Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Flood Plan Coordination Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

SARIGOYAIN-PIYAIN BASIN

PRE-FEASIBILITY STUDY

Draft Final
December 1993

Shawinigan Lavalin (1991) Inc.
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services
Institute For Development Education and Action
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ACRONYMS AND ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
BFRSS	Bangladesh Fisheries Resource System Survey
BMD	Bangladesh Meterological Department
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
EIA	environmental impact assessment
EIRR	economic internal rate of return
EMP	Environmental Management Plan
EPWAPDA	East Pakistan Water and Power Development Agency
FAP	Flood Action Plan
FFW	Food for Work
FPCO	Flood Plan Coordination Organization
FW	future with project scenario
FWO	future without project scenario
HTW	hand tube well
HYV	high yielding variety
IBRD	International Bank for Reconstruction and Development
IEE	Initial Environmental Examination
ISPAN	Irrigation Support Project Asia Near East
LLP	low-lift pump
LT	local transplanted
MPO	Master Planning Organization
NERP	Northeast Regional Water Management Project
NGO	non-governmental organization
NHC	Northwest Hydraulic Consultants Ltd
NPV	net present value
PD	person-day
PWD	Public Works Department
RCC	reinforced concrete
SLI	SNC-Lavalin International

US $1 = Tk 38

MPO Land Classification Terminology

Class F0	Land inundated to a depth of less than 0.3 m
Class F1	Land inundated to a depth of between 0.3 m - 0.9 m
Class F2	Land inundated to a depth of between 0.9 m - 1.8 m
Class F3	Land inundated to a depth of more than 1.8 m
Class F4	Land inundated to a depth of more than 1.8 m and on which deepwater aman cannot be grown

EXECUTIVE SUMMARY

The purpose of the project is to protect rice crops from pre-monsoon and monsoon flooding, to provide flood relief to homesteads within the area, to improve navigation, and to reduce the risk of further channel avulsions which threaten homesteads and cultivable land.

The project area borders the Meghalaya Hills which experience very high rainfalls and generate large quantities of sand and gravel sediment. Sediment deposition on the Dhalai Gang alluvial fan is modifying land use — the deepest areas are infilling which is destructive to fisheries and natural ecosystems, while arable higher lands are being lost to sand deposition. Under these conditions, flooding is frequent and unpredictable and the Piyain and Dhalai channels are highly unstable. The deposition has also seriously hampered river transport of stone aggregate from quarry operations at the fan apex to Companiganj.

After reviewing various options, this initiative proposes intervention at three strategic locations in the basin as follows:

- The *Rauchunni Beel Project* would include flood protection (19.5 km full embankment with two regulators). The embankment would provide protection from inflows to the north but the southern side would remain open for drainage. Drainage improvement would involve re-excavation mainly of the Lain Khal (21 km), and low embankments around Raua and Kurundi *Beels* (about 6 km) to increase *beel* storage for fisheries.

- The *Nainda Haor Project* would provide pre-monsoon flood protection using 20 km of submersible embankments with 6 regulators, improved management of accumulated rainfall and inflows by constructing 15 km of embankments configured as compartmental bunds, and drainage improvement by excavating the Kaliurigang, Mirza, Shaheb, and Holakar Hoar channels (31 km).

- The *Dhalai Gang Project* infrastructure consists of a low-height closure dam across a recently formed distributary channel of the Dhalai Gang; bank revetments on the main channel left bank upstream and downstream of the present avulsion site; partial re-excavation of 4 km of the main channel up- and down-stream of the avulsion site; 4 km submersible embankment along the right bank of the Piyain River to the south with a regulator at the Rautir Khara channel; and re-excavation of 2 km of Rautir Khara.

The project would be implemented by BWDB and the combined cost of all three components will be an estimated US $6.7 million.

NERP DOCUMENTS

The Northeast Regional Water Management Plan is comprised of various documents prepared by the NERP study team including specialist studies, the outcome of a series of public seminars held in the region, and prefeasibility studies of the various initiatives. A complete set of the Northeast Regional Water Management Plan Documents consists of the following:

Northeast Regional Water Management Plan

Main Report
Appendix: Initial Environmental Evaluation

Specialist Studies

Participatory Development and the Role of NGOs
Population Characteristics and the State of Human Development
Fisheries Specialist Study
Wetland Resources Specialist Study
Agriculture in the Northeast Region
Ground Water Resources of the Northeast Region
Surface Water Resources of the Northeast Region
Regional Water Resources Development Status
River Sedimentation and Morphology
Study on Urbanization in the Northeast Region
Local Initiatives and People's Participation in the Management of Water Resources
Water Transport Study

Public Participation Documentation

Proceedings of the Moulvibazar Seminar
Proceedings of the Sylhet Seminar
Proceedings of the Sunamganj Seminar
Proceedings of the Sherpur Seminar
Proceedings of the Kishorganj Seminar
Proceedings of the Narsingdi Seminar
Proceedings of the Habiganj Seminar
Proceedings of the Netrokona Seminar
Proceedings of the Sylhet Fisheries Seminar

Pre-feasibility Studies

Jadukata/Rakti River Improvement Project
Baulai Dredging
Mrigi River Drainage Improvement Project
Kushiyara Dredging
Fisheries Management Programme
Fisheries Engineering Measures
Environmental Management, Research, and Education Project (EMREP)
Habiganj-Khowai Area Development
Development of Rural Settlements
Pond Aquaculture
Applied Research for Improved Farming Systems
Manu River Improvement Project
Narayanganj-Narsingdi Project
Narsingdi District Development Project
Upper Kangsha River Basin Development
Upper Surma-Kushiyara Project
Surma Right Bank Project
Surma-Kushiyara-Baulai Basin Project
Kushiyara-Bijna Inter-Basin Development Project
Dharmapasha-Rui Beel Project
Updakhali River Project
Sarigoyain-Piyain Basin Development

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1. INTRODUCTION

1.1 General Information

BWDB Division:	Sylhet
Districts:	Sylhet and Sunamganj
Thanas:	Kotwali (Sylhet Sadar), Jaintiapur, Gowainghat, Chhatak, Companiganj, and Dowarabazar.
MPO Planning Area:	24
Gross Area:	126,590 hectares
Net Area:	93,090 hectares

1.2 Scope and Methodology

This is a pre-feasibility study that was undertaken intermittently over a period of four months in 1993. The field study team consisted of a water resources engineer, a social anthropologist, an agronomist, a fisheries specialist, and a wetland resources specialist. Additional analytical support was provided by an environmental specialist and an economist.

1.3 Data Base

The project analyses presented in this report were carried out using mainly secondary data sources, and information obtained during field inspections and personal interviews.

The information and data sources used in different specialist analyses are listed below:

Engineering analysis: Existing topographic maps and MPO developed one square kilometre grid, historic climatological and hydrological records, river and khal cross-sections surveyed by BWDB Morphology Directorate and SWMC, BWDB reports, MPO reports, personal field observations and interviews with beneficiaries, recommendations by BWDB officials and local representatives.

Agricultural analysis: Soils information was obtained mainly from data published in the *Land Resources Appraisal for Agricultural Development in Bangladesh* (AEZ Reports); agricultural inputs were obtained from the work prepared by the Water Resources Planning Organization (WARPO); production (outputs) were abstracted from the NERP *Agriculture Specialist Study* (1993). All of the secondary information was substantiated with field interviews with individuals and groups of farmers in different areas and on each land type and was correlated with the hydrological data generated by the hydrology and engineering sections of NERP.

Fisheries analysis: Topographic maps, BFRSS data, CIDA Inception Report, NERP Fisheries Specialist Study, field observations and local interviews, information provided by local representatives during field seminars held at Sylhet in June, 1992.

Wetland analysis: Topographic maps, local revenue department records, personal field observations and interviews with local people, CIDA Inception Report (1990) and *Nerp Wetlands Specialist Study* (1993).

Socio-economic analysis: Published BBS data on demographic features, education and agriculture; reports of the Directorate of Public Health and Engineering, and NERP data base on Population and Human Development, personal field observations and field interviews with various cross-sections of local people, opinion and suggestions from local representatives including NGO personnel and the Honourable Members of Parliament.

1.4 Report Layout

A description of the biophysical features of the project area is provided in Chapter 2. Chapter 3 describes the current status of development and resource management including a summary of the types of problems faced by the people living in the area. Chapter 4 briefly reviews previous studies directed towards development of the water resources and Chapter 5 lists trends which are occurring and which will continue if no interventions are made. Chapter 6 reviews water resource development options which were considered and Chapters 7,8 and 9 provide an analysis of the best options suitable at strategic locations. The annexes consist of detailed information to support the main body of the report.

2. BIOPHYSICAL DESCRIPTION

2.1 Location

The Sarigoyain-Piyain Basin covers a gross area of 126,590 ha in the north, north east and western parts of Sylhet district, between latitudes 24°54′ and 25°11′ north, and longitudes 91°33′ and 92°13′ east. The project area is bounded by the Surma River to the south, the international boundary to the north, the Sylhet-Jaintiapur road to the east, and the Nawa Gang to the west (Figure 1).

2.2 Climate

The climate of the project area is monsoon tropical with hot wet summers and cool dry winters. The highest temperature in the area was recorded at 40.6 C in May and the lowest at 8.9 C in December and February. The lowest monthly temperature is in January, when the mean is 18.7 C and highest monthly temperature is in July, when the mean is 28.8 C.

Rainfall distribution shows a general pattern of gradual increase from south to north. Average annual rainfall in the area ranges from about 4500 mm in the south near Sylhet to about 7600 mm in the north at Bholaganj near the international boundary. Mean monthly rainfall varies from 10 mm in January to 820 mm in June, and the mean annual rainfall is 5700 mm. Potential evapotranspiration is lowest in December at 102.6 mm per month and highest in March at 162.4 mm per month. Data on the climate of the area is based on Bangladesh Meteorological Department (BMD) information and is summarized in Table A.1.

2.3 Land (Physiography)

2.3.1 General Description

Figure 1 shows the main geographical features in the project area. The area is bounded by the Meghalaya Hills (Shillong Plateau) to the north and by the Surma River to the south. The northern portion of the project area (about 15% of the total) consists of a series of coalescing alluvial fans and piedmont stream deposits. The fans merge into the floodplain of the Surma River. This floodplain makes up the largest portion of the project area (about 65%). The land generally slopes from north to south and east to west and drains towards the Surma River. About 15% of the land in the project area consists of uplands composed of Pleistocene-Pliocene or Oligocene sediments. These uplands (maximum elevation up to 60 m) are found along the northeast and southern boundaries of the project.

Figure 2 and Table A.2 summarize the area - elevation distribution throughout the project area. Most of the land ranges from about 5 m PWD to 20 m PWD. The highest agricultural land-use occurs in the Goyainghat and Companiganj thanas in the north and along the Sylhet-Jafflong road. Elevations in these areas typically range between 6-12 m PWD.

2.3.2 Soils

The main soils on the relatively high floodplain consist of a grey, massive, puddled silt loam or silty clay loam topsoil, strongly to medium acid, overlying a grey mottled yellowish-brown silty clay loam to clay subsoil with coarse blocky structure. Soils in the flood basin are similar, but are generally clays throughout and have a very strongly acid topsoil. Stratified material, medium acid to neutral, occur below 60 to 90 cm in most of the floodplain. Almost all soils are flooded during the rainy season and dry out by the middle of the dry season. Most appear to have low permeability in the subsoil and substratum. Just below the ploughed layer there is generally a massive and slowly permeable ploughpan, 5 to 10 cm thick. Organic matter contents are generally low. Natural fertility is moderate, but appears to be maintained quite well in spite of continuous cultivation without much manuring. In most areas topsoil becomes neutral in reaction after a few week's flooding, and becomes acidic again in the dry season.

Subrecent piedmont and alluvial fan soils are poorly drained, and are intermittently flooded for a few days after heavy rains. The sandier soils have a grey massive, puddled topsoil with a ploughpan. The more silty and clayey soils have a stronger subsoil structure and a less hard ploughpan. They dry out generally by the middle of the dry season. The highest parts of the subrecent piedmont have somewhat poorly to moderately well drained soils. They generally have a greyish-brown topsoil overlying a greyish-brown mottled subsoil with generally a weak or moderate blocky structure.

The hill soils are generally steep to very steep, well drained, and dry out by the middle of the dry season. Most soils have brown to yellowish-brown colours, weak to moderate blocky structure, and a strong to very strong acid reaction.

2.4 Water (Hydrology)

2.4.1 Runoff Patterns

The hydrological regime of the Sarigoyain-Piyain basin is governed by six principal water courses: Sarigoyain, Piyain, Dhalai, Umium (Chela), Nawa Gang and Surma Rivers. Alluvial fans have formed on most of the rivers at the base of mountain canyons. The fans all appear to be moderately active, and the channels have all been subjected to periodic shifting and bank erosion. Almost all the rivers are extremely flashy with flash peaks occurring several times during both the pre-monsoon and monsoon seasons (Figure 3).

The range of daily discharges for the principal rivers are given in Table 2.1. The discharges show a wide fluctuation in runoff patterns from one to 5310 m^3/sec. Details of mean monthly flows (minimum, mean and maximum) are provided in Annex A, Table A.3.

The Sarigoyain River originates in the Shillong hills and flows westward upon entering the plains of Bangladesh. After several kilometres, the Baa Naya Gang branches off from the Sarigoyain River and flows back to the Sarigoyain a few kilometres downstream. The Baa Nawa Gang intercepts the run off from the Shillong hills and carries it into Sarigoyain above Goyainghat. Sediment deposition has gradually taken place in the Sarigoyain River. This has resulted in reduced drainage and consequently more over-bank spills. The Sarigoyain River also receives

a substantial amount of flood water around Salutikar from the Surma and Lubha Rivers through the Kapna Nadi during the pre-and monsoon seasons.

The Piyain River originates in the Meghalaya hills and bifurcates at the canyon mouth into Piyain and Dauki Rivers. Piyain flows westward and at Companiganj joins with Dhalai Gang, which in turn flows to the Surma River above Chhatak. Piyain River has shifted its channel three times in the recent past due to sedimentation in the channel bed (see Figure 1). Currently, the entire dry season discharge flows to Dauki River, which in turn flows to the Sarigoyain River above Gowainghat. This has increased Sarigoyain discharge substantially, resulting in more over-bank spills. The Dauki River has also shifted its channel. Previously Dauki River flowed to the Sarigoyain River at Gowainghat. Now it flows to the Sarigoyain River at Birbirighat.

Dhalai Gang has shifted its course to the east by about three kilometres, due to siltation of the Piyain River around Companiganj. This new channel joins the Piyain River, which in turn flows to the Kata Khali Khal. Kata Khali Khal was excavated in the 1960's and has become the main drainage channel for the Dhalai-Piyain basin, due to siltation of Piyain below Companiganj. Currently the entire dry season discharge of the Dhalai Gang flows to the Kata Khali Khal which in turn flows to the Surma River above Chhatak.

The Umium and Nawa Gang Rivers originate in the same drainage basin of the Meghalaya plateau and bifurcate before entering Bangladesh. They flow to the Surma River between Chhatak and Dowarabazar. Flow measurements were started in 1991 by SWMC. Local information and observed flow records show that these rivers become almost dry during the winter season but convey substantial flood flows during the pre-monsoon and monsoon seasons (Table 2.1).

Table 2.1: Recorded Mean Discharge (m^3/sec)

River	Station Number & Name	Range of Daily Discharge			Period (years)
		Minimum	Mean	Maximum	
Surma	267:Chhatak	5	800	4814	1966-73
Piyain	233:Ratnerbhanga	1.8	100	2730	1988-91
Dauki	233A:Jafflong	1	100	772	1965-77
Dhalai Gang	332:Islampur	1	119	5310	1988-91
Sari-Goyain	251:Sarighat	2.5	130	1730	1964-89
Umium	341:Chelasonapur	<1.0	99	1225	1986-91
Nawa Gang	337:Urugaon	<1.0	50	240	1991

Source: NERP

2.4.2 Flooding

The project area experiences two types of floods: the pre-monsoon flash floods from March to May, and seasonal monsoon floods from June to October. These floods damage boro, aus and aman crops. In some years flash floods also occur in the post-monsoon season from October to December.

Pre-monsoon and monsoon season peak water levels for various return periods at ten gauging stations are presented in Table A.4. Monsoon peak water levels are about 2.2 to 3.0 meters higher than the pre-monsoon water levels for an average year (with a 1:2 year return period). The highest water levels occur in the Chhatak, Companiganj and Salutikar areas.

The Sarigoyain-Piyain basin has been divided into 10 units for planning and analytical purposes (Figure 4). The areas flooded (by depth category) during the pre-monsoon and monsoon seasons are given in Table A.5. Table 2.2 shows that overall pre-monsoon inundation occurs over 27,300 ha for an average year (1:2 year return period). The magnitude of individual pre-monsoon inundation ranges from 2 - 66% (Table A.5). Table A.5 also shows that the units X2, X9, and X10 are almost flood free during the pre-monsoon season.

During the monsoon season about 85,200 ha (82% of the unprotected area) is inundated in an average year (1:2 year return periods). About 44,300 ha are flooded to depths exceeding 1.8 m (Table 2.2). Table A.5 also shows that inundation exceeds over 90% of the gross area in units X3, X4,and X5 for an average year (1:2 return periods). Mean monthly water levels for eight gauges in the project area are given in Table A.6

2.4.3 Drainage

Water levels in the Surma River remain above that of the surrounding agricultural lands for most of the monsoon season and this hampers gravity drainage. Over 90% of the basin drains through the Sarigoyain and Piyain Rivers to the Surma River. Due to the channel avulsion and siltation in the Piyain River, much of the area now drains to the Sarigoyain River. However sediment deposition has also taken place in Sarigoyain River and this has reduced the channel's capacity and further impeded drainage of the area. The depth and duration of flood water on the land on both sides of Sarigoyain River has now increased.

Table 2.2: Area Flooded by Depth

Flood Condition	Return Period	Flooded Area (ha)				
		0.3-0.9 m	0.9-1.8 m	>1.8 m	Total	%
Pre-monsoon	1:2	13900	9600	3800	27300	26
Monsoon	1:2	17500	23400	85200	85200	82

Source: NERP

There is little flow in the Piyain River below Companiganj due to severe siltation. This has increased the drainage load through the Kata Khali Khal and impeded drainage of the Piyain basin. Increased flow through the Kata Khali Khal has resulted in more breaches in the embankments on both banks of the Kata Khali Khal.

Local people requested that: the Piyain River be re-excavated from Companiganj to its outfall on the Surma River, the Dhalai Gang distributary channel be closed at Dhalarpar village, and the Dhalai Gang main channel be re-excavated. Field visits and local information indicate that the drainage facilities along the Sylhet-Companiganj road are not adequate. This causes drainage congestion on the eastern side of the road.

2.4.4 Water Bodies

Open water bodies
About 82% of the unprotected gross project area (85,200 ha) is seasonally inundated to a depth of greater than 0.3 m of which over seven percent (8181 ha) is perennial beels (Table A.7). The larger permanent water bodies (beels) are: Rauchunni, Rangauti, Kurundi, Gatu, Benda, Ghatkuri, Kaliura, Bishnain, Sharifnagar, Badauri, Kholakhal, Kuyadal, Nijail Chandal, Silchand, Siyala, Simul, Satkuri, Choto Rauti, Baoa, Panichapra, Loom beel, Shilakuri, Khailtajuri and Pokahair beel.

Closed water bodies
There are about 11,800 ponds in the project area which are mainly used for fish production. The ponds have a total area of about 910 ha (Table A.8). The highest concentration of ponds is in Sylhet Sadar (about 10 ponds/km^2), and the lowest is in Dwarabazar Thana (about 8 ponds/km^2). The average pond size is 770 m^2.

2.4.5 Surface Water Availability

Surface water availability for irrigation (80% dependable low flow) for the months of January, February, and March is given in Table 2.3. Flow availability in the Surma and Sarigoyain Rivers is over 4 m^3/sec, and in the Piyain River is about 3 m^3/sec during the critical months of February and March. The dry season discharge in Sarigoyain River below Sarighat has increased to about 8 m^3/sec due to channel shifting of the Piyain River. Dhalai Gang, Umium and Nawa Gang

Rivers are also perennial but because no flow measurements are made during the dry season their flow availability is not known.

LLP irrigation is already practiced along both banks of the Sarigoyain River downstream of Gowainghat. Surface water availability in the Sarigoyain River indicates that LLP irrigation could be further increased south of Gowainghat.

Table 2.3: Surface Water Availability

River	Location	Decade	Low flow, 80% dependable (m3/sec)		
			January	February	March
Surma	Sylhet	I	7.84	5.16	4.53
		II	6.56	4.59	4.55
		III	5.57	4.97	5.75
Piyain	Ratnerbhanga	I	5.92	3.62	
		II	4.86	3.01	
		III	3.67	3.45	
Sarigoyain	Sarighat	I	7.14	5.34	4.42
		II	6.65	4.91	4.67
		III	5.92	4.82	5.44

Notes: Inadequate data is available for frequency analysis for Ratnerbhanga for March.
Decade is a 10 day period.
Source: NERP

2.4.6 Ground Water

The estimated total usable ground water recharge within the project area is some 100 Mm^3. Of this about 54 Mm^3 could be developed using DTW force mode technology. Suction mode STW technologies can not be developed in the area due to aquifer constraints, but some 11 Mm^3 could be withdrawn by deep-set STWs (Table 2.4).

Table 2.4: Estimated Ground Water Recharge

Mode	Usable Recharge (Mm^3)	Available Recharge (Mm^3)
STW	0.26	0.14
DSSTW	20	11
DTW	100	54

Source: MPO (WARPO)

2.5 Land/Water Interactions

2.5.1 Sedimentation

Large quantities of boulder and gravel-sized sediments are being deposited on the Dhalai and Piyain fans. However, due to the flat gradients of the fans, virtually all of this coarse sediment is deposited in a short braided channel deposition zone near the apex of the fans. This zone extends only a few kilometres downstream from the point where the streams exit from their narrow canyons at the base of the Meghalaya Hills. The stone and gravel in this zone are an important natural resource and are being actively quarried from the river and used for building materials.

Most of the sediments deposited on the middle and lower reaches of the fans consists of coarse-medium sand. Aggradation in the active channels leads to higher water levels, bar formations and a greater incidence of channel shifting and instability. In the past, this has led to periodic channel avulsions across the fan surface. The partial avulsion of the Dhalai Gang eastwards towards Rautir Beel is an example of this process. This avulsion commenced around 1988 when bar formation in the Dhalai Gang deflected flows into an abandoned distributary channel. Subsequent erosion and channel widening along the distributary has resulted in most of the low flow being captured so that during the dry season the main Dhalai River is virtually dry. Furthermore, this shift has resulted in rapid sand deposition downstream of the avulsion point in the various beels and khals, including Rautir Haor, Baoa Beel and Burohingal Beel.

Sand deposition extends to the distal ends of the fans and has resulted in serious deposition at the outfall of the Dhalai Gang and Piyain Rivers. For example, sand deposition has completely infilled the entrance to the Old Piyain River just below Companiganj, in the Sarigoyain River upstream of Sarighat and in the lower reaches of the Dauki River (locally called the Dhaleswari River).

The main impacts of this sand deposition include: increased damage to homesteads and roads as a result of channel instability, reduced fishery resources due to beel siltation, and increased drainage congestion which has intensified flooding during the pre-monsoon and monsoon seasons.

2.5.2 River Erosion

Loss of land and homesteads due to channel shifting along the Dhalai Gang and Piyain River has been identified as a serious problem. The partial avulsion of the Dhalai Gang is causing channel widening and frequent channel shifting along the new channel as it adjusts to the increased discharges. Furthermore, ongoing sand deposition in the old main channel is contributing to bank erosion during the flood season. As a result, Companiganj is under threat from ongoing erosion. In recent years BWDB has had to construct works after each flood season to protect the town.

During 1991, erosion occurred below the canyon mouth of the Piyain River near Jafflong and damaged homesteads and the Bangladesh Rifles (BDR) camp. Ongoing bank erosion around Jafflong is threatening the market place and primary school. No projects are currently planned in this area.

There is no river bank erosion along the Surma River within the project boundaries. Channel migration rates in some bends have reached a few metres per year.

2.5.3 Crop Damage

Crops are damaged, mainly in the X1 and X7 units, mostly by flash floods in the pre-monsoon season (Figure 4). Minor damage also takes place in other units. Crops damaged include local varieties of boro rice at the reproductive phase, and local varieties of broadcast aman at the early vegetative growth phase. This type of damage prevents farmers from shifting to high yielding varieties of boro rice. Local varieties of transplanted aman are damaged by monsoon season flooding over a small area in unit X4.

2.6 Wetlands, Swamp Forest and Reed Swamp

2.6.1 Natural Wetlands

There are seven important wetland areas situated within this basin. Each consists of one or more different haor complexes with several perennial beels. The wetlands are: Khas haor complex (240 ha), Kakunakhai haor complex (900 ha), Shalta haor complex (450 ha), Langura haor complex (950 ha), Huara haor complex (300 ha), Pokahair haor complex (935 ha) and Nainda haor complex (250 ha). The total area of perennial water bodies (beels) in the basin is about 8180 ha, which includes the seven important wetlands as well as many other smaller beels.

All of these wetlands are associated with reed swamps, except Nainda haor. The ecology of these wetlands are quite similar. They are mostly flat, shallow wetlands which provide a good habitat for submerged and rooted floating plants. The most dominant plant species is Hydrilla Verticillata. Other important species are Limnophila, Trapa, and Nymphaea. Due to the presence of surrounding reed swamps, resident waterfowl concentrations are high. Migratory bird population is also fairly high. The area between the water and the reeds provides a good habitat for smaller mammals like fishing cats, otters and rats. Rana temporalis, a very rare amphibian, inhabits this area.

Nainda haor, the other important wetland, is also flat and shallow but is surrounded by rice fields, not reeds. As a result human interference is very high. Moreover, due to the use of its water for irrigation and because of dewatering for fish harvesting, most of the area becomes dry in the winter. In the monsoon season, the area provides a good habitat for submerged and rooted floating plants but the plants of other communities do not grow profusely. Due to a lack of habitat any type of wildlife is rare. Migratory waterfowls are not common here because of its high disturbance.

2.6.2 Swamp Forest Trees

There are only two swamp forest tracts in the basin: one is in Ratargul and the other is in Luchir bag. Ratargul has an area of about 350 ha and is designated as a *Reserved Forest*. There are many smaller patches which contain a few trees. These are the last remaining trees from the vast forests which covered the area in earlier times. Individuals of species like Barringtonia acutangula and Pongamia pinnata can be found in homestead groves.

2.6.3 Reed Swamp

There are six patches of reed swamps within the basin (North Sylhet Forest Range) with the status of Acquired Forest Class. The names and sizes of these reed lands are given in Table 2.5. An approximate location map of these areas is presented in Figure 5.

The main species in these reed swamps is Phragmites karka (*khagra*), associated with Saccharum spontaneum (*khag*). The latter species generally prefer to grow on more elevated ground. Other grass species present are Vetiveria zizanioides (*binna*), Arundo donax (*baranol*), Sclerostachya fusca (*ekor*) and some Hemarthria protensa (*chilla*). Other than grass some woody shrubs and climbers are very common including Ficus heterophylla, Lippia javanica, Asparagus recemosus and Asclepias. These swamp lands also produce Clinogyne dichotoma (*murta*), an economically important wetland species. There is one murta mahal in Ratargul Reserved Forest, covering an area of about 40 ha scattered over the entire Ratargul reserve. In addition there are four other

murta mahal in the Unclassed State Forest covering about 2390 ha scattered over the North Sylhet Range within the project area. Except in Ratargul, the areas are no longer productive and have mostly been destroyed.

In earlier times these reed swamps were the habitat of many larger mammals including Single-Horned Rhinoceros, Asian Elephant and Swamp Deer. Now the swamps can only support smaller mammals such as fishing cats, jackal, Smooth Coated Otters and Bandicot Rats. There is a high concentration of both resident and migratory bird populations as there is less human disturbance. Resident birds make nests in the reeds including the Little Grebe, Little Cormorant, Bittern, Egret, Openbill Stork, Purple Swamphen, Pheasant-tailed Jacana and Common Moorhen. These lands also support many smaller birds such as the Bush Chat.

Table 2.5: Reed Areas of the North Sylhet Range

Name	Approx. Area (ha)
Gouripur Nizgaon Ban Mahal	1000
Dhargram Banker Mahal	2200
Companiganj Dastidar Estate	2500
Pyangul Banker Mahal	3400
Chailtabari Lengura Ban San Mahal	4100
Chailakhal Banu haor Ban San Mahal	3500
Total for the Range	**16700**

Source: Forestry Master Plan.

3. SETTLEMENT, DEVELOPMENT, AND RESOURCE MANAGEMENT

3.1 Human Resources

3.1.1 Land Use and Settlement Pattern

Land Use
Current land use is summarized in Table 3.1.

Table 3.1: Current Land Use

Use	Area (ha)
Cultivated (F0+F1+F2+F3)	93090
Homesteads	2570
Beels	8180
Ponds	910
Channels	1900
Hills	2600
Fallow/Reeds[1]	17000
Infrastructure[2]	340

[1] Multi-use land, wetlands, grazing lands, village grounds. Includes F4 land.
[2] Government-owned land not appearing elsewhere.

Settlements
Settlements within the project area are mainly villages found along the levees of the rivers and along roadways. Exceptions are the District City of Sylhet and along the hills of Sylhet-Salutikar area. The portion of Sylhet Municipality which falls within the project area is densely populated, while in the hills, settlements are mainly scattered along the foot of the hills. While settlements are also found along the various roads, settlements along the west side of the Sylhet-Jaintiapur road and around the periphery of Rauti beel (Companiganj thana) and Nainda beel (Chhatak and Dowara bazar thana) are extremely sparse. These are areas where the land elevation is low.

Flood Damage to Housing
Recently many villages of Gowainghat thana, especially along the banks of the Sarigoyain River and along the Sarighat-Gowainghat road, are reporting damage to homesteads as a result of flashy monsoon floods during July-September. The damage mainly occurs when the river banks are overtopped. Some villages along the Dhalai khal in Companiganj thana are also affected by flashy monsoon floods from the Piyain River. Obviously, the lower the elevation of the homesteads, the worse the risk of flooding.

Coping Strategies
Homestead platforms are usually raised by one meter or more to avoid monsoon flooding. Within the villages in the low lying beel areas, homesteads are raised even higher to avoid flooding. Wave action which erodes homestead platforms in some areas is almost non-existent here. Flood waters from the monsoon flash floods usually recede from the homesteads within two or three days. If there is severe flooding, villagers generally make platforms inside their houses and shift their belongings to a safer place. In such situations, the poor suffer the most.

Table 3.2: Population Distribution by Age Group (%)

Sex	Population Age Group (Years)						Total
	0-4	5-9	10-14	15-54	55-59	>60	
Male	16.3	15.6	14.7	46.2	2.0	6.2	100.00
Female	17.4	16.6	13.1	46.9	1.3	4.7	100.00
Total	16.8	16.1	13.4	46.5	1.7	5.5	100.00

Source: BBS, 1981 Population Census

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be 604,500 of whom 296,000 are female. The gender ratio is calculated to be 104 (males to 100 females). The total households are estimated to be 97,200 within 912 villages. The population increased by 27.7% between 1981-91 in the district of Sylhet and by 23.8% in the district of Sunamganj during the same period.

The cohort distribution for males is: 32% are below 10 years of age, 46% are between 15 and 54 years of age, and 6% are above 60 years of age. The corresponding distribution for females is 34%, 47% and 6% (see Table 3.2).

The average population density is 478 persons per km^2, with a maximum density of 1040 persons per km^2 in Sylhet Sadar, which also includes Sylhet city. The most sparsely populated is Jaintiapur thana which has 353 persons per km^2. The average household size in the area is estimated to be 6.23 persons.

3.1.3 Quality of Life Indicators

Quality of life is usually determined by several key indicators. Those described here are literacy, access to health, sanitation, and pure drinking water facilities.

Literacy

In the project area the literacy rate is found to be extremely varied. According to the 1981 census, the literacy of the population at 5 years of age and above varied from 9% in Companiganj thana to 31% in Sylhet Sadar thana. The corresponding figures for females were 4% and 23% respectively for the same thanas. The rate appears to have increased over the last 10 years. According to the 1991 census, the literacy rate of all ages of the population of Sylhet district is recorded as 25% for both male and female. The corresponding rate for Sunamganj district is only 17%.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 11% in Companiganj thana to 28% in Sylhet Sadar thana. Attendance for females in this age cohort in these two thanas varies from 8% to 25% respectively.

Attendance for all youths between the ages of five and 24 is 9% and 24% for these thanas while the corresponding attendance for females is 5% and 20%.

The situation is worse for the rural poor. They can not afford to send their children to school. Moreover, many villages, especially in Companiganj, Dowarabazar, Gowainghat and Jaintiapur thanas, have no primary schools. The average number of primary schools per 10,000 population is estimated to be 5.5 for Sylhet district and 5.6 for Sunamganj district. (BANBEIS, 1990).

Access to Health Services

The district headquarters of Sylhet has a medical college with a hospital. The district headquarters of Sunamganj has a hospital and all thanas have hospital facilities located only at their headquarters. Access to health services are generally limited for rural villagers and is out of reach of the poor. According to the Directorate General of Health Services (1992), there is one hospital for every 162,190 persons and one doctor for every 9,915 persons in the district of Sylhet. The corresponding figures for the district of Sunamganj are 176,910 and 24,234 persons respectively. One hospital bed is meant for 2,350 people in Sylhet district and 6,630 people in Sunamganj district. Immunization coverage of children below two years of age is quite high for the project area. The rate varies from 51% in Chhatak thana to 65% in Golapganj thana (1990).

Rural Water Supply

Detail information on access to rural water supply for drinking purposes are not available for the project area. However, for the rural areas of the district of Sylhet, DPHE[1] reports the availability of one working tube well for 134 persons. The corresponding figure for Sunamganj is 180 persons. In 1990, 82% of the households had access to potable water in Sunamganj district and 59% for Sylhet district. It is noted that most tubewells are located in the houses of the rich. This results in the poor having very limited access to potable water.

Sanitation

Specific information on sanitation facilities are not available at the project level. During field reconnaissance, it was noted that open space defecation is a common practice in the rural villages, particularly for males. Women generally use kutcha latrines or defecate at a fixed spot which is protected by banana or betel nut leaves. During the monsoon months, the villagers defecate in open water, especially in the haor areas. Sanitary latrines are uncommon in the village environment, except for the very well-off and educated families.

3.1.4 Employment and Wage Rates

Village employment opportunities are mainly limited to agricultural activities. Many other employment opportunities exist in the city of Sylhet. Transplanted aman is the major crop in the area. Employment for men mainly consists of transplanting which occurs between August and September and harvesting which occurs in late November and December. Employment during boro cultivation is limited to the labourers living in low-lying villages — mainly in Chhatak and Dowara bazar thanas.

The wage rates for agricultural activities varies from Tk 30 to 50 with or without a meal per day during peak agricultural months. During months when there is no agricultural work, the wage rate varies from Tk 20 to 25. It is reported that during the monsoon months, many labourers

[1] DPHE, 1991-92

(20-50 from a village) migrate to Companiganj and Jaintiapur thanas to transport sand and stones. These materials are generally transported from the quarries to various construction sites and sales centres throughout Sylhet district. The average daily income from this activity varies from Tk 60 to Tk 100.

During months when employment opportunities in agricultural are limited, some poor people migrate to Sylhet city to work as rickshaw pullers, as construction workers or sometimes in household activities. Employment opportunities for women are very limited in the area, except for the Rural Maintenance Program of CARE, where a few poor women are employed. A number of poor women from different villages in Chhatak thana are reportedly working in the Chhatak Cement Factory. Women also migrate to Sylhet city to perform household works, but their numbers are very limited. Many villages have no such migrant woman labourers.

Migration to outside countries, particularly to the UK, is common in Sylhet Sadar and part of Chhatak thanas. However, such migration is less in other thanas of the project area.

There is in-migration into the project area, particularly to the city of Sylhet from Comilla, Faridpur, Mymensingh, Manikganj and Noakhali. They come to the city mainly to work as rickshaw pullers and construction workers. There is some in-migration to Chhatak, Companiganj and Jaintiapur thanas, where the immigrants transport stones from the quarries. These immigrants come mainly from Tangail, Comilla and Manikgonj. Other immigrants to the project area stay seasonally to work on harvesting of rice crops and earthworks.

3.1.5 Land Ownership Pattern

Land ownership is extremely skewed in the project area. Nearly half of the households are landless (with cultivable land less than 0.20 ha). If the definition of landless includes landholdings up to 0.4 ha, the number of households included increases by an additional 8%. Among the others, the small (0.21 - 1.00 ha), medium (1.01 - 3.00 ha) and large farmers (more than 3.00 ha) are 26%, 21% and 6% respectively.

The project area has large areas of fallow land in Companiganj (along Kata Khal and Rauti beel) and Gowainghat (along Sylhet-Jaintiapur road and north of Gowainghat) thanas. This land is reported to be khas land and is now under chhon and reed (grass/bush used for housing materials) production. This land is also used by neighbouring villagers as community grazing lands. In certain areas, influential people are reportedly taking this land for their personal use. The price of agricultural land varies from Tk 10,000 to Tk 75,000 per ker (0.12 ha) depending on the quality of the land and the intensity with which it can be cropped.

3.1.6 Land Tenure

Owner operation is the common practice in the area. A few large land owners, particularly from Chhatak and Sylhet Sadar thana share out their lands to tenants for operation. The share cropping system is that one-half of the produce is retained by the land owners. For local rice production they provide no inputs. For hyv boro rice, the land owner pays half the cost of the fertilizer and irrigation. The leasing out of land in kind (chukti) is almost nonexistent in the area. However, the leasing out of land with advance cash (Pattani) is practised in some cases. The usual rate for such arrangements varies from Tk 400 to Tk 700 per ker (0.12 ha) and this is paid in advance to the land owner for a particular crop season. Landless people have very little access to land

under this tenurial arrangement due to their inability to provide the cash and then purchase agricultural inputs.

3.1.7 Fishermen

Fishing is an important activity in the project area and competition over the fisheries resource is increasing. There are mainly two types of fishermen: traditional and non-traditional. For traditional fishermen, fishing is their livelihood and their families have been engaged in the profession for generations. The jalmohals are generally leased out to them through their cooperatives. Often the richer fishermen act as financiers and take much of the profit, while the poorer fishermen sell out their share in the cooperative. Sometimes the poorer fishermen work as fishing labourers. There are an estimated 2000 to 2500 traditional fishermen households in the project area.

The non-traditional fishermen are mainly an emerging group from the landless and poorer agriculturists. They fish in open water especially during monsoon months and sell the catch. Such non-traditional fishermen are increasing and nearly 20% to 25% of the households are reportedly engaged in catching fish. Additional information on fishing practices and so on is given in Section 3.5.1.

3.1.8 Situation of Women

Women's role is agricultural production is important. Their contribution, however, tends to be less recognized and under reported. Women are not very mobile in the area and they generally do not work in the field. However, some poor women are reported to be working outside their homes, mainly for the Road Maintenance Program of CARE and activities like gathering wild vegetables and collecting fuel. Most women say they would prefer working on homestead gardening and raising poultry/ducks in addition to other common household works. The village women generally work in the post-harvesting activities of rice crops, especially drying, winnowing, per-boiling and storing of rice. Most women also work on homestead gardening and raising poultry.

3.1.9 People's Perception

General

Local peoples perception of their problems were solicited. These were related mainly to water and its impact on their livelihood and their suggestions as to the nature of interventions which solve these problems. These were collected through personal interviews, group discussions and meetings with various cross-sections of people during the relatively short field work in the project area. These are described below.

Problems

Flooding, both pre- and monsoon, was described as a major problem of the area. This flooding mainly damages rice crops. Boro is damaged almost every year by pre-monsoon floods between April and May. These flash floods enter through the Porakhai, Bausi and Birbiri khals from the Sari River and flood boro fields in Nowakhet and Kakunakhai areas in Gowainghat thana. Boro crops of the Nainda beel area (Chhatak and Dowara bazar thanas) are damaged by flash floods from the Surma River which enter through Mirza khal, and from the Piyain River which enter

the area through Sirajdhala and Naukerbhanga. Rauti beel area in Companiganj thana is affected by flash floods from the Dhalai and Piyain Rivers.

Transplanted aus and transplanted aman are damaged by flashy monsoon floods during June and September, particularly in Gowainghat, Companiganj and Dowarabazar thanas. Flood waters mainly enter through khals and from the Sari, Piyain, Dhalai and Noyagong Rivers which all overtop river banks, roads and embankments. Sometimes there is back water flow from the Surma through the Chela khal at Chhatak. These flood waters generally last for three to seven days in the upper areas, but there are two to four such occurrences reported every monsoon season.

Drainage congestion is not perceived as an acute problem for boro cultivation, except for very small localised pockets. However, the silting of all the hilly rivers, including the Surma River, is referred to as a serious cause of flooding in the area. Sand deposition in the upper areas of Gowainghat, Dowarabazar and Companiganj thanas is reported as a serious problem as it affects soil fertility.

Poor fishermen stated that the prohibition of open water fishing by powerful jalmohal lease-holders was a major problem for them. It was observed that the local fishermen take more care of a leased jalmohal to ensure the sustainability of their resource. Fishermen considered that the dewatering of jalmohals was a major factor causing the decrease in fish production. They also stated that roads and embankments in the flood plains reduced fish production. Concern was expressed about fish migration in the project area: from the Surma River if Saheb and Mirza khals were closed, and from the Sarigoyain River if the Koknakhai and Porakhai khals were closed.

Fishermen in Chhatak and Dowarabazar thanas expressed their concern about the industrial effluent being discharged into the Surma River from the Chhatak cement plant and the pulp and paper factory. They felt that the polluted water may have a negative impact on fish production in the area.

People expressed the need for boat transportation between the haors and the rivers. If provision for such transport is not made, there would be a need to cut embankments during the early monsoon months.

Suggestions

The most common suggestions made by local people were:

- Stop intrusion of pre- and monsoon flood water to the area through Porakhai khal, Bausi khal, Birbiri khal, Nauka bhanga khal, and Mirza khal and construct sluice gates with a provision for boat passage in Porakhai and Mirza khal.
- Develop the entire Magura right bank from Tilagaon to Tengargaon to prevent pre-monsoon flood waters entering the Nainda beel area.
- Dredge along the original channel of the Dhalai River to protect crops, to lessen erosion to villages along the new river channel, and to improve boat access for boulder transportation.

- The closure of the Pandar khal on the left bank of the Surma River has caused problems for the people on the opposite right bank of Surma River in Dowarabazar thana. Many villagers said that rice crops in the area are damaged every year by pre-monsoon and monsoon flash floods. The farmers suggested that the khal should be re-opened with a provision for a sluice gate, if necessary, to protect boro crops in the lower areas.

- Lease jalmohals only to local fishermen.

- Allow poor and subsistence fishermen to catch fish in the flood plain.

- Conserve sufficient fish habitat for normal production of fish.

- Retain an adequate provision for movement of fish from the Surma and Sari-Goyain Rivers to the beels.

- Any structures constructed on Porakhai, Koknakhai, Mirza and Saheb khals should allow provision for navigation.

- Stop industrial wastes entering the Surma River from Chhatak cement plant and the pulp factory.

3.1.10 Local Initiatives

People stated that it is their traditional practice to organize local people to counteract crisis which arise as a result of flash floods and drainage congestion. The main activity is to construct dams on various localised canals to stop the intrusion of pre-monsoon flash floods to save the boro crop. They would also assemble to re-excavate canals for quick drainage. This is generally done on a voluntary basis by the villagers around a particular canal which is threatening their property. More recently the Union Parishad also allotted wheat for this purpose.

3.2 Water Resources Development

3.2.1 Flood Control & Drainage

The existing water development includes three completed projects as follows (refer Figure 1):

Patherchuri Haor Project: The project provides partial flood protection to a gross area of 6060 ha on both banks of Kata Khali Khal by two polders. The project was completed in 1987 under an EIP programme. It includes 33 km of embankments along both banks of Kata Khali Khal and along part of the right bank of the Surma River. Each polder is provided with one drainage regulator and a pipe sluice. The project is effective but reportedly there are increased water levels in the Kata Khali Khal and more breaches in the embankments.

Zilkar Haor Project: The project area consists of two sub-projects: Zilkar Haor and Haparu Haor. They are separated by a full flood embankment which is also used as a road.

- Zilkar Haor provides partial flood protection to a gross area of 2150 ha. The sub-project includes eight kilometres of submersible embankments along the left

bank of Sarigoyain River and two drainage structures: one two regulator (1.52 m x 1.83 m) and one pipe sluice (90 cm diameter). The sub-project provides adequate protection to boro crops.

- Haparu Haor provides full flood protection to a gross area of 3110 ha. The sub-project includes 16.2 kilometres of embankments along the Sarigoyain River (Singar Khal) and two drainage structures: one three vent regulator (1.52 m x 1.83 m) and one pipe sluice (90 cm diameter). The project has not performed as intended due mainly to inadequate drainage facilities.

Sarigoyain Project: The project objective was to provide monsoon flood protection to a gross area of 5385 ha. The project includes 15.5 kilometres of full flood embankments along the Sarigoyain and Baa Nawa Gang Rivers. Pre-and monsoon season drainage facilities include a 20-vent regulator and a 90 cm diameter pipe sluice. The project has not achieved its full intended benefits due to flooding caused by rainfall within the project and drainage congestion.

Piyain Flood Embankment: The project includes a flood embankment along the left bank of the Piyain River-Patnai Gang system from Goragaon to Monugaon village. The embankment was constructed in 1980 under a WFP programme. No maintenance has been carried out on the embankment since its construction. The embankment has been breached at several locations. Local people said the embankment used to protect the monsoon crops before it was breached and they requested that it be rehabilitated.

Water Retention Structures (WRS): There are three water retention structures in the project area: at 1) Naljuri Khal, 2) Baranayagang, and 3) Rangpani and Napti Khal. All three structures are in Jaintiapur thana and were implemented under IDA Credit 950-BD. Reportedly none of the structures have functioned since their installation.

Bank Protective Schemes: There are three bank revetments in the project area to protect homesteads and infrastructure. Each uses stone boulders. The schemes are at:

- Companiganj on the right bank of Dhalai Gang to protect the thana headquarters complex;
- Jafflong on the left bank of Piyain River below the canyon mouth, to protect the local homesteads; and
- Sarighat on the left bank of Baa Nawa Gang immediately upstream of Sarighat bridge, to protect the Sarigoyain project embankment.

3.2.2 Irrigation

Surface Water

Present surface water irrigation coverage by LLPs and traditional modes is about 13,000 ha based on Agriculture Sector Team (AST)reports, 1991. There are 72 LLPs operating in the project area. Each LLP has a capacity of about 55 l/s (about 2cfs). The total area irrigated is about 960 ha.

Ground Water

Present ground water abstraction for irrigation use is not significant. Based on AST reports (1991), there are 12 STWs, 11 MOSTI, and seven DTWs in the project area. Reported ground water irrigated areas are 80, 11, and 142 hectares for STW, MOSTI and DTW developments, respectively, which corresponds to a irrigation water use of about 1.5 Mm3 based on a ground water irrigation duty of 160 ha/Mm3 (MPO, 1991). The specific locations of each ground water development is not known.

3.3 Other Infrastructure

A Roads and Highways Department regional highway runs along the eastern boundary of the Sarigoyain-Piyain basin from Golapganj to Jafflong via Sylhet. Feeder roads connect the highway with Goyainghat, Badhaghat and Salutikar. The elevations of these roads are probably at about average annual flood water level and are damaged each year.

There is a RHD Feeder Road Type A from Sylhet to Companiganj. The road is paved from Sylhet to Salutikar and is unpaved from Salutikar to Companiganj. The RHD are planning to upgrade the road from Salutikar to Companiganj, possibly in 1993/94.

There are about 190 km of main village roads in the project area and most of these roads are not accessible during the monsoon season due to flooding. The flooded roads are damaged annually, with an average damage rate estimated at about 15% of the capital cost. This translates into an average annual flood damage of Tk 3.60 million.

3.4 Agriculture

Agricultural practices in the Sarigoyain-Piyain basin vary widely depending on the hydrologic regime. Of particular importance is the extent and frequency of pre-monsoon flooding and the depth of inundation in the monsoon season. Local varieties of boro rice are dominant on F3 land types while local varieties of broadcast aman are grown on F2 land types. Production of high yielding varieties of boro rice depends on the availability of irrigation facilities and the timing of pre-monsoon floods on the F2 land type. Local and high yielding varieties of aman paddy are grown on F0 and F1 land in sequence with aus paddy in the first kharif season and rabi crops in the winter season. Present cropping patterns in the Sarigoyain-Piyain basin are presented in Table 3.3

The yield level of crops reflect the level of management and damage suffered by the crop. Low to moderate yields are obtained for most crops. Yield levels are very low in areas suffering flood damage. Present crop production data are presented in Table 3.4 indicating areas and yield levels of crops in damage-free and damaged areas.

Crop marketing patterns within the basin are largely traditional. Most of the produce is sold in the village markets to outside traders. Most farmers, specially the small and marginal farmers, are compelled to dispose of the bulk of their produce immediately after harvest as they need cash and lack storage facilities. Prices at harvest are usually very low and often farmers later have to replace their food grain at a much higher price to meet daily consumption requirements.

Homestead agricultural production varies with the level and size of homestead area. Trees namely banana, mango, betel nut, bamboo and so on are common on higher homesteads. These

Table 3.3: Present Cropping Patterns in Sarigoyain-Piyain Basin

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	
b aman-fallow					18081	70	2121	5	20202
fallow-l boro							40299	95	40299
fallow-hyv boro					2583	10			2583
b aus - fallow - hyv wheat			1034	5					1034
b aus - fallow - rabi	419	10	4134	20					4553
b aus - lt aman - fallow	2093	50	10335	50					12428
b aus - hyv aman - fallow	1047	25							1047
fallow - lt aman - fallow	628	15	2067	10					2695
fallow - lt aman - rabi			3101	15					3101
b aman - rabi					5166	20			5166
Total	4186		20670		25830		42420		93106

provide fruit, fuel, and building materials. Lower homesteads have fewer trees. Most of the vegetables consumed by farming families are produced in the homestead area, or on lower land adjoining it. Most families maintain a few poultry and cattle.

Homesteads are an integral part of the farming system. Courtyards are used for post-harvest activities (threshing, winnowing, parboiling, drying) where women of the family work along with the male members.

3.5 Fisheries

3.5.1 Floodplain fishery

There are about 200 important permanent beels in the project area. The most important for fisheries are: Rauchunni, Rangauti, Kurundi, Gatu, Benda, Ghatkuri, Kaliura, Bishnain, Badauri, Kholakhal, Nijail, Silchand, Siyala, Simul, Choto Rauti, Baoa, Panichapra, Loom beel, Khailtajuri and Pokhair beels (Figure 7). Beels serve as overwintering refuges for the fish species present in the area. During the monsoon season, water enters the basin from the Sarigoyain, Piyain, Dhalai, Kata Gang and Surma Rivers through open khals, breaches in dykes, and by overtopping the river banks. Most of the beels are isolated basins but in a few cases they are interlinked by narrow canals.

Table 3.4: Present Crop Production in Sarigoyain-Piyain Basin

Crop	Damage free area			Damaged Area			Total Prod. (mt)
	Area (ha)	Yield (mt/ha)	Prod. (mt)	Area (ha)	Yield (mt/ha)	Prod. (mt)	
b aus	19061	1.25	23826	0	0	0	23826
b aman	19818	1.75	34682	5550	1.45	8048	42729
lt aman	17023	2.15	36600	1200	1.75	2100	38700
hyv aman	1047	3.95	4133	0	0	0	4133
l boro	33299	2.25	74923	7000	1.75	12250	87173
hyv boro	2583	4.55	11753	0	0	0	11753
Paddy (total)			185917			22398	208314
wheat	1034	2.05	2118				
pulses	1923	0.85	1634				
oilseeds	6410	0.75	4807				
spices	641	2.25	1442				
vegetables	3846	3.75	14421				

There are a few larger fisheries (jalmohals) in the project area, of which the Rowa beel, Rauchunni beel complex and Sarigoyain River are the most important. Most of the larger fisheries are leased by rich, influential persons for a period of three years. The lease-holders generally reside in the city of Sylhet or at thana headquarters and appropriate the profits from the catch. This system deprives local fishermen of access to the fisheries resources. Neither is there much opportunity for local fishermen to serve as labourers for the final catch since fishermen from outside areas are generally hired for this purpose.

Conflicts and tension are common over the issue of fishing the jalmohals in the area. The lease-holder of Nainda beel constructs and maintains water retention dams on the beels' drainage canals and this prevents timely boro cultivation in the peripheral zone of the beel. On the other hand, it is also reported that water is completely drained during early February each year to maximize the catch. Fishing by the dewatering of beels is, reportedly, common in the area. This seriously affects boro cultivation.

It is also reported that lease-holders do not allow fishing by either traditional or non-traditional fishermen in the vicinity of the jalmohals even during monsoon months. This assertion was not cross-checked. The extent of the lease-holder's control over the area needs to be verified more closely during feasibility studies since it will have a significant bearing on the operability of any proposed intervention.

3.5.2 Species present in the area

Of the 150 species in the region, about 40-50% species inhabit the project area. The most common of these species are listed in Table 3.5

3.5.3 Duar fishery

Duars, which are an indispensable part of a typical floodplain fishery, act as a refuge for the larger broodfish during the winter season. These fish then migrate to a suitable spawning ground for breeding when water levels begin to rise. In total there are 33 duars: 25 in the Sarigoyain River, five in the Surma River and three in the Biliajore/Kata Khal River. Duars are listed in the (Table A.9).

3.5.4 Sources of fish and breeding

It is generally understood that early rain, thunder, flooding, temperature, grassy or rocky land all influence spawning of fresh water fish. If conditions are favourable, during the pre-monsoon and early monsoon periods, fish migrate into shallow areas, usually from beels to adjacent grassy areas, to the rivers, and vice-versa. In the case of localized rain in the haor area, the area will drain into the beel and water will flow from the beel to the khal into the river. In this case, fish will tend to move from the river along the khal to the beel. Some species, such as Boal, Ghonia, Pabda, and Foli migrate against the current and travel from the beels up to the highland khals, where they breed in the special grasses like Chailla bon. For the Koi, Puti, Tengra, Magur and some other species, localized breeding migration occurs within the haor area. Icha, Taki, Shol, Gazar, and Singi can breed within the beel complex during late April to June (depending on flood conditions and local rain).

It is generally considered that most of the perennial water bodies with shallow floodplains are the breeding grounds for many of the smaller fish. The smaller fish constitute about 60-70% of the total production of the area, except at Rauti and Baoa beel complexes in area X4, where there is more large fish (about 50-60% of the total catch is large fish). There are six main channels which fish use to move from the main rivers to the haor area. These channels are: Nawagaon canal of Rauti beel; Hidhar khal, Koi khal and Kapna nadi of Rauchunni complex; and Mirza khal and Shaheb khal of Nainda haor complex. The fish using these channels are mainly carp, Air, Chital, Chapila, Batashi, Chela, Gulsha and so on. Duars, adjacent to the project area provide overwintering grounds for mainly larger fish. It is considered that Rauti beel and Baoa

Table 3.5: Major Fish in the Sarigoyain-Piyain Basin

Large Fish	Small Fish
Catla, Rui, Mrigel, Kalibaus, Air, Chital, Ghagot, Guzi, Shol, Gazar, Boal, Ghonia, Ilish.	Singi, Magur, Koi, Bheda, Kholisha, Pabda, Kanipabda, Bashpata, Rani, Kachki, Batashi, Tengra, Gulsha, Bajari, Taki, Cheng, Chela, Fhul chela, Darkina, Mola, Dhela, Chanda, Lal chanda, Balichata, Foli, Chapila, Napit, Boicha, Kaikka, Baim, Cirka baim, Potka, Ek Thuita, Puti, Laiya, Along, Lacho, Gutum, Pahari gutum, Shilong, Bailla, Icha.

Source: NERP Case Study, 1992

beel areas together with their adjacent rivers are the spawning grounds for carp and other commercially important fish.

3.5.5 Production trends

Fish production in the area has apparently declined by 20-30% over the last five years. While no real estimates have been made of overall fish production for the project area, the estimated production is 9131 metric tonnes per year (see Table 3.6).

Table 3.6: Present Estimated Fish Production

Regime	Area (ha)	Production (kg/ha)	Total Production (mt)
Beel	8181	550	4499
Floodplain	88,920	44	3912
Pond	910	800	720
Total	98,011		9,131

According to NERP analysts, fish abundance is directly related to the level and duration of flooding, and access to the flood lands. Fish production in the project area has been declining. The identified causes for the fish decline are outlined below:

- Beels infilling with Sediment. The beel area has been reduced on average by 15-20% over the last two decades; both, the depth of water and the water hectare-months are declining. Some of the beels in Companiganj have reduced in area by as much as 80-90%, due to sand deposition from the avulsion of the Dhalai River.
- Over-fishing.
- Reduction of reproductive stock due to indiscriminate use of some fishing gear (current jal, kona jal, jam jal).
- Increased fish mortality due to fish disease caused by water pollution in the beels, particularly during the months of December to January.
- Reduction of fish habitat as a result of agriculture encroachment into fish producing beels.
- Absence of proper extension services for the pond owners to develop culture based fish farming in the existing ponds.

3.5.6 Fishing practice

Floodplain

Open water fisheries are the major source of fish in the area (floodplain 42%, beels 50% and ponds 8%). Subsistence fishing occurs mainly during the flooding period and large-scale beel fishing occurs from November to February. In most cases, beel fishing is done on an annual basis by complete dewatering of the beels. Usually piles are not maintained (except for the Rauchunni, Rauti, Silakui, Nijail Chandal beels and some others) as a part of the biological management of the fishery resource. In all cases, the installation of katha is common. Jarul,

hizal, koroch, shawra and mango tree branches are widely used for katha. They are installed in the months of August and September when water is receding from the floodplain.

Closed Water

Pond fish culture practices are different here than in other parts of the country. Most pond owners in the project area release an uncounted number of fingerling into their ponds without undertaking other basic management activities such as predatory fish eradication and regular application of feed and fertilizer. Monitoring the growth and health of the fish is also not done on a regular basis. The fish are usually harvested during the dry season. It should be noted that many ponds that adjoin homestead land provide domestic water supply for a wide variety of activities (bathing, washing clothes and dishes, occasionally watering homestead vegetable plots, and so on).

3.6 Navigation

The Surma River is navigable year-round up to Chhatak, due to the back-water effects from the Meghna River. Upstream of Chhatak around Sylhet, the Surma River is almost dry during the winter season and cannot be used by large vessels.

The Sarigoyain River is navigable for medium-sized country boats up to Goyainghat. Many of the smaller streams in the project area are perennial but have inadequate flow for navigation during the dry season. However, small and medium-sized motorized country boats can operate in these areas for three to six months each year.

In the past, the Dhalai Gang has been used by small boats to transport boulder and gravel materials form near the Bholaganj quarry to Companiganj, a distance of about 11 km. Since the avulsion upstream of Companiganj, the boats have not been able to reach Companiganj directly. Instead, they follow the newly formed channel to the Piyain and then head up to Companiganj via Teli Khal. This change has doubled the travel distance required for the trip. Furthermore, the new route has reduced the number of boats that can operate during the dry season. In 1992 (after the avulsion occurred) it was estimated that about 2,00 boats were engaged in transporting the stone material to Companiganj. Given the boatmen are paid 250 taka per trip, this implies the existing activity amounts to roughly 65 million taka over a five month period.

3.7 Wetland Resources Utilization and Management

3.7.1 Utilization

The most important use of natural wetlands products is industrial raw material for the production of pulp and paper. The wetland products used for this are Phragmites karka (*khagra*) and Saccharum spontaneum (*khag*). The Sylhet Pulp and Paper Mill (SPPM) was established to produce pulp from this raw wetland material. At the time of the first feasibility study for the mill (1967), the area of reeds available for commercial exploitation was estimated at more than 30,000 ha, with a biomass production of 4.5 MT ha^{-1} (air dry basis). The Forest Department estimate of the present reed area is about 27,000 ha, out of which 17,000 ha are within the project area. Productivity has now decreased to an estimated 2 MT ha^{-1} giving an estimated gross total production from the project area of up to 34,000 MT. Reeds have good economic value; the

price is Tk. 200-250 MT^{-1}. As a result, the estimated gross total value is about Tk. 7 million per year. At least 4 md ha^{-1} is required for harvesting and drying this material. Hence the total md required is about 68,000.

The next important use is fuel material. All the grasses and shrubs grown in the reed swamp are used for this purpose. More than 90% of the lime used in Bangladesh comes from the Northeast Region, and the region's lime-burning industry uses reeds extensively as a fuel. People living around the reed swamps use them for their everyday household fuel needs. The economic value and employment in gathering the reeds has been estimated (see above paragraph).

Another important use of these products is as a thatching material, including roofs and wall panels for houses and for mats. Vetevaria (*binna*) is mostly used to build the roof and Phragmites (*khagra*) and Sclerostachya (*ekor*) are used to build the wall panels. Murta is extensively used for mats. Murta is an attractive product since it has a higher price and a good dependable market. From one hectare of land 60,000 murta stems can be harvested annually which could earn at least Tk 15,000 when sold as raw material to a mat producer. Hence the estimated total value could be Tk 0.6 million from the Ratargul area only. The estimated gross amount from the project area is about Tk 1.8 to 2 million (with the area's low productivity and inferior quality). Harvesting and processing requires a large amount of manpower. For harvesting, about 7 pd ha^{-1} are required giving a total employment requirement of about 1,000 pd. Post harvest processes for mats are very complicated and need about 4,200 pd ha^{-1}.

Other uses of the wetlands products are:

- Fodder material. Mostly from various grasses and other species like *Nymphaea* (shapla), *Nymphoides* (panchuli).
- Food. Mostly from *Nymphaea* (shapla), *Ottelia* (panikola) and *Aponogeton* (ghechu). The total value for food and fodder could be as much as Tk. 0.8 million and requires about 2,000 Md.
- Medicinal Plants. Mostly from *Limnophila* (karpur), *Polygonum* (kukra), and *Nymphaea* (shapla).
- Duck feed. Molluscs are used for this purpose.

These common property resources are of some importance to the poor, who are the most likely to engage in wetland gathering, to eat wetland food in times of scarcity, to depend on income from wetland products, and so on. Fodder and building materials tend to be collected by men, and food and medicinal materials tend to be collected by women.

3.7.2 Management

All the reed swamp areas are owned by the Ministry of Land but the authority responsible for their management has changed several times. Initially the land was managed by the Revenue Department. The Sylhet Pulp and Paper Mill then assumed management of 17,000 ha some years ago. This was not successful (propagation was limited to only 2000 ha in the Chhatak, Companyganj and Jaintiapur areas) and now management of the land is being transferred to the Forest Department.

The Jalurmuk and Rouchunnir bag swamp forests are being managed by the Forest Department. Jalurmuk (Ratargul) is designated as an acquired forest. At the end of 1992 the Forest Department started planting murta and various tree saplings at Rouchunnir haor under a floodplain plantation program. Luchir bag is being managed by the nearby villagers.

4. PREVIOUS STUDIES

4.1 Gravity Diversion - Bara Haor Project

A feasibility report was prepared on the Bara Haor Project in 1963. About half of the proposed Bara Haor Project area is located within the present boundaries of the Sarigoyain-Piyain Basin.

The project plan was to divert the dependable flow of the Sarigoyain River during the winter months to the higher lands of the Bara Haor for boro rice expansion. Three alternatives were evaluated as follows:

- Pumping and gravity diversion for winter crops
- Partial flood control dikes for protection against early spring floods
- Full flood control dikes for protection against monsoon floods

The study showed that dikes for monsoon floods were not feasible because accumulated rainfall within the protected area very quickly reaches an elevation of about 1.3 meters lower than the maximum flood levels outside the project in Sarigoyain River. Pumped drainage for the protected area was found to be economically not viable.

Partial flood control embankments for early spring floods were found to be not economic. When this partial flood control option was combined with a gravity diversion barrage the scheme was less economic. The study showed that both pumping and gravity diversion are technically feasible and economically viable. The gravity diversion plan has higher capital costs but over the life of the project is more economic.

4.2 National Water Plan Project (NWPP), MPO

The Sarigoyain-Piyain basin is located within MPO's Planning Area 24, which has a net cultivable area of about 160,000 hectares. The total flood vulnerable area in Area 24 is 119,000 hectares, of which 28% is recommended for flood control and drainage development during the National Plan period up to Year 2020 (Table 8-14, Vol-II, NWP,1991).

4.3 Early Implementation Projects (EIP), BWDB

EIP carried out a hydrological study of the Piyain River flood plain in 1983 under the Netherlands Technical Assistance Programme. The aim of the study was to gain further information about the hydrological conditions of the Piyain River, its tributaries and flood plain.

Three alternatives for the development of water management in the flood plain area were studied. These were as follows:

- Diversion of Dhalai Gang into the Old Piyain River course by constructing a cross dam between Companiganj and Teli Khal to reduce discharge and consequently crop damage on both banks of the Kata Khali Khal;

- Construction of a full flood embankment on the left bank of the new course of the Piyain River between Jafflong and Chhatak

- Construction of submersible embankments at locations throughout the basin.

The following findings were outlined in the study:

- Diversion of Dhalai Gang will prevent crop damage for only two years out of 14, and therefore was found not attractive;

- Full flood protection may increase annual high water levels at Chhatak by more than one meter due to a reduction in the flood storage capacity. This was not considered acceptable; and

- Construction of submersible embankments for pre-monsoon flood protection were recommended. Submersible embankments projects should be developed in stages. The impacts of the projects built in the initial stages should be studied before further submersible embankments are built. Particular attention should be paid to assess any severe negative impacts on the adjacent areas.

5. WITHOUT - PROJECT TRENDS (NULL OPTION)

The purpose of this chapter is to characterize the future of the project area with no intervention. It focuses on important trends and briefly describes the likely future scenario if these trends continue through 2015. as follows:

- Net population growth: about 2.0% per year to year 2000 and 1.8% per year to year 2015. This future growth rate will be down from the yearly growth rate of 2.2% experienced over the last ten years. The project population will be 726,000 by year 2000 and 950,000 by year 2015.

- Foodgrain production growth: 0% per year. Without intervention, crops will continue to be damaged in the Sarigoyain-Piyain basin. Damage to local boro crops will continue and there will be no increase in the planting of high yielding varieties of boro rice. There is very little damage to the high yielding varieties of aman rice and to local varieties of transplanted aman, except in Unit X4. Some expansion of high yielding varieties of aman rice on the existing F0 land can be expected (F0 lands cover about four percent of the area). Any gains in aman production would be offset by losses in arable land due to sediment deposition.

- Openwater fisheries production: to assess project fish impacts (FW production minus FWO production), some assumption must be made about FWO trends. Observations of past fish production indicates a decline of 1-3% per year overall. Conversely, estimates of future production taking into account interventions to improve biological fisheries management suggest that increases in fish production are possible. If the FWO trend is assumed to be negative, project negative impacts on fish production will be of significantly smaller magnitude than if the FWO trend is assumed to be positive. Lacking any way to decide between these two scenarios, it is assumed that FWO production will be equal to present production.

- River course changes: The Surma and Sarigoyain channels are quite stable, and no significant changes are expected in the future; the present erosion is considered to be normal. The Piyain and Dhalai channels are unstable; periodic shifting and avulsions will continue in the future. Homesteads and cultivable lands will continue to be damaged. Channel erosion and widening along the newly formed avulsion channel east of the Dhalai Gang will probably accelerate over the next few years sand deposition in low lying areas adjacent to the avulsion channel (such as Rauti Beel) will also be expected to accelerate as more of the flow is captured.

- Loss of arable land: The loss of arable lands to settlements is expected to be negligible. Significant arable land losses due to sand deposition are expected to continue.

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- Navigation: Navigation along the Dhalai Gang between quarrying operations and Companiganj will decline due to the expected channel changes and siltation.

6. WATER RESOURCES INFRASTRUCTURE DEVELOPMENT OPTIONS

6.1 Summary of Problems

The main problems of the area are:

- *Floods and seasonal inundation over a major part of the area.* Flooding of crops during the pre-and monsoon seasons causes yield reduction and limits the cropped area to the higher lands. In addition to the losses in agriculture, floods cause substantial damage to homesteads and roads.

- *Channel avulsions and siltation on the Dhalai Gang Alluvial fan.* The main hazards on the fan include periodic channel erosion and flooding by high velocity spills, overland flow and inundation. Large amounts of coarse sand are deposited which damages homestead, reduces cultivable areas and fisheries habitat and impairs navigation.

6.2 Water Resources Development Options

There are three basic options for water resources development in the project area outside of the Dhalai Gang fan:

- *Full flood protection throughout the basin by constructing polders* (Option A).

- *Protection against monsoon flooding for part of the basin* (Option B). Flood control facilities would be provided along the Surma and Lubha Rivers in the east and along Sarigoyain River in the north

- *Constructing selected pre-and monsoon season flood control and drainage facilities* (Option C). The type and selection of infrastructure for inclusion in the project would be based on preliminary analysis and on the outcome of discussions with people who reside in the area.

The first two options are briefly discussed in this chapter. The third option, which was selected for more detailed study, is described in Chapters 7 and 8. Discussion about development options on the Dhalai fan are summarized in Section 6.2.4 and described in Chapter 9.

6.2.1 Option A: Full Flood Protection by Constructing Polders

During the monsoon season over 85,200 ha (82% of the unprotected area) is inundated by floods in an average year (1:2 year return period). Water balance computations show that pondage due to rainfall is almost equal to or higher than the design heights of the embankments in this locality. This indicates that full flood protection would not benefit the protected area. Pumped drainage is technically feasible but is not economically viable.

6.2.2 Option B: Full Flood Protection from the Surma, Lubha, and Sarigoyain Rivers.

The objective is to protect a part of the Sarigoyain-Piyain Basin from monsoon flooding by closing all the drainage channels (Kapna Nadi, Khorish Nadi, Khepa Gang and so on) along the Sylhet-Jaintiapur road and constructing a full flood embankment from Sarighat to Goyainghat along the left bank of Sarigoyain River (Figure 8).

The peak water levels, with and without the proposed intervention, are presented in Table 6.1. It appears that with this intervention the depth of flooding may be reduced over one meter even during the monsoon.

During the monsoon season over 800 m^3/sec of flood water flows through three channels: the Kapna Nadi (110 m wide, 8 m deep), Khorish Nadi (40 m wide, 6 m deep), and Khepa Gang (30 m wide, 5 m deep). The reduction of flows through these channels will increase the maximum discharge in the Surma River at Sylhet; possibly from 2480 to about 3200 m3/sec. Possible adverse impacts are:

- increased levels at Sylhet by about one meter (see Figure 9);
- increased damage to infrastructure and monsoon crops in the Baa Haor area;
- reduced benefits from the proposed intervention of the Surma Right Bank Project;
- increased water level in the Baa Haor area may decrease backflows through the Lain-Pabijuri River and consequently increase water levels in the Sarigoyain River. This may further impede drainage from the Sarigoyain Project which currently suffers from drainage congestion.

The proposed intervention decreases the depth of flooding in the project area, but impacts adversely on the adjoining areas. Hence, no further studies or evaluation have been carried out during this investigation. However, the above discussions demonstrate that, if monsoon flows could be diverted from the Surma River below Sylhet in the south without affecting existing conditions, substantial benefit could be achieved in the upstream areas.

Based on discussions with area residents and the above analysis, it was concluded that the area bounded by the Sarigoyain River and Sarighat- Goyainghat road (Figure 4; unit X1) requires protection. The gross area of this unit is about 3200 ha and has mainly boro crops. Peak water levels of this area (unit X1) - with and without embankments for different return periods are given in Table 6.2. The flood depths during pre- and monsoon seasons would be reduced by

Table 6.1: Peak Water Levels With and Without Embankments

	15 May Water Levels (m)				Monsoon Water Levels (m)			
	1:2	1:5	1:10	1:25	1:2	1:5	1:10	1:25
Without Embankment	8.85	9.98	10.45	10.75	11.73	12.03	12.16	12.27
With Embankment	7.75	8.65	8.96	9.18	10.64	10.95	11.08	11.18
Decrease	1.10	1.33	1.49	1.57	1.09	1.08	1.08	1.09

Source: NERP

1.25 m and 0.90 m respectively, for an average year (Table 6.2) and the area of flood free lands would increase.

The benefits of the full flood protection scheme are that it also protects infrastructure including roads and homesteads from flood damage and reduces the depth of flooding not only in the project area but also south of the Sarighat-Gowainghat road. This project, named the Rauchunni Beel Project, was studied at pre-feasibility level and is presented in Chapter 7.

6.2.3 Option C: Submersible Embankment

The objective of this option is to protect boro crops from pre-monsoon floods up to 15 May. About 27,300 ha of the project area is inundated during the pre-monsoon season up to 15 May (Table 2.2). These areas are mainly located in X1, X3 to X7 and X8 units (Table A.5). About 1400 ha are inundated in the remaining units (X2, X9, and X10). These lands are in smaller scattered units which would be difficult to protect.

About 1,600 ha in Unit X6 are inundated by pre-monsoon floods. The majority of this land produces reeds which are used as a raw material for the Sylhet Pulp and Paper Mill. Moreover, the area has been identified as reed swamps (Acquired Forest Class). Based on the above considerations, no intervention has been proposed for this area.

In Unit X8, areas subjected to pre-monsoon floods are mainly located along the foot hills. These lands are scattered and generally do not support boro crops. No interventions have been proposed for these areas.

Unit X5 includes about 2500 ha of pre-monsoon flooded lands. Some of these lands are scattered. A small area of boro crops were observed along the southeastern boundary of Pathar Churi Haor Project which may require pre-monsoon protection. However protection in the area may further impede drainage from the uplands which already suffer from drainage congestion. No intervention is currently proposed.

Table 6.2: Peak Water Levels With and Without Embankments (Unit X1)

	15 May Water Levels(m)			Monsoon Flood Levels(m)			
	1:2	1:5	1:10	1:2	1:5	1:10	1:25
Without Embankment	10.05	11.37	11.87	12.61	12.92	13.05	13.16
With Full Embankment	8.80	10.22	10.71	11.71	12.05	12.19	12.32
Decrease	1.25	1.15	1.16	0.90	0.87	0.86	0.84

A large area requires pre-monsoon protection in units X3 and X7 (Table A.5). The area could not be visited due to difficult accessibility and time constraints. Detailed topographical mapping (at a scale of 4 inch:1 mile) indicates that pre-monsoon protection may be required at the northeast corner of unit X3. During seminars held in Sylhet and Sunamganj (see *Proceedings of Sylhet Seminar, June, 1992 and Proceedings of Sunamganj Seminar, February, 1993*), no proposals were forwarded by local people for protection of this area. No development proposals have been presented for the area but further attention could be given during future feasibility studies of the basin.

Unit X7 is divided by the existing very high earthen embankment which was constructed in the early 1900's as a tram line for transporting boulders (Figure 4). Most of the area to the west of the embankment remains above pre-monsoon flood level. About 800 ha are shallowly inundated (to depths of 0.3-0.90 m) during the pre-monsoon season in an average year (1:2 year return period). Based on existing flood data it appears that most of the area does not require protection.

The area to the east of tram line is locally called Nainda Haor and has a gross area of about 8070 ha. Over 4000 ha (about 51% of the gross area) is inundated during the pre-monsoon season (Table 6.3). Up to 92% of the area is inundated during the monsoon season by average year peak water levels (1:2 year return period). During field visits to the area and in the public seminar at Sunamganj local people requested that their boro crops be protected. Nainda Haor is a separate unit and pre-monsoon protection of boro crops would have little adverse impact on adjacent areas. The project was studied at pre-feasibility level and is presented in Chapter 8.

Table 6.3: Area Flooded by Depth Category (Nainda Haor)

Flood Condition	Return Period	Flooded Area (ha)				
		0.3-0.9m	0.9-18m	>1.8m	Total	%
Pre-monsoon	1:2	2288	830	970	4088	51
Monsoon	1:2	1820	1506	4088	7414	92

6.2.4 Dhalai Gang Development

The high sediment loads, large flood discharges and unstable nature of the Dhalai Gang fan constrain the types of water resource developments that are appropriate on the fan. For example, confining the channel within narrow embankments is unlikely to be feasible or desirable due to the high maintenance that would be required and the magnitude of downstream sediment impacts that would be incurred. Furthermore, it is clear that any future developments on the fan will require careful monitoring and ongoing channel maintenance to prevent local problems from developing into major channel changes. Given these considerations, concepts were developed for two main areas on the Dhalai Gang fan:

- the middle portion of the fan between the current avulsion site near Rautir Haor and Companiganj; and
- the outlet channel of the fan from Companiganj to its junction with the Surma River.

Three options were considered for controlling future channel instability and sedimentation along the middle reach of the Dhalai Gang. These are:

- *Channel Maintenance and Upstream Channel Control*: dredging the former main channel to restore its conveyance and providing river training structures to deflect flows away from the newly formed avulsion channel;
- *Full Closure of Avulsion Channel*: closing the avulsion completely to monsoon flood spills and return all of the flow to the Dhalai Gang channel.
- *Partial Closure of Avulsion Channel*: constructing a low weir across the newly formed avulsion channel just below its bifurcation point to reduce pre-monsoon flood spills and to prevent further flow capture from the main channel. Some dredging and river training would also be carried out on the main channel to restore its conveyance.

These three options are described below.

Channel Maintenance and Upstream Channel Control

The objective of this option is to improve the dry season flow conditions in the original Dhalai Gang channel to improve navigation between the apex of the fan and Companiganj. There are also some associated drainage improvements.

Approximately one kilometre of the old main channel would be excavated along its western side (Figure 10). This would divert part of the flow away from the entrance to the newly formed avulsion channel and maintain low flows in the former main channel that extends down to Companiganj. Additional flow control could be achieved by constructing a series of spurs on the left bank, upstream of the existing bifurcation to deflect high flows away from the entrance to the avulsion channel. This would force more of the flow into the main channel and would reduce the rate of growth of the newly formed avulsion channel. It is expected that after a period of a few years the avulsion channel would gradually silt in and carry less flow than at present. During this period, ongoing sediment deposition in the reach upstream of Companiganj could require periodic channel re-excavation, otherwise the river would try to shift out of its course again.

This scheme would increase the amount of flow carried by the old main channel but would still allow water and sediment to pass down the new avulsion channel, particularly during the first few years after the work was completed. Division of the dry season flows between two channels could result in neither channel having adequate depths for boats to operate. Therefore, this option could actually worsen the existing situation in some years and hence the concept was not studied further and is not presented in this report.

Full Closure of Avulsion Channel

This option would divert the entire flow of the Dhalai back into the old Dhalai Gang channel by closing the avulsion channel with a dam a short distance below the bifurcation point. The Dhalai Gang would also have to be re-excavated over a distance of about 4 km upstream of Companiganj.

The main benefits of this concept would be improved navigation and flood protection along the present avulsion channel. The main problem with this concept is that flood flows would be confined into the Dhalai Gang which in the long-term, may not have the hydraulic capacity to carry all of the incoming flow. Closing off the new channel completely could induce higher flood levels along the Dhalai Gang and increased erosion in the vicinity of Companiganj. Furthermore, ongoing aggradation or other channel changes on the Dhalai could lead to a new avulsion on the main channel, which would cause the closure to be by-passed. This would eliminate any benefits of the scheme. Based on these considerations, it was concluded that a complete closure of the avulsion channel would not be desirable at this time.

Partial Closure of Avulsion Channel

This concept involves constructing a submersible weir across the avulsion channel to divert the low flows during the dry season back into the old Dhalai Gang channel. The structure, which would be submerged during the monsoon season, would also limit the amount of flow and sediment that could spill down the new channel. Therefore, it would prevent further progression of the avulsion and reduce sediment inflows to Rautir Haor. By apportioning flood flows between the two channels, this scheme would reduce the intensity of flooding near Companiganj and reduce the risk of future channel avulsions. The scheme would require re-excavation and channel stabilization measures along the old Dhalai Gang channel over a distance of about 4 km

from just upstream of the bifurcation point to near Companiganj. This scheme is described in more detail in Chapter 9.

Flow Control Downstream of Companiganj

There is one further option for flow control and this is in the lower reaches of the Dhalai Gang downstream of Companiganj. Here the flow of the Dhalai Gang can be conveyed to the Surma River by three different routes:

- total flow through Teli Khal;
- total flow diverted through a re-excavated Old Piyain River channel;
- flow distributed between the two channels;

The hydraulic gradient between Companiganj and Chhatak during average pre-monsoon floods and monsoon floods are 1.3 m and 0.9 m respectively. These figures suggest that faster drainage could be achieved by re-excavating the Old Piyain River channel just below Companiganj. A preliminary analysis indicated about 3,600 ha of land could be made flood-free during the pre-monsoon season. However, the volumes of material that would have to be excavated to re-open the Old Piyain channel are expected to be very large. At present there is no survey data available to estimate these quantities precisely. Order of magnitude calculations using existing cross sections from SWMC and Regime Theory calculations indicate that volumes of around 1.3 million m^3 would be required to provide a channel that could carry 250 m^3/s and over 5 million m^3 would have to be removed to pass 1000 m^3/s. The area required for spoil material from this excavation would also be large. Furthermore, since the land near the river banks is densely populated it may be difficult to organize the disposal operations. It is unlikely that the spoil could simply be dumped on cultivated land since it contains a substantial amount of sand, which would make the land unsuitable for cultivation. Therefore, re-opening the Old Piyain channel has not been considered further in this investigation. Instead, it has been assumed that the main flow will continue to be passed down Teli Khal and into the Piyain River.

7. PROPOSED RAUCHUNNI BEEL PROJECT

7.1 Rationale

This plan provides for full flood control embankments and improved drainage. It will increase the total flood-free gross cultivable area from 400 ha to about 1,900 ha, an increase of 1,500 ha. The plan also provides low height embankments for beel bunding to increase the dry season surface area by about 30 ha for the fishery resources. Roads and homesteads located within the project area and to the south of the Sarighat-Goyainghat road will be protected from river flooding (Figure 12).

7.2 Objectives

The objectives of the proposed project are:

- to reduce flood damage to boro rice and monsoon crops;
- to promote expansion of HYV rice onto lower lands by reducing flood depths, improving internal drainage, and reducing risk of early flooding;
- to promote expansion of fishery resources by increasing the dry season surface area by constructing low height dikes around the large permanent water bodies and installing regulating structures; and
- to reduce flood damage to homesteads and infrastructure.

7.3 Description

The proposed project includes protection of flooding from the Sarigoyain River from Sarighat to Goyainghat by providing a full flood embankment to prevent over bank spill. Two drainage regulators are proposed. One regulator is at the outlet of the main drainage channel below Birbirighat and will prevent flooding before the boro harvest, and will allow flood water with spawn and fingerlings to enter the area after harvest. The second drainage structure is at Hadir Khal and will allow free passage for fish from the Sarigoyain River to Rauchunni Beel and other beels. Low height embankments are provided around these beels to increase the dry season water surface area. Project drainage is improved by re-excavating the existing drainage channels (Figure 12). The project components are:

- 19.5 km of full flood embankment
- 6 km of low dikes
- 2 drainage regulators
- 3 inlet pipes
- re-excavation of 24 km of drainage channels

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7.3.1 Flood Protection

Embankments

Both full flood and submersible embankments were investigated. The average heights for full flood and submersible embankments are 3 m and 2 m, respectively (Table A.10). The capital costs for submersible embankments are about Tk.9 million lower than that for full flood embankments. However, the Sarigoyain River is a flashy river with high peak velocities, and submersible embankments would be subject to severe erosion and high annual maintenance costs. Full flood protection would provide protection to roads and infrastructure and is expected to reduce flooding to the south of the Sarighat-Gowainghat road. For the proposed project, full flood embankments were considered more appropriate.

Table 7.1: Design Embankment Crest Elevations

Locations	Section (km)	Crest Level (m PWD)
Sarigoyain River		
Sarighat	0.0	14.96
Hadir Khal Offtake	6.0	14.50
Goyainghat	27.5	13.0

The proposed full flood embankments along the Sarigoyain River are designed for a 1:20-year return period flood. The proposed height of the embankment is about 3 m. The embankment design section has a 4.27 m crest width, with side slopes of 1(V):2(H) and 1(V):3(H) on the country and river sides, respectively. Design crest elevations are shown in Table 7.1. Details are given in Table A.10.

The proposed intervention reduces the flood depths during the pre-monsoon and monsoon seasons by 1.25 m and 0.90 m, respectively, for an average year (Table 6.2). Changes in flood-free land due to the reduced flood levels are given in Section 7.3.4.

7.3.2 Drainage

Following completion of the project, the drainage requirements of the area will be greatly reduced since the present flood spills from the Sarigoyain River will be eliminated, and the outflow discharge will be smaller.

The proposed drainage system includes: improvements to the main drainage channel, Lain Khal, re-excavation of lateral khals, and some minor improvements to the existing natural drainage system of khals and beels.

Channels

The improvement works of the Lain Khal include about seven kilometres of re-excavation from its offtake at Hadir Khal to its outfall at Sarigoyain River.

To eliminate water logging and to improve local drainage, it is proposed to re-excavate about 17 km of lateral khals: Hadir Khal, Bekra Nadi, Tilagati Khal and so on. Hadir Khal will also be used for flushing and spawn entry to adjacent beels.

The design parameters of the main channel are: 1(V):1(H) side slopes; a single slope bed with elevation 2.50 m PWD at the outfall and 4.60 m PWD at the offtake from the Hadir Khal; and a bed width varying from five meters at the offtake to about ten meters at the outfall. The channel is designed to convey the annual flood flow generated by a 5-day basin rainfall with a 1:10-year return period.

7.3.3 Structures

Regulators
Two new regulators and three inlet structures are proposed. The two regulators are: an eight-vent (1.5 * 1.8 m) flushing cum drainage regulator at Lain Khal outfall, and a one-vent (1.5 * 1.8 m) flushing regulator at Hadir Khal. Both regulators will facilitate fish movement. The three inlet structures will connect three beels with Hadir Khal and provide for fish movement.

7.3.4 Expected Benefits

The benefits expected from the project mainly relate to agriculture. The present cropping patterns and the corresponding yields and production are given in Tables 7.2 and 7.3.

Changes in land type and flooding for the pre-monsoon and monsoon seasons (Tables 7.4 and 7.5) are expected to lead to changes in areas under different cropping patterns as shown in Table 7.6. The increase in area under F0 and F1 land types is expected to lead to an increase in the area under local and high yielding varieties of aman rice with a corresponding reduction in area under b aman. Assuring farmers of a safe harvest would also result in some local boro being converted into hyv boro.

Table 7.2: Present Cropping Patterns for Rauchunni Beel (Unit XI)

Cropping Pattern	F0		F1		F2		F3		Total
	ha	%	ha	%	ha	%	ha	%	ha
b aman - fallow					225	75	182	10	407
fallow - fallow - l boro					0	0	1643	90	1643
fallow - hyv boro	0	0	0	0	30	10	0	0	30
b aus - potato	0	0	40	10	0	0	0	0	40
b aus - fallow - rabi	0	0	80	20	0	0	0	0	80
b aus - lt aman	36	40	280	70	0	0	0	0	316
b aus - hyv aman	54	60	0	0	0	0	0	0	54
b aman - rabi	0	0	0	0	45	15	0	0	45
Total	90		400		300		1825		2615

Table 7.3: Present Crop Production

	Damage free area			Damaged Area			Total
Crop	ha	mt/ha	mt	ha	mt/ha	mt	mt.
b aus	490	1.25	612	0	0	0	612
b aman	202	1.75	354	250	1.45	362	716
lt aman	316	2.15	679	0	0	0	679
hyv aman	54	3.95	213	0	0	0	213
l boro	642	2.25	1445	1000	1.75	1750	3195
hyv boro	30	4.55	136	0	0	0	136
Total Rice			3439			2112	5551
potato	40	12	480				
pulses	19	0.85	16				
oilseeds	62	0.75	47				
spices	6	2.25	14				
vegetables	37	3.75	140				

Protection from floods (both flash floods and seasonal floods) would reduce the damage to the different varieties of rice. Projected crop production has been estimated assuming that the yields presently being obtained in flood free areas would be obtained under similar flood free conditions for the future with-project scenario (Table 7.7).

The agricultural production and per capita consumption resulting from these agricultural changes are presented in Section 7.8, Evaluation.

7.3.5 Mitigation Measures Incorporated

To minimize negative impacts on fisheries, two regulators and three inlets are proposed. One regulator is located at the outfall of Lain Khal and would permit fish movement into Chunni Beel complex. Immediately after harvesting boro crops, the regulator would be opened to maintain, as far as possible, the natural water regime both for fishery and the various wetlands in the western part of the project area. In the eastern area, natural water movement between the Sarigoyain River and the three beels will be maintained by flows through Hadir Khal regulator and the three inlet structures. These proposed structures along with beel bunding will also increase the dry season water surface area in the beels and consequently increase fishery resources.

7.4 Project Operation and Maintenance

The operational requirements of the project will be minimal since the project is aiming only to provide controlled flooding. Operation requirements would mainly be to open and close the flushing/drainage regulators. Maintenance of the flood embankments and the drainage channels would be required to assure effective flood control and drainage. An Environmental Management Plan, detailing actions necessary to achieve acceptable environmental impacts, will need to be prepared and costed as part of the feasibility study.

Table 7.4: Pre-Monsoon Depth of Flooding
(by 1:2 Year Flood before 15 May)

Flood Depth (m)	Gross Area (ha)	
	Pre-Project	Post-Project[a]
0.00-0.30	1100	1900
0.30-0.90	600	700
0.90-1.80	800	600
>1.80	700	0
Total	3200	3200

[a] These figures do not reflect cultivable land acquired for infrastructure. Production impacts of land acquisition are documented in the Evaluation section.

7.5 Organization and Management

During the early part of the feasibility study process, a client group would need to be organized to oversee project development. The client group would be composed of representatives from the local farming community, fishing community, and would include relevant thana-level technical officers. The group would ensure that the problems of the area are clearly understood and adequately reflected in the feasibility work and that the technical solutions being proposed address the problems in an acceptable manner. .

Table 7.5: Monsoon Depth of Flooding
(by 1:2 Year Max Annual Flood)

Flood Depth (m)	Gross Area (ha)	
	Pre-Project	Post-Project[a]
0.00-0.30	400	1900
0.30-0.90	400	700
0.90-1.80	300	600
>1.80	2100	0
Total	3200	3200

[a] These figures do not reflect cultivable land acquired for infrastructure. Production impacts of land acquisition are documented in the Evaluation section.

BWDB would be responsible for undertaking technical work related to implementation of the project in accordance with current practice but would be responsive to the client group described above. The general tasks include completion of final designs, preparation of tenders, pre-qualification of contractors, contract awards and construction supervision. The general management of BWDB activities would be under the Executive Engineer stationed in Sylhet. Construction supervision would be carried out by sub-divisional field staff.

Table 7.6: Projected Cropping Patterns (ha)

Cropping Patterns	F0	F1	F2	F3	Total
fallow - l boro	0	0	309 (95)	0	309
fallow - hyv boro	0	630 (90)	16 (5)	0	646
b aus - potato	79 (5)	0	0	0	79
b aus - fallow - rabi	159 (10)	70 (10)	0	0	229
b aus - lt aman	239 (15)	0	0	0	239
b aus - hyv aman	239 (15)	0	0	0	239
lt aman - fallow	159 (10)	0	0	0	159
lt aman - hyv boro	398 (25)	0	0	0	398
hyv aman - hyv boro	318 (20)	0		0	318
l boro - fallow					
Total	1590	700	325	0	2615

Notes: Numbers within parenthesis indicate percent of cultivated area under the relevant land type
Areas are net cultivable area.

Table 7.7: Projected Crop Production

Crop	Area (ha)	Yield (t/ha)	Production (t)
b aus	785	1.25	982
lt aman	795	2.15	1709
hyv aman	556	3.95	2198
l boro	309	2.25	695
hyv boro	1362	4.55	6196
Total Rice			11780
potato	79	12	954
pulses	34	0.85	29
oilseeds	114	0.75	86
spices	11	2.25	25
vegetables	69	3.75	258

The Department of Agricultural Extension (DAE) is responsible for the provision of extension services to the farmers within the project. Bangladesh Rural Development Board (BRDB) is responsible for assisting with command area development through farmers' training and by organizing farmers into cooperatives which will then have access to short term crop production loans. Medium term credits are available to these cooperatives from all nationalized banks.

7.6 Cost Estimates

Total project costs are estimated at Tk 94.2 million.

The estimates of land requirement and physical works are based on preliminary designs and lay-out plans prepared using four inch to one mile topographic maps, and historic hydrological data.

Land costs reflect the current prices obtained from field interviews: land which was single cropped was estimated at Tk 120,000/ha; land that could be double cropped was Tk 300,000/ha; and, land suitable for homesteads and gardens (including high ridges along the rivers) was Tk 500,000/ha. Earthwork costs are based on BWDB Schedule of Rates for Sylhet indexed to June 1991 prices. Structure costs are based on parametric costs developed for the Region, also indexed to June 1991 prices in accordance with the FPCO Guidelines for Project Assessment.

The summary of total costs is presented in Table 7.8 with details provided in Table A.11.

Table 7.8: Capital Cost Summary

Item	('000 Tk)
Structures	15,700
Embankments	21,200
Channels	10,600
Land Acquisition	18,000
BASE COST	65,500
Physical Contingencies (25%)	16,400
SUBTOTAL	81,900
Study Costs[1] (15%) of Subtotal	12,300
TOTAL	94,200
Net Area (ha)	2615
Unit Cost (Tk/ha)	36,023

[1]Includes preparation of EIA and Environmental Management Plan.

7.7 Project Phasing and Disbursement Period

Three years are required to implement the project. One year (year zero) is required for completion of feasibility studies and conducting field surveys. Preparation of detail designs should start in year zero and be completed in year one. Land acquisition should commence in year one, be implemented in phases preceding construction, and completed in year two. Construction activities should start in year one and be completed in year three. An itemized implementation schedule is shown in Table 7.9.

7.8 Evaluation

7.8.1 Environmental

The key areas of environmental impact for this project are described briefly below. Additional information is given in Annex C, Initial Environmental Evaluation.

Table 7.9: Implementation Schedule

Activity	Year (% Completion)			
	0	1	2	3
Preconstruction Activities				
Feasibility Study	100			
Engineering Investigation	100			
Detail Designs	60	40		
Land Acquisition		50	50	
Construction Activities				
Construction of Embankments		20	60	20
Excavation of Channels		20	50	30
Construction of Structures		20	50	30

Land Use

Land use changes are summarized in Table 7.10. A total of 60 ha of land (about 1.9% of the project gross area) will be required for embankments, regulators and so on. Of this:

- 42 ha will be taken from the cultivated area. Assuming average yields and that this is all under rice, this corresponds to incremental cereal production foregone of about 84 tonnes per year or about 6% of total incremental cereal production.

- 10 ha will be taken from winter floodplain wetland areas. These are mostly producing reeds and grasses worth roughly Tk 800 ha^{-1}, which means a total wetland production foregone of Tk 8,000 per year. Employment in wetland gathering is about 4.0 pd ha^{-1}, which means employment foregone of 40 pd yr^{-1}.

Table 7.10 Changes in Land Use

Use	Present Area (ha)	Change in Area (ha)
Cultivated	2615	-42
Homesteads	60	-8
Beels	240	-
Ponds	23	-
Channels	35	-
Hills	0	-
Fallow[1]	200	-10
Infrastructure[2]	27	-

[1] Multi-use land, wetlands, grazing lands, village grounds.

[2] Government-owned land not appearing elsewhere.

- Eight hectares will be needed from homestead area. River bank homesteads are located above the high flood level. Therefore, embankments will be connected to these high homestead lands. There will be no displacement of homesteads.

Table 7.11: Indicators of Food Availability
(grams/person/day)

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	1316	2391	1772	848
Non-Cereals	165	273	202	105
Fish	51	33	24	32

Agriculture

The project is expected to facilitate annual cereal production to increase from about 5,640 tonnes (FWO) to about 11,780 tonnes (FW), an increase of 6,140 tonnes (109%), inclusive of the impacts of land use changes described above.

The cereal production increase implies a per person increase in cereal availability from 848 (FWO) to 1,772 (FW) gm per person per day, an increase of +109% (Table 7.11), allowing 10% for seed, feed, and waste, and 65% for conversion of paddy to rice. Current Bangladesh average consumption is 440 gm per person per day.

Non-cereal production is expected to increase from 699 tonnes (FWO) to 1,346 tonnes (FW) (+92%). This results from a 145 ha increase in area cultivated to non-cereals from 165 ha to 310 ha and implies an increase in the availability of non-cereals from 105 to 202 grams per person per day (Table 7.11).

Openwater Fisheries Production[1]

The project is expected to impact on fisheries in four ways: some improvement to migration routes, the floodplain will be reduced, the depth of the main drainage channels will be increased, and the dry season water surface area will be increased. The sign and magnitude of these impacts is provided in Table 7.12.

The flood control infrastructure will reduce the floodplain fishery habitat of the project by about 1,500 ha (59%). Production will decrease to a future with-project level of 66 tonnes per year.

Beel fisheries will increase. The dry season water surface area will be increased (by about 30 ha) by constructing low height embankments and fish inlet structures around the main beels (Rauchunni complex). Silt deposition in the beels will be reduced substantially.

[1] The model used to estimate impacts on fisheries is described in Annex D.

Table 7.12: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production ('000 kg)	Area (ha)	Area Equivalent	Production Impact ('000 kg)	Net Value ('000 Tk)
Flood Plain	2525	111	1025	1025	-66	-2173
Beels	240	98	270	270	+12	+735
Channels /River	35	6	42	42	+1	+79
Net Project	2615	215	2615		-53	-1359

The increase in depth of the main drainage channels will have a positive impact on fisheries production since it will improve the overwintering habitat and provide better migration routes. Channel re-excavation will improve the water linkage with Sarigoyain River and increase dry season water depth.

It is expected that the project will promote some expansion of aquaculture.

The total annual openwater fisheries production impact is -53 tonnes, which is 24.6% of the FWO annual production of 215 tonnes. This implies a decrease in openwater-source fish availability per person due to the project from 32 (FWO) to 24 (FW) gm per person per day (Table 7.11).

Homestead flooding
Homestead flood damage would be significantly reduced. Due to the lack of historical data on flood damage costs, a simple model was used to estimate future costs. There are about 2,270 homesteads in the area, and the average plinth level is at about the 1:5 year flood level. About 20% of homesteads are affected by flooding of 20-30 cm in the 1:10 to 1:20 year floods. The estimated annualized economic value of reduced flood damage is Tk 180,000.

Wetland Habitats and Grazing Area
Impacts are difficult to quantify, but a general impression is given by Table 7.13 which shows the impact on:

- "Winter grazing area". Defined as F0, F1, and F2 lands that lie fallow in the dry season (winter) plus any perennially-fallow highlands. This land would have limited residual moisture. While it is clear that animals do graze on such areas, productivity per unit area is not known.

- "Winter wetland". Defined as F3 land that lies fallow in the dry season, plus any perennially-fallow lowland (F4), beel, and channel areas. This land would likely have considerable residual moisture and could support a range of wetland plant communities.

- "Summer wetland". Defined as F1, F2, and F3 land that lies fallow in the summer, plus perennially-fallow lowland (F4 area), beel, and perennial channel areas. This land would be inundated to >0.3 m and would support submerged, free-floating, rooted floating, and sedge or meadow plant communities.

The impact of the project would be to increase winter grazing area by 7%, decrease winter wetland area by 30%, and decrease summer wetland area by 34%.

Economic and employment impacts of the project on wetland plant and animal production can only be roughly estimated. Assuming an annual economic production of Tk 100 per hectare for both summer and winter wetland areas gives a total annual loss of Tk 93 thousand per year. Assuming 2.0 pd (ha yr)$^{-1}$ for harvesting, the employment impact would be -1856 pd per year.

Table 7.13: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	90	637	+547	
sc/wf F1	280	0	-280	
sc/wf F2	225	0	-225	
Fallow Highland	10	10	0	
Total	605	647	42	+7

Land Type	Winter Wetland			
sc/wf F3	182	0	-182	
F4, Beel, Channel	465	455	-10	
Total	647	455	-192	-30

Land Type	Summer Wetland			
wc/sf F1	0	630	+630	
wc/sf F2	30	325	+295	
wc/sf F3	1643	0	-1,643	
F4, Beel, Channel	465	455	-10	
Total	2,138	1,410	-728	-34

FW areas shown here do not reflect cultivable land acquired for infrastructure (see Land Use, Section 7.8.1). 'sc' - summer cultivated. 'wc' - winter cultivated. 'sf' - summer fallow. 'wf' - winter fallow.

Transportation/navigation

Transportation along the northern periphery of the project area will be transformed from navigation based to road based.

The total length of existing main roads in the project is about 36 km of which 10 km is inundated every year. The project would make these roads flood-free (up to 1:20 year flood). Assuming a capital cost of Tk 190,000/km and 15% flood damage, the annual benefit of flood protection is Tk 376,200.

Higher Sarigoyain flood levels

Sarigoyain flood levels at Sarighat and down stream could increase by not more than 5-10 cm. This small increase in flood levels will have little impact on the area outside the project as most of the area is fallow or reed lands. However, the project will have substantial positive impact to the south of Sarighat-Goyainghat road. Water levels in this area are expected to decrease by about 0.3 m during the monsoon season and this will have a positive impact on aus and aman production, and homesteads. These benefits have not been included in the project analysis.

7.8.2 Social

The key areas of social impact (or lack thereof) for this project are described below.

Employment

There will be an overall increase in employment of 0.16 million person-days per year. This is composed of:

- an increase in owner-labour employment of +0.153 million pd yr^{-1}, of which very roughly 20% is post-harvest processing activities traditionally done by women of the household. This increase is partly enhanced by . . .

- an net increase in employment opportunities for landless people of 0.007 million pd yr^{-1}, composed of changes in the following areas:

  - Agricultural hired labour: +0.114 million pd yr^{-1}, of which about 10% is for post-harvest processing traditionally done by women hired in (mainly by larger farmers) for this purpose.

  - Fishing labour: -0.105 million pd yr^{-1}; in addition to this, there would be a corresponding loss in support activities such as net-making and post-catch processing (mainly drying) much of which is done by women.

  - Wetland labour (gathering wetland products): Negligible (0.002 million pd yr^{-1}). Fodder and building material is gathered mainly by men. Food, fuel, and medicine is gathered mainly by women.

Displacement impacts due to land use changes

There are no displacement impacts for the project.

Conflicts

Improved drainage will encourage farmers to extend cultivation further into the deeper parts of Rauchunni Haor complex. This will bring farmers into conflict with fishermen who will find the fishing area reduced. This conflict will affect the way the regulator is operated and will have a direct bearing on the extent to which some of the crop production benefits are realized.

Equity

The net equity impact would appear to be somewhat *regressive*. Who benefits?

- Landowners, in proportion to landholdings, benefit directly from investment in agriculture production. This is the main benefit of the project and its distribution is somewhat *regressive*.

- Residents, living within and outside the project area will get direct benefit due to protection of homesteads. *Progressive*

- Residents, living within the project area will have better health and communication. *Progressive*.

Who loses?

- Families dependent upon fishing labour. These families are mainly landless and tend to be poorer than average. *Regressive.*

- Families involved in gathering wetland products. These families are mainly landless and tend to be poor. This is also true even without the project as wetlands are decreasing due to siltation. *Regressive.*

Gender Equity

The net equity impact would appear to be somewhat *progressive*. Employment opportunities for women will increase in all categories except wetland gathering. Reduced homestead flood damage will disproportionately favour women, given that most women still spend most of their lives within the homestead.

Qualitative Impact Scoring

The qualitative criteria shown in Table 7.14 are scored on an 11 level scale of -5 to +5. Scoring of those criteria that are impacts (some are not, like "responds to public concerns") is shown in Table 7.16. The scoring procedure is analogous to that used in the FAP 16 EIA case studies, but simplified to eliminate half-point scores (1.5, 2.5, 3.5, etc). Here, each score sums across five equally weighted logical (true/false) criteria, with each "true" counting for a value of one and each "false" for zero. The sign reflects whether the impact is positive or negative.

Table 7.14: Qualitative Impact Scoring

		True=1 False=0					
Qualitative Impact	Impact Sign	Sensitive	Magnitude	Immediate	Sustainable Pos Impact/ Irreversible Neg Impact	No Mitigation Required/ Possible	Score
Ecological Character of Rauchunni Beel	-1	0	0	0	0	0	0
Regional Biodiversity	-1	0	0	1	1		-2
Road Transportation	1	1	1	1	1	1	5
Navigation	-1	0	0	1	0		-1
Flood Levels Outside Project Area	+1	1	0	0	0	0	+1
Conflicts	-1	1	1	0	0	0	-2
Socioeconomic Equity	-1	1	0	1	1	1	-4
Gender Equity	1	1	0	0	1	1	3

7.8.3 Economic

The project has an economic rate of return of 35%, which compares well to the required rate of 12% as prescribed by government. It is a relatively low investment project, at about Tk 94 million or Tk 36,000 per hectare, and covers a small geographic area (3,200 ha gross). The rate of return, however, is quite sensitive to increases in capital costs (a 20% increase in capital costs would reduce the rate of return to 30%). The other sensitive variable is the timing of the benefits, and a delay in benefits by two years would reduce the ERR to 23%.

The foreign costs associated with the project are low, at 7% (excluding FFW contributions), making it a relatively small project from a donor perspective. Donor funding considerations would clearly need to include funding local costs.

Almost all of the benefits of the project relate to increased rice production, mostly as a result of shifts from b aman to lt aman and from l boro to hyv boro. Average crop yields would increase as a result of reduced flood damage, and cropping intensity would increase by 40%. Non-cereal production would increase by 92%. Floodplain fish production would fall to about 25% of future-without-project production. The value of the lost fisheries output amounts to about 4% of the value of increased agricultural output. Less than 1% of project benefits would result from reduced homestead and roads flooding in each case. But it does not includes homestead located in the south of Sarigoyain-Sarighat road. A summary of salient data in provided in Table 7.15.

It is anticipated that the established crop marketing system will handle incremental crop production without any reduction in prevailing average price levels. Assuming the current annual growth in the demand for grain remains about 3%, the increased cereal production is unlikely to present any marketing difficulties.

7.8.4 Summary Analysis

From a multi-criteria perspective (Table 7.16), the project is neutral.

The positive aspects of the project would be:

- The rate of return is acceptable.
- There is a substantial increase in rice production.
- There are increased economic returns to land owners.
- There is a Reduction in flood damage to homesteads and roads.
- Flood damage to monsoon crop outside the project area in the south is reduced.
- There is an increase in non-cereal production.
- Gender equity of impacts is somewhat progressive.
- The Project responds to some public concerns.

The negative aspects of the project would be that:

- Conflicts between farmers and fishermen would increase.
- Flood levels would increase by about somewhat.
- The project has a high dependency on central government for implementation.
- There is only a marginal increase in employment.
- The project results in a significant decline in fish production.

Table 7.15: Summary of Salient Data

Economic Rate of Return (ERR)	35			
Capital Investment (Tk million)	94			
Maximum O+M (Tk million / yr)	3			
Capital Investment (Tk/ha)	36006			
Foreign Cost Component (%)	7			
Net Project Area (ha)	2615			
Land Acquisition Required (ha)	60			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	25			
Cropping Intensity		1.2	1.2	1.6
Average Yield (tonnes/ha)		2.0	2.0	3.2
Average Gross Margins (Tk/ha)		11069	11307	15819
Owner Labour (md/ha)		118	118	128
Hired Labour (md/ha)		28	28	49
Irrigation (ha)		113	113	1521
Incremental Cereal Prod'n (' 000 tonnes / yr)	6			
Incremental Non-Cereal (' 000 tonnes / yr)	1			
Incremental Owner Labour (' 000 pd / yr)	153			
Incremental Hired Labour (' 000 pd / yr)	114			

FISHERIES IMPACTS		Flood plain	Beels	Spawning Channel
Incremental Net Econ Output (Tk million / yr)	-0.95	-1.51	+0.51	+0.05
Impacted Area (ha)		1500	0	0
Average Gross Margins (Tk/ha)		1540	28700	12250
Remaining Production on Impacted Area, %		50%	100%	100%
Incremental Fish Production (tonnes / year)	-53	-66	+12	+1
Incremental Labour ('000 pd / yr)	-105	-110	+4	+1

FLOOD DAMAGE BENEFITS				
Households Affected		454		
Reduced Econ Damage Households (Tk M / yr)	0.18			
Roads/Embankments Affected -km		10		
Reduced Econ Damage Roads (Tk M / yr)	0.20			

OTHER IMPACTS				
Wetland Incr Net Econ Output (Tk million / yr)	0.093			
Wetland Incremental Labour ('000 pd / yr)	-1.8			
Acquired Cult & Homestead Lands, Incr Net Econ Output (Tk million / yr)	0.8			
Persons Displaced by Homestead Acquisition	0			

Table 7.16: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	35
EIRR, Increase Capital Costs by 20%	per cent	30
EIRR, Delay Benefits by Two Years	per cent	23
Net Present Value	Tk	83,797

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	6140	109
Incremental Non-Cereal Production	tonnes	647	92
Incremental Fish Production	tonnes	-53	25
Change in Floodplain Wetland/Fisheries Habitat	ha	1500	59
Homesteads Displaced Due to Project Land Acquisition	homesteads	-	-
Homesteads Protected From Floods	homesteads	454	20
Roads Protected From Floods	km	10	38
Sarigoyain Flood Levels	m PWD	0.05-0.10	-
Owner Employment	million pd/yr	0.153	41
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	0.007	2.3

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	**Rank**
Regional Biodiversity	-2
Road Transportation	+5
Navigation	-1
Flood Levels Outside Project Area	+1
Conflicts	-2
Socioeconomic Equity	-4
Gender Equity	+3
Decentralized Organization and Management	-3
Responds to Public Concerns	+5
Conformity to Regional Strategy	+1

[1] Percent changes are calculated relative to future-without-project values of: total production of cereal, non-cereal, and fisheries; total floodplain area; total number of homesteads (for displacement due to land acquisition); flood-affected homesteads; flood-affected roads; Sarigoyain water level; and total employment for owners and hired labourers.

[2] Includes incremental production foregone due to acquisition of cultivated land.

8. PROPOSED NAINDA HAOR PROJECT

8.1 Rationale

This plan provides for partial flood control embankments and improved drainage. It will protect boro crops over a gross area of 8,070 ha from pre-monsoon flash floods up to 15 May. The plan also provides compartmental bunds (low height embankments) to retain water during the post-monsoon season for irrigation use, and to distribute the accumulated rainfall into two units to reduce the depth of inundation (Figure 13).

8.2 Objectives

The objectives of the Nainda Haor Partial Flood Control and Drainage Project are:

- to reduce flood damage to boro crops;
- to promote expansion of HYV rice onto lower lands by reducing flood depths using the concept of compartmentalization, improving internal drainage, and reducing the risk of flooding before harvest.

8.3 Description

The proposed project includes the installation of drainage cum flushing regulators at the outfalls the Kaliuri Gang and Mirza Khal to prevent pre-monsoon flooding entering the project area from the Surma River. The right bank of the Surma River along the project boundary does not overtop before the harvest of boro crops. Moreover, there is an earthen road from Chhatak ferryghat to Dowarabazar. Reportedly, this embankment is not overtopped for an average year (1:2 year return period) during the monsoon season. Partial flood control embankments along the right bank of the Umium River (where required) would provide protection against pre-monsoon flooding.

The project also includes construction of compartmental bunds which will divide the project area into three smaller units and consequently reduce the depth of flooding due to accumulated rainfall. These compartmental bunds will follow the existing village road from Boet Kandi village to Baliura market and from Baliura market to Chhankhai village. The borrow pit along the right bank of the compartmental bund from Baliura to Chhankhai village will be used as a drainage channel for the third unit (Figure 13).

Drainage of the project area will be improved by re-excavating the existing drainage channels. The first compartmental unit will be drained through the Kaliura Gang; the second unit through Mirza Khal; and the third unit through the Shaheb Khal. Submersible embankments will be provided on both banks of the Shaheb Khal to protect boro crops from pre-monsoon floods. The outfall of Shaheb Khal will be kept open so that the third unit can be drained directly to the Surma River. The proposed development will also protect Holakar Haor area from upland

flooding. In addition, the plan includes improvement of the village road from Jaynagar to Naorai village to prevent spill from the third unit entering the second unit. Drainage from the Holakar Haor area will be accomplished through the installation of a pipe sluice. The project components are:

- 15 km of submersible embankment;
- 15 km of compartmental bunds;
- 2 drainage regulators;
- 2 pipe sluices; and
- re-excavation of 31 km of drainage channels

8.3.1 Partial Flood Protection

Submersible Embankments

Submersible embankments are proposed along the Umium River (wherever necessary) and Shaheb Khal for pre-monsoon flood protection. Embankments are designed for a 1:10-year return period flood. The required height of submersible embankment along both the Umium River and Shaheb Khal is about 2.5 m. The proposed embankment cross section has a 4.27 m crest width, with side slopes of 1(v):2(h) and 1(v):3(h) on the country and river sides, respectively. Design embankment crest elevations are shown in Table 8.1.

The required height of the compartmental bunds is about 2.5 m. The proposed bund cross section has a 3.66 m crest width, with side slopes of 1(v):2(h) on both sides.

8.3.2 Drainage

Following completion of the project, the drainage requirements of the area will be greatly reduced since the present flood spills from the Umium and Nawagang Rivers will be eliminated, and consequently the outflow discharge will be smaller. The existing natural drainage system of khals and beels with some minor improvements will be used for drainage of the project area. The project basin internal rainfall runoff will be evacuated through the main drainage collectors of the project: Kaliuri Gang, Mirza Khal, and the Shaheb Khal. The Kaliuri Gang and the Mirza Khal will be provided with regulating structures while Shaheb Khal will be left open for fish movement.

The improvement works include about seven kilometres of re-excavation in the lower reaches of Kaliuri Gang, about three kilometres of re-excavation in the lower reaches of Mirza Khal, and about six kilometres of re-excavation along Shaheb Khal from its outfall to Jaynagar village. To eliminate water logging and to improve local drainage, it is proposed to re-excavate about 15 km of lateral khals.

Table 8.1: Design Embankment Crest Elevations

Locations	Section (km)	Crest Level (m PWD)
Shaheb Khal		
At Surma River	0.0	8.86
Kachbari	2.5	8.86
Umium River		
Chhatak	0.0	8.86
Chelasonapur	10.0	11.4

The design parameters of the main channels are: 1(v):1.5(h) side slopes; a constant longitudinal bed slope with an elevation of about 3.0 m PWD at the outfall and about 5.10 m PWD at the offtake; and a bed width varying from 5-7 m at the offtake to about 12-15 m at the outfall. The channel is designed to convey the annual flood flow generated by 5-day basin rainfall with 1:10 year return period.

8.3.3 Structures

Two new regulators are proposed: one eight-vent (1.5 * 1.8 m) flushing cum drainage regulator at the Kaliuri Gang outfall; and one seven-vent (1.5 * 1.8 m) flushing regulator at Mirza Khal. There are two pipe sluices: one single vent (90 cm dia) flushing cum drainage pipe sluice at Holakar Haor (which connects to Shaheb Khal); and a single vent (90 cm dia) pipe sluice to drain local runoff from unit I (Figure 13).

8.3.4 Expected Benefits

The benefits expected from the project mainly relate to agriculture. The present cropping patterns and the corresponding yields and production are given in Tables 8.2 and 8.3. As a result of the flood protection measures, the depth of flooding will be reduced and the area of flood-free land will be increased (Table 8.4).

Protection from pre-monsoon flash floods will reduce the damage to rice crops. Projected crop production has been estimated assuming that the yields presently being obtained in areas free of damage would be obtained within the project area under with-project conditions. Areas under different crop types (FW), and projected crop production are presented in Table 8.5. Assuring farmers of a safe harvest will also result in increased yields and some local boro being converted to hyv boro.

Table 8.2: Present Cropping Patterns in Nainda Haor

Cropping Patterns	F0		F1		F2		F3		Total Area (ha)
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	
b aman - fallow					904	60	183	5	1088
fallow - l boro					226	15	3504	95	3730
fallow - hyv boro	0	0	0	0	151	10	0	0	151
b aus - potato	0	0	182	10	0	0	0	0	182
b aus - fallow - rabi	0	0	364	20	0	0	0	0	364
b aus - lt aman	142	60	1274	70	0	0	0	0	1416
b aus - hyv aman	94	40	0	0	0	0	0	0	94
b aman - rabi	0	0	0	0	226	15	0	0	226
Total	236		1820		1506		3688		7250

Table 8.3: Present Crop Production in Nainda Haor

Crop	Damage Free Area			Damaged Area			Total Prod (mt).
	Area (ha)	Yield (mt/ha)	Prod (mt).	Area (ha)	Yield (mt/ha)	Prod (mt).	
b aus	2056	1.25	2570	0	0	0	2570
b aman	264	1.75	462	1050	1.45	1523	1984
lt aman	1416	2.15	3044	0	0	0	3044
hyv aman	94	3.95	373	0	0	0	373
l boro	730	2.25	1641	3000	1.75	5250	6891
hyv boro	100	4.55	455	50	2.75	138	593
Paddy			8545			6311	14855
potato	182	12	2184				
pulses	89	0.85	76				
oilseeds	295	0.75	221				
spices	30	2.25	68				
vegetables	177	3.75	664				

The agricultural production and per capita consumption resulting from these agricultural changes are documented in Section 7.8, Evaluation.

8.3.5 Mitigation Measures Incorporated

To minimize the negative impact on fisheries, particularly in the Nainda Beel complex, regulators have been proposed for fish movement. These regulators would be located at the outfalls of the Kaliuri Gang and Mirza Khal.

Table 8.4: Pre-Monsoon Depth of Flooding
(by 1:2 Year Flood before 15 May)

Flood Depth (m)	Gross Area (ha)	
	Pre-Project	Post-Project[a]
0.00-0.30	3982	5100
0.30-0.90	2288	1670
0.90-1.80	830	700
>1.80	970	600
Total	8070	8070

[a] These figures do not reflect cultivable land acquired for infrastructure. Production impacts of land acquisition are documented in the Evaluation section.

Table 8.5 Projected Crop Production

Crop	Damage free area			Damaged area			Total Production. (mt)
	Area (ha)	Yield (mt/ha)	Production (mt)	Area (ha)	Yield (mt/ha)	Production (mt)	
b aus	2056	1.25	2570	0		0	2570
b aman	1314	1.75	2300	0		0	2300
lt aman	1416	2.15	3044	0		0	3044
hyv aman	94	3.95	373	0		0	373
l boro	3400	2.25	7650	0		0	7650
hyv boro	500	4.55	2275	0	3.25	0	2275
Total Rice			18210				18210
potato	182	12	2184				
pulses	89	0.85	76				
oilseeds	295	0.75	221				
spices	30	2.25	68				
vegetables	177	3.75	664				

Immediately after harvesting the boro crops, regulators will be opened to maintain the natural water regime both for fishery and the various wetlands in the southern part of the project area. In the third unit, to maintain a water linkage between the Surma River and the various wetlands, no structure is planned at the outfall of Shaheb Khal. This open link, in combination with the above two regulators, are expected to ensure that the integrity of the wetlands are maintained.

8.4 Project Operation and Maintenance

The operational requirements of the project will be minimal since the project is aiming only to provide partial flood protection. Mainly, requirements would be to open and close the flushing cum drainage regulators which are provided for fish passage and drainage. Maintenance of the submersible embankments and the drainage channels would be required to assure effective flood control and drainage. An Environmental Management Plan, detailing actions necessary to achieve acceptable environmental impacts, will need to be prepared and costed as part of the feasibility study.

8.5 Organization and Management

A client group would need to be organized to oversee project development. This client group and other organization and management aspects of the project would be similar to that for the Rauchunni Beel Project (see Section 7.5).

8.6 Cost Estimates

Total project costs are estimated at Tk 118.2 million.

Land costs, earthwork, and structure costs are indexed to June 1991 prices. The unit rates and cost estimating methodology are similar to that used for Rauchunni Beel Project (see Section 7.6).

The summary of total costs is presented in Table 8.6 with details provided in Table A.12.

8.7 Project Phasing and Disbursement Period

Three years are required to implement the project. One year (year zero) is required for feasibility studies and conducting field surveys. Preparation of detail designs should start in year zero and be completed in year one. Land acquisition should commence in year one, be implemented in phases preceding construction, and completed in year two. Construction activities should start in year one and be completed in year three. An itemized implementation schedule is shown in Table 8.7.

Table 8.6 Capital Cost Summary

Item	('000 Tk)
Structures	23,600
Embankments	21,600
Channels	15,500
Land Acquisition	21,600
BASE COST	82,300
Physical Contingencies (25%)	20,600
SUBTOTAL	102,800
Study Costs[1] (15% of Subtotal)	15,400
TOTAL	**118,200**
Net Area (ha)	7,250
Unit Cost (Tk/ha)	16,303

[1]Includes preparation of EIA and Environmental Management Plan.

Table 8.7 Implementation Schedule

Activity	Year (% Completion)			
	0	1	2	3
Preconstruction Activities				
Feasibility Study	100			
Engineering Investigation	100			
Detail Designs	60	40		
Land Acquisition		50	50	
Construction activities				
Construction of Embankment		40	60	
Excavation of Channels		30	50	20
Construction Of structures		20	50	30

8.8 Evaluation

8.8.1 Environmental

The key areas for this project are described briefly below. Additional information is given in Annex C1, Initial Environmental Evaluation.

Land Use
Land use changes are summarized in Table 8.8. A total of 72 ha of land (about 0.9% of the project gross area) will be required for embankments, drains, and regulators. Of this:

- 54 ha will be taken from cultivated area. Assuming average yields and that this is all under rice, this corresponds to incremental cereal production foregone of about 103 tonnes per year or about 3.5% of total incremental cereal production.

Table 8.8: Changes in Land Use

Use	Present area (ha)	Change in area (ha)
Cultivated	7250	-54
Homesteads	180	-
Beels	250	-
Ponds	60	-
Channels	150	-
Hills	152	-
Fallow[1]	10	-
Infrastructure[2]	18	+18

[1] Multi-use land, wetlands, grazing lands, village grounds.
[2] Government-owned land not appearing elsewhere.

- 18 ha will be required to develop compartmental bunds which will follow the existing village roads.

Agriculture
The project is expected increase annual cereal production from 14,855 tonnes (FWO) to 18,210 tonnes (FW), an increase of 3,325 tonnes (+22%), exclusive of the impacts of land use changes describe above.

The cereal production increase implies a per person increase in cereal availability from 462 (FWO) to 567 (FW) gm per person per day, an increase of about +23% (Table 8.9), allowing 10% for seed, feed, and waste, and 65% for conversion of paddy to rice. Current Bangladesh average consumption is 440 gm per person per day.

Non-cereal production remains the same (3212 tonnes) under either the with (FW) or without-project (FWO) condition.

Table 8.9: Indicators of Food Availability
(grams/person/day)

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	748	802	567	462
Non-Cereals	162	141	100	100
Fish	22	18	12	14

Table 8.10: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production ('000 kg)	Area (ha)	Area Equivalent	Production Impact ('000 kg)	Net Value ('000 Tk)
Flood Plain	7014	308.6	7014	6313	-30.9	-1016
Beels	250	102.5	300	270	+8.2	+490
Channels /River	150	26.3	165	149	-0.3	-17
Net Project	7250	437.4	7250		-23.0	-543

Openwater Fisheries Production[1]

The project is expected to impact on fisheries in three ways: some restriction to migration routes, the depth of the main drainage channels will be increased, and the dry season water surface area will be increased. The estimated future-without (FWO) production is assumed to be the same as the present condition. The FWO and the estimated FW productions and the magnitude of impacts (and sign) are provided in Table 8.10.

The area of the floodplain will remain the same but by restricting migration routes the flood control infrastructure is expected to reduce the overall floodplain fishery habitat by an amount equivalent to about 700 ha. About 30% of the project area will have an improved water linkage with the Surma River due to re-excavation of Shaheb Khal. The net decrease in floodplain production is estimated at about 31 tonnes per year.

The project is expected to have a positive impact on beel fisheries. The regulators will control post-monsoon drainage and increase the dry season water surface area. Under present conditions water drains from the beels up to March but with the regulators in place the gates would be closed in January and water levels in the beels would be maintained at a higher level.

The increase in depth of the main drainage channels will have a positive impact on fisheries production since it will improve the overwintering habitat. The project is not expected to have a negative impact on spawning or aquaculture.

The total annual openwater fisheries production impact is -23 tonnes, which is 5% of the FWO annual production of 437 tonnes. This implies a decrease in openwater-source fish availability per person due to the project from 14 (FWO) to 12 (FW) gm per person per day (Table 8.9).

[1] The model used to estimate impacts on fisheries is described in Annex D.

Homestead flooding
The project does not provide protection to homestead flooding.

Wetland Habitats and Grazing Area
Impacts are difficult to quantify, but a general impression is given by Table 8.11, which shows the impact on:

- "Winter grazing area". Defined as F0, F1, and F2 lands that lie fallow in the dry season (winter) plus any perennially-fallow highlands. This land would have limited residual moisture. While it is clear that animals do graze on such areas, productivity per unit area is not known.

- "Winter wetland". Defined as F3 land that lies fallow in the dry season, plus any perennially-fallow lowland (F4), beel, and channel areas. This land would likely have considerable residual moisture and could support a range of wetland plant communities.

- "Summer wetland". Defined as F1, F2, and F3 land that lies fallow in the summer, plus perennially-fallow lowland (F4 area), beel, and perennial channel areas. This land would be inundated to >0.3 m and would support submerged, free-floating, rooted floating, and sedge/meadow plant communities.

Table 8.11: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	236	200	-36	
sc/wf F1	1274	1256	-18	
sc/wf F2	904	904	0	
Fallow Highland	10	10	0	
Total	2,424	2,370	-54	-2

Land Type	Winter Wetland			
sc/wf F3	184	184	0	
F4, Beel, Channel	400	400	0	
Total	584	584	0	0

Land Type	Summer Wetland			
wc/sf F1	0	0	0	
wc/sf F2	377	377	0	
wc/sf F3	3504	3504	0	
F4, Beel, Channel	400	400	0	
Total	4,281	4,281	0	0

FW areas shown here do not reflect cultivable land acquired for infrastructure (see Land Use, Section 8.8.1). 'sc' - summer cultivated. 'wc' - winter cultivated. 'sf' - summer fallow. 'wf' - winter fallow.

The impact of the project would be to decrease winter grazing area by 2%. There will be no change in winter and summer wetland area.

Economic and employment impacts of the project on wetland plant and animal production is very difficult to quantify here, but overall impacts are expected to be very small. The project is not eliminating any plant community that would have economic value. More over, shallow flooding could increase the production of aquatic plants which are used for fodder.

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Transportation/navigation
Transportation will remain largely unchanged. There will be some improvement in communications for about 4-6 months due to the construction of the submersible embankments and compartmental bunds. The total length of existing roads in the project is 30 km of which 20 km is inundated every year.

Higher Umium flood levels
Umium River pre-monsoon flood levels could increase by about 0.10 m. This could affect areas outside the project, most likely on the left bank of the Umium River. Improved understanding of this impact requires regional flooding analysis, which is ongoing as a part of NERP.

8.8.2 Social

The key areas of social impact (or lack thereof) for this project are described below.

Employment
There will be an overall increase in employment of +0.013 million person-days per year. This is composed of:

- an increase in owner-labour employment of +0.026 million pd yr^{-1}, of which very roughly 20% is post-harvest processing activities traditionally done by women of the household.

- a net decrease in employment opportunities for the landless people of -0.013, composed of changes in the following areas:

  - Agricultural hired labour: +0.046 million pd yr^{-1}, of which about 10% is for post-harvest processing traditionally done by women hired in (mainly by larger farmers) for the purpose.

  - Fishing labour: -0.059 million pd yr^{-1}; in addition to this, there would be a corresponding loss in support activities such as net-making and post-catch processing (mainly drying) much of which is done by women.

  - Wetland labour (gathering wetland products): Negligible. Fodder and building material is gathered mainly by men. Food, fuel, and medicine is gathered mainly by women.

Displacement impacts due to land use changes
No homestead lands will be acquired for the construction of the submersible embankments.

Conflicts
Improved drainage will encourage farmers to extend cultivation into deeper parts of the haor areas. This will bring farmers into conflict with fishermen who will find the fishing area reduced. This conflict will affect the way the regulator is operated and will have a direct bearing on the extent to which some of the crop production benefits are realized.

Equity
The net equity impact would appear to be *regressive*. Who benefits?

- Landowners, in proportion to landholdings, benefit directly from investment in agriculture production. This is the main benefit of the project and its distribution is *regressive*.

Who loses?

- Families dependent upon fishing labour. These families are mainly landless and tend to be poorer than average. However, this is also true without the development of the project. *Regressive*.

Gender Equity
The net equity impact would appear to be somewhat *progressive*. Employment opportunities for women will increase in all categories except wetland gathering.

Qualitative Impact Scoring
The qualitative criteria shown in Table 8.12 are scored on an 11 level scale of -5 to +5. Scoring of those criteria that are impacts (some are not, like "responds to public concerns") is shown in Table 8.14. The scoring procedure is analogous to that used in the FAP 16 EIA case studies, but simplified to eliminate half-point scores (1.5, 2.5, 3.5, etc). Here, each score sums across five equally weighted logical (true/false) criteria, with each "true" counting for a value of one and each "false" for zero. The sign reflects whether the impact is positive or negative.

Table 8.12: Qualitative Impact Scoring

		True=1 False=0					
Qualitative Impact	Impact Sign	Sensitive	Magnitude	Immediate	Sustainable Pos Impact/ Irreversible Neg Impact	No Mitigation Required/ Possible	Score
Ecological Character of Nainda Haor	-1	0	0	0	0	0	0
Regional Biodiversity	-1	0	0	1	1	1	-3
Road Transportation	1	1	1	1	1	1	5
Navigation	-1	1	0	1	0	1	-3
Flood Levels Outside Project Area	-1	0	1	1	0	0	-2
Conflicts	-1	1	1	0	0	0	-2
Socioeconomic Equity	-1	1	0	1	1	1	-4
Gender Equity	1	1	0	0	1	1	3

8.8.3 Economic

The project has an economic rate of return of 16%, which is above the required rate of 12% as prescribed by government. It is a relatively low investment project, at Tk 118 million or about Tk 16,300 per hectare. It covers a small geographic area (8,070 ha gross). The rate of return, however, is quite sensitive to increases in capital costs (a 20% increase in capital costs would reduce the rate of return to 13%). The other sensitive variable is the timing of the benefits, and a delay in benefits by two years would reduce the ERR to 11.5%.

The foreign costs associated with the project are low, at 7% (excluding FFW contributions), making it a relatively small project from a donor perspective. Donor funding considerations would clearly need to include funding local costs.

Almost all of the benefits of the project relate to increased rice production, resulting mostly from reduced crop damage. Average crop yields would increase as a result of reduced flood damage. Non-cereal production would remain constant. Floodplain fish production would be about 95% of the future-without-project production. The value of the lost fisheries output amounts to about 2.4% of the value of increased agricultural output. A summary of salient data in provided in Table 8.13.

It is anticipated that the established crop marketing system will handle incremental crop production without any reduction in prevailing average price levels. Assuming the current annual growth in the demand for grain remains about 3%, the increased cereal production is unlikely to present any marketing difficulties.

A significant caution is that the economic benefits are based largely on the protection of boro crops, and if this did not occur, the project would not be viable.

8.8.4 Summary Analysis

From a multi-criteria perspective (Table 8.14), the project is attractive:

The positive aspects of the project would be:

- Rate of return is acceptable.
- Substantial increase in rice production.
- Increased economic returns to land owners.
- Gender equity of impacts is somewhat progressive.
- Project responds to some public concerns.

The negative aspects of the project would be:

- Benefits derive almost entirely from increased rice production, at the expense of fisheries.
- The net employment impact, while positive, is composed of a large gain in employment for owners at the expense of a significant number of jobs for hired labourers.

- Conflicts between farmers and fishermen would increase.
- The project has a high dependency on central government for implementation.

Table 8.13: Summary of Salient Data

Economic Rate of Return (ERR)	16			
Capital Investment (Tk million)	118			
Maximum O+M (Tk million / yr)	4			
Capital Investment (Tk/ha)	16318			
Foreign Cost Component (%)	7			
Net Project Area (ha)	7250			
Land Acquisition Required (ha)	72			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	15.6			
Cropping Intensity		1.3	1.3	1.3
Average Yield (tonnes/ha)		1.9	1.9	2.2
Average Gross Margins (Tk/ha)		9959	9959	11992
Owner Labour (md/ha)		118	118	121
Hired Labour (md/ha)		27	27	31
Irrigation (ha)		539	539	889
Incremental Cereal Prod'n (' 000 tonnes / yr)	3			
Incremental Non-Cereal (' 000 tonnes / yr)	0			
Incremental Owner Labour (' 000 pd / yr)	26			
Incremental Hired Labour (' 000 pd / yr)	46			

FISHERIES IMPACTS		Flood plain	Beels	Spawning Channel
Incremental Net Econ Output (Tk million / yr)	-0.38	-0.711	+0.343	-0.012
Impacted Area (ha)		0	50	0
Average Gross Margins (Tk/ha)		1448	24490	11250
Remaining Production on Impacted Area, %		100%	100%	100%
Incremental Fish Production (tonnes / year)	-23	-30.9	+8.2	-0.3
Incremental Labour ('000 pd / yr)	-59	-60	+1	0

FLOOD DAMAGE BENEFITS				
Households Affected		0		
Reduced Econ Damage Households (Tk M / yr)	0			
Roads/Embankments Affected -km		0		
Reduced Econ Damage Roads (Tk M / yr)	0			

OTHER IMPACTS				
Wetland Incr Net Econ Output (Tk million / yr)	0			
Wetland Incremental Labour ('000 pd / yr)	0			
Acquired Cult & Homestead Lands, Incr Net Econ Output (Tk million / yr)	0.5			
Persons Displaced by Homestead Acquisition	0			

Table 8.14: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	16
EIRR, Increase Capital Costs by 20%	per cent	13
EIRR, Delay Benefits by Two Years	per cent	11.5
EIRR, 20% Decrease in Fishery Benefits	per cent	13
Net Present Value	Tk	16,309

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	3	22
Incremental Non-Cereal Production	tonnes	0	0
Incremental Fish Production	tonnes	-23	5
Change in Floodplain Wetland/Fisheries Habitat	ha	0	0
Homesteads Displaced Due to Project Land Acquisition	homesteads	0	0
Homesteads Protected From Floods	homesteads	0	0
Roads Protected From Floods	km	0	0
Umium Flood Levels	m PWD	0.10	-
Owner Employment	million pd/yr	0.026	2.3
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	-0.013	-1

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	
Ecological Character of Key Wetland Site	0
Regional Biodiversity	-3
Road Transportation	+5
Navigation	-3
Flood Levels Outside Project Area	-2
Conflicts	-2
Socioeconomic Equity	-4
Gender Equity	+3
Decentralized Organization and Management	-2
Responds to Public Concerns	+5
Conformity to Regional Strategy	+2

[1] Percent changes are calculated relative to future-without-project values of: total production of cereal, non-cereal, and fisheries; total floodplain area; total number of homesteads (for displacement due to land acquisition); flood-affected homesteads; flood-affected roads; Umium water level; and total employment for owners and hired labourers.

[2] Includes incremental production foregone due to acquisition of cultivated land.

9. PROPOSED DHALAI GANG PROJECT

9.1 Rationale

The scheme will reduce flood spills and sediment inflows into the newly developing Dhalai Gang avulsion channel that has formed upstream of Companiganj and will divert all of the flow during the dry season back to the original main channel. This will improve navigation during the dry season and will reduce by half the travel distances between quarry operations at the fan apex and Companiganj. The plan also provides flood protection to land in the vicinity of Rautir Haor during the pre-monsoon flood season and improves drainage. The gross area of the boro crop that will be protected amounts to 1225 ha (Figure 14).

9.2 Objectives

The objectives of the Dhalai Gang Development Project are:

- to facilitate navigation through the Dhalai Gang main channel during the dry season;
- to reduce the risk of future channel avulsion by distributing flows between the channels and consequently save homesteads and cultivable lands from erosion and sand deposition;
- to provide partial flood protection to boro crops in Rauti Beel area; and
- to reduce siltation in Rauti Beel.

9.3 Description

The proposed project includes construction of a closure dam across a recently formed avulsion channel of the Dhalai Gang, and bank revetments on the main channel left bank, upstream and downstream of the present avulsion site. In addition, flow control is to be achieved by constructing spurs to maintain the dry season flow in the main channel. These would be used to deflect flow away from the entrance to the avulsion channel. The proposed plan also requires partial re-excavation of the Dhalai Gang main channel.

The plan provides protection to the Rauti Beel area from pre-monsoon flooding through the construction of submersible embankments along the right bank of the southern part of Piyain River. This will prevent damage to boro crops and also protect fisheries habitat in Rauti Beel from siltation.

The Dhalai drainage basin also requires improvement of two existing drainage channels which pass through the Sylhet-Companiganj road. These drainage channels are located about one kilometre downstream of Barnai village.

The project consists of:

- 4 km re-excavation of the Dhalai Gang main channel;
- construction of a low height dam across the distributary channel, and bank revetment works;
- submersible embankments for 4 km along the right bank of the Piyain River from the outfall of the distributary channel to Companiganj;
- one drainage regulator, one pipe sluice, and one fish pass structure; and
- re-excavation of Rautir Khara drainage channel.

Table 9.1: Design Embankment Crest Elevations

Locations	Section (km)	Crest Level (m PWD)
Piyain River		
Companiganj	0.0	10.30
Fethergaon	4.0	10.30

9.3.1 Partial Flood Protection

Flood protection of the Rauti Beel area against pre-monsoon floods will be provided by submersible embankments along the right bank of the Piyain River. The embankments are designed for a 1:10-year return period flood and have a proposed height of about 2.0 m. The proposed design cross sections for these embankments are 4.27 m crest width, with side slopes of 1(v):2(h) and 1(v):3(h) on country and river sides, respectively. Design embankment crest elevations are shown in Table 9.1.

Submersible embankments will have a relatively small impact on the 1:2 year pre-monsoon flood. Without irrigation facilities, boro crops can only be planted on F2 and F3 lands which total 950 ha (Table 9.2: F2 and F3 flood depths are calculated using monsoon flood conditions). Of this area, some 150 ha are beels and 50 ha are reed lands and hence the boro cultivable area is 750 ha. About 200 ha will be inundated during the pre-monsoon season due to accumulated rainfall (based on area elevation and water balance data for the project area: Table A.13 & Figure 15) which corresponds to the beel and reed areas. The present practice of the farmers is to plant above this area which is inundated by local rainfall. Therefore, boro can safely be planted on the estimated area of 750 ha.

Table 9.2 : Flood Depth Categories

Flood Condition	Return Period	Gross Area corresponding to Depth of Flooding (ha)			
		F0 <0.3 m	F1 0.3 to 0.9 m	F2 0.9 to 1.8 m	F3 > 1.8 m
Monsoon	1:2	0	275	550	400

9.3.2 Drainage

It is proposed that the existing natural drainage system of khals and beels be used for drainage of the project area. Some minor channel improvements will be required. Rautir Khara would be the main drainage collector.

There is about one kilometre of improvement works along the Rautir Khara and another two kilometres of re-excavation for other internal drainage channels.

The design parameters of the main channel are: 1(v):1(h) side slopes; a constant longitudinal bed slope with an elevation of 6.50 m PWD at the outfall and 7.0 m PWD at the offtake; a bed width varying from 3.0 m at the offtake to about 5.0 m at the outfall to the Piyain River. The channel is designed to convey the annual flood flow generated by 5-day basin rainfall with 1:10-year return period. These are preliminary designs which will need updating during feasibility studies.

9.3.3 Structures

Regulators

One regulator and one pipe sluice are proposed for the Rauti Beel area. The regulator is a three-vent (1.5 x 1.8 m) flushing cum drainage structure at the Rautir Khara outfall. The pipe sluice is 90 cm. in diameter and is located in the eastern part of the project.

Fish Pass Structure

One fish pass structure is proposed. Preliminary designs of a typical single slot fishway are provided in Figures 16 and 17.

9.3.4 Dhalai Gang Development

Works on Avulsion Channel

Diversion of dry season flow into the main channel of the Dhalai Gang will be accomplished with a low cross dam (stone weir) across the avulsion channel at a point approximately 300 m below the bifurcation point. A critical issue concerns the design of this structure - both in terms of providing appropriate flow control and being able to withstand overtopping without sustaining major damage by scour or erosion. Given the very limited hydrologic and hydraulic data at the site, only a conceptual design has been prepared at this time. One possible concept for the structure is shown in Figure 18. This weir extends about 2 m above the channel bed and has a flat slope on the downstream side (1(v):9(h) with a launching apron of heavy stone to prevent undermining.

Works on Main Channel

Works on the main channel of the Dhalai Gang includes a revetment on the left bank upstream and downstream of the avulsion bifurcation point, and re-excavation of the main channel over a distance of about 4 km. The revetment will have to be protected with stone to prevent erosion and a suitable launching apron will have to be provided to prevent undermining by scour. A preliminary sketch for the stone protection of the revetment is shown in Figure 18.

9.3.5 Expected Benefits

The benefits expected from the project mainly relate to agriculture and fishery. The present cropping patterns and the corresponding yields are given in Tables 9.3 and 9.4.

Table 9.3: Present Cropping Patterns in Dhalai Gang (ha)

Cropping Pattern	F0		F1		F2		F3		Total
	Area	%	Area	%	Area	%	Area	%	Area
fallow	0	0	50	20	55	10	60	30	165
fallow - l boro					440	80	140	70	580
fallow - hyv boro	0	0	0	0	55	10	0	0	55
b aus - fallow - rabi	0	0	25	10	0	0	0	0	25
b aus - lt aman	0	0	25	10	0	0	0	0	25
lt aman - fallow	0	0	100	40	0	0	0	0	100
lt aman - rabi	0	0	50	20	0	0	0	0	50
Total	0		250		550		200		1000

Table 9.4: Present Crop Production in Dhalai Gang

Crop	Damage Free Area			Damaged Area			Total
	Area (ha)	Yield (mt/ha)	Prod. (mt)	Area (ha)	Yield (mt/ha)	Prod. (mt)	Prod. (mt)
b aus	50	1.25	62.5	0	1.05	0	62.5
lt aman	75	2.15	161.25	100	1.75	175	336.25
l boro	330	2.25	742.5	250	1.75	437.5	1180
hyv boro	45	4.55	204.75	10	3.25	32.5	237.25
Total Rice			1171			645	1816
pulses	11.25	0.85	9.562				
oilseeds	37.5	0.75	28.125				
spices	3.75	2.25	8.437				
Vegetables	22.5	3.75	84.375				

Changes in pre-monsoon depth of flooding (Table 9.5) are expected to lead to changes in area under different crop patterns as shown in Table 9.6.

The dominant expected change in cropping patterns is a shift from local to high yielding boro varieties. This is expected to occur if farmers are assured of a safe harvest.

Projected crop production has been estimated assuming that the yields presently being obtained in areas free of damage would be obtained within the project area under with-project (FW) conditions (Table 9.7).

Table 9.5: Pre-Monsoon Depth of Flooding
(by 1:2 Year Annual Flood)

Flood Depth (m)	Gross Area (ha)	
	Pre-Project	Post-Project[a]
0.00-0.30	825	925
0.30-0.90	305	205
0.90-1.80	95	95
>1.80	0	0
Total	1225	1225

[a] These figures do not reflect cultivable land acquired for infrastructure. Production impacts of land acquisition are documented in the Evaluation section.

As a result of the project there would be increases in cereal and non-cereal production of about 65% and 33% respectively. Agricultural production and per capita consumption figures are described in Section 9.8, Evaluation.

Table 9.6: Projected Cropping Patterns

Cropping Patterns	F0		F1		F2		F3		Total (ha)
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	
fallow - l boro	0	0	0		385	70	160	80	545
fallow - hyv boro	0	0	0	0	165	30	40	20	205
b aus - rabi	0	0	50	20	0	0	0	0	50
b aus - lt aman	0	0	50	20	0	0	0	0	50
lt aman - fallow	0	0	100	40	0	0	0	0	100
lt aman - rabi	0	0	50	20	0	0	0	0	50
Total	0		250		550		200		1000

Table 9.7: Projected Crop Production

Crop	Damage free area			Damaged area			Total prod. (t)
	Area (ha)	Yield (t/ha)	Prod. (t)	Area (ha)	Yield (t/ha)	Prod. (t)	
b aus	100	1.25	125	0	1.05	0	125
lt aman	200	2.15	430	0	1.75	0	430
l boro	545	2.25	1226.3	0	1.75	0	1226.3
hyv boro	205	4.55	932.75	0	3.25	0	932.7
Total Rice			2714				2741
pulses	15	0.85	12.75				
oilseeds	50	0.75	37.5				
spices	5	2.25	11.25				
vegetables	30	3.75	112.5				

9.3.5 Mitigation Measures Incorporated

Submersible embankments are proposed to minimize the negative impact on fisheries from siltation of the Rauti Beel complex. These embankments, however, will obstruct fish migration during the pre-monsoon season. To minimize the negative impact on fish migration, a fish pass structure and a drainage cum flushing regulator have been included in the project design. It is assumed that this infrastructure together with efficient management will prevent further siltation of the Rautir Beel complex and increase fishery beel production.

9.4 Project Operation and Maintenance

The operational requirements of the project will be minimal since the project is aiming only to provide controlled flooding. The regulator gates would be closed at the end of January (last date of plantation) to retain water in the beels and control post-monsoon drainage. When river water levels outside the project are higher (in March) the regulator gates would be opened to allow water into the project area and allow free passage for fish. Under average year pre-monsoon floods (1:2 year return period), the regulator gates could be kept open, as boro crops will be planted above the average flood level. The gates would have to be closed during extreme flood conditions but could be re-opened when water levels recede. The fish pass structure would be operated throughout the season.

Maintenance of the flood embankment and the drainage channels would be required to assure effective flood control and drainage. An Environmental Management Plan, detailing actions necessary to achieve acceptable environmental impacts, will need to be prepared and costed as part of the feasibility study.

9.5 Organization and Management

A client group would need to be organized to oversee project development. This client group and other organization and management aspects would be similar to that for the Rauchunni Beel Project (see Section 7.5). The Department of Fisheries, Companiganj are responsible for the technical services for the Rauti Beel fishing communities. The thana fisheries officer at Companiganj, who is responsible for Rauti beel, should be included in the client group.

9.6 Cost Estimates

Total project costs are estimated at Tk 30.1 million.

Land costs, earthwork, and structure costs are indexed to June 1991 prices. The unit rates and cost estimating procedure are similar to that used for Rauchunni Beel Project (see Section 7.6).

The summary of total costs is presented in Table 9.8 with details provided in Table A.14.

Table 9.8: Capital Cost Summary

Item	('000 Tk)
Structures	12,000
Embankments	1,700
Channels	6,300
Land Acquisition	900
BASE COST	20,900
Physical Contingencies (25%)	5,200
SUBTOTAL	26,200
Study Costs[1] (15% of Subtotal)	3,900
TOTAL	**30,100**
Net Area (ha)	1,000
Unit Cost (Tk/ha)	30,100

[1]Includes preparation of EIA and Environmental Management Plan.

9.7 Project Phasing and Disbursement Period

Three years are required to implement the project. One year (year zero) is required for completion of feasibility studies and conducting field surveys. Preparation of detail designs would be completed in year one. Land acquisition should commence in year one, be implemented in phases preceding construction, and completed in year two. Construction activities should start in year one and be completed in year two. An itemized implementation schedule is shown in Table 9.9.

Table 9.9: Implementation Schedule

Activity	Year (% Completion)		
	0	1	2
Preconstruction Activities			
Feasibility Study	100		
Engineering Investigation	100		
Detail Designs	60	40	
Land Acquisition		50	50
Construction Activities			
Construction of Embankments		50	50
Excavation of Channels		20	80
Construction of Structures		20	80

9.8 Evaluation

9.8.1 Environmental

The key areas of environmental impact for this project are described briefly below. Additional information is given in Annex C3, Initial Environmental Evaluation.

Land Use

Land use changes are summarized in Table 9.10. A total of 5 ha of land (about 0.4% of the project gross area) will be required for embankments, drains, and regulators. Of this:

- 2 ha will be taken from the cultivated area. Assuming average yields and that this is all under rice, this corresponds to incremental cereal production foregone of about 4 tonnes per year or 0.4 % of total incremental cereal production.

Table 9.10: Changes in Land Use

Use	Present Area (ha)	Change in Area (ha)
Cultivated	1000	-2
Homesteads	15	-
Beels	150	-
Ponds	0	-
Channels	5	-
Fallow[1]	50	-3
Infrastructure[2]	5	-

[1] Multi-use land, wetlands, grazing lands, village grounds.

[2] Government-owned land not appearing elsewhere.

- 3 ha will be taken from winter floodplain wetland areas. These are mostly producing reeds and grasses worth roughly Tk 800/ha, which means a total wetland production foregone of Tk 2400 per year. Employment in wetland gathering is negligible (about a reduction of 4.0 pd/ha-yr, which means employment of 12 pd/yr).

Table 9.11: Indicators of Food Availability
(grams/person/day)

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	141	82	137	83
Non-Cereals	10	12	9	7
Fish	19	17	13	5

- Some embankment work is proposed around the homestead area. However there will be no displacement of homesteads and in general the homestead garden areas will benefit from increased ground levels.

Agriculture

The project is expected to facilitate annual cereal production to increase from 1,647 tonnes (FWO) to 2,714 tonnes (FW), an increase of 1067 tonnes (+35%), inclusive of the impacts of land use changes described above.

The cereal production increase implies a per person increase in cereal availability from 83(FWO) to 137 (FW) gm per person per day, an increase of +65% (Table 9.11), allowing 10% for seed, feed, and waste, and 65% for conversion of paddy to rice. Current Bangladesh average consumption is 440 gm per person per day.

Non-cereal production is expected to increase from 131 tonnes (FWO) to 147 tonnes (FW) (+33%). This results from a 10 ha increase in area cultivated to non-cereals from 246 ha to 256 ha and implies an increase in the availability of non-cereals from 7 to 9 grams per person per day (Table 9.11).

Openwater Fisheries Production[1]

The project is expected to impact on fisheries in three ways: 1) some restriction to migration routes, 2) the control of further sediment entering the beels, and 3) the dry season water surface area will be increased. The FWO and the estimated FW productions and the magnitude of impacts (and sign) are provided in Table 9.12.

The area of the floodplain will remain the same but by restricting migration routes the submersible embankment is expected to reduce overall floodplain fishery habitat by an equivalent 80 ha. The net decrease in floodplain production is estimated at about four tonnes per year.

[1] The model used to estimate impacts on fisheries is described in Annex D.

Table 9.12: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production ('000 kg)	Area (ha)	Area Equivalent	Production Impact ('000 kg)	Net Value ('000 Tk)
Flood Plain	800	35	800	720	-4	-116
Beels	150	62	150	162	+5	+294
Channels /River	5	0.9	5	5.4	+0.1	+5
Mother Fishery*	0	0	150	150	+150	+3000
Net Project	1000	97.9	1000		+151.1	+3183

** Area overlaps with beels and channels*

The project is expected to have a positive impact on beel and mother fisheries. The regulators will control post-monsoon drainage and increase the dry season water surface area. Under present conditions water drains from the beels up to February but with the regulators in place the gates would be closed in January and water levels in the beels would be maintained at a higher level. Furthermore, the project will protect Rautir beel from siltation (which has been identified as a mother fishery). Without the project, sedimentation of this beel would continue and this would destroy existing spawning grounds.

The project is not expected to have a negative impact on aquaculture.

The total annual openwater fisheries production impact is +151 tonnes, which is a 54% increase over the FWO annual production of 98 tonnes. This implies that openwater-source fish availability per person due to the project from will increase from 5 (FWO) to 13 (FW) gm per person per day (Table 9.11).

Homestead flooding

Homestead flood damage will be reduced since the excavated earth will be placed along both banks of the Dhalai Gang main channel. Some material will be used to raise homesteads. In addition, the risk of further channel avulsion will be reduced by distributing flood flows between the two channels. This will reduce damage to homesteads on both banks of the Dhalai Gang main and distributary channels. Due to the lack of historical data on flood damage costs, a simple model was used to estimate future costs. There are about 1,400 homesteads in the area, and the average plinth level is at about the 1:5 year flood level. About 30% of homesteads are affected by flooding of 20-30 cm in the 1:10 to 1:20 year floods. The estimated annualized economic value of reduced flood damage is very small (Tk 0.10 million).

Wetland Habitats and Grazing Area
Impacts are difficult to quantify, but a general impression is given by Table 9.13, which shows the impact on:

- "Winter grazing area". Defined as F0, F1, and F2 lands that lie fallow in the dry season (winter) plus any perennially-fallow highlands. This land would have limited residual moisture. While it is clear that animals do graze on such areas, productivity per unit area is not known.

- "Winter wetland". Defined as F3 land that lies fallow in the dry season, plus any perennially-fallow lowland (F4), beel, and channel areas. This land would likely have considerable residual moisture and could support a range of wetland plant communities.

- "Summer wetland". Defined as F1, F2, and F3 land that lies fallow in the summer, plus perennially-fallow lowland (F4 area), beel, and perennial channel areas. This land would be inundated to >0.3 m and would support submerged, free-floating, rooted floating, and sedge/meadow plant communities.

The impact of the project would be to decrease winter grazing area by 47%, decrease winter wetland area by 1%, and decrease summer wetland area by 5%.

Table 9.13: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	0	0	0	
sc/wf F1	175	150	-25	
sc/wf F2	110	0	-110	
Fallow Highland	0	0	0	
Total	285	150	-135	-47

Land Type	Winter Wetland			
sc/wf F3	0	0	0	
F4, Beel, Channel	205	202	-3	
Total	205	202	-3	-1

Land Type	Summer Wetland			
wc/sf F1	50	0	-50	
wc/sf F2	550	550	0	
wc/sf F3	200	200	0	
F4, Beel, Channel	205	202	-3	
Total	1,005	952	-53	-5

FW areas shown here do not reflect cultivable land acquired for infrastructure (see Land Use, Section 7.8.1). 'sc' - summer cultivated. 'wc' - winter cultivated. 'sf' - summer fallow. 'wf' - winter fallow.

Impacts on the reed swamp community would be mixed. The project would have a positive impact on the community by restricting sediment into the area. The introduction of intense agricultural activity on its border would have a negative impact.

Economic and employment impacts of the project on wetland plant and animal production can only be roughly estimated. Assuming an annual economic production of Tk 800 per hectare for both summer and winter wetland areas gives a total annual loss of Tk 45 thousand per year. Assuming 4.0 pd/ha-yr for harvesting, the employment impact would be -224 pd per year.

Transportation/navigation
Navigation will be improved significantly between quarrying operations at the head of the Dhalai Gang and Companiganj. Boulder transportation distance will be reduced by about 50%. Collection of stones from Bholagnaj quarry may be doubled from its present level, particularly during the dry months from December through March. Currently, an average of 2000 boats/day are engaged in boulder collection. Each boat requires two persons and carries about 0.8 m^3 of stone/trip. Reportedly for a double trip/day, one more person/boat is required. Also, it is estimated that an additional 500 boats could be engaged for boulder collection. This implies that an additional 288,000 m^3 of boulders could be collected which corresponds to about Tk 75 million/year at the rate of about Tk 200-210/boat for 120 days. This will increase the employment opportunities for landless people by 420,000 pd/yr.

9.8.2 Social

The key areas of social impact (or lack thereof) for this project are described below.

Employment
There will be an overall increase in employment of +0.465 million person-days per year. This is composed of:

- an increase in owner-labour employment of +0.038 million pd yr, of which very roughly 20% is post-harvest processing activities traditionally done by women of the household.

- an net increase in employment opportunities for landless people of +0.427 million pd/yr composed of changes in the following areas:

  - Agricultural hired labour: +0.021 million pd/yr, of which about 10% is for post-harvest processing traditionally done by women hired in (mainly by larger farmers) for the purpose.

  - Fishing labour: -0.014 million pd/yr (not including spawning benefits); in addition to this, there would be a corresponding loss in support activities such as net-making and post-catch processing (mainly drying) much of which is done by women.

  - Wetland labour (gathering wetland products): Negligible. Fodder and building material is gathered mainly by men. Food, fuel, and medicine is gathered mainly by women.

  - Boulder transportation labour (from Bholaganj quarry): +0.42 million pd/yr. In addition, there would be a corresponding increase in support activities such as boat-making, boat-repairing, small business centres for daily commodities and so on.

Displacement impacts due to land use changes
The project does not have a negative impact on homesteads as there will be no displacement of homesteads. Instead some spoil material will be used to raise homestead platforms.

Equity
The net equity impact would appear to be strongly *progressive*. Who benefits?

- Landowners, in proportion to landholdings, benefit directly from investment in agricultural production of the project and its distribution is *regressive*.
- Landless people get a direct employment benefit from boulder transportation which is about seven times higher than the agricultural employment benefit. Strongly *progressive*.
- "Mother" fisheries will be protected from sedimentation and fish population will increase. *Progressive*.

Who loses?

- Families involved in gathering wetland products. These families are mainly landless and tend to be very poor. However, this is true even without the project condition. *Regressive*.

Gender Equity
The net equity impact would appear to be *progressive*. Employment opportunities for women will increase in all categories except wetland gathering. Reduced homestead flood damage will disproportionately favour women, given that most women still spend most of their lives within the homestead.

Qualitative Impact Scoring
The qualitative criteria shown in Table 9.14 are scored on an 11 level scale of -5 to +5. Scoring of those criteria that are impacts (some are not, like "responds to public concerns") is shown in Table 9.16. The scoring procedure is analogous to that used in the FAP 16 EIA case studies, but simplified to eliminate half-point scores (1.5, 2.5, 3.5, etc). Here, each score sums across five equally weighted logical (true/false) criteria, with each "true" counting for a value of one and each "false" for zero. The sign reflects whether the impact is positive or negative.

9.8.3 Economic

The project has an economic rate of return of 25% without navigation benefits, which compares well to the required rate of 12% as prescribed by government. It is a relatively low investment project, at about Tk 30 million or about Tk 30,300 per hectare. The project covers a small geographic area (gross area of 1,225 ha). The rate of return is quite sensitive to increases in capital costs (a 20% increase in capital costs would reduce the rate of return to 21%). The other sensitive variable is the timing of the benefits, and a delay in benefits by two years would reduce the ERR to 18%.

Table 9.14: Qualitative Impact Scoring

		True=1 False=0					
Qualitative Impact	Impact Sign	Sensitive	Magnitude	Immediate	Sustainable Pos Impact/ Irreversible Neg Impact	No Mitigation Required/ Possible	Score
Ecological Character of Rauti Beel	+1	1	1	0	1	1	+4
Regional Biodiversity	+1	0	0	1	1		+2
Road Transportation	1	0	1	0	0	0	1
Navigation	+1	1	1	1	1	1	+5
Flood Levels Outside Project Area	-1	0	0	0	0	0	0
Conflicts	-1	1	1	0	0	0	-2
Socioeconomic Equity	+1	0	0	0	0	1	+1
Gender Equity	1	1	0	0	1	1	3

The foreign costs associated with the project are low, at 9% (excluding FFW contributions), making it a relatively small project from a donor perspective. Donor funding considerations would clearly need to include funding local costs.

The agricultural benefits of the project are mainly due to increasing crop yields preventing damage from pre-monsoon floods and some local boro being converted into hyv boro. Average crop yields will increase as a result of reduced flood damage, and cropping intensity will increase by 30%. Non-cereal production will increase by 33%. Annual open water fisheries production will increase by about 54%. About 2.0% of the project benefits will result from reduced homestead flooding. A small amount of disbenefits will result from loss of food, shelter, and tree products that are currently harvested from the seasonal wetlands. A summary of salient data in provided in Table 9.15.

It is anticipated that the established crop marketing system will handle incremental crop production without any reduction in prevailing average price levels. Assuming the current annual growth in the demand for grain remains about 3%, the increased cereal production is unlikely to present any marketing difficulties.

A significant caution is that the economic benefits are based largely on full protection of the boro crops and maintenance of dry season flow in the Dhalai Gang main channel. If these conditions can not be met the project would not be viable.

9.8.4 Summary Analysis

From a multi-criteria perspective, the project is attractive: (Table 9.16). The main features of the project are:

- benefits derive from increased rice and fish production and increased boulder collection.
- landless people get a substantial share of the benefit from improved navigation and expanded quarrying operations.
- the net employment impact is positive and is composed of gain in employment for owners and hired labours, landless people and fishing labours.
- the rate of return is acceptable.
- reduced flood damage to homesteads and roads.
- small increment in non-cereal production.
- gender equity of impacts is somewhat progressive.
- the project responds to some public concerns.

As a result of implementing the project, there will be potential for incresed conflict between farmers and fishermen which will affect the way project infrastructure is operated and its impact on the "benefitted area".

Table 9.15: Summary of Salient Data

Economic Rate of Return (ERR)	25*			
Capital Investment (Tk million)	30.1			
Maximum O+M (Tk million / yr)	1			
Capital Investment (Tk/ha)	30,300			
Foreign Cost Component (%)	9			
Net Project Area (ha)	1,000			
Land Acquisition Required (ha)	9			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	4.63			
Cropping Intensity		0.9	0.9	1.2
Average Yield (tonnes/ha)		2.1	2.1	2.5
Average Gross Margins (Tk/ha)		12266	12103	13812
Owner Labour (md/ha)		121	121	124
Hired Labour (md/ha)		33	32	43
Irrigation (ha)		81	81	240
Incremental Cereal Prod'n (' 000 tonnes / yr)	1			
Incremental Non-Cereal (' 000 tonnes / yr)	0			
Incremental Owner Labour (' 000 pd / yr)	38			
Incremental Hired Labour (' 000 pd / yr)	21			

FISHERIES IMPACTS		Flood plain	Beels	Spawning
Incremental Net Econ Output (Tk million / yr)	+2.23	-0.08	+0.21	+2.1
Impacted Area (ha)		-80	+5	+150
Average Gross Margins (Tk/ha)		1448	24490	11250
Remaining Production on Impacted Area, %		100%	100%	100%
Incremental Fish Production (tonnes / year)	+151	-4	+5	+150
Incremental Labour ('000 pd / yr)	-0.007	-0.008	+0.001	-

FLOOD DAMAGE BENEFITS				
Households Affected		140		
Reduced Econ Damage Households (Tk M / yr)	0.1			
Roads/Embankments Affected -km		0		
Reduced Econ Damage Roads (Tk M / yr)	0			

OTHER IMPACTS				
Wetland Incr Net Econ Output (Tk million / yr)	0			
Wetland Incremental Labour ('000 pd / yr)	0			
Acquired Cult & Homestead Lands, Incr Net Econ Output (Tk million / yr)	0.024			
Persons Displaced by Homestead Acquisition	0			

* Without navigation benefit.

Table 9.16: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	25*
EIRR, Increase Capital Costs by 20%	per cent	21
EIRR, Delay Benefits by Two Years	per cent	18
Net Present Value	Tk	19,452

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	1000	65
Incremental Non-Cereal Production	tonnes	43	33
Incremental Fish Production	tonnes	151	154
Change in Floodplain Wetland/Fisheries Habitat	ha	0	-
Homesteads Displaced Due to Project Land Acquisition	homesteads	0	0
Homesteads Protected From Floods	homesteads	140	10
Roads Protected From Floods	km	0	0
Owner Employment	million pd/yr	+0.038	36
Hired Employment (Agri+Fishing+Wetland+Navigation)	million pd/yr	+0.427	73

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	**Rank**
Ecological Character of Key Wetland Site (Rautir Beel)	+4
Regional Biodiversity	+2
Road Transportation	+1
Navigation	+5
Flood Levels Outside Project Area	0
Conflicts	-2
Socioeconomic Equity	+1
Gender Equity	+3
Decentralized Organization and Management	+1
Responds to Public Concerns	+5
Conformity to Regional Strategy	+3

[1] Percent changes are calculated relative to future-without-project values of: total production of cereal, non-cereal, and fisheries; total floodplain area; total number of homesteads (for displacement due to land acquisition); flood-affected homesteads; flood-affected roads; Dhalai water level; and total employment for owners and hired labourers.

[2] Includes incremental production foregone due to acquisition of cultivated land.

[3] The Rate of Return Calculation does not include navigation benefits.

ANNEX A

TABLES

TABLE A.1: METEOROLOGICAL DATA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C) Max.	28.3	32.2	36.7	38.9	40.6	35.0	40.0	35.0	35.0	35.0	31.7	28.9
Min.	9.4	8.9	12.8	16.7	18.3	21.1	23.9	23.3	21.7	18.3	12.8	8.9
Mean	18.7	20.4	24.2	27.2	26.9	27.8	28.8	28.2	28.1	26.6	19.7	19.7
Humidity (%)	76.9	70.9	63.8	75.0	83.5	87.7	89.5	89.5	87.5	87.3	81.0	79.9
Sunshine (hr/day)	8.8	9.0	8.4	7.5	6.8	3.5	4.1	4.4	4.6	7.5	9.0	7.8
Wind speed (kph)	2.4	2.8	5.0	6.0	5.0	5.4	5.6	5.0	3.7	2.4	1.9	1.9
Evapotranspiration (mm/month)	105.6	124.4	162.4	157.1	153.4	124.9	125.0	130.6	121.5	128.4	114.5	102.6
Rainfall (mm) Mean monthly	9.2	36.5	101.4	397.1	514.0	916.5	747.2	555.0	282.2	198.7	53.7	30.2

3 DC

Table A.2

Area - Elevation and Storage Volume

Elevation (mPWD)	Area (ha)	Storage (ha-m)
4.88	989.32	0
5.50	4946.60	1909.38
6.00	4946.60	4382.68
6.50	8903.88	7845.31
7.00	19786.4	15017.87
7.50	28690.28	27137.04
8.00	38683.47	43955.48
8.50	58369.87	68193.82
9.00	68263.07	99852.05
9.50	73209.19	135220.24
10.00	84092.19	174545.7
10.50	94974.71	219312.42
11.00	102889.3	268778.41
11.50	106486.5	321212.36
12.00	111793.1	375872.29
12.50	112782.5	432016.89
13.00	116739.6	489396.74

Elevation (mPWD)	Area (ha)	Storage (ha-m)
13.50	117729.1	548013.94
14.00	118718.4	607125.80
14.50	120697.0	666979.65
15.00	120697.0	727328.16
15.50	120697.0	787676.67
16.00	120697.0	848025.18
16.50	121686.3	908621.02
17.00	122675.7	969711.52
17.50	122675.7	1031049.35
18.00	122675.7	1092387.18
18.50	122675.7	1153725.01
19.00	124654.3	1215557.50
19.50	124654.3	1277884.65
20.00	124654.3	1340211.81
20.50	125643.6	1402786.28
20.58	126632.9	1412877.35

Table A.3 : Mean Monthly Discharges (m3/sec)

Month	Gauge 251 SARIGOYAIN at Sarighat			Gauge 267 SURMA at Sylhet		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	4	69.3	164.9	31.6	238.1	677.6
May	27.6	146.1	303.0	107.8	489.9	933.3
June	93.8	294.6	555.5	318.9	1109.8	1829.3
July	176.1	387.7	563.1	1038.9	1471.3	1918.7
Aug	155.2	281.2	431.5	825.9	1322.8	1667.1
Sept	90.4	212.0	391.8	554.0	1074.7	1447.2
Oct	32.9	98.9	286.5	211.6	614.5	1302.4
Nov	11.6	21.7	59.2	19.6	130.2	406.6
Dec	7.8	12.7	52.1	6.6	32.9	123.5
Jan	5.2	7.7	12.1	4.5	11.9	33.0
Feb	4.1	6.6	17.8	4.2	7.8	22.8
Mar	4.3	14.8	59.6	3.9	36.2	193.4

Month	Gauge 252.1 SARIGOYAIN at Salutikar			Gauge 332 DHALAI GANG at Islampur		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	NA	NA	Na	5.9	24.6	57.2
May	142.8	387.2	542.5	57.0	153.9	293.1
June	368.6	778.1	1198.8	142.7	232.8	394.1
July	728.4	929.4	1188.8	168.2	315.4	488.8
Aug	667.2	835.1	959.6	104.2	274.9	442.5
Sept	442.5	603.9	857.3	70.3	333.0	743.9
Oct	61.5	295.7	540.5	56.5	101.7	203.8
Nov	18.7	78.5	132.9	10.0	12.2	16.7
Dec	3.7	19.1	26.9	4.2	6.7	12.1
Jan	NA	NA	NA	3.2	3.5	4.0
Feb	NA	NA	NA	2.4	3.1	4.5
Mar	NA	NA	NA	2.9	7.2	18.8

TABLE A-3 (Cont'd): Mean Monthly Discharge (m3/esc)

Month	Gauge 233 PIYAIN at Ratnerbhanga			Gauge 233 A PIYAIN at Jafflong		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	15.5	36.5	56.7	67.6	140.7	250.3
May	52.0	103.7	162.8	121.1	303.2	530.9
June	159.3	255.9	494.0	238.8	403.2	522.7
July	110.4	278.7	560.0	231.7	466.3	707.7
Aug	116.0	215.7	474.5	359.4	419.1	584.5
Sept	100.0	176.8	361.1	295.7	441.3	601.0
Oct	32.7	90.4	144.5	159.5	225.8	318.5
Nov	7.8	20.9	30.9	13.9	29.1	47.0
Dec	5.1	13.0	25.5	1.2	12.7	47.1
Jan	3.5	8.4	14.4	0.1	1.8	6.1
Feb	2.5	7.2	14.1	0.4	5.9	13.0
Mar	5.5	8.9	11.6	0.6	28.3	82.1

Table A.4 : Estimated Flood Levels for Different Return Periods

River	Station No	15 May Water Levels; mPWD			Annual Flood Levels; m PWD			
		1:2	1:5	1:10	1:2	1:5	1:10	1:25
Sarighat	251	11.31	12.53	13.03	13.51	13.80	13.91	14.00
Goyainghat	252	8.88	10.22	10.81	11.71	12.05	12.19	12.32
Salutikar	252.1	7.75	8.65	8.96	10.64	10.95	11.08	11.18
Sylhet	267	8.75	9.64	9.94	11.22	11.53	11.68	11.82
Chhatak	268	7.02	7.72	7.96	10.02	10.49	10.72	10.94
Sunamganj	269	6.61	7.18	7.37	8.63	8.89	9.07	9.29
Piyain	233	11.12	12.17	12.86	14.14	14.67	14.92	15.16
Piyain	234	8.35	9.04	9.42	10.89	11.34	11.58	11.85
Mirza Khal		6.84	7.48	7.70	9.40	9.78	9.99	10.21
Nawagang	337	10.5					11.5	
Nawagang Outfall		6.78	7.41	7.62	9.22	9.57	9.77	9.99
Umium	341	10.5					11.2	

Table A.5: Area Flooded by Different Depth Categories (ha)

Unit	0-.3m	Pre-monsoon						Monsoon						
		.3-.9m	.9-1.8m	>1.8 m	Total Area	Flooded Area	%	0-.3m	.3-.9m	.9-1.8m	>1.8 m	Total Area	Flooded Area	%
X1	1100	600	800	700	3200	2100	66	400	400	300	2100	3200	2800	88
X2	24860	180	360	-	25400	540	2	6400	6000	8000	5000	25400	19000	75
X3	9400	1660	340	-	11400	2000	18	900	1100	3400	6000	11400	10500	92
X4	6000	3800	2900	600	13300	7300	55	500	1500	2500	8800	13300	12800	96
X5	7700	1400	900	200	10200	2500	25	200	2000	2500	5500	10200	10000	98
X6	5000	1300	300		6600	1600	24	1000	1400	1000	3200	6600	5600	85
X7	7000	3100	900	1000	12000	5000	42	2000	2000	2700	5300	12000	10000	83
X8	5500	1500	2700	1300	11000	5500	50	2100	800	1600	6500	11000	8900	81
X9	6130	302	198	0	6630	500	8	2630	1900	1000	1100	6630	4000	60
X10	3700	100	200	0	4000	300	8	2400	400	400	800	4000	1600	40

TABLE A.6 : Mean Monthly Water Levels (m PWD)

Month	Gauge 268 SURMA at Chhatak			Gauge 251 SARIGOYAIN at Sarighat		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	2.04	4.07	6.77	5.84	7.28	9.05
May	4.34	6.11	7.75	6.39	8.75	11.22
June	6.53	7.94	9.13	8.20	10.55	12.06
July	7.21	8.82	9.37	10.46	11.29	11.99
Aug	7.74	8.44	9.19	9.65	10.69	11.54
Sept	6.99	7.91	9.02	8.62	10.07	11.18
Oct	5.85	6.76	7.83	6.74	8.45	10.09
Nov	3.96	4.87	5.77	5.99	6.40	7.04
Dec	2.75	3.47	4.70	5.8	5.99	6.84
Jan	1.84	2.34	3.33	5.70	5.82	6.12
Feb	1.37	1.80	2.82	5.61	5.75	6.20
Mar	1.47	2.00	4.50	5.58	5.97	7.53

Month	Gauge 252 SARIGOYAIN at Goyainghat			Gauge 252.1 SARIGOYAIN at Salutikar		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	2.50	5.13	8.23	2.12	4.36	6.77
May	4.69	7.20	9.28	4.67	6.50	8.46
June	6.71	9.41	10.98	5.98	8.56	9.98
July	9.69	10.47	11.09	8.88	9.57	10.11
Aug	9.12	9.98	10.60	8.44	9.22	9.90
Sept	7.98	9.36	10.42	7.46	8.68	9.91
Oct	6.14	7.67	9.48	5.94	7.25	8.79
Nov	4.16	5.09	6.18	4.18	5.00	7.08
Dec	2.99	3.66	4.94	2.79	3.49	4.74
Jan	2.25	2.71	3.45	1.91	2.34	3.28
Feb	2.05	2.40	3.11	1.49	1.84	2.61
Mar	2.07	2.59	4.57	1.40	2.01	3.71

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TABLE A.6 (Cont'd): Mean Monthly Water Levels (m PWD)

Month	Gauge 233 PIYAIN at Ratnerbhanga			Gauge 234 PIYAIN at Companiganj		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	9.26	9.72	10.37	6.34	6.92	8.08
May	9.45	10.17	11.27	6.83	7.73	8.93
June	9.91	11.18	13.80	7.31	8.98	10.36
July	10.95	11.75	12.37	9.21	9.76	10.37
Aug	10.57	11.40	12.37	8.78	9.35	9.89
Sept	10.25	10.98	12.04	8.01	8.83	9.73
Oct	9.80	10.33	11.69	6.86	7.78	8.77
Nov	9.47	9.73	10.43	6.39	6.77	6.99
Dec	9.28	9.54	10.35	6.28	6.55	6.80
Jan	9.14	9.43	10.11	6.03	6.45	6.69
Feb	9.05	9.37	10.05	6.12	6.41	6.60
Mar	8.93	9.40	9.95	6.03	6.42	6.78

Table A.7 : Water Bodies in the Sarigoyain - Piyain Basin

Thana	Total beel area (ha)	Thana	Total beel area (ha)
Dwarabazar	151	Jaintiapur	259
Chhatak	195	Goyainghat	4488
Sylhet	1088	Companyganj	2000
Total : 8181			

Table A. 8 : Closed Water Bodies in the Sarigoyain - Piyain Basin

Thana	% of area under project	Total number of ponds	Combined pond area (ha)	Average pond size (ha)	Pond concentration (km^2)
Dwarabazar	32	772	60	0.077	8.12
Chhatak	8	330	25	0.075	10.2
Sylhet Sadar	42	2106	160	0.075	10.06
Jaintiapur	57	1062	82	0.077	9.04
Goyainghat	94	4893	379	0.077	9.18
Companyganj	100	2674	207	0.077	9.22
Total :		11,837	913	0.077	12.30

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Table A.9 : Duars Around the Project Area

Name of duar	Approx. depth during dry season (m)	Baramach Occurred	Chotomach occurred
River : **SARIGOYAIN**			
Nayakhal	9-10	LC, C, MC	B, Ch, Ca, R
Kakunkhai	6-7	As above	As above
Hatir dor	6-7	As above	As above
Budhigaor dor	6-7	As above	As above
Boalir dor	6-7	As above	As above
Gatur dor	9-10	As above	As above
Noanagarar dor	9-10	As above	As above
Nogrir dor	6-7	As above	As above
Gonkir dor	5-6	LC, MC	As above
Nihain dor	6-7	As above	As above
Laxminagar	6-7	As above	As above
Gatur dor	6-7	As above	As above
Chaltabari	6-7	As above	As above
Kumarpara	6-7	As above	As above
Tokargaon	6-7	As above	As above
Paglar dor	6-7	As above	As above
Shalutikar	7-8	As above	As above
Ular dor	6-7	As above	As above
Pirgaon	6-8	As above	As above
Chamurar dor	7-8	As above	As above
Banghaghat	6-7	As above	As above
Rajgaon	6-7	As above	As above
Nawagaon	8-9	LC, MC, C	As above
Dhumkhal	8-9	LC, MC	As above
Lalpur	6-8	As above	As above
River : **SURMA**			
Perkul	9-10	LC, C, MC	Ch, Ca. Pu, B
Bagairar dor	13	As above	As above
Muktigaon	16	As above	As above
Boali	12	As above	As above
Thanar dor	17	As above	As above

Table A.10 : Design and Volume Estimates; Rauchunni Beel

Location	Distance	Ground Elevation		Design Height,mPWD		Area,m^2		Volume, m^3	
				pre-mon	monsoon	pre-mon	monsoon	pre-mon	monsoon
	(km)	SOB	mPWD	(1:10)	(1:20)	(1:10)	(1:20)	(1:10)	(1:20)
Hadir Khal	0.0	40.0	12.7	13.76	14.50	7.7	16.3	0	0
	0.5	38.0	12.0	13.71	14.46	14.0	24.9	5431	10299
	1.0	38.0	12.0	13.66	14.42	13.4	24.2	6838	12271
	1.5	37.0	11.7	13.61	14.38	16.7	28.7	7506	13234
	2.0	37.0	11.7	13.56	14.35	16.0	28.0	8161	14186
	2.5	35.0	11.1	13.51	14.31	24.2	38.7	10053	16691
	3.0	37.0	11.7	13.46	14.27	14.7	26.7	9724	16361
	3.5	35.0	11.1	13.41	14.23	22.6	37.2	9324	15977
	4.0	34.0	10.8	13.36	14.19	26.8	42.6	12351	19954
	4.5	34.0	10.8	13.31	14.15	25.9	41.8	13176	21111
	5.0	33.0	10.5	13.26	14.11	30.3	47.6	14065	22345
	5.5	33.0	10.5	13.21	14.08	29.4	46.7	14942	23567
	6.0	33.0	10.5	13.16	14.04	28.6	45.9	14497	23143
	6.5	31.0	9.9	13.11	14.00	39.1	59.2	16909	26255
	7.0	31.0	9.9	13.06	13.96	38.1	58.2	19290	29340
	7.5	30.0	9.6	13.01	13.92	43.3	64.9	20349	30779
	8.0	29.0	9.3	12.95	13.88	48.9	72.0	23053	34220
	8.5	29.0	9.3	12.90	13.85	47.8	70.9	24164	35724
	9.0	29.0	9.3	12.85	13.81	46.6	69.9	23603	35205
	9.5	27.0	8.7	12.80	13.77	59.7	86.0	26600	38974
	10.0	27.0	8.7	12.75	13.73	58.5	84.9	29564	42718
	10.5	27.0	8.7	12.70	13.69	57.3	83.7	28946	42151
	11.0	27.0	8.7	12.65	13.65	56.1	82.6	28334	41588
	11.5	27.0	8.7	12.60	13.61	54.9	81.5	27729	41028
	12.0	27.0	8.7	12.55	13.58	53.7	80.4	27130	40473
	12.5	27.0	8.7	12.50	13.54	52.5	79.3	26537	39921
	13.0	27.0	8.7	12.45	13.50	51.3	78.2	25951	39372
	13.5	27.0	8.7	12.40	13.46	50.2	77.1	25371	38827
	14.0	27.0	8.7	12.35	13.42	49.0	76.0	24797	38286
	14.5	29.0	9.3	12.30	13.38	35.2	59.0	21063	33757
	15.0	32.0	10.2	12.25	13.34	19.0	37.8	13553	24189
Goyainghat	15.5	35.0	11.1	12.20	13.30	7.4	21.0	6593	14684
Total						1138.8	1771.9	565603	876632

Table A.10 (cont'd) : Design and Volume Estimates; Rauchunni Beel

Location	Distance	Ground Elevation		Design Height,mPWD		Area, m^2		Volume,m^3	
				pre-mon	monsoon	pre-mon	monsoon	pre-mon	monsoon
	(km)	SOB	mPWD	(1:10)	(1:20)	(1:10)	(1:20)	(1:10)	(1:20)
Hadir Khal	0.0	40.0	12.7	13.76	14.50	7.7	16.3	0	0
	0.5	40.0	12.7	13.81	14.54	8.2	16.9	3992	8300
	1.0	40.0	12.7	13.86	14.58	8.6	21.7	4212	9632
	1.5	40.0	12.7	13.91	14.62	16.7	33.0	6331	13656
	2.0	40.0	12.7	13.96	14.65	17.7	34.0	8592	16738
	2.5	40.0	12.7	14.01	14.69	10.8	24.3	7126	14564
	3.0	40.0	12.7	14.06	14.73	8.3	20.4	4794	11161
upto	3.5	40.0	12.7	14.11	14.77	6.1	16.8	3606	9300
protection	4.0	40.0	12.7	14.16	14.81	6.7	17.6	3204	8597
Average:			12.7	14.0	14.7				
Total								41857	91947
Grand Total								607460	968580

Table A.11 : Estimated Capital and O & M Costs (Rauchunni Beel)

Item of Works	Quantity	Unit	Unit Price	Capital Costs (mtk)	O& M%	O & M Costs (mtk)
Partial Embankment	78000	m^3	24.27 tk/m^3	1.50	6	0.09
Full Flood Embankment	970000	m^3	24.27 tk/m^3	18.80	6	1.13
Fine Dressing and Turfing	405000	m^2	2.27 tk/m^2	0.90	1	0.01
Drainage Channel Re-excavation	450000	m^3	23.5 mtk/m^3	10.60	3	0.32
One Vent Regulator(1.52m*1.63m)	1	no	3.50 mtk/no	3.50	2	0.07
Seven Vents Regulator(1.52m*1.63m)	1	no	12.0 mtk/no	12.00	2	0.24
Pipe Inlets (45 cm dia)	3	nos	0.60 mtk/no	0.20	2	
Land Acquisition	60	ha	0.30 mtk/ha	18.00		-
Project Buildings	-			-	3	-
BASE COST:				65.50		1.90
Physical Contingency 25%				16.40		0.46
SUB_TOTAL:				81.90		2.32
Engg & Admin 15%				12.30		0.35
TOTAL COST				94.20		2.67
NET AREA (ha):				2615		
UNIT COST (Tk/ha):				36023		

Table A.12: Estimated Capital and O & M Costs (Nainda Haor)

Item of Works	Quantity	Unit	Unit Price	Capital Cost (mtk)	O & M % Capital Costs	O & M Costs (mtk)
Partial Embankment	650000	m3	24.27 tk/m3	12.6	6	0.76
Compartmental Bund	400000	m3	24.27 tk/m3	7.8	6	0.47
Fine Dressing and Turfing	533000	m2	2.27	1.2	1	0.01
Drainage Channel Re-excavation	658000	m3	23.5	15.5	3	0.46
Eight Vents Regulator(1.52m*1.83m)	1	no	12.00	12.0	2	0.24
Seven Vents Regulator(1.52m*1.83m)	1	no	10.50	10.5	2	0.21
Pipe Sluice (90 cm dia)	2	no	0.55	1.1	2	0.02
Land Acquisition	72	ha	0.3	21.6		-
Project Buildings	-		-	-	3	-
BASE COST:				82.3		2.2
Physical Contingency 25%				20.6		0.54
SUB_TOTAL:				102.8		2.71
Engg & Admin 15%				15.4		0.41
TOTAL:				118.2		3.12
NET AREA (ha):				7250		
UNIT COST (Tk/ha):				16303		431

Table A.13 : Water Balance : Dhalai Gang Project

Item	Unit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Rainfall	mm	11	34	101	369	560	1055	1227	877	627	240	40	15
Storage	ha-m	13	42	124	452	686	1292	1503	1074	768	294	49	18
Data :													
ETO	mm	105.62	124.4	162.42	157.12	153.41	124.95	125.05	130.6	121.49	128.38	114.5	102.64
KC factor		1.2	1.25	1.25	1.2	1.1	1.1	0.95	1.1	1.1	1.1	1.1	1.15
Deep Percolation	mm	62	56	62	60	31	30	0	0	0	0	0	31
Losses :													
Boro, 135 ha	ha-m	17	21	27	25								
Aus, 95 ha	ha-m				18	16	13	11					
Aman, 625 ha	ha-m								90	84	88	79	74
ETO (natural)	ha-m	39	46	60	58	57	46	46	48	45	48	42	38
Deep Percolation	ha-m	76	69	76	74	38	37	0	0	0	0	0	38
Total Loss :	ha-m	132	136	163	175	111	96	58	138	128	136	121	150
Accumu Srorage	ha-m	-119	-94	-40	277	575	1196	1446	936	640	158	-72	-131

Table A.14: Estimated Capital and O & M Costs (Dhalai Gang Project)

Item of Works	Quantity	Unit	Unit Price	Capital Cost (mtk)	O & M % Capital Costs	O & M Costs (mtk)
Partial Embankment	81000	m3	24.27 tk/m3	1.6	6	0.09
Fine Dressing and Turfing	61000	m2	2.27 tk/m2	0.1	1	0.00
Drainage Channel Re-excavation	15000	m3	23.5 tk/m3	0.4	3	0.01
Main Channel (Pilot Excavation)	250000	m3	23.5 tk/m3	5.9	3	0.18
Boulders	11200	m3	255.0 tk/m3	2.9	2	0.06
Two Vents Regulator(1.52m*1.63m)	1	no	5.00 mtk/no	5.0	2	0.10
Fish Pass Structure	1	no	3.5 mtk/no	3.5	2	0.07
Pipe Sluice (90 cm dia)	1	no	0.55 mtk/no	0.6	2	0.01
Land Acquisition	9	ha	0.1 mtk/ha	0.9		-
Project Buildings	-		-	-		-
BASE COST:				20.9		0.5
Physical Contingency 25%				5.2		0.11
SUB_TOTAL:				26.2		0.57
Engg & Admin 15%				3.9		0.09
TOTAL:				30.1		0.65

ANNEX B

FIGURES

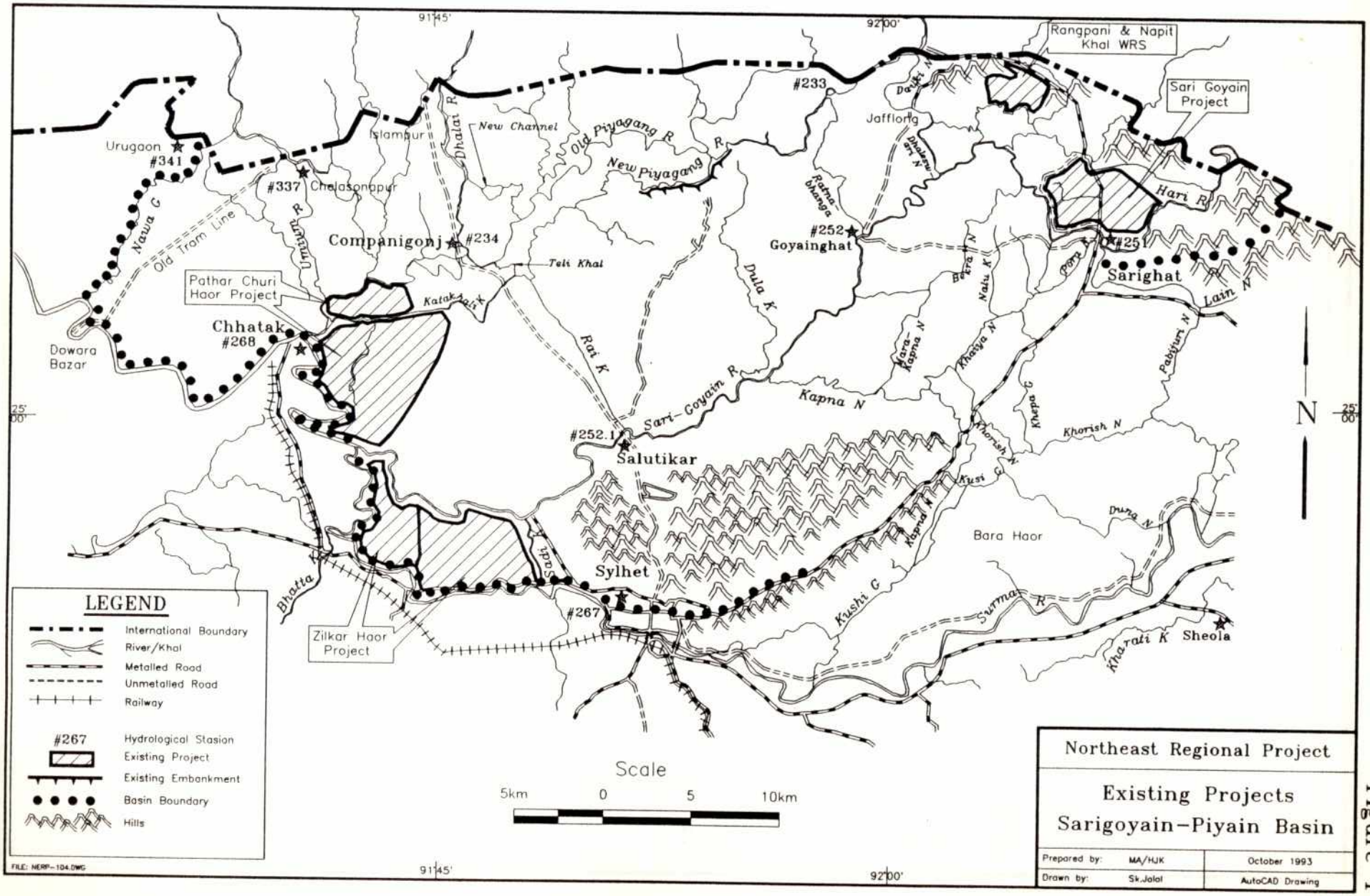
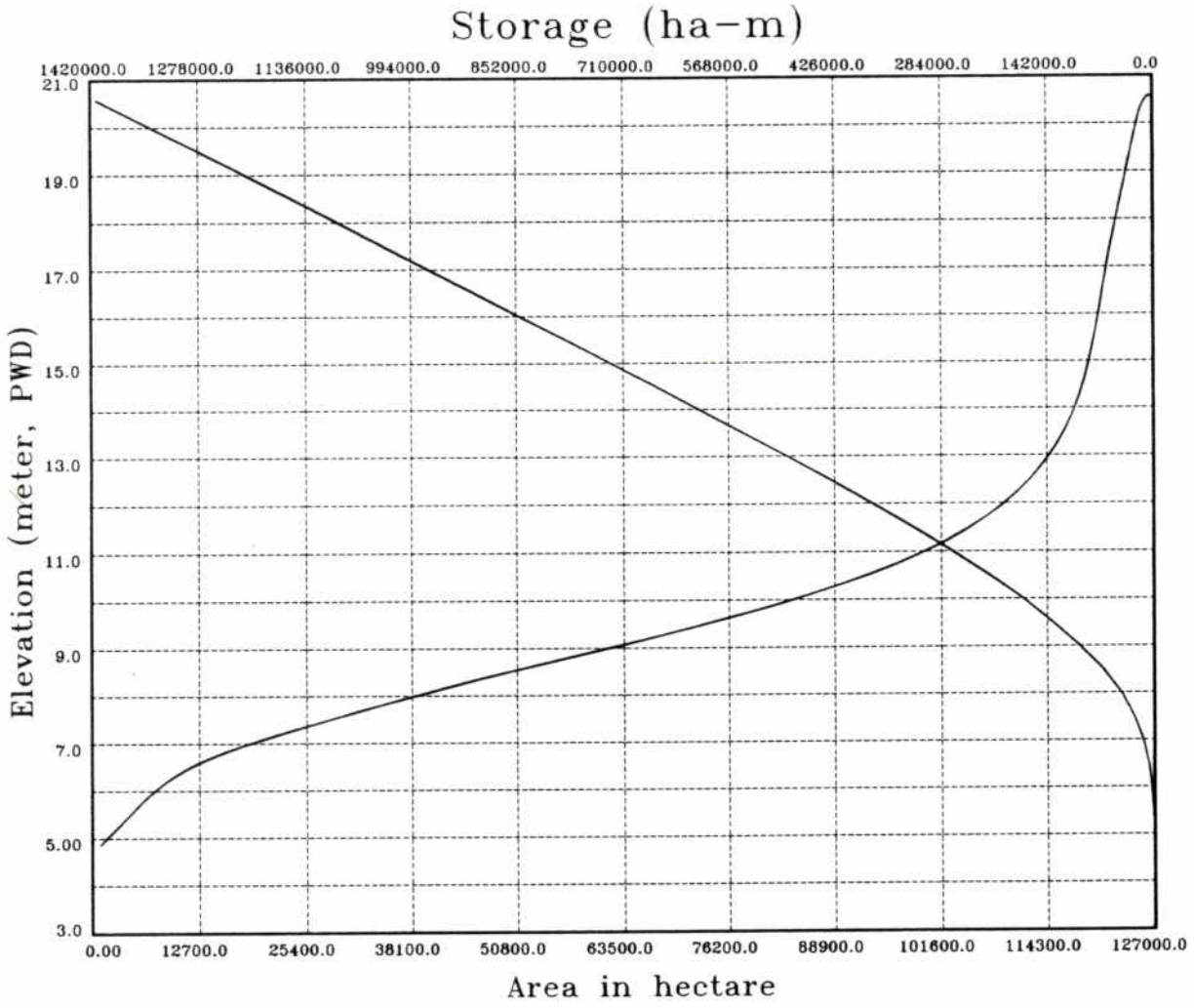

91°45'
92°00'
Rangpani & Napit Khal WRS
Sari Goyain Project
#233
Jaflong
Dauki R
Dhalai R
New Channel
Old Piyagang R
New Piyagang R
Ratna-bhanga
Urugaon
#341
Islampur
#337 Chalasonapur
Dhalai R
Nawa G
Old Tram Line
Companigonj
#234
Teli Khal
#252
Goyainghat
Hari R
#251
Sarighat
Lain N
Pathar Churi Haor Project
Chhatak
#268
Dowara Bazar
Kata-Jali K
Rai K
Dula K
Sari-Goyain R
Kapna N
Mara-Kapna N
Khaiya N
Nalu K
Bera N
Pora
Pabiyura N
Khepa G
Khorish N
#252.1
Salutikar
Kusi G
Kapna N
Dura N
Bara Haor
Sylhet
#267
Bhatta K
Surma R
Kushi G
Khaiati K
Sheola
Zilkar Haor Project
25' 00"
N
LEGEND
International Boundary
River/Khal
Metalled Road
Unmetalled Road
Railway
#267 Hydrological Stasion
Existing Project
Existing Embankment
Basin Boundary
Hills
Scale
5km 0 5 10km
FILE: NERP-104.DWG
Northeast Regional Project
Existing Projects
Sarigoyain-Piyain Basin
Prepared by: MA/HJK
October 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 1

220

Figure 2



Northeast Regional Project		
Area Elevation and Storage Volume Curve Sarigoyain-Piyain		
Prepared by:	M.Ali/Nasim	December 1993

FILE: SARLDWG

WATER LEVEL HYDROGRAPHS
1987–1988

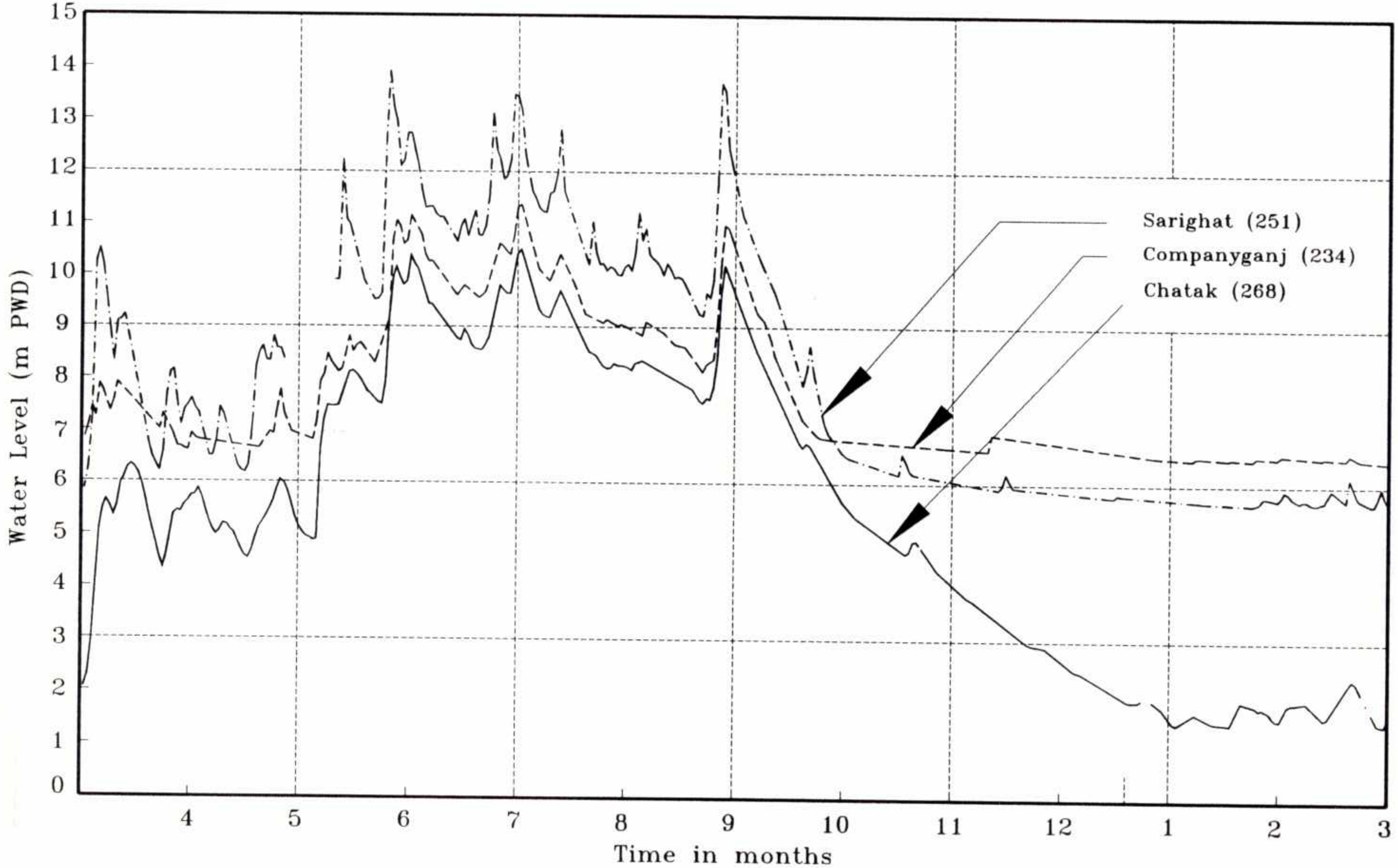


Figure 3

222

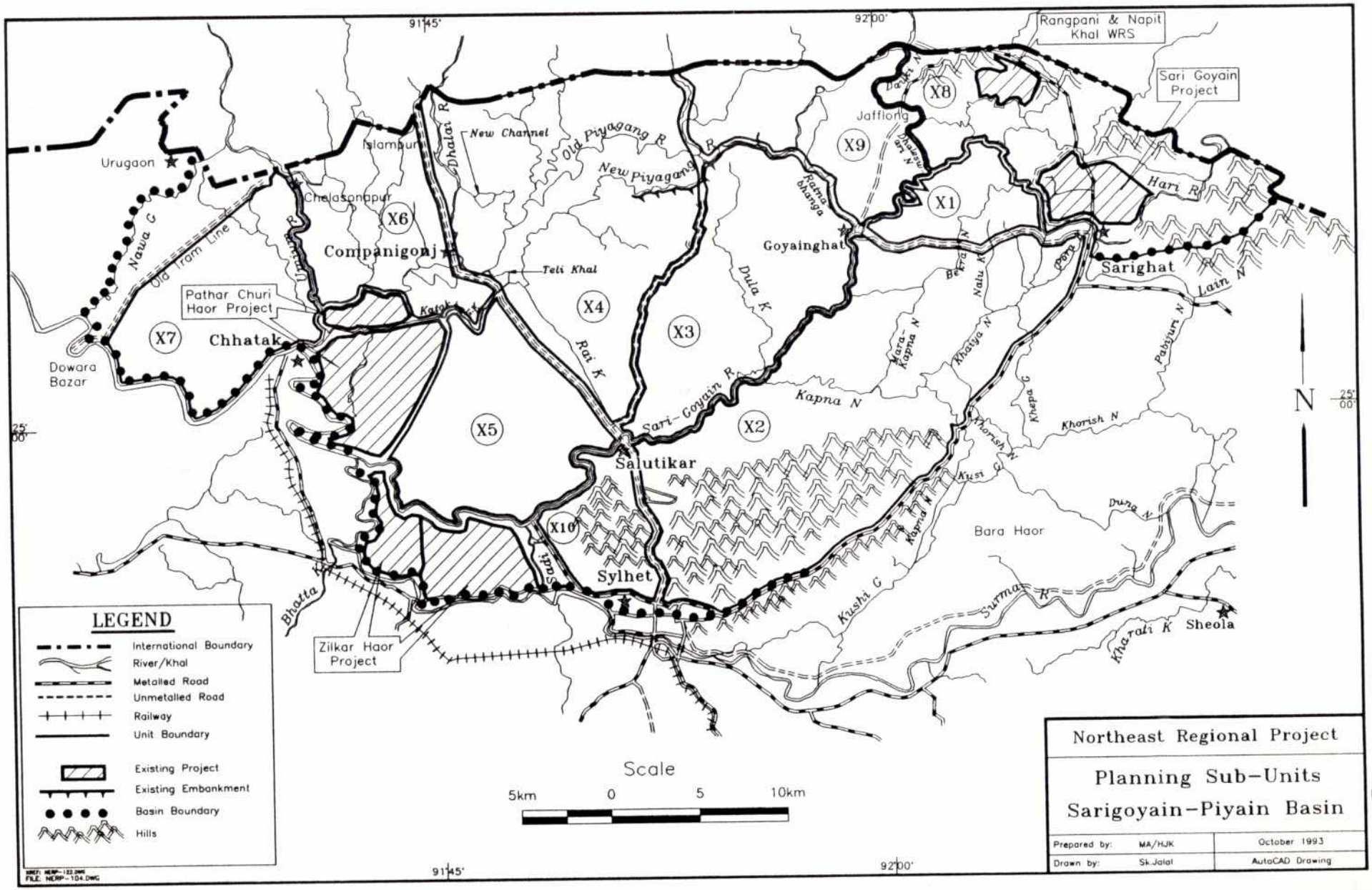

91°45'
92°00'
25° 00'
Rangpani & Napit Khal WRS
Sari Goyain Project
Urugaon
Islampur
Dhalai R
New Channel
Old Piyagang R
New Piyagang R
Jafflong
X8
X9
X1
Hari R
Chelasonapur
X6
Companigonj
Nawa G
Old Tram Line
Teli Khal
Goyainghat
Ratnabhanga
Sarighat
Lain N
Pathar Churi Haor Project
X7
Chhatak
X4
X3
Rai K
Dula K
Dowara Bazar
Sari-Goyain R
Kapna N
X5
X2
Salutikar
Khorish N
Khepa G
Pabijuri N
Bara Haor
Dura N
X10
Sylhet
Bhatta
Zilkar Haor Project
Kushi G
Surma R
Kharali K
Sheola
N
Scale
5km 0 5 10km
LEGEND
International Boundary
River/Khal
Metalled Road
Unmetalled Road
Railway
Unit Boundary
Existing Project
Existing Embankment
Basin Boundary
Hills
Northeast Regional Project
Planning Sub-Units
Sarigoyain-Piyain Basin
Prepared by: MA/HJK
October 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 4

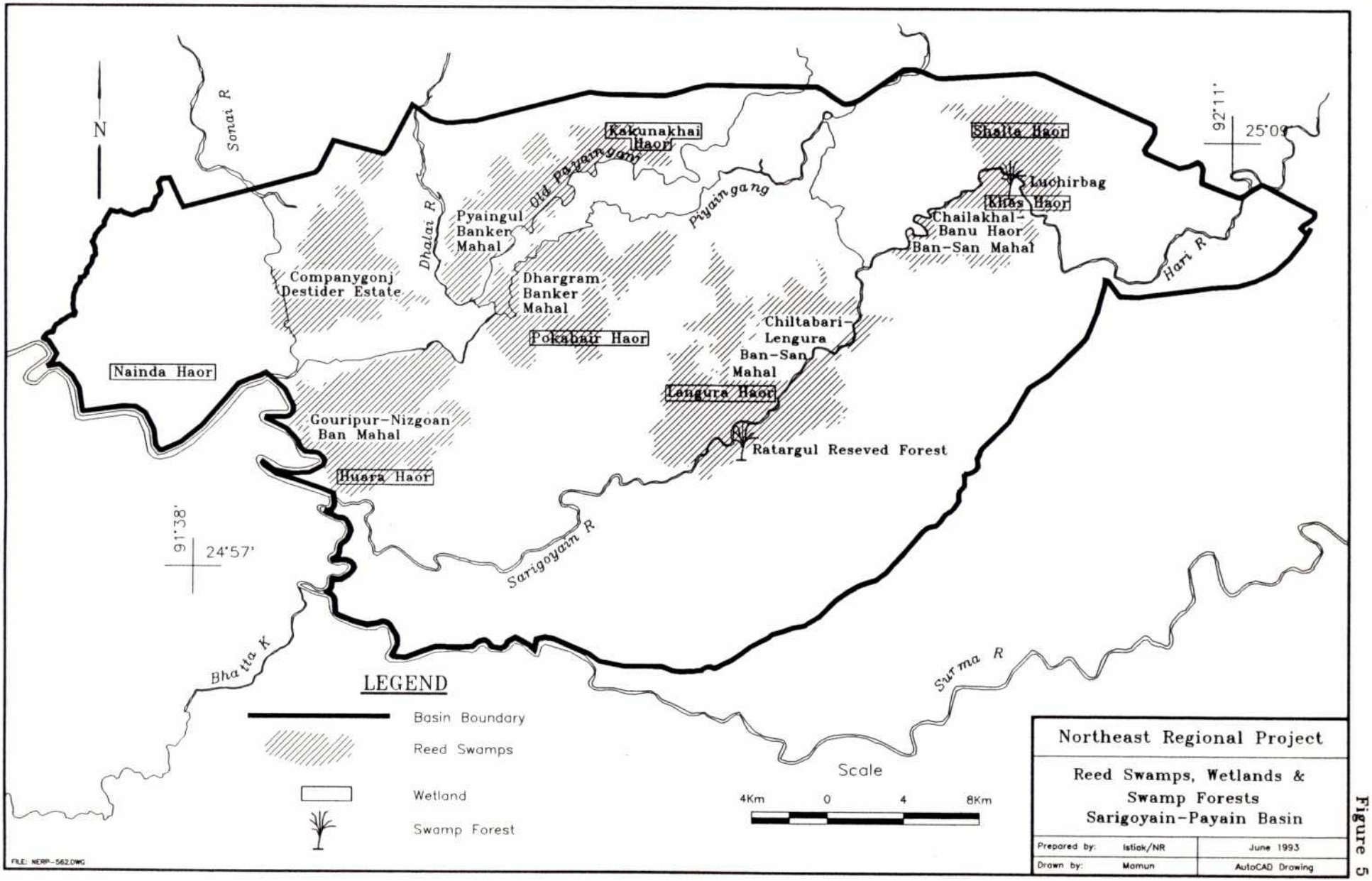

N
Sonai R
Dhalai R
Old Payaingang
Piyain gang
Kakunakhai Haor
Pyaingul Banker Mahal
Dhargram Banker Mahal
Companygonj Destider Estate
Pokabair Haor
Nainda Haor
Gouripur-Nizgoan Ban Mahal
Huara Haor
Chiltabari-Lengura Ban-San Mahal
Lengura Haor
Ratargul Reseved Forest
Shalta Haor
Luchirbag
Khas Haor
Chailakhal-Banu Haor Ban-San Mahal
Hari R
92°11'
25°09'
91°38'
24°57'
Sarigoyain R
Bhatta K
Surma R
LEGEND
Basin Boundary
Reed Swamps
Wetland
Swamp Forest
Scale
4Km 0 4 8Km
FILE: NERP-562.DWG
Northeast Regional Project
Reed Swamps, Wetlands & Swamp Forests Sarigoyain-Payain Basin
Prepared by: Istiak/NR June 1993
Drawn by: Mamun AutoCAD Drawing

Figure 5

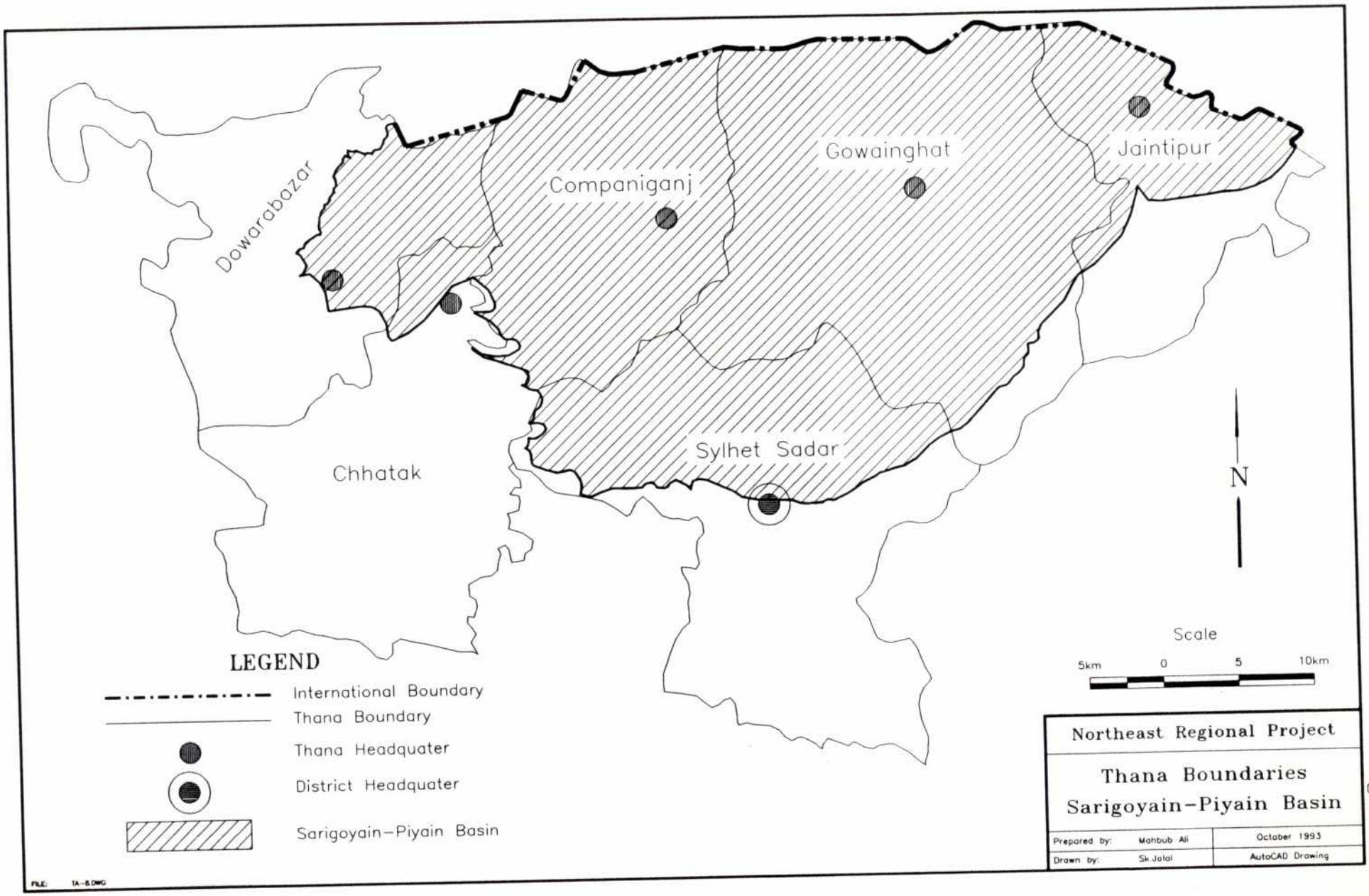

Dowarabazar
Companiganj
Gowainghat
Jaintipur
Chhatak
Sylhet Sadar
N
Scale
5km 0 5 10km
LEGEND
International Boundary
Thana Boundary
Thana Headquater
District Headquater
Sarigoyain–Piyain Basin
Northeast Regional Project
Thana Boundaries
Sarigoyain–Piyain Basin
Prepared by: Mahbub Ali
October 1993
Drawn by: Sk Jalal
AutoCAD Drawing
FILE: TA-6.DWG

Figure 6

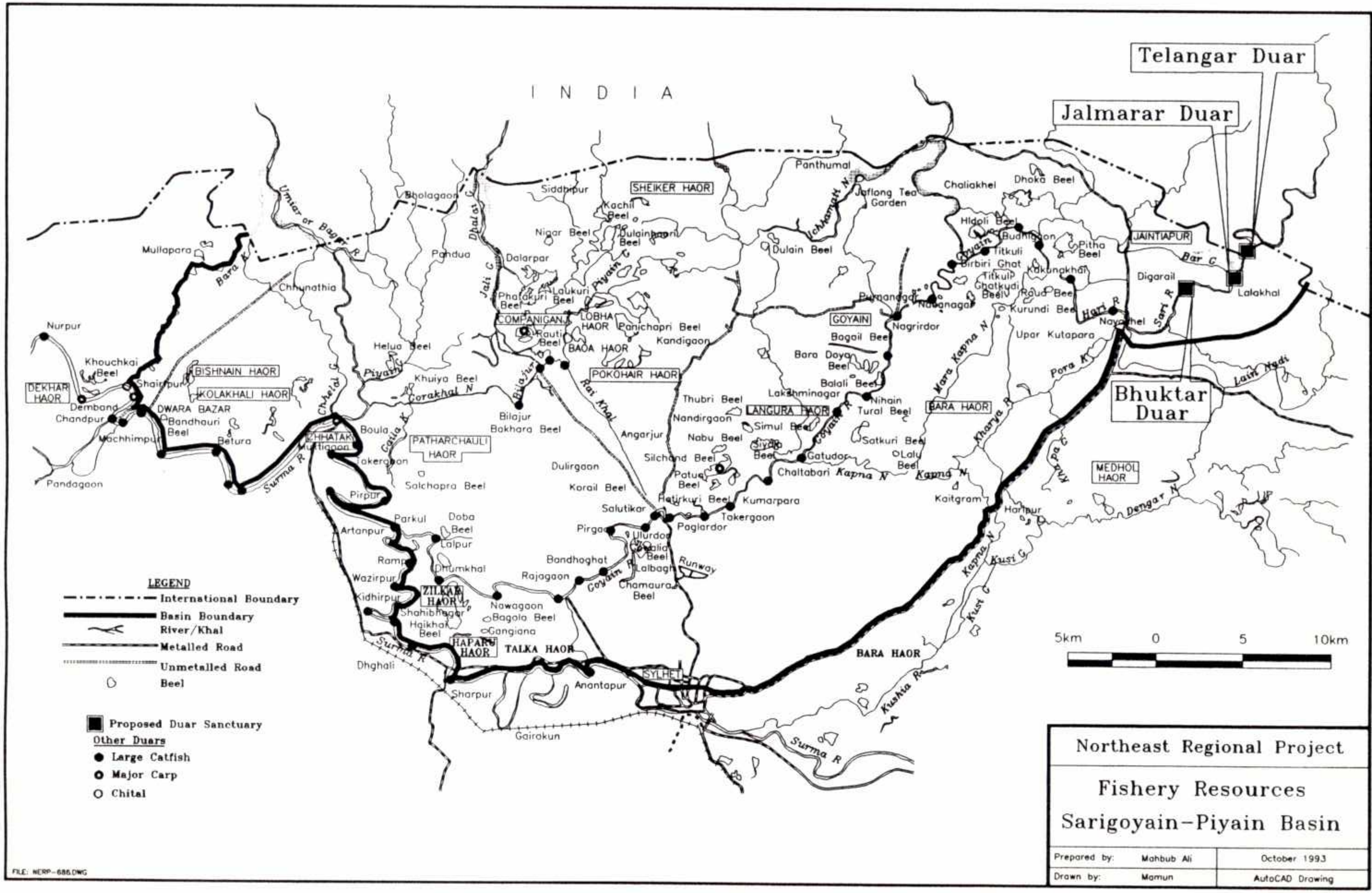

INDIA
Telangar Duar
Jalmarar Duar
Bhuktar Duar
SHEIKER HAOR
COMPANIGANJ
LOBHA HAOR
BAOA HAOR
POKOHAIR HAOR
PATHARCHAULI HAOR
CHHATAK
BISHNAIN HAOR
KOLAKHALI HAOR
DEKHAR HAOR
DWARA BAZAR
GOYAIN
LANGURA HAOR
BARA HAOR
MEDHOL HAOR
JAINTIAPUR
ZILKAR HAOR
HAPARU HAOR
TALKA HAOR
SYLHET
Surma R
Piyain G
Goyain R
Kapna N
Mara Kapna N
Sari R
Bar G
Rai Khal
Runway
LEGEND
International Boundary
Basin Boundary
River/Khal
Metalled Road
Unmetalled Road
Beel
Proposed Duar Sanctuary
Other Duars
Large Catfish
Major Carp
Chital
5km 0 5 10km
Northeast Regional Project
Fishery Resources
Sarigoyain-Piyain Basin
Prepared by: Mahbub Ali
October 1993
Drawn by: Mamun
AutoCAD Drawing
FILE: NERP-686.DWG

Figure 7

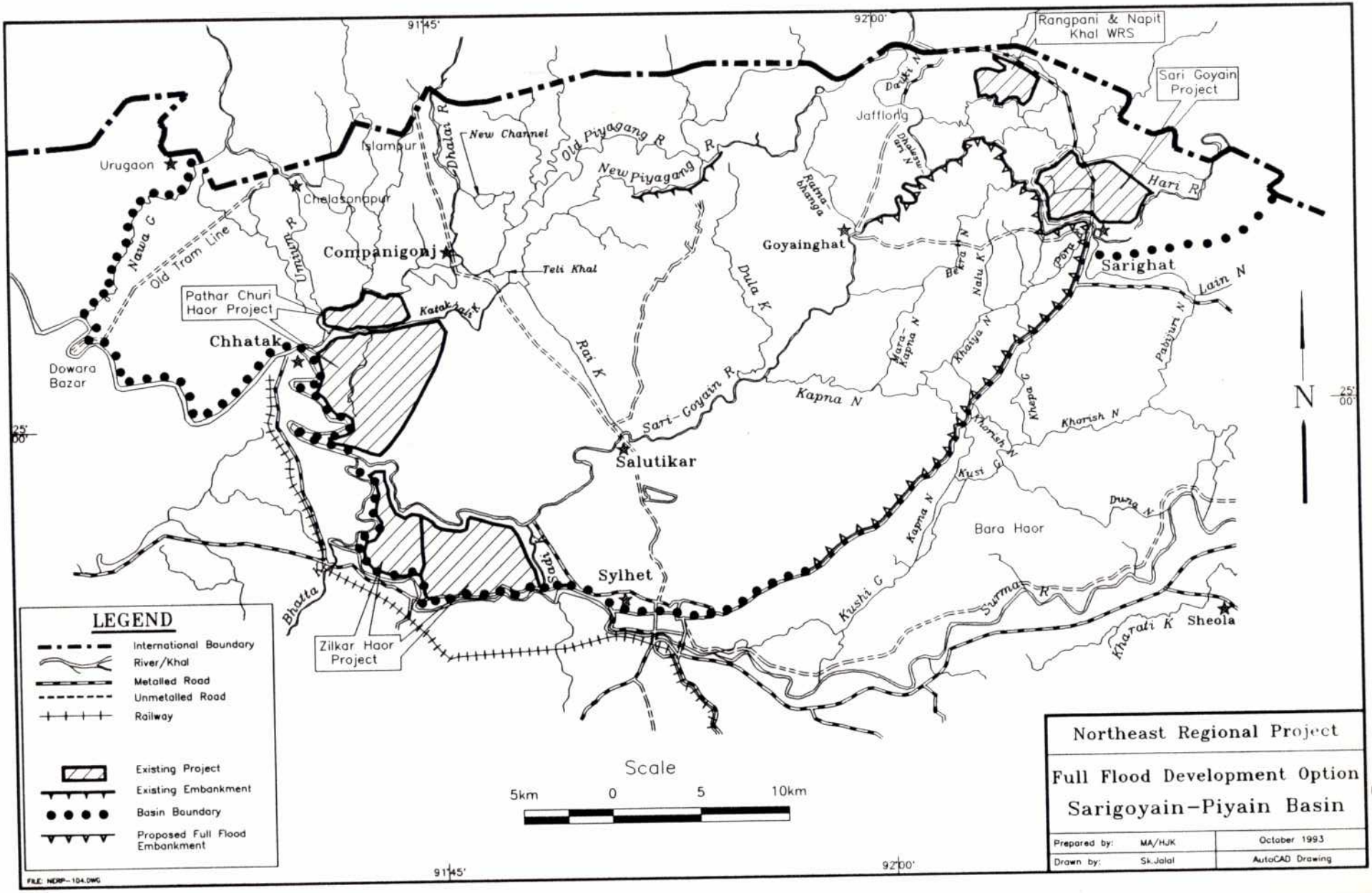

91°45'
92°00'
25° 00'
Rangpani & Napit Khal WRS
Sari Goyain Project
Hari R
Jaflong
Dauki N
Dhalai R
New Channel
Old Piyagang R
New Piyagang R
Ratna-bhanga
Urugaon
Islampur
Chelasonapur
Nawa G
Old Tram Line
Umiam R
Companigonj
Teli Khal
Goyainghat
Dula K
Pathar Churi Haor Project
Katakhali K
Chhatak
Dowara Bazar
Rai K
Sari-Goyain R
Kapna N
Salutikar
Sylhet
Bhatta
Zilkar Haor Project
Sarighat
Lain N
Bera N
Nalu K
Para-Kapna N
Khaiya N
Khapa G
Kharish N
Pabijuri N
Kust G
Dhuna N
Bara Haor
Kushi G
Surma R
Kharati K
Sheola
N
Scale
5km 0 5 10km
LEGEND
International Boundary
River/Khal
Metalled Road
Unmetalled Road
Railway
Existing Project
Existing Embankment
Basin Boundary
Proposed Full Flood Embankment
FILE: NERP-104.DWG
Northeast Regional Project
Full Flood Development Option
Sarigoyain-Piyain Basin
Prepared by: MA/HJK
October 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 8

Figure 9

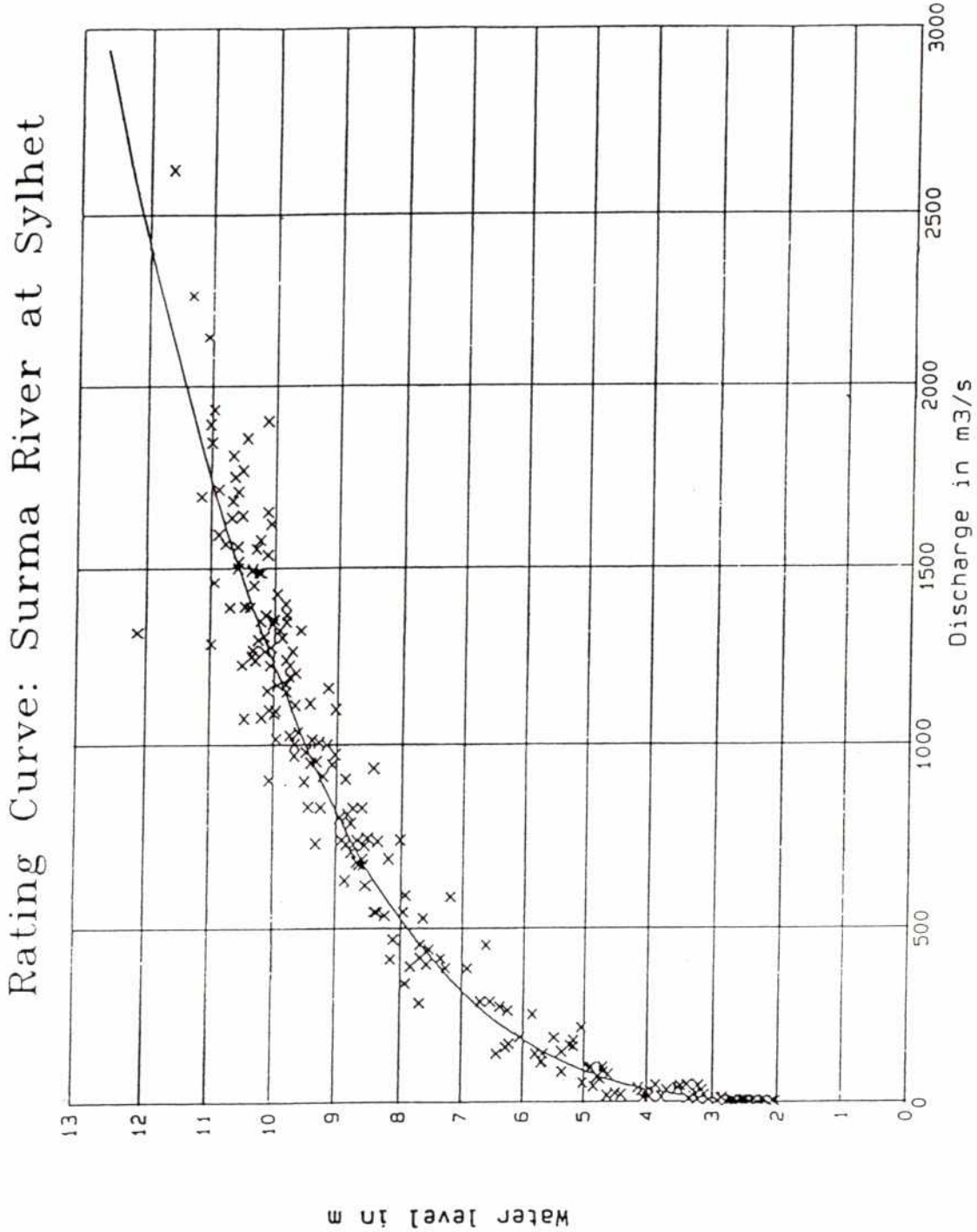
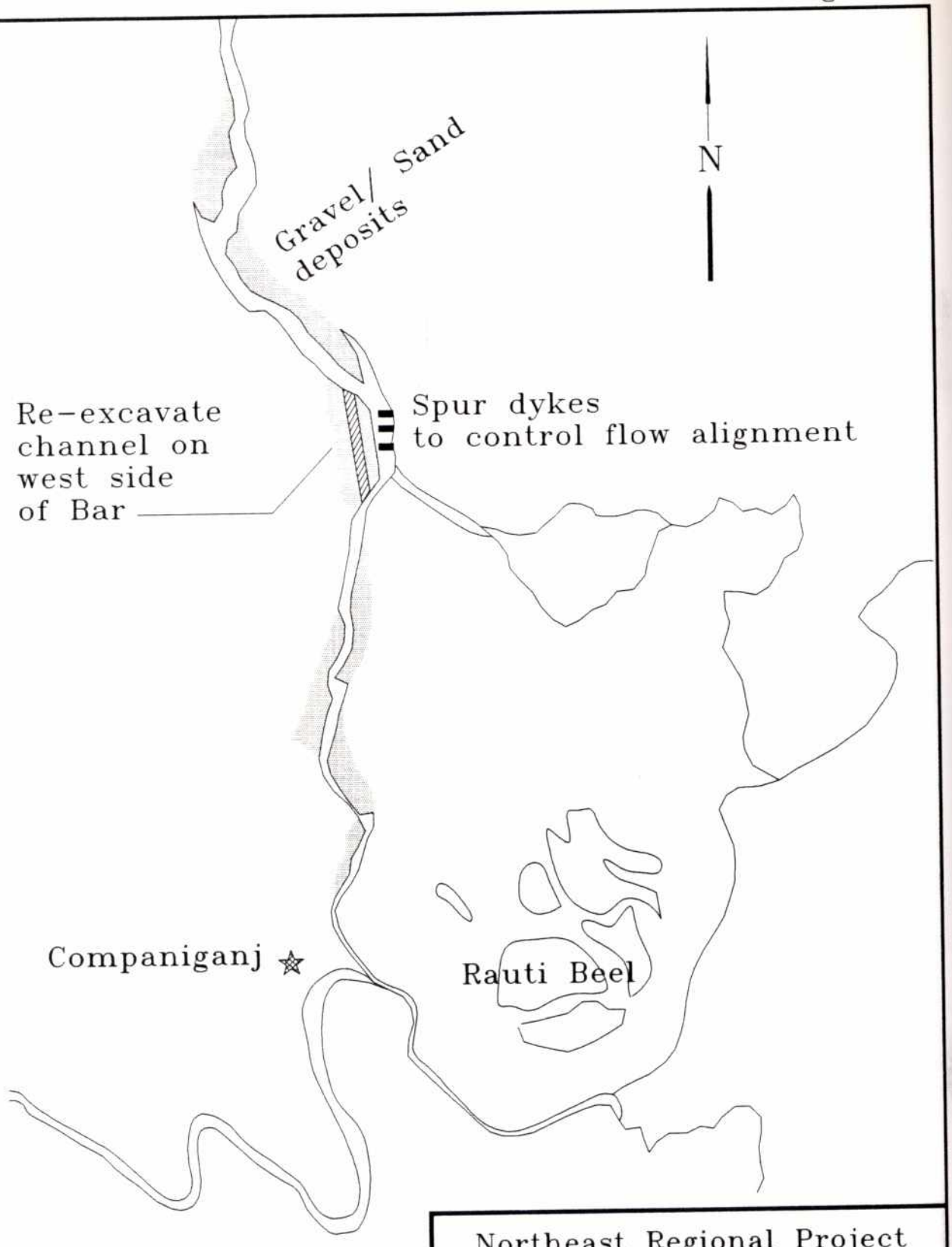

Rating Curve: Surma River at Sylhet
Discharge in m3/s
0
500
1000
1500
2000
2500
3000
water level in m
0
1
2
3
4
5
6
7
8
9
10
11
12
13

Figure 10



Northeast Regional Project	
Channel Maintenance and Upstream Channel Control Dhalai Gang Development	
Prepared by: Mahbub Ali	October 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-135.DWG

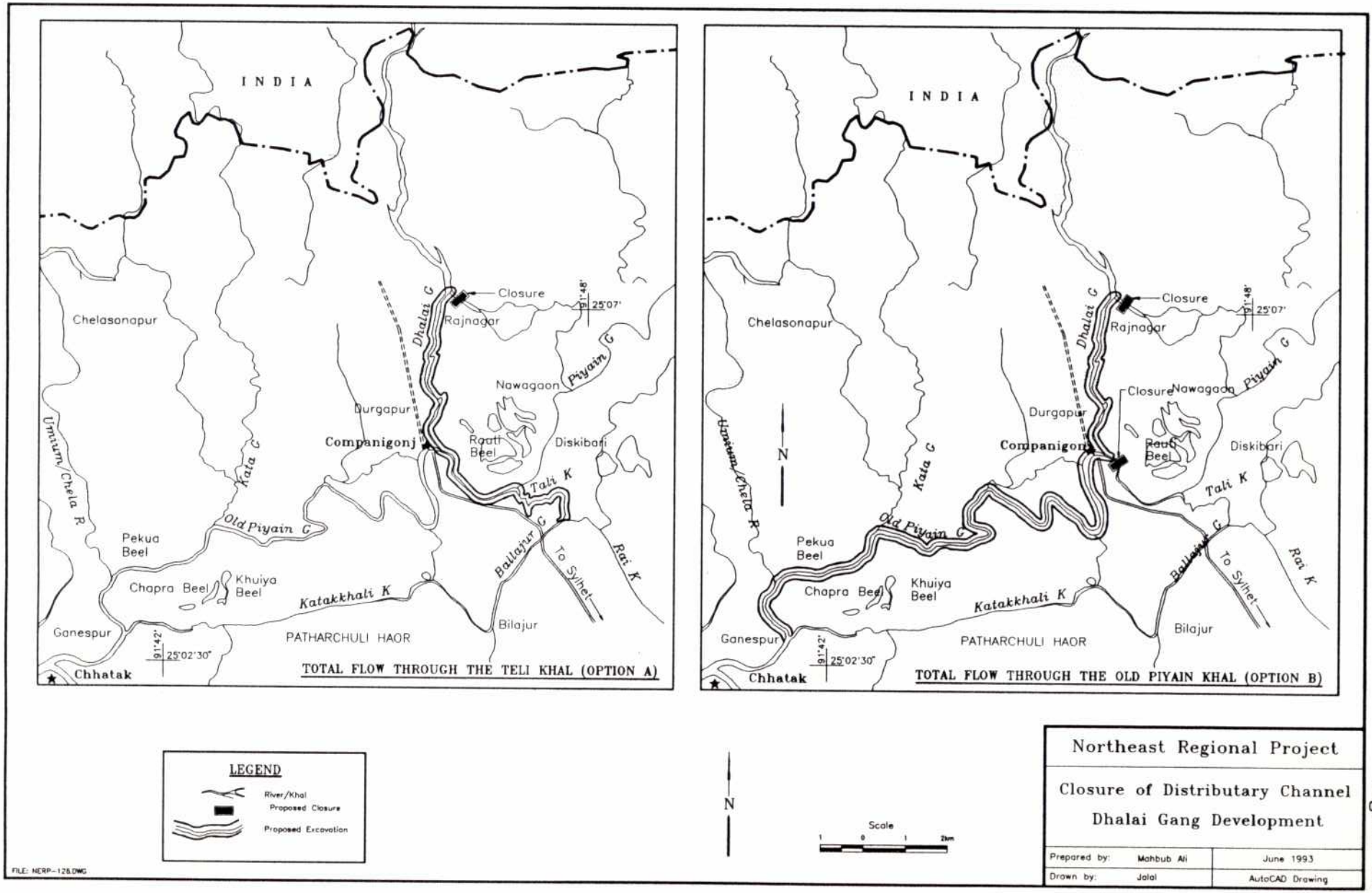

INDIA
Chelasonapur
Dhalai G
Closure
Rajnagar
91°48'
25°07'
Nawagaon
Piyain G
Durgapur
Companigonj
Rauti Beel
Diskibari
Umium/Chela R.
Kata G
Tali K
Old Piyain G
Pekua Beel
Chapra Beel
Khuiya Beel
Katakkhali K
Ballajur G
To Sylhet
Rai K
Ganespur
91°42'
25°02'30"
PATHARCHULI HAOR
Bilajur
Chhatak
TOTAL FLOW THROUGH THE TELI KHAL (OPTION A)
INDIA
Chelasonapur
Dhalai G
Closure
Rajnagar
91°48'
25°07'
Nawagaon
Piyain G
Durgapur
Companigonj
Rauti Beel
Diskibari
Hamiam/Chela R.
N
Kata G
Tali K
Old Piyain G
Pekua Beel
Chapra Beel
Khuiya Beel
Katakkhali K
Ballajur G
To Sylhet
Rai K
Ganespur
91°42'
25°02'30"
PATHARCHULI HAOR
Bilajur
Chhatak
TOTAL FLOW THROUGH THE OLD PIYAIN KHAL (OPTION B)
LEGEND
River/Khal
Proposed Closure
Proposed Excavation
N
Scale
1 0 1 2km
FILE: NERP-128.DWG
Northeast Regional Project
Closure of Distributary Channel
Dhalai Gang Development
Prepared by: Mahbub Ali
June 1993
Drawn by: Jalal
AutoCAD Drawing

Figure 11

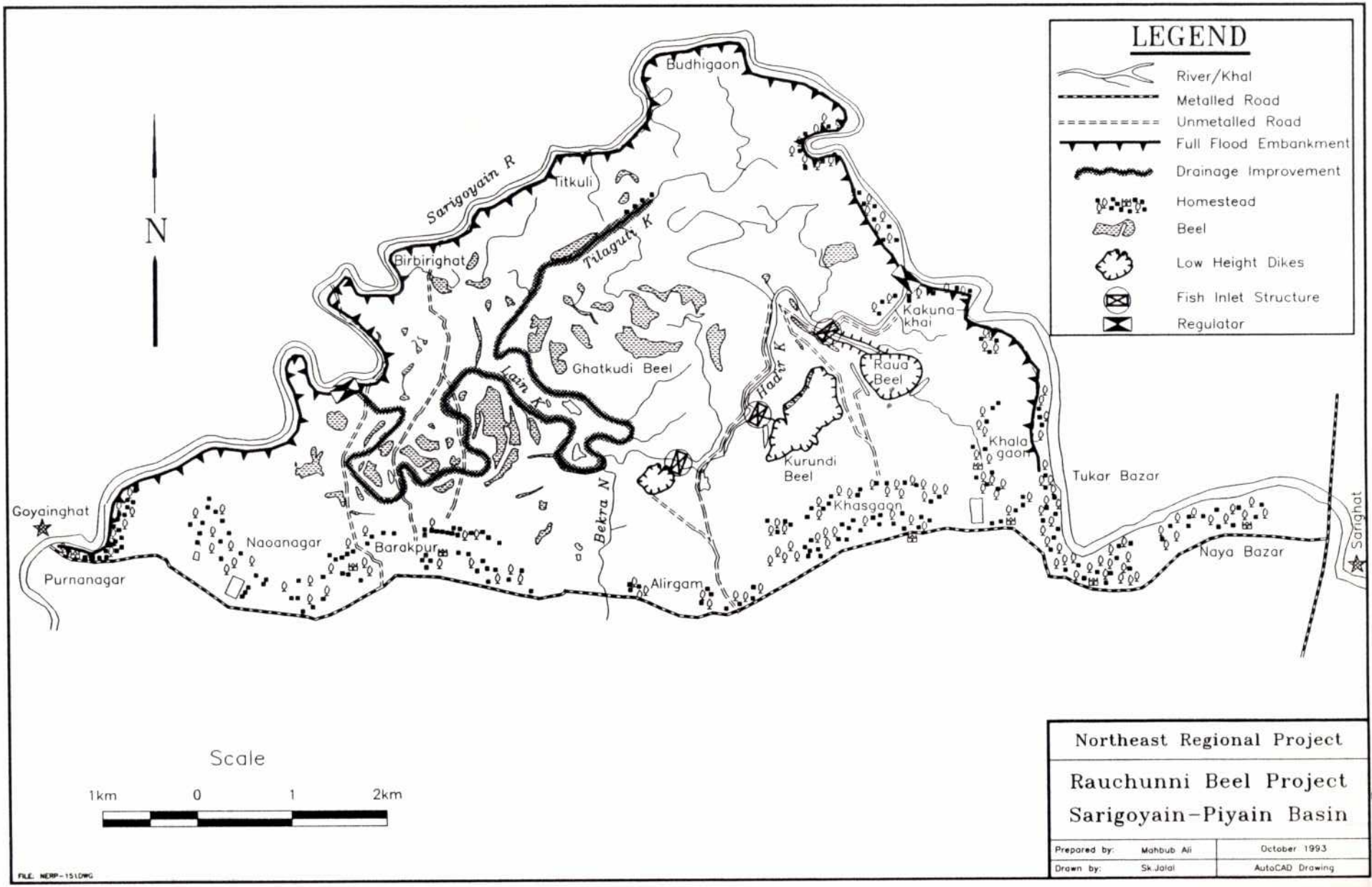
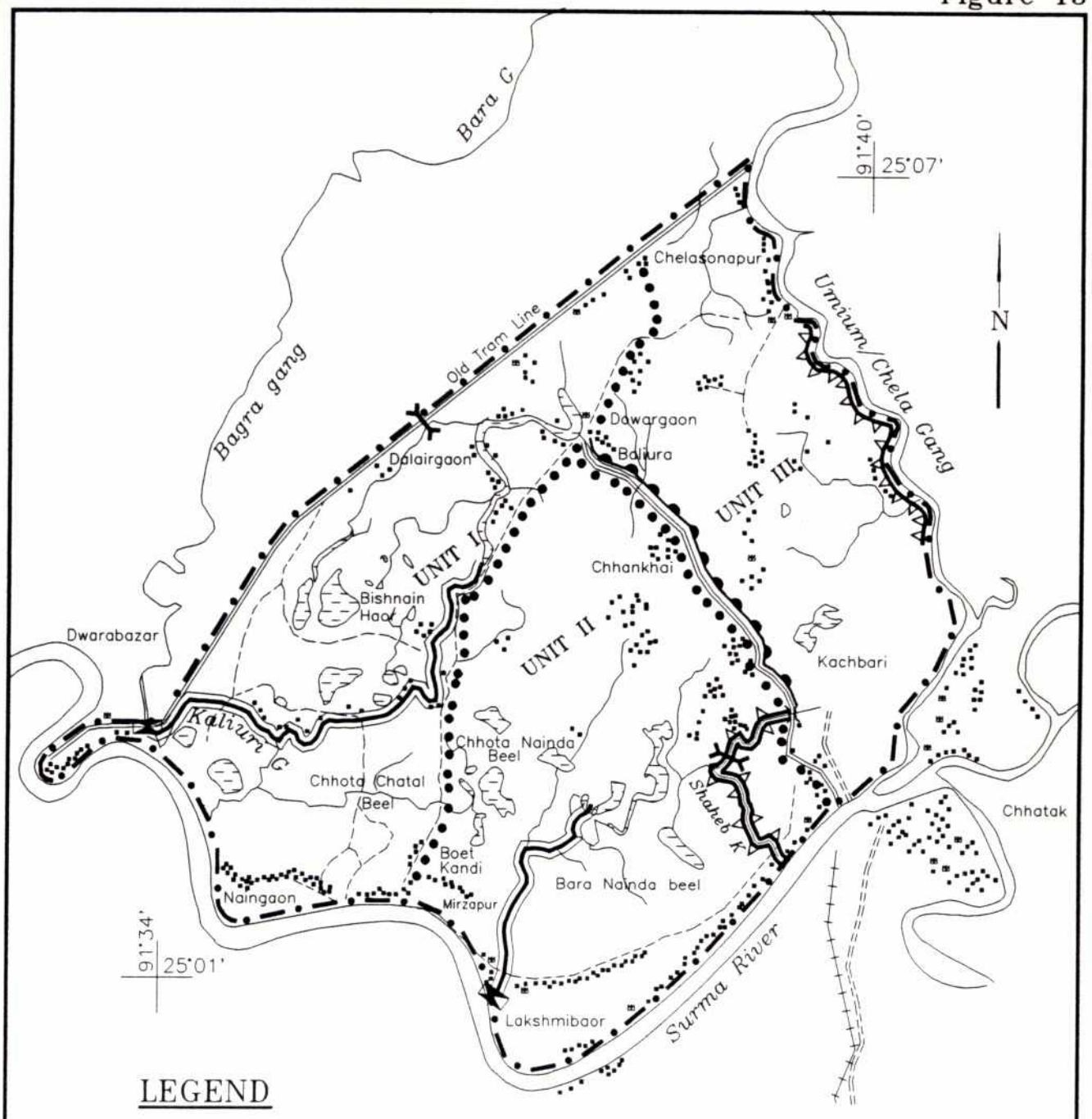

LEGEND
River/Khal
Metalled Road
Unmetalled Road
Full Flood Embankment
Drainage Improvement
Homestead
Beel
Low Height Dikes
Fish Inlet Structure
Regulator
N
Budhigaon
Sarigoyain R
Titkuli
Tilaguti K
Birbirighat
Kakuna khai
Ghatkudi Beel
Lain K
Haati K
Raua Beel
Khala gaon
Kurundi Beel
Tukar Bazar
Goyainghat
Naoanagar
Barakpur
Bekra N
Khasgaon
Purnanagar
Alirgam
Naya Bazar
Sarighat
Scale
1km 0 1 2km
FILE: NERP-15.DWG
Northeast Regional Project
Rauchunni Beel Project
Sarigoyain-Piyain Basin
Prepared by: Mahbub Ali
October 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 12

Figure 13



LEGEND

- Project Boundary
- Submersible Embankment
- Drainage Improvement
- Compartmental Bund
- Borrow Pit cum Drainage Channel
- Regulator
- Pipe Sluice
- Road Improvement
- Footpath/Road
- Homestead

Scale

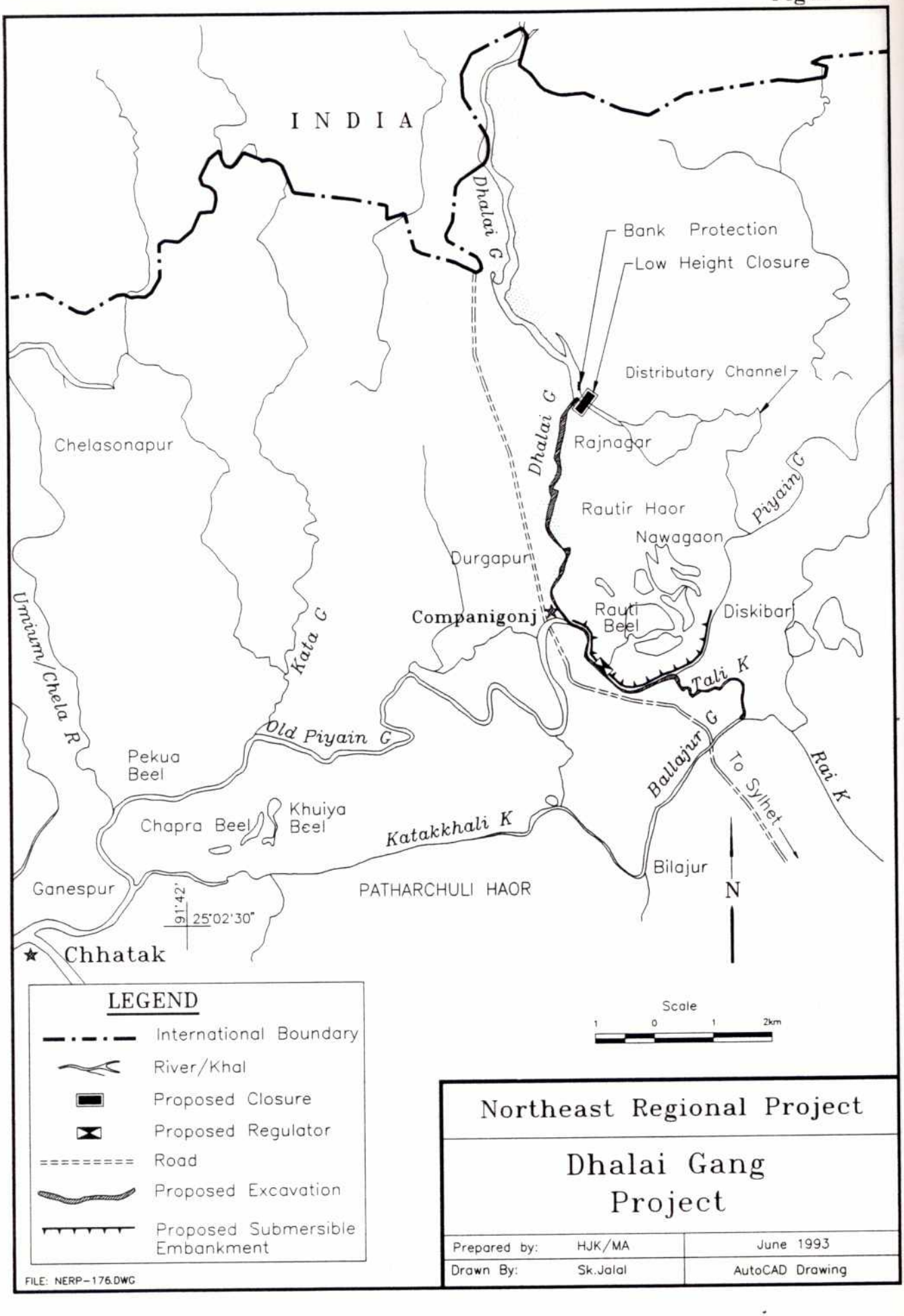
1km 0 1 2km

Northeast Regional Project

Nainda Haor Project
Sarigoyain–Piyain Basin

Prepared by:	Mahbub Ali	June 1993
Drawn By:	Sk.Jala	AutoCAD Drawing

FILE: NERP-137.DWG

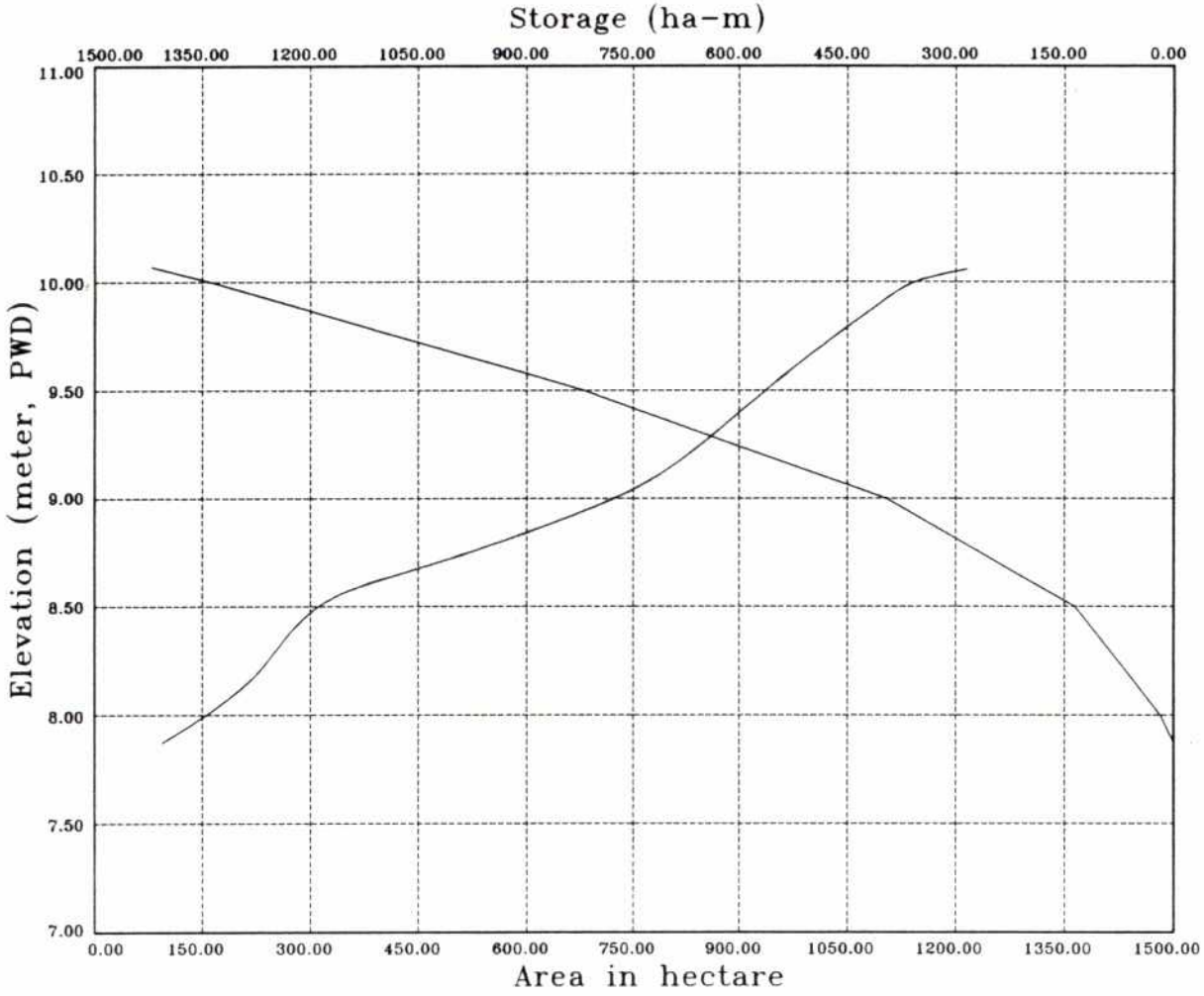


Northeast Regional Project

Dhalai Gang Project

Prepared by:	HJK/MA	June 1993
Drawn By:	Sk.Jalal	AutoCAD Drawing

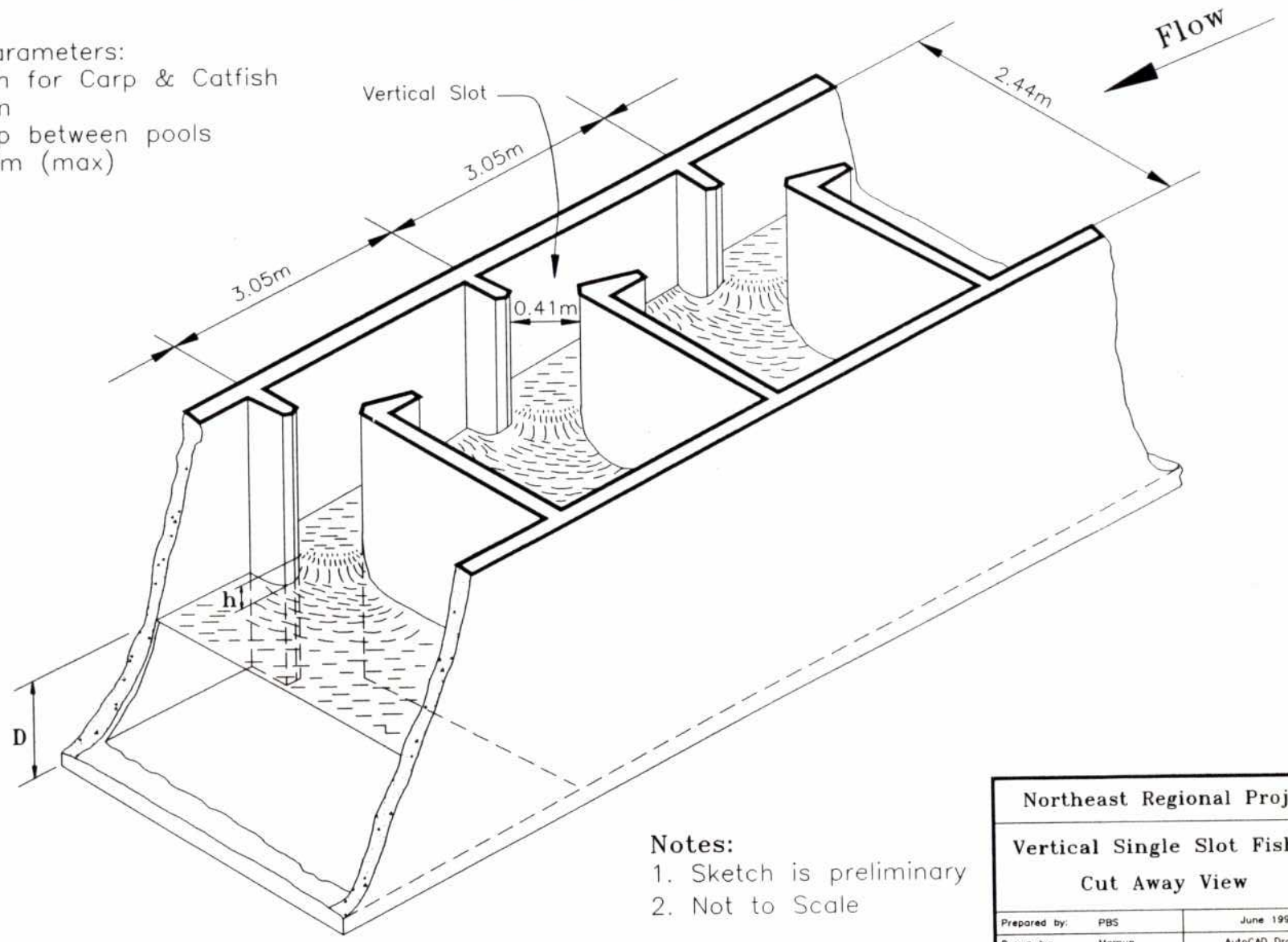
Figure 15



Northeast Regional Project		
Area Elevation and Storage Volume Curve Dhalai Gang Project		
Prepared by:	M.Ali/Nasim	December 1993

FILE: DHALALDWG

Design Parameters:
Min. depth for Carp & Catfish
D = 1.0m
Head drop between pools
h ≈ 0.25m (max)

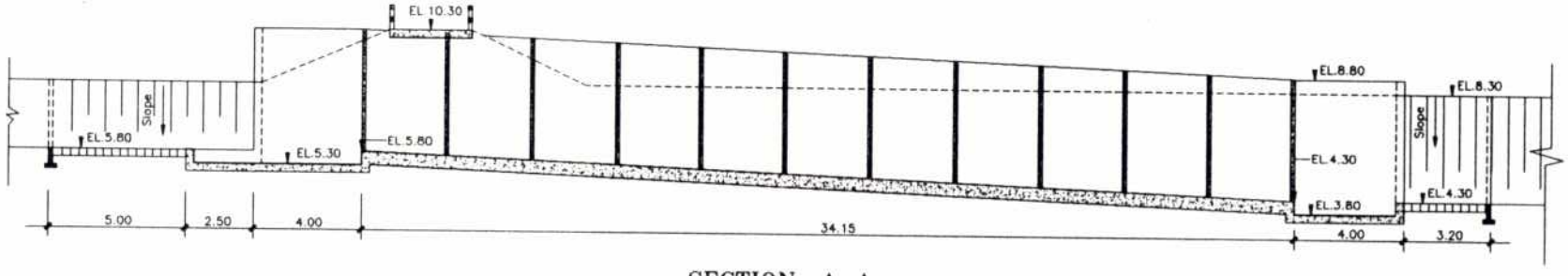


Notes:
1. Sketch is preliminary
2. Not to Scale

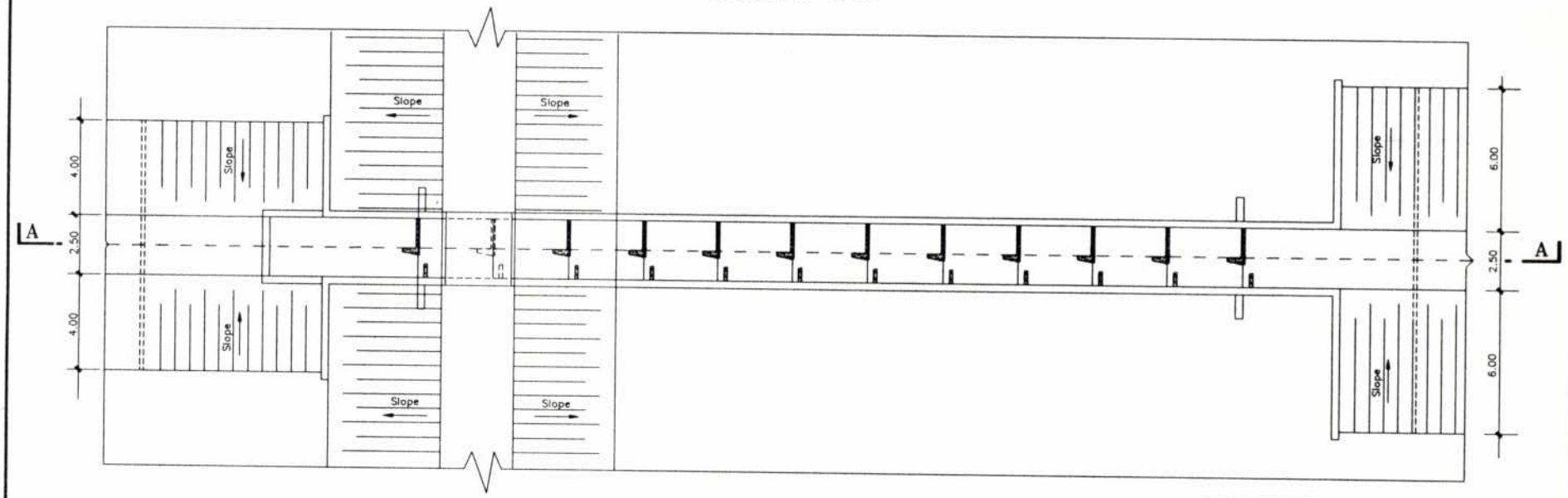
Northeast Regional Project	
Vertical Single Slot Fishway Cut Away View	
Prepared by: PBS	June 1993
Drawn by: Mamun	AutoCAD Drawing

FILE: FISH-B2.DWG

Figure 16



SECTION: A–A



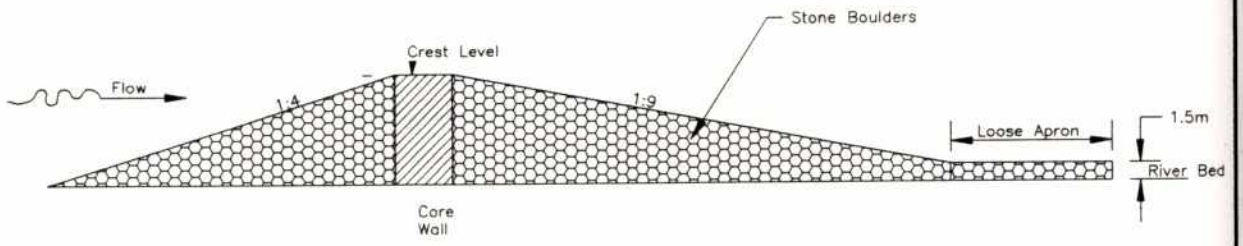
PLAN

NOTE:–
Preliminary drawing only.

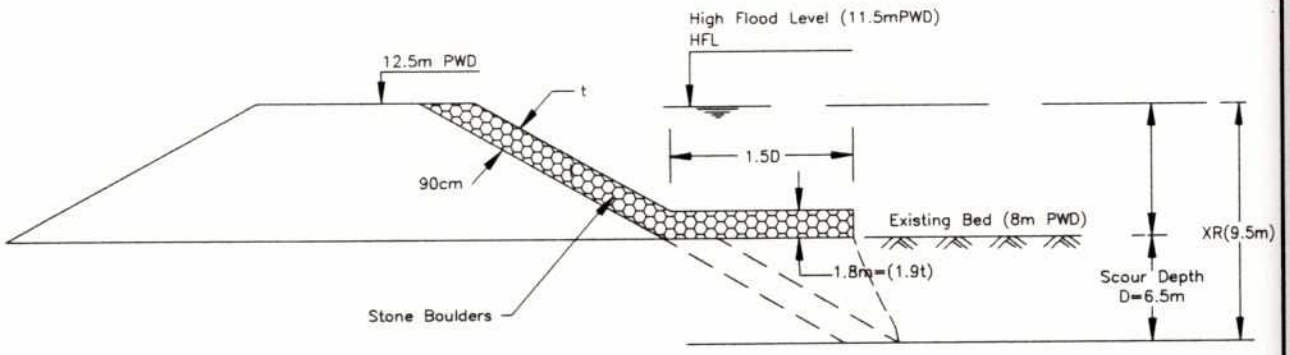
FILE: NERP-194.DWG

Northeast Regional Project	
Typical Single Fish Pass Structure	
Prepared by: NR	December 1994
Drawn by: Sk.Jalal	AutoCAD Drawing

Figure 17



Typical Section, Cross-Dam



Bank Revetment

Northeast Regional Project	
River Training Works Dhalai Gang Project	
Prepared by: Mahbub Ali	October 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-053.DWG

ANNEX C1

INITIAL ENVIRONMENTAL EXAMINATION

RAUCHUNNI BEEL PROJECT

ANNEX C: INITIAL ENVIRONMENTAL EXAMINATION

C.1 Introduction

This Initial Environmental Examination (IEE) (pre-feasibility level Environmental Impact Assessment or EIA) follows the steps specified in the *Bangladesh Flood Action Plan Guidelines for Environmental Impact Assessment* (ISPAN, 1992). These steps are illustrated in Figure 2 of ISPAN (1992).

Much of the information required for the IEE/EIA appears in the main body of the study. The section and chapter references given below cite this information.

C.2 Alternative 1: Proposed Partial FCD Project

C.2.1 Project Design and Description (Step 1)

As in Section 7.3, Project Description.

C.2.2 Environmental Baseline Description (Step 2)

As in Chapter 2, Biophysical Description, and Chapter 3, Settlement, Development, and Resource Management.

C.2.3 Scoping (Step 3)

Technical:

Literature review: Presented in Chapter 4, Previous Studies.

Local community: As described in Section 3.1.9, People's Perception.

C.2.4 Bounding (Step 4)

Physical:

Gross area: 3200 ha.

Impacted (net) area: 2615 ha.

Impacted area outside project: Sarigoyain flood levels at Sarighat and down stream could increase by not more than 5-10 cm. There will be little impact on the area outside the project due to these increased flood levels since most of the area are fallow and reed lands. However, the project will have substantial positive impact to the south of Sarighat-Goyainghat road. Water levels in this area will be reduced by about 0.3 m during the monsoon season. This will partially protect aus and aman crops and save the homesteads. These benefits have not been included in the project benefit analysis since they occur outside the project area.

Temporal:

Preconstruction: years 0 through year 2 (see Table 7.9).

Construction: year 1 through year 3 (see Table 7.9).

Operation: year 4 through year 20.

2662

Abandonment: after year 20.

Cumulative impacts:

With other floodplain infrastructure: This will be looked at in the context of the Regional Plan.

With pre-existing no-project trends. Described in Chapter 5.

C.2.5 Field Investigations (Step 5)

Field investigations were limited to seven to ten days of informal reconnaissance by a multi-disciplinary team.

C.2.6 Impact Assessment (Step 6)

At this level of detail, a screening matrix (Table C.1) was filled out by the project team. Impacts are designated by:

+	positive impact
-	negative impact
•	neutral impact (such as conversion from one productive land use to another)
?	insufficient information to designate

Impacts are discussed in Section 7.8.

C.2.7 Quantify and Value Impacts (Step 7)

Quantification and evaluation of impacts is documented in Section 7.8 and Tables 7.14 through and 7.16.

C.2.8 Environmental Management Plan (Step 8)

At a pre-feasibility level, this section focuses on "identification of broad management options and major constraints" (p. 28, ISPAN, 1992).

Mitigation and enhancement. Documented in Section 7.3.5 and 7.8.1 (openwater Fisheries Production).

Compensation. Mandated requirements for land acquisition must be adhered to. Beyond this, consideration should be given to:

- In-kind rather than cash compensation for households whose homestead land is taken.
- Compensation for persons other than landowners who are impacted negatively by land acquisition and construction/infrastructure-related land use changes. Example: project implementation could be made contingent upon successful resettlement of squatters displaced from embankment/structure sites under local initiative; local communities could work with NGOs to accomplish this.

Monitoring. There is a need to define monitoring needs and methodologies at regional,

institutional (BWDB), and projects levels. This exercise should reflect (i) the need for greater people's participation in all project activities, which would include monitoring project function and opportunities for discussion with BWDB and (ii) the need for greater emphasis on operation and maintenance, of which monitoring can play an important role.

People's participation. There is a need at regional, institutional, and project levels to maintain enthusiasm for people's participation, and to develop effective and efficient public participation modalities.

Disaster management (contingency planning). Once the flood protection is operational, investment in agriculture will likely rise. This increases the total amount of farmers' assets that are at risk should an extreme flood event occur or the embankment fail for any reason. Currently in Bangladesh, these risks are borne by individual investors (in this case farmers). Unsustainable solutions (such as government subsidy of crop insurance) should be avoided however.

EMP institutionalization. Arrangements for sharing EMP responsibility between BWDB and local people would need to be worked out. Project implementation should be contingent upon agreement on this matter between BWDB and local people.

Residual impact description. This should be generated as part of the feasibility-level EIA.

Reporting and accountability framework. At a national or regional scale, there is a need to develop satisfactory reporting/accountability arrangements involving BWDB, DOF and DOE, probably through an Environmental Cell within BWDB linked to DOE and DOF. At the project level, the client committee and local BWDB staff should develop reporting/accountability arrangements satisfactory to themselves. Project implementation should be contingent upon development of satisfactory arrangements at the local level, at a minimum.

Budget estimates. These should be generated as part of the feasibility study.

Environmental Screening Matrix : C1

Screening matrix / PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydrologic, climatic, socio-economic, land use, natural resource										
		Land acquisition										
		People's participation activities		+	+				+			
	Abnormal											
Construction	Normal	Site preparation: vegetation removal, infrastructure removal/relocation, resettlement, levelling, temporary structure installation (access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)										
		Canal excavation: labor and materials mobilization, crossdam construction, spoil transport, spoil disposal							+			
		Embankment construction: labor and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving							+			
		Structure (sluice gate, culvert, pump house, and so on) construction: labor and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling, turfing, paving										
		Tube well installation: boring, distribution facilities, electrification N/A										
	Abnormal	Suspension of construction before completion, construction delays		−								
		Incorrect construction practices or techniques		−	−							

Environmental Screening Matrix : C 1

Screening matrix PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Construction (continued)	Abnormal (cont'd)											
Operation	Normal	Pre-monsoon flood protection		+	−		+				+	
		Monsoon flood protection		+	−		+			−		
		Surface water irrigation N/A										
		Ground water irrigation N/A										
		Drainage		+	+		+					
		Agriculture: operation of institutions, extension, credit, seed distribution, fertilizer and pesticide storage and use, farmer groups							+			
		Water management: activities of BWDB, subproject implementation committee, local water user groups, structure committees and guards							+			
	Abnormal (relative to FWO, not FW normal)	Pre-monsoon flooding (due to extreme event, infrastructure failure)										
		Monsoon flooding (due to extreme event, infrastructure failure)		−							−	
		Embankment overtopping		−				−	−		−	
		Under- and over-drainage		−		−						
		Improper operation (public cuts, mistiming of scheduled O&M events etc)										
		Riverbed aggradation/degradation										
Abandonment	Normal	Re-occupation of infrastructure sites										
		Reclamation of materials										
	Abnormal											

ANNEX C2

INITIAL ENVIRONMENTAL EXAMINATION

NAINDA HAOR PROJECT

ANNEX C2: INITIAL ENVIRONMENTAL EXAMINATION

C.1 Introduction

This Initial Environmental Examination (IEE) (pre-feasibility level Environmental Impact Assessment or EIA) follows the steps specified in the *Bangladesh Flood Action Plan Guidelines for Environmental Impact Assessment* (ISPAN, 1992). These steps are illustrated in Figure 2 of ISPAN (1992).

Much of the information required for the IEE/EIA appears in the main body of the study. The section and chapter references given below cite this information.

C.2 Alternative 1: Proposed Partial FCD Project

C.2.1 Project Design and Description (Step 1)

As in Section 8.3, Project Description.

C.2.2 Environmental Baseline Description (Step 2)

As in Chapter 2, Biophysical Description, and Chapter 3, Settlement, Development, and Resource Management.

C.2.3 Scoping (Step 3)

Technical:

Literature review: Presented in Chapter 4, Previous Studies.

Local community: As described in Section 3.1.9, People's Perception.

C.2.4 Bounding (Step 4)

Physical:

Gross area: 8070 ha.

Impacted (net) area: 7250 ha.

Impacted area outside project: Umium River pre-monsoon flood levels could increase by about 0.10 m. This could affect areas outside the project, most likely on the left bank of the Umium River. Improved understanding of this impact requires regional flooding analysis, which is ongoing as a part of NERP. During feasibility studies, this impact needs to be assessed.

Temporal:

Preconstruction: years 0 through year 2 (see Table 8.7).

Construction: year 1 through year 3 (see Table 8.7).

Operation: year 4 through year 20.

Abandonment: after year 20.

Cumulative impacts:

With other floodplain infrastructure: This will be looked at in the context of the Regional Plan.

With pre-existing no-project trends. Described in Chapter 5.

C.2.5 Field Investigations (Step 5)

Field investigations were limited to seven to ten days of informal reconnaissance by a multi-disciplinary team.

C.2.6 Impact Assessment (Step 6)

At this level of detail, a screening matrix (Table C.2) was filled out by the project team. Impacts are designated by:

+	positive impact
-	negative impact
•	neutral impact (such as conversion from one productive land use to another)
?	insufficient information to designate

Impacts are discussed in Section 8.8.

C.2.7 Quantify and Value Impacts (Step 7)

Quantification and evaluation of impacts is documented in Section 8.8 and Tables 8.12 through 8.14.

C.2.8 Environmental Management Plan (Step 8)

At a pre-feasibility level, this section focuses on "identification of broad management options and major constraints" (p. 28, ISPAN, 1992).

Mitigation and enhancement. Documented in Section 8.3.5.

Compensation, monitoring, people's participation, disaster management, EMP institutionalization, and other aspects are similar to that for Rauchunni Beel Project (see Annex C1).

Environmental Screening Matrix = C2

Screening matrix / PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydrologic, climatic, socio-economic, land use, natural resource										
		Land acquisition										
		People's participation activities		+	+				+			
	Abnormal											
Construction	Normal	Site preparation: vegetation removal, infrastructure removal/relocation, resettlement, levelling, temporary structure installation (access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)							+			
		Canal excavation: labor and materials mobilization, crossdam construction, spoil transport, spoil disposal							+			
		Embankment construction: labor and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving							+			
		Structure (sluice gate, culvert, pump house, and so on) construction: labor and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling, turfing, paving										
		Tube well installation: boring, distribution facilities, electrification N/A										
	Abnormal	Suspension of construction before completion, construction delays		—								
		Incorrect construction practices or techniques										

Environmental Screening Matrix : C2

Screening matrix / PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Construction (continued)	Abnormal (cont'd)											
Operation	Normal	Pre-monsoon flood protection		+	−		+				+	
		Monsoon flood protection										
		Surface water irrigation		+			+					
		Ground water irrigation N/A										
		Drainage		+	+		+					
		Agriculture: operation of institutions, extension, credit, seed distribution, fertilizer and pesticide storage and use, farmer groups			±				±			
		Water management: activities of BWDB, subproject implementation committee, local water user groups, structure committees and guards		+					±			
	Abnormal (relative to FWO, not FW normal)	Pre-monsoon flooding (due to extreme event, infrastructure failure)		−	−				−			
		Monsoon flooding (due to extreme event, infrastructure failure)										
		Embankment overtopping										
		Under- and over-drainage										
		Improper operation (public cuts, mistiming of scheduled O&M events etc)										
		Riverbed aggradation/degradation										
Abandonment	Normal	Re-occupation of infrastructure sites										
		Reclamation of materials										
	Abnormal											

ANNEX C3

INITIAL ENVIRONMENTAL EXAMINATION

DHALAI GANG PROJECT

ANNEX C3: INITIAL ENVIRONMENTAL EXAMINATION

C.1 Introduction

This Initial Environmental Examination (IEE) (pre-feasibility level Environmental Impact Assessment or EIA) follows the steps specified in the *Bangladesh Flood Action Plan Guidelines for Environmental Impact Assessment* (ISPAN, 1992). These steps are illustrated in Figure 2 of ISPAN (1992).

Much of the information required for the IEE/EIA appears in the main body of the study. The section and chapter references given below cite this information.

C.2 Alternative 1: Proposed Partial FCD Project

C.2.1 Project Design and Description (Step 1)

As in Section 9.3, Project Description.

C.2.2 Environmental Baseline Description (Step 2)

As in Chapter 2, Biophysical Description, and Chapter 3, Settlement, Development, and Resource Management.

C.2.3 Scoping (Step 3)

Technical:

Literature review: Presented in Chapter 4, Previous Studies.

Local community: As described in Section 3.1.9, People's Perception.

C.2.4 Bounding (Step 4)

Physical:

Gross area: 1225 ha.
Impacted (net) area: 1000 ha.
Impacted area outside project: The project does not have any negative impact outside the project area.

Temporal:

Preconstruction: years 0 through year 2 (see Table 9.9).
Construction: year 1 through year 2 (see Table 9.9).
Operation: year 3 through year 20.
Abandonment: after year 20.

Cumulative impacts:

With other floodplain infrastructure: This will be looked at in the context of the Regional Plan.
With pre-existing no-project trends. Described in Chapter 5.

C.2.5 Field Investigations (Step 5)

Field investigations were limited to seven to ten days of informal reconnaissance by a multi-disciplinary team.

C.2.6 Impact Assessment (Step 6)

At this level of detail, a screening matrix (Table C.3) was filled out by the project team. Impacts are designated by:

+	positive impact
-	negative impact
•	neutral impact (such as conversion from one productive land use to another)
?	insufficient information to designate

Impacts are discussed in Section 9.8.

C.2.7 Quantify and Value Impacts (Step 7)

Quantification and evaluation of impacts is documented in Section 9.8 and Tables 9.14 through 9.16.

C.2.8 Environmental Management Plan (Step 8)

At a pre-feasibility level, this section focuses on "identification of broad management options and major constraints" (p. 28, ISPAN, 1992).

Mitigation and enhancement. Documented in Section 9.3.6.

Compensation, monitoring, people's particapation, disaster management, EMP institutionalization, and other aspects of the project are similar to that of the Rauchunni Beel Project (see Annex C1).

Environmental Screening Matrix :C3

Screening matrix PHASE	Normal/ Abnormal	Important Environmental Component Activity	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydrologic, climatic, socio-economic, land use, natural resource										
		Land acquisition										
		People's participation activities		+	+				+			
	Abnormal											
Construction	Normal	Site preparation: vegetation removal, infrastructure removal/relocation, resettlement, levelling, temporary structure installation (access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)	−						±			
		Canal excavation: labor and materials mobilization, crossdam construction, spoil transport, spoil disposal							+			
		Embankment construction: labor and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving							+			
		Structure (sluice gate, culvert, pump house, and so on) construction: labor and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling, turfing, paving							+			
		Tube well installation: boring, distribution facilities, electrification N/A										
	Abnormal	Suspension of construction before completion, construction delays	−	−	−							
		Incorrect construction practices or techniques										

EDL

Environmental Screening Matrix

Screening matrix / PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Construction (continued)	Abnormal (cont'd)											
Operation	Normal	Pre-monsoon flood protection	+	+	+		+		+		+	
		Monsoon flood protection									+	
		Surface water irrigation N/A										
		Ground water irrigation N/A										
		Drainage		+			+					
		Agriculture: operation of institutions, extension, credit, seed distribution, fertilizer and pesticide storage and use, farmer groups		+	−/+				+			
		Water management: activities of BWDB, subproject implementation committee, local water user groups, structure committees and guards /DOF		+	+				+			
	Abnormal (relative to FWO, not FW normal)	Pre-monsoon flooding (due to extreme event, infrastructure failure)		−	−				−	−	−	
		Monsoon flooding (due to extreme event, infrastructure failure)							−		−	
		Embankment overtopping	−	−	−				−	−	−	
		Under- and over-drainage										
		Improper operation (public cuts, mistiming of scheduled O&M events etc)										
		Riverbed aggradation/~~degradation~~		−	−				−		−	
Abandonment	Normal	Re-occupation of infrastructure sites										
		Reclamation of materials										
	Abnormal											

ANNEX D

FISHERIES MODEL

FISHERIES MODEL

This annex briefly describes the model used to analyze fisheries impacts for the project.

The openwater fishery ecosystem is extremely complex. Impacts on production are assessed here using a highly simplified model. The limitations of the model mirror the limitations of the current understanding of and information about the system.

The major system processes about which some insight exists are:

- Migration access and timing. It seems to be accepted that:
  - a multiplicity of access points is desireable (i.e. that closing any or some channels is still deleterious,
  - the most important channels are those at the downstream end of the system (that with flood onset, fish mainly migrate upstream and onto the floodplain, and downstream out of the beels into the river), and
  - delay of flooding, as in partial flood control schemes, is highly disruptive

- Overwintering (dry season) habitat extent.

- Wet season habitat (floodplain grazing extent and duration). [It is expected that production also varies as a function of land type (F1, F2, F3) — probably such that shallower (F1, F2) land is more productive than deeper (F3) land — but as data to show this has been lacking it has been neglected from the model.]

- Habitat Quality. Habitat quality would include water quality, vegetation, and other conditions (presence of preferred types of substrate e.g. rocks, sand, brush). Water quality would appear to be most relevant during low volume/flow periods, and during the time of flood onset and recession when contaminants can disperse or accumulate.

- Spawning. Production outside the project area can also be impacted if habitats suitable for spawning within the project are adversely affected. It is believed that most of the region's fish production stems from spawning occurring in: mother fishery areas, which are those exhibiting extensive, well-interconnected, and varied habitats with good water quality; key beels; and river duars. Duars are somewhat a separate problem as they are located in rivers and larger channels, not on the floodplain.

The foregoing is represented quantitatively here as:

FWO production =

$$(R_0 * P_{R0}) + (B_0 * P_{B0}) + (W_0 * P_{W0})$$

FW production =

$$[M * Q * (R_1 * P_{R0})] + [M * Q * (B_1 * P_{B0})] + [M * (W_1 * P_{W0})]$$

Thus,

$$\text{Impact} = \text{FW} - \text{FWO production} =$$

$$\{ [(M * Q * R_1) - R_0] * P_{R0} \} +$$

$$\{ [(M * Q * B_1) - B_0] * P_{B0} \} +$$

$$\{ [(M * W_1) - W_0] * P_{W0} \}$$

where

sub-0 and sub-1 refer to FWO and FW respectively

R, B, and W are river/channel, beel, and floodplain (F1+F2+F3) areas, in ha

P is the unit FWO production in kg/ha for the respective habitats. Estimated regional average values are 175, 410, and 44 respectively.

M is the FW quality-weighted migration access remaining, relative to FWO conditions (range 0 to 1 for negative impacts, >1 for positive impacts)

Q is the FW acceptability of habitat/water quality relative to FWO conditions (range 0 to 1 for negative impacts; >1 for positive impacts).

A_M is the area of mother fishery and key beels affected times a factor (range 0 to 1 for negative impacts, >1 for positive impacts) reflecting the degree of degradation/enhancement

T is the estimated annual regional fish production attributable to spawning exported from mother fisheries/key beels (a constant of 50,000 tonnes, which is 50% of the total regional fish production of 100,000 tonnes)

A_T is the estimated regional mother fishery/key beel area (a constant of 100,000 ha).

Estimated values for the three proposed projects for the Sarigoyain-Piyain basin are shown in the following tables. Where standard values, established for the region or for a particular project type, are used, this is noted. Comments on project-specific values are also shown.

It is estimated that one person-day is required to capture one kilogram of fish on the flood plain.

Table D1: Fisheries Parameters (Rauchunni Beel Project)

Var	Value	Stnd value	Prod'n (mt)	Comments
M	1.0	0.7		Migration routes will be improved and fishing area will be connected.
Q	1.0	0.7		Beels will be protected from siltation and water linkage will be maintained.
R_0	35		6	
R_1	42		7	17 km. of channels will be re-excavated.
B_0	240		98	
B_1	270		110	Through beel bunding dry season water surface will be increased.
W_0	2525		111	
W_1	1025		45	
P_{R0}	175	175		
P_{B0}	410	410		
P_{W0}	44	44		
A_M				

Table D2: Fisheries Parameters (Nainda Haor)

Var	Value	Stnd value	Prod'n (mt)	Comments
M	0.9	0.7		Fish migration routes will be improved.
Q	1.0	0.7		Dry season water surface will be increased and rates of siltation will be reduced.
R_0	150		26	
R_1	165		26	About 31 km. of channels will be improved.
B_0	250		103	
B_1	300		106	
W_0	7014		309	
W_1	7014		278	
P_{R0}	175	175		
P_{B0}	410	410		
P_{W0}	44	44		
A_M	—			

Table D3: Fisheries Parameters (Dhalai Gang Project)

Var	Value	Stnd value	Prod'n (mt)	Comments
M	0.9	0.7		For average year pre-monsoon floods, the regulator will be kept open for fish movement. One fish pass structure is proposed.
Q	1.2	1.0		Rautir Beel will be protected from large scale sedimentation from Dhalai Gang channel avulsion.
R_0	5		0.88	
R_1	5		0.98	
B_0	150		62	
B_1	150		67	
W_0	800		35	
W_1	800		31	
P_{R0}	175	175		
P_{B0}	410	410		
P_{W0}	44	44		
A_M			150	