scale irrigation development is minimal, particularly in the Southwest Region. Surface water irrigation is the only other viable alternative for this region and therefore an adequate supply is of paramount importance.

Marginal differences in potential benefit values do exist between different areas on the basis of present land conditions with respect to inundation and soil types. Given the scarcity of surface water and the high costs of augmenting the supplies, the comparative advantage of allocating water to different areas needs to be recognised.

Also, irrigation would be competing with salinity control and navigation needs for dry season supply, and the relative merits of these should also be examined.

4.4.4 Surface Water Augmentation via the Gorai

The studies undertaken of options for surface water augmentation conclude that the most valuable choice is that which make use of the Gorai. Other routes exist, of which transfers along the Hisni and through the Arial Khan/MB route are clear second choices.

The Gorai River is very important to the Southwest Region. There is a strong probability that if nothing is done to secure it then it will cease to become connected to the Ganges. How soon this would happen is impossible to predict given the cyclical nature of its decline but what is clear is that, if allowed to happen, it would have a major impact on downstream conditions. Since there are effectively no opportunities at present to exploit the minimal dry season flows to irrigation, the principal outcome of the loss of these would be a marginal northward shift of the maximum intrusion of the saline front. This small movement would nevertheless be significant with regard to maximum salinities at Khulna. The greater impact however would be the loss of wet season inflows from the Ganges through the Gorai. This would again affect saline intrusion but would more importantly encourage even greater siltation problems in the coastal area.

Augmentation of the dry season flows in the Gorai presents a major opportunity to expand irrigation within the Gorai/Nabaganga corridor which would have the effect of substantially enabling food security to be achieved through to the year 2020 in the benefitted areas. Expansion of surface irrigation in these areas would greatly assist enforcement of the groundwater buffer zone, particularly in the critical area north of Khulna.

Amongst the choices for securing the Gorai mouth, the favoured one includes provision of an intake structure to control wet season flows. This will benefit downstream reaches in two ways. Firstly it will reduce flooding along the Gorai and increase the drainability of this land. Secondly by controlling the rate of recession of wet season inflows siltation and the volume of maintenance dredging can be reduced. These are both significant benefits. The amount to which wet season inflows are limited is constrained however by the possible impacts that reductions in Gorai discharges would have on regime conditions in the coastal area. Options have been considered which limit the reduction to somewhere between just below bank full (to maximise drainage benefits) and dominant discharge (to minimise downstream regime changes). It will be prudent that design of the structure accommodates a reasonable range of discharges so that any future adverse impacts can be minimised.

Maintaining a controlled discharge in the Gorai will have benefits beyond irrigation. Opportunities exist, if Ganges flows are available, to release additional amounts for the purposes of controlling intrusion of the saline front. In addition year-round discharges will enhance measures proposed for the coastal polders by increasing flows in those rivers which are targeted as the main drains, thus increasing their sustainability. The Gorai will also function better as a navigation route notwithstanding that structures at the mouth and below the Kamarkhali bend at Mohammadpur which will impede progress at those points.

The two main problems with the Gorai Augmentation project as outlined above are the necessary long term commitment to maintenance dredging and the limited discharge that is attainable. Analyses undertaken indicate that a peak dry season abstraction from the Ganges of about 180 m^3/s for irrigation is optimal which combined with the approximately 120 m^3/s taken by the G-K project amounts to a total abstraction of some 300 m^3/s. Given a further commitment to 100 m^3/s minimum flow to meet downstream requirements in the Ganges, this leaves only a very small margin between the total commitment and the minimum flow recorded in the Ganges since Farakka was built in India.

In the period since 1989 corresponding to expiry of the Agreement with India over releases from Farakka, the mean and 80% dependable flows in the Ganges have been reduced to 576 and 517 cumec respectively with an absolute minimum of about 260 cumec. This may be contrasted with mean and 80% dependable flows for the driest month between 1978 and 1988 of 1063 and 663 cumec respectively. Comparison with the figures above, and acknowledging that without a control structure in the Ganges it would be impossible to abstract all of the available flow, underlines the limitations upon future development in the Southwest Region beyond the development of approximately 180,000 ha of surface water irrigation associated with the 180 m^3/s abstraction. Furthermore, development of irrigation to that extent precludes any reliable allocation of base flow in the Gorai to salinity control, particularly as the latter to be significant, needs to exceed 100 m^3/s. It is not considered sensible to set aside water for salinity control unless that flow can be maintained with a high degree of reliability, given the consequences to future developments which would have been based on the assumption of fresh water availability.

4.4.5 Ganges Barrage

Whilst augmentation of the Gorai as described above offers a worthwhile investment and addresses the immediate risks associated with closure of the Gorai mouth, at a regional level the impact is limited to a relatively small proportion of the Southwest Region. To maximise opportunities for long term development it is necessary to both control water levels in the Ganges to maximise abstraction capability and to provide storage within the water resource system. Together with groundwater development, FCD and surface irrigation schemes, the Ganges Barrage facilitates food security throughout the Southwest and South Central Regions with the exception of areas to the south of Khulna and in the lower portions of the South Central Region where salinity limits the potential for irrigated agriculture.

The Ganges Barrage through control of the Ganges flows enables transfers to be made into the Hisni river, which given the priority afforded to the Gorai, could not otherwise be implemented. The Hisni transfer has a major impact on the dry northwest of the Area to the west of the G-K project. The Barrage will also have other advantages. It will reduce the pumping head required at the G-K intake thereby securing the supply during the critical months in the dry season. Depending upon when the Ganges Barrage is implemented, it could also reduce capital dredging works at the Gorai also. Thus, in investment and maintenance cost terms, construction of the Barrage should proceed with the minimum of delay providing its construction is consistent with parallel investment in downstream irrigation facilities.

The viability of the Ganges Barrage is nevertheless dependent on the adequacy of dry season releases downstream of Farakka. Establishment of a new agreement over the sharing of Ganges flows is therefore essential. Alternatively, augmentation of the Ganges flows by other means (eg. transfer from Brahmaputra) needs consideration.

4.4.6 Arial Khan - Madaripur Beel Route Transfer

The Arial Khan - MB Route was identified at an early stage as an alternative means of augmenting the surface water resources of the Southwest Region. Its particular attractions are that its main source of water is drawn from the Jamuna/Padma system (which, with Farakka, is more reliable than the Ganges), its importance as a navigation route (which would be reinforced if flows were increased) and its comparative effectiveness at achieving salinity control at Khulna. Its main disadvantages are that the degree of augmentation is limited to about 50-100 m^3/s by the head available, its incompatibility with a Gorai augmentation (which reduces the head and thus the Arial Khan - MB route discharge further) and the susceptibility for the Arial Khan intakes to be silted up. There are three possible intakes and their history indicates that at least one is usually working. However it would be extremely expensive to secure all three to account for this.

The Arial Khan - MB route transfer is thus not suited as a prime means of salinity control and it is limited in ability to expand irrigation within the Area. It is possible to consider it as a supplementary source to the Gorai but even in this instance the benefits are marginal. An alternative use for this transfer is to augment surface flows into the Bagerhat area to help sustain the main drainage channel for this area, but even with substantial investment the impact of these extra flows may still be small.

4.4.7 Ganges - Padma Right Embankment

The Ganges - Padma Right Embankment, together with works on the Arial Khan, would provide flood protection to some 300,000 ha to the east of the Gorai in both the Southwest and South Central Regions. These are areas where further groundwater development potential is at its greatest and clearly such works would enhance the future value of tubewell irrigation in this area.

Embanking of the Padma was originally conceived in a plan drawn up in the 1960's, but its construction has been implemented in a series of discontinuous reaches and at present continuous to allow Padma spills into the Area. Providing future works continue to permit these spills to enter the river systems (as is the intention) then there should be no significant effect on the regional channel morphology.

The sizing of the Ganges - Padma RB is dependent on conditions upstream. FAP25 have indicated that with full embanking of the main river systems, there would be rises of 0.23m to 0.5m for a 1:100 year flood. The construction of a barrage on the Ganges would not significantly effect these figures. Embanking of the Jamuna in particular would increase discharges at peak events, and increase velocities by 5-10%. Whilst this is significant, its impact on embankment design is small in so far as the major factor is the immaturity of the river and its likely range of lateral movement.

The Flood Policy Study in 1989 indicated that works on the Padma RB should be postponed to 2010 to enable account to be taken of upstream works. It is reasoned in this Report that this is not the major factor in the design and that, given that the embankment is substantially in place already, the further modest investment to complete the works to a full 1:100 year standard should proceed within the short term. Delaying the works to 2010 will not significantly improve the design or risk as in such a short period of time the Padma will have not matured to a substantially more stable alignment.

4.4.8 Lower Meghna Right Bank

The right bank of the Lower Meghna is dissected by a number of spill rivers. A number of areas have individually some flood protection embankments. In contrast to the Ganges and to a lesser extent the Padma, the Lower Meghna is still a young river exhibiting episodic erosion and accretion rates which can be braised by extreme floods. Chars within the river move with a periodicity of 10 - 20 years and overall the river is showing a net eastwards movement. Whilst this movement favours protection of the right bank it is nevertheless considered that the river should be allowed a further 50 - 100 years or so to stabilise itself. It is noted however that works on the left bank at Chandpur to reinforce the bank are in conflict with these trends and that the possibility exists that these might force a crossing to develop and shift the meander by, say, half a wavelength (approximately 15 - 30 km). Thus while the right bank will come under threat, downstream the flow could be directed further away from the right bank allowing accretion to take place and threatening the existence of the spill rivers. Loss of these spill rivers would have a major impact upon the freshwater supply of the South Central Region.

Thus for the Lower Meghna Right Bank, no embankment is recommended. Individual poldering could be possible but considerable forethought is necessary. Careful monitoring is therefore essential.

4.4.9 Coastal Polder Rehabilitation

Three basic options have been considered to address the problems of drainage congestion in the coastal polder areas. The first of these is the "do-nothing" situation which would permit the delta to progress itself to a new equilibrium based on interventions within the polder area in the near and medium term past and the effects of agreed actions inland, such as on the Gorai. This would not preclude investment within polders to improve water management and promote appropriate land use and would allow land building to continue in un-poldered areas.

The third option would require massive investment programmes over a period of 30 - 50 years to create a non-tidal coastal zone by construction of tidal barriers and major water control measures. Such a solution would have enormous impact on the coastal area, much of which would be positive but accompanied by substantially unpredictable changes to the rivers morphology and to the environment.

The second option, which is favoured, is an intermediate solution in which a controlled transition to tidal equilibrium is advocated. Areas where deterioration of drainage either has or is expected to occur would be targeted first and the programme of works could be expected to continue in a progression thereafter towards eventual equilibrium. In this manner, in contrast to the third option, early returns on investment could be achieved accompanied by positive social impacts. The three main areas for early attention are near Satkhira, Khulna and Bagerhat. The solutions proposed focus on identifying outfall channels which can be expected with appropriate interventions to remain stable with reasonable certainity in the future. These interventions which include some dredging and for Khulna creation of macro-polders, are favoured over the alternative of setting aside land as tidal surge basins to enhance cubuture.

In the longer term the consequences of sea level rises due to global warming and of continued settlement of land have to be taken account of. The order of magnitude of the combined effect is an increase in water levels of about 40 cm over the next 50 years. In some areas, current relative levels of land and water are already at a stage where dredging combined with increases in ventage may not be an effective solution and pumped drainage may be the only recourse if drainability is to be secured. It has to be anticipated that in the longer term therefore that pumped drainage may become an increasingly necessary measure.

4.5 Summary

The development options described above have linkages and the key linkage of all is the augmentation of dry season flows through the Gorai. By controlling flows in the Gorai in the wet season by means of a control structure at the mouth and completing the embankments along the right bank of Ganges/Padma, and the Arial Khan the drainage of the flood prone areas of the north-east of the SWA, north of Gopalganj could be controlled. By managing the floods by compartmentalisation, areas which were hitherto cannot be cultivated could be brought under agriculture. Together with irrigation available during the dry season by augmentation of the Gorai, additional areas would benefit during the dry season. The development measures taken and the projects that emerge from these are described later in Section 6.

5 PLANNING FRAMEWORK

5.1 General Approach

5.1.1 Work Plan

The Terms of Reference call for a planning framework that will allow the Government to identify and evaluate in a systematic way, justifiable development options and to formulate first priority projects.

The regional water resources management plan is being prepared during the period of the GOB's Fourth Five Year Plan (FFYP). This and the National Water Plan Phase II, which was published in 1991, provided a basis and starting point to the planning process.

The broad approach to the regional planning was discussed in earlier Interim Reports. The strategy adopted may be briefly summarised as:

- Appreciation of the Area by site visits, field surveys and investigations
- Hydraulic and morphological studies supported by mathematical modelling techniques
- Engineering and sectoral studies
- Review of Government policies and quantitative assessment of the Area's needs and constraints
- Identification of possible development options
- Multi-criteria analysis to evaluate the advantages and disadvantages of alternative development strategies
- Impact studies of selected development options
- Finalisation of the Regional Plan.

5.1.2 Needs Assessment

The regional and pre-feasibility level assessment of community's needs was approached within the limited boundaries of the possible water resources management development proposals that were the study's objective.

The existing SWA situation has been described in Chapter 2. In 1983/84 45% of households had access to less than 0.5 ha and over half of this group was landless. The area is not self-sufficient in food production consequently poverty alleviation, increasing the Area's food production capacity in so far as is possible through improved water resources management and the maintenance of local transport routes, including country boat access, were taken as the major needs of the population. Within this broad spectrum, employment, health, energy and income distribution were identified as needs that are to be addressed.

At this early stage of regional planning and project selection the detailed assessment of needs has not been possible over the entire study area. However the proposals for further feasibility studies include recommendations for assessing these needs which include an examination of the institutional requirements to ensure as full participation as possible by all groups in the community including the least influential and most vulnerable.

The approach used to assess the needs of the people are by visits and interviews with communities and target groups, formal meetings and seminars.

5.1.3 Field Surveys and Investigations

As part of the planning process to understand and identify the needs of the Area, field surveys and investigations were carried out throughout the Area. Site visits were carried out to most of the Project area by various team members and discussions were held with villagers, farmers, fishermen, women, Government officials, NGOs and others. The following field surveys were carried out during the course of the Project to collect data:

- River surveys including topographic and cross-sectional surveys
- Salinity observations and sampling
- Limited Agricultural survey
- Socio-economic surveys (RRA type)

5.1.4 People's Participation and Seminars

People's participation in development programmes is a key element in the planning process. In addition to the many informal discussions, as mentioned above, during the planning stage to help identify the key issues and problems that need to be addressed, a formal seminar was arranged within the Project Area to discuss the Project's objectives, development options, issues etc. The first such public meeting was held in Jessore in January 1993 which was attended by Members of Parliament (which included two ministers) from all political parties, local government officials, officials from government departments. The FAP-4 team briefly presented the study's findings so far, to the meeting and heard the views of the public through their representatives. A brief description of the interaction is given in Appendix 2 of this Report.

5.1.5 Data Bases and Process Models

To fulfill the study requirements a wide range of data bases and process models have been established. The data bases provide catalogues, inter alia of hydrological data, land resources, topography, fisheries, forestry, population, transport etc. A cornerstone to the data system is the Geographical Information System (GIS), which holds spatially important data such as river alignments (past and current), administrative and planning boundaries, transport routes, soils, population and other pertinent data.

The main process models that have been used are the hydrodynamic and runoff models, the sediment transport models and a regional planning model. These are each described in the relevant Annexes to this Report. In addition to these a wide range of models ranging from simple to moderately complex have been used to investigate such issues as impacts on flood phases, population growth, water requirements, engineering cost function, agricultural inputs and outputs and food sufficiency.

5.2 Methodology

5.2.1 Water Resource Assessment

Assessment of water resources for regional planning requires an analysis of basic hydrological parameters such as rainfall and climate to estimate the runoff from the region which would be available for use. Other objectives include an estimation of storm frequencies and flood levels. Basic rainfall data has been collected from BWDB and BMD by Northwest Hydraulics Consultants and computerised. This data was kindly supplied by them and was checked for trends and inconsistencies. Other climatic parameters including evaporation was collected from BMD and BARC. Ground water levels were also collected from BWDB. This data was used as input to a rainfall runoff model (NAM) which is a lumped parameter conceptual type model to estimate the runoff and recharge in various catchments. Drainage coefficients were also estimated.

Water level data was collected from BWDB and FAP-25 and was analysed to give estimates of the flood levels at various return periods. Whilst this data is of limited use for future development scenarios involving changes to the current network of channels, it provides a basis for comparison. Discharge data was also collected from BWDB and FAP-25. It was checked for trends and comparisons were made where appropriate to highlight the reduction in flows as in the Gorai.

Long term simulation for various development scenarios were also carried out and results of water levels and discharges at critical locations in the region analysed to give flood levels and available flow in the region in the future.

5.2.2 Agriculture Assessment

To facilitate regional planning, databases of soil and agriculture have been established. Soil information has been obtained from the SODAP database held by BARC and linked to the soil association maps held in the project GIS. This has allowed the calculation of areas of different soil type and the production of thematic maps.

Agricultural data has been obtained largely from MPO. This has been done because MPO is the only organisation to estimate crop areas by land type and mode of irrigation. This data has been transferred from MPO planning areas to project planning units and forms the basis of the calculation for the assessment of the present situation.

The assessment of changes in crop production arising as a result of FCD/I follows FPCO Guidelines. This assumes that an increase in the area of a land type is followed by an expansion of the cropping pattern already associated with that land type rather than a new pattern. Further assumptions are that inputs also follow those that are being currently used on that land type and that the yields obtained are those already achieved by the farmer on the land type in question.

In order that comparisons can be made that reflect only the benefits to be derived from FCD/I, no non-engineering interventions are assumed. This means that no specific interventions such as extension or input supply are assumed above those that already exist in the area.

At the pre-feasibility study level, farmer interviews have been conducted to collect information on crop production and cropping patterns and to assess crop losses.

5.2.3 River Systems and Morphology

A significant amount of data exists for use in examining and establishing the morphological history of the Boundary, Regional and Inland rivers that control the evolution of the SWA and the supply of water to it. However, most of the data is recent and comes in the form of satellite imagery translated onto GIS. The older maps, essential in order to give the medium and long term historical perspective, have proved surprisingly accurate.

Publications such as the Statistical Account of Bengal (1877) and the History of the Rivers in the Gangetic Delta (1780-1918), have provided useful sources of information on the history of the developing river systems and morphology.

The first available map, in the form of a chart, was that by Rennell in 1767 which, with other regional maps in the 18th and 19th centuries and the 4 inch to 1 mile maps of the 20th century, have been used to provide the medium and long term histories. Their accuracy can be checked as it has been possible to identify the now defunct courses in the old maps, on the recent satellite imagery and aerial photos. The satellite data also allow very detailed analyses of major and minor changes such as chars, chute channels, anabranches etc. In particular, it has been possible to use them to identify local trends. Where possible, specific areas have been examined in detail during field visits and by hydrographic surveys, the latter in both April and June last year. These recent surveys have also been compared with earlier surveys by BIWTA and BWDB.

Geological survey maps, papers and field data have been used to examine the long term trends, which are important in an area where there is significant crustal movement. Analyses of future trends have been made both by extrapolation from the existing long, medium and short term ones and from the interpretations of flows and flow changes provided by mathematical models.

5.2.4 Coastal Processes

The methods used to assimilate and generate information are summarised in Section 9.4.1 and described in detail in Volume 4. Background information has been available from both historic studies and those that are ongoing at the present time. Survey data has come from similar sources, but in addition the BWDB Executive Engineers' reports have provided much useful and relevant information to supplement further data collected in the field by the study team.

The regime analysis has provided the corner stone on which to build a picture of potential future river conditions in response to different intervention strategies. In the course of this study much effort has been put into corroborating present day evaluation of river condition, siltation trends and hence polder performance with hard evidence in the form of field visits, public meetings, analysis of satellite and aerial photography and mathematical modelling of sediment transport. The regime analysis similarly relies on the hydrodynamic mathematical model to provide present day and predicted peak discharges.

Having determined polder performance through the above methods, a separate framework for polder drainability has also been established based on relating the area/elevation statistics and precipitation to long term time series of internal and external water levels, thus allowing different scenarios to be assessed.

The combination of these different methods has allowed prediction of trends to be made with some confidence as well as of the interdependences that exist in this complex tidal environment.

5.2.5 Water Requirements

Estimates have been prepared for potable and industrial water supply requirements based on present and future population forecasts in the rural and urban sectors. The estimates allow for increases in population, rises in expectations, changes in technologies and system losses.

Irrigation water requirements have been calculated based on MPO consumptive use factors and updated estimates of rainfall and evaporation for the full range of crops identified within the area. Account is taken of presaturation and the impacts of inundation and of differing soil permeability. Field requirements were calculated for the reference cropping pattern of each flood phase in each Planning Unit on light or heavy soils based on 80% dependable or mean rainfall. Irrigation efficiencies are based on FAO Paper on Guidelines for Predicting Crop Water Requirements and allowances have been made for return flows to the river systems and from surface irrigation to groundwater. The results have been compared to earlier estimates prepared by MPO and have been found to be reasonably consistent and the manner in which they have been calculated enables rapid evaluation of the impact of changing flood phases on future water requirements, which otherwise would not have been possible.

5.2.6 Social Issues

Resources given to the study for the investigation of social issues were limited. No sociologist was approved until June 1992. The social studies therefore started in late July.

Study specific investigations were confined to three surveys at a reconnaissance level. The first was directed to existing FCD/I and non FCD/I areas in the north east of SWA. Its aim was to provide profiles of different social groups, their resources and two sensitive issues associated with FAP: public/community participation in FCD/I schemes and basic gender issues and the opportunities for work created by FAP.

The two other surveys were directed to the two areas selected for pre-feasibility studies during the final phase of the SWA study. These were the Chenchuri Beel Rehabilitation Project (Pus SW5 and SW10) and the Gorai Augmentation Project (Pus SW4, 5, 6, 7 and 10). These studies were to provide a basic level of socio-economic data for the two proposed project areas.

In addition, the SWA social studies were broadened to include a component covering institutions. Apart from seeking an appreciation of the Area's institutional structure the study particularly addressed aspects relevant to public participation in the context of projects such as FAP related to water management that embrace entire communities rather than being targeted solely to individual groups. Even so the studies have emphasised the need to strengthen the representation of less advantaged groups such as landless and fishing households in the participation process.

As noted earlier the social and institutional SWA studies have been at a preliminary and necessarily limited level. Detailed, project specific studies will be essential components of the future feasibility studies.

5.2.7 Economics and Financial Evaluation

The SWA economic and financial evaluations have been confined to flood control and drainage (FCD) and irrigation (I) development possibilities with no Non-FCD/I interventions. The FPCO requires that FAP studies follow certain standard analysis methods to ensure that proposals prepared for the different regions are directly comparable. The economic and related analyses follow the FAP Guidelines for Project Assessment dated May, 1992. All costs and benefits are at 1991 prices. Two levels of analysis were carried out : regional and project specific.

The regional level analyses were directed to the ranking of technically feasible development proposals in terms of their benefit: cost ratios (B/C) and net present values (NPV) of net benefits. The analyses were undertaken at economic prices (or values) and two other major evaluation parameters; labour and nutrition.

Prefeasibility studies, in addition, included estimates of the selected project's economic internal rates of return (EIRR) and a range of sensitivity analyses were also undertaken. Seven projects resulting from the regional analyses were presented at a pre-feasibility level in the Second Interim Report. Each project was subjected to separate, rather more detailed analyses as far as possible using project specific as well as Planning Unit data.

As noted earlier, the SWA studies have been limited to the costs and benefits directly related to three water management aspects; regional allocation, FCD, and irrigation.

If full advantage of FCD/I projects is to be taken, there will be other costs associated with increasing the effectiveness of institutional support, credit, the provision of production inputs etc. However, these would be generally applicable to development in SWA even if no water resource projects were implemented and have not been included at this pre-feasibility stage.

5.2.8 Environmental Assessment

The methodology adopted for environmental assessment has been directed at identification of the main environmental issues, isolation of any major negative impacts of proposed actions and consideration of the potential for mitigating against these. Attention has also been given in the light of this assessment, to the key concerns for individual projects or types of interventions with recommendations made for future studies and their data requirements.

A major part of the data collected in many of the fields has been secondary data from previous and related studies. This has been supplemented by the knowledge of local specialists, and by modelling aspects of the data to predict future conditions. Data has been collated from the many different components of the project, from which environmental data has been isolated and analysed. Analysis has been subjective, as there is considerable variance and large gaps in the environmental database.

To provide confirmation that information taken from secondary sources is both relevant and up-to-date, some field observations have been made by the environmental specialists and anecdotal data gained from discussions with local groups in the affected project areas, as well as Government officials, other FAP and project workers, and interested parties.

Important environmental components (IECs) that could be examined against project options were defined subjectively; and evaluation of project options took into account the importance of each component; its spatial magnitude; the permanence of the impact; reversibility and whether there were cumulative effects.

Coupled with this was a detailed consideration of the possible linkage and consequences between plan elements. This allowed a full understanding of the changing environment of the Study Area, and to suggest mitigation measures where these could be effected. More importantly, gaps in the data were identified and future studies recommended, either as separate components or as part of the Environmental Impact Assessments (EIAs) recommended at feasibility study stage.

5.2.9 Development Criteria

FPCO's Guidelines for Project Assessment (GPA) - May 1992 provide an overall framework for evaluation of alternative development strategies and individual projects and the approaches given in the GPA have been generally adopted. A base of 1991 pricing has been used throughout this study.

In general terms the criteria adopted relate to the perceived development objectives which require assessment and formulation of the plan taking account of a wide range of factors. These include economic, financial, social and environmental assessment as well as establishment of technical viability. The objectives and the relevant factors under consideration have been evolved during the course of the study, the nature of which has been discussed in earlier reports and which, in finality, is set out later in this section.

5.2.10 Planning Horizons

The Terms of Reference do not specify required planning horizons and the GPA only alludes to a period of 30 years, being the period which should be adopted for discounting purposes. For this study four horizons have been considered, being:

Short Term	:	Investments and actions required up to the end of the century (2000)
Medium Term	:	- ditto - between approximately 2000 and 2010
Long Term	:	- ditto - between approximately 2010 and 2020
Very Long Term	:	Considerations of events over the next 50 to 100 years

The specification of precise years above, is intended primarily as a guideline which enables planners to visualise the progression of events more clearly and as a basis to forecasting demands during the various terms. It is not intended that these dates are absolute criteria in themselves, which would imply, inter alia, pre-agreement to all of the investment proposals as set out in this report. It should also be noted that the confidence of demand forecasting as well as the certaintity of events becomes less between short and long term and it is recommended that, in any event the planning in reviewed at approximately 10 yearly intervals as successive major investment decisions arise.

5.2.11 Resource Allocation and Optimisation Model

To assist with the evaluation of alternative strategies, and in doing so to facilitate understandings of the land and water resource limitations, a Resource Allocation and Optimisation Model (RAOM) has been built. Details are provided in Volume 5 of this Report.

The RAOM is a mixed integer linear programming model which investigates feasible allocations of both land and water resources and seeks optimal solutions of these to best satisfy a set of declared objectives. The model incorporates inflows and outflows to the river systems, the costs and impacts of the principal interventions and constraints reflecting the limitations imposed upon development opportunities. Impacts are measured in terms of economic incremental benefits (NPV), food, protein and fuel sufficiency, labour requirements etc. The principal interventions considered are surface and groundwater irrigation, new FCD and rehabilitation of existing FCD schemes and augmentation of surface water resources, including Gorai intake works, a Ganges Barrage and sub-regional basin transfers.

The RAOM has been used primarily to assess the best choices of these interventions at different points in the future in each Planning Unit and thus to identify not only appropriate strategies within each unit but also the sequence of overall development which may be expected to give the most advantageous cash flow. The model also allows specific interventions to be tested and for comparisons to be made of these against optimal ones.

5.2.12 Multi-Goal Programming

The facilities provided by the RAOM enable rapid examination of the impact of alternative strategies and objectives. As part of the studies undertaken, investigations have been made of how different objectives or goals would affect the solutions and by comparison of these results, what are the economic opportunity costs that may be attributed to each in relation to the most economic. Of particular interest are the questions of food security and allocation of water for salinity control purposes, but others have been tested also (see Section 5.3).

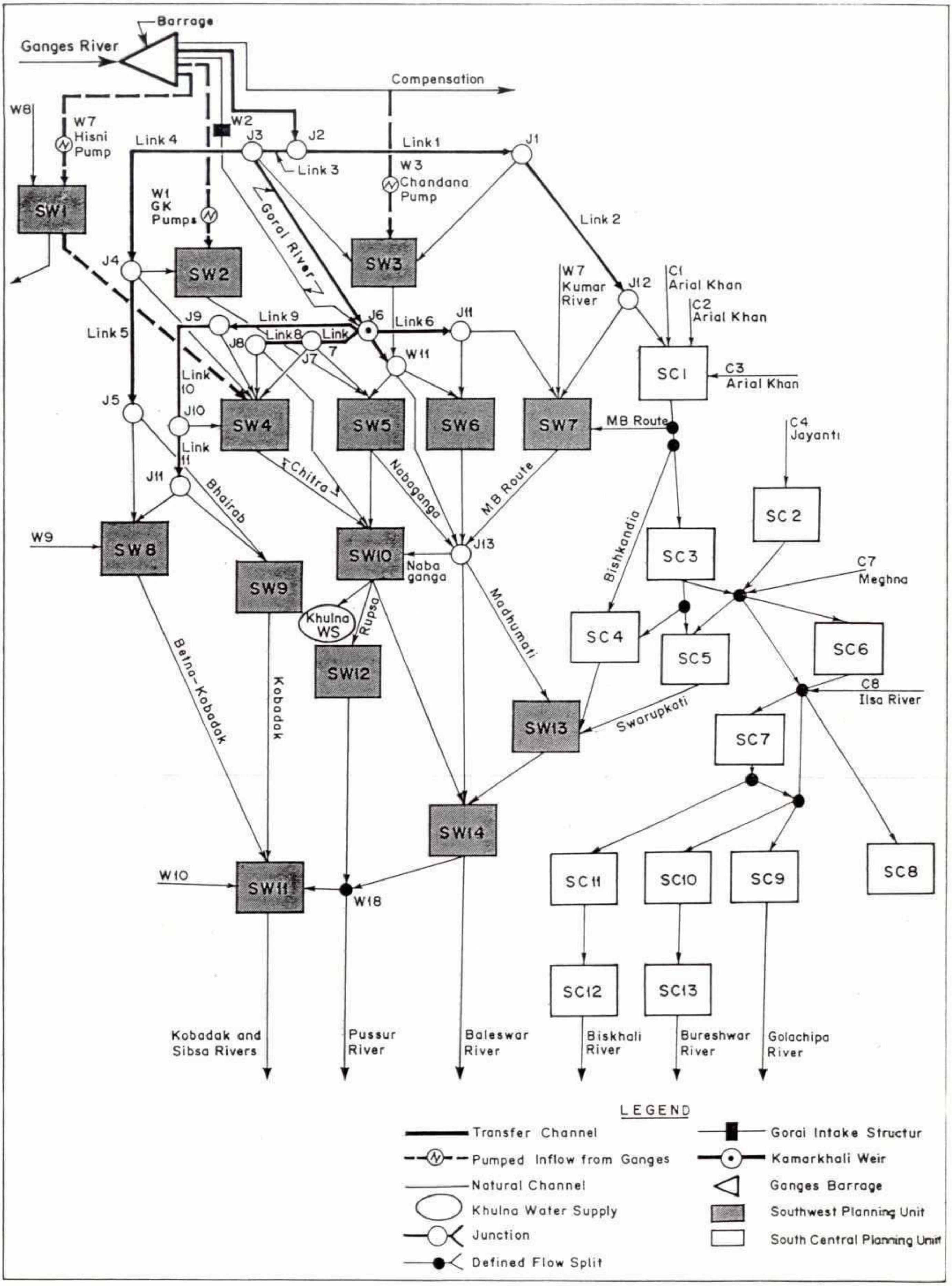
5.2.13 Plan Formulation

In the following Section 5.3 on Strategic Studies a discussion is given of the analyses undertaken to select the interventions proposed within the Regional Development Plan and the implementation sequence which appears most beneficial. These analyses have been made possible however only by the extensive understandings of the resources available, the processes active within the two Regions, the choices of interventions and their relative impacts.

The methodology for plan formulation thus has been broadly as follows:

- definition of land, water and human resource availability
- assessment of land use by land type in terms of cropping patterns, labour and water requirements, and productivity in terms of net value and food, fuel, protein and fodder generation
- assessment of future population growth, needs and demands
- appreciation of how the river and coastal systems are currently behaving, the likely future trends and how these may impact on land quality
- identification of possible interventions, assessment of their positive and negative impacts as well as their likely costs
- from the above, refinement of development objectives and physical or strategic constraints
- preliminary assessment of possible strategies (see Second Interim Report, November 1992) and therefrom identification of principal development options and further information needed
- refinement of development options through more detailed assessment of costs and impacts
- detailed assessment of strategies and selection of preferred strategy
- translation of the preferred strategy into a development programme with quantified components and evaluated impacts.

Figure 5.1



Schematic Layout of RAOM

As indicated earlier, consultations have been held extensively throughout the planning process with various interest groups within the Area, with relevant organisations and, by no means least, amongst the various sectoral specialists within the study team.

5.3 Strategic Studies

5.3.1 Introduction

The strategic studies have been undertaken primarily with the aid of the Resource Allocation and Optimisation Model (RAOM). The studies have been progressed hand-in-hand with development and refinement of the model, with parts of the model being expanded as, with greater appreciation of the key issues, the need to increase the accuracy or sophistication of certain representations has been perceived. A schematic representation of the RAOM is given in Figure 5.1 and the location of Planning Units in Figure 5.2.

It was originally intended that RAOM would embrace all development options throughout the area to enable a complete overview of the strategy. It has transpired that it has been more expeditious to examine the coastal zone strategy outside of the model due to the different nature of the issues to be analysed.

Thus, whilst mindful of the linkages that do exist, the analyses undertaken using RAOM are directed to the question of development in the areas principally to the north of the coastal zone. The following text therefore refers essentially to the issues in the upper part of the SWA. Discussion of strategies for the coastal zone are given separately in Section 9.4.

Following preliminary runs to validate the RAOM model, the analyses have been ultimately progressed through the following general scenarios:

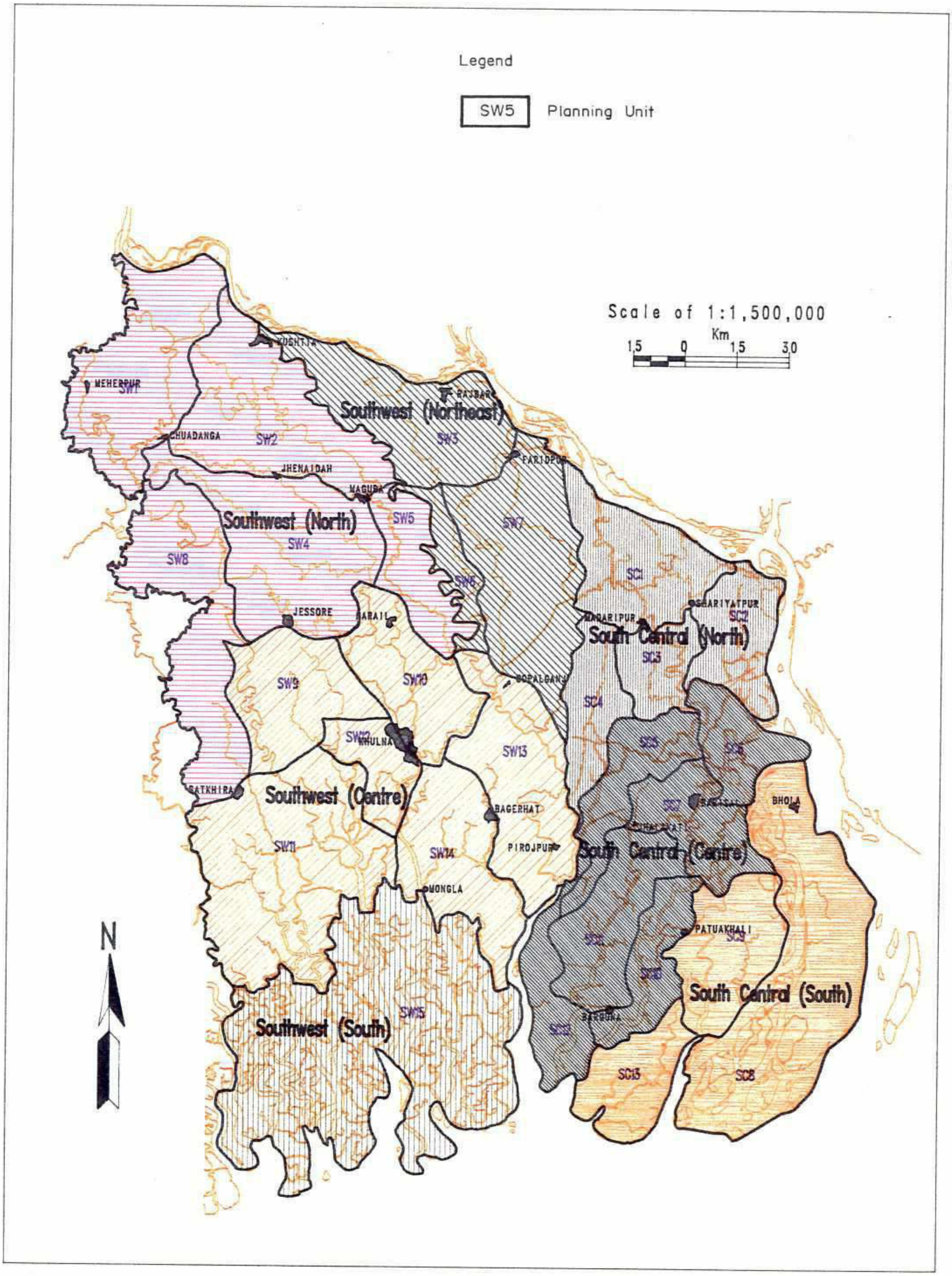
(i) Reference Situation:
Definition of a reference situation in which no interventions are made other than the progressive development of groundwater irrigation which achieves full resource utilisation by the year 2005; implicit within the reference situation is that groundwater development is essentially a private sector investment which may be presumed to continue to expand irrespective of public sector investments in FCD, surface irrigation and surface water augmentation.

(ii) Development without surface water augmentation:
A similar series of investigations in which it is assumed that public sector investment in FCD and surface water irrigation will progress at an approximately even rate through to the year 2020 alongside groundwater development, the ultimate extent of the works being constrained by physical resources and a minimum benefit/cost ratio of unity (at 12% discount rate) but not by any overall investment limit.

(iii) Development with the Gorai Augmentation Project:
As (ii) above but with the preferred arrangements for the Gorai intake and Kamarkhali weir being in place by the year 2000 and transfer channels completed by 2005, development continuing thereafter to the year 2020.

(iv) Development with a Ganges Barrage:
As (iii) above with Barrage completed by 2005, the main transfer canals by 2010 and a Hisni transfer by 2020.

Figure 5.2



Location of Planning Units

(v) Alternative Long-Term Development Options:
Analyses of the impacts of alternative strategies, such as allocation of flows for the purposes of salinity control, augmentation of South Central Region surface water resources, impacts of varying Ganges flows and alternative objectives for development aside from economic growth.

5.3.2 The Reference Situation

The Reference Situation is taken as one in which, whilst population continues to increase together with food demands, the only development of water resources is groundwater. It is assumed that by the year 2005 all currently available resources would have been developed.

The results indicate that there is potential to develop about 138,000 ha in the Southwest Region and about 156,000 ha in the South Central Region. The main areas of best development potential are in Planning Units SW3, SW5, SW7, SC1, SC2, SC3 and SC4 with limited potential in adjacent Units. The total economic capital cost of this development is approximately Taka 2.9 billion and the NPV (benefits less capital and recurrent costs) is about Taka 19.1 billion, giving an overall benefit cost ratio of about 3.5.

These figures emphasise the profitability of groundwater development and substantiate the assumption that it will continue to occur, providing the necessary credit and technical capability are available.

The main shortcoming of development in the reference situation is that there is relatively little impact at a regional level on the supply of food with shortages in 1991 of 33% and 34% in the Southwest and South Central Regions rising to 50% and 46% respectively.

5.3.3 Development without Surface Water Augmentation

In this series of analyses it was assumed that rehabilitation and construction of new FCD schemes together with surface water irrigation could develop alongside groundwater. It was assumed that development in the South Central of FCDI/I would be phased over 30 years to 2020 whereas, given the more limited opportunities, development in the Southwest Region would be substantially completed by 2005.

In the Southwest Region it was concluded that development of about 100,000 ha of new FCD schemes was economically viable, together with rehabilitation of around 80,000 of FCD and development of surface water irrigation (LLP) of about 16,000 ha. The figures for irrigation, as throughout the strategic analyses, are based on mean runoff within the two Regions as it is considered this is a more representative assessment of how LLP irrigation would tend to develop than the alternative of using 80% dependable values. (A test was made of the sensitivity to this assumption of irrigable area which revealed about a 17% increase in augmentation flow requirements).

The conjunctive use of groundwater and surface water for irrigation is clearly optimal in terms of resource allocation but implementation of such schemes, particularly in institutional aspects are extremely difficult. The studies undertaken show that there is only limited potential for groundwater development in the north and northeast areas. This potential can best be realised in most areas by deep tubewell technology. Such measures jeopardise the security of rural potable supplies reliant on suction lift. Within this limitation in the analyses undertaken limited conjunctive use of groundwater and surface water for irrigation have been taken into account.

Development of new FCD in the Southwest was found to be worthwhile mainly in Planning Units SW3 and SW7 where value could be added to groundwater development, with rehabilitation shown viable for similar reasons in SW3, SW5, SW7, SW10 and SW13. The very limited opportunities for expansion of surface irrigation are best focussed on SW10 (using what little Gorai flows are available combined with MB route outflows) and SW13 which benefits from flows from the Swarupkati system.

A similar pattern emerges for the South Central Region with new and rehabilitated FCD found worthwhile mainly in the north-east corner in Planning Units SC1 - SC6 with the exception of SC2 for which little other than groundwater is assessed as viable.

The estimated economic capital costs of the total development (including groundwater) are Taka 1.9 billion and Taka 5.9 billion respectively in the Southwest and South Central Regions with an NPV (benefits less costs) of about Taka 35 billion overall. The benefits/cost ratio overall is estimated to be about 3.5.

Whilst in both Regions these again represent attractive options, in the Southwest Region the development leads only to a marginal improvement in food production, due mainly to the small increase in irrigated area. In the South Central Region, a significant improvement is attained with shortages in 2020 reduced from 49% in the reference situation to 30% with these interventions.

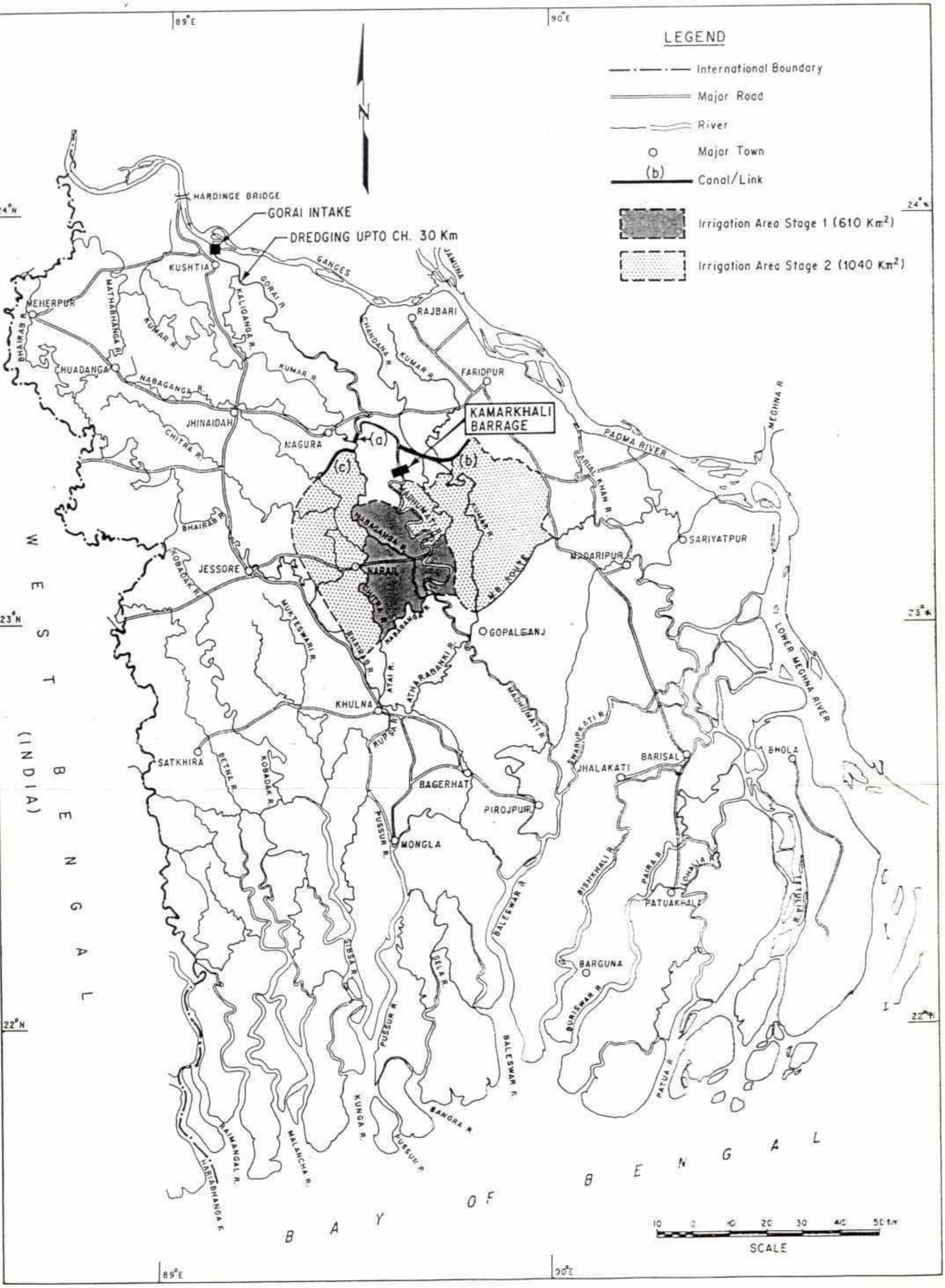
5.3.4 Development with Augmentation of the Gorai

The principal features of the augmentation works and possible transfer canals are illustrated in Figure 5.3. The main options open are to build an intake structure with associated capital and maintenance dredging, to build a control structure downstream of the Kamarkhali bend, to transfer water east (Link 6) to serve Planning Units SW6 and SW7, or to the west (Links 7 and 8) serving Planning Units SW5 and SW4 respectively, or any logical combination of these. Links 9-11 are options to serve the western areas possible only with the higher command levels available with a Ganges Barrage in place.

The RAOM enables these options to be tested rapidly against each other. Analyses undertaken reveal that Link 7, serving Planning Unit SW7 and enabling a reliable supply to reach the proposed intake for Khulna water supply, should be developed first with Links 6 and 8 following thereafter. Whilst assumptions regarding the South Central Region remained as before, it was assumed that the Gorai intake, Kamarkhali weir and Link 7 could all be constructed by the year 2000, with the remaining two Links by 2005 and all other developments completed by 2020.

The South Central Region's results are the same as for the previous situation as no changes in assumptions occur. For the Southwest, development potential is significantly increased to about 168,000 ha of new FCD, 139,000 ha of rehabilitated FCD and 186,000 ha of surface irrigation. The availability of cheaper surface irrigation supplies compared to groundwater development indicate that only about 100,000 ha of groundwater would be developed by 2020 compared with about 138,000 ha in the reference situation. Such a conclusion adds credence to the idea that provision of surface water would help enforce a groundwater buffer zone.

The total economic capital costs (including groundwater) in the Southwest are Taka 8.8 billion of which the intake works and NPV of dredging are Taka 2.9 billion and the transfer canals and diversion weir are Taka 1.8 billion. The augmented flow in the Gorai at full development would be about 180 cumec with about 60 cumec to Link 6 and 110 cumec to Link 7, the small balance passing downstream of the weir. The NPV of benefits less costs is about Taka 17.9 billion with benefit cost ratio of about 2.5 overall for the Southwest Region.



Gorai Augmentation Project

The Gorai Augmentation Project brings marked benefits to areas within the Gorai corridor where water may be transferred to, securing significant reductions in food shortages most notably in Planning Units SW5 and SW6 as well as good improvements in SW7 and SW10. However, overall the Southwest Region would still be some 42% short of food in 2020.

5.3.5 Development with a Ganges Barrage

In the main studies of development potential with a barrage on the Ganges it is assumed that inflows to the barrage would correspond to the 80% dependable monthly flows based on analysis of actual discharges in the period 1975 to 1988. The minimum flow occurring in April is thus taken as 664 cumec. As discussed later, the impact of lesser flows has also been considered. A minimum compensation flow downstream of 100 cumec has also been assumed necessary in all situations.

The presence of a Ganges Barrage enables construction of any of the eleven transfer channels shown on Figure 5.4. It also enables flows to be allocated, if required, to salinity control south of Khulna, to augmenting supplies to the South Central Region and, with construction of a Hisni transfer, to the Hisni - Mathabanga system. When constructed, the Barrage will raise water levels to an extent that will virtually eliminate the need for maintenance dredging in the Gorai. It is assumed that if a Gorai intake structure is constructed then at least 100 cumec must be passed through the structure to sustain the channel and facilitate navigation in the upper reaches of the Gorai.

From the preliminary analyses undertaken the following conclusions can be drawn:

(i) Links 9, 10 and 11 are the least favourable means of diverting water to the west and a combination of Links 1 - 5 and Links 6 - 8 give the best solution

(ii) The preferable sequence of Link development is Link 7, Links 6 and 8, Link 3, Links 4 and 5 and finally Links 1 and 2

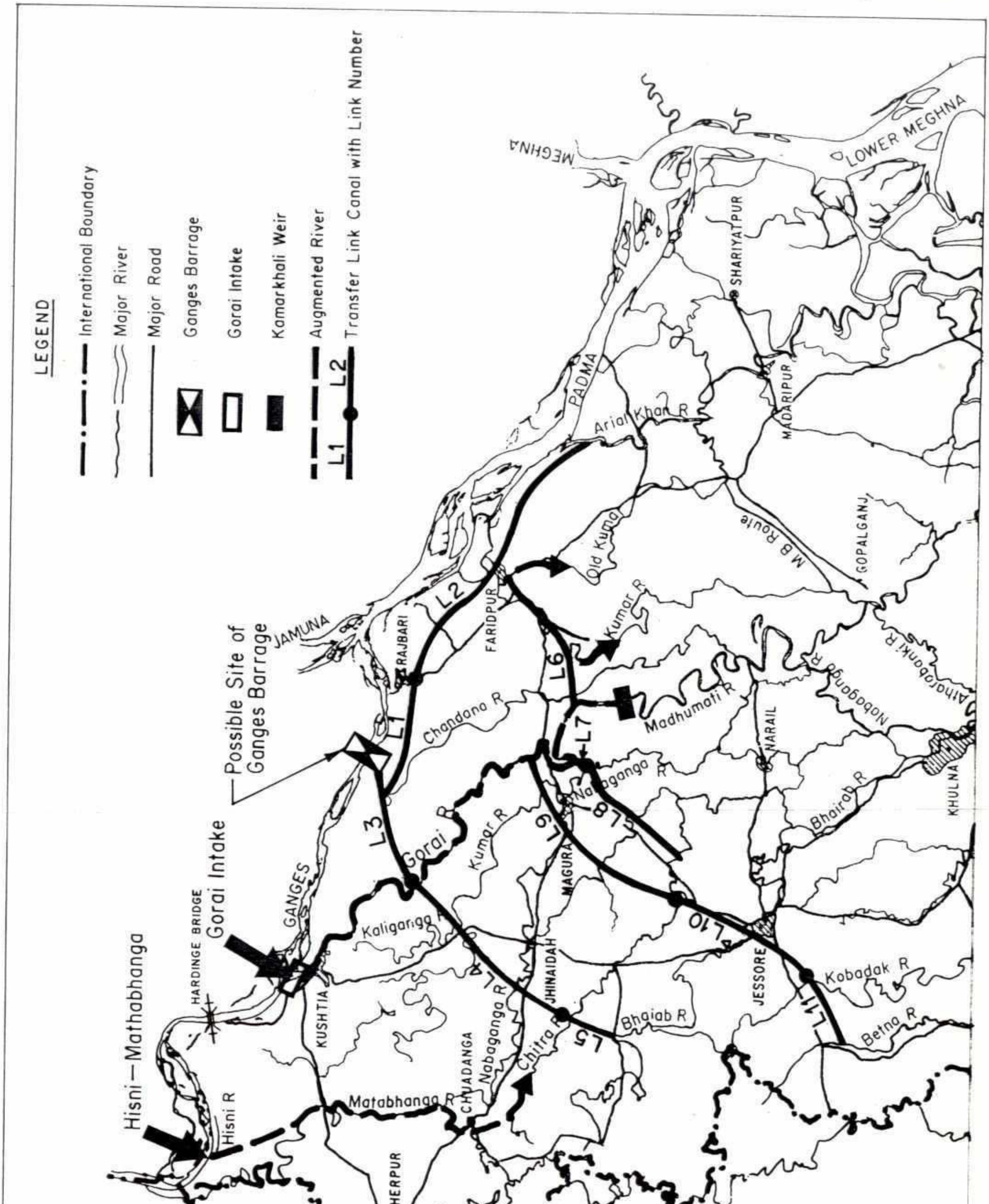
(iii) Allocations of water to salinity control lead to less favourable results economically and these are not considered in the base case described below

(iv) Allocations of water to the South Central Region are favourable compared to parts of the Southwest Region which are more expensive to serve : however, in these analyses no specific provisions have been made for the necessary means of controlling flows transferred into the South Central river systems and this conclusion is tentative only; accordingly the base case excludes transfers to the South Central Region.

(v) Allocations to the Hisni - Mathabanga system are worthwhile but should be considered at a later date after development of the main transfer systems.

The base case for the Ganges Barrage is thus the progressive development of the Gorai intake, Kamarkhali weir, Links 7, 6, 8, 3, 4, 5, 1 and 2 and the Hisni transfer with the Barrage and Link 3 being constructed by 2005, Links 4 and 5 by 2010 and Links 1 and 2 and the Hisni by 2020. With these Links in place the estimated live storage behind the Barrage is 1128 MCM. At full development in 2020 the total areas that are estimated to be viable to develop in the Southwest Region are approximately 253,000 ha of new FCD, 147,000 ha of rehabilitated FCD and 580,000 ha of surface water irrigation. Groundwater development would be reduced from the reference situation by 49,000 ha to 89,000 ha. The total economic capital costs (including groundwater) would be about Taka 43 billion of which about Taka 34 billion would be spent on major structures and transfer works. The NPV of net benefits less costs would be about Taka 8.6 billion giving an overall benefit/cost

Figure 5.4



Main Augmentation and Transfer Choices

ratio of about 1.16. As in all of the conclusions drawn from these comparative studies using RAOM, these figures should be treated as indicative rather than absolute, and as means of readily distinguishing preferable choices from those less advantageous.

As would be expected, the Ganges Barrage development as described has a major impact on food production and in Planning Units SW1 to SW6 and SW8 would create surpluses in 2020. Significant improvements would also be achieved in SW7, SW9 and SW10 also and overall shortages within the Region would be reduced to 25% in 2020. However it may be noted that SW11 to SW14 will still remain in considerable deficit.

5.3.6 Alternative Long - Term Development Options

As indicated a number of variations to the Ganges Barrage base case development above have been tested. These are briefly described below.

Maximum Irrigated Areas

A number of alternative assumptions have been tried out. If there is no limitation on flows in the Ganges, then without salinity control the surface irrigated area in the Southwest could be increased from 580,000 ha to 648,000 ha and in the South Central to 423,000 ha. Peak abstraction from the Ganges would rise from about 730 cumec to about 1010 cumec, with the overall benefit/cost ratio falling to just over 1.0. The minimum Ganges flow to sustain this development (given that flows remain month by month in proportion to the base case) is at least 700 cumec. It should be recognised however that in practice a somewhat higher flow may be necessary as this minimum value assumes fore-knowledge of month-by-month flows, no significant daily variation from the average flow in each month and optimal operation of the reservoir storage, none of which may be expected in practice. Additionally, the calculation is based on mean values of sub-regional runoff and to assure 80% dependable irrigation supplies a higher figure would be required. Even higher flows would be needed if salinity control is also required.

By contrast if the minimum flow in the Ganges fell to 150 cumec between January and May, then the surface irrigated area in the Southwest would be reduced to about 190,000 ha, some 390,000 ha less than assumed in the base case. This would reduce the benefit/cost ratio to 0.63 if the situation were sustained.

Salinity Control

From the hydrodynamic modelling studies, assessments have been made of the areas in each Planning Unit that would be brought into the fresh water zone under salinity control flows of 150, 250 and 500 cumec. The results are summarised in Table 5.1.

TABLE 5.1

Comparison of Ganges Barrage Development with and without salinity control

Southwest Region only	Salinity Control Flow			
	Base Case	150 cumec	250 cumec	500 cumec
Surface Irrigation(ha)	580,000	575,000	472,000	254,000
NPV (Benefits-Costs) M. Taka	8,563	8,505	6,218	- 6,710
Benefit Cost Ratio	1.16	1.16	1.13	0.85

These figures substantiate earlier impressions that salinity control, if measured against direct benefits to agriculture and set against overall resource constraints, has a rapidly diminishing return. It does indicate however only very marginal disbenefits for flows up to 150 cumec (or possibly slightly more) and suggests that if other reasons should prevail in the future, allocations to salinity control up to this level would be feasible.

Allocation of Flows to the South Central Region

With the same assumptions as in the Ganges Barrage base case but with flow allowed to pass from Link 2 into the Arial Khan and thus into the South Central River system, an additional 182,000 ha could be irrigated in the South Central Region. A discharge of about 210 cumec would be required in Links 1 and 2. Overall NPV (Benefits - Costs) for both Regions would be increased from Taka 32.3 billion to Taka 36.4 billion and the overall benefit/cost ratio would increase from 1.50 to 1.54. As previously mentioned, no specific allowance has been made for flow control measures within the South Central Region. If the NPV of economic capital costs of these exceeded Taka 4.1 billion then the advantage gained would be lost. Such a development would however have a significant impact on food security in the South Central Region, reducing overall shortage in 2020 by 8% to 22%.

If flows are allowed to the South Central Region whilst 150 cumec is allocated to salinity control in the Southwest Region, the area developed for surface water irrigation in the South Central reduces to 283,000 ha and the NPV of Benefits less Costs falls back to Taka 34.1 billion and the overall Benefit/Cost ratio to 1.53. This confirms that, with the costs as estimated, allocation to the South Central has more potential benefit than allocation to salinity control.

Investment in Irrigation Improvements

An additional analysis has been undertaken to investigate the benefits associated with a 10% rise in irrigation efficiencies. These circumstances have been applied to the ultimate Gorai Augmentation Project rather than the Ganges Barrage (where optimal use of storage might disguise the real impact of increased efficiencies). The results are compared in Table 5.2 below:

TABLE 5.2

Impact of 10% Increase in Irrigation Efficiency on the Gorai Augmentation Project

	Standard Efficiency	Improved Efficiency	Difference
Surface Irrigated Area (ha)	186,000	203,000	17,000
Groundwater Area (ha)	101,000	120,000	19,000
Total irrigated	287,000	323,000	36,000
NPV (Benefits - Costs) M.Taka	17,872	20,793	2,921

This very simple comparison indicates that a programme worth up to about Taka 2.9 billion NPV economic would be justifiable. In very rough terms this would be equivalent to the NPV cost of the Gorai intake works and dredging themselves or to a long term programme costing about Taka 40 million per year.

Alternative Land Use Policies

A basic assumption in all of the analyses is that land is not transferred from agriculture into alternative uses. A series of analyses have been undertaken which investigate the impact of alternative land use policies. The main new assumptions made are that land can be freely converted from rainfed agriculture to culture fisheries or, to social forestry or, if within saline areas, to shrimp/rice culture. Land conversion is not allowed to exceed 0.05 ha per household (roughly 10% of the average farm size) and social forestry is not allowed to expand beyond an extent that would cause fuel energy surpluses in each Planning Unit.

The primary comparison was made between a scenario with these assumptions and the Ganges Barrage base case. The salient points are summarised in Table 5.3.

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Table 5.3

Economic Impacts of Alternative Land Development Strategies

Region	Incremental Areas (km²)					B/C	NPV Net	Margin	
	Total Irrigated	Land out of Agric.	Culture Fisheries	Shrimp +/(-)	Social Forestry	Ratio	Benefits (M.Taka)	on 978 (M.Taka)	
Run	962 *Maximised net benefits with agricultural land decrements not allowed*								
SW total	6,690	-	-	-	-	1.16	8,563	(35,793)	-81%
SC total	3,224	-	-	-	-	3.34	23,749	(32,623)	-58%
SWA Total	9,914	-	-	-	-	1.50	32,312	(68,416)	-68%
Run	1062 *Maximised net benefits with proposed Ganges Barrage development programme*								
SW total	6,468	-	-	-	-	1.14	7,224	(37,132)	-84%
SC total	2,325	-	-	-	-	3.23	18,323	(38,050)	-67%
SWA Total	8,793	-	-	-	-	1.41	25,547	(75,182)	-75%
Run	978 *Proposed Ganges Barrage development programme with agricultural land decrements*								
SW total	6,318	(1,122)	205	140	537	1.83	44,356	-	-
SC total	2,258	(947)	183	-	762	8.10	56,372	-	-
SWA Total	8,576	(2,070)	388	140	1,299	2.64	100,729	-	-
Run	971 *Maximised net benefits with agricultural land decrements allowed*								
SW total	4,323	(3,088)	954	184	1,113	2.90	92,453	48,097	108%
SC total	3,205	(1,127)	221	-	870	7.71	66,679	10,307	18%
SWA Total	7,528	(4,215)	1,174	184	1,983	3.71	159,133	58,404	58%
Run	974 *Food Energy shortages minimised*								
SW total	5,625	(1,393)	98	-	468	1.96	51,430	7,074	16%
SC total	4,349	(238)	-	22	30	2.91	31,500	(24,873)	-44%
SWA Total	9,974	(1,631)	98	22	497	2.18	82,929	(17,799)	-18%
Run	975 *Protein shortages minimised*								
SW total	4,925	(2,147)	868	-	674	2.37	68,394	24,037	54%
SC total	3,380	(1,015)	233	-	745	7.08	62,173	5,800	10%
SWA Total	8,305	(3,162)	1,101	-	1,419	3.17	130,567	29,838	30%
Run	976 *Fuel Energy shortages minimised*								
SW total	5,316	(2,074)	21	-	1,165	2.56	82,068	37,712	85%
SC total	3,391	(1,104)	196	-	870	7.57	67,189	10,816	19%
SWA Total	8,707	(3,178)	217	-	2,035	3.37	149,257	48,528	48%
Run	977 *All shortages minimised*								
SW total	5,457	(1,828)	272	-	941	2.27	71,261	26,905	61%
SC total	4,028	(866)	28	22	742	5.12	60,558	4,185	7%
SWA Total	9,485	(2,693)	300	22	1,682	2.86	131,819	31,090	31%

Source : RAOM calculations

The analyses given in Table 5.3 illustrate the considerable impact of encouraging appropriate land use. The difference in economic NPV terms between the Ganges Barrage base case and the same with agricultural land allowed to decrement (Runs 1062 and 978) is of the order of Taka 75 Billion. If food energy shortages are targeted to be minimised then more land would be chosen to be irrigated in the South Central offset by slightly less in the Southwest, but overall for the SWA the total NPV would be reduced by some 18%. In other words, pursuit of minimum food energy shortages would have an economic opportunity cost of about Taka 18 billion NPV compared to the proposed strategy. It is similarly interesting to note that policies to reduce other shortages such as protein and fuel energy are more economic than tackling the food energy problem, presumably because of the relatively high price of irrigation associated with the latter.

In the absence of detailed studies to evaluate the costs associated with land redevelopment and the impacts on commodity prices of such potentially major land use changes, the analyses should be treated as indicative only. They most probably overstate the net values of non-agricultural land to an increasing degree as divergence occurs from the current state. Nevertheless it may be concluded that the proposed development programme is largely compatible with overall development of the Southwest Area land resources and that there are clearly additional benefits to be gained from promoting alternative uses of non-irrigated land.

5.3.7 Conclusions

The conclusions drawn from the preceding strategic analyses are as follows:

(i) The economic return on investment generally reduce as the size of area developed increases

(ii) Development of groundwater only, leaves significant food shortages in both Regions by 2020

(iii) Development without augmentation substantially improves food security in the South Central Region but does little to address the problems of the Southwest Region

(iv) Development with augmentation of the Gorai has a positive impact on food security in the Planning Units along the Gorai corridor, but overall for the Region provides a marginal improvement only

(v) Development with a Ganges Barrage substantially solves food security problems through to 2020 in the Southwest Region except in the coastal zone

(vi) Salinity control flows in the Southwest Region much over 150 cumec appear uneconomic

(vii) Transfer of flows to the South Central are beneficial providing river control measures in that Region can be achieved at an NPV economic cost not exceeding about Taka 4.1 billion

(viii) The viability of the Ganges Barrage development hinges on the availability of dry season flows in the Ganges

(ix) Substantial benefits may be obtained from a programme targeting improvements in irrigation efficiency and, providing a 10% gain can be achieved, an investment not exceeding Taka 2.9 billion (NPV, economic) appears justifiable

(x) Parallel developments targeting expansion in appropriate areas of culture fisheries, social forestry and shrimp/rice farming would lead to significant additional benefits in the Area as a whole

(xi) Development of agriculture alone cannot absorb the growing labour and employment opportunities in other sectors, notably by expansion of industries in the SWA, should be created.

Thus the overall general conclusions are that:

- Development of flood control, drainage and irrigation works should be maximised in order to best meet long term food security subject to levels affordable by the Government
- From the analyses undertaken, this leads to ultimate development of the Ganges Barrage, preceded if preferred by works on the Gorai River
- During detailed study of the Ganges Barrage development, active consideration should be given to transferring water to the South Central Region and of allowing up to about 150 cumecs for salinity control
- Parallel programmes targeting irrigation efficiencies, culture fish, shrimp and social forestry should be developed.

5.4 Proposed Strategy

5.4.1 Underlying Policies

As discussed in Section 3, the underlying policies within the water resources management plan are to address the perceived socio-economic and environmental needs of the growing population of the Area within the context of the changing resource setting and within the framework of Government's policies and objectives. This leads to recognition that the land and water resources of the Area should be developed efficiently to promote the continued growth of agriculture as a prime source of food, employment and income. To ensure a balanced approach and to minimise the negative impacts on different sections of the community, fisheries and forestry should be promoted in parallel to agriculture. Where appropriate within the Area, these activities may be given precedence over agriculture if comparative advantages exist and especially where agricultural alone is seen to be unable to meet the people's needs.

To sustain the growing population, a fundamental policy has to be to give priority to the provision of potable domestic water supplies and to industrial water requirements on the reasonable assumption that the latter represents the highest value of water use other than domestic supplies.

Given the scarcity of resources the prudent use of groundwater should continue to be encouraged and it is recommended that with certain provisos the impetus for this development should be left with private sector. The provisos are ensuring the means by which to mitigate against greater draw-downs affecting hand operated shallow tubewell supplies for domestic use and institution, at least temporarily, of a buffer zone to protect against northwards movement of saline groundwater. The current trend that wherever possible potable supplies should be drawn from groundwater is also to be encouraged.

A further fundamental aspect of the strategy is recognition that the surface water resources of Area are inadequate to meet long term needs and that augmentation is a necessity. From the studies made, water resource development and augmentation in particular will not meet all the Area's needs and it is fully recognised that throughout the Area and more so in certain parts, parallel social programmes will be required to promote income generation and social equitability.

5.4.2 Principal Features of the Overall Strategy

The principal features of the proposed strategy fall into the following general categories:

- Structural water resource development interventions
- Non-structural and institutional measures
- Parallel development in related sectors

Structural Water Resource Development Interventions

The structural water resource development interventions are targeted primarily at the development of an environment best suited to the growth of agriculture in the two Regions in a manner compatible with the overall objectives as previously outlined. These measures are also aimed at controlling the salinity intrusion from the south. The measures proposed and their phasing are directed at achieving best returns on investment in the shortest period of time given a reasonable investment schedule. The measures relate to activities within the period to 2020 and are subject to the conclusion of more detailed studies in the future as well as periodic reviews to assess whether assumptions and/or performance targets remain valid. The measures fall into the categories of:

- Augmentation of surface water resources
- Development of surface water irrigation schemes
- Rehabilitation and/or construction of new flood control and drainage schemes
- Maintenance of river channels

For the Southwest Region the main interventions relate to the two main issues of FCDI development and of rehabilitation of the coastal polder area. The strategy for irrigation development hinges on securing the Gorai intake and augmentation of dry season flows initially and the phased introduction of low lift pump schemes in a sequence determined by the construction of transfer canals from the Gorai. The Gorai Augmentation Project has two main phases. The first involves a dry season minimum flow of 60 cumec which would provide sufficient water to develop approximately 60,000 ha within the Gorai corridor on both the left and right banks by the year 2005. The intake structure, by capping wet season flows, would also bring immediate benefits to flood control and drainage improvement to the areas draining into the Gorai. The second phase is conditional on whether a final decision has been taken to proceed with the Ganges Barrage by that time. If this is the case then there is no need to undertake further capital dredging of the Gorai, since the Barrage will provide sufficient head through the intake structure. This, together with reduced maintenance dredging requirements would represent a significant reduction in costs associated with the Gorai as well as mitigation of environmental impacts arising from continued long term dredging. If the decision is not taken then to complete the Gorai Augmentation Project, additional capital dredging would be required to facilitate further irrigation development.

Although it would be advantageous and necessary to allocate some augmented flow through the Gorai for salinity control, the analyses indicate that with the present flows in the Ganges and with no control of water levels in the Ganges, no appreciable amount could be withdrawn. It is also clear from the studies that for any significant impact on salinity a minimum of 150 m^3/s is required at Khulna.

Within the Southwest Region the development of FCDI would be phased taking account of the above, the anticipated growth of groundwater irrigation and the viability of rehabilitating or constructing new flood control and drainage schemes. Development of flood control and drainage of the areas affected by the Ganges - Padma and Arial Khan Rivers are seen as key measures as a consequence of this. FCD schemes would be based on the philosophy of controlled flooding in order to minimise disruption to existing water management practices and to capture fisheries generally. Attention would be given in the design of all FCD schemes to preserving existing beels and baors by either excluding them from the protected areas or by ensuring that inflows are possible in a manner which least hinders the normal migrations of fish. Artificial stocking of fish may also be appropriate as a means of both mitigation and increasing productivity. The design of FCD schemes would also take account of the conclusions reached by FAP 20 in their compartmentalisation pilot project in a manner appropriate to the conditions of topography and flooding prevalent within the Southwest Area.

Surface water irrigation would be based on the development generally of low level channels serving privately financed LLP's and local area development. Water level control in these channels would be facilitated by control structures in the main and minor regional rivers and by transfer canals between rivers.

It is proposed that to meet future requirements a Barrage is built on the Ganges, subject to detailed study of its feasibility. Studies of the Barrage should proceed without delay in order that a final decision to build can be made within the next five years. In the meantime, the first phase of the Gorai Augmentation Project should proceed immediately to full feasibility study taking account of the conclusions drawn from the pre-feasibility study given in this Report. When constructed the Barrage would transfer water via contour canals to the main regional rivers of the Southwest Region and together with a separate transfer into the Hisni realise full development of all areas outside the saline front.

The viability of the Ganges Barrage depends on the adequacy of dry season flows in the Ganges, which in turn is dependent on releases from the Farakka Barrage. A water sharing Agreement between Bangladesh and India is therefore essential for the development of the Ganges Barrage. Alternatively, consideration must be given for augmenting the Ganges flow within Bangladesh.

As indicated earlier analyses undertaken indicate that for allocation of flows specifically for salinity control in the Khulna area is not prudent until the Ganges Barrage is constructed and that, with the Barrage, this use of water should be compared with transfer into the South Central Region via the Arial Khan. The preliminary results show that transfers to the South Central Region is a more productive use of the Ganges water. Since solutions to Khulna water supply have been identified which do not rely upon moving the saline front, the benefits of salinity control to the Southwest Region hinge upon the relatively small additional areas which could be reclaimed for agriculture (albeit politically important ones) and the uncertain benefits to be gained in the Sundarbans from minor salinity changes. Given the comparative advantages of artisinal shrimp farming for these areas (providing adequate investment is made) it would seem prudent to undertake more detailed studies of the alternatives. It may also be noted that should the Lower Meghna disconnect its right bank spill channels at some time in the future, then the South Central Region will desperately need dry season augmentation.

Otherwise in the South Central Region the proposed strategy is, as previously noted, to complete the Ganges - Padma and Arial Khan embanking to enable controlled flooding, to not proceed with embanking the Lower Meghna within the next 50 - 100 years and to develop FCDI schemes where resources and conditions are favourable.

In the coastal zone, the proposed strategy in the long term is to progressively improve drainage conditions in different areas as and when such measures become viable as a result of deterioration. Such interventions overall will be in the context of allowing the coastal zone to move towards a new tidally dominated equilibrium, and individually the interventions will have to take account of the effects they will cause in both a regional and local perspective. The interventions proposed include dredging of those rivers considered sustainable in the long term, the creation of macro-polders to promote this sustainability, improvements to drainage outfall structures to increase drainability and to internal water management. Recognition is given to the long term consequences of sea level rises and land subsidence and acknowledgement made of the probability, that resort may be made in the future to pumped drainage as a more viable alternative to improvements of gravity drainage systems.

In the short to medium terms, priority areas and outline measures to relieve drainage congestion have been identified and recommendations made to undertake pilot schemes in two areas and further studies at a third. It is to be anticipated that thereafter further areas will have deteriorated sufficiently to merit more studies and further structural measures. Such a pattern will continue through and until tidal equilibrium is achieved and sea level rises and subsidence have stabilised, all of which may take 100 years or more. In such a time-scale, it is to be expected that the economy of Bangladesh will grow substantially. Together with population increases this will bring new pressures to bear on land use priorities and the viability of sustaining the polder areas for predominantly agricultural use. In the near-term the prospect exists for expanded shrimp culture in certain areas and it is important that detailed studies of individual projects take account of this.

Non-structural and Institutional Measures

The structural measures above represent important investments that will enable substantial development of both Regions. Whilst most of the Area will be provided with a large degree of flood protection, the risks of flooding will continue to persist whilst construction proceeds and in other areas, notably adjacent to the Lower Meghna where no flood protection is envisaged within the planning horizons considered. In addition, it may be expected that cyclones will continue to create high risk situations for which coastal protection measures can only partially protect against.

The strategy for development of these Regions therefore includes provision for flood proofing and flood preparedness in those areas where flood protection does or will not exist accompanied by a system for flood warning. Within the coastal area cyclone protection shelters and refuges are planned to supplement existing facilities together with continued support for the expansion of coastal plantations. These measures are being addressed in detail by FAP supporting studies Nos 7, 10, 11 and 23, to which reference should be made.

The institutional aspects of the Flood Action Plan are being reviewed under FAP 26, Institutional Development Programme. The strategy proposed for the Southwest Area requires a high degree of multisectoral coordination, a strong overall management team and technically sound implementation. Monitoring and evaluation of progress and impacts of development are key issues also, together with effective motivation of and coordination with the private sector. In broad terms it is envisaged that the development of the major infrastructural works would be initially planned under similar arrangements to those existing, with FPCO taking the lead role to ensure effective inter-agency coordination. Implementation of these works would be expected to come under BWDB with appropriate technical assistance and resourcing. Major works construction is expected to be mainly appropriate for international competitive bidding with conditions applied to maximise the use of local resources and labour and to minimise environmental impact, eg to enforce the use of coal rather than local timber to fire bricks. All feasibility studies should take full account of this and carefully assess the pros and cons of such measures in terms of cost effectiveness to the economy as whole, as well as the expected social impacts.

At a local level it is anticipated that the impetus for irrigation development will increasingly be borne by the private sector. The National Minor Irrigation Development Project (NMIDP) under the Ministry of Agriculture represents a major step forward in this respect. NMIDP will provide support to LLP schemes in the Southwest Area in the form of technical guidance, credit and monitoring. In its early stages NMIDP's groundwater component is focussed on other Regions and additional support will be required to cover this aspect for the Southwest Area. This is of particular importance in relation to establishment of the proposed buffer zone and the monitoring and definition of mitigation requirements of the impacts of further development on potable water supplies.

Operation and maintenance of the various works is expected to be the responsibility of the owners. Thus the major works will fall to Government to look after whilst the farm level systems will be the responsibility of the private sector. Strengthening of both sectors is considered desirable and training and support schemes are to be encouraged. The conclusions of FAP 13's O & M study are pertinent in this respect.

Parallel Development in Related Sectors

The forecast achievements of food security indicates that with development of the Ganges Barrage and related works, food surpluses will be achieved in most of the areas directly affected. Nevertheless by 2020 average deficits of 25% and 30% in the Southwest and South Central Regions can still be expected. To make up these shortages an underlying growth in agricultural productivity (excluding the impacts of FCDI) of between 0.75% and 1.00%, per annum is required. Whilst this may appear modest in relation to trends over the last 10 years (eg 1.7% pa for HYV Boro), it is clear that continued support and advice for farmers is required through continued research, extension and improved supplies of inputs and credit.

The studies undertaken indicate that the least developed areas by 2020 will be the coastal areas for which in general irrigated agriculture is not feasible, but for which shrimp or shrimp plus rice farming is more appropriate. The experiments in Polder 20 demonstrate that many of the social and technical problems can be overcome with prudent planning based on local participation and cooperation. Such measures will precipitate the need for more shrimp hatcheries and in the shorter term reinforce the need to sustain the natural supply of larvae and juveniles within the Sundarbans and immediately offshore. Such a policy is consistent with taking no immediate steps to augment freshwater supplies to these areas.

In economic terms in most areas the development of social forestry (homestead groves) is beneficial as well as offsetting the Area's fuel energy deficits. Similarly in non-saline areas culture fisheries is an advantageous source of both income and protein. Both culture fisheries and social forestry compete directly with agriculture for land and whilst generating better cash incomes will reduce overall food production. The strategy proposed is that both these sectors should be encouraged and supported in the expectation that full development would take many years and that during that time rises in agricultural productivity would offset the land losses. Monitoring of the situation in the long term is clearly very desirable.

The proposed strategy for the Sundarbans is that the area should be managed as a complete eco-system with due account taken of the multisectoral benefits obtainable. It is proposed that whilst studies continue to enable a clear understanding of the complex inter-relationships within the area, no specific measures should be taken to significantly alter the quality and quantity of surface water flows entering the area. This is consistent with the overall strategy of not initially augmenting dry season Gorai flows for the purposes of salinity control and with the general short term measures proposed to relieve drainage congestion in the polder areas. Nevertheless it is recommended that flows entering the Sundarbans are rigorously monitored to ensure that such conditions are being adhered to in practice. It is also recommended that further encroachment into the Sundarbans be halted and to this end it is to be hoped that the proposed investment policies within the coastal areas will lessen the pressure to develop more agricultural land.

The considerable importance of river transport is acknowledged within the overall strategy for the Area, as is the value of Mongla Port as a major transportation hub for the area serving the needs of inter-regional and international trade. The measures proposed for the Area do not conflict with any of the established major routes serving the Area, and generally favour the situation for Mongla Port. Augmentation of dry season flows of the Gorai and, related to this, of other regional rivers, will generally improve their year round navigability. On the other hand, in order to obtain adequate control for irrigation purposes a number of rivers on minor navigation routes will require control structures. Similar situations will arise with the creation of macro-polders in the coastal areas. Many of these structures and closures will interfere with the passage of country boats. Due account will have to be taken in designing these structures to allow for locks or boat lifts to minimise these negative impacts. Similarly, where appropriate adequate provision for fish passes would be required. It is recognised however that whilst current knowledge of fish migration patterns is very limited, many of the control structures would be on rivers which are currently dry or virtually dry during low flows and therefore that in terms of mitigation alone attention needs to be addressed to preserving conditions in the wet season.

6 REGIONAL WATER RESOURCES MANAGEMENT PLAN

6.1 Introduction

The proposals for the future water resources management in the Southwest Area have been drawn up taking full account of the insight and understandings achieved of the current and future resource settings of the Area, the present and future needs within the Area and the stated policies of Government. They also take full account of the analyses undertaken to assess the impacts of alternative interventions and strategies on the natural processes active within the two Regions (SWR and SCR) and of the peoples of the Area.

The Plan addresses the three 'burning issues' as identified in the TOR and various options have been proposed to solve them.

The Plan as presented represents a current best estimate of the required future developments. It is therefore necessary at feasibility level to establish the detailed justification of each component and the forecast changes in the area that result both from natural processes and the proposed interventions. The Plan includes provision for updating as well as monitoring and evaluation and it is to be noted that these are vital for effective decision taking in the future.

Although clearly there are some development measures which can proceed immediately, there are others which are contingent upon the reliable flow in the Ganges. Whilst it is very difficult with the available data, to place a reliable figure on probability of minimum flows being achieved during the dry season in the Ganges, it should be possible to evaluate the impacts of different flows in the viability of these schemes. Some preliminary indications are given in this Report but more detailed studies are necessary to evaluate these risks properly.

As indicated the Ganges Barrage development has positive impacts on the Gorai Augmentation Project through reduction of long term maintenance dredging requirements which brings both financial benefit and mitigation of the environmental consequences that dredging may have on the Gorai river eco-system and on the G-K Project. However, the Gorai Augmentation Project (Phase I) can go ahead as it is not contingent upon the Ganges Barrage.

Decisions makers need to reflect upon these important linkages and more detailed studies will be necessary to assess these reliably.

6.2 Components of the Plan

The components of the Plan have been divided into structural and non-structural water management measures and developments advocated in parallel sectors. The structural measures are considered in two parts reflecting what can be achieved with and without the use of the Ganges waters.

6.2.1 Structural Measures without reliance on Ganges Flows

The Plan recommends development in the short term of the following projects which can proceed independently of Ganges flows. Figure 6.1 gives a summary of the Regional Plan and Figure 6.2 provides a location plan.

Southwest Area Water Resources Development Plan
Summary

Figure 6.1

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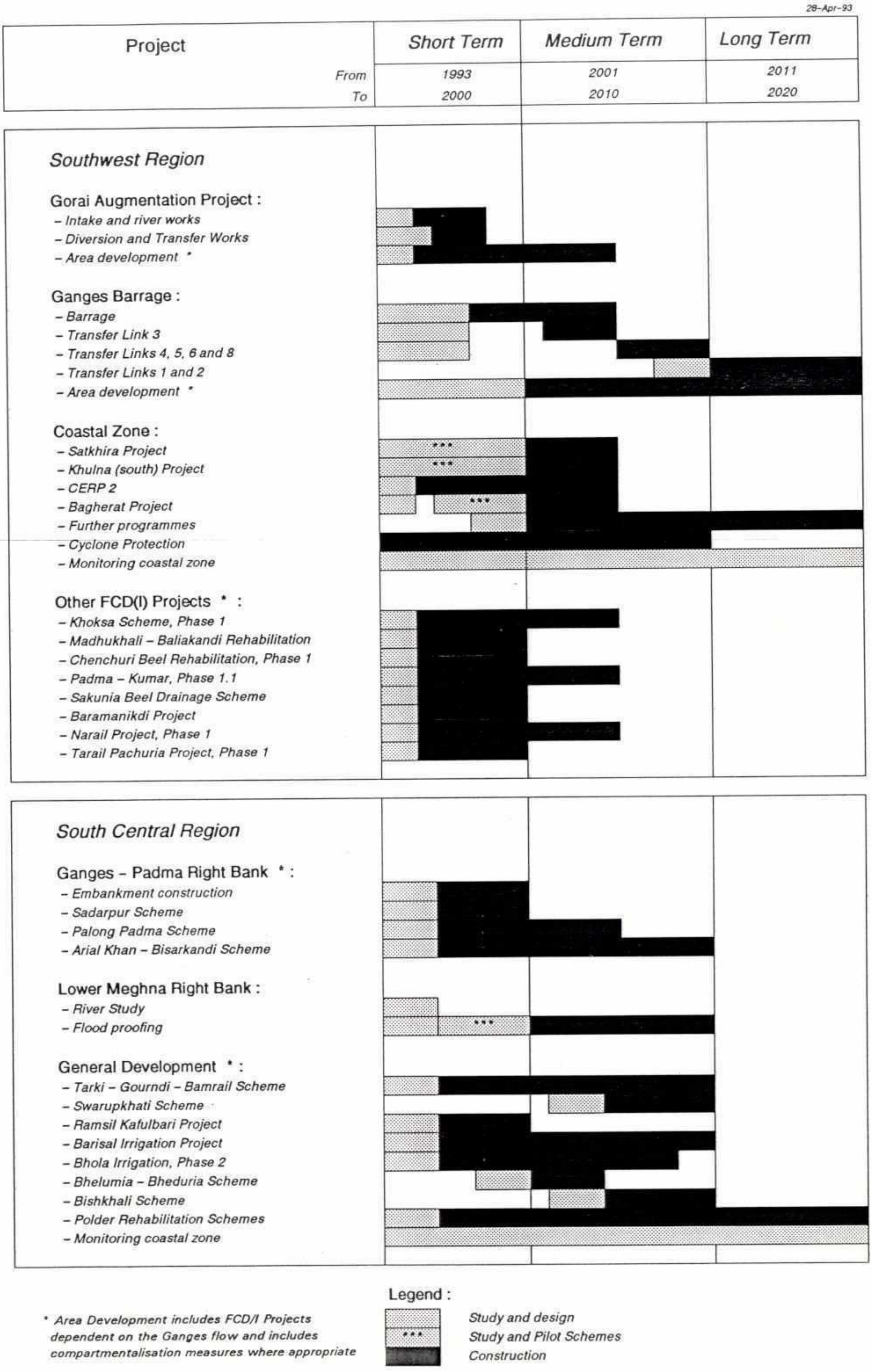
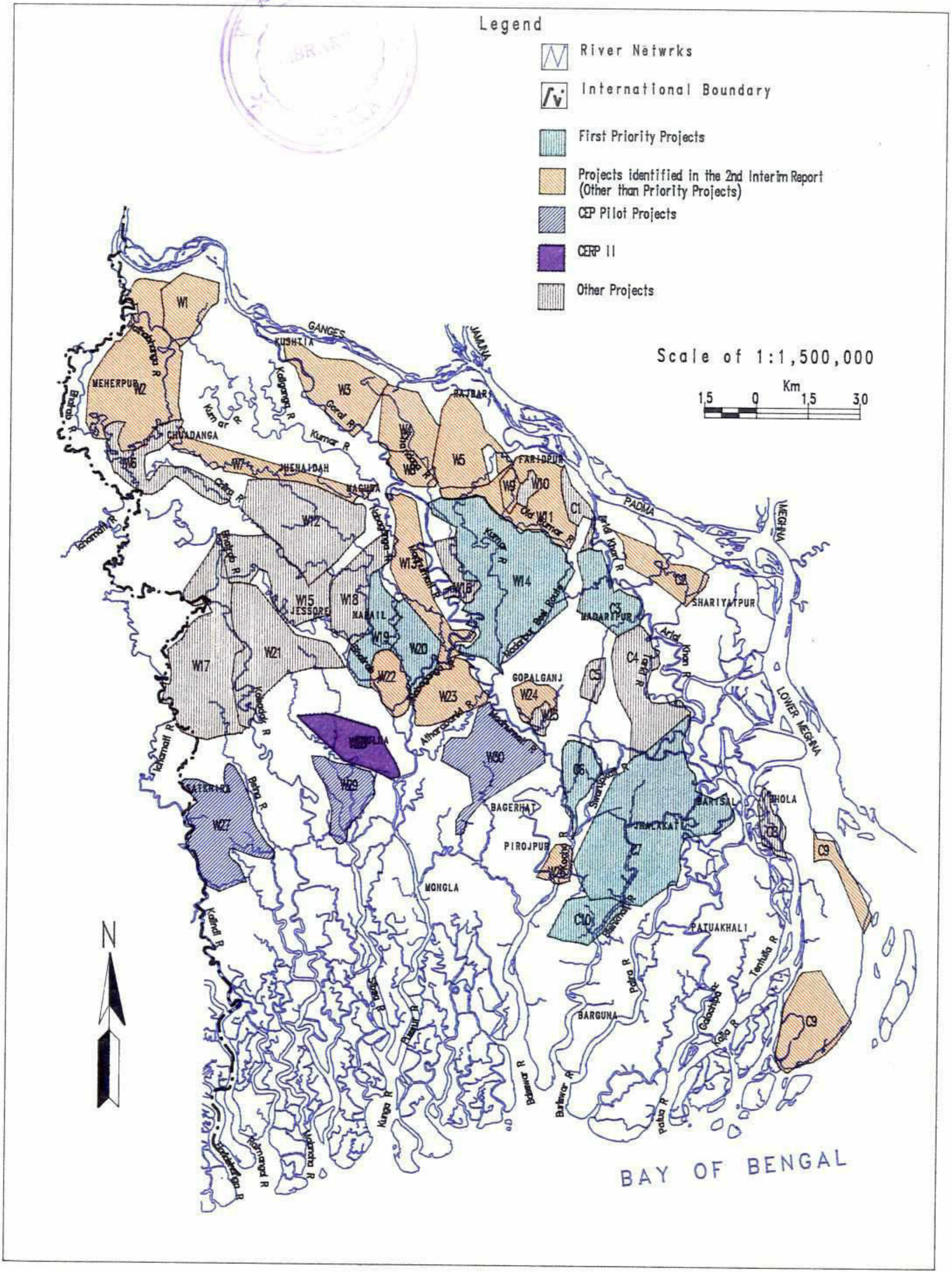


* Area Development includes FCD/I Projects dependent on the Ganges flow and includes compartmentalisation measures where appropriate

Figure 6.2



Development Plan

Southwest Region

- Khoksa Scheme, Phase I	Ref W3
- Madhukhali - Baliakandi Rehabilitation	Ref W8
- Chenchuri Beel Rehabilitation, Phase I	Ref W20
- Padma - Kumar, Phase I	Ref W14
- Sakunia Beel Drainage Scheme	Ref W9
- Baramanikdi Project	Ref W10
- Narail Project Phase I	Ref W19
- Tarail Pachuria Project, Phase I	Ref W25, W24
- Satkhira Area Drainage Relief	Ref W27
- Khulna Area Drainage Relief	Ref W29
- CERP II	Ref W28
- Bagherhat Area Drainage Relief	Ref W30

South Central Region

- Completion of the Ganges-Padma Right Embankment	
- Sadarpur Scheme	Ref C1
- Palong - Padma Scheme	Ref C2
- Arial Khan - Bisharkandi Scheme	Ref C3
- Tarki - Gourndi - Barnal Scheme	Ref C4
- Ramsil Kafulbari Project	Ref C5
- Barisal Irrigation Project	Ref C7
- Bhola Irrigation Project, Phase 2	Ref C9
- Polder Rehabilitation Schemes	

These are not grouped in any order of priority.

Other projects in the two Regions that could proceed are recommended as medium term projects, since at evaluation they appear to offer a viable but less attractive return on investment than those listed above.

Southwest Region

- Drainage improvement in the G-K area	
- Padma Kumar, Phase 2	Ref W11

South Central Region

- Swarupkhati Scheme	Ref C6
- Bhelumia-Bheduria Scheme	Ref C8
- Bishkhali Scheme	Ref C10

6.2.2 Structural Measures contingent on use of Ganges Flows

On the assumption that a reliable flow in the Ganges by Agreement or by other internal development can be established then the following are recommended for the Southwest Region.

Short Term:

Gorai Augmentation Scheme, Phase 1:

- Salikha Scheme Phase I	Ref W18

- Madhumati-Nabaganga Rehabilitation, Phase I	Ref W13
- Chenchuri Beel Scheme, Phase 2	Ref W20
- Alfadanga-Boalmari Phase I	Ref W16
- Barnal-Salimpur-Kolabashukhali, Phase I	Ref W23
- Pirojpur Project, Phase I	Ref W26

Medium Term:

- Ganges Barrage includes Links 3-6 and 8	
- G-K Extension, Phase I	Ref W7
- Chandana Scheme	Ref W4
- Rajbari Scheme, Phase I	Ref W5
- Salikha Scheme, Phase 2	Ref W18
- Jhenaidah Scheme	Ref W12
- Kaliganj Scheme	Ref W15
- Alfadanga-Boalmari, Phase 2	Ref W16
- Betna Irrigation Project	Ref W17
- Harihar-Kobadak Irrigation Project	Ref W21
- Singia-Nebugati Project	Ref W22
- Barnal-Salimpur-Kolabashukhali, Phase 2	Ref W23
- Tarail Pachuria Project, Phase 2	Ref W24
- Pirojpur Project, Phase 2	Ref W26

Long Term:

- Hisni - Mathabanga Transfer	
- Transfer Channel Links 1 and 2	
- Hisni Scheme	Ref W2
- G-K Extension Phase 2	Ref W1
- Mathabanga - Upper Bhairab Scheme	Ref W6
- Madhumati-Nabaganga, Phase 2	Ref W13
- Padma-Kumar, Phase 1 Extension	Ref W14
- Padma-Kumar, Phase 2 Extension	Ref W11
- Barnal - Salimpur - Kolabashukhali, Phase	Ref W23

6.2.3 Non-Structural Measures

The recommended non-structural measures within the Plan which should be carried out in parallel with the structural measures are:

- Flood proofing in areas expected to remain vulnerable within the medium to long term

- Continuation of the Cyclone Protection Project

- Study of the possible impacts of flood protection works at Chandpur on the long term alignment of the Lower Meghna and how this may affect the South Central Region, notably the right bank spill rivers

- Institution of a temporary buffer zone against further groundwater development in an east-west line to the north of Khulna combined with upgraded groundwater monitoring and resource evaluation and assessment of rural water supply needs

- Support to the private sector for the long terms efficient development of minor irrigation

- Institutional support and training in project planning, coordination, implementation and operation and maintenance.

6.2.4 Parallel Sector Measures

This Report has identified that in parallel with the structural water resources management measures the following programmes should be taken up:

- General development within the agricultural sector including extension, training, credit and input supplies and marketing

- Support and development of social forestry as a key element within the forestry sector

- Support and development of culture fisheries

- Support and mitigative actions to preserve capture fisheries

- Development of artisanal shrimp and shrimp/rice culture in appropriate areas together with the development of hatcheries

- Social programmes including income generating projects targeted especially at low income groups and groups such as those involved in capture fisheries.

6.3 Implementation Programme

The proposed implementation programme for the Regional Water Resources Management Plan is presented in Figures 6.3 to 6.5 which illustrate:

- Development Plan for the Southwest Region
- Development Plan for the South Central Region
- Interventions in the Coastal Area

These programmes are divided into Short, Medium and Long Terms, the periods shown being indicative.

The overall programme reflects the priorities attached to the key issues identified in the Terms of Reference and supported by the conclusions of this study viz:

- Augmentation of the surface water resources of the Southwest Region

- Relief from drainage congestion in the coastal zone, and

- Flood control on the Ganges - Padma right bank.

The key aspects to the implementation programme are as follows:

(i) Priority should be given to a feasibility study of the Gorai Augmentation Project with early implementation of the first phase

(ii) Priority should be attached to a regional pre-feasibility to 'investment' of the Ganges Barrage and related components such that a decision can be taken as soon as possible on whether or not to proceed with the Barrage or a second phase of the Gorai Augmentation Project

Southwest Region Development Plan

Figure 6.3

Flood Control, Drainage and Surface Irrigation Schemes

Development Plan

28-Apr-93

PU	Ref.	Project	Short Term (From 1993 To 2000)	Medium Term (From 2001 To 2005)	Medium Term (From 2006 To 2010)	Long Term (From 2011 To 2020)
SW1	W2	Hisni Scheme				
SW1	W1	GK Extension, Phase 2				
SW1	W6	Mathabanga - Upper Bhairab Scheme				
SW2	W7	GK Extension, Phase 1				
SW3	W3	Khoksa Scheme				
SW3	W8	Madhukhali - Baliakandi Rehabilitation				
SW3	W4	Chandana Scheme				
SW3	W5	Rajbari, Phases 1 and 2				
SW4	W18	Salikha Scheme				
SW4	W12	Jhenaidah Scheme				
SW4	W15	Kaliganj Scheme				
SW5	W13	Madhumati - Nabaganga Rehabilitation				
SW5/10	W20	Chenchuri Beel Scheme Rehabilitation				
SW6	W16	Alfadanga - Boalmari Project				
SW6/7	W14	Padma - Kumar, Phase 1				
SW7	W11	Padma - Kumar, Phase 2				
SW7	W9	Sakunia Beel Drainage Scheme				
SW7	W10	Baramanikdi Project				
SW7	W25	Tarail - Pachuria Project (Polder 3)				
SW8	W17	Betna Irrigation Project				
SW9	W21	Harihar - Kobadak Irrigation Project				
SW10	W22	Singia - Nebugati Project				
SW10/13	W23	Barnal - Salimpur - Kolabashuakhali				
SW10	W19	Narail Project				
SW13	W24	Tarail Pachuria Project (Polders 1,2,3,4,5 &6)				
SW13	W26	Pirojpur Project				

			1993–2000	2001–2005	2006–2010	2011–2020	Totals
SW	TOTALS	New FCD	94,000	83,000	39,000	37,000	253,000
		Rehab FCD	87,000	15,000	3,000	42,000	147,000
		Surface Irrig.	72,000	187,000	176,000	122,000	557,000

Legend :

- (black) *Predominantly new FCD and/or surface irrigation*
- (shaded) *Predominantly rehabilitation of FCD with/without irrigation*

Figure 6.4

South Central Region Development Plan
Flood Control, Drainage and Surface Irrigation Schemes
Development Plan

28-Apr-93

PU	Ref.	Project		Short Term	Medium Term		Long Term	Totals
			From	1993	2001	2006	2011	
			To	2000	2005	2010	2020	
SC1	C1	Sadarpur Scheme						
SC1	C2	Palong - Padma Scheme						
SC1/3	C3	Arial Khan - Bisarkandi Scheme						
SC3/5	C4	Tarki - Gourndi - Bamrail Scheme						
SC4	C6	Swarupkhati Scheme						
SC4	C5	Ramsil Kafulbari Project						
SC5/6/7	C7	Barisal Irrigation Project						
SC8	C9	Bhola Irrigation Project, Phase 2						
SC8	C8	Bhelumia - Bheduria Scheme						
SC11/12	C10	Bishkhali Scheme						
SC		TOTALS	New FCD	57,000	52,000	60,000		169,000
			Rehab FCD	30,000	33,000	46,000		109,000
			Surface Irrig.	55,000	34,000	17,000		106,000

Legend :

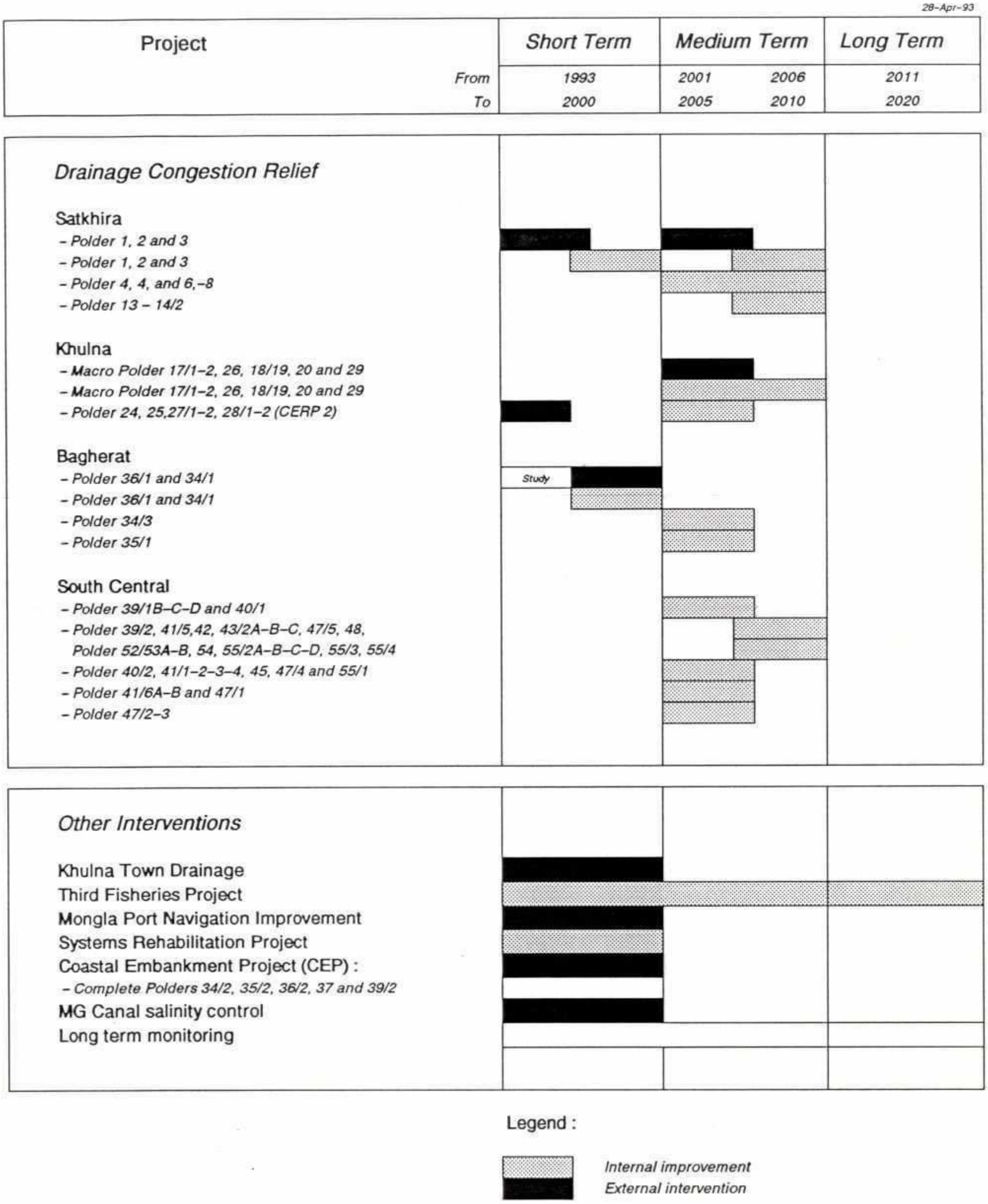
Predominantly new FCD and/or surface irrigation

Predominantly rehabilitation of FCD with/without irrigation

Note : *In the RAOM analyses, the Bishkhali scheme is treated as rehabilitation although it is acknowledged that BWDB treat it as a new scheme*

Southwest Area Water Resources Development Plan
Interventions in Coastal Area

Figure 6.5



(iii) Priority should be attached to instituting more detailed studies and pilot schemes of drainage congestion relief works at Satkhira, Khulna and, following a pre-feasibility study, at Bagherhat

(iv) Priority should be attached to the study of the Lower Meghna river and its possible impact on the right bank spills to the South Central Region.

Each of the above are in some way related to events external to the development programme. The Gorai study anticipates the risk of early disconnection from Ganges. The Ganges Barrage study should proceed so that decisions can be taken with regard to the second phase of the Gorai Augmentation Project. The drainage schemes in the coastal area should not be delayed in the face of a rapidly deteriorating without-project situation. Finally, the Lower Meghna study should proceed in order to assess the risks that may or may not be inherent in the strategy for the development of its left bank.

All of the other interventions proposed may be progressed at any time, subject only to whether they are linked to the augmentation project or not. The proposed scheduling of these projects is based on the assessment of their relative returns on investment and the order proposed takes account of this and generally maintaining an approximately smooth rate of investment in FCD(I).

Whilst the order in which these projects are implemented is a question of preference and availability of funds, the overall importance of proceeding with development programme as a whole is considerable in the face of the rising population and demands and the expected continued deterioration of the resource base.

6.4 Economic Evaluation

6.4.1 Introduction

The following sections summarise the forecast economic impact of the SWA Regional Plan (6.4.2), the two projects selected for pre-feasibility study after the Second Interim Report (SIR) (6.4.3) and six other projects that were identified as possible developments during the preliminary screening of projects for SIR.

6.4.2 The Regional Plan

The SWA Regional Plan for water resource development is a comprehensive programme of flood control, drainage and irrigation within a framework for the optimal allocation of surface water throughout SWA. The Plan takes into account existing developments and the potential for groundwater exploitation within its sustainable limits. However the economic analysis of the Plan assumes that if it is not implemented groundwater will be developed in any case, and this is the basis for the without-project position when arriving at the forecast level of incremental benefits to the Regional Plan.

The development programme and its constituent major projects are described earlier. Detailed background for the basis of the economic analyses and the derivation of costs and benefits are provided in Volume 10, Economics and the FPCO Guidelines for Project Appraisal issued in May 1992 have been followed. A full account of the analysis of the Regional Plan and the options from which it was chosen is given in Volume 5, Part 3, Resource Allocation and Optimisation Model.

The investment and incremental benefit flows for the Regional Plan are summarised in Table 6.1. Details are shown separately for the Southwest Region (SWR) and South Central Region (SCR) and, combined, for SWA. The programmes for water resources development in the two Regions are only weakly limited.

Table 6.1
Economic Cash Flows
Ganges Barrage minus Reference Situation

Agriculture	7 *years build up*	*Discount rate*	12%	Cost Factors : *Ganges Barrage*	100%
Capture Fisheries	1 *years build up*	*Benefit Factor*	100%	*Other Capital Costs*	100%
Damage reductio	1 *years build up*			*Maintenance Costs*	100%

	Year	1993	1994	1995	1996	1997	1998	1999	2000
		1	2	3	4	5	6	7	8
Economic Benefit Cash Flows (Million Taka)									
Southwest	*NPV*								
Agricultural benefits	26,903.9	-	104.6	209.3	313.9	476.8	698.0	956.5	1,252.3
Capture Fisheries and Shrimp	(3,196.3)	-	(23.3)	(46.6)	(58.3)	(113.9)	(169.5)	(225.1)	(280.7)
Damage reduction (MTk/yr)	124.3	-	3.6	7.2	9.0	10.8	12.5	14.3	16.0
Total	**23,831.9**	-	**84.9**	**169.9**	**264.7**	**373.7**	**541.0**	**745.6**	**987.6**
South Central									
Agricultural benefits	17,496.2	-	128.4	256.8	385.3	570.5	812.5	1,085.7	1,390.0
Capture Fisheries and Shrimp	(7,796.0)	-	(100.6)	(201.3)	(251.6)	(371.7)	(491.8)	(611.8)	(731.9)
Damage reduction (MTk/yr)	208.7	-	3.7	7.4	9.2	11.1	13.1	15.0	16.9
Total	**9,909.0**	-	**31.5**	**62.9**	**142.9**	**210.0**	**333.8**	**488.9**	**675.0**
Totals for Southwest Area									
Agricultural benefits	44,400.1	-	233.1	466.1	699.2	1,047.3	1,510.5	2,042.1	2,642.3
Capture Fisheries	(10,992.3)	-	(123.9)	(247.9)	(309.9)	(485.6)	(661.3)	(836.9)	(1,012.6)
Damage reduction (MTk/yr)	333.0	-	7.3	14.6	18.2	21.9	25.6	29.3	33.0
Total	**33,740.9**	-	**116.4**	**232.8**	**407.6**	**583.7**	**874.8**	**1,234.5**	**1,662.6**
Economic Investment Cash Flows (Million Taka)									
Total Capital Costs	*NPV*								
Southwest incl.Barrage	16,626.0	101.3	135.3	270.5	1,181.1	1,181.1	1,364.6	1,548.0	1,548.0
South Central	1,559.7	128.1	170.8	341.7	224.9	224.9	224.9	224.9	224.9
Total	**18,185.7**	**229.4**	**306.1**	**612.2**	**1,406.0**	**1,406.0**	**1,589.5**	**1,772.9**	**1,772.9**
Total Recurrent Costs									
Southwest incl.Barrage	2,059.0	0.0	(56.8)	(113.6)	(142.0)	(121.6)	(101.1)	(80.6)	(60.2)
South Central	(812.9)	(0.0)	(30.6)	(61.3)	(76.6)	(86.5)	(96.3)	(106.2)	(116.0)
Total	**1,246.1**	**0.0**	**(87.5)**	**(174.9)**	**(218.6)**	**(208.0)**	**(197.4)**	**(186.8)**	**(176.2)**
Total Expenditure									
Southwest incl.Barrage	18,685.0	101.3	78.4	156.9	1,039.1	1,059.6	1,263.5	1,467.4	1,487.9
South Central	746.7	128.1	140.2	280.4	148.3	138.4	128.6	118.7	108.9
Total	19,431.8	229.4	218.6	437.3	1,187.4	1,198.0	1,392.1	1,586.1	1,596.7
Net Economic Cash Flows (Million Taka)									
Southwest Region (incl.Barrage	*NPV*								
Total Expenditure	18,685.0	101.3	78.4	156.9	1,039.1	1,059.6	1,263.5	1,467.4	1,487.9
Total Benefits	23,831.9	-	84.9	169.9	264.7	373.7	541.0	745.6	987.6
Net Benefits	5,146.9	(101.3)	6.5	13.0	(774.4)	(685.9)	(722.5)	(721.8)	(500.3)
	14.8%	*EIRR*							
South Central									
Total Expenditure	746.7	128.1	140.2	280.4	148.3	138.4	128.6	118.7	108.9
Total Benefits	9,909.0	-	31.5	62.9	142.9	210.0	333.8	488.9	675.0
Net Benefits	9,162.2	(128.1)	(108.7)	(217.4)	(5.4)	71.5	205.3	370.1	566.1
	47.8%	*EIRR*							
Overall Southwest Area									
Total Expenditure	19,431.8	229.4	218.6	437.3	1,187.4	1,198.0	1,392.1	1,586.1	1,596.7
Total Benefits	33,740.9	-	116.4	232.8	407.6	583.7	874.8	1,234.5	1,662.6
Net Benefits	14,309.1	(229.4)	(102.2)	(204.4)	(779.8)	(614.3)	(517.2)	(351.6)	65.8
	19.8%	*EIRR*							

Source : Southwest and South Central Region Combined RAOM

Note: All analyses are based on mid 1991 prices

Table 6.1 (contd.)
Economic Cash Flows
Ganges Barrage minus Reference Situation

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	9	10	11	12	13	14	15	16	17	18
Economic Benefit Cash Flows (Million Taka)										
Southwest										
Agricultural benefits	1,585.4	2,024.3	2,568.8	3,181.7	3,863.0	4,612.6	5,478.3	6,460.2	7,489.8	8,567.3
Capture Fisheries and Shrimp	(336.3)	(405.0)	(473.6)	(542.3)	(610.9)	(679.6)	(759.4)	(839.3)	(919.1)	(998.9)
Damage reduction (MTk/yr)	17.8	16.1	14.4	12.7	11.0	9.3	16.1	23.0	29.9	36.7
Total	1,266.9	1,635.4	2,109.5	2,652.1	3,263.0	3,942.2	4,735.0	5,643.9	6,600.6	7,605.1
South Central										
Agricultural benefits	1,725.4	2,099.1	2,511.2	2,930.4	3,356.9	3,790.6	4,222.5	4,652.8	5,074.1	5,486.5
Capture Fisheries and Shrimp	(852.0)	(985.8)	(1,119.6)	(1,253.4)	(1,387.2)	(1,521.0)	(1,722.3)	(1,923.7)	(2,125.1)	(2,326.4)
Damage reduction (MTk/yr)	18.9	25.2	31.5	37.9	44.2	50.6	55.5	60.4	65.4	70.3
Total	892.2	1,138.5	1,423.1	1,714.9	2,014.0	2,320.2	2,555.7	2,789.5	3,014.4	3,230.5
Totals for Southwest Area										
Agricultural benefits	3,310.8	4,123.4	5,080.0	6,112.2	7,219.9	8,403.2	9,700.9	11,113.0	12,564.0	14,053.8
Capture Fisheries	(1,188.3)	(1,390.8)	(1,593.2)	(1,795.7)	(1,998.1)	(2,200.6)	(2,481.8)	(2,763.0)	(3,044.1)	(3,325.3)
Damage reduction (MTk/yr)	36.6	41.3	45.9	50.5	55.2	59.8	71.6	83.4	95.3	107.1
Total	2,159.1	2,773.9	3,532.7	4,367.0	5,276.9	6,262.4	7,290.7	8,433.5	9,615.1	10,835.5
Economic Investment Cash Flows (Million Taka)										
Total Capital Costs										
Southwest incl.Barrage	7,885.8	7,885.8	7,885.8	7,885.8	7,885.8	994.2	994.2	994.2	994.2	994.2
South Central	207.3	207.3	207.3	207.3	207.3	221.1	221.1	221.1	221.1	221.1
Total	8,093.1	8,093.1	8,093.1	8,093.1	8,093.1	1,215.3	1,215.3	1,215.3	1,215.3	1,215.3
Total Recurrent Costs										
Southwest incl.Barrage	(56.5)	141.7	339.9	538.2	736.4	934.6	963.0	991.4	1,019.8	1,048.2
South Central	(125.9)	(126.4)	(126.8)	(127.3)	(127.8)	(128.2)	(140.5)	(152.9)	(165.2)	(177.5)
Total	(182.4)	15.4	213.1	410.9	608.6	806.3	822.4	838.5	854.7	870.8
Total Expenditure										
Southwest incl.Barrage	7,829.3	8,027.5	8,225.7	8,423.9	8,622.2	1,928.8	1,957.2	1,985.6	2,014.0	2,042.4
South Central	81.4	80.9	80.4	80.0	79.5	92.9	80.5	68.2	55.9	43.6
Total	7,910.7	8,108.4	8,306.2	8,503.9	8,701.7	2,021.6	2,037.7	2,053.8	2,069.9	2,086.1
Net Economic Cash Flows (Million Taka)										
Southwest Region (incl.Barrage										
Total Expenditure	7,829.3	8,027.5	8,225.7	8,423.9	8,622.2	1,928.8	1,957.2	1,985.6	2,014.0	2,042.4
Total Benefits	1,266.9	1,635.4	2,109.5	2,652.1	3,263.0	3,942.2	4,735.0	5,643.9	6,600.6	7,605.1
Net Benefits	(6,562.4)	(6,392.2)	(6,116.2)	(5,771.9)	(5,359.2)	2,013.5	2,777.8	3,658.3	4,586.6	5,562.6
South Central										
Total Expenditure	81.4	80.9	80.4	80.0	79.5	92.9	80.5	68.2	55.9	43.6
Total Benefits	892.2	1,138.5	1,423.1	1,714.9	2,014.0	2,320.2	2,555.7	2,789.5	3,014.4	3,230.5
Net Benefits	810.9	1,057.6	1,342.7	1,635.0	1,934.5	2,227.3	2,475.2	2,721.3	2,958.5	3,186.8
Overall Southwest Area										
Total Expenditure	7,910.7	8,108.4	8,306.2	8,503.9	8,701.7	2,021.6	2,037.7	2,053.8	2,069.9	2,086.1
Total Benefits	2,159.1	2,773.9	3,532.7	4,367.0	5,276.9	6,262.4	7,290.7	8,433.5	9,615.1	10,835.5
Net Benefits	(5,751.6)	(5,334.5)	(4,773.5)	(4,136.9)	(3,424.7)	4,240.8	5,253.0	6,379.6	7,545.1	8,749.5

Table 6.1 (contd.)
Economic Cash Flows
Ganges Barrage minus Reference Situation

	2011 19	2012 20	2013 21	2014 22	2015 23	2016 24	2017 25	2018 26	2019 27	2020 28
Economic Benefit Cash Flows (Million Taka)										
Southwest										
Agricultural benefits	9,692.4	10,798.5	11,885.4	12,905.5	13,858.6	14,744.9	15,564.2	16,316.7	17,069.2	17,821.6
Capture Fisheries and Shrimp	(1,078.7)	(1,125.0)	(1,171.2)	(1,217.4)	(1,263.6)	(1,309.8)	(1,356.0)	(1,402.3)	(1,448.5)	(1,494.7)
Damage reduction (MTk/yr)	43.6	43.6	43.7	43.7	43.8	43.8	43.9	43.9	44.0	44.0
Total	8,657.3	9,717.2	10,758.0	11,731.8	12,638.8	13,478.9	14,252.1	14,958.4	15,664.6	16,370.9
South Central										
Agricultural benefits	5,890.1	6,257.5	6,588.7	6,892.8	7,169.7	7,419.4	7,641.9	7,837.1	8,032.4	8,227.7
Capture Fisheries and Shrimp	(2,527.8)	(2,631.0)	(2,734.2)	(2,837.4)	(2,940.6)	(3,043.8)	(3,147.0)	(3,250.2)	(3,353.4)	(3,456.6)
Damage reduction (MTk/yr)	75.3	74.7	74.0	73.4	72.8	72.2	71.5	70.9	70.3	69.7
Total	3,437.6	3,701.1	3,928.6	4,128.9	4,301.9	4,447.8	4,566.4	4,657.9	4,749.3	4,840.8
Totals for Southwest Area										
Agricultural benefits	15,582.5	17,056.0	18,474.2	19,798.3	21,028.3	22,164.3	23,206.1	24,153.8	25,101.6	26,049.3
Capture Fisheries	(3,606.5)	(3,755.9)	(3,905.4)	(4,054.8)	(4,204.2)	(4,353.6)	(4,503.0)	(4,652.5)	(4,801.9)	(4,951.3)
Damage reduction (MTk/yr)	118.9	118.3	117.7	117.1	116.6	116.0	115.4	114.8	114.3	113.7
Total	12,094.8	13,418.3	14,686.5	15,860.7	16,940.7	17,926.6	18,818.5	19,616.2	20,414.0	21,211.7
Economic Investment Cash Flows (Million Taka)										
Total Capital Costs										
Southwest incl.Barrage	674.0	674.0	674.0	674.0	674.0	674.0	674.0	674.0	674.0	674.0
South Central	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Total	680.1	680.1	680.1	680.1	680.1	680.1	680.1	680.1	680.1	680.1
Total Recurrent Costs										
Southwest incl.Barrage	1,076.7	1,091.4	1,106.2	1,120.9	1,135.7	1,150.4	1,165.2	1,179.9	1,194.7	1,209.4
South Central	(189.8)	(189.1)	(188.4)	(187.8)	(187.1)	(186.5)	(185.8)	(185.1)	(184.5)	(183.8)
Total	886.9	902.3	917.7	933.1	948.6	964.0	979.4	994.8	1,010.2	1,025.6
Total Expenditure										
Southwest incl.Barrage	1,750.6	1,765.4	1,780.2	1,794.9	1,809.7	1,824.4	1,839.2	1,853.9	1,868.7	1,883.4
South Central	(183.7)	(183.0)	(182.3)	(181.7)	(181.0)	(180.3)	(179.7)	(179.0)	(178.4)	(177.7)
Total	1,567.0	1,582.4	1,597.8	1,613.2	1,628.7	1,644.1	1,659.5	1,674.9	1,690.3	1,705.7
Net Economic Cash Flows (Million Taka)										
Southwest Region (incl.Barrage										
Total Expenditure	1,750.6	1,765.4	1,780.2	1,794.9	1,809.7	1,824.4	1,839.2	1,853.9	1,868.7	1,883.4
Total Benefits	8,657.3	9,717.2	10,758.0	11,731.8	12,638.8	13,478.9	14,252.1	14,958.4	15,664.6	16,370.9
Net Benefits	6,906.6	7,951.8	8,977.8	9,936.9	10,829.1	11,654.5	12,412.9	13,104.4	13,796.0	14,487.5
South Central										
Total Expenditure	(183.7)	(183.0)	(182.3)	(181.7)	(181.0)	(180.3)	(179.7)	(179.0)	(178.4)	(177.7)
Total Benefits	3,437.6	3,701.1	3,928.6	4,128.9	4,301.9	4,447.8	4,566.4	4,657.9	4,749.3	4,840.8
Net Benefits	3,621.2	3,884.1	4,110.9	4,310.5	4,482.9	4,628.1	4,746.1	4,836.9	4,927.7	5,018.5
Overall Southwest Area										
Total Expenditure	1,567.0	1,582.4	1,597.8	1,613.2	1,628.7	1,644.1	1,659.5	1,674.9	1,690.3	1,705.7
Total Benefits	12,094.8	13,418.3	14,686.5	15,860.7	16,940.7	17,926.6	18,818.5	19,616.2	20,414.0	21,211.7
Net Benefits	10,527.9	11,835.9	13,088.7	14,247.4	15,312.0	16,282.6	17,159.0	17,941.3	18,723.6	19,505.9

Table 6.1 (contd.)
Economic Cash Flows
Ganges Barrage minus Reference Situation

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	29	30	31	32	33	34	35	36	37	38
Economic Benefit Cash Flows (Million Taka)										
Southwest										
Agricultural benefits	18,574.1	19,219.0	19,756.5	20,186.5	20,509.0	20,724.0	20,831.5	20,831.5	20,831.5	20,831.5
Capture Fisheries and Shrimp	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)
Damage reduction (MTk/yr)	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1
Total	17,077.2	17,722.2	18,259.7	18,689.6	19,012.1	19,227.1	19,334.6	19,334.6	19,334.6	19,334.6
South Central										
Agricultural benefits	8,423.0	8,590.3	8,729.8	8,841.4	8,925.1	8,980.9	9,008.8	9,008.8	9,008.8	9,008.8
Capture Fisheries and Shrimp	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)
Damage reduction (MTk/yr)	69.0	69.0	69.0	69.0	69.0	69.0	69.0	69.0	69.0	69.0
Total	4,932.2	5,099.6	5,239.1	5,350.7	5,434.3	5,490.1	5,518.0	5,518.0	5,518.0	5,518.0
Totals for Southwest Area										
Agricultural benefits	26,997.0	27,809.4	28,486.3	29,027.9	29,434.1	29,704.8	29,840.2	29,840.2	29,840.2	29,840.2
Capture Fisheries	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)
Damage reduction (MTk/yr)	113.1	113.1	113.1	113.1	113.1	113.1	113.1	113.1	113.1	113.1
Total	22,009.4	22,821.8	23,498.7	24,040.3	24,446.5	24,717.2	24,852.6	24,852.6	24,852.6	24,852.6
Economic Investment Cash Flows (Million Taka)										
Total Capital Costs										
Southwest incl.Barrage	-	-	-	-	-	-	-	-	-	-
South Central	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-
Total Recurrent Costs										
Southwest incl.Barrage	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2
South Central	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)
Total	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1
Total Expenditure										
Southwest incl.Barrage	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2
South Central	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)
Total	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1
Net Economic Cash Flows (Million Taka)										
Southwest Region (incl.Barrage										
Total Expenditure	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2
Total Benefits	17,077.2	17,722.2	18,259.7	18,689.6	19,012.1	19,227.1	19,334.6	19,334.6	19,334.6	19,334.6
Net Benefits	15,853.0	16,498.0	17,035.5	17,465.4	17,787.9	18,002.9	18,110.4	18,110.4	18,110.4	18,110.4
South Central										
Total Expenditure	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)
Total Benefits	4,932.2	5,099.6	5,239.1	5,350.7	5,434.3	5,490.1	5,518.0	5,518.0	5,518.0	5,518.0
Net Benefits	5,115.4	5,282.7	5,422.2	5,533.8	5,617.5	5,673.3	5,701.2	5,701.2	5,701.2	5,701.2
Overall Southwest Area										
Total Expenditure	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1
Total Benefits	22,009.4	22,821.8	23,498.7	24,040.3	24,446.5	24,717.2	24,852.6	24,852.6	24,852.6	24,852.6
Net Benefits	20,968.4	21,780.7	22,457.7	22,999.2	23,405.4	23,676.2	23,811.6	23,811.6	23,811.6	23,811.6

Table 6.1 (contd.)
Economic Cash Flows
Ganges Barrage minus Reference Situation

	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
	39	40	41	42	43	44	45	46	47	48
Economic Benefit Cash Flows (Million Taka)										
Southwest										
Agricultural benefits	20,831.5	20,831.5	20,831.5	20,831.5	20,831.5	20,831.5	20,831.5	20,831.5	20,831.5	20,831.5
Capture Fisheries and Shrimp	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)	(1,540.9)
Damage reduction (MTk/yr)	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1
Total	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6
South Central										
Agricultural benefits	9,008.8	9,008.8	9,008.8	9,008.8	9,008.8	9,008.8	9,008.8	9,008.8	9,008.8	9,008.8
Capture Fisheries and Shrimp	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)	(3,559.8)
Damage reduction (MTk/yr)	69.0	69.0	69.0	69.0	69.0	69.0	69.0	69.0	69.0	69.0
Total	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0
Totals for Southwest Area										
Agricultural benefits	29,840.2	29,840.2	29,840.2	29,840.2	29,840.2	29,840.2	29,840.2	29,840.2	29,840.2	29,840.2
Capture Fisheries	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)	(5,100.7)
Damage reduction (MTk/yr)	113.1	113.1	113.1	113.1	113.1	113.1	113.1	113.1	113.1	113.1
Total	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6
Economic Investment Cash Flows (Million Taka)										
Total Capital Costs										
Southwest incl.Barrage	-	-	-	-	-	-	-	-	-	-
South Central	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-
Total Recurrent Costs										
Southwest incl.Barrage	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2
South Central	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)
Total	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1
Total Expenditure										
Southwest incl.Barrage	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2
South Central	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)
Total	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1
Net Economic Cash Flows (Million Taka)										
Southwest Region (incl.Barrage										
Total Expenditure	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2	1,224.2
Total Benefits	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6	19,334.6
Net Benefits	18,110.4	18,110.4	18,110.4	18,110.4	18,110.4	18,110.4	18,110.4	18,110.4	18,110.4	18,110.4
South Central										
Total Expenditure	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)	(183.1)
Total Benefits	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0	5,518.0
Net Benefits	5,701.2	5,701.2	5,701.2	5,701.2	5,701.2	5,701.2	5,701.2	5,701.2	5,701.2	5,701.2
Overall Southwest Area										
Total Expenditure	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1	1,041.1
Total Benefits	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6	24,852.6
Net Benefits	23,811.6	23,811.6	23,811.6	23,811.6	23,811.6	23,811.6	23,811.6	23,811.6	23,811.6	23,811.6

The cost benefit flows in Table 6.1 are over a 50 year period in order to include the benefits from the construction of the proposed Ganges Barrage scheduled between 2001 and 2005. The Barrage is an integral part of the lóng term development of SWA.

The analysis indicates that the programme will achieve an overall economic internal rate of return (EIRR) of 19.8%; 14.8% for SWR including the Ganges Barrage and 47.8% for SCR. The net present values (NPV) at a 12% discount rate and benefit : cost ratios will be:

	NPV M Tk	B/C ratio
SWR	5147	1.28
SCR	9162	13.27
SWA	14309	1.74

A number of sensitivity analyses were carried out with the results summarised in Table 6.2.

TABLE 6.2

Summary of Regional Plan Sensitivity Analyses

	South West Region			South Central Region			Southwest Area		
	EIRR %	NPV (12%) Mtk	B/C ratio	EIRR %	NPV (12%) Mtk	B/C %	EIRR %	NPV (12%) Mtk	B/C ratio
Base Case	14.8	5147	1.3	47.8	9162	13.3	19.8	14309	1.7
Sensitivity Analyses									
Costs +20%	12.7	1410	1.1	43.1	9013	11.1	16.8	10423	1.5
Benefits -20%	12.2	381	1.0	42.1	7180	10.6	16.1	7561	1.4
Costs +20% and benefits -20%	10.3	(3357)	0.9	38.0	7031	8.9	13.7	3675	1.2
Benefits delayed 2 years	12.1	172	1.0	34.3	7112	10.5	15.2	7284	1.4
Switching values									
Benefits minus %		(22.5)			(92.1)			(43.0)	
Costs plus %		29.0			1160			75.0	
Ganges Barrage Costs only %		(50.0)							

Source: Consultants' estimates.

The sensitivity analyses show that the overall Regional Plan proposed is likely to be acceptable, in all cases it exceeds the required 12% opportunity cost of capital set by FPCO. The programme for SCR will definitely be acceptable, even if costs increase by 20% and benefits fall by a similar proportion or benefits are delayed two years the EIRR does not fall below 34%. In contrast the proposals for SWR which include the Ganges Barrage can be considered marginal. The EIRR falls below 12%, to 10.4%, if both costs and benefits change by 20%. The three other sensitivity analyses all reduce the EIRR to between 12% and 13%. However the estimates of costs and benefits have assumed that the full cost of the Barrage is offset against benefits from the Ganges Right Bank. It has not been possible to assess benefits that may be realised from development on the Left Bank. If these were included the SWR Plan could be more attractive.

A preliminary economic analysis was carried out for the progressive development of the Area and the results may be summarised as in Table 6.3.

TABLE 6.3

Summary of Economic Analysis for Progressive Development of SWA

Phase	Flow required through Gorai (m^3/s)	Area benefitted (ha)	EIRR
With Gorai Augmentation only	170	165,000	15.6%
With Ganges Barrage (current flows)	660	663,000	19.8%
With Ganges Barrage (unlimited flows)	1010	1,070,000	17.0%

The results, though approximate at this level of study, clearly indicate that the proposals are worth considering further and feasibility studies should be initiated to assess the viability in more detail.

As would be expected, the Ganges Barrage development as described has a major impact on food production and in Planning Units SW1 to SW6 and SW8 would create surpluses in 2020. Significant improvements would also be achieved in SW7, SW9 and SW10 also and overall shortages within the Region would be reduced to 25% in 2020. However it may be noted that SW11 to SW14 will still remain in considerable deficit.

Benefits from the Regional Plan expressed in terms of nutritional energy have also been assessed. The results are summarised in Table 6.4.

TABLE 6.4

Food Energy Balances Without and With the SWA Regional Plan

	1991	1995	2000	2010	2020
Deficit percent					
Without Plan					
SWR	33	36	40	45	50
SCR	34	35	37	40	46
With Plan					
SWR	33	35	33	24	25
SCR	34	27	27	24	30
No. Planning Units with no deficit					
Without Plan					
SWR	2	2	1	-	-
SCR	-	-	-	-	-
With Plan					
SWR	3	3	3	6	7
SCR	1	1	1	1	-

Source: Consultants' estimates.

The results, though approximate, indicate that the SWA proposals will substantially reduce the area's present food energy deficits particularly in SWR, both before and after the Ganges Barrage is constructed.

6.4.3 Prefeasibility Studies

The results of the economic analyses for the Chenchuri Beel Rehabilitation Project and the Gorai Augmentation Project reflect the two schemes' very different cost-benefit structures.

The results of the analyses set out in Table 6.5 are based on FPCO's May 1992 GPA and data from MPO, BBS as well as the Consultants' own investigations. The analyses assumed a 30 year project life with no residual value and a discount rate of 12% in line with FPCO's requirements.

TABLE 6.5

Summary Results of the Economic Analyses of the Chenchuri Beel and Gorai Augmentation Projects (1991 economic values)

Project Indicator	Base case	Costs x 1.2	Benefits x 0.8	Costs x1.2 + Benefits x0.8	Benefits delayed 2 years
Chenchuri Beel					
EIRR %	30.7	25.3	24.1	19.2	20.7
NPV (12%) Mtk	351.9	282.3	211.9	142.3	212.8
B/C ratio	2.01	1.68	1.61	1.34	1.62
Gorai Augmentation					
EIRR %	15.6	12.3	11.6	8.6	11.9
NPV (12%) Mtk	1799.5	174.3	(185.6)	(1810.8)	(44.5)
B/C ratio	1.22	1.02	0.98	0.81	0.99

Source: Consultants' estimates.
Gorai Augmentation Project, Volume 12.
Chenchuri Beel Project, Volume 13.

The results indicate that the Chenchuri Beel Rehabilitation Project is likely to be a favourable national investment. The Gorai Augmentation Project in contrast is marginal in economic terms if a 12% opportunity cost of capital is accepted as necessary. Details of the analyses and costs are given in Volumes 12 and 13.

6.4.4 Other Development Projects

Seven development projects were identified during the study's preliminary screening of development prospects one of which, the Chenchuri Beel Rehabilitation Project, was carried forward for further assessment after the Second Interim Report (Section 6.4.2).

The results of the base economic analyses for the other six Projects are given in Table 6.6. The high returns reflect the chosen objective to select at this stage only those projects that are likely to give rapid returns and the targeting of the projects to parts of the study area which the SWA studies indicated appear likely to give the greatest benefits to irrigation and related FCD development.

Details of the analyses and costs are given in Volume 13.

TABLE 6.6

Summary of SWA Selected Projects Economic Analyses (1991 Economic values)

Project	Base Case		
	EIRR %	NPV 12% M Tk	B/C ratio
Chenchuri Beel	30.7	352	2.01
Arial Khan	33.7	2122	1.87
Padma Kumar	32.5	1340	1.73
Barisal Irrigation	24.6	251	1.37
Swarupkati	29.6	275	1.40
Bishkhali	30.0	466	1.58
Narail	21.0	359	1.29

Source : Consultant's estimates.

Benefit/Cost Ratio is generally accepted as a good measure to rank independent projects to determine the order in which they should be undertaken. For each project this is given in Table 6.6 as part of the base analysis. The ranking that result from this is :

Project	Ranking
Chenchuri Beel	1
Arial Khan	2
Padma Kumar	3
Bishkhali	4
Swarupkati	5
Barisal	6
Narail	7

6.5 Investment Requirements

The chosen option of Regional Development with FCD, surface irrigation, augmentation of flows in the Gorai river and the Ganges Barrage will require an investment of Tk 82115 M between 1991 and 2020 at 1991 financial prices.

The flow of investment is summarised in Table 6.7 by five year periods and in Table 6.8 by individual year.

Table 6.7
Proposed Ganges Barrage Development
Financial Investment Cash Flows
(Million Taka and Million Taka per Year)

From : / To :		1993 / 1995	1996 / 2000	2001 / 2005	2006 / 2010	2011 / 2015	2016 / 2020	2021 / 2025	2026 / 2030	2031 / 2035	2036 / 2040
Overall Capital Investment (excluding Groundwater)											
	M.Taka										
Ganges Barrage	48,000.0	–	1,200.0	46,800.0	–	–	–	–	–	–	–
Southwest	28,923.7	673.0	7,754.3	4,903.9	6,823.6	4,384.4	4,384.4	–	–	–	–
South Central	5,191.7	838.9	1,470.9	1,356.0	1,445.9	40.0	40.0	–	–	–	–
Total	82,115.4	1,511.9	10,425.2	53,059.9	8,269.5	4,424.5	4,424.5	–	–	–	–
Overall Pumping and O&M (excluding Groundwater) [1]											
	M.Taka/year										
Maintenance Dredging	6.6	–	11.5	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Southwest	1,377.9	(15.8)	(3.8)	669.7	1,604.4	1,798.7	1,897.7	1,957.1	1,957.1	1,957.1	1,957.1
South Central	220.5	14.4	83.5	191.0	256.8	277.9	276.9	276.3	276.3	276.3	276.3
Total	1,605.1	(1.4)	91.3	867.5	1,868.1	2,083.4	2,181.4	2,240.2	2,240.2	2,240.2	2,240.2
Groundwater Development Capital											
	M.Taka										
Southwest	958.3	352.0	409.2	194.6	1.3	0.6	0.6	–	–	–	–
South Central	2,676.9	803.9	1,094.9	772.7	2.3	1.5	1.5	–	–	–	–
Total	3,635.1	1,155.9	1,504.1	967.3	3.7	2.1	2.1	–	–	–	–
Groundwater Pumping and O&M Costs [1]											
	M.Taka/year										
Southwest	210.9	185.4	197.4	213.2	217.8	217.4	216.2	215.4	215.4	215.4	215.4
South Central	132.9	72.2	103.1	135.4	148.1	145.3	145.1	145.0	145.0	145.0	145.0
Total	343.8	257.6	300.5	348.6	365.9	362.6	361.3	360.4	360.4	360.4	360.4
Total Capital Costs											
	M.Taka										
Southwest incl.Barrage	77,882.0	1,025.0	9,363.5	51,898.4	6,824.9	4,385.0	4,385.0	–	–	–	–
South Central	7,868.6	1,642.8	2,565.8	2,128.7	1,448.2	41.5	41.5	–	–	–	–
Total	85,750.5	2,667.8	11,929.3	54,027.2	8,273.2	4,426.6	4,426.6	–	–	–	–
Total Recurrent Costs											
	M.Taka/year										
Southwest incl.Barrage	1,595.5	169.7	205.2	889.8	1,829.0	2,022.9	2,120.7	2,179.3	2,179.3	2,179.3	2,179.3
South Central	353.5	86.6	186.6	326.4	404.9	423.1	422.0	421.3	421.3	421.3	421.3
Total	1,948.9	256.2	391.8	1,216.2	2,233.9	2,446.0	2,542.6	2,600.6	2,600.6	2,600.6	2,600.6
Total Expenditure											
	M.Taka										
Southwest incl.Barrage	93,836.5	1,194.7	9,568.7	52,788.3	8,653.9	6,407.9	6,505.7	2,179.3	2,179.3	2,179.3	2,179.3
South Central	11,403.3	1,729.4	2,752.4	2,455.1	1,853.2	464.6	463.5	421.3	421.3	421.3	421.3
Total	105,239.7	2,924.0	12,321.0	55,243.3	10,507.1	6,872.6	6,969.2	2,600.6	2,600.6	2,600.6	2,600.6

Note [1] : *O&M costs are split approximately by proportioning on capital costs*
Source : Southwest And South Central Region Combined RAOM Results

Table 6.8

Financial Investment Cash Flows (Million Taka)

Proposed Ganges Barrage Development

		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
		1	2	3	4	5	6	7	8	9	10	11	12
Overall Capital Investment (excluding Groundwater)	Total												
Ganges Barrage	48,000.0	–	–	–	–	–	240.0	480.0	480.0	9,360.0	9,360.0	9,360.0	9,360.0
Southwest	28,923.7	142.0	177.0	354.0	1,550.9	1,550.9	1,550.9	1,550.9	1,550.9	980.8	980.8	980.8	980.8
South Central	5,191.7	168.1	223.6	447.2	294.2	294.2	294.2	294.2	294.2	271.2	271.2	271.2	271.2
Total	82,115.4	310.1	400.6	801.2	1,845.0	1,845.0	2,085.0	2,325.0	2,325.0	10,612.0	10,612.0	10,612.0	10,612.0
Overall Pumping and O&M (excluding Groundwater) [1]	*Average*												
Maintenance Dredging	6.9	–	–	–	–	5.8	11.5	17.3	23.0	6.8	6.8	6.8	6.8
Southwest	1,436.0	29.2	(15.8)	(60.7)	(83.2)	(43.5)	(3.8)	35.9	75.6	115.4	392.5	669.7	946.9
South Central	229.1	0.8	14.4	28.0	34.8	59.1	83.5	107.9	132.2	156.6	173.8	191.0	208.2
Total	1,672.0	29.9	(1.4)	(32.7)	(48.4)	21.4	91.3	161.1	230.9	278.8	573.2	867.5	1,161.9
Groundwater Development Capital	*Total*												
Southwest	958.3	126.1	75.3	150.6	81.8	81.8	81.8	81.8	81.8	38.9	38.9	38.9	38.9
South Central	2,676.9	253.1	183.6	367.2	219.0	219.0	219.0	219.0	219.0	154.5	154.5	154.5	154.5
Total	3,635.1	379.2	258.9	517.8	300.8	300.8	300.8	300.8	300.8	193.5	193.5	193.5	193.5
Groundwater Pumping and O&M Costs [1]	*Average*												
Southwest	212.0	183.2	185.4	187.7	188.9	193.1	197.4	201.7	206.0	210.3	211.8	213.2	214.7
South Central	135.4	61.6	72.2	82.8	88.0	95.6	103.1	110.6	118.1	125.7	130.5	135.4	140.2
Total	347.4	244.8	257.6	270.5	276.9	288.7	300.5	312.3	324.1	335.9	342.3	348.6	355.0
Total Capital Costs	*Total*												
Southwest incl.Barrage	77,882.0	268.2	252.3	504.5	1,632.7	1,632.7	1,872.7	2,112.7	2,112.7	10,379.7	10,379.7	10,379.7	10,379.7
South Central	7,868.6	421.2	407.2	814.4	513.2	513.2	513.2	513.2	513.2	425.7	425.7	425.7	425.7
Total	85,750.5	689.3	659.5	1,319.0	2,145.9	2,145.9	2,385.9	2,625.9	2,625.9	10,805.4	10,805.4	10,805.4	10,805.4
Total Recurrent Costs	*Average*												
Southwest incl.Barrage	1,654.9	212.3	169.7	127.0	105.7	155.4	205.2	254.9	304.7	332.5	611.1	889.8	1,168.5
South Central	364.6	62.4	86.6	110.7	122.8	154.7	186.6	218.5	250.4	282.3	304.3	326.4	348.4
Total	2,019.4	274.7	256.2	237.7	228.5	310.1	391.8	473.4	555.0	614.7	915.4	1,216.2	1,516.9
Total Expenditure	*Total*												
Southwest incl.Barrage	157,315.1	480.5	422.0	631.6	1,738.4	1,788.1	2,077.9	2,367.6	2,417.4	10,712.2	10,990.8	11,269.5	11,548.2
South Central	25,368.9	483.6	493.8	925.1	636.0	667.9	699.7	731.6	763.5	708.0	730.0	752.1	774.1
Total	182,684.0	964.1	915.7	1,556.7	2,374.4	2,456.0	2,777.6	3,099.3	3,180.9	11,420.2	11,720.9	12,021.6	12,322.3

Source : Southwest and South Central Region Combined RAOM

Note: All analyses are based on mid 1991 prices

Table 6.8 (Contd)

	2005 13	2006 14	2007 15	2008 16	2009 17	2010 18	2011 19	2012 20	2013 21	2014 22	2015 23	2016 24	2017 25
Overall Capital Investment (excluding Groundwater)													
Ganges Barrage	9,360.0	-	-	-	-	-	-	-	-	-	-	-	-
Southwest	980.8	1,364.7	1,364.7	1,364.7	1,364.7	1,364.7	876.9	876.9	876.9	876.9	876.9	876.9	876.9
South Central	271.2	289.2	289.2	289.2	289.2	289.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total	10,612.0	1,653.9	1,653.9	1,653.9	1,653.9	1,653.9	884.9	884.9	884.9	884.9	884.9	884.9	884.9
Overall Pumping and O&M (excluding Groundwater) [1]													
Maintenance Dredging	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Southwest	1,224.1	1,501.3	1,552.8	1,604.4	1,655.9	1,707.5	1,759.1	1,778.9	1,798.7	1,818.5	1,838.3	1,858.1	1,877.9
South Central	225.4	242.6	249.7	256.8	264.0	271.1	278.3	278.1	277.9	277.7	277.5	277.3	277.1
Total	1,456.3	1,750.7	1,809.4	1,868.1	1,926.8	1,985.5	2,044.2	2,063.8	2,083.4	2,103.0	2,122.6	2,142.2	2,161.8
Groundwater Development Capital													
Southwest	38.9	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
South Central	154.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	193.5	0.7	0.7	0.7	0.7	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Groundwater Pumping and O&M Costs [1]													
Southwest	216.2	217.7	217.7	217.8	217.8	217.8	217.9	217.6	217.4	217.1	216.9	216.6	216.4
South Central	145.1	149.9	149.0	148.1	147.2	146.3	145.3	145.3	145.3	145.2	145.2	145.2	145.1
Total	361.3	367.6	366.8	365.9	365.0	364.1	363.2	362.9	362.6	362.4	362.1	361.8	361.5
Total Capital Costs													
Southwest incl.Barrage	10,379.7	1,365.0	1,365.0	1,365.0	1,365.0	1,365.0	877.0	877.0	877.0	877.0	877.0	877.0	877.0
South Central	425.7	289.6	289.6	289.6	289.6	289.6	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Total	10,805.4	1,654.6	1,654.6	1,654.6	1,654.6	1,654.6	885.3	885.3	885.3	885.3	885.3	885.3	885.3
Total Recurrent Costs													
Southwest incl.Barrage	1,447.1	1,725.8	1,777.4	1,829.0	1,880.6	1,932.2	1,983.8	2,003.3	2,022.9	2,042.4	2,062.0	2,081.5	2,101.1
South Central	370.5	392.5	398.7	404.9	411.2	417.4	423.6	423.4	423.1	422.9	422.7	422.4	422.2
Total	1,817.6	2,118.3	2,176.1	2,233.9	2,291.7	2,349.5	2,407.4	2,426.7	2,446.0	2,465.3	2,484.7	2,504.0	2,523.3
Total Expenditure													
Southwest incl.Barrage	11,826.8	3,090.8	3,142.4	3,194.0	3,245.6	3,297.2	2,860.8	2,880.3	2,899.9	2,919.4	2,939.0	2,958.6	2,978.1
South Central	796.2	682.1	688.4	694.6	700.8	707.0	431.9	431.7	431.4	431.2	431.0	430.7	430.5
Total	12,623.0	3,772.9	3,830.7	3,888.6	3,946.4	4,004.2	3,292.7	3,312.0	3,331.3	3,350.6	3,370.0	3,389.3	3,408.6

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Table 6.8 (Contd)

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	26	27	28	29	30	31	32	33	34	35	36	37	38
Overall Capital Investment (excluding Groundwater)													
Ganges Barrage	–	–	–	–	–								
Southwest	876.9	876.9	876.9	–	–								
South Central	8.0	8.0	8.0	–	–								
Total	884.9	884.9	884.9	–	–	–	–	–	–	–	–	–	–
Overall Pumping and O&M (excluding Groundwater) [1]													
Maintenance Dredging	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Southwest	1,897.7	1,917.5	1,937.3	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1
South Central	276.9	276.7	276.5	276.3	276.3	276.3	276.3	276.3	276.3	276.3	276.3	276.3	276.3
Total	2,181.4	2,201.0	2,220.6	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2
Groundwater Development Capital													
Southwest	0.1	0.1	0.1	–	–								
South Central	0.3	0.3	0.3	–	–								
Total	0.4	0.4	0.4	–	–	–	–	–	–	–	–	–	–
Groundwater Pumping and O&M Costs [1]													
Southwest	216.2	215.9	215.7	215.4	215.4	215.4	215.4	215.4	215.4	215.4	215.4	215.4	215.4
South Central	145.1	145.1	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0
Total	361.3	361.0	360.7	360.4	360.4	360.4	360.4	360.4	360.4	360.4	360.4	360.4	360.4
Total Capital Costs													
Southwest incl.Barrage	877.0	877.0	877.0	–	–	–	–	–	–	–	–	–	–
South Central	8.3	8.3	8.3	–	–	–	–	–	–	–	–	–	–
Total	885.3	885.3	885.3	–	–	–	–	–	–	–	–	–	–
Total Recurrent Costs													
Southwest incl.Barrage	2,120.7	2,140.2	2,159.8	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3
South Central	422.0	421.7	421.5	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3
Total	2,542.6	2,562.0	2,581.3	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6
Total Expenditure													
Southwest incl.Barrage	2,997.7	3,017.2	3,036.8	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3
South Central	430.3	430.1	429.8	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3
Total	3,427.9	3,447.3	3,466.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6

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Table 6.8 (Contd)

	2031 39	2032 40	2033 41	2034 42	2035 43	2036 44	2037 45	2038 46	2039 47	2040 48
Overall Capital Investment (excluding Groundwater)										
Ganges Barrage										
Southwest										
South Central										
Total	-	-	-	-	-	-	-	-	-	-
Overall Pumping and O&M (excluding Groundwater) [1]										
Maintenance Dredging	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Southwest	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1	1,957.1
South Central	276.3	276.3	276.3	276.3	276.3	276.3	276.3	276.3	276.3	276.3
Total	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2	2,240.2
Groundwater Development Capital										
Southwest										
South Central										
Total	-	-	-	-	-	-	-	-	-	-
Groundwater Pumping and O&M Costs [1]										
Southwest	215.4	215.4	215.4	215.4	215.4	215.4	215.4	215.4	215.4	215.4
South Central	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0
Total	360.4	360.4	360.4	360.4	360.4	360.4	360.4	360.4	360.4	360.4
Total Capital Costs										
Southwest incl.Barrage	-	-	-	-	-	-	-	-	-	-
South Central	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-
Total Recurrent Costs										
Southwest incl.Barrage	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3
South Central	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3
Total	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6
Total Expenditure										
Southwest incl.Barrage	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3	2,179.3
South Central	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3	421.3
Total	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6	2,600.6

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In addition there is expected to be an investment of Tk 3635 M with or without the implementation of the Plan for exploitation of SWA's groundwater resources.

The phasing of costs will be:

	1991 1995	1996 2000	2001 2005	2006 2010	2011 2015	2016 2020
Percent total investment						
SWR [1]	1	10	69	9	6	5
SCR	16	28	26	28	1	1
SWA	2	11	66	10	6	5

[1] including Ganges Barrage.

The Ganges Barrage will account for 58% of total expenditure and results in almost 70% of expenditure in SWA being scheduled for 2001-2005.

The costs of operation and maintenance of the Plan are also given in the two tables. They will rise to Tk 2240 M each year which capital development is complete in 2020.

The expenditures in terms of the total available cultivable area of 25608 km² will be:

		Capital investment Tk/ha	O & M Costs from 2021 Tk/ha
SWR			
	With Barrage	47130	
	Without Barrage	17720	1203
SCR		5590	300
SWA		32070	875

7 SOCIAL AND ENVIRONMENTAL IMPACTS

7.1 Introduction

This section summarises the potential social and environmental impacts of the Regional Water Resources Management Plan. It also attempts to identify areas where mitigatory measures need to be undertaken. The methodology for social and environmental studies are described in Sections 5.2.6 and 5.2.8 respectively and the resources allocated were limited and therefore the studies lack in depth. However two limited RRAs were carried out, one in the flood prone area and existing FCD schemes in the north east and the other was directed to the two specific projects which were studied to pre-feasibility level. The results of these and the Initial Environmental Examination are given in Volume 9 - Impact Studies.

7.2 The Strategy for Water Resources Development

Within the Government's overall strategic framework, lies the implementation of a comprehensive system of flood control and drainage for the entire country. This is of significant social and environmental importance, since urban, rural, commercial, industrial, public utility infrastructures and communication network are to be protected from potential damages through effective land and water management. The regional plan proposes to make optimal use of the available water resources in coordination with one another, and with minimum dislocation to the people and the environment. Beneficiary participation is to be included as an essential component in the phases of planning, implementation, and the subsequent operation/evaluation and maintenance of all projects. The strategic regional plan has been constructed within this framework, for the water resources development in the region in the context of an environmentally and socially equitable development policy.

Within this context the Regional Water Resources Management Plan (RWRMP) is programmed to increase the per-capita rural income principally through better management of the Area's water resources that will enable further growth of agricultural production. Thirty-eight short, medium, and long-term structural water resources development options have been identified, in agreement with overall objectives of the regional plan. These projects are to provide flood protection, drainage congestion relief, augment surface water resources for irrigation and maintain the river channels. By the year 2020, the regional plan is expected to bring about 16.33% (7,010 km^2) of the entire project area under new and rehabilitated FCD schemes, and 23.77% (9,260 km^2) of it into surface and groundwater irrigation.

7.3 Social Impacts

7.3.1 Present Situation

The population of the SWA is about 26.1m and is increasing at a rate of about 1.89% which is slightly lower than the national average of 2.01%. About 91% of the SWAs population live in rural areas and most of them live below the poverty line. Literacy rate in the Area is under 25%. Landless and marginal farmers account for more than a third of the households.

The social problems are many and varied in the Area. At present, the situation in the Southwest Area does not look good. A special problem which is particular to the Area is the conflict between culture fishermen and agricultural farmers, since the introduction of shrimp-farming. This problem, however, is applicable only in the southern parts where brackish water allows shrimp-culture. While saline water helps the culture fishermen, it hurts the crop producer. The harmony has been disturbed because of rapid increases in culture shrimp farming, which is in itself, highly lucrative and generally practiced by the more influential who have access to development resources including credit and land. Between the other social groups, no major conflicts are prevalent.

The capture fishermen are facing a formidable economic state, which is adversely affecting their social standing. The causes underlying this are manifold. A dramatic decline has occurred in the stock of inland open-water capture fishery, causing loss of production and breeding areas through FCD developments, by fish diseases and possibly the increasing use of fertilisers and pesticides. Poor enforcement of governmental mandates against the catching of small fish has also contributed to the depletion of fish-stocks. The employment environment is undoubtedly becoming increasingly competitive as the proportion of capture fishermen is decreasing. Some of them migrate out of the region as economic refugees, a few switch to shrimp culture, while the remaining seek employment locally as unskilled labourers. Capture fishermen usually do not own land except those of their dwelling sites. Culture fishermen, on the contrary, usually have more capital assets, and a comparatively better social status. The non agricultural labour-force is mainly comprised of daily wage-labourers, professional servicemen, petty businessmen, and female workers engaged in various in-door and out-door activities. Unemployment and underemployment abound because of a high population density and low levels of literacy. Female participation in the active labour force is steadily increasing, and so is their level of literacy vis a vis that of males. But their social status is still much undermined as they continue to be looked down upon. And though their status may have improved in the recent past, it still has a long way to go, to achieve a reasonable degree of equity. Health, hygiene, and sanitation facilities still remain poor and there are inadequate opportunities for recreation, entertainment, and enjoyment. The rate of deforestation in the southern parts, e.g., the Sundarbans, exceeds that of social forestation. Source of safe potable water are threatened in areas where over exploitation of shallow aquifer through uncontrolled use of shallow tubewells has resulted in the drying up of manually operated tubewells used for potable water.

Stagnant open water bodies, ponds, borrow pits etc, and the spread of water weeds provide excellent breeding conditions for disease vectors such as mosquitoes and parasites. From areas where the salinity level has exceeded the level suitable for human consumption eco-migration occurs mostly to the north and north-west of the country, and to the west into India (West-Bengal).

7.3.2 Social Impact Evaluation

Improved water management will principally benefit those directly related to the agricultural sector. The FCD/I schemes will increase crop productivity and cropping intensities, because most farmers, it is predicted, will switch to HYV cultivation. The escalating demand for agricultural labour will decrease unemployment and disguised unemployment which abound in the region. Additional temporary employment generation will occur during project implementation works. Intra-regional migration of labour, which transpires seasonally within the region, may also likely to lessen. The labour-wage rate should increase consequently, commensurate with the increase in labour demand. Though incremental agricultural output will be the principal benefit from the projects, non-agricultural labour demand will also increase for the marketing processes of additional production.

Embankments will provide rural transport and improved land communication. People will benefit from psychologically as well. They will enjoy a greater sense of security from flooding being within the protection of FCD/I projects. Increased average incomes will lead to improved diets and food security. Enhanced confidence from financial stability will afford them the necessary impetus to be entrepreneurial. The application of the "grassroot" approach if effective will invite the beneficiaries to be included in the project itself. They will be more willing to support the operation and maintenance measures. Overall, the standard of living of the beneficiaries will improve, along with their health and sanitation facilities if the Regional Plan is implemented with the political will to ensure that planning and design as well as O&M are sensibly carried out.

Particular problems exist in FCD schemes with respect to the dwellers on the char islands, and the special needs of the char dwellers should be addressed in the cases of the Ganges, Padma and Lower Meghna embankments. Although outside the project area these peoples' needs should be integrated into these FCD schemes. These needs should be identified by peoples' participation programmes, and addressed in project design, so as to ensure that they are also able to benefit (or be less disadvantaged) by these particular projects.

Villages should have sufficient pit latrines to ensure that open defecation in or near the channels does not occur. These should be sited well away from water bodies, as part of project works. In addition to these measures, hygiene education should be put in place by suitable NGOs as a part of the project.

Land acquisition, estimated at approximately three percent of the project area, is undoubtedly destined to be one of the greatest disbenefit arising out of the regional plan. Unfortunately, it is a necessary and an inevitable concomitant to the implementation of any structural project. The minimal area of land will be acquired, and adequate compensation should be given to the owners, but the institutional arrangements are such that the actual disbursements of money follows a tedious process. Corruption in the system is an additional detriment that needs to be addressed.

The fishery of the inland rivers, beels, and floodplain, are the most vulnerable to the effects of FCD developments because of the obstruction to fish spawning, feeding migrations, and the draining of the many formerly productive and consequent reductions in floodplain areas. Capture fishery will suffer from further decline as their natural movement area is restricted. The coastal polders will hurt the capture fishermen for the same reason. A reduction in capture fishermen will change their traditional heritage in the area. The natural and physical changes, due to the constructions, will impede with, and hinder water navigability, both in the rivers and in their tributaries though project design is expected to reduce this adverse effect as far as possible.

The impetus for development beyond the projects are left to the private sector; but the possible adverse social effects will need to be ascertained and minimised. Despite the disbenefits, the regional plan has the potential to satisfy long-standing social needs through the optimal use of the water resource.

At the feasibility study level, the negative impacts that are identified will be addressed in detail and mitigatory measures will be taken into account in the project design.

7.4 Environmental Impacts

7.4.1 Introduction

The balance of the environmental factors in the ecosystem of the Southwest Area is extremely complicated and delicate. Within these complex physical conditions, many factors are interrelated, and changes in one affects the others. Predictions of the effects of man-made changes in its environment are therefore, difficult. In consideration of the potential impacts of the Regional Water Resources Management Plan (RWRMP), a number of important environmental issues are to be dealt with. The most important amongst these are salinity levels, ground and surface water uses, sedimentation, spreading of water-borne diseases, water and soil pollution, impacts on fisheries, agriculture, forestry, land and water transport, and population.

The Southwest Area is presently facing a dire state of affairs in terms of its natural environmental harmony and the preservation thereof. The repercussions of reduced water levels in the Ganges river, and its principal distributaries such as the Gorai, Arial Khan etc., has disrupted fishing and navigation, brought unwanted salt deposits into rich farming soil, allowed greater saline intrusion northwards, affected agricultural and industrial productions, changed the hydraulic characteristics of the rivers, and caused changes in the ecology of the delta.

A primary objective of the Regional Plan is to ensure that both dry season and wet season surface water flows are secured for the Area. No formal groundwater development strategy as such is included in the regional plan. However, there are reasons for expecting that groundwater exploitation will inevitably occur, financed by the private sector. Surface water augmentation; and Flood Control, Drainage, and Irrigation (FCD/I) schemes however, are likely to have both positive and negative effects on the environment. The negative effects, however, need to be studied in detail so that mitigation measures can be recommended.

7.4.2 Initial Environmental Examination

(a) Impacts of surface water augmentation

The benefits of surface water augmentation schemes would mainly be to the agricultural sector, through increased crop productivity, cropping intensity, and a greater distribution of agricultural income. The overwhelming majority of farmers, it is predicted, will switch to HYV cultivation, as a result of the additional water availability in the rivers and canals in the dry season. Surface water augmentation, depending upon its volume, will reclaim certain portions of land area already affected by salinity.

The option for initial and subsequent maintenance dredging will pose considerable problems for spoil disposal, year after year, and the sand dredged from Gorai is an unsuitable medium for agriculture. Dredged material would be used for construction of the offtake embankments, filling of the existing borrowpits and widening of river embankments. Some navigation improvements may also be expected from dredging. During construction work, substrate displacement, caused by the dredging, will severely harm the riverine capture fishery. Therefore the economic returns will be reduced from local fish culture. The amount of fish loss, however, is unquantifiable at this stage. Riverine communities that rely heavily on boat transport, will be disadvantaged by barriers to movement posed by barrages and structures. Land will be excavated after acquisition, for the construction of link canals and irrigation systems. Khulna municipal water supply will be benefitted, as 10 cumecs (m^3/s) water will be diverted into Chitra river.

(b) Impacts of FCD and FCD/I schemes

The proposed development comprises improvements of existing FCD areas, embankments along unprotected boundary rivers, controlled flooding and drainage, and compartmentalisation of the area, using the existing rural road networks. It also includes the rehabilitation of flood embankments along the Padma and Arial Khan rivers. Both surface and groundwater have been considered to be available for irrigation. Improved water management will principally benefit those directly related to the agricultural sector, and the reasons have already been mentioned.

In the Regional Plan, land acquisition, estimated at approximately three percent of the project area, is undoubtedly a principal disbenefit arising out of FCD/I projects. Unfortunately, in terms of both loss of agricultural production and available homestead land, it is a necessary evil, and an inevitable concomitant of the FCD/I schemes. Material excavated during the canal/drain construction will be mainly used to improve the existing road network, and to construct new ones. The expansion of agricultural land may require forest areas, resulting in deforestation. The fishery of the inland rivers, wetlands, and consequent reductions in floodplain areas. Capture fishery is likely to suffer from further declines as their natural movement area is restricted. The coastal polders may hurt the capture fishermen for the same reason. The natural and physical changes, due to constrictions, will impede with, and hinder water navigability, both in the rivers and their tributaries.

The expansion of water surfaces resulting from FCD/I projects is very likely to increase water-related diseases. Insects that breed in the water, however, can be controlled through chemical means. The problem of these water-borne diseases will increase further, when people start using canals for bathing and drinking purposes. Those mainly reliant on groundwater for irrigation may adversely affect rural potable water supplies, decreasing the underground freshwater aquifer levels. In addition, all FCD/I projects are likely to have a degree of operational complexity, as far as operations and maintenance are concerned. Embankments will help serve rural land transport, and hamper navigation. The possibility exists of a fall-off in the surface water quality with increasing HYV cultivation, due to dissolved agrochemicals as a result of irrigation. If the potential and expected increase in agricultural production is attained, resulting from FCD/I schemes, nitrate pollution of the soil may occur. The enormous quantities of pesticides necessary for the cultivation of HYV's may cause bio and chemical degradation and cause a threat to the environment.

(c) Impacts of Groundwater utilisation

The Regional plan does not include formalised groundwater utilisation in any of its projects, but it is expected that farmers, in need of additional fresh water supplies will exploit that resource through the use of shallow and deep tubewells. In the northern-half of the Southwest Area, there is enough groundwater available and even appreciable exploitation should not pose any significant problems. But in the southern part, where salinity levels are comparatively higher, excess use of groundwater will deplete the fresh water aquifer, with detrimental effect on the potable and irrigation water supply. But in the region as a whole, the farmers must take care not to use too many DTWs in close proximities, because doing so might decrease the ground water table to the extent that potable water is inaccessible through hand tubewells.

(d) Impacts of Coastal Embankment Projects

The recommended strategy would intervene in the coastal zone to revitalise the Coastal Embankment Project (CEP) and prevent further deterioration. Interventions would be required progressively as the delta attains a new equilibrium, based on augmented flows from the upstream strategies. The strategy presumes that the Southwest Area will remain tidally dominated. The projects would open up channels which would drain to the Sundarbans. The impacts of these flows may change the rates of sedimentation, and affect the water quality, due to upstream irrigated agriculture. The main industrial effluent artery, the Bhairab river, would benefit from maximum flows for dilution. The recommended macro polder is the most disruptive, in terms of works. Closure of channels may disrupt commercial and rural navigation.

(e) The Sundarbans

The main threat to the Sundarbans is over-felling, but the forestry management and development of forest products from the area is under study by the Sundarbans Integrated Management Project.

The problems posed by increasing or changed rates of sedimentation due to changes in channel flows still need to be determined. This will require both data collection, hydraulic and environmental modelling, as well as an understanding of the hydrology/botany interactions within the mangrove ecosystem. This work is beyond the resources of an EIA at feasibility study.

Accordingly it is recommended that a separate study be initiated to determine the dynamics of the wetlands ecosystem of the mangrove mosaic, with specific reference to determining the interactions between the hydrology, water chemistry, sedimentation rates and structure, and the mangrove community structures. This study should develop from its research a management plan for monitoring and managing the Sundarbans as a wetland ecosystem. This would provide a basis for future EIA work in connection with impacts on the Sundarbans, as well as being complementary to existing projects on the forest resources.

7.4.3 Mitigation of the Negative Environmental Impacts

Some of the negative impacts identified above can be mitigated and the following measures are proposed at this regional study stage.

With minimal land acquisition, landless can largely be mitigated through adequate monetary compensation, or alternatively, by designing embankments that can provide accommodation. The latter concept has an additional advantage, because villagers will have a vested interest in the maintenance of the embankments, which is essential to ensure flood protection over the long-term. The provision of roads as a substitute for navigation is not necessarily a mitigation solution in all areas. The provision of locks on barrages and regulators would allow the continuation of the use of rivers by country boats. This will mitigate the long-standing boatman-regulator conflict.

The fishing communities should be targeted for income support measures; the population growth rate should be minimised as much as possible within the region, by ensuring both home and food security, as well as alternative income generation activities, other than those related to agriculture. National efforts in population control through family planning must be rendered every support. Diseases transmitted through water may be avoided by good personal hygiene, therefore the projects need to identify the concerns of public health and sanitation. Deforestation in the Sundarbans must be controlled by the respective forestry management authorities. All mitigation measures, before application, should be subjected to public participation, in order to determine their actual impacts through primary surveys.

However, the major impacts on the river environment, due to considerable dredging requirements, do not allow significant mitigation. The removal of bed material has to be disposed of in some other area. The damage and disturbance to fish cannot be avoided, and fishing livelihood will be seriously affected. The only means by which this dredging impact could be avoided would be to have a sufficient flow of water that would dilute the suspended solids to a level tolerable to the fish. This solution, however, is unavailable from the Gorai augmentation scheme. But this mitigation can be successful in consideration of a Ganges Barrage, either with a long-term water sharing agreement with India to allow significant dry season flows down the Gorai, or with the construction of a link canal to allow flows from the Brahmaputra river to be diverted through the Ganges to maintain the hydraulic head upstream of the Ganges Barrage. The former is always the more favoured approach in financial and environmental terms and a water sharing agreement still remains the best option if it can be achieved.

8 RECOMMENDATIONS

8.1 General

The strategic analyses for the development and management of the water resources of the Southwest Area undertaken taking account of the policies and objectives of the GOB are described in detail in Section 5.

The recommended strategy may be summarised as follows:

- As a matter of priority securing the Gorai intake to preserve and control wet season flows and as an interim means of augmenting dry season flows
- Further expansion of irrigated agriculture and salinity control is possible only with further augmentation and control of dry season flows from the Ganges by a Ganges Barrage
- Phased Development of a programme of FCDI projects, including at an early stage, completion of the Ganges - Padma Right Bank protection works
- No embankment is constructed along the right bank of Lower Meghna and initiate studies to study the effects of left bank protection proposals on the right bank spill to SC Region
- Detailed studies and priority works to relieve drainage congestion within the polder area near Satkhira, and south of Khulna and preliminary studies of the area near Bagerhat
- Studies for improving the internal drainage of the polders in the South Central Region and implementation of it
- Long term programme for further drainage congestion relief works in the coastal areas in response to observed needs
- Non-structural measures like flood proofing and cyclone protection programmes in vulnerable areas accompanied by disaster preparedness and flood warning measures
- Parallel sector support for the development of agriculture, social forestry, capture and culture fisheries and, in the coastal areas, development of artisanal shrimp culture
- Programmes for institutional strengthening, technical and credit support facilities to assist private sector in minor irrigation development, and initiate action for improved operation and maintenance, cost recovery and, monitoring and evaluation.

8.2 Immediate Actions

Following the strategic analyses and the recommended strategy the Regional Water Resources Management Plan was formulated as shown in Figure 6.1. The Plan is structured into several phases linked to the estimated progressive increases in demands and to the necessity for major investments to create additional wealth in the Area. The different needs of the two regions in the Area (SWR and SCR) are recognised in the formulation of the Plan.

Within the short-term plan, clearly there are components which need immediate action. The Gorai Augmentation Project is one of the priority projects which is recommended to proceed as a matter of urgency. The pre-feasibility study undertaken as part of the present study, has shown the project to be feasible economically and technically, and therefore detailed feasibility studies should commence immediately followed by detailed design and tender documents. The pre-feasibility study, however, is based on the current dry season flows and during the feasibility study stage the risks related to basing the project on the existing rate of flows should be studied and if possible, quantified. Draft Terms of Reference for the Feasibility Study, together with a work programme, is included in the Pre-feasibility Study Report (Volume 12).

Parallel with this there are other FCD/I developments which could be implemented and benefits realised in the short term. There are several such schemes identified of which the following schemes are recommended for implementation in the first instance. These schemes were selected on the basis of their superior B/C Ratio, impacts on environment and the relative social benefits (eg: distribution of income).

(a) Chenchuri Beel FCD Rehabilitation Project
(b) Padma Kumar FCD/I Project
(c) Arial Khan FCD/I Project

In the Coastal zone three pilot schemes have been recommended for early implementation and these should be taken up as soon as possible. Out of the three, two schemes have been recommended for feasibility studies, which are :

- Khulna macro polder (Polders 17/1-2, 26, 18/19, 20 & 29)
- Satkhira polders (Polders 1, 2, 3)

The other scheme, Bagerhat Polder Drainage Scheme should be studied to pre-feasibility level in the first instance.

CERP II which includes Polder 25 (Beel Dakatia) is programmed in the short term and its implementation is recommended as soon as detailed designs including an Environmental and Social Impact Assessment surveys are completed.

The Study has concluded that for further expansion by irrigated agriculture beyond year 2000 and for maintaining the present morphology of the rivers and for salinity and environmental control, further augmentation of surface water by a Ganges Barrage is required. In order that a decision can be taken to implement this Project, detailed investigation and studies should be undertaken as a matter of priority.

8.3 Further Studies

In order that the priority developments as detailed in the Plan can proceed further, detailed studies to feasibility level should be undertaken for the following projects as a matter of priority.

- Gorai Augmentation Project
- Chenchuri Beel FCD Rehabilitation Project
- Padma Kumar FCD Project
- Arial Khan FCD Project
- Coastal Zone Pilot Projects
    - Khulna macro polder
    - Satkhira Polders

In addition to these, investigation and studies should be undertaken for the following projects :

- Ganges Barrage Project
- Lower Meghna River Study

In parallel with the above there are other studies which need to be undertaken in certain other sectors. These include :

- Institutional Development and Training Support
- Improved Operation and Maintenance and Cost Recovery
- Assessment of groundwater recharge potential
- Strengthening of groundwater monitoring and resource assessment
- Support for Minor Irrigation development
- Rural and Urban water supply programmes
- Initiating and continuation of monitoring of the Sundarbans
- Flood Proofing study and implementation
- Continuation of cyclone protection

It is further recommended that this Water Resources Management Plan be reviewed every five years and be subjected to a full re-evaluation every 10 years.

8.4 Data Collection

One of the drawbacks that was highlighted during the study is the lack of reliable baseline data. This, necessarily has meant relying on secondary data which are out-of-date and in some cases do not reflect the present situation. It is therefore recommended that a data collection programme be initiated either within the FAP or as a separate programme. Undoubtedly some primary data collection will be carried out when feasibility studies of the recommended projects are undertaken, but these will be of a short time scale and will be of little use for the regional/national data base.

Several areas have been identified during the course of the study which need primary data collection, principal amongst these are :

- River Discharges
- Water Quality Measurements (salinity, sediment sampling, etc)
- Agriculture
- Fisheries
- Navigation, country boats in particular
- Forestry (including Sundarbans)
- Environmental

Some of the supporting FAP studies have already started on this programme (eg: FAPs 24, 17) and this should be continued even after the related studies are completed so that up-to-date data is available for future studies. The newly reconstituted WARPO under the Ministry of Irrigation, Agriculture & Flood Control is in an ideal position to carryout some of the tasks.

9 REGIONAL WATER RESOURCE MANAGEMENT OPTIONS

9.1 Introduction

The objectives, needs and issues of the development of water resources in the Southwest Area are discussed in Chapter 3 in Part 1 of this Report. Taking these into cognisance and the policies of the GOB a wide range of options have been identified for the water resource development. Three major issues have been identified as the 'burning issues' in the TOR, which are:

- the augmentation of the dry season flows in the Gorai river
- flood control along the right bank of the Ganges - Padma river
- drainage improvement in the Coastal Embankment area.

These issues have been studied in detail and various options have been discussed in the subsequent sections. In addition other issues including salinity intrusion, water supply to Khulna, navigation including Mongla Port and the Sundarbans are also addressed and options are identified.

Options identified include structural as well as non-structural measures like controlled flooding, compartmentalisation, flood proofing and flood warning. Beneficiary participation has also been recognised as a pre-requisite to future planning and included in the development option.

9.2 Augmentation of Dry Season Flows

9.2.1 Introduction

Augmentation of dry season flows is a necessity for long term food security and sustainability of the Southwest Region whereas flows to the South Central Region are relatively abundant. Augmentation to the SWR in theory could be achieved from groundwater resource and/or surface water resource. The studies undertaken show that there is limited potential for groundwater development in the north and northeast areas of the region. However even with full exploitation of this resource there is a wide gap in the food grain sufficiency and augmentation from surface water resource becomes paramount.

To meet the current dry season requirement for water in the Southwest Region, flows from the boundary rivers must be effectively transferred to the areas of demand. A wide variety of options of how to do this have been considered including consideration of abstractions at various points from the Ganges or from the Padma as illustrated in Figure 9.1. The dry season water levels in the Padma and Meghna are low and to develop these sources extensive pumping against the gradient of the land would be required to command much of the Area. The Ganges therefore provides the most suitable source of surface water for augmenting the water supply to the Southwest Region and part of the South Central Region.

The distribution of water from the boundary rivers should ideally utilise existing rivers. The older Ganges spill rivers such as the Chandana and Matabhanga however are at too high a level for gravity flow with the current levels in the Ganges and in the last 25 years only the Gorai River has carried significant dry season flow. The active spil rivers on the Padma supply the Arial Khan which principally supplements the large Lower Meghna spill rivers. The saline front in the Meghna is normally downstream of the offtaking spill channels and therefore the rivers remain fresh. With increasing upstream abstractions the saine front will advance with the risk that the Lower Meghna spill rivers become saline. The impact of this on the South Central Region would be dramatic and the downstream effects of extraction must be taken into account on a National basis as in the National Water Plan. This allows for abstraction of water from the Ganges with maximum compensation releases of 100 m^3/s and the options considered by FAP-4 are consistent with this.

9.2.2 Identification of the Requirements and Options for Augmentation

The strongly perceived need for augmentation comes from a variety of sectors. These requirements have been studied and the potential benefits and alternative means of achieving the desired objectives have been considered. Because the costs of supplying water are likely to be relatively high, unrealistic expectations can be quickly identified and the approach has been to consider the use of water in the best way as a scarce and limited resource. Ideally the flow requirements in India should be considered in the same way to achieve an equitable distribution of the Ganges water.

Through extensive data collection and analysis it has been possible to quantify most of the requirements and benefits of augmentation. However sufficient study has been completed to prioritise the needs for augmentation and timing of the development of the source of water has been considered. The perceived needs are summarized in Table 9.1.

TABLE 9.1

Identification of needs for Augmentation of Dry Season Flows

Sector	Requirement	Desirable Flowrate in Dry Season (m^3/s)
Agriculture	Irrigation	1000
Khulna Water Supply	Salinity control Direct supply for domestic and industrial uses	150 - 200 10
Forestry	Commercial Production of Sundri in Sundarbans	> 250
Transportation	Mongla Port	1000

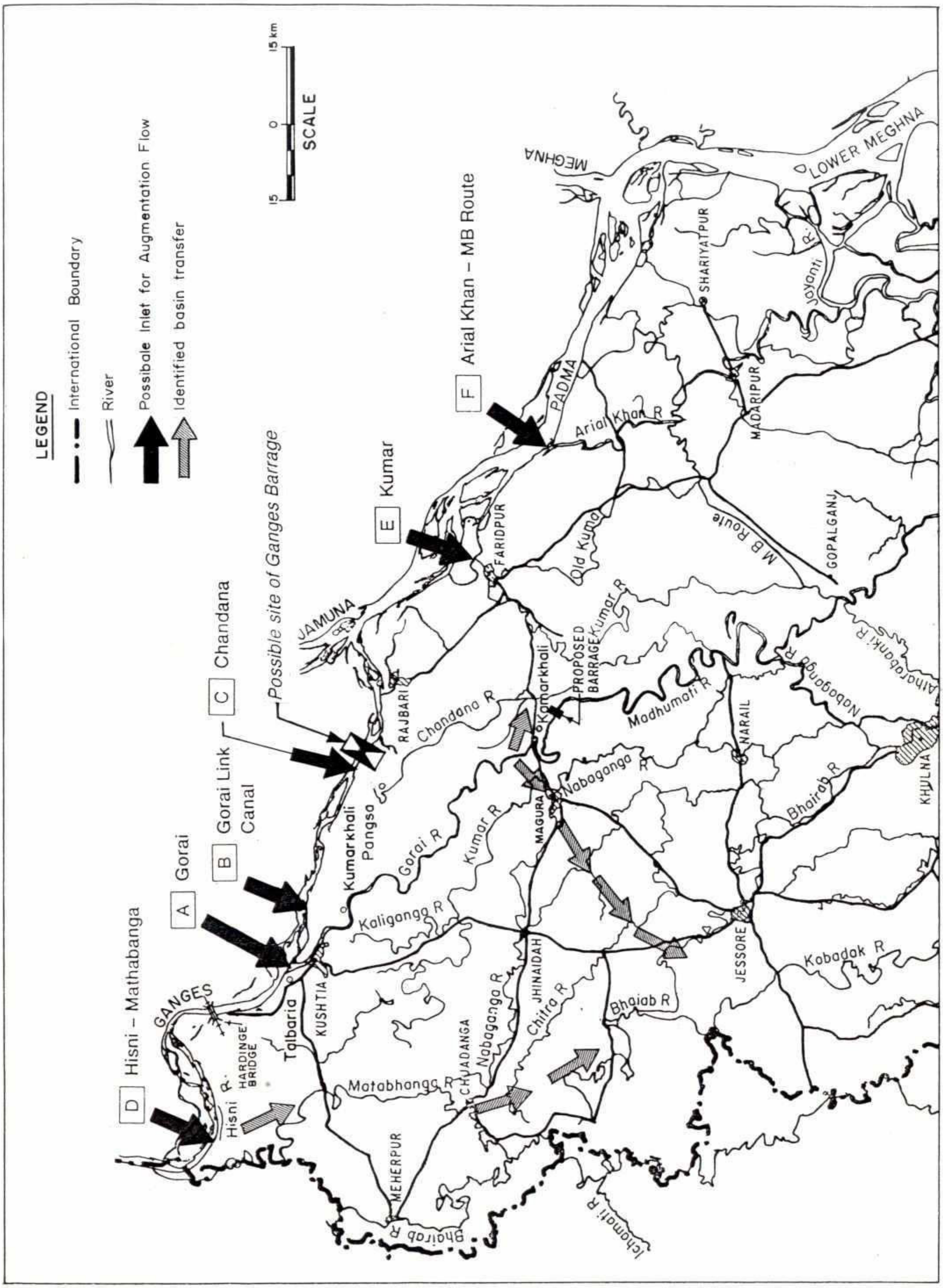
The actual requirements must be considered in light of what is practically attainable and it is therefore worth summarising the options for augmentation.

Considering the availability of the Ganges flows the current situation may be summarized:

Condition	Flow rate (m^3/s Monthly Average) Driest Month		
	Post Agreement 1989-1992	During the period 1976-1988*	Pre-Farakka 1934 - 1975
Minimum	517	664	1260
Mean	576	1063	2031

* 1978 to 1982 - Agreement with India
1983 to 1984 and 1986-1988 - Memorandum of Understanding

Figure 9.1



Augmentation Choices

Daily flow data show that minimum of less than 400 m^3/s have been recorded in 1992 and 1993.

The record since expiry of the agreement with India is too short to perform a valid statistical analysis and given the early monsoon of 1988 and the unusual dry nature of 1991 and 1992, the lowest expected mean monthly flow in the Ganges has been taken as 576 m^3/s for the current period until there is a new agreement with India.

The amount that may reasonably be abstracted without control on the Ganges is estimated as 350 m^3/s if there is 576 m^3/s in the river leaving 226 m^3/s flow downstream. The amount extractable with control in the Ganges can exceed the inflow by up to 250 m^3/s if storage is utilised.

9.2.3 Development Options

It is apparent that currently the water available in the Ganges is very limited. The G-K irrigation system already has a requirement for 100 - 120 m^3/s, leaving a maximum of 250 m^3/s that could be used elsewhere. Other posible options to increase this figure would be:

- Pumping from the Ganges or Padma with large pump stations (another 50 to 100 m^3/s could possibly be extracted from the Ganges).
- Improving the Arial Khan/Kumar/MBR link, however model simulations show this could provide only 50 m^3/s.
- Storage of water in Beels, silted rivers etc. Given the difficulty in finding suitable sites, the water supplied would only be limited and at a low level.
- Development of a barrage on the Ganges.
- Inter basin transfer within Bangladesh.
- Storage Dams in the Upstream Catchment.
- Long Term Agreement with India and other upstream users on the sharing of the low flows of the Ganges.

The final two "options" may be taken as desirable but require cooperation of the countries involved and are the subject of current Inter-Governmental negotiations the results of which will not be available during FAP-4. For planning purposes two scenarios are therefore assumed: "with agreement" flows in the Ganges, and the current condition "no agreement" but no deterioration.

9.2.4 Choices for Augmentation Routes

As discussed in section 9.2.2 there are a limited number of possible routes for major augmentation of dry season flows. In addition, there is the possibility of developing a limited number of schemes for smaller irrigation projects such as now being completed on the Nabaganga at Magura or as proposed for the Mathabanga/Upper Bhairab.

Without development of a major augmentation route such development will be limited.

The choices for main augmentation routes that were shown in Figure 9.1 are summarised in Table 9.2. The preferred route is through the Gorai for which more detailed costs and estimates of maintenance requirements have been prepared.

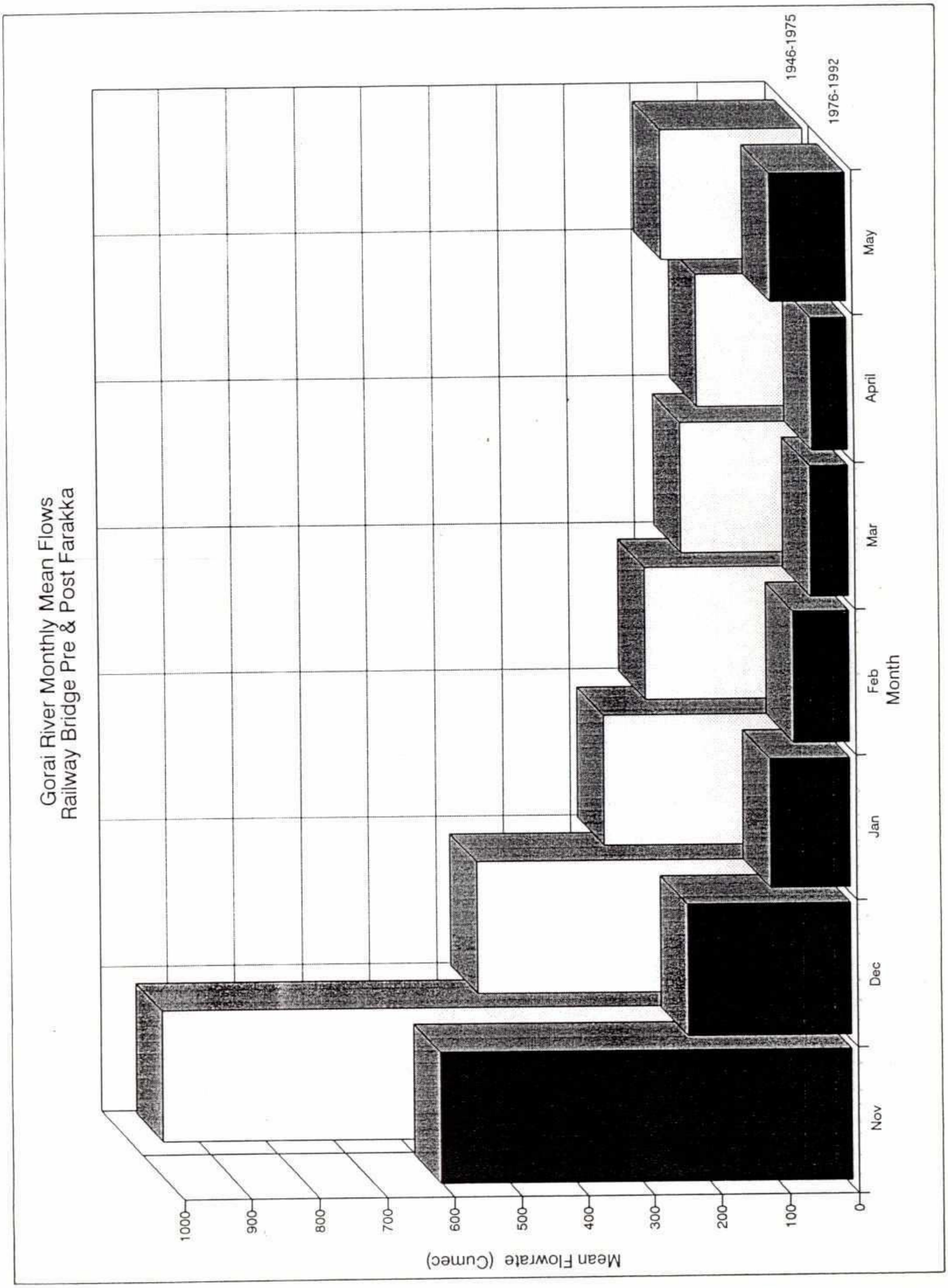
9.2.5 Gorai Schemes Routes A & B

The Gorai is the most suitable conveyor of flow to the Southwest Area given its position, the higher level of Ganges water at its offtake and the relatively lower bed level compared with any other spill river. The Gorai has carried minimum dry season flows of the order of 150 m^3/s in the pre-Farakka years (except during the cyclical low years) but in the past ten years flow has declined to practically zero and the river was dry throughout January to May in 1992 Figure 9.2).

The flowrate in the Gorai depends on water levels in the Ganges, its flow hydraulics and critically on accretion and erosion of the bed which are largely determined at high flows. Calculations show that there is a balanced transport of sediment down the Gorai river at flows in the Ganges of around 15000m3/s and that more sediment enters from the Ganges than can be transported through the Gorai at flows above this value. The Gorai system is potentially unstable and, once it starts to accrete significantly, accretion can be expected to accelerate.

The results from a morphological model of the Gorai and from extensive hydraulic modelling have been used to refine the estimates of initial dredging required and two dimensional modelling of the bed profiles around bends have been used to improve the estimates of maintenance dredging given in the Interim Report.

Figure 9.2



Gorai River Monthly Mean Flows, Pre & Post Farakka (Railway Bridge)

TABLE 9.2

Low Flow Augmentation Schemes and Indicative Costs

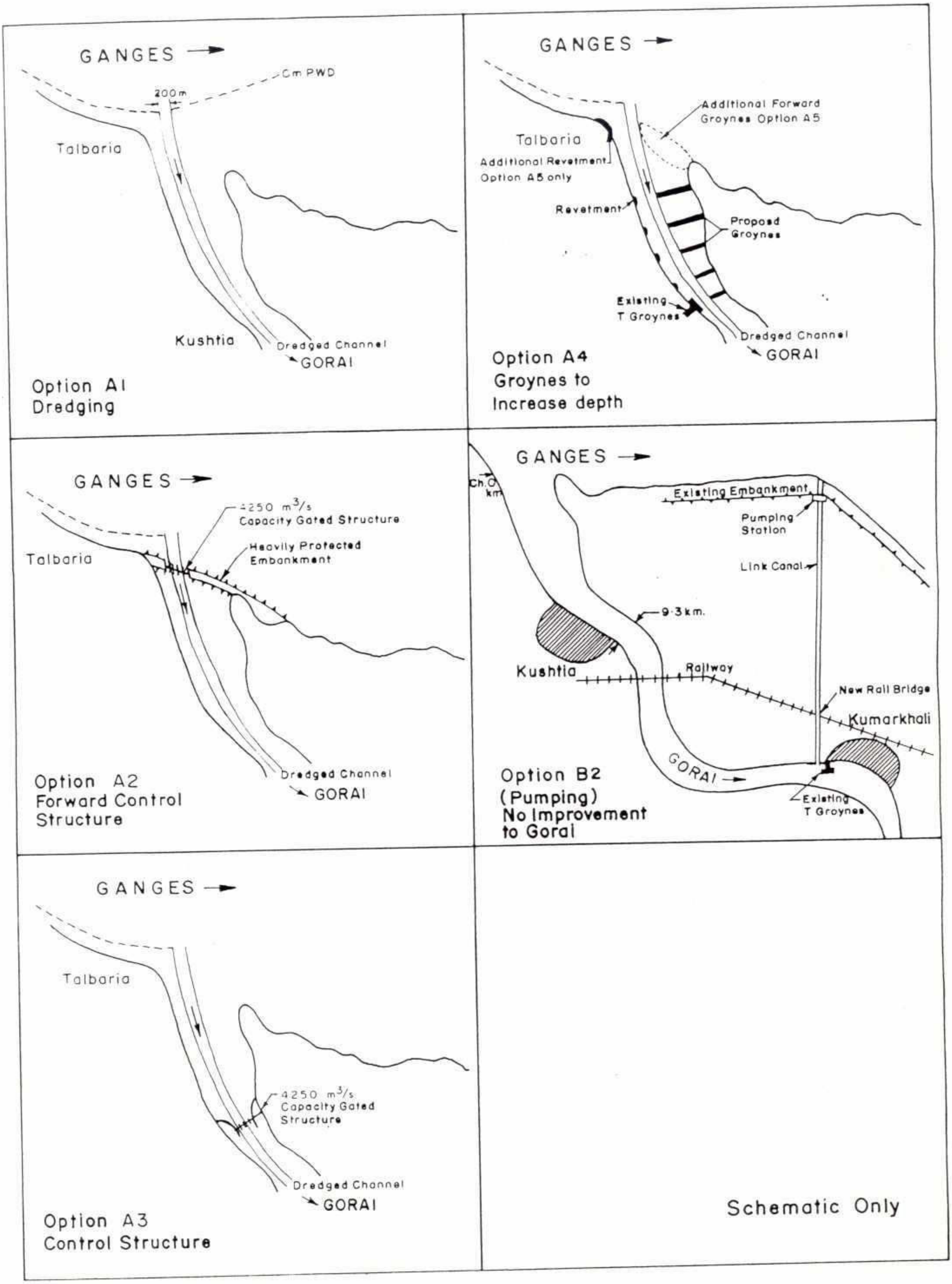
Distributor	Reference No	Description	Capital Costs (Annual Cost)+ MTK (1991 prices) For Augmentation Flowrate (m^3/s)				Remarks
			50	100	150	250	
Gorai	A1 Gravity Flow	Dredging of first 30 km of Gorai & disposal of Spoil. For 250 m^3/s augmentation river realignment at Kamarkhali necessary.	-	1785 (46)	2056 (71)	3453 (176)	Could be implemented quickly. Maintenance Dredging requirement should reduce if spoil disposal outside river system.
	A2 Gravity Flow	Control structure and Training embankment. Dredging of first 30 km of Gorai disposal of spoil. For 250 m^3/s augmentation realignment at Kamarkhali necessary.	-	4593 (31)	4892 (46)	6189 (116)	Control structure capacity in Flood = 4250 m^3/s to maintain size of channel in Madhumati; Gates to restrict flow post monsoon to induce slower recession of flow in Gorai.
	A3 Gravity Flow	Control structure set back and works as option A1.	-	3391 (42)	3690 (61)	4987 (151)	Increased maintenance before implementation of Ganges Barrage.
	A4 Gravity Flow	Training Groynes in Gorai + Dredging Realignment as option A1.	-	2600	3300	4200	Training Groynes restricts width of Gorai to induce deeper section and reduce maintenance dredging.
	B1 Gravity	Link Canal (8.5 km) to Kumarkhali Dredging & Kamarkhali realignment for Q = 250 m^3/s. Control structure at take off position in Ganges Right Embankment.	-	-	-	8300 (352)	Augments flow but does not improve Gorai mouth. Greater excavation than to improve Gorai.
	B2 Pumped	Pumping station to link canal alignment as B1. New rail bridge. No works in Gorai river.	-	1050 (164)	1800 (181)	2400 (204)	Major Pumping station and link canal. Land acquisition 105 ha. Significant construction time, possible power generation requirement.
Chandana	C1 Gravity	Excavation of deep channel along course of Chandana River. Control structure at Intake and upstream dredging to Ganges.	-	-	-	15000 (460)	Large Excavation required.
	C2 Pumped	Construct pumping station at existing embankment. Improve channel for higher flow rates than 50 m^3/s. Excavate upstream channel for Ganges	610 (96)	-	3000 (195)	4025 (236)	Existing channel most suited to flow of 50 m^3/s. Realignment of upstream channel could be considered.
Hisni/ Mathabhanga	D1 Pumped	Construct pumping station and link to supply dry season Flow to Mathabanga. Control structure on Mathabanga and improved link to Bhairab/Chitra.	1830 (110)	2560 (130)	3215 (200)	4470 (256)	Supplies area not easily reached by other schemes. Significant upstream dredging at mouth of Mathabanga.
Arial Khan	F1	Dredging of Kumar River linking Arial Khan and MBR. Construct half tide weir on Madhumati and dredge Atharbanki.	1600 (60)	-	-	-	Low flow only as low head available in Padma. Flow reduces if there is inflow from Gorai. Arial Khan rises earlier than Ganges.
	F2	Dredge Kumar and construct weir on Madhumati. Dredge Madhumati from Halifax cut to MBR.	-	2780 (125)	-	-	As option F1. Large amount of dredging in Madhumati.
Various + Link canals	G	Ganges Barrage at nodal point near to Chandana. Control at Gorai mouth necessary.	58000 - 87000 —— 600+ m^3/s				8-10 years construction period. Storage capacity could be used for balancing peak water demands.

+ Annual Costs Shown in parenthesis include maintenance dredging

Note: Financial Capital Costs given for development of water source but not including costs of distribution system.

Gravity schemes on the Gorai (as opposed to pumped options) improve both the dry season flow regime as well as the discharge and therefore may be expected to have benefits to the general "health" of the river. Having control over the flow rates at high flood levels may also have flood control and drainage benefits, but the capacity of any control structure has to be set to allow flows greater than the dominant discharge. This is to ensure that the morphology of the downstream reaches are not affected as they form a critical part of the Pussur/Sibsa system upon which the land drainage of a large area is dependent. As a result, whilst some measure of improved flood protection appears possible, improvements to drainage are likely to be not significant. Choosing an optimal balance between the various benefits and potential disbenefits requires further study. The morphology and hydraulics of the Ganges and Gorai have been studied including analyses of cross sections, planform changes and changes in rating curves at Hardinge Bridge, Gorai Railway Bridge and Kamarkhali. Further details of the comprehensive studies are presented in the final morphological report. Quantities of excavation required for the schemes were based on surveys carried out in 1992 as part of the study. The options for interventions that have been identified, including their component parts, are given in Table 9.3 and shown in Figure 9.3.

Figure 9.3



Possible Interventions at Gorai Mouth

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Table 9.3
Options for Interventions at Gorai Mouth

WORK COMPONENT		DRY SEASON AUGMENTATION OPTIONS										
		A1	A2	A3	A4	B1	B2	C1	C2	D1	F	G1
(a)	**Control Structures**											
a1	Control structure in Gorai Mouth			■								■
a2	Control structure at entrance to the Mouth		■									
a3	Weir on Madhumati										■	
a4	Control Structure on Matabhanga									■		
(b)	**Groynes in Gorai / Madhumati**											
b1	T - Groynes in Gorai Mouth (at intervals) up to Kushtia				■							
b2	Forward T - Groynes at entrance to the Mouth											
b3	Groynes at upstream and downstream of railway bridge	░	░	░	░							
b4	Kicker Groynes at flow cross-over locations	░	░	░	░							
(c)	**Capital Dredging**											
c1	Gorai dredging from Mouth to Kumarkhali (km 16)	■	■	■	■							
c2	Gorai dredging downstream of Kumarkhali (km 14)	■	■	■	■	■						
c3	Chandana dredging upstream of embankment											
c4	Hisni dredging upstream of embankment											
c5	MRB/Kumar dredging & Atharabanki dredging											
c6	MBR/Kumar & Madhumati dredging											
(d)	**Link Canal**											
d1	Kumarkhali link canal with control structure and railway bridge					■	■					
d2	Chandana link canal with new control structure							■	■░			
d3	Hisni P.S. to Matabhanga/Link to Chitra/Bhairab									■		
(e)	**River Realignment / Bend Cutoff - Gorai River**											
e1	Kamarkhali bend	■░	■░	■░	■░	■░						
e2	Lower reach bends (Gorai)	░	░	░	░	░						
(f)	**Pump Station**											
f1	Kumarkhali Pump Station						■					
f2	Chandana Pump Station								■			
f3	Hisni Pump Station									■		
(g)	**Ganges Control**											
g1	Ganges Barrage											■
g2	Low cost measures in Ganges at Gorai Mouth	░	░	░	░							
g3	Training Groynes in Ganges at Gorai Mouth	░	░	░	░							

■ Component part of Intervention, ░ Optional Component,
■░ Required for Higher Flowrates

[tony\tab9-3]

Extracting a significant proportion of the Ganges flow at the Gorai will slightly lower the water level at the G-K irrigation scheme intake. This has been studied as part of the pre-feasibility study (Volume 9) and the results show the effect is at most of the order of 0.1m depending on the flows in the Ganges and Gorai. This is a small impact compared to changes due to lowering of flows in the Ganges (the impact of Farakka has been to lower levels at Bheramara by approximately 1.5m).

Capital dredging is a component common to all schemes for increased flow into the Gorai mouth and entails a significant cost. The sensitivity of the capital dredging requirement to the flow in the Ganges is shown in Figure 9.4. This was derived using model simulation results using 1992 survey of bed levels in the Ganges and Gorai with cross-sections at 500m intervals to locally supplement the BWDB cross-sections which are more widely spaced. A contour map of the Ganges and Gorai based on the 1992 survey by FAP-4 in the area concerned is shown in Figure 9.5.

By disposing spoil in the Ganges near the river constriction (Figure 9.5) it may be possible to raise water levels slightly giving more flow into the Gorai. The need for such a measure is dependant on the flow in the Ganges and further measures such as bandaling to induce silting of the river where desired (as studied by FAP-21) could be considered as a way of increasing the Ganges water levels and thereby reducing the Gorai dredging requirements. The constricted sections move each year and surveys would need to be done in early October each year for work to be started later that month.

The disposal of spoil from the capital works would be partially in the Ganges, some at the Gorai near the railway bridge and a very limited amount on land bordering the Gorai. For maintenance works disposal could be within the river.

Option A1-Dredging Only

This option entails a major dredging and spoil disposal programme some of which will be on land and some pumped into the Ganges. Three flow rates have been considered,100, 150 and 250 m^3/s, for the highest flow a loop cutoff at Kamarkhali is necessary to improve flow conditions which should also help to maintain lower bed levels upstream. The cutoff is not essential for the lower flowrates and is therefore omitted, but could be desirable for reducing maintenance dredging. By dredging the upper reaches of the Gorai, the river realignment at Kamarkhali should not induce significant siltation downstream: morphological modelling of this aspect has shown this to be the case. The dredging component for obtaining a minimum flow of 250 m^3/s comprises 22 million m^3 in the first 30Km. Although there are parts of the river further down which do not have sufficient cross-sectional area, yothers, particularly near bends, have greatly excess capacity and it is assumed that with increased low flow some sediment will be redistributed by normal sediment transport.

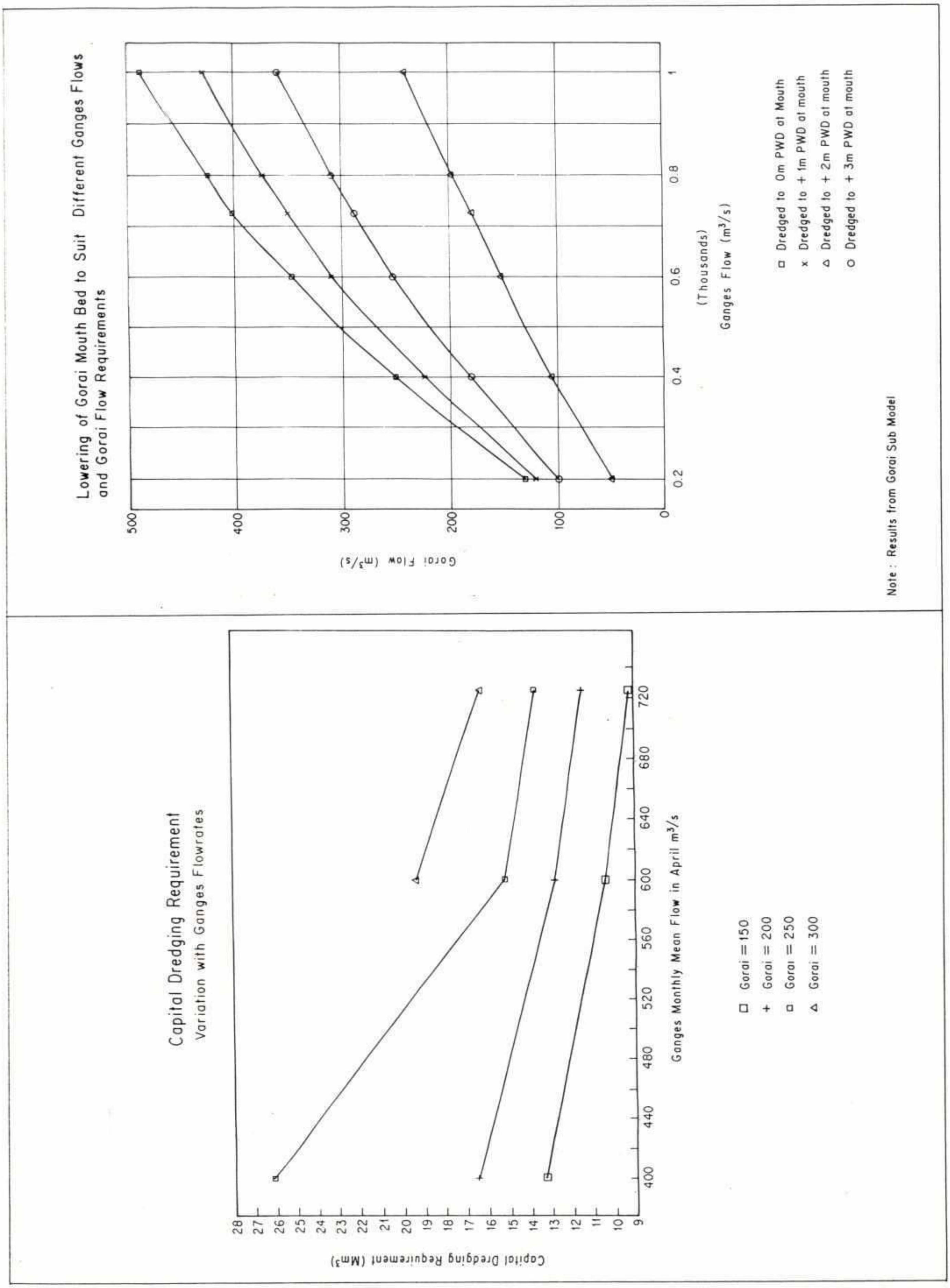
For 250 m^3/s, annual maintenance dredging is estimated as around 6 million m^3 though this will reduce as the Ganges orientation becomes more favourable and the condition of the Gorai improves. The costs of maintenance dredging have been included in the annual costs given in Table 9.2. The logistics involved in this amount of dredging is significant.

There will be an increased flood flow due to the increased areas of flow near the mouth which would result in increased flood peaks of about 10%. Towards the end of the wet season there would need to be a fairly high level of commitment to dredging at key points though a greater part of the spoil could be retained in either the Ganges or the Gorai river system.

Option A2 - Control Structure

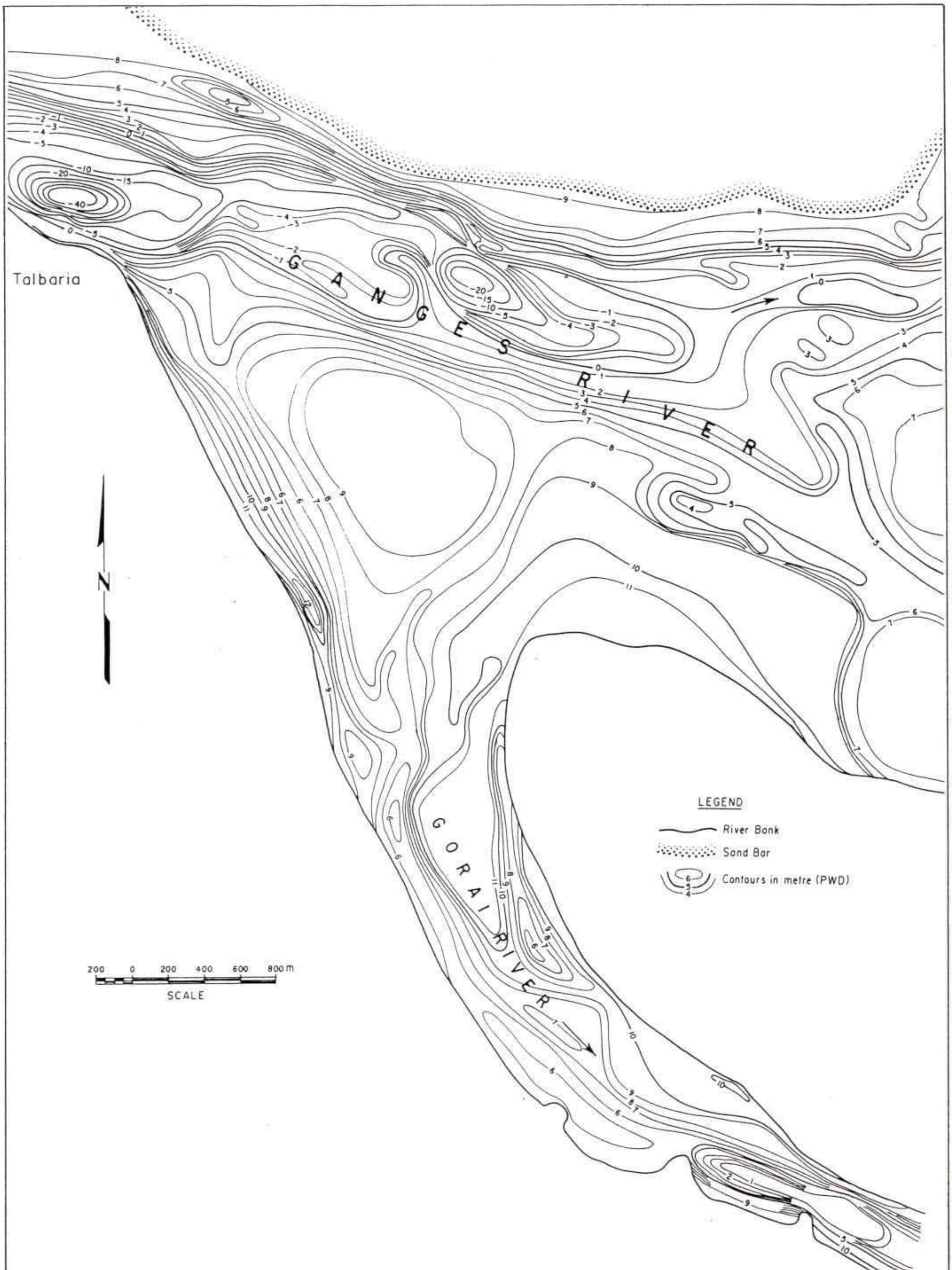
To control downstream flooding and to give the opportunity to control the rate of recession

Figure 9.4



Flow in Gorai for Different Dredging Options

Figure 9.5



Site Survey of Gorai Mouth, July 1992

of Gorai flows, a control structure could be provided in the mouth of the Gorai in a similar location to that proposed by IECO in 1980. The site is close to the Ganges to minimise maintenance requirement. At present the channel length that would need to be dredged in front of the structure is 500m though this can be expected to reduce as the Ganges returns to a more North-South orientation at Talbaria in about 2005. For 150 m^3/s the annual maintenance dredging quantity is estimated as 0.4 Million m^3. It is not sufficient to have a control structure alone and extensive capital dredging (components c1 & c2) is required. With the increase in section area proposed the potential for higher discharges in the wet season is about 10% and the control structure therefore has the additional advantage of preventing any increases in flooding. As well as dredging to chainage 30 Km the bend cut off at Kamarkhali has been considered as this gives significant reduction in maintenance dredging. However the expense of cutting off the Kamarkhali bend seems to outweigh the benefits.

The normal flood peak design flowrate for the control structure is 4250m^3/s, the dominant discharge of the Gorai. A high design discharge for the structure ensures flexibility for relieving the Padma and maintaining the size of channel in the tidal part of the Gorai (Madhumati), which provides an important part of the tidal volume of the Pussur Sibsa system. Limiting flows to 4250 m^3/s has advantages for structure protection works and for reducing maintenance.

The requirement for maintenance dredging that was identified in the interim report was high and improved estimates have been made together with morphologically based proposals for intervention. Four guide banks in the reach to the Gorai railway bridge are proposed. These will have the effect of ensuring well defined cross over points to aid the formation of a stable meandering flow channel. Currently the low flow channel is shifting each year giving a wide section and causing high bed levels. By stabilising the alignment of the channel a deeper narrower low flow channel will be formed reducing the maintenance requirements.

Option A3-Control Structure Set Back

This is essentially similar to option A2 but the structure is set back into the Gorai. This gives a reduced need for scour protection but greater and less predictable maintenance costs. The option would be favoured if the Ganges Barrage were to be implemented at an early stage.

Option A4-Groynes only

Where the channel is wide it can be expected that the channel bed will be shallow. The change in the Ganges alignment has left a very wide channel at the mouth through which the Gorai flow passes. It may also be seen that around the tip of the T groynes at Kushtia there is a deep channel due to local scour effects. This option therefore comprises construction of two groynes in the mouth plus some training banks to restrict the flow areas with local scouring producing a deep low flow channel. The area from the mouth to Talbaria would need to be dredged annually.

In addition, there is a need for initial capital dredging of the first 30Km reach to Kamarkhali and the control structure at Mohammadpur.

On construction of the Ganges Barrage a control structure would be required.

Option B1-Link canal to Kumarkhali

Because many and the most serious of the Gorai problems arise in the mouth, a suitable alternative site (though not as good as Talbaria where the Ganges has always flowed adjacent to the right bank) could be developed some 16 Km downstream. A link canal from here, some 150m wide, combined with dredging downstream, gives a possible option. The canal would be closed with a control structure at high Ganges flow to reduce siltation which, like the A3 control structure would require scour protection.

This option reduces the amount of dredging required in the upper reaches of the Gorai although to ensure that wet season flows do not continue to decline some dredging/excavation would be needed. A railway crossing would also be required.

Unfortunately the amount and cost of earthwork required to build the canal at a low level across a virgin, high ground is comparable to that needing to be excavated from the Gorai upper reach and thus this is unlikely to be a viable option.

On completion of the Ganges Barrage this option would be obsolete.

Option B2 - Link Canal to Kumarkhali with Major Pumping Station

If a similar route is adopted as B1 for a link canal with booster pumping station then the size of the canal can be reduced to a bed width of 50m and can be designed to give the desired flows without intervention on the Gorai. The capital costs of such a scheme are lower but there is no improvement in the river. There is a requirement for continuing dredging upstream of the Pump House (in similar fashion to that carried out for the G-K scheme). Given the experience of the G-K scheme with shortage of power, large pumping station should not be favoured.

This option would become obsolete when the Ganges Barrage is built.

Preferred Option

For augmentation through the Gorai various options have been considered as above and from these Option A2 - Control Structure at the mouth emerges as the preferred scheme.

Principal reasons for selecting Option A2 in preference to others are summarised below:

Option	Reason for rejecting
A1 - Dredging only	High maintenance cost.
A3 - Control structure set back	High maintenance cost.
A4 - Groynes only	High capital cost; a control structure would be required on construction of the Ganges Barrage.
B1 - Link canal to Kumarkhali	High capital cost; does not improve the Gorai mouth; scheme would become obsolete on completion of the Ganges Barrage.
B2 - Link canal with pump station	Significant construction time; high maintenance costs for pump station and possible power generation requirement.

9.2.6 Chandana Schemes-Route C

Option C1 - Gravity Link Canal Chandana River

Although the head available in the Ganges is lower at the Chandana offtake, it is possible to extend the intake to a reasonably stable nodal point and excavate the existing river bed. Although the river corridor is larger than the current channel size, the amount of excavation required is greater and more expensive than that to improve the Gorai.

Option C2 - Pumping into the Chandana

The Chandana channel has a dominant discharge of 50 m^3/s and is an ideal conveyor of flows of this magnitude into the Area for irrigation. The flow must, however, be pumped and there would be a continuing dredging requirement for a channel of about 3Km length upstream of the embankment where the pumping station would be positioned. For flows of 250 m^3/s and 150 m^3/s excavation in the river is required to increase the conveyance capacity and a new cut to the Gorai is required to utilise water in the Southwest Region.

Gravity Link Canal, Chandana/Kumar River

The upper reach of Kumar also had a branch extending to the Ganges near Rajbari which seems to follow a lower level route than the Chandana, potentially reducing the excavation required. However, the head available is lower so the canal must be larger.

None of the Chandana schemes is compatible with a Ganges Barrage Development.

9.2.7 Hisni/Matabhanga Options-Route D

The Matabhanga is the uppermost right bank spill river in the Southwest Area but it is silted to a much higher level than the Gorai (bed level about + 12 m PWD) and, due to its position on the Indian Border the mouth is an unsuitable connection for improvement works. The Hisni is a smaller river cutoff from the Ganges by an embankment at which an offtake could be made to feed into the Matabhanga. At this offtake flow would have to be pumped in the dry season and a channel cut and maintained upstream of the embankment close to which the pumping station would be positioned. Gravity flow in the dry season would require extensive improvement to all the rivers concerned and a link canal would be required as the necessary improvements to the Mathabhanga could not easily be carried out where it forms the border with India. The financial and social costs of such a works would be prohibitive as the terrain is high and extensive cutting would be required.

Water would be diverted from the Matabhanga/Ichamati by means of a gated barrage into the Nabaganga, Bhairab, Chitra and eventually also reaching the Kobadak. The former connections with the distributary rivers would also need improvement. This scheme has the advantage of being able to supply the western side of the Southwest Region without major transfer canals. The control of water necessary for dry season would also offer benefits in the wet season when flow would not need to be pumped.

The scheme could be made compatible with the development of the Ganges Barrage and possibly have additional benefits for the Bhairab and Kobadak.

9.2.8 Old Kumar (Faridpur) Route E

The Kumar at Faridpur is on an anabranch of the Padma and has a dry channel about 4 Km in length upstream of the embankment. The level in the Padma during the dry season is little different to that at the Arial Khan offtake, which has a strong connection with the main river. This anabranch of the Padma has declined as the main channel moved northeast since 1973, and this route is therefore considered of low merit compared with other available options.

9.2.9 Arial Khan/Madaripur Beel Route - Route F

The Arial Khan is the major distributory of the Padma and has a dominant discharge of 2000 m^3/s. It is, however, tide affected and is very active, eroding its banks by several tens of metres in a season. The Arial Khan is connected with the Madaripur Beel Route (MBR) via the Kumar, which is a relatively restricted 20 Km reach. The old shipping route from the outfall of the MBR on the Madhumati to Khulna via the Atharabanki is heavily silted and tortuous and forms a further constriction. The flow in the Chowdhury Hut branch of the Arial Khan is currently high enough to support such abstraction. However with the expected planform movement of the Padma, the Dulatdia branch of the Arial Khan would become more active and flows in the Chowdhury Hut branch would reduce to as low as 15 m^3/s. The Kumar link to the Arial Khan may be satisfactory though some flow reduction can be expected.

As there is very little head available and tidal effects dominate, a number of options were therefore studied using the hydrodynamic model. The possible uses of water include not only augmentation of the Khulna basin, but possibly irrigation development with extractions along the MBR and use by polders east of Khulna as described in Section 9.4. Improvement of the route to Khulna would also offer navigation benefits.

Improvement of the Kumar and the entrance of the Kumar from the Arial Khan would be the first requisite and the removal of approximately 6M m^3 would increase the net flow in the MBR from 19 m^3/s to 52 m^3/s when the flow in the Gorai is 140 m^3/s, or from 37 m^3/s to 93 m^3/s when the Gorai flow is somewhat lower (50 m^3/s). This increased flow augments only the Madhumati which flows into the Baleswar which is already adequately supplied by the Swarupkati. To supplement the Khulna area it would be necessary to build a diversion weir on the Madhumati and either improve the Atharabanki or the Madhumati upstream to the Halifax for flow into the Nabaganga. A fixed weir that is submerged at high tide (crest level +0.8m PWD) is more effective than a higher weir that excludes tidal flow from coming up the Madhumati. Augmentation via this route is incompatible with increased flow down the Gorai to Khulna as the flows attained in the MBR rapidly fall off with increased level in the Madhumati.

The augmentation of flows in the Gorai would appear to limit the amount of any additional water brought into the Region via the MBR.

The difficulty in finding a stable off-take coupled with the limited amount that can be augmented makes this option unattractive.

9.2.10 Other Schemes

Offtakes

A number of other possible supply routes such as increased pumping at the G-K inlet works to supply areas outside the scheme and using the Kaliganga were examined and rejected as being impractical with the present conditions of low flow in the Ganges. The possibility of helping the Gorai to open a new mouth was also considered but rejected on the basis of morphological studies of the Ganges, which indicate that, although not currently in a favourable orientation, in the longer term there is no better position for an offtake.

Gorai Lower Reach Bend Realignments

The length of the lower reach has increased by some 10Km since 1973. Accretion of the river bed due to changes upstream together with the additional lengthening is probably causing an increase in bed level upstream, as shown by a rise in the rating curve at Kamarkhali. Measures could be taken to reduce the river length but there would be difficulties in trying to stabilise this mobile part of the river and pilot cuts alone would probably be satisfactory. This option could be considered if monitoring shows that further measures are required.

Training Groyne in the Ganges

It is clear that some of the problems of the Gorai are caused by fluctuation in the Ganges' alignment. Consideration has therefore been given to whether training the River Ganges permanently into a favourable alignment is a possible option. This is a relatively high risk option that would probably be best implemented when the Ganges next takes up a favourable alignment which could be maintained.

9.2.11 Ganges Barrage

A Ganges Barrage in Bangladesh has been proposed in a number of studies over the past 30 years TAMS (1963), ACE (1969), IECO (1980), Halcrow (1984). Control of the Ganges level offers several major advantages that cannot be achieved otherwise namely:

- Possible use of all water released upstream
- Provision of storage to increase releases at critical times
- Reduction of pumping needs and hence reduction of energy requirements
- Reduction of dredging requirements at G-K and other schemes developed
- Miscellaneous benefits such as road and rail crossings and improved navigation
- Required for possible future development such as Jamuna link canal.

The barrage is technically straight forward and can use proven technology and is therefore relatively low technical risk considering the experience of training the Ganges at Hardinge Bridge and the construction of the Farakka Barrage in 1966 at a geographically similar site.

The main uncertainty regarding the barrage is the availability of water released upstream during the dry period. Siting the barrage at a downstream position allows extra storage to be utilised but to use greater fluctuation in pond level would be at the expense of needing pumping for high areas.

Siting of a barrage

The various positions considered previously are at (a) Talbaria (TAMS 1963) (b) Downstream of Hardinge Bridge (ACE 1969 and IECO 1980) and (c) about half way towards the Jamuna confluence near Pangsa (Halcrow 1984). The advantage of a downstream location lies in increased storage and avoidance of any increased afflux extending into Indian territory. A barrage near Hardinge Bridge reduces costs of the barrage as shorter guide banks are needed but this is at the increased expense of longer distribution canals. Studies of bankline changes by FAP-4 suggest that a location similar to that proposed in 1984 but closer to Rajbari would be the suitable point to site the barrage (Figure 9.1).

Layout of Service Areas

An initial layout of canals for irrigation distribution with the Ganges Barrage was set out by ACE in 1969. This was modified by others in accordance with the changes in barrage location and proposals for intermediate developments by IECO (1980). More significant changes to the proposed canal system were made in 1984 (Halcrow 1984). It is important to note that the estimated cost of the barrage was 50%-60% of the total cost of development, including link canals and irrigation facilities. The layout of canals and control structures is therefore important. The most obvious carrier of water, the Gorai is not fully utilised in previous studies. One of the reasons for this is the perceived need for silt exclusion from a main canal system. Given the low velocities that will be apparent in the Ganges in the post monsoon period, little sand size sediment should enter any canal system at that time. The requirement for sediment exclusion arises in the monsoon season when sediment concentration in the rivers are highest and demands are lowest. At this time inflows from the main river should be restrained and carefully designed inlets and settling basins could be used to minimise maintenance requirements. Taking account of the costs associated with the various canal routes, an initial optimisation of parameters gives the layout shown in Figure 9.6. Early development of the Gorai river as a major conveyor of irrigation supplies is compatible with the complete development of the Ganges Barrage scheme.

Other Major Hydraulic Structures

The Ganges Barrage would have associated with it training works and strengthening of the existing embankments to account for the additional afflux caused by the barrage. A control structure at the mouth of the Gorai is needed and this should have a discharge capacity of 4250 m^3/s. For control of water on the Gorai a barrage is required, the selected location is Mohammadpur, downstream of the Kamarkhali bend. To serve the area to the west of the G-K project the Ganges main canal can be extended and the flows through the Kushtia main canal may be reduced by allowing intake from the Gorai or via a link canal and siphon.

Return flows

There are likely to be sizeable increases in dry season flows in the smaller rivers as water not used for irrigation is collected in drains and khals. Possibly up to a third of the water diverted could return to the rivers which would amount to approximately 100 m^3/s on the right bank of the Gorai. This will help to hold back the saline front in the tidal zone but as can be seen from the high salinity in the western coastal zone even in the monsoon season, the effect is likely to be limited. Distribution of water to the polders is only practical for more northern areas and others must continue to depend on rainfall and the lower salinity river water immediately after the monsoon.

From existing data it is difficult to come to any firm conclusion regarding the effect of return flows on sedimentation but this needs further study.

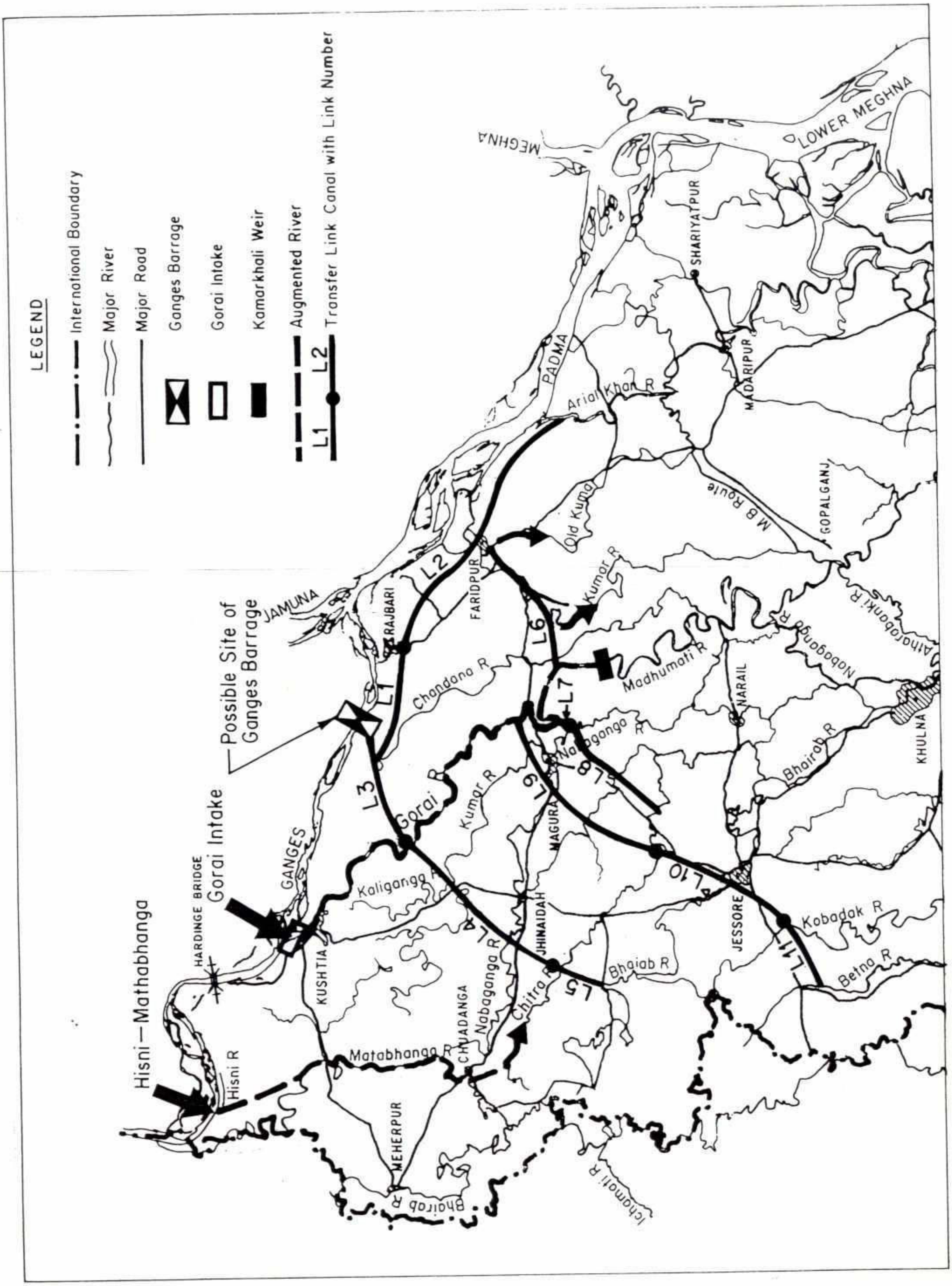
9.2.12 Augmentation Choices

The principal choices for augmentation of the dry season flows may be summarised:

(a) Pumping schemes : Hisni, Chandana, Kumarkhali etc.
(b) Gorai Augmentation
(c) Ganges Barrage

The pumped schemes though apparently economically attractive, the experience with large scale pumping at the G-K Project and in the Barisal Irrigation Scheme makes these schemes unattractive. Additionally such schemes at Chandana and Kumarkhali are generally incompatible with the development of a barrage.

Figure 9.6



Main Augmentation and Transfer Choices

Gorai augmentation is favoured as it improves the general 'health' of the river which is now thought to be deteriorating. For the Gorai Augmentation the preferred scheme is Option A2 with control structure at the mouth, guide banks and capital dredging. Annual maintenance dredging is required but is manageable.

The major augmentation option is the Ganges Barrage which though initially has a high capital cost, the technology is proven and the advantages offered cannot be gained by other means. Even with the current low level of flows in the Ganges, long term sustainability of the Gorai can be improved and large areas (than the Gorai scheme) will be benefitted. However, for long term sustainability an Agreement with India on the sharing of the Ganges water or augmentation of the Ganges by other means within Bangladesh is required.

9.2.13 Augmentation Development Strategy

A number of development strategies have been considered for the augmentation of the dry season flows in the SWA and the following option emerges as the best choice. The option is a phased development of the water resource starting with the development of the Gorai. The phased development may be summarised as follows:

Short term strategy:	Development of the Gorai Augmentation Project as shown in Figure 9.7. Detailed feasibility studies of the Ganges Barrage should be completed.
Medium term strategy:	Continue development of Irrigation areas with simultaneous construction of the Barrage.
Long term strategy:	Complete development of additional irrigation areas. Secure the supply to the Ganges through Agreement with India or transfer from within Bangladesh.

9.2.14 Impacts of Augmentation

Irrigation

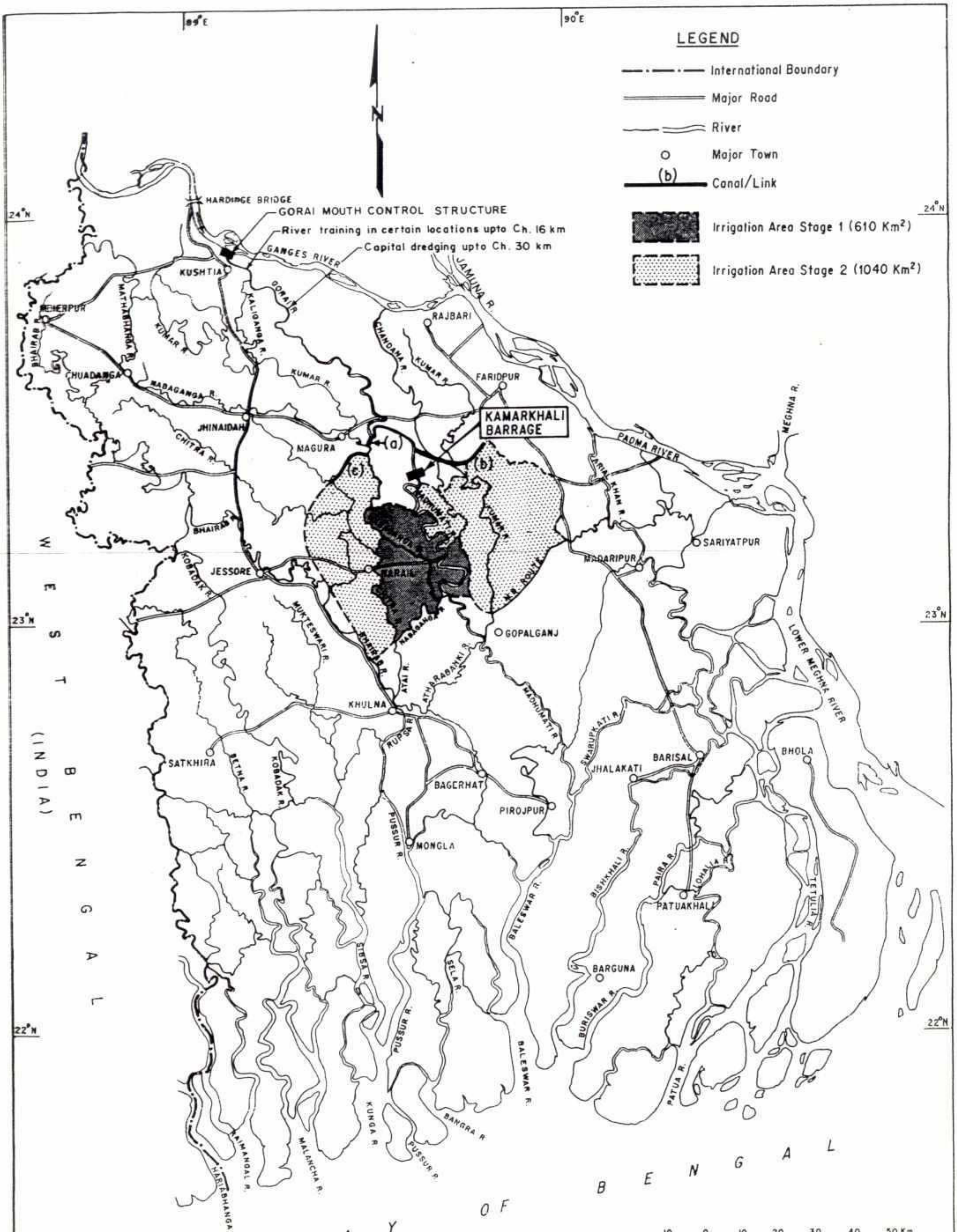
The requirement to develop the agricultural potential of the area results in high demands for water with a potentially high return. The potential for future development of groundwater is limited and surface water supplies are required. With little run-off in the inland rivers the only significant source of additional water is through augmentation from the main rivers.

Developing irrigation can increase the incidence of water-related diseases but there appears to be little evidence to show that this is a particular problem in large irrigation schemes in Bangladesh.

Salinity Control for Sundarbans

The importance of salinity control in the Sundarbans relates primarily to the conservation of the Sundri *(Heritiera fomes)*, a species of considerable commercial value. Although present throughout the Sundarbans, Sundri is only marginally salt tolerant showing stunted growth with increasing salinity levels. The plant is also susceptible to smothering of its pneumatophores (aerial root tips) by heavy sediment deposition.

Figure 9.7



Gorai Augmentation Project
Proposed Irrigation Areas

Increased siltation, and saline ingress, is most likely a result of increase tidal ranges following poldering. More importantly, the monsoon peak flows should be maintained to ensure some diminution of tidal levels and a reduction in sedimentation.

Sundri would benefit from a less saline regime in the Sundarbans, if other environmental conditions remained beneficial. Whilst augmentation may be considered as a mitigation measure, its effect will be limited. The facts can be summarised:

- The present area of the Sundarbans lies within a perennially saline, estuarine environment
- Recorded changes in salinity,over the past 25 years, in the present area of the Sundarbans have been small
- Regional rivers such as the Gorai have dried up in the past (the Gorai was dry in the early 1950's)
- Salinity has now been discounted as the single, or primary, cause of top-dying of Sundri
- High flows of the order of 250 m^3/s would be needed, in the Sundarbans channels, to have any significant effect on even a limited area

A greater understanding of the dynamics of the Sundarbans as a wetlands ecosystem is required, in order to predict the effects of intervention. The ecosystem maintains a delicate equilibrium between the botanical, hydrological and chemical water quality, and alteration of a single parameter (salinity) would not guarantee beneficial change.

Khulna Water Supply

The water supply of Khulna for domestic and industrial use is presently dependent on groundwater. A limited number of industries such as the Goalpara power station, Khulna hardboard and paper mills and some Jute mills also extract water from the Lower Bhairab. The domestic demands for water are small compared to the fresh water that would be required to make a significant impact on the salinity of the rivers around Khulna. The total domestic and Industrial demand for untreated water is about 6 m^3/s (0.5 Mcm/day). As shown in Figure 9.8 at least 150 m^3/s flow down the Gorai would be needed to control salinity to allow extraction of water of the required salinity at the town.

The alternatives for the Khulna supply include:

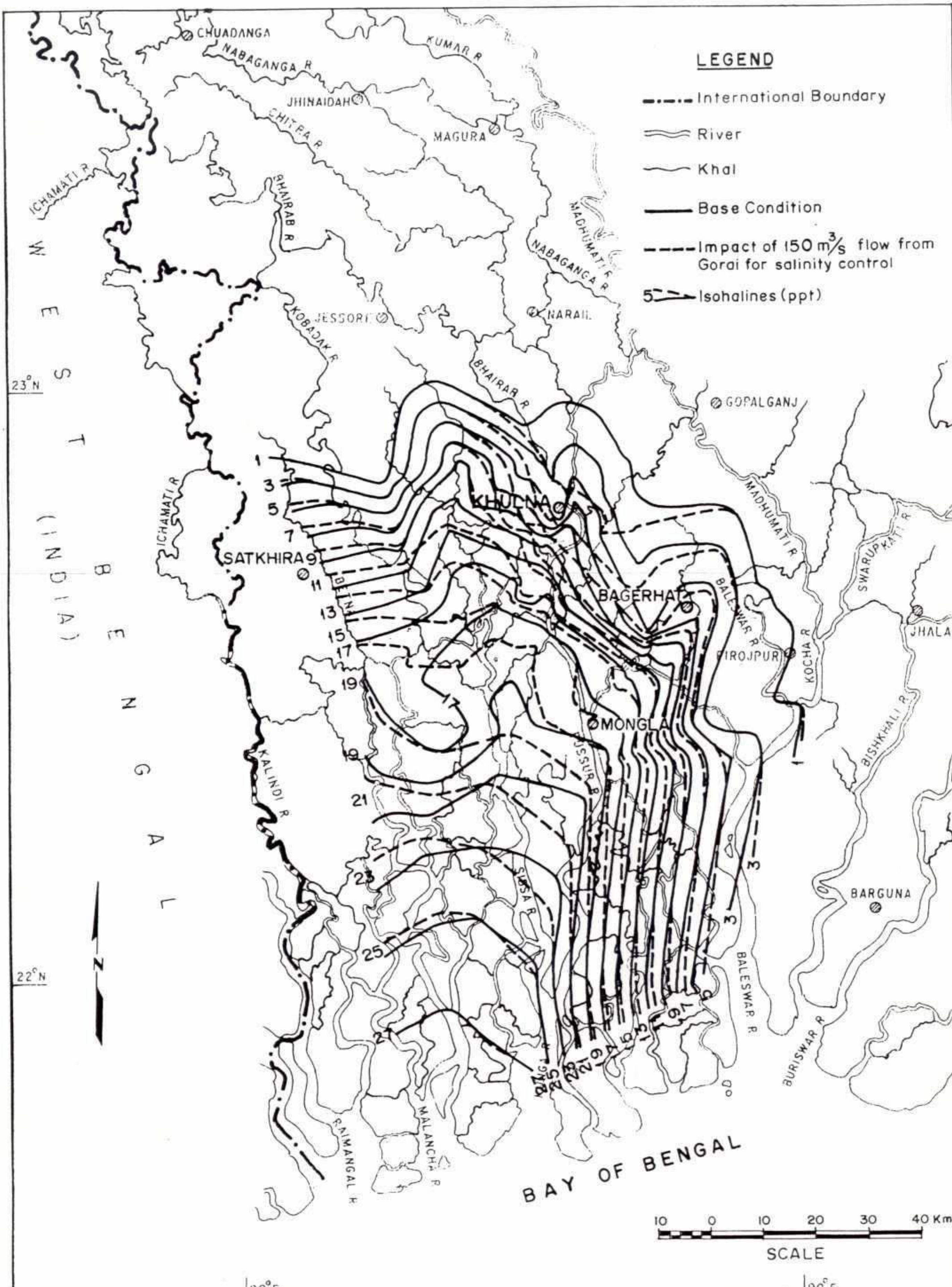
(a) Extraction of surface water upstream of the critical saline front

(b) Storage of water in a raw water reservoir/beel area

The preferred option can only be selected following more detailed studies but for the purpose of augmentation an allowance of 10 m^3/s extra flow into the Nabaganga/Chitra can be made for all augmentation schemes considered. The options are considered in Section 9.5.2.

There would be some impact on the groundwater quality if it was ensured that the saline front was maintained downstream of Khulna due to the complexity of groundwater lenses in the coastal zone. With control of the Ganges and extensive irrigation development the saline front will most likely be controlled by the return flows from irrigation drainage and therefore in the long term the industrial requirement for fresh water could be satisfied.

Figure 9.8



Simulated Assessment of Impact on Salinity ($150\ m^3/s$ Flow from Gorai)

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Pollution Control

There are two aspects of pollution of the water environment associated with augmentation:

(a) Public Health benefits due to increased net flows and hence flushing of water from the rivers concerned

(b) Some additional pollution burden associated with the use of chemicals in increasing agricultural production.

In Bangladesh it is generally the case that the industrial users of water discharge waste without treatment directly into the rivers. The Department of Environment is taking on powers to reduce harmful discharges and this should help control future increases in pollutant load. At present there is no data available to show whether the rivers require improvement, but because of the limited industrial development in the country it appears that critical conditions have not yet been reached. Control on the use of the more harmful agro chemicals are already in place. With development of industries in line with Government Policy, pollution control will need further study and possibly planning controls considering the high value of the Sundarbans resource downstream of the potentially polluting sites.

Public health issues relate more to the use of rivers for both discharge of latrine wastes and for bathing and washing. Higher river flows will improve flushing, but not necessarily in tidal areas. Incorporation of pit latrines, or separated bathing areas in development plans would be a further mitigation measure to ensure public health.

Navigation and Mongla Port

The benefits of increased dry season fresh water flow for Mongla port would be in reducing the rate of siltation due to landward movement of fine sediments. The potential dry season fresh water flows are unlikely however to have significant impact as concluded by Farleigh (1984). The option identified in the Pussur-Sibsa studies (DHI 1992) of allowing 1000 m^3/s for reducing siltation is therefore unrealistic. The more important aspect of the augmentation lies in ensuring that the Gorai-Madhumati does not continue to decline and hence the tidal volume is maintained.

If a barrage is built on the Madhumati to give command for irrigation this will allow movement of country boats for the whole length of the Gorai-Madhumati system which is not currently possible in the dry season. Suitable locking in any structure across the rivers should therefore be considered.

Shrimp Farming

The physical controls on the development of shrimp farming are:

(a) Availability of suitable land with access to water of appropriate salinity

(b) Availability of shrimp fry

With limited changes in salinity the total area of suitable land will not be altered greatly. With augmented fresh water flow some shrimp fry may be lost due to the length of brackish river being reduced. The impact depends on the extent of augmentation and is likely to only be significant for a high degree of augmentation such as when a barrage is developed.

Present projections indicate that shrimp larvae catches may have peaked, and shrimp hatchery development may become necessary in any case to sustain the industry.

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Rice Farming

Reducing salinity in the poldered areas due to direct releases or return flows from upstream irrigation will allow increased use of tidal water for expanding rice production. This may require additional tidal inlets into the polders and continued improvement of the internal water management. Only when major augmentation flows are available is this likely to be significant.

The trend towards HYV with irrigation may lead to greater concentrations of agrochemicals in the return waters. This situation needs careful monitoring, to provide baseline condition data and to effect control measures in the future.

Social Issues

There is widespread support for augmenting dry season flows, this was apparent at the public participation meeting held by FPCO in Jessore in January 1993 to discuss these issues. It is inevitable however that actually carrying out the works will disadvantage some individuals due to loss of land etc. This can be minimised by using existing river courses and khals for irrigation canals.

The main beneficiaries of any scheme are likely to be the small farmers who gain irrigation potential but the degree to which benefits accrue to other groups such as landless labourers, suppliers and distributors of produce and inputs, boatmen etc is generally quite high for agricultural development. The type of low lift irrigation being considered also allows for development of opportunities for the landless to be involved in the supply of water.

The construction phase of an augmentation project is likely to include building of major structures, excavation can be carried out with a high degree of manual labour, benefiting the most disadvantaged social groups. The development of construction camps at sites on the Gorai to ensure adequate housing and sanitation for laborers will be required.

Care will be needed to ensure that construction and long term negative impacts on fisheries and navigation are minimised.

9.2.15 Conclusions

It is apparent that for the long term sustainability of the Area augmentation is a necessity. Although significant dry season flow is available in the Padma, water levels are low for gravity abstractions. The dry season flow in the Ganges is limited by the abstractions upstream at Farakka. Technically it is feasible to abstract significant quantities of water from the Ganges through the existing spill river sites.

The options for 100, 150 and 250 m^3/s diversions, based on the historical dry season flows, have been outlined and costs given. For gravity flow the main Gorai channel appears to be the most feasible routing. The basic gravity options may be divided between those that include controlling flow into the Gorai and those that do not. The extra benefits associated with building a regulating structure exceed the cost. The maintenance costs can be kept at acceptable levels by training of the Gorai using guide banks attuned to the natural frequencies of the river.

The Arial Khan MBR route offers a possible gravity supply route for smaller flowrates of 50-100 m^3/s, although any increase in flow is lost when there are higher flows in the Madhumati from the Gorai. Building a weir on the Madhumati, dredging the Kumar connection to the Arial Khan and either dredging the Atharabanki or the Madhumati is required. The earlier rise in the dry season flow in the Jamuna than the Ganges helps to increase flow through the MBR at times of lowest flow down the Gorai. The route is at risk from a sudden movement of the Padma cutting off supply.

For smaller pumped schemes the Chandana and Hisni/Matabhanga offer possible alternatives for different supply areas. Early development of such pumping schemes is not favoured.

The preferred augmentation option through the Gorai includes a control structure at the mouth, capital dredging at the mouth and downstream and a barrage at Kamarkhali. The Gorai augmentation scheme as proposed is technically feasible and economically viable as a 'stand alone' project (see Volume 12 - Pre-feasibility of Gorai Augmentation Project). A phased development is recommended for the proposed Project.

The options highlight the limitations of the quantity of water that can be abstracted from the Ganges with the present flows. A barrage across Ganges would significantly increase the reliability during the dry season by way of storage during the critical months. Ensuring adequate flows in the Ganges for long term reliability is dependant on an Agreement between India and Bangladesh on the sharing of Ganges water or other developments within Bangladesh (like a link canal from the Brahmaputra). The benefits from the barrage will include agriculture, salinity control, impacts on Sundarbans, increased depths for navigation, movement of sediment. Although the Ganges Barrage is considered to be a medium/long term option, investigations and studies should commence as soon as possible in parallel with the Gorai works, which can be integrated into the larger Barrage scheme when it is in place.

9.3 Flood Control and Drainage

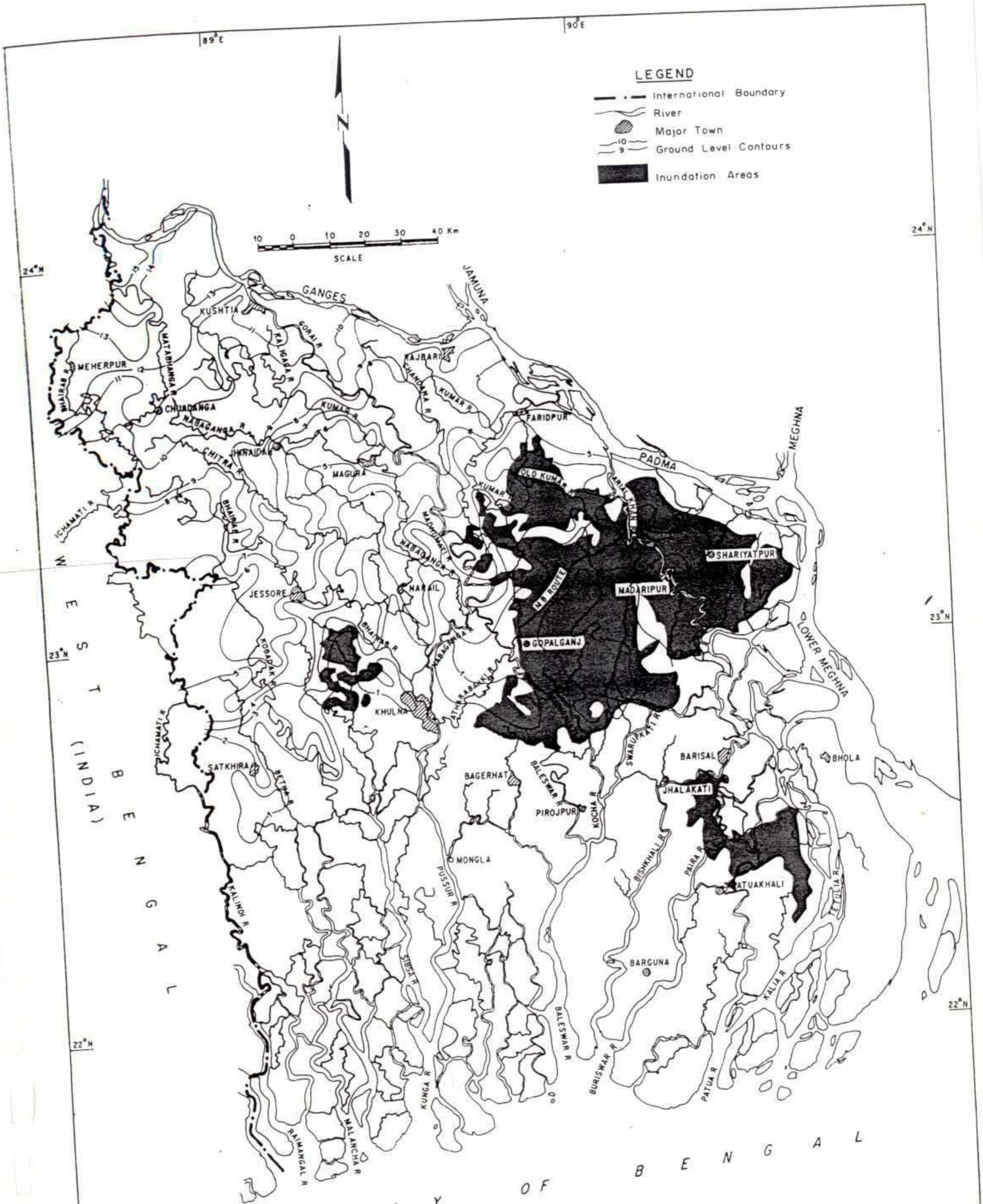
9.3.1 Introduction

Major overbank spill into the Southwest Area presently occur mainly from the Padma, Lower Meghna and Arial Khan. Though internal runoff accounts for only 11% of the total flow through the Southwest Region and 5% in the Southcentral Region, relatively high water levels in the inland rivers cause drainage congestion in most areas generally south of the Jessore-Magura-Faridpur line.

Since the floods of 1987 and 1988 certain flood control measures along the Ganges and the Padma right banks have been implemented by BWDB and by local government generally through Food for Work Programmes. However, the Consultant's field inspection in 1992 and cross-section survey of these embankments at maximum 500 m intervals show that there are still gaps in the flood control embankments along the Padma. Using a model simulation of overbank spill through these gaps which considers the 1987 river stage levels for the period July-September, it is estimated that a cumulative inflow of about 3000 Mm^3 could still occur. May be 40%-60% of this inflow would go towards the low lying areas in Planning Unit SW7 that lie north of the MBR canal. Compared to this, the probable contribution to inundation of the same area from the internal rainfall runoff during the same period is about 1600 Mm^3. However, this simulation is based on a fixed bed model and, therefore, the spill estimate should be considered with care as discussed later in Section 9.3.4.

According to MPO estimates large pockets (totalling about 2700 km^2) within an area bounded by Magura, Khulna, Barisal, Sariyatpur, Faridpur and Rajbari would be inundated to depths greater than 90 cm during an average monsoon year. Therefore further measures are necessary to control overbank spill and drainage in Planning Units SW3, SW7, SC1,

Figure 9.9



Indicative Inundation Areas

SC2, SC3 and SC5. In the remaining Planning Units north of the Coastal Embankment Polders, mainly drainage improvement and congestion relief would be required.

Figure 9.9 shows the indicative areas of inundation.

9.3.2 Drainage

The study area could be divided into the southern Coastal Embankment Project (CEP) area which is criss-crossed by a network of rivers and creeks that are predominantly influenced by tides, and the remaining areas further north on which there is marginal or no impact of tides. Drainage issues relating to the CEP area and possible interventions to resolve them are discussed in Section 9.4, while those for the non CEP areas are discussed here. The gross area north of the CEP area is about 23,000 km² and the main inland rivers which impact on this area are the Mathabhanga, Kobadak, Bhairab, Chitra, Begabati, Nabaganga, Gorai/Madhumati, Chanda/Barasia, Kumar, Old Kumar, Swarupkati and Arial Khan. The boundary rivers are the Ganges in the north and the Padma/Lower Meghna in the east. The Gorai/Madhumati is the main distributary of the Ganges into SWA, while the Arial khan is the main one for the Padma/Lower Meghna.

NAM catchments and Drainage Complexes

SWMC has sub-divided the drainage basins of the entire country into a number of catchments (NAM) to facilitate its hydraulic modelling exercise. In SWA, the area north of the CEP is covered by 37 NAM catchments. For the purpose of this study, this area has been divided into 12 drainage complexes by taking into consideration the topography and relief, soil characteristics and the catchment boundaries (Figure 9.10).

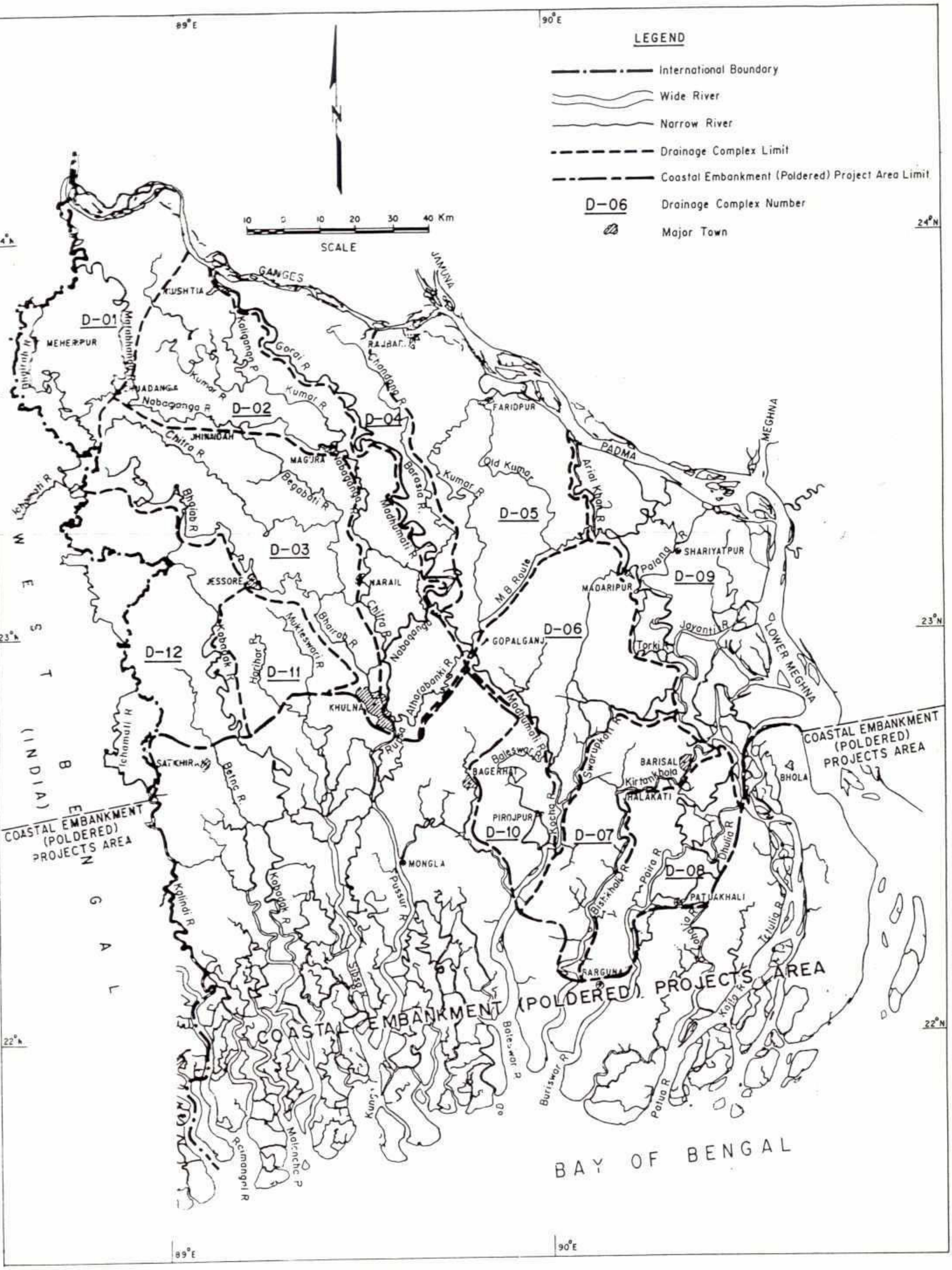
Coefficients of Runoff

Previous studies (including that carried out by FAO in 1988) have considered some relevant agroecological criteria and divided the study area into four, the High Ganges Floodplain (HGF), the Low Ganges Floodplain (LGF), the Ganges Tidal Floodplain (GTF) and the Old Meghna Estuarine Floodplain (MEF).

The HGF, which is predominantly high and medium high land, has a smooth landscape of nearly level to very gently sloping broad ridges, inter-ridge depressions and nearly level to very gently undulating broad basins. Ground level varies from El. 15.0 m PWD at he high land to El. 1.0 m PWD at the lower end. Drainage Complexes D-01, D-02, D-03 and D-12 fall within HGF. 60-70% of these complexes are covered by broad ridges and inter-ridge depressions; their soils are moderately permeable. Broad basins cover the remaining areas of the complexes, particularly in the south, and their soils are generally low permeability clay.

The LGF is predominantly high and medium high land and has typical meander landscape: relief along the sides of the rivers crossing the area is somewhat irregular, comprising narrow ridges, inter-ridge depressions, broad low lying basins (particularly in the south) and cut-off channels. The difference in elevation between the ridge top and the corresponding basin bottom generally varies between 3.0 and 5.0 m. Accordingly, the northern half of the study area has a comparatively rolling topography, while the central and southern areas have fairly flat terrain. Furthermore, the central and southern areas have a large number of extensive beels. Drainage Complexes D-04, D-05, D-06 (part), and D-09 (part) belong to LGF. Except for about 30-40% of these complexes in the north which have generally narrow ridges with wide inter-ridge depressions, the remaining areas are usually covered by wide, low lying basins that have soils of low permeability.

Figure 9.10



Drainage Study Area

The GTF has a number of inter-connecting tidal channels and creeks which carry freshwater in the rainy season. The area is slightly basin shaped, and where unprotected, it could be shallowly flooded by high tides. Most soils are moderately permeable. Drainage Complexes D-06 (part), D-07, D-08, D-10 and D-11 belong to GTF.

The MEF is smooth, almost level with floodplain ridges and shallow basins. Soils are relatively uniform and the permeability is moderate in the higher lands and low in the depressions. A part of Drainage Complex D-09 falls within MEF.

In view of the variations in the reliefs and soil texture, the different drainage complexes and the integral NAM catchments show differences in their runoff and groundwater recharge capabilities. Results of catchment model simulation based on mean annual rainfall are given in Table 9.4 and they illustrate the variation in area weighted runoff coefficients (0.38 to 0.67) of the drainage complexes.

These coefficient of runoff values relating to annual rainfall though appear high but are considered realistic on the basis of comparison of simulated runoff with measured flow in rivers at selected locations made by FAP-25.

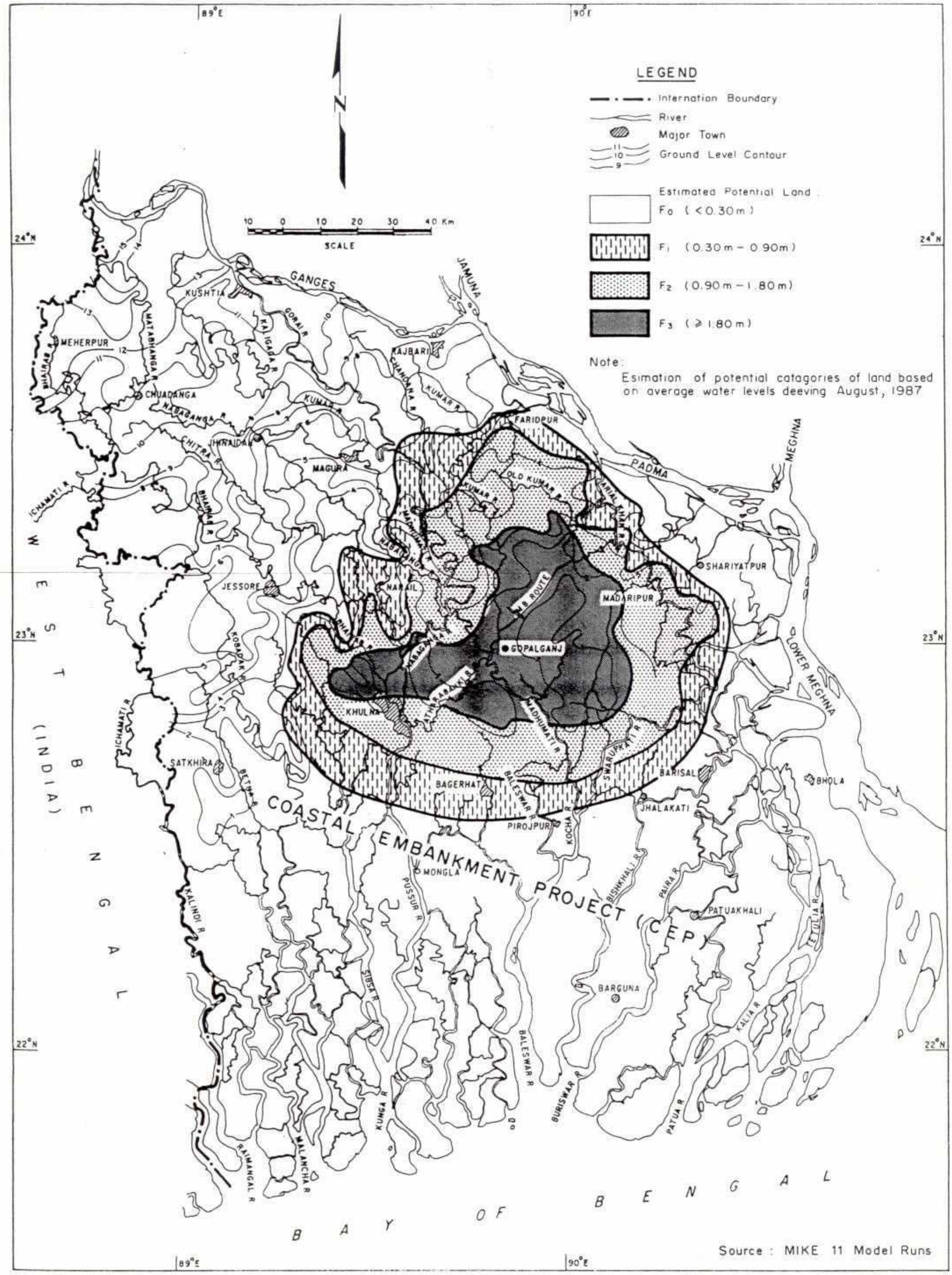
Drainage Disposal

Plot of the river stage contours for the study area for the months July, August and September based on the results of the simulation of measured daily flows corresponding approximately to a 1 in 5 return period year shows that about half the total area that lies south of Magura-Faridpur (Figure 9.11) would be subjected to drainage congestion in view of the relatively lower land levels there. The simulation results further showed that the drainage congestion in these southern areas on an average lasts for periods ranging from 5 to 8 weeks (during July to September). This broadly agrees with information collected during field visits.

Except the Gorai-Madhumati-Lower Nabaganga conveyance system and the Arial Khan system that function as the main distributary of the Ganges, and the Padma/Lower Meghna respectively, the other rivers are almost entirely dependent on internal runoff. The Gorai/Madhumati system, which runs almost along the median line of the study area, also operates as one of the main drainage disposal rivers in the Southwest Area.

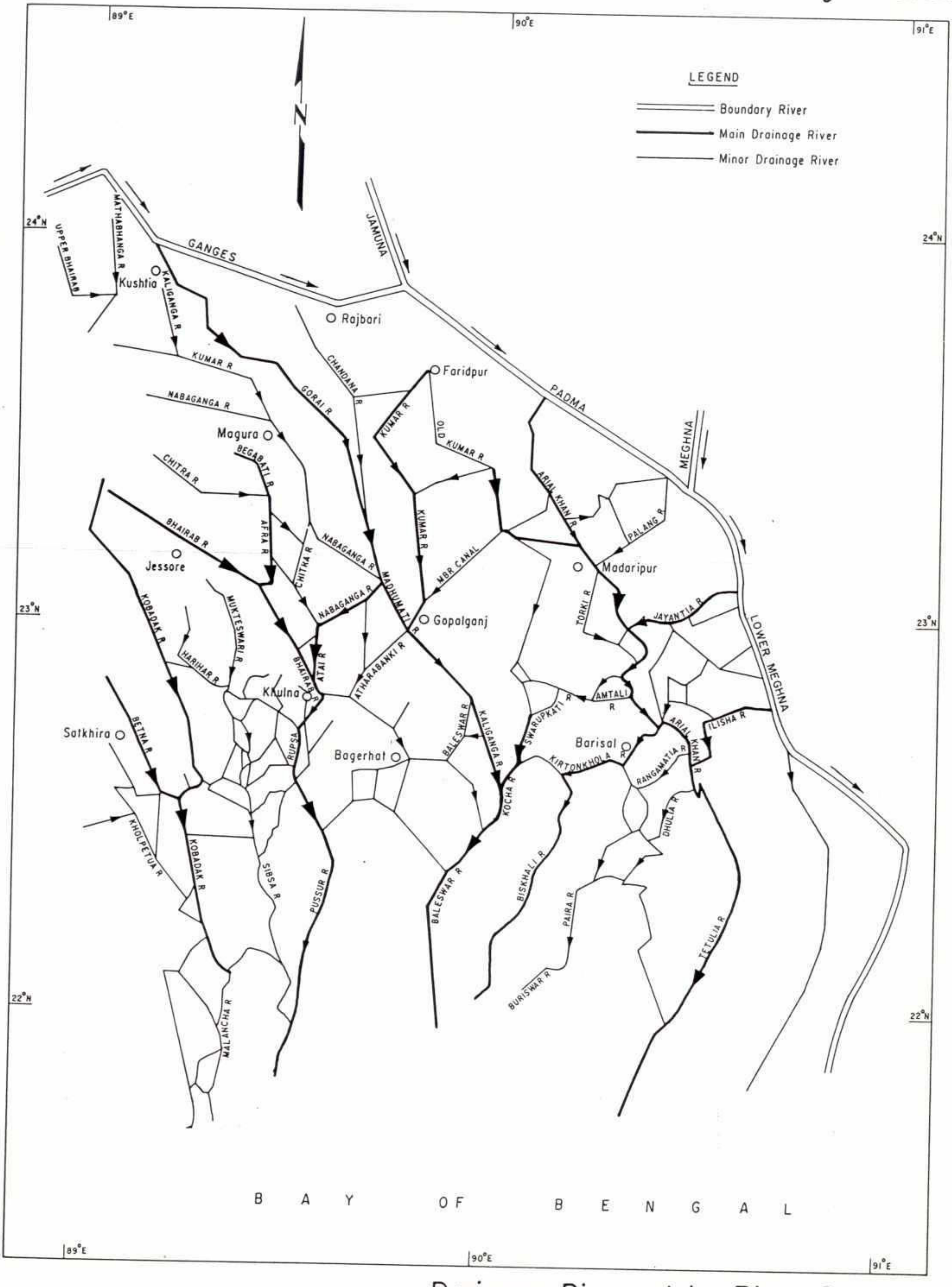
It is seen from the available river cross section data pertaining to the inland rivers and river stage levels obtained through simulation of flows by the hydrodynamic model for different years that presently the Kobadak-Betna and the Begabati-Bhairab systems function as the main drainage lines for the areas West of the Gorai/Madhumati. In the east the Kumar and the Old Kumar-Arial Khan systems carry out a similar function (Figure 9.12).

Figure 9.11



Indicative Inundation due to Drainage Congestion for 1 in 5 year Flood Through Gorai (Areas North of CEP)

Figure 9.12



Drainage Disposal by River Systems Schematic Network

TABLE 9.4

Rainfall-Runoff-Recharge Rates in the Drainage Complexes (Area North of the Coastal Embankment Polders)

Drainage Complex Name	NAM catchments partly/fully in the Drainage complex	Area Km²	Annual Mean (weighted) Rainfall mm	Runoff mm	Ground water Recharge mm	Runoff co-efficient
D-01 Upper Bhairab-Mathabhanga Drainage Complex	SUW-1, 6	1510	1513	699	504	0.46
D-02 Kaliganga-Kumar-Nabaganga-Chitra-Atharbanki Drainage Complex	SUW-2, 3, 7, 10, 14B & 15	2813	1709	732	419	0.43
D-03 Begabati-Chitra-Bhairab Drainage Complex	SUW-8, 9, 13, 14A & 14B	2142	1692	642	503	0.38
D-04 Gorai-Madhumati-Chandana-Barasia Drainage Complex.	SUW-4, 11	2068	1699	792	428	0.46
D-05 Kumar-MBR canal Drainage Complex.	SUW-5, 12, 16, 17 & SUC-1	2455	1821	749	435	0.41
D-06 Madhumati-Swarupkati-Kocha-Drainage Complex.	SUW-16, 17 & SUC-2, 4, 5, 7, 17	1840	1936	975	442	0.50
D-07 Kirtonkhola-Bishkhali Drainage Complex.	SUC-7, 8, 11, 17	1116	2265	1471	623	0.65
D-08 Rangamatia-Paira-Buriswar Drainage Complex.	SUC-9, 10, 11, 12, 13	1450	2431	1625	698	0.67
D-09 Arial khan-Palang-Jayanti-Torki-Ilisha Drainage Complex.	SUC-1, 2, 3, 5, 6, 9, 10	2308	2135	922	583	0.43
D-10 Baleswar Drainage Complex.	SUW-16, 25	988	2167	1123	645	0.52
D-11 Mukteswari-Harihar-Bhadra Drainage Complex.	SUW-20, 21	698	1845	849	430	0.46
D-12 Betna-Kobadak Drainage Complex.	SUW-13, 14A, 18,19	1462	1656	658	561	0.40
For all the Drainage Complexes	37 Nos.	*20850	1875	890	508	0.47

* Excluding the areas of the major rivers such as the Ganges, Padma, L.Meghna etc.
Source : Consultant's model analysis

Other main rivers like the Chitra, Nabaganga (the reach between Magura and the Halifax cut), Chandana/Barasia and Kumar which discharge directly or indirectly into the Madhumati are presently affected by the high monsoon flow levels in the Madhumati. The backwater effects of these flow curtailments appear to be transmitted to fair distances upstream in the Nabaganga, Chitra, Barasia and Kumar, thus causing drainage congestion in the areas adjoining these rivers.

Model studies indicate that if the flood inflow through the Gorai mouth could be limited to its dominant discharge (4250 m^3/s), the backwater effects in the affected rivers could be appreciably reduced and their water levels lowered. A simulation of the August-September 1987 flows in the river network, but incorporating a reduced flow in the Gorai (4250 m^3/s), shows that the resulting river levels are upto 0.6m lower than those recorded for the same period (Figure 9.13). This would have relieved drainage congestion in areas totalling more than 10,000 km^2.

The model studies have also shown that monsoon water levels in the Chitra and Nabaganga could be further lowered, and correspondingly the drainage of the related areas improved, if the capacity of the channel connecting the Chitra with the Bhairab is adequately increased.

9.3.3 Options for Flood Control and Drainage

Full Flood Protection

This option entails the construction of a flood control embankment that is high enough to prevent floods for a selected return period and protects the area behind. Regulators or control gates have usually been incorporated in embankments to allow disposal of rainfall runoff from within the protected area. In certain selected locations within the study area, these regulators have been modified to also operate as intake structures, particularly during the pre-monsoon period, to enable abstraction of water from the river for supplementary irrigation.

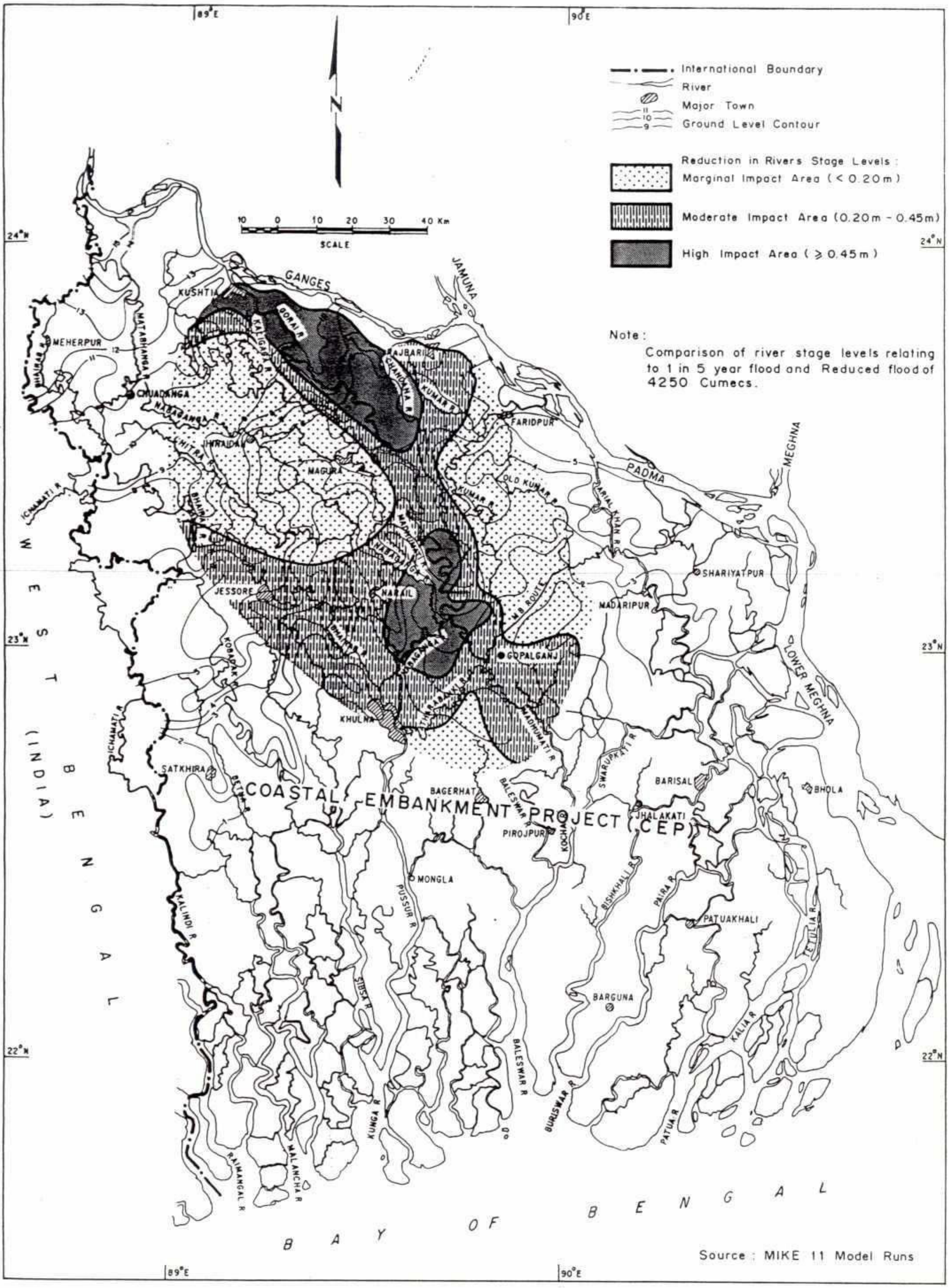
A full flood control has some associated negative impacts on the protected area : notably it interferes with floodplain fisheries and cuts off supply of fingerlings to beels; it not only prevents deposition of fertile silt on the protected floodplain, but also encourages unfavorable deposition of silt on the riverside, thereby raising the river/outfall bed level, and it also decreases the potential groundwater recharge. Floodplain fisheries losses however could be partly mitigated by introducing culture fisheries programmes within the beels.

Controlled Flooding and Flood Proofing

It is not always possible or desirable to protect all areas that are susceptible to flooding. Though the numerous homesteads on the chars of the Padma/Lower Meghna rivers and along river banks are vulnerable to flooding, it would be physically impossible to construct embankments to protect these forward areas, particularly when there are risks of extensive planform movement of rivers like the Padma and the Arial Khan.

The main alternative to full flood protection is provision of partial protection in which the higher land areas are protected from flooding, while lower land, for which it is not possible or desirable to provide full protection, will therefore suffer some degree of flooding. Partial flooding, whilst it reduces agricultural benefits also reduces some disbenefits associated with full flood control, notably the interference with floodplain fisheries and diminision of potential groundwater recharge.

Figure 9.13



Impact of Reduced Flood Flow Through Gorai in Areas North of CEP

Coupled with partial flood protection, flood proofing is also considered. The concept of flood proofing is to provide appropriate measures to prevent or reduce the loss of human life, damage to property, etc. The measures include raised earth filled platforms and shelters; community areas; raised homesteads, raised potable water wells, latrines, etc. FAP 23 has carried out flood proofing studies and has provided guidelines and recommendations for other FAPs. Their recommendations have been taken into consideration in the cost estimates for flood proofing option in the FAP-4 Studies.

Controlled flooding of an area to be partially protected could be achieved by incorporating either dwarf embankments to allow flood to spill over the embankments (submersible) or appropriate river intakes, or both. Submersible embankments have been introduced, particularly near the foothills of the Northeast and Northcentral regions of Bangladesh to protect Rabi/Boro crops from pre-monsoon flash floods, but they are not appropriate for areas in the Southwest where the main rivers (the Padma, Arial Khan, etc.) generally exhibit well attenuated hydrographs during the pre-monsoon and monsoon periods. River intakes are therefore the favoured intervention for controlled flooding.

Flood Warning and Communication

No flood proofing measure could be a success unless an adequate and dependable flood warning and communication system is in operation. Studies have been carried out under FAP-10 to improve the existing system in Bangladesh. Any flood proofing intervention in the Southwest Area should incorporate the recommendations of the FAP-10 study.

Compartmentalisation

The concept of compartmentalisation for controlled flooding and controlled drainage is based on temporary retention of flood/local runoff within each sub-compartment, or any other smaller operational unit, to avoid accumulation of the flood/runoff from the entire area at the main outfall location. Compartmentalisation will also facilitate integrated water management for irrigation, drainage and fisheries. However, since overbank spill into protected areas is not recommended for the Southwest Area, compartmentalisation will be adopted only to introduce controlled drainage in the developments proposed by FAP-4. Compartmentalisation of areas in the Southwest Area would follow the guidelines set out in the FAP-20 study.

The contribution of controlled drainage in transforming the deeply flooded areas (F2, F3 and F4) into lands of moderate flooding that suits enhanced agricultural production has been assessed. This assessment has been carried out for a sample area (the existing Chenchuri Beel FCD Project : gross area is about 25,600 ha) based on collected field information and computer simulation of the flow routing process. Interviews with farmers in this area show that the concept of compartmentalisation is appreciated by them.

The results from the above computer simulation have been used as a guide for estimating the expected extent of land category (flood depth) transformation that could be achieved by the proposed controlled drainage in other project areas.

Issues Relating to Gravity Drainage

As already stated above, one of the important issues relating to gravity drainage is the high water levels in the rivers that function as the main drainage disposal channels. Another important issue that has been noticed during the Consultant's visit to various existing FCD projects is the siltation in the outfall channels, both in the upstream and downstream (river side) of regulators which has appreciably reduced the disposal capacity in projects such as the Alfadanga, Boalmari, Sonamukhi-Bonmander, Makle Beel, etc.

The main reson for this situation is the lack of any annual routine maintenance programmes, particularly relating to silt removal. Until the importance of routine maintenance is appreciated by the beneficiaries and the operators, the situation would not improve.

Pumped Drainage

In certain areas where drainage congestion has been identified (Section 9.3.2), there could be a need to introduce pumped drainage systems if they could be proved cost effective.

However if flood inflow through the Gorai mouth is controlled, an assessment of drainage disposal requirements of the areas north of the Coastal Embankment Polders at regional level does not identify the need for any pumped drainage disposal. But there are a number of low lying areas (beels) in Planning Unit SW7, both in the north and south of the MBR canal, which should require more detailed study before pumping could be altogether ruled out. Furthermore, the future study should also take into account the beels' potential for fisheries development.

Rehabilitation of Existing Projects

Almost all the existing projects in the study area are basically for flood control and drainage disposal. Very few projects that were implemented in the 1970s and early 1980s have any adequate measures for providing supplementary irrigation to further enhance agricultural production. Since routine maintenances have not been carried out, many of these existing projects are in a state of disrepair and require rehabilitation.

Furthermore, an environmentally friendly and more appropriate development concept, as presently advocated, relates to integrated water management within the protected areas incorporating controlled flooding, controlled drainage (with provisions for future fisheries development) and irrigation.

Therefore, any future rehabilitation programmes should take note of the need to introduce the integrated water management concept.

Impact of Flood control on Madaripur Beel Area

It is estimated that taking the 1987 (July-September) flows in the Padma as an extreme event, a cumulative overbank spill of about 3000 Mm^3 would occur through the gaps that presently remain in the Padma right bank embankment. About 40-60% of this flow would go towards the low lying areas situated north of the MBR canal; the remainder would mainly enter the Old Kumar - Arial Khan system, but is considered to be too small to cause any overtopping of the Arial Khan banks and flow towards the Madaripur beels lying south of the MBR canal. Furthermore, there are no direct links across the MBR canal between the northern and southern beels. Consequently, closing the existing gaps in the Padma right bank embankment would not cause appreciable change to the present hydrology of the Madaripur beels. However, the Madaripur beels are considered to be an ecologically and environmentally sensitive area and before any intervention is planned upstream that is likely to interfere with the beels' hydrology, detailed study of the impacts on the area need to be undertaken.

9.3.4 Ganges-Padma Right Embankment

Existing Works

The Project survey covered over 260 km of the flood embankments along Ganges/Padma from their starting point at Ramkrishnapur near the border to Nandansar. It established the level and condition of the embankment at about 500m intervals. While some sections of embankment are quite recent eg Ganges CH 4 to 8 km by CARE in 1991 and Padma CH 40 km by the BWDB in 1992, other sections such as at Hardinge Bridge were built over 80 years ago.

The existing 144 km of embankment on the Ganges (see Figure 9.14) is in a reasonable condition structurally and typically cross-sections conform to the relevant BWDB design criteria. This is particularly so from CH 0 at Ramkrishnapur to CH 45 km, but damage was noted between CH 0 and 3.5, at Bheramara and CH 59 km east of the Gorai mouth. Flooding seen in the region of CH107 to 117 km in 1987 appeared to relate to the operation of the sluices rather than to the condition of the embankment. However, many reaches of embankment still do not satisfy the design criterion of a 1 in 100 year return period flood. Details of the existing designs for the Ganges and Padma and proposed remedial works are given in Volume No. 8 - Engineering of this report.

Flood control measures are also present along the whole of the right bank of the Padma from Rajbari to Nandansar (Sariyatpur), a length of about 120 km (see Figure 9.15). They appear to be in reasonable condition and were mainly built or supervised by the BWDB. However, there are a number of vulnerable reaches eg CH 25 and 44 km and the embankment was damaged between CH 15 and 17 km and cut in 1988 at CH 33 and 36 km.

Sections of the embankment between CH 44 and 67 km on the Padma (to the mouth of the Arial Khan) were built in the 1980s, but were intermittent, and certain reaches were damaged by the 1988 flood eg between CH 45 to 51 km. They were largely rebuilt between 1990 and 1992, but contain gaps. Unfortunately, the cross-sections vary widely and in general the crest elevation is significantly lower than the design level. The remaining 16 km of embankment, down the right bank of the Arial Khan (CH 51 to 67), was constructed in the 1980s and is in reasonable condition.

The Arial Khan dissects the embankment which, to the east is in a reasonable condition; certain sections between CH 67 and 119 km however have been deliberately cut to promote flooding and irrigation and/or have been damaged by the 1988 floods. The various sections of this reach were constructed between 1984 and 1991 by a variety of Government Agencies.

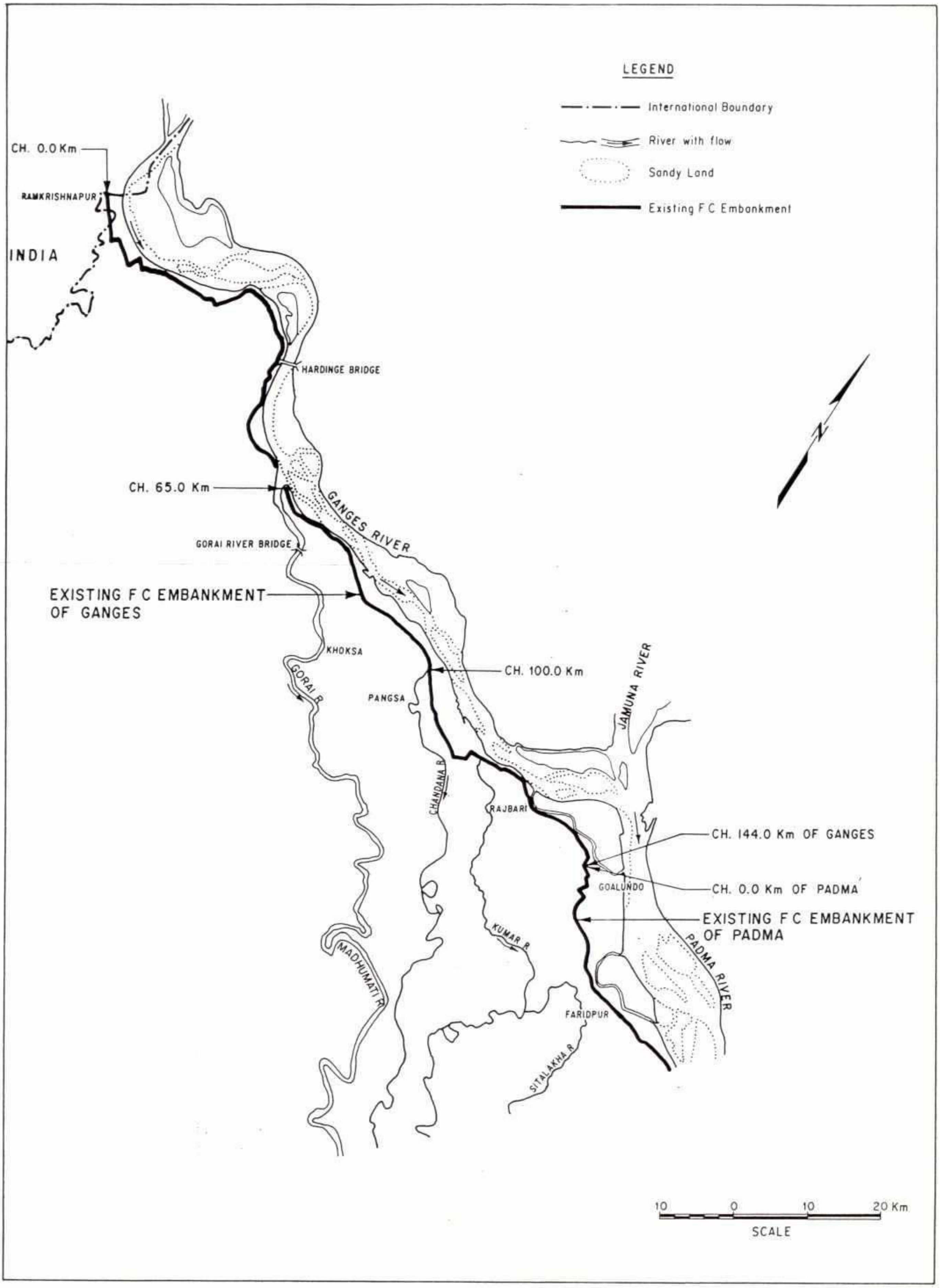
Relationship with Existing and Planned Upstream Works

The Ganges-Padma right embankment can and will be affected by large works upstream, such as other embankments or major works (barrages, etc). For the Ganges right embankment, apart from the construction of its left embankment, the only possible upstream impact would come from the Farakka Barrage. However, even though the operations of Farakka enhances peak flows, the changes are too small to have an impact on the embankment. What might be significant and applies equally to other areas, is crustal movement and this should be considered and monitored in the medium and long term.

Changes in flood water elevations due to embankments for the main rivers in Bangladesh have been examined by FAP-25 using a fixed bed model. For the Ganges the predicted increase in levels, for full upstream embanking (Scenario No 5 of FAP-25), over the base case for the 1988 flood at Hardinge Bridge, Sengram and Mahendrapur were 0.06m, 0.08m and 0.18m, respectively. The equivalent figures for the 1 in 100 year flood are estimated at 0.23m; 0.23m and 0.50m respectively.

The major impact in terms of upstream works will be mainly on the Padma due to embanking on the Jamuna. The impact assessment by FAP-25 for extreme events using

Figure 9.14



Ganges : Existing Flood Embankment

a fixed bed model has a number of limitations concerning river morphology, and the results have to be interpreted with care, because:

- a fixed bed model cannot respond dynamically
- there are inaccuracies in representing spill patterns and
- channel morphology is controlled by the dominant discharge, which will be largely unaffected.

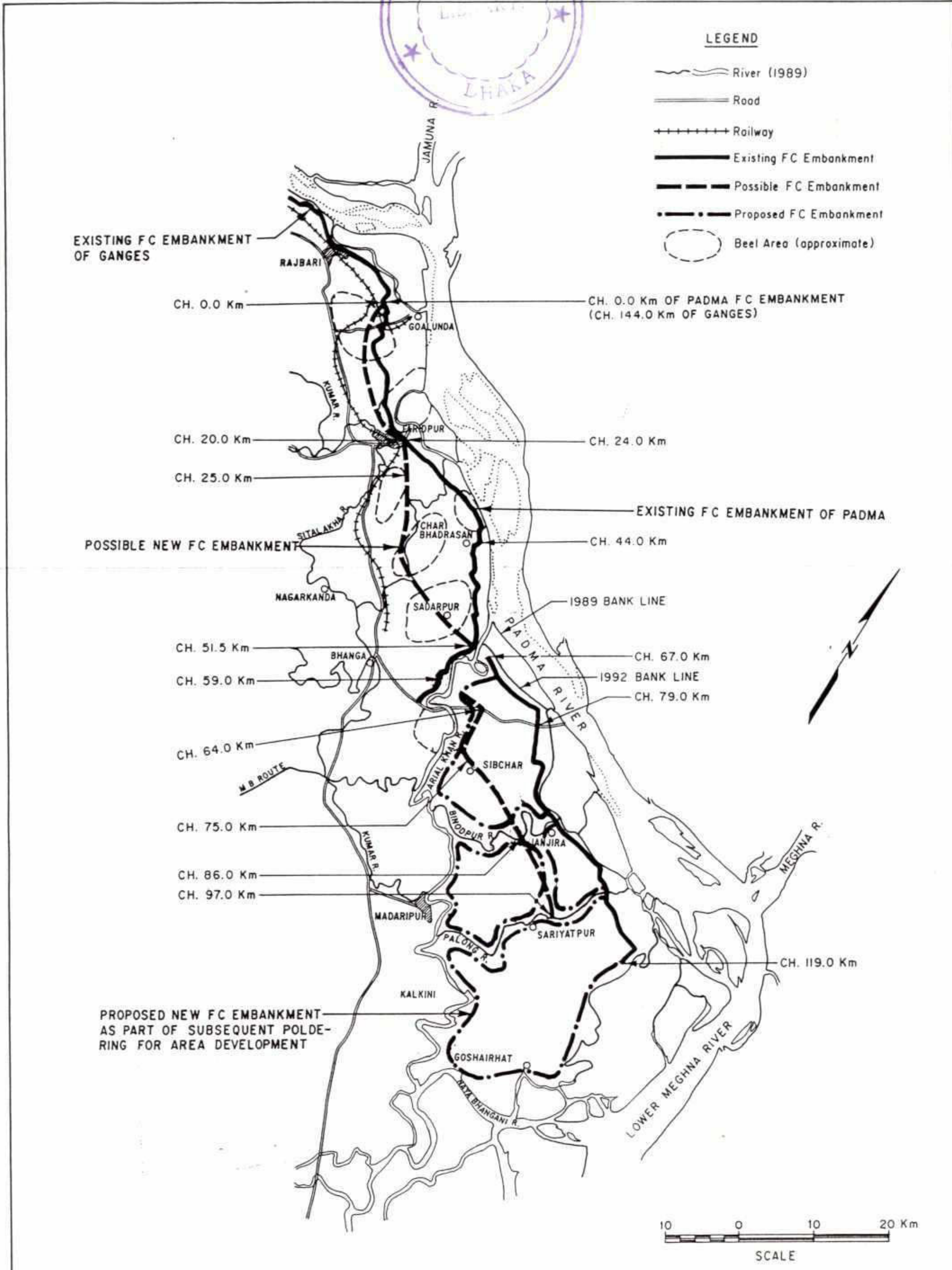
However, the FAP-25 output time series data relating to the 1988 flows in conjunction with the ultimate stage of development of the flood control embankments (Scenario 5) on all major rivers and main distributaries were used as the boundary inflows and the SWAM Model was run to estimate the impact of Scenario 5 on the main river network of the Southwest Area. A comparison of the resulting flows and levels with the base situation that actually prevailed in 1988 shows that the predicted increase in levels for the 1988 flood in the Padma for Baruria and Mawa are 0.33m and 0.36m, respectively. These changes are smaller than those predicted for Sirajganj (0.87m) for the 1988 flood. Also, the peak flow figures of Scenario 5 are 149,000 m^3/s for Baruria and 142,000 m^3/s for Mawa, or an increase of about 13% for both over the 1988 flood discharge. Under these extreme conditions and with full embanking the velocity increase averages 5%, and is up to 10% greater at the confluence with the Ganges. This would be equivalent to a channel width increase of 5% and, as such, is small compared with the existing channel width and the natural variations seen in this immature river. The time scale of such changes is significant, as while one third of the changes can occur in the first 5 years, it may take the river 50 to 100 years to finally adjust. Thus, whatever additional changes are seen, they will be relatively slow and unlikely to adversely affect the siting of the Padma's right embankment as proposed later in this section.

The Overall Flood Embankment Implementation Schedule (Flood Policy Study, 1989) shows construction of the Ganges Embankment by 1997, while the Padma RB embankment is delayed until 2010. As the whole of the Ganges-Padma right embankment is almost complete, it is recommended that the embankment be completed as soon as is practicable in order to allow its economic benefits to be realised as soon as possible. The risks, in terms of river morphology, of doing this should be small as in the short and medium term the embankments should be safe. It is only in the long term, in the Padma, they may be under threat in localised areas. Thus the risks in 2010 will be similar to the present ones. Furthermore, the proposed irrigation areas on the left bank of the Madhumati under the Gorai augmentation will require that any uncontrolled flood through existing gaps in the Padma FC embankments (Ch. 0 to 67 km) is eliminated to assure increased agricultural production (Figure 9.15). In addition, if it is not completed soon, it will deteriorate, cost more to refurbish and threaten those relying on it for their protection. Clearly, it will have to be upgraded in line with current BWDB practice and the predicted flood levels relating to Scenario 5.

The completion of the Ganges/Padma right embankment prior to the Padma left embankment can be expected to raise flood water levels in the Padma. As there is no data on this scenario, it is recommended that FAP-25 determine the water level rise so that its impact on the present left bank of the Padma can be established and appropriate action be taken on the left bank. However, a comparison of the Scenario 3 and 5 results of FAP-25 shows that the additional increase in level in Mawa produced by Scenario 5 is insignificant (about 5 cm); it is reasonable to assume that a similar impact could be expected on the Padma left bank when the right bank is embanked.

Again, the SWAM simulation based on FAP-25 Scenario 5 output shows that the predicted increase in flow in the Arial Khan upto Madaripur (Ch. 55 km) compared with the base

Figure 9.15



Padma : Existing and Proposed Flood Embankments situation (1988) is about 15% and the corresponding increase in level is about 0.33m. The lower reach of the Arial Khan (Ch. 148 km) shows higher increases due to further inflow, particularly from the Lower Meghna. The expected increase in water level in Arial Khan due to the construction of an embankment on its right bank is in the order of 5 cm. For the worst case (Scenario 5), the velocity increases are in the order of 12%. These expected changes are considered in assessing the set back and crest level requirements for the proposed Arial Khan FC embankment (right bank).

Development Opportunities.

The right flood embankment on the Ganges is generally in reasonable condition and when upgraded will provide protection to the land behind. While there are no obvious benefits of upgrading as the present embankment has proved effective and areas previously flooded have been minor, the benefits should come from the increased level of security that will be required once full embanking takes place elsewhere. The only exceptions to this are at Bheramara, the Chandana mouth and east of the mouth of the Gorai. In the latter, benefits will accrue from the elimination of problems due to the existing flooding and additional security once the Gorai is regulated.

In the remaining areas, the completion of the existing Padma right embankment west of the Arial Khan with its regulators would allow the introduction of controlled flooding even when major events such as the 1987 and 1988 floods occur. However, the existing low embankments and embanked local roads south of the Faridpur to Sariatpur road were severely inundated in both 1987 and 1988. Morphological analyses have shown that the Arial Khan in this area is very mobile and has a wide corridor, but that the changes should develop relatively gradually in a known pattern. Thus it is proposed to provide some 52 km of new embankment, set back from the river as far as Madaripur (see Figure 9.16). Where the Kumar (which feeds the MB route) forms a tributary of the Arial Khan, the embankment would have to be returned to the main Faridpur/Patuakhali road. This would allow the development of the Arial Khan-Bisarkandi Scheme (Figure 9.29).

The area to be protected and brought under controlled flooding along the Padma and to the west of the Arial Khan covers about 1300 km² of NCA of which presently some 18% is irrigated and some 82% is rainfed. Integrating this development with controlled drainage through compartmentalisation and introducing irrigation would bring about a highly beneficial impact to the area. In addition, there would be scope for fisheries development.

To the east of the main Arial Khan off-take upgrading of the existing embankment adjacent to the Padma would have to be combined with poldering, as the area is dissected by a number of small rivers which feed into the Arial Khan. The area to be developed covers about 1000 km² of NCA of which some 20% is irrigated and some 80% rainfed. When poldered and developed as an integrated scheme as proposed above the irrigated area could be increased to about 70% and the flooding seen during 1988 would be reduced by 50%.

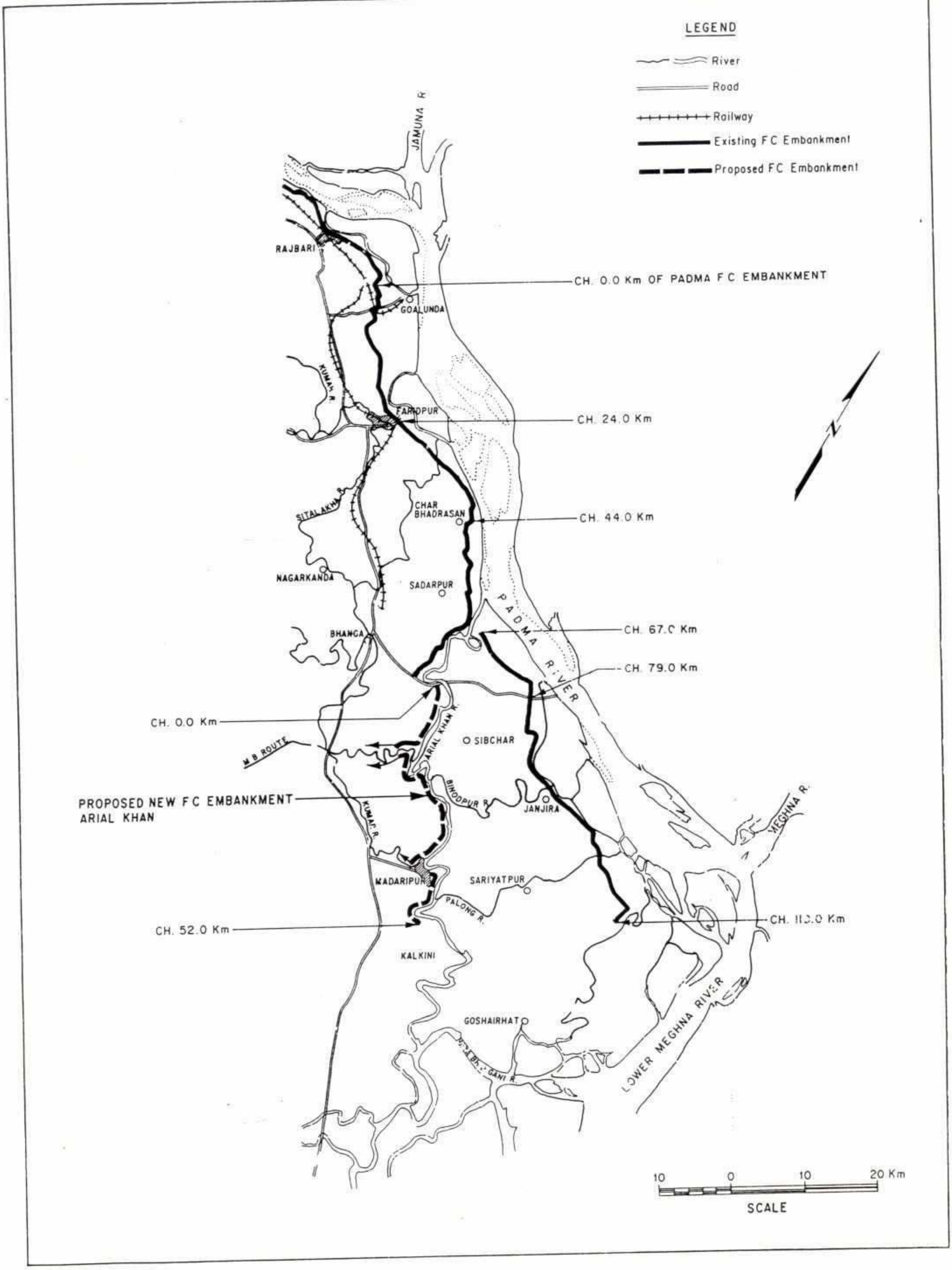
The proposed 52 km of new embankment along the right bank of the Arial Khan, to the south of Madaripur, would protect about 720 km² of NCA and allow the introduction of the above proposed integrated development.

Proposed Works

Ganges

As discussed, morphological analyses of the Ganges indicate that, over the long term, right bank movement will continue northwards and there is no pressing need to retire the embankment. One exception might be between about CH 95 to 105, which lies across the position of the right bank of the Ganges in 1779 and 1860. However, as; the present bank

Figure 9.16



Arial Khan : Proposed New Embankment

lies over 1 km away; the Ganges has not moved this far south in over 130 years; and the rate of bank movement is relatively slow, the embankment should be left where it is. Should bank erosion become active again, the embankment should be retired, but there should be sufficient time available to do so.

The total cost for repairing and resectioning the Ganges right embankment is estimated at 60 M Tk. It should proceed as soon as is practicable and before the date given in the Overall Flood Embankment Implementation Schedule (Flood Policy Study, 1989). Apart from the upgrading of the sections around CH 47 and 59, upgrading of the Ganges right embankment could follow on from that proposed for the Padma.

Details of the existing sections and proposed remedial works are given in Volume No. 8 - Engineering of this report.

Padma

The Padma is a younger river than the Ganges and thus the siting of embankments requires greater caution. Thus, following the analyses of the morphology and other technical requirements, two main options for the Padma have been considered, namely:

Option 1 - Upgrading the existing embankment

The Padma's river corridor limits are more difficult to define and an upgraded embankment will be at risk, especially in the area around CH 40 (see Figure 9.15). When combined with compartmentalisation, it could protect an area of about 2300 km² and provide improved water management between June and December. The estimated costs for the above works is 260 M Tk ie embankment upgrading (west of Arial Khan mouth) 160 M Tk and flood proofing 100 M Tk.

The Option has a disadvantage in that it would isolate four major beels from the river and thus an additional four regulators would be required to feed them. In additional these regulators must allow fish movement in both directions for the full range of flood condition and must be carefully controlled.

Option 2 - Retire the embankment

The Padma, bank line can change by up to 1 km in one season and this option considers the provision of a new embankment along a more secure alignment (see Figure 9.15), mainly east of Faridpur, but could also include the area to the west to Goalunda. The set-back varies between 5 and 12 km and, as it is so extensive, controlled flooding has not been considered. It does,however, leave the main beel areas connected to the river. The total area being protected in this case is 1600 km².

A new embankment east of Faridpur would cost 200 M Tk but with the upgrading of the remaining existing embankment and extensive flood proofing, the total scheme cost would be about 600 M Tk.

As Option 1 is less than half of the cost of Option 2 and represents the utilisation of a considerable existing investment, Option 1 is preferred. It contains provisions for supplying the beels and will require a careful monitoring of bank changes in the Padma so that it can be retired or possibly protected in advance of the Padma's course approaching too closely.

The old course of the combined flows of the Ganges and Jamuna lay between the present course of the Arial Khan and Sariyatpur. The Padma only adopted its present course between about 1830 and 1860. Even in recent times the movement of the Padma right bank at the Arial Khan's mouth has been, say, 1 km annually and the morphological

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analyses indicated that the safe embankment line should be some 5 to 12 km back from the existing (1992) river bank and embankment. However, the floodplain is traversed by a number of important spill rivers and adoption of this safe line would have created small protected areas, while leaving much larger areas unprotected. It is therefore recommended to utilise the existing embankment and create large poldered areas (see Figure 9.15). The embankment would terminate to the east in an area of Chandana Alluvium, which appears to be relatively high and resistant to erosion (see Volume 3 of this Report).

The crest elevation of the existing Padma embankment east of the Arial Khan mouth is significantly below that which will be required for the water levels associated with full embanking upstream. The cost of raising the embankment will be about 140 M Tk and the cost of new polders some 370 M Tk ie a scheme cost of 510 M Tk.

Arial Khan

In addition to the above poldering which affects the left bank of the Arial Khan, it is proposed that 52 km of new embankment be built between the Faridpur/Sariatpur road to the south of Madaripur. The cost of the scheme, which includes controlled flooding, would be about 340 M Tk.

The Implementation Schedule (Flood Policy study, 1989) shows studies of this embankment and that for the Naria starting in 1997 with the work being completed in 2003. Nevertheless, it is recommended that the works described above are implemented in the very near future. Before implementation it is essential that FAP-25 establish the design water levels for the situation with full embanking upstream. This will be required for both the right embankment and left bank polder schemes.

9.3.5 Lower Meghna Right Embankment

Existing Works

Existing embankments on the right bank of the Lower Meghna are essentially polders and limited to the protection of specific areas such as Bhola Island. This is because the right bank is dissected by the numerous spill rivers which feed fresh water into the South Central Region.

The Lower Meghna is the youngest of the regional rivers and perhaps, with its many spill rivers, is rather like what the Ganges must have been several centuries ago. The Lower Meghna is also the recipient of the majority of the sediment load from the rivers which combine to form it and, while most sediment passes through to the Bay of Bengal, a proportion must accrete in order to balance the relatively rapid rate of subsidence in the area. The Lower Meghna estuary is therefore very dynamic and the existing polders can be affected by the following morphological changes, namely:

- episodic erosion and accretion rates which can be biased by extreme events
- char movement with a periodicity of between 10 and 20 years
- a tendency for the main channel to move eastwards and for the right bank (Southwest Area) to accrete.

The existing polders can therefore only be considered in the short term.

The Lower Meghna is also different from other rivers in that it is fully tidal and thus dominated by tidal effects. However, the net freshwater flows still form a significant proportion of the total tidal flux in the wet season.

Relationship with Existing and Planned Upstream Works

Like the Ganges-Padma right embankment, the Lower Meghna will be affected by the major works upstream, the most significant being the embanking. As the estuary represents the collection point for all river discharges, the impact of the other works can be expected to be higher in this area. In addition, tidal effects have to be considered as must the impact of the significant rise in water level due to tidal surges and the tidal boar and waves that accompany cyclones.

The Overall Flood Embankment Implementation Schedule (Flood Policy study, 1989) shows embanking for Bangladesh starting inland and progressively moving downstream. Nothing is shown for the Lower Meghna right embankment. From an analysis of the morphology of the estuary, the policy of having no embankments on the Lower Meghna appears correct. The river is too young, too unstable and dissected by too many spill rivers for embanking to be considered as viable in the next 50 to 100 years or so.

9.3.6 Impacts of FCD

The impacts of all these schemes have elements in common. Construction of embankments requires the acquisition of land for embankment and borrow areas. Borrow areas in the past, have been excavated with little thought for their future use. This land loss can be in the order of 3%, which taken over the entire project areas represents a considerable impact, unless this land can be returned to some future, productive use.

The incorporation of control structures and revetments in flood protection and irrigation brings about an indirect, but significant impact on the timber resources of the country by the use of bricks.

Social forestry may suffer in two ways: (i) the use of timber in brick making, and (ii) the cutting of trees land for extra agricultural land to expand irrigated crops.

An ongoing requirement in the schemes will be needed to take account of the impact on floodplain fisheries. These fisheries have been severely affected by existing schemes throughout the country, and further FCD projects will serve to make a bad situation worse. It is possible that, at some point in time, the cumulative impact of denial of recruitment may irreversibly damage stocks of certain species, particularly in local rivers. Even rehabilitation of existing embankments need to consider the fishery aspect, as there may have been an improvement in the floodplain/beel fisheries as a result of embankments being eroded, breached or cut.

Particular problems exist in the FCD schemes on the boundary rivers with respect to the dwellers on the char islands. Many of these people are at risk from flood, and erosion of the chars. They may be disadvantaged further if river flows are locally channeled and increased, and their boat transport to inland areas interrupted.

In many parts rural transport is dependent on country boats. These ply both internally within FCD schemes, as well as being the means of transport for both humans and commercial cargo. Whilst increasing mechanisation allows such transport to move cargos more freely, smaller family craft and trade boats (including small fishing craft) are dependent on oars and/or tidal movements. Interventions that close channels may severely impact on the ability of local people to move within their area, or to take their produce easily to market.

In the northern part of the SWA, embankments may serve to replace artisanal boat transport by the use of cycle, rickshaws and lorries. Motorised vehicles are generally outside the means of rural families, whilst small boats (dinghis) are both affordable and a means of transport and livelihood in many cases.

Projects need to address the concerns of public health, whether or not they are primarily directed towards these issues. Projects in particular should consider the implications of aquifer recharge through denial of flood, and of improving sanitation as part of the overall drive towards better rural health, providing (through the projects) systems and services designed to offset potential problems.

9.3.7 Mitigation

It is essential that feasibility studies for FCD schemes should include a detailed investigation into local fisheries, and the impact of schemes on local fishing communities. Where possible embankments should be built inland of beel areas, to allow these areas to flood in the monsoon and to retain some of the floodplain recruitment.

The use of structures and controlled flooding is an alternative, but this system requires immediate actions at specific times of the year, and even some hours delay may reduce the value of this form of mitigation. Structures need to admit surface waters at the beginning of flood, and the deeper, outward flows (containing the juvenile and adult fish) as the flood recedes. This requires a degree of operational complexity which is not always achievable in practice.

With respect to land loss for homesteads this can largely be mitigated by designing embankments that can accommodate 'linear villages'. Whilst increasing land acquisition costs, this concept has the added attraction that the villagers have a vested interest in the maintenance of the embankment which is essential to ensure flood protection over the long term.

The special needs of the char dwellers should be addressed in the cases of the Ganges, Padma and Lower Meghna embankments. Although outside the project area, these peoples' needs should be integrated into these FCD schemes. These needs should be identified by peoples' participation programmes, and addressed in project design, so as to ensure that they are also able to benefit (or be less disadvantaged) by these particular projects.

Feasibility studies should carefully assess the present water supplies and sanitation existent in the project area. It will then be possible to determine how the project may impact on public health, and what integrated measures should be taken in mitigation.

Concern about water supplies is greatest in areas where rural supplies placed at risk by excessive draw-down in the aquifer (below suction hand-pump capabilities) and recharge by flood is prevented by FCD works. The use of piston hand-pumps (Tara pumps) with greater lift should be considered for all future installations for rural water supplies, to overcome this potential (and actual) threat.

Villages should also have sufficient pit latrines to ensure that open defecation in or near the channels does not occur. These should be sited well away from water bodies, as part of project works.

In addition to these measures, hygiene education should be put in place by suitable NGOs as a part of the project.

9.3.8 Conclusions

The flood control and drainage study of the areas north of the Coastal Embankment Polders has identified that drainage congestion of varying degrees occurs during the monsoon period (lasting upto 8 weeks), generally in areas bounded by Magura, Khulna, Barisal, Sariyatpur, Faridpur and Rajbari. In addition, some overbank spill through gaps in the existing flood control embankment along the Padma right bank is experienced during certain periods when the river levels are relatively high. The overbank spill particularly affects the low lying areas just north of the MBR Canal.

It is possible to achieve appreciable improvement in the drainage disposal if the monsoon water levels in the related inland rivers could be lowered by controlling the inflow to the Gorai from the Ganges to a maximum of 4250 m^3/s, which is infact the dominant discharge of the Gorai. The drainage disposal could be further improved for the areas west of the Madhumati if the capacity of the river link between the Chitra and the Bhairab could be increased.

The 1992 field survey indicates that almost the entire lengths of the Ganges/Padma right bank have been provided with flood control embankments, and the gaps that now exist are for incorporating water control structures/regulators. The proposed location and capacity of these structures need to be reassessed to ensure that they are in conformity with the controlled flooding concept. A study of the FAP-25 results and the field survey findings shows that some resectioning of these flood control embankment is necessary. Once these improvements are completed, they will complement the drainage improvements recommended above. It is estimated that the required incorporation of structures and improvement of embankments are cost effective and they should be implemented early. Appropriate flood proofing measures should also be incorporated.

The Lower Meghna, being morphologically young, is still dynamic and has not found its equilibrium. No embankment therefore, should be constructed until the impacts of the proposed left bank works are monitored.

Any measures to provide controlled flooding and drainage should also incorporate compartmentalisation of the protected areas in order to introduce integrated water management.

Any future programmes for rehabilitation of existing FCD projects should conform to the concept of controlled flooding, controlled drainage and integrated water management.

9.4 Drainage Improvements in the Coastal Area

9.4.1 Introduction

The coastal studies have sought to produce an understanding of the current situation and predict future conditions with and without interventions. There have been a variety of sources of information and analysis that have been used for this purpose and it has not been assumed that any one of these is sufficient on its own to deal with the technical complexity and large scale of the coastal and river delta systems. For example, although field surveys are essential for obtaining information on existing conditions they are, on their own, insufficient for predicting future conditions. On the other hand numerical models are only able to produce meaningful predictions of future conditions if the model realistically reproduces the existing situation as verified by field surveys.

The various sources of information and analysis, details of which may be found in Volume 4 are summarised:

- Current and Previous Studies
- Current and Historic survey data

- Reports from BWDB Executive Engineers
- Satellite Imagery and Historic Maps
- Hydrodynamic modelling
- Regime analysis using field survey and modelling results
- Sediment Transport modelling results
- Drainage analysis for each individual polder
- Field visits and public meetings

The other factor which has been taken into account is a keen awareness that the coastal region is a complex dynamic system and the consequences of actions which disrupt the natural processes can have significant negative effects, in addition to the potential positive effects. The CEP is a particular example of a project where the state of knowledge at the time of inception was apparently not sufficient to predict both the beneficial and adverse consequences of the project. The adverse consequences have now materialised in the form of drainage congestion. In this situation interventions should be planned on a stage by stage basis, with reliable monitoring of each stage constituting an essential part of the intervention package.

9.4.2 Long Term Coastal Strategy

The aim of the long term (15 years onwards) coastal strategy is to enable the Region to make the most beneficial use of the resources in the coastal zone. Drainage congestion is the major problem which currently prevents these benefits from being realised. Other problems are related to salinity intrusion during the dry season, the social conflicts that arise between shrimp and rice cultivation, internal water management within the polders and primary navigation including Mongla Port.

A number of options for improving the prevailing situation have been considered during the course of the study, some of which for various reasons were considered to be untenable. This sifting process reduced the number of options that were considered further to three and the positive and negative aspects of these on the "burning issues" and the Regional Plan were assessed and are summarised in the following paragraphs and tables.

Option 1 - no interventions in the coastal zone and allow the delta to progress to a new tidal equilibrium based on augmented Gorai flows and the existing tidal cubature. Whilst this does not involve any large capital investments it does not address the problems of a continuing deterioration and the full realisation of an even larger investment that has already been made. The population in some of the areas are already unhappy about the drainage capability of the polders and the pressures on these areas will increase with population growth. The possible change of land use to shrimp, fish culture and salt production, though possible is not a solution that is likely to be socially acceptable. Furthermore, these activities, although not dependent on freshwater flows, still require relatively frequent water exchange and thus good conveyance characteristics for the primary rivers around the polders. It is concluded that this option has more fundamental negative than positive aspects.

TABLE 9.5

Option 1 - No External Coastal Interventions

Positive	Negative
No large capital investments would make more funds available for operation, maintenance and improved farming and fishing training.	Social discontent because expectations of CEP have not been fulfilled. Loss of farming and homestead lands in unsustainable drainage.
Some poldered areas might be more productive if turned over exclusively to shrimp, fish culture and salt production all of which are valuable commodities.	Drainage congestion will become progressively worse and where land use cannot be changed to suit congested condition pumping may be required.
Areas that cannot be drained could be used as freshwater reservoirs for industry, drinking water and irrigation.	Loss of some navigation routes Long term consequences are not known If Gorai flows are cut off conditions will become worse
In areas where tidal flooding is permitted ground levels will be raised naturally.	Increased risk and frequency of flooding in congested areas
Time scale - immediate	Exposure to cyclonic surge is unchanged Saline intrusion may increase in congested channels.

Option 2 - intervene in the coastal zone to revitalise the CEP and prevent further deterioration. Interventions in the CEP area will direct drainage to sustainable rivers and future interventions should not cause these rivers to deteriorate. Interventions will be required progressively as the delta attains a new tidal equilibrium based on augmented Gorai flows and a tidal cubature which is modified by future interventions. The interventions will, however, be based on the premise that the Region will remain tidally dominated. In the longer term this option would allow realistic and sustainable planning of land use to increase farming and fisheries production to meet some of the future needs of the population. It is anticipated that it would be a popular option, based on interviews with farmers, BWDB officers and M.Ps who represent the various areas in the region. The sustainment of selected rivers would maintain drainage conditions, aid navigation planning and assist in attempting to maintain the delicate ecological balance that exists within the Sundarbans forest. In order to maximise the benefits from this option the flows from the Gorai need to be maintained at least at their present levels to avoid deterioration of the future system. Interventions would proceed in a phased development allowing impacts to be monitored over time and, if necessary, schemes could be revised to meet changing needs and contitions. The perceived positive and negative aspects of this option are summarised in Table 9.6.

TABLE 9.6

Option 2 - Controlled Transition to Tidal Equilibrium

Positive	Negative
Socially acceptable because expectations of CEP will be fulfilled (partially at least)	Capital works interventions will be needed progressively until estuary stabilises which may take many decades.
Controlled interventions allows realistic and sustainable future planning of land-use	Medium to high Cost
Minimum impact on the ecological balance within the Sundarbans	If Gorai wet season flows are cut-off in the future system will deteriorate wasting investment made in the coastal areas
Selected channels will remain open thereby allowing long term navigation planning	Lacks the political attractions of a 'single solution' to drainage congestion problems.
Saline intrusion will be controlled at, or marginally better, than present day levels	
Development is in harmony with natural changes.	

Option 3 - transform the Region into a non-tidal area by the introduction of major tidal barriers accross all of the rivers that connect to the Bay of Bengal and control of the water quality and level throughout the Region to suit farming, fishing and industrial needs. This option constitutes a "brute force" approach, the main attribute of which would be to control or eliminate saline intusion. Large scale storage of fresh water would be provided, but this would only reduce the need for augmented frash water flows to the upper areas of the region. Existing land use practices of shrimp farming in certain areas would no longer be possible and the Sunderbans forest would go into rapid deterioration. Implementation could be carried out in a phased manner, but during the intervening period the rivers in those areas not converted could silt up more rapidly due to the loss of tidal cubature through interconnections. These positive and negative aspects are summarised in Table 9.7.

TABLE 9.7

Option 3 - Non Tidal Coastal Zone

Positive	Negative
Saline intrusion removed	Very High Cost for 30-50 years and full benefits will not be realised until all closures are complete
Large scale storage of fresh water in existing rivers will reduce dependence on future Gorai flows.	Benefit of tidal drainage systems will be lost.
Risk of cyclonic surge penetrating the Region is reduced, but not eliminated	Brackish water shrimp and fish farming will not be possible inside the non tidal zone
Major changes in land use will be offset by increased rice production due to elimination of saline water.	Navigation outside the region will be through lock gates.
Siltation in the non tidal zone from marine sources will be eliminated.	Large areas of standing water may create health hazards
	Heavy siltation downstream of the barriers
	Environmental damage and morphological impact cannot be reliably predicted with present day state of knowledge, but can be anticipated to be extensive

9.4.3 Preferred Long Term Strategy Option

The preferred strategy option is Option 2. The reasons for this choice are as follows:

- Option 2 recognises that the coastal zone is a changing environment and, to ensure sustainability, development should be in harmony with these changes
- It aims to obtain the maximum benefit from the CEP, provided this is not in conflict with the requirement for sustainability
- Mongla Port and navigation in general will benefit from sustained river system
- Investment in interventions which follow this strategy will be complementary to investments in augmentation of fresh water flows
- It will allow small scale and immediate interventions to be carried out, and yield benefits in a short time scale, without relying on the future development of a large scale high cost project
- Impact of each intervention can be monitored and future interventions tailored to suit the results

- It will provide continual evolution of the polder system as the delta progresses towards stable tidal equilibrium

- The linkages between the long term coastal strategy and the Regional 'burning issues' are shown diagrammatically on Figure 9.17.

The main uncertainty is the consequences of the Gorai becoming separated from the Ganges inflows and the negative impacts this would have on the coastal areas. This preference for option 2 is strengthened further if commitments are made to sustain the Gorai mouth.

9.4.4 Near Term Coastal Strategy

There clearly must be strong links between the near term and long term strategies. The near term (0-15 years) strategy proposes ways to meet the current urgent requirements in the coastal zone in line with the long term strategy. The near term coastal strategy is primarily concerned with projects related to drainage congestion in the CEP area.

The key link is that near term projects and interventions must not interfere with the sustainable rivers identified in Section 9.4.7. This means that projects must be planned on a Regional basis so that adverse effects are not caused elsewhere as a consequence of the project.

Near term projects in the CEP which are likely to impact on, or improve, drainage congestion are summarised in Table 9.8.

Figure 9. 17

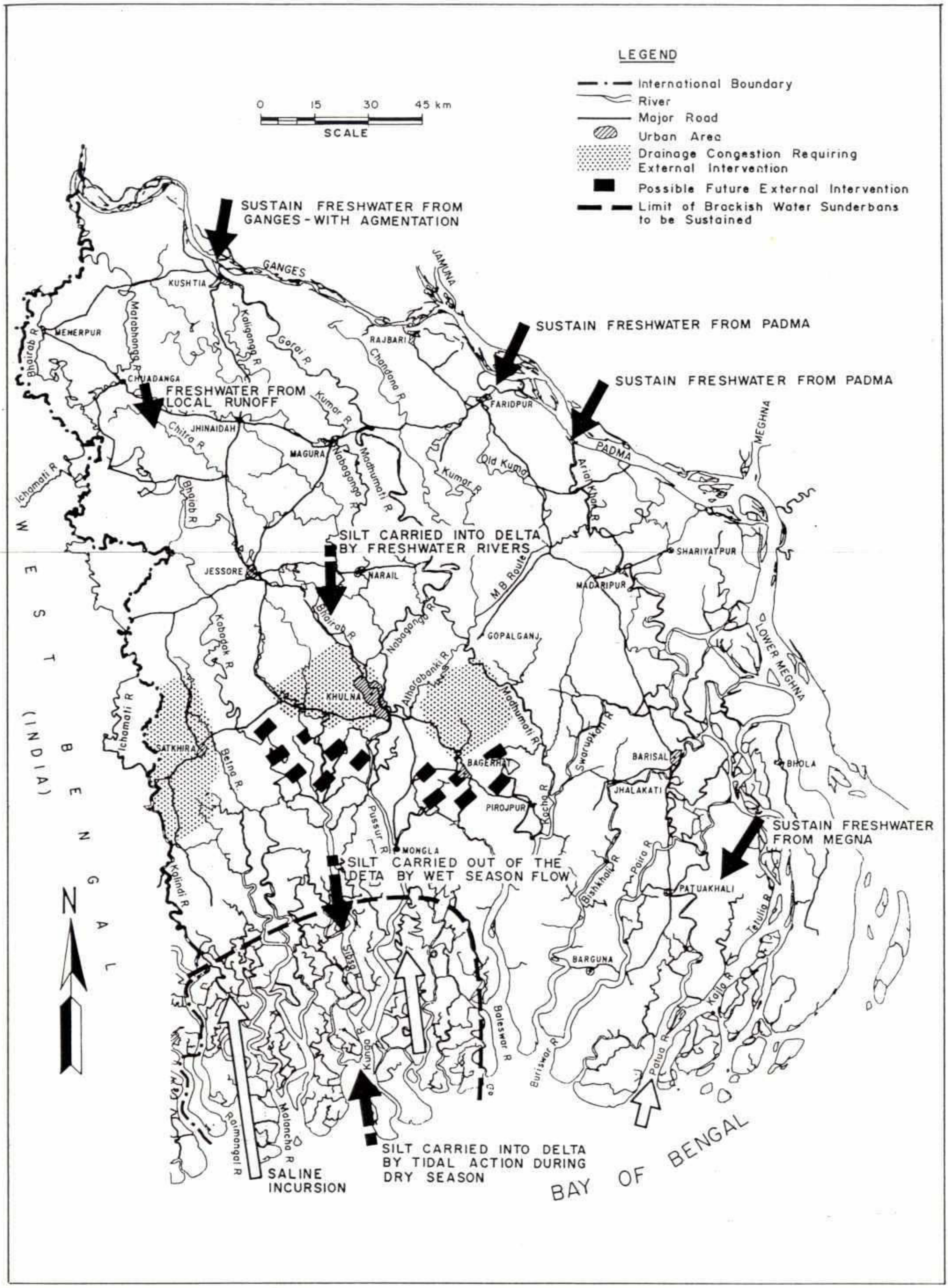

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TABLE 9.8

Near Term Projects in the CEP Area

Project	Purpose	Status
Satkhira - dredging in Labangabati; Morichap; Kanksiali & Guntiakhali	- to create tidal interchange between Ichamati and Kholpetua to assist drainage in Polders: 2, 3 and partially 4 & 5	Conceptual as part of the Regional strategy under FAP4
Khulna - CERP II proposals by Haskoning	- to drain Beel Dakatia, Polders 24; 25; 27/1; 27/2; 28/1; 28/2	Feasibility study completed January'93
Khulna - create a macro- polder comprising polders 17/1;26;18/19;20 & 29	- to provide sustainable drainage to polders 24 & 25 under CERP II proposals by creating a sustainable channel in the U.Bhadra & U.Salta Rivers - to eliminate siltation and control saline intrusion in Teligati; Gangrail; Salta(W); Gunkhati & Haria rivers - to prevent deterioration of polders 17/1; 26; 18/19; 20 and 29 due to drainage congestion.	Conceptual as part of the Regional strategy under FAP4
Khulna - Khulna town drainage outlet to L.Solmari as proposed by FAP 9A	to improve town drainage	Outline design stage completed under FAP 9A
Bagerhat - dredging in Chitra river in Polder 36/1 and augmentation of fresh water flows in the MB Route	to improve drainage in Polder 36/1 to improve drainage in 36/2; 34/3 & 35/3 by sustaining the Poylahara River	Conceptual as part of the Regional strategy under FAP-4
3rd Fisheries - Development of shrimp farming in polder 5; 23; 16;18/19; 31; 32 & 33	to improve shrimp farming	Study stage under 3rd Fisheries Project

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TABLE 9.8 (continued)

Near Term Projects in the CEP Area

Project	Purpose	Status
Mongla Port - Pussur-Sibsa Study of alternative interventions at, or near, Mongla Port	to improve navigation at Mongla Port	Numerical Model studies under Danida have identified 12 options for pre-feasibility studies
Systems Rehabilitation Project - sub-projects in the Southwest	to study as sub-projects polders 4; 5; 7/1; 7/2; 13-14/2; 14/1; 15; 32; 34/3; 35/1; 35/3; 40/2; 48	Possible options to be studied under BWDB System Rehabilitation Project
CEP - Completion of polders 34/2; 35/2; 36/2; 37 & 39/2	to improve productivity of these polders	Conceptual as part of the Regional Strategy under FAP4
CEP - Internal intervention	to improve internal drainage of all polders shown on Table 9.4(6)	Conceptual as part of the Regional Strategy under FAP4
M.G. Canal Salinity Control	to prevent salinity intrusion from Pussur to Baleswar River	Problem identified as a project requiring detailed study

Some of the projects described in Table 9.8 above were conceived before the FAP-4 study commenced. It is therefore important to check that the project proposals are compatible with the strategy and identify any conflicts. Table 9.9 summarises the outcome of this check.

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TABLE 9.9

Compatibility between Near Term Projects and Strategy

Project	Compatibility
Satkhira - dredging	- Compatible with strategy of sustaining Kholpetua River. - Impact on salinity intrusion is subject to salinity levels in the Ichamati
Khulna - CERP II	- Drainage of Polders 27/1; 27/2; 28/1; 28/2 into the L. Solmari in compatible with strategy of sustaining this river. - Drainage of polders 24 & 25 into U.Bhadra is not compatible with strategy of only draining into sustainable rivers. Proposals to sustain U.Bhadra by dredging or macro-poldering to the south require further study.
Khulna - Macro polder	- Drainage of macro polder into Lower Salta; L. Bhadra; Deluti and Sibsa is compatible with strategy of sustaining these rivers. - Compatible with strategy of sustaining the Poylahara.
Bagerhat - dredging in Chitra river and MB Route	- Compatible with strategy of sustaining the Poylahara.
3rd Fisheries - Shrimp production in polders 5; 23; 16; 18/19; 31; 32 & 33	- Shrimp in polders 5; 23; 31; 32 & 33 is compatible with strategy - Shrimp in polders 16 & 18/19 may conflict with Khulna macro polder proposal
Mongla Port - 12 options (see Figures in Section 8, Volume 4)	- Schemes 1, 5, 6, 8, 9, 10 & 12 are not compatible with strategy of sustaining the Pussur-Sibsa tidal river system and should not be persued further - Schemes 2 & 3 are compatible with the strategy and should be examined further - Scheme 4 is compatible with the strategy but conflicts with CERP II

TABLE 9.9 (continued)

Compatibility between Near Term Projects and Strategy

Project	Compatibility
	- Scheme 7 conflicts with Regional strategy of augmenting dry season Gorai flow to 150 m^3/sec. The proposed 1000 m^3/sec exceeds the dry season Ganges flow and may not be feasible even with the Ganges Barrage. - Scheme 11 conflicts with the strategy of maximising the benefits of the CEP and should not be persued. A reduced scheme involving only polders 34/2 and 35/2 should be studied before these polders are completed
Systems Rehabilitation Project	- Compatible with strategy because polders to be studied are able to drain to sustainable rivers
CEP - Completion of polers 34/2; 35/2; 36/2, 37 & 39/2	- Compatible with strategy of drainage to sustainable rivers but impact of this large change in tidal cubature requires detailed study of the impact on these rivers and particularly the impact on navigation to Mongla
CEP - Internal intervention	- Compatible with strategy of maximising benefits of the CEP
MG Canal - Salinity control	- Control gate on the canal to limit ebb tide flows from Pussur to Baleswar would affect flows in Poylahara. If flows are improved such controls would be compatible with strategy. Conversely reduced flows would be incompatible.

The main area of incompatibility relates to many of the schemes that have been proposed to improve navigation depths within the Pussur River upstream to Mongla Port. Some of these involve major interventions that would result in extremely large changes in the discharge characteristics of the regional rivers. Whilst these would be effective in increasinf flows in the Pussur River itself it has been deduced from morphological modelling that the benefits with respect to improving navigation depths in the long term would not be realised for several decades and conditions would be worse in the intervening periods. It should also be noted that none of these schemes have been recommended for implementation.

9.4.5 Application of Coastal Strategy to Drainage Improvement

The key to developing the coastal strategy has been to identify the sustainable rivers in conjunction with data and analyses relating to the present day and projected polder performance, linked to drainability. The following considerations underly the strategy:

- Rivers that are likely to silt-up and cannot feasibly be sustained will be converted into internal polder drains by combining adjacent polders and inserting drainage regulators where necessary.
- Future polder use will be linked to the river conditions that can be sustained by minimum intervention. Unless shown to be strategically essential, interventions will not be used to create major change, eg. attempts to convert the saline regions of the west to a fresh water zone will not be attempted.
- Polders have been classified according to their existing and predicted future performance. Further studies will be required to confirm prioritisation of interventions to obtain maximum financial and social benefit. Thus, interventions to prevent a 'good' polder going 'bad' may have priority over interventions to save a 'bad' polder.
- The selection of sustainable channels will also be linked to non-polder requirements such as navigation and forestry requirements to ensure the maximum overall benefit.

The steps involved in deciding where to carry out interventions have been as follows:

(i) Establish the existing polder performance

(ii) Establish the existing river characteristics

(iii) Predict the future river characteristics

(iv) Predict the future polder performance from (iii)

(v) Predict future polder drainability

(vi) Identify the link between (iii), (iv)/(v) and the Regional Plan

(vi) Propose interventions where (iv)/(v) is insufficient to achieve the requirements of the Regional Plan.

The technical complexity and large scale of the river system and the severe consequences of errors should not be under estimated. The existing data, reports and analytical framework that has been developed, as summarised in Section 9.4.1 and fully described in Volume 4, provide a matrix of information which has allowed the stategy to be developed with some confidence. However, each scheme will need to be subject to pre-feasibilty and full feasibilty studies prior to implementation.

It must be emphasised that modelling has not been used as a substitute for field visits and surveys. Extensive field data, both qualitative and quantitative has been used to check that model simulations are realistic. The main purpose of the models is to assist with prediction of future conditions with and without interventions. This is an essential requirement in formulating a coastal strategy and in this respect the models have been very useful.

9.4.6 Alternative Drainage Strategy

The prediction of the present performance status of the polders viz-a-viz drainage disposal is an important aspect of the present study. Due to the limitation and quality of data, the prediction has to be made on the basis of a preliminary drainage discharge (routing) analysis. Using a simple mathematical model the maximum and minimum inundation condition was estimated in each polder.

This was repeated with various conditions including 150% of ventage (present condition is taken as 100%), 50% ventage and increase and decrease in river water levels etc.

The results of the simulation analyses are given in Volume 4 : Coastal Studies. An examination of the results shows that the prevailing drainage congestion in some polders, such as Polders 24, 25, 28/1, 28/2 and 36/1, could not be eliminated by increasing the ventage or dredging the associated rivers; some appreciable areas would remain inundated. This is because predominant areas in these polders are fairly low lying compared with the water levels in the associated rivers. Pumped drainage systems may have to be incorporated to relieve congestion. However, further studies with additional data will be necessary before finally selecting the most appropriate and cost effective option.

9.4.7 Interventions in CEP Area

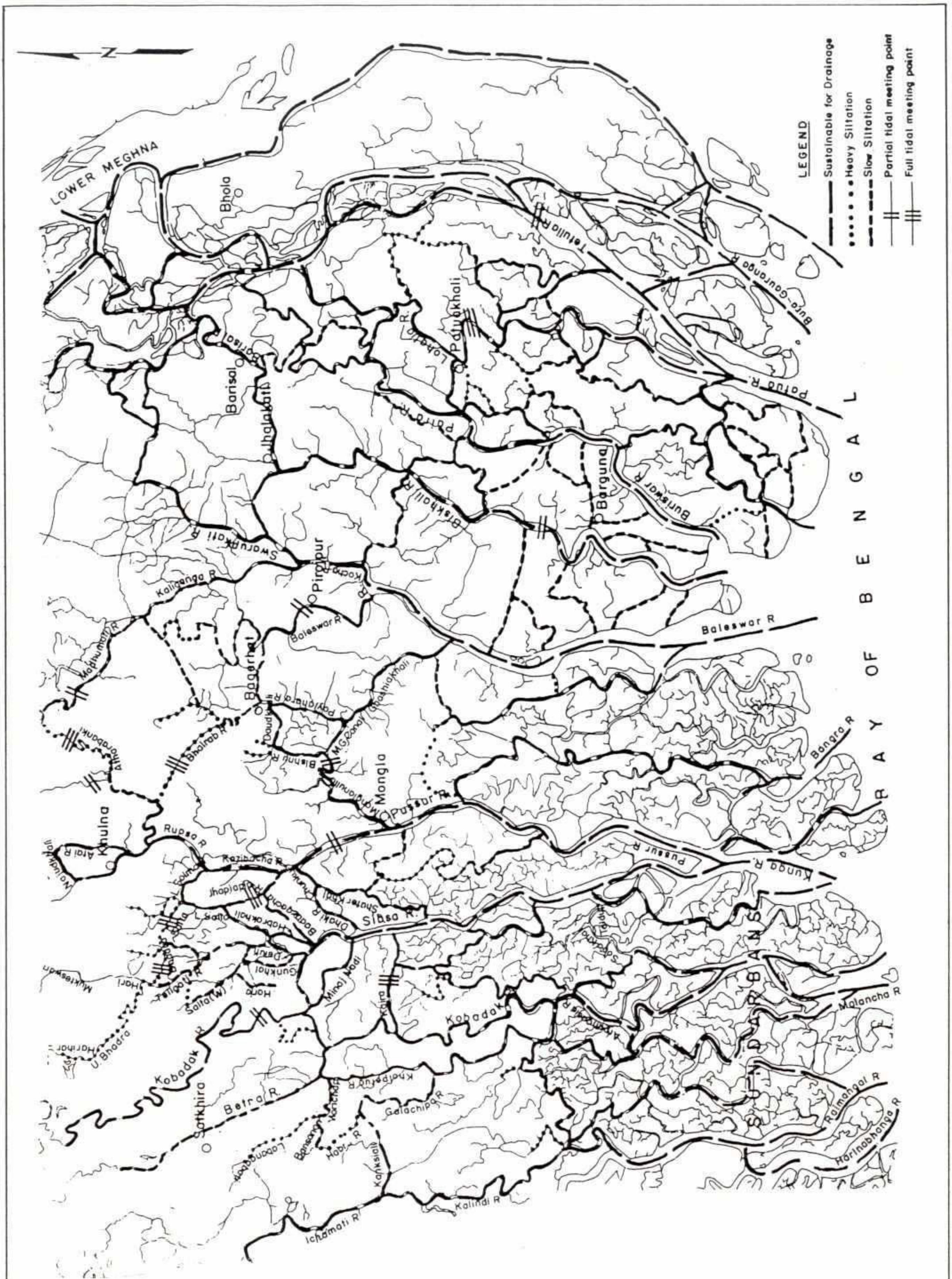
As discussed in Volume 4 polder drainage deterioration is a combination of "internal" and "external" factors. Internal factors relate to channels and sluices in the polder and external factors relate to the condition of the external rivers.

Table 9.10 shows the polders which will require revitalising and the type of intervention required. As discussed in Section 9.10 drainage will be directed towards sustainable rivers and where external interventions are proposed the necessary steps will be taken to ensure that these rivers remain sustainable. Table 9.10 also shows the nearest sustainable river adjacent to each polder. These rivers are also shown on Figure 9.18. It is essential that interventions in the CEP or elsewhere do not interfere with these rivers.

Table 9.10 is essentially a schedule of necessary projects in the CEP. Obviously they cannot all be carried out at once and an order of priority is required.

For the purposes of initial prioritisation it is assumed that internal and external interventions are carried out as separate exercises. External interventions are considered as major projects and internal interventions are considered as operations and maintenance projects.

Figure 9.18



Tidal River Characteristics-Present Situation

TABLE 9.10

Schedule of Interventions

Polder No.	Area	Present Land Use		Change in Polder Performance		Intervention required	Adjacent Sustainable Rivers
	Net (Ha)	Rice	Shrimp				
		% of the net area within the Polder	% of the net area within the Polder	Present	Future		
1	26420	50	50	us	us	A + B	
2	10000	75	25	M	us	A + B	
3	14698	50	50	M	us	A + B	
4	7200	75	25	S	M	B	
5	42045	75	25	M	M	B	
6-8	20688	85	15	M	M	B	Kholpetua, Kobadak & Ichamati
7/1	3108	80	20	S	S	none	
7/2	7600	75	25	S	S	none	
10-12	16200	60	40	S	S	none	
13-14/2	10400	60	40	S	M	B	
14/1	2000	60	40	S	S	none	
15	2520	50	50	S	S	none	
16/1&16/2	10120	80	20	M	us	A + B	
17/1	3808	60	40	M	us	A + B	
17/2	2611	70	30	M	us	A + B	
18-19	3238	60	40	S	M	B	
20	1620	50	50	S	S	none	
21	1620	50	50	S	S	none	
22	1134	60	40	S	S	none	
23	4050	60	40	S	S	none	Sibsa, Deluti, Habarkhali, Bhadra, L. Salta, L. Solmari & Rupsa
24	23720	50	-	us	us	A + B	
25	13620	-	-	us	us	A + B	
26	2157	90	10	S	us	A + B	
27/1&27/2	3249	70	10	us	us	A + B	
28/1	4269	50	-	us	us	A + B	
28/2	1966	50	-	M	M	A + B	
29	6235	85	15	S	S	none	
30	5668	80	20	S	S	none	
31	9920	80	20	S	S	none	
32	9700	80	20	S	S	none	
33	7862	76	-	S	S	none	
34/1	1942	60	-	M	us	A + B	Swarupkati, Baleswar, Mongla, Nulla, Gashikhali, Rupsa & Pussur
34/3	2590	64	-	M	M	A + B	
35/1	13396	80	-	S	M	A + B	
35/3	4945	76	10	S	S	none	
36/1	32020	60	10	us	us	A + B	
39/1A	9400	86	-	S	S	none	Baleswar, Bishkhali, Buriswar, Patuakhali, Tentulia & Lohalia
39/1B&1D	10284	86	-	M	M	B	
39/1C	4003	86	-	S	M	B	
39/2	33260	83	-	M	M	B	
40/1	1747	77	-	M	us	B	
40/2	2834	77	-	M	us	B	
41/1	2632	81	-				

Note : A = external intervention to ensure adjacent rivers remain sustainable
B = internal improvement in polders drainage system

TABLE 9.10 (Continued)

Polder No.		Present Land Use		Change in Polder Performance		Intervention Required	Adjacent Sustainable Rivers
	Net (Ha)	Rice	Shrimp	Present	Future		
		% of the net area within the Polder	% of the net area within the Polder				
41/2	2308	81	-	M	US	B	
41/3	729	90	-	M	US	B	
41/4	1012	83	-	M	US	B	
41/5	2024	83	-	M	US	B	
41/6A	2834	70	-	S	US	B	
41/6B	5560	70	-	S	US	B	
41/7	4858	70	-	S	M	B	
42	2291	82	-	S	M	B	
43/1&43/1A	12978	80	-	S	M	B	
43/2A	3239	67	-	S	M	B	
43/2B	5247	75	-	S	M	B	
43/2C	2146	78	-	S	M	B	
43/2D	6000	78	-	S	M	B	
43/2E	1350	82	-	S	M	B	Baleswar
43/2F	3250	80	-	S	M	B	Bishkhali
44	14024	71	-	M	US	B	Buriswar
45	3108	76	-	M	US	B	Patuakhali
46	2834	70	-	M	US	B	Tentulia
47/1	1870	90	-	S	US	B	Lohalia
47/2	850	83	10	US	US	B	
47/3	2105	87	10	US	US	B	
47/4	2632	72	10	M	US	B	
47/5	1457	89	10	S	M	B	
48	4861	90	10	S	M	B	
52/53A&B	6440	80	-	S	M	B	
54	7545	90	-	S	M	B	
55/1	7800	72	10	M	US	B	
55/2A	10715	90	-	S	M	B	
55/2B	2378	90	-	S	M	B	
55/2C	6024	90	-	S	M	B	
55/2D	18224	90	-	S	M	B	
55/3	7403	75	-	S	M	B	
55/4	4288	80	-	S	M	B	
56-57	74992	90	-	S	S	none	
	621977						

9.4.8 Options for Interventions in the CEP, South West Region

A number of options for interventions to relieve drainage in the CEP have been considered in the areas where external interventions are urgently required. These are Satkhira, Khulna and Bagerhat. An outline of the problems and possible solutions is discussed below:

(i) Satkhira

The problem in this area is that the 'lateral' rivers: Labangabati; Morichap; Sapmara; Habra; Kanksiali and Galghasia are partially or totally silted. Polders 1,2 and 3 and to a lesser extent polders 4 and 5, do not have drainage access to sustainable rivers and hence polder performance is deteriorating. Active tidal rivers in the area are the Ichamati and the Kholpetua which run north-south and the aim of the external interventions is to make use of them. Two possible options, as shown on Figure 9.19, have been considered:

Option 1 - carry out dredging in the Labangabati; Morichap; Kanksiali and Guntiakhali to create a tidal interchange between the Ichamati and Kholpetua. Existing information indicates that there is a significant head difference between these rivers which would help create sustainable lateral rivers;

Option 2 - remove the embankment in places and use the existing beel and flooded areas to act as a tidal surge basin with dredging to improve the channel cross-sections linking the basin with the Kholpetua. The anticipated benefit would be improved tidal flushing in the Kholpetua system.

(ii) Khulna

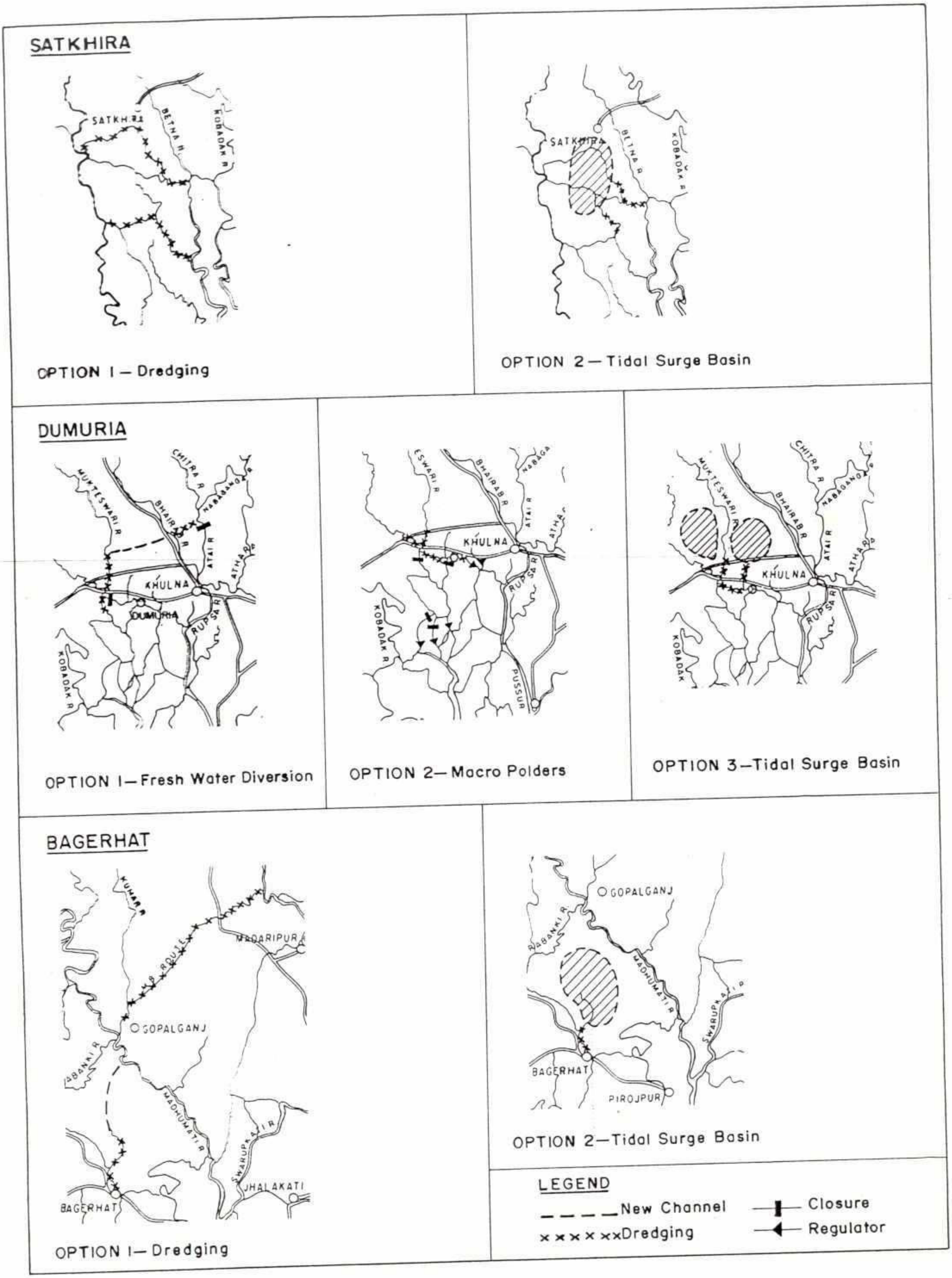
The problem in this area is that the tidal siltation, which has caused severe drainage congestion to polders 24, 25, 27/1, 27/2, 28/1 and 28/2, is progressively spreading southwards and will cause congestion in polders 16/1, 16/2, 17/1, 17/2, 18-19 and 26. The main rivers which are deteriorating are the Sreenadi/Hari Hamkura, Upper Solmari, Telighati, Middle Bhadra, Upper Salta, Gengrail and Salta West. The sustainable river systems, which could be used to prevent this deterioration, are the Kobadak-Lower Haria - Sibsa system and the Sibsa-Deluti-Lower Bhadra - Lower Solmari - Rupsa system. Three options as shown on Figure 9.19 have been considered for realigning drainage towards these systems:

Option 1 - improve the freshwater flow in the Sreenadi/Hari - Telighati - Gengrail system by diverting flow from the Nabaganga via the Majudkhali and a new canal to the Mukteshwari thereby creating a new sustainable north - south system;

Option 2 - create a macro polder by closing the Telighati and Middle Bhadra, dredging the Middle Bhadra and Upper Salta to create a sustainable lateral river and installing regulators on the upper Solmari, Upper Salta, Gengrail, Gunkhali and Haria to prevent silt re-entering the rivers adjacent to the congested polders listed above;

Option 3 - remove the embankment in places and use the two existing flooded areas in polders 24 and 25 as a tidal surge basin to create improved tidal flushing in the rivers to the south.

Figure 9.19



External Interventions in C.E.P. Polders

(iii) Bagerhat

The problem in this area is that the rivers surrounding polders 36/1, 34/1 and 34/3 are either heavily silted, as is the case with the Atharabanki, Lower Madhumati and Bhairab or deteriorating as is the case with the Duadkhali and Poylahara, thereby creating drainage congestion in the external sluices. In addition, the central part of polder 36/1 is lacking an active drainage canal. Two options, as shown on Figure 9.19 have been considered:

Option 1 - creating an active north-south river through polder 36/1 by dredging the Poylahara and reopening the Chitra river northwards to meet the Madhumati. The aim is to provide a drainage channel through the centre of the polder and to provide additional freshwater flushing to sustain the Poylahara.

Option 2 - use the existing flooded area in polder 36/1 as a tidal surge basin to improve tidal flushing in the Poylahara.

The model results of these options have been evaluated by comparison of the 'before' and 'after' situations in water level, discharge volumes, regime analysis and polder drainability, details of which are provided in Volume 4.

The results are summarised as follows:

(i) Satkhira

Dredging in the Labangabati, Morichap, Kanksiali and Guntiakhali is shown to have a significant impact on the net flows in these rivers - in excess of a ten times increase in dry season flows and doubling in wet season flows. Regime analysis of the results shows that these rivers would be transformed from dying to active, sustainable rivers with further improvement to the Kholpetua system. These changes would create improved drainage in polders 1, 2, 3, 4 and 5. However, it must be pointed out that field data in this area is of low quality and further data to improve model boundary conditions will be required if it is decided to proceed further with this option.

Utilizing the existing flooded areas as tidal surge basins results in an improvement in flow characteristics in the rivers close to the surge basin, but a redistribution of flows are shown in the short term at locations further away. This could result in initial siltation at these locations which should gradually migrate downstream.

Analyses of the drainability of polders in the area indicate that polders 1,2 and 3 in particular would benefit from improved ventage at the sluice outlets.

(ii) Khulna

Diversion of freshwater flow from the Nabaganga to the Mukteshwari does not provide sufficient flow in the dry season to prevent the Mukteshwari from silting. Although the wet season flow is greatly increased, it is considered that the dry season effects will dominate.

The creation of macro polders causes significant increases in maximum flow in the Lower Solmari and Habarkhali. The additional flow in the Habarkhali creates a slight backwater effect on the Sibsa flood tide thereby forcing additional flow westwards to the Kobadak and eastwards to the Pussur through the lateral rivers. This effect is, however, considered to be short term until the Lower Bhadra cross-section has increased sufficiently to accommodate the increased flow, when flow patterns will return to the existing stable condition.

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The tidal surge basin option demonstrated similar effects to those observed at Satkhira with improved tidal flushing adjacent to the polder but potential siltation further south, which will migrate downstream.

Analyses of polder drainability show that polders 24, 25, 28/1 and 28/2 are particularly difficult to drain by gravitational means. Increases in ventage do not indicate significant improvements in the highest flood area classifications (F2 and F3). However, improvements in the lower categories (from F1 to F0) would be possible. This situation arises because the land in this area is particularly low. If these areas are incorporated into a macro polder some improvements will be effected. If these improvements were insufficient to justify the investment, pumped drainage may be considered as a possible alternative. This would need to be established as a result of more detailed studies.

(iii) Bagerhat

Dredging of the Chitra - Poylahara was only found to create a sustainable channel when this was combined with increased flow from the Madaripur Beel Route (MBR). The necessary increase was created by dredging the Kumar River and MBR. Even with this additional flow, the dry season period is likely to show some siltation, however, the improved wet season flows are likely to dominate. In order to control flows through the Chitra within the polder, control structures would be required at both the northern and southern boundaries. The southern control would prevent saline intrusion during the dry season and the northern control would regulate flooding and flushing during the wet season.

As in Satkhira and Dumuria, utilising the flooded area as a tidal surge basin appears to provide only localised benefit with potential siltation further south.

Analyses of polder drainability indicate that polder 36/1 has particularly poor gravity drainage characteristics due to the tidal characteristics surrounding the polder. Increases in ventage do not appear to effect significant improvement in the distribution of flood area classifications and only changes some F3 category to F2. Therefore in this case pumped drainage should be considered as a possible viable alternative to be investigated at the pre-feasibility stage.

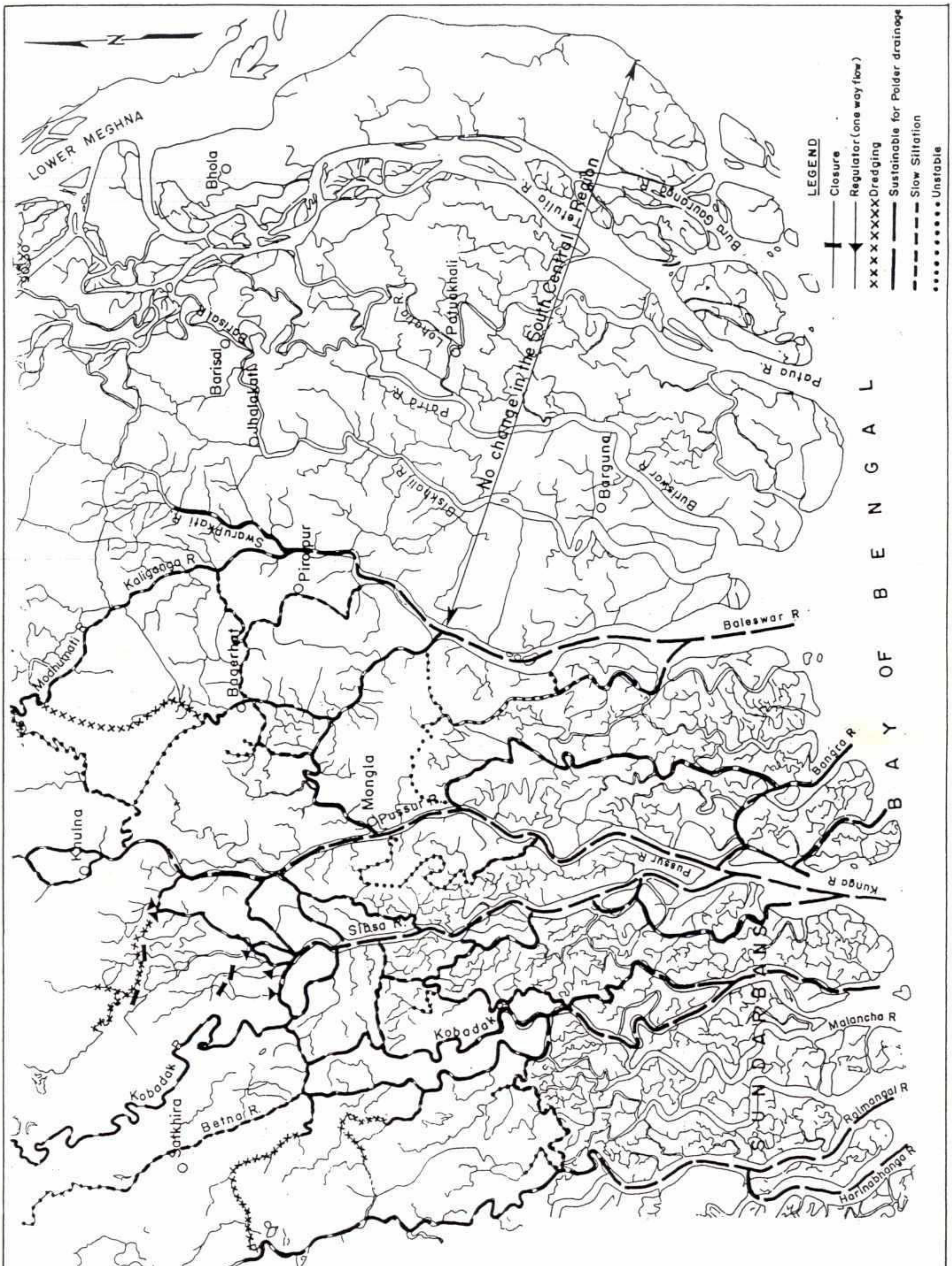
Based on the above analysis the preferred options for external interventions are:

Satkhira	-	Option 1, dredging
Khulna	-	Option 2, macro polders
Bagerhat	-	Option 1, dredging

It should be noted that the Bagerhat option is the least robust of the three. There are a number of difficulties in providing freshwater flows to the area and a very high degree of control would be required to provide adequate drainage even with the scheme in place. It will also be noted in Section 9.4.10 that the initial capital cost is estimated to be extremely high when compared to other areas and this must be considered together with the potentialy high costs associated with maintaining adequate discharge through maintenance dredging in the Madaripur Beel Route.

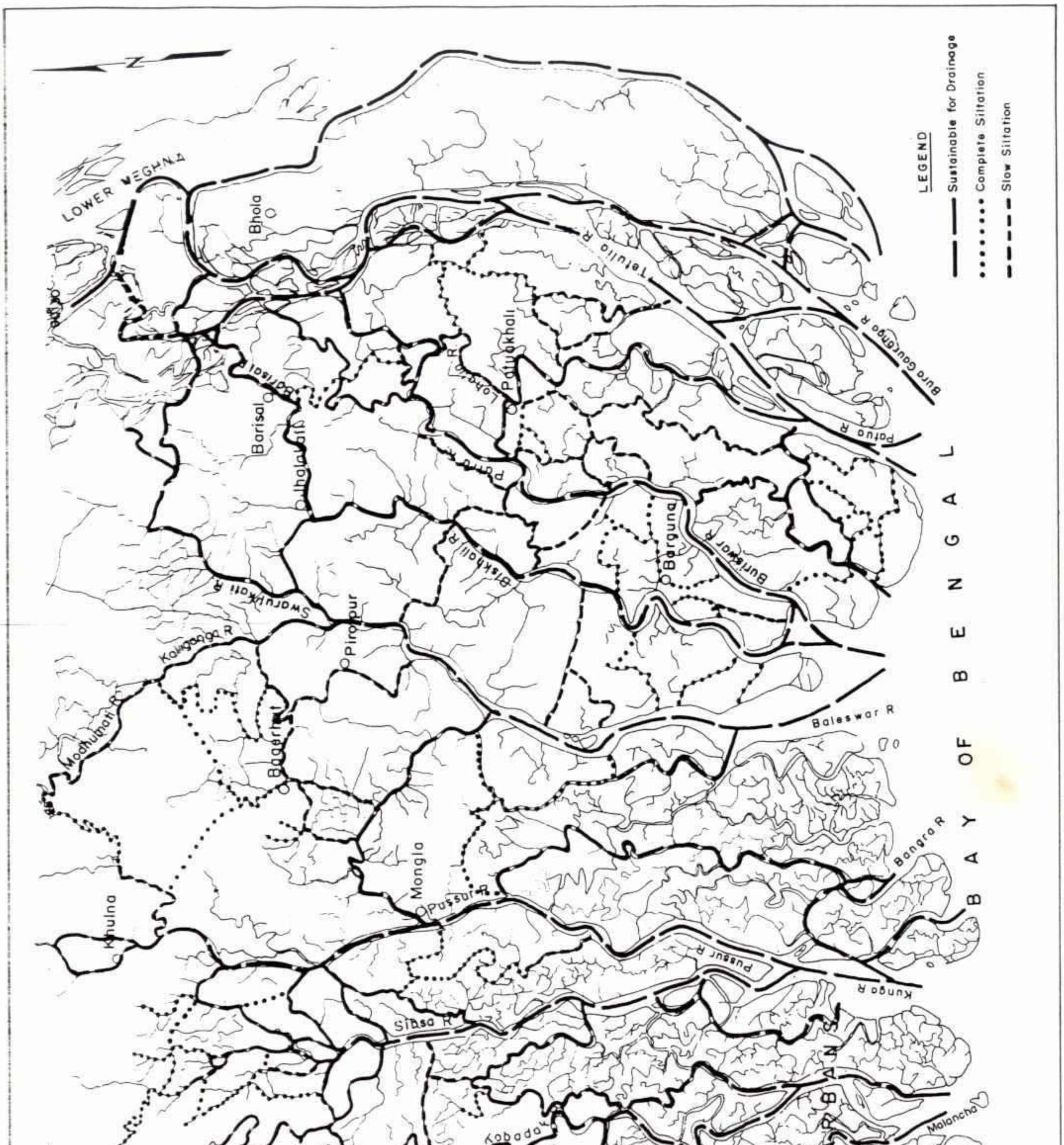
The results of carrying out regime analysis of the river system with these three options combined are shown in Table 9.11 where the influence on the rivers throughout the coastal region can be seen. Figure 9.20 shows the corresponding river characteristic and should be compared with Figure 9.21 which shows the future "do nothing" situation. It can be seen that the proposed interventions do not cause deterioration of the sustainable rivers.

Figure 9.20



Tidal River Characteristics After Interventions

Figure 9.21



Tidal River Characteristics – Future "Do Nothing" Situation

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TABLE 9.11

River Characteristics After Interventions

X-section No.	River Name	Regime Analysis	Sediment Model	X-section Comparison	Maps & spot Image Analysis
1	KOBADAK U	Moderate siltation	Slow siltation	Slow siltation	Slow siltation
2	KOBADAK M	Slow siltation	Slow siltation	Slow siltation	Slow siltation
3	KARULLA	Erosion	Erosion		Equilibrium
4	CONNECTION	Slow siltation	Slow siltation		Equilibrium
5	KATAKHALI-K	Erosion	Erosion	Erosion	Equilibrium
6	KOBADAK L	Slow siltation	Equilibrium	Equilibrium	Equilibrium
7	KOIRA	Slow siltation	Slow siltation		Slow siltation
8	HADDA	Slow siltation	Slow siltation		Slow siltation
9	BETNA	Moderate siltation	Slow siltation	Slow siltation	Slow siltation
10	BETNA	Slow siltation	Equilibrium	Equilibrium	Slow siltation
11	MORIRCHAP	Equilibrium	Slow siltation		Slow siltation
12	LABANGABATI	Heavy siltation	Heavy siltation	Heavy siltation	Heavy siltation
13	BANSANA	Equilibrium	Heavy siltation	Slow siltation	Heavy siltation
14	HABRA	Heavy siltation	Heavy siltation	Heavy siltation	Heavy siltation
15	KANKSIALI	Heavy siltation	Erosion	Heavy siltation	Heavy siltation
16	GALGHASIA	Slow siltation	Moderate siltation	Slow siltation	Moderate siltation
17	KHOLPETUA	Slow siltation	Moderate siltation	Equilibrium	Slow siltation
18	LINK-KK	Equilibrium			Equilibrium
19	ARPANGASIA	Equilibrium			Equilibrium
20	ARPANGASIA	Equilibrium			Equilibrium
21	CHALKIGANG	Equilibrium			Equilibrium
22	BAL	Equilibrium			Equilibrium
23	BARAPANGA				Equilibrium
24	BETMARAGANG	Equilibrium			Equilibrium
25	MALANCHA	Equilibrium			Equilibrium
26	MALANCHA-E	Equilibrium			Equilibrium
27	SONAKHAL	Equilibrium	Erosion		Equilibrium
28	TALDUP	Equilibrium	Erosion		Equilibrium
29	HARIHAR	Heavy siltation	Heavy siltation		Heavy siltation
30	BURIBHADRA	Heavy siltation	Heavy siltation		Heavy siltation
31	U-BHADRA	Heavy siltation			Heavy siltation
32	MUKTESWARI	Heavy siltation	Moderate siltation		Heavy siltation
33	HARI	Heavy siltation	Erosion		Heavy siltation
34	M-BHADRA	Moderate siltation	Equilibrium	Slow siltation	Moderate siltation
35	HAMKURA	Moderate siltation	Slow siltation		Moderate siltation
36	BHADRA	Heavy siltation	Slow siltation		Moderate siltation
37	BHADRA	Moderate siltation	Erosion	Erosion	Moderate siltation
38	TELIGATI	Slow siltation	Erosion		Slow siltation
39	SALTA(W)	Slow siltation	Slow siltation		Slow siltation
40	HARIA	Slow siltation	Slow siltation	Slow siltation	Slow siltation
41	GHENGRAIL	Slow siltation	Slow siltation	Slow siltation	Slow siltation
42	BHANGARIA	Heavy siltation			Heavy siltation
43	GUNAKHALI	Slow siltation	Heavy siltation		Slow siltation
44	U-SOLMARI	Moderate siltation	Slow siltation		Moderate siltation
45	L-SOLMARI	Equilibrium	Erosion	Equilibrium	Equilibrium
46	SALTA	Moderate siltation	Erosion		Heavy siltation
47	L-SALTA	Equilibrium	Equilibrium	Equilibrium	Equilibrium
48	L-BHADRA	Equilibrium	Erosion	Slow siltation	Equilibrium
49	HABARKHALI	Equilibrium	Equilibrium	Equilibrium	Equilibrium
50	DELUTI	Erosion	Erosion		Equilibrium
51	MINAJNADI	Slow siltation	Slow siltation		Equilibrium
52	SIBSA	Slow siltation	Slow siltation		Equilibrium
53	SIBSA	Erosion	Erosion		Equilibrium
54	SIBSA	Erosion	Equilibrium		Equilibrium
55	JHAPJHAPIA	Heavy siltation	Heavy siltation	Heavy siltation	Heavy siltation
56	BADURGACHA	Erosion	Erosion	Equilibrium	Equilibrium
57	MANGA	Erosion	Slow siltation		Equilibrium
58	JHAPJH-MANGA	Heavy erosion	Erosion	Erosion	Equilibrium
59	CHUNKURI	Equilibrium	Equilibrium		Equilibrium
60	DHAKI	Erosion	Erosion		Equilibrium
61	SUTARKHALI	Equilibrium	Slow siltation		Equilibrium
62	SUTARKHALI	Equilibrium	Slow siltation		Equilibrium
63	BHAIRAB U	Moderate siltation			Heavy siltation
64	BHAIRAB U	Slow siltation	Equilibrium		Moderate siltation
65	NABAGANGA-M	Equilibrium			Equilibrium

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TABLE 9.11 (Continued)

X-section No.	River Name	Regime Analysis	Sediment Model	X-section Comparison	Maps & spot Image Analysis
66	ATAI	Equilibrium			Equilibrium
67	NABAGANGA-M	Slow siltation	Low flow		Slow siltation
68	RUPSA	Erosion	Equilibrium		Equilibrium
69	KAZIBACHA	Equilibrium	Equilibrium	Equilibrium	Equilibrium
70	NALUANULLAH	Slow siltation			Equilibrium
71	PUSSUR	Slow siltation			Equilibrium
72	PUSSUR	Equilibrium	Equilibrium		Equilibrium
73	PUSSUR	Slow erosion	Equilibrium		Equilibrium
74	MONGLANULLA	Equilibrium	Slow siltation		Equilibrium
75	BISHNU	Slow siltation	Erosion		Slow siltation
76	DAUDKHALI	Slow siltation	Erosion		Slow siltation
77	M.G.CANAL	Slow siltation	Erosion		Equilibrium
78	GASHIAKHALI	Slow siltation	Erosion	Erosion	Equilibrium
79	ATHAROBANKI	Heavy siltation	Low flow	Equilibrium	Heavy siltation
80	ATHAROBANKI	Moderate siltation	Slow siltation	Equilibrium	Moderate siltation
81	BHAIRAB	Heavy siltation	Low flow		Heavy siltation
82	POYLAHARA .	Heavy siltation	Heavy siltation	Slow siltation	Moderate siltation
83	BHAIRAB L	Slow siltation	Heavy siltation	Slow siltation	Moderate siltation
84	KUMAR	Moderate siltation			
85	MADHUMATI	Heavy siltation	Slow siltation	Slow siltation	Slow siltation
86	BALESWAR	Heavy siltation	Now flow	Heavy siltation	Heavy siltation
87	BALESWAR	Moderate siltation	Heavy siltation	Heavy siltation	Moderate siltation
88	BALESWAR	Slow siltation	Equilibrium	Equilibrium	Equilibrium
89	BALESWAR	Equilibrium	Equilibrium	Slow siltation	Equilibrium
90	KALIGANGA	Moderate siltation	Moderate siltation		Slow siltation
91	KOCHA	Erosion	Moderate siltation		Equilibrium
92	SHIKARPUR	Equilibrium			Slow siltation
93	UZIRPUR	Equilibrium			Equilibrium
94	SHANDHA	Equilibrium			Equilibrium
95	AMTALI	Equilibrium			Equilibrium
96	NAYABHANGANI	Equilibrium			Slow siltation
97	DHARMAGANJ	Slow siltation			Equilibrium
98	KALABADAR-1	Slow siltation			Equilibrium
99	KALABADAR-2	Equilibrium			Equilibrium
100	ILSHA				Equilibrium
101	RANGAMATIA	Slow siltation		Slow siltation	Slow siltation
102	KIRTONKHOLA	Slow siltation		Slow siltation	Equilibrium
103	KIRTONKHOLA	Equilibrium		Equilibrium	
104	KATAKHALI	Equilibrium			Slow siltation
105	BISHKHALI	Equilibrium		Equilibrium	Equilibrium
106	PANDAB-1	Slow siltation			Slow siltation
107	PANDAB-2	Erosion			
108	DHULIA	Equilibrium			Equilibrium
109	PAIRA	Equilibrium		Equilibrium	Equilibrium
110	BURISWAR	Equilibrium			Equilibrium
111	PATUAKHALI	Erosion			Equilibrium
112	LOHALIA	Slow siltation		Heavy siltation	Slow siltation
113	LOHALIA	Equilibrium			Equilibrium
114	SWARUPKATI	Erosion			Equilibrium

Note : 'After' situation is scenario 6.4.9 which comprises Satkhira dredging, Khulna macro Polder and Bagerhat dredging.

'-' indicates 'no change'

The primary components of the preferred options are shown schematically on Figures 9.22 to 9.24.

9.4.9 Drainage Improvements in the CEP, South Central Region

Most of the emphasis in this study has been placed on the south west region due to the significantly greater problems that exist, not only due to drainage congestion, but also saline intrusion. Conditions in the south central region are rather more favourable due to the fresh water inflows from the Padma River and Lower Meghna Estuary which provide good flushing characteristics for the rivers coupled with less saline conditions, even in the dry season.

The regime analysis has shown the main rivers to be sustainable in the region and the primary cause of siltation of the interconnecting rivers. In some cases these channels were originally internal, but the polders have been split up, e.g.polder 41.

The studies have concluded that sufficient drainage improvements can be effected through improved internal drainage and water management without having to resort to external interventions. This would include re-combining polders in accordance with their original design.

9.4.10 Implementation Programme and Cost

Figure 9.25 shows a preliminary near term programme for interventions in the coastal zone. As discussed earlier the most pressing need is for relief of drainage congestion in the CEP area, activities (1) to (18) but this must proceed in parallel with other activities (19) to (24).

For the proposed internal and external interventions to improve the drainage condition of polders in the CEP area, the year proposed when work should commence is generally related to the present and future predicted conditions of the polders, see Figures 2.13 and 2.15 respectively, as shown in the following Table 9.12.

TABLE 9.12

Preliminary intervention programme

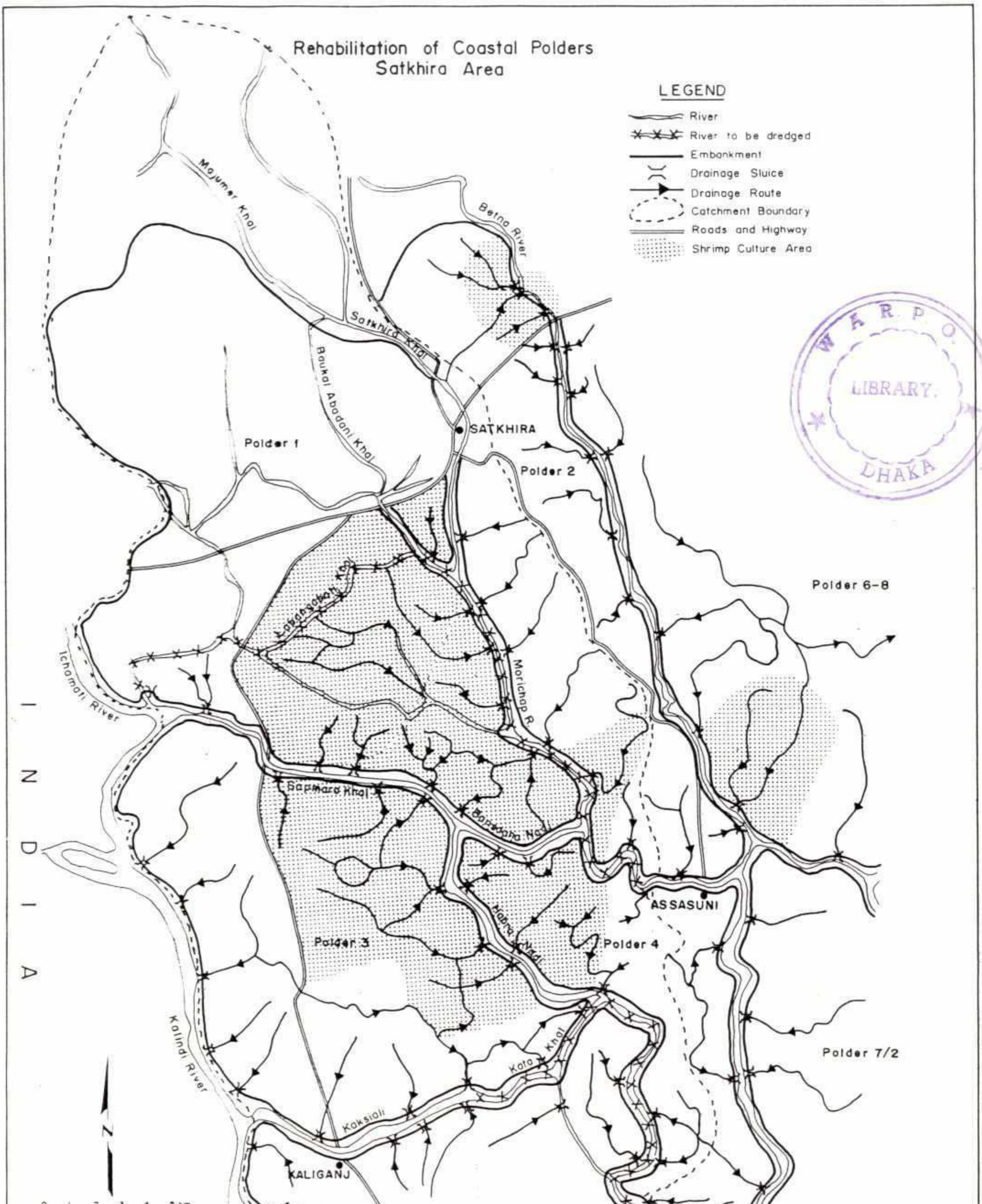
Polder Condition		Years from now to Commence Intervention
Present	Predicted Future	
Satisfactory	Marginal	10
Marginal	Unsatisfactory	5
Unsatisfactory	Unsatisfactory	1

The exceptions are where both external and internal interventions are required, for example Satkhira, when it would not be worthwhile completing the internal intervention ahead of the necessary external intervention.

(ii) Costs

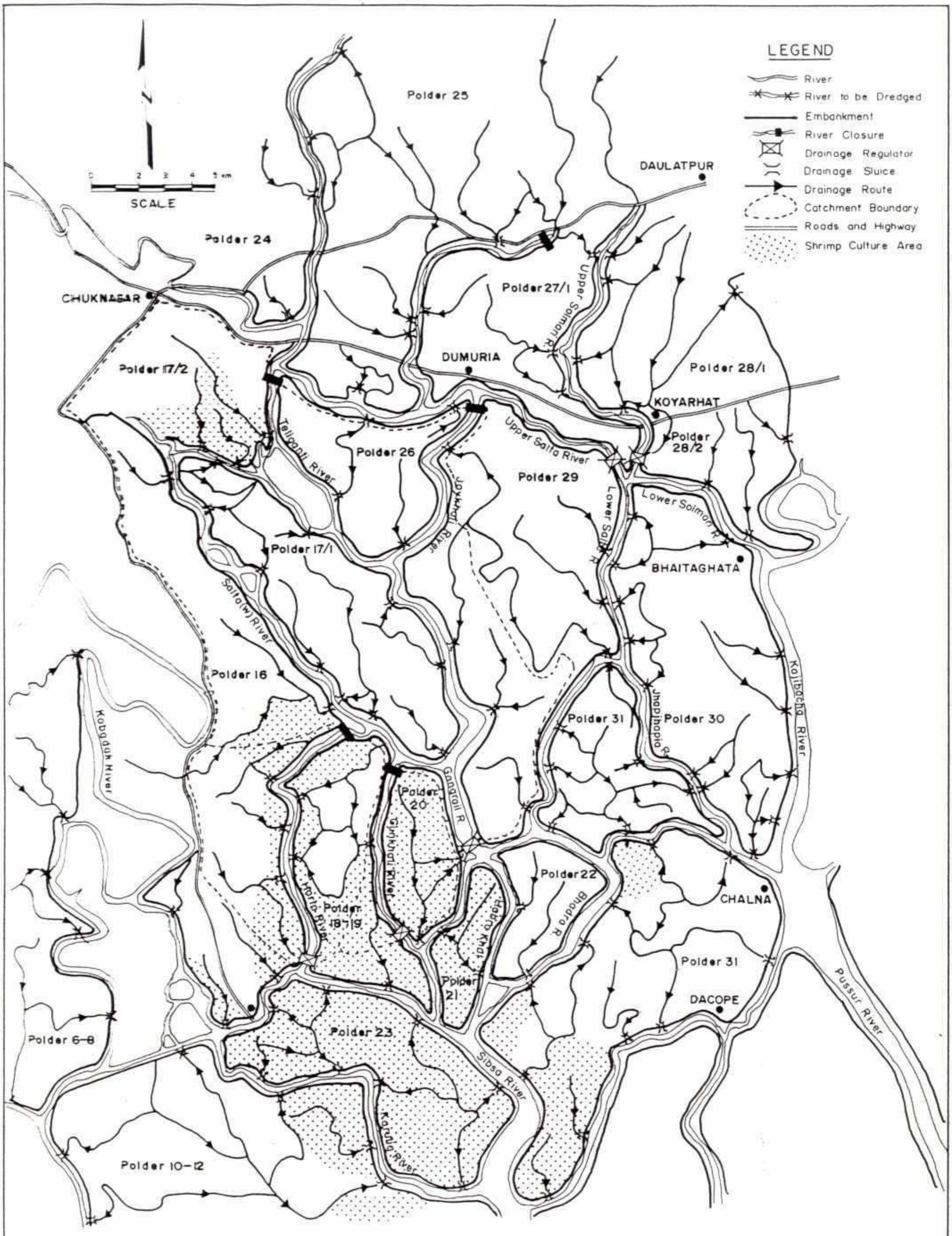
Indicative capital costs for carrying out the interventions discussed in this chapter are given in Table 9.13. The costs cover the interventions needed to improve the polder systems identified in the Table and do not include routine maintenance in these or other polders.

Figure 9.22



Satkhira Area: Drainage Conditions after Interventions

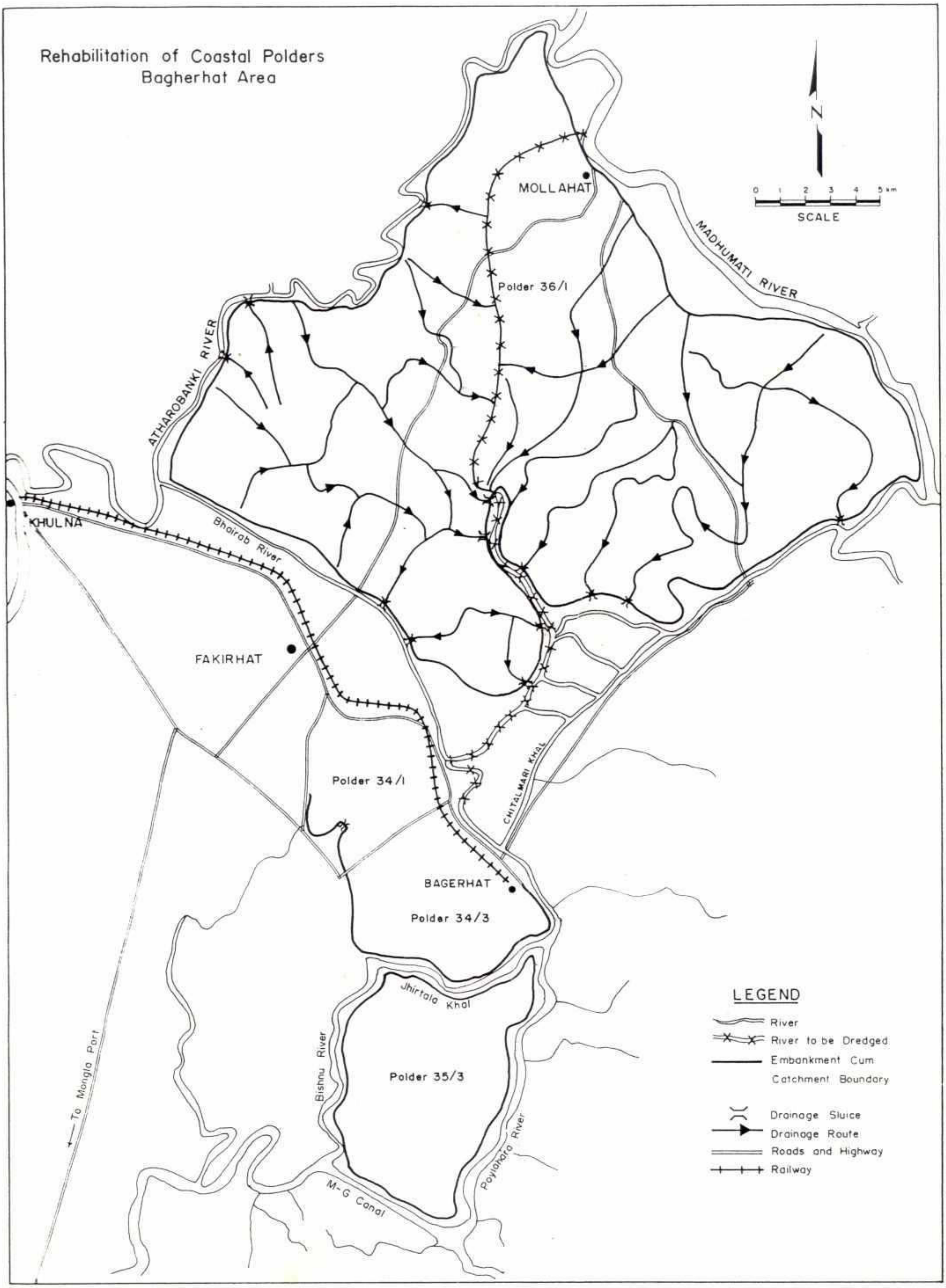
Figure 9.23



Rehabilitation of Coastal Polders Dumuria Area

Khulna Area: Drainage Conditions after Interventions

Figure 9.24



Bagerhat Area: Drainage Conditions after Interventions

TABLE 9.13

Capital Cost of Interventions

Location	Net Area (Ha)	Intervention Cost (M.Taka)			Unit Cost (Tk/net ha)
		External	Internal	Total	
Satkhira (1,2,3,4,5,6-8)	121000	1200	1210	2410	19900
Satkhira (13-14/2)	20500	0	154	154	7500
Khulna (CERP II & macro polder)	112000	273	1106 (incl.CERPII)	1379	12300
Bagerhat (36/1,34/1,34/3)	36600	878	366	1244	34000
Bagerhat (35/1)	79000	0	948	948	12000
South Central	179000	0	895	895	5000
Totals	548200	2351	4679	7030	
					Average Unit Cost = Tk 12,800/net ha

Note: assumed unit rates:

external improvement
- dredging - 65 Tk/m^3
- closures - 2.0 to 4.6 M Tk depending on size
- regulators- 8.5 to 48.0 M Tk depending on size

internal improvement
- Satkhira - 10000 Tk/net ha
- Paikgacha - 7500 Tk/net ha
- Dumuria - 5000 to 12000 Tk/net ha
- Bagerhat - 10000 Tk/net ha
- Rampal - 12000 Tk/net ha
- South Central- 5000 Tk/net ha

completion of polders 34/2; 35/2; 36/2; 37 & 39/2 not included.

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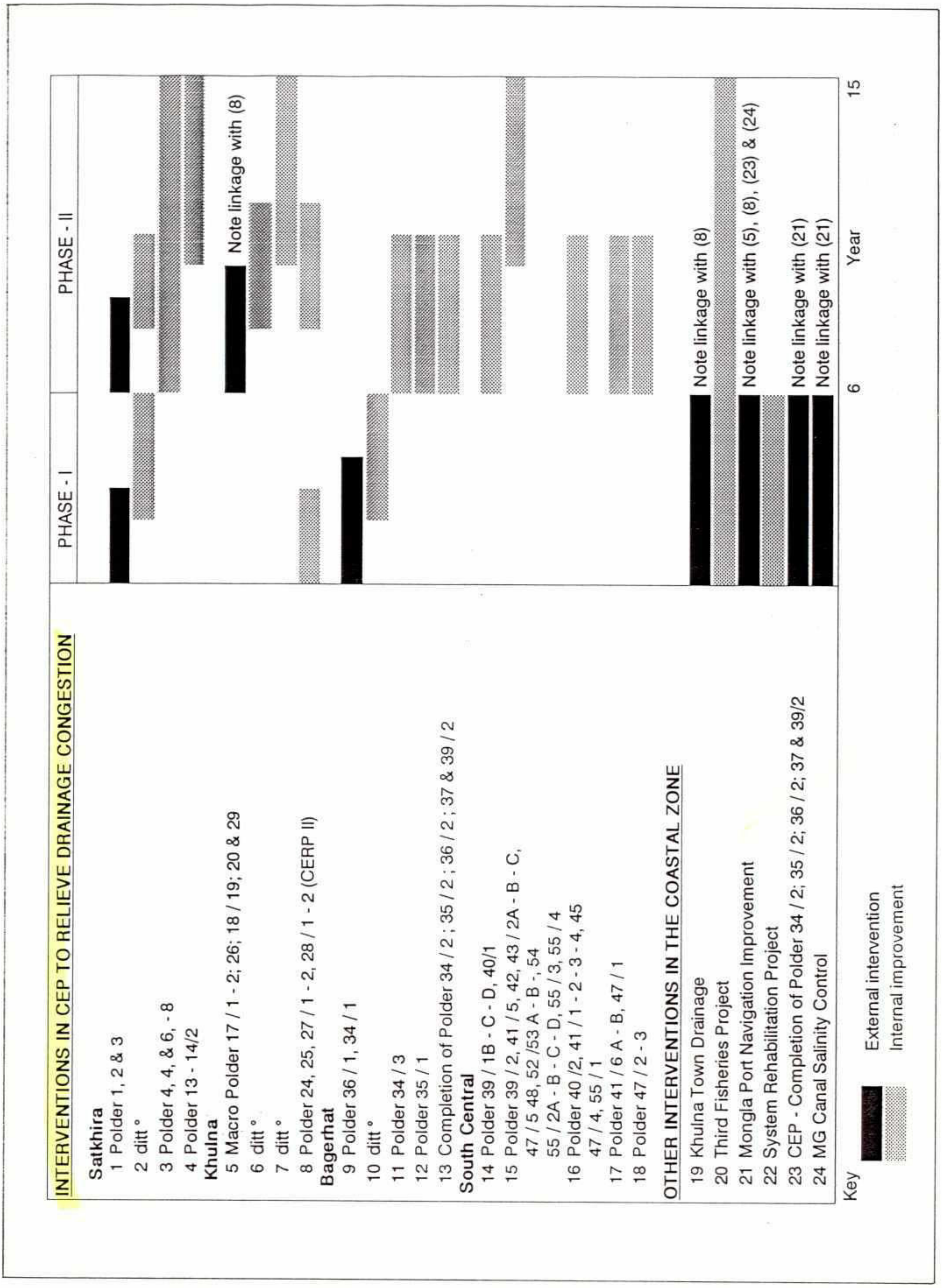
Figure 9.25



Preliminary Near Term Intervention Programme in the Coastal Zone

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9.4.11 Pilot Study Proposals

As discussed above, different solutions have been proposed for different areas of the CEP, to relieve drainage congestion. Clearly the interventions proposed are over a long period and the investment required is large. Before committing to this large investment, it is essential to have confirmation that the interventions proposed in one area of the CEP do not adversely impact on other areas. It is therefore recommended that Pilot Projects are initially taken up to 'test' the interventions proposed and monitor the results before embarking on a full scale investment in the CEP. As the solutions suggested for the polders in the SC Region are relatively less complex and consist mainly of internal improvement to the drainage and water management, these can go ahead as shown in Figure 9.25.

Before any pilot projects are taken up detailed feasibility studies need to be completed. For the Bagerhat Pilot Project, because of the estimated high cost of the scheme, it is proposed a pre-feasibility study is undertaken before further studies are carried out.

Details of these Pilot Projects are given in Volume 4 - Coastal Studies, a summary of which is given below:

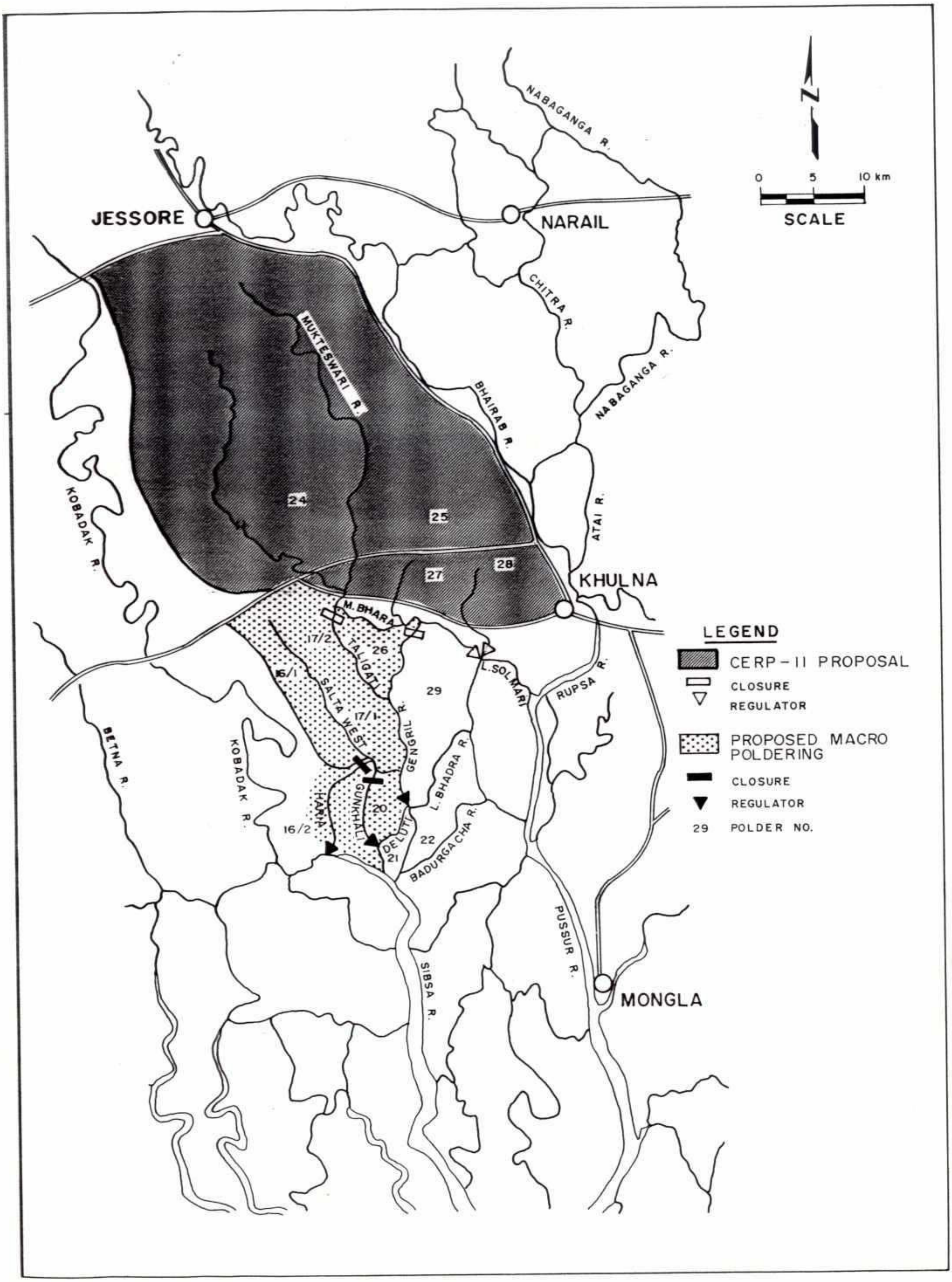
(i) Satkhira: The project that has been identified involves a large quantity of dredging which according to the modelling results will result in quite significant improvements in river discharges in the region. It has been concluded that this will be sufficient to sustain the rivers without the need for large maintenance commitments. Drainability calculations for the polders in the area indicate that quality of land would benefit from improved ventage. Much of the area is used for shrimp farming and this requires good flushing characteristics for maintaining adequate water quality. However, this aspect would not require the same degree of tide level variation as would be required for drainage of agricultural crops. Thus, there needs to be balance that matches the use and that provides benefits commensurate with the investment. These aspects should all be addressed in a detail feasibility study for the proposed intervention scheme.

(ii) Khulna: In this case a pilot project is proposed that would lead towards a macro polder within a sub-area of the full scheme as it is finally envisaged. The polders to be combined would be 26, 17/1, 17/2, 16/1-2 (part), an area of about 16,500 ha. These polders are just south of the CERP II area and it is proposed to use this as a 'pilot' project for the ultimate strategy of amalgamating most of the polders in the area. An initial survey indicates that most of the area is under rice cultivation and there is no significant shrimp cultivation.

The proposed works would involve construction of regulators and closure of the Telighati and Bhadra Rivers in addition to closing the Gunkhali and Haria Rivers as shown in Figure 9.26. The investment would mitigate the agricultural production losses related to drainage congestion and raise water management efficiency. The incremental crop production due to the project would result in decline of water related crop losses, and changes in cropping pattern, cropping intensity and production practices. The change in cropping pattern is envisaged to be largely to higher yielding varieties and the increase in cropping intensity should be at least 40%. The project is considered to have sufficient technical, economic and social justification identified at this stage to proceed to full feasibility study. This would assess the technical and economic feasibility of the scheme together with the social and environmental impacts.

(iii) Bagerhat: The project as identified involves the dredging of the river through the centre of polder 36/1 combined with capital and maintenance dredging of the MB Route. There are very large tidal variations around the polder and all but the

Figure 9.26



Pilot Project (Macro-Poldering)

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northern boundary river has silted. It has been pointed out that regulators would be required at both ends of the central river. The river dredging would by now have been completed by BWDB if it had not been for a land dispute. Although investigations at the present level of detail indicate that the project is technically feasible, the overall benefits may not be that large and the estimated costs are exceptionally high to the extent that pumped drainage might be a viable alternative. It is therefore proposed that this scheme should be subject to a pre-feasibility study in order to identify these issues rather more definitively before proceeding further.

9.4.12 Impact of Interventions

Impact of the proposed interventions are discussed fully in Volume 9, Impact Studies and are summarised below:

(i) Environmental

Internal intervention in the polders will improve drainage within the polders and the existing agricultural and fishing environment.

External interventions will be aimed at making use of existing active tidal rivers which will sustain and possibly enhance the existing environment, resulting from these rivers. Rivers which are likely to silt-up in the long term will eventually be closed and converted into internal drains within macro polders. This will reduce the salinity and the tidal action of these rivers and the quantity of material they currently carry in suspension. Where this change has been created elsewhere in the CEP a sustainable freshwater environment exists in place of the previous brackish water environment providing an adequate drainage system is established.

Dredging in Satkhira may cause local changes in the salinity pattern but the extent of change cannot be reliably predicted until more salinity and tidal measurements are made on the Ichamati river. It is anticipated that most of the dredged material will be silt which can be used beneficially by spreading on low lying polder fields. Where the material is clay it will require stockpiling on land for future use on embankment raising and repair and other construction activities.

Dredging in polder 36/1 and augmentation of the fresh water flows in the MB Route will reduce the rate of siltation in the Poylahara and cause some local reduction in salinity level which will benefit the farmers.

(ii) Social

Interventions in the CEP area will cause significant social impacts.

Reduction of drainage congestion will improve condition for both rice and shrimp farmers providing both groups work together. Elimination of some flooded land may reduce capture fish yields.

Creation of macro polders may create areas of potential conflict with shrimp cultivation in polders 16 and 18-19 and this will require further study in conjunction with the Third Fisheries Project.

Navigation in the major rivers will be sustained with resulting benefits in long term transport planning. Navigation by country boat will be affected in the proposed macro polder area. Transfer from internal to external river may require a lockgate or simple transfer system depending on the traffic. In some cases, e.g. U. Salta an internal river will be created where there is currently a fully silted tidal river thereby improving country boat navigation.

9.4.13 Conclusions

- Drainage congestion in the CEP area should be resolved as part of an overall long term coastal strategy.
- The long term strategy is based on the premise that the coastal zone will remain as a tidal delta.
- Sustainability of the tidal delta depends on sustained dry season flows in the Gorai and sustained non saline dry season fresh water flows from the Arial Khan and Meghna.
- Sustainable rivers have been identified by analysis of field measurements and model results and modelling techniques with regime analysis have been used to predict the impact of proposed interventions.
- The near term intervention programme proposes that present drainage congestion problems are tackled by dredging at Stakhira, implementation of CERP II and amalgamation of selected polders (macro poldering) at Khulna, dredging at Bagerhat and completion of unfinished polders in the Mongla, Bagerhat and Khulna areas (subject to resolution of potentially adverse consequences on navigation at Mongla and siltation in other rivers that must be sustained).
- The performance of each intervention will require monitoring and subsequent intervention design will depend on the nature of the monitoring results.
- The timing of the proposed macro polder at Khulna will depend on the performance of CERP II.
- The prediction of inundation changes by the proposed intervention in the low lying beel areas of Satkhira, Khulna and Bagerhat requires further investigation before the conceptional design of interventions proceeds further.
- The proposed long term strategy involves a new approach to evaluating interventions in the coastal zone. Identification of sustainable rivers has not previously been attempted on a Regional scale and even proposals as recent as 1989 (Pussur-Sibsa study) are considering blocking these essential rivers.

9.5 Irrigation and Water Supply Development

9.5.1 General

Estimates on the present dry season agricultural production in the Southwest Area show that there is still appreciable scope and need for the development of irrigated agriculture. Previous developments in this sector have been mainly based on groundwater, involving both the shallow tubewells (STW) and the deep tubewells (DTW). Any further large scale utilisation of groundwater for this purpose could have detrimental impact on rural water supply systems.

Adequate water supply to Khulna, to meet the domestic and industrial needs is an important issue that needs to be resolved.

There are various options for developing the potable water supply and irrigation needs, but appropriate options have to be chosen based on other factors such as scope for beneficiary participation, etc.

9.5.2 Options for Water Supply Development

General

The major source of domestic and industrial water supply in the Southwest Area is groundwater. Hand-pumped tubewells (HTW) are associated with rural water supply, while deep tubewells (DTW) generally cover the district headquarters townships (sadars) and other municipal areas. Also some of the major properties in the municipal areas have individual HTW. Considering the limitation of HTW to shallow water table, their operation during the peak period of the dry season (March/April) could be put under threat by extensive use of DTW in the neighbouring areas for irrigation. Though in the coastal areas DTW irrigation is not widely used, saline intrusion can effectively disrupt or reduce potable supplies.

Rural Water Supply

According to data collected by UNICEF (1992) and the DPHE there are about 207,200 HTWs in the 122 Thanas that cover the 21 districts in the Study Area. The average number of people served by a HTW in the rural areas varies between 88 and 204. It appears from information gathered during the Consultants' field visits that the operation of some of the HTWs in Rajbari, Meherpur, Chuadanga and Kushtia districts was not possible during the 1992 peak dry period (March/April). Though presently the number of unproductive HTWs in the different thanas could be low, any further concentrated DTW development could undermine the effectiveness of the existing HTWs there.

In the 1970s and 80s the suction-mode HTWs, which have a maximum lift of 6m, were generally installed for rural water supply, and each HTW served a population of about 300. According to UNICEF, the new schemes implemented in the 90s, however, use a higher per capita consumption rate (36 l/capita/day) and the population served by each HTW has been reduced to 100 to 130. In addition, some of the old suction - mode HTWs that became non-effective due to lowering of the water table have been replaced with Tara pumps (force-mode) which have a maximum lift of about 15m. Simulated results from the MPO development potential model indicate that Tara pumps could remain operative during peak dry periods in certain districts (Kushtia, Magura, Narail, Rajbari, Faridpur, Gopalganj, Madaripur and Sariatpur) even if additional DTW irrigation development takes place in these areas as long as the DTW spacing and their distance from the homestead areas/villages are more than the minimum stipulated (800 m) by MPO and BADC. Thus, Tara pump HTW should be advocated in those villages where DTW irrigation is set to significantly increase. For other villages suction-mode HTW would suffice.

Urban Water Supply

The 21 district headquarters in the Study Area have formalised water supply systems, including piped distribution. A system generally consists of a 20m deep DTW, a 50 m^3 overhead tank and a pipe network providing some individual connections to houses and commercial establishments and some street hydrants for public use. Depending on the population size, a district headquarter would have one or more of these systems.

According to available information, only the systems in Faridpur, Jessore, Gopalganj and Barisal have incorporated a treatment process, which is only for the removal of iron.

Further expansion of urban water supply could continue to be based on DTW for most districts except those along the coastal belt (eg: Khulna) which should look for alternative fresh water sources.

Industrial Supply

Industries in the Study Area are concentrated primarily in Khulna, Jessore, Kushtia and Barisal. Most are small scale industries although some larger industrial units are found at Khulna.

In general, industries rely on their own DTWs for their water supply, although some small scale industries use the municipal supply. Few industries questioned by the Consultant during field visits indicated any high demand for potable supplies.

Cooling water is considered to be a major problem for many industries, particularly around Khulna. The use of river water is widespread amongst those industries with a high cooling water demand; but low flows and high salinity in the dry season are quoted as major constraints to river abstraction. Already industries are resorting to transport of water from rivers further north in barges, during the months of March and April.

Khulna Water Supply

Khulna city, one of the 21 district headquarters in the Southwest Area, is the third largest city in Bangladesh. The city covers the sadar and the northern industrial town of Daulatpur. A secure water supply to this important city is not only a basic necessity to the vast population (1991 estimate is 681,100), but a vital requirement for the survival of the industries which it includes.

The current source of water for industrial supply is mainly groundwater, with some abstraction from the Bhairab River when its salinity level is low. During periods of high salinity levels in the dry season, the major industries bring in better quality water using barges from rivers further north.

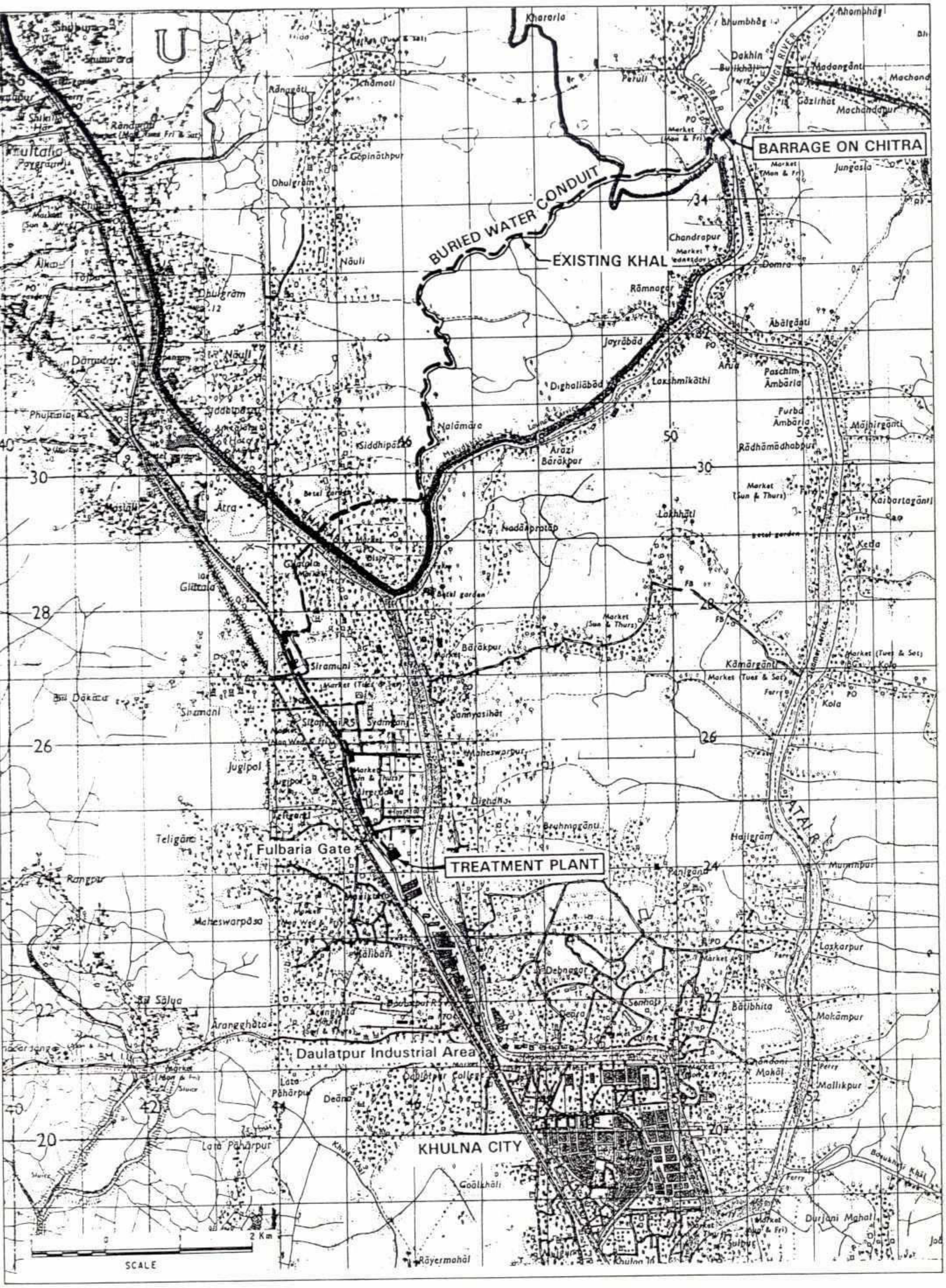
The main town supply comes from deep wells (45 Nos) most of which were installed in the 1970s and are now operated by the Khulna City Corporation Waterworks Department. There are also 1460 HTWs. The limited available data consulted indicate that effects of saline intrusion are being experienced in these wells. A 1987 report (Aqua, 1987) relating to the construction of seven new deep wells, indicated chloride concentrations of 35 - 318 mg/l when the wells were tested. Currently, the chloride values are up to 941 mg/l, a significant deterioration in quality. Though the current salinity levels are being tolerated by the population in Khulna, it is only a matter of time before the wells become unusable.

Possible future options to have a robust and reliable fresh water supply are:

(a) Surface water augmentation: to release during the dry season at least 150 cumecs into the Nabaganga River system with a view to push the saline front of the downstream rivers (Chitra and Bhairab) south of Khulna. The domestic and industrial water supply could then be based entirely on abstractions from the Bhairab River. Appropriate water treatment would be required. The opportunity cost of the 140 cumecs (net of abstraction of 10 cumecs for water supply) for salinity control is about 7000 million taka, and the pumping and treatment cost of the water supply would be another 980 million Taka.

(b) Surface water supply direct to the waterworks from an upstream river system : fresh water, about 5 - 10 cumecs as necessary could be diverted from the Chitra

Figure 9.27



Water Supply to Khulna

River (just upstream of its confluence with the lower Nabaganga, south of Narail) through a canal (about 8 km) up to the bank of the Bhairab River, and pumped across and conveyed to the water works in a pipeline (about 10 km) (Figure 9.27). This option could only be met by augmenting the flow in the lower Chitra River. The cost of providing treatment, transmission and pumping would be about 1400 million Taka.

(c) Storing rainfall runoff in a part of Beel Dakatia : A low level reservoir of capacity about 180 million m^3 in the lower most areas of Beel Dakatia could be formed by excavating and forming the containment dyke. The estimated cost of the reservoir including land acquisition, pumping, transmission and treatment would be 2,110 million Taka.

Considering the above financial implications, the second option which involves supplying potable water from the Chitra direct to the demand areas is recommended.

9.5.3 Options for Irrigation Development

For the Southwest Area three different options could be considered for the provision of irrigation facilities: a surface water full gravity system, a surface water low lift pumping system (LLP) and a groundwater tubewell system. In addition, for certain areas the irrigation facilities could be based on a combined use of surface water and groundwater facilities.

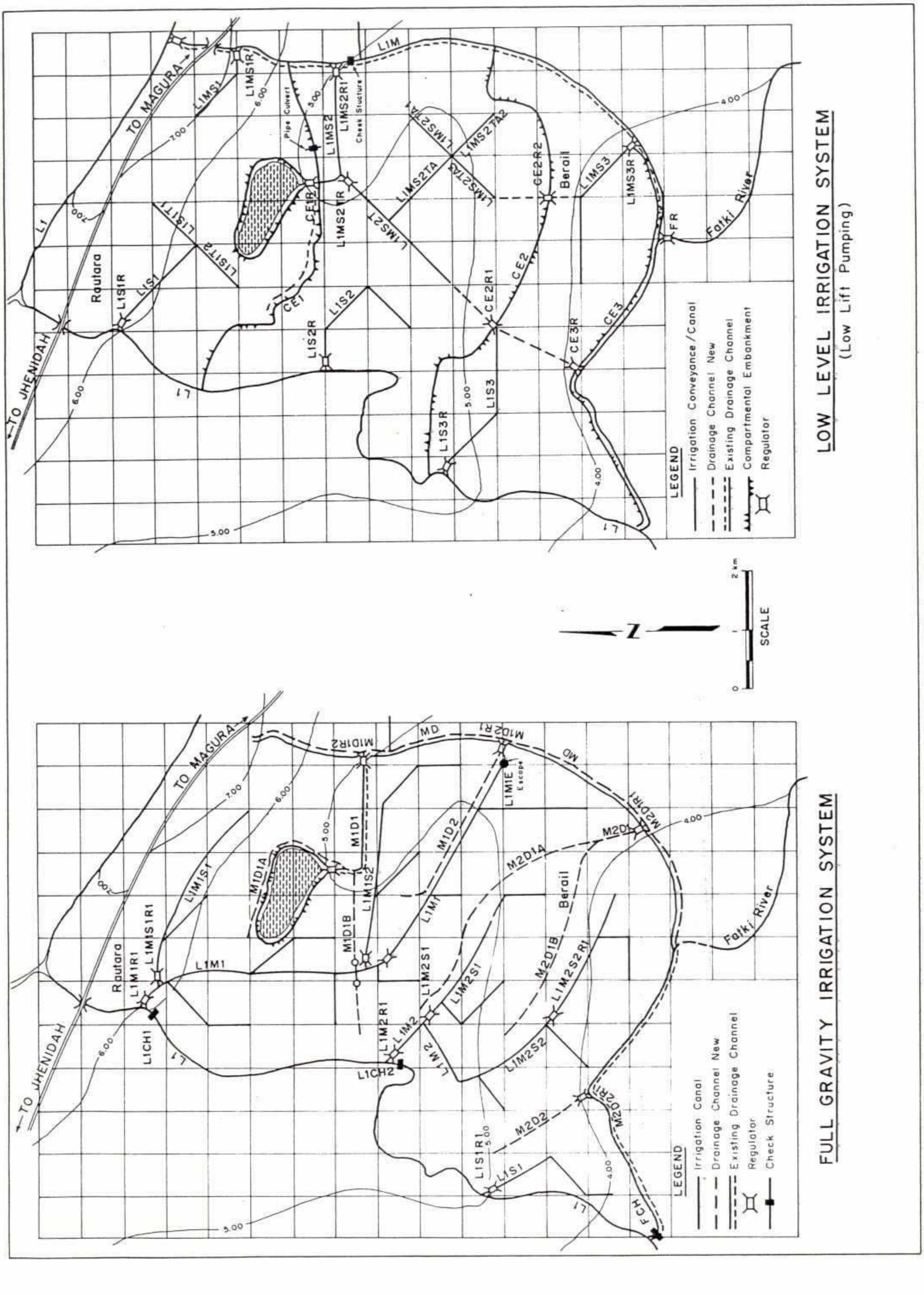
Full Gravity System

When the water level in a supply canal/river is relatively high and could command an adjoining, large irrigable area which has a mild slope (about 0.1% slope), then a full gravity system could be provided for irrigating the area. Water could be diverted from the supply canal/river into a network of distribution canals and led directly on to the farmers' plots, all based on gravity flow. The distribution canals would have to be routed along relatively higher elevation in order to be able to command the adjoining plots. In addition, the system should have a network of drains to take away from the area, the return flows from the irrigation application, and also to drain the area during the rainy season. The cost of provision of the two networks of channels and associated water control structures to equitably and efficiently distribute the water is high compared to a low lift pumping or a tubewell system. A full gravity system is estimated to cost about 3.8 million taka per km^2 (NCA), of which almost 3.7 million taka per km^2 would have to be borne by the government to ensure that the required flow reaches the top most corner of every 50 ha unit of collective farms unit (Figure 9.28), while the beneficiaries within each 50 ha unit could be expected to provide a simple network of farm ditches at their own cost (approximately 0.1 million taka per km^2) to distribute the water, on the basis of any agreed rotation, to their individual plots. Once the system is implemented, the annual operating and maintenance cost (to be recovered from the farmers) will be relatively low about 60,000 taka per km^2 (about 2% of the initial capital investment).

Low Lift Pumping System (LLP)

A relatively low cost water distribution system could be provided to the same area (Figure 9.28) if a low level conveyance network, that could incorporate any existing water courses/khals within the area, is adopted. The main system would convey the water to a convenient corner of every 50 ha collective farm unit and the beneficiaries would then be expected to lift the required water on to their network of farm ditches and distribute to their individual plots, all at their own cost. This type of water distribution would not only suit mildly sloping land, but also flat areas or a mix of the two as generally found in the

Figure 9.28



Irrigation Systems Comparison

Southwest Area. The main system which would be implemented by the Government is estimated to cost about 2.8 million taka per km², while the beneficiaries would have to bear the additional cost of 0.3 million taka per km² for providing their own collective pumps and farm ditches. Thus, the total development cost for this system would be 3.1 million taka per km², about 0.7 million taka per km² lower than the full gravity system. However, the operating and maintenance cost of this low lift pumping system which has to be borne by the farmers could be relatively high : about 270,000 taka per km² per annum (about 8.7% of the initial capital investment).

Comparison of the Full Gravity and LLP Systems

Though the initial capital cost of development of a LLP system is relatively low, its annual operating and maintenance cost that the farmers have to bear will be about 210,000 taka/km² higher than that for the gravity system. This will put an extra burden on the farmers, increasing his production cost per ha for the rabi/boro crop season by about 13% (about 1500 Taka per ha). Furthermore, it would not be possible to achieve the same level of equitable and efficient distribution of water as is possible with a full gravity system.

However, a LLP system would involve a greater degree of participation in the development by the farmers and the private sector (particularly the provision of the pumps) which is one of the main requirements for sustaining the development. But this need for greater financial contribution to the development by the farmers and the private sector could cause some delay in achieving the envisaged full development compared to the gravity system development.

Another important consideration that should be given when selecting the type of irrigation system is the need of the government to spread its investment to cover as large areas as possible such that more people would benefit from a limited investment potential of the government. A low investment LLP systems development would not only satisfy this requirement, but would conform to the main concept of the National Minor Irrigation Development Project of the government, the implementation of which is due to commence in mid 1993.

Taking into cognisance the above pros and cons of the two surface water systems, the LLP system has been selected for planning purposes as the means of provision of irrigation in most of the proposed agricultural development areas in the Southwest Area.

Groundwater Development

The Southwest Area groundwater resources evaluation in the Hydrogeology Section of the Final Report (Volume 5) has identified 5 of the 21 districts (Faridpur, Gopalganj, Madaripur, Sariatpur and Kushtia) as having potential for further DTW irrigation development : more than 50% of their groundwater resources are yet to be developed. Another three districts (Magura, Narail and Rajbari) have between 35% and 50% of their resources undeveloped. Four of the remaining 13 districts (Jhenaidah, Jessore, Chuadanga and Meherpur) have almost fully developed their available resources, while the other eight districts cover the coastal areas and their groundwater potential has been always very low or nil.

The above evaluation is based on MPO estimates of available recharge, which according to field information appear rather conservative. It is likely, in practice, that more groundwater is available for irrigation than has been assumed.

As shown in the Hydrogeology Section of the Final Report, DTW is the recommended main source of groundwater, the method which is most likely to have a detrimental effect on other users, particularly on the HTWs (rural water supply). In addition, in areas around Khulna and further south the issue of saline intrusion is a special complication. In the past, BADC have had a major role in controlling groundwater abstraction by DTW, but under the current deregulated development some consideration therefore needs to be given to the matter of groundwater management, to avoid problems.

DTW installation will be an important vehicle for minor irrigation development and it will basically be in the form of joint ventures between the farmers and the private sector: it will be self financing and driven by market forces. It is therefore considered that some action is required to particularly protect HTW supplies. As stated in Section 9.5.2, this could be achieved by instigating programmes to install force-mode Tara HTW in those areas where irrigation by DTW is to be extended. The project cost of the irrigation development should include the cost of this mitigation programme for the rural water supply. The programme should be funded by the government and implemented through DPHE.

Under a regulated groundwater development programme it could have been possible to maximise the use of the groundwater and surface water resources for irrigation by adopting a conjunctive use of the two resources. This would particularly be advantageous where the surface water supply is not arriving from a regulating reservoir. A basic form of conjunctive use is presently being practiced in some areas of the GK Project, where groundwater is utilised when the canal supply is either shut off during the fixed maintenance period each year or insufficient to meet the crop water demand. But this small scale groundwater abstraction (a maximum of 56 l/s) will cause the conjunctive use to be a non cost-effective programme in the GK Project.

However, under the present emphasis on minor irrigation development based on the deregulated groundwater utilisation, a large conjunctive use scheme is out of context.

Rehabilitation of Existing Schemes

In the Southwest Area, only three formalised irrigation schemes have been in operation for some years: the G-K Project, the Barisal Irrigation Project and the Bhola Irrigation Project (Phase I). Already, the rehabilitation of the G-K Project is underway with emphasis on incorporating an appropriate water management programme. As stated earlier in Section 2.2.4, the Barisal Irrigation Project is presently operating at much below its envisaged capacity, and any future rehabilitation study should consider not only the structural aspects, but also the social and institutional aspects that would promote cost recovery.

All the other existing BWDB projects are basically flood control schemes with some provision for drainage disposal. They generally do not have comprehensive drain networks. Introduction of irrigation facility to these existing projects should therefore be in conjunction with the rehabilition of its drainage system (including compartmentalisation), which together could allow an integrated water management to be practiced.

Furthermore, future development programmes should place emphasis on maximising the returns from the existing projects through appropriate rehabilitation, introduction of workable O&M measures and cost recovery.

9.5.4 Institutional and Social Issues

A number of institutional and social issues have been identified which will need to be resolved before implementation of projects within the Regional Plan. The issues primarily concern public participation, the equitable distribution of benefits and reducing physical and social adverse effects of developments to a minimum.

The main issues are:

- minimisation of disturbance of existing land holdings, transport routes and fisheries;

- provision of adequates compensation where disturbance or loss of land or water resources is unavoidable. This could be through monetary compensation; resettlement on FCD embankments or, if practical elsewhere; giving employment priority to families that are adversely affected; the involvement of NGOs through funding of programmes to assist this target groups within project areas to adjust to changed circumstances; similar provision and training for staff of GOB organisation concerned with implementation and O & M (BWDB, DOA etc.) and to credit organisation including the Grameen Bank and KSS;

- provision of potable water supplies;

- the encouragement of public health measures to improve sanitation and minimise conditions conducive to the spread of water borne diseases and parasites.

The institutional issues start with the need for complete political commitment at national and local levels to the FAP programme and its constituent projects. Given this, the formation and use of strong linkages between implementation agencies and all groups within the benefitting communities may be possible. The identification of the most appropriate method of ensuring such linkages in each project area is a central issue, and the establishment of suitable institutions are discussed in Section 9.7 (Table 9.16).

9.5.5 Identified Projects

The identification of areas for controlled flooding, drainage and irrigation developments and their phasing has been based on the Resources Allocation and Optimisation Model (RAOM) studies. The studies evaluate the incremental net benefits that would accrue from irrigated agriculture, domestic and industrial water supply, navigation, etc as a result of the augmentation flows. The identification exercise also covers existing projects and their rehabilitation costs. In addition, the Model takes into account the type of interventions proposed in Sections 9.3 and 9.5.

The subsequent formulation of projects has, however, placed emphasis on social and environmental needs. Further information was collected on the needs of the people in the identified areas, their willingness to participate in activities relating to implementation, operation and maintenance and payment towards O&M making the before selection. The formulation also took account of the natural boundaries like rivers and topography and other existing boundaries such as embankments, road, etc.

A list of the identified projects is given in Table 9.14 and their locations are shown in Figure 9.29. The list does not include interventions proposed in Section 9.4. A total area of about 560,000 ha would be provided with surface irrigation facilities in the Southwest Region (SWR). In addition, groundwater irrigated areas could be expected to increase by about 87,000 ha in SWR. Proposed interventions (new and rehabilitation of existing FCD) to achieve controlled flooding in some of the irrigated and other areas in the Region account for 256,000 ha. In the South Central Region (SCR), the proposed interventions relating to surface water irrigation and controlled flooding cover 110,000 ha and 157,000 ha respectively. In addition, the groundwater irrigated area could be expected to increase by about 120,000 ha in SCR.

TABLE 9.14
Proposed Development

Southwest Region

Planning Unit	Ref. No.	Project	Total Project area (ha)
SW 1	W 2	Hisni Scheme	56,000
SW 1	W 1	G K Extension Phase 2	29,000
SW 1	W 6	Mathabhana - Upper Bhairab Scheme	13,000
SW 2	W 7	G K Extension Phase I	23,000
SW 3	W 3	Khoksa Scheme	37,000
SW 3	W 8	Madhukhali - Balia Kandi Rehabilitation	10,000
SW 3	W 4	Chandana Scheme	23,000
SW 3	W 5	Rajbari, Phases I & 2	56,000
SW 4	W 18	Salika Scheme	27,000
SW 4	W 12	Jhenaidah Scheme	38,000
SW 4	W 15	Kaliganj Scheme	43,000
SW 5	W13	Madhumati - Nabaganga Scheme Rehabilitation	38,000
SW 5, 10	W 20	Chenchuri Beel Scheme Rehabilitation	25,000
SW 6	W 16	Alfadanga - Boalmari Project Rehabilitation	12,000
SW 6, 7	W 14	Padma - Kumar, Phase I	60,000
SW 7	W 11	Padma - Kumar, Phase 2	39,000
SW 7	W 9	Sakunia Beel Drainage Scheme Rehabilitation	4,000
SW 7	W 10	Baramanikdi Project Rehabilitation	3,000
SW 7	W 25	Tarail - Pachuria Project (Polder 3) Rehabilitation	5,000
SW 8	W 17	Betna Irrigation Project	52,000
SW 9	W 21	Harihar - Kobadak Irrigation Project	22,000
SW 10	W 22	Singia - Nebugati Project Rehabilitation	7,000
SW 10, 13	W 23	Barnol - Salimpur - Kolabashukhali Project Rehab	17,000
SW 10	W 19	Narail Project	27,000
SW 11	W 27	Satkhira Area Drainage Relief	51,000
SW 11,12	W 29	Khulna Area Drainage Relief	17,000
SW 12	W 28	CERP II	47,000
SW 13	W 24	Tarail Pachuria Project (Polders 1,2,4,5&6) Rehab	15,000
SW 13	W 26	Pirojpur project	6,000
SW 13	W 30	Bagherhat Area Drainage Relief	32,000

South Central Region

Planning Unit	Ref. No.	Project	Total Project area (ha)
SC 1	C 1	Sadarpur Scheme	14,000
SC 1	C 2	Palong - Padma Scheme	29,000
SC 1, 3	C 3	Arialkhan - Bisarkandi Scheme	72,000
SC 3, 5	C 4	Tarki - Gournadi - Bamrail Scheme	27,000
SC 4	C 6	Swarupkati Scheme	13,000
SC 4	C 5	Ramsil Kafulbari Project	6,000
SC 5, 6, 7	C 7	Barisal Irrigation Project Rehabilitation	88,000
SC 8	C 9	Bhola Irrigation Project Phase 2	38,000
SC 8	C 8	Bhelumia - Bheduria Scheme	10,000
SC 11, 12	C 10	Bishkhali Scheme	21,000

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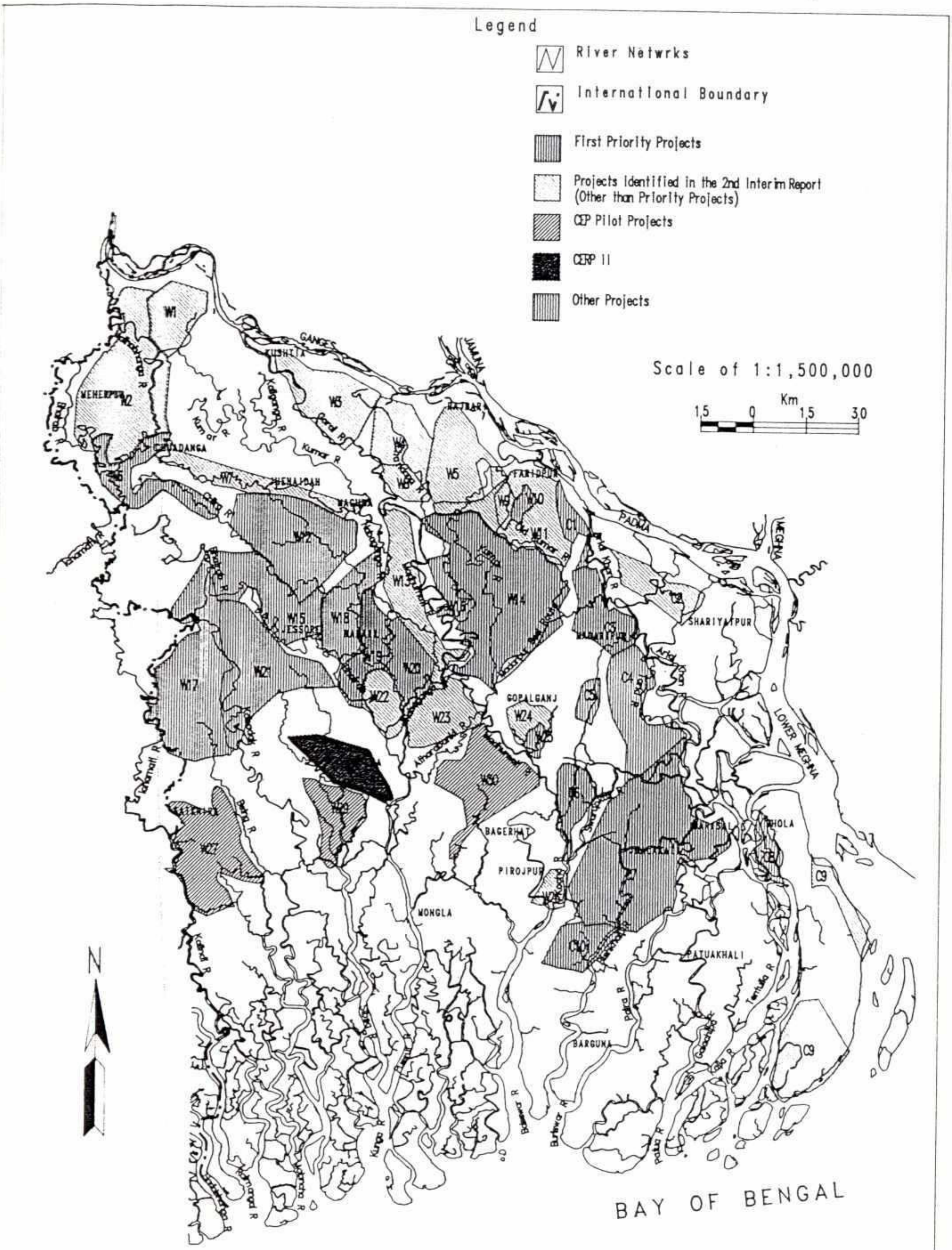
Figure 9.29



Development Plan

9.5.6 Conclusions

Indiscriminate development of groundwater irrigation systems, particularly when deep tubewells are adopted will have detrimental impact on many rural water supply systems in the Southwest Area: the ensuing drawdown of the water-table would put a large number of the suction mode hand-tubewells (HTW) out of action. Possible mitigation is to convert the affected suction mode HTWs to force mode (Tara pumps).

Supplying domestic and industrial water to Khulna from an upstream river (the Chitra), which generally remains within the allowable salinity limits, is found to be relatively cheaper than augmenting the dry season flows in the Bhairab in order to push the salinity front south of Khulna, or even conserving local rainfall runoff in a selected beel for this purpose.

The low lift pumping systems involving low level network of canals and drains have the potential to attract private sector investment in the form of provision, operation and maintenance of low lift pumps. This support from the private sector will reduce some of the burden of funding of the government and can even allow the government to widen the sphere of the benefitting areas/people. Furthermore, the overall investment cost per unit area for this system is lower than a full gravity system. However, the operating cost of the low lift system will be higher than the gravity system in view of the pumping involved. Considering the above into account, the low lift system has been recommended for any surface irrigation development in the Southwest Area. This is also in consistent with the policies of the National Minor Irrigation Development Project due to start shortly.

9.6 Cyclone Protection and Disaster Management

9.6.1 Current Programme

Major cyclones occur in the pre and post monsoon seasons and have been reported for centuries as causing loss of human life, livestock and devastating crops, property and flood embankments. During the last 125 years more than 42 cyclones have crossed the coastal belt, of which fifteen have occurred during the last 25 years. The most severe recent ones were in November 1970, May 1985, November 1988 and April 1991. The latter was the worst, killing some 140,000 people but only a relatively small number in the SWA. However, the November 1988 cyclone hit the Khulna coast, had wind speeds of 160 km/hour, produced 4.4m surge at Mongla, killed about 6000 people, 150,000 deer, 9 tigers, 65,000 cattle and damaged over Tk 9 billion in crops. This surge was about 4m above mean sea level, though its return period is not known as frequency analyses only exist for the Chittagong area.

Cyclones can travel at 30-40 km/hour and the path of most cyclones takes them to the east of the SWA. Their winds rotate anticlockwise, producing the highest winds and surge conditions on their right side. Thus, while most of the SWA can expect some damage, it is most severe in the Lower Meghna. Cyclone occurrences have averaged 1 every 5 years in the SWA since 1882, although there is a gap in the records from 1926 to 1941. However, their frequency appears to be increasing as this century their occurrence was 1 in 3 and since 1950 has been less than 1 in 2 years. This increase in frequency may be due to changes in climate or, with increased population, an increase in impact. The frequency of severe cyclones has been the same for the two periods, pre and post monsoon.

The 1989 agreement between GOB and the EEC resulted in the Cyclone Protection Project II (CPP II). This comprised feasibility and design studies for protective measures against cyclones flooding and the studies are now complete (Cyclone Protection Project II- FAP7, Feasibility and Design Studies, May 1992). The study completed proposals for a 5 year Mid

Term programme for coastal embankments, the designs for the First Year programme and an Emergency Project after the April 1991 cyclone.

FAP-7's objectives have been to protect the polders, minimise flooding and protect specific industrial areas. It covered 23 polders, which it ranked according to their benefit/cost ratios, in relation to the repair and strengthening of existing embankments; construction of new and retired ones; protective works; hydraulic structures and afforestation. In general, the embankments will have 1:7 and 1:3 outer and inner slopes, respectively, and a crest width of 4.3m. Most of the recommended areas lie outside the SWA.

Afforestation has been proved to provide a very efficient protection to embankments and the hinterland against both waves and surges, by reducing their energies ie a 100 to 200m wide stip of dense mangrove can reduce wave energies by 20 to 25%. The Sundarbans have been very effective in this regard for the southwest. An afforestation programme is included in the Mid Term plan.

In addition to FAP-7, the precursor to the proposed FAP-11 study (Comprehensive Disaster Preparedness Programme), entitled Assistance to Ministry of Relief in Monitoring and Coordination of Cyclone Rehabilitation, was completed in June 1992. The object of the project was to strengthen the GOB's capability to co-ordinate and monitor disaster related activities; review existing procedures and organisations with a view to their expansion and training; prepare a disaster preparedness/management programme; and in conjunction with the FAP, prepare a concept plan for measures to protect coastal areas. The report highlights the recommendations in earlier reports for the coastal zone of the SWA like the need to give disaster preparedness a higher priority; to the continual update of plans; to separately plan for coastal areas; consider cyclone resistant housing; give careful consideration to environmental impacts; rehabilitation and complete embankments; and to undertake mangrove planting on a massive scale. In this latter case, some 120,000 ha of mangrove have been planted since 1966 (Saenger and Siddiqi, 1993).

The report also considers of cyclone warning, including the operations and co-ordination of the various organisations such as the Meteorological Office, the wireless, SPARRSO etc. These aspects, which relate to flooding are also covered in the FAP-10 report, Improvement of Flood Forecasting and Warning System. The development of an early warning system is critical in that cyclones can build up within hours, whereas floods take days.

Cyclone shelters are the most important structures for accommodating people during storms. At present there are 300 shelters, built in the 1970's. While they can accommodate up to 2000 people, their distribution is very uneven and, according to FAP-7, reflect political influence rather than exposure to cyclones. There are 73 and 61 in the Bhola and Patuakhali Divisions, respectively, but none in the Khulna or Satkhira Divisions.

Killas have proved effective for protecting livestock and there are some 160 of them in the country. The numbers in the SWA are unknown.

The recommended 1 in 20 year significant wave heights and periods offshore are 8.8 m, 12.5s and 10.2m, 13.6s, respectively. Wave heights at the coast are depth limited and 1.5m, 8s and 3.5m, 9s waves will break in water depths of 2 m and 5 m respectively.

9.6.2 Future Needs

As described in Section 9.6.1, the various reports by FAP-7, FAP-10 and FAP-11 cover the existing and future needs of the country, including the SWA, in relation to cyclones. They cover design requirements, to organisation and management through communication to cyclone warnings. All their recommendations should be applied to the SWA and these needs must be addressed if Area is not to continue to suffer damage.

The overall Project Costs for FAP-7 for the Mid Term programme (January 1992 prices) was almost Tk 3.7 billion with a yearly budget of Tk 38 million for maintenance and Tk 60 million for cyclone repairs. Details of the four polders in the SWA to be included in the Mid Term programme, in descending priority according to the EIRR, are given in Table 9.15.

TABLE 9.15

SWA, Project Ranking in the Mid Term Cyclone Protection Programme

Polder	Name	Embankment Length (km)	Cultivable Area (ha) and Crop type	Investment Cost $Tk x 10^6$	EIRR %
48	Kalapara	9.0	3,715 Paddy/Shrimp	14.1	36.2
35/1	Sarankhola	4.3	8,980 Paddy/Shrimp	57.5	30.4
40/2	Patherghata	9.5	2,380 Paddy/Shrimp	59.9	24.3
56/57	Bhola	62.3	78,100 Paddy/Shrimp	317.4	14.0

Because of the rapid changes in river morphology described in Section 2.2.1, the maintenance budget will need to be higher in Bhola than other areas.

All the SWA polders are shown as being in the Phase II of the programme, which is due to start this year and be completed by the end of 1995. No work has been undertaken as yet, but it is recommended that it proceeds as soon as possible. The report also recommend afforestation of about 700 km of foreland/embankment over three years at a cost of Tk 210,000/km, to start this year. Details are not given of specific areas but, it is strongly recommended that this work starts without delay as, it is effective, relatively cheap and is a renewable asset. Since 1965, over 43,000 ha of afforestation have taken place in the Barisal and Patuakhali Divisions and, over a 23 year period its annual benefits can be almost Tk 290,000/km. It should also encourage accretion in areas, providing further protection and, eventually land for development. The resettlement of these reclaimed areas' must however, be strictly controlled.

It is recommended that proper planning and maintenance be introduced in participation with Local Bodies and the Beneficiaries, including the employment of destitute women, labour groups and Landless Contracting Services. There should also be an integrated master plan for protection against cyclones covering all aspects as well as embankments such as warning systems, cyclone shelters, means of evacuation, emergency plans etc. This applies to the SWA, but it must be coordinated countrywide. In particular, there is a need to plan and co-ordinate transport, including emergency boats, in the coastal region as they are essential if effective cyclone relief is to be achieved.

It will also be essential to build more cyclone relief shelters in each village or population centre. They should be two storey buildings and have other uses such as schools, mosques etc. Further studies of shelters are ongoing and should include other protective measures such alternative types of shelter (depending on the degree of exposure), suitable roads for evacuation etc. In the SWA, where dredging in the preferred option for improving the poor drainage associated with the CEP, spoil disposed should in some areas not be considered a problems, but be used to raise land levels to provide protection and as an embankment construction material.

Recommendations elsewhere regarding improving forecasting and early warning systems are fully endorsed. In addition, further and more accurate modelling and field data are required in order accurately predict design flood levels in the SWA. At present it is difficult assess design levels for embankments against the risks of them being overtopped. This applies to all the embankments, in addition to those identified in the Mid Term Plan and should include surge/tide joint probability analyses.

If the above plans are implemented they will, overall, have a beneficial environmental impact. There are, however, some negative sociological impacts, which affect some landless people and land owners in the coastal margins.

It appears that the net economic impact of the project on fisheries would be positive. In fact, the economic value in terms of the protection, expansion and improvement of cultural fisheries, is expected to be substantially greater than the negative impact on open water fisheries.

9.7 Institutional Development

9.7.1 Planning and Design

The need for proper planning, design and execution in any project, large or small, cannot be stressed enough and is essential for major projects, as the consequences of their failure to perform can prove extremely costly in life and resources. Projects which are not acceptable to the 'people' are bound to fail and in line with the FAP philosophy, peoples participation in the early stages of planning and design is therefore essential. It is not enough to discuss with the people after the project has been formulated. Before project formulation, beneficiaries views must be heard and incorporated, as far as possible, in the project planning and then in the design stage. It is particularly important to make provision in the project planning stage for other income generating activities, for the underprivileged groups like the landless and women who may not benefit from the project. If there are groups or people who will be disadvantaged by the implementation of the project then these people must be specially targeted for in other income generating activities.

9.7.2 Construction Management

An important element of the Flood Action Plan is the need to devise a realistic workable plan, which can probably be implemented and sustained in the long term. Proper planning and implementation of the development programmes for the Area become very important.

A particular aspect of implementation is construction management. The structural aspects of the schemes planned must certainly be reflected in their complexity and cost. Examples of the structures/methods being considered range from barrages/barriers, control structures, regulators, groynes, guide banks, dredging, embankments etc. The selection of construction method appropriate to the structure is very important. As far as possible construction should be carried out by manual labour so that the local community, especially the landless and unemployed, will benefit from the project. However the importance of monitoring quality, standards and timely completion cannot be overemphasised.

Major and complicated structures/schemes will clearly be carried out by international contractors but local contractors with local knowledge must be encouraged to associate, so that the technology and technical 'know-how' can be transferred to the Bangladesh contractors.

9.7.3 Operation, Maintenance and Cost Recovery

General

Preliminary assessment of existing FCD/I schemes in the study area shows inadequacies in their operation and maintenance (O&M). One of the main reasons for this is the non-availability of the required funds. Annual budget allocations for O&M to BWBD, who hold the responsibility for these field activities in addition to project implementation, are used mainly on payment of staff salaries. Therefore, there is a need to find adequate funds to meet costs of operation and routine maintenance of completed schemes. Recovering these costs from the beneficiaries is the most plausible way.

Cost recovery from the beneficiaries of water resources development projects is a complex issue. FCD/I projects do not benefit the target beneficiaries equally and benefit will vary even from one plot to another, depending on the topography. In the case of some owners of F0 land, the benefits may even be negative. Moreover, as in protection against flooding, the creation of new facilities and their O & M for agricultural development have historically been considered solely as Government's responsibility, and the generally accepted view is that beneficiaries should not be directly charged. Unless cost recovery is done through a land productivity-based system, it is not possible to design an equitable and practical system of direct cost recovery.

There have been statutory provisions since 1976 for collection of water rates from farmers benefitting from any BWDB sponsored FCD/I developments. A revised Irrigation Water Rate Ordinance went into effect in July 1983, and new water rules were issued in January 1984. Specific water charges for completed gravity irrigation projects were published in June 1984. These rates were based on estimates of the O & M costs in each project area and amount to Tk 125 - 375 per ha for each crop season depending upon the crops grown. Under the existing rules, BWDB would be responsible for both the assessment and collection of water charges; beneficiary participation in this aspect is not provided for. Government initiated efforts for collection of the new water rates in 1990 but success has been very limited. For example, in the GK Project, which is the largest irrigation development in the Southwest Area, it is estimated that only about 2% of the pump station operating costs were recovered from the beneficiaries during the last financial year.

Appreciating the need for cost recovery, the government has initiated a number studies through its relevant agencies to identify suitable mechanisms for achieving it.

Related O&M Studies

BWDB have been carrying out the following four major programmes under external aid to study the present status of O&M in various projects and identify suitable measures for improved O&M and cost recovery :

(a) Systems Rehabilitation Project

(b) Second Small Scale Flood Control, Drainage and Irrigation Project

(c) G K Rehabilitation Project

(d) Early Implementation Project

In addition, LGED has been carrying out similar studies with particular emphasis on participation of thana and other lower level local government institutions (Unions) in promoting these activities.

There is an on-going pilot programme of the Systems Rehabilitation Project for achieving cost recovery. This is attached to the Ichamati Unit of the Karnafuli Irrigation Project (near Sylhet, Northeast Region of Bangladesh). However, the progress in implementing the required measures has been slow. The programme endeavours to enlist the support of the relevant staff of the local thanas and unions and NGOs to form viable Water User Groups which would then take responsibility for collecting the water rates as well as participating in O&M activities.

Constraints to Operation and Maintenance

The major constraint for operation and maintenance is the lack of trained O&M staff and necessary funds to meet the requirement. In addition, in some of the existing projects in the Study the following constraints have been noted :

- inadequate capacity of some of the draininge structures, particularly due to the prevalence of high river stages outside the embankment.
- social conflicts of different interested groups inside the project, particularly in polder areas, and also influence of the local elites.
- conflicts between farmers on high and low lands and between farmers within the protected area and outside.
- lack of specific and clear demarcation of responsibility among the operational staff for the operation works of a project.
- lack of beneficiary participation.
- theft of fall boards used in water control structures.
- Inadequacy in the managerial system.

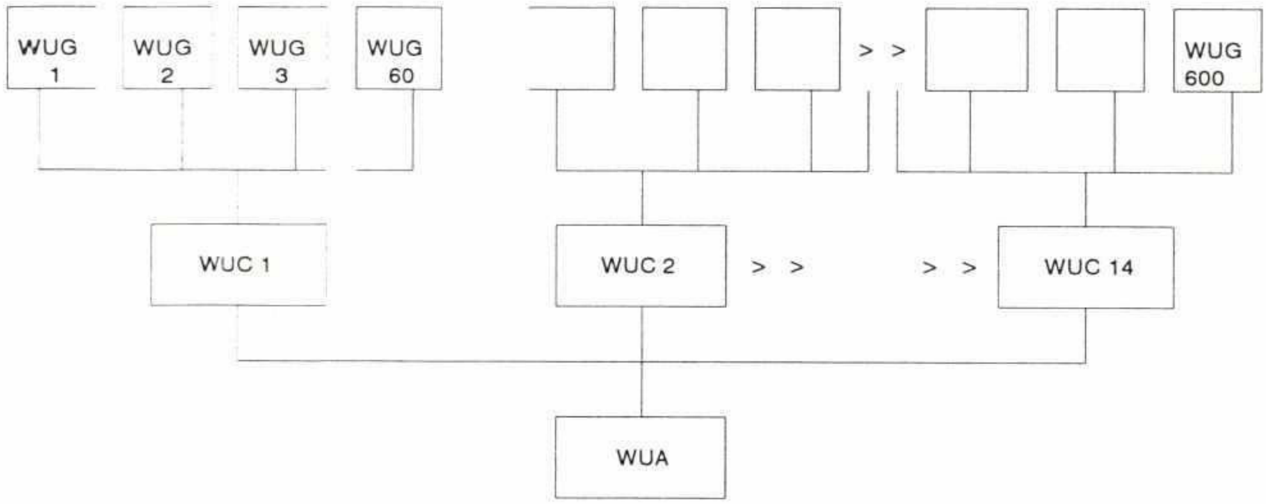
Proposed Measures for Implementation, O&M and Cost Recovery

The operation and maintenance activities of BWDB in the Southwest Area is suffering from the various constraints as outlined above and there are manifold measures which may be proposed for the satisfactory operation and maintenance of works. The cost of O&M would be recovered from the imposed water rates and other cost generating activities adopted within the project infrastructure. The schematic institutional arrangement shown in Table 9.16 is recommended as the means to carry out O&M and achieve cost recovery for a sample area within the SWA. This also takes into account the need for beneficiary participation at the initial planning and implementation stages and the subsequent O&M stage. Similar institutions could be developed for individual schemes in the SWA.

9.7.4 Monitoring and Evaluation

Implementation monitoring is intended as a project management tool. It covers project related activities up to the point when facilities are ready to deliver services to the potential beneficiaries. Performance evaluation is meant to measure the performance of the system design in terms of services delivery. It will also cover aspects related to the effectiveness of the services.

TABLE 9.16
Recommended Institutional Arrangement for Implementation, Operation & Maintenance And Cost Recovery



Note :
The number of WUGs & WUCs relates to Chenchuri Beel Rehabilitation Project (NCA = 17,900 ha) for which this sample study was done.

Name of Water User Units	Composition of Water User Units	Responsibilities of Water User Units	Participating Agencies
Water User Group (WUG)	20-50 ha Canal Unit. 10-20 farmers associated with a LLP or outlet to form Water User Group.	Responsible for provision of watercourses / field channels / pumps and their O & M.	Supported by field extension staff involved in Agriculture, Fisheries etc. and NGOs.
Water User Committee (WUC)	500-1500 ha sub-compartment. One representative from each WUG within a sub-compartment.	Participate in main, secondary and tertiary canals/drains network planning;	BWDB staff supported by Union Parishad staff & NGOs.
		Organise WUGs to participate in tertiary canals/drains construction on the basis of payment for work done.	-- Do --
		Responsible for cost recovery to finance O & M of the main, secondary and tertiary network.	Union Parishad staff supported by BWDB staff and NGOs.
		Organise WUGs to participate in all O & M activities on the basis of payment for work done.	-- Do --
Water User Association (WUA)	Covers the entire project / compartment area of 1,000 to 20,000 ha.	Participate in formulating O & M criteria and work programme for each of the sub compartments.	----
	WUA comprises a representative from each WUC, SDE of BWDB and a representative from relevant government agencies (DAE, BRDB, LGED, BADC etc.). WUA shall be chaired by the XEN of BWDB O & M Division.	Coordinate and supervise the activities of all WUCs and WUGs.	
		Liaise with relevant Government and other agencies.	

[vp\tab9-16]

(a) Implementation Monitoring: A system need to be devised and established during the feasibility phase within BWDB HQ and Regional offices covering SWA to monitor the progress and quality of the various implementation programmes/work: the physical program of the designed work; the flow of funds from the central office to the O & M Division office; the parameters affecting farmers participation and the project support services including extension services, beneficiaries group formation, information dissemination, etc. The parameters to be monitored will be selected with the understanding that monitoring will be a continuous process aimed at identifying constraints to timely implementation of the project and devising solutions to remove them.

(b) Performance Evaluation: This activity will cover: FCD/I operations and related agricultural/fisheries performance; the effect on the beneficiaries in taking advantage of the system including the degree of equity between groups in the community related to benefits and responsibilities after it becomes operational; the provision of support services; O & M status of the facilities provided. As far as possible M and E systems should be compatible with, and use the results of existing or proposed system in DOA and other GOB productive sector support agencies.

Environmental Monitoring

Environmental monitoring requires an inter-active programme of ground monitoring, coupled with feed-back systems from affected communities, interested parties in both the public and private sectors, and the regulatory and development institutions. The National Environmental Management Action Plan (NEMAP) is presently being drafted, and it is expected that it will take account of the institutional needs.

The need is for a holistic understanding of the environment, as well as monitoring the changes that occur as a result of development. There are no authorities that, at present, have the institutional capabilities or resources, at a local level, to monitor environmental change, or adequately provide a record of environmental and social change at this time. Accordingly a method must be found whereby some records can be presented at regular intervals to allow for independent scrutiny and evaluation of any on-going negative impacts.

The Department of the Environment (DoE), under the Ministry of Environmental and Forests, has the national mandate for environmental control. This institution would therefore be the coordinating centre for environmental management, and it should be the agency capable of providing the necessary holistic overview. However, the DoE is presently a small, young organisation that will need considerable support and strengthening to undertake this role and discharge its mandate.

Liaison will be required between local administration, other public institutions and utilities, and local public interest groups; all of which will require different degrees of inter-action with the project. The NGOs have been identified as a group in the liaison process that have specialised roles that would be of importance at specific times during the project cycle. There are a number of active NGOs in Bangladesh in addition to international agencies that have programmes of assistance to rural areas. These bodies can play an important role in the liaison process, as well as in developing public awareness and providing assistance to specific communities.

9.7.5 Role of the Private Sector

Government policies recently have been to accelerate the liberalisation and deregulation of the economy and reduce its role from monopoly provide, such as in the case of BADC, to supporter of the private sector. As a result although subsidies are being reduced, the choice and availability of production inputs and capital goods would generally improve.

In the water resource development sector the distribution and installation of minor irrigation equipment has been deregulated and GOB is encouraging and supporting the introduction and development of cost-effective irrigation technologies through commercial channels. This policy is designed to support the private sector in minor irrigation development using technologies which, though proven viable, have not been commercially available before because of trade restrictions, excessive regulations, inadequate credit facilities and a high level of public subsidy. This policy is leading to a transition from a supply-driven, public sector controlled system to a demand-driven competitive supply. Although the transition will take time, the private sector has an increasingly significant role in the implementation of GOB development policies. The IDA/CEC funded National Minor Irrigation Development Project (NMIDP) and Low-lift pump and Shallow Tubewell Irrigation Project will promote this strengthening of the private sector participation.

Similar policies have lead to improvement in the provision of production inputs, such as seed and fertiliser, that are related to the realisation of opportunities made available by FCD and irrigation programmes.

The private sector's role in marketing agricultural and other commodities and their redistribution from surplus to deficit areas is very well established. It is also generally effective within the limits set by effective demand and the transport and market infrastructure that GOB is responsible for.

9.7.6 Role of Non Government Organisations

Non Government Organisations (NGOs) have for many years been active in a wide range of development activities, generally directed towards poorer groups in the community. NGOs have gained the confidence of their target groups and are in an excellent position to prepare and assist them to participate in the implementation and operation of development projects and to liaise and coordinate their interests with other groups and government organisations. The experience gained by many of the NGO's in terms of identifying and realising local community needs has enabled them to gain considerable insight into appropriate measures for successful development at a local level. Whilst these lessons do not necessarily address the regional level issues, the successful implementation of regional policies will ultimately depend upon satisfaction of these local issues and thus account of NGO experience if highly relevant. It is increasingly realised that coordinated involvement of NGOs in the water resources sector is important if full and equitable benefit of the development in the sector is to be achieved, particularly to promote the formation of Water User Groups and Water User Committees and cost recovery relating to O&M, etc (Table 9.16).

A number of NGOs; Proshika, BRAC, CARITAS, CARE etc; are already active in the water sector in SWA. They are working with government agencies towards improving management of existing facilities through traditional organisations such as farmers cooperatives and water users associations. Proshika and Grameen Bank are trying to implement a new system of management modules with groups of landless peoples. The Land Reclamation Project (LRP) in Khulna for example has successfully involved the rural Women-based NGO - Nijera Kori in the maintenance of project facilities. However, to date these efforts have been marginal and isolated, without effective linkages with similar government programmes, necessary in large scale water resources projects. But with proper design and control, they may be effective and able to deliver the required services. Their role in assessing local needs and representing groups with little influence in public administration is seen as vital if benefits and responsibilities within FCD/I and other developments are to be fairly spread. NGOs role can also go beyond the direct needs of the proposed schemes to include assistance to groups to take full advantage of the improved conditions resulting from FCD and irrigation - provision of credit, and inputs, extension advice etc as well as group formation for the purchase and use of irrigation systems and pumps.

9.7.7 People's Participation

The importance of beneficiary or people's participation (PP) in planning, implementation and operation of development projects has been recognised. FPCO guidelines (GPP) for FAP projects are still being prepared and a parliamentary bill to provide public participation in flood control, drainage and irrigation introduced in 1992 is under consideration.

Participation is a political and a local issue. How effective the proposed GPP will be when applied to FCD/I schemes will be largely determined by the political will and commitment of project implementing agencies towards incorporating people in project activities. Apart from the lack of political willingness at the government and the project level, effective people's participation may be restricted and made ineffective by localised village politics and/or individuals.

Although the concept of people's participation defined in FPCO (1992) is very comprehensive, evidence suggests that PP in FCD/I projects has so far been used within a very narrow context. Two different concept of people's participation in development programmes can be identified: participation as a functional element to achieve overall project or centrally planned objectives; and participation as an end in itself where the stress is on enabling people to take control over development processes and opportunities to more closely tailor them to their particular circumstances and needs.

In FAP and FCD/I projects so far PP has been used as a functional element. Dialogue with local communities to identify projects, listening to people about their opinions on the proposed schemes and joint consideration of project options so as to incorporate community views in the project formulation and design process has not occurred.

Evidence from FCD/I schemes suggests that project implementation, operation and overall socio-economic benefits are better when people are involved at all stages of project development, and small-scale projects produce better results than large-scale projects. Regional water management programmes are likely to provide only limited scope for PP but the constituent components will be small enough to permit active participation. While studies at the feasibility stage will address details of PP and recommend appropriate, practical institutional arrangements, the following paragraphs highlight some key requirements for successful long term participation.

There needs to be free access to information about the projects; its objectives, method of implementation and a degree of openness about the expected effects on all groups in the affected community. Only those likely to be affected can judge the consequences (good or bad) for themselves and put forward practical ideas in response. Such a process may increase the time required for planning and design, but will result in project design modifications to avoid physical, social and institutional problems and also develop in the majority of the community a sense of "ownership", direct interest and responsibility for schemes' future operation and maintenance. Communities are less likely to feel eliminated if such an approach is followed.

In order to involve all groups within a FCD/I, or other community-wide scheme there is a need for accountability and a focus for project activities. As with routine monitoring and regular evaluation of development projects peoples participation can only be positive if the implementing and operating agencies are willing to take account of the views and suggestions expressed and act upon them. Strong linkages between the people and the project agencies are necessary. The proposed approach to this is through the establishment of a Project Coordination Council (PCC) consisting of representatives from the BWDB, other relevant government departments at the Thana level, Union Parishad elected representatives and representatives from different local socio-economic groups nominated by the group members, but possibly based on the format suggested in Table 9.16. However, due to the lack of sufficient detailed knowledge about the existing organisational facilities in the project area, it is too early to specify exactly how this ought to be organised. A sensible approach in these circumstances is to have the identification of the most appropriate form of participation as a main objective in initial meetings and discussions in the project area. In this way, the organisation of participation itself can become a participatory process.

Where some form of village organisations exist these can often be utilised to form an institutional base to act on behalf of the people. How effectively the existing organisations can be used to voice the needs of the people will depend on which socio-economic group(s) they cater for. For example, farmers' cooperatives, would not represent the interests of other socio-economic groups. It is important to create an institutional base which would voice the needs of people from all social strata, especially the disadvantaged groups, i.e. marginal farmers, landless labourer, the fishing community, boat men and female headed households. Appropriate social organisation have to be created where they do not exist.

NGOs are considered as important agents in organising the different interest groups in the project areas of the FCD/I schemes (see for example, Adnan et al 1992; FPCO 1992). Indeed, NGOs operating at the village or thana level may be the best option for helping to organise local level institutions and linking them up to thana level representation of the central government (Ministry of local government and cooperatives).

10 RELATED SECTORAL POLICY OPTIONS

10.1 Introduction

The water resources management options are discussed in detail in the preceding sections. Accompanying those development measures there are parallel developments in related sectors linked to water resource management which could be carried out. Important amongst these sectors are agriculture, fisheries, forestry and navigation for which policy options are discussed in the following sections.

10.2 Agriculture

10.2.1 Physical Constraints

The climate of the region dictates that there are three distinct seasons each influencing crop production in a different way. The kharif period, whilst it generally reflects an excess of rainfall over PET which can lead to accumulation of runoff and inundation, is also marked by dry periods which can retard crop growth and reduce yields. The end of the kharif period is variable and this can lead to problems of water shortage during the grain filling period of Aman rice unless irrigation is provided.

The rabi season is when crops are dependent on stored soil moisture for the majority of their growing period. Delays in harvesting the Aman crops or an early end to the kharif period can reduce the residual soil moisture and limit the opportunities for rabi cropping. Farmers will not invest in inputs for a low output crop unless irrigation is provided. Without irrigation, cropping is confined to lower lying areas which dry out later than the ridge soils.

The pre-kharif period is also marked by variability in rainfall which can lead to yield reduction in the crop and also in boro rice.

The soil of the SWA presents a number of constraints to crop production. In the coastal districts, dry season soil salinity limits rabi season cropping and delays kharif production until rainfall is sufficient to reduce salinity below a threshold which varies with the crop grown. Potential acid sulphate soils do not directly limit crop production other than through poor drainage and, perhaps seasonal flooding. However, they should not be drained as the acidity will increase dramatically and prevent crop growth.

Peat and muck soils are cultivated but have limited potential. They should not be drained as they will dry irreversibly and shrink thereby lowering the ground level. Any improvement to the agriculture on these soils must come via other means.

Nutrient deficiencies are likely to occur in almost any soil. If high yields are to be obtained from improved varieties then fertilisers must be used at rates higher than at present. Further problems exist for other nutrients eg sulphur, zinc and other micronutrients depending on the crop grown.

The texture and drainage of soils present problems. Lower lying, fine textured soils of poor drainage status remain wet into the dry season. They are sticky and plastic when wet but very hard when dry which restricts the period when the soil is at a suitable moisture content for cultivation. Further, they dry quite rapidly, limiting rainfed rabi crop production. Soils on ridges are often of coarser texture with higher permeability. They are easier to cultivate but moisture retention also limits rainfed rabi production. Such soils are often in land type F0 which may be above normal flood/inundation levels and do not provide a receding water table for crop growth.

The depth of inundation/flooding is a limiting factor to crop production. Although cropping patterns have developed in response to the seasonal pattern of flooding, benefits accrue from the changes in land use that occurs when land types change.

The area of land flooding at some period to a depth greater than 90cm (F2 and above) is about 5450 km^2 or approximately 25% of the net cropped area. The area of lowland, F3 is about 6% of the net cropped area.

It must be remembered that flooding and inundation may have beneficial effects such as the addition of silt to the land which contains weatherable minerals which will release nutrients to crops.

10.2.2 Objectives and Policies for Agricultural Development

The constraints identified in the SWA by the review of land resources and agriculture are broadly similar to those faced by the remainder of the country. Some are unique to coastal areas such as salinity whilst others are not of the some magnitude as faced elsewhere, as in flooding which presents a greater problem in the north east and north west regions of the country.

The agricultural development policy of GOB, as set out in the Fourth Five Year Plan (FFYP) has the following objectives:

- achievement of food self-sufficiency
- increase in the production of minor crops, and
- continued increase in growth of other crops.

The means to achieve this will be through a strategy focused on the following areas:

- crop diversification
- minor irrigation
- input delivery; fertiliser, seeds, pesticides and mechanisation
- research and extension
- marketing, and
- area development and targeted programmes.

The policy will be implemented through a combination of the strengthening of the private sector and government intervention. Particular GOB sponsored programmes that will impact on the SWA are:

- Crop Diversification Project
- Agricultural Services Support Project
- Minor Irrigation Project.

The FFYP also stresses that the programmes to stimulate agricultural development are complementary to FCD. Although they can in some instances be seen as alternatives, the benefit from FCD can be enhanced through such complementary programmes. It is recognised in FFYP that sustained agricultural growth requires more efficient and balanced utilisation of Bangladesh's natural resources, including improved management of water resources.

10.2.3 Crop Diversification

The north of the south west region is an important pulse producing region. In 1991 the SWA, and particularly the central and northern districts, produced 65% of the national output of lentil and 61% of the output of chickpea. Pulses are an important source of dietary protein and at a national level production declined, on average, by 2.67% annually between 1979-80 to 1987-88. In the SWA production has in fact increased. The FFYP aims to continue this increase by focusing the development effort in pulses, oilseeds and other minor crops through the crop diversification programme. In fact, the target for the increase of minor crops is set at 7.6% per annum (1989-90 to 1994-95), including an increase in cropped area of 2.4% for pulses, 3.1% for oilseeds and 5.7% for spices.

Given the overriding preference of farmers to produce rice, the crop diversification strategy will aim not to compete with cereal crops directly, but rather to demonstrate the profitability of these crops by offering 'high technology packages' and demonstration.

10.2.4 Minor Irrigation

The National Water Plan (MPO, 1991), identified 19,145 sq km of land as suitable for irrigation in the SW and SC region. The climate of the region identifies three periods when irrigation is required. The first period is the rabi season, the second is the pre-kharif transition to benefit the latter half of the boro crops and/or the beginning of the aus crop and the third period(s) is during the kharif when dry periods can occur at almost any time but are particularly damaging at transplanting of aman rice and during grain fill.

The intensity of cropping during the rabi period is generally low with an overall intensity of about 50%. There is considerable need and scope to increase the area irrigated to increase crop production. There is scope for this as only about 32% of the land suitable for irrigation in the SWA is currently irrigated.

Minor irrigation has increased significantly, particularly in the taken half of the 1980's. The FFYP proposes an increase of 300,000 ha in irrigated area per annum nationally. If this was translated to the SWA this would mean an increase in irrigated area of about 70-80,000 ha per year mainly through STW's, LLP's and DTW's.

The principal objective of the National Minor Irrigation Development Project (NMIDP), which is programmed to commence shortly, is to continue the expansion of area served by irrigation facilities through investments by the private sector in minor irrigation equipment. The project plans to realise this objective through the involvement of the farmers, alternative cost effective tubewell designs, credit assistance, training and institutional strengthening. The parallel measures recommended in Section 8, to the structural interventions, complement this.

10.2.5 Input Supply and Credit

This is taken to include fertilisers, pesticides, seeds, mechanisation and extension. The strategy for promoting the increased use of fertiliser, seeds, pesticides and mechanisation relies on

- promoting competitive markets
- educating farmers about proper use
- deregulating import
- removing subsidies

The strategy for improving extension, and to an extent inputs, includes the strengthening of DAE through the Agricultural Sector Support Project.

10.3 Fisheries

10.3.1 Constraints to Fisheries Development

As noted earlier, the fisheries sector in SWA has been characterised in recent years by a drastic fall in inland capture fisheries production, which is still continuing but is partly offset, in terms of volume of fish, by an expansion in cultured fish and in value terms by a rapid growth of shrimp farming.

The principal constraints to fisheries development and in particular to attainment of an overall increase in fish production in SWA, include:

(a) low social status of fishermen versus farmers and other land users competing for resources;
(b) pressure for converting floodland into FCD protected rice-land;
(c) institutional weakness in DOF, especially with regard to law enforcement, fisheries statistics, extension service and fisheries management;
(d) deteriorating environmental conditions, especially in rivers, for fish reproduction and growth;
(e) human population pressure and escalating demand for fish, leading to over fishing already depleted stocks;
(f) non-availability of formal low-cost credit to fishermen and most small scale fish farmers, forcing recourse to local moneylenders (mahajan) at very high interest rates.

10.3.2 Government Policies and Objectives

The main policy objectives for fisheries as stated in the Fourth Five-Year Plan are:

- to increase fish production and improve nutritional standards;
- to expand employment opportunities in fisheries and ancillary industries;
- to improve the socio-economic conditions of the fishing communities, fish farmers and others engaged in the sector;
- to increase exports;
- to improve environmental conditions and public health; and
- to increase GDP.

Before there can be any overall increase in fish production, it will first be necessary to halt and reverse the ongoing catastrophic fall in river fish stocks and catches, and the decline in beel and floodplain fisheries.

If there is to be any hope of increasing fish production and thereby of improving nutritional standards, enforced, fairly but firmly, and that DOF must ensure that all the necessary staff and other resources needed to do the job will be provided. Minimum net mesh size and other regulations intended to protect fish stocks do exist but are almost universally ignored by the fishing communities and by the authorities who are supposed to be responsible for their enforcement. This attitude must be checked and corrected as otherwise there will be no viable future for any new investments in capture fishing or for the fishing communities who depend on such fish stocks.

10.3.3 Capture Fisheries

Capture fisheries in SWA comprise the coastal artisanal capture fisheries, and the inland open water capture fisheries in rivers, estuaries, beels and floodplains.

The fisheries of the inland freshwater rivers, beels and floodplain are the most vulnerable to the effects of FCD developments, and the network of associated road embankments because of the obstructions caused to fish spawning and feeding migrations, the draining of many formerly productive beels, the consequent reduction in floodplain area and production and the enforced concentration of artisanal fishing effort onto the depleted river fish stocks. In the six years to 1988/89 the combined riverine and estuarine annual catch has fallen by about 31%, whilst the Padma River fishery has suffered an 85% loss. Every effort must be made to halt this collapse and to rejuvenate the river fish stocks, by enforcing all necessary controls, restocking as and whenever feasible and retaining or restoring as many open links between rivers and beels as is possible so that natural regeneration may occur. Finally, it is essential to relieve the pressure on river fish stocks by a major effort to resettle fishermen onto non-riverine jalmohal waters and borrow-pit fisheries under NFMP arrangements.

10.3.4 Culture Fisheries

In the seven years from 1983/84 to 1989/90, farmed fish production has increased by 48% to 47,700 mt, and can be expected to continue growing slowly, under its own momentum now that the private sector has largely taken over the production and sale of hatchery fry and fingerlings. Acceleration of the expansion process is possible but will depend on the injection of resources and trained manpower into the fisheries extension service and on satisfactory arrangements for providing low-cost credit.

The first target should be to persuade their owners to up-grade as many of the remaining derelict or non-cultured ponds as possible, or to lease them to fishing groups who can carry out the necessary work with NGO assistance. Thereafter it may be possible to encourage additional new pond excavation or to generate interest in other ways of increasing productivity, such as, growing fish in paddy fields, carp polyculture or fish/duck/poultry combinations, all of which are established systems in other parts of Bangladesh, but require effective extension work to popularise them more widely.

Extension of the culture based baor fisheries in the northwestern part of SWA is already in progress under the new IFAD/DANIDA project and production, which is currently about 1400 mt/pa, should increase rapidly from now on and eventually peak at around 5000 mt provided that none of the water bodies concerned are damaged by future FCD/I schemes. It is considered that baors should be treated in the same way as khas beels, namely that where they occur within a project area, provision should be included for improving the fishery, by defining boundaries, restocking and assigning the fishing rights to properly established groups of bonafide fishermen, under NFMP arrangements.

10.3.5 Shrimp Farming

Brackish water shrimp and fish farming is now a firmly established and substantial industry of great importance to export earnings and the national foreign trade balance. Shrimp farms operate over large areas of otherwise unprotected land subject to regular tidal, saline inundation and also inside many of the coastal polders despite the fact that they were originally intended to exclude salt water.

The collection of shrimp post-larvae along the banks of estuaries, tidal lagoons and khals, provides an income for many thousands of coastal residents, including women and children. Buyers and agents collect and deliver the post-larvae to the shrimp farms where they are reared in the ponds, usually from Dec/Jan until late May or early June, when they are harvested and the ponds drained and flushed with freshwater ready for planting the rice crop. Inturn the paddy is harvested in November in time for the next shrimp rotation. The entire industry is dependent on the wild stock, which is also heavily fished at sea and thus highly vulnerable to over-exploitation. A reliable hatchery will ease pressure on the shrimp stocks, stabilise prices and encourage higher stocking rates and productivity and should therefore be a matter of the highest priority.

There are now two freshwater prawn hatcheries in the country, one of which is at Kaliganj in Satkhira District. When they have resolved their remaining teething problems, their production of post-larval Macrobrachium will enable ordinary fishpond owners to produce marketable sized prawns in addition to their carp harvest, brackish shrimp farmers will be able to produce a monsoon season freshwater shrimp and fish crop after harvesting their saltwater shrimp, and rice farmers will also be able to raise Macrobrachium in their paddy fields. The potential for increased production of export quality freshwater prawns therefore seems almost limitless.

10.3.6 Extension

The inadequacy of existing fisheries extension has been referred to in earlier sections relating to the culture fisheries. The only form of extension applicable to capture fishing is the advice and technical support given to fishing groups, as and when they become responsible for water bodies under New Fisheries Management Policy terms. As regards culture fisheries, extension is a function for the thana fisheries officer and his small staff, few of whom have any training in extension work. Some of the district fishery offices have an Extension Officer who will have had such training and whose job it is to coordinate the extension efforts of the thana staff. In parts of the North West Region (Rajshahi Division), it was reported that additional extension officers were being posted to thana fishery offices, and it is to be hoped that there will be a similar injection of properly trained extension staff into SWA fisheries.

It is also to be hoped that they will be provided with the transport, finance, equipment and extension materials, all of which have been in acute short supply in DOF divisions throughout Bangladesh. Planners of future FCD projects should be aware of the probable need to reinforce DOF's efforts with cash, materials and possibly, with specialist extension coordinators, if the potential benefits are to be realised.

10.3.7 Credit

The lack of access to institutional sources of low-cost credit has long been a constraint to fisheries development. Finance is often needed for re-excavating and restocking old derelict ponds, or for creating a new pond, for restocking a jalmahal or to cover the cost of building a new boat, etc. Unfortunately, rural credit in general and including fisheries has been bedeviled by loan recovery problems, excessively bureaucratic procedures, graft and other difficulties. It is of interest to note that the loan recovery rate for agriculture is no better than for fisheries loans, according to a 1991 World Bank review. Prospective borrowers lose patience with the protracted handling of applications and either cancel their development plans or are forced to obtain private loans usually at exhorbitant rates of interest.

Despite these difficulties credit remains an indespensible requisite for development of fisheries at all levels and in the context of rural credit as a whole, there is need for a re-assessment of the earlier approaches and their failings, to devise more effective means for the future. The experience of the Bangladesh Krishi Bank, Sonali Bank and the Grameen Bank should be crucial in that the latter has a successful supervised credit scheme for landless people in various fields, including fisheries. The Krishi and Sonali Banks were initial participants in the IDA Shrimp Culture Project credit scheme but subsequently withdrew because they claimed that they could not cover the cost of lending, under the credit conditions, and what they saw as the high risks of both capture and culture fish production.

It appears that some more direct approach to fisheries lending will be necessary, excluding the commercial institutions, but perhaps directing credit funding through NGOs to the target groups.

10.4 Forestry

10.4.1 Constraints to Development

The present project is primarily aimed at water resource management to assist sustained growth within a well defined and integrated environmental management framework for the region, encompassing multi-sectoral activities including forestry. Though a major thrust of the development choices would use water resources for increased agricultural production, a benign course has been taken to ensure the appropriate measures necessary to sustain the Sundarbans; the coastal forestry; and for the use of plants for coastal embankment and river bank protection.

The main constraints to the development of the forestry sector, for traditional forest exploitation are:

(i) Competing uses for land and water
(ii) The limitations on land availability
(iii) Over-exploitation of the existing forest resources
(iv) Increased area of high salinity (with respect to certain commercial species)
(v) Silviculture methods incompatible with the long-term forest landscape changes.

10.4.2 Government Policies and Objectives

The policy objectives for the forestry sector under the Fourth Five Year Plan can be summarised:

- To rehabilitate or re-afforest the denuded and degraded national forest lands;
- To bring all possible vacant public and private lands under tree cover;
- To meet basic needs of all forest products by integrating trees with farming and traditional land-use;
- To improve the general environment for supporting agricultural and other biological production;
- To create employment opportunities for the landless poor, marginal farmers and women;
- To adopt different wood conservation techniques.

To achieve these objectives, and in the light of the constraints to development, there will need to be some strengthening and improvement in the direction and institutional infrastructure of the forestry sector. Greater consideration of forestry requirements and benefits will need to be ensured in other development sectors, particularly with regard to FCD schemes, and flow diversion for agriculture and navigation.

Over-exploitation constraints will require enforcement of existing regulations, both by the Forestry Department in respect to logging activities; and by the other appropriate authorities with respect to timber use, particularly in brick making and paper industries.

Social forestry issues may best be addressed through specific NGOs. Whilst present initiatives do consider the involvement of poor and landless people in such schemes, it is important that all sections of the rural community be involved if the expansion of the homestead/social forestry reserves are to be expanded.

10.4.3 The Sundarbans

The Sundarbans forest resources has recorded an historic decline in terms of timber and fish production. The decline in wood is attributable to two causes: over-exploitation of the resource and increasing salinity and sedimentation due to reductions in freshwater flows resultant on upstream FCDI schemes.

Increased salinisation influences the species pattern and affects plant growth. Plant growth that is luxuriant in low salinity zones becomes stunted in higher salinity zones.

The most productive Sundarban area for commercial timber is the eastern region fed by the Gorai-Madhumati river system. In this area the dominant species is Heriteria fomes (Sundri), or a varying officinalis, Excoecaria apetala (Gewa), and Xylocarpus spp. The fall-off in dry season flows through this system has placed considerable stress on this area. In addition to saline stress, there has been the phenomenum of Sundri 'top-dying', which has further depressed the availability of this valued timber species.

The previous view that salinity was the cause of 'top-dying' is now discredited as the tree grows in high saline conditions. Recent studies suggested that the cause may be a synergistic effect of a number of factors including: salinity, sedimentation, waterlogging, cyclone damage, and accumulation of toxic elements from agricultural wastes and port discharges.

Whilst augmentation of the dry season flow through the Gorai would be beneficial, it is not the complete solution to the overall problem of falling timber production in the Sundarbans. The western portions are likely to remain higher in salinity, with a dynamic mosaic of species, which are suitable for fuelwood and poles. The present system of logging, and particularly the over-exploitation of species for the pulp/hardboard industry should be discouraged.

If forest production is to be enhanced in the Sundarbans, the present system of selection forestry should be reviewed. This form of silviculture requires an established climax forest, and the mosaic of the mangrove communities is so complex and dynamic as to require an alternative approach for successful management. The Sundarbans should be managed as a total ecosystem, with the tree species in separate patches determining the species, frequency, and degree of exploitation.

The objective will be to develop a sustainable forest products industry, which will provide a wide variety of products, and varying quantities of saw logs, fuelwood and poles. The emphasis should be on the latter two classes of timber; and pulpwood extraction should be severely cut-back. In degraded areas, particularly adjacent to the polders, individual commercial plantations could be established.

10.4.4 Village Homestead Groves

Expansion of FCDI in the South West Area would increase the crop production, with a commensurate increase in the demand for fuelwood. Improvements in general income, associated with increased population growth, will extend the demand for forest products. Where housing needs compete for agricultural land, the homestead groves are likely to increase where new homesteads are established.

The present practice of timber-firing in the brick fields places a considerable demand on the timber resources of the village groves. The projected increasing demand for timber products may therefore be (in part) met by enforcement of the prohibition on the use of fuelwood in brick making.

In the polder areas where seasonal saline flooding is carried out for shrimp culture, repeated inundation is affecting the established homestead trees. If this practice is maintained, these groves will require re-afforestation with saline tolerant species.

It is recommended that forest development for village homesteads on marginal and F_0 land, represents the best possibility to increase both the area and production of the South West Area's forests. Current productivity is about 15 m^3/ha/year, which could be increased up to 25 m^3/ha/year within 25 years on 0.1 m.ha of homesteads.

The best means to achieve this would be through the DAE, ADB/NGO Upazila Re-afforestation Project, and the ADB Coastal Cyclone Green Belt project. The latter should be approached to extend its mandate to include the coastal zone of the South West Area.

10.4.5 Coastal Plantations

The available land in the coastal areas of the SWA has become limited. New plantations should be considered on degraded coastal land, where pioneer species are being reduced by increasing siltation and elevation of the land. Research and development is rapidly required to find the correct successional species to underplant or replace these pioneer species.

The plantations should be managed primarily as a cyclone protection belt, but with a secondary wood production function that should not impair their primary use. Such production could be sustainably managed (apart from cyclone damage) and be used to supplement the industrial wood supply.

10.4.6 Monitoring

Monitoring of the forestry sector should include environmental conditions, vegetation/forestry evaluation and silviculture improvement.

A number of environmental parameters related to hydrology and water quality would require continuous monitoring for all development options. These indicators would serve as an early warning system, allowing planners, decision makers, and managers to take timely, appropriate, mitigatory or preventative action. Such monitoring will require coordination and collaboration between a number of agencies and authorities responsible for forestry, agriculture, flood protection, drainage and irrigation.

The vegetation/forestry elements will require the development and up-dating of a database on natural and plantation vegetation in the major forest and development areas. Data should be collected at regular intervals to record changes in forest types, canopy density, height, volume numbers, growth rates, and regeneration.

In state forests and plantations permanent sample plots should be established and maintained. The 120 such plots in the Sundarbans (neglected since 1986) should be reactivated. In future water management feasibility studies, the site's general vegetation quality, stream bank vegetation conditions (present or absent) and the natural width of flats along embankments (for future planting) should be recorded.

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For improvement in the homestead groves, nurseries of hardy and true-growing strains should be produced for distribution to the villages. These should initially concentrate on fruit species, but once the system has become established, further timber species may be added as market demands and village preferences dictate.

10.5 Navigation

10.5.1 Development Constraints

The further development or even the continued operation at present levels of the ocean going traffic on Port of Mongla, the modern river passenger and cargo traffic and the country boat operation are physically restricted by continued siltation. This siltation is a natural process in the development of a delta, but in the case of the Southwest Area the process is exacerbated by human interventions such as poldering and the abstraction of water for irrigation and other purposes.

Dredging is a remedy and substantial dredging has been carried out at Mongla but with limited success. Apart from this and dredging at Barisal Port, maintenance dredging has not been carried out in the SWA on a regular basis.

10.5.2 Government Policies and Objectives

The present Government appears to give high priority to "revival" and further consolidation of the inland waterway traffic. The intention is that inland waterway traffic shall be recognised as one of the three elements (the three "R's", river, rail and road) forming the national traffic system where the modal split shall be governed by an overall least-transportation-cost criteria. Within the frame-work of this policy the Government intends to release funds for maintenance dredging.

As a part of the above mentioned policy the Government is considering carrying out an integrated master plan study of Chittagong, Mongla and Dhaka New Container Ports with the purpose of determining the optimal split of import/export on the two sea ports and perhaps also in the Dhaka New Container Port, taking into consideration the morphological problems facing Port of Mongla.

There is however, deviation in this policy as regards to the ferry and the coastal passenger sector, both of which shall remain the responsibility of BIWTC.

10.5.3 Mongla Port

If the siltation problem in the Pussur channel and at Mongla can be solved then very considerable savings could be obtained annually. These savings arise from a less expensive domestic transport system as a result of an increased use of the more centrally located Mongla Port. The scheme may also require improvements to the rail and road connections to the port, but these are relatively simple compared to the central problem.

Various studies have been carried out in the past to solve the siltation problem at Mongla but none of them have come up with any firm recommendation. One of the schemes mooted is to constrict the cross-sectional area of the river off the present berth facilities whereby the velocity and the scouring effect are increased to an extent which will maintain the required depth in front of the berths. This scheme will have very little effect on other parts of the river network and needs further study.

10.5.4 The BIWTA Maintained Routes

The inland waterway network is divided into four classes. Class I & II routes carry by far the major part of the inland water traffic. BIWTA has made it their responsibility to maintain these routes to a high standard with respect to navigable depth and day and night markings of the channels.

The cargo carried by inland water transport between Khulna/Mongla and Dhaka/Narayanganj in 1988/89 and 1990/91 averaged 6.4M and 5.4M tons respectively. The sailing distance is as much as 352 km due to the alignment of the trunk route. Once the siltation problems in Mongla solved and the export/import through this port is increased the traffic on this trunk route is bound to increase considerably.

However, it seems possible to re-open the former waterway from Khulna via Atharabanki, M.B. canal, Kumar River, Arial Khan River to Padma and on to Dhaka. This would reduce the above mentioned distance by approximately 65 km to 285 km. Based on rough calculations it is expected that this scheme would save 35 to 70m Taka annually from the reduced cost of the transport of cargo. Savings would also be generated from reduced cost of transport of passengers, diversion of traffic from road to river, and the value of time saved by passengers.

10.5.5 Country Boats

The importance of the country boat sector is indisputable. The mechanisation of this sector commenced in 1980 and today about 70% of it is mechanised. This has remarkably increased the sector's potential. Siltation will have little effect on country boats as they will be able to sail with little draught and further than any other river transport.

It is important that the country boat sector is recognised and institutionalised. Steps should be taken to expand the sector so that other sectors like agriculture, fisheries can be benefitted and the rural areas served.

The amount of cargo which is necessary to switch from road transport to river transport by country boat in order to obtain a saving sufficient to pay for the dredging of a 24 m wide channel from a water depth of 0.3m - 0.6m to a depth of 0.9m - 1.2m has been estimated and found that the volumes needed are great and it is not realistic.

10.5.6 Alternative Transportation Modes

It is understood that some years ago a Hovercraft was introduced for the passenger transport. This experiment was abandoned after trials, as safety of other vessels were threatened.

An aspect the river traffic will have to face in the future is the containerised cargo. There is very large difference from todays river traffic which use relatively simple berthing facilities, in some cases even the bare river bank where cargo can be handled by head load, to modern container traffic which is based on high tech terminals where a large number heavy but standard units are handled.

Appendices

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Appendix I

Terms of Reference

BANGLDESH: SOUTHWEST AREA WATER RESOURCES MANAGEMENT STUDY

Terms of Reference
For the Consultant Services

I. SCOPE AND OBJECTIVE OF THE STUDY

1. The objective of the Study is to assist the Government in formulating a comprehensive regional water resources development and management plan for the southwest region, thereby helping the Government achieve its long-term goal for sustained growth through the balanced, systematic, development and management of the region's land and water resources. Within this broad objective, the Study is intended to provide an understanding of the region's land and water regimes and to develop a capacity to forecast the impact of development activities on the delicate resources setting of the region.

2. In accordance with the above, a main component of the Study is a planning study for the entire Study area, differentiating for subregions, as is justified considering the varying resources setting in the area. Water and land resources are critical elements for the preparation of the plan and agricultural growth is a main indicator. However, other economic activities, like shipping, fisheries and forestry should not be lost sight of. Possible impact on the Study area's delicate environment is an important aspect in evaluating different options. While economic growth is a broad objective of the plan, equitable distribution of income is important as well.

3. The outcome of the Study will include:

- a phased, long term, land and water resources management plan aimed at sustained development of the area's production potential, avoiding undue inter-project interactions and undesirable environmental impacts; for areas that are subject to rapid changes the long term plan can only be indicative, with emphasis on logical and practical intermediate steps;
- a framework that will allow the Government to identify and evaluate, in a systematic way, justifiable development options and to formulate first priority projects;
- a portfolio of identified priority projects; and
- feasibility study(ies) of selected first priority project(s).

II. TERMS OF REFERENCE

4. The Study is to be implemented in a number of phases, some of which are sequential, while others may be overlapping.

1. Preparation of Resources Data Base

(i) Review and examine the available reports and data relevant to a comprehensive understanding of the region's environmental and resources setting;

(ii) Compile the available and relevant hydrological, hydrogeological, morphological, geographical, agricultural, fishery, navigational, environmental, ecological and other social and economic data in a systematic and comprehensive data base, which will facilitate easy data input and updating and serve as the basic data storage and retrieval system for the various analyses, planning and design throughout the Study; and

(iii) Prepare an inception report describing the availability and quality of key data and the detailed work program for the entire Study period;

2. Understanding of the Changing Resources Setting

(i) Carry out, in coordination with the existing data collection mechanisms of the public agencies, additional survey and data collection covering hydrological, morphological, environmental, agricultural and other social and socioeconomic parameters, which are essential to formulate a land and water resources management plan and to monitor the region's hydromorphological and ecological changes;

(ii) Assist the Surface Water Simulation Modelling Center (SWMC) in the development of the "pilot-level" mathematical simulation models for the study area, and transfer the developed models for applications for the regional water resources management analyses to be carried out under the Study;

(iii) Carry out a hydromorphological study through examination of historical maps, satellite images and other means and information available, and identify the past and ongoing morphological changes, including river networks, changes in discharge distribution in major intra-regional rivers, morphological changes in river courses and cross-sections, salinity concentration in river water and soil, patterns of siltation, flooding and drainage congestion, flora and fauna, etc., and analysis as to how such morphological changes have affected, or are affecting, the region's overall resources setting. In the examination of the above, due attention should be paid to the impacts of the man-made intra- and inter-regional activities;

(iv) Review and examine the design, concept and implementation of the various past and ongoing water resources and agriculture projects in the region, and assess how the projects' envisaged benefits are affected by the region's changing environment, and how these works accelerated, or modified, the natural hydromorphological processes identified in 2.(iii) above, and also how the surrounding resources and environmental setting have been altered. Such projects should include the Coastal Embankment Project, Coastal Embankment Rehabilitation Projects, Ganges-Kobadak Irrigation Project, Delta

Development Project and other medium-scale projects under FCD III and System Rehabilitation Project under the Ministry of Irrigation, Water Development and Flood Control, the navigation improvement works under the Ministry of Ports, Shipping and Inland Water Transport, as well as a number of shrimp culture projects, such as the Second Aquaculture Project, under the Ministry of Fisheries;

3. Identification of Water Resources Management Options

(i) Identify the various medium to long-term water resources management options, including those aimed at preventive measures (drainage improvement, flood control, etc.) as well as development measures (inter-regional and intra-regional water transfer, surface and subsurface and major and minor irrigation, etc.), both of which are necessary to ensure the sustained agricultural growth through balanced development and management of the region's land and water resources. Priority areas as identified under the FAP for further examination include flood control along the right bank of the Ganges-Padma river, drainage improvement in the coastal embankment area and augmentation of the dry-season flows in the Gorai river; and

(ii) Examine the possible impacts of each of the identified options on the region's environment and resources setting through use of mathematical simulation models and other techniques. In forecasting such impacts, due attention should also be paid to the existing and planned water management measures outside the region, such as national-level water resources management measures and the upstream FAP projects;

4. Formulation of the Regional Resources Management Plan

(i) Examine and assess the medium and long-term resources potential and constraints of the multi-sectoral resources harvesting activities (aquaculture, forestry, navigation, industry, etc.) within the context of the changing and variable resources setting of the region. Also, identify relevant policy options which affect the long-term production potential and resources setting, and present in appropriate policy matrices showing the plausible policy options and their impacts;

(ii) Develop an analytical framework/model to enable systematic evaluation and assessment of the identified water management options within the broader, multi-sectoral resources allocation/utilization context. Such framework/model may either relate to the entire study area or separate models may be developed for different sub-regions. They should be designed to reflect the resources setting (including possible changes that will take place), relative to the selected resources management options. Taking into account possible future multi-sectoral resources demand (e.g., agriculture, navigation, fishery, industry, forestry, environment, water supply, etc.), the frameworks/models should be capable of forecasting the possible outputs in terms of increased production, as well as possible side effects, like flooding, siltation, salinity, environmental degradation, etc. Appropriate training in the use of such framework/models should also be provided to the counterpart personnel;

(iii) Evaluate and assess each of the identified water resources management options, and formulate a comprehensive long-term water resources management plan, which is outlined by the time-frame-specific (phased) water resources management options and will best permit the balanced development and sustained growth of the water and land resources of the region within the Government's capabilities for implementation and operation and maintenance. In some areas the changing environment (e.g., the Khulna-Satkhira area) may render the preparation of a long term plan difficult for all practical purposes. In consultation with the implementing agency and the Bank, it may be decided that in such cases the plan will be indicative for the long term, giving emphasis to logical and realistic intermediate steps that will eventually lead to a plausible long term perspective. In evaluating and formulating such a resources management plan, considerations should also be given to the inter-regional and national-level water management policy, particularly under the other FAP studies, as well as other external factors, including global sea level rises, etc.;

(iv) Further in line with the established resources management plan, prepare a long-term investment portfolio of the water resources management projects in a specific time frame, together with the resultant land-use plan as well as the related Government policy framework required to ensure the effective resources management. Such a portfolio should include, among others, location, outline designs and alignments of major works, order-of-magnitude costs, annual operation and maintenance requirements, economic internal rate of return, etc. for each of the projects, and annualized investment outlay for the entire plan; and

(v) Design a mechanism which will allow: (a) sustained monitoring of the changes in the region's environmental and resources setting; and (b) efficient information management, including a feed-back of the collected information onto the appropriate decision making/plan implementation. In examining such mechanism, consideration will be given to possible mobilization of the local administration, women and NGOs, etc. for the data collection;

5. <u>Formulation of Priority Water Resources Projects</u>

(i) Propose an appropriate set of criteria for identification of the priority, near-term water management measures for review and approval at the tripartite meeting. Such criteria shall include the duly justified need for carrying out a detailed study on an urgent basis, and the confirmation that the implementation of such priority works shall not constrain the broader, long-term options for the region's water resources management to be examined in parallel in 4.(iii) and (iv) above.

(ii) Identify and formulate the priority, near-term water management measures on a pre-feasibility level, and produce outline designs and alignments of major works, order-of-magnitude costs, annual operation and maintenance requirements, economic internal rate of return, and farm budget analyses;

(iii) Examine the preliminary study results and recommend priority scheme(s) for further detailed feasibility study. In selecting the priority scheme(s), the development impact of the identified schemes on the environment and on other multi-sector water users shall be carefully assessed. In addition, such priority works shall also be examined and justified in the light of the Government's available resources and absorptive capacity for implementation and O&M within the national development framework, as well as the usual economic and financial assessment; and

(iv) Carry out a feasibility-level design of the selected priority project(s), covering drawings of relevant project components, cost estimates of the project works in annual disbursement schedules in both foreign and local currency costs, assessment of benefits, including impacts on growth, employment creation and poverty alleviation, and sensitivity analyses. Outputs should also include the recommendations for implementation and O&M/cost recovery arrangements, including monitoring for impact assessment, and preparation of TOR for additional investigation and studies and implementation assistance, together with estimated cost and manpower requirements.

III. REVIEW AND REPORTING

5. The consultants shall submit the following reports to the Bank and the Ministry of Irrigation, Water Development and Flood Control:

(i) Inception report three months after the commencement of the technical assistance. This report will contain a detailed (updated) approach, work plan and staffing schedule for the entire duration of the technical assistance, a description of the data storage and retrieval system to be implemented, identification and selection criteria for early implementation priority projects, and information on the progress of the preparation of the surface water simulation models;

(ii) Interim report on the progress of the morphological and hydraulic study within eight months from the commencement;

(iii) Pre-feasibility report of the selected schemes, including the recommendation for selection of the priority scheme for further study, within eight months from the commencement;

(iv) Interim report on the development of the water resources management plan, including a list of identified regional water management options with their possible impacts on the region's resources and environmental setting, within twelve months from the commencement;

(v) Report on the regional water resources management plan, including a detailed description of the development and the results of the hydraulic and morphological studies within 18 months from the commencement; and

(vi) Feasibility report of the selected early implementation priority project within 18 months from the commencement.

6. The consultants' work will be subject to review at tripartite review meetings attended by representatives of the Government, UNDP and the Bank. Such reviews are expected at least four times during the duration of the technical assistance to examine the consultants' specific outputs, including:

(i) the detailed work plan, the recommended data base format and selection criteria for the early implementation priority water management measures (within four months from commencement);

(ii) the pre-feasibility study report, the recommendation for selection of the priority scheme for the feasibility study, an interim hydromorphological study report (within nine months from commencement);

(iii) a list of identified regional water management options and their impacts on the region's morphological/hydrological setting, and the alternative strategies leading to the formulation of the regional resources management plan (within 13 months from commencement); and

(iv) the draft feasibility study report on the priority near-term scheme and the draft terminal report on the regional water resources management plan (within 18 months from commencement).

7. All these reports will be submitted within the specified time frame as a draft, and will be finalized within one month after receipt of the comments from the Government and the Bank. In addition, four quarterly progress reports will be prepared starting from the sixth month from commencement. All draft and progress reports shall be submitted in 20 copies and the final reports in 30 copies each.

8. The Study is expected to be completed within 19 months, including one month after submission of the draft final report for finalization of the final report.

BAN: SOUTHWEST AREA WATER RESOURCES MANAGEMENT STUDY (TA NO. 1498)
TECHNICAL MEETING BETWEEN FPCO/ADB/CONSULTANT
(02 JULY 1992)
COURSE OF ACTIONS TO BE TAKEN REPORT 31 OCTOBER 1992

A. Consultant shall have prepared the Second Interim Report to present:

(1) a list of identified regional water management options to address key regional water management issues as indicated in the TOR (and any other critical issues identified by the consultant);

(2) a preliminary-level examination of each of the identified water management options for technical feasibility, financial implications (capital and recurrent costs, and financial sustainability) and development impacts on regional economy, environment and social implications;

(3) a description on how each identified options are inter-linked each other (mutual exclusivity, time and area-specific combination of options);

(4) a list of identified investment packages as a first-phase intervention aimed at the improved regional water management as identified and examined in the technical examination in (1) to (3) above, with prima-facie justification for investment action on an urgent basis as a part of the long-term regional water management plan;

(5) a work program describing how to proceed with further preparation of the first-phase investment packages;

(6) a work program describing how to proceed with further preparation of the long-term regional water plan, and how to ensure that the identified first-phase investment packages will be tested and incorporated as an integral part of such regional plan; and

(7) a proposal for the preparation of a comprehensive presentation of the Study's interim findings for: (a) a donor coordination meeting in November 1992; and (b) a series of local presentation meetings aimed at local opinion leaders, NGOs and medias in late 1992 and early 1993.

B. FPCO shall make necessary arrangements to:

(1) post an Executive Engineer on a full time basis to liaise and coordinate the implementation of the Study, particularly to ensure smooth exchange of views between the Consultant and the Government and to ensure timely transfer of necessary data and information to the Consultant; and

(2) ensure full coordination between the ADB-financed Technical Assistance for the Second Coastal Embankment Rehabilitation Project and the Study.

C. The Bank shall make necessary arrangements to:

(1) ensure full coordination between its Technical Assistance for the Second Coastal Embankment Rehabilitation Project and the Study.

Revised

Minutes of the Meeting in FPCO on 9 March 1993

TA No.1498-BAN:
Southwest Area Water Resources Management Study

Present were:

Mr. M. H. Siddique, Chief Engineer, FPCO
Mr. A. K. M. Halimur Rahman, Superintending Engineer, FPCO
Mr. Abu Sufian, Executive Engineer, FPCO
Mr. Nurul Huda, Chairman, Local Panel of Experts
Mr. P. Kulapongse, Sr. Project Engineer, BRO
Mr. Y. Kobayashi, Project Engineer, ADB
Mr. D. Lucock, Agricultural Economist (Staff Consultant), ADB

The Bank Mission conveyed the massage to the Government (FPCO) as follows:

1. The Bank is not in a position to provide additional funding for this TA.

2. The Bank will provide a TA loan in 1993 consisting of feasibility study ($500,000 of which $250,000 may be a grant) and detailed design ($1.5 million) for three priority projects identified under this TA if it is found necessary to make feasibility study after review of the pre-feasibility study prepared under this TA.

3. Feasibility study for the Gorai Augmentation Project will be considered after studying the Consultants' final report very carefully. The TA Consultants have been requested to pay attention to consensus made by the last Bank mission, in particular, on implementation capability, O&M and environmental/social implication of the Gorai Augmentation Project.

The Government (FPCO) made following observations:

1. Gorai Augmentation Project is the number one of the priority projects in the southwest region considering water management, environmental, social and other issues.

2. After completion of the pre-feasibility study of the Gorai Augmentation Project, this project should go for feasibility study on a priority basis.

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The Meeting concluded as follows:

1. The Consultants services will be completed in May 1993 as scheduled.

2. Feasibility study for the priority projects under the TA will not be made due to inclusion of pre-feasibility study for the Gorai Argumentation Project, instead, pre-feasibility study for the seven priority projects has been made.

3. The draft final report shall include; Regional Water Resources Management Plan, Pre-feasibility Study of the Gorai Argumentation Project, Pre-feasibility Study of seven Priority Projects and Post or Enhanced Pre-feasibility Study of the Chanchury Beel Project.

4. The Bank will process a TA loan included in 1993 program to prepare the feasibility study and detailed engineering design for the proposed three priority projects if it is found necessary to make feasibility study after review of the Consultants' Final Report.

5. The Government may seek future Bank assistance for the feasibility study of the Gorai Augmentation Project after reviewing the Final Report.

6. FPCO opined that Japan Special Fund (JSF) would be utilized for the feasibility study of the Gorai Augmentation Project, but the Bank informed that it would not be possible to request additional fund from JSF to make such a large scale feasibility study under present technical assistance by extending the scope of works.

Y. Kobayashi
Yoshiharu Kobayashi
Project Engineer, ADB

cc:
Mr. A.M. Khan Chowdhury, Additional Secretary, MOIWDFC
Mr. M.A. Razzak, Chairman, BWDB
Mr. K. A. Hafiz, Assistant Resident Representative, UNDP
Mr. Ross C. Wallace, FAP Coordinator, the World Bank
Mr. R. I. Thiagarajah, Team Leader, Sir William Halcrow & Partners Ltd.
Mr. G. van der Linden, Chief, BRO

GOVERNMENT OF
THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF
IRRIGATION, WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN CO-ORDINATION ORGANIZATION
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13 DEC 1992

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Memo No 3557(11)/FPCO/A-004 dated 12-12-92

MINUTES OF THE MEETING HELD IN THE CONFERENCE ROOM OF FPCO ON 22ND NOVEMBER, 1992 IN CONNECTION WITH THE 2ND INTERIM REPORT OF SOUTHWEST AREA WATER RESOURCES MANAGEMENT PROJECT FAP-4

A meeting amongst ADB mission, FPCO and the consultants of FAP-4 was held in the conference room of Flood Plan Co-ordination [Orga]nization (FPCO), 7 Green Road, Dhaka on November 22, 1992 to discuss the 2nd Interim Report of Southwest Area Water Resources Management Project (FAP-4). Mr. M. H. Siddiqi, Chief Engineer, FPCO, presided. The list of participants is attached as appendix.

The chairman welcomed the participants and initiated the discussion. Mr. R. I. Thiagarajah, Team Leader of the Consultants made a brief presentation on the key issues of the report.

Mr. K. Matsunami, Member of ADB mission, pointed out that though Gorai River is an urgent water management issue in the region, the consultant proposed augmentation of the Gorai river highlighting the requirements of irrigation and without reflecting other important implications for navigation, fisheries, industries, domestic water supply and environment. Mr. Matsunami also opined that among the identified priority projects, the one having huge pumping facilities should be deferred while other projects with linkage to the regional characteristics may be selected for feasibility level study.

All the participants agreed to the proposal and it was also pointed out that in the pre-feasibility level study of the Gorai Augmentation Project, the consultants should clearly specify the staged development starting from interim measures to the ultimate Ganges Barrage which is needed to sustain the supply of sweet water to the region (South West).

Mr. A.K.M. Halimur Rahman, Superintending Engineer, FPCO pointed out that as per TOR the Consultants should conduct the feasibility study (ies) for one or more projects during the next phase of study. But in the report only pre sibility study of Gorai Augmentation has been proposed considering shortage of time.

After discussion of the proposed package of 19 priority projects, the following 4 (four) were initially selected for feasibility level study under the present T.A.

(1) a) Norail FCDI Schemes and (b) Chenchuri FCD Improvement schemes in Southwest Region and (c) Arial Khan Bisarkandi Scheme and (d) Bishkhali FCDI Scheme in South Central Region.

(2) The consultant pointed out that due to time and resource constraints it might not be possible for them to conduct the feasibility of the above four schemes in addition to the:

a) Pre feasibility study of Gorai Augmentation project and

b) Finalization of the Regional plan by May, 1993

After detailed discussion it was decided that the consultant would:

- Study the Gorai flow Augmentation to prefeasibility level.
- Study one or two of the above scrutinized 4(four) priority projects at feasibility level
- Submit the proposal for work programme as decided by mid-December, 1992.

The meeting ended with a vote of thanks from the chair.

(M. H. Siddiqi)
Chief Engineer, FPCO
7, Green Road, Dhaka.

APPENDIX 2

Summary of Seminar

APPENDIX 2

REGIONAL SEMINAR ON

SOUTHWEST AREA WATER RESOURCES MANAGEMENT PROJECT

(FLOOD ACTION PLAN : FAP-4)

As part of the programme for people's participation in the planning of development projects, a one day seminar was held in Jessore on 15th January 1993 where the different water resources management options for the Southwest Area were discussed. The discussion focussed on the various regional and local issues, the people's needs and the scope of the interventions suggested by the Consultants to overcome the issues and satisfy the needs.

The Chief Engineer, FPCO and some members of the Consultants' team (Team Leader, Deputy Team Leader, Irrigation and Drainage Engineer and Coastal Engineer) presented the results of the FAP-4 studies and the development options to the meeting.

Various representatives of the people, including Ministers (Minister for Agriculture, Irrigation, Water Development and Flood Control and the Minister for Foreign Affairs), Members of Parliament and Members of Local Governments who represent different areas within the Southwest Region, and the Mayor of Khulna City Corporation participated in the discussion.

The salient points of the discussion are given hereunder.

In addition to the formal seminar, numerous informal meetings, interviews and discussions were held by the Team members, with interested groups including farmers, fishermen, women groups, landless and these are described in Volume 9 - Impact Studies.

1. <u>S.M. Mustafizur Rahman, MP</u>, Bagerhat-2 & Hon'ble Minister, Foreign Affairs:

- Augmentation of Gorai river flow (dry season) along with increase of Ganges flow (dry season) needs, immediate action.
- Problem of Drainage Congestion in Beel Dakatia should be solved on emergency basis.
- All actions required on national basis.

2. <u>Salahuddin Yousuf, MP</u>, Khulna-5

- Diversion of Ganges water at Farakka created serious salinity and siltation problems in Khulna & adjoining areas - need immediate solution.
- Problem of drainage congestion in Beel Dakatia to be solved on urgent basis. Solmari river and Hamkura river should be dredged.

3. <u>SK. Ansar Ali, MP</u>, Satkhira-1

- Drainage congestion in Dantbhanga Beel (between Tala and Kalaroa thana in Satkhira Dist) to be removed by re-excavating existing khals of excavating new ones.
- Drainage congestion in Kadar Beel (between Tala & Dumuria thana) to be removed.
- Construction of Ganges Barrage should be taken up immediately.
- Shrimp culture and paddy cultivation together is difficult due to salinity problem.
- All policy should be taken on national basis under one cell comprising all concerned ministers.

4. <u>Abdur Rouf Chowdhury, MP</u>, Kushtia-2

- Serious problems created in the operation of G-K Project due to shortage of Ganges water in dry season.
- Augmentation of Gorai river flow along with Ganges flow (dry season) is essentially and immediately needed.
- Ganges Barrage should be constructed immediately.
- Other Smaller rivers of the area to be re-excavated to remove drainage congestion.

5. <u>Dr. Mozammel Hossain, MP</u>, Bagerhat-1

- CEP Polders 37, 36/2 & 35/2 should be implemented immediately. No Paddy cultivation in the area is possible now due to salinity.
- Heavy siltation observed at Mongla Port area.
- Augmentation of Gorai river flow (dry season) and construction of Ganges Barrage is immediately needed.

6. <u>Mufti Mowlana A. Sattar, MP</u>, Bagerhat-4

- Excavation of Mongla-Ghashiakhali (MG) khal created problem by increasing salinity in new area.
- CEP Polders 37 & 35/2 should be implemented immediately.
- Mara Balleswar river should be re-excavated.

7. <u>Abdur Rouf Mia, MP</u>, Faridpur-1

- Defects in the construction of Regulators in Chandana-Barashia Project should be rectified.

8. <u>Dhirendra Nath Saha, MP</u>, Narail-1

- Ganges Barrage Project should be implemented.
- Augmentation of Gorai river flow (during dry season) needed.
- Dredging of Gorai, Nabaganga & Attarabanki rivers needed.

9. <u>Moulana Md. Sakhawat Hossain, MP</u>, Jessore-6

- Monitoring of Project implementation is essential.
- Drainage congestion created after construction Gangrail closure (south of CEP Polder 24) should be removed.

10. <u>SK. Tayabur Rahman, Mayor</u>, Khulna City Corporation

- Problem of salinity and siltation near Khulna and surrounding areas should be solved.

11. <u>Mansur Ahmed, MP</u>, Satkhira-4

- Problem of drainage congestion (in Polder) areas should be solved.
- Ganges Barrage Project should be implemented.
- Augmentation of Gorai river flow during dry season is essentially needed.

12. <u>Khan Tipu Sultan, MP</u>, Jessore-5

- Drainage congestion in Bhabadaha area (north of CEP Polders 24 & 25) should be removed.
- Ganges Barrage Project should be implemented.
- Agreement between Bangladesh & India should be made for acceptable dry season flow of the Ganges in Bangladesh.

13. <u>Shah Hadiuzzaman, MP</u>, Jessore-4

- Problem of drainage congestion in Bhabadaha area should be removed.

14 **Abdul Khaleque Talukder, MP**, Bagerhat-3

- Problems of drainage congestion and salinity in Bagerhat area should be solved.
- CEP Polders No. 34/2, 35/2 and 37 should be implemented immediately.
- Excavation of Mongla-Ghashiakhali (MG) khal created problem by increasing salinity in Bagerhat area.
- Ganges Barrage Project should be implemented.
- Augmentation of Gorai river flow during dry season is essentially needed.

15. **Kazi Shamsur Rahman, MP**, Satkhira-2

- Public participation in implementation of projects is essentially needed.
- Serious adverse effect in Bangladesh due to withdrawal of Ganges water at Farakka.

16. **Shah Md. Ruhul Quddus, MP**, Khulna-6

- Adverse effect in Bangladesh due to withdrawal of Ganges water at Farakka.
- Problem of river bank erosion in some areas around Khulna, Paikgachha needs solution.
- GW should be made available for irrigation through DTW.
- Shrimp Projects should be registered under appropriate laws.

17. **Moulana Habibur Rahman, MP**, Chuadanga-2

- Irrigation facilities should be extended in Chuadanga area.
- Upper Mathabhanga river should be re-excavated.

18. **A.M. Riasat Ali, MP**, Satkhira-3

- Adverse effect in Bangladesh due to withdrawal of Ganges water at Farakka.
- Problem of serious salinity and drainage congestion in Satkhira area.
- Problem of river bank erosion is some rivers in Satkhira.

19. **Maj. Gen.(Rtd) M. Majid-ul Haq, MP**, Magura-1 & Hon'ble Minister, Irrigation, WD & FC and Agriculture

- Management of water resources in the area is of vital importance for development.
- Problems of the area should be solved jointly by all as a national issue.
- Government determined to solve the problems created by Farakka withdrawal with all available resources.
- Peoples participation is of vital importance in formulating and implementing projects.