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)

HABIGANJ - KHOWAI AREA DEVELOPMENT

23

Draft Final
November 1993

NOT FOR CIRCULATION
PRELIMINARY DRAFT

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
Nature Conservation Movement

Canadian International Development Agency

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ACRONYMS AND ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
BFRSS	Bangladesh Fisheries Resource System Survey
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DPHE	Department of Public Health Engineering
EIA	environmental impact assessment
EIRR	economic internal rate of return
EMP	Environmental Management Plan
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 Evaluation
ISPAN	Irrigation Support Project Asia Near East
LLP	low-lift pump
LT	local transplanted
MPO	Master Planning Organization
NERP	Northeast Regional Water Management Planning Organization
NGO	non-governmental organization
NHC	Northwest Hydraulic Consultants
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 proposed project is to protect Habiganj town, homesteads, infrastructure and agriculture from Khowai River monsoon flooding; and to protect mainly winter season crops on low-lying areas below Habiganj from Khowai River pre-monsoon flooding.

In 5 of the last 10 years flooding along the Khowai has damaged or threatened urban infrastructure and dwellings, destroyed crops and damaged rural infrastructure. A solution to flooding along the Khowai River is thus considered the paramount water management issue in this area. So far, failures on the Khowai embankment have been caused not by overtopping but by breaching due to piping failures at structures, bank erosion, and scour at the toe of the embankment. Spills into the Karangi River system have originated in the unembanked reach of the Khowai River between Ballah and Chunarughat.

To improve the level of protection against Khowai River monsoon flooding in the reach between Ballah and Habiganj it is proposed to:

- Divert Nalmukh *Khal* to the Karangi River (2 km diversion) and the Isali *Chara* to the Sutang River (4.5 km), thereby reducing Khowai River flood discharges by an estimated 10%. Both the Karangi and Sutang Rivers will require channel improvements;

- Improve the Khowai River within the existing embankments (remove encroachments such as homesteads, eliminate sugar cane plantations during the flood season, raise and increase the span of all bridges and provide adequate setbacks to embankments);

- Provide a drainage channel from Habiganj town to the Sutang River (8 km);

- Extend and improve the high embankments (design for a 1:50 year return period) on both banks of the Khowai River (17 km required on the right bank and 16 km on the left bank) plus some re-sectioning.

To reduce pre-monsoon damages it is proposed to excavate the existing channel below Habiganj and shorten the channel length by 4 km through a diversion into the An Gang. Submersible embankments along the lower Khowai are not advised since they will tend to raise upstream water levels in the fully embanked reach and they will tend to concentrate sediment deposition within the channel. The project will cost an estimated US $14.5 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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LIST OF TABLES

1. INTRODUCTION

1.1 General Information

BWDB Division:	Habiganj
District:	Habiganj
Thanas:	Nabiganj, Baniachong, Bahubal, Habiganj, Lakhai, Chunarughat
MPO Planning Area:	25, 28, 29
Gross Area:	159,264 ha
Net Area:	112,115 ha
Population:	953,677
Households:	166,756

1.2 Scope and Methodology

This is a pre-feasibility study that was undertaken over a period of one month in mid 1993. The study team consisted of a water resources engineer, a socio-economist, an agronomist, a fisheries specialist, and a wetland resources specialist. Additional analytical support was provided by an environmental specialist and economist. The Rapid Rural Appraisal (RRA) technique was followed for collecting primary data where applicable.

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 as listed below.

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

- **Agricultural analysis:** data published in *Land Resources Appraisal for Agricultural Development in Bangladesh* (AEZ Reports) for soils and Water Resources Planning Organization (WARPO) for agricultural inputs, interviews with individuals and groups of farmers in different areas and on each land type;

- **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 in Sylhet on June 26,1992 and in Sunamganj on February 13,1993.

2A

- **Wetlands analysis:** topographic maps, local revenue department records, personal field observations and interviews with local people, CIDA Project Inception Report.

- **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 observation and field interviews with various cross-section of local people, opinion and suggestions from local level representatives including NGO personnel and the Honorable Members of Parliament.

1.4 Report Layout

Chapter 2 provides an overview description of the biophysical features of the project area. Chapter 3 describes the current status of development and resource management including a summary of the types of problems faced by 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. Chapter 7 provides a technical analysis of selected options and a preliminary evaluation of their performance. Future work that is needed to develop a feasibility study of the project area is outlined in Chapter 8. Annex A contains technical data, results of analyses and design information to support the main body of the report. Annex B provides an itemized cost analysis of the proposed project. Annex C contains an initial environmental evaluation of the project.

2. BIOPHYSICAL DESCRIPTION

2.1 Location

The Habiganj Flood Control and Drainage Improvement Project covers a gross area of 159,264 ha in Habiganj district, between latitude 24° 05' and 24° 30' N, and longitude 91° 05' and 91° 38' E. The project area boundaries are defined by the NE Region boundary along the Dhaleshwari River in the west, by the Ratna Nadi and Bijna River channels in the north, by tea gardens and Tarap Hills of the Tripura uplands in the east and by the Indian border and the regional boundary in the south (Figure 1).

2.2 Climate

The project area experiences the sub-tropical monsoon climate typical of Bangladesh, but with variations due to its location and topography. Rainfall is the most significant and variable aspect of the climate, causing severe floods and flooding in summer and drought in winter.

2.2.1 Variations in Annual Rainfall

The variation of annual rainfall over the project area is best represented by data for 1961-90 for the eight BWDB rain gauges in, or around the periphery of, the project area. The locations of these rain gauges are given in Table A1, and the data for 1961-90 in Table A2 (Annex A).

The data show that annual rainfall increases from an average of 2195 mm/year in the south to 3556 mm/year in the northwest, or by 62% across the project area. This latitudinal increase is mainly attributable to the presence of the Shillong Plateau to the north (Figure 2).

A regional analysis of annual rainfalls (NERP, 1993a) has shown that mean annual rainfall for 1961-90 was 10% greater than that for 1901-30, and that the variability of annual rainfalls for 1961-90 was 1.95 times that for 1901-30. These disturbing trends have been reflected in increased floods and flooding in recent years, but it is not known whether they will continue into the future, level off, or be reversed. Climate modelling research being undertaken in the West suggests these trends, particularly that in variability of the annual rainfalls, will continue in the decades ahead.

There are four more or less distinct seasons in the project area relative to the annual cycle of water resource activity which reflects the seasonal distribution of the annual rainfall. The seasons are shown in Table 2.1.

The most distinctive climatic events of the year are the onset and withdrawal of the monsoon. In the project area onset occurs on average on 1 June plus or minus about 4 days, and withdrawal occurs on average on 7 October plus or minus about 14 days. The average duration of the monsoon is 122 days, but it has varied from 112 days to 139 days.

The seasonal distribution of the annual rainfall is shown in Table 2.2.

Table 2.1: Definition of Seasons in the Project Area

Season	Activity	Calendar Period
Dry	Irrigation	December through March
Pre-Monsoon	Flash Floods	April and May
Monsoon	Flooding	June through September
Post-Monsoon	Drainage	October and November

Table 2.2: Seasonal Distribution of Rainfall in the Project Area

Season	Percent of Annual Rainfall in Project Area	
	South (Itakhola)	North (Itna)
Dry	4	3
Pre-Monsoon	25	26
Monsoon	63	68
Post-Monsoon	8	7
Year	100	100

These figures show that the rainfall is heavily concentrated in the monsoon season, but more so in the north than in the south, and that the dry season is slightly more intense in the north than in the south.

2.2.2 Climatological Averages and Extremes

The climate of the project area as a whole is best represented by data for Srimangal, the nearest BMD climatological station, located east of the project area. Data are available for 1948-91 (44 years). The averages are given in Table A3, and the extremes of record in Table A4.

Annual sunshine hours average 6.2 hours/day, and average monthly sunshine hours range from a minimum of 4.2 hours/day in July to a maximum of 8.1 hours/day in February. No radiation data are available.

The mean annual temperature is 24.9°C, and average monthly temperatures range from a minimum of 17.6°C in January to a maximum of 28.7°C in August.

Monthly mean minimum temperatures range from 9.3°C in January to 25.1°C in July/August, and extreme minimum temperatures of record range from 2.8°C in January to 21.2°C in August.

Monthly mean maximum temperatures range from 25.6°C in January to 33.2°C in April, and extreme maximum temperatures have ranged from 31.1°C in January to 43.4°C in April.

The annual mean humidity is 81%, and monthly averages range from 73% in March to 88% in August and September.

The annual mean windspeed is 7.3 km/hour from the east-southeast. Monthly average wind speeds range from 5.7 km/hour to 9.9 km/hour, but the extreme gust of record is 167 km/hour. Winds are generally from the southeast during the monsoon season, and vary between southeast and east-northeast in the other seasons.

The mean annual rainfall is 2431 mm. Average monthly rainfalls range from 6 mm in December to 483 mm in June, and monthly rainfalls have ranged from 0 mm in November through April to as much as 1285 mm in June. The extreme daily rainfall of record is 514 mm.

Potential evapotranspiration averages 1460 mm/year, and ranges from 141 mm (4.7 mm/day) in September to 243 mm (8.1 mm/day) in April.

The surface water balance shows an annual excess of 971 mm which runs off into the river system or recharges the aquifers. The monthly water balance is positive in April through October and ranges up to 324 mm/month in June, but during October through April the balance is negative reaching as low as -139 mm in January. The winter surface moisture deficit is generally met from residual soil moisture until February after which a demand for irrigation normally arises.

2.3 Land

2.3.1 Project Area Description

The Project area encompasses the entire portions of the Khowai River, Karangi River and the Sutang Rivers within Bangladesh and lowlands bounded by the Bijna-Ratna, Kushiyara-Dhaleshwari and Barbhadra Rivers.

All the rivers and khals within the project area originate from the Tripura Hills and flow to the north and west. The Khowai River, which is the principal river in the project area, originates in Tripura State, India. The Indian portion of the catchment is approximately rectangular in shape, being 50 km long and 25 km wide. The basin is bounded by two south-north trending anticlinal ridges which reach up to 500 m above sea level and are composed of Pliocene-Pleistocene sediments. However, about 90 % of the catchment consists of relatively flat low-lying Piedmont floodplain that is intensely cultivated. The drainage area at the International boundary near Ballah is 1,113 km^2.

Downstream of Ballah, the Khowai River flows along the crest of a naturally leveed floodplain. This gives the river a "perched" appearance since the land near the channel is typically several meters higher than the adjacent floodbasin land. This feature tends to cause overflows from the Khowai River to drain towards the west or east, out of the river system. As a result, there is virtually no additional contributing drainage downstream of the border. The river is embanked from about 6 km downstream of Habiganj to Chunarghat on the right bank and to Raja Bazar on the left bank. In the upper reach close to the Indian border the Khowai drains a small area of about 20 km^2 on the right bank (Rema Tea Gardens and Nalmukh Khal) and on the left bank it drains about 107 km^2 of hilly basins of Isali and Bhui charas out of which about 60% is located in India. In the lower reach downstream from Habiganj town the River flows through flat lowlands along with beels and interconnected local khals. The general drainage pattern of these lowlands is westward to the Kalni-Dhaleshwari River.

The Karangi and the Sutang Rivers traverse the bottom land of the valley on the right and left banks of the Khowai River respectively. The Karangi drains into the Ratna River (Gangajuri River) near Habiganj and the Sutang River which flows approximately parallel to the Khowai along its entire course, drains into Dhaleshwari River (Kayania Nadi) at Lakhai.

The headwaters of the Karangi River originate just inside the Indian border on the long anticlinal ridge east of Ballah. The Sutang River drains mainly Piedmont floodplain lands. Unlike the Khowai River, virtually all of the catchments of the Karangi and Sutang Rivers are located within the project area.

Throughout this report the project area has been divided into two approximately homogeneous sub-regions. The two areas, designated as the "Upper Basin" and "Lower Basin" are demarcated by the sudden change in land slope along the foot of the hills and in part along the Dhaka-Sylhet railway track. The boundary of the sub-regions is shown on Figure 3.

The Upper Basin, which includes the hills in the east and south, has relatively steep land gradients and a dense network of hilly streams (charas) cut deeply into the slope of the hills. The hills along the project boundaries vary from about 30 to 50 m above sea level. The average elevation of the land in the Upper Basin is about 10 m PWD.

The Lower Basin is almost flat and there are many beels and floodplain channels cutting through it. The Gangajuri Haor depression also falls within this area. The average ground elevation in the Lower Basin varies from about 3 m to 10 m PWD and about 1.5 m PWD in the lowest depressions.

The relation between land elevation, drainage area and storage volume for the project area is summarized in Tables A.5 and A.6 (Annex A) and in Figures 4 and 5.

2.3.2 Physiography and Soils

The project area encompasses three major landform types including:

- uplands and hills;
- Piedmont floodplain;
- Lowland floodplain and flood basins of the Surma-Kushiyara River, Sylhet basin, and Old Meghna Estuarine Floodplain.

The Upper Basin includes Piedmont Plains and hills. The Piedmont Plains occur as a narrow strip of land at the foot of the hills in the south-western and eastern parts of Upper Basin. They are complex in pattern due to the irregular deposition of sediments of different textures during successive flash floods. Deposits range from sands to clay. Brown hill soils, Grey Piedmont Soil and Non-calcareous Grey Floodplain soils are the major general soil types. Soils are loams to clay in texture. The more loamy ridge soils have rapidly permeable subsoils, but the puddled topsoil and ploughpan of soils used for transplanted rice cultivation have slow permeability. Heavy basins or valley clays soils have slow permeability. Moisture holding capacity is low in heavy basins or valley clays and ridge soils used for transplanted rice cultivation, especially in puddled topsoils and ploughpans.

The Lower Basin includes portions of the Surma-Kushiyara River Floodplain, Sylhet Basin and Old Meghna Estuarine Floodplain. The north-eastern margin of the Lower Basin occupies the relatively higher parts of the Surma-Kushiyara Floodplain, formed on sediments of the rivers draining into the Meghna catchment area from the hills. Grey, heavy silty clay loams predominate on the ridges and clay in the basin. Except in beels, the cultivated layer of the predominate soils is lighter in texture than lower layers, and there is a strong ploughpan. Non-calcareous Grey Floodplain soils is the general type. Permeability is slow in most soils. Moisture-holding capacity is inherently moderate but it is reduced by puddling of the surface layer and the formation of a strong ploughpan in soils used for transplanted rice cultivation. Except in beels, therefore, topsoil quickly become hard and dry after the end of the rainy season, and basin soils crack widely.

The Sylhet Basin occupies north-western part of the Lower Basin adjoining Old Meghna Estuarine Floodplain. Two main kinds of soils occur here: grey silty clay loams and clays with developed profiles on the relatively higher land which dries out seasonally, and grey (often bluish grey or greenish grey) clays with raw alluvium at a shallow depth which occupy basins and stay wet throughout the year. There are minor inclusions of dark grey loamy and clay soils of the adjoining Old Meghna Estuarine Floodplain and peat in some haors. Buried soils with dark-colored topsoil are common. Permeability is generally slow, except in some loamy ridge soils. Moisture-holding capacity is moderate in deep loamy ridge soils, but low in basin clays. Un-irrigated soils become very hard when dry, and basin clays crack widely. Soils which dry out in the dry season become very hard and widely cracked, but most soils stay wet because of irrigated boro rice cultivation.

Old Meghna Estuarine Floodplain deposits are found in low lying areas in the south-eastern and northern parts of the Lower Basin. This unit comprises smooth level, floodplain ridges and shallow basins with relatively uniform, predominantly silty soils. Most soils have dark grey to black topsoil. In depression soils, the upper part or all of the subsoil is also dark colored. In higher soils, the subsoil is grey-brown to yellow-brown with dark grey coatings on the faces of subsoil cracks. Non-calcareous Dark Grey Floodplain is the predominate general soil type. Permeability is mainly moderate in the higher soils and low in depression soils. Higher soils used for transplanted aman have puddled topsoils and strong ploughpans which make permeability slow. Moisture-holding capacity is medium. The predominant deep silty soils have a high capillary potential which keeps most soils wet (and poorly aerated) in the early part of the dry season and moist for most or all of the dry season. Depression soils generally stay wet early in the dry season and many areas stay wet through the dry season.

2.4 Water (Hydrology)

2.4.1 Runoff Patterns & Surface Water Availability

Runoff patterns in the project area are governed primarily by flows generated in the Khowai River catchment in India, and by local runoff generated from rains over the Karangi and Sutang River catchments. During monsoon season, the Lower Basin of the study area is affected by backwater from the Upper Meghna River and it remains flooded from June through October.

Discharges have been measured intermittently since 1964 on the Khowai River at Shaistaganj, Sutang River at the railway bridge crossing and Karangi River near Sofiabad. Water levels have been recorded on the Khowai River at Ballah, Chunarghat, Shaistaganj and Habiganj.
The following comments provide a brief overview of the runoff pattern and availability of surface waters. Additional data and analysis are summarized in Annex A, Tables A.7 - A.12.

Khowai
Based on 27 years of records at Shaistaganj, the mean discharge of the Khowai River is 36.4 m^3/s. During this period of record the daily discharges have reported to range from 0.8 to 1050 m^3/s. The seasonal distribution of the flow is as follows:

Season	Mean Discharge m^3/s	Mean Runoff (MCM)	(%)
Pre-Monsoon	37.7	198.6	17.6
Monsoon	60.3	635.4	56.5
Post-Monsoon	32.6	171.6	15.3
Dry Season	11.5	120.5	10.6
Year	36.4	1126.1	100.0

Water levels in the Khowai have been observed at Ballah, Chunarghat, Shaistaganj and Habiganj. The indications of the records are as follows:

Gauge	Water Levels (m PWD) Mean	Minimum	Maximum
Ballah	20.19	19.04	26.10
Chunarghat	13.64	12.45	18.17
Shaistaganj	9.36	8.12	15.05
Habiganj	6.75	4.76	10.96

Sutang
Based on 10 years of records at the Sutang railway crossing, the mean discharge was estimated to be 9.6 m^3/s. During this period the daily discharges ranged from 0.1 m^3/s to 253 m^3/s, while the water levels varied between 2.70 m PWD to 8.13 m PWD. The seasonal distribution of the flow was estimated as follows:

Season	Mean Discharge m^3/s	Mean Runoff (MCM)	(%)
Pre-Monsoon	7.5	39.4	13.0
Monsoon	21.3	224.1	73.7
Post-Monsoon	6.1	32.2	10.6
Dry Season	0.8	8.3	2.7
Year	8.6	304.0	100.0

Karangi
The 23 years of record indicate a mean annual discharge of 8.1 m^3/s, and a range of daily discharges from 0 to 500 m^3/s. The corresponding water levels at Sofiabad ranged from a minimum of 7.44 m PWD to a maximum of 12.31 m PWD. The seasonal distribution of the flow is as follows:

Season	Mean Discharge m^3/s	Mean Runoff (MCM)	(%)
Pre-Monsoon	9.1	47.9	18.7
Monsoon	15.7	165.8	64.8
Post-Monsoon	5.6	29.3	11.5
Dry Season	1.3	13.1	5.0
Year	8.1	256.1	100.0

2.4.2 Flooding
For planning purposes, flooding has been defined for two key time periods:

- pre-monsoon floods (between April and May 15);
- monsoon season floods (between May 15 and October 31)

In general, the pre-monsoon floods affect lands in the Lower Basin where b aman and boro are the main crops, and the monsoon floods affect lands in the Upper Basin where hyv aus, hyv aman and hyv boro are the main crops.

Pre-monsoon Floods
Most pre-monsoon floods are confined within the river banks in the Upper Basin but spill overbank in the Lower reach. The Khowai River spills regularly in the unembanked portion downstream from Habiganj and the Sutang River spills on average once every two years below the railway bridge. As a result, boro rice, which is the main crop grown in the lowlands of Habiganj, is frequently damaged. Partial submersible embankments exist on the right bank of the Khowai River downstream from Habiganj, but they are not continuous and not sufficient to prevent spilling of the early floods. Also the Khowai right bank lowlands get inundated by spills from the Ratna Nadi. The southern part of the Habiganj lowlands also get flooded by the Balbhadra River which is partly silted. When the Balbhadra and the Sutang pre-monsoon floods coincide, most of the boro rice grown in their lower basin are destroyed.

Table A.14 (Annex A) lists estimated pre-monsoon flood discharges for the Khowai, Karangi and Sutang Rivers.

Monsoon Floods
During the monsoon season, floods are primarily caused by high discharges from the Khowai River and, in the Lower Basin, by backwater from the Upper Meghna River. The floods on the Khowai River are flashy and often occur several times during the year. Damaging floods have occurred on the Khowai River every two or three years during the last decade. During this

period there have been spills from the Khowai River into the Karangi River and Sutang River systems. These spills occur through breaches in the embankment and from the unembanked portion of the Khowai River between Ballah and Chunarghat. The spills can substantially increase (doubling in some years) the flood discharges in the Karangi and Sutang Rivers. These events damage monsoon season crops grown in the Karangi and Sutang basins and also in the Gangajuri Project area, which has not been designed to accommodate the Khowai spills. The reach of the Karangi River between the railway bridge and Bahubal has been embanked with local dikes, but has silted-in to the point where floods regularly spill over the paddy fields.

During the monsoon season, the Habiganj lowlands are submerged by backwater from the Meghna-Kalni River. The mean monsoon water level in Dhaleshwari at Madna (6.03 m PWD) is about 1 m above the average ground level. The monsoon floods in the area below the railway line are a combination of the water levels in the Meghna River and inflows from the Khowai, Karangi and Sutang Rivers.

Figure 7 shows the discharges at Shaistaganj on the Khowai River and at Sofiabad on the Karangi River over the last 25 years. The highest daily discharge on the Khowai River is reported to be 1,050 m^3/s on October 20, 1988. However, this figure is very approximate, mainly because of the great difficulty in measuring discharges during flood conditions (the highest observed discharge during 1988 was 370 m^3/s). Attempts to estimate the 1988 flood discharge using backwater computations suggested the actual discharge could have been substantially lower at Shaistaganj - in the order of 850 m^3/s. On the other hand, major spills of around 200 m^3/s are believed to have occurred from the Khowai River into the Karangi River during the 1988 flood. Therefore, a value of 1,050 m^3/s may be a fairly reasonable estimate of the total flow inflow to the Khowai River at Ballah during the 1988 flood.

The long-term (1964-1991) average annual maximum daily discharge at Shaistaganj is 300 m^3/s. The average annual maximum daily discharge in the periods between 1964-1979 and 1980-1991 are 208 m^3/s and 422 m^3/s, respectively. The maximum discharges in 1981, 1982, 1985, 1986, 1988, 1989, 1990 and 1991 exceeded all flows in the 15 year period between 1966 and 1980. Only the flood in June 1964 (566 m^3/s) is comparable in magnitude to the high flows that have occurred during the 1980's.

Figure 8 shows water levels at all hydrometric stations along the Khowai River as well as at Madna on the Dhaleswari/Kalni River. The water level records show a somewhat different pattern from the discharges at Shaistaganj. For example, at Ballah, the highest water level occurred in 1983, not 1988. Furthermore, flood stages equalled or exceeded the maximum level in 1988 during 1964, 1966, 1967 and 1976. A statistical analysis showed the water level record at Ballah to be stationary and homogeneous over time. At Shaistaganj and Habiganj, the annual maximum water levels show an abrupt rise around 1980, coinciding with construction of the embankments on the Khowai River. The average high water at Habiganj during the period 1980-1991 is about 2 m higher than the level during the period 1964-1979. At Shaistaganj, the average annual maximum water level increased by about 1.5 m over the same time interval.

The unusually low flood discharges on the Khowai River during the 1970's suggest the causative storms were not of uniform intensity and did not cover the entire catchment in this period. Furthermore, construction activity associated with early loop cutting and embankment construction along the Khowai River may have caused increased flow diversions to the Karangi River at that time. For example, BWDB (1974) indicated cross dams were constructed in the

Khowai River channel during the construction of the loop cuts near Shaistaganj. Temporary works of this sort could account for the situation in 1979 and 1980 when the flood flows on the Karangi River at Sofiabad equalled or exceeded the flows on the Khowai River at Shaistaganj.

The high flood levels and discharges and on the Khowai River experienced throughout the 1980's and early 1990's has been attributed to several possible factors, including:

- increased rainfall;
- land-use changes in India;
- confinement effects from the embankments which has increased in-channel flows at Shaistaganj;

If the effects were primarily caused by upstream changes in India, this would show up as a non-stationary water level record at Ballah. In fact, the flood levels show no strong evidence of an increasing trend over time (statistical tests show the records at Ballah are stationary and homogeneous). This suggests the main cause for the changing flood regime at Shaistaganj and Habiganj has been due to the construction of the high embankments and associated morphologic changes along the river. Furthermore, the pattern and magnitude of flooding has continued to change over time in response to the ongoing extension and upgrading of the embankments that has taken place.

Table A.14 (Annex A) summarizes the results of a flood frequency analysis using the historic flow record at Shaistaganj on the Khowai River, at Sofiabad on the Karangi River and at the railway crossing on the Sutang River. The frequencies were estimated using a General Extreme Value (GEV Type II) distribution. A discharge of 1,050 m^3/s (1988 flood) had a return period of about 35 years. Estimates of the 50 year and 100 year flood were 1,274 m^3/s and 1,975 m^3/s respectively.

Flood frequencies were also estimated using only discharges from the period 1980-1991, when most high flows have occured. Given the modifications to the flow regime from the embankments, it was considered that these recent flows would be more representative of future conditions on the river. Flood magnitudes of 2 - 10 year return period events were noticeably higher than estimates using the entire period of record. However, at greater return periods the results tended to converge. For example, the 1:50 year flood ranged from 1264 m^3/s using a Gumbel (GEV I) distribution to 1360 m^3/s using a log normal distribution. Therefore, the values in Table A.14 were used in the remaining sections of this investigation.

Given the low accuracy of the flow measurements and the largely unknown effects of past flow spills, the magnitude and frequencies of flood discharges used in this pre-feasbility study should be considered as preliminary values only. There is a need to improve flood discharge estimates along the Khowai River by obtaining reliable high discharge measurements at Ballah (upstream of any spills) and at Shaistaganj. Such a program should be instituted as part of any feasibility studies for this project.

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2.4.3 Drainage

The Khowai River flows in a perched channel above its adjacent floodplain and so does not drain the area downstream of Ballah with the exception of about 100 km^2 at the upper reach near the Indian border and about 100 km^2 downstream of Habiganj. The Sutang River and Karangi Rivers collect runoff from most of the Habiganj-Khowai area. The Balbhadra River drains the southern part of the Habiganj lowlands through its right bank tributaries.

In the hilly parts of the Upper Basins drainage is effected through a dense network of charas and small khals which are perpendicular to the major drains.

2.4.4 Water Bodies

Open water bodies

About 59% (93,232 ha) of the project area is seasonally inundated to a depth greater than 0.3 m, of which about 1% (1,426 ha) is perennial beels. The larger permanent water bodies in the Habiganj-Khowai Area are listed in Table 3.8.

Closed water bodies

In addition to the open beels and khals there are 12,992 ponds used for fish trapping, bathing, washing etc. The ponds have a total area of about 1,006 ha.

2.4.5 Ground Water

The estimated total usable ground water recharge within the project area is some 324 Mm^3. Of this about 200 Mm^3 could be developed using DTW force mode technology, about 8 Mm^3 could be developed using STW technology and about 37 Mm^3 could be withdrawn by deep-set STWs (Table 2.3).

2.5 Land/Water Interactions

2.5.1 Sedimentation

Khowai River

Sediment aggradation can affect the degree of protection offered by flood control works and may adversely affect fisheries habitat and agricultural productivity. Most sediment is supplied from the Khowai catchment in India. Sediment carried by Karangi/Sutang is derived from Khowai spills and bank/channel erosion. The annual suspended sediment inflows are estimated to be around 1.2 million tonnes/year on average and up to 5 million tonnes/year during extreme floods, based on BWDB's miscellaneous point samples collected at Shaistaganj. Due to the design of the sediment

Table 2.3: Estimated Ground Water Recharge

Mode	Usable Recharge (Mm^3)	Available Recharge (Mm^3)
STW	11.75	8.52
DSSTW	53.90	37.16
DTW	258.56	200.16

Source: MPO 1991.

sampler, method of observations, and loss of flows due to spills between Ballah and Shaistaganj, the measured sediment inflows are thought to underestimate the actual loads.

Prior to the early 1980's, the reach from Ballah to Habiganj was probably a "transport reach" while the reach downstream from Habiganj was a "depositional reach". The transition occurs as a result of the decrease in channel gradient and backwater effect from the Upper Meghna River downstream of Habiganj when the river leaves the Piedmont plain and spills on the low-lying floodplain and flood basin lands. In the transport reach some sand deposition probably occurred on the natural levees during floods and on the adjacent floodplain, however the overall channel cross section probably remained fairly stable. In the deposition zone below Habiganj, the suspended load was deposited over a wide area in the low velocity, deeply flooded land including beels, khals and flood basins.

There is evidence (mainly from analysis of hydrometric data and comparison of river surveys) that the pattern of sediment deposition has changed since the early 1980's. Channel degradation, or lowering of the river bed appears to have occured between Chunarghat and Shaistaganj following construction of flood control embankments and loop cuts in this reach. This initial degradation occurred as a result of the confinement effects and increased velocities due to the channelization works. Aggradation has apparently occurred downstream of Habiganj, with the greatest deposition (up to 2 m) occurring near the downstream end of the embankments (about 7 km below Habiganj). Comparison of surveys in 1993 and 1988 suggests more or less continuous deposition has occured between Lumbabkah (at the dowstream end of the embankments) and Habiganj. This aggradation will tend to propogate upstream with time and will contribute to increasing water levels.

Deposition of fine sediment (silts and clays) occurs over a wide area during the monsoon season in the deeply inundated lands traversed by the Barak River. Fine sediment deposition has reduced the cross sectional areas of channels and khals throughout this Lower Basin. This siltation has contributed to flooding and spills during the pre-monsoon season.

Preliminary computations with the mathematical model HEC-6 "Scour and Deposition in Rivers and Reservoirs" were made to simulate sediment deposition patterns along the river between Habiganj and Ballah. These runs provided qualitative agreement with the field data and evidence reported by local people. However, additional morphologic computations using new survey information should be conducted during feasibility studies to make engineering assessments about future sediment impacts on flood levels.

Sutang River
The lower reaches of the Sutang River and the Balbhadra River are partly silted-in which reduces the channel's bankfull capacity. This restricted cross section contributes to pre-monsoon flooding. Siltation of local khals in the lowlands also contributes to pre-monsoon flooding by reducing drainage.

2.5.2 River Erosion

Khowai River
In the unembanked reach between Ballah and Chunarghat is subject to channel instability from overbank spills and bank breaching. For example, major spill have occurred regularly over the last 5 years upstream of Chunarghat into the Karangi River. A site visit in August 1993 indicated

two major breaches occurred on the right bank of the river near Abdasalia — one had a length of 355 m, the other a length of 100 m. The spills into the Karangi River are the major cause for erosion damage to the Gangajuri Project and have also contributed to the failure of the railway line in recent years.

In the embanked reach of the Khowai River downstream of Chunarghat, bank erosion occurs as a result of meander migration and deflection of flow from obstructions and channel constrictions. The most critical erosion occurs where embankment set-backs are inadequate, so that high velocity channel flows impinge against embankment slopes. There are about 10 locations in this reach where deep scour and high velocity erosion has caused serious undermining to the embankment.

Karangi River
Erosion along the Karangi River is primarily associated with spills from the Khowai River.

Sutang River
The upper reaches of the Sutang River have a steep gradient and highly sinuous channel. This combination has produced a laterally unstable channel that is subject to rapid bank erosion and meander migration. This instability results in loss of land (mostly homesteads) and frequent sand deposition on paddy fields.

2.5.3 Crop Damage

Most of the Lower Basin is subject to flash floods, particularly along the foothills and around beels. Early flash floods in this part damage maturing boro and/or young aus as well as deepwater aman. Frequent breaching of embankments along rivers draining from the hills in Upper Basin aggravates this problem. Moderately deep or deep seasonal floods damage transplanted aman crop. Deep flooding in basins centers, with rapid rise of flood water, prevents cultivation of deepwater aman.

Large parts of piedmont plains in Upper Basin are subject to shallow flash floods, which damage boro and aus. Lower parts are shallowly to moderately deeply flooded in the rainy season and transplanted aman grown in this area is damaged. Valley soils in hill area are poorly drained and subject to flash floods, which damage aus, hyv boro and transplanted aman.

2.6 Wetlands, Swamp and Reed Forest

2.6.1 Natural Wetlands

The two sub-regions of the project differ greatly in topographic and ecological characteristics. There are no wetland sites in the Upper Basin. In the Lower Basin there are several important small and medium size wetlands. The major wetlands comprising perennial beels are: Salbilla Beel, Tin Beel, Begunai Beel, Daskanai Beel, Bardur Beel, Angan Beel, Punibari Beel, Gul Beel, Bhagur Beel, Patul Beel, Garbhanga Beel, Berigang Beel, Ratna Beel, Bhomabad Beel, Bajni Beel, Sankardanga Beel, Bawa Beel, Bhanga Beel, Dhapna Beel. The total area of the beels, including other smaller perennial water bodies is about 1,420 ha.

The characteristics of these wetlands relate to their location. The wetlands which are located on the eastern side of the project boundary such as Patul and Dhapna Beel are flat and shallow having very little perennial water body. This situation creates a good habitat for numerous submerged and rooted floating annual plant community in the monsoon. But excessive human interference through encroachment of paddy field inside these wetlands make them unsuitable for both wild flora and fauna. Moreover utilization of water from beels for winter irrigation makes the area more exposed and unsuitable for perennial wetland plants.

In the mid portion of the project area where flooding is more severe, major wetlands are Garbhanga, Berigang and Ratna Beel. The deeper pockets and the vast floodplain make these wetlands a very diverse habitat for wetland flora and fauna. In deeper regions, because of deep flooding and high wave action floating plant communities don't survive in the monsoon. But submerged plants grow very well particularly at the time of water recession. In the shallow floodplain floating plant community grow profusely but sedge/meadow is the most important plant community here. These wetlands also suffer from heavy human interference. With almost all of the floodplain used for rice cultivation very little land is left for the natural inhabitants.

The western part, specifically the southwest, is the most deeply flooded portion of the project. The major wetlands located in this area are: Bardur Beel, Angan Beel and Punibari Beel. All these beels remain under deep flooding in the monsoon and cannot support lot of natural vegetation. But with the recession of water plant communities start growing up and very rapidly they spread over most of the area. The most important wetland plant community of this area is sedges/meadow, which produce lot of valuable grasses. These grasses are grown on very low land, and at the border of the perennial water bodies, where residual moisture remains high throughout the dry season. Although interference is lower in this area, the encroachment is still a big prohlem here and most of the land where water is available for irrigation has already gone under rice cultivation. Habitat degradation makes the wildlife rare in almost the entire area. All the higger mammals have already disappeared. Smaller mammals like otter, rat and cats are the major wildlife still existing in the area. Concentrations of waterfowls are restricted to the larger wetland complexes mostly in the western part of the project.

2.6.2 Swamp Forest Trees

There is no major swamp forest plot within the project area, but small patches with few trees are quite common. Individual swamp forest species can also be found in homestead groves.

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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	112,115
Homesteads	3360
Beels	1426
Ponds	1006
Channels	900
Hills	27000
Fallow[1]	5525
Infrastructure[2]	4600

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

General Description of Settlements

Settlements within the project area are mainly found as villages along the levees of rivers, especially in the low-lying areas and along various road sides on higher areas. Homesteads are also constructed on the higher portions of floodplains, i.e on kanda. In upland tea garden areas, houses are found in the form of colonies.

The district city of Habiganj is situated in the project area. The river banks and road sides are densely settled, as are areas around the Headquarters of thanas and marketing centers. Settlements tend to be sparsely scattered in the floodplain kanda and along the hillsides. Settlements are also extremely sparse in the south western low-lying haor areas where land elevations are very low, especially in west Baniachang, Lakhai and Astagram thanas.

Flood Damage to Housing

Generally, homesteads located on higher lands are not damaged by floods, such as in the east and northeastern part of the project area within Chunarughat, Bahubal, Madhabpur, Baniachang and Nabiganj thanas. Village homesteads along the Karangi and Khowai Rivers are damaged if their banks are overspilled by flash floods. Damage to homesteads by monsoon flooding is very common in the low-lying haor areas covering the south-western part of the project area, where homesteads are frequently threatened to erosion as a result of wave action. Many villages in this part (Baniachang, Ajmiriganj, Lakhai and Astagram thanas) are found to experience annual damage from wave erosion.

Coping Strategies

Homestead platforms are commonly raised by one meter (and in low-lying areas by three to five meters) to avoid monsoon flooding. To protect homesteads against monsoon wave action, the residents construct seasonal protection walls around the homesteads out of soil, bamboo and locally available grasses. Some of the well-off households construct brick walls around their homesteads for such protection. The monsoon flood waters stay in the area, especially in the lower elevations, for a period of about five to six months from late May or early June. In the hilly areas and uplands, the flash floods generally recede within a week or so. If there is severe flooding, villagers generally make platforms inside their houses and shift their belongings to safer places, if available. However, in such a situation, the poor suffer the most.

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be 953,677 of whom 471,677 are female. The gender ratio is calculated to be 102 (males to 100 females). The total households, are estimated to be 166,765 within 1335 villages. The population increased by 22.5% between 1981 and 1991.

The cohort distribution for males is: 32.6% below 10 years of age, 45.4% between 15 and 54 years of age, and 6.7% above 60 years of age. The corresponding distribution for females is 33.9%, 47.7%, and 5.3% (see Table 3.2).

The average population density is 611 persons per km^2, with density ranging from a maximum of 870 persons per km^2 in Habiganj thana to 417 persons per km^2 in Astagram thana. The average household size in the area is estimated to be 5.7 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

According to the 1981 census, the literacy of the population at 5 years of age and above varied from 11.0% in Astagram thana to 23.5% in Habiganj thana. The corresponding figures for females were 6.2% and 15.6% respectively for the same thanas. The rate appears to have slightly increased over the last 10 years. According to the 1991 census, the literacy rate for all people of Habiganj, and Kishorganj districts is recorded as 18.87%, and 16.42% respectively for both male and female.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 12.2% in Astagram thana to 24.7% in Nabiganj thana. Attendance for females in this age cohort in these two thanas varies from 9.8% to 23.3% respectively. Attendance for all youths between the ages of five and 24 is 12.1% and 19.3% for these thanas while the corresponding attendance for females is 8.2% and 15.9%.

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	16.9	15.7	13.2	45.4	2.1	6.7	100.0
Female	17.7	16.2	11.5	47.7	1.6	5.3	100.0
Total	17.3	16.0	12.3	46.6	1.8	6.0	100.0

Source: BBS, 1981 Population Census

The situation is worse for the rural poor. They can not afford to send their children to school. Furthermore, many villages, especially in Astagram, Lakhai and Chunarughat thanas, have no primary schools. The average number of primary schools per 10,000 population is estimated to be 5.4 for Habiganj district, and 4.1 for Kishorganj districts. (BANBEIS, 1990).

Access to Health Services
The district headquarters of Habiganj, and Kishorganj have hospitals, and all thanas have hospital facilities located at their headquarters. Access to health services is 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 195,780 persons, one hospital bed for every 5,866 people and one doctor for every 23,377 persons in the district of Habiganj. The situation is similar for Kishorganj district. Immunization coverage of children below two years of age is high for the project area except for Astagram thana. The rate varies from 30% in Astagram thana to 59% in Habiganj thana (1990).

Rural Water Supply
Detailed information on access to rural water supply for drinking purposes is not available for the project area. However, for the rural areas of the district of Habiganj, DPHE[1] reports the availability of one working tube well for 110 persons. In 1990, 85% of the households had access to potable water in the district. The situation is comparatively worse in Kishorganj district where a tubewell is meant for 122 persons. It is noted that most tube wells 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 bamboo mats or betel nut leaves. The villagers of haor areas of Lakhai, Baniachong, Astagram and Nabiganj thanas generally defecate in running water during monsoon months. 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. The major crop in the area is boro and transplanted aman. Employment for men mainly consists of activities such as transplanting and weeding, which occur between January and February and harvesting which occurs in late April and May. Employment during aman cultivation is mainly limited to the laborers living in the eastern side of the project area.

The wage rates for male agricultural laborers vary from Tk 25 to Tk 40 with one or two meals per day during peak agricultural months. During months when there is no agriculture work, the daily wage rate varies from Tk 15 to Tk 30. Employment is also available to poor fishermen who catch fish in the jalmohals during the winter season. In most cases, the wages are fixed on catch basis, for example 35% - 40% of the catch value is reportedly paid as wages to labourers.

[1] DPHE, 1991-92

During months when employment opportunities in agriculture are limited, some poor people migrate to their respective district headquarters, as well as in Sylhet and Dhaka cities to work as rickshaw pullers, as construction workers, or sometimes in household activities. Some poor also migrate to Chittagong District to participate in agricultural activities and a few migrate to Chhatak-Bholaganj area to work at stone collection and carrying.

Employment opportunities for women are very limited in the area. Some poor women are employed by the well-off farmers on seasonal contracts with wage rates varying from 6 to 12 maunds of rice for work extending the duration of the winter months. A few poor women are also employed for the Rural Maintenance Program of CARE. Sometimes, a few women migrate to towns to work as domestic help in household, but their numbers are very limited. Many villages have no such migrant woman laborers. The tribal women, particularly from Chunarughat thana, work in agriculture. Their daily wages vary from Tk. 20 to Tk 30, without provision for meals.

Migration to outside countries is not very common in the project area. There is in-migration into the project area, mainly from Mymensingh, Manikganj, Pabna, Comilla and Barisal. These people stay seasonally to participate in the rice harvest or undertake earthwork. Fishing labourers from Brahmanbaria district and Bhairab thana also migrate to the project area, especially in Astagram and Baniachong thanas during winter months to fish the jalmohals.

3.1.5 Land Ownership Pattern

Land ownership is extremely skewed in the project area. More than 48.0% of the households are landless (with cultivable land less than 0.2 ha). Among the landless, about 2.5% have no homesteads of their own. If the definition of landless includes landholdings up to 0.4 ha, the proportion of households included increases by 7.0%. 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 31.0%, 16.4%, and 4.5% respectively.

The project area has substantial amount of uncultivable land, which include the deeper wetlands, kanda and community pastures. The price of agricultural land varies from Tk 5,000 to Tk 50,000 per bigha (0.12 ha) depending on the demand and quality of the land and the intensity with which it can be cropped.

3.1.6 Land Tenure

Owner operation is common in the area. The large land owners, generally share out their lands to tenants for operation. The share cropping system is that one-half of the produce for local varieties is retained by the land owners but they provide no inputs. For hyv rice, the land owners provide 50% of the inputs costs. In the area, land is generally leased out in kind (chukti). Under this arrangement, a leaseholder has to pay to the landowner an amount of 6 to 10 maunds of rice per bigha each year after the harvest. Leasing out land with advance cash (rangjama) is also practiced. The usual rate for such arrangements varies from Tk 500 to Tk 1000 per bigha (0.12 ha) and this is paid in advance to the land owner for one season. Landless people have very little access to land under these tenurial arrangements due to their inability to provide the cash after which they must still purchase agricultural inputs.

3.1.7 Fishermen

Fishing is an important activity in the project area, particularly in the south-western haor areas, and competition for the fish resource is increasing every year. There are mainly two types of fishermen who catch fish to generate an income; traditional and non-traditional.

Traditional fishermen live on fishing and have been engaged in the profession for generations. The jalmohals are generally leased out to them through their cooperatives. However, the rich among them, act as the financiers and appropriate most of the profit from the catch while the poor catch fish on a regular basis and sell out for their survival. They also work as fishing laborers. There are an estimated 6,000 to 10,000 traditional fisherman households in the project area, especially from Lakhai, Baniachong and Astagram thanas. Additional information on fishing practices is provided in Section 3.5.1.

The non-traditional fishermen are mainly an emerging group from the landless and poor agriculturists in the haor areas. They fish in open water, particularly during the monsoon months and then sell the catch. The number of non-traditional fishermen is increasing and up to 35% of the households, especially from the south-east area, are reportedly engaged in catching fish.

Another group of people who catch fish but should not be referred to as "fishermen" are area residents. They do not sell fish but catch them for their own consumption. Sometimes, the rich among them lease the jalmohals for profit and they may also act as financiers for the fishermen cooperatives. This latter group is found most commonly in the haor areas.

3.1.8 Situation of Women

Women's role is agricultural production is important, especially in post-harvesting activities. Women's contribution, however, tends to be devalued and under reported. Though women generally do not work in the field, 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. The village women generally work in the post-harvesting activities of rice crops, especially drying, winnowing, per-boiling and storing of rice. Most women prefer working on homestead gardening and raising poultry/duck in addition to other common household works. The tribal women work for agricultural activities and the women laborers used to pluck tea leaves in the tea gardens.

3.1.9 People's Perception

General

Local people's 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. Also, opinions and suggestions were sought in a one-day seminar held at district headquarters of Habiganj, and Kishorganj with the Honourable Members of the Parliament, District and Thana level officials, Union Parishad Chairman, representatives from village level organizations and NGOs. The comments and suggestions from these various groups are presented below.

Problems

The major problems of the project area are flooding and sand deposition. Pre- and monsoon flash flooding is considered to be the most serious problem and is widespread throughout the project area except for a few locations in the eastern part. The flooding mainly damages rice crops though it can result in the destruction of infrastructure. Boro is affected almost every year and damaged fully or partly in many haors and beels by the pre-monsoon flash floods during April and May. These flash floods generally enter into the area through various channels and tributaries of the Khowai, Sutang, and Karangi; their banks overspill and the low-lying boro crops are inundated. The situation is further aggravated in the lower pockets as a result of intensive rainfall during the same period. In recent years, flooding caused by the Khowai River over-spilling its banks has caused severe damage to crops and property. Back water from the Dhaleswari into the Ratna River was also reported to cause considerable to low lying boro fields.

Aus and seed beds of transplanted aman are also damaged by pre- and early monsoon floods in the north-eastern and eastern part of the project area in Bahubal, Chunarughat, Nabiganj and Habiganj thanas. Transplanted aman is also sometimes flood affected in these areas during June to September when the Khowai, Karangi, Sutang and Bijna-Ratna Rivers and their tributaries over-spill their banks. The flood waters generally last for seven to ten days in the upper areas and there are three to four such occurrences reported in every monsoon period.

Sand deposition is the second most important problem reported in the upland areas of Chunarughat and Bahubal thanas. The sediments are transported by flash floods in the hill streams and are deposited on agricultural land causing extensive damage.

Drainage congestion is also reported to be a problem; particularly in Lakhai, Baniachong and Astagram thanas. Drainage is hampered by sediment deposition along the bank of the Khowai River and silting up of the Khowai, Sutang, and Bijna-Ratna river system, as well as other internal smaller rivers and channels. At best, this delays transplanting boro (local and high yielding varieties) and in some pockets it has become impossible to transplant boro at all.

Damage to homesteads by monsoon wave action was also mentioned as a serious problem, particularly in the southwestern part of the project area in Baniachong, Lakhai and Habiganj thanas. Many villages are eroding rapidly such that their very existence is being threatened.

The poorer fishermen expressed two concerns: the powerful jalmohal lessees were probiting them from fishing in the open water, and since the jalmohal lessees were usually not from the area, their primary concern was short term profits at the expense of long term sustainability of the resource. It has generally been observed that local fishermen provide better management of a leased jalmohal to ensure the long term sustainability since it constitutes the sum total of their resource base. Fishermen considered that fishing by de-watering the jalmohals was a major cause of declining fish production. This combined with the the loss of fish habitat and large scale deforestation in the flood plains did not provide them with a very positive outlook.

The fishermen also stated that roads and embankments in the flood plains were detrimental to fish migration and reduced production. Concern was expressed that fish migration into the project area from the Kushiyara and the Ratna Rivers would he affected as a result of closures that had been constructed across various channels and smaller rivers.

Suggestions
Various suggestions for improvements were proposed in the discussions with local people. While some of these suggestions were focused on very localized issues all were relevant to the problem at hand. The most common suggestions that were received include:

- Embank both banks of the Khowai River, re-excavate and straighten its bends, and remove agricultural crops (such as sugarcane) from within the embanked floodway of the river.

- Re-excavate the Ratna, Karangi and Sutang Rivers and if necessary widen them. Re-construct the railway bridge over the Sutang River.

- Prevent back flow of flood water through the Ratna River from the Kalni-Dhaleswari system.

- Take appropriate measures to protect the most vulnerable villages from wave erosion.

- Lease jalmohals only to local fishermen.

- Stop leasing the rivers fishermen to avoid siltation due to the installation of katha along the banks.

- Allow poor and subsistence fishermen to catch fish from the floodplain.

- Conserve enough fish habitat for normal production of fish and undertake an afforestation program to provide water resistant trees such as hijol and koroch in the flood plains and on river banks to improve the habitat.

- Identify the duars in the area and protect them as fish shelters.

- Designate selected suitable jalmohals for fishing by complete de-watering.

3.1.10 Local Initiatives

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

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3.2 Water Resources Development

3.2.1 Flood Control & Drainage

The existing water development infrastructure in the study area includes the Khowai River flood embankments and Gangajuri Flood Control and Drainage Project.

The high embankments along the Khowai River were constructed by BWDB as part of the Khowai River Project. Phase I of the project dealt with protection from Shaistaganj to Habiganj. A feasibility study was prepared by Associated Consulting Engineers Ltd. in May 1969. The project was reviewed by BWDB in 1974 and was submitted to ADB for review. After the project was turned down, BWDB went ahead without external funding. Details about the sequence of construction and dates of completion are scarce. It was reported that by 1976 a cutoff had been made just upstream of Shaistaganj and high embankments were constructed on both sides of the cutoff channel. Several other loop cuts were subsequently made (mainly between Chunarghat and Shaistaganj) which has shortened the river's course by about 12 km. Embankments were constructed between 1976 and 1985 from Habiganj to near Chunarghat on the right bank and up to Raja Bazar on the left bank. The embankments were breached at many points in the 1984 flood which required them to be re-constructed. At present, the Khowai high embankments extend into the lowlands to Chandpur village, about 6 km downstream of Habiganj. The project also provided two drainage regulators in the left bank, the 1-vent (1.5x1.8 m) Haripur Regulator at Habiganj and the 3-vent (1.5x1.8 m) Ahkandi Regulator near Chunarghat.

The Khowai River flood embankments were originally designed for protection against a flood of 700 m^3/s, which was believed to be the 1:50 year annual flood. This design flow appears to have been accepted during BWDB's 1974 Revision and Updating of the Feasibility Report. In that study, it was indicated the 1:50 year flood level at Shaistaganj was 13.7 m PWD after construction of the embankments (afflux due to confinement was estimated to be 0.9 m). An additional 0.9 m of freeboard was indicated for establishing embankment crest elevations. Water levels at Shaistaganj have exceeded 13.7 m virtually every year since 1985. Based on the historic data recorded between 1964-1991, the level of protection afforded by the original project design (which was not approved for funding) was in the order of 1:10-years, not 1:50 years as originally intended.

Surveys from 1988 and 1991 indicate the embankments were raised by 1.5 m - 3 m above the original design levels. For example, the embankments at Shaistaganj are now around El. 16 m while early design drawings showed a proposed level of 14.5 m. Furthermore, BWDB's survey 1988 surveys show the embankment crest was typically 1 m - 2 m above the maximum flood stage during the 1988 flood. Therefore, the embankments have been gradually raised to accomodate the higher discharges that have been experienced in the 1980's. Since additional land was not acquired during this work, raising the embankments has further constricted the river channel and reduced the embankment set-back.

Submersible embankments were first constructed in 1953-1955 on the right bank of Barak River (lower Khowai) extending from Hangarbhanga Beel to Dattapur village, a distance of 6.4 km. BWDB's work program for 1993/94 includes construction of submersible embankments and re-excavating 9.8 km of the Barak River downstream of Habiganj beyond the high embankments.

The Gangajuri FCD Project covers a gross area of 15,850 ha located on the right bank of the Khowai between Shaistaganj and Habiganj (See Figure xx). The project is designed to provide pre-monsoon flood protection in the western part near Habiganj and along Gangajuri River and full flood protection in the southeastern part with higher land. The area is protected by the Khowai right embankment and flood embankments constructed along both banks of the Karangi River. The Karangi River has been re-excavated to accommodate the 1:20-year Karangi basin annual flood. The local runoff drains into the Karangi and Gangajuri through drainage sluices constructed on the major khals. The project designs include construction of two flushing regulators for irrigation and re-excavation of 124 km of khals for improvement of local drainage; these works have not been completed yet.

At present the Karangi River is embanked from the road crossing at Sofiabad to the confluence with the Gangajuri River. The lower section from the Gangajuri River to the road crossing at Bahubal was re-excavated and embanked in 1990/92 under the Gangajuri FCD Project. The embanked river section was designed to accommodate the annual flood of 1:20-year return period.

The river is also embanked (with local low dikes) upstream from Bahubal to the railway crossing at Sofiabad. This section is badly silted and the dikes do not serve the purpose, also due to siltation the section upstream of Sofiabad is insufficient to drain local rainfall runoff. Monsoon floods regularly overtop the banks causing damage to crops and infrastructure. In July 1993, when the Khowai overtopped the local dike upstream of Chunarghat, the bank eroded and the entire Karangi floodplain including the Gangajuri Project remained flooded through September.

3.2.2 Irrigation

At present, about 25% of the cultivated project area is under irrigation. Traditional irrigation methods are used in about 40% of the irrigated land and pump irrigation is used in the remaining 60%. According to the water source, ground water is used in about 10% and surface water in about 90% of the irrigated area. Groundwater irrigation is least developed in the upper area of the project, with only 6 STWs and 5 DTWs in Bahubal thana and 14 STWs and 1 DTW in Chunarghat thana. Also there is little surface water development in the Chunarghat thana, where 713 ha is irrigated using traditional methods and 152 ha is irrigated with a total of 29 LLPs (AST 1991). Details on irrigation in the Habiganj - Khowai Area are provided in Table 3.3.

Table 3.3: 1991 Irrigated Area

Item	Mode of Irrigation				
	STW	DTW	LLP	Traditional	Total
Area (ha)	1055	1876	13,789	10,812	27,532
Number	142	70	993	-	1205
% of Total	3.8	6.8	50.1	39.3	100

(Source AST 1991)

3.3 Other Infrastructure

The project area is served with road and railway connecting main urban centers. Two railway lines cross the area, the Dhaka-Sylhet track with railway stations at Shaistaganj and Sofiabad and the Habiganj-Balla track via Shaistaganj.

The main roads are, the Dhaka-Sylhet and the Shaistaganj-Habiganj national highways, and the Shaistaganj-Ballah road. Thana centers are connected with metalled roads, with the exception of Lakhai. The Habiganj-Lakhai thana connecting road is a kutcha road having partly improved surface with brick soling; the Lakhai town is not accessible by road during monsoon due to flooding. Besides the main roads there are several un-metalled roads connecting villages and market places.

The road network is better developed in the Upper Basin where all the roads are accessible year-round. In the Lower Basin, which is deeply flooded during monsoon, most of the roads are suitable for vehicular traffic only during the dry season.

There are about 122 km of railway tracks, 170 km of metalled roads and about 160 km of village roads in the project area. About half of the village roads are not accessible during the monsoon season due to flooding. About 25 km of the metalled roads and railway tracks and about 145 km of other roads are threatened by the monsoon floods. The annual flood damage to the roads and railways including bridges and culverts is estimated at about Tk 2.6 million.

3.4 Agriculture

In the lower basin, farmers generally plant aus-transplanted aman, followed in some areas by rabi crops on highlands and medium highlands. If irrigation is available, hyv boro is cultivated in some areas followed by transplanted aman. On medium lowlands, farmers plant deepwater aman. Rabi crops are also grown on early draining medium lowlands after the deepwater aman is harvested. In some areas, where slow drainage of topsoils delays sowing rabi crops, irrigated hyv boro is grown. In low-lying areas, local boro varieties are widely grown on residual water supplemented by irrigation where needed. On relatively higher land, irrigated hyv boro is grown. The present cropping intensity in the Lower Basin is 139%. The present cropping patterns and the area they occupy in the lower basin are presented in Table 3.4.

In the upper basin, farmers plant mainly aus-transplanted aman and transplanted aman-hyv boro on the higher lands. On medium highland, the main practice is to plant transplanted aman-hyv boro. On medium lowlands, deepwater aman in some moderately deeply flooded areas is found. Sugarcane is grown primarily in the floodway of the Khowai River between the flood control embankments and the river bank. The present cropping intensity in the Upper Basin is 196%. Table 3.5 shows the present crop patterns and the area each occupies in the upper basin.

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Table 3.4 Present Cropping Patterns
Lower Basin

Crop Pattern	F0	F1	F2	F3	Total
sugarcane	1920 (10)				1920
b aman			9937 (75)		9937
l boro				23750 (95)	23750
hyv boro			1325 (10)	1250 (5)	2575
b aus-rabi		448 (5)			448
b aus-lt aman	3456 (18)	1793 (20)			5249
b aus-lt aman-rabi	1536 (8)	448 (5)			1984
b aus-hyv aman	768 (4)	628 (7)			1396
b aus-hyv aman-rabi	576 (3)				576
hyv aus-rabi	768 (4)				768
hyv aus-lt aman	1344 (7)	538 (6)			1882
hyv aus-hyv aman	960 (5)	179 (2)			1139
lt aman	1920 (10)	2241 (25)			4161
lt aman-potato	384 (2)	269 (3)			653
lt aman-rabi	1152 (6)	359 (4)			1511
lt aman-hyv boro	1536 (8)	1345 (15)			2881
hyv aman	768 (4)				768
hyv aman-wheat	192 (1)	359 (4)			551
hyv aman-potato	384 (2)				384
hyv aman-rabi	576 (3)				576
hyv aman-hyv boro	960 (5)	359 (4)			1319
b aman - hyv boro			1987 (15)		1987
TOTAL	**19200**	**8966**	**13249**	**25000**	**66415**

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

Table 3.5: Present Cropping Patterns
Upper Basin

Crop Pattern	F0	F1	F2	F3	Total
b aman			780 (15)		780
hyv boro			4160 (80)		4160
b aus-lt aman	801 (3)	1380 (10)			2181
b aus-lt aman-potato		414 (3)			414
b aus-lt aman-rabi	1335 (5)	1380 (10)			2715
b aus-hyv aman	534 (2)				534
hyv aus-wheat	267 (1)				267
hyv aus-rabi	1335 (5)				1335
hyv aus-lt aman	2403 (9)	1380 (10)			3783
hyv aus-hyv aman	6675(25)	690 (5)			7365
lt aman-potato		414 (3)			414
lt aman-rabi		1104 (8)			1104
lt aman-hyv boro	2670(10)	5520 (40)			8190
hyv aman-wheat	801 (3)	138 (1)			939
hyv aman-potato	1068 (4)	276 (2)			1344
hyv aman-rabi	2136 (8)	414 (3)			2550
hyv aman-hyv boro	6675(25)	690 (5)			7365
b aman-rabi			260 (5)		260
TOTAL	**26700**	**13800**	**5200**		**45700**

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

Rice is the major crop in the Habiganj-Khowai area. However, the average rice yield is quite low due to the severe flood hazard. About 77% of the rice area produces low-yielding local varieties in the lower basin due to the present flood risk. The average yield in this area is 2.4 t per ha. The average yield is somewhat better in the upper basin (3.3 t per ha) since high yielding varieties cover more area than the local varieties. Rabi crops including wheat and potatos are grown in 8% of the total cropped area in the lower basin and 13% of the total cropped area in upper basin. Slow drainage, which delays sowing, is the major constraint to the cultivation of rabi crops. Flood risk and drainage problems influence the process whereby farmers select which crops they grow. It also affects sowing or transplanting time, the level of inputs used and crop yields. Present crop production in the project is presented in Table 3.6 and Table 3.7.

Table 3.6 Present Crop Production - Lower Basin

Crop	Damage Free Area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Total (t)	Area (ha)	Yield (t/ha)	Total (t)	
b aus	8153	1.25	10192	1500	1.05	1575	11767
hyv aus	3289	3.75	12335	500	2.75	1375	13710
b aman	9924	1.75	17367	2000	1.45	2900	20267
lt aman	15321	2.15	32941	3000	1.75	5250	38191
hyv aman	5708	3.95	22547	1000	3.55	3550	26097
l boro	19250	2.25	43313	4500	1.75	7875	51188
hyv boro	6262	4.55	28491	2500	3.25	8125	36616
wheat	551	2.05	1129				1129
potato	1037	12.00	12444				12444
pulses	879	0.85	748				748
oilseeds	2932	0.75	2199				2199
spices	293	2.25	660				660
vegetables	1759	3.80	6596				6596
sugarcane	1920	45.00	86400				86400

Table 3.7: Present Crop Production - Upper Basin

Crop	Damage Free Area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Total (t)	Area (ha)	Yield (t/ha)	Total (t)	
b aus	5344	1.25	6680	500	1.05	525	7205
hyv aus	11250	3.75	42188	1500	2.75	4125	46313
b aman	1040	1.75	1820				1820
lt aman	16801	2.15	36122	2000	1.75	3500	39622
hyv aman	19097	3.95	75433	1000	3.55	3550	78983
hyv boro	16215	4.55	73778	3500	3.25	11375	85153
wheat	1206	2.05	2472				2472
potato	2172	12.00	26064				26064
pulses	1195	0.85	1015				1015
oilseeds	3982	0.75	2987				2987
spices	398	2.25	896				896
vegetables	2389	3.80	8960				8960

3.5 Fisheries

3.5.1 Floodplain fishery

About 65-70 important permanent and seasonal beels exist within the project area. The most important beels for fish production are listed in Table 3.8. The permanent beels serve as over-wintering refuges for the species present in the area.

During the monsoon season, water from the Kalni-Dhaleswari, Sutang, Khowai, Karangi and Bijna Rivers overtop the banks inundating the low lying areas of the floodplain and flood basins. Most of the beels which have isolated basins at low levels are merged during high water levels, and in a few cases, the beels are inter-linked with each other by narrow channels through which fish can move freely between rivers, channels, beels, and floodplain.

Most of the large fisheries are leased by a few rich influential persons for a period, usually of three years. They generally reside in cities and appropriate the profits from the catch. This system deprives local fishermen of access to the fisheries resources. Neither is there much opportunity to serve as laborers 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, particularly between farmers and fishermen. The jalmohal lessees construct and maintain water retention dams on the khals which control drainage from the beels at the end of monsoon; this prevents timely boro cultivation in the peripheral zone of the beels. On the other hand, a complete draining of the beels during an annual beel fishing in mid-winter is a common practice in the area after which the farmers are left with no water for irrigation.

It was reported that lessees do not permit fishing by either traditional or non-traditional fishermen in the vicinity of the jalmohals even during the monsoon months. This assertion was not verified but it is in agreement with another study in the area (Minken, 1992). The extent of the jalmohal lessees' control over the area needs to be verified more closely during feasibility studies, since this will have a significant bearing on the operability of any proposed intervention.

Table 3.8: Major Fisheries in the Habiganj-Khowai Area

Perennial Beels		Seasonal Beels	
Salbilla Beel	Garbhanga Beel	Kurail BeelJualia	Alla Beel
Tin Beel Begunai	Berigang Beel Ratna	Beel Bandra Beel	Kuki Beel
Beel Daskanai Beel	Beel Bhomabad Beel	Goakara Beel Telia	Nowabad Beel Kata
Bardur Beel Angan	Bajni Beel	Beel Moragang Beel	Beel
Beel Punibari Beel	Sankardanga Beel	Pokra Beel Goala	Balkar Beel Dhanna
Gul Beel	Bawa Beel	Beel	Beel Sonaduba Beel
Bhagur Beel	Bhanga Beel	Horiduba Beel	Kamripuli Beel Ura
Patul Beel	Dhapna Beel		Beel

3.5.2 Fish species present in the area

Of the 155 species identified in the region, about 70-75 species inhabit the Habiganj-Khowai Area. The most common species are listed in Table 3.9.

3.5.3 Duar Fishery

Duars, which are an indispensable part of a typical floodplain fishery, act as a refuge for the larger mother fish during the winter season. These fish then migrate to a suitable spawning ground for breeding when water levels begin to rise. There are two duars in the Dhaleswari River adjacent to the project area, Adampurar duar and Echordir duar (See Annex A).

3.5.4 Sources of Fish and Breeding

It is generally understood that early rain, thunder, flooding, temperature, grassy or rocky land influence spawning of freshwater fish. If conditions are favorable, during the flooding time, fish migrate from beels to adjacent grassy areas, to the rivers, and vice-versa. Migrations are usually against the direction of the prevailing currents at that time. In most cases fish will tend to move from the river up to the khal, to the beel and then to the adjacent floodplain. Except for major *carp*, *Pangus* and *Illish*, most of the species breed more or less everywhere in the area. Localized breeding migration can be seen for *Boal, Ghonia, Sarputi, Chapila, Pabda, Fali, Koi, Singi, Magur, Puti, Chanda, Tengra, Gulsha, Kholisha, Along, Bheda, Laso, Lati, Shoal, Gazar* and some other smaller varieties fish.

Fish breeding (except major Carp) has been reported in the following locations: Shakaeti khal area, Daskanai Beel, Berigang Beel area, Nowabaid, Punibari Beel, Bhanga Nadi area. Suitable areas for fish breeding are typically characterized by the presence of permanent water bodies surrounded by a low floodplain.

Within the project area (excluding the river duars), species composition of capture fishery is dominated by chotomaach (70-75%) followed by catfish (15-20%) and carp (5-10%).

Table 3.9: Major Fish Species

Boromach	Chotomach			
Catla	Singi	Napit Darkina	Tatkini	Kaikka
Rui	Magur	Mola	Kanipona	Shilon
Mrigel Kalibaus	Gang Magur Koi	Chata	Baashpata	Poa
Ghonia	Kholisha Lati	Dhela	Batashi Bacha	Ek Tuitta
Boal	Cheng Pabda	Chela	Rani	Chanda Golda
Air	Tengra Gulsha	Tit Puti	Chapila Keski	chingri
Ghagot	Bajori Bheda	Puti	Laso	Icha
Rita	Fali	Sarputi	Tara Baim	
Chital		Kani Pabda	Baim	
Gazar		Pabda Chanda	Gutum	
Shoal		Boicha	Cirka	
Ilish				

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The giant freshwater prawn (M. rogenbergii) and Ilish (Hilsa ilisha) are also available (but only to a very minor scale) in the adjacent Lakhai, Ratna, Lower Kushiyara Rivers and the floodplain. Both the species are highly valuable.

3.5.5 Production Trends

Fish abundance is directly related to the level and duration of flooding, and access to the flooded lands. The overall fish production for the project area is estimated to be 4,556 tonnes/year, based on figures provided from BFRSS (Table 3.10). Fish production in the project area is believed to have declined by 25-30% over the last 10 years. The identified causes of the fish decline are as follows:

- Siltation of beels. The beel area has been reduced by about 40-50% over the last 50 years; both the depth of water and water hectare-months are declining.
- Reduction of fish population due to over-fishing and loss of fish habitat.
- Reduction of reproductive stock due to indiscriminate use of some fishing gear in the duars (kona jal, current jal).
- Increased fish mortality due to fish diseases caused by water pollution in the beels, particularly during the months of December and January.
- Lack of proper extension services for pond owners to develop culture-based fish farming in the existing flood free ponds.
- Reduction of fish habitat by encroachment of agriculture into beels.

3.5.6 Fishing Practice

Floodplain
Open water fisheries are the major source of fish in the area (floodplain 61%, beels 17%, ponds 18% and channel 4%). 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.

Installation of katha is common in the months of August and September when the water begins to recede from the floodplain. Since *hizal* and *koroch* trees are scarce in the area, *shawra* and *mango* tree branches are widely used.

Closed Water
Pond fish culture practices are different here than in other

Table 3.10: Present Fish Production

Type of Water Body	Area (ha)	Yield (kg/ha)	Total Production (mt)
Beel	1426	550	784
Floodplain	63348	44	2787
River/channel	900	200	180
Pond	1006	800	805
Total			4556

Source: BFRSS

3.6

3.7

parts of the country. Most ponds (about 70%) are located in the flood prone areas and owners usually do not release fingerling into their ponds. Ponds are used to trap varieties of fish from the floodplains and in most cases kathas are installed during the flood recession time. On the other hand, flood free ponds are used to release uncounted numbers of fingerlings without undertaking basic management activities, such as eradication of weed and predatory fish, liming and fertilizing. The fish are usually harvested during the dry season. Many ponds that adjoin homestead land provide a domestic water supply for a wide variety of activities during the dry season (bathing, washing clothes and dishes, and watering of homestead gardens.

3.6 Navigation

During monsoon when most of the roads are flooded, navigation is the main mode of transportation in the Lower Basin. Passengers and goods are carried through the Khowai-Barak River between Habiganj and other important river ports of the country such as Bhairab Bazar, Ashuganj, Ajmiriganj, Baniachung and Dhaka. Small country boats travel along the Lower Sutang and Karangi Rivers, across the floodplain in the Gangajuri Haor area and in the floodplain west of Habiganj. At higher river stages there is regular boat service between Habiganj and Shaistaganj. During the winter season, the Sutang and Karangi Rivers dry up and only smaller boats can pass between Madna and Habiganj due to siltation of the Barak River channel.

3.7 Wetland Resources Utilization and Management

The most important use of natural wetlands products is fodder. In the western part of the project (in most of the Lower Basin) people depend largely on wetland fodder, particularly during the monsoon season when flood waters cover almost all of the grazing land. People from the shallowly flooded areas also depend of this material. Plants such as *Nymphaea* sp. (shapla), *Nymphoides* sp. (chandmela) and other available grasses are commonly used. Quantification of their real economic value is very difficult, more over, most of the people collect their own requirement by themselves. Therefore, estimation of their value was made primarily by considering their replacement value and from data collected in other projects. The wetland producing area comprises mostly land classified as F3, which remains fallow in the summer. The project wetland area is estimated at about 36,000 ha, and its annual production value could reach up to Tk 1.4 million per year, considering estimated yield of 40 Tk per ha. The estimated employment in gathering is about 0.036 million person days per year (1 pd per ha).

A second important use of natural wetland products in this area is for thatching materials. Its use is confined mainly to deeply flooded areas. Different types of grasses are used for different purpose, one is for making structures to protect homesteads from wave action and another for making roofs and panels of houses and for mats. The species used for protecting homesteads is *Hemarthria protensa* (chilla). The species most commonly used for other purposes are *Vetiveria zizanioides* (binna), *Sclerostachya fusca* (ikor), *Phragmites karka* (khagra) and *Clinogyne dichotoma* (murta). These species generally grow at the border of perennial beels. The grass producing area is estimated to be about 800 ha, and the value of annual production is estimated at about Tk 120,000, at 150 Tk/ha yield. The estimated employment in gathering wetland products is about 16,000 pd/year, at 2 pd/ha.

Another important use of these resources is fuel wood. Due to the high scarcity of fuel wood around the homesteads, people are becoming increasingly dependant on wetlands products for fuel. Swamp forest trees other than Hizal are the most demanded fuel wood. All the other

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woody shrubs as well as grasses are also used for this purpose, and as a result, the saplings of swamp forest trees are suffering badly.

Other uses of the wetlands are:

- Food material. Mostly from *Nymphaea* sp. (shapla) and *Aponogeton* sp. (ghachu).

- Bio-fertilizer. From various weeds of the wetland.

- Medicinal plants. Mostly form Polygonum sp (kukra) and many others.

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, and to depend on income from wetland products. Fodder and building materials tend to be collected by men, and food and medicinal materials tend to be collected by women. Information on resource management practices is not available.

4. PREVIOUS STUDIES

A preliminary study of water resources development in the Habiganj area was carried out in 1964 under the EPWAPDA Master Plan by M/S International Engineering Co. Inc. The area, as proposed to be developed under the Shaistaganj Project of the Master Plan included the Khowai River, the Gangajuri Haor and the area bounded by Sutang River, Dhaleshwari River, Titas River, Sonai River and the railway line from Shaistaganj towards Akhaura.

In 1969 Messrs Associated Consulting Engineers Ltd. completed a feasibility study of the Khowai River Project. The report recommended development of the Khowai basin in two phases. Phase I included partial flood protection of the area north of the Dhaka-Sylhet railway line and Phase II included full flood protection, drainage and irrigation of the area south of the railway line. The 1969 Study was reviewed and updated by Sarm Associates Limited and a final report entitled "Khowai River Project, Revision and Updating of Feasibility Report" was issued in April 1973. The 1973 report focused on Phase II development, including full flood embankments from Shaistaganj to Ballah, gravity and tubewell irrigation, drainage and a barrage across the Khowai River at Chandpur near the Indian border.

The Phase II development, dealing with flood protection downstream from Shaistaganj was reviewed by BWDB, and a final report was issued by the Directorate of Planning (Feasibility Studies) in June 1974. The report included designs of high flood embankments on both banks of the Khowai River between Shaistaganj and Habiganj and channel improvement of the Barak River (lower Khowai) from Habiganj to the outfall into Dhaleshwari near Madna.

In 1986 Northwest Hydraulic Consultants Ltd. and SARM Associates Ltd. prepared the report "Pre-Feasibility Study for Northeast Rivers Flood Protection". This study included a review of three concepts for improving flood protection along the Khowai River. The three concepts included extending the existing embankments up to Ballah, providing a diversion from the Khowai River to the Sutang River just upstream of Shaistaganj, and providing a diversion from the Khowai River into the Karangi River. It was concluded that preliminary economic comparisons indicated an advantage to extending and raising the present embankments without provision for flood relief. However, it was suggested that the concept for retaining a flood relief route to the Sutang River should receive more detailed investigation.

In 1988/87 Engineering and Planning Consultants Ltd, Bangladesh, carried out a feasibility study for the development of Gangajuri Haor under BWDB Small Schemes Project. The final Feasibility Report of the Gangajuri Flood Control and Drainage Sub-project was issued in August 1987. The Gangajuri Project covers the area on the right bank of the Khowai River from Shaistaganj and Habiganj town, which was also included in the Khowai River Project Phase II.

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5. WITHOUT-PROJECT TRENDS (NULL OPTION)

The purpose of this chapter is to characterize the likely future characteristics of the region, focusing on important trends that will affect the project area over the 1991 to 2015 period. The scenario presented herein is a "future without project", that is it characterizes the project area as it would appear without implementing the strategy and project initiatives described in Chapter Seven. The main trends are as follows:

- Net population growth: decreasing gradually to 1.2% per year by 2015. The average growth rate of the past 10 years in the project area was 2.04% per year. This will result in a population by 2015 of 1.698 million persons.

- Food grain production growth: Current trends in agricultural production will continue in the absence of any intervention in the Habiganj area. High yielding varieties of aman will continue to replace local varieties of transplanted aman, especially on Class F0 land type. On F3 land, sedimentation will continue to take out some area from local varieties of boro rice. Farmers have indicated they were growing local varieties of broadcast aman in these areas mainly due to a shortage of water in the dry season. This will mean continued damage to the b aman and local boro rice.

  The cropping pattern will remain virtually unchanged. The risk of flooding will be the major constraint to increasing the cropped area and production. There will be little increase in HYV rice cropped area. However, major rice cropped area will be used for the cultivation local varieties. There will be a slight increase in the rabi cropped area resulting in the increase in the cropping intensity. The future cropping patterns (without project) are presented in Tables 5.1 and 5.2.

  Damage to local and high yielding varieties of transplanted aman through drainage congestion, specially in F1 land type, will continue. As a result, no change in the extent of damage to these crops can be expected.

  There will be a slight increase in rice production due to the increase in hyv rice cropped area. The hyv rice cropped area will increase mainly in the transplanted aman season in the Upper Basin and in the boro season in the Lower Basin. There will be no changes in sugarcane, wheat and potato production. However, the production of pulse, oilseed, spices and vegetables may increase a little. The expected future crop production (without project) is presented in Table 5.3 and Table 5.4.

  Marginal expansion of irrigation facilities will take place due to the limited availability of water during the dry season. This will facilitate expansion of high yielding varieties of boro that will continue to be exposed to damage from pre-monsoon floods. However, before making these investments, farmers are expected to use their judgements in selecting sites with the least possibility of flood damage.

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- Openwater fisheries production: Observations of past fish production indicate that it is declining by 1-3% per year overall. Conversely, interventions to improve fisheries management could greatly increase fish production. Given the uncertainties in assessing these trends, it has been assumed that the future production (without project) will be approximately equal to the present production.

- Sedimentation: Ongoing aggradation will continue to occur downstream of Habiganj. This deposition is expected to contribute to a trend of increasing flood levels at Habiganj and Shaistaganj.

- River Erosion and Channel Instability: No major changes in river courses are expected. However, bank erosion along the Khowai River will continue and more breaches in the existing embankments can be expected.

- Loss of arable land to settlement: Negligible.

Table 5.1: Projected Cropping Patterns-Future Without Project Lower Basin

Crop Pattern	F0	F1	F2	F3	Total
sugarcane	1920 (10)				1920
b aman			9274 (70)		9274
l boro				22500 (90)	22500
hyv boro			1325 (10)	2500 (10)	3825
b aus-rabi		448 (5)			448
b aus-lt aman	3072 (16)	1524 (17)			4596
b aus-lt aman-rabi	1920 (10)	448 (5)			2368
b aus-hyv aman	768 (4)	97 (10)			1665
b aus-hyv aman-rabi	576 (3)				576
hyv aus-rabi	768 (4)				768
hyv aus-lt aman	1344 (7)	538 (6)			1882
hyv aus-hyv aman	960 (5)	179 (2)			1139
lt aman	1536 (8)	1793 (20)			3329
lt aman-potato	384 (2)	269 (3)			653
lt aman-rabi	1152 (6)	807 (9)			1959
lt aman-hyv boro	1920 (10)	897 (10)			2817
hyv aman	384 (2)				384
hyv aman-wheat	192 (1)	359 (4)			551
hyv aman-potato	384 (2)				384
hyv aman-rabi	576 (3)				576
hyv aman-hyv boro	1344 (7)	807 (9)			2151
b aman-rabi			663 (5)		663
b aman - hyv boro			1987 (15)		1987
TOTAL	**19200**	**8966**	**13249**	**25000**	**66415**

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

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Table 5.2: Projected Cropping Patterns-Future Without Project
Upper Basin

Crop Pattern	F0	F1	F2	F3	Total
b aman			520 (10)		520
hyv boro			4420 (85)		4420
b aus-lt aman	534 (2)	690 (5)			1224
b aus-lt aman-potato		414 (3)			414
b aus-lt aman-rabi	1335 (5)	2070 (15)			3405
b aus-hyv aman	801 (3)				801
hyv aus-wheat	267 (1)				267
hyv aus-rabi	1335 (5)				1335
hyv aus-lt aman	1068 (4)	1380 (10)			2448
hyv aus-hyv aman	8010 (30)	690 (5)			8700
lt aman-potato		414 (3)			414
lt aman-rabi		1104 (8)			1104
lt aman-hyv boro	1335 (5)	5520 (40)			6855
hyv aman-wheat	801 (3)	138 (1)			939
hyv aman-potato	1068 (4)	276 (2)			1344
hyv aman-rabi	2136 (8)	414 (3)			2550
hyv aman-hyv boro	8010 (30)	690 (5)			8700
b aman-rabi			260 (5)		260
TOTAL	**26700**	**13800**	**5200**		**45700**

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

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Table 5.3: Crop Production-Future Without Project Lower Basin

Crop	Damage Free Area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Total (t)	Area (ha)	Yield (t/ha)	Total (t)	
b aus	8153	1.25	10192	1500	1.05	1575	11767
hyv aus	3289	3.75	12335	500	2.75	1375	13710
b aman	9924	1.75	17367	2000	1.45	2900	20267
lt aman	14604	2.15	31399	3000	1.75	5250	36649
hyv aman	6426	3.95	25381	1000	3.55	3550	28931
l boro	18000	2.25	40500	4500	1.75	7875	48375
hyv boro	8280	4.55	37673	2500	3.25	8125	45798
wheat	551	2.05	1129				1129
potato	1037	12.00	12444				12444
pulses	1104	0.85	938				938
oilseeds	3679	0.75	2759				2759
spices	368	2.25	828				828
vegetables	2207	3.80	8278				8278
sugarcane	1920	45.00	86400				86400

Source: NERP estimates.

Table 5.4: Crop Production-Future Without Upper Basin

Crop	Damage Free Area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Total (t)	Area (ha)	Yield (t/ha)	Total (t)	
b aus	5344	1.25	6680	500	1.05	525	7205
hyv aus	11250	3.75	42188	1500	2.75	4125	46313
b aman	780	1.75	1365				1365
lt aman	13864	2.15	29808	2000	1.75	3500	33308
hyv aman	22034	3.95	87034	1000	3.55	3550	90584
hyv boro	16475	4.55	74961	3500	3.25	11375	86336
wheat	1206	2.05	2472				2472
potato	2172	12	26064				26064
pulses	1298	0.85	1103				1103
oilseeds	4327	0.75	3245				3245
spices	432.7	2.25	974				974
vegetables	2596	3.8	9736				9736

Source: NERP estimates.

6. WATER RESOURCES INFRASTRUCTURE DEVELOPMENT OPTIONS

6.1 Summary of Problems

The main problems in the project area relate to two main factors:

- the Khowai River flood control project was never completed, which has allowed flood spills upstream of the embanked reach;
- the existing flood control embankments along the Khowai River are inadequate.

The Khowai River flood control project ends 6 km upstream of Chunarghat. This has allowed flood flows to spill from the 23 km long unembanked reach below Ballah. These floods damage monsoon season crops in the Karangi and Sutang basins and also in the Gangajuri Project area which has not been designed to accommodate the spills.

The embankments between Chunarghat and Habiganj have experienced recurring failure by breaching due to erosion, undermining by scour and piping at structures. Aus and aman crops, homesteads and infrastructure such as roads, railway lines and bridges are frequently damaged by the monsoon floods. There are many contributing causes to these embankment failures. Ongoing channel shifting has resulted in inadequate embankment set-backs. Allowing habitation inside the embankments has encroached the floodway, increased water levels and promoted channel shifting. Cultivation of sugar cane on the floodway has also encroached the river and has promoted overbank sediment aggradation. Inadequate maintenance and policing of locally constructed works has been cited as a contributing factor to embankment breaching. Ongoing extension and modification of the embankments has affected the flow regime along the river, which has led to higher flood levels upstream. The occurrence of higher water levels tends to become self-inducing. For example, flood stages have increased now to the point where the river reaches the decks of the three bridges between Shaistaganj and Habiganj. As a result, the backwater effects from the bridges are now substantially greater than in the past when the maximum stages did not reach the low chords. Finally, channel aggradation is believed to be occurring downstream of Habiganj, which is leading to a loss of channel conveyance.

In the Lower Basin, floodplain crops are damaged by the pre-monsoon flash floods. Deep seasonal flooding also restricts monsoon season cropping in this area. Most of the pre-monsoon floods originate from the Khowai River (Barak River) which has a small and partly silted-in channel downstream of Habiganj. The Sutang and Balbhadra Rivers and some local khals are also partly infilled by silt in some locations.

6.2 Water Resources Development Options

Water development options have been provided for both the Upper Basin and Lower Basin of the project area.

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Upper Basin
Since the Khowai River is the main source of flooding in the area (severe floods also occur along the Karangi and Sutang Rivers when the Khowai spills into these rivers), the project development options basically relate to flood protection from the Khowai River. The possible means of flood protection against the river floods are: by reservoir, by dredging, by embankments, by channel improvement and by diversion.

There are no suitable site for a flood control reservoir within Bangladesh. Channel dredging over the entire length of the Khowai River to accommodate monsoon flood peaks is also not practical due to the huge quantities involved and the need for frequent re-excavation. Some consideration was given to splitting the Khowai River flow at Ballah and passing a portion of the inflow down either the Karangi or Sutang Rivers. However, the concept of a flood by-pass to either the Karangi River or Sutang River appears to be unattractive because of the serious impacts to the existing infrastructure and developments along these rivers and because of the social objections to a substantial diversion of the flow.

Based on these considerations, the following development options were considered in the Upper Basin of the project area:

U1 *Upgrade the existing embankments and complete the Khowai River high flood embankments up to Ballah.* A policy of attempting to retain all flood flows in the Khowai River places a large burden on the design, construction and maintenance of the embankments. Furthermore, this approach may entail excessive risk since geotechnical hazards will increase with the height of the embankment. Another disadvantage of this concept it that the upper areas of the basin which drain into the Khowai River would suffer drainage congestion and increased flooding during high stages of the river. Nevertheless, on purely economic grounds, this approach may be very attractive and should be reviewed further during feasibility investigations.

U2 *Upgrade the existing embankments and complete the high flood embankments up to Ballah with diversion of tributary catchments to the Karangi and Sutang Rivers.* By diverting the upper tributary catchments, the Kowai River flood discharges will be reduced by about 10% and the required embankment height would be lower. Furthermore, drainage and flood protection would be provided in the upper Khowai areas. As part of this work, the upper Sutang River channel would be enlarged and stabilized to accommodate the increased flows. At present, channelizing the upper Sutang may not be justifiable by the level of damage that is incurred to-day.

Lower Basin
The main objective of these works is to prevent damage from pre-monsoon floods in the Lower Basin of the project area. Flood protection can be improved by excavating the channel and by constructing submersible embankments. The following three options utilize these measures to varying degrees.

L1 *Construct submersible embankments on both banks of the Barak River (lower Khowai) with some channel re-excavation.* Submersible embankments will increase monsoon flood levels near Habiganj. There will also be increased sediment deposition in the lower section within the embankments. This sediment aggradation will induce erosion along the embankments so that they will require frequent maintenance and re-construction. Sediment aggradation will also lead to increased upstream water levels during both pre-monsoon and monsoon conditions. Ongoing monitoring would be required to determine if siltation is reducing the channel's conveyance capacity.

L2 *Re-excavate Barak River and complete the existing partial submersible embankment on the right bank.* Under this option, the maintenance cost would be lower, but while the right bank would be protected from the pre-monsoon floods, the left bank area would be exposed to higher floods and sediment deposition.

L3 *Re-excavate Barak River to accommodate the 1:10-year pre-monsoon flood.* This approach will lower flood levels during the pre-monsoon and monsoon seasons in the lower reach of the Khowai and Barak Rivers. Spoil from the excavation would be used to prevent spills through low-lying areas. By not confining the monsoon flows, the impacts of sediment deposition should be less since the material will be deposited over a wide area (rates of channel aggradation should be less). Ongoing monitoring will be required to determine if siltation is reducing the channel's conveyance.

In addition to these concepts, improvement of local drainage by development of other channels in the area are an ancillary works. These should include channel improvement of the Balbhadra, Sutang, Karangi and Ratna Rivers. Improvement of the Ratna River is planned under the Kushiyara-Bijna Interbasin Project proposed under the Northeast Regional Water Management Plan as a separate initiative.

The proposed development concept described in Chapter 7 combines Option U2 with Option L3. This includes full flood protection in the Upper Basin by means of embankments along the Khowai River with upper tributary diversions and channelizing of the Karangi and Sutang Rivers, and partial flood protection and drainage improvement in the Lower Basin by means of de-silting and re-excavation of the khals and rivers in their lower sections.

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7. PROPOSED FLOOD CONTROL AND DRAINAGE PROJECT

7.1 Rationale

This plan provides for pre-monsoon flood protection in low lying area of Habiganj District (the Lower Basin) and monsoon flood protection in the higher lands along the Khowai, Sutang and Karangi Rivers (upper basin).

Pre-monsoon flood protection will be achieved through improved drainage by re-excavation of existing channels. Re-excavation of the existing channels in the Habiganj Lowlands will also improve local navigation and accessibility of irrigation water.

Full flood protection will be achieved by flood proofing of the Khowai River (embanking of upper Khowai and upgrading of the existing embankments) and improvement of the Karangi and Sutang Rivers.

As a result of project implementation, the net flood free area will increase from 45,900 ha to 96,588 ha during the pre-monsoon and from 38,400 ha to 48,500 ha during the monsoon season.

7.2 Objectives

The objectives of the Habiganj-Khowai Area Development Project are:

i) protection of boro rice from the pre-monsoon floods;

ii) protection of aus and aman crops from the monsoon season floods, and

iii) prrotection of homesteads and infrastructure from the monsoon season floods of the Khowai River.

7.3 Description

The proposed project designs are based on full flood control in the upper basin and partial flood control in the lower basin. Improving the drainage capacity of the channels is an integral part of the flood control project.

In the lower basin, both the drainage improvement and the pre-monsoon flood control will be achieved by increasing discharge capacities of the channels; there is no scope for reducing the monsoon season flooding. In the upper basin, which is flood free during the pre-monsoon, the flood control will be secured mainly by means of embankments along the Khowai River.

The proposed project components include: upgrading of the existing and construction of new embankments, excavation of diversion channels, re-excavation of existing channels and construction of hydraulic structures.

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The present conditions, and the proposed improvement works on the project rivers are outlined below.

7.3.1 Flood Protection and Drainage

Khowai River
To improve the level of protection against Khowai River flooding during the monsoon season it is proposed to:

- Divert Nalmukh Khal to the Karangi River (2 km diversion) and the Isali Chara to the Sutang River (4.5 km diversion), thereby reducing Khowai River flood discharges by an estimated 10%. Both the Karangi and Sutang Rivers will require channel improvements;

- Improve the Khowai River within the existing embankments (remove encroachments such as homesteads, eliminate sugar cane plantations during the flood season, raise and increase the span of all bridges over the Khowai River;

- Raise, upgrade and re-section the existing embankments so that they will be capable of withstanding a flood having a return period of at least 50 years. In some locations the existing embankments will have to be retired to provide an adequate set-back from the river;

- Provide a drainage channel from Habiganj town to Sutang River (8 km long channel);

- Extend the high embankments on both banks up to Ballah so that they can withstand a 1:50 year flood with adequate freeboard. This will require extending the embankments by 17 km on the right bank and by 16 km on the left bank.

The proposed right bank embankment from the end of the existing embankment at Chunarghat to the Rema Hills will cut off drainage of Nalmukh Khal into the Khowai River (about 10 km^2 catchment). Construction of an embankment sluice on this khal would create drainage congestion in the Nalmukh flood valley, as there would be no flow through the sluice during high stages in the Khowai River. Therefore, it is proposed to divert the Khal into the Karangi River. The borrow pit along the village road from Muchikandi to Parajar village should be re-excavated for this purpose.

The left bank embankment from Raja Bazar to Ballah will block the outflow from the Isali and Bhui Charas with a total catchment of 107 km^2. Local people identify these two charas as the main source of floods in the area between the railway line and the Khowai River. They also state that the Khowai does not spill overbank between Ballah and Assampara. Provision of an embankment sluice would create drainage congestion and further aggravate flooding conditions. To solve the above flood problem it is proposed to divert these charas into the Sutang River through a 4.5 km long canal excavated on the western side of the railway line. The area on the eastern side of the railway will drain back into the diversion canal through the Bhui Chara (See Figure 6).

An additional benefit from the proposed diversions is a reduction of the Khowai discharges by about 10%, and a possible increase of the dry season flow in the Sutang River. Data on the Isali Chara low flow are not available.

The flood control embankments would be extended to Ballah to prevent spills into the Karangi River or Sutang River. These embankments would be designed to provide a minimum freeboard of 1.2 m during a 1:50 year monsoon flood peak.

The proposed improvement of the existing high flood embankments includes: construction of retired embankments in sections threatened by river erosion, strengthening/upgrading weak or low sections, shifting back embankments to provide a minimum 25 m set back distance, removal of local silt deposits, and prohibition of high vegetation within the embankments. BWDB have identified 24 locations where the embankments are prone to erosion. The existing embankments would have to be raised on average by 1 m downstream of Shaistaganj even with these channel improvements in-place. If the improvements could not be carried out due to social or economic factors then the embankments would have to be raised even further. Plans for further raising of the Khowai embankments should be subject to thorough geotechnical review and investigation to assess the feasibility of such works.

Sugar cane growing within the embanked Khowai River floodway is identified as a contributing factor to increased water levels and sediment aggradation. Acquisition of the land between the flood embankments (550 ha) was considered as one of the options for removal of the sugar cane to improve the discharge capacity of the river. Under this option the project capital cost would increase by about 20% and the ERR would go down by 3% from 32% to 29%. However, taking more than 500 ha of land out of production may not be acceptable socially. Instead, other approaches, such as switching from the sugar cane to short stem winter crops and leaving the land between embankments fallow during the flood season is recommended. Financial compensation and/or credit assistance to the farmers, to motivate them to change the cropping pattern, should be explored during feasibility.

In the lower basin of the Khowai River the following works are proposed to provide protection against pre-monsoon floods:

- Re-excavate the Barak River from Chandpur to Durgapur, a length of 16 km;
- Divert the Barak channel into the An Gang channel and re-excavate the An Gang channel from Durgapur to Madna, a distance of 3.5 km;

To prevent overbank spill from the Barak River (Lower Khowai) during the pre-monsoon flash floods it is proposed to re-excavate the remaining section of the river downstream of Habiganj. A channel with 40.0 m bed width is sufficient to convey 150 m^3/s discharge; the approximate 1:10-year pre-monsoon flood discharge with the proposed upstream diversion of about 33 m^3/s. The total volume of material needed to be excavated amounts to roughly 2.4 million m^3. The Barak River channel length will be reduced by 4.0 km by diverting the flow into the An Gang as shown in Figure 6.

It is not recommended that submersible embankments be constructed in the lower section of the Khowai River (Barak River) at this time. Submersible embankments in the low floodplain will have the following effects:

- They will tend to raise upstream water levels in the fully embanked reach since a greater proportion of the flows will be confined. This confinement effect will impact flood levels during the monsoon season which will lead to higher levels near Habiganj.

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- They will concentrate sediment deposition over a narrow area within the embankments. This sediment aggradation will induce erosion and instability along the embankments so that they will require frequent maintenance and re-construction. Sediment aggradation will also lead to increased upstream water levels during both pre-monsoon and monsoon conditions.

Karangi River
The following works are proposed to improve the drainage and flood conditions in the Karangi basin.

- Re-excavate the Karangi Channel upstream of Bahubal to accommodate 1:10-year annual flood (including runoff from the Nalmukh Khal basin), 17 km.

- Re-excavate branch channels of the Karangi River within the Gangajuri Haor area. (This work is a part of the ongoing Gangajuri FCD Project, and its cost is not included in this study).

Sutang River
The proposed development works in the Khowai River will solve the problem of the pre-monsoon flooding in the lower section of the Sutang River; with no spills from the Khowai the Sutang discharges will be lower. However, the Isali Chara diversion (from the Khowai into the Sutang, see above) will increase discharge in the Sutang River. To accommodate the additional discharge ($Q = 70.2\ m^3/s$ at 10-year annual flood) the Sutang River channel needs to be improved.

The proposed improvement works include:

- Channelize the Sutang River upstream of the railway bridge, 31 km;

- Construct drop structures across the channel in the upper river section. Based on available topographic mapping it is believed three structures will be required;

- Re-excavate the river channel in the lower section, total 5.0 km.

The required channelizing works involve re-excavation of the channel to accommodate a 1:10-year return period annual discharge (including the Isali Chara diversion), and loop cuts. The proposed bed width of the channel varies from 10.0 m at the offtake from the Isali Chara to 25.0 m at the railway bridge. Downstream of the railway bridge the channel has sufficient capacity and improvement works are required only at few sections that are silted-in.

The Sutang channel has not been surveyed in the upper section, therefore, the proposed river works are based on visual field observations and the available topographic maps (1956). The proposed Sutang River channel profile is shown in Figure 10.

At present, intensive channel erosion occurs in the upper section of the river caused by high flow velocities and a high channel gradient. With the channelizing works, which include loop cuts, the river gradient will increase further. It is proposed to decrease the flow velocity by reducing the longitudinal slope of the channel by constructing drop structures across the channel. The proposed structures, with a total drop of 4.0 m, are as follows:

- Isali Chara Diversion channel:
  (1) at section 1.5 km, b = 10.0/10.0 m, h = 1.0 m

- Sutang River channel:
  (1) at section 10.0 km (below road bridge at Chunarghat),
  b = 15.0/20.0 m, h = 1.5 m

  (2) at section 14.0 km, b = 20.0/25.0 m, h = 1.5 m.

De-silting and improvement of the Sutang channel in the lower section will improve drainage, navigation and the availability of water for LLP irrigation.

Other Drainage Improvement Works
Other work required to improve drainage of the system includes:

- Construct a drainage channel from Habiganj town to Sutang River, 8.0 km.
- Re-excavate Balbhadra River, total 3.0 km.
- Re-excavate other internal khals, total 20.0 km.

The Habiganj drainage channel will revitalize the drainage system through the lowlands west of town which has deteriorated after construction of the flood embankments. The works involve re-excavation of the Babar Khal and Langlia Nadi (about 6.0 km) and excavation of link channels (about 2.0 km) to the outlet into the Sutang River at Bhumapur village. The design section of the channel is 5.0 m bed width and 1:1.5 side slopes.

Re-excavation of the lower section of the Balbahadra River will remove drainage congestion in the southern part of the project and also improve access to irrigation water.

Several recommendations were made by local representatives during the Habiganj Seminar (April 17, 1993) related to re-excavation of local khals across the Habiganj floodplain. Since these could not be cross checked with BWDB or verified during field inspections in August 1993 (the entire area remained deeply flooded), a general provision has been made for improvement of local drainage.

The development of Maidur Haor Flood Control Project has not been considered in this pre-feasibility study due to the small area of the project (about 500 ha gross).

7.3.2 Impact on Flooding

As a result of the flood protection measures and drainage improvement, the depth of flooding will be reduced and the area of flood-free land will increase.

During the pre-monsoon season, the flood-free net area will increase by 50,688 ha. The change will occur mainly in the Lower Basin of the Habiganj area which, after the project implementation will become free of the pre-monsoon flash floods. The direct impact of the pre-monsoon flood protection in the Lower Basin will be increased crop production due to reduced flood damages and increased cropping intensity.

In the monsoon season the flood-free area will increase by 10,100 ha. The change will occur in the Upper Basin which will become free from the Khowai monsoon floods. There will be no change in the depth of flooding in the Lower Basin which is under the backwater effect of the Dhaleswari River (Lower Kalni), however, the improved drainage system will allow for quick evacuation of water at the end of monsoon.

As a result of the flood control measures in the Upper Basin, monsoon season crop damages will be eliminated and the homesteads and infrastructure will be protected from the Khowai River floods, which in recent years spill on average every second year.

Tables 7.1 and 7.2 show areas under different depths of flooding in the Habiganj-Khowai Area during the pre-monsoon and monsoon seasons.

Table 7.1: Pre-Monsoon Area by Depth of Flooding

Flood Depth (m)	Gross Area (ha)		Net Area (ha)	
	Pre-Project	Post-Project	Pre-Project	Post-Project
< 0.30	78,566	136,092	45,900	96,588
0.30-0.90	30,839	13,640	22,766	10,960
0.90-1.80	19,100	6,200	18,449	4,300
> 1.80	27,427	-	25,000	-
Total	155,932	155,932	112,115	112,115

Table 7.2: Monsoon Area by Depth of Flooding

Flood Depth (m)	Gross Area (ha)		Net Area (ha)	
	Pre-Project	Post-Project	Pre-Project	Post-Project
< 0.30	62,700	68,524	38,400	48,500
0.30-0.90	27,705	23,132	26,966	21,919
0.90-1.80	24,472	17,221	21,749	16,549
> 1.80	41,055	41,055	25,000	24,880
Total	155,932	155,932	112,115	111,848

7.3.3 Expected Benefits

Project benefits relate mainly to agriculture where the benefits are direct, in the form of increased crop production, and to protection of homesteads and infrastructure, where the benefits are indirect, in the form of savings by averting flood damages. The present flood damages are estimated at about Tk 10.5 and Tk 2.6 million per year respectively for homesteads and for roads and railways. Also, there will be a small increase in fish production (estimated at about 18 tonnes or Tk 0.82 million) following re-excavation and de-silting of the river channels in the Lower Basin. The project benefits in agriculture are described below.

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Future With Project Crop Production
Flood control and drainage improvements in the project area will secure crops, which will enable farmers to increase hyv areas by replacing low-yielding local varieties. Early drainage could help to increase rabi cropped areas. The cropping intensity will increase to 144% in the Lower Basin and 208% in the Upper Basin; a 2% and 10% increase over the expected FWO project cropping intensities. In addition to shifts in cropping patterns, the yield will increase on 26,500 ha of land on which rice crops are presently damaged by floods.

The annual cereal crop production is expected to increase by 49,169 tonnes from 474,209 tonnes (future without) to 523,378 tonnes as a result of the project, an increase of 10.3%. Non-cereal production would increase by about 2,944 tonnes which is a 4.4% increase. This increase is mainly due to shifts from local varieties to high yield varieties of aman and boro rice, and due to elimination of the flood damage to the winter as well as monsoon season crops. The cereal production increase implies a per person increase in cereal availability from 540 (FWO) to 596 (FW) gm per person per day, an increase of 10.4% (Table 7.3). Current Bangladesh average consumption is 440 gm per person per day.

The future cropping patterns with project are presented in Tables 7.3 and 7.4, and the future crop production is presented in Tables 7.5 and 7.6.

7.3.4 Mitigation Measures Incorporated

The project is not expected to have adverse impacts on the hydrological and environmental conditions which would require mitigation either within or in the area surrounding the project.

7.4 Project Operation and Maintenance

Under this development plan there is no operation requirement due to the nature of the components (earthworks, improved river channels, and ungated drop structures). Maintenance of the earthworks and structures is required to assure effective flood control and drainage in the project area. The embankments require regular inspections and scheduled and unscheduled maintenance. The unscheduled maintenance would include emergency repair works during the flood season. Regular surveys of the river channels will be required to monitor ongoing channel changes and siltation patterns on the rivers. This monitoring will be necessary to plan future maintenance works such as re-excavation of channels or retirement of embankments due to channel migration.

Most of the maintenance works such as repair of embankments and structures, and de-silting or re-sectioning of rivers and khals will be major works which requires experienced professional management. These works should be entrusted with BWDB.

Maintaining the Khowai River embanked floodway free of sugar cane plantations should also be carried out under the project maintenance program. However, as it requires mainly community participation and policy planning, it could be entrusted with local bodies.

Table 7.3: Projected Crop Patterns-Future With Project Lower Basin

Cropping Pattern	F0	F1	F2	F3	Total
sugarcane	1920 (10)				1920
b aman			6625 (50)		6625
l boro				19904 (80)	19904
hyv boro			2650 (20)	4976 (20)	7626
b aus-rabi		448 (5)			448
b aus-lt aman	3072 (16)	1524 (17)			4596
b aus-lt aman-rabi	1920 (10)	448 (5)			2368
b aus-hyv aman	768 (4)	897 (10)			1665
b aus-hyv aman-rabi	576 (3)				576
hyv aus-rabi	768 (4)				768
hyv aus-lt aman	1344 (7)	538 (6)			1882
hyv aus-hyv aman	960 (5)	179 (2)			1139
lt aman	1536 (8)	1793 (20)			3329
lt aman-potato	384 (2)	269 (3)			653
lt aman-rabi	1152 (6)	807 (9)			1959
lt aman-hyv boro	1920 (10)	897 (10)			2817
hyv aman	384 (2)				384
hyv aman-wheat	192 (1)	359 (4)			551
hyv aman-potato	384 (2)				384
hyv aman-rabi	576 (3)				576
hyv aman-hyv boro	1344 (7)	807 (9)			2151
b aman-rabi			1987 (15)		1987
b aman - hyv boro			1987 (15)		1987
TOTAL	**19200**	**8966**	**13249**	**24880**	**66295**

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

Table 7.4: Projected Crop Patterns-Future With Project
Upper Basin

Cropping Pattern	F0	F1	F2	F3	Total
b aus-lt aman		175 (2)			175
b aus-lt aman-potato		263 (3)			263
b aus-lt aman-rabi	1840 (5)	1313(15)			3153
b aus-hyv aman	368 (1)				368
hyv aus-wheat	368 (1)				368
hyv aus-rabi	1840 (5)				1840
hyv aus-lt aman	1472 (4)	874 (10)			2346
hyv aus-hyv aman	9200(25)	438 (5)			9638
lt aman-potato		263 (3)			263
lt aman-rabi		700 (8)			700
lt aman-hyv boro	3312 (9)	3764(43)			7076
hyv aman-wheat	1104 (3)	87 (1)			1191
hyv aman-potato	1472 (4)	175 (2)			1647
hyv aman-rabi	2944 (8)	263 (3)			3207
hyv aman-hyv boro	12880(35)	438 (5)			13318
TOTAL	**36800**	**8753**			**45553**

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

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Table 7.5: Crop Production-Future With Project
Lower Basin

Crop	Damage Free Area		
	Area (ha)	Yield (t/ha)	Production (t)
b aus	9653	1.25	12067
hyv aus	3789	3.75	14210
b aman	10599	1.75	18549
lt aman	17604	2.15	37849
hyv aman	7426	3.95	29331
l boro	19904	2.25	44784
hyv boro	14581	4.55	66342
wheat	551	2.05	1129
potato	1037	12.00	12444
pulses	1302	0.85	1107
oilseeds	4341	0.75	3256
spices	434	2.25	977
vegetables	2605	3.80	9768
sugarcane	1920	45.00	86400

Source: NERP estimates.

Table 7.6: Crop Production-Future With Project
Upper Basin

Crop	Damage Free Area		
	Area (ha)	Yield (t/ha)	Production (t)
b aus	3959	1.25	4948
hyv aus	14193	3.75	53224
lt aman	13977	2.15	30050
hyv aman	29368	3.95	116005
hyv boro	20393	4.55	92790
wheat	1560	2.05	3197
potato	2172	12.00	26067
pulses	1335	0.85	1135
oilseeds	4450	0.75	3337
spices	445	2.25	1001
vegetables	2670	3.80	10012

Source: NERP estimates.

7.5 Organization and Management

During the early part of the feasibility study process, a client group will need to be organized to oversee project development. These client groups will be composed of representatives from the local farming community, fishing community, and should include relevant thana-level technical officers. The groups will 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. They will be continually briefed as the feasibility work is carried out and will need to confirm the conclusions of the exercise. They will also be informed about details of designs being proposed by BWDB engineers whose designs, in the end, will require their approval. The groups will also monitor the construction program which will be carried out by BWDB.

BWDB will 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 Habiganj. Construction supervision would be carried out by sub-divisional field staff.

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.

The supply of all agricultural inputs has been deregulated and the distribution placed into the hands of the private sector.

In summary, the organization and management of this project has a high dependency on central government for key inputs. The extent to which project targets are realized will be determined by how effectively it serves people's needs and how actively the local community participates in all stages of project development.

7.6 Cost Estimates

Total project costs are Tk 578,569.9 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.

Table 7.7 Capital Cost Summary

Item	('000 Tk)
Structures	31,500.0
Embankments	61,145.0
Channels	148,487.0
Roads	-
Bridges	96,000.0
Buildings	1,500.0
Land Acquisition	63,850.0
BASE COST	402,482.0
Physical Contingencies (25%)	100,620.5
SUBTOTAL	503,102.5
Study Costs[1] (15% of Subtotal)	75,465.4
TOTAL	**578,569.9**
Net Area (ha)	112,115
Unit Cost (Tk/ha)	5,160

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

Land costs reflect the current prices obtained from field interviews: land on the higher ridges along the rivers was priced at Tk 200,000/ha, and land in lowlands (for re-excavation of drainage channels) was priced at Tk 150,000/ha. Earthwork costs are based on BWDB Schedule of Rates for Sylhet Circle indexed to June 1991 prices. Structure costs are based on preliminary line drawings and 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 7.7 with details provided in Annex B.

7.7 Project Phasing and Disbursement Period

Five 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 one and be completed in year three. Land acquisition should commence in year one, be implemented in phases preceding construction, and completed in year three. Construction activities should start in year one and be completed in year four. An itemized implementation schedule is shown in Table 7.8.

Table 7.8 Implementation Schedule

Activity	Year (% Completion)				
	0	1	2	3	4
Preconstruction Activities					
Feasibility Study	100				
Engineering Investigation	70	30			
Detail Designs		70	30		
Land Acquisition		30	40	30	
Construction Activities					
Construction of new Khowai R. Embankments (Chunarghat to Ballah)		60	40		
Upgrading of existing Khowai R. Embankments		20	40	40	
Diversion of Nalmukh Khal		100			
Diversion of Isali Chara		80	20		
Re-excavation of Barak River (Lower Khowai River)		40	40	20	
Re-excavation of Kharangi River		50	50		
Re-excavation of Upper Sutang River		30	30	30	10
Re-excavation of Lower Sutang River		60	40		
Re-excavation of other channels				40	60
Construction of Sutang Drop Structures		40	60		
Upgrading of Khowai Bridges		40	60		
Construction of Project Buildings		100		100	

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.

Land Use

Land use changes are summarized in Table 7.9. A total of 319 ha of land (about 0.2% of the project gross area) will be required for construction of flood embankments and improvement of river channels. These figures exclude 23 ha of land presently under the flood embankments which will be retired. Out of this 319 ha:

- 267 ha will be taken from cultivated areas. Assuming average yields and that the land is all used for rice, this corresponds to an incremental cereal production foregone of about 908 tonnes per year or about 1.8% of total incremental cereal production.

- 32 ha will be taken from homesteads. This is 0.9% of the total homestead area, which implies that 1,600 households or about 9,100 persons will be displaced. Also, homestead agricultural production from these sites will be lost. Roughly estimating homestead garden agricultural production at Tk 1,000 per decimal or Tk 200,000 per ha, the lost income amounts to Tk 1.28 million per year. (Homestead gardens are assumed to cover 20% of the total homestead plot for this analysis).

Table 7.9: Changes in Land Use

Use	Change in area (ha)
Cultivated	-267
Homesteads	-32
Beels	0
Ponds	0
Channels	+90
Hills	0
Fallow[1]	-20
Infrastructure[2]	+252

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

Agriculture
Increased cereal production is documented in Section 7.3.4, Expected Benefits. The cereal production increase implies a per person increase in cereal availability from 540 (FWO) to 596 (FW) gm per person per day, an increase of +10.3% (Table 7.10), 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 66,367 tonnes (FWO) to 69,311 tonnes (FW) (+4.4%). This results from a 1,620 ha increase in area cultivated for non-cereals (from 19,221 ha to 20,841 ha) and implies an increase in the availability of non-cereals from 129 to 135 gm per person per day (Table 7.10).

Fisheries production
Impacts on open water fisheries production were assessed using a simplified model that represents the major system processes. These factors include migration, overwintering habitat extent, wet season habitat, habitat quality and spawning habitat. The basis for this model is summarized in Section C.2.7 of Annex C. The sign and magnitude of these impacts is provided in Table 7.10.

The analysis indicated that the total annual open water fisheries production impact from the project will be positive (+18 tonnes per year). This increased production amounts to 0.5% of the expected FWO annual production of 3,751 tonnes per year. This implies the open water source fish availability per person will remain at 7 gm per person per day after project implementation.

Table 7.10: 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	63348	2787	63348	63348	0	0
Beels	1426	784	1426	1426	0	0
Channels /Rivers	900	180	990	990	18	1170
Totals	65674	4556	65764	65764	18	1170

The project will not impact aquaculture as most ponds are located in the flood-free areas. Therefore, the total fisheries production impacts will be +18 tonnes due to increased channel production. The impact from the project to total fisheries production amounts to +0.4% of the FWO annual production of 4,677 tonnes. This implies a fish availability per person remaining at 9 gm per person due to the project (Table 7.11).

Homestead flooding

Homestead flood damage will be significantly reduced. Due to the lack of historical data on flood damage costs, only a rough estimate can be made of future costs. There are about 167,000 homesteads in the area including Habiganj town, and the average plinth level is at about the 1:5 year flood level. About 9% of homesteads are affected by flooding of 10-20 cm in the 1:10 to 1:25 year floods. Based on these considerations, the estimated annualized economic value of reduced flood damage is approximately Tk 10.5 million.

Wetland Habitats and Grazing Area

Impacts on wetland habitats and grazing areas are difficult to quantify, but a general impression is provided in Table 7.12. The four main types of lands that will be affected include:

- "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 has 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-

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

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	774	742	596	540
Non-Cereals	173	168	135	129
Fish	13	11	9	9

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fallow lowland (F4), beel, and channel areas. This land has considerable residual moisture and can 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 is inundated by more than 0.3 m and supports submerged, free-floating, rooted floating, and sedge/meadow plant communities.

The expected impact of the project will be to decrease winter grazing area by 10%, increase winter wetland area by 2%, and decrease summer wetland area by 12%. There should be no impact on swamp forest trees.

Economic and employment impacts of the project on wetland plant and animal production can only roughly estimated. Assuming an annual economic production of Tk 100 per ha for both summer and winter wetland areas, gives a total annual loss of Tk 424,000 per year. Assuming 1.0 pd per ha-yr for harvesting, the employment impact will be -4,240 pd per year.

Table 7.12: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	18477	19013	536	
sc/wf F1	7691	6444	-1247	
sc/wf F2	9794	6625	-3169	
Fallow Highland	2500	2500	0	
Total	38462	34582	-3880	-10

Land Type	Winter Wetland			
sc/wf F3	0	0	0	0
F4, Beel, Channel	5351	5441	90	2
Total	5351	5441	90	2

Land Type	Summer Wetland			
wc/sf F1	0	0	0	
wc/sf F2	5745	1325	-4420	
wc/sf F3	25000	25000	0	
F4, Beel, Channel	5351	5441	90	
Total	36096	31766	4330	-12

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.

Higher flood levels
The project will not cause increase in water levels in the adjacent areas.

7.8.2 Social

The key areas of social impact (or lack thereof) for this project are described below. Additional information is given in Annex C, Initial Environmental Evaluation.

Employment
There will be an overall increase in employment of 2,593,000 person-days per year. This is composed of:

- an increase in agricultural owner-labour employment of 918,000 pd/yr, of which very roughly 20% is post-harvest processing activities traditionally done by women of the household.

- an increase in agricultural hired labour of 1,673,000 pd/yr, of which about 10% is for post-harvest processing traditionally done by women hired in (mainly by larger farmers) for the purpose.

- an increase in fishing labour of 6,000 pd/yr. There will be a corresponding loss in support activities such as net-making and post-catch processing (mainly drying) much of which is done by women.

- a net decrease of about 4,000 pd/yr in employment opportunities for landless people in wetland labour (gathering wetland products). 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
Households whose homestead land is acquired for proper cash compensation, by the project may have difficulty relocating. This is because suitable homestead lands are so scarce that availability of replacement land for purchase is not assured.

Two mitigation options bear consideration. Embankments could be constructed with berms at strategic locations to support homesteads. Alternatively, provision could be included for the construction of raised housing platforms to facilitate relocation. The experience of BWDB in resettling landless people on embankments in the Cyclone Protection Project may be relevant to the requirements of this project area.

Conflicts
Improved drainage will encourage farmers to extend cultivation further into beel areas west of Habiganj. This will bring them into conflict with fishermen who will find the fishing area reduced.

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

- Landowners, in proportion to landholdings, benefit directly from investment in agriculture production. This is the main benefit (94% in economic terms) of the project and its distribution is quite *regressive*.

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

Who loses?

- Families involved in gathering wetland products. These families are mainly landless and tend to be very poor. *Regressive*.

- Families displaced from their homesteads by project land acquisition. Insofar as more wealthy families can influence infrastructure siting/alignment, this is *regressive*.

Gender Equity
The net equity impact would appear to be somewhat *progressive*. Employment opportunities for women will increase in all categories <u>except</u> wetland gathering. Reduced homestead flood damage will dis-proportionately favour women, given that most women still spend most of their

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lives within the homestead. By the same token, the adverse effects of acquisition of 32 ha of homestead land (1600 households) may fall mainly on the women in those households.

Qualitative Impact Scoring
The qualitative criteria shown in Table 7.15 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 7.13. The scoring procedure is analogous to that used in the FAP 19 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.

7.8.3 Economic

The project has an economic rate of return of 31.9%, which compares well to the required rate of 12% as prescribed by government. It is a medium size capital investment project, at Tk 578.6 million, and only Tk 5,160 per hectare, and it covers a large geographic area (159,264 ha gross). The rate of return remains above the required 12% under different economic scenarios. A 20% increase in capital costs would reduce the rate of return to 27.1%, a delay in benefits by two years would reduce the rate to 21.2%, and decrease in agricultural and fisheries production by 20% would reduce the ERR to 26.9%.

The foreign costs associated with the project are low, at 8% (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 benefits of the project relate to increased rice production and protection of infrastructure. Average crop yields would increase mostly as a result of shifts to HYVs and reduced flood damage. The cropping intensity would increase from the present and FWO of 1.6 to 1.7 under FW project scenario. Non-cereal production would increase by 4.4%. The project would not affect the open water fisheries, while re-excavation and de-silting of rivers would increase the perennial channel area by about 10%.

Table 7.13 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	-1	0	0	1	1	1	-3
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	0	1	1	1	3
Conflicts	-1	0	0	0	0	1	-1
Socioeconomic Equity	1	1	0	0	1	1	3
Gender Equity	1	1	0	0	1	1	3

The project would avert flood damage to homesteads and roads and railways. Substantial benefits would result from flood protection and maintaining uninterrupted road and railway link between Dhaka and Sylhet (the benefits of maintaining the links have not been quantified in the pre-feasibility study).

A very small amount of disbenefits would 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 7.14.

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 partly on assumed shifts in cropping patterns, and if this did not occur, the project would not be viable. Lessons of the past have shown that producers have not always responded as predicted, and this case warrants special efforts in predicting producer responses.

7.8.4 Summary Analysis

From a multi-criteria perspective (Table 7.15), some aspects of the project are not attractive:

- A number of households would lose their homestead land to project land acquisition.
- Conflicts between farmers and fishermen are expected to increase.
- The project has a high dependency on central government for implementation.

The positive attributes of the project include:

- Benefits derive from agriculture (90%) and homesteads protection (7%) and roads and railway protection (3%).
- There would be no negative impact on openwater fisheries (expected 10% increase in channel production).
- The net employment impact is positive.
- The project would not affect adversely regional biodiversity.
- Rate of return is high.
- Substantial increase in rice production though disproportionate benefits would accrue to landowners.
- Small increment in non-cereal production.
- Gender equity of impacts is somewhat progressive.
- Project responds to public concerns.

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Table 7.14: Summary of Salient Data

Economic Rate of Return (ERR)	31.9			
Capital Investment (Tk million)	579			
Maximum O+M (Tk million / yr)	17			
Capital Investment (Tk/ha)	5,160			
Foreign Cost Component	8%			
Net Project Area (ha)	111,848			
Land Acquisition Required (ha)	319			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	135			
Cropping Intensity		1.6	1.6	1.7
Average Yield (tonnes/ha)		3.4	3.4	3.
Average Gross Margins (Tk/ha)		15,512	15,655	16,166
Owner Labour (md/ha)		122	122	123
Hired Labour (md/ha)		39	41	48
Irrigation (ha)		38,282	41,324	46,329
Incremental Cereal Production (1,000 tonnes / yr)	49			
Incremental Non-Cereal (' 000 tonnes / yr)	3			
Incremental Owner Labour (' 000 pd / yr)	918			
Incremental Hired Labour (' 000 pd / yr)	1,673			

FISHERIES IMPACTS		Flood plain	Beels	Channels
Incremental Net Econ Output (Tk million / yr)	0.82	0	0	0.82
Impacted Area (ha)		0	0	90
Average Gross Margins (Tk/ha)		0	0	14,000
Production Impacts %		0	0	100%
Incremental Fish Production (tonnes / year)		0	0	18
Incremental Labour ('000 pd / yr)	6	0	0	6

FLOOD DAMAGE BENEFITS				
Households Affected		15,000		
Reduced Econ Damage Households (Tk M / yr)	10.55			
Roads/Railways Affected (km)		25		
Reduced Econ Damage Roads (Tk M / yr)	2.61			

OTHER IMPACTS				
Wetland Inc Net Econ Output (Tk million / yr)	nil.			
Wetland Incremental Labour ('000 pd / yr)	negl.			
Acquired Cult & Homestead Lands, Inc Net Econ output (Tk million / yr)	-1.3			
Persons Displaced by Homestead Acquisition	9,100			

Table 7.15: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	31.9
EIRR, Increase Capital Costs by 20%	per cent	21.2
EIRR, Delay Benefits by Two Years	per cent	21.2
EIRR, Decrease in Agr/Fish by 20%	per cent	26.9
Net Present Value	'1000 Tk	478,592

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	49,000	10.3
Incremental Non-Cereal Production	tonnes	3,000	4.4
Incremental Fish Production	tonnes	18	0.5
Change in Floodplain Wetland/Fisheries Habitat (channels)	ha	90	10
Homesteads Displaced Due to Project Land Acquisition	homesteads	1,600	0.9
Homesteads Protected From Floods	homesteads	15,000	9
Roads and Railways Protected From Floods	km	25	9
Khowai Flood Levels	m PWD	0.3	
Owner Employment	million pd/yr	+0.92	5.0
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	+2.59	11.6

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	Rank
Ecological Character of Key Wetland Site (Kaliajuri Haor)	-3
Regional Biodiversity	-3
Road Transportation	+5
Navigation	+3
Flood Levels Outside Project Area	+3
Conflicts	-1
Socioeconomic Equity	+3
Gender Equity	+3
Decentralized Organization and Management	-1
Responds to Public Concerns	+3
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); project affected (displaced) river embankments; Khowai water levels; and total employment for owners and hired laborers.

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

8. OUTSTANDING ISSUES

There are several outstanding issues that can not be resolved satisfactorily under the scope of a pre-feasibility level investigation. The main technical issues are as follows:

- Investigations are required to improve estimates of flood discharges on the Khowai River. Efforts should be made to measure high discharges during the 1994 flood season at Ballah, upstream of any spills and at Shaistaganj. Historic water level data collected at all stations in the project area need to be reviewed and revised to account for datum corrections that have been established from the recently completed Second Order Levelling Program of the northeast region.

- Up to-date cross sections are required along the Barak River, Khowai River, Sutang River, and Karangi River. Surveys along the Khowai River/Barak River should be used to assess channel changes and to improve forecasts of future sedimentation rates.

- Geotechnical investigations and input from a recognized geotechnical specialist is required to assess the feasibility of raising the embankments along the Khowai River.

ANNEX A

ENGINEERING DATA ANALYSIS AND DESIGN

ANNEX A
ENGINEERING DATA ANALYSIS AND DESIGNS

A.1 Climatic Data

The project area experiences the sub-tropical climate typical of Bangladesh, but with variations due to its location and topography. Rainfall is the most significant and variable aspect of the climate, causing severe flooding in summer and drought in winter.

The weather stations within the Habiganj-Khowai Area Development Project are listed in Table A1. The monthly averages of the climatic parameters are presented in Tables A2 and A3, and the extremes of records in Table A4.

Table A1: **BWDB Weather Stations Relevant to the Habiganj-Khowai Area Development Project, 1961-1990**

Name of Station	Number	Location Relative to Project Area
Nasirnagar	R-132	Peripheral, to the southwest
Itakhola	R-111	Peripheral, to the southwest
Chandpur Bagan	R-105	Inside, south
Srimangal	R-126	Peripheral, east central
Moulvi Bazar	R-122	Peripheral, to the northeast
Habiganj	R-110	Inside, central
Markuli	R-120	Peripheral, to the north
Itna	R-112	Peripheral, to the northwest

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Table A2: Average Rainfall over the Habiganj-Khowai Area, 1961-1990 (mm)

Period	Itakhola R-111	Chandpur Bagan R-105	Srimangal R-126	Nasirnagar R-132	Habiganj R-110	Moulvi Bazar R-122	Markuli R-120	Itna R-112
	(S)	(S)	(E)	(SW)	(C)	(NE)	(N)	(NW)
Jan	4	7	10	9	13	9	7	10
Feb	24	27	27	23	23	29	26	21
Mar	61	68	96	58	71	87	63	68
Apr	206	231	263	205	224	263	341	235
May	344	390	434	394	446	426	558	481
Jun	423	470	471	426	491	535	823	575
Jul	383	354	361	413	415	433	673	659
Aug	336	331	338	395	398	394	465	487
Sep	242	252	248	296	272	289	393	489
Oct	153	158	149	185	152	150	145	197
Nov	29	36	41	37	25	27	24	33
Dec	8	10	12	10	9	8	11	9
Year	2195 (100%)	2336 (106%)	2447 (111%)	2476 (113%)	2542 (116%)	2687 (122%)	3501 (159%)	3556 (162%)

Table A3: Climatological Averages
Srimangal, 1948-1991

Month	Sunshine (hrs)	Temperature Mean Max (°C)	Temperature Mean Min (°C)	Temperature Mean (°C)	Humidity (%)
Jan	7.8	25.6	9.3	17.6	83
Feb	8.1	27.9	11.7	19.8	77
Mar	7.3	31.9	16.8	24.5	73
Apr	7.1	33.2	21.1	27.2	75
May	6.7	32.4	22.9	27.7	81
Jun	5.0	31.7	24.7	28.3	86
Jul	4.2	31.9	25.1	28.5	87
Aug	4.8	32.2	25.1	28.7	88
Sep	4.4	32.0	24.5	28.3	88
Oct	6.4	31.1	21.8	26.7	87
Nov	8.1	28.9	15.9	22.4	85
Dec	8.0	26.4	10.9	19.1	78
Year	6.2	33.2	9.3	24.9	81

Month	Wind Speed (km/hr)	Wind Direction	Rain (mm)	PET (mm)	Surplus/ Deficit
Jan	5.7	SSE	7	146	-139
Feb	7.6	SSW	39	160	-121
Mar	9.0	S	84	214	-130
Apr	7.8	SSE	237	243	-6
May	7.5	SSE	404	198	206
Jun	7.3	SSE	483	159	324
July	7.3	SSE	319	158	161
Aug	7.1	SSE	345	133	212
Sep	7.1	SE	265	141	124
Oct	7.1	SE	159	177	-18
Nov	5.7	SE	50	171	-121
Dec	9.9	SE	6	143	-137
Year	7.3	SSE	2431	1460	971

Station: Location 24°18'N, 91°44'E
Elevation 22.0 m

Source: BMD
BARC for PET

Table A4: Climatic Extremes of Record
Srimangal, 1948-1992

Month	Daily Temperature		Monthly Rainfall		Maximum Daily	
	Max (°C)	Min (°C)	Max (mm)	Min (mm)	Rainfall (mm)	Wind Speed (km/hr)
Jan	31.1	3.4	71	0	42	20
Feb	34.4	2.8	129	0	86	33
Mar	38.4	6.7	376	0	91	67
Apr	43.4	10.6	695	0	213	130
May	40.0	14.8	651	12	177	80
Jun	39.8	20.3	1285	283	225	39
Jul	37.8	16.2	655	119	131	167
Aug	37.3	21.2	544	181	260	65
Sep	37.0	19.1	602	22	514	30
Oct	35.3	14.3	398	36	155	65
Nov	33.9	6.5	211	0	96	28
Dec	31.2	4.4	66	0	18	22
Period	43.4	2.8	1285	0	514	167

Source: BMD

A.2 Topographic Data

The Habiganj FCD Project covers a gross area of 155,932 ha comprising hills in upper catchments of the Khowai, Sutang and Karangi Rivers and the Habiganj lowlands. Most of the lowland area, which remains inundated throughout the monsoon by backwater from the Kalni River, suffers crop damages caused by the pre-monsoon floods. The upper catchment is above the backwater line and it is free of pre-monsoon floods, but monsoon floods caused by spills from the Khowai River are common.

To facilitate the project analysis and designs, the project area has been divided into two sub-areas referred to as the *Upper Basin* (76,090 ha gross) and Lower Basin (79,842 ha gross) shown in Figure 2.

The Area-Elevation and Storage Volume Relations for the Upper and Lower Basin given in Tables A5 and A6 are shown in Figures 4 and 5 respectively.

Table A5: Basin Elevation vs Area-Storage Volume Relation
Upper Basin

Elevation (m PWD)	Area (ha)	Storage (ha-m)	Elevation (m PWD)	Area (ha)
5.7	100	0	21.0	60469
6.0	100	25	22.0	65810
7.0	806	403	23.0	68128
8.0	4031	2671	24.0	69539
9.0	8768	8692	25.0	71151
10.0	14109	19904	26.0	71555
11.0	19652	36861	27.0	71756
12.0	26001	59612	28.0	72764
13.0	31041	88234	29.0	73067
14.0	35777	121467	30.0	73570
15.0	41925	160797	31.0	73772
16.0	46460	205065	32.0	74477
17.0	48980	252811	33.0	74780
18.0	52306	303378	34.0	75384
19.0	55732	357447	35.0	75586
20.0	58554	414641	36.0	75888

Table A6: Basin Elevation vs Area-Storage Volume Relation
Lower Basin

Elevation (m PWD)	Area (ha)	Storage (ha-m)
1.8	101	0
2.0	101	21
3.0	2728	1133
4.0	16372	9749
5.0	35878	35798
6.0	57203	83072
7.0	69230	146869
8.0	75496	219081
9.0	78730	296245
10.0	79539	375531
11.0	79640	455145
11.9	79842	526907

A.3 Hydrologic Data

The water level and discharge data available within the project area are given in Table A7.

Table A7: Hydrologic Records

River	Gauging Station, Number	Type of Observation	Record (Years)
Kalni	Madna, 272	L (Tidal)	20
	Astagram, 272.1	L (Tidal)	22
Khowai	Ballah, 157	L	28
	Chunarghat, 158	L	28
	Shaistaganj, 158.1	L/Q	27
	Habiganj, 159	L	28
Karangi	Sofiabad, 138	L/Q	23
Sutang	Sutang RB,	L/Q	10

Table A8: Recorded Discharges along the Khowai, 1964-91

Station	Years of Record	Mean (m^3/s)	Minimum (m^3/s)	Maximum (m^3/s)	Range (m^3/s)
Shaistaganj	27	36.4	0.8	1050	1049

Table A9: Recorded Water Levels along the Khowai, 1964-91

Station	Years of Record	Mean (m,PWD)	Minimum (m,PWD)	Maximum (m,PWD)	Range (m)
Ballah	28	20.19	19.04	26.10	7.06
Chunarghat	28	13.64	12.45	18.17	5.72
Shaistaganj	27	9.36	8.12	15.05	6.93
Habiganj	28	6.75	4.76	10.96	6.20

Table A10: Monthly Distribution of Mean Discharges and Water Levels
Karangi at Sofiabad

Period	Discharge m^3/s	Volume		Water Level m PWD
		MCM	%	
Apr	3.7			8.19
May	14.3	9.6	3.7	8.84
Jun	20.5	38.3	15.0	9.27
Jul	15.1	53.1	20.7	8.97
Aug	15.1	40.4	15.8	8.84
Sep	12.3	31.9	12.5	8.74
Oct	8.2	22.0	8.6	8.40
Nov	2.8	7.3	2.9	8.02
Dec	1.6	4.3	1.7	7.92
Jan	1.1	2.9	1.1	7.88
Feb	1.0	2.4	0.9	7.88
Mar	1.3	3.5	1.3	7.88
Year	8.1	256.1	100.0	8.41

Table A11: Monthly Distribution of Mean Discharges and Water Levels
Khowai at Shaistaganj

Period	Discharge m^3/s	Volume		Water Level m PWD
		MCM	%	
Apr	23.4	60.7	5.4	8.95
May	53.2	137.9	12.2	9.55
Jun	66.4	172.1	15.3	10.04
Jul	62.1	161.0	14.3	10.04
Aug	60.6	157.1	14.0	10.02
Sep	56.0	145.2	12.9	9.91
Oct	45.1	116.9	10.4	9.58
Nov	21.1	54.7	4.9	9.05
Dec	14.5	37.6	3.3	8.86
Jan	11.0	28.5	2.5	8.75
Feb	10.0	25.9	2.3	9.70
Mar	11.0	28.5	2.5	8.69
Year	36.4	1126.1	100.0	9.36

Table A12: Monthly Distribution of Mean Discharges and Water Levels
Sutang at Sutang Railway Bridge

Period	Discharge m^3/s	Volume		Water Level m PWD
		MCM	%	
Apr	3.5	9.1	3.0	3.62
May	11.3	30.3	10.0	4.32
Jun	19.9	51.6	17.0	5.31
Jul	22.5	60.3	19.8	6.31
Aug	23.6	63.2	20.8	6.62
Sep	18.9	49.0	16.1	6.34
Oct	9.9	26.5	8.7	5.44
Nov	2.2	5.7	1.9	3.77
Dec	1.1	2.9	1.0	3.39
Jan	0.8	2.1	0.7	3.30
Feb	0.7	1.7	0.5	3.29
Mar	0.6	1.6	0.5	3.28
Year	9.6	304.0	100.0	4.59

A.4 Flood Frequency Analysis

Flood frequency analysis was carried out separately for the pre-monsoon floods expected before 15 May and for the maximum annual floods expected during the monsoon months. Pre-monsoon flood levels are needed for planning and design of flood protection for *bore rice*, and the annual flood levels are needed for design of high flood embankments and for planning monsoon season cropping patterns.

The Habiganj FCD Project designs and agricultural planning are based on the pre-monsoon flood levels with 1 in 10-year return period in the Lower Basin, and on the monsoon flood levels with 1 in 50-year return period in the Upper Basin.

Preliminary frequency analysis using historical flood levels at selected sites in the Habiganj area are given in Table A13. A preliminary frequency analysis of discharges are given in Table A14. Frequencies were estimated using a Generalized Extreme Value (Type II) distribution. Flood discharges have been affected by upstream spills in some years. Water level records at Habiganj and Shaistaganj are non-stationary, showing an increasing trend over time which makes the estimation of frequencies and magnitudes highly dubious.

Table A13: Flood Water Levels in Rivers of the Habiganj Area
GEV (Type II) Distribution

River	Station	Return Period (Years)						
		2	5	10	20	25	50	100
(Pre-Monsoon Floods) (m PWD):								
Kalni	Madna	3.20	3.59	3.83	4.04	4.10	4.29	4.47
	Astagram	2.94	3.27	3.45	3.59	3.63	3.74	3.83
Khowai	Ballah	21.29	22.16	22.68	23.12	23.26	23.65	24.01
	Chunarghat	15.40	16.40	16.94	17.38	17.51	17.86	18.16
	Shaistaganj	11.20	12.11	12.48	12.73	12.79	12.94	13.05
	Habiganj	8.23	8.94	9.24	9.46	9.51	9.65	9.75
Karangi	Sofiabad	10.23	11.06	11.58	11.88	11.95	12.15	12.29
Sutang	Sutang RB	5.35	6.25	6.69	7.03	7.12	7.37	7.57
Annual (Monsoon) Floods (m PWD):								
Kalni	Madna	7.10	7.52	7.74	7.92	7.97	8.11	8.22
	Astagram	6.79	7.24	7.49	7.71	7.77	7.95	8.10
Khowai	Ballah	24.00	24.86	25.27	25.58	25.66	25.87	26.04
	Chunarghat	17.41	17.81	17.98	18.09	18.12	18.18	18.23
	Shaistaganj	12.57	13.31	13.88	14.50	14.71	15.41	16.20
	Habiganj							
Karangi	Sofiabad	11.90	12.11	12.19	12.25	12.26	12.15	12.32
Sutang	Sutang RB	7.55	7.88	8.02	8.11	8.13	7.37	8.23

Table A14: Flood Discharges in Rivers of the Habiganj Area
(GEV-Type II Distribution)

River	Station	Return Period (Years)						
		2	5	10	20	25	50	100
Pre - Monsoon Floods (m^3/s):								
Khowai	Shaistaganj	110	155	178	196	200	213	224
Karangi	Sofiabad	32	47	53	57	58	60	62
Sutang	Sutang RB	21	43	64	91	100	136	182
Annual (Monsoon) Floods (m^3/s):								
Khowai	Shaistaganj	191	320	478	723	829	1274	1975
Karangi	Sofiabad	85	137	191	266	296	417	580
Sutang	Sutang RB	66	109	151	206	227	307	412

Given the influence of past engineering works on spills and flow diversions, as well as the possible non-stationarity of the flow conditions, it was felt that some comparisons of flood frequencies should be made using only the data collected since 1980. Table A15 summarizes estimates of flood frequencies using discharges recorded at Shaistaganj during the period 1980-1991. This period includes the major high flow events that have been experienced since the original Khowai River project was initiated. Using only this recent period, the magnitude of relatively frequently occuring floods (return periods around 1.5 years to 10 years) are noticeably higher than estimates based on the entire period of record. However, for more extreme floods (return periods of 20 years to 50 years) the magnitudes are close to the estimates using the long-term records. Therefore, for the purposes of this pre-feasibility investigation, a 1:50 year discharge value of 1,270 m^3/s was used in the subsequent analysis.

Table A15: Frequency and Magnitude of Annual Maximum Daily Discharges Khowai River at Shaistaganj, 1980-1991

Return Period	Gumbel GEV I	Log-Normal
10	912	814
50	1264	1360
100	1410	1600

A.5 Fisheries

Table A16: Closed Water Bodies in The Project Area

Thana	% of Area Under Project	Total Number of Ponds	Combined Pond Area (ha)	Average Pond Size (ha)	Pond Concentration (nos/km2)
Baniachong	35	1588	123	0.07	9.11
Lakhai	100	1743	135	0.07	9.17
Habiganj	100	2245	174	0.07	8.90
Chunarghat	100	3868	300	0.07	7.76
Bahubal	100	2316	179	0.07	9.22
Nabiganj	30	1232	95	0.07	9.33
Total		12,992	1006	0.07	

Source: BFRSS, 1986

Table A17: Water Bodies in The Habiganj-Khowai Project

Name of Beel complex	Area (ha)	Name of Beel Complex	Area (ha)
Salbilla (3)	30	Bhomapur (2)	96
Tin Beel (2)	72	Bajni (3)	65
Daskanai	96	Sankardanga	66
Bardur (2)	48	Baurabandha	48
Angang (2)	44	Baura (2)	60
Bandra	34	Bhanga nadi	84
Punibari	49	Chitalia (4)	92
Gul Beel (2)	60	Goala (5)	46
Garbhanga (2)	96	Kamripule (2)	67
Berigang	84	Bhagur (4)	59
Ratna	48	Patal (2)	82
Total:	1426 ha		

Source: NERP, 1993.

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Table A18: Duars Bordering the Project Area

Name of Duar	Approximate Depth During Dry Season (m)	Baramaach Occurred *	Chotomaach Occurred *
River: Dhaleswari			
Adampurar duar	12-13	LC,C,MC	B,Ch,Ca,Ba
Echordir duar	28	As above.	As above.

B:Bacha; Ba:Bailla; C:Chital; Ca:Chapila; Ch:Chela; LC:Large catfish. (Source: Fisheries Specialist Study, NERP, 1992)

Table A19: Habiganj-Khowai Area Fisheries

Type of Water Body	Area (ha)			Rate of Production (kg/ha)
	Present	FWO	FW	
Beel	1426	1426	1426	550
Floodplain	63348	63348	63348	44
River/Channel	900	900	990	200
Pond	1006	1157	1157	800

Table A20: Fish Production in the Habiganj-Khowai Project Area (tonnes/year)

Year	Beel	Floodplain	Pond*	River/khal	Total
Present	784	2787	805	180	4556
FWO	784	2787	926	180	4677
FW	784	2787	926	198	4695

* Pond production estimated with an annual growth rate of 3% in the next five years.

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Table A21: Fisheries Employment
(Person Days)

Year	Beel	Floodplain	Pond	River/ Channel	Total
Present	98000	5574000	89444	60000	5821444
FWO	98000	5574000	102888	60000	5834888
FW	98000	5574000	102888	66000	5840888

Note: Fishing level of effort is estimated as follows: in Beels — one personday per 8 kg of fish caught; for the floodplain — one personday per 0.5 kg of fish caught; for ponds — one person day per 9 kg of fish caught; and in rivers or channels — one personday per 3 kg of fish caught.

A.6 Engineering Designs

A.6.1 Khowai River

Preliminary estimates of water levels were made along the Khowai River to assess requirements for raising the embankments and improving the channel. The calculations were made using a steady flow, standard step backwater program, HEC-2. A total of 87 cross sections were used to represent the channel topography along 85 km reach from the end of the flood control embankments below Habiganj to Ballah, at the Indian border. These cross sections were provided by BWDB and were surveyed around 1988. The channel geometry along the Barak River (from the end of the embankments to its junction with the Kalni River near Madna) were based on 1991 cross sections surveyed by SWMC. Since there were only three cross sections to represent 18 km of river channel, some intermediate sections were added by interpolating the available data.

The railway bridge near Habiganj and Shaistaganj highway bridge were represented using the "Normal Bridge Routine" in the HEC-2 program since these structures are known to induce substantial head losses during high flows. The low chord elevations (obtained from the Habiganj Executive Engineer) for the two bridges are as follows:

- railway bridge low chord = 15.0 m PWD
- Shaistaganj highway bridge low chord = 15.45 m PWD.

Water levels from hydrometric stations at Ballah, Chunarghat and Shaistaganj were used to verify the HEC-2 model. Inflows at Ballah had to be set using recorded discharges at Shaistaganj. The downstream boundary condition was set to the water levels at Habiganj.

Flood conditions from 1988 and 1991 were used for the verification runs. The published 1988 discharges reached up to 1,050 m^3/s. However, the highest actually observed discharge was much lower - around 360 m^3/s. Therefore, the accuracy of the published peak flows is probably quite low. A second verification was made using data from 1991 at a discharge of 376 m^3/s. This is the highest measured discharge on the river.

Verification runs were repeated using three different sets of roughness values:

Series "A"	Manning "n" (channel) = 0.035 Mannings "n" (floodplain) = 0.10
Series "B"	Mannings "n" (channel) = 0.022 Mannings "n" (floodplain) = 0.08
Series "C":	Mannings "n" (channel) = 0.025 Mannings "n" (floodplain) = 0.08

Computed water levels varied by between 1.0 - 1.5 m when roughness values were changed from 0.022 to 0.035. Water Levels computed with a Mannings roughness value of 0.035 were consistently too high by 0.7 - 1.0 m at Shaistaganj, 0.7 - 1.4 m at Chunarghat and 1.1 - 1.8 m at Ballah. The best agreement occurred with an n value of 0.025 for the 1991 flow condition and 0.022 for the highest flows in 1988. However even with these lower roughness values, the computed water levels at the highest discharge in 1988 (1050 m^3/s) exceeded the observed levels by about 0.7 m. The reason for this overestimation is probably related to the low accuracy of the flood discharge value, as well as the fact that breaches occurred during the 1988 flood.

Further calculations were made by varying the discharges for the 1988 flood condition until the water levels matched the recorded levels at Ballah, Chunarghat and Shaistaganj. This analysis suggested that the actual discharge in 1988 may have been around 1050 m^3/s at Ballah and about 850 m^3/s below Chunarghat, with 200 m^3/s spilling at the upstream end of the embankment near Chunarghat.

Based on this preliminary analysis, it was concluded that adopting a channel roughness value of 0.025 was conservative for estimating flood levels with the 1988 cross section data. However, there is a strong need to re-assess hydraulic conditions using up to-date survey information and improved estimates of discharges along the river. This work should be carried out during feasibility investigations.

The following discharge conditions were used for estimating embankment height requirements along the river:

- Estimated 1:50 year flood inflow on Khowai River = 1,270 m^3/s
- Diversion of 1:50 year Isali Chara flow to Sutang River = 110 m^3/s
- Diversion of 1:50 year flow to Karangi River = 30 m^3/s
- Adopted 1:50 year flood discharge on Khowai River = 1,130 m^3/s

The following channel improvements were made to the river cross sections:

- The Barak River/lower Khowai River was dredged to provide a channel with aninvert level of 0.3 m PWD at Madna, 1V:1.5 H side slopes and a bottom width of 40 m. The longitudinal slope of the excavated channel varied from 0.00012 near Madna to 0.0002 near Habiganj. The total volume of material excavated from the channel was estimated to be 2,400,000 m^3;

- Inner embankments, local dikes and floodplain obstructions such as homesteads and sugar cane were removed from the floodway of the Khowai River;

- A minimum set-back of 25 m was provided from the top of the bank to the toe of the embankments;

- All bridges were raised so that their low chords were above the estimated flood levels. Spans were added to the bridges so that the floodway was no longer significantly constricted;

- The existing embankments were raised so that no spills occured out of the floodway;

- The embankments were extended upstream from near Chunarghat to Ballah.

Preliminary estimates of water levels and embankment crest levels (water level + 1.2 m freeboard) are summarized in Table A.22. The computations indicate the existing embankments will need to be raised by 1.5 m to 2.0 m in many locations between Habiganj and Shaistaganj to provide 1.2 m of freeboard during the adopted flood conditions. The new embankments were assumed to have 4.3 m crest width and side slopes of 1V:2.5H.

The railway bridge and Shaistaganj highway bridge will need to be raised by at least 1.8 m and provided with additional spans to reduce their constriction of the 1:50 year flow. However, it is recommended that the replaced bridges be designed to accomodate a flood having a return period of 1:100 years since these structures are important infrastructure in the region.

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Table A22: Preliminary Estimate of Water Levels along Khowai River

Distance from Ballah (km)	Existing Channel (m PWD)	Improved Channel (m PWD)	Water Level + 1.2 m (m PWD)	Location
61.53	8.8	8.8	10.0	Lumbabukh
59.92	10.5	10.0	11.2	
59.10	11.0	10.2	11.4	
57.88	11.4	10.4	11.6	
56.81	11.5	10.5	11.7	
56.16	12.1	11.1	12.3	
54.94	12.4	11.5	12.7	
53.72	12.8	11.9	13.1	Habiganj
53.11	12.9	12.0	13.2	
52.50	13.1	12.2	13.4	
52.05	13.1	12.2	13.4	
51.50	13.1	12.3	13.5	
50.19	13.6	12.8	14.0	
49.49	13.9	13.0	14.2	
48.27	14.1	13.2	14.4	
47.41	14.1	13.4	14.6	
46.13	14.5	13.8	15.0	
44.91	15.5	14.7	15.9	
43.70	15.7	14.9	16.1	
43.15	15.9	15.0	16.2	
42.05	16.1	15.3	16.5	
40.98	16.3	15.4	16.6	
39.98	16.4	15.6	16.8	
39.10	16.5	15.7	16.9	
39.00	16.4	15.6	16.8	
38.99	16.4	15.6	16.8	
38.89	17.0	15.6	16.8	
38.50	17.1	15.8	17.0	Shaistaganj
38.19	17.1	15.9	17.1	
38.09	17.1	15.9	17.1	
38.08	17.1	15.9	17.1	
37.98	17.3	15.9	17.1	
37.48	17.5	16.1	17.3	
36.87	17.6	16.2	17.4	

Table A22: Preliminary Estimate of Water Levels along Khowai River

Distance from Ballah (km)	Existing Channel (m PWD)	Improved Channel (m PWD)	Water Level + 1.2 m (m PWD)	Location
35.65	17.8	16.4	17.6	
34.53	17.9	16.6	17.8	
33.31	18.2	16.9	18.1	
32.25	18.4	17.2	18.4	
31.03	18.6	17.4	18.6	
29.69	18.7	17.6	18.8	
28.65	18.9	17.8	19.0	
27.43	19.1	18.0	19.2	
26.21	19.5	18.5	19.7	
24.99	19.8	18.8	20.0	
24.40	20.0	19.1	20.3	
23.96	20.1	19.3	20.5	Chunarghat
23.35	20.3	19.4	20.6	
22.74	20.5	19.7	20.9	
22.13	20.8	20.0	21.2	
21.52	20.9	20.1	21.3	
20.91	20.9	20.1	21.3	
20.30	21.0	20.2	21.4	
19.69	21.2	20.5	21.7	
19.08	21.4	20.6	21.8	
18.47	21.6	20.9	22.1	
17.86	21.8	21.1	22.3	
16.93	21.9	21.1	22.3	
16.89	21.8	21.1	22.3	
16.28	21.9	21.2	22.4	
15.67	22.1	21.4	22.6	
15.06	22.3	21.6	22.8	
14.45	22.4	21.7	22.9	
13.84	22.5	21.8	23.0	
13.17	22.6	21.9	23.1	
12.56	23.0	22.4	23.6	
11.94	23.3	22.7	23.9	
11.34	23.4	22.7	23.9	
10.73	23.6	22.9	24.1	

Table A22: Preliminary Estimate of Water Levels along Khowai River

Distance from Ballah (km)	Existing Channel (m PWD)	Improved Channel (m PWD)	Water Level + 1.2 m (m PWD)	Location
10.12	23.7	23.0	24.2	
9.51	23.8	23.2	24.4	
8.90	24.0	23.4	24.6	
8.29	24.0	23.4	24.6	
7.68	24.3	23.6	24.8	
7.07	24.4	23.8	25.0	
6.77	24.5	23.9	25.1	
6.16	24.7	24.1	25.3	
5.55	24.9	24.3	25.5	
4.94	25.0	24.4	25.6	
4.48	25.1	24.5	25.7	
4.33	25.2	24.6	25.8	
3.72	25.2	24.7	25.9	
3.11	25.3	24.8	26.0	

A.6.2 Sutang River

Both the pre- and monsoon flood damages along the Sutang River have been identified with spills from the Khowai River.

The pre-monsoon season floods occur along the lower Sutang downstream of the railway bridge when the Barak (Lower Khowai) left bank overflow augments the discharge in the Sutang. The flooding is further aggravated by siltation of the Sutang channel between Lakhai and Bolla.

The monsoon season floods occur along the Upper Sutang when the Upper Khowai spills over its left bank in the unembanked section. The flood waters cause lodging of standing aus and aman crops, and deposition of sand over the paddy fields. Intensive channel erosion also affects homesteads. There are no pre-monsoon season floods along the Upper Sutang, and during the monsoon season the banks of the Lower Sutang are submerged by backflow from the Dhaleswari (Upper Meghna).

The proposed development works on the Khowai River could partly solve the flood problem along the Sutang River, since elimination of spills from the Khowai will reduce discharges on the Sutang during some years. However, the proposed Isali Chara diversion will increase the total catchment area of the Sutang River by about 30%. To accommodate the additional discharge from the Isali Chara, the Sutang channel needs to be improved.

The proposed improvement works are:

- Channelizing of the Sutang River upstream of the railway bridge, 31 km.
- Construction of drop structures across the channel in the upper river section, 3 Nos.
- Re-excavating the river channel in the lower section, total 5.0 km.

Design of Sutang River and Isali Chara Diversion Channels
The upper section of the river (upstream of railway bridge) needs to be improved and re-excavated to accommodate the discharge of the Isali Chara diversion.

As per BWDB guidelines, the recommended protection against a 1 in 5-year annual flood is considered for protection of the monsoon season crops, and homesteads will be protected against a 1 in 20-year flood.

Since at this level of investigation it was not possible to assess separately the potential flood damage to homesteads due to inundation and due to Sutang channel erosion, a 1 in 10-year annual flood has been selected as the design discharge for sizing of the Upper Sutang River channel.

Design unit runoff in Upper Sutang basin:

$$q_{10\text{-annual}} = 151 \text{ m}^3/\text{s} : 230 \text{ km}^2 = 0.656 \text{ m}^3/\text{s}/\text{km}^2$$

The design discharges in the Sutang River, based on discharges measured at the Sutang RB gauging station (see Table A12 above), are shown in Table A23.

Considering the similar basin characteristics, the Isali Chara basin unit runoff was assumed to be equal to the runoff of the Sutang at railway bridge.

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Table A23: Isali Chara Diversion and Upper Sutang River Design Discharges (1:10-year Annual)

Location	Distance (km)	Catchment Area (km^2)	Design Discharge (m^3/s)
Isali Chara Diversion	4.5	107	70.2
Sutang River at:			
	0.0	(107)	(70.2)
Chunarghat Road Bridge	9.0	168	110.2
Dauna Road Bridge	18.0	215	141.0
Railway Bridge	31.0	337	221.1
Outfall into Kayanja Nadi	65.0	473	310.3

With the exception of three cross section of the Lower Sutang surveyed by SWMC in 1991, topographic surveys of the Sutang River are not available.

The designs of the Upper Sutang and the Isali Chara Diversion channel are based on elevations shown in the topographic maps (1956). The existing cross sections, as well as information provided by BWDB and local residents were used in designing of the Lower Sutang (downstream of RB) improvement works.

The Upper Sutang channel is designed to convey the 1 in 10-year annual flood discharge within the banks. As no freeboard has been provided, construction of low dikes may be required in some local depressions.

A single trapezoidal section channel with 1V to 1.5H side slopes is proposed. To maintain the flow velocity within non-erodible limits (assumed max about 1.6 m/s for the local soil) the river longitudinal slope will be controlled by means of drop structures constructed across the channel. The proposed channel bed width varies from 10.0 m at the Isali Chara to 25.0 m at the Railway Bridge section. The increases of the bed width should be at the drop structures.

Most of the river downstream of the rail bridge is submerged during the monsoon, and as such there is no need to re-excavate its channel to full monsoon flow capacity. The proposed improvement works would include de-silting and enlargement of the channel at strategic points. The construction of loop cuts, as requested by local elite during the Habiganj Seminar, needs to be investigated in detail during the feasibility study.

The proposed structures will provide a total drop of 4.0 m as follows,

- Isali Chara Diversion channel:
  (1) at section 1.5 km, b = 10.0/10.0 m, h = 1.0 m

- Sutang River channel:
  (1) at section 10.0 km (below road bridge at Chunarghat), b = 15.0/20.0 m, h = 1.5 m

  (2) at section 14.0 km, b = 20.0/25.0 m, h = 1.5 m.

The design parameters of the Sutang River channel are given in Table A24, and the profile is shown in Figure 11.

Table A24: Isali Chara Diversion and Upper Sutang River Channel Parameters

Location	Section (km)	Design Bed Width (m)	Remarks
Isali Chara Diversion:	0.0 4.5	10.0 10.0	 Sutang 0.0 km
Sutang River at:	0.0	15.0	Isali Ch. 4.5 km
Chunarghat Road Bridge	9.0	15.0	
	10.0	15.0/20.0	1.5 m Drop
	14.0	20.0/25.0	1.5 m Drop
Dauna Road Bridge	18.0	25.0	
Railway Bridge	31.0	25.0	Channel de-silting and re-excavation at constrictions
Outfall into Kayanja Nadi at Lakhai	65.0	Variable	

A.6.3 Karangi River

The lower section of the Karangi River downstream of Bahubal has been re-excavated and embanked under Gangajuri FCD Project. The embanked channel capacity is 180 m^3/s, which corresponds to a 1:20-year annual flood based on discharge data measured at Sofiabad Station.

Upstream of Bahubal the Karangi is partly embanked with local dikes. This section of the river is badly silted, and its drainage capacity is reduced by the dikes which obstruct flow of the local runoff into the channel. Crops grown in the Karangi valley suffer pre-monsoon and monsoon flood damage.

It is proposed to improve the upper reach of the Karangi by re-excavating the channel to provide a 1:10-year annual flood discharge capacity. The works would comprise channel re-excavation and enlarging in some sections, as well as levelling of the existing local dikes.

Survey data of the upper Karangi are not available and the existing discharge records are not satisfactory, as most of the measured peak flows include spills from the Khowai River. Therefore, the proposed designs, which are based on field observations, are very preliminary and were carried out mainly for the purpose of costing.

A single trapezoidal section with 1V to 1.5H side slopes and bed width varying from 10.0 to 20.0 m is proposed for the improved Karangi River channel upstream of Bahubal. The average depth of the channel is 3.0 m and the total length of re-excavation is estimated to be 17.0 km.

The Karangi works also include diversion of the Nalmukh Khal (about 10.0 km^2 catchment) into the Karangi. (During high stages of the Khowai the Nalmukh Khal would not drain through a gated sluice and retired embankments would create drainage congestion.)

The Nalmukh Khal Diversion requires excavation of a 2.0 km long and 3.0 m deep canal along the eastern side of the village road from Muchnandi to Raraja. The required cross section of the canal is 4.0 m bed width with side slopes 1V to 1.5H. The present outfall of the Khal would be closed with the proposed Khowai River embankment.

A.6.4 Other Flood Control and Drainage Improvement Works

The other proposed improvement works, based on information collected during field inspections and information provided BWDB and by local representatives during the FAP-6 Seminar held in Habiganj on April 17,1993 are:

- Provision of a drainage channel for the Habiganj town. Excavation of a 2.0 km long, 5.0 m bed wide new link channel and re-excavation of existing khals, 6.0 km.
- Re-excavation of Balbhadra River, total 3.0 km.
- De-silting of minor khals in the Lower Basin, total 20.0 km.

The Habiganj drainage channel will revitalize drainage system through the lowlands west of the town which has deteriorated after the construction of flood embankments. (The existing BWDB 1-vent 1.5 x 1.8 m Drainage Regulator does not provide sufficient drainage into the Khowai River during monsoon. It gets completely silted up on the river side during the passage of peak flows and needs to be re-opened (by high pressure water jet) several times a year.)

The proposed alignment of the channel is through the Babar Khal and Langlia Nadi linked with Sutang River at Bhumapur village.

ANNEX B

ENGINEERING COST ANALYSIS

ANNEX B: ENGINEERING COST ANALYSIS

An itemized estimates of earthwork work volumes along with the unit rates and the direct costs are shown in Table B1 and Table B2. The costs of structures and project buildings are shown in Tables B3 to B5. Land acquisition is shown in Table B6, and a summary of the project capital cost is shown in Table B7.

Table B1: Earthworks - Excavation

Item	Quantity (m^3)	Rate (Tk)	Amount (Tk)
Barak River (Lower Khowai):			
- Channel re-excavation, 19.5 km (bed width = 40.0 m)	2400000	28.59	68616000
Nalmukh Khal Diversion:			
- New channel, 2.0 km	51000	20.26	1033260
Isali Chara Diversion:			
- New channel, 4.5 km	339100	20.26	6870166
Karangi River:			
- Re-excavation, 17.0 km	569700	20.26	11542122
Sutang River:			
- Re-excavation			
- upper section, 31.0 km	1984000	21.80	43251200
- lower sect. 5.0 km	200000	21.80	4360000
Habiganj Town Drainage Channel:			
- Excavation, 2.0 km	57000	20.26	1154820
- Re-excavation, 6.0 km	85500	20.26	1732230
Balbhadra River:			
- Re-excavation, 3.0 km	90000	20.26	1823400
Other Khals:			
- Re-excavation, 20.0 km	400000	20.26	8104000
Total:	6,176,300		148,487,198

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Table B2: Earthworks - Flood Embankments

Item	Quantity	Rate (Tk)	Amount (Tk)
Khowai River Flood Embankments:			
Upgrading and raising of existing embankments between Shaistaganj and Habiganj			
- left bank	305000 m^3	27.51	8390550
- right bank	304000 m^3	27.51	8363040
Turfing	480000 m^2	2.27	1089600
Construction of New Embankments from Chunarghat to Ballah			
- left bank, 16 km	846000 m^3	25.66	21708360
- right bank, 17 km	781000 m^3	25.66	20040460
Turfing	684000 m^2	2.27	1552680
Total: - Fill - Turfing	 2,236,000 m^3 1,164,000 m^2		
Total Embankments:			61,144,690

Table B3: Sutang River Drop Structure

Item	Quantity	Unit	Rate (Tk)	Amount (Tk)
Excavation	15120	m^3	30.00	453600
Back Filling	5500	m^3	20.00	110000
Sand Filling	3100	m^3	148.00	458800
CC Work	65	m^3	1804.00	117260
RCC Work	782	m^3	2495.00	1951090
Form Work	1700	m^2	223.00	379100
MS Reinforcement	80	t	32360.00	2588800
Steel Sheet Piling	246	m^2	9258.00	2277468
Graded Filter	448	m^3	339.54	152114
CC Blocks	402.5	m^3	1829.00	736173
Dewatering			LS	500000
Mobilization			LS	150000
Carriage of Materials			LS	600000
			Total:	10,474,404

Table B4: Khowai River Bridges

Item	Quantity	Rate ('000 Tk)	Amount ('000 Tk)
Raising and Upgrading of Shaistaganj Road Bridge	1	39,000	39,000
Raising of Shaistaganj Railway Bridge	1	30,000	30,000
Raising and Upgrading of Habiganj Road Bridge	1	27,000	27,000
Total	3		96,000

Table B5: Project Buildings

Item	Quantity	Rate ('000 Tk)	Amount ('000 Tk)
Office/Residence/Material Storage for Khowai River Embankment Monitors	3	500	1,500

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Table B6: Land Acquisition

Item	Area (ha)	Rate (Tk)	Amount (Tk)
Nalmukh Khal Diversion Channel, 2.0 km	3.2	200000	640000
Isali Chara Diversion Channel, 4.5 km	12.0	200000	2400000
Karangi River Re-excavation, 17.0 km	23.0	200000	4600000
Sutang River Re-excavation:			
- upper section, 31.0 km	77.5	200000	15500000
- lower section, 5.0 km	0.0		
Habiganj Town Drainage Channel			
- excavation, 2.0 km	3.4	150000	510000
- re-excavation, 6.0 km	0.0		
Balbhadra River			
- re-excavation, 3.0 km	0.0	150000	
Other Khals			
- re-excavation, 20.0 km	0.0	150000	
Khowai River:			
- re-excavation of Barak River, 19.5 km	88.0	150000	13200000
- upgrading of existing embankments	25.0	200000	5000000
-new embankments, 33.0 km	107.0	200000	21400000
(left bank = 16 km, right bank = 17 km)			
- 3 Nos. Drop Structures	1.5	200000	300000
- 3 Nos. Buildings	1.5	200000	300000
Total:	342.0	Tk.	63,850,000

Table B7: Capital Cost Summary

Item	Quantity	Cost ('000 Tk)
Structures	3 Nos	31,500.0
Embankments: - re-sectioning and upgrading - construction of new	 83.0 km 41.0 km	 17,843.3 43,301.5 61,144.8
Channels: - excavation of new - re-excavation and de-silting	 8.5 km 101.5 km	 9,058.2 139,429.0 148,487.2
Bridges: - raising of existing bridges	 3 Nos	 96,000.0
Buildings: - embankment monitor quarters	 3 Nos	 1,500.0
Land Acquisition: - structures - embankments - channels - buildings	 1.5 ha 132.0 ha 207.0 ha 1.5 ha 342.0 ha	 300.0 26,400.0 36,850.0 300.0 63,850.0
BASE COST		402,482.0
Physical Contingencies (25%)		100,620.5
SUBTOTAL		503,102.5
Study Cost (15%)		75,465.4
TOTAL:		578,567~~0~~.9

ANNEX C

INITIAL ENVIRONMENTAL EXAMINATION

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 Proposed 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: 159,264 ha.

Impacted (net) area: 112,115 ha.

Impacted area outside project: Peak pre-monsoon flood levels could increase somewhat in Lower Kalni-Dhaleswari River along the western boundary of the project. Elimination of the Barak River pre-monsoon overbank spill into the Habiganj Lowlands will increase the peak discharges in the Dhaleswari River.

Impacted area inside project: Peak monsoon flood levels in the Khowai are not expected to increase. Prevention of flood spills from the upper Khowai would likely result in lower flood peaks in the Sutang and Karangi Rivers. The upstream diversion works will result in increased lower discharges in the Sutang and Karangi. During feasibility studies, these impacts need to be assessed.

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Temporal:

Preconstruction: years zero through year three (see Table 7.8).
Construction: year one through year four (see Table 7.8).
Operation: year four through year thirty.
Abandonment: after year 30.

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 openwater fisheries production impacts were estimated with a simplified model. The limitations of the model mirror the limitations in our current understanding of and information about the system. Results of the analysis are summarized below and Chapter 7.15 of the main report (multi-criteria analysis).

The major system processes about which we have some insight are:

- Migration access and timing. It seems to be accepted that:
  - a multiplicity of access points is desirable (i.e. that closing any or some channels is still deleterious),
  - the most important channels are those at the downstream end (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 suspected 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 is lacking it has been neglected in the model.]

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

- Spawning. Production <u>outside the project area</u> 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 <u>duars</u>. <u>Duars</u> 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 =

$$(R_0 * P_{RO}) + (B_0 * P_{BO}) + (W_0 * P_{WO})$$

FW production =

$$[M * Q * (R_1 * P_{RO})] + [M * Q * (B_1 * P_{BO})] + [M * (W_1 * P_{WO})]$$

Thus,

Impact = FW - FWO production =

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

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

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

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 200, 550, 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.

Estimated values for this project are shown in Table C.1. 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.

The total annual openwater fisheries production impact is + 18 tonnes, which is 0.5% of the FWO annual production of 3751 tonnes. This implies the openwater-source fish availability per person remaining at 7 gm per person per day after the project implementation.

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 7.3.4.

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.

Table C.1: Fisheries Indicators

Var	Value	Stnd value	Comments
M	1	1	
Q	1	1	
R_0	900	1	
R_1	990	1	Re-excavation and de-silting of channels
B_0	1426	1	
B_1	1426	1	
W_0	63348	1	Areas presently flooded for short periods by flash floods of Khowai and Sutang Rivers not included
W_1	63348	1	
P_{RO}	200	1	BFRSS average yields for Mymensingh and Sylhet Districts
P_{BO}	550	1	
P_{WO}	44	1	
A_M	0	1	

- Compensation for persons other than landowners who are impacted negatively by land acquisition and construction / infrastructure-related land use changes. Examples: (i) project implementation could be made contingent upon successful resettlement of squatters displaced from embankment / structure sites under local initiative; (ii) financial and technical assistance could be provided to farmers for abandoning cultivation of sugar cane within the Khowai River embankments and for switching to short stem crops. 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 and DOE, probably through an Environmental Cell within BWDB linked to DOE. 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.

Table C.2: 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
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydralogic, 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										
	Abnormal	Suspension of construction before completion, construction delays	.	-					-			
		Incorrect construction practices or techniques							-			

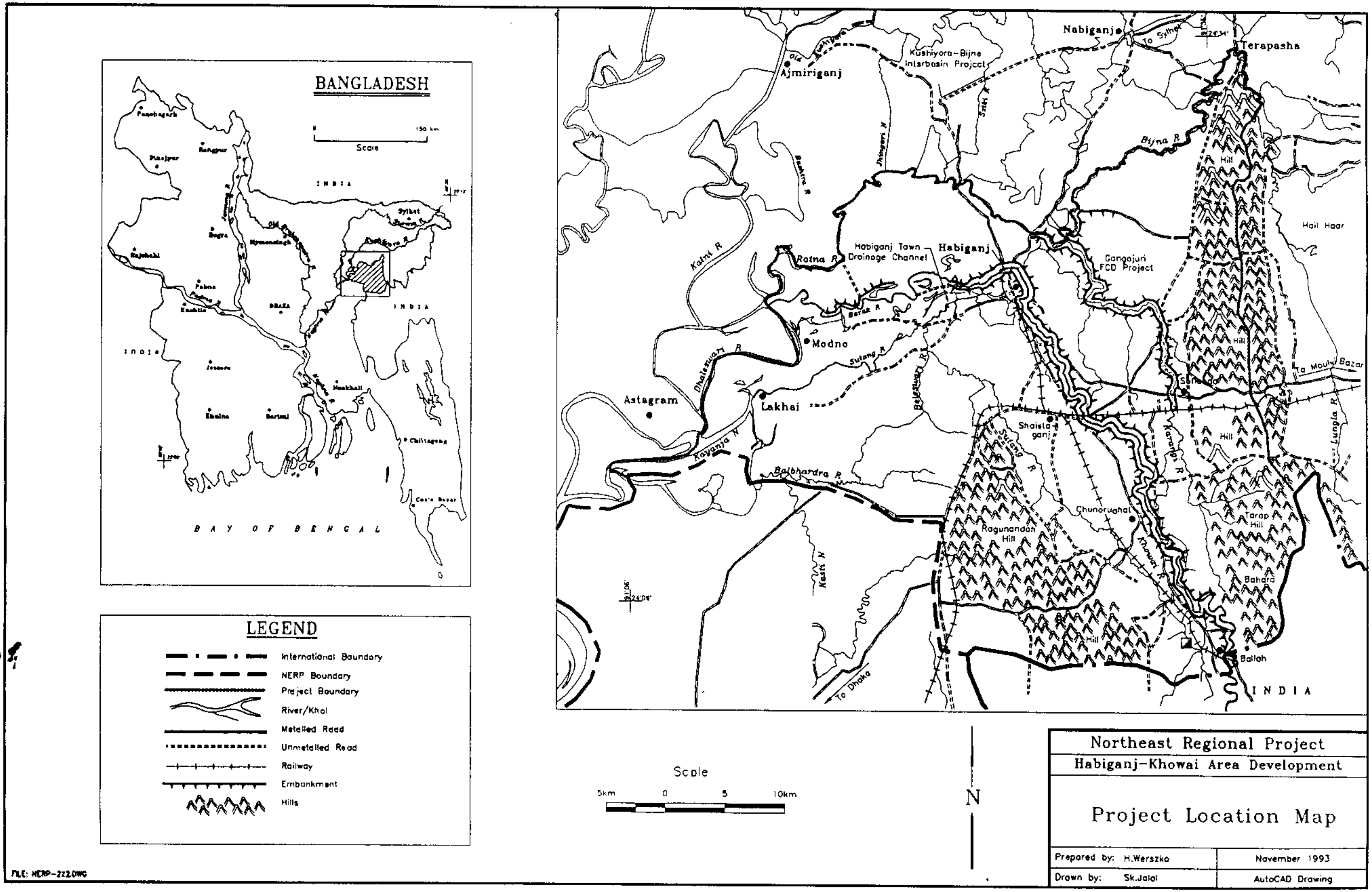
Table C.2: Environmental Screening Matrix

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							+			
	Abnormal (relative to FWO, not FW aormal)	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

FIGURES

Figure 1


BANGLADESH
Scale
150 km
INDIA
BAY OF BENGAL
LEGEND
International Boundary
NERP Boundary
Project Boundary
River/Khal
Metalled Road
Unmetalled Road
Railway
Embankment
Hills
FILE: NERP-222.DWG
Nabiganj
To Sylhet
Terapasha
Ajmiriganj
Kushiyara-Bijne
Interbasin Project
Bijna R
Hill
Hail Haar
Habiganj Town
Drainage Channel
Habiganj
Gangajuri
FCD Project
Ratna R
Kalni R
Barak R
Madna
Sutang R
Dhaleswari R
Astagram
Lakhai
Kayanja R
Balbhadra R
Shaista-
ganj
Chunarughat
Khowai R
Karangi R
Ragunandan
Hill
Tarap
Hill
Bahara
Ballah
INDIA
To Moulvi Bazar
Lungla R
Kasti R
To Dhaka
Scale
5km
0
5
10km
N
Northeast Regional Project
Habiganj-Khowai Area Development
Project Location Map
Prepared by: H.Werszko
November 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

229

Figure 2

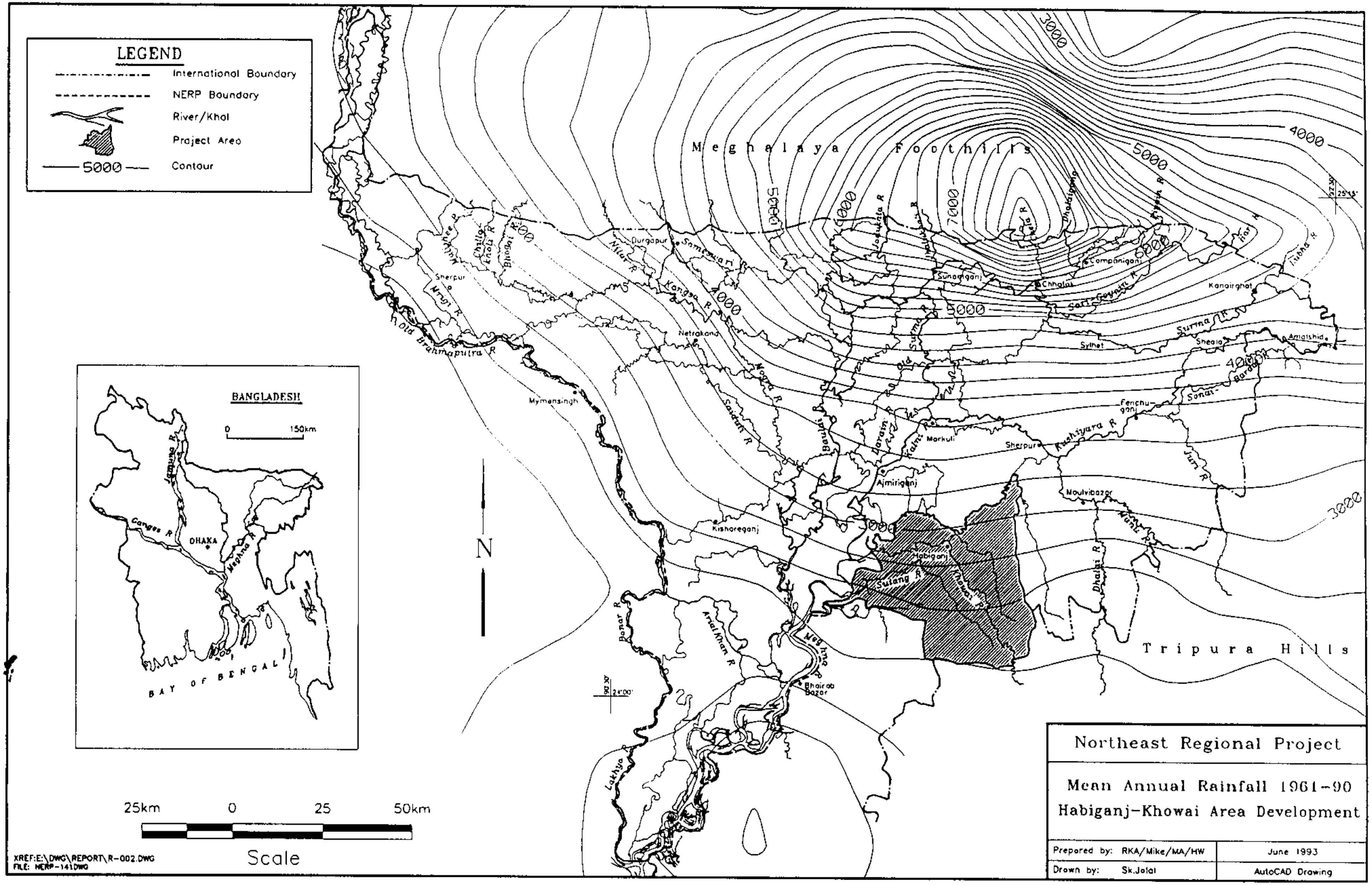
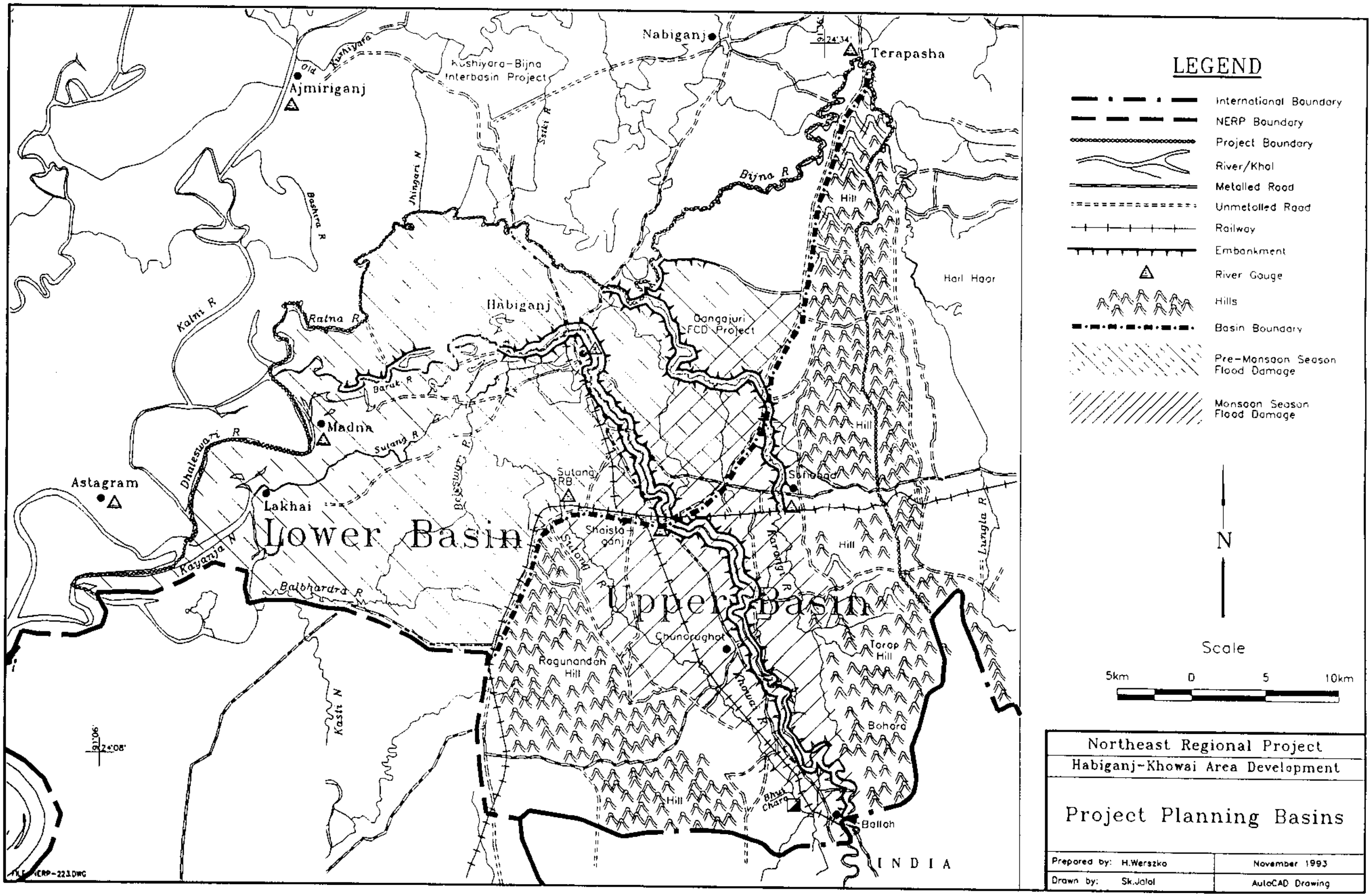
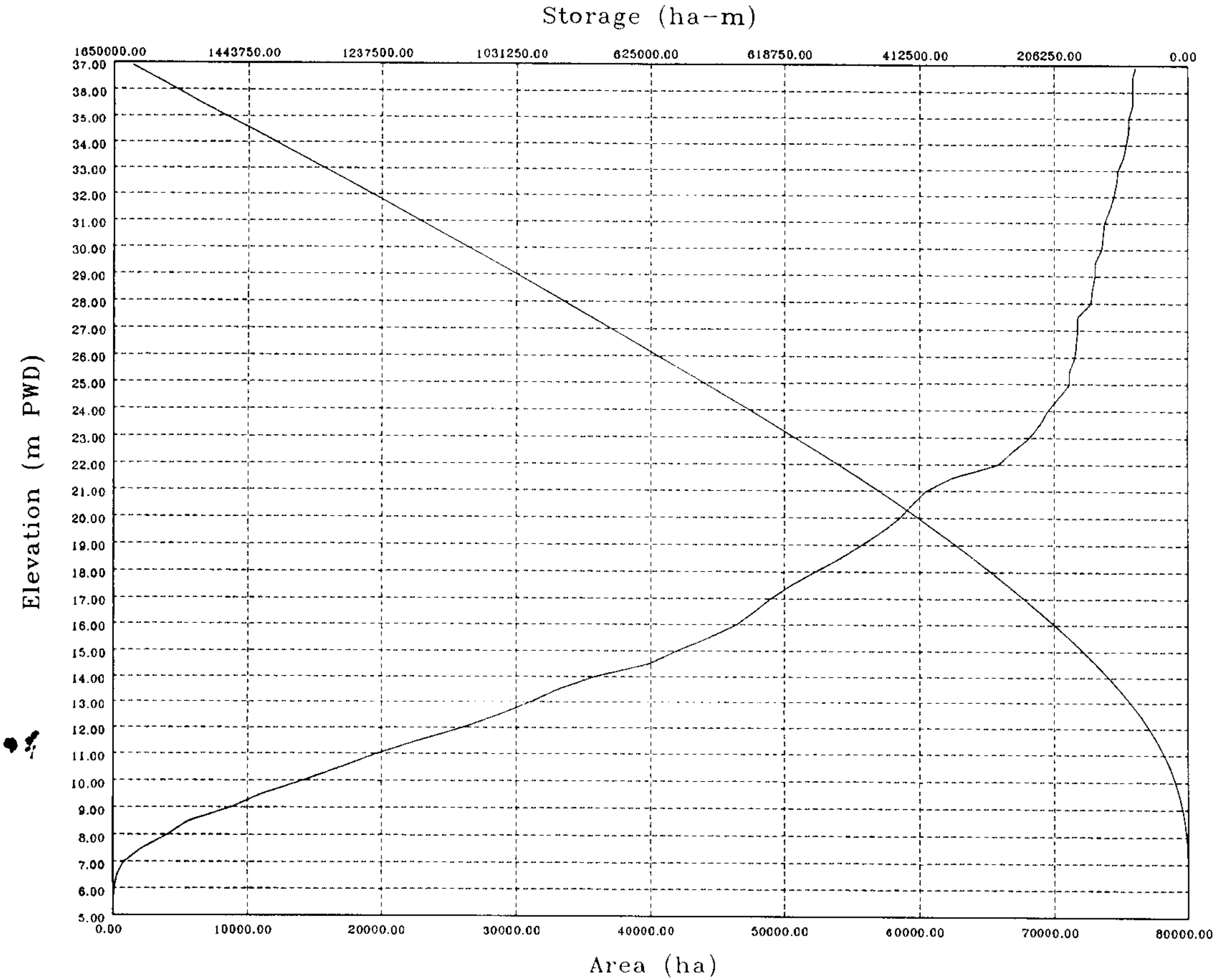

LEGEND
International Boundary
NERP Boundary
River/Khal
Project Area
5000
Contour
Meghalaya Foothills
Tripura Hills
BANGLADESH
0
150km
DHAKA
Ganges R
Jamuna R
Meghna R
BAY OF BENGAL
25km
0
25
50km
Scale
N
Durgapur
Sherpur
Netrakona
Mymensingh
Kishoreganj
Sunamganj
Chhatak
Companiganj
Kanairghat
Sylhet
Sheola
Amalshid
Fenchuganj
Sherpur
Markuli
Ajmiriganj
Moulvibazar
Habiganj
Bhairab Bazar
Old Brahmaputra R
Surma R
Kushiyara R
Sari-Goyain R
Kangsa R
Someswari R
Nitai R
Baulai R
Mogra R
Dhalai R
Juri R
Khowai R
Sutang R
Meghna R
Arial Khan R
Banar R
Lakhya R
Northeast Regional Project
Mean Annual Rainfall 1961-90
Habiganj-Khowai Area Development
Prepared by: RKA/Mike/MA/HW
June 1993
Drawn by: Sk.Jalal
AutoCAD Drawing
XREF:E:\DWG\REPORT\R-002.DWG
FILE: NERP-141DWG

Figure 3



LEGEND
International Boundary
NERP Boundary
Project Boundary
River/Khal
Metalled Road
Unmetalled Road
Railway
Embankment
River Gauge
Hills
Basin Boundary
Pre-Monsoon Season Flood Damage
Monsoon Season Flood Damage
N
Scale
5km
0
5
10km
Northeast Regional Project
Habiganj-Khowai Area Development
Project Planning Basins
Prepared by: H.Werszko
November 1993
Drawn by: Sk.Jalal
AutoCAD Drawing
Lower Basin
Upper Basin
Nabiganj
Terapasha
Ajmiriganj
Habiganj
Madna
Astagram
Lakhai
Shaistaganj
Chunaraghat
Ballah
INDIA
Kushiyara-Bijna Interbasin Project
Gangajuri FCD Project
Hari Haor
Raghunandan Hill
Torap Hill
Bohora
Hill
Sutang RB
Bijna R
Ratna R
Kalni R
Barak R
Sutang R
Dhaleswari R
Kayanja N
Balbhadra R
Khowai R
Karangi R
Lungla R
Kasti N
Jhingari N
Bashira R
Sutki R
Old Kushiyara

Figure 4

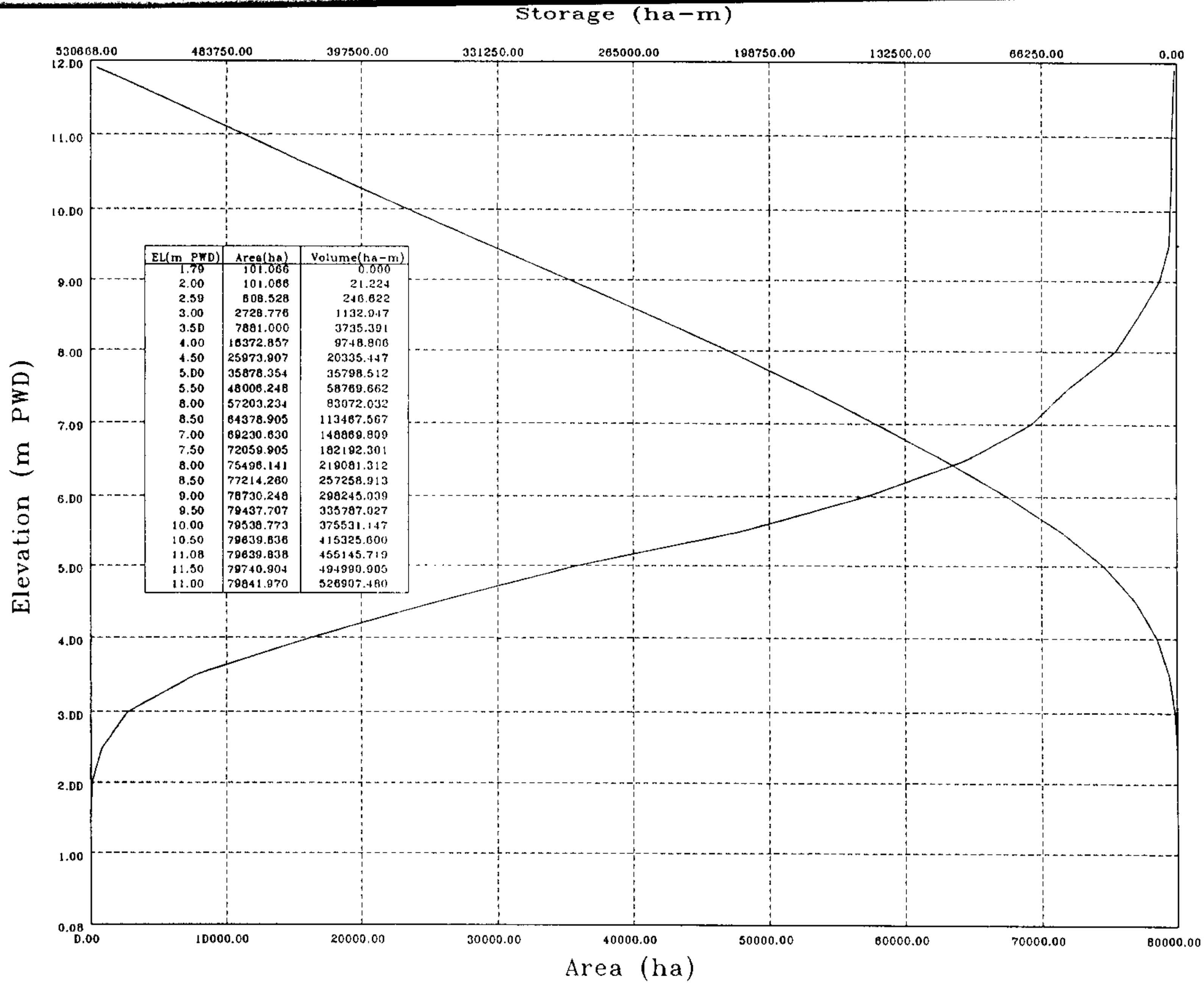


Elevation vs Area/Capacity Relation-Upper Basin

EL(m PWD)	Area(ha)	Volume(ha-m)
5.75	100.782	0.000
6.90	190.782	25.195
8.50	302.349	125.977
7.99	606.255	403.127
7.56	2116.419	1133.796
6.90	4931.274	2670.719
8.50	5843.783	5089.483
9.90	8789.920	6692.434
9.50	10985.221	13630.744
10.90	14109.459	19904.414
10.50	17032.131	27689.811
11.00	19852.459	38880.958
11.50	22675.914	47443.052
12.00	28001.715	59612.459
12.59	28722.825	73293.594
13.00	31940.697	68234.502
13.50	33058.440	104258.815
14.00	35777.554	121487.314
14.50	39800.827	140383.909
15.00	41925.249	100797.427
15.50	44344.919	182364.741
16.00	46460.429	205085.851
18.50	47770.593	228623.606
17.00	48979.975	252811.248
17.50	59491.702	277879.108
18.00	52305.776	393379.537
18.59	54119.849	329984.943
19.00	55732.356	357447.995
18.59	57244.088	385992.106
29.00	58554.250	414641.690
29.50	59481.206	444145.574
21.00	80489.105	474126.171
21.50	82383.960	504841.437
22.00	85819.542	530890.083
22.5D	66919.142	570072.484
23.00	68128.525	603834.401
23.50	68934.779	836100.227
24.D0	69539.470	672718.769
24.50	79345.725	707890.068
25.09	71151.900	743064.514
25.59	71151.999	776640.504
26.00	71555.107	814317.279
26.50	71855.889	650120.025
27.00	71756.871	685973.165
27.50	71758.671	921851.500
29.90	72784.480	957981.700
28.59	72965.271	994389.230
29.80	73988.835	1030872.257
28.59	73088.835	1987405.674
30.00	73570.744	1194085.089
30.50	73971.526	1149875.639
31.D0	73772.308	1177738.595
31.50	74175.435	1214723.530
32.D0	74477.781	1251986.834
32.50	74679.344	1289176.115
33.00	74766.126	1328540.983
33.50	75183.253	1384031.828
34.90	75384.817	1491673.845
34.50	75566.361	1439418.845
35.D0	75588.381	1477299.835
36.50	75886.728	1515076.812
36.00	75888.728	1553022.975
38.59	75868.728	1590987.338
36.90	79080.299	1821383.142

Figure 5

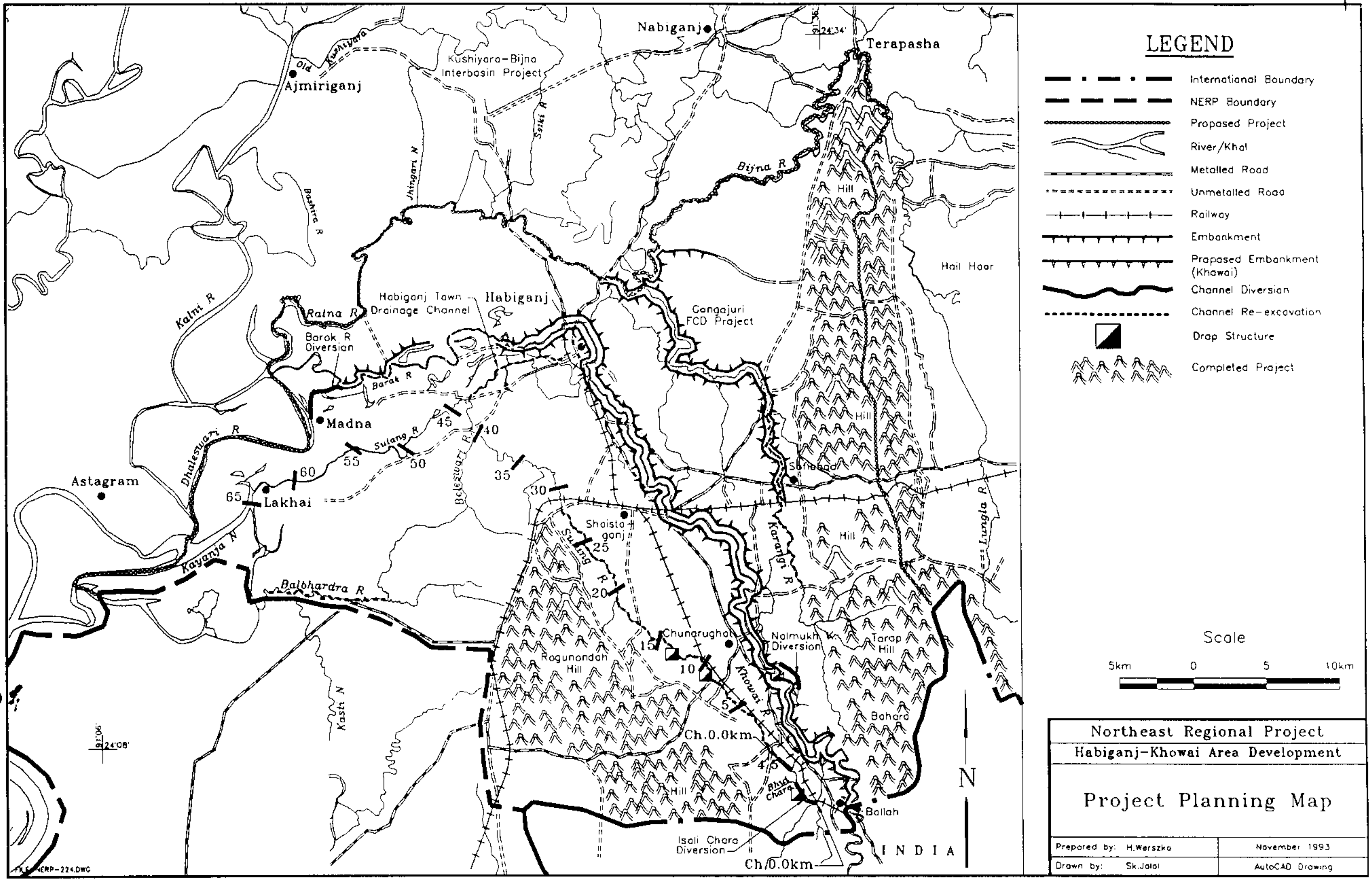
Elevation vs Area/Capacity Relation-Upper Basin



EL(m PWD)	Area(ha)	Volume(ha-m)
1.79	101.066	0.000
2.00	101.066	21.224
2.59	608.528	246.622
3.00	2728.776	1132.047
3.5D	7881.000	3735.391
4.00	16372.857	9748.806
4.50	25973.907	20335.447
5.D0	35878.354	35798.512
5.50	48006.248	58769.662
6.00	57203.234	83072.032
6.50	64378.905	113467.567
7.00	69230.630	148869.809
7.50	72059.905	182192.301
8.00	75496.141	219081.312
8.50	77214.260	257258.913
9.00	78730.248	298245.039
9.50	79437.707	335787.027
10.00	79538.773	375531.147
10.50	79639.836	415325.600
11.08	79639.838	455145.719
11.50	79740.904	494990.905
11.00	79841.970	526907.480

Elevation vs Area/Capacity Relation-Lower Basin

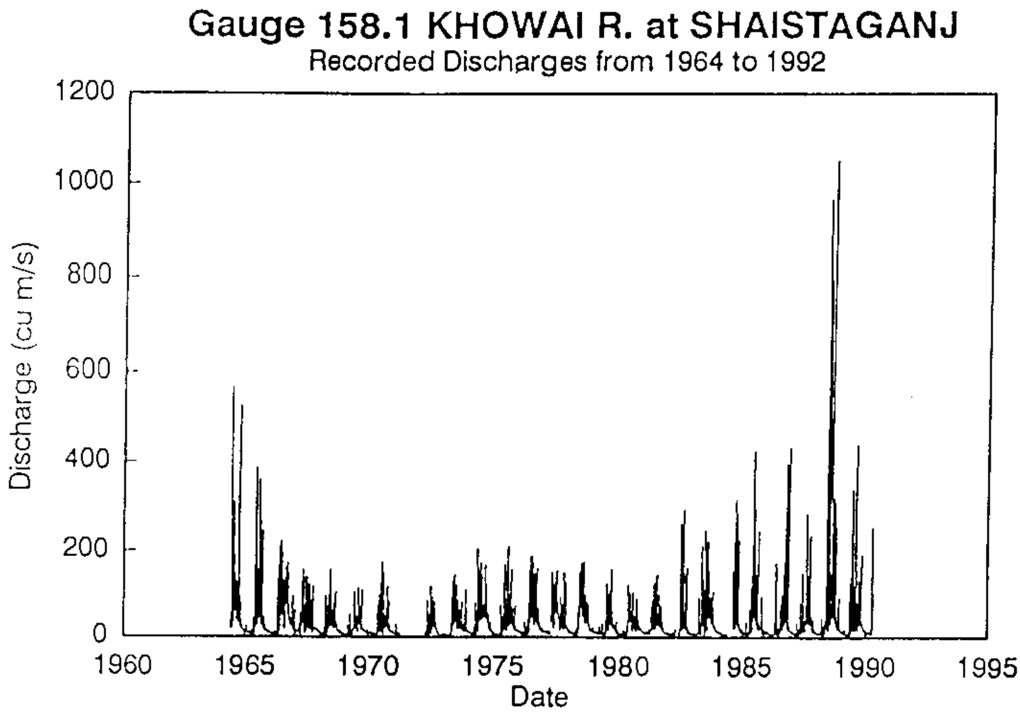
Figure 6

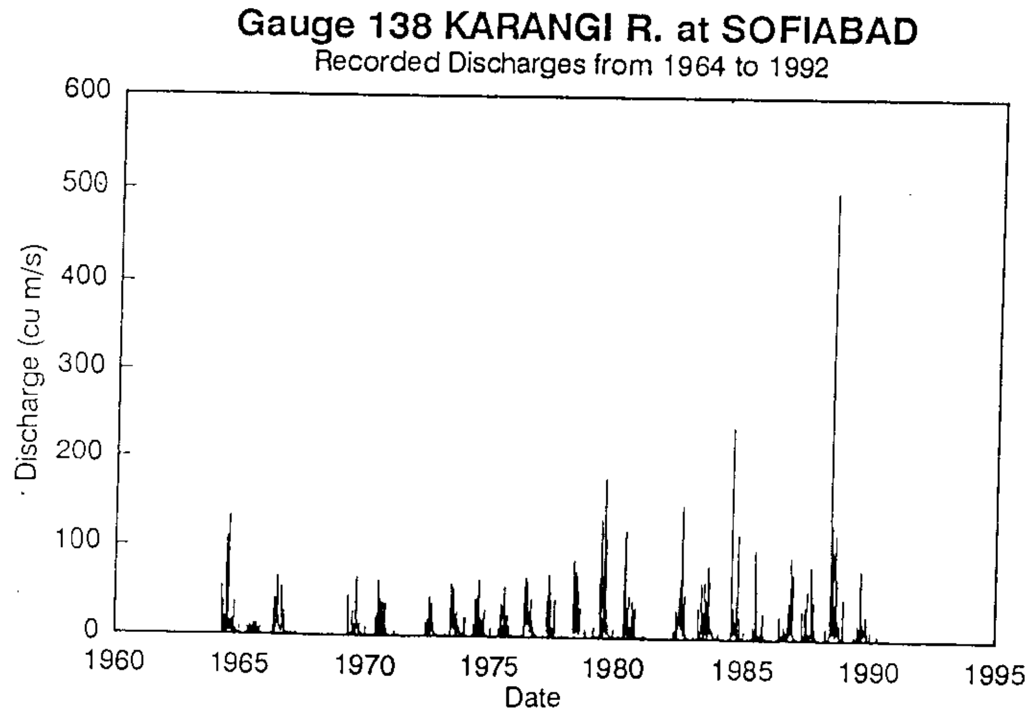


LEGEND
International Boundary
NERP Boundary
Proposed Project
River/Khal
Metalled Road
Unmetalled Road
Railway
Embankment
Proposed Embankment (Khowai)
Channel Diversion
Channel Re-excavation
Drop Structure
Completed Project
Scale
5km 0 5 10km
N
Northeast Regional Project
Habiganj-Khowai Area Development
Project Planning Map
Prepared by: H.Werszko
November 1993
Drawn by: Sk.Jalal
AutoCAD Drawing
Nabiganj
Terapasha
Ajmiriganj
Old Kushiyara
Kushiyara-Bijna Interbasin Project
Bijna R
Hail Haor
Hill
Habiganj
Habiganj Town Drainage Channel
Gangajuri FCD Project
Ratna R
Barok R Diversion
Barak R
Madna
Sutang R
Astagram
Lakhai
Dhaleswari R
Kalni R
Bashira R
Jhingari N
Ssiki R
Baleswari R
Kayanja N
Balbhardra R
Kasti N
Shaistaganj
Sofiabad
Karangi R
Lungla R
Rogunondon Hill
Chunarughat
Nalmukh Diversion
Tarap Hill
Bahara
Khowai R
Ch.0.0km
Isali Chara Diversion
Bhui Chara
Ballah
INDIA
65 60 55 50 45 40 35 30 25 20 15 10 5 4.5
NERP-224.DWG

228

Figure 7

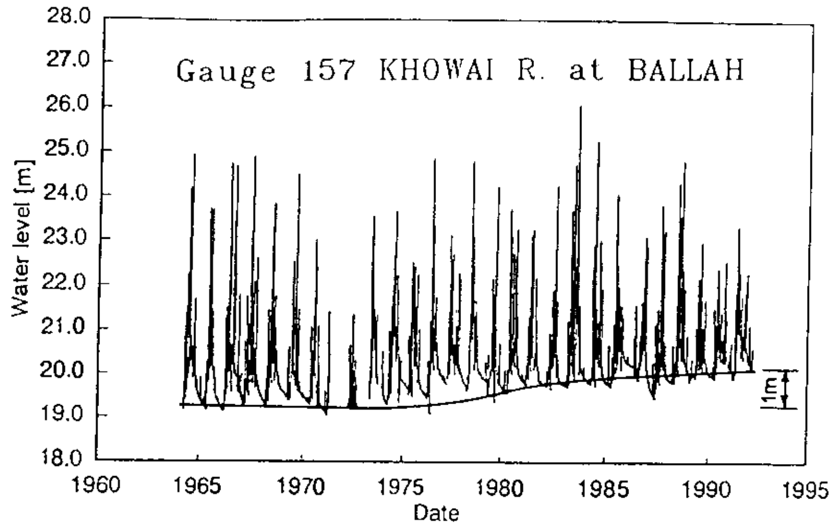


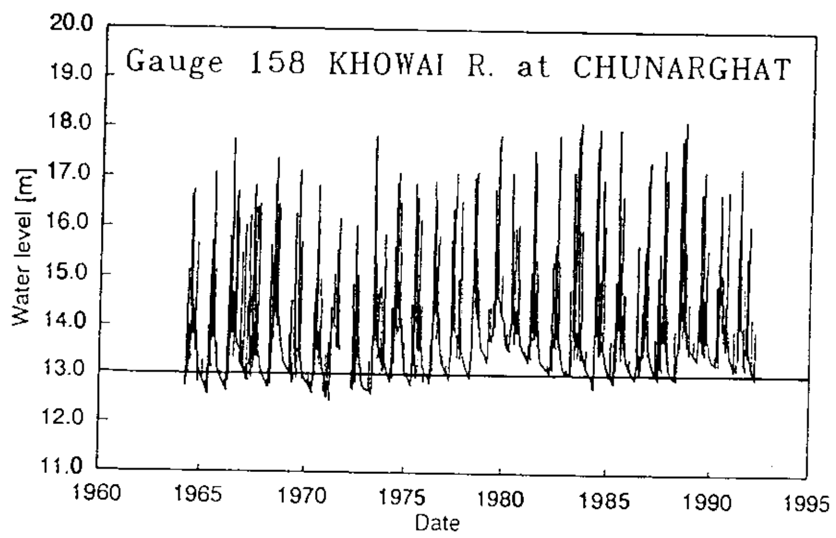


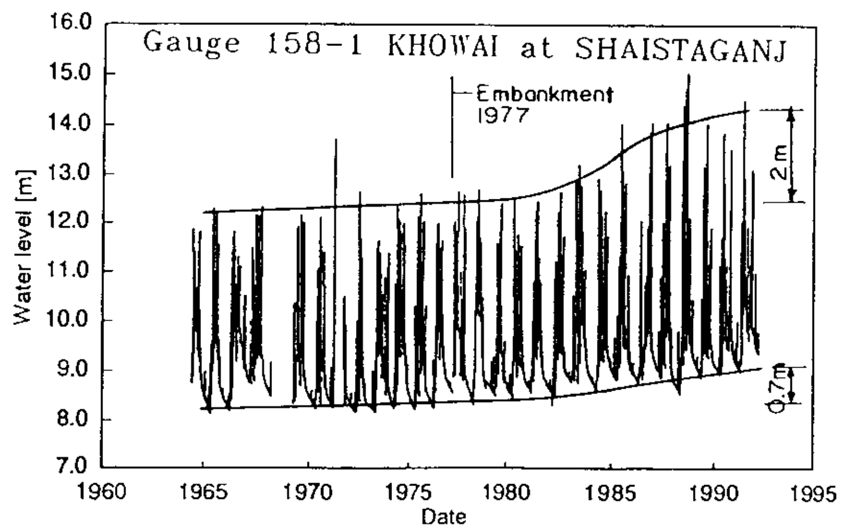
Northeast Regional Project	
Historic Discharge Khowai River	
Prepared by: CHW	May 1993

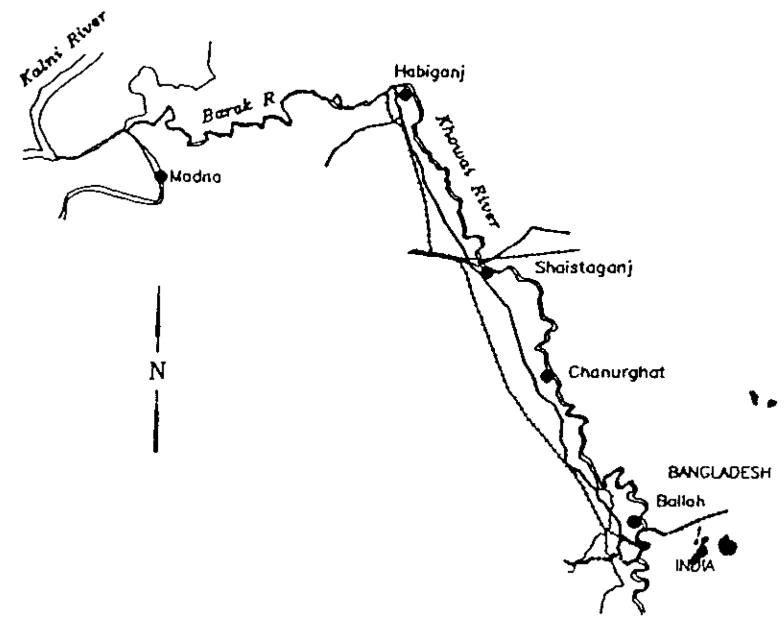
FILE: BORD3.DWG

Figure 8

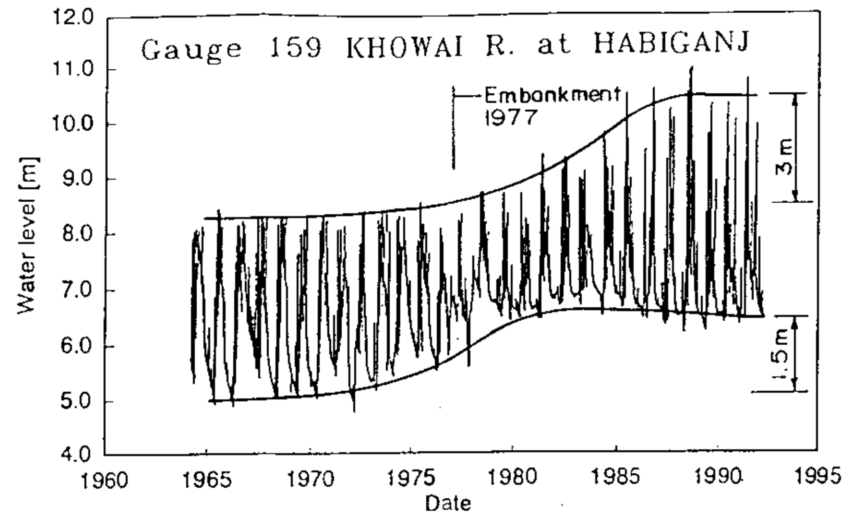


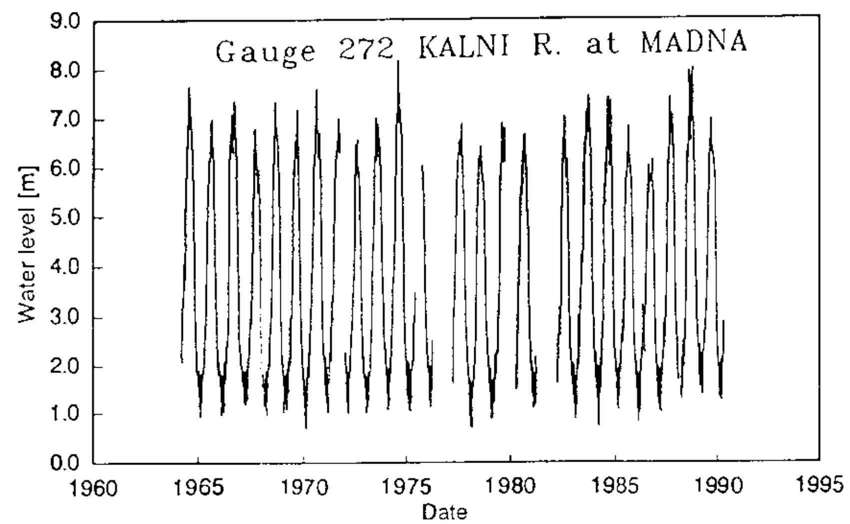






Location Plan



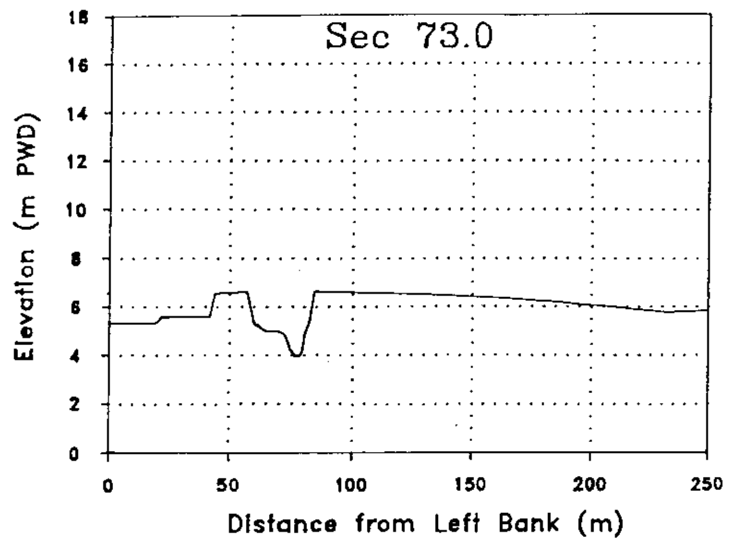


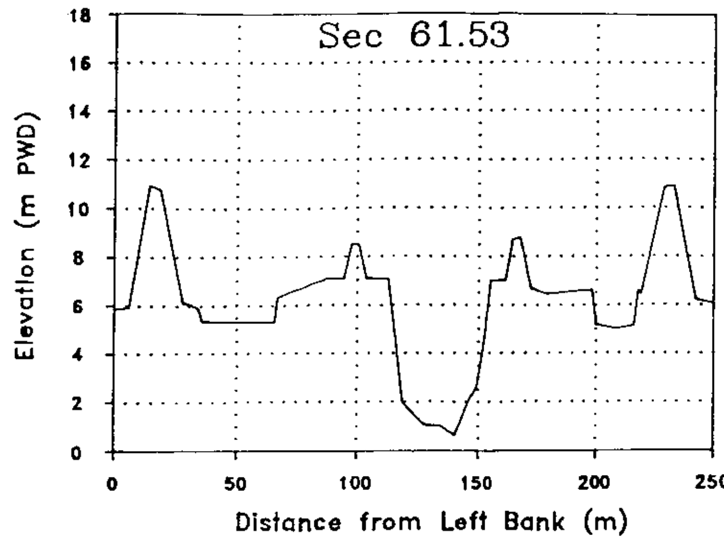
Northeast Regional Project	
Historic Water Levels Khowai River	
Prepared by: CHW	May 1993

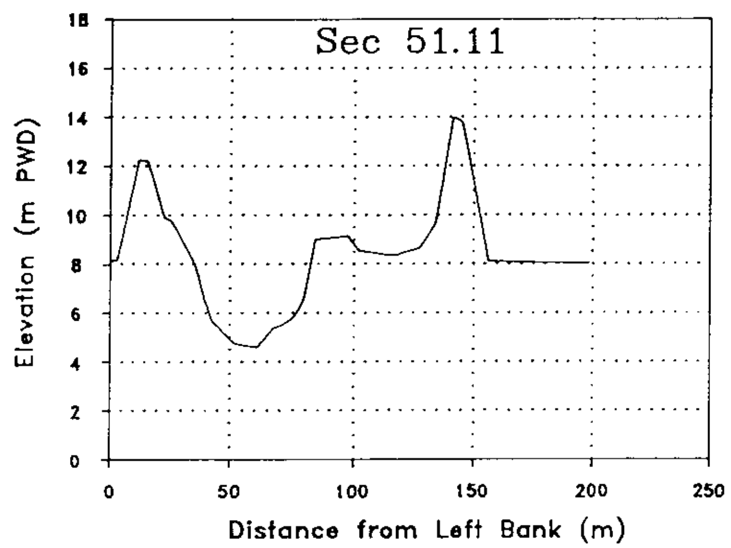
FILE: BORD2.DWG

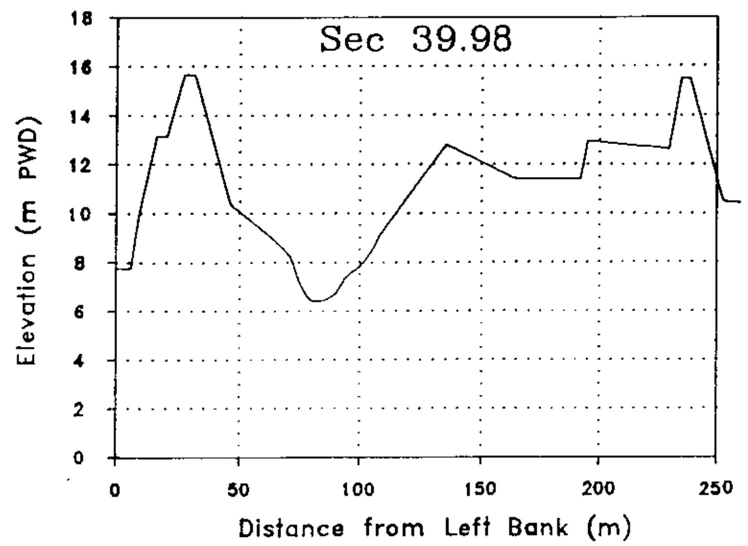
229

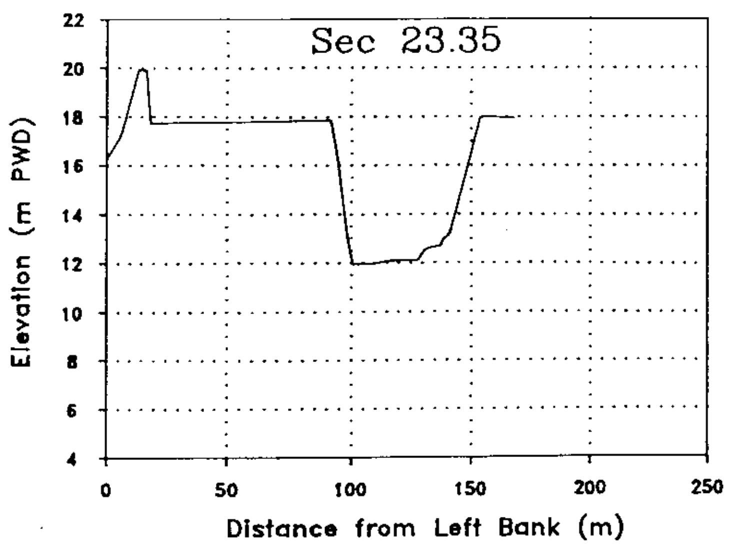
Figure 9

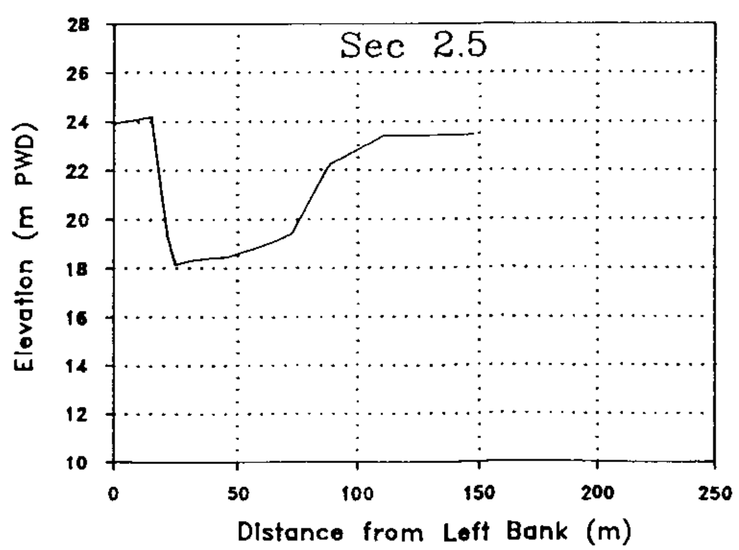


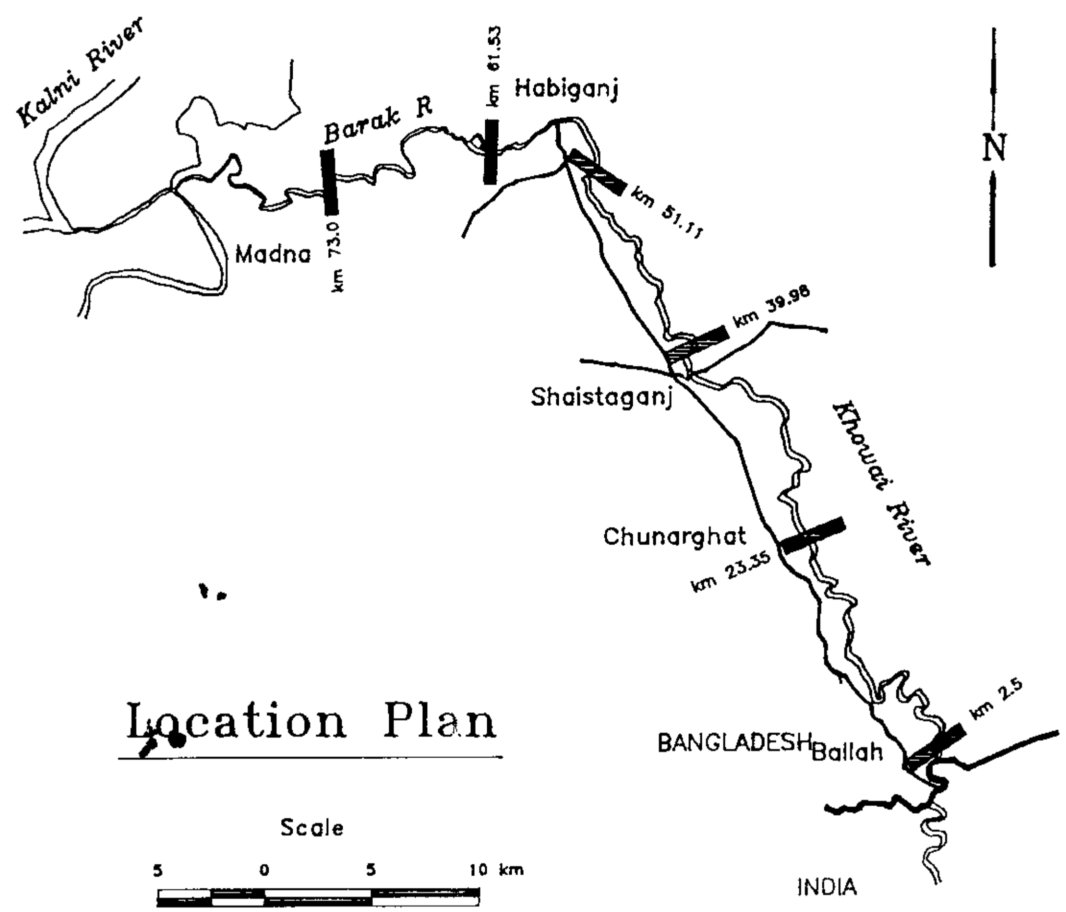










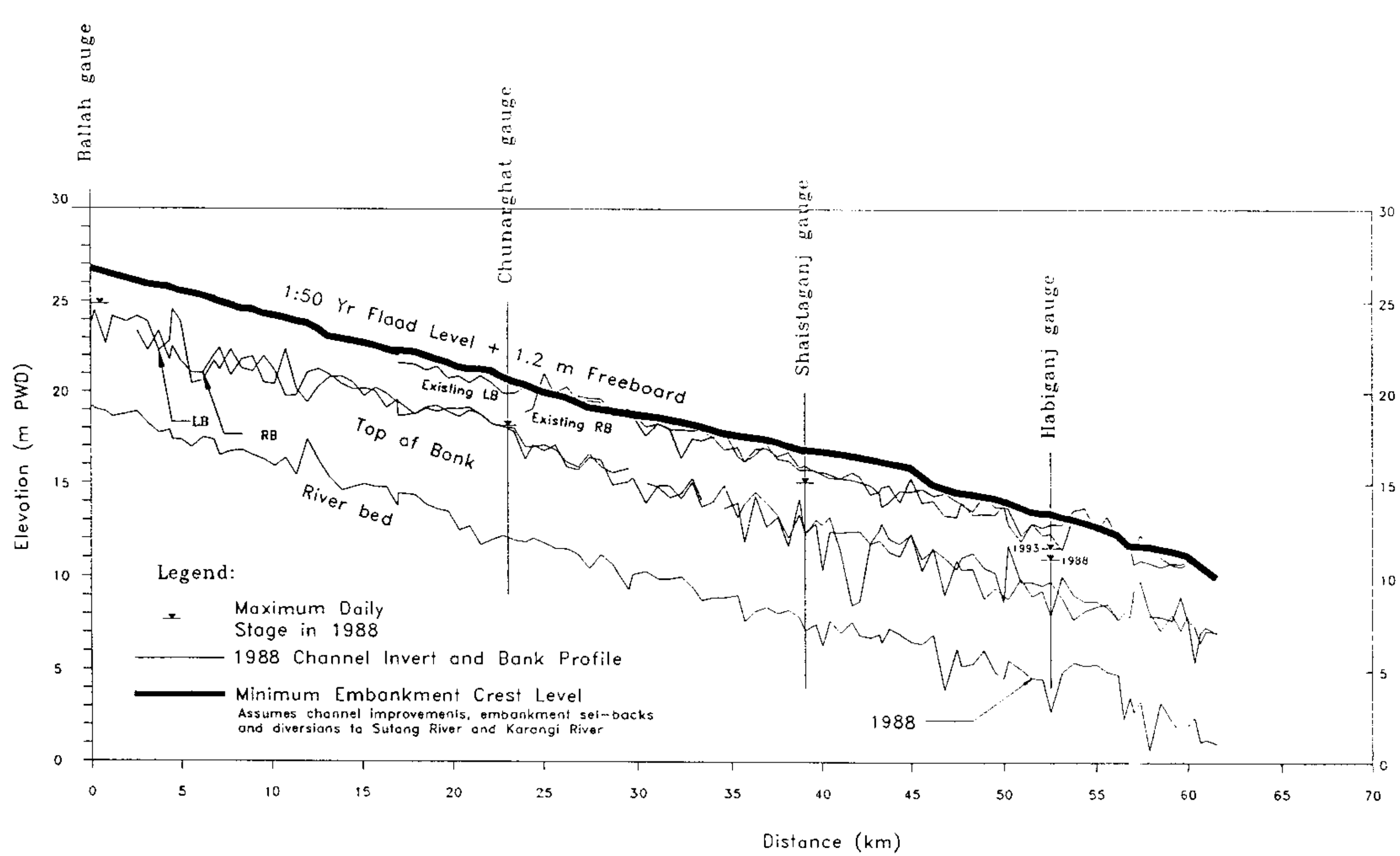


Note:
All cross-sections except Sec 73.0
Surveyed by Habiganj Div. BWDB
in 1988.
Section 73.0 surveyed by SWMC in 1990.

Northeast Regional Project	
Cross-Sections Khowai River	
Prepared by: CHW	May 1993

FILE: DM-240.DWG

Figure 10



Nate:
All chainages based an BWDB Habiganj W.D. Divisian Long Section of Khawai River showing Deep Channel Line dated 6/2/88

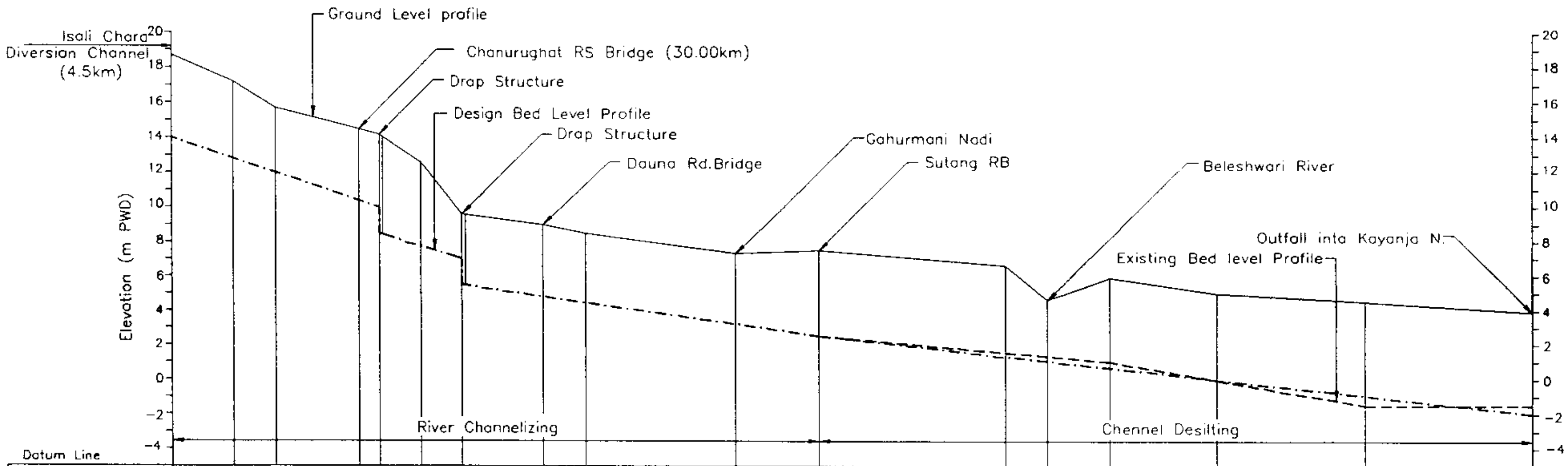
FILE: kho-pro.DWG

Northeast Regional Project

Longitudinal Profile of Khowai River

Prepared by: DMc

June 1993



Distance (km)	Ground Level	Existing Bed Level	Design bed Level	Design Bed Width(m)
0.00	18.7		14.00	15.00
3.00	17.20			
5.00	15.70			
9.00	14.50			
10.00	14.20		10.00 / 8.50	20.00
12.00	12.60			
14.00	9.60		7.00 / 5.50	25.00
18.00	9.00			
20.00	8.50			
27.00	7.30			
31.00	7.50	2.50	2.50	Variable
40.00	6.60			
42.00	4.60			
45.00	5.90	1.00		
50.00	5.00			
57.00	4.50	(-) 1.50		
65.00	3.90	(-) 1.50	(-) 2.00	

Northeast Regional Project

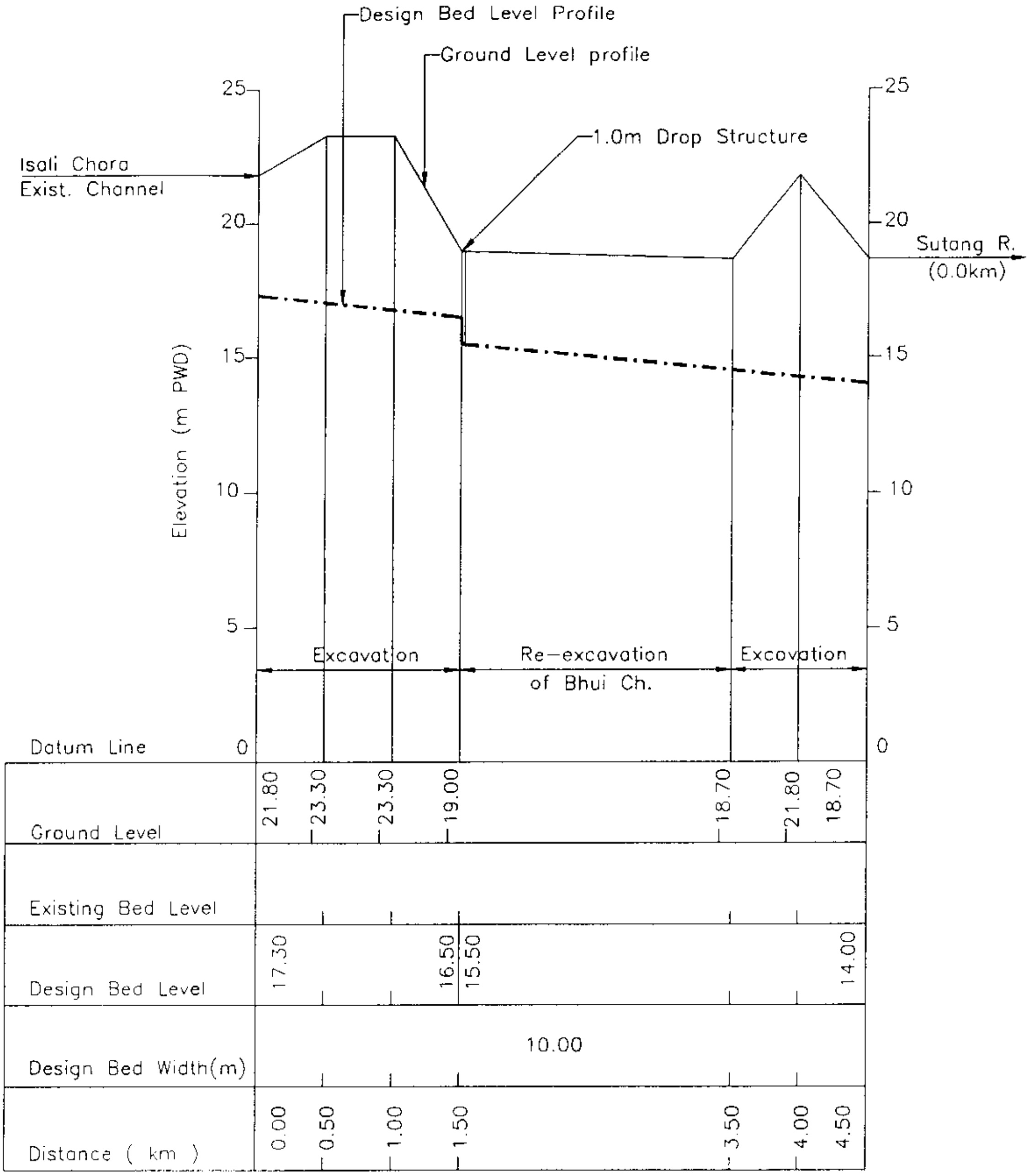
Habiganj-Khowai Area Development

Sutang River Profile

Prepared by: H.Werszko	November 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-225.DWG

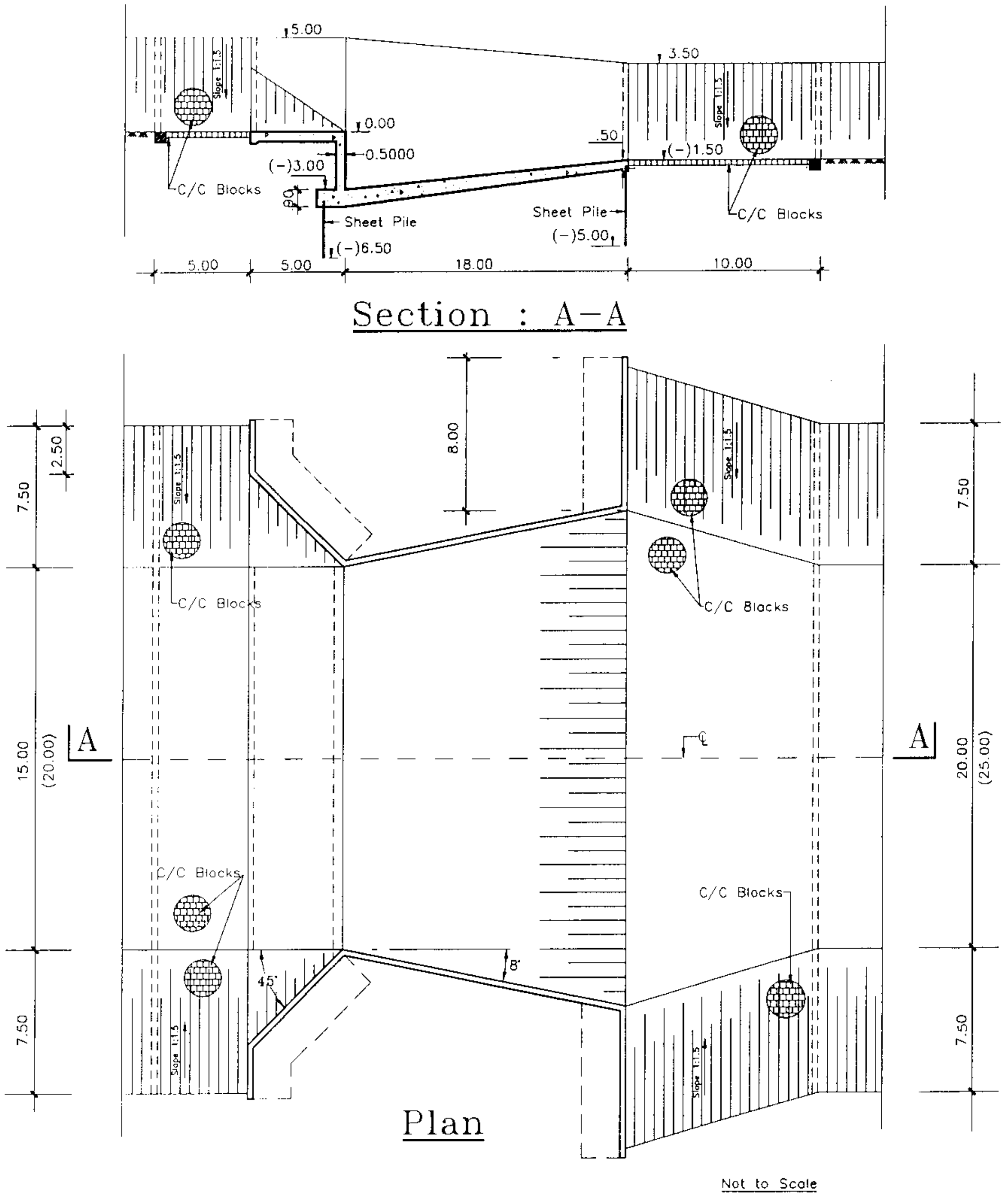
Figure 11



Northeast Regional Project
Habiganj–Khowai Area Development
Isali Chara Diversion Channel Profile

Prepared by: H.Werszko	November 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-226.DWG



Northeast Regional Project	
Habiganj-Khowai Area Development	
Sutang River Drop Structure	
Prepared by: H.Werszko	November 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-048.DWG