Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Water Resources Planning Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

KANGSHA BASIN WATER MANAGEMENT PLAN

Final Report
April 1997

VOLUME II - ANNEXES A, B, C, D & E

SNC • LAVALIN International
Northwest Hydraulic Consultants

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Bangladesh Engineering and Technological Services

Canadian International Development Agency

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COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is created to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is all that remains of the past lowland forest. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal by the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

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Annex A: Resource Base and Present Use
Annex B: Hydrologic Data
Annex C: Modelling
Annex D: Someswari River Stabilization Project
Annex E: Groundwater Resources

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ACRONYMS AND ABBREVIATIONS

ADAB	Association of Development Agencies in Bangladesh
BAU	Bangladesh Agricultural University
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BIWTMAS	Bangladesh Inland Water Transport Master Plan
BMD	Bangladesh Meteorological Department
BFRI	Bangladesh Forest Research Institute
BFRSS	Bangladesh Fisheries Resource System Survey
BLRI	Bangladesh Livestock Research Institute
BRAC	Bangladesh Rural Agricultural Cooperative
BRDB	Bangladesh Rural Development Board
BRRI	Bangladesh Rice Research Institute
BSS	Destitutes' Cooperative Society
BWDB	Bangladesh Water Development Board
CARITAS	a Non-governmental organization
CIDA	Canadian International Development Agency
CITES	Convention on International Trade of Endangered Flora and Fauna
CLF	Civilian Labour Force
CO	Community Organizer
DAE	Department of Agricultural Extention
DANIDA	Danish International Development Agency
DC	District Commissioner
DLS	Department of Livestock Services
DOL	Department of Livestock
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
DSK	Dustha Shastha Kendra
DSSTW	Deepset Shallow Tube Well
DTW	Deepset Tube Well
EIA	Environmental Impact Assessment
EPCB	Environmental Pollution Control Board
FAO	Food and Agriculture Organization/
FAP	Flood Action Plan
FCDI	Flood Control, Drainage, and Irrigation
FEAVDEP	Flood- and Erosion-affected Villages Project
FP	Family Planning
FPCO	Flood Plan Coordination Organization
FSR	Farming Systems Research
GDP	Gross Domestic Product
GO	Government Organization
GOB	Government of Bangladesh
HD	Hydrodynamic, as in the hydrodynamic routing portion of the MIKE 11 model
HTW	Hand Tube Well
HYV	High Yield Variety
IEC	Important Environmental Component
IEE	Initial Environmental Examination

ISPAN	Irrigation Support Project Asia Near East
KRIP	Kangsha River Improvement Project
KSS	Farmers' Cooperative Society
LGED	Local Government Engineering Department
LGRD&C	Local Government Rural Development and Cooperatives
LLP	Low-lift Pump
MIKE11	The hydrodynamic modelling package which is used to simulate flows and water levels in the river system
MIWT	Mechanized Inland Water Transport Fleet
MP	Member of Parliament
MPO	Master Planning Organization
MSS	Women's Cooperative Society
NAM	The rainfall-runoff model used to simulate the inflows from border rivers and local catchments
NEMREC	Northeast Regional Environmental Management, Research, and Education Centre
NERP	Northeast Regional Water Management Project
NGO	Non-governmental Organization
NHC	Northwest Hydraulic Consultants
NIDP	Netrokona Integrated Development Programme
NMIDP	National Minor Irrigation Project
O&M	Operation and Maintenance
OFRD	On-farm Research Division
PCC	Project Coordination Committee
PDEU	Population Development and Evaluation Unit
PRA	Participatory Rural Appraisal
PVDO	Private Voluntary Development Organization
PWD	Public Works Department
RDB	Red Data Book
RMP	CARE Bangladesh Rural Maintenance Programme
SLI	SNC-Lavalin International
SMEC	Snowy Mountains Engineering Corporation
SOB	Survey of Bangladesh
SRP	Systems Rehabilitation Project
SRDI	Soil Research Development Institute
STW	Shallow Tube Well
SWMC	Surface Water Modelling Centre
TNO	Thana Nirbahi Officer
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UP	Union Parishad
WARPO	Water Resources Planning Organization
WFP	World Food Programme
WHO	World Health Organization
WRS	Water Retention Structure
WUG	Water User Group
XEN	Executive Engineer

GLOSSARY

aman	monsoon rice crop
arat	open space especially for wholesale transaction/warehouse
aus	pre-monsoon rice or rice grown in *Kharif I* season
bari	several *ghar*s having kinship lineage
beel	land depression within a *haor*
bhita	raised area used as a homestead
biri	indigineous cigarette
boro	rice grown during the winter season
bundh	earthen dam, closure
chorra	channel that drains the base of the Meghalaya Hills
current jal	a kind of gill net
doon	manually operated traditional irrigation tool
duar	deep scout hole in a river
ghar	the equivalent of a nuclear family
hizal	a species of tree (Barringtonia acuntangula)
haor	land depression on a floodplain
Jatiya Sangsad	Bangladesh national parliament
katha	0.08 acres of land
khal	drainage channel
kharif I	pre-monsoon season (March-June)
kharif II	monsoon season (July-October)
koroch	a species of tree (Pongamia pinnata)
mouza	governmental revenue administrative unit
para	a cluster of *baris* socially recognizable as a neighbourhood
purdah	seclusion
rabi	dry season crops
samaj (*mallot*)	informal social institution
sangstha	non-governmental organization
t. *aman*	transplanted *aman*
Tara pumps	improved hand pumps that abstract water upto 15 m deep
thana	governmental administrative unit
thana parishad	a committee of all *union parishads* in a *thana*
union parishad	local government structure
zila parishad	a committee composed of MPs of a district

ANNEX A

RESOURCE BASE AND PRESENT USE

ANNEX A
RESOURCE BASE AND PRESENT USE

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1. INTRODUCTION

1.1 Purpose

This Annex provides the context for the Kangsha Basin Water Management Plan by describing the water and related natural resources of the Basin. It also describes the socio-economic and institutional setting in which the Plan is founded and which provide both constraints and opportunities for its implementation. Finally it provides a review of the existing water management projects in the hope that we can learn from past mistakes.

1.2 Structure of the Annex

- ***Chapter 1***, the present chapter, provides an introduction to the Annex;

- ***Chapter 2, Physical Features,*** provides a brief introduction to the Basin, its geology, climate, and river system;

- ***Chapters 3 through 6*** describe the water and related natural resources:

  Chapter 3 - Land Resources
  Chapter 4 - Surface Water Resources
  Chapter 5 - Groundwater Resources
  Chapter 6 - Wildlife and Vegetation Resources

- ***Chapters 7 through 9*** provide an analysis of the present resource use, problems, and constraints:

  Chapter 7 - Agriculture
  Chapter 8 - Fisheries
  Chapter 9 - Transportation

- ***Chapter 10, Socio-economic Setting***, describes the social environment under which the plan is formulated;

- ***Chapter 11, Institutional Framework,*** describes the institutional environment in which the plan will be implemented;

- ***Chapter 12, Existing Water Management Projects,*** reviews the history of the existing water management projects and their problems based on field work conducted in this study.

Referenced Figures are located at the back of this Volume (Volume II). Tables and graphs are found where they are first referenced within the text.

2. PHYSICAL FEATURES

2.1 Location

The Kangsha Basin is located in the northwest corner of the northeast region of Bangladesh between latitude 24° 57'N and 25° 16'N and between longitude 90° 0' and 90° 58'. It spreads over thirteen thanas in Sherpur, Mymensingh and Netrokona Districts and covers a gross area of 231,000 ha. It is bounded on the north by the international border, on the south by the Sherpur-Nakla-Netrokona-Thakurakona Road, on the east by Thakurakona-Kalmakanda Road, and on the west by the Sherpur-Kurua-Balijuri Road (Figure A.1).

The project area lies within the districts of Sherpur, Mymensingh, and Netrokona. It wholly or partially includes thirteen thanas as summarized in Table 2.1. Thana and district boundaries are shown in Figure A.2.

Table 2.1 : Thana Coverage

District	Thana	Thana Area within Basin (ha)	Fraction of Thana[1]
Sherpur	Sribardi	3,837	0.14
	Jhenaigai	20,213	0.88
	Nalitabari	32,761	1.00
	Sherpur	10,119	0.28
	Nakla	7,002	0.40
Mymensingh	Haluaghat	35,607	1.00
	Dhobaura	25,105	1.00
	Phulpur	14,079	0.24
Netrokona	Durgapur	29,342	1.00
	Kalmakanda	18,592	0.49
	Purbadhala	17,471	0.56
	Netrokona	13,720	0.40
	Barhatta	3,181	0.14
Total Area		231,029	0.56

[1] Proportion of the *thana* lying within the study area. Statistics which are derived from *thana* statistics within this report are pro-rated on the basis of area.

2.2 Physiography and Soils

The main landform units in the basin are Uplands, Piedmont Floodplain, Alluvial Fans, and Lowland Floodplains. Figure A.3 shows the extent of each unit and Table 2.2 summarizes their extent.[1]

Uplands
Uplands cover an area of 50 km^2 (2.1 percent of the basin) along the edge of the Meghalaya Hills in India. These hills are composed of weathered and poorly consolidated sandstone, siltstone and conglomerate.

Piedmont Floodplains
Piedmont floodplains occur in the northwest portion of the region primarily along the Malijhee, Chelakhali, and Bhogai Rivers. They are formed by deposition along tributary streams that join the larger mainstream rivers. Land elevations range between 9 m and 24 m. The landform unit covers an area of 552 km^2 (23.9 percent of the basin).

1/ Land unit boundaries have been synthesized from the classifications published by Geological Survey of Bangladesh (1990) and Rashid (1991).

Alluvial Fans
Alluvial fans are found along the foot of the Meghalaya Plateau and cover an area of 231 km^2 (10 percent of the basin). The fans are produced when steep mountainous streams exit from their canyons and spread over the flat, unconfined land of the lowland floodplains. The decrease in channel gradient and reduction in velocity as the streams leave their canyons causes deposition of sand and gravel sediments in the form of a "fan-shaped" conical delta. Alluvial fans are found on the Someswari and Lengura Rivers. Elevations range from 12 to 16 m.

Table 2.2 : Physiographic Summary

Physiographic Unit	Area (km^2)	Percent of Basin
Uplands (Susang Hills)	50	2.1
Piedmont Floodplain	552	23.9
Meghalaya Fans	231	10.0
Old Brahmaputra Floodplain	1477	63.9

Lowland Floodplains
This is the major landform unit covering an area of 1,477 km^2 (almost two-thirds of the basin). It has been created by deposition from the Old Brahmaputra River. Land elevations typically range between 9 and 22 m. Natural levees are common; they are formed by deposition of sediment when a stream overtops its banks. They are as much as 3 to 5 m above the adjacent back basins.

Soils and Topography
Figure A.4 shows the generalized distribution of soils in the basin. Figure A.5 shows the contours of land elevations in the basin. In general the land slopes from northwest to southeast. Elevations vary from 34 m (PWD datum[2]) in the northwest to 4.0 m east of Jaria Janjail. The contact zone between the two major depositional landforms is low and poorly drained. This includes the Sherpur depression and low-lying areas along the Kangsha River which are most affected by seasonal flooding of the Kangsha River.

2.3 Climate

The climate is sub-tropical having a hot, wet monsoon season (June to September) and a cooler dry winter season (December to February). Monthly average temperatures at Mymensingh vary from 21.5°C in January to 30°C between March and October. January is the coldest month. The average daily minimum temperature falls to 9.8°C. In April, the hottest month, the average daytime maximum temperature reaches 35°. Cropping is possible year-round although January temperatures are not conducive to early growth of boro crops.

Evaporation follows the annual cycle of temperatures and humidity. The average annual potential evapotranspiration is 1,506 mm at Mymensingh. The lowest monthly amount occurs in December (87 mm) and the highest monthly amount occurs in April (162 mm).

[2/] Elevations in this report are quoted from Public Works Department (PWD) data as is the common practice in Bangladesh. SOB (Survey of Bangladesh) data, also knows as GTS data, can be converted to PWD by adding 0.46 m (1.51 feet)

Rainfall is extremely variable in both space and time. Rainfall in the catchment causes extensive flooding which damages agricultural crops or precludes their cultivation; this occurs mainly during the monsoon season but can also occur at other times of the year. During the dry season the rainfall is so sparse as to require irrigation to sustain most crops.

As shown in Figure A.6 the rainfall increases from southwest to northeast. The mean annual rainfall varies from 2,200 mm near Sherpur to 4,400 mm near Kalmakanda. The isohyets (contours of equal rainfall) are for the period 1961-90.

The typical seasonal pattern of rainfall is illustrated in Figure A.7 (for Jaria Janjail). There is little or no rain in the dry season, from December to March. About 85% of the annual rainfall occurs during the monsoon months of May to September when flash floods are regular and frequent.

Monthly rainfall statistics (maximum, minimum, mean, 80% and 90% dependable rainfall) are provided in Annex B for the six rainfall stations operated by the BWDB within the basin.

2.4 River System

The Kangsha River forms the backbone or main stem of the drainage system to which a number of tributary streams are connected. Tributary streams, of which the Bhogai and Someswari are the largest, provide the main inflow.

Figure A.8 shows the outline of the catchment and the main tributary areas. A summary of the drainage areas is provided in Table 2.3.

Table 2.3 : Drainage Areas of the Kangsha Basin

Catchment	Drainage Area (km2)
Upper Malijhee	565.7
Chelakhali	110.9
Bhogai	427.6
Nitai	341.2
Someswari	2407.7
Someswari/Lengura Flood Plain	772.2
Lower Malijhee	557.8
North Flood Plain	894.0
Dampara Project	148.0
Kangsha River Improvement Project	112.2
Thakurakona Sub-Project	30.9
Total	6368.1

2.4.1 Meghalaya Tributaries

The Meghalaya tributary area is drained by the Malijhee, Chelakhali, Bhogai, Nitai, Someswari, and Lengura Rivers as well as some smaller streams that drain smaller areas along the edge of the hills. These catchments are small but steep and experience heavy rainfall and heavy and rapid runoff.

Flood events in the border tributaries are flashy and occur several times during the monsoon season, occurring frequently and without warning. The spilled water collects in inter-fluvial lowlands which are flooded until the water drains out. Overbank spills are of short duration but cause damage to homesteads and agricultural lands.

The Chelakhali River has been embanked on both sides along most of the reach between the international border and the Malijhee lowlands. Deposition is occurring in this reach, and together with erosion of the confining embankments, results in periodic breaching of the embankments and flooding of the adjacent lands. The Bhogai River has been embanked along both banks as well - these embankments are higher and more robust and provide flood protection in all but the most severe floods.

Winter flows are sustained by discharge from groundwater. These streams carry a small flow throughout the year. All of these streams are used for irrigation water supply during the winter months. The Malijhee, Chelakhali, and Bhogai Rivers all have water retention and/or diversion structures that were built for this purpose. Smaller streams including the Nitai and various *chorras* which drain small areas at the base of the Meghalaya region are generally blocked by cross-dams constructed each year. Water is diverted from these streams for irrigation water supply, primarily for winter *boro* rice crops.

These piedmont streams carry large sediment loads which are deposited in piedmont plains and in low-lying floodplains. Where the transported bed materials are slightly coarser (sands), in the Someswari and Lengura Rivers, the outwash plain takes the form of an alluvial fan. There the channels are unstable due to active deposition of the suspended load and they frequently form avulsions, which are sudden and large-scale shifts in channel location. The Someswari River is particularly unstable; its main channel, the Shibganjdhala, has shifted westward since the 1960's and presently is in the process of developing a new channel (the Atrakhali channel) toward the east. Shifting of the channels provides an extra dimension to the flood risk and uncertainty faced by people in this area.

Malijhee River

The Malijhee River is formed by the confluence of the Marisi and West Someswari Rivers. Both the Marisi and West Someswari Rivers originate in the Meghalaya Hills (Tura Range) and have a combined catchment area of 342 km^2 within India. The Malijhee River passes through a series of beels to the north of Sherpur before confluence with the Chelakhali River and joins the Bhogai River at Urpha, below Nalitabari. The river length from the international border to Urpha is about 44.0 km.

The Malijhee and its tributaries spill overbank during floods.

Chelakhali River

The Chelakhali River also originates in the Tura Range of the Meghalaya Hills and has a catchment area of 105 km^2. The Chelakhali River continues southward for 21.0 km within Bangladesh before joining the Malijhee River at Balurghata.

The River has a shallow perched channel whose banks are well above the main floodplain. It also has a steep longitudinal slope and carries substantial quantities of sand during floods. The river does not receive drainage from the overbank areas; flood spills do not return to the river but rather collect in the lower, flatter area of the Malijhee floodplain.

Bhogai River

The Bhogai River also originates in the Tura Range of the Meghalaya Hills. It has a catchment area of 422 km^2 in India. Within Bangladesh the river flows in a southerly course for 20 km from

Nakuagaon to its confluence with the Malijhee River at Urpha, five kilometres south of Nalitabari. The Bhogai River has a steep longitudinal slope and has substantial capacity for transporting sand-bed material during floods.

Both bank areas are perched above the main floodplains such that overbank spills and drainage are directed away from the river. Drainage of the right bank area is collected in the Malijhee floodplain. The left bank area is drained eastward through the Mora (Dead) Bhogai, other relic channels, and Gudaria Khal to join the Kangsha River at Phutkai.

Nitai River

The Nitai River originates from the Tura Range of the Meghalaya Hills and enters Bangladesh at Ghosegaon. The river has a catchment area of 335 km^2 within India. Below Ghosegaon the Nitai flows southeasterly for 30 km before joining the Kangsha River 10 km upstream of Jaria, crossing enroute a low-lying area that is perennially flooded.

The river is actively developing its floodplain and river section in the downstream area. Avulsions are also taking place, forming new distributary channels. About seventy percent of the area's homesteads are on the river levees.

Someswari River

The Someswari River originates in the Meghalaya Hills and enters Bangladesh at Bijoypur, 5 km above Durgapur. The River has a catchment area of 2377 km^2 within India.

The Someswari River is located on an alluvial fan, and is very unstable and prone to frequent changes in location. The Rennell Map, published in 1768, showed the Someswari River to split into two at Durgapur: one branch flowed southward to the Kangsha River, more or less following the present Durgapur-Jaria Road. The other branch flowed eastward into the Baulai system. In maps prepared in 1952 the Someswari River appeared as a single braided channel which turned eastward into the Baulai system. By 1963 the river had shifted to the west of its earlier position and is presently known as the Shibganjdhala River. The abandoned channel remains and continues to carry flood spills but is now called "Old Someswari River".

During the 1988 flood the river formed a new channel to the east called Atrakhali Khal; about one kilometre upstream of Durgapur. The channel is further developing with every flood in the Someswari River and appears destined to eventually become the main outlet.

In 1989, the river made an avulsion through the Sakhait channel just downstream of the Old Someswari River. The Sakhait channel is believed to be the relic of the Someswari River south branch which existed in the eighteenth century. However, this channel has been closed in 1994 at Birisiri.

Relic channels of these and earlier channels are still visible in the maps and satellite images in this area.

2.4.2 Malijhee Lowlands

The Malijhee and Chelakhali Rivers all but disappear into the low-lying area upstream of their confluence with the Bhogai River. There, the rivers spill overbank during the monsoon season and flood the area known as the Sherpur depression. This overbank spill acts as a damper for the system, absorbing the flashy flood peaks and releasing them at a lower rate over a longer period of time. Flooding occurs for several days or weeks at a time on three or four occasions during a typical monsoon season. The Bhogai River serves as the outlet from this area.

In the winter season most of this area drains, except for the lowest areas or beels. Most of the area is cropped in winter rice and is irrigated from the remaining surface water, from the rivers when flow is available, and from groundwater.

A short distance downstream the Bhogai River splits at Tarakanda into two branches. The north branch continues on to Sarchapur as the Bhogai River. The south branch is believed to be an ancient channel of the Malijhee River.

Before the 1980s the south channel had no connection with the Bhogai River; then a channel was excavated to provide winter water supply from the Bhogai River to Putia Beel for irrigation of winter rice crops. The connection and south channel have developed during the past 25 years until they presently form the main channel. Winter flows are now carried entirely by the Malijhee channel. Further development of this channel is retarded somewhat by cohesive clay soils in places, but will likely continue until the north channel, the Bhogai, is filled in by silt and sand carried by the Bhogai River.

The south branch of the Malijhee River rejoins the Bhogai River a short distance upstream of Sarchapur to form the Kangsha River. At this location, a small distributary channel, Naka Nadi, splits off to eventually rejoin the Kangsha River upstream of the Kharia River outfall. Its significance is primarily that it bypasses the discharge measurement site at Sarchapur.

At a location near Amtail, the Bhogai River spills to the north through the Gangina and the Kodalia Khals. This causes flooding of the adjacent areas. Various attempts have been made through the years to close off these channels and the overbank spills, causing intense conflicts between the people living inside and outside of the protected area.

2.4.3 Kangsha Main Stem

The Kangsha River originates from the confluence of the Bhogai and Malijhee Rivers, just upstream of Sarchapur, from where it follows an easterly course until it joins the Baulai River just south of Sukdebpur. The Kangsha River intercepts the cross-boundary inflows coming from the north via the Malijhee, Chelakhali, Bhogai, Nitai, Someswari, and many other hilly streams, and also receives runoff from the Bangladesh area which is mostly located to the north of the Kangsha.

Upstream of Jaria the river meanders in a wide meander belt which appears to be a relic of an old channel of the Brahmaputra River. The river is relatively stable in this reach other than point-bar accretions and lateral erosion where meanders impinge on higher deposits at the edge of the floodway and may be infilling slowly.

Downstream of Jaria the Kangsha River is affected by the avulsion of the Someswari River into the Shibganjdhala River that occurred in 1963. It is believed that approximately six million cubic metres of predominantly fine sand and silt was eroded during the avulsion and that much of this sediment has been carried into the Kangsha River and deposited further downstream. This sediment inflow is increasing the lateral shifting and deposition in the reach between Jaria and

Thakurakona.

The downstream sediment deposition is thought to be responsible for splitting of the Kangsha River into three channels at Thakurakona: the Ghulamkhali Khal, the Kangsha River, and Dhonaikhali Khal. The original main stem, the Kangsha channel, has infilled with sediment and is virtually blocked. A previously small channel, the Ghulamkhali Khal, has become the main channel; it flows to the northeast to eventually join the original Someswari River and the Baulai River. The third distributary channel, Dhonaikhali Khal, flows southward to join the Mogra River downstream of Netrokona. The combined flow becomes the Dhanu River and eventually joins the Baulai River some 50 km further south.

At present about 70% of the Kangsha River's monsoon flow is conveyed through the Ghulamkhali Khal, 10% through the lower Kangsha River, and 20% through the Dhonaikhali Khal. However, the entire dry season flow is conveyed by the Dhonaikhali Khal.

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3. LAND RESOURCES

3.1 Land Use

The total area of the Upper Kangsha River Basin is 231,000 ha, of which about 70% is cultivable[3,4]. The remaining 30% is composed of homesteads, roads, market places, rivers, canals, etc, and a small area of remaining forest. Land uses are summarized in Table 3.1.

Table 3.1 : Summary of Land Use

Land type	% of Total
Cultivated	65.0
Culturable	4.3
Homesteads, infrastructure, rivers, etc	28.6
Forest	2.1
Total	100.0

3.2 Flooding Pattern

According to MPO's classification, about 60% of the cultivable area is affected by flooding during the monsoon season to a degree that imposes a constraint on cropping. The cultivated area (excluding beels, etc) has been broken down according to MPO's classification in Table 3.2.

The MPO classification is a somewhat qualitative system based on data from thana agricultural offices and on hydrologic mapping. It is supposed to represent average or normal conditions. F_0 lands are considered to be essentially flood-free while F_1 to F_4 lands have progressively greater constraints due to flooding. F_4 lands are flooded too deeply to permit monsoon season crops to be grown although winter crops may be grown.

3.3 Land Capability for Agriculture

Much of the area suffers from flooding during the monsoon season - recurring flash floods in the upper basin and persisting seasonal flooding in the lower basin and lower areas of the upper basin. Floods cause damage of rice crops in the fields, especially when they occur during the late monsoon period after transplantation of aman rice is complete. The risk and uncertainty caused by flooding also discourages farmers from adapting HYV rice.

Drainage is also a problem in some areas due to deposition of silts and sands from flood waters spilled overbank from the main-stem and tributary rivers. Low-lying areas are poorly drained and

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3/ Areas have been estimated from MPO data, adjusting for the basin boundaries and for cultivated area as published in Yearbook of Agricultural Statistics of Bangladesh, 1992, Bangladesh Bureau of Statistics, 1992 (published June 1993). The estimate of cultivable land is subject to some uncertainty - estimates as high as 90% have been made.

4/ Cultivable land included fallow land and culturable waste land which is cultivable but remains un-cropped for more than one year.

2[8]

Table 3.2 : Classification of Flood Depth in the Basin

Land Class	Description	Flood Depth (m)	Area (ha)	Percent of net cultivated area (%)
F_0	highland	0 to 0.3	59,100	39.6
F_1	medium-high	0.3 to 0.9	41,400	27.7
F_2	medium-low	0.9 to 1.8	29,300	19.6
F_3	lowland	more than 1.8	19,400	13.0
F_4	very low	permanent water bodies	116	0.1
Net cultivated area			149,300	100.0
Non-cultivated area			80,900	

Source: Based on MPO (1987) and BBS (1993).

vulnerable to drainage congestion and waterlogging.

In general all areas experience deficiencies in soil moisture during the dry season. Winter rabi crops can be grown with residual soil moisture in some areas but they require irrigation of ridge soils and in the highlands areas where soil moisture conditions are low. Lowlands areas are well suited for winter rice (boro) production under irrigation.

The cultivated land in the project area can be sub-divided into seven zones based on differences in agricultural constraints and development potential. The classification reflects differences in flood conditions, physiography, agro-climate, and soil conditions. Sources of data for this classification included soils mapping by SRDI in 1966 and 1968 as well as agro-ecological analysis by FAO/UNDP in 1988.[5,6] This information has been synthesized together with field data on soils and crop conditions and updated knowledge of flooding and drainage conditions to produce the land use capability map shown in Figure A.9. The different zones are organized from east to west, more-or-less grading from lowland to highland.

Zone A: Lowland Floodplain

Zone A is mainly lowland floodplain. The main constraint is seasonal monsoon flooding which damages t. aman crops. Floods occur more than once per year between June to September,

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[5/] Reconnaissance Soil Survey of Jamalpur Subdivision, 1966 (Rev 1972), and Netrokona and Sadar North Subdivisions, 1968, Department of Soil Survey (presently Soil Resources Development Institute).

[6/] Land Resources Appraisal of Bangladesh, FAO/UNDP, 1988.

damaging the re-transplanted aman rice. In some years farmers will transplant two or three times to replace the damaged crops, and if the floods occur so late that farmers can not re-transplant they keep their land fallow. Early flooding also damages boro rice crops in low-lying areas. The risk of flooding and the occurrence of crop damage discourages farmers from growing high-yielding modern varieties in many areas.

Other constraints are drainage congestion and low moisture-holding capacity of soils. Deposition of sand also occurs along Atrakhali channel.

The primary requirement in this zone is improved protection against floods which would permit a substantial increase in t. aman rice production. This zone is suitable for intensive rice cultivation in both the monsoon and winter seasons with flood protection, drainage improvement, and dry season irrigation. In parts of this area, particulary the Dampara Project area, irrigation from groundwater has been extensively developed. Non-rice crops can be cultivated between the two rice crops with improved drainage.

Zone B: Medium Floodplain
This zone includes higher areas of the Kangsha floodplain. It is similar to Zone A except that it drains more quickly after the monsoon season, allowing T. Aman crops to be transplanted earlier. The t. aman crops are also less likely to be damaged by late-monsoon flooding than in Zone A.

Two rice crops per year are possible in about one-half of this zone, but irrigation is required during the dry season. Drainage improvement and soil management can increase the production of crops throughout the year in much of this area. Non-rice crops can be grown under irrigation on ridge soils and on the margins of depressions.

Zone C: Piedmont Plain
This zone is relatively flood-free but is affected locally by runoff from the hill areas. Monsoon flooding occurs in the lower areas. It suffers from drought conditions in the dry season due to heavy soils with low organic content.

Rice production in the monsoon season can be increased with drainage improvements. Intensive winter rice cultivation is also possible with irrigation and non-rice crops can be cultivated in the higher margins around depressions. Crops can be grown in all seasons in about 25% of this area.

Zone D: Upper Basin
Zone D comprises floodplain areas in the upper basin. These areas are affected by flash floods which occur in the monsoon season and sometimes in the post-monsoon season and persist for a few days at a time. Flood control embankments exist along the Bhogai and Chelakhali Rivers but these are breached in large floods.

Soils are porous and have low organic content; consequently they dry out in mid-rabi season. This area is ideal for monsoon rice crops and winter non-rice crops. Winter rice cultivation is limited by the availability of surface water and groundwater for irrigation. Some irrigation presently occurs from surface water, notably along the Bhogai and Chelakhali Rivers, and from groundwater in the upper Malijhee River area. Dryland crops can be cultivated with small-scale

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irrigation.

Zone E: Lowlands
Flooding and late drainage are the major problems in these low-lying areas. Flooding persists for most of the monsoon season but the depth of flooding is highly variable due to flash flooding. Boro is the only crop in parts of this zone but is vulnerable to pre-monsoon flooding in low-lying areas. Flood protection would increase rice production in the monsoon season and would enable more T. Aman to be cultivated.

Zone F: Uplands
This zone is well drained; soils are sandy loam, clay loam, or loam and low in organic matter content. Soil moisture dries out in the early-to-mid rabi season.

Intensive cultivation of vegetables is possible with irrigation from the Malijhee and Chelakhali Rivers.

Zone G: Susang Hills
Small areas along the border with India consist of dissected low hills which suffer from steep slopes, thin soils, and limited soil moisture. The area has limited agricultural potential and is best suited to tree crops. Rabi crops can be grown with irrigation in the dry season wherever the ground-slopes permit terracing.

3.4 Distribution of Land Ownership

Most farms in the basin are small. According to the 1983-84 Agriculture Census data almost two-thirds of the farms are smaller than 1 ha. Only 7% of all farms are larger than 3 hectares but these represent 30% of the total farm area.

3.5 Irrigable Area

A summary of the irrigable area in each thana is provided in Table 3.3.

The irrigable area is defined as that portion of the land on which the topographic and soil conditions are suitable for irrigation provided that adequate supplies of groundwater are

Table 3.3 : Gross and Irrigable Land Areas in the Basin

Thana	Gross Area in the Basin (ha)	Irrigable Area in the Basin (ha)
Jhenaighati	19,900	11,631
Nalitabari	32,800	18,514
Haluaghat	35,600	19,954
Dhubaura	25,100	17,632
Durgapur	29,300	16,084
Sribordi	1,800	987
Sherpur	9,200	7,181
Nakla	6,700	5,190
Phulpur	16,000	12,160
Purbadhala	25,800	19,761
Netrokona	14,100	9,392
Barhatta	1,100	879
Kalmakanda	13,700	9,032
Basin Total	231,100	148,397

available. By this definition about 148,000 ha or 64% of the total basin area is considered to be irrigable.[7]

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[7] The estimate of irrigable area differs from the BBS figure of 140,600 ha. For the groundwater study the hilly areas which represent about 17% of the basin, mostly in the northern area along the border with India, were excluded. The cultivated portion was estimated to be 91% of the remainder (based on MPO data) and the irrigable area was assumed to be 85% of the cultivated area.

2X

4. SURFACE WATER RESOURCES

4.1 Data Base

BWDB measures water levels and discharges at a number of locations in the area as summarized in Table 4.1. NERP has also operated a short-term hydrometric program in 1994 and 1995 to help define flood levels and to help calibrate the computer model. Data availability is summarized in Table 4.2. Gauge locations are shown in Figure A.10. Average monthly flows at discharge gauges are summarized in Table 4.3.

A summary of the hydrologic characteristics follows:

Malijhee River
Prior to 1994 there was no gauging station on this River. In 1994 NERP measured water levels at Barakanda, Balughata, and Urpha and weekly discharge at Barakanda. The 1994 water levels of these three stations are shown in Figure A.11 along with water levels at Nalitabari, Sarchapur, and Jaria.

Chelakhali River
Water levels in the Chelakhali River have been observed by BWDB at Bathkuchi. The data indicate that the highest level occurred in 1985. Discharges have been observed since 1988; however, the observed discharge data are too limited and the rating curve is too variable to define the peak flow accurately.

Bhogai River
Water levels are measured at Nakuagaon and Nalitabari and discharges are measured at Nakuagaon. The 24 years of discharge records indicate a range of daily discharge from 0.60 m^3/sec (1988) to 1,240 m^3/sec (1983).

Nitai River
Water levels and discharges for the river are measured at Ghosgaon. The 24 years of record indicate a range of daily discharge from 0 m^3/sec (1967) to 981 m^3/sec (1991).

Someswari River
Discharges in the Someswari River have been measured by BWDB at Durgapur. Prior to 1974 the discharge was measured sporadically in both distributaries, but since 1974 it has been measured in the right distributary (Shibganjdhala) only. More recently, since 1988, the discharges have been measured in each of the three branches and have been combined to give the total flow. However the available discharge observations are too limited, the channel changes have been too severe, and the overbank spills have been too variable to allow the flood peaks to be established with any reliability.

From 1992 to 1994 the Someswari River flow has been measured at Bijoypur where water level data have been collected since 1964. Measurement at Bijoypur represents the total cross-boundary inflow through this channel. Based on the 1993 rating curve, the maximum discharge in the channel is estimated to have been 4,348 m^3/sec (1982).

Table 4.1 : Summary of BWDB Hydrometric Data

Gauge No.	Name of Station	Name of River	Water Level Data	Discharge Data
53	Bathkuchi	Chelakhali	1964-1994	1988 to 1994
34	Nakuagaon	Bhogai	1964-1994	1964-1994 (except 1971, 1981-1982)
35	Nalitabari	Bhogai	1964-1994 (except 1968)	
35.5	Sarchapur	Bhogai	1964-1994	1991-1994
36	Jaria Janjail	Kangsha	1964-1995	1964-1995 (except 1969, 1971, 1982)
36.1	Mohanganj	Kangsha	1964-1994 (except 1968)	1991-1993
SWMC	Thakurakona	Dhonakhali	1991-1993	1991-1993
314	Ghosegaon	Nitai	1964-1994 (except 1987-1988)	1965-1994 (except 1971, 1981, 1982)
262	Bijoypur (Bagmara)	Someswari	1964-1995	1991-1994
263.1	Kalmakanda	Someswari	1964-1995	1991-1993
263.2	Madhyanagar	Someswari	1983, 1991-1993	
263	Durgapur	Shibganjdhala	1958-1995	1964-1994 (except 1971)
		Old Someswari		1964-1970, 1972-1973, 1979, 1984-1994
		Atrakhali	1995 monsoon	1990-1994
311	Atpara	Mogra	1982-1994 (except 1984)	
310	Netrokona	Mogra	1977-1994 (except 1981-1982)	1991-1993

Table 4.2 : Summary of NERP Hydrometric Data

Gauge No.	Name of Station	Name of River	Water Level Data	Discharge Data
1	Barakanda	Malijhee	1994	1994 monsoon
2	Balughata	Malijhee	1994 monsoon	
35	Nalitabari	Bhogai		1994 monsoon
3	Urpha	Bhogai	1994	
4	Porba Durail	Kodalia Khal	1994 monsoon	
35.5	Sarchapur	Kangsha floodplain		1994 monsoon
12/95	Latirkhanda	Kangsha	1995 monsoon	
17/95	Purba Pathar	Kangsha	1995 monsoon	
5C	Kangsha Regulator (country side)	Kangsha	1994 monsoon	
5R	Kangsha Regulator (river side)	Kangsha	1994 monsoon	
6	Jalalpur	Mogra	1994	1994 monsoon
263C	Someswari	Atrakhali offtake	1995 monsoon	
7	Birsidli	Someswari	1994, 1995 monsoon	
8	Thakurakona	Dhonaikhali	1994 monsoon	
9	Dasdhar	Ghulamkhali	1994 monsoon	
10	Rampur	Saiduli	1994	
18	Nagla	Nagla	1994 monsoon	1994 monsoon
19	Ganginapar	Gangina	1994 monsoon	
4/95	Baliapar	Balia	1995 monsoon	
20	Panishana	Kalihar	1994 monsoon, 1995 monsoon	
21	Nazirpur Bazar	Atrakhali	1994, 1995 monsoon	

Table 4.3 : Mean Monthly Discharges (m^3/sec) in the Kangsha Basin

Month	Malijhi R. at Barakanda	Chelakhali R. at Bathkuchi	Bhogai R. at Nakuagaon	Nita R. at Ghosegaon	Someswari R. at Bijoypur	Kangsha R. at Sarchapur	Kangsha R. at Jariajhanjail
January	n/a	1.2	4.9	4.1	27.5	9.2	35.2
February	n/a	0.7	3.7	2.9	19.3	5.2	20.4
March	n/a	0.6	3.2	3.1	16.2	4.3	16.7
April	n/a	1.1	5.8	5.3	35.5	8.7	34.9
May	n/a	8.8	23.6	23.1	170.8	53.8	191.0
June	40.8	9.6	66.9	60.3	461.9	133.5	503.8
July	30.9	19.4	129.7	104.3	782.4	193.8	759.3
August	27.8	6.8	83.8	68.9	506.5	155.4	657.8
September	15.9	10.2	79.7	65.3	471.8	143.3	600.8
October	23.7	6.0	40.1	30.8	304.6	113.5	400.1
November	n/a	2.3	11.0	8.9	67.1	22.5	105.8
December	n/a	1.8	6.6	5.5	39.2	14.9	58.4
Average	n/a	5.7	38.3	31.9	241.9	71.5	282.0
No.of years of data	1	6	25	8	25	8	26

n/a = not available

Kangsha River
Water levels in the Kangsha River have been observed by BWDB at Sarchapur, Jaria-Jhanjail, and Mohanganj but until recently the discharges were measured only at Jaria Janjail.

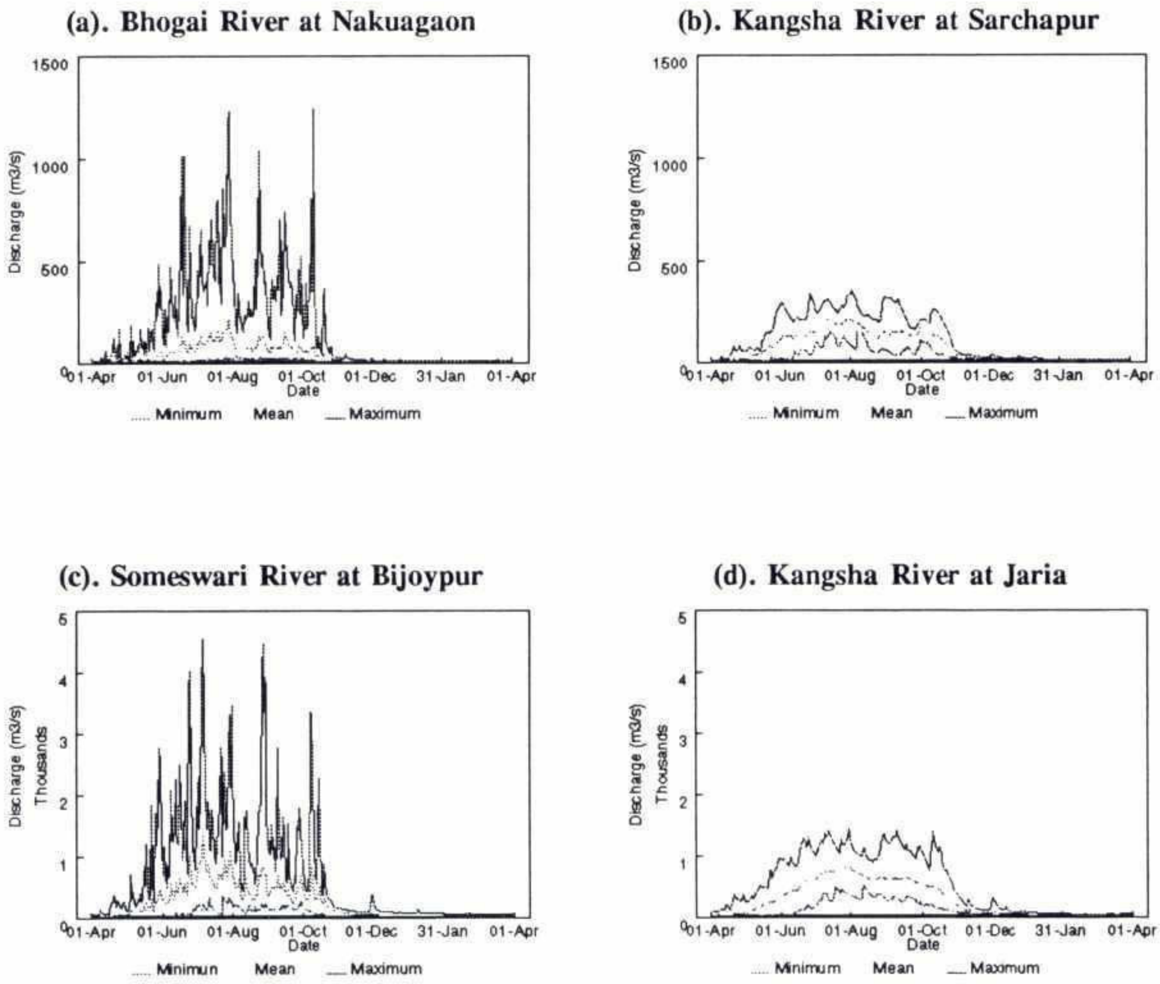
The 25 years of discharge record at Jaria indicate a range of daily discharges from 0 m^3/sec (1979) to 1,430 m^3/sec (1989). Peak flows are substantially lower than even those in the Someswari River, the single largest tributary, owing to overbank spills and floodplain storage.

Discharges have been measured at Sarchapur since 1991 when the peak flow was 300 m^3/sec. Water level records show that the highest water level occurred in 1983, corresponding to an estimated discharge of 350 m^3/s.

4.2 Streamflow Characteristics

Discharges in the Kangsha and its tributaries vary over a wide range, both seasonally and spatially as shown for four locations, Nakuagaon, Sarchapur, Bijoypur, and Jaria, in Graph 4.1.

Graph 4.1 : Seasonal Runoff Characteristics in The Kangsha basin



Most of the annual runoff occurs during the monsoon season, from June to September. Winter flows are very low due to the lack of winter rainfall.

Monsoon-season discharges are highly variable and are very flashy in the border rivers. These peaks are absorbed into floodplain storage and as a result the downstream peaks are damped considerably. Downstream peak flows are often significantly lower than those in the border rivers due to floodplain storage and spills.

All of the larger tributaries maintain at least a small discharge through the winter months, but most of this flow is used for irrigation in the upper reaches. As a result the streamflows are very low in the upper Kangsha River from Sarchapur to Jaria during the winter period. Streamflows are higher downstream of the confluence with the Shibganjdhala River, the main branch of the Someswari River. The Someswari River is the largest source of flood peaks as well as winter base flows.

4.3 Surface Water Availability

While there is abundant water available during the monsoon season, there is precious little during the dry season when it is required for irrigation. Table 4.4 provides an estimate of the lean-period flows at selected locations in the basin as well as an estimate of the sustainable area that could be irrigated with the available streamflow.[8] The table is for present conditions; on-going morphological changes, particularly in the Someswari River, and changes in water use may change the winter flows and their distribution.

Estimates of low flows are only approximate as the available data are affected by errors and inconsistencies introduced by channel shifting and the practical difficulties in accurately measuring such small discharges. Better streamflow data is required for all border tributaries and particularly in the Kangsha River at Sarchapur.

The data show that the lean-period flows are very small except in the Someswari/Shibganjdhala and lower Kangsha Rivers, which are supplied primarily from the Someswari River. Excluding the Someswari River the available flows are able to support irrigation of about 2,000 ha of rice crops. Most of this potential is already developed in the upper tributaries with the result that lean-period flows are very low in the Kangsha River upstream of Jaria Janjail.

Some 8,200 ha could be supplied by the Someswari River if its flows could be tapped. There is, however, little use of this water due to unfavourable (permeable) soil conditions and instability of the Someswari/Shibganjdhala channels. A number of LLP's have been installed along Atrakhali Khal after the avulsion of the Someswari River occurred in 1988, but the area of land which is irrigated from this source is still small.

There is more potential for irrigating land along the Kangsha River below Jaria Janjail. Based on recent stream flow data it is estimated that approximately 5,000 ha could be supplied from the

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[8]/ Dependable flow is defined for the 1:2 year and 1:5 year annual minimum decade. Flows are lower than these values over a 10-day period in 50% and 20% of the years respectively. Estimates of irrigable areas assume a crop water requirement of 1.5 m^3/ha.

Table 4.4 : Streamflow Availability for Irrigation

River Reach	Gauge Location	1:2 Year Dependable Flow (m^3/s)	1:5 Year Dependable Flow (m^3/s)	Sustainable Area (ha)
Malijhee	-	0.9	0.1 to 0.5	50 to 300
Chelakhali	Bathkuchi	0.6	0.1	60
Bhogai	Nakuagaon	1.8	1.3	850
Nitai	Ghosegaon	2.5	1.5	1,000
Someswari	Bijoypur	14.0	12.3	included with Atrakhali and Lower Kangsha
Atrakhali	Durgapur	5.0	4.3	2900
Lengura	-	n/a	n/a	na/
Old Someswari	Durgapur	negligible	negligible	negligible
Shibganjdhala	Durgapur	9.0	8.0	included with Lower Kangsha
Upper Kangsha	Sarchapur	negligible	negligible	negligible
Lower Kangsha	Jaria Janjail	9.0	8.0	5,300
Total				10,400

Note: Estimates of dependable flow are for annual minimum decade.
n/a = estimate not available.

Kangsha River. However the winter flows are threatened by on-going morphological changes in the Someswari River which supplies most of the winter flows to the Kangsha River. At present Shibganjdhala channel is silting in and Atrakhali channel is growing. These changes will cause a further increase in Atrakhali discharges which will cause discharges to decrease in Shibganjdhala channel and the lower Kangsha River. It is possible that the entire winter discharge may be captured by Shibganjdhala which would reduce the Kangsha lean-period discharges to near zero.

4.4 Present Use

Table 4.5 provides a summary of the present use of surface water for irrigation in the Basin. Present projects include irrigation control structures on three of the larger streams (Chelakhali, Bhogai, and Malijhee Rivers), a number of cross-dams constructed on smaller streams, and a number of LLPs drawing water directly from main-stem rivers. The total area irrigated from surface water is about 9,100 ha (some small areas may not be included). Comparison with Table

4.4 indicates that the sustainable flows are fully used in most areas and are over-developed in some areas.

Irrigation Structures
Larger irrigation structures exist on the Chelakhali, the Bhogai, and formerly on the Malihjii Rivers.

The Chelakhali Water Retention Structure consists of a number of irrigation inlets and a 23 vent control structure in the Chelakhali River. It was constructed by the BWDB between 1985 and 1988. The stop-logs of the control structure are no longer operated but local people make cross-dams at the structure each year to raise upstream water levels high enough to supply the irrigation offtakes.

The project was originally planned to irrigate 1,220 ha but presently serves about 115 ha. Streamflow data indicate that the available flows are only sufficient to support about 50 to 100 ha in a dry year.

The Bhogai River irrigation project consists of a two-vent irrigation inlet in the Bhogai River upstream of Nalitabari which discharges water into Dugdha Khal from where it is pumped by LLP. It supplies water to 1,030 ha of land. Earthen cross dams are reportedly constructed in the river during lean-flow periods to help divert water from the river. The project was constructed in 1990 by LGED and is operated by a local committee.

The Malijhee Water Retention Structure was constructed by BWDB in 1986 to supply an area of 2,820 ha. It was subsequently damaged and has not been used since 1988. A number of earthen cross dams are now constructed annually by local people in two main tributaries, the Marisi River and the West Someswari River. The total serviced area is estimated to be 1,500 ha but the dependable flows are estimated to be only sufficient for 300 ha at most. Streamflows are ungauged so the dependable flows and sustainable area have been estimated from data for the adjacent Chelakhali and Bhogai Rivers. Irrigation from groundwater has become commonplace in this area.

Cross Dams
Earthen cross dams are built by local people on most border tributaries in the winter season and the flow is diverted by gravity or LLPs to the fields for irrigation. This is an important source of water for these people but the command area of each cross-dam is small and total irrigated area irrigated is estimated to be no more than 1,000 to 2,000 ha. Conflicts sometimes occur when upstream users cut off the supply to downstream users.

Low-lift Pumps (LLPs)
LLPs are common on most streams in the Basin and are used to draw water directly from the from river, from small impoundments created by cross-dams, and from the larger water retention projects. During field reconnaissance in October 1994 it was observed that there were about 5 pumps per kilometre in the Upper Kangsha River and 1 or 2 per kilometre downstream of Sarchapur. Pumped water supplies for irrigation have become common along Atrakhali Khal and inside the Dampara Project area. Each pump has a capacity in the order of 20 to 50 l/s and can supply an area of 5 to 10 ha. The total area irrigated by LLP is estimated by AST to be 10,000 ha.

Table 4.5 : Present Use of Streamflow For Irrigation

River Reach	Project	Irrigated Area (ha)
Malijhee-Marisi	10 cross-dams	1,500 ha (2,820 ha assumed in WRS design)
Chelakhali	4 cross-dams Chelakhali WRS (BWDB)	115 ha 1,200 (design figure)
Bhogai	LGED irrigation project: LLPs 3 cross-dams (gravity flow)	 709 ha 324 ha
Nitai	4 cross-dams	3,522 ha
Someswari/Shibganjdhala		minor
Atrakhali	9 cross-dams on 5 *charra* (small tributaries) from the Meghalaya Hills 32 LLPs are used on the main channel in 22 river-bank villages	1,227 ha assume 300 ha
Lengura	2 cross-dams	730 ha
Upper Kangsha	LLP's (estimated 30 from field reconnaissance)	assume 300 ha
Dampara (internal): Kalihar Nadi Balia Nadi Tutiar khal	 30 LLP LLPs 4 LLP	 300 ha 100 ha assume 40 ha
Lower Kangsha	LLP's	minor

Surface water sources are often used while they are available. Later in the season, when surface water sources are depleted, the farmers convert to groundwater sources.

Other Water Bodies
Beels and haors are used for irrigation supply through LLP and manual methods. This use reduces the area available for fish overwintering and for conservation of wetlands areas.

4.5 Development Potential

The above data indicate that most of the available dependable water supplies are presently developed for irrigation by projects located in the upper catchment. The present demand outstrips the dependable supply in many areas and there is little scope for further development of rice crops. There is considerable scope for conservation by using less water-intensive crops in the existing areas.

Surface water can continue to be used for supplemental irrigation to substitute for groundwater supplies when streamflows are higher.

4.6 Flooding

The Kangsha River and its tributaries are the source of flooding in the area. In the monsoon, rainfall occurs almost at the same time. As a result, the tributaries attain their peaks almost simultaneously and overload the Kangsha River. Consequently the Kangsha River spills over its banks and damages standing crops, homesteads, roads, and other infrastructure. The tributaries also spill out of their channels and cause flooding in adjacent areas.

Flash floods occur more than once a year as is illustrated in Figure 12. Generally flooding occurs during the monsoon season and damages to t. aman crops and delays transplanting. Often the crops are transplanted two or three times if they are damaged by floods. Late-winter or pre-monsoon floods can be more damaging due to flooding of boro crops during the harvest season. Early monsoon floods damage the mature aus rice.

Figure A.12 shows the depth and extent of the area flooded in 1991, a year of average floods (areas flooded by less than 0.5 m are not shown).

Figure A.13 depicts the nature and extent of flooding throughout the Basin. Flood hazard zones are discussed below:

Zone A: Piedmont Tributaries
The steep piedmont tributaries (Malijhee, Chelakhali, and Bhogai) spill over their banks and onto the adjacent piedmont plains. Spills cause damage to crops and deposition of sand and silt. Impacts tend to be localized as the piedmont areas are relatively steep and drain quickly after the flood. Roadways on the Chelakhali floodplain are sometimes overtopped and eroded due to insufficient culvert capacity to carry the overbank spills.

Embankments have been constructed to confine the overbank flows but they are breached regularly. The Chelakhali embankments are breached due to inadequate setback, erosion by the river, and aggradation in the embanked reach.

Zone B: Malijhee Floodplain
The boundary rivers spill onto the flatter and low-lying areas along the Malijhee River. Flooding is extensive and persists for several days or weeks at a time. T. aman and deepwater aman crops are heavily damaged and are not possible in parts of this area.

Zone C: Overbank Spills from the Bhogai River

Overbank spills cause damage to rice crops along Kodalia Khal and Gangina Khal and other low-lying areas. Local dikes are breached in many places and the Kodalia closure is cut by local people. The major problem is that the closure is some distance from the river. People living between the river and the closure are flooded and they cut the embankment to help alleviate the flooding. It is a highly emotional issue that pits neighbour against neighbour and has resulted in the death of at least two people (see sidebar - Battle of Kodalia Khal).

The problem can be solved by extending the existing Konapara embankment to cut off the overbank spills. The extension should be located nearer to the river bank.

Zone D: Backwater and Overbank spills from the Kangsha River

This area is affected by a combination of overbank spills from the Kangsha River and backwater flooding from the confluence of the Shibganjdhala River and the Kangsha River near Jaria. Some improvement in flood levels may occur as the Someswari River continues to shift into Atrakhali Khal, which will reduce the flood discharges in the Kangsha River. However, this change will take some time to materialize and cannot be assured.

The Konapara embankment was constructed to prevent spills from the Kangsha River onto the north floodplain. There are reports of drainage problems in the area lying to the north of the embankment which have not been confirmed in the field. Because the embankment has been cut in one or two places and has not been tied to high ground at its upstream end it is not completely effective. The project area needs to be kept open to the Kangsha

The Battle of Kodalia Khal

***Bundh* to shield the east**

In the beginning, Maulana Zohuruddin Talukder of village Amtail took an initiative to close *Kodalia Khal*. A small *bundh* (cross-dam) was built to protect monsoon crops in the eastern side.

Conflict chronicle

Conflicts arose when the low-lying area to the south of the closure was settled between 1910 and the 1950s. Flooding of crops in this area was blamed on the closure. The Phulpur-Haluaghat road, built in 1953/54, caused waterlogging in vast areas of Durail, Shingheswar, and Chhandhara unions. The affected people attempted to cut the *Kodalia bundh* to drain out water but the downstream people resisted.

The skirmish continued between these two rival groups. Periodically the people of the eastern side attempted to cut the dam. In 1966 there was a big fight, the *bundh* was cut, and one person was killed on the spot. *Kodalia khal* was closed in 1968, cut in 1972, closed again then cut in 1977, and closed in 1978. There was a violent encounter in 1983 in which one person from Jhaogora was abducted and killed. His body was thrown into a sack and was dumped into the river.

Transient truce

A committee was formed in August 1984 comprising representatives from each group. This committee decided to build a *down bridge* on *Kodalia khal*. However, *aman* crops were flooded in vast areas in the east in 1985-86 and the *down bridge* was washed away in the flood of 1987. The *Zila Parishad* started to rebuild *Kodalia bundh* in 1993 but the people of Durail union resisted and the work was abandoned.

Plight and politics

The battle of Kodalia Khal illustrates the passions that conflicts can generate. Persons who play an animated role in the debate have been elected Chairman or Member of the *Union Parishad*. Groups with conflicting interests are at loggerhead.

In 1994 the people from the eastern side of *Kodalia bundh* built another closure in Amtail. The people of Durail union say that they will cut the closure if there is a flood. The battle continues....

River at its downstream end to permit drainage from this area, and thus much of this area remains vulnerable to backwater flooding.

The south floodplain is affected by overbank spills from the Kangsha River and by backflows from the Kangsha River via Kalihar Khal. Conditions in the southeast portion of this area have been aggravated since 1990 by construction of the Kangsha Project which blocks the overland drainage to the southeast. This area lies within the Greater Dampara Project area for which a separate feasibility study is being conducted. Embankments are planned to close off the overbank spills and a regulator will be constructed at the outlet of Kalihar Khal to prevent the reverse flows. An existing regulator on the Balia Khal will also be rehabilitated to provide drainage from this area.

Zone E: Kangsha River Improvement Project (KRIP)
This zone is flooded by overbank spills from the Kangsha River even though it has embankments along the river. The road which serves as an embankment along the west side of the project area is overtopped by floodwater spilling from the Kangsha River into the Greater Dampara area. People living to the west of the road say that they will cut it to relieve their flooding if the road is not breached. Thus the success of the KRIP depends on extending the existing embankments upstream to close off the overbank spills.

Zone F: Backwater from the Sylhet Basin
Low-lying areas on the east side of the Basin are affected during the monsoon season by backwater from the Sylhet Basin. Flooding persists for most of the monsoon season and cannot be prevented. Pre-monsoon flood protection of boro rice crops is possible using submersible embankments.

Zone G: Someswari River and Lengura River
Flooding on the Someswari fan is complicated by the morphological activity that results in the river shifting its course from time to time and is causing major changes to the Shibganjdhala River and Atrakhali Khal.

For the past 30 years the Shibganjdhala River has been developing as the main channel and the Old Someswari River channel has been infilling. Recently, the locus of deposition has shifted upstream and water levels have been rising at Durgapur. These changes have led to the formation of a new channel, Atrakhali Khal, which has been growing since 1988 and is likely to become the main channel if it is not checked. This change will be accompanied by infilling and possible abandonment of the present main channel and the Old Someswari River.

The people living in the avulsion path are adaptive to changing environments. They are probably not equipped, however, to deal with a full-scale shift of the Someswari River and the increased flooding and sediment deposition that would occur along the Atrakhali. These processes will cause major increases in the flooding and sediment problems on the east side of the fan.

Interventions in the Someswari River are constrained by the huge volumes of sediment that are being carried in from India and are being deposited on the fan. It is not possible to confine the river permanently in one position. The Atrakhali is the most likely path of avulsion at present as the gradients are steepest in this direction.

4.7 Drainage

Basin drainage takes place from the north towards the south and southeast. The Kangsha River is the main drainage outlet for the northern area including cross-boundary inflows. Drainage from the southeast area is mainly effected through the Mogra River. Many of the smaller drainage channels have been silting in due to overbank spills during floods and large sediment loads in the piedmont streams.

Areas between the piedmont streams in the upper watershed are generally well drained. River channels are "perched" such that the overbank spills drain away from the river and return some distance downstream. Low-lying areas are affected by ponding of water spilled from the river channels during flash floods, but flooding persists for only one or two days at a time.

Low-lying areas in the Malijhee Depression are extensively flooded for days or weeks at a time due to ponding of flashy flood peaks from the piedmont streams. Spillage from the upper portions of the Bhogai, Chelakhali, and Malijhee Rivers collects in the Malijhee floodplain at the Bhogai-Malijhee confluence. Drainage is poor because the land slopes is shallow and beels and drainage channels have been filled in by deposition from the piedmont streams. Overbank spills to the north drain affect areas along Kodalia and Gangina Khals.

In the mid-basin areas between Sarchapur and Jaria the drainage is controlled by water levels in the Kangsha River and backwater conditions from the confluence of the Shibganjdhala River. Overbank spills occurring during floods contribute to drainage problems; many of the drainage channels on the floodplain have silted in. There have been complaints about drainage problems in some areas lying immediately to the north of Konapara embankment, suggesting that drainage regulators or other improvements need to be added.

Drainage from downstream area in the east side of the Basin is affected by backwater from the Sylhet Basin. The Kangsha River spills over both of its banks onto the floodplain at several locations. There are numerous small channels and beels in this area; many of them are silting in due to spills from the Someswari and Kangsha Rivers, especially near Birsidli.

The Someswari fan presently drains to the south via the Shibganjdhala River and toward the east along the Atrakhali River. Low-lying areas along these channels are affected by flooding and siltation from overbank spills.

4.8 River Morphology and Sedimentation

Kangsha River

The following brief comments are intended to highlight changes in channel stability and sedimentation processes along the river.

The Bhogai River, between the Indian border to Nalitabari is a steep piedmont stream (0.28 m/km), that is characterized by an irregularly meandering sand-bed channel that is incised into primarily sandy floodplain bank materials. The Bhogai River can probably be considered a "Transport Reach", meaning that over the long-term, the river is neither degrading or aggrading since it can transport all of the incoming sediment load. There is evidence of recent bank erosion and widening, possibly in response to the unusually high floods that have occurred in recent years.

Downstream of Nalitabari, the river's gradient flattens as the channel spills onto the Old Brahmaputra River floodplain and turns eastward. Rennell's map of 1768 shows no major channel in this reach, with the Bhogai River apparently occupying a channel several kilometres north of its present location. This suggests the reach below Nalitabari has formed relatively recently. Maps from 1955 show this reach had a tortuously meandering channel with frequent ox-bows and meander scars. Efforts to channelize the river in recent years have produced a second branch to the south of the 1955 channel[9]. This southern branch is less sinuous and appears to be capturing more of the flow. The banks are much lower in this reach than along the Bhogai River, which allows sediments to be stored overbank during spills. This feature, and the reduction in gradient below Nalitabari, suggests that this is a natural deposition zone. However, this long-term deposition process may be affected by other factors, particularly if one of these channels is abandoned and the other one becomes the major flow-carrying channel.

The dimensions of the channel and the tendency to meander increase noticeably just below Sarchapur, near the point where the Kharia River enters the Kangsha. The Kharia River is virtually completely silted-in and is morphologically inactive. However, according to the Rennell's survey, 200 years ago the Kharia was a major distributary channel of the Brahmaputra River. At that time the Kangsha River was a direct continuation of the Kharia River and displayed a similar channel pattern. Therefore, the present Kangsha River is occupying a former distributary spill channel which probably had a substantially different hydrologic regime than presently. The channel is probably still adjusting to this change, and appears to be very slowly reducing its size and slope by point bar accretion. The tortuous meander pattern and active formation of inner levees within a wide active floodplain are signs of this adjustment as the river forms a new channel that is approximately one-half the width of the original channel.

The Someswari River enters the Kangsha River through the Shibganjdhala channel, just upstream of Jaria Janjail. There has been an avulsion on the alluvial fan of the Someswari River during the last 30 years which has resulted in increased discharges and sediment loads along the Kangsha River. Prior to this avulsion, most water and sediment from the Someswari River did not enter the Kangsha River system; instead it flowed north of the Kangsha River and entered the Baulai River. This major channel shift has significantly altered the stability of the lower Kangsha River and its two main distributaries - the Ghulamkhali channel and the Dhonakhali channel. Sand deposition at the entrance to the Dhonakhali and lower Kangsha River has virtually blocked off these channels during the dry season and has caused more flow to be diverted into the Ghulamkhali channel. As a result, the Ghulamkhali channel has widened from a minor khal into the dominant river channel. This widening and degradation has added large volumes of sediment to the lower reaches, and this sediment is being deposited in the deeply flooded backwater zone as the Ghulamkhali approaches the Baulai River. This deposition is causing additional channel instability and aggradation near the junction with the Baulai River. These processes illustrate how some morphologic disturbances can propagate along a river system and cause additional channel shifting and sedimentation problems that are far removed from the point of the initial disturbance.

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[9] The south branch existed prior to 1955 but was not connected to the Bhogai River except through a minor channel. It is identified on topographic maps as the Malijhee River and appears to be a relic channel of the Malijhee River. It originally drained Putia Beel and the area south of the Bhogai River.

Someswari River

Sedimentation and channel instability associated with the Someswari River alluvial fan constitutes one of the most difficult flood control issues in the project area. Alluvial fans are formed when steep mountain streams exit from their canyons and spread over flatter unconfined lowlands. The decrease in channel gradient and reduction in velocity causes deposition of sand and gravel in the form of a fan shaped conical delta. Alluvial fans are characterized by sudden, irregular channel shifts which result in periodic abandonment of some channels and the creation of new channels across the fan surface. As a result, channel shifting on alluvial fans is usually unpredictable and erratic.

The alluvial fan of the Someswari River covers an area of approximately 138 km^2. The overall gradient on the fan is relatively low for an alluvial fan; 0.5 m/km between the fan apex at Bagmara and Durgapur and 0.15 m/km downstream of Durgapur. As a result, the land surface has been built up only a few metres (typically less than 3 m) above the surrounding low-lying floodplain and beels. Most land on the active fan lies between elevation 9 and 15 m PWD. Consequently, the lower portion of the fan is deeply inundated during the monsoon season by backwater from the Kangsha River (backwater extends upstream to near Durgapur).

Most of the channels on the fan are composed of uniform sand, with a median size ranging between 0.25 and 0.40 mm and maximum sizes ranging between 1 and 2 mm. Unlike other fans in the region there is virtually no gravel or cobble-sized material in the river-beds.

Figure A.14 shows past channel changes on the alluvial fan, based on maps from 1768 (Rennells' survey), 1952 (1:40,000 mapping from air photography), and 1989 (SPOT image). In 1768 a single channel of the Someswari River flowed southwards from its canyon mouth to the Kangsha River. East of the Someswari River Rennell's showed a large haor area (marked as "marshy lake" on Figure A.14). In 1952 the Someswari River flowed in a single braided channel which turned east into the Baulai River system. This channel is called "Old Someswari River" in this report. The presence of channel scars and abandoned channels on the east and west side of the fan suggests the river probably shifted at least two other times in the interval between 1768 and 1952.

Local inhabitants reported that a landslide occurred in the upper catchment in the early 1960s. The resulting channel deposition on the fan is believed to be responsible for the river shifting back towards the west and excavating a new channel to the Kangsha River in the early 1960s. This new channel is termed the Shibganjdhala channel in this report. Approximately 6 million m^3 of predominantly fine sand and silt-sized sediment was eroded during the course of this avulsion. Much of this sediment has been deposited overbank into low lying areas on the fan such as Sitli Beel.

The present-day Shibganjdhala channel has an incised width at bankfull stage of about 100 m; however, the river spills out of bank i0n many locations and is depositing lobes of sediment over a 3 km wide zone. These broad sandy deposits extend as far east as the Jaria - Durgapur highway and as far west as the low lying haors near Sitli Beel.

Two new avulsion paths have opened up since 1988 on the east side of the Someswari River; upstream of Durgapur near the fan apex. Local residents reported the Atrakhali channel developed after the 1988 flood when flow spilled through a minor distributary. Since then the channel has widened to approximately 60 m and has developed a permanent channel which flows eastward, through Rennells' "marshy lake", into a former course of the Old Someswari River

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channel. A second spill channel is evident approximately 1 km upstream of the Atrakhali channel. There is also evidence of recent sand deposition near the west side of the fan apex, which suggests the river may also have spilled towards the Nitai River system. These features suggest that the locus of deposition and channel avulsion may be progressing up the fan.

Table 4.6 : Estimated Annual Bed Material Loads (tonnes/year)

Year	Fan Apex	Mid-Fan	Kangsha River
1987	2,600,000	680,000	390,000
1988	3,600,000	1,300,000	510,000
1989	2,210,000	380,000	390,000

There has been a trend of aggradation in the Old Someswari River since 1960; specific gauge heights have risen by as much as two metres with the largest changes occurring in the floods of 1960, 1973, and 1988. During the same period the Shibganjdhala has degraded by approximately one metre, which occurred primarily between 1965 and 1975 probably in response to channel widening and incision following the avulsion. Since 1975 the Shibganjdhala River levels have been relatively stable and may be rising following the flood of 1988. Formation of the Atrakhali channel since 1988 is likely a factor in the recent aggradation in the Someswari River and Shibganjdhala channels.

Estimated annual bed material loads carried by the Someswari River at different locations of the Someswari fan is given in Table 4.6. It is estimated that virtually all (85%) of the incoming bed material load at Bagmara (Fan Apex) is deposited on the fan.

These estimates do not include the finer wash load (silt and sand finer than 0.15 mm) which is flushed through the Shibganjdhala channel into the Kangsha River. It is this finer sediment that is causing aggradation in the lower Kangsha River.

These features indicate that the pattern of flooding and channel shifting on the fan is very dynamic and is likely to continue. Bed material transport rates are very high. Most of the sand-sized sediments are presently being deposited on the fan, either within the existing channels or overbank in lower areas such as Sitli Beel, while the finer sand and silt are being carried downstream into the lower Kangsha River where they are deposited. These processes must be taken into account in the implementation of any works which are planned to control the flooding, sedimentation, or river avulsions on the fan.

4.9 Crop Damage

Floods from the tributaries damage boro and aus crops during the pre-monsoon season as well as deepwater and transplanted aman crops during the monsoon season. In response to a survey regarding the extent of crop damage around Phulpur[10], it was noted that significant (more than

10 / The People of Phulpur (Kangsha River Basin); A Monograph Prepared by the Social Anthropology Team, NERP, July 1993.

50%) damage was reported by more than 50% of the responding households[11] in seven of the nine years between 1983 and 1991. Only in one year (1987) was there no damage reported in any of the three cropping seasons (Kharif I, Kharif II, or Rabi) and in one year (1986) the reported damage was slight.

In general, throughout the Basin, high and late flood water occurs in the deepwater aman and transplanted aman fields when the crops are in their vegetative growth phase. The flash flood may occur more than once in a year damaging the re-transplanted aman. The damage is more severe when the flood occurs so late that farmers have no chance to re-transplant the crop. The aus is damaged by random flooding which can occur either at early or mature phases of the crop. The boro damage usually occurs when the crops are nearly or fully mature.

4.10 Water Bodies

Open water bodies
The Basin contains more than 600 ha of beels and 12,600 ha of rivers and channels. Sitli, Chinakuri, Koilakuri, Omriputi, Rajdhala, Pakish, Hoogla, Mohishaura, Mandharua, Pagli, Raipha, Aspat, and Baipha Beels are the major beels in the Basin. Of these beels, Sitli Beel in Durgapur thana is the most prominent. However, this beel is being infilled with sediment from the Someswari River which enters via Shibganjdhala.

There is a good network of rivers and channels in the area. Kangsha and Someswari are the most prominent rivers.

Closed water bodies
In addition to open water bodies, there are about 24,000 ponds and ditches in the Basin used for fish stocking and other household purposes. The ponds cover a total area estimated at 2,500 ha. The highest concentration of ponds is in Kalmakanda thana (10 per km^2).

A general problem for pond aquaculture in this area is that flash floods annually inundate most of the ponds which discourages people from investing in intensive pond aquaculture systems.

11/ Boro was damaged in one year, aman was damaged in four years, and aus was damaged in two years.

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5. GROUNDWATER RESOURCES

The area is blessed with abundant groundwater resource owing to its heavy rainfalls and favourable soil conditions which contribute to high recharge of groundwater. Transmissivities and specific yields are generally good to excellent in most of the Basin, although the lithologic composition of the aquifers is complex and highly variable. Consequently, the area has a high rate of groundwater development and use for irrigation relative to the rest of the region and Bangladesh generally.

Groundwater is used extensively for irrigation in the Basin; on about one-half of the irrigable land or 40% of the gross area. Demands on the groundwater resource will increase since there is little surface water available during lean periods.

A detailed analysis of groundwater availability, present use, and development potential is provided in Annex E. The salient points and a discussion of the pertinent issues follows.

5.1 Groundwater Table

Groundwater levels vary seasonally and are lowest during the dry season. They recover to near the ground surface during the monsoon season provided that dry-season extraction for irrigation does not exceed the monsoon-season recharge.

Figure A.15 shows the maximum depth of the groundwater table in the dry season of 1995. The groundwater level is deepest in the northwest, where ground elevations are highest.

5.2 Maximum Sustainable Yield

The potential recharge rate is the maximum amount of recharge that can occur for given conditions of rainfall and permeability of soils.

Table 5.1 shows the estimated thana-wise potential recharge in the Basin, computed using the groundwater recharge model.

The average potential recharge over the Basin is 625 mm per year. Regional differences reflect the variations in rainfall and infiltration rates of the soil.

Table 5.1 : Potential and Usable Recharge in Kangsha River Basin

Thana	Potential Recharge (mm/yr)	Useable Recharge (mm/yr)
Jhinaighati	523	392
Nalitabari	500	375
Haluaghat	550	413
Duboura	725	544
Durgapur	600	450
Sribardi	663	497
Sherpur	710	538
Nakla	675	506
Phulpur	800	600
Purbadhala	800	600
Netrokona	792	594
Barhatta	933	700
Kalmakanda	729	547

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WARPO has adopted the concept of "usable recharge" which was defined as 75 percent of the potential recharge, leaving a safety factor to allow for uncertainties in the groundwater model and its input data. Usable recharge in the Kangsha Basin is 1,133 Mm^3 (million cubic metres), which is equivalent to 490 mm if spread over the entire Basin.

Flood control reduces the recharge slightly by reducing the area of flooded land. Model simulations indicate that the potential reduction is about 10 percent, varying from 2 percent in Nalitabari thana to 34 percent in Sribordi thana.

5.3 Resource Availability

The available groundwater resource is the portion of the annual recharge which can be abstracted using a given pump technology. Shallow-tube wells (STWs) and deepset shallow-tube wells (DSSTWs) have the lowest lift capacity (7 m and 9 m respectively) and therefore have the lowest "available recharge". Their pumps that are set at or near the ground surface and operate by suction mode. Deep tube wells (DTWs), on the other hand, use force mode pumps that can operate at depths of 20 m or more and theoretically have the capacity to use the entire resource.

Groundwater abstraction is further constrained by the need to protect the HTWs that are used for domestic water supply. The most common is the No. 6 pump which typically draws water from the surface aquifer and has a lift capacity of only 6 m. With the increasing use of groundwater for irrigation, many of the wells equipped with No. 6 pumps, in some areas, run dry during the irrigation season. They will need to be replaced with Tara pumps that can abstract water to 15 metres deep. Approximately 11,000 domestic wells in the Basin are equipped with No. 6 pumps and 2,000 wells are equipped with Tara pumps.

Estimates of the available recharge are provided in Table 5.2 for the different pumping technologies. The limits to permissible abstraction, based on the lift capacity of domestic wells, are also shown. For comparison the irrigation duty, which is the amount of water that is required for irrigation in one season, is also shown for each thana. The table shows that the recharge available to STWs is about 50 to 100 mm of water per year (10 to 20% of the potential recharge). DTWs can abstract typically between 300 and 600 mm/yr depending on the location. Available recharge is highest in the Old Brahmaputra formation which occurs in the southwest and central portions of the Basin, and are lowest in the northern areas where groundwater levels are quite deep. Available recharge is also lower in the eastern side due to the impermeability of soils in this region.

The estimated irrigation requirement per hectare (irrigation "duty") is also provided in Table 5.2. Comparison with the estimates of available recharge reveals that the available resource is sufficient to irrigate between 50 and 70% of the gross area lying in the Piedmont thanas (provided it is economically feasible) and almost 100% of the area lying in the Old Brahmaputra floodplain. These estimates assume that groundwater levels can be allowed to be lowered to 15 m in parts of the Basin; the limits of Tara pump capability.

Table 5.2 : Available Groundwater Resource and Irrigation Duty in the Basin

Thana	Irrigation Duty (mm/yr)	Available Recharge to the Technology (mm/yr)				HTW Constraints (mm/yr)	
		STW (14 l/s)	DSSTW (14 l/s)	DTW2 (56 l/s)	DTW1 (28 l/s)	No. 6 pumps	Tara Pumps
Piedmont Plain:							
Jhenaighati	588	51	90	333	392	51	247
Nalitabari	588	71	113	368	375	71	375
Haluaghat	676	78	124	413	413	78	413
Dhobaura	595	49	98	256	468	49	375
Durgapur	595	95	135	410	450	95	329
Brahamaputra Floodplain:							
Sribardi	613	134	209	497	497	134	497
Sherpur	649	258	387	538	538	258	538
Nakla	625	385	506	506	506	385	506
Phulpur	592	120	192	600	600	120	600
Purbadhala	671	126	240	600	600	126	600
Netrokona	704	95	190	594	594	95	594
Sylhet Basin:							
Barhatta	602	35	77	196	406	35	373
Kalmakanda	606	38	109	323	547	38	547

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5.4 Present Use

Groundwater is used in the Kangsha Basin for irrigation water supply as well as domestic purposes (drinking water) and limited industrial use. Irrigation use is by far the majority, representing 85% of the total groundwater use.

About 75,000 ha are presently under irrigation, one-third of the total Basin area, of which 55,000 ha are supplied from groundwater. The limited amount of surface water available makes groundwater the prime source for future expansion of irrigation. Table 5.3 provides a breakdown by thana using 1992/93 AST census data.

Table 5.3 : Present Irrigation Development (1992-1993 data)

Thana	From Groundwater (ha)	From Surface Water (ha)		Total Irrigated Area (ha)
		LLP	Traditional Methods	
Piedmont Plain:				
Jhenaighati	3,462	777	3,153	7,391
Nalitabari	7,930	2,507	577	11,014
Haluaghat	8,925	1,164	1,148	11,237
Dhubaura	3,337	1,119	1,724	6,180
Durgapur	4,370	932	970	6,272
Brahmaputra Floodplain:				
Sribordi	1,206	10	69	1,285
Sherpur	3,377	3	116	3,495
Nakla	3,130	81	244	3,456
Phulpur	4,037	111	166	4,314
Purbadhala	4,175	1,162	329	5,667
Netrokona	2,136	909	524	3,569
Sylhet Basin:				
Barhatta	349	198	328	874
Kalmakanda	2,271	1,557	311	4,139
Basin Total	48,705	10,531	9,658	68,894

Source : AST

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Table 5.4 : Development Trend of Minor Irrigation in the Basin

Census year	Number of wells			
	STWs	DSSTWs	DTWs	MTWs
1990-91	5,208	99	819	2,943
1992-93	6,439	60	900	2,589
Change in no	+1,231	-39	+81	-354
Change in %	+24%	-40%	+10%	-12%

Source : AST census 1991 and 1993 adjusted to basin boundaries
MTW = manual tube well

Table 5.4 shows the number and type of pumps in operation in the basin between 1990 and 1993. In most places the seasonal groundwater levels are still within the limits of STWs. There is little sign of large-scale conversion to DSSTWs or DTWs. DTWs are being used in various areas but predominate in the northern area and are an indication that withdrawals have more-or-less reached the limits of STW's in places.

The present annual use for irrigation is estimated to be 419 Mm^3 based on the present cropping pattern and irrigation duty as summarized above. Domestic and industrial uses account for an additional 24 Mm^3 per year.

5.5 Potential for Development

Table 5.5 summarizes the groundwater resource available for development. The total available groundwater resource is estimated to be 934 Mm^3 assuming that groundwater levels can be drawn seasonally to a depth of 15 m, the limiting capacity of the Tara pumps used for domestic water supply. Of this, 50 Mm^3 is reserved for domestic and industrial uses (to Year 2015 expansion), which leaves 884 Mm^3 for irrigation. At present there are about 67,000 ha under groundwater irrigation which uses 419 Mm^3 per year, leaving a balance of 465 Mm^3 available for future expansion of agriculture, sufficient to irrigate about 77,440 ha of land.

Thanas lying to the north have lower development potential because of the greater depth to groundwater table and the constraints required to protect domestic groundwater supplies; there the available recharge is only 50 to 70% of what would be required for full development. Development of groundwater wells is also more expensive in this area and the soils are more pervious and not conducive to efficient irrigation. It is expected that these constraints will impose significant limits to irrigation development in this zone. The available groundwater resource would be better used for high-value, lower water-use crops in this region.

Table 5.5 : Net Groundwater Resources Available for Future Development

Resources	Mm3
a) Constrained maximum Groundwater Available	934
b) Reserved for Domestic and Industrial use	50
c) Available for irrigation	884
d) Present (1994-95) use in Agriculture	419
e) Net Available for Future Development	465

Note:
a) Constrained to prevent groundwater levels more than 15 m below ground surface based on the limit for Tara pumps
b) Year 2015 forecast
c) = a) minus b)
d) Crop demand for present irrigation coverage (67,000 ha) under present cropping pattern.
e) = c) minus d)

The thanas located on the Old Brahmaputra floodplain have significant potential for further development by DTW's or alternative technology. In places this will result in lowering of groundwater tables below the lift capacity of the No. 6 pumps used for domestic water supply.

5.6 Groundwater Quality

The presently available analytical data is insufficient to produce a meaningful picture of the groundwater quality in the Kangsha Basin. Only a few samples of groundwater quality have been taken. These include a few samples taken by BWDB from 1979 to 1983 which are considered outdated. Two more recent samples were collected by BWDB in Netrokona thana.

Based on the limited sampling there do not appear to be any serious problems. The water quality falls well within the acceptable range for drinking water standards of the Environmental Pollution Control Board, Bangladesh (EPCB), and World Health Organization (WHO).

In-situ measurements of iron content are generally not available and the reported data can only be regarded as indicative. The total iron content value of the groundwater is likely to vary in the ranges from the high value of 10 mg/l in Sherpur thana, within the Brahmaputra plain to less than 1.5 mg/l in the rest of the Basin. The standard value is in the range of 1-5 mg/l.

Nitrate is present in trace to negligible amounts. The increased use of high nitrogen fertilizers for HYV Boro rice crops may result in contamination of the groundwater. Although beneficial in irrigation water, values higher than 50 mg/l may be detrimental to human health. SAR (Sodium Absorption Ratio) values, essential for assessing the suitability or water for irrigation purposes are not available.

Of major concern is the quality of drinking water which is drawn from hand dug or shallow hand tube wells. Due to poor sanitary conditions the water in this zone is subject to bacterial contamination (E-Coli) and may present serious health hazards in some areas. The critical areas are those where the No. 6 HTW, with its limited 6-metre suction capacity, is unable to reach the lower aquifer. These same wells are also the first to run dry during the irrigation season.

5.7 Domestic Water Supply

Hand tube wells (HTWs) are the main source of drinking water, serving more than 90% of the households. Three percent of households use pond water. Piped water facilities are available only on a limited basis in core administrative zones of thana headquarters; where government offices are located.

There are 113 persons per operational tube well within the rural areas of the Basin (Table 5.6). This ratio is slightly lower (better) than the Northeast Region and the country as a whole. Most HTWs are shallow and are therefore vulnerable to contamination and over-extraction of groundwater for irrigation. About half of the tube wells are privately owned.[12]

Table 5.6 : Status of Rural Water Supply, 1991/92

District/ Region	Number of TW		% operational	Population per TW*	
	Total	Operational		Total	Operational
Sherpur**	9,962	9,688	97.3	114	117
Mymensingh**	34,009	32,030	94.2	116	123
Netrokona**	16,626	16,181	97.3	104	106
Total	60,597	57,899	95.5	113	118
NE Region	203,255	194,289	95.6	120	125
Bangladesh	857,790	817,244	95.3	123	130

Source: DPHE

* Population estimates are based on 1991 census.
** Figures correspond to whole districts, part of which lie outside the Basin boundaries.

[12] Mitra and Associates: The 1991 National Survey on Status of Rural Water Supply and Sanitation for DPHE/UNICEF, Dhaka, 1992.

5.8 Issues Arising from Irrigation Development

Development Potential

There is significant potential for further development of irrigation for groundwater, particularly in the southern and central portions of the Basin. In general, this can only be accomplished by adoption of DTW or other high-lift technologies capable of extracting groundwater from depths of 14 to 15 metres. STWs have a suction lift capability of 7 m and they may need to be replaced with higher-lift technologies if further development occurs.

In the Brahmaputra Floodplain formation, where groundwater is close to the surface and saturation development of STWs has occurred, it may be possible to preserve the use of the suction mode technology via a system of zonal groundwater development. Such zoning would restrict development of groundwater for STWs to areas where this technology is adequate and able to cover the crop duty and required command area.

The estimates made in this study are based on a regional scale of analysis. Local conditions must be considered during implementation of any development program. The onus now lies in the private sector since development of the groundwater resource has been privatized.

Mixed-mode Technology

To some extent the potential for depleting the available groundwater resource is self-limiting provided that one type of pump/well technology is used. This is less the case with DTW's that will be more extensively used for further development of groundwater and may result in lowering of the water levels below the lift capacity of existing STWs. However, the impacts will be localized in the sense that they will primarily affect the users in the immediate area, thus providing a natural constraint to development. Therefore the role of government may continue to be one of monitoring and providing technical guidance and leadership.

Preliminary investigations indicate that tube wells are being added inside existing command areas without reducing the amount of irrigation water supplied by each well. This is the result of fragmented land ownership and socio-economic conditions.

Domestic Water Supplies

Introduction of such new technology will further aggravate the domestic water supply situation by increasing drawdown of groundwater levels. The traditional No. 6 HTWs, already under strain in many areas, would no longer be able to reach the water table in many places. The lift capacity of the various types of pumps is shown in Table 5.7.

Table 5.7 : Lift Capacity of Hand Pumps

Hand Pump Type	Lift Capacity
No. 6	<=6 m
Marginal Tara	6 m -8 m
Tara	8 m - 15 m
Marginal Super Tara	15 m -16 m
Super Tara	>16 m

Source : UNICEF, June 1994

UNICEF has concluded that Tara pumps would be required in about half of the thanas by the Year 2015 based on projected expansion of groundwater uses to the end of that period. Table 5.8

provides a thana-by-thana summary.

Industrial and Domestic Uses
Capacity must be reserved for domestic and industrial needs. These needs are, however, less than 5% of the available groundwater resource. Urban areas of Sherpur and Netrokona have a significant piped water system supplied from groundwater. Based on projections to Year 2015 the groundwater levels would be lowered locally to about 10 m below ground surface. Areas within these urban areas that are not supplied from the piped system will need to have Tara pumps to ensure adequate water supply.

Monitoring
Careful monitoring of the groundwater levels will be required to ensure that problems do not occur. The current groundwater observation network is not sufficient to provide reliable data regarding the fluctuations in the water table caused by both natural losses and abstraction for irrigation purposes. Since siting of new wells is unlikely to be proceeded by hydrogeological investigations, more careful monitoring is required and the results should be made available to the private sector well-drillers.

Table 5.8 : Future Tubewell Requirements for Rural Potable Water Supply

Thana	Recommended Technology for Rural water supply	
	Upper Aquifer	Lower Aquifer
Sribordi	Tara	Tara
Jhinaigati	Marginal Super Tara	Tara
Sherpur	Marginal Tara	Marginal Tara
Nalitabari	Tara	Tara
Nakla	No. 6	No. 6
Haluaghat	Tara	Super Tara
Phulpur	Tara	Tara
Durgapur	Tara	Super Tara
Dhubarra	Tara	Marginal Super Tara
Kalmakanda	Tara	Tara
Purbadhala	Tara	Tara
Netrokona	Tara	Tara
Barhatta	Super Tara	Super Tara

6. WILDLIFE AND VEGETATION RESOURCES

6.1 Terrestrial Habitat

The terrestrial habitats include forest and afforested areas, grasslands, and homestead forests.

Forests
At one time the Basin area was completely covered by moist deciduous forest. Human encroachment has since reduced the forest area to a small belt that lies along the foot of the Garo Hills of India. Since 1956 all the forests in the Basin remain vested in government ownership as Acquired Forest.

Table 6.1 provides a summary of the present-day forest cover in the Basin. There are a total of 5,800 ha administered under the Mymensingh Forest Division.

Afforested Areas
Forest areas, degraded and encroached, have been brought under the people participated forestry program. Under this program several exotic species are mostly planted, such as Eucalyptus sp. and Cassia sp.

Grassland
The Basin used to support vast tracts of localized grassland comprised of *chon*, *ikor*, etc. These were favourite spots for hunting a wide variety of game and birds. These have mostly been replaced by cultivable land. Only small patches of grassland remain in fallow land and on the banks of the major rivers. Grasses from these areas are commercially used for thatching and fencing purposes and they also support specialized fauna and flora.

Homestead Forest
Homestead vegetation is an important plant community, both for its diversity and its economic output. The community includes two types of plants: those which are cultivated for their economic value and those which are self-propagating.

Homestead forests play an important role in providing cover and shelter to many wildlife species. They also supplement the daily fuel need and presently occupy more area than the reserved forests owned by the government. The homesteads are not as diverse as the forests since the people tend to plant only the economically important and more useful species.

According to land use surveys, about 8 percent (18,000 ha) of the total area of

Table 6.1 : Forest Cover in the Basin

Forestry Beat	Primary Forest Cover	Area (ha)
Rangtia	High Forest	405
Gazni	Coppice	1383
Tawakucha	Encroached land	774
Sandhakura	Rubber Plantations	405
Someshchura	Social Afforestation and Agro-forestry	1671
Bathkuchi		
Durgapur Independent Beat		1194

(Source: Range Office, Rangtia)

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the Basin is under homestead settlement. About 70% of this area (12,600 ha) is vegetated with various trees and shrubs.

Cropland and Open Woodland
The edges of the cultivated fields provide a small but important cover for smaller animals. Solitary trees or shrubs amidst the vast tracts of cropland provide perching and roosting surface to raptors and other insectivorous birds.

6.2 Aquatic Habitat

Since the project is situated in the seasonally flooded area, the wetlands are characteristically seasonally flooded. Most of the wetlands are flat and shallow containing some small deep pockets (beels) which retain water perennially. The total area of these perennial beels is about 3000 ha, which is a very small fraction of the monsoon wetland.

The ecological characteristics of the wetlands in this area vary according to their location. The entire northern belt is highland and the wetlands located in this area are all seasonal. The larger perennial wetlands are located in the eastern part of the project. Other major perennial wetlands are located at the confluence of the Malijhee and Bhogai Rivers.

Permanent Wetlands (Beels)
Beels are areas which remain under water throughout the year. The Basin has only a few wetlands, about 30, of this nature. All of them have shrunk tremendously because of increasing demand for cultivated land. Most are quite small - only Rajdhala Beel near Purbadhala is of moderate size. All are important habitat and overwintering areas for fish.

Seasonal Wetlands
The Basin mostly supports seasonal wetlands which are inundated for part of the year, usually for two to three months. Most are drained and used for agriculture in the dry season but are replenished by rainfall and over-bank spills from the rivers during the monsoon season. These beels play an important role in fish production and floral and faunal diversity.

Rivers and Canals
The Basin has several important rivers which provide a significant habitat for aquatic biological resources, most important of which is the fishery. High water during the monsoon season facilitates the movements of aquatic mammal such as the Gangetic Dolphin and freshwater turtles. The rivers dry out during the dry season except for deeper sections or scour holes called *duars*, thus hampering the movement and breeding of many water-dependent faunal species and exposing them to human and natural predators.

Fish Artificial Ponds
Fish ponds within the homesteads retain water throughout the year and are vital for the aquatic and water-dependent wildlife. Usually the ponds are surrounded by good marginal vegetation which provides shelter to water-dependent species.

6.3 Wetland Vegetation

Because the wetlands are flat and shallow, they support a large number of aquatic plants in the monsoon, particularly submerged and rooted floating plants. The most common plants are

Hydrilla verticillata, Nymphaea, Aponogeton and Otellia alismoide. Various species of grasses are found in these areas although there are no high grasses such as reeds.

Compared with other major natural forms of landscape, wetlands are young and dynamic. They change as vegetation changes, sediments are laid down, or land sinks. Due to continuous submergence, wetland habitat is characterized by anaerobic condition which inhibits normal plant growth. Wetlands are colonized by a group of plants known as hydrophytes which have adapted to such extreme habitat conditions.

Depending on the hydrological conditions these landscapes form distinct habitats for both plants and animals. Wetland conditions range from virtually perennial aquatic lowlands to seasonally dry uplands. Vegetation consists of a large number of plant species. In natural condition these habitat patterns change very slowly, but long and persistent human interventions have modified these landscapes and their hydrology.

There are four wetland plant communities in the Basin, classified with the basis of their adaptation to water and preferences for habitat: submerged, free floating, rooted floating, and sedge meadows.

Submerged

This type of vegetation remain fully submerged except for its flower for its whole life cycle. These plants are highly susceptible to seasonal fluctuation of water level because they need water for their survival and regeneration. Their composition differs from place to place. Some of the frequent species are, Hydrilla verticillata, Najas sp., Ottelia alismoides, Vallisnaria spiralis and Aponogeton sp.

Free floating

Free floating plants are most commonly found floating freely on and collecting nutrients from the water. Most of them can also survive for a certain period with their roots on or in moist soil. They are among the dominant plant communities in the area with species like Eichhornia crassipes, Utricularia sp. and Salvinia sp. being the most abundant.

Rooted floating

These plants root deeply in the soil while their leaves and flowers float on the water surface. To accomplish this, most plants have very long stalks. This community is common in the area. Community composition differs sharply from one beel to another, although Nymphaea stellata, N. nouchali, Nymphoides cristatum, and N. indicum are found more or less in almost all the beels. Species like Nelumbo nucifera and Trapa are found only in the deeper beels at Purbadhala thana.

Sedges and meadows

These are amphibian plants having leaves exposed to the air and roots remaining under water. Inundation and desiccation are tolerated to some degree. This community has the greatest diversity of species and in this sense it is one of the most important wetland plant communities in the area. Generally this vegetation type occupies the water margin.

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6.4 Fauna

The Upper Kangsha Basin supports at least 265 species of amphibians, reptiles, birds, and mammals and innumerable species of invertebrates, notably insects and molluscs. Over 100 of these species are aquatic or partially aquatic. Table 6.2 provides a summary of these species.

Amphibians
A total of eight species of frogs and toads are known to occur in the Basin. All the species are directly dependent on the availability of water for breeding. All the amphibians eat insects, many of which are pests to crops.

Export of froglegs was banned in 1993, but is still conducted clandestinely under different names. Smaller ones are used as bait to catch large carnivorous fish.

Turtles
At least eight species of turtles are known to occur within the project area. Seven of them are dependent on the freshwater wetlands.

Turtles are consumed by the tribal people (Garos, Hajangs) living along the northern boundary of the project area. Turtle shell and turtle oil is used by the local people for medicinal purposes and are of commercial importance. Turtles also help to control the snail population, some of which carry diseases that affect cattle and human beings.

Populations have declined markedly because of over-exploitation and loss of wetlands.

A number of species are included in the CITES (Convention on International Trade on Endangered Species of Flora & Fauna) which prohibits trade and requires monitoring. The GOB is a signatory to this convention.

Table 6.2 : Species of Fauna in the Basin

Major Animal Groups	Aquatic Species		Terrestrial Species			Total Number of Species
	Totally	Partially	Forest	Homestead	Grassland	
Amphibians	7	-	1	-	-	8
Turtles	7	-	1	-	-	8
Lizards	-	3	1	2	1	7
Snakes	5	3	8	3	-	19
Aves (Birds)	48	29	35	54	26	192
Mammals	1	-	10	19	1	31
TOTAL	**68**	**36**	**55**	**78**	**28**	**265**

Lizards

There are seven species of lizards including monitor lizards Varanus bengalenso (*kalo gui*) and *V. flavescens* (halud gui), which are well known for their commercial importance. They are widely exported although such export has been illegal since 1977 and since signing of the CITES convention in 1982. They are used locally for making fancy leather products like bags, belts, shoes, etc.

Some collection continues because local people are not fully aware that the Varanus is protected under the law. It is not possible to say how many skins are procured from within the project area.

The monitor lizards are omnivorous and scavengers. They feed on rats, snake eggs, and small birds and scavenge dead animal matter and wastes. Thus they play a vital role in controlling rodent population and in helping to control the spread of disease. They do, however, prey on young chicken and ducklings. All other lizards are insect-eaters.

Snakes

The project area supports at least 19 species of snakes, of which 4 species are poisonous. Eight species are dependent on aquatic and water-dependent habitats.

Snakes occupy an important niche in the ecosystem. Snakes are well known to control the rodent population and they also form the diet of other predators. Snakes are very secretive animals but are often found around homesteads because that is where their natural food, rodents, are usually found. People kill them on sight due to ignorance, fear, and hatred. Snake skins have a great demand in the international market and for making handicraft and fancy goods. Venom from the poisonous snakes is also in demand by some pharmaceutical companies, mostly for medical research.

Birds

The project area supports at least 104 species of resident and 88 species of migratory birds. Seventy-seven species are dependent on wetlands and water-dependent habitats. Because the wetlands are small in area, fragmented and have a high level of human activity, the waterfowl concentration is low and other forms of wildlife are not common.

The resident species, which represent 40% of the avian fauna, are most vulnerable to the increasing rate of habitat destruction and human disturbance. Various species have either emigrated or have become locally extinct. These include Little Grebe (*duburi*), Lesser Adjudant Stork (*modontak*), Cotton Teal (*badi hans*), Spotbill Duck (*patihans*), Pallas's Fish Eagle (*kura baj*), Greyheaded Fish Eagle (*kural*), Purple Swamphen (*kalim*), Pheasant-tailed Jacana (*jal pipi*), etc. The project basin area supports some of the globally endangered and threatened bird species like Adjutant Stork and Pallas's Fish Eagle.

Mammals

There are at least 31 mammalian species within the Basin. Survival is difficult due to degradation of habitat and hostile attitude from the general public.

There is only one freshwater aquatic mammal, Gangetic Dolphin (Platanista gangetica, *shusuk*). It is estimated that there are only 5 dolphins resident within the Basin but more dolphins visit the y2

area from other river systems during the monsoon season when the river level is higher. The existing population within the Basin is not viable and is under serious threat. Much of the dolphins' range has degraded drastically due to accumulation of silt and increases in turbidity and suspended materials in most of the rivers.

The area supports some mammalian species which are listed in the RDB and CITES Schedules for reasons of their rarity and commercial importance. Most of these species are carnivorous and nocturnal in nature and inhabit forests or areas with dense vegetation. These species have become more secretive and many have emigrated in search of better habitat and food.

Many of the mammals depend directly on water for food, water, and survival. Changes in the water regime or in the wetland ecosystem therefore affect these mammals directly.

7. AGRICULTURE

7.1 Agroclimate

The cropping year can be broadly divided into three periods, Kharif I, Kharif II, and Rabi, corresponding roughly with the pre-monsoon, monsoon, and dry seasons. The *kharif* growing period generally extends from the beginning of April to mid-December. The *rabi* growing period extends from the end of October to the beginning of March.

Kharif I occurs from the end of March to June. Rainfall is variable - both drought and flash flooding can occur. Aus is the primary crop. Deepwater aman is also planted in the Kharif I season but has a longer growth period and is harvested in the Kharif II season.

Kharif II, from July to October, is the monsoon season. High humidity, heavy rainfall, and widespread flooding occur. The major crop is transplanted aman.

The rabi season, from late October to March, is characterized by low rainfall, high solar radiation, and lower temperatures. These conditions are very favourable for high yields but most crops require irrigation during this season. Boro rice is the main crop; local boro in the lower areas and HYV boro in higher areas where drainage is better. A wide variety of vegetables and other non-rice crops are also grown; these crops require 250 mm of soil moisture supply compared with about 600 mm for rice.

A generalized crop calendar for the Basin, showing the cropping season of each crop, is provided in Figure A.16. Soil moisture mainly determines the growth of crops. Temperatures are suitable for cultivation and growth of crops throughout the year.

7.2 Crop Areas

The total crop area in the Basin is 225,800 ha, giving an average crop intensity (ratio of total crop area to net cultivated area) of 1.5. Rice is the dominant crop representing more than 85% of the total cropped area. Jute and oilseeds are the largest of the non-rice crops and together account for about 6% of the total area.

7.3 Cropping Pattern

Cropping patterns are determined by:

- physical factors including topography in relation to flooding, flooding characteristics, climate, availability of moisture and irrigation water, length of the growing season, availability of inputs;
- biological factors such as growth duration of crops, varietal characteristics, availability of draft power, food habits, incidence of pest and diseases;
- socio-economic factors such as financial resources and availability of labour and credit.

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The general cropping pattern in the Basin is shown in Figure A.17 based on the work of SRDI and NERP's field studies. The lower portions of the Basin which are most deeply flooded predominately have one crop, boro, which is grown in the winter season. Medium-high lands have two crops, usually t. aman in conjunction with boro or aus. The highest parts of the Basin have aus often in conjunction with vegetables and other non-rice crops.

A summary of the typical cropping patterns in various areas is given below:

High ridges
Permeable soils on high ridges are favourable for aus rice, jute, sugarcane, groundnut, pulse and oilseeds under rainfed conditions. Wheat, potato, winter vegetables, spices and tobacco grow well with irrigation.

Highland and medium highland soils
Aus or jute, followed by t. aman and then pulse or wheat, is grown in some areas. High-yielding varieties of aus and t. aman grow well in rainfed conditions. HYV boro is grown with irrigation in the dry season.

Medium lowland soils
Rainfed aus, deepwater aman, jute, and irrigated HYV boro grow well on medium lowland soils.

Lowland soils
Deepwater aman, pulse, oilseed, and wheat are grown on lowland basins soils under rainfed conditions, and HYV boro is grown with irrigation in higher margins. In low-lying parts, the physical and hydrological characteristics of soils are favourable for only local boro.

Hills
Hill areas are mainly under scrub thicket, grassland, or bamboo. A small area is under forest. Crops such as t. aman, aus, and various non-rice crops are grown on a limited basis and are mostly rain-fed. Tribal people in the northern part of Mymensingh district grow cassava. Different forms of agro-forestry are practised in home gardens and boundary plantings.

7.4 Flood Regime

Flood regime mainly determines the cropping pattern. A summary of crops according to prevailing flood conditions is provided in Table 7.1.

Table 7.1 : Distribution of Major Crop Area by Land Types

Crop	Crop Area (ha)					
	F0	F1	F2	F3	F4	Total
Local Aus	19,000	12,000	3,100			34,100
HYV Aus	2,100	900				3,000
B Aman				800		800
LT Aman	34,300	36,500	3,900	2,500		77,200
HYV Aman	8,700	3,500	700			12,900
Local Boro		400	1,900	9,800	100	12,200
HYV Boro	11,500	15,700	20,900	3,400		51,500
Wheat	1,500	1,200	300	100		3,100
Potato	300	900	200	1,700		3,100
Jute	4,000	3,900	700			8,600
Sugarcane	200					200
Pulses	700	1,400	600	400		3,100
Oilseeds	1,900	1,900	900	1,100		5,800
Spices	1,400	800	200			2,400
Minor (winter vegetables, tobacco etc)	2,100	3,900	300			6,300
Orchard	1,200	200	100			1,500
Total Cropped Area	**88,900**	**83,200**	**3,380**	**19,800**	**100**	**225,800**
Net Cultivated Land	**59,100**	**41,400**	**29,300**	**19,400**	**100**	**149,300**
Crop Intensity	**1.5**	**2.0**	**1.2**	**1.0**	**1.0**	**1.5**

7.5 Irrigation

One third of the total crop area, or 75,000 ha, is irrigated. Most of this is for boro cultivation (64,000 ha) and other rabi crops. All of the boro is irrigated as are three-quarters of the wheat and sugarcane.

A summary of irrigation usage by various crops is provided in Table 7.2.

Most irrigation is from groundwater using tube wells, which accounts for 59% of the total irrigated area. About 25% is irrigated by LLP from surface water sources. Traditional methods (swing baskets and *doons*) and canals are mostly used in beel areas and represent about 14% and 2% of the irrigated area respectively. A summary of irrigated areas by source of water is provided in Table 7.3.

Table 7.2 : Irrigated Area by Type of Crop

Crop	Area (ha)	Percent Irrigated
Aus	1019	2.7
Aman	1406	1.6
Boro	63655	100.0
Wheat	2340	74.6
Potato	694	24.8
Vegetables	835	17.4
Sugarcane	177	71.7
Spice	947	39.6
Other	4130	19.8

7.6 Input Use

Primary inputs to agricultural production in the Basin are:

Seeds:	12,000 tons
Fertilizer:	38,100 tons urea (nitrogen)
	9,300 tons TSP (phosphate)
	1,900 tons MP (potash)
	400 tons others
Pesticides:	82 tons

Most of the fertilizers and pesticides are used for HYV boro rice. About 8% percent of the total crop area is treated with insecticides and 1.2% with fungicides.

7.7 Crop Production

Crop areas and the annual production of each crop are summarized in Table 7.4. Rice is the main crop, representing almost 85% of the total production. Table 7.5 provides a breakdown of rice production by local and high-yielding varieties.

Table 7.3 : Irrigated Area by Source of Water

Method	Area (ha)	Percent of Total Irrigated Area
LLP	18,818	25.0
DTW	17,638	23.5
STW	25,447	33.8
HTW	1,135	1.5
Canal	1,453	1.9
Traditional	10,712	14.2
Total	75,203	100

Table 7.4 : Crop Areas and Annual Production

Crop	Crop Area (ha)	Percent of Total Cropped Area	Annual Production (tons)
Rice	192,000	84.9	318,100
Wheat	3,100	1.4	5,300
Sugar cane	200	0.1	10,200
Potato	2,800	1.4	21,900
Jute	8,600	3.8	77,400 bales
Pulses	3,100	1.4	2,350
Oilseeds	5,800	2.6	4,370
Spices	2,400	1.0	5,550
Minor Crops (Vegetables, maize, tobacco, cotton, etc.)	6,300	2.8	33,400
Fruit	1,500	0.6	10,200
Total	**225,800**	**100.0**	**411,370**

Source: Average of 1989 to 1992 data from Yearbook of Agricultural Statistics, BBS, adjusted using 1983/84 Agriculture Census data.

Table 7.5 : Local and HYV Rice Production

Type of Rice	Area (ha)		Annual Production (tons)	
	Local	HYV	Local	HYV
Aus	34,100	3,000	32,200	5,400
Aman	78,000	12,900	104,500	26,600
Boro	12,200	51,500	18,500	131,700
Total	**124,300**	**67,400**	**154,400**	**163,800**

7.6.1 Rice Production

The Basin produces 150,000 tons of boro, 130,000 tons of aman, and 38,000 tons of aus rice per year. Total rice production is 318,100 tons per year. All rice productions are in paddy.

Rice is grown in a multitude of environments, either solely or in rotation with dryland crops. Almost all segments of the cultivated land are cropped with at least one rice crop a year.

Deepwater aman varieties, which were once common, have virtually disappeared and presently account for only 800 tons of production per year. Almost all aman and most boro are sown in planting beds and later transplanted to the fields; much of the aus is sown directly by broadcast methods.

HYV varieties are becoming more common and have been introduced into all three rice seasons. They represent about 80% of the boro rice area and one-third of the aus and aman crop areas with the remainder being made of local varieties. HYVs presently account for 51 percent of the total rice production. The average HYV rice yield is nearly 2.43 tonnes/ha, approximately twice that of local varieties. As HYVs require a stable water regime to respond well to fertilizers they are best suited for irrigated conditions.

8. FISHERIES

Fisheries are an important sector of the basin's economy. Thirteen thousand people and their families depend on it for their sole source of employment, directly supporting some 70,000 people or 5% of the population. In addition large numbers of people are engaged part-time in fishing or depend on it for subsistence. Fish are the primary source of protein for most of the people. Preservation and enhancement of this resource is a priority of government.

The available data indicate that the average production of the floodplain fishery is between 33 and 45 kg per hectare, which is one-half to two-thirds of the normal productivity in the Northeast Region, even though as much as two-thirds of the Basin is flooded annually. This is due to a number of factors:

- the depth of flooding is shallow to moderate and is variable throughout the monsoon due to the flashy nature of runoff in the Basin,
- there are few overwintering areas in the Basin and as a result the brood stock are forced to migrate a long distance from the Sylhet Basin. Beels are mostly shallow and are silting in due to deposition of silt carried by overbank spills of flood waters from the major rivers. The Kangsha River itself is virtually a dry channel during lean periods, upstream of the Shibganjdhala River, which further impedes the habitat and movement of fish,
- over-fishing and lack of effective management deplete the remaining overwintering fish stock thus impairing the ability of the natural eco-systems to regenerate annually. Further reduction is occurring as the remaining beel areas are cultivated in rice and are depleted for irrigation water supply.

Productivity of the culture fishery is also low due to minimal management and inputs, siltation, and impacts of flooding. Flooding causes direct damage, siltation of suspended sediments, and allows the fish stock to escape. These factors tend to discourage local people from investing in culture fisheries. Reliable data on the productivity of the ponds, their vulnerability to flooding, and the number of derelict ponds is not available.

The southern and southeastern areas, where flooding is greatest, are rich in open water fisheries and fish ponds. Important areas occur in the Sherpur-Nalitabari-Sarchapur depression, in the Greater Dampara area, near Jaria, and near Kalmakanda.

The northern portion is shallower and is generally not favourable for open water fisheries. It is, however, suitable for culture practice.

8.1 Open-water (Capture) Fisheries

8.1.1 Habitat

Rivers
The Kangsha, Bhogai, Chelakhali, Malijhee, Nitai, and Someswari Rivers are the major rivers. Smaller rivers such as the Kalihar and Balia Rivers are also important for fish. The total area of river channel is estimated to be 12,600 hectares.

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Most of the tributary inflow is used in the upper reaches for irrigation during the dry season, except in the Someswari/Shibganjdhala River. As a result the smaller rivers and portions of the larger rivers dry up in winter. The Kangsha River itself dries up for most of its length, except for deeper pools upstream of the confluence of the Shibganjdhala River at Jaria.

Water levels starts increasing in May after the start of rain. Initially the streamflow enters the beels through smaller channels. Later, in June to July, the major floodplains submerge.

There are no major industries to pollute the water. However, increased use of insecticide and pesticide in agriculture are deteriorating the water quality. Silt in the flood water affects the water quality and there are reports that the silt runoff from India is increasing.

Floodplain

Floodplains are the primary grazing and brood areas. About 140,000 hectares, or 60% of the Basin area, are flooded in an average wet season. The depth of flooding varies up to 4.5 m but is mostly shallow to moderate (less than 2 m). The shallow floodplains are most important as feeding grounds as the natural production of plankton and benthos is high in the shallow areas.

About 30,000 ha are flooded to depths greater than 1.8 m, including the perennial beels. These areas are important as they provide sanctuary for the larger fish.

Beels

There are approximately 112 seasonal beels and more than 30 perennial beels in the Basin (a perennial beel is one that retains water through the winter in most years). The largest are Rajdhola and Pakua Beels which are 47 ha and 28 ha in size, respectively. Thana-wise names of the beels and their areas are given in Table 8.1. Locations of the most important beels are shown in Figure A.18.

Beels are permanent or semi-permanent water bodies. They are good fish habitat and overwintering areas and are most important to the survival and productivity of fish.

Most of the beels are shallow and dry out during the winter months. Only a few are deep enough to provide overwintering grounds for fish. Beels in the Malijhee floodplain have been silting in and are mostly shallow. The total area of beels is about 580.0 ha of which area of perennial beels is 230 ha.

Dampara Area

This area is the most productive in the Basin. Kalihar Khal and Balia Khal provide good links between the Kangsha River and the floodplain. More than two-thirds of the floodplain goes under water in the monsoon season, and most of the flooding is relatively shallow which makes for ideal grazing conditions. Because the area is largely in a backwater condition the water quality is relatively good (has little silt).

There is a large breach which circumvents the Kangsha River Improvement Project regulator at the outlet of Balia Khal. A regulator (water retention structure) also exists at the outlet of Kalihar Khal but it is not operational. Fisheries in this area will be reduced if these structures are made operational.

Table 8.1: Thana-Wise Beels (within Basin) and Their Areas

Sl	Name of the Beel	Area	Sl	Name of the Beel	Area
Thana: Sribardi; No. of Beels: 1; Total Area: 4.2 ha					
1.	Kuri Kahama	4.2			
Thana: Jhenaigati; No. of Beels: 15; Total Area: 23.1 ha					
2.	Kasimmara	1.4	3.	Golarmari	0.9
4.	Dariarpar	5.5	5.	Sonajkura	1.8
6.	Naya	0.9	7.	Baila	0.9
8.	Dhali	0.9	9.	Kumirkhali	0.4
10.	Konagaon	1.8	11.	Puila	1.8
12.	Bagjani	1.4	13.	Burubai	0.4
14.	Palka	1.4	15.	Bandhapai	0.8
16.	Baidabhanga	2.8			
Thana: Sherpur; No. of Beels: 8; Total Area: 24.5 ha					
17	Buria	1.4	18	Isli (P)	1.0
19	Aurabaura	4.6	20	Gawa	4.2
21	Dhala	2.3	22	Rewa (P)	5.5
23	Durungi	3.2	24	Doavi	2.3
Thana: Nalitabari; No. of Beels: 22; Total Area: 63.0 ha					
25	Beki	1.4	26	Bardul	0.9
27	Kuski (P)	5.3	28	Pachaduba	0.9
29	Ruruli	1.4	30	Palkla	2.3
31	Bara	1.4	32	Duramari	1.4
33	Kaya	0.9	34	Kasti	1.4
35	Kaiyakuri	0.9	36	Balkbaz	1.8
37	Jutdoba	1.4	38	Bordubi	4.6
39	Nisbja	0.4	40	Choitjan (P)	6.0
41	Buadhirdoba	2.8	42	Barigai (P)	5.5
43	Ghoramara (P)	6.9	44	Bali (P)	6.9
45	Dombari	3.0	46	Boro (P)	5.5

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Table 8.1: Thana-Wise Beels (within Basin) and Their Areas (Cont'd)

Sl	Name of the Beel	Area	Sl	Name of the Beel	Area
Thana: Nakla; No. of Beels: 8; Total Area: 51.4 ha					
47	Medirpar	2.3	48	Tekhain (P)	4.6
49	Hapnoi (P)	6.9	50	Kuri	1.8
51	Jinga	3.7	52	Chepa Kuri	1.8
53	Bausi	2.3	54	Pekua (P)	28.0
Thana: Haluaghat; No. of Beels: 14; Total Area: 60.5 ha					
55	Aspat	3.7	56	Tenglakuri	4.6
57	Sibdara	9.2	58	Fatakuri	2.8
59	Japur	7.8	60	Phulaiti	4.6
61	Gazaria	4.2	62	Atla	1.4
63	Sola	3.7	64	Raipha	4.6
65	Kointa	2.8	66	Luita	4.6
67	Podo	2.8	68	Chilka	3.7
Thana: Phulpur; No. of Beels: 29; Total Area: 80.3 ha					
69	Putia	0.9	70	Barbhita	6.9
71	Lukuri	3.2	72	Tarakuri	0.9
73	Putia (P)	9.0	74	Betgaicha	1.4
75	Chila	1.8	76	Khailakuri	1.8
77	Doba	1.4	78	Barbita	1.8
79	Katora	2.3	80	Ingli (P)	4.6
81	Rahar	0.9	82	Barbait	1.8
83	Ulla (P)	4.2	84	Han	3.7
85	Behi	1.4	86	Pata	2.8
87	Nalkati	2.3	88	Boalmari	1.8
89	Doba (P)	3.2	90	Hoogly (P)	4.2
91	Beki	1.4	92	Kuripara	2.3
93	Chauliabad	2.3	94	Deota	2.8
95	Ramsona	4.6	96	Dhengal	1.8
97	Koma	2.8			

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Table 8.1: Thana-Wise Beels (within Basin) and Their Areas (Cont'd)

Sl	Name of the Beel	Area	Sl	Name of the Beel	Area
Thana: Dhobaura; No. of Beels: 12; Total Area: 46.6 ha					
98	Chinakuri	6.9	99	Kailakuri	4.6
100	Jidore	4.2	101	Kalda	1.4
102	Dor	1.8	103	Garja	4.6
104	Ula Kanda	3.7	105	Horkura	3.2
106	Kakra	1.4	107	Pholosota	2.8
108	Pagli	4.6	109	Holiakhatra	7.4
Thana: Durgapur; No. of Beels: 8; Total Area: 56.4 ha					
110	Diga	4.2	111	Sitli	20.0
112	Jangli (P)	6.0	113	Kabor (P)	6.9
114	Banda Meda (P)	6.9	115	Hurdhum	4.6
116	Bagi	2.3	117	Gayatra	5.5
Thana: Purbadhala; No. of Beels: 18; Total Area: 139.1 ha					
118	Dopa	7.4	119	Barahar	5.6
120	Pansa (P)	6.0	121	Kusmai (P)	7.0
122	Chakia (P)	5.2	123	Dudhghara (P)	4.6
124	Urdha (P)	5.0	125	Pakata	4.1
126	Padmai (P)	6.0	127	Kharchail (P)	4.6
128	Budhir	4.2	129	Maua	6.0
130	Dhalikuri (P)	6.0	131	Rajdhala (P)	47.0
132	Kuma (P)	7.0	133	Hatli	4.6
134	Boalia (P)	4.6	135	Magura	4.2
Thana: Netrokona; No. of Beels: 3; Total Area: 11.1 ha					
136	Akhtar	4.6	137	Kamrail	3.7
138	Dubni	2.8			
Thana: Kalmakanda; No. of Beels: 4; Total Area: 21.2 ha					
139	Chochpara	4.6	140	Radhanathpur	4.6
141	Silua	5.0	142	Beri	7.0

Note: (P) indicates perennial beel
Source: NERP field survey

There are about 20 seasonal and 10 perennial beels in this area. The perennial beels provide good overwintering grounds.

There are 1,200 fishermen in this area.

The Malijhee Depression

The area in the western part of the study area bounded by Sherpur, Nalitabari, Sarcharpur, and Nakla is a flat depression that contains a large number of perennial and shallow seasonal beels. Several river channels also pass through this area. Earlier this was a good fisheries area. However a large number of beels have silted in and the water quality has degraded due to increased siltation. Fish production has declined. Some beels in this area need to be re-excavated and declared as sanctuaries to protect and enhance the remaining fish populations.

A large number of people - nearly 5,000 fishermen and their households - depend on the fisheries resource in this area. Some of them have switched to other work as the fisheries resource has declined.

Someswari River/Kalmakanda Area

The area has good connections with the Kangsha River and the Sylhet Basin for fish breeding, feeding, and migration. Extensive floodplains exist along the Shibganjdhala River, on the North floodplain of the Kangsha River, and in the eastern side of the area which is flooded by backwater from the Sylhet Basin. The area around Kalmakanda is especially productive, as it has several good beels, direct links to the Sylhet Basin, and is extensively flooded throughout the monsoon season. The Someswari, Shibganjdhala, and Atrakhali Rivers are large and productive. They are supplied brood stock by fish migrating from the upper Someswari River.

There are about 15 beels in the Someswari area although only 3 or 4 are perennial.

Fish production is declining along Atrakhali Khal due to heavy deposition of sand and clay caused by the recent avulsion of the Someswari River into the Atrakhali. Plankton, necton benthos, and other aquatic organisms are directly impacted and this reduces the food availability to fish.

8.1.2 Species Diversity and Abundance

A large number of species occur in the Basin area, especially in the Greater Dampara project area, near Jaria, Kalmakanda, and Sherpur-Nalitabari depression. The northern areas, especially in the Chelakhali, Bhogai, and Someswari Rivers, where deposition of silt is more common, have less diversity.

Nearly 100 out of the 155 species which occur in Northeast Region were observed in the Basin. Most of these species are small fish which, owing to their large numbers, actually comprise the majority (70%) of the fish catch. Larger fish, primarily carp and large catfish, make up about 10% and 20% of the catch respectively. The most common species of carp are Rui, Lachu, and Calibaus and the most common species of large catfish are Boal and Aor.

Small prawn are also common. Veda, Sarputi, Pabda are becoming rare. Nanid, Mohasoal and Pipla are among the threatened species.

Species diversity and fish population are directly related to the hydrological cycle. The number of fish is lowest during the winter months. Smaller fish breed in April and May while larger species breed from May to June when the major floodplains are inundated. Large number of fish and greater diversity of species were observed during the flood recession time (October to December).

8.1.3 Breeding

The major rains occur slightly later than in the rest of the Northeast Region and therefore the small fish breed later. Breeding occurs in April to May. Major carp usually breed in mid-May. Juveniles of some small fish are generally available from February to August but some are available year-round.

It was reported by professional fishermen that the Kangsha and Someswari Rivers are important breeding areas for carp and large catfish. Other fish breed all over the area and its floodplains.

8.1.4 Migratory Behaviour

A few isolated overwintering grounds are located in a few perennial beels located within the Basin. However, most beels in the study area dry out during the winter. The Kangsha River itself is shallow or dry for much of its length upstream of Jaria during the winter and pre-monsoon periods, which further hampers the migratory movement. Carp and catfish normally over-winter in the Sylhet Basin, returning annually to breed in the pre-monsoon season. Thus the migration routes are long and difficult and pose a significant constraint on the productivity of the basin's fisheries.

Figure 19 shows the primary directions of fish migration. Fish normally migrate upstream to breed, following a natural instinct to return to beels and floodplains from their overwintering areas. They return to their overwintering areas when water levels recede after the end of the monsoon season. Fishermen in Durgapur report that a large number of fish also migrate downstream from India via the Someswari River. Their explanation for this unusual behaviour is that the overwintering areas are located upstream in this case, in a large number of *duars* (deep scour holes) which are located in India. They believe that the fish's basic instincts cause them to migrate toward floodplains, which in this case are located downstream in Bangladesh. The strong flow of water helps to encourage the downstream migration.

8.1.5 Fishing Community

According to DOF thana data, adjusted to the Basin boundary, there are more than 12,000 full-time professional fishermen.[13] This estimate excludes Nalitabari and Dhobaura thanas for which no recent data are available, seasonal fishermen who have other employment during the winter months, and subsistence fishermen. Some fishermen complain that declining fish are forcing them to adopt other professions.

A large number of professional fisherman live in the Malijhee depression and near Jaria and Kalmakanda.

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13 / A professional fisherman is one who makes his living wholly or substantially by fishing. DOF does not include fishermen who have other employment.

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In addition, subsistence fishing from the rivers, beels, and floodplain is common.

8.1.6 Fish Landing and Marketing

The best available data on marketing facilities are summarized in Table 8.2. The data should be considered indicative only as it is incomplete for several thanas.

There are approximately 200 fish markets in the Basin. Most fish are sold locally but some are sent to regional markets in the thana or district headquarters.

There are at least 12 fish *arats* (wholesale markets) in this area. Buyers purchase the fish from fishermen and sell it to the *arats*. Jaria is the largest export centre - some 120 tonnes worth Tk 4,800,000 were sold in four months, June to September 1995, alone.

There are only three small fish landing centres (collection place where traders buy fish in bulk), two of which are located in Phulpur and one in Purbadhola.

There is no fish processing facility in the study area.

Locations of the principal fish marketing facilities are shown in Figure A.19.

8.1.7 Fisheries Management

Most perennial beels and some seasonal beels are leased to professional fishermen or fishermen's societies. Most have short-term leases. Portions of the rivers are also leased. Twelve large ponds in Haluaghat thana (total area 10 ha) are under lease but such pond leasing is rare in other thanas.

The productivity of some beels is decreasing, especially in the Malijhee depression where siltation is occurring. Therefore many beels are no longer leased.

Overfishing is a serious problem. Lease holders often catch all the fish in the beel as they are given only short term (one-year) leases. Fishermen catch undersized fish and brood fish, often using pumps to de-water the area and leaving no brood fish for the next year. Agricultural people catch as many fish as possible in their fields; a similar practice was observed in several canals. Fine meshed nets are often used. Poor enforcement of fishing regulations was observed throughout the area.

There are 5 hatcheries and 217 nurseries in the Basin area. Except for one government hatchery in Sribardi thana the fish hatcheries are privately owned. All nurseries are privately owned.

A considerable number of fish spawn and fry were released under the open-water fry release program of DOF. There is no data on the survivability. Major areas are Haluaghat, Phulpur (near Sarcharpur bridge), Netrokona, Jhenaigati (in Balia beel), and Durgapur. DOF plans to release 165,000 fry in Netrokona during 1995, and 310 kg of spawn in Dhobaura. No such programme are planned for other thanas.

Most thanas also release some fry every year during the Fish Fortnight.

Table 8.2 : Summary of Fisheries Resources in the Kangsha Basin

Name of Thana	No. of Full-time Professional Fishermen	No. of Fishermen Societies	No. of Ponds	No. of Hatcheries	No. of Nurseries	No.of Fish Processing Centres	No.of Fish Arot	No.of Landing Centres	No. of Ice Factories	No. of Fish Markets
Sribardi	35	1	96	1						2
Sherpur	85	1	1,419		3		1		4	10
Jhenaigati	107	1	1,042		5					24
Nalitabari	n/a	6	6,000	2	137				1	25
Nakhla	90	1	332		4				1	7
Phulpur	1,740	2	3,795	1	30		1	2	4	15
Haluaghat	625	n/a	3,005		12		1		2	31
Dhobaura	n/a	n/a	1,180		12					25
Purbadhola	1,653	5	2,285		5		3	1	2	22
Durgapur	1,931	5	2,216		3				2	11
Kalmakanda	958	2	1,214		1		2		1	0
Netrokona	5,204	2	1,051	1	5		4		4	20
Barhatta	118	1	98							3
Total	**12,546**	**27**	**23,733**	**5**	**217**	**0**	**12**	**3**	**21**	**200**

Note: Data are based on thana statistics adjusted to the area lying inside the Basin.
n/a = data not available
Number of markets in Jhenaighati markets are based on NERP observations. Remaining data are from thana offices.
Pond areas for Sherpur, Nakla, Nalitabari, Phulpur, Purbadhola, and Netrokona thanas were estimated from DANIDA pond survey in 1994. Data from thana fisheries officers were used for Nakla and Purbadhala thanas. Pond areas were estimated for four other thanas for which data was not available, using the average density for the Basin.

8.2 Culture Fisheries

Abundance
Fish culture in captive ponds is an important component of the Basin fisheries. About 23,700 ponds and ditches are present in this area. They have a total surface area of 2,500 ha and an average size of 0.1 ha.

Figure A.20 shows the distribution of ponds in the Basin. Table 8.1 includes an estimate of the number of ponds in each thana. There are an average ten ponds in one square kilometre of land. The highest concentration occurs near Phulpur and near Nalitabari. The lowest occurs in Jhenaigati, Sribardi, Nakla, and Dhobaura thanas (CARITAS has reported a much higher concentration in Haluaghat and Dhobaura[14]). The density and average pond area are generally similar to those of the Northeast Region.

The number of flood-prone and derelict ponds are not identified in the available data. NERP studies indicate that 30% of the ponds are flood-prone in the Greater Dampara area but the average for the Basin is probably lower. Field observations indicate that a significant percentage are affected by siltation, especially in the Malijhee area, or otherwise derelict.

Culture Practice
Most ponds are operated with minimal management and inputs. The number of fingerlings are often not known and the growth and health of the fish are generally not monitored. Few pond owners use fertilizer or fish feed.

Various species are present. The dominant species are rui, catla, and mrigel (35, 30, and 25% of the total numbers, respectively).

Most of the fingerlings are provided by nurseries. Sometimes fingerlings are caught from open water or obtained from seed traders.

Extension of Fish Culture
Several organisations are involved in improving fish culture within the Basin. DANIDA has taken up a major program in Nalitabari, Nakla, Sherpur, Phulpur, Purbadhola, and Netrokona thanas. CARITAS, Dustha Shastha Kendra (DSK), and World Vision are involved in the Durgapur area. Recently excavation of new ponds (including ponds used for both paddy and fish culture) was observed in the southern area.

8.3 Fish Production

Open Water Fishery
Production estimates for the open water capture fishery were derived from estimates of floodplain areas and unit production per hectare in each flood depth class. The calculation is summarized in Table 8.3. Estimates are based on field studies in the Greater Dampara area and the Someswari area and also based on relevant data from FAP-17, FAP-20, Department of Fisheries (DOF) and experience in other parts of the Northeast Region. The total annual production in the Basin is

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[14] Unpublished report on pre-feasibility study to set up two fish hatcheries in Haluaghat and Dhobaura thanas.

Table 8.3: Estimated Production of Capture Fisheries

Depth Series	Area (ha)	Productivity of Flood Depth Class (kg/ha per year)	Production in Flood Depth Class (Tonnes/yr)
F_0	59,100*	5	296
F_1	41,400	20	828
F_2	29,300	70	2,051
F_3	19,400	40	776
F_4	116	120	14
Rivers	12,600	80	1,008
Total	149,316		4,972

Source: NERP estimates
* F_0 area includes flood-free land

estimated to be 5,000 tnnes. DOF data for 1993-1994 suggest that this estimate may be on the high side.[15]

Culture Fishery
The total production rate of the culture fishery is estimated to be 2,030 tonnes per year.[16] This estimate is based on NERP's pond survey conducted in the Dampara area and allows for low productivity in flood-prone and derelict ponds and in ponds that are not intensively managed.

Total Production and Demand
The annual production of fish in the basin is estimated to be 7,000 tonnes/year, composed of 5,000 T/yr from the capture fishery and 2,000 T/yr from the culture fishery. The annual consumption in the Basin is estimated to be 1,100 T/yr based on household surveys in the Dampara project area; thus the Basin is a net exporter of fish almost 6000 tonnes/yr of fish.

The dietary need for protein is generally accepted to be 72 g/person per day, most of which is supplied from fish. The actual consumption based on household surveys in the Dampara project

15/ DOF data, obtained from thana fisheries officers, are available for lease areas only, not including subsistence or part-time fishing, and are missing for three of the largest thanas. Estimated production using these data is 3,000 T/yr.

16/ Reliable estimates of pond production are difficult to obtain. Much higher estimates (6,000 T/yr) were obtained using available DOF data for nine thanas extrapolated to the entire Basin but were not considered reasonable.

is 8.1 g/person per day (based on limited short-term data), which is about 10% lower than the national average. Thus the people of the Basin consume far less than is optimal (this situation is common throughout Bangladesh).

Average Production per Unit Area
The average production of the open-water (capture) fishery is estimated to be between 30 and 45 kg/ha of floodplain. These rates are about one-half to two-thirds of the normal rate for the Northeast Region. Highest production rates occur in the Greater Dampara area, in the Malijhee depression, and near Kalmakanda. The average production of the culture fishery is estimated to be 818 kg/ha. DANIDA data indicate that the production rate could be three to four times higher in ponds that are protected against flooding and are more intensively managed.

8.4 Effects of Existing FCDI Projects

Malijhee Regulator
This regulator is not working and therefore has no impact on fish. Local people have developed small-scale irrigation schemes upstream of this regulator using small cross-dams across the channel, thus reducing the dry-season flow and fish habitat for some distance downstream.

Chelakhali and Bhogai Embankments and Regulators
By preventing overbank spills the Chelakhali and Bhogai embankments are causing more silt to be deposited in the Malijhee depression. Many beels have silted up and fisheries resources have declined significantly. If the breaches which occur in the embankment of the Chelakhali River are closed the effect of this project will be increased.

The Chelakhali regulator is not operated but the local people construct a cross-dam in the dry season to divert water to the fields. Fish migration is prohibited in the dry season and for some time in the early pre-monsoon season.

The Bhogai River is totally diverted to irrigation in dry periods and as a result the Kangsha River between Urpha and Jaria goes dry except for the deeper pools. This has a serious impact on over-wintering fish habitat.

Konapara Embankment
Local people believe that fisheries have declined in this area due to the embankment. This report has not been confirmed. This embankment has reduced but has not eliminated the overbank spill from the Kangsha river to the north floodplain.

Kangsha River Irrigation Project and Thakurakona Sub-Project
Fishermen report that fish migration from river to beel has been disrupted. This has been confirmed in NERP's field studies. One regulator in the north is not working properly and it permits movement of fish to the beels; this will change in the future if this project is rehabilitated.

9. TRANSPORTATION

9.1 Navigability Conditions

The project area has a large number of rivers and water bodies. Its basin-shaped topography, sloping from northwest to southeast, gives a natural waterway connection to the country's arterial water transport routes through the Surma/Baulai and Meghna River system. However, winter flows are low and thus most rivers are only seasonally navigable. At present the water transport system is available to the people over 4 to 5 monsoon months in the upper areas and 6 to 10 months in the lower areas.

The navigability conditions of the rivers in the Basin are summarized in Table 9.1 and are more fully described below.

Kangsha River
The Kangsha River is the longest river (135 Km) and the main navigation route. Almost 80% of the total river traffic passes via the Kangsha River using country boats round the year and launches in the monsoon season.

Winter flows are too low upstream of the Shibganjdhala River confluence at Jaria to maintain a year-round navigation channel. Further decreases are occurring due to use of river water for irrigation in the upstream reaches and tributaries.

Conditions are more favourable downstream of Jaria where the channel is deeper due to the increased flow, greater depth of channel, and backwater from the Sylhet Basin. Downstream of the trifurcation near Thakurakona the original Kangsha River branch has silted in and is mostly

Table 9.1 : Navigability of the Basin Rivers

Name of River	Navigable Period
Kangsha River:	
Sarchapur to Jaria	June-December
Jaria to Thakurakona	May-January
Someswari River:	
Shibganjdhala channel	May-January
Atrakhali channel	May-January
Old Someswari channel	July-August
Bhogai River	June-September
Chelakhali River	June-September
Malijhee River	June-September
Ubdakhali River	May-February
Nitai River	May-October

Source: Field observations and interviews in the dry season of 1995.

dry during the winter period. The Ghulamkhali River has become the main branch and is navigable by small boats year-round and by large engine boats and launches during the monsoon season. A shallow reach near Madhynagar creates draft limitations in the dry season.

Bhogai River
The Bhogai River is seasonally navigable (June-October). The river is too steep and the flows are too small to sustain a navigable channel during lean periods. Launches ply from Jaria to Nalitabari during 5 months of monsoon season. This river was the only means of transport and communication for the area around it before roads were constructed.

Malijhee River
Despite siltation and bank erosion the river is navigable for 4 to 5 months of the monsoon season by boats up to 40 ton capacity. During the dry season no boats can pass from upstream of the Sherpur-Nalitabari road at Tinanibazaar due to shallow depth, low flows, and nine earthen irrigation cross-dams in the river.

Chelakhali River
The 20 km long Chelakhali River is seasonally navigable for about 4 months of the monsoon season. The depth of flow is too shallow for navigation in the dry season and the channel is blocked by cross dams used for irrigation. Road communication and transportation are now predominant.

Someswari River
The Shibganjdhala River was formed by an avulsion of the Someswari River at Birishiri in 1963 and has since developed to become the main channel of the Someswari River from Durgapur to Jaria. Deposition is occurring but the Shibganjdhala River remains navigable throughout most of the year.

The original main channel, the Old Someswari River, is virtually dead except during brief periods during the monsoon season when it carries a portion of the flood flow from the Someswari River. Navigation of the Old Someswari River is negligible.

The Atrakhali channel was created in 1988 by an avulsion in the left bank of the Someswari River a short distance upstream of Durgapur. The channel is widening during every monsoon season, but due to shallow depth at its offtake the channel is only seasonally navigable. The lower reach from Nazirpur to Kalmakanda via the Updakhali River is navigable round the year but shallow draft creates difficulties at several places. The Updakhali River is navigable from Kalmakanda to Madhyanagar but the draught drops to 0.5 m at several points in March and April.

Navigability of these three channels will change over time with the morphological changes that are taking place near Durgapur. It is expected that the Atrakhali River will continue to develop and the Shibganjdhala River continue to infill.

Natural Wetlands
There are many small rivers and khals linking the natural waterbodies. These are also important for local transportation and communication. As in the case of the bigger rivers the navigability of these khals has been gradually deteriorating due to natural siltation, by construction of flood control embankments, and by man-made cross dams for irrigation.

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9.2 River Transport

The rivers have been used through the ages as a means of transporting cargo and passengers. However there is very little or no recorded data regarding the use of water, road, and railway transport systems in the Basin. A limited amount of primary data was collected by NERP through field surveys using structured questionnaires over the four-month period December to April 1995. Results are summarized in Table 9.2 - 1995 Dry Season, Table 9.3 - 1995 Monsoon Season, and 9.4 - Annual Total. Estimates are considered to be order-of-magnitude only.

Over twenty markets and river stations/ghats are located on the Kangsha River alone. Jaria Janjail is the most important transport centre, accounting for about 60% of the passenger movements and 40% of the cargo. It should be noted that much of the traffic at this location is by ferry across the river between the towns of Jaria and Jhanjail.

The volume of traffic is much greater during the monsoon season. Country boats operating during the monsoon season are much larger, having capacities up to 40 tons.

Table 9.2 : Estimated Water Transport in the 1995 Dry Season

Station/ghat	Cargo (Tonnes)			Passengers		
	Incoming	Outgoing	Total	Incoming	Outgoing	Total
Deutokon	370	0	370	30,032	23,688	53,720
Durgapur	2,307	174	2,481	173,008	83,688	256,696
Fakirer Bazar	2,604	660	3,264	18,420	0	18,420
Ghagra	139	0	139	0	0	0
Jamdhala	204	528	732	33,600	22,976	56,576
Jaria	11,460	8,920	20,380	498,912	711,420	1,210,332
Jhanjail	13,100	8,800	21,900	711,420	498,912	1,210,332
Kalmakanda	6,766	4,467	11,233	552,660	55,800	608,460
Kapasia	48	0	48	15,344	11,712	27,056
Muktir Bazar	552	800	1,352	161,140	81,440	242,580
Nazirpur	605	1,464	2,069	0	0	0
Porakandulia	160	28	189	22,360	22,230	44,590
Thakurakona	5,041	10,135	15,176	242,988	95,172	338,160
Total	43,356	35,977	79,333	2,459,884	1,607,038	4,066,922

Note : Includes small ferry boats used for crossing the river.
Source : Navigation Component study of NERP in dry season of 1995.

Table 9.3 : Estimated Water Transport in the 1995 Monsoon Season

Station/ghat	Cargo (Tonnes)			Passengers		
	Incoming	Outgoing	Total	Incoming	Outgoing	Total
Deutokon	925	816	1,741	32,025	31,820	63,845
Durgapur	3,900	1,600	5,500	89,305	88,784	178,089
Fakirer Bazar	1,225	2,715	3,940	116,676	120,498	237,174
Ghagra	894	780	1,674	77,875	61,952	139,827
Jamdhala	535	475	1,010	16,000	15,850	31,850
Jaria	9,940	12,200	22,140	858,884	796,398	1,655,282
Jhanjail	8,860	10,400	19,260	802,484	890,935	1,693,419
Kalmakanda	12,900	8,800	21,700	548,043	602,540	1,150,583
Kapasia	375	380	755	12,250	12,000	24,250
Muktir Bazar	975	890	1,865	86,448	92,847	179,295
Nazirpur	1,050	915	1,965	82,500	90,150	172,650
Porakandulia	5,080	2,620	7,700	59,047	38,045	97,092
Thakurakona	6,880	7,300	14,180	245,814	226,762	472,576
Total	53,539	49,891	103,430	3,027,351	3,068,581	6,095,932

Note : Includes small ferry boats used for crossing the river.
Source : Navigation Component study of NERP in dry season of 1995.

Table 9.4 : Estimated Water Transport in the 1995 Calendar Year

Station/ghat	Cargo (Tonnes)			Passengers		
	Incoming	Outgoing	Total	Incoming	Outgoing	Total
Deutokon	1,294	816	2,110	62,057	55,508	117,565
Durgapur	6,207	1,774	7,981	262,313	172,472	434,785
Fakirer Bazar	3,829	3,375	7,204	135,096	120,498	255,594
Ghagra	1,033	780	1,813	77,875	61,952	139,827
Jamdhala	739	1,003	1,742	49,600	38,826	88,426
Jaria	21,400	21,120	42,520	1,357,796	1,507,818	2,865,614
Jhanjail	21,960	19,200	41,160	1,513,904	1,389,847	2,903,751
Kalmakanda	19,666	13,267	32,933	1,100,703	658,340	1,759,043
Kapasia	423	380	803	27,594	23,712	51,306
Muktir Bazar	1,527	1,690	3,217	247,588	174,287	421,875
Nazirpur	1,655	2,379	4,034	82,500	90,150	172,650
Porakandulia	5,240	2,648	7,889	81,407	60,275	141,682
Thakurakona	11,921	17,435	29,356	488,802	321,934	810,736
Total	96,895	85,868	182,762	5,487,235	4,675,619	10,162,854

Note : Includes small ferry boats used for crossing the river.
Source : Navigation Component study of NERP in dry season of 1995.

Data in the dry season of 1994/95 indicate that paddy transport is the largest component and accounted for 43% of the cargo transported by this mode. Transport of fertilizer represented 28% of the total (see Table 9.5).

Table 9.5 : Itemwise Flow of Cargo Traffic by Water Transport, 1994-95 (Tonnes)

Items	Inflow	Outflow	Total
Paddy	-	75,840	75,840
Fertilizer	48,572	-	48,572
Petroleum Products	25,500	-	25,500
Salt	10,320		10,320
Others	9,094	8,880	16,334
Total	93,486	84,720	178,206

Source: Field Survey by Navigation Component Team of NERP in dry season of 1995.

9.3 Rail and Road Transport

Traditionally the rivers and waterways were the only transportation link between the Kangsha Basin and the rest of the county. Times have changed, however, beginning with construction of the railway to Mohanganj in the British era to transport fish from the area. More recently, roads have been constructed since the 1960s and have provided an alternative mode of transport.

A number of roads were constructed during the 1970s in the western part of the Basin. Two roads from Netrokona, one going to Kalmakanda and the other going to Durgapur, have already been completed. Bridges at Jaria Janjail and Thakurakona are also expected to be completed soon. These bridges will provide a vertical clearance of 7.6 m for river navigation. These developments will provide trucks and buses with full access to the important interior points of the Basin and will provide serious competition with water transport.

9.4 Inter-Modal Comparison

Road transport offers greater speed and flexibility and tends to be used often for cargo of high value and small bulk. Water transport is cheaper and is widely used for heavy and bulky cargo for which delivery time is less of a concern. It is also used for local transportation of cargo and passengers during the monsoon season when many of the roads are impassable and there are no other means of access to large portions of the basin.

Cargo Volumes

A total of 528,00 tons of cargo were moved during the 1994/95 dry season, of which 56% was transported by boat and 42% was transported by road (see Table 9.6). Rail transport was used for less than 3% of the total.

Table 9.6 : Flow of Cargo by Mode of Transport, Dry Season 1994/95 (Tonnes)

Modes	Inflow	Outflow	Total
Water Transport	93,486	84,720	178,206
Road	76,980	56,040	132,930
Railway	8,000		8,000
Total	187,150	140,760	319,136

Source: Field Survey by Navigation Component Team of NERP in dry season of 1995.

Sixty percent of the cargo was transported over long distances to or from places outside the basin.

Cost

Field data collected in the dry period of 1995 indicate that boat transportation is substantially cheaper than the other modes (Table 9.7). Transport costs by road are 2.5 to 8 times higher than by water. Rail transport costs are 2 to 6 times higher. The cost of transport by road and railway would be even higher if the capital and maintenance costs for their infrastructure were included.

Table 9.7 : Freight Transport Rates to Selected Locations

Destination	Freight Cost (Taka per ton)		
	Water	Road	Rail
Bhairab Bazar	540	1,368	1,080
Dhaka	780	2,252	1,778
Mymensingh		532	420
Sylhet	450	3,515	2,775

10. SOCIO-ECONOMIC SETTING

10.1 Demographic Characteristics

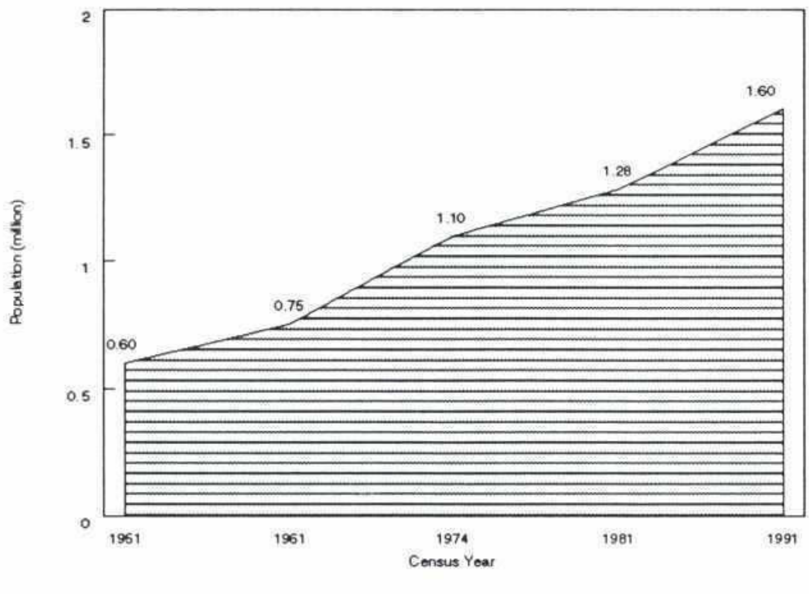
10.1.1 Population

The population of the basin is estimated to be 1,600,000 based on 1991 enumerated census data.[17] It accounts for 11.4% of the population of the Northeast Region and 1.5% of the total population of Bangladesh.

The population in the study area has more than doubled during the thirty year period from 1961 to 1991 (see Graph 10.1). The annual growth rate has been 2.3% which is slightly higher than for the rest of the Northeast Region (1.9%) and the country as a whole (2.0%).

The population of the study area is more or less evenly distributed among the three districts. Table 10.1 provides a breakdown of population data by thana and a summary of demographic characteristics. Thanas which are partially inside the basin are pro-rated by area.

Graph 10.1 : Population Growth



[17] After enumeration is complete, census data are adjusted for under-count. Such adjustments are not available at the thana level and therefore enumerated or un-adjusted data have been used in this report for consistency.

Table 10.1 : Area and Population Distribution in Kangsha Basin, 1991

Thana	Area of thana (ha)	Thana-wise statistics of the study area								
		Fraction in study area[1]	Study area (ha)	No. of households	Population[2]			Density per km²	Average size of household	Gender ratio
					Male	Female	Total			
Nalitabari	32,761	1.0000	32,761	42,698	114,864	111,468	226,332	691	5.30	103
Jhenaigai	23,100	0.8750	20,213	26,349	61,819	60,447	122,266	605	4.64	102
Nakla	17,480	0.4006	7,002	13,413	33,312	31,966	65,279	932	4.87	104
Sherpur	36,001	0.2811	10,119	22,514	55,305	51,912	107,217	1,060	4.76	107
Sribardi	27,034	0.1419	3,837	6,797	16,477	15,904	32,381	844	4.76	104
Haluaghat	35,607	1.0000	35,607	49,520	122,816	119,523	242,339	681	4.89	103
Dhobaura	25,105	1.0000	25,105	30,491	79,334	77,693	157,027	625	5.15	102
Phulpur	58,021	0.2427	14,079	21,529	56,793	54,618	111,410	791	5.17	104
Durgapur	29,342	1.0000	29,342	32,245	85,395	83,740	169,135	576	5.25	102
Purbadhala	31,230	0.5594	17,471	25,061	66,965	64,872	131,837	755	5.26	103
Netrokona	34,035	0.4031	13,720	20,574	54,998	52,083	107,081	780	5.20	106
Kalmakanda	37,741	0.4926	18,592	19,347	52,587	50,544	103,131	555	5.33	104
Barhatta	22,150	0.1436	3,181	3,832	10,497	9,919	20,416	642	5.33	106
Total	409,607	0.5640	231,029	314,369	811,160	784,690	1,595,849	691	5.08	103

[1] Proportion of *thana* within the study area. Statistics of the study area are pro-rated from *thana* statistics on the basis of area.
[2] Components may not add to totals due to rounding

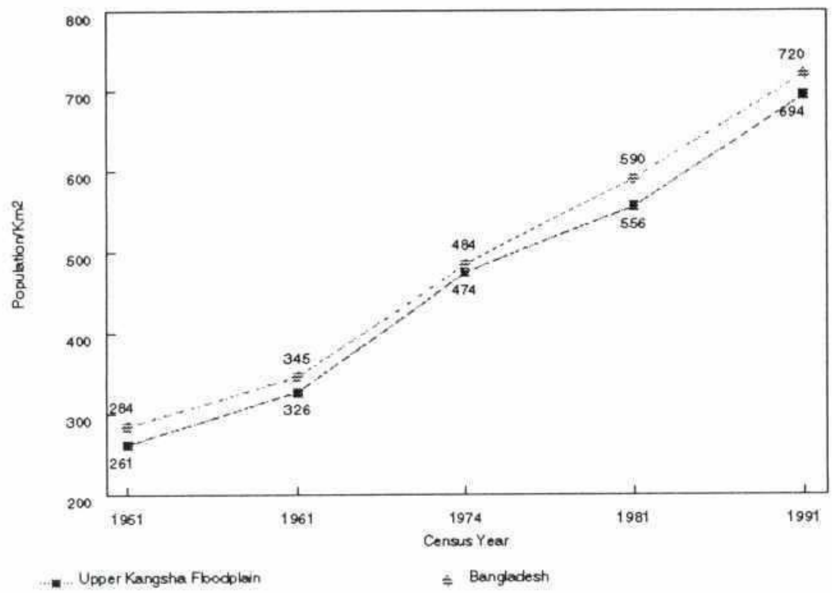
Source: BBS

10.1.2 Population Density

Population density and the extent of urbanization are lower than in the rest of the country. Based on 1991 census data there are 691 persons per square kilometre area in the basin, compared with the average of 707 persons per square kilometre in the Northeast Region and 720 persons per square kilometre in Bangladesh.

Population densities are generally highest in the southern portion of the basin and lower in the northern portion bordering India. Population density ranges from 555 persons per km^2 in Kalmakanda *thana* to 1,060 persons in Sherpur *thana*.

Graph 10.2 : Population Density



10.1.3 Household Size

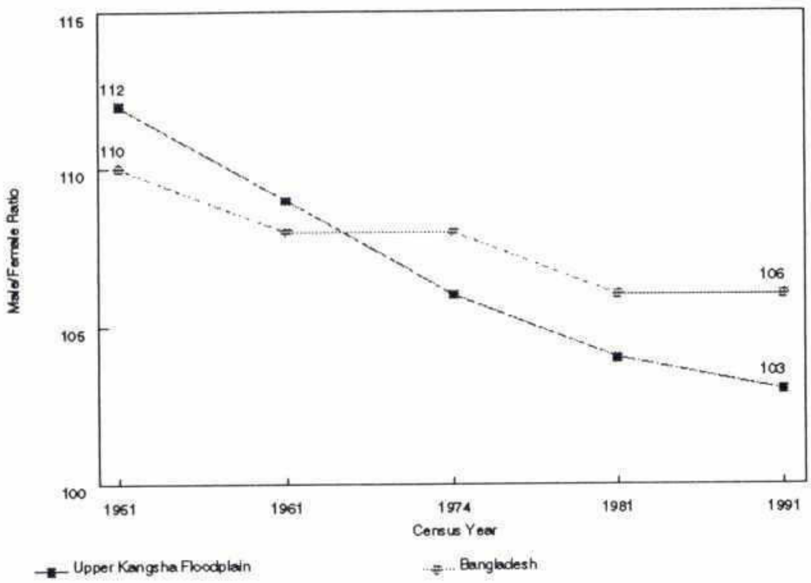
There are 5.1 persons per household on average. This is lower than the average household size in the rest of the region and the country (5.5 persons per household). In all *thanas* of the study area the average size of household is less than the national average. Household size is lower in the western part of the Kangsha floodplain (less than 5 persons per household).

10.1.4 Gender Ratio (Male/Female)

There are 103 males per 100 females in the study area. This ratio is lower than the ratio in the Northeast Region (105) and in the rest of Bangladesh (106), which may be due to less urbanization in the basin. Large cities have higher male/female ratios. There are more men than women in all *thanas* of the basin.

The ratio of males to females has declined in the study region at a faster rate than that in the country as a whole (see Graph 10.3).

Graph 10.3 : Gender Ratio



10.1.5 Age Distribution

The 1991 census indicates that the adult population (18 years and older) is 0.78 million people, almost 50% of the population. There are more females than males in the adult population.

10.1.6 Religion and Ethnicity

Muslims are the majority religious group in the study region and represent approximately 90 to 95% of the total population. This proportion has increased from 75% in 1911. The hindu population is the second largest religious group.

There are a few indigenous communities, primarily Hajong, Koch, and Mande (also known as Garo). According to the 1991 census, ethnic minorities together constitute only about 1.5% of total population.

10.2 Urban Areas

The urban population is relatively small compared with the rest of the country. According to 1991 data only 7.4% of the total population of the study area *thanas* live in urban centres compared with 19.6% nation-wide. The actual urban population in the basin is even less as the data include some of the larger urban centres which are located outside the basin boundary.

The rate of growth is higher in the urban areas than in rural areas. During the period 1974-1991 the population grew at a rate of 3.42% per year in Sherpur municipal area and 3.33% in Netrokona municipal area[18]. Growth of urban centres occurs mainly by net in-migration from the villages to take advantage of better opportunities for off-farm employment and education,

[18] Northeast Regional water Management Project: Study on Urbanization, Dhaka, 1994.

particularly at the secondary and higher secondary levels. Almost all government secondary schools and colleges are located in *thana* or district headquarters.

Influx of people from rural to urban areas has accelerated following independence of the country in 1971 and, more recently, following administrative decentralization at the *thana* level in the early eighties.

Sherpur, with a population of more than 50,000 people, is the largest urban centre. Netrokona and Nalitabari each have more than 25,000 people. The rest of the urban centres have populations of less than twenty thousand each.

10.3 Employment

10.3.1 Labour Force

According to census data about 67% of the population belong to the "potential labour force". This includes:

- all persons of age 10 years and above who are either employed or unemployed during the reference period of the census,
- self-employed and unpaid family helpers who spent at least 20 hours during the one-week reference period for gainful economic activity.[19]

Excluding the 'unemployed' and the 'inactive' proportion only about one-half of the total population is 'economically active'. The agriculture sector (including fisheries and forestry) is the largest employer, generating about two-thirds of the employment.[20] 'Unpaid family workers' represent 23% of male employment and 91% of female employment.[21]

10.3.2 Industry

The Upper Kangsha basin has a disproportionately small manufacturing sector. While the study region accounts for 11% of population in the Northeast Region it has only 9.4% of the large and medium scale industries (employing 10 or more people, except handloom units).

Most of the manufacturing establishments are in the food and allied industry especially in medium and large scale rice mills (88% of establishments). These are mostly concentrated in Sherpur district. There are some *biri* factories, wood processing plants, and brick fields. Brick fields are mainly concentrated in Sherpur, Phulpur, and Netrokona *thanas*.[22] There are also about 550 handloom units in the thirteen *thanas* of the study region, mostly in Jhenaigati *thana* (212),

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19/ BBS: Bangladesh Population Census 1991, Volume 1, Analytical Report, Dhaka, 1994, p.142.

20/ Nation-wide statistics are quoted since disaggregated data for the districts and *thana* are not available for the basin.

21/ BBS: Report on Labour Force Survey 1990-91, Dhaka, 1995.

22/ BBS: Directory of Manufacturing Establishments 1989-90, Dhaka, 1993.

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Sherpur *thana* (146), and Haluaghat *thana* (77).[23]

These industries together employ only about eight thousand workers, about 80% of whom work in the 'food and allied' industry and 16% in brick fields.

10.3.3 Seasonal Migration of Workers

Many people go to other places outside the village or even outside the district for several months at a time for employment. Many agricultural labourers in the study region go to the greater districts of Sylhet and Chittagong to work on contract basis.

There is scarcity of employment from mid-September to mid-November and mid-February to mid-April. During these lean periods some people go to other districts for work.

Migrating labourers leave their families behind and stay in the house of their employers. Sometimes they borrow money to meet the needs of their families and repay the loan when they are paid. Some labourers visit their families once or twice a month and also bring some money for living.

10.3.4 Women in the Labour Force

Most women (91% of the 'economically active' women nation-wide) are engaged in the agricultural sector as 'unpaid family workers'. Very few women are employed in typical field activities such as ploughing, sowing, plantation, weeding, and harvesting (less than 1% of employed women).[24] Main activities of women are poultry farming, post-harvest processing, cattle rearing, operating treadle pumps for irrigation, and selling from door to door.

Women labourers are usually hired on a seasonal basis for two months, Choitra and Boishakh. for parboiling and drying of rice, cooking food for male labourers, etc. Those who go outside the village for work are socially disgraced and the integrity of their "moral character" is questioned.

Many women work as labourers in rice mills. They perform the work of parboiling, drying, and winnowing while male workers usually perform transportation and supervisory work. The majority of the workers in *biri* factories are women. About half of the workers in the handloom sector are self-employed women. Brick fields employ only male workers.

10.4 Quality of Life Indicators

10.4.1 Literacy

Literacy rates in the study area are among the lowest in Bangladesh[25]. Out of 64 districts in

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23/ BBS: Bangladesh Handloom Census 1990, Dhaka, 1991.

24/ BBS: Report on Labour Force Survey 1989, Dhaka, 1992.

25/ Literacy has been defined in the 1991 population census as the capability of a person of age 7 years and above to write a letter. Previously the reference age was 5 years and above. Hence the literacy rate may seem higher compared with previous census data because of this change in the definition, and may not necessarily reflect a change in the quality of life.

Bangladesh the districts of Netrokona, Mymensingh, and Sherpur rank 45, 48, and 64 respectively.[26] The combined literacy rate (including both men and women) ranges from 18% in Jhenaigati *thana* to 28% in Netrokona *thana* compared with 32% nation-wide. The rates for both sexes are much lower than the national average (see Table 10.2).

There has been some improvement in school attendance during the period 1981-1991, particularly among the girls. However only about one-fourth of all girls are enrolled in schools (see Table 10.3) and the overall attendance rate is among the lowest of all districts in Bangladesh.

Literacy rates are higher in urban areas such as Haluaghat, Durgapur, and Netrokona. Literacy rates are much higher among the Christians and the Hindus than that among the Muslims. Netrokona district has a sizable Hindu population while Haluaghat and Durgapur have a sizable Christian population.

Table 10.2: Literacy of Population of 7+ Years, 1991(%)

Thana	Combined			Rural			Urban		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
Nalitabari	19.5	24.7	14.0	17.2	22.2	12.0	37.5	43.9	30.4
Jhenaigati	17.9	23.5	12.1	17.3	22.8	11.6	36.5	44.2	28.3
Nakla	22.4	26.9	17.7	21.2	25.4	16.6	47.3	53.7	39.8
Sherpur	19.4	24.2	14.2	15.4	19.8	10.7	38.6	45.0	31.5
Sribardi	18.5	24.2	12.4	18.0	23.7	12.0	29.1	36.0	21.7
Haluaghat	22.8	28.0	17.4	21.3	26.3	16.0	56.5	62.3	50.1
Dhobaura	18.7	23.6	13.6	18.4	23.2	13.4	34.2	42.9	24.6
Phulpur	20.9	25.9	15.6	20.4	25.3	15.3	37.2	43.9	29.5
Durgapur	23.0	28.1	17.8	20.8	25.7	15.8	47.5	54.1	40.5
Purbadhala	23.0	28.6	17.2	22.4	27.8	16.8	31.5	38.5	23.0
Netrokona	28.4	34.0	22.3	23.2	28.5	17.5	54.2	60.3	47.2
Kalmakanda	21.4	26.3	16.2	20.7	25.4	15.8	35.2	42.5	26.6
Barhatta	23.8	28.8	18.5	22.9	27.8	17.6	46.0	53.3	38.1
Bangladesh	32.4	38.9	25.5	27.9	34.0	21.5	49.8	56.3	41.8

[26] Ibid.

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Table 10.3: School Attendance Rate of Population of Age 5-24 (%)

District	1991			1981		
	Combined	Male	Female	Combined	Male	Female
Mymensingh	31.69	35.79	27.46	18.00	21.96	13.95
Netrokona	29.84	33.20	26.33	15.96	19.36	12.45
Sherpur	25.65	29.52	21.67	14.41	18.17	10.61
Bangladesh	36.52	40.66	32.21	21.90	26.80	16.80

10.4.2 Health and Sanitation

Access to Health Services

Table 10.4 shows the state of public health facilities in each district. There are 50-bed hospitals in Sherpur and Netrokona district headquarters. There is a 500-bed Medical College Hospital in Mymensingh district. There is a *Thana* Health Complex in each *thana* headquarters with limited laboratory facility and few beds. There is also one Family Welfare Centre at the union level which primarily provides family planning services. Access to public health facilities is poorer than the national average in the districts of Sherpur and Netrokona and better than the national average in Mymensingh.

Table 10.4: Public Health Infrastructure, 1992

District	Population	No. of Doctors	No. of Nurses	No. of Hospital Beds	Population per		
					Doctor	Nurse	Hospital Bed
Mymensingh	3,957,182	209	217	991	18,934	18,236	3,993
Sherpur	1,138,629	43	32	174	26,480	35,582	6,544
Netrokona	1,730,935	81	52	298	21,370	33,287	5,809
Bangladesh	106,314,992	5,420	4,149	24,197	19,615	25,624	4,394

Note: Population figures are from 1991 census
Source: Directorate General of Health Services

These facilities are concentrated in urban centres. The people in the villages mainly depend on "quack" physicians for their day-to-day needs.

Only about one-fifth of the children in the districts of Sherpur, Netrokona and Mymensingh have been immunized, well below government targets[27]. The government aims for 85% immunization coverage of children up to one year age by 1995 and universal coverage by year 2000.

27/ Population Development and evaluation Unit, Bangladesh Planning Commission: Impact of Population Program Performance at District Level, Dhaka, 1990.

Access to Potable Water

Urban Water Supply
The urban population of the Kangsha Basin depends mainly on hand tube wells and partially on piped water supply for potable water. Of the Basin's 11 urban centres, piped water supply is limited to Netrokona and Sherpur only, the two district towns of the area. The other nine urban areas which are *thana* centres are yet to receive this essential urban service.

In 1991 a survey was conducted to assess the water supply and sanitation conditions in Netrokona and Sherpur towns. The survey found that only 15% of the population in Netrokona town (45,700 as of 1991 census) used piped water for domestic purposes. Another 83% of the population used tube well water for drinking purposes but 55% of them performed other domestic services (cooking, bathing and washing etc) with pond and river waters. The remaining 2% of the population are dependent on surface water for all domestic works.

In Sherpur town it was found that only 3% of the population (62,800 as of 1991 census) used piped water for domestic purposes. The remaining 97% of the population were dependent on tube well, and dug well water for drinking and cooking purposes. About 17% of the population used pond and river waters for bathing and washing.

The *thana* centres solely depends on hand tube wells for domestic water supply. According to 1991 BBS data, about 85% population of these *thana* centres depends on tube wells, 9% on dug wells and 6% on pond and rivers for drinking water but most of them use surface water for other domestic works.

Rural Water Supply
The 1991 BBS data shows that about 78%, 12% and 10% of the rural population of the Kangsha Basin depend on hand tube well, dug well, and pond and river respectively as a source for their drinking water but almost all of them use dug well, pond and river water for other domestic purposes. In the area there were an estimated 13,300 hand tube wells (HTW) in 1991/92, yielding an average of one public tube well per 121 persons.

People of the area are using two types of hand pumps - one No. 6 suction pump which have shallow lift capacity and the other force mode (TARA) pumps which can lift water from greater depths. About 95% of these HTWs are of No. 6 suction pump type. The TARA pumps which constitute about five percent of the total HTWs of the area are the replacement of those No.6 pumps which became inoperative during the dry season when groundwater levels went down due to withdrawl for irrigation. The situation is growing worse as more and more groundwater is being used for irrigation. Many villagers use water from ponds and canals for drinking during the period from mid-February to mid-May.

Sanitation

Urban Sanitation
Sanitation conditions both in two district towns and nine *thana* centres are very appalling. There is no sewer line in any of the 11 urban centres. Sanitation facilities is limited to septic tanks, sanitary pit latrines, pit latrines and surface (water) latrines.

The 1991 survey reveals that only 38% of Netrokona Town people use hygienic sanitary latrines (sanitary pit latrine or septic tank). About 10% use a moderate quality facility (pit latrine), 33% have poor sanitary facilities (surface latrine) and 19% of the population have no facilities at all.

In Sherpur, the survey finds that only 40% of the population uses safe sanitary facilities and 6% use moderate quality facilities. Surface (water) latrines serve about 25% of the population. The remaining 29% of the population have no facilities.

The sanitary conditions in the nine *thana* centres are even worse. According to 1991 BBS data, only 18% of the population avails safe sanitary facilities, 56% use non-sanitary latrines and the remaining 26% of the population do not use latrine at all.

Rural Sanitation
Though over 78% of the area's rural population have access to tubewell for drinking water, but the full health benefit of improved access to safe water has not been realized because of general unsanitary environment and apathy of people towards hygienic practices and excreta disposal. Morbidity and mortality from water and excreta related diseases persist at a high level.

According to 1991 BBS data, out of 291,000 households in the rural areas of the Kangsha Basin, only 8,300 households (less than 3%) have sanitary latrines. About 53% households use surface (water) latrines and the remaining 44% have no facilities at all.

The Department of Public Health Engineering (DPHE) produces and distributes slab and ring latrines among the villagers at a subsidized rate. However, the utilization rate is still low because many people are not aware of the sanitation issue and many poor people cannot afford even the subsidized price.

10.5 Land Tenure

Continuous high growth of population has made land scarce. The present population in the Upper Kangsha Basin is estimated to be 1.6 million, implying a population density of 690 per sq km and cultivable area of less than 0.09 ha per person.

Updated macro-level statistics on land ownership are not available. The last agriculture census, conducted in 1983/84, indicated that about 60% of the rural households in the basin are functionally landless (owning no more than 0.2 ha of land). The extent of landlessness is slightly higher in the western part of the basin (Sherpur district).

Many small land-owners work as share-croppers of big land-owners. The most common sharing arrangement is that the cultivator provides all input and pays half of the produce to the land-owner as rent. The share-cropper's right to cultivate in successive years is not legally protected although it is the common practice.

Land is generally acquired through inheritance. Because of flood, people sometimes sell their land at a cheaper price to pay off debts. Private ownership over land is widely recognized.

10.6 Village Structure

There are 1,528 villages in the basin. Each village contains 192 households on average. Villages

Table 10.5: Distribution of Rural Population

Thana[1]	No. of villages	No. of households	Population	Average per village	
				Household	Population
Sherpur	51	19,025	89,556	376	1770
Sribardi	10	6,550	31,154	655	3115
Jhenaigati	76	25,561	118,500	336	1557
Nakla	47	12,842	62,341	274	1330
Nalitabari	138	38,212	201,234	277	1458
Netrokona	139	17,327	89,897	125	648
Purbadhala	187	23,300	122,888	125	658
Durgapur	215	29,729	156,136	138	726
Kalmakanda	169	18,519	98,508	110	583
Barhatta	33	3,670	19,612	112	599
Phulpur	100	20,983	108,427	210	1087
Haluaghat	205	47,757	232,612	233	1135
Dhobaura	158	29,795	154,000	189	975
Total	1,528	293,270	1,484,865	192	973
Bangladesh	86,038	15,608,654	85,442,788	181	993

[1] Data include only the portion of the than which lies within the Kangsha Basin
Source: BBS

tend to be larger in the higher land on the western side of the basin than those in the *haor* on the eastern side. Data on village structure are provided in Table 10.5.

The smallest social unit is the *ghar* which is the equivalent of a nuclear family (members belonging to one economic unit sharing the same kitchen). Several *ghar* having kinship lineage forms a *bari*. Members of a *bari* usually share some resources among themselves: a common courtyard (for threshing and drying of rice and similar other purposes), a pond, and a graveyard. A cluster of bari form a *para* which is socially recognizable as a 'neighbourhood'. One or several *para* form a village.

Villages are raised above the crop land and are easily identifiable from a distance. The *bhita* is the most raised area used as homestead. Rich people are able to raise the *bhita* high enough so that it can withstand flood conditions. Many poor people cannot afford to raise their *bhita* sufficiently and thus they remain vulnerable to flood.

To accommodate increasing population, people either divide their *bhita* or they expand the homestead platform laterally. The size of a village tends to be smaller in low-lying areas than in high-land areas, because raising of land for a homestead platform is difficult, costly, and constrained by *khals* and drainage channels.

10.7 Social Stratification

Political power is concentrated in hands of those people who own the economic resources. People who own businesses also own large tracts of cultivable land, and have contracts for construction of public works. Elected officials in the *Union Parishad* and *Jatiya Sangsad* (national parliament) are mostly from this stratum.

Many people are involved in trading activities and some of them own shops and *aarats* in market places. Large land-owners are also owners of big shops and *aarats*.

Most of the cultivable land is owned by a small number of households, about three or four per village. Below this stratum are many small land-owners, many of whom also work as share-croppers of big land-owners.

The landless are the most vulnerable section in the society. They work as farm labourers but when there is scarcity of employment, particularly in the pre-harvesting period, they are forced to migrate to other places for work and to borrow money or rice from rich neighbours or traditional money-lenders for subsistence.

The very poor people, particularly women and children, live on communal property to a large extent. They live a subsistence lifestyle largely dependent on wetlands products and rice salvaged from the fields after harvest for food and income.

10.8 Survival of the Poor

The poor people live on wage labour including farm labour outside the district. Female members of these households also work in others' houses. Work is mostly available during the harvesting period and during the plantation period in the *boro* season. Work is scarce in the *aman* season as land remains under water; during this period farm labourers go to other districts, mainly to Chittagong, Comilla, Noakhali, Feni, and Sylhet, to look for work.

Many people are caught in a downward spiral of poverty. During the lean period some people are forced to expend their savings and some sell their assets. When all other means of survival are exhausted they borrow money or rice at high rates of interest. Typically a loan of tk 1,000 is re-paid with tk 1,500 or 9 to 10 *maunds* of rice after four months. Women borrow from the *sangstha* (NGO) to repay the loans of their husbands; to repay the loan to the NGO they have to sell their poultry, goats, ornaments, and other possessions. Many people have only one meal per day.

10.9 Water Management Issues

The water management issues identified from the PRA analysis and the case studies are summarized below:

- Certain action which may benefit the farmers in one village may have adverse impact in a wider context. This phenomenon clearly indicates the dichotomy between the "local" and the "global" contexts.

- Conflicts occur between different social groups over the use of water. For example, farmers want to drain water quickly in late monsoon, whereas the fishers want to retain it for longer period.

- Conflicts also occur even between same social groups. For example, farmers in the upper catchment hold water in the dry season for irrigation depriving the farmers of the lower catchment. Again, when there is heavy rainfall, farmers of the upper area divert drainage water to lower area damaging crops there.

- Another facet of the scenario is the interaction and cooperation of people at a micro setting with respect to use of water. This is manifested in the construction of earthen dam in some places where the people mobilize their own resources to build manageable structure at reasonable cost without entering major conflict with other group. There are examples where the upstream-downstream conflict with respect to sharing of water for irrigation is resolved through consultation and the cognizance of each others' need.

- In the northern part of the basin, groundwater is not available for irrigation at economic depth but in the south, it is available. But at a few locations, the southern people, by using their political influence establish their rights over the use of surface water though the rivers run from north to south.

- Conflicts also arises out of alternative use of groundwater. In many areas of the basin where farmers use STWs for irrigation, people do not get water in their hand tube wells on which they solely depend for their drinking purpose.

- Some individuals exercise control over resources available for collective use. This happens to be one form of appropriation of public resources. Economic and political power are major determinants of such appropriation.,

- People cut embankments when they feel that these are obstructing drainage.

- It has been observed that embankment fail almost every year. Gaps are not closed in time. People do not come forward to repair the dyke in a way they take care of their irrigation structures and other interventions made with their own means. Embankments are rather perceived as government property and their maintenance is also the responsibility of the government.

11. INSTITUTIONAL FRAMEWORK

11.1 The Administration

Structure

The most basic feature of Bangladesh public administration is that it is very centralized with almost all planning and administrative decisions made in Dhaka. For administrative purposes the country is divided into six geographic regions although this division or a version of it is, to some extent, a remnant of former administrations and no longer has much real meaning. In current administrative practice, the district is the basic unit of the civil administration.

Every district has a team of civil servants who perform all the administrative functions of the government of Bangladesh. A Deputy Commissioner (DC) is supposed to coordinate the activities of the line ministries at the district level, but he has limited power in day-to-day activities over the line ministries all of whom report directly to their own Ministers. The DC's power comes from his appointment through the Establishment Ministry which the Prime Minister controls. DCs are often called upon to mobilize the Administration to deal with national disasters.

Each district is divided into a number of *thanas* and each *thana* into a number of *unions*. At the district and thana levels there are a number of offices of national ministries although some ministries have their own structures which do not coincide with these administrative divisions. These include especially BWDB, Roads and Highways, and Forests besides some others which have special geographic demands like BIWTA and the rather new Environment Directorate.

As in most centrally administered systems, liaison between regional administrations and line ministries which have their own structure is somewhat uncertain. Barenstein, for example, remarks that "... even in those *thana* headquarters where the local offices of most of the relevant actors happen to coincide physically.... they supposed to coordinate by going up in the hierarchies of their respective institutions.[28]"

The Ministry of Local Government, Rural Development and Cooperatives, the Ministry of Health, and the Ministry of Agriculture have a presence down to the union level. The Ministry of Social Welfare, which handles women's affairs, also has a strong presence in the Union headquarters. For ministries which have a presence in unions the union office is usually concerned with extension or outreach services, for example family planning outreach programs, agricultural extension and so forth. BWDB, Roads & Highways and Forestry do not generally have offices below the district level.

The agencies and their distribution are set out in Table 11.1.

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[28] Jorge Barenstein, 1994, *Overcoming Fuzzy Governance in Bangladesh: Policy Implementation in LDCs, Page 139.*

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Table 11.1: Government of Bangladesh Agencies and their Distribution Among Different Administrative Levels

Institution	District	Thana
Ministry of Local Government, Rural Development and Cooperatives (LGRD & C)		
LGED	XEN	Asstt. Engineer
DPHE	XEN	SAE
BRDB	Regional Director	Rural Development Officer
Department of Cooperatives	District Cooperative Officer	Thana Cooperative Officer
BWDB (Ministry of Water Resources)	No Correspondence	
Food Directorate (Ministry of Food)	Controller of Food	Thana Food Officer
Ministry of Agriculture		
Directorate of Agricultural Extension	Deputy Director	Thana Agricultural Officer
Ministry of Fisheries and Livestock		
Directorate of Fisheries	District Fishery Officer	Thana Fishery Officer
Directorate of Livestock Services	Deputy Director	Thana Livestock Officer
Ministry of Environment and Forest		
Forest Directorate	District Forestry Officer	Office
Environment Directorate	No presence yet	
Ministry of Health and Family Planning		
Directorate of Health	Civil Surgeon	Thana Health Officer
Directorate of Family Planning	District Family Planning Officer	Thana Family Planning Officer
Department of Education (Ministry of Education)	District Education Officer	Thana Education Officer
Department of Roads and Highways (Ministry of Communication)	XEN	
BIWTA (Ministry of Shipping)	No presence	
Ministry of Land	Additional Deputy Commissioner (Revenue)	Sub-Registrar
Ministry of Home Affairs	Superintendent of Police	Police Inspector/Sub-Inspector
Ministry of Establishment	Deputy Commissioner	Thana Nirbahi Officer

Bangladesh Water Development Board (BWDB)

BWDB is the key agency in the water sector and is involved in flood control, drainage, and irrigation. It is under the jurisdiction of, and takes direction from, the Ministry of Water Resources. It is mainly run by water resource engineers.

The BWDB has its own internal structure that does not correspond to the Administration boundaries. It includes a Board in the headquarters which is responsible for overall planning and management. Under the Board there are several layers of management which are responsible for implementation of projects. Their structure is as follows:

Board	: National, headed by a Chairman.
Zone	: Responsible for a large geographic area that covers several districts, headed by a Chief Engineer.
Circle	: Part of a zone, headed by a Superintending Engineer.
Division	: Part of a circle, headed by an Executive Engineer. It may be responsible for a district, part of a district, or more than one district.
Sub-Division	: A part of a division, responsible for specific projects and headed by a Sub-Divisional Engineer.

The Kangsha Basin includes parts of three BWDB Divisions: Netrokona Water Development Division, Mymensingh O&M Division, and Tangail O&M Division. These Divisions are all within the administrative jurisdiction of the Mymensingh Circle under the North-Central Zone.

Planning is done under the auspices of the Chief Engineer, Planning, who reports directly to the Board. This office includes several directorates, each headed by a Director who is at the level of Superintending Engineer. The present Kangsha Basin Water Management Plan is the responsibility of the Directorate of Planning Schemes-I having its office in Dhaka.

LGRD&C

Perhaps the Ministry with, at least structurally, the most potential in the rural areas is the Ministry of Local Government, Rural Development and Cooperatives (LGRD&C). LGRD&C is well placed and has a number of semi-autonomous agencies designed to deliver particular services in the rural areas. Among these are:

- Local Government Engineering Department (LGED): mainly responsible for the rural physical infrastructure. This includes construction and maintenance of roads connecting growth centres, small-scale water management initiatives, etc. Overall planning and management is done in the headquarters under the supervision of a Chief Engineer. LGED has offices at the district and *thana* level supervised respectively by an executive engineer and a thana engineer.

- Department of Public Health Engineering (DPHE): involved in the fields of public health and sanitation. It runs a national programme for domestic water supply and sanitation. It has offices at the district and the *thana* level.

- Bangladesh Rural Development Board (BRDB): promotes cooperative societies at the grass-roots level. It has a two-tier cooperative structure: a primary society at the village level and a federation of primary societies at the *thana* level. It promotes three distinct types of cooperative societies: farmers' cooperatives (KSS), women's cooperatives (MSS) and destitutes' cooperatives (BSS). It also provides management training and credit support for members of cooperative societies. BRDB has an office in each district and *thana*.

FPCO and WARPO

FPCO (Flood Plan Coordination Organization) is another autonomous agency constituted under the Ministry of Water Resources. It has the specific purpose of preparing the Flood Action Plan (FAP). FAP contains five regional studies, including the Northeast Regional Water Management Study (NERP), as well as a number of supporting studies. Recently it has been merged with the WARPO (Water Resources Planning Organisation), another organisation under the same Ministry.

The BWDB is currently the lead agency responsible for implementing the recommendations of FAP.

Implications for the Kangsha Basin Water Management Plan

The basic lesson from all of these administrative considerations for the present Water Management Plan is that there is no immediately obvious agency that can take on the task of coordinating the basin water management project. Civil servants, who exercise overwhelming authority in the administration of local affairs, are guided by policies decided at their respective ministerial headquarters. Although the FPCO guidelines recommend a PCC located in the Water Board, it seems unlikely that it would be able to coordinate activities located in several ministries.

11.2 Political Structure

Above and around the administrative structures sketched out in the preceding section there are national, regional, and local political structures.

The most significant part of the political structure is the national. A Member of the *Jatiya Sangsad* (national parliament) represents a constituency of about 380,000 people. The constituency may or may not coincide with a thana but if the thana is big it often does. Thus at the district level, which is the key decision-making level for the administration, a number of parliamentary constituencies are represented and these do not necessarily correspond to thana boundaries.

At the district level, development activities are supposed to be planned and monitored by the *Zila Parishad* (district council). However, this body is almost non-functional. It was a creation of the British administration and has no powers devolved to it under the present structure of government. A *Zila Parishad* is composed of MPs of the respective district.

There is also a local government structure, the *Union Parishad* (UP), which is elected for a term of four years by popular vote. This body has little direct control over the Administration and for practical purposes it reports to the TNO (*thana* executive officer). While the UP has little administrative or financial authority it can exercise a decisive influence in local affairs. The Chairman and Members are instrumental in the allocation of material relief and in the identification of infrastructure projects like UP roads and culverts. They can also bring political pressure to have their recommendations accepted by the line agencies. UPs have been involved in a number of local water-sector initiatives in the Kangsha Basin.

There is a *thana Parishad* composed of a committee of all union Parishads, with each union representative taking turns at the chair.

Basically what all this adds up to is that there is currently no elected local government structure at the district level. MPs' formal authority is exercised through the Jatiya Sangsad and they are not really mandated to influence administrative or development activities in their constituencies. In practice, of course, MPs (particularly those who belong to a ruling party) exercise considerable influence on the district and *thana* administration by virtue of their linkage with Ministers. They also play an important role in the allocation of public resources for such things as the allocation of relief materials such as Food for Work and for local physical infrastructure such as roads, culverts, and so forth.

Once again the lesson seems to be that there is no organization for guiding water resource development at the river basin scale from within the political framework.

11.3 NGOs

NGOs became involved following the war of independence in 1971, in response to the need for a massive relief and rehabilitation program. Later they started responding to development needs of the communities. Social welfare activities, social mobilization, and rural development have become the main thrust of the NGO sector for last two decades.

There are many foreign, national, and local NGOs. The smaller NGOs are listed in Table 11.2. The larger ones are listed in Table 11.3 which sketches out the kinds of activities on which they are working.

Few NGOs are involved in the water sector, principally CARITAS and CARE. CARITAS has been involved in constructing embankments along the Someswari and Shibganjdhala Rivers.

Table 11.2: Local NGOs in the Northeast Region

1. Adarsha Samaj Seba Samity
2. Alor Sandhan Samaj Sebi Sangsthan
3. Friends in Village Development B'desh
4. Gram Unnayan Sangstha
5. Grameen Jana Kalyan Sangsad
6. Jana Kalyan Kendra
7. Khasdabir Youth Action Group
8. Palli Unnayan Kendra.
9. Provati Samaj Kalyan Sangstha
10. Rural Development Health Center Foundation
11. Shimantik
12. Sunnity Sangha
13. Social Association for Rural Advancement
14. Uddam Bahumukhi Samaj Kalyan Sangstha
15. Unnayan Sahayak Sangstha
16. Unnayan Sangha
17. Voluntary Association for Rural Development
18. Sabalamby Unnayan Samity
19. Bahubal Samaj Unnayan Sangstha.
20. Community Development Association
21. Gazipur Unnayan Sangstha
22. Gonobani Sangstha
23. Inst. for Develm't Education & Action
24. People Oriented Program Implementation.
25. Paharika Samaj Unnayan Sangstha.
26. Social Progress Service
27. Samaj Unnayan Sangstha
28. Shoshika.

Table 11.3: National NGOs Working in the Kangsha Water Management Plan Area

Name of Organization	Location of nearest Regional Office	Focus in Kangsha Basin
BRAC	Mymensingh, Sherpur & Netrakona	Comprehensive village development, NFEP, Health & Education.
Grameen Bank	Mymensingh (Zonal office-Administration) Netrokona and Sherpur (6 Area offices & 66 Branch offices)	Credit Bank
Proshika-MUK	Mymensingh, Netrokona & Sherpur	Comprehensive village development
ASA	Netrokona, Sherpur and Mymensingh	Adult education and credit.
CARITAS	Mymensingh	Coop rural development, fisheries, public health etc. Provides funds in support of local initiatives in water sector.
Gonoshasthya Kendra (GK)	Mymensingh & Netrokona (Baghshala)	School & health education
NGO Forum for Drinking Water Supply and Sanitation.	Office in Mymensingh covers all three districts.	Potable water sanitation (latrine production). Discussion forum. Training in human development.
Family Planning Assocation of Bangladesh	Netrokona	Service delivery, IEC (news about family planning methods.)
Palli-Karma-Sahayak Foundation.	No regional office in NE	Credit programs

Role of NGOs
There is sometimes a tendency in certain kinds of development projects to assume that project "externalities" can be undertaken by NGOs. These projects include infrastructure projects whose natural constituencies may be different from those currently emphasized by development agency policies. Water sector projects experience this difficulty because their "natural constituencies" tend to be cultivators who either own or have access to land. Landless people, women, and other groups currently favoured in development projects are thus excluded from their programs unless special steps are taken to include them.

Most NGOs work with a "target group" approach. In general their clients are people, to quote one mission statement, "... whose lives are dominated by extreme poverty, illiteracy, disease and malnutrition, especially women and children. Their economic and social empowerment is the primary focus ...."

At the core of most NGOs activities is an approach to development which is intensely bottom-up. Their activities are based on village-based groups. Their experience and their strength lies in their ability to organize beneficiary groups at the grassroots level and to promote horizontal and vertical linkages between these groups.

In this context project designers sometimes turn to NGOs as a sort of service organization or sub-contractor to undertake the work of community organization involving the poor, strengthening women's participation, rescuing wetlands, and many other difficult aspects of development by foreign donors. Not only are NGOs assumed to be able and willing to pick these activities up but they are often assumed to be able to do so over the long-term and on an almost voluntary basis. As shown below this view of NGOs is inappropriate and incompatible with their own definition of their mission.

The Role of NGOs in Development Activities Driven from Outside the NGO Perspective
NGOs in Bangladesh are characterized by at least two features. They are probably better developed than NGOs in any other country. They have also developed considerable independence based on a clear sense of their own mission. Their support from foreign donors has allowed them to strengthen their autonomy.

This success has also forced them to monitor their own processes with special vigilance. In fact they have moved away from the title "NGO" which they see as increasingly inappropriate to their current level of professionalism. The larger ones have, as one commentator writes "blurred the conceptual boundaries of a traditional NGOs by virtue of [their] size and the span of [their] programming." They think of themselves as "Private Sector Development Organizations." In a sense they have *had* to become what many contemporary businesses aspire to: "learning organizations."

Some of these NGOs are by now big enough to constitute a national development agency. However they have been careful not to be seen to be trying to assume this role. They have their own agendas and, because of this, they have tended to keep within strict boundaries.

GOB in contrast with, for example, the Governments of India and the Philippines, has never explicitly recognized NGOs as development partners. Nevertheless NGOs do have relationships with line agencies of GOB. One expression of this kind of cooperation can be seen in projects where there is an overlap between the mission of the NGO and the commitment of a government department. NGOs have cooperated with departments such as DPHE to provide services that both organizations are trying to deliver in the rural areas. Such collaboration is taking place mainly in health and sanitation, family planning, fisheries, livestock and poultry, afforestation, education and training.

The role, then, of the NGO as a sub-contractor which can take care of "externalities" is obviously not an appropriate one. Although it is not unknown[29] NGOs rarely take on the role of sub-contractors. BRAC says it never does this. NGOs do not see themselves as picking up the pieces of other people's projects. Ideally they seem to see themselves as "interweaving" with Government Organizations (GOs). What this seems to imply is that the NGOs see the ideal relationship with the government as one of *inter*-dependence.

It has to be said, however, that NGOs seem to have an especially ambiguous relationship with developments in the water sector. They have often formed centres of criticism of Flood Action Plan projects and especially of the way in which water sector projects have been implemented. (See for example the report sponsored by Oxfam-Bangladesh, "People's Participation NGOs and the Flood Action Plan: An independent review."[30]). When the NERP-sponsored regional meetings were held in all districts of the Northeast Region, no major NGO attended any meeting. While this should not be read as outright opposition, it is clear that they do not see water sector projects as central to their mandate.

Structures for NGO Cooperation and Coordination
Within the NGO community the need has been recognized for structures to coordinate and encourage cooperation among different organizations working in the same area. One of the first mechanisms that has arisen for this purpose is ADAB, the Association of Development Agencies in Bangladesh. ADAB sees its mission as "Coordinating, monitoring, networking and advocacy for an enabling environment for the non-profit development sector in Bangladesh". The quotation is taken from ADAB's 1995 "Directory of PVDOs/NGOs in Bangladesh". It refers to non-profit non-governmental agencies that are involved in development work as "Private Voluntary Development Organizations" (PVDOs).

ADAB then would seem to hold some promise for focussing whatever contribution PVDOs/NGOs have to make to the river basin development. ADAB's role is, however, somewhat circumscribed by other factors. The first is that compared to some of the larger existing organizations ADAB is rather limited in resources. Their coordination at the moment is structured around 14 Chapters throughout Bangladesh. This is too little to achieve the kind of coordination that would be required for a project like Kangsha Basin Water Management. ADAB itself recognizes these limitations and reports a plan "... to decentralize its functions and promote various sectoral fora...."

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[29] In the Delta Land Reclamation and Development projects, NGOs like Nijera Kori have acted as sub-contractors to the Dutch development contractor. They worked to deliver certain specifically defined services to the project. This, however, is quite unusual. Their services were discontinued as soon as the project ended and the only value that flowed from using an NGO as a "sub-contractor" was that the work was presumably done more cheaply than it could have been done by the Dutch company.

[30] Shapan Adnan, Alison Barrett, S.M. Nurul Alam, Angelika Brustinow *et al* 1992. People's Participation NGOs and the Food Action Plan: An independent review. Dhaka: Research & Advisory Services

Apart from ADAB's own efforts there has been some growth throughout Bangladesh of thana-based NGO forums. This seems to be a very promising development which offers some opportunities for a project of this kind to find some of the coordination that it would need.

There are several other mechanisms that NGOs have used to increase the amount of cooperation that exists among the different organizations working in the same area. Some of these may offer opportunities that could be explored in the Upper Kangsha River Basin. For example, some of the bigger organizations like BRAC have taken on the roles of franchiser, of banker, of trainer and of wholesaler of NGO services. What has to be remembered is that all of these roles are constrained by the requirement that the works to be undertaken must be within the overall strategic commitment of the senior organization.

11.4 Informal Institutions

It is frequently the case that small functional organizations are found in local areas. They may be quite modest, for example, a village-based cross-dam "committee" for local irrigation management. Local groups of men or women can form around the purchase and operation of tube wells; among fishing families there is often cooperation in the purchase and operation of specialized gear such as the *tanaber* which typically requires two boats and the participation of about 15 or 16 people. Many small water management initiatives have been constructed in the Kangsha Basin by such organizations - for example the Sakhait Bundt was constructed by a group of local people who mobilized local forces and support from local NGOs to close a spill channel of the Someswari River.

The distinguishing features of these organizations is that they are ad hoc. They emerge in response to specific needs and do not usually assume any political or community organizational role. Most of the locally-initiated interventions for water management are undertaken by informal groups or coalitions like these. These collectives are autonomous in character, financed from member or local contributions, and wither away as soon as the activity is over. They have no scope or capacity for coordinating water management activities on a basin-wide scale and have little scope to deal with forces that transcend their immediate area of interest.

Other informal institutions exist in rural areas. Typical of such organization is the traditional *samaj* or *mallot*[31]. They are generally more involved in adjudicating disputes and settling issues of traditional local jurisprudence than in development activities.

11.5 Community Participation in the Development Process

In the past five years many attempts have been made to bring about a development process that is more inclusive of local perspectives. Attempts have also been made to make project clients more involved throughout the process of project identification, evaluation, design, and implementation. The hope has been that if this process is successful, local people will feel a stronger sense of ownership of the projects which are designed to serve them. An exhaustive discussion of this work is outside the scope of the present report but reference can be made to

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[31] The *samaj* assumes different forms in different areas. In parts of Mymensingh it is called the *geramer dashjan* (literally a collective of ten people, usually village leaders).

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several documents which are listed in the References[32].

Two motives can be discerned. The first is to increase the level of consultation between project administrators and local people. This initiative aims to avoid mistakes based on assumptions that have not been ground-truthed in the field. It is also designed to provide local people with opportunities to make their perspective known to the development agency. The methods that have been followed to achieve this in the Kangsha Basin Water Management Plan are described elsewhere in this report.

The second motive is more ambitious. It is designed to not only consult local people but to get them actively involved in project management. A number of projects have tried to implement this perspective. They include, among others, the Netherlands-supported BWDB Systems Rehabilitation Project, the Tangail Compartmentalization Project, GK Project, and the CIDA-World Bank Small-scale Water Control Project. In these projects substantial effort was undertaken to make the communities themselves the real managers of the project.

In our opinion the most signification contribution of these attempts has been that they have been able to field test some of the theories about issues such as ownership of the works, the length of time that is needed to develop locally-based management, what form it should have, whether it is sustainable, the conditions under which it is sustainable, and so forth. From our perspective, two significant findings come from these trials.

The first is that most of the organizations that emerged are very issue-oriented. While it is relatively easy to mobilize local involvement for a specific task, for example for construction of a specific project, other tasks such as operation and maintenance require infrastructure that has a dedicated long-term focus and exceeds the inclination and capabilities of a local group. Project planning also requires a long-term focus and a degree of coordination that is probably not possible at the local level. It is most true for BWDB flood control and drainage projects which is the arena in which most of the trials mentioned above have been undertaken. It is least true for NGO-based activities like non-formal primary education, self-selected small groups that seek credit from Grameem Bank, and so forth, which have shown more substantial staying power.

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32 / Ministry of Water Resources/ FPCO Third Conference on Flood Action Plan, May 17-19, 1993, Dhaka. "People's Participation in Compartmentalization Pilot Project FAP-20." by Md. Obaidur Rahman, Superintending Engineer, Project Director CPP, FAP-20, BWDB Tangail.

Ministry of Water Resources/ FPCO "Guidelines for People's Participation in Water Development Projects." August 22, 1994.

Ministry of Water Resources/ FPCO Manual for Environmental Impact Assessment (ISPAN) December 1994.

Second Small-scale Flood Control Drainage and Irrigation Project, Small-scale Water Control Structures III Project "Community-based Operation and Maintenance: Case Studies and Lessons Learned." (September 1994).

SRP Technical Report No. 36 "SRP's Approach towards Users' Participation in Water Management Development Projects." (July 1993)

The second significant finding is that the smaller projects are more likely to succeed - in fact *only* small projects can be community based and locally managed. Only small projects can be developed within the time-frame of participation under community-based management.

It must be recognized that there is often conflict between a project schedule and the time required to develop community-based management organizations. If donors or organizations are serious about "community participation throughout the project cycle," they seem to have three options:

1. They can build in to the project enough time for community organization to be achieved;

2. They can design projects of limited scope that have "natural" communities (the small-scale local fisheries projects proposed under this Water Management Plan are good examples of this kind of project);

3. They can design projects that are solely or principally community-based and which completely depend on the success of the community management program. This is essentially the approach of the NGO village-based organizations.

For water sector projects which are larger and involve coordination on a basin scale, it will be the first of the above three that will have to be followed.

From the above discussion it can be seen that:

- local initiative is vital if a project is to meet the needs of a community;

- local institutions must be project-based and orientated toward specific issues;

- adequate time and organization must be allowed to mobilize community participation;

- the project must be small or it must be broken down into small components that are within the capability of local organizations to manage;

- there remains a need for an external planning/executing agency to maintain a larger view, to coordinate the community involvement, to maintain long-term commitment on a basin-wide scale, and to operate and maintain the infrastructure.

11.6 Role of the Water Management Plan

The basic elements of a development plan are a development strategy, an implementing agency, and a funding formula. Like the Regional Plan that preceded it, the Upper Kangsha Basin Water Management Plan can really have none of these although some are implied. This is not a shortcoming of the work or its designers; rather it is a weakness of the institutional framework in which the plan has had to be developed.

Development Strategy
The Water Management Plan sets out a basic strategy for development. It provides a description of the constraints and water management problems in the basin, an analysis of the issues leading from these, and a recommended strategy for dealing with these issues as well as a list of specific interventions (projects) that can be implemented and that are consistent with the needs of the people and the constraints within the basin. In the absence of a regional planning authority the Plan itself forms the basic institution to guide further development; but is really only one step in the planning process and is not likely by itself to ensure that the proposed projects are implemented. It will require a funding formula and an implementing agency to translate the basic strategy into specific works that can be implemented.

Funding Formula
It can be said that the funding formula is faith in the donor community and the foreign aid process. Perhaps the Planning Department could be said to have the most opportunity to influence the time frame. They are, at least, in the position to approach donors for project and to, at the very least, *influence,* even if they do not actively determine, donor choices. BWDB has shown an interest in some of the projects that are proposed in this Plan and even a willingness to proceed without foreign donations if required. It remains clear, however, that little progress will occur in implementing the recommendations of this report until a foreign donor steps forward.

Implementing agency
Implementation of the Plan will require more advanced planning, coordination between various government agencies and NGOs, and mobilization of local involvement and community participation in the projects and the plan itself. The present plan anticipates work that would be implemented through many different GOB line agencies including BWDB, DOF, Department of Forestry, DPHE, and so forth. The institutional designer has to accept that there is, at present, no formal structure to provide cooperation among these line ministries. Nor is there any institutional change on the horizon that can be looked to for a remedy to this situation.

The BWDB is the obvious agency for implementing many of the projects such as flood control embankments that are proposed within this Plan. However it lacks the breadth to carry out a water management plan as diverse as that proposed under the present mandate.

This observation leads to the conclusion that this report itself has to, in some sense, provide for the integrating even if it cannot stand for the development institution. In time the NERP project will be superseded by other projects and this report by other reports. Each successive review or report will then have to constitute some kind of current development perspective which builds, hopefully, on previous plans. That is, this report has to recommend a development strategy which, like that of the Northeast Regional Water Management Plan which preceded it, has to be without a firm time-frame and without a clear funding formula.

Limitations of the Water Management Plan
Most of the decisions that will be made in the region will be driven by forces over which no water resource planner or floodplain administrator has any control. These forces include the formidable forces of nature, the policies of donors, the desires of landowners, the needs of politicians, and the special interests of persons who may make money from the projects. All of these are part of the reality that constitutes the social backdrop to development.

Moreover there is competition and sometimes even conflict among the different constituencies that water management serves. For example, serving the constituency of "basic human needs" or the poor requires doing different things than those that need to be done if one is serving the constituency of food growers or land-owners. In fact a good development plan probably involves serving the interests of all of these groups.

When one considers competition and opportunity costs, a water resource management project that is attempting to deal with poverty reduction may be quite different from one that is attempting to deal with increasing agricultural productivity. A dollar spent on infrastructure may produce more labour opportunities than if it spent on increased agriculture production (from, say, a second cropping season). The benefit of having a few tens of days additional labour for a limited number of landless persons may be offset by the loss of a valuable capture fish resource, and these compromises involve more than economic consideration.

These are very complex questions that, even if development were driven by a completely rational process, would be extremely difficult to resolve. They certainly cannot be resolved here and will require much deeper public dialogue and consultation.

It also needs stating that the realities of current Bangladesh law enforcement limits the options that are available. It is necessary to accept the fact that the Government of Bangladesh has only limited and circumscribed control over either the urban or rural life of the country. This implies that proposing legislation about floodways or ground water use is not an effective option in the present state of Bangladesh development. Such a policy would probably never become legislation; if it did the legislation would quite possibly not be enacted; if it were enacted, it could well be impossible to enforce.

Thus while the Water Management Plan may set out a basic framework for development it has little real power for implementing its recommendations and for resolving the competing and sometimes conflicting interests that are involved in its implementation. Other mechanisms are required within the context of an implementing agency to invoke the Plan.

How then can the report become an agent of development? Given that the present document represents a first cut at the development process it would be unfair to expect it to play such a role. The present document constitutes a working paper for a presentation plan not the presentation plan itself. It would need to be extensively reworked if it were going to assume an expanded role. The report as development plan would need to have a form similar to a set of business development plans. It would need to be clear and persuasive and easily divided up into discrete bits for distribution to and adoption by individual donor agencies. Each package would represent a discrete project and would need to assume the form of a presentation document with an appeal appropriate to its task. In short this means that the project concepts which are provided herein would need to be developed to the pre-feasibility stage of planning. Such a product would require special treatment which is outside the reach and budget of the present task.

11.7 The Institutional Approach: A Proposed Regional Water Management Project

With this perspective the present Water Management Plan would like to introduce the considerations below hoping that they will be persuasive to other agencies who may wish to take up particular projects recommended by the plan.

In the absence of a regional development authority it is hoped that a donor could support a regional development project. The project would undertake the necessary coordination among ministries and the organization of the community participation. They would prepare the pre-feasibility study reports and present them to the community for approval and to prospective donors for funding.

Other international donors would be approached to fund individual projects. Design and administration of specific projects would be handled within each individual project but the regional development project office could retain a coordinating role during the implementation process.

The most popular home for such projects at the present time is the LGED. However LGED, for all its strengths, is becoming overloaded; it may not have the capacity to absorb any more projects at the present time. Perhaps the Planning Ministry itself would be prepared to act as a nominal sponsor. Even if it represented a departure from present practice, this would seem to be an appropriate activity.

The project would establish a structured set of Project Coordinating Committees (PCCs) to organize the community participation. The FPCO guidelines (or at least the FAP-16 Manual) recommends PCCs for a project of this size which would be composed of perhaps two or three organizational levels. At the superior level there would, to quote the guidelines, "normally be a PCC convened by the BWDB. The PCC at this level should be chaired by a senior MP from the region, and should have representatives from sub-PCCs created around local water management areas by elected district and/or *thana* leaders."

At the next level below this (4,000 to 10,000 ha) the manual anticipates that there will be other committees "... at the *zila* level, with sub-PCCs at lower levels organized around technically rational water management areas or structures." "Here," it says, "the PCC should be organized by the local MP or, if the area covers more than one constituency of the *Jatiya Sangsad*, by the senior MP". An example is the Someswari River Management Committee which is proposed as part of the Someswari River Hazard Management initiative under this Plan. Such a committee would be struck only for programs that span a larger part of the project area and involve a number of inter-related or complex components, and it would provide the necessary regional perspective and continuity over time to ensure that such a project recognizes the global constraints.

At the lowest level the project would employ a number of Community Organizers that would organize project committees responsible for input to undertake detailed planning and implementation of a project. For example in the Dampara Project it is envisioned that 8 to 10 COs will work to organize the local communities into committees that will contribute to the detailed planning, design, and construction of the project. This approach is similar to one developed by the Dutch-funded Systems Rehabilitation Project (SRP). They start with a Water User Group (WUG) at the lowest level which is roughly equivalent to FAP-16's "local water management area". SRP works, however, from the bottom up; the WUG is set up, not by a local politician, but by something like the Community Organizers used by the Small-scale Water Control Structures Project.

Such a project organization is the most likely to be able to mobilize the local involvement and external resources which are required to successfully implement the Water Management Plan.

12. EXISTING WATER MANAGEMENT PROJECTS

12.1 Flood Control and Drainage

BWDB has implemented a number of projects in the area. These projects are summarized in Table 12.1 and their locations are shown in Figure A.21. The projects are intended to provide full flood control improvement to a gross area of 19,678 ha and irrigation to 8,090 ha. In addition a number of projects have been implemented by local authorities and NGOs; these are described below.

Table 12.1: Existing BWDB Water Management Projects

Project Name	Type	Gross Area (ha)	Project Component
Malijhee River WRS Sub-Project	Irrigation	6650	A 7 vent (2.44mx2.54m) water retention structure
Chelakhali Sub-Project	Flood Control and Irrigation	1,440	14 km of flood embankment along Chelakhali River; A 23 vent (8-1.5mx3.0m, 15-1.5mx1.5m) water retention structure
Konapara Embankment Project	Flood Control and Drainage	3,480	22 km of flood embankment along the left bank of the Kangsha River from Bahir Shimul to Phutkai. 26 small pipe drainage structures (pipe diameter: 30 cm - 45 cm)
Kangsha River Improvement Project	Flood Control and Drainage	11,600	19 km of full flood control embankment along Kangsha River right bank from Jaria to Baroari village; Drainage regulators of various sizes at seven locations
Thakurakona Sub-Project	Flood Control and Drainage	3,158	13 km of full flood control embankment along the Kangsha River and Dhonaikhali khal Right bank from Baroari to Thakurakona; Three drainage regulators.

12.2 Malijhee Catchment

Malijhee Water Retention Structure
A seven-vent water retention structure was completed on the *Malijhee* river near Hatibandha village in 1986. The objective of the project was to restore and enhance the availability of water to irrigation during the dry season - the river had previously been deepened to improve drainage which lowered the water levels.

Flash floods damaged the structure in May 1988 while it was under repair. It could not be opened because the gates were locked and the responsible BWDB staff were not present. The gates were washed away, and since then the structure has not operated despite requests by the people to the BWDB to get the structure repaired. The people say that the WRS is too small to withstand the flashy runoff of water from the hills. It also needs to be opened quickly in the event of a flash flood.

In 1986/87 about 120-150 LLPs were installed for irrigation. Some low-lying areas were irrigated directly from the river through drains. Now irrigation is done mostly from groundwater.

Malijhee River Embankment
An embankment was built along the south bank of the Malijhee River by the *thana* authority in 1983. It was improved by the BWDB in 1984/85 at the time of the construction of the WRS. The embankment was breached in the floods of 1988 and 1993 and has been repaired by local efforts.

Marishi River Embankment
The Marishi River is the largest tributary of the Malijhee River. It has been embanked through its entire length by the Union Parishad between 1973 and 1988. However breaching occurs at many locations during floods; as happened in 1983, 1988, and 1993. Repairs have been made by the Union and local forces with some assistance from *Shapla Neer* (a Japanese NGO) but the embankment is in poor condition in many places.

12.3 Chillakhali Catchment

Chillakhali Sub-Project
The project consists of 14 km of flood-control embankment and a 23-vent water retention structure.

Flood-control embankments were constructed by BWDB at the request of local residents in 1981-82 and were extended about 7 km downstream in 1988-90. The embankments were constructed with minimal setback in places. They are prone to frequent breaching caused in part by deposition within the embanked section. Large breaches were observed in the floods of 1993 and 1995. The river is "perched" and the embanked reach is aggrading such that the channel bed is now 1.5 m above the land outside the embankments.

The water retention structure was originally constructed in 1985 as an 8-vent structure along with four irrigation offtakes for gravity irrigation. The closure and protective works were damaged in 1985 and 1986 and the structure was extended by adding 15 vents in the years 1986 to 1988. It has never operated because the structure does not have any operating deck and the stop logs are extremely difficult to remove. Local people have reverted to building earthen cross-dams upstream of the structure and charge fees from the local farmers. Irrigation water is drawn by LLP from the impounded area.

Several committees were formed to try to manage the project. Conflicts have arisen over:

- water sharing - people living to the south are deprived of water and have cut the dam and taken legal action to try to stop the people upstream from impeding the flow of water,
- operating levels - farmers inlets are at different levels,
- political and ethnic differences - these seem to a factor in other disputes,
- jurisdiction over control of the structure - two villages have competing interests.

12.4 Bhogai Catchment

Flood Embankments
Dykes were built by the UP along both banks of the river in 1972/73 and were rebuilt in 1976/77. The original embankments were damaged due to flood almost every year and are no longer effective. As a result the roads along two sides of the river serve as the embankment.

During the flood of 1995 the dyke breached at 11 different locations. Flooding occurred twice, causing damage to *aus* crops, *aman* seedbeds, and t. *aman* crops and sedimentation on about 50 ha of land. Downstream areas were affected to a greater degree.

Irrigation Diversion
The LGED constructed a two-vent inlet at Shimultala in 1990, drawing water from the Bhogai River into Dugdha Khal where is it used for irrigation during the dry season. The offtake replaced an earlier concrete pipe that had been installed by the local people. It is reported that local people build a cross dam in the Bhogai River immediately downstream of the structure to help divert the flow during lean periods.

In the 1995 *boro* season, 75 LLPs were operating along the Dugdha Khal and serving a command area of about 709 ha. The downstream farmers built three cross-dams to hold water for gravity-flow irrigation to about 324 ha.

12.5 Konapara Embankment

This embankment extends for about 20 km along the left bank of the Bhogai and Kangsha Rivers from Bahirshimul Bazar (upstream of Sarchapur) to Futkai village. It was started by BWDB in 1980-81 and was repaired in 1989 following the 1988 flood. The project affords some measure of flood protection to the area lying to the north but the land in the eastern (downstream) portion is still flooded by backwater from the lower Kangsha River which serves as the outlet from the area. Spills also occur upstream of the embanked reach through Kodalia Khal and Gangina Khal and overbank as the embankment is not tied to high ground (see sidebar - The Battle of Kodalia

Khal). These khals have been closed but not securely. The embankment was breached in two places in 1988 and 1993 floods and was cut by local people in the 1983 flood.

The main embankment follows the route of an earlier road which is located some distance away from the river in places. Consequently a number of villages located between the embankment and the river are not protected and the affected people cut the embankment in 1993. A secondary embankment has since been started by BWDB closer to the river.

12.6 Kangsha River Project

Embankments
The project consists of 19 km of flood control embankment along the right bank of the Kangsha River from Jaria to Baroari. It was completed in 1990. Existing roadways are on the west, south and east boundaries of the project. The purpose of the project was to protect t. aman and boro crops from flash flooding.

A major problem with the project is that it intercepts the natural west-to-southeast drainage. Overflows from the Kangsha River are trapped by the Purbadhala-Jaria roadway on the west side, and the road is overtopped and breached during floods. This has happened on two or three occasions since the project was completed, including the flood of 1995, and the result is that the project does not afford the full flood protection that was intended. Homesteads are flooded and t. aman crops are damaged.

Drainage Regulators
A large 10-vent sluice gate was constructed to pass the drainage from the west side into the Kangsha River downstream of Jaria. It has a reportedly has a vibration problem in the gates which prevents it from operating at capacity. The structure is overloaded by the Kangsha River spills from upstream, through the Dampara Project area, and has been outflanked by a cut made in the embankment during flood conditions in 1993. The cut was made to drain the flood water from the upstream side and has been left open. These problems will be largely solved if the Dampara Project is completed as it will cut off the upstream spills.

Some repairs are needed to the regulators. People complain that the regulator on the Larai River at Jalalpur, which drains a large part of the project, is not operated by BWDB. One of the gates was found to be broken in late 1994 and had reportedly been in that condition for some time. Changes in design and operation of these gates are required.

Benefits and Impacts
Even though the project area is still subject to flooding there has been a significant increase in the area cultivated in T aman crop and there have been visible changes in the economy of the area. Previously most of the area had only one crop, boro. More rapid drainage of khals and beels occurs to the benefit of agriculture and farmers are demanding further drainage improvements. Demand for farm labour has increased along with higher wage rate due to the increased T aman crop. In these respects at least the project has had some success.

The project has brought other changes to the area including:

- reduced availability of farm labour as more people are producing two crops,
- reduction in fisheries, fishing income, and livelihood of fishermen,
- loss of water transportation and connections for water transportation to the Kangsha River, and increased dependency on and use of land transport,
- increased irrigation from groundwater and increased depletion of HTWs used for domestic water supply,
- threefold increase in land values; land is now available only to rich people,
- reduced dependency on borrowing at high rates of interest for boro production as it is no longer the single crop.

The possibility of such changes should be considered in planning and implementing water management projects in the basin.

12.7 Thakurakona Project

The project was completed in 1992 as an extension to the Kangsha Project which is located to the west and shares a common boundary, a roadway on the west side. Embankments on the north protect the area from the Kangsha River floods. The purpose is to provide year-round flood protection to the area and thus protect *boro* and T *aman* crops.

The roadway on the west side had been breached or cut in every flood since the project was completed, including the flood of 1995. Breaching of the Kangsha Project embankments causes flood waters from the west to accumulate against this road and causes flooding to large areas. The people living to the west cut the road to allow the water to drain and to relieve their flooding; but this contributes to flooding inside the Thakurakona Project area.

Farmers complain that the regulator gates are not water-tight. Drainage is also difficult due to high Kangsha River levels much of the time

Ultimately the prospects for success of this project will depend on implementation of the Dampara Project and improvement to the Kangsha Project so as to reduce the inflows of flood water.

The project area has seen changes similar to those of the Kangsha Project. There has been an increase in T aman plantation, even in flood years. Land values/prices have increased as have labour wage rates. Fewer workers leave the area and more enter in search of employment. River transport routes through the project area have been cut off.

12.8 NGO and Community Initiatives for Flood Control

A number of projects have been undertaken by NGOs under local initiative in the Someswari Project area.

Right Bank of the Someswari River
A road along the right bank of the Someswari River from the border to Durgapur serves as an embankment to protect the areas to the west. Some portions were raised by CARE in 1995. An avulsion of the Someswari River began to form in 1995 and breached the embankment. Deposition of sand occurred downstream but the avulsion has not yet developed to form a full channel.

Right Bank of the Shibganjdhala River
A dike was constructed by CARITAS along the right bank of the Shibganjdhala River for some 5 km downstream of Durgapur in 1980. More work was done in 1990 and 1993. The dike is 7-10 feet high, 8-10 feet wide at the crest level and 15-20 feet wide at the base, and is protected by banana and mulberry trees.

Left Bank of the Someswari River
The left bank upstream of Durgapur is overtopped during floods and threatens to form an avulsion. A major avulsion formed in the 1988 flood to become the present Atrakhali which has subsequently grown and threatens to become the main branch. Another avulsion formed upstream at Agar village in 1988 where the bank was overtopped in 1984, 1988, and 1992. It was closed in 1992 by a 2 km long embankment funded by CARITAS and is presently maintained under the RMP.

Left Bank of the Shibganjdhala River
An embankment was constructed by the thana council before 1988, extending along the left bank from Durgapur to Jhanjail. Although it is set back some distance from the river, it is nevertheless eroded by floods. It was breached in 1988 a short distance downstream of Durgapur and a large channel called Sakhit River formed as an avulsion on the floodplain. The dike is not maintained and has been eroded and breached over about 25% of its length.

The Sakhit River in 1988 spilled across the Jaria-Durgapur Road. It threatened the Jaria-Durgapur Road, the campus of the Cultural Academy, the Garo Baptist Mission, and part of Birishiri. Local people created a closure called Sakhit Bundt with help from Union Parishad, thana, local organizations, and an NGO (World Vision). The embankment is one mile long. It is built of sand and is strengthened with earth and grass, bamboo, sandbags, and pillars. It remains vulnerable but withstood record flood conditions in 1995.

Netrokona Integrated Development Programme (NIDP) Embankment
An embankment was started in 1991 along Toerkhali Khal to protect aman crops, but was not completed. Construction was stopped because the local share of 25% of construction cost was not paid. Many people contributed to a common fund but the fund was not paid to NIDP. It affords some protection of crops but sand which is carried down from the Someswari River is deposited over 300 ha at the downstream end of the completed section rendering the land unusable. Sixty STWs became inoperative and several beels have been degraded.

12.9 Small Scale Irrigation Projects under Local Initiative

A number of small scale irrigation projects were built under local initiative. Virtually all of the small streams in the area are closed with cross-dams during the dry season and the remaining water is drawn by gravity or pumped out by LLP to irrigate crop lands. This practice is especially common in the foothill streams which are fed by groun dwater discharge from India. On some streams a series of dams are sometimes built which leads to water-sharing conflicts between the upstream and downstream owners. Sometimes the people come to an agreement between themselves; in other instances they resort to violence or to cutting the upstream dam. In other cases the downstream dams are supplied by outflow of groundwater between the two locations. Some of the known occurrences are summarized below.

Earthen Dam on the Marishi River
Five or six cross-dams are built by local people every year to irrigate fields between the villages of Khoilkura and Chatol. The group which builds the dams allows only 'excess' water to pass downstream; consequently the dams must be guarded to prevent people who live downstream from cutting the dam in order to get water into their land.

There are two cross-dams at Borajani and Khailakora on the Mora Bhogai River and three cross-dams at Polasia, Naokata and Bhalukakora on Sutia Khal. The total command area for irrigation is over 200 ha. There were 15 LLPs in operation in the *boro* season of 1995.

Nitai
Four cross dams supply water to 3,500 ha using are 112 LLPs.

Two examples illustrate how water management issues are resolved at the local level.

Dighirpar
A cross-dam was built on the Marisha River at Dighirpar by a group of ten persons from two villages. One person owns four acres of land but the rest are almost landless. They construct the project as an income-generating enterprise.

Constructing the dam costs them tk 6,000 and their labour. Maintenance of the dam and irrigation canals during the *boro* season costs them an additional tk 12,000 to 15,000 plus labour. They sell water to land-owners in the vicinity who pay according to the distance to their plots. Some people do not pay; others who cannot pay the total amount at once make weekly instalments.

The dam is guarded round the clock due to fears that it may breach due to the pressure of water, and that downstream people may cut the dam in order to get water into their land. The group which builds the dam allows only 'excess' water to pass downstream.

Kushaikura
Farmers of Nolkura union tried to build a cross-dam near the village Kushaikura for irrigating their fields in 1992. This resulted in scarcity of water for irrigation for downstream users who cut the dam. The dam was rebuilt and was cut again. The dam was built once more, this time by the *Union Parishad*, and was guarded by one hundred people round the clock. The affected farmers living downstream demanded that the dam be demolished and they complained to the *thana* and district authorities. The Deputy Commissioner of Sherpur district came to Jhenaigati to hear from both parties but the dam breached due to the pressure of water before the issue was resolved.

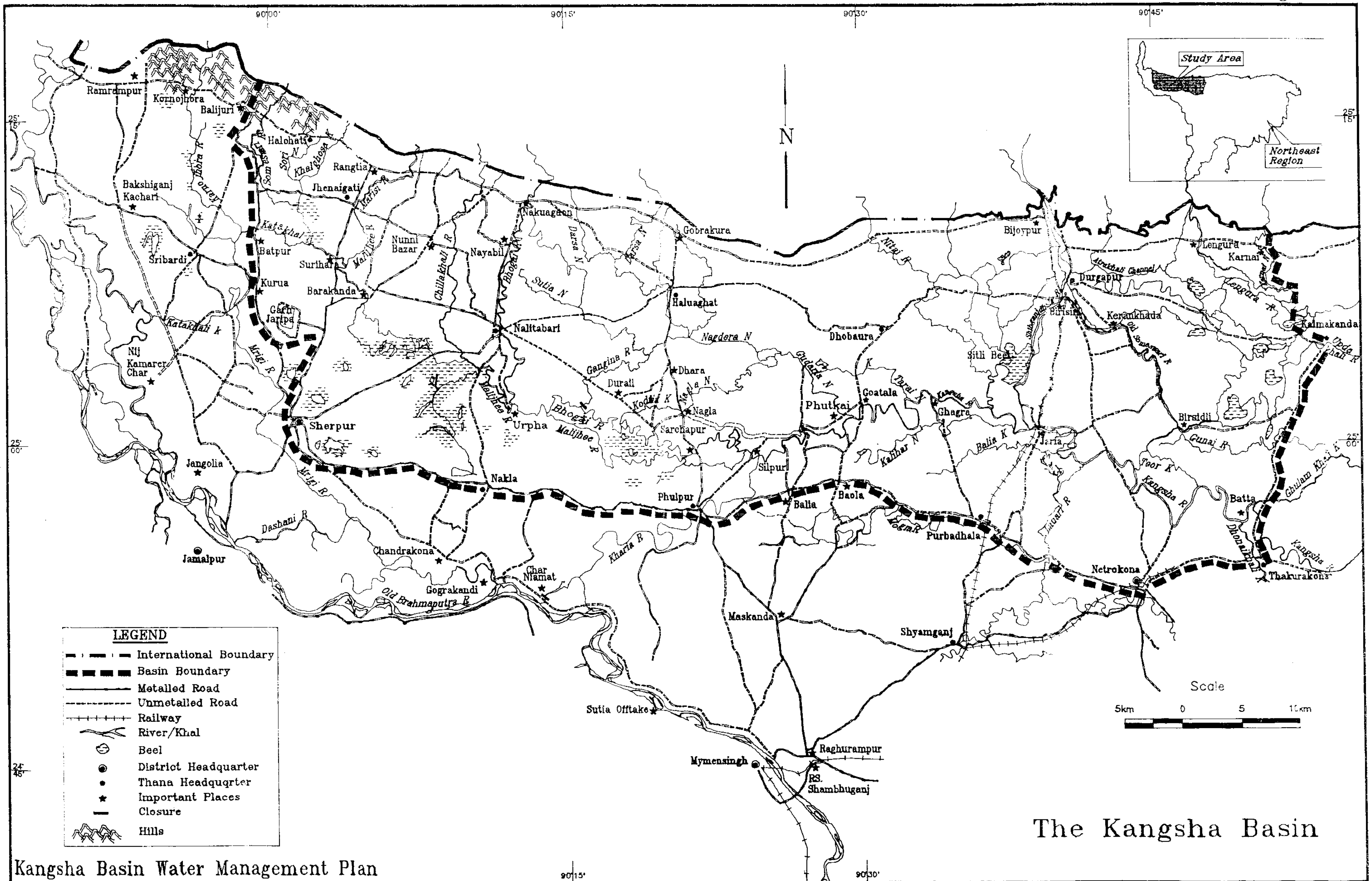
Lengura River
There are two cross dams in the Lengura River which compete for water for irrigating HYV boro rice crops. Downstream users are affected as the winter flows are cut off. They depend on winter crops as the monsoon water levels are too high to permit t. aman to be grown. They plant their crops earlier when water is still available and they try to cut the upstream dams when water is scarce.

Chorras
There are seven small foothill tributaries between the Someswari and Lengura Rivers. All of these are used for irrigation water supply and most are cross dammed in at least one location. Some conflicts occur between upstream and downstream users regarding sharing of the water. In other cases there appears to be enough to supply all needs, possibly because sandy soil conditions are conducive to discharge of groundwater which enters aquifers in the hills to the north.

Dampara Area
Four channels provide drainage from this area. There is considerable use of the water for irrigation. Closures or bundts are built at several places and the water is pumped out by LLP. Surface water is used for irrigation as long as it is available, and then the farmers draw groundwater from STWs. Domestic wells sometimes go dry as a result.

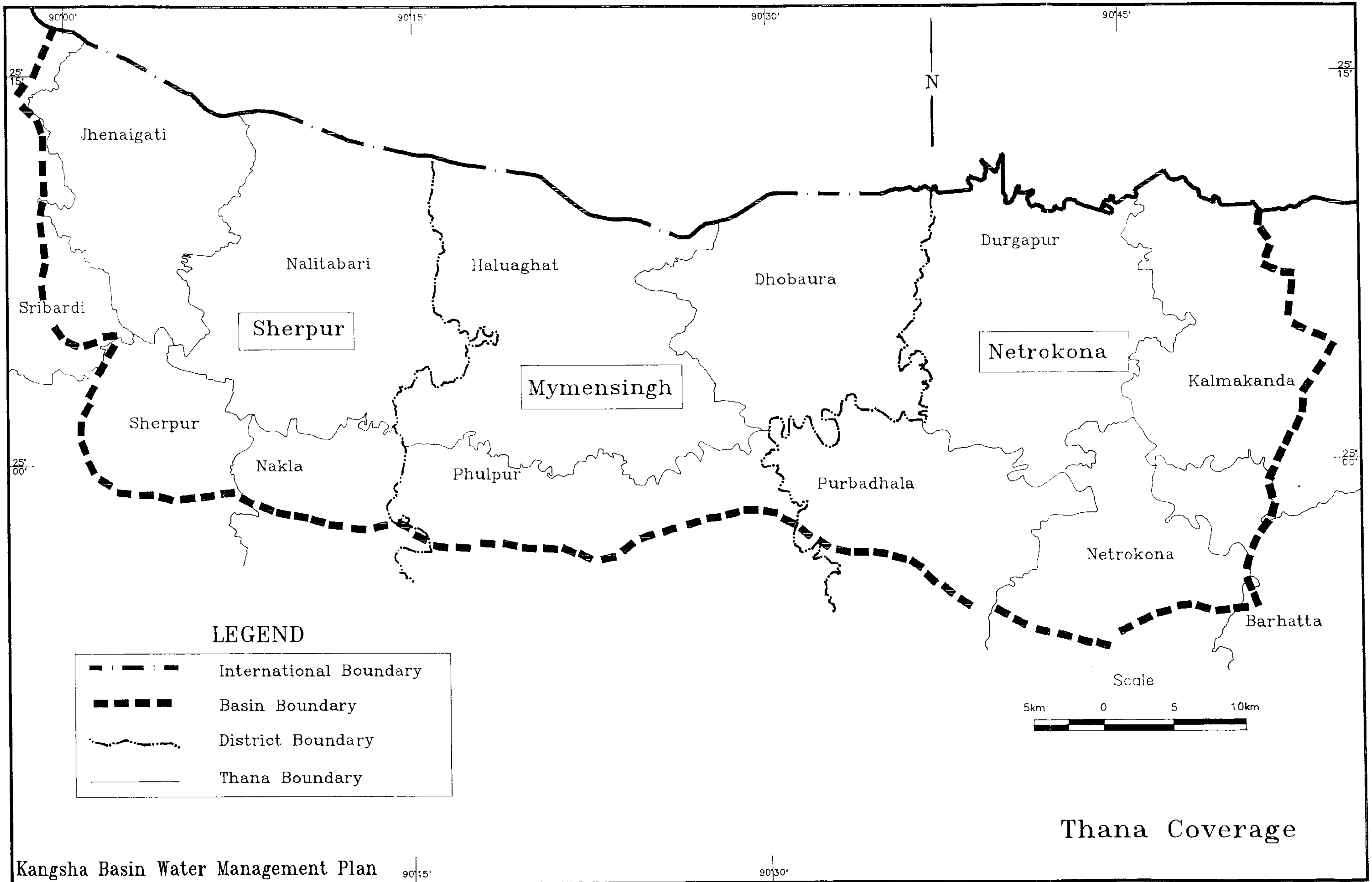
Farmers use the bed and banks of the khals for crop in the dry season, leaving only a narrow strip for the remaining flow. Sometimes they excavate deeper pools to retain water for their use.

Figure A.1



FILE: NERP-371.DWG Prepared by: Jalal

Figure A.2

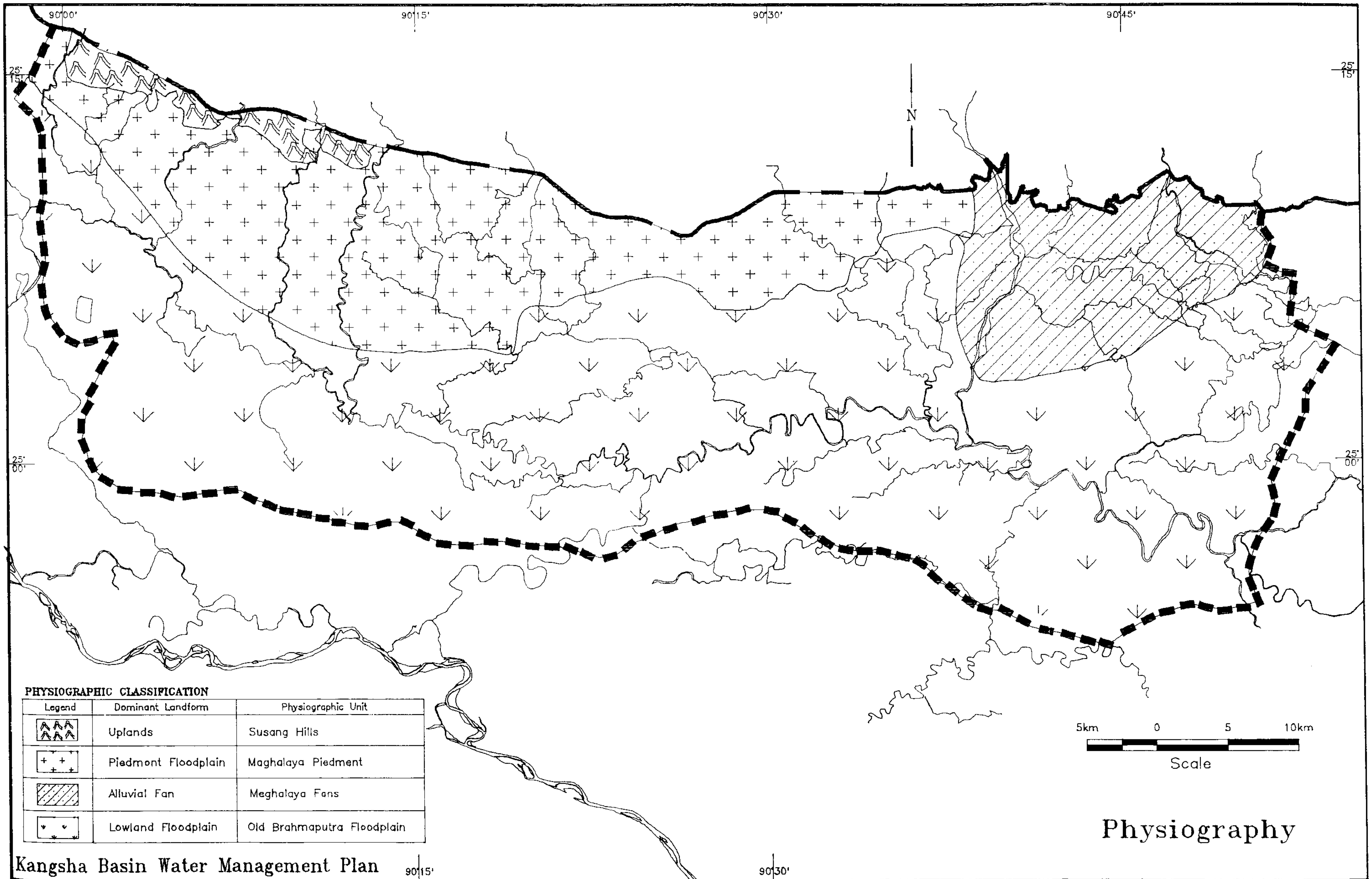


Thana Coverage

Kangsha Basin Water Management Plan

FILE: NERP-372.DWG

Figure A.3



Physiography

Kangsha Basin Water Management Plan

FILE: NERP-373.DWG

Figure A.4

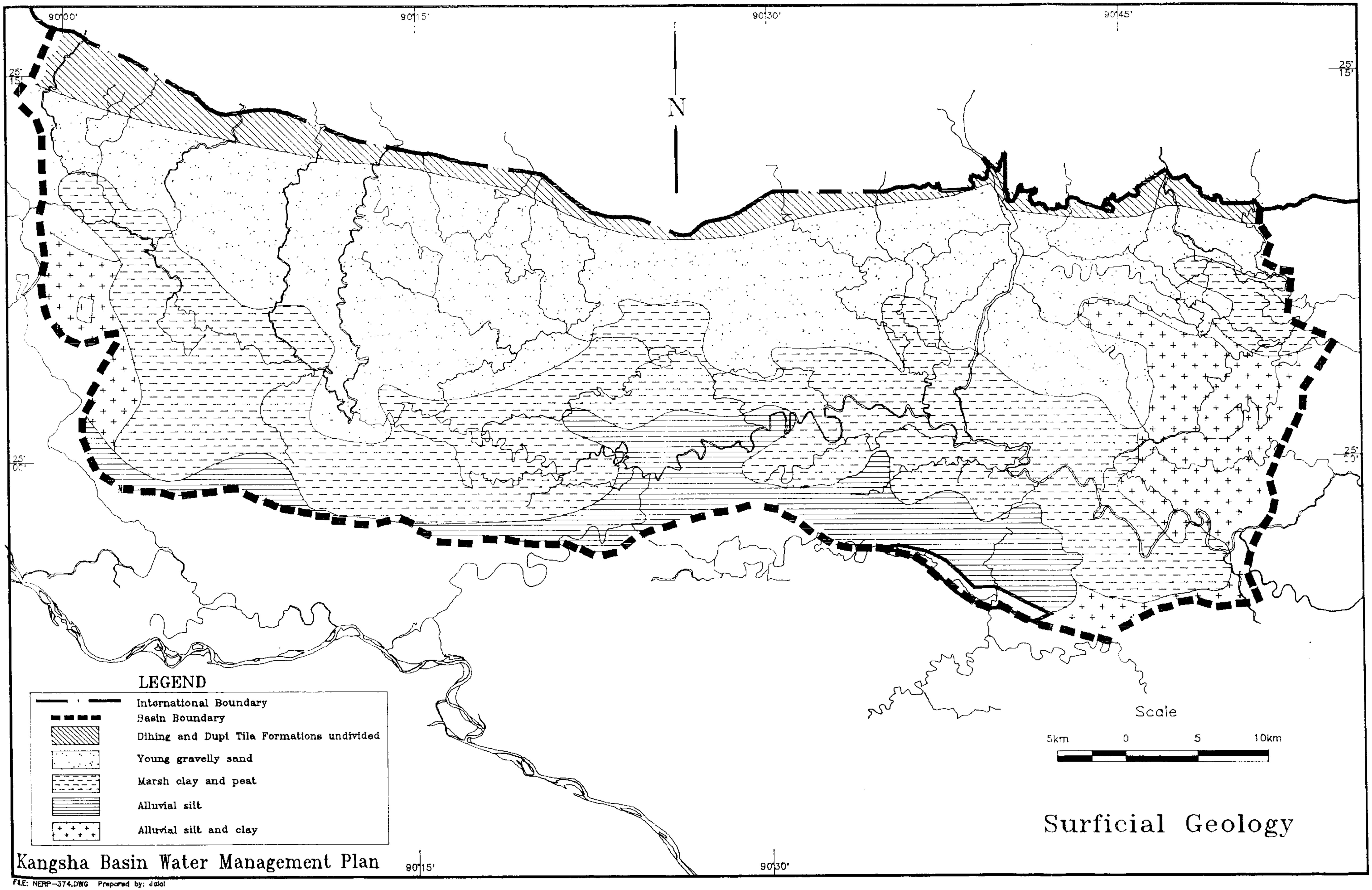
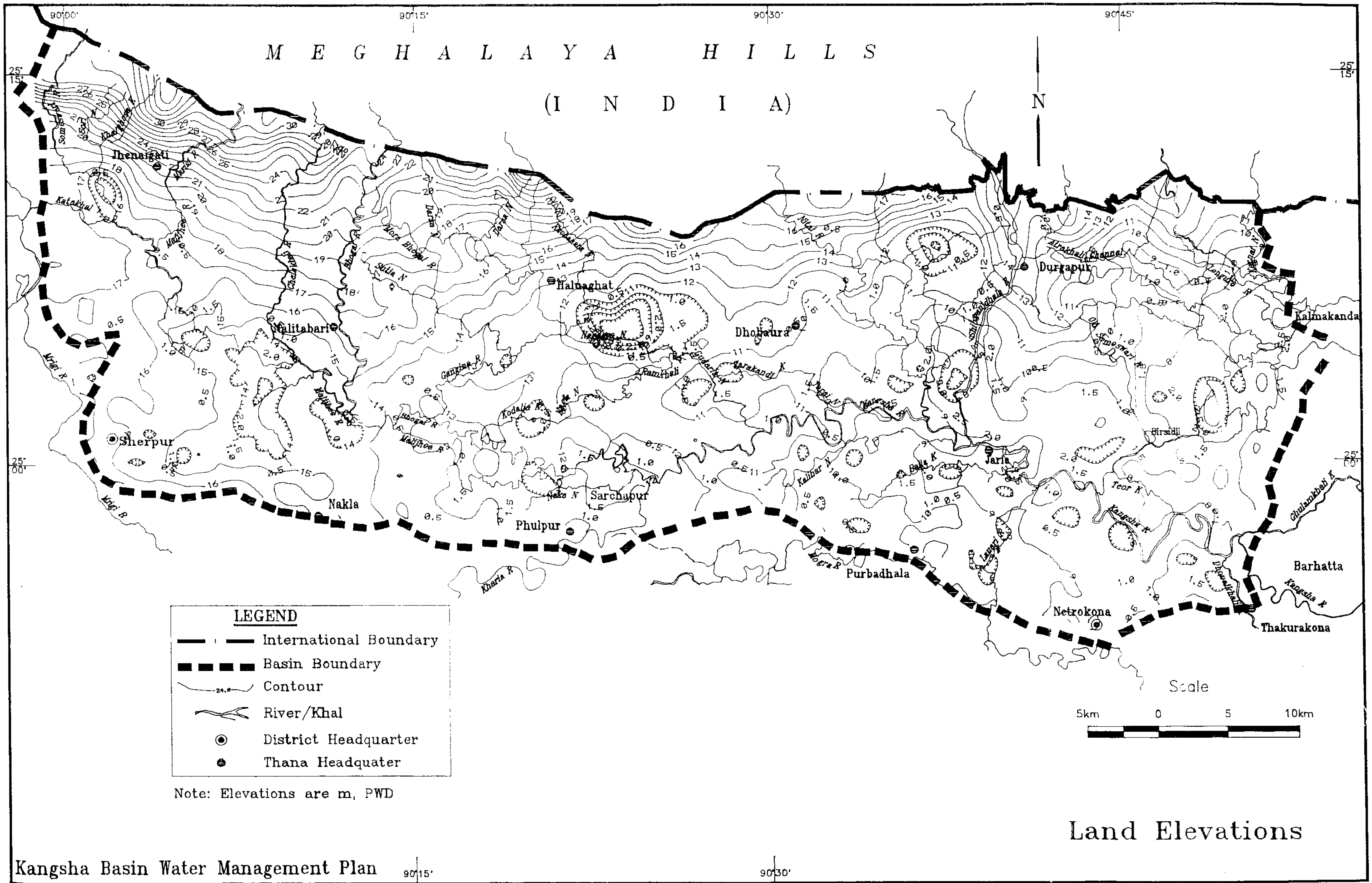

90°00'
90°15'
90°30'
90°45'
25° 15'
25° 00'
N
LEGEND
International Boundary
Basin Boundary
Dihing and Dupi Tila Formations undivided
Young gravelly sand
Marsh clay and peat
Alluvial silt
Alluvial silt and clay
Scale
5km 0 5 10km
Surficial Geology
Kangsha Basin Water Management Plan
FILE: NERP-374.DWG Prepared by: Jalal

Figure A.5

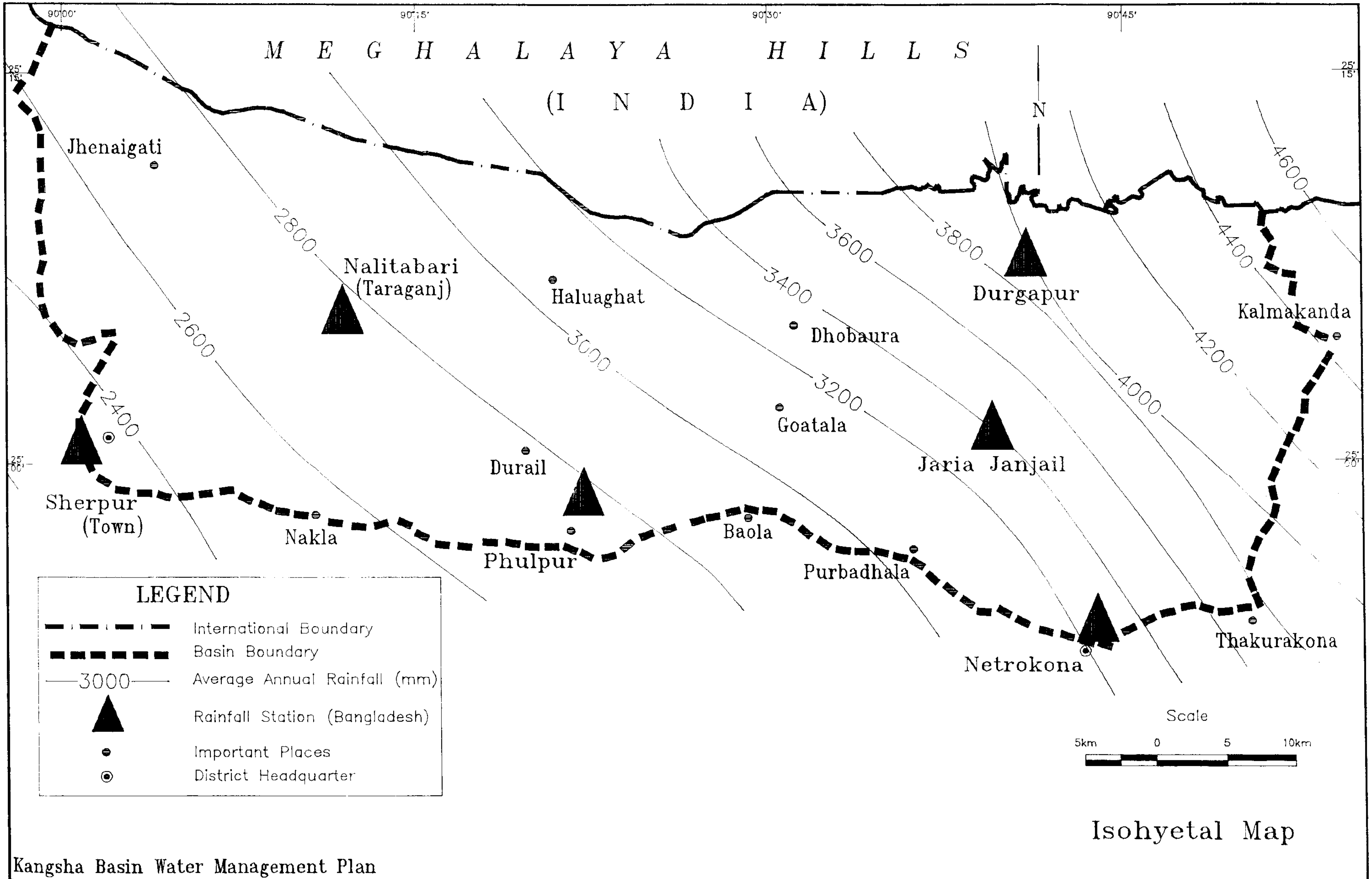


Land Elevations

Kangsha Basin Water Management Plan

FILE: NERP-388.DWG+BASINCON

Figure A.6

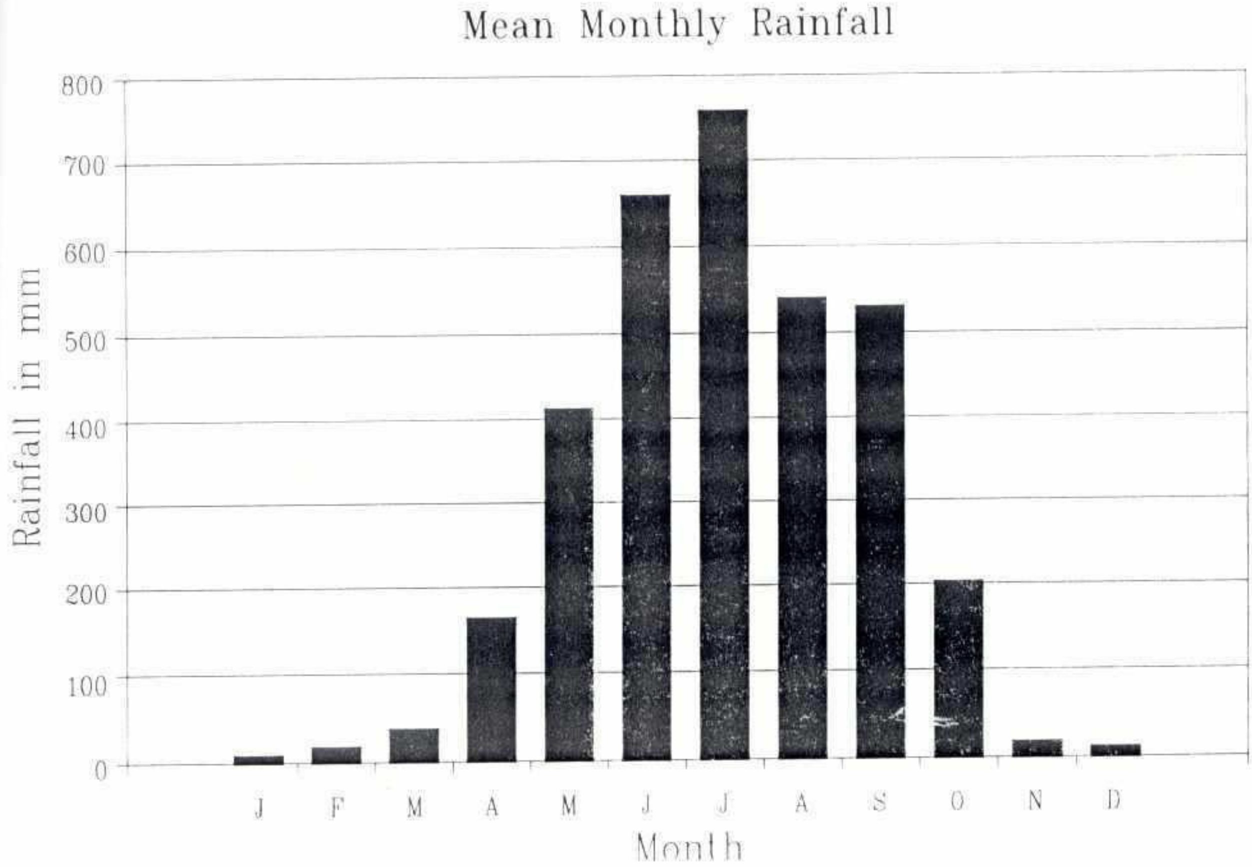


Isohyetal Map

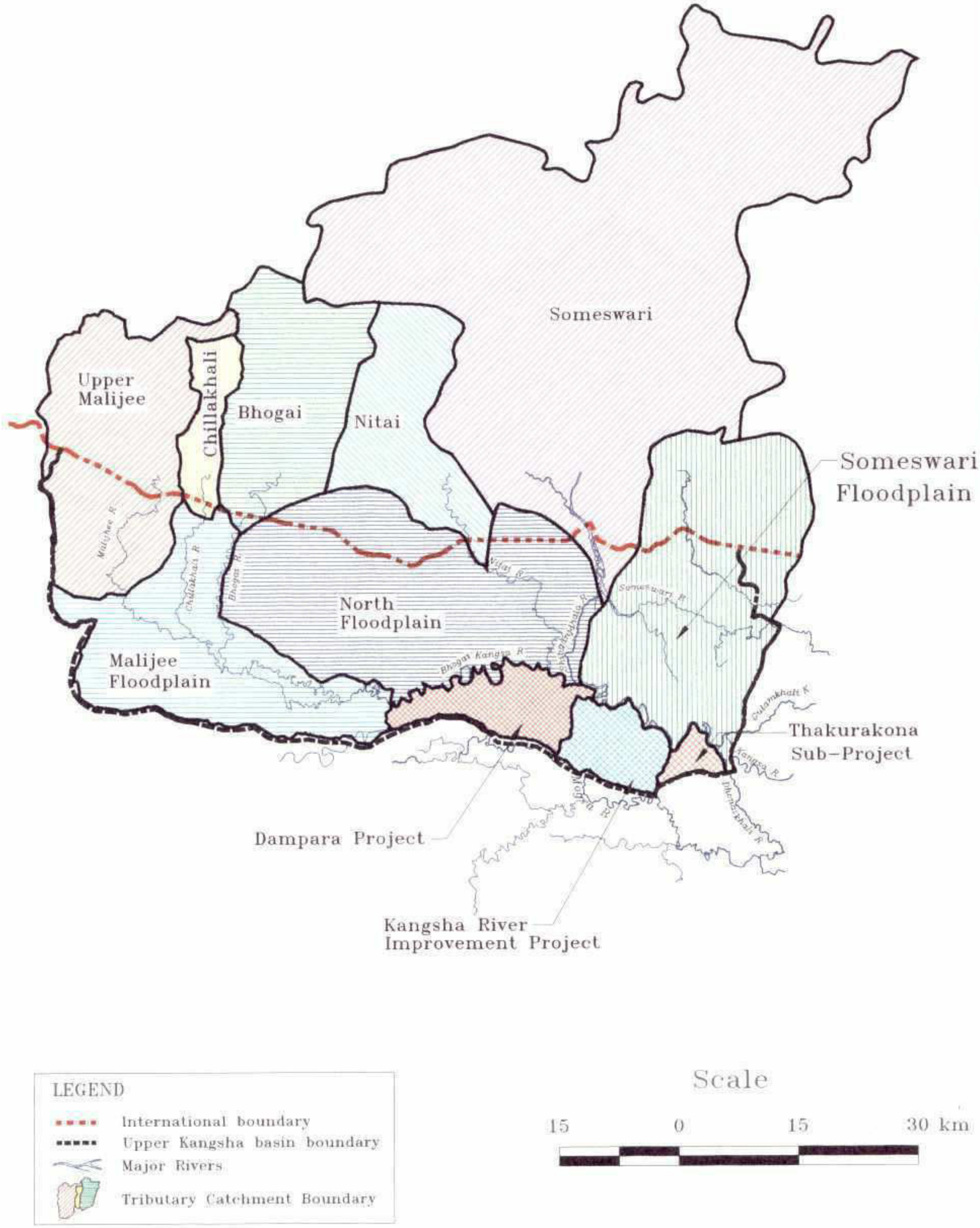
Kangsha Basin Water Management Plan

FILE: NERP--376.DWG Prepared by: Jalal

Figure A.7



Mean Monthly Rainfall
Station: Jaria–Jhanjail



Kangsha River Basin Tributary Catchment

Figure A.9

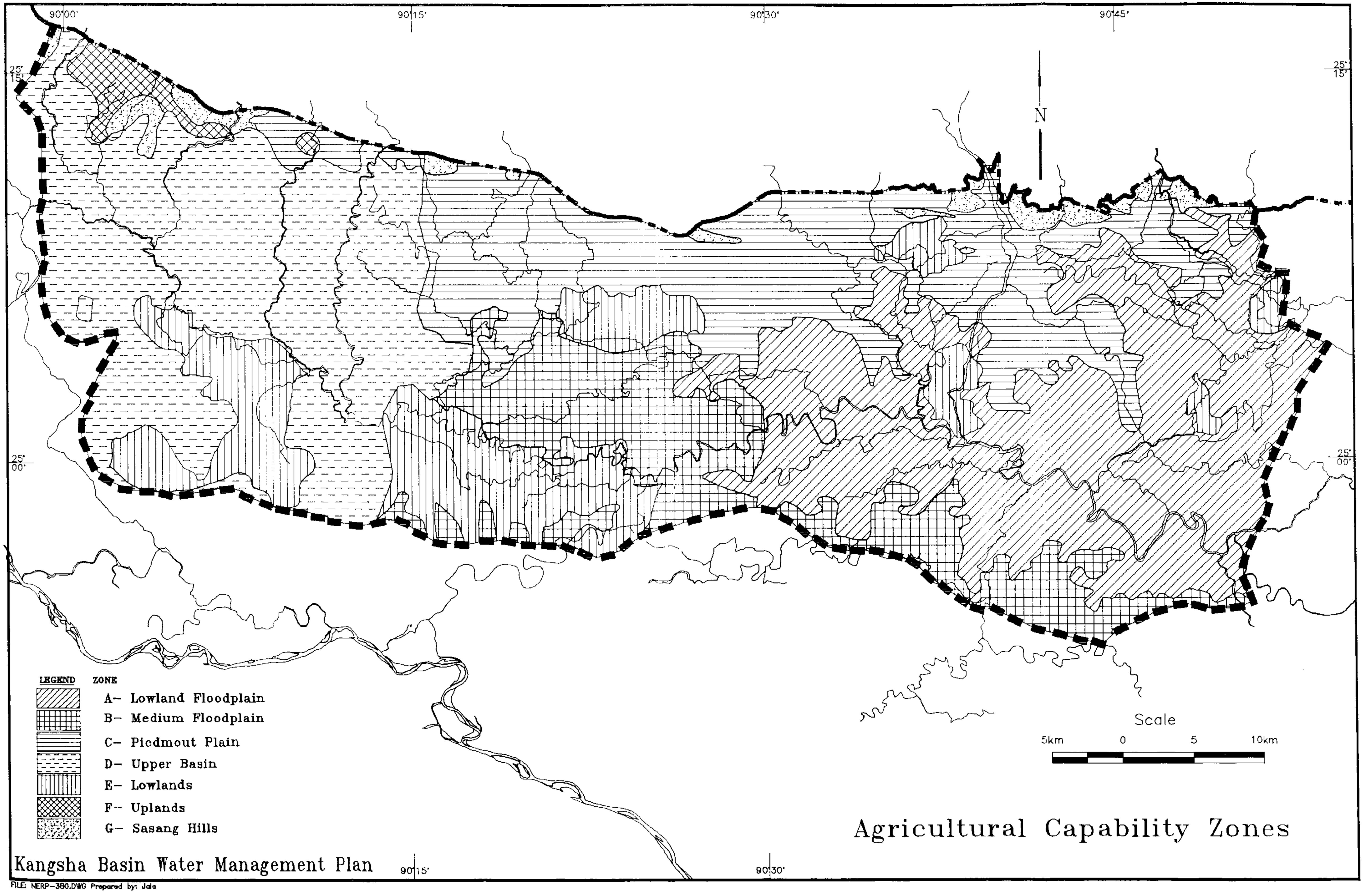
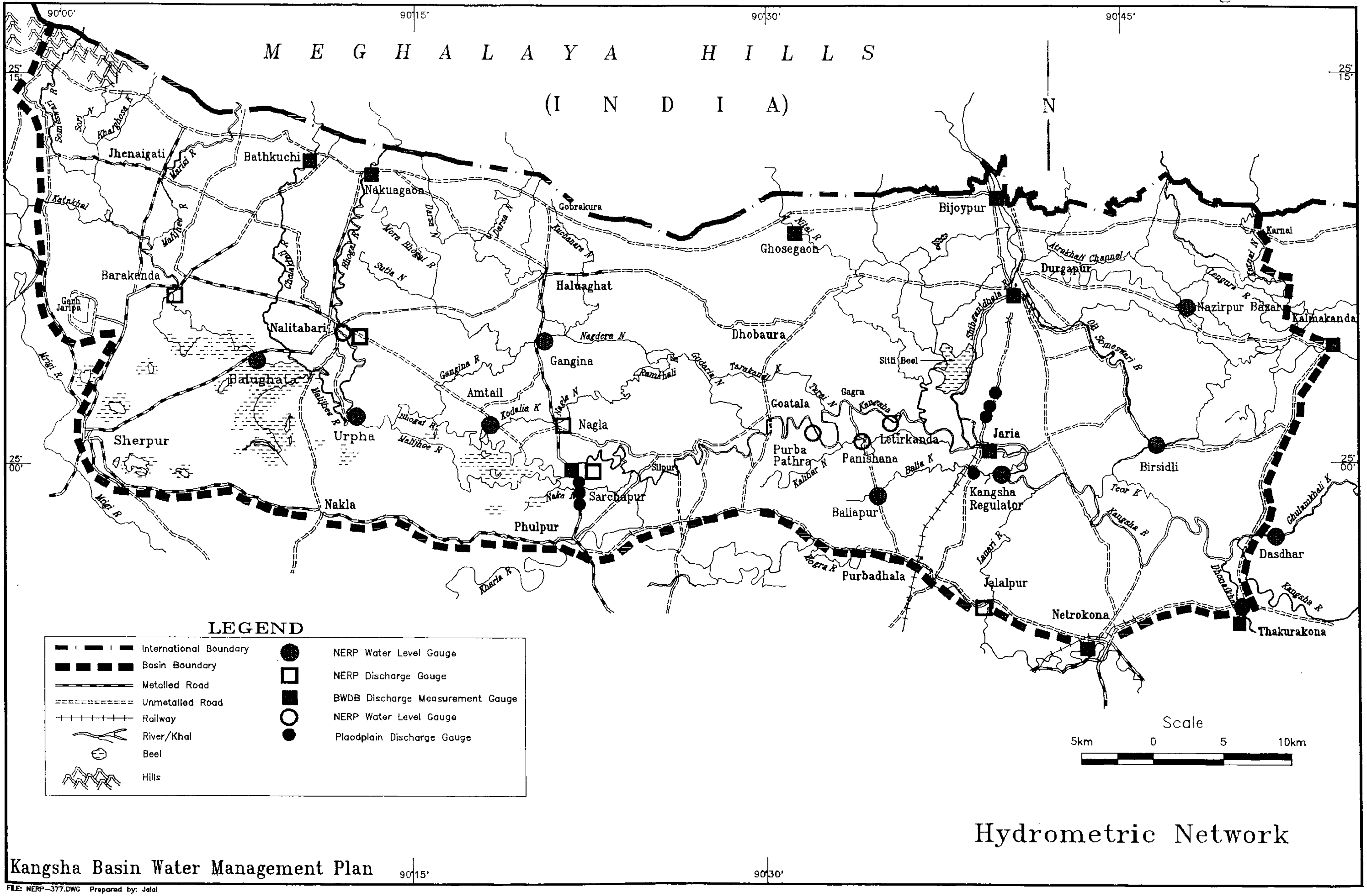

90°00'
90°15'
90°30'
90°45'
25° 15'
25° 00'
N
LEGEND
ZONE
A– Lowland Floodplain
B– Medium Floodplain
C– Picdmout Plain
D– Upper Basin
E– Lowlands
F– Uplands
G– Sasang Hills
Scale
5km
0
5
10km
Agricultural Capability Zones
Kangsha Basin Water Management Plan
FILE: NERP-380.DWG Prepared by: Jala

Figure A.10



Hydrometric Network

Kangsha Basin Water Management Plan

FILE: NERP-377.DWG Prepared by: Jalal

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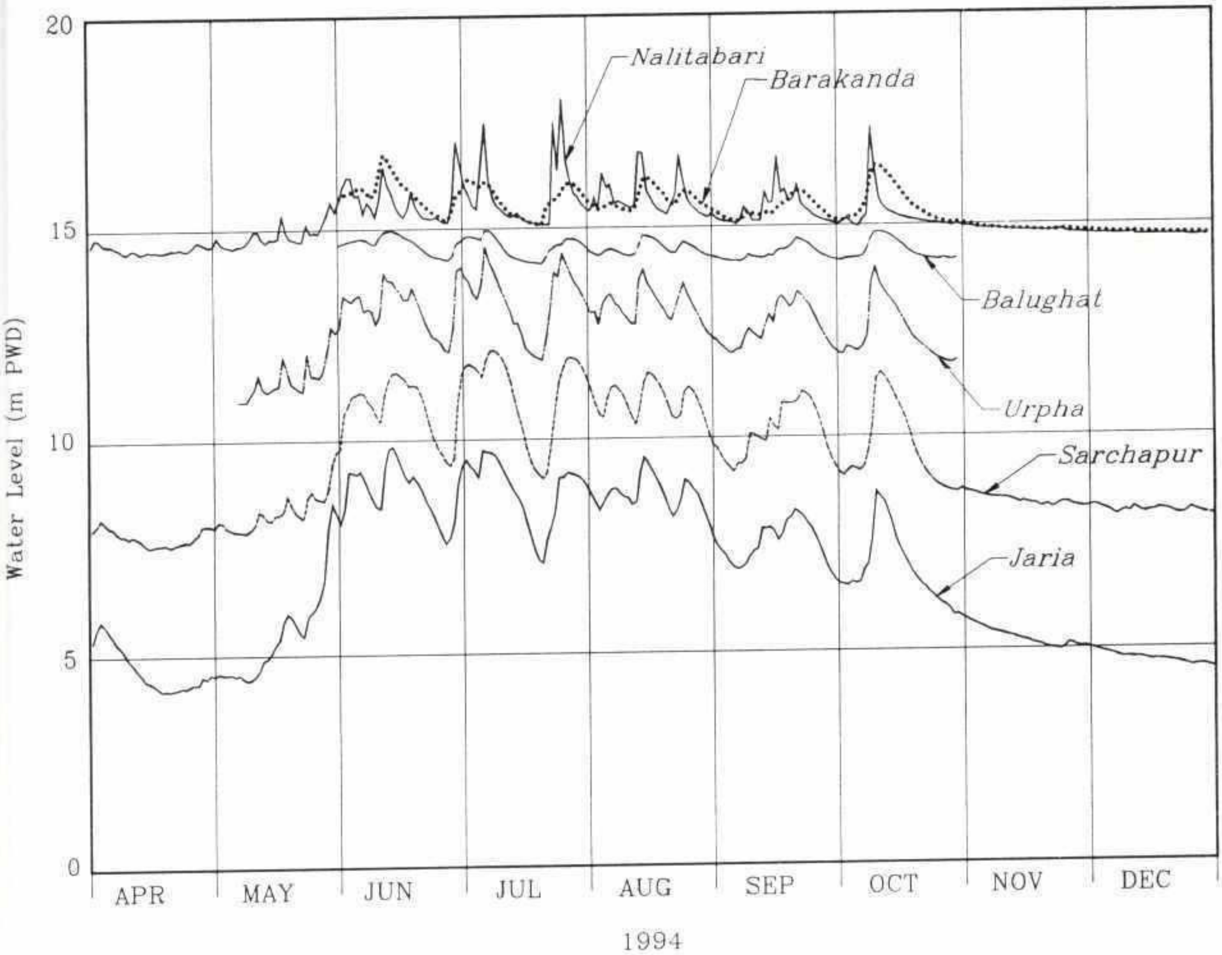
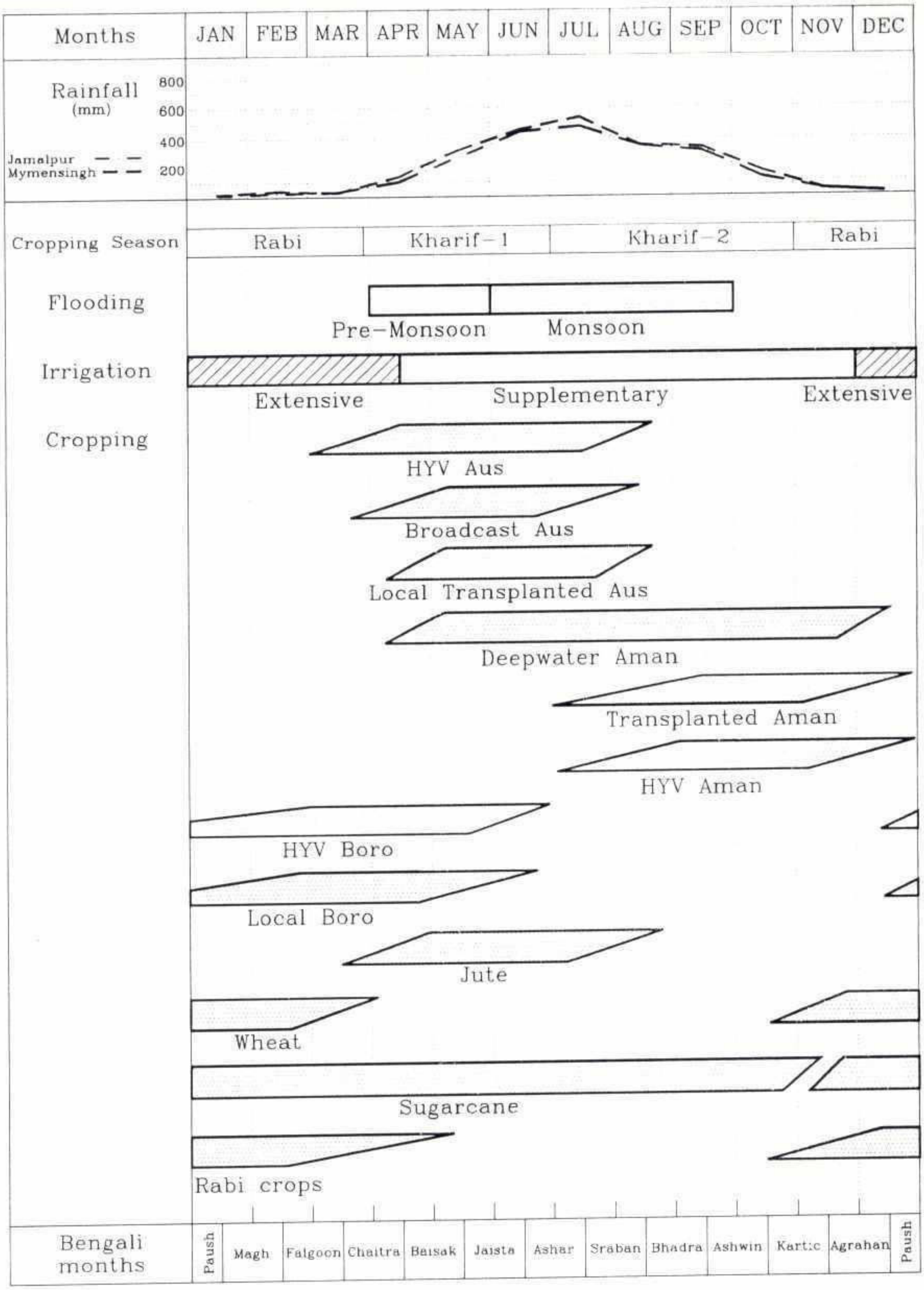


Water levels at
Selected Location

Kangsha Basin Water Management Plan

FILE: NERP-394.DWG

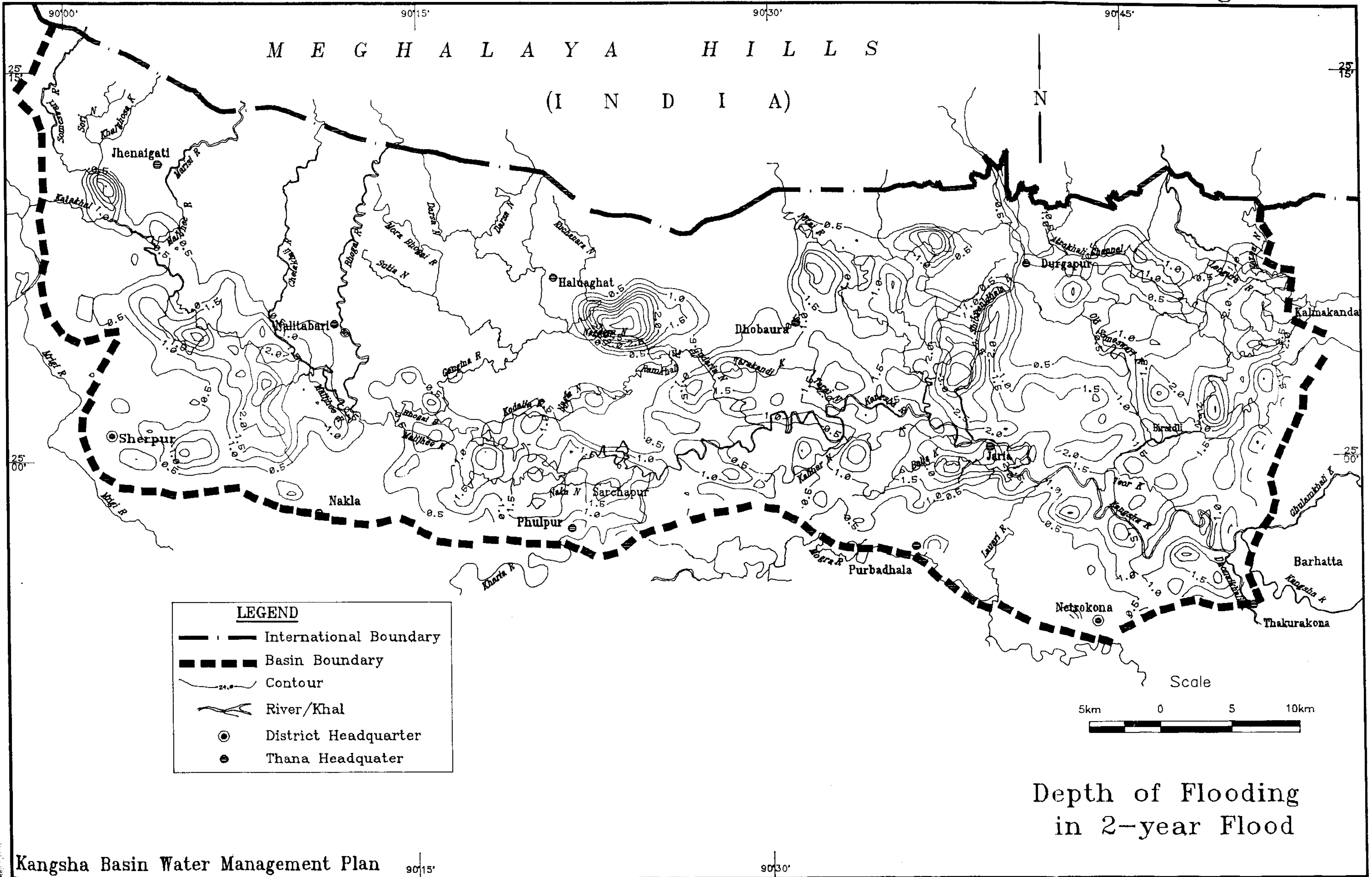
Figure A.16



Major Crop Calendar

Kangsha Basin Water Management Plan

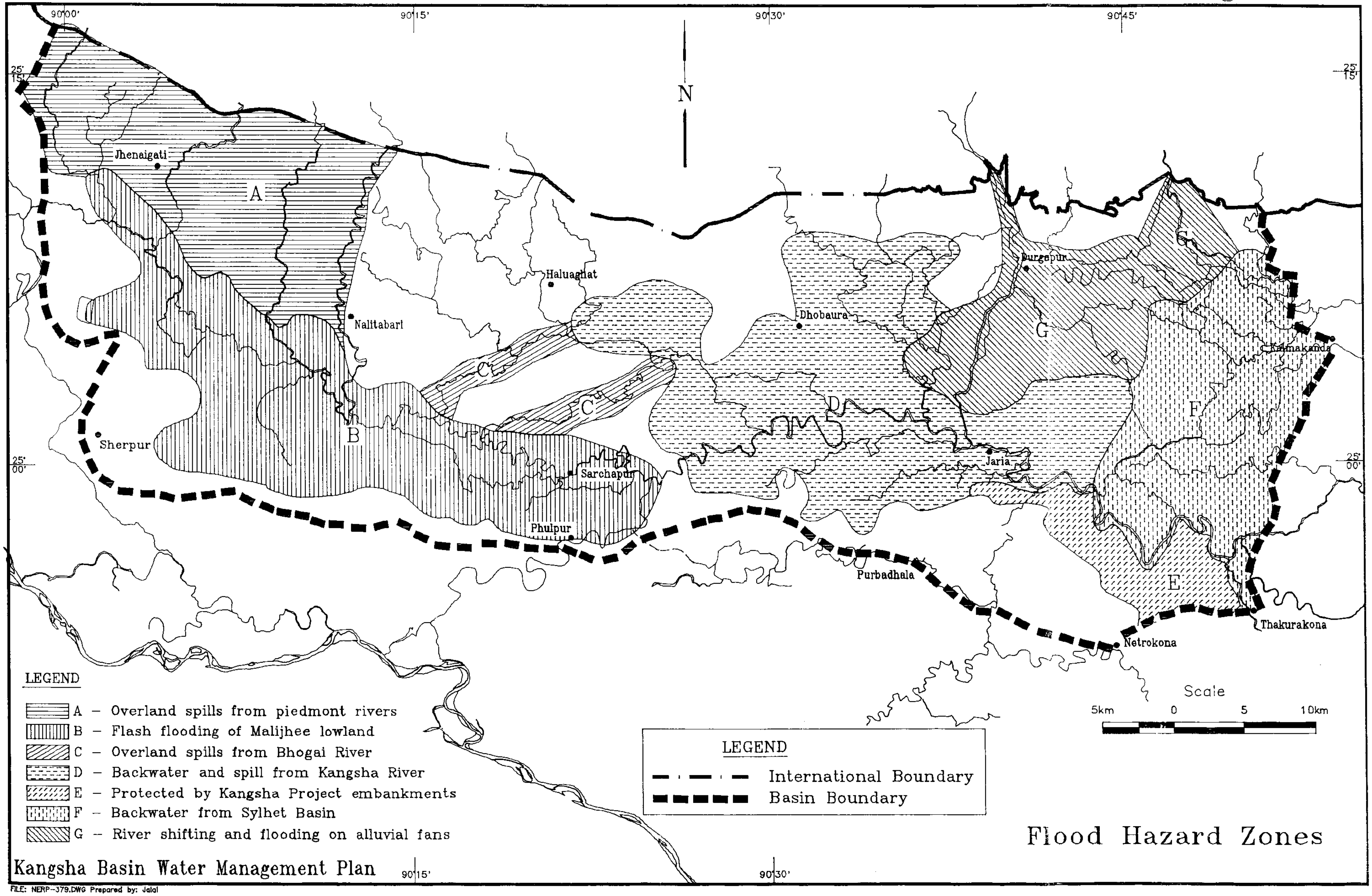
FILE: NERP-382.DWG



Depth of Flooding in 2–year Flood

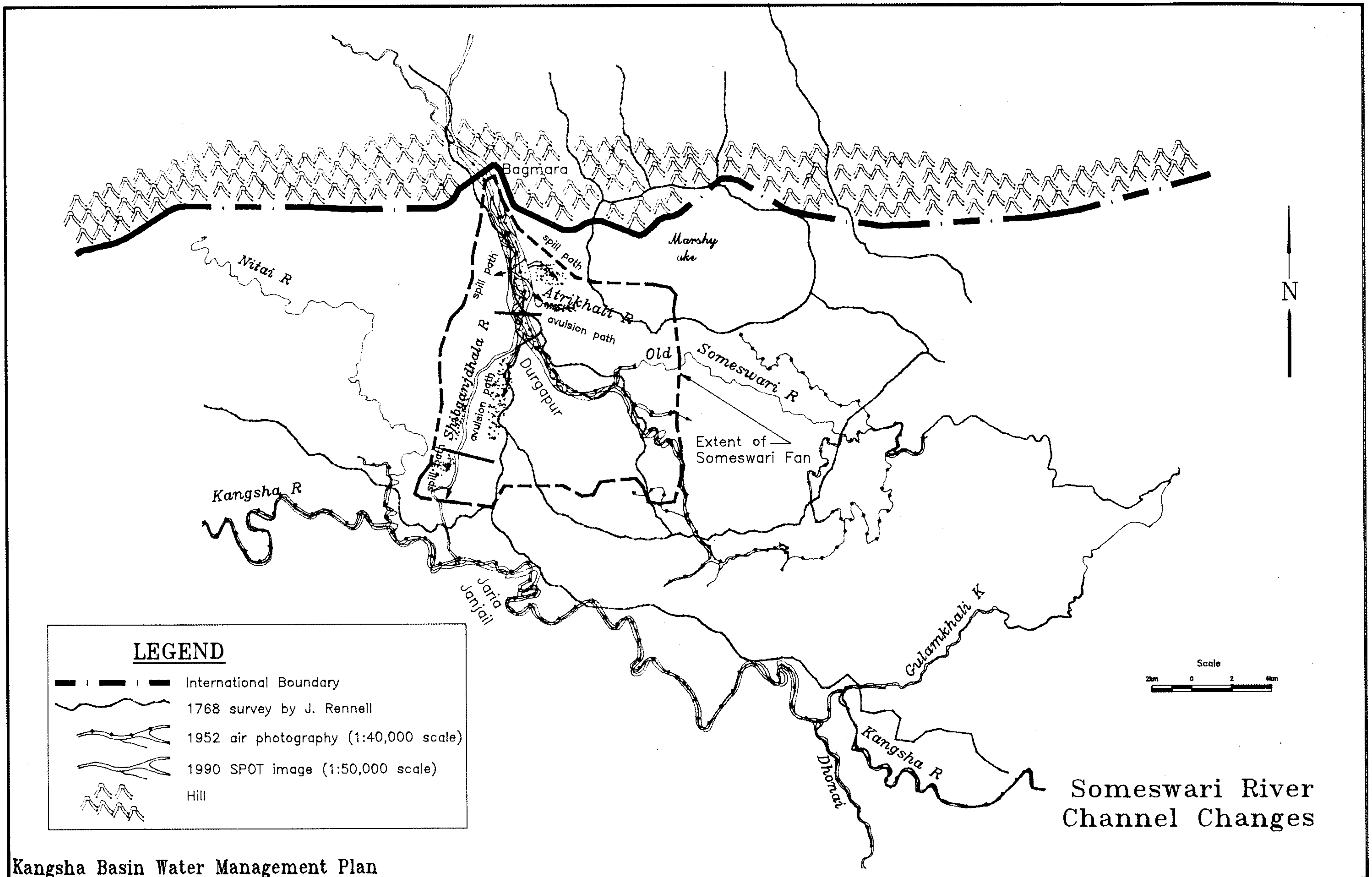
Kangsha Basin Water Management Plan

Figure A.13



Flood Hazard Zones

Figure A.14

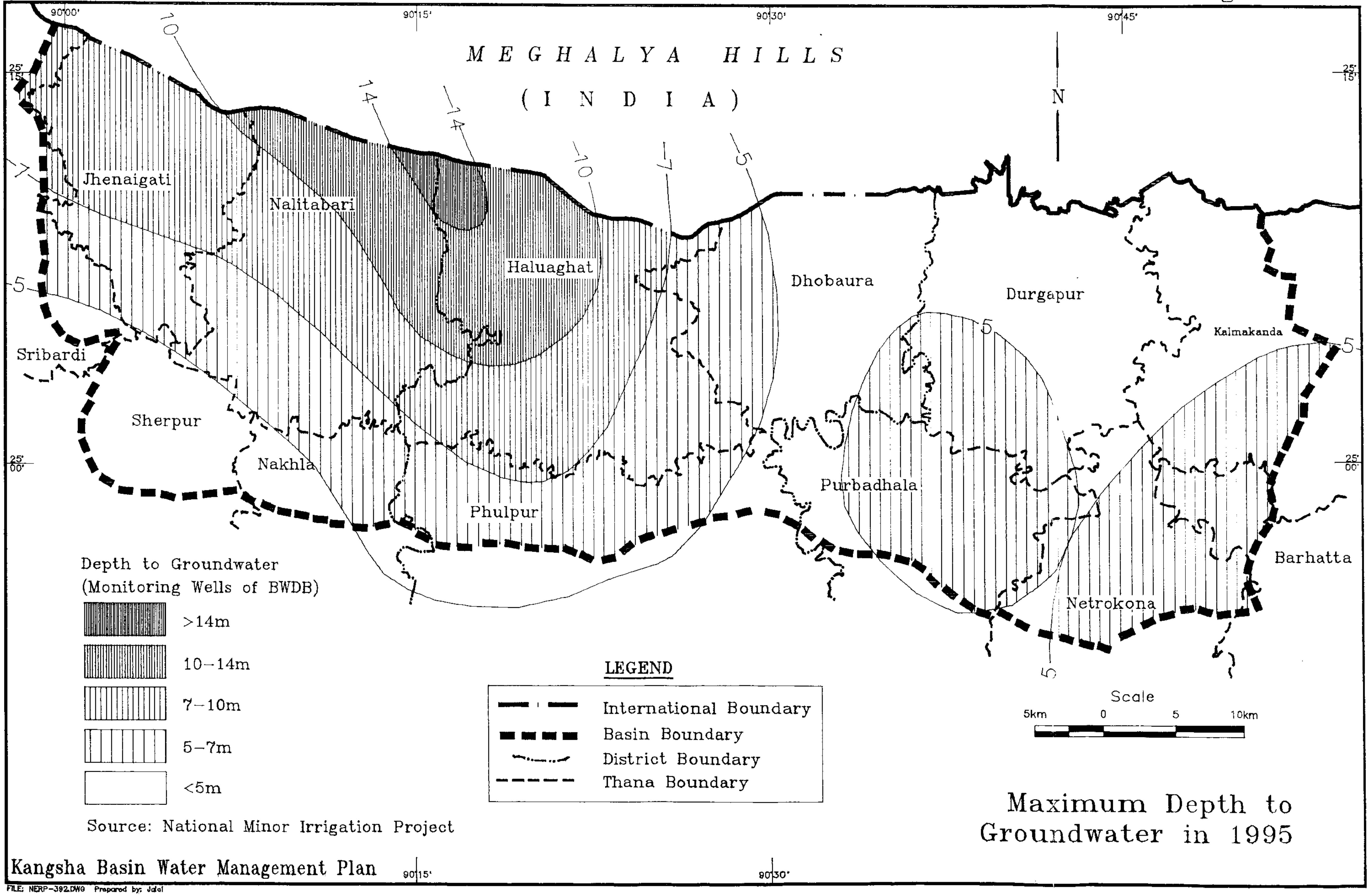


Someswari River Channel Changes

Kangsha Basin Water Management Plan

FILE: NERP-378.DWG

Figure A.15



90°00'
90°15'
90°30'
90°45'
25° 15'
25° 00'
MEGHALYA HILLS
(INDIA)
N
Jhenaigati
Nalitabari
Haluaghat
Dhobaura
Durgapur
Kalmakanda
Sribardi
Sherpur
Nakhla
Phulpur
Purbadhala
Netrokona
Barhatta
10
14
14
10
7
5
7
5
5
5
5
Depth to Groundwater
(Monitoring Wells of BWDB)
>14m
10–14m
7–10m
5–7m
<5m
Source: National Minor Irrigation Project
LEGEND
International Boundary
Basin Boundary
District Boundary
Thana Boundary
Scale
5km
0
5
10km
Maximum Depth to Groundwater in 1995
Kangsha Basin Water Management Plan
FILE: NERP-392.DWG Prepared by: Jalal

ANNEX B

Hydrologic Data

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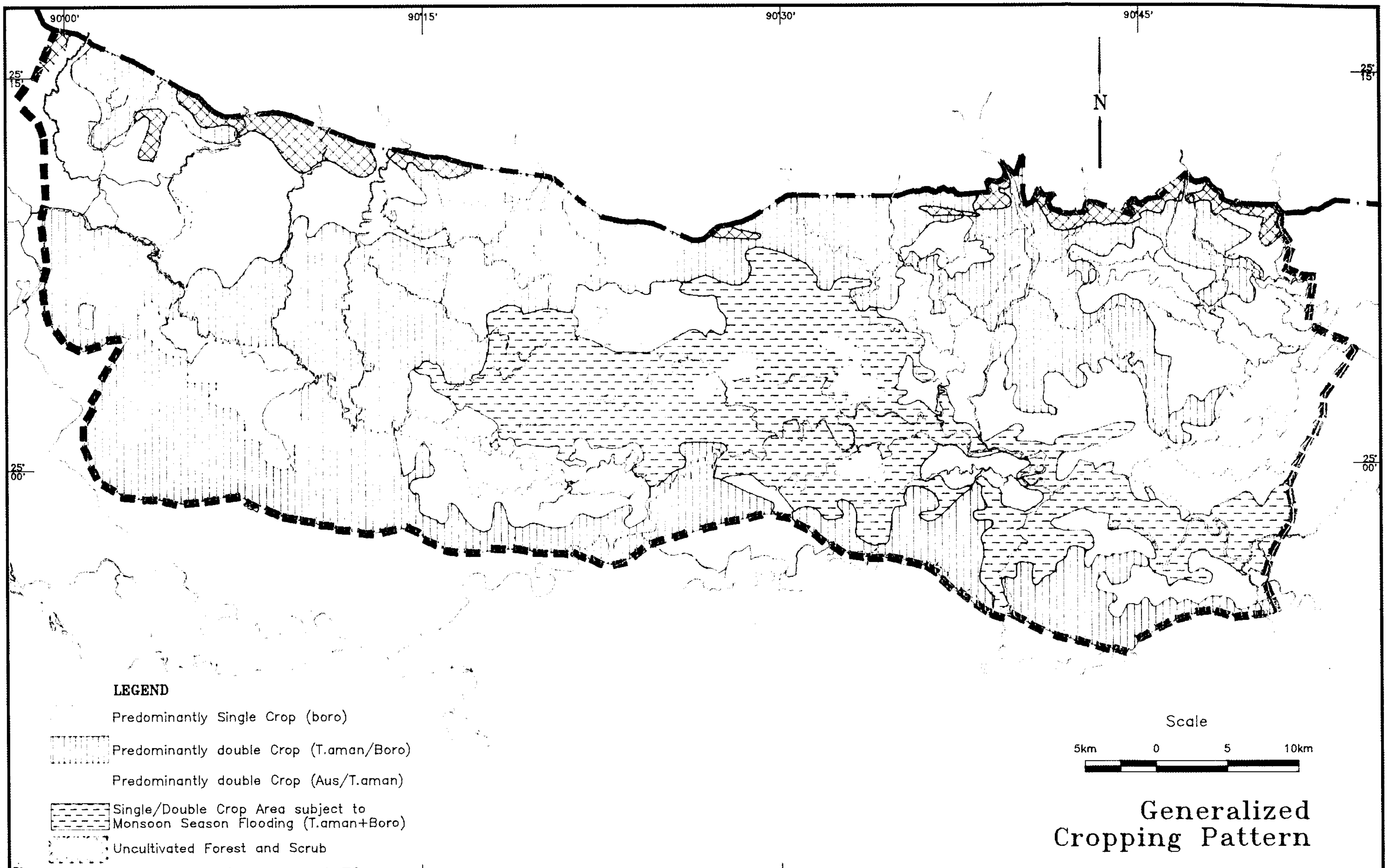
Figure A.17

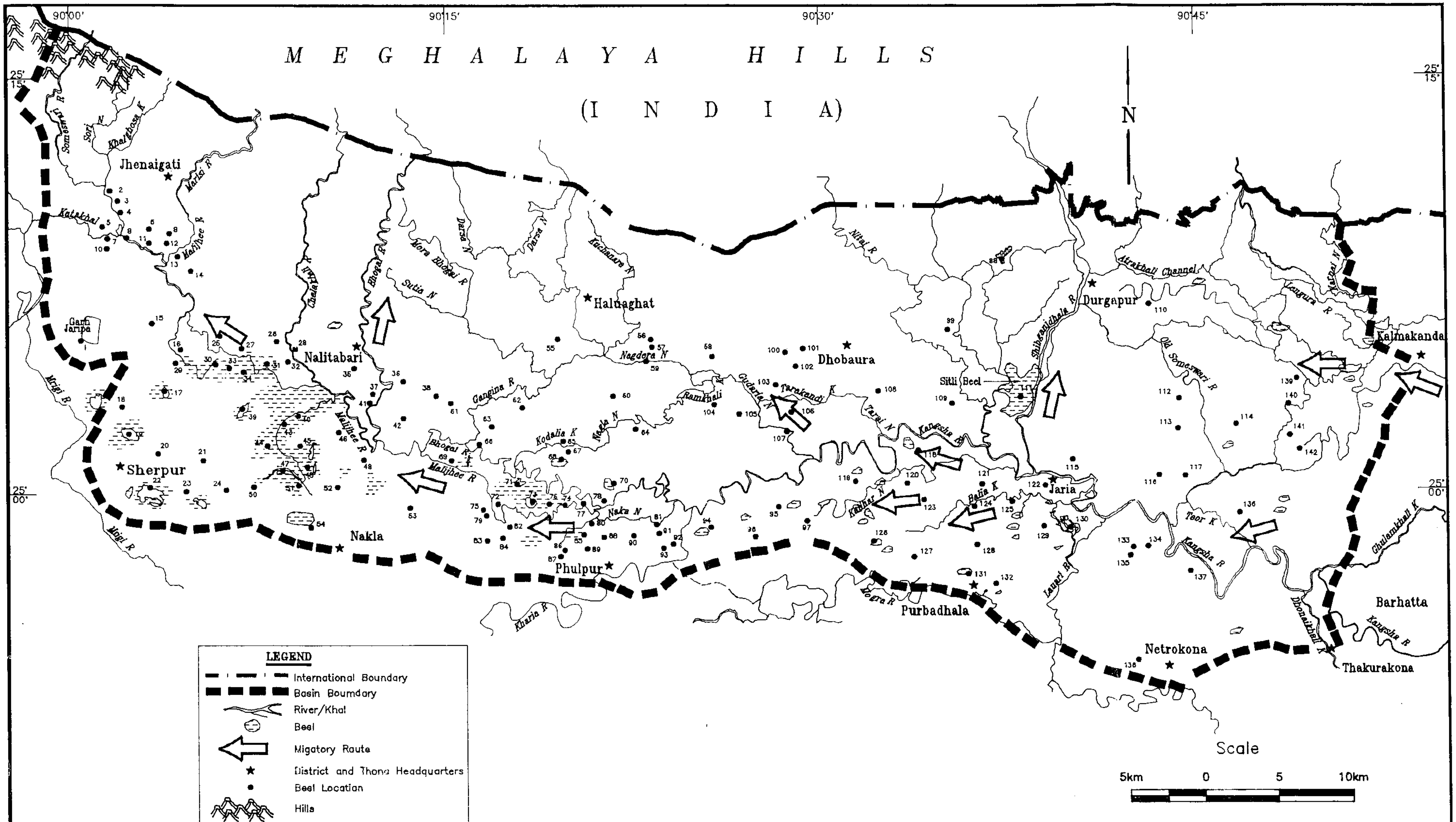


Generalized Cropping Pattern

Kangsha Basin Water Management Plan

FILE: NERP-381.DWG

Figure A.18



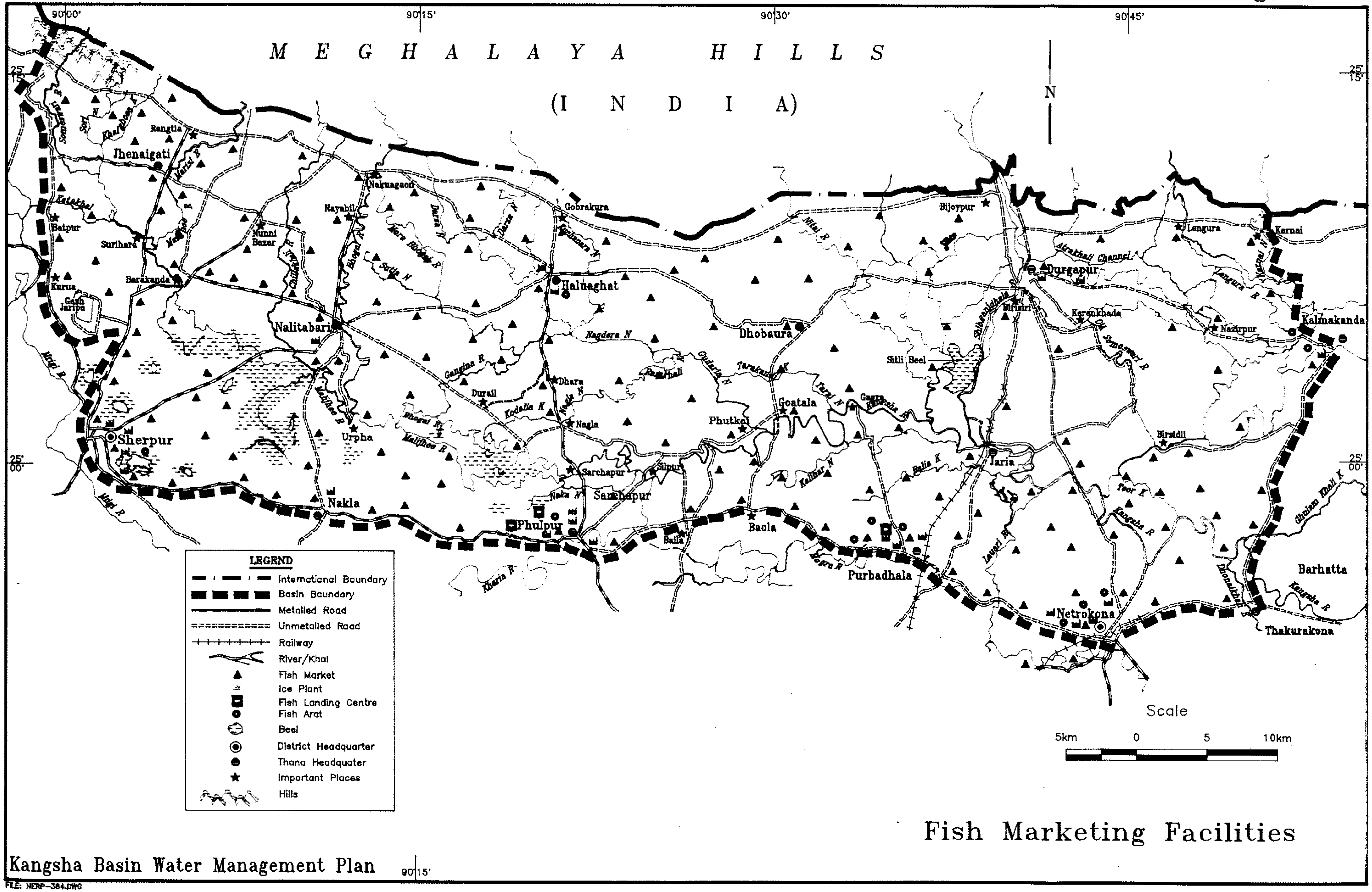
Note : Serial 1, 2, 3 etc. denote the the beels.
For beel names, please see Table 8.1

Beels and Migratory Routes

Kangsha Basin Water Management Plan

FILE: NERP-383.DWG

Figure A.19



Fish Marketing Facilities

Kangsha Basin Water Management Plan

FILE: NERP-384.DWG

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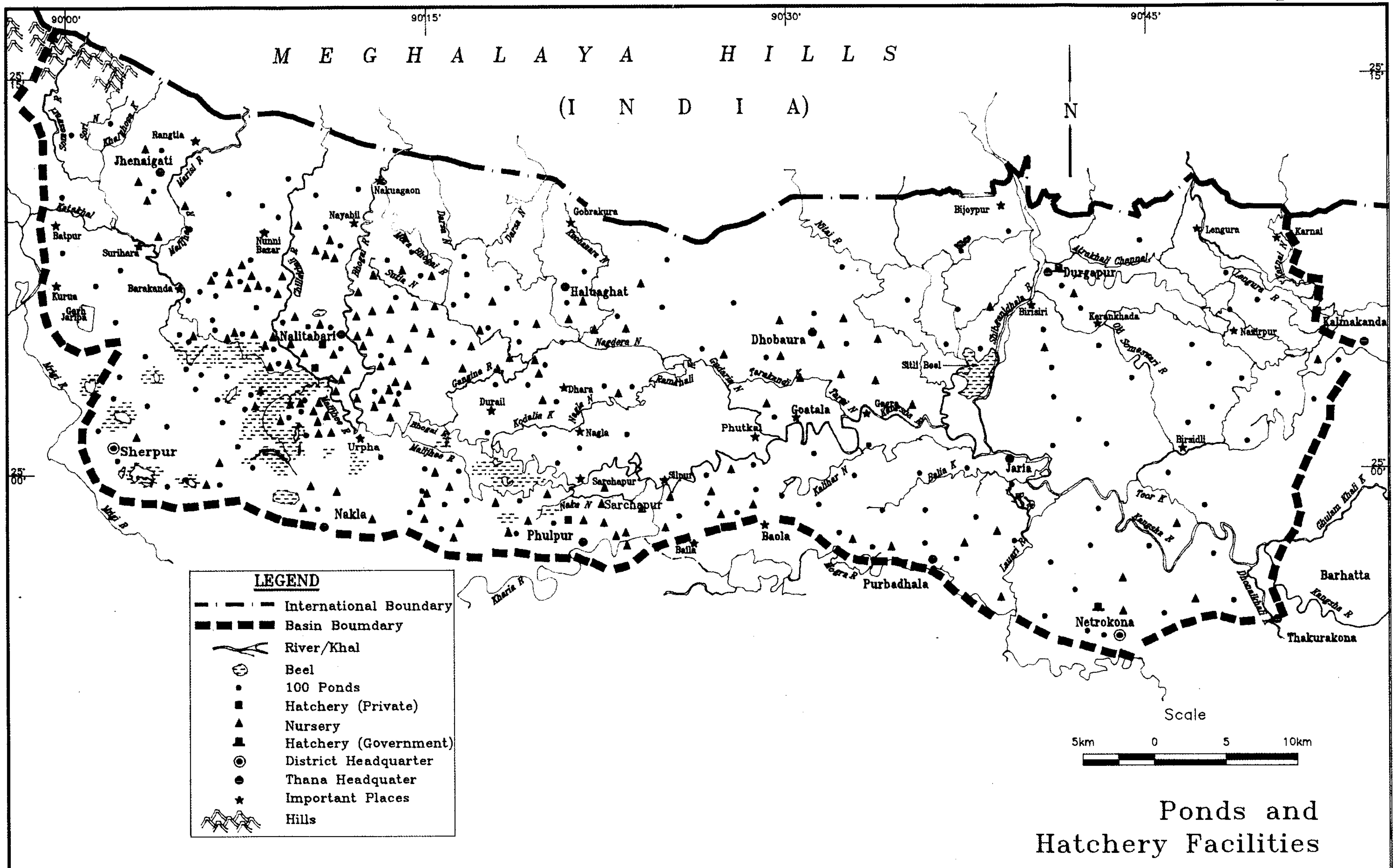
Figure A.20

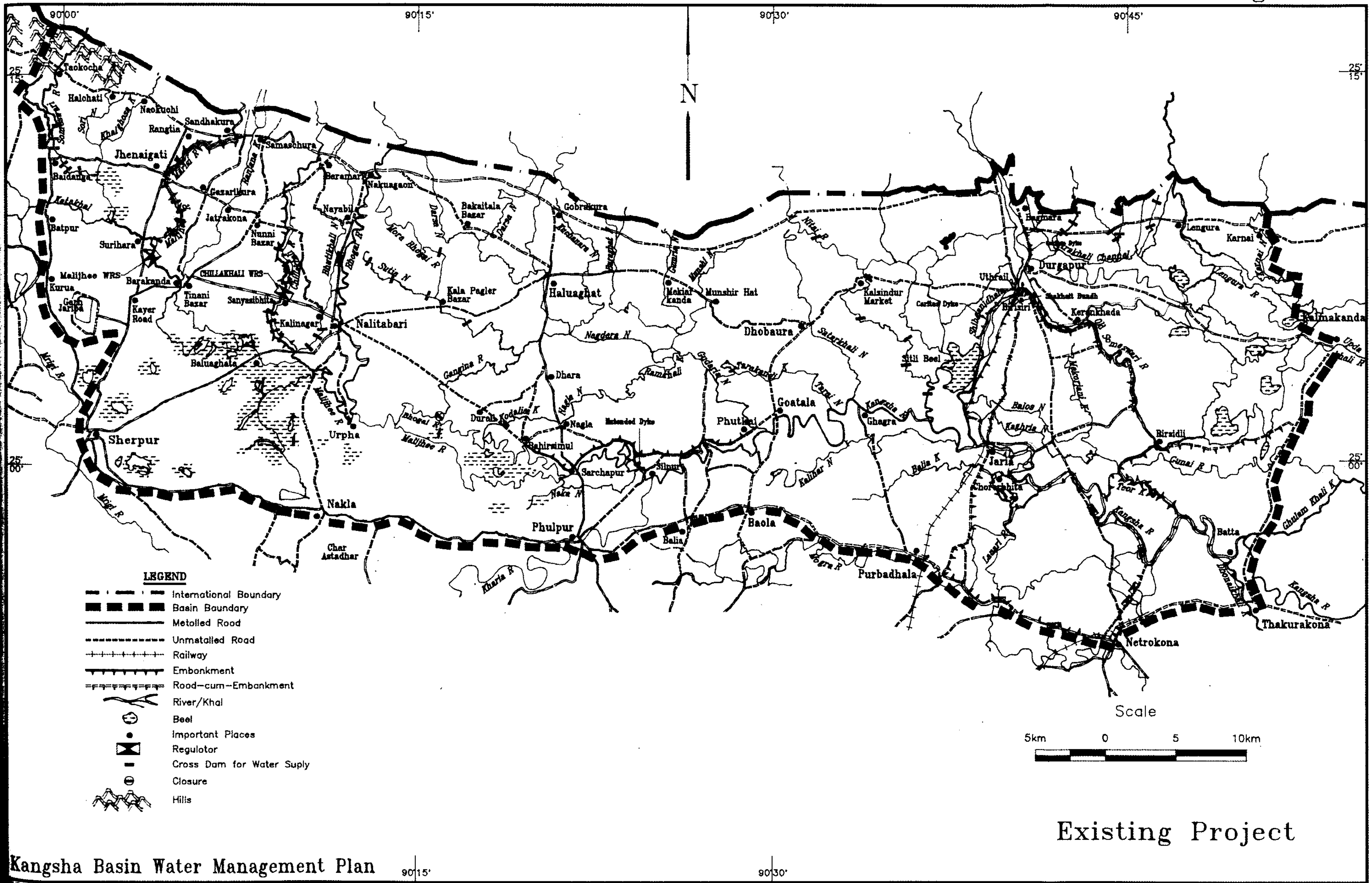


Ponds and Hatchery Facilities

Kangsha Basin Water Management Plan

FILE: NERP-389.DWG

Figure A.21



Existing Project

Kangsha Basin Water Management Plan

FILE: NERP-395.DWG

ANNEX B

Hydrologic Data

Table B.1 Monthly Rainfall Statistics (mm)

Month	Sherpur					Nalitabari				
	Monthly maximum	Monthly minimum	Mean	Dependable rainfall		Monthly maximum	Monthly minimum	Mean	Dependable rainfall	
				80%	90%				80%	90%
Jan	70.90	0.00	7.50	0.00	0.00	59.00	0.00	7.60	0.00	0.00
Feb	67.80	0.00	12.70	0.00	0.00	64.50	0.00	15.00	0.00	0.00
Mar	103.00	0.00	23.50	4.03	1.55	111.00	0.00	32.30	4.69	0.52
Apr	273.30	0.50	110.20	19.52	9.12	307.80	0.80	121.40	32.60	27.40
May	886.20	80.20	317.00	160.80	90.80	1320.50	82.50	371.70	224.52	134.30
Jun	879.80	147.70	440.40	206.40	153.60	860.50	176.10	477.60	327.46	239.99
Jul	984.70	45.50	464.00	330.30	120.30	1084.50	237.10	581.10	470.74	286.72
Aug	585.30	68.40	314.20	193.32	93.16	772.10	144.40	357.10	219.46	179.84
Sep	873.00	59.00	307.30	157.02	88.72	716.60	109.20	382.60	232.06	130.36
Oct	388.20	0.00	156.50	48.69	19.08	513.90	25.40	188.30	232.06	130.36
Nov	56.70	0.00	12.80	0.00	0.00	82.50	0.00	14.90	0.00	0.00
Dec	114.20	0.00	11.60	0.00	0.00	108.50	0.00	9.20	0.00	0.00
Ann	3329.20	1322.90	2200.80	1796.80	1595.88	3669.80	1745.80	2588.10	2039.90	1800.60

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Table B.1 Monthly Rainfall Statistics (mm) continued

Month	Phulpur					Durgapur				
	Monthly maximum	Monthly minimum	Mean	Dependable rainfall		Monthly maximum	Monthly minimum	Mean	Dependable rainfall	
				80%	90%				80%	90%
Jan	67.00	0.00	7.00	0.00	0.00	66.90	0.00	5.80	0.00	0.00
Feb	89.40	0.00	15.10	0.00	0.00	63.50	0.00	13.50	0.00	0.00
Mar	66.80	0.00	18.10	0.00	0.00	107.80	0.00	38.10	4.75	0.00
Apr	307.40	0.80	114.30	15.80	6.60	414.60	29.70	169.70	69.06	54.09
May	1032.50	3.00	337.80	145.24	82.16	911.90	137.60	436.60	274.72	199.28
Jun	1612.90	67.30	519.40	303.04	133.70	1139.70	149.50	703.70	274.72	199.28
Jul	1424.00	114.00	587.80	298.84	224.35	1862.50	464.90	821.40	607.20	535.94
Aug	980.60	71.60	367.80	237.54	206.36	1340.40	319.30	596.00	418.46	351.70
Sep	723.00	110.80	376.40	215.40	176.46	1525.20	63.60	561.30	292.66	241.67
Oct	500.70	0.30	210.60	73.80	15.42	615.10	7.10	227.30	292.66	241.67
Nov	129.50	0.00	19.10	0.00	0.00	106.60	0.00	14.70	0.00	0.00
Dec	74.90	0.00	7.20	0.00	0.00	91.40	0.00	11.60	0.00	0.00
Ann	5831.40	1104.50	2658.80	1629.80	1467.49	4935.20	2510.90	3568.60	3157.02	3054.69

Table B.1 Monthly Rainfall Statistics (mm) continued

Month	Netrokona					Jaria Jhanjail				
	Monthly maximum	Monthly minimum	Mean	Dependable rainfall		Monthly maximum	Monthly minimum	Mean	Dependable rainfall	
				80%	90%				80%	90%
Jan	47.50	0.00	6.00	0.00	0.00	55.70	0.00	6.70	0.00	0.00
Feb	53.30	0.00	17.70	0.00	0.00	80.70	0.00	16.70	0.62	0.00
Mar	179.90	0.00	44.80	2.58	0.00	101.10	3.10	36.80	9.30	4.81
Apr	490.00	0.00	176.70	88.00	61.75	498.50	16.80	164.00	62.26	40.75
May	866.80	94.30	401.40	229.76	178.76	1028.30	163.00	411.20	282.42	183.28
Jun	1487.20	132.10	624.80	409.86	275.90	1365.00	191.70	656.50	452.56	286.86
Jul	1165.00	260.00	598.40	388.60	272.30	1161.40	442.10	755.70	578.80	523.13
Aug	949.40	193.60	464.50	283.70	233.74	1184.40	237.90	537.00	308.72	270.56
Sep	842.50	85.20	430.30	191.94	170.09	1177.10	162.40	527.60	362.68	308.36
Oct	626.00	0.00	223.70	73.84	51.97	529.70	0.00	201.60	82.36	35.02
Nov	183.90	0.00	24.60	0.00	0.00	82.60	0.00	16.80	0.00	0.00
Dec	127.00	0.00	12.60	0.00	0.00	67.30	0.00	9.70	0.00	0.00
Ann	4320.80	1899.30	3067.40	2495.24	2349.44	4951.60	2296.40	3368.70	2742.86	2685.74

Table B-2 Seasonal Distribution of Rainfall (Mean)

Station	Pre-monsoon			Monsoon					Post - monsoon			Dry					Annual
	Apr	May	Total	Jun	Jul	Aug	Sep	Total	Oct	Nov	Total	Dec	Jan	Feb	Mar	Total	
Sherpur	110.20 5.06	317.00 14.56	427.20 19.62	440.40 20.22	464.00 21.31	314.20 14.43	307.30 14.11	1525.90 70.07	156.50 7.19	12.80 0.59	169.30 7.77	11.60 0.53	7.50 0.34	12.70 0.58	23.50 1.08	55.30 2.54	2177.70 100%
Nalitabari	112.40 4.74	371.70 14.53	493.10 19.27	477.60 18.66	581.10 22.71	357.10 13.96	382.60 14.95	1798.40 70.28	188.30 7.36	14.90 0.58	203.20 7.94	9.20 0.36	7.60 0.30	15.00 0.59	32.30 1.26	64.10 2.51	2558.80 100%
Phulpur	114.30 4.43	337.80 13.09	452.10 17.52	519.40 20.13	587.80 22.78	367.80 14.25	376.40 14.59	1851.40 71.74	210.60 8.16	19.10 0.74	229.70 8.90	7.10 0.28	7.00 0.27	15.10 0.59	18.10 0.70	47.30 1.83	2580.60 100%
Durgapur	169.70 4.71	436.60 12.13	606.30 16.84	703.70 19.55	821.40 22.82	596.00 16.56	561.30 15.59	2682.40 74.52	227.30 6.31	14.70 0.41	242.00 6.72	11.60 0.32	5.80 0.16	13.50 0.38	38.10 1.06	69.00 1.92	3599.70 100%
Netrokona	176.70 5.84	401.40 13.27	578.10 19.11	624.80 20.65	598.40 19.78	464.50 15.35	430.30 14.22	2118.00 70.00	223.70 7.39	24.60 0.81	248.30 8.21	12.60 0.42	6.00 0.20	17.70 0.59	44.80 1.48	81.10 2.68	3025.50 100%
Jaria Jhanjail	164.00 4.91	411.20 12.31	575.20 17.22	656.50 19.56	755.70 22.62	537.00 16.08	527.60 15.79	2476.80 74.15	201.60 6.04	16.80 0.50	218.40 6.54	9.70 0.29	6.70 0.20	16.70 0.50	36.80 1.10	69.90 2.09	3340.30 100%

NOTE: First line in each row is the monthly rainfall in mm, second line is the percent of annual total

Table B.3 Climatological Data
Station : Mymensingh
Location : 24° 46'N : 90° 24'E

Month	Temperature			Rainfall (mm)	Evaporation (mm/day)	Relative Humidity (%)	Sunshine Hours (hrs /day)	Wind Speed Knots	Potential Evapotranspiration (mm)
	Mean Max (°C)	Mean Min (°C)	Mean (°C)						
Jan	25.7	9.8	21.5	11	2.3	74	8.0	6	91
Feb	28.4	13.6	23.9	18	3.3	68	7.5	4	106
Mar	32.2	17.3	27.8	40	4.4	67	8.1	5	149
Apr	34.7	20.2	30.2	103	5.9	71	7.7	6	162
May	32.2	20.5	29.4	327	5.5	79	6.4	6	160
Jun	32.2	21.7	29.7	419	4.7	84	4.5	5	132
Jul	32.1	21.7	29.9	410	4.6	85	3.5	5	134
Aug	32.2	21.7	30.2	367	4.6	84	3.7	5	134
Sep	32.1	21.5	29.7	319	3.9	84	3.9	4	122
Oct	32.1	21.3	29.2	202	3.9	81	7.0	4	124
Nov	30.5	15.9	26.7	23	2.9	75	8.0	3	105
Dec	27.3	11.4	23.1	5	2.4	75	8.4	3	87
Year	30.5	19.1	27.7	2219	4.0	77	6.4	4	1506

Source : Bangladesh Meteorological Department (BMD)
Note: Potential evapotranspiration estimates were computed using the Penman Method.

Table B.4 : Crop Water Requirements (mm) for HYV Boro Rice

Factors	Dec	Jan			Feb			Mar			Apr			May		
	Decade	Decade			Decade			Decade			Decade			Decade		
	3	1	2	3	1	2	3	1	2	3	1	3	3	1	2	3
ETo (mm/day)		*1.45	2.90	2.90	3.80	3.80	3.80	4.80	4.80	4.80	5.40	5.40	5.40	5.20	5.20	5.20
Kc		1.10	1.10	1.10	1.10	1.10	1.10	1.25	1.25	1.25	1.25	1.25	1.25	1.10	1.10	1.10
ETc(mm)		15.95	31.9	35.09	41.8	41.8	33.4	60.0	60.0	66.0	67.5	67.5	67.5	57.2	57.2	62.9
Percolation loss (mm)		8.75	17.5	19.25	17.5	17.5	17.5	17.5	17.5	19.25	17.5	17.5	17.5	17.5	17.5	19.3
Land Preparation (mm)	*100	*100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Effective Rainfall(mm) 80% dependable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decade net field requirement (mm)	100	124.7	49.4	54.34	59.3	59.3	50.9	77.5	77.5	85.25	85.0	85.0	85.0	74.7	74.7	82.2
**Diversion requirement(mm)	152	189	75	82	90	90	77	117	117	129	129	129	129	113	113	124
Irrigation requirement (l/sec/ha)	1.60	2.19	0.87	0.86	1.04	1.04	0.99	1.35	1.35	1.36	1.49	1.49	1.49	1.31	1.31	1.30

Where,

ETo (mm/day) = Average monthly evapotranspiration
Kc = Crop coefficient
ETc (mm) = Total crop evapotranspiration

* 200 mm of water is required for land preparation. 50% of the area is assumed to be prepared in December, the remainder in January.

** irrigation efficiency is assumed to be 66 % in calculating the diversion requirement.

Table B.5 Water Requirement by Different Crops

Name of Crop	Water requirement in inches	Water requirement in mm
Rice	35-50	889-1270
Jute	10-12	254-305
Potato	12-18	305-457
Chili	10-12	254-305
Maize	16-20	406-508
Sugarcane	40-60	1016-1524
Peanut	12-18	305-457

ANNEX C

Modelling

ANNEX C - MODELLING

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1. INTRODUCTION

1.1 Objective and Scope

This Annex describes the mathematical river modelling component of the Kangsha Basin Water Management Plan.

The purpose of the modelling was to simulate the proposed flood control interventions in the Basin Water Management Plan and to determine what effect they might have on flood levels and discharges. It was intended to be a relatively coarse simulation since many of the alternatives are at a conceptual level of planning.

The model was built around a version of the Northeast Regional Model which was used at NERP for the regional studies. Additional detail was added in the Dampara Project, in the Someswari area, and in the Malijhee area; these are locations where the schematization of the earlier model was not adequate for simulation of the proposed projects.

The model includes the major river network of the Kangsha Basin, including the Malijhee, Chillakhali, Bhogai, Kangsha, Nitai, Someswari, and the Shibganjdhala Rivers. It essentially includes that portion of the Northeast Regional Model which is west of the Baulai River. Figure C.1 shows the extent and a schematic representation of the hydrodynamic model (Figures are located at the back of this Volume).

1.2 The Computer Model

The model generates a time series of water levels and discharges at all points in a river system. It does so by simulating the passage of flows through the channel system using a fully dynamic solution of the equations of flow in a gradually varied river system. The model includes a rainfall-runoff model (NAM) and a hydro-dynamic river model (MIKE11), both developed by the Danish Hydraulic Institute.

The NAM model simulates the land phase of the hydrological cycle, that is to say the runoff into the river system. Inputs to the NAM model are rainfall and evaporation; outputs are runoff from catchments and supplementary information such as groundwater levels.

The MIKE11 hydrodynamic model simulates the passage of flow through a network of rivers and floodplains. The inputs to the MIKE11 model are:

- time series of flows at upstream locations (boundaries) on rivers near the international border,
- NAM-generated time series of runoff from the local catchment area which drains to the river system further downstream,
- water levels at downstream boundaries.

Outputs from MIKE11 include time series of water levels, cross sectional mean velocities, and flows at desired points along the rivers.

MIKE11 is a one-dimensional model that is suitable for modelling general flow and water level conditions. It is not intended to simulate local flow conditions that are highly two- or three-dimensional such as stratified flow or local velocities in bends.

1.3 The Kangsha Sub-model

Figure C.1 shows the major rivers of the northeast region and a schematic presentation of the model.

The Kangsha sub-model was constructed from a part of the Northeast Regional Model. The Dampara, Someswari, and Malijhee areas were schematized in greater detail to improve the calibration and to better quantify the impacts of proposed interventions in these areas. Cross-sections were added in some rivers and many floodplain channels were schematised as discrete channels to replace the conceptual routing channels or flood cells of the regional model. An earlier version of this sub-model was used earlier during the pre-feasibility studies at NERP.

Boundary conditions were specified at the upstream ends of the major channels by means of time series of discharges. The NAM rainfall-runoff model was used to generate the runoff from the various subcatchments inside the model area. Water levels at downstream boundaries at the Baulai River were taken from the full Northeast Regional Model.

The sub-model was calibrated for existing conditions. It was run for each year from 1991 through 1993 separately. The calibrated model was then modified to represent the proposed project initiatives and to simulate the effects of these projects.

1.4 Limitations of the Model and Their Implications

In designing the model and interpreting its results in planning and design studies the following limitations need to be considered:

- The hydrodynamic model is large in extent and it is impossible to reproduce the river system in every detail. Thus a number of simplifications of the river system and hydrologic processes are required, which lead to approximations in the results.

- NAM is a "lumped" conceptual type of rainfall-runoff model in the sense that the parameters and variables for a catchment are average or lumped values. Given the quantity and quality of data in Bangladesh, this is an adequate approximation.

- There is no coupling of the surface inundation from the hydrodynamic model into the subsurface storage in NAM and the implicit channel routing for minor streams is restricted in NAM. These are not of major consequence in modelling floods in the rivers provided that the NAM catchments are sufficiently small.

- It is assumed in the hydrodynamic model that the river bed is fixed and does not change with time. In fact, the cross-section may change due to erosion of the bed and bank and deposition in the channel and on the floodplain. This is a particular concern in the border rivers.

2. DATA COLLECTION FOR THE KANGSHA SUB-MODEL

2.1 Cross-section Survey

River cross-sections are required for the hydrodynamic model to prepare a hydraulic description of the conveyance of rivers. A large number of cross-sections were surveyed during 1994 and 1995 in the Bhogai, Kangsha, Mogra, Baulai, Jadukata, Malijhee, Atrakhali, Bakhara, Shibganjdhala, Old Someswari, Balosmora, Gunai, Jaria, Lauari, and Upper Mogra rivers. These cross-sections were included in the Kangsha sub-model. Cross-sections were also surveyed in the Kalihar and Balia Rivers, inside the Dampara Project area, for drainage studies. These drainage cross-sections are spaced at 100m intervals and extend 20 to 25 metres beyond the channel banks; some of them were included in the sub-model.

2.2 Hydrometric Data Collection

Water levels and discharge data are required for input to and calibration of the model. Water levels and discharges were collected from regular stations managed by BWDB in the upper Kangsha area. NERP also installed 19 water level gauges in the Kangsha floodplain in June 1994 for detailed feasibility studies. NERP also measured discharges regularly through joint programmes with SWMC and BWDB at Bijoypur on the Shibganjdhala, Barakanda on the Malijhee, and Jalalpur on the Upper Mogra. Spot discharges were measured during monsoon-season spills in the floodplains at Dhopaguchina on the Nagla River and at bridges located in the Phulpur-Sarchapur road in the south floodplain of the Kangsha River.

Most of these gauges were operated through the 1994 monsoon season. A selected number of water level gauges were continued through the dry season. There were no significant spills during the 1994 monsoon as it was a relatively dry year.

3. SCHEMATIZATION OF THE KANGSHA SUB-MODEL

3.1 Purpose

The Kangsha sub-model was built for quick availability and rapid evaluation of model runs. It takes much less time to run the sub-model than the full model. Results of calibration runs and impacts of proposed interventions can be evaluated more quickly with the help of the sub-model than with the full model.

The Kangsha sub-model was developed to quantify the impacts of interventions that are proposed in the Dampara and Someswari Project areas and in the upper Kangsha River. The schematization was revised to permit assessment of impacts of various interventions.

The model helped in developing an understanding of the physical mechanism involved in flooding of the river-floodplain system of the Kangsha river. This physical insight is essential for formulating and evaluating the various flood control alternatives.

3.2 HD Model Schematization

The full Northeast Regional Model had been first calibrated and verified against observed data of 1991, 1992 and 1993 during the development of the regional model. The Kangsha sub-model was built out of the full model and it covers the Upper and Lower Kangsha portion of the full Northeast Regional Model. The sub-model generally provides a more detailed description of the Dampara and Someswari Projects and the Malijhee basin by schematising the rivers carrying significant flow inside the projects.

Additional cross-sections which were surveyed by NERP were included in the sub-model setup. Some rivers which had not been schematised earlier in the regional model were added to the sub-model; these included the Atrakhali, Bakhara, Old Someswari, Kamarkhali (Chipakhali), Balosmora, Gunai, Kalihar, Balurgate, Balia, Jaria, Lauari, Upper Mogra, and Malijhee Rivers. These rivers are located in the Someswari and Dampara Projects and in the Malijhee area. The Someswari River was resurveyed because of recent changes in the river and to provide better resolution. Some cross-sections were also replaced or were added in the Bhogai and Kangsha Rivers.

The data of cross-sections and water level records were checked during the calibration exercise. The model uses the datum which was established during the joint Second Order Levelling Programme of SOB and NERP.

New inflow boundaries were created at Barakanda on the Malijhee River and at Jalapur on the Mogra River.

3.3 Boundary Conditions

The conditions imposed at the model extremities or boundaries determine to a large extent the water movement inside the model area. There are 7 upstream (discharge) boundaries and 8 downstream (water level) boundaries in the sub-model.

Upstream discharge boundaries were selected on each schematised channel as far upstream as possible. Downstream boundaries were located sufficiently far from the Dampara and Someswari Project and other areas that the impacts of proposed interventions would not reach or change the model boundaries. Downstream water levels were taken from the full model results.

3.4 NAM Model Schematization

Catchment boundaries are shown in Figure C.2.

At two locations, Barakanda on the Malijhee River and Jalalpur on the Mogra River, the model boundaries were extended upstream to permit modelling of development scenarios. As there had been no flow gauges at these locations the boundary inflows were generated using the NAM model. Two temporary discharge gauges were installed and operated during 1994 to provide data for calibrating the NAM model.

Catchment boundaries were revised to reflect these changes. NAM catchment NE-33A (Malijhee basin) was subdivided into two subcatchments, namely NE-33A and NE-33B. Catchment NE-59B was subdivided into NE-59B and NE-59C. These are shown in Figure C.2.

The "Irrigation" module of NAM was used to simulate the catchments.

3.5 Structures

Exchange of flow between the rivers and the floodplains are simulated through longitudinal broadcrested weirs representing the crest of embankments or the top of the river bank.

3.6 Temporal and Spatial Resolution

The number of computational or grid points and the length of the simulation time step in a river depend on the flood wave period. Distance steps ranges from 3 to 5 kilometres in flashy rivers and about 10 km in main rivers. A time step of 30 minutes was used. A relatively small time step was necessitated by the flashy nature of certain rivers. Testing with a shorter time step, 15 minutes, gave comparable results and confirmed that the selected time step was adequate.

4. MODEL CALIBRATION

Calibration is the process of adjusting the model to ensure that it is capable of reproducing actual conditions within acceptable limits. The schematisation, discretization, and even the roughness value are changed within physically meaningful limits to improve calibration results. Once calibrated, the model can be used to find impacts of alternative development options on water levels and flows in and around the area, and especially to determine the impacts that an intervention proposal can have on flood conditions outside the project.

4.1 NAM Model Calibration

Three rainfall stations were used for each of the two catchments for generating mean areal rainfall; all are located outside the catchments. The stations and their weights were selected on the basis of trial model runs. Catchments NE-33B and NE-59C were calibrated against available 3-hourly discharge data at Barakanda on the Malijhee and at Jalalpur on the Upper Mogra respectively. Discharges were measured at these two stations for the period June 1994 to November 1994.

Comparison of simulated and recorded runoff hydrographs is made in Figure C.3. Results were judged to be only fair. Differences between simulated and recorded discharges are due to the following:

- the short period of record which was available for model calibration represented a relatively dry year and a limited range of conditions;
- variable rainfall conditions resulted from there being no raingauges directly within the catchments;
- effects of upstream beels and floodplain storage could not be accurately represented in the lumped model runoff.

Adjusted model parameters were CK1 and CK2, the overland flow and interflow time constants which represent the response time of the catchment. Adopted values were 100 hours for catchment NE-59C and 50 hours for catchment NE-33B. These values are lower than those found earlier for the larger catchments. These lower values imply that the two new catchments are more quick to respond to rainfall events than are the larger catchments, as would be expected.

4.2 Hydrodynamic Model Calibration

Portions of the HD model were calibrated for 1994 using two smaller sub-models. These were the upper Malijhee River from Barakanda to Urfa and the upper Mogra from the Dampara project to downstream of Jalalpur. These two reaches had been added to the model and had not been previously calibrated. Then the entire model was re-calibrated for the period 1991 to July 1993 which were years of high flow in the region.

In most locations, calibration results were judged by comparing simulated water levels and discharges with recorded values at the same location. However, in at three locations the simulated results were judged by comparison with "hindcast" data. Hindcast data are estimated for an earlier period using correlations derived from measurements taken during a more recent period. These locations were Birsidli on the Old Someswari River, Baluaghata on the Malijhee River, and Atrakhali offtake on the Someswari River. Hindcasting relationships were established from the results of the 1994 monitoring program. This technique effectively allows a limited data base to be extended to earlier periods.

4.3 Assessment of Calibration Results

During calibration, recorded hydrographs were compared with the simulated ones. Various adjustments were made to the model schematization and roughness values, and several additional cross-sections were surveyed and added to the model until the results were deemed suitable.

Calibration results for key locations are presented in Figures C.4 to C.9 and are summarized briefly below:

Urfa (Figure C.4)
- Good agreement in hydrograph shape but peak water levels are underestimated by as much as 0.5 m
- Problems are believed to be related to errors in boundary inflows at Barakanda

Nalitabari (Figure C.5)
- Excellent agreement in water levels (no discharge data are available)

Sarchapur (Figure C.6)
- Excellent agreement in both water levels and discharges

Jaria Jhanjail (Figure C.7)
- Excellent agreement most of the time in both water levels and discharges but two individual late-season peaks are under-estimated in 1991 and 1992; reason is unknown

Durgapur Figure (C.8)
- Good agreement in both water levels and discharges

Atrakhali Offtake (Figure C.9)
- Excellent agreement compared with "hindcast" data for 1991 and 1993.

The model was found to have sufficient accuracy at all locations. It was also judged to be able to estimate the hydraulic effects of the proposed interventions, where the magnitude of the change is more important than the absolute accuracy of predicted water levels. Generally more importance is attached to the accuracy of flood stages than the accuracy of low stages. Simulated peak water levels are within 0.3 m of observed values in almost all cases.

Exact coincidence of the simulated and recorded levels should not be expected under all conditions due to the practical limitations of model schematization, resolution, data accuracy, and bed level changes during floods.

5. SIMULATION OF INTERVENTION SCENARIOS

5.1 Introduction

The calibrated Kangsha sub-model was used to assess impacts of alternative interventions on water levels, flows, and flooded areas in and around the proposed projects. Simulations were made for the 1991 water year which had a 1 in 2 year flood and the 1988 water year which had a 1 in 20 year flood. The impacts on water levels and flows and the areal extent of flooding are described below. The following scenarios were modelled:

1. Existing conditions plus Dampara Project
2. Scenario 1 plus Konapara Embankment Project
3. Scenario 2 plus Bhogai Bypass channel
4. Scenario 3 plus the Atrakhali avulsion in the Someswari River
5. Malijhee Diversion to the Mrigi River and Old Brahmaputra River

This series replicates the most likely progression of project development and thus represents the cumulative impacts. The incremental effects of each individual project can be determined by comparing the results of its scenario with the previous one. The Atrakhali avulsion scenario assumes that the recent trends in river shifting will continue until the Atrakhali channel captures most of the Someswari flow.

5.2 Dampara Project

Modelling of the Dampara Project included simulation of the two main drainage channels, the Kalihar Nadi and the Balia Khal, as well as the proposed regulators at the outlet of each channel. In the project scenario the existing overbank spills from the Kangsha into the project area were closed to represent the effects of the embankments, and the regulators were assumed to be closed whenever the river water levels exceeded the floodplain levels. The purpose of the simulation was to determine what impact closing off the overbank spills would have on river levels outside the project.

Results of the simulation are presented in Figure C.10 which shows that flood conditions outside the project would be insignificantly raised, by less than 0.1 m, by the embankments. The impacted area is confined to the immediate vicinity of the project. The effect on discharges around the Dampara Project was also found to be insignificant.

Simulation results confirmed that flood levels inside the project would be reduced by 1.0 m or more. It is to be mentioned here that this project has been studied at feasibility level. Detailed analysis dealing with the adequacy of drainage regulators have been furnished in the feasibility report.

5.3 Konapara Embankment

In the mathematical model simulations, the Konapara Embankment was simulated by closing off the overbank spill to the north. The purpose of the simulation was to determine what impact the proposed project would have on flood levels in the Bhogai and Kangsha Rivers, especially at the offtake of the Gangina and Kodalia Khals where the effects would be greatest.

Resulting water levels are compared with pre-project conditions for Sarchapur in Figure C.11. Results indicate that the project would raise flood levels in the Bhogai by a maximum of 0.2 m in a 2-year flood and 0.3 m in a 20-year flood. At Sarchapur the rise would be 0.1 m in a 2-year flood and 0.2 m in a 20-year flood (Figure C.11). Changes are not detectable upstream of Urfa or downstream of Ghagra.

Simulation results depend directly on assumptions regarding the magnitude of the existing overbank spills. Unfortunately there is little direct data with which to confirm these assumptions. Furthermore conditions are extremely variable due to flash flooding conditions and breaching of the existing closures and embankments. Collection of more discharge data is recommended in the spill path further downstream as was attempted in 1994 (conditions were too dry in 1994 to give useful data).

5.4 Bhogai By-Pass Channel

The Bhogai by-pass floodway was approximated in the model through the simple device of applying a lateral outflow at Nakuagaon and an equal lateral inflow near Ghagra (upstream of Jaria). This simulates the actual operation of the bypass which would carry flood water from the Bhogai River to the Kangsha River further downstream.

The purpose of the simulation was to determine what effects the bypass would have on lowering flood levels in the Bhogai and Malijhee Rivers and whether flood levels would rise in the lower Kangsha.

In the simulation the diversion channel was assumed to carry no flow as long as Bhogai discharges were less than 50 m^3/s, a typical monsoon season maximum baseflow. Diversion flows were then assumed to increase progressively with increasing Bhogai discharges until the entire flow was diverted above a river flow of 150 m^3/s. The diversion flow was limited to a maximum of 1,000 m^3/s, the assumed capacity of the diversion channel.

The results show that flood levels in the Bhogai River at Urfa would be lowered by 0.3 to 0.5 m in a 20-year flood and 0.1 m in a 2-year flood (Figure C.12). At Sarchapur, the flood levels would be lowered by 0.80 m and 0.40 m respectively for the same return periods. By comparison the water levels at Nalitabari, upstream of the confluence, would be lowered by as much as 5 m. This implies that the potential benefit of this scheme are reduced considerably by local runoff and inflows from the Chillakhali River and Malijhee River. Floodplain storage is also a factor.

The flood reduction extends upstream into the Malijhee basin where flood levels would be reduced by about 0.2 m and downstream almost as far as Ghagra.

Thus this scheme would lower the flood levels in the key area of interest, the Malijhee floodplain, by about 0.2 to 0.8 m. But Flood levels at Jaria Janjail would rise by about 0.10 m due to the loss of upstream floodwater storage. This is shown in Figure C.13.

However, the above findings are based on assumptions and coarse data. Further studies at pre-feasibility and feasibility levels are required to assess the impacts on various important environmental components including siltation, extent of flooding and possible drainage congestion due to the diversion.

5.5 Someswari River Avulsion to Atrakhali Khal

A set of model runs was made to simulate the effects of the on-going changes in the Atrakhali and Shibganjdhala Rivers, assuming that these changes would be allowed to continue. The primary area of interest with respect to the modelling was the effect that these changes would have on flood discharges and water levels at Jaria.

Growth of the Atrakhali Khal was simulated by widening its cross-sections in the model and raising the Shibganjdhala channel bed until the Atrakhali channel was carrying two-thirds of the total peak flow. This assumption has been made based on the Old Someswari and the Shibganjdhala Rivers' historical discharge data.

Results of the simulation indicated that flood levels would be lowered by about 0.7 m at Jaria (Figure C.14). The changes would be evident for some distance upstream and downstream of Jaria. Discharges would be reduced by about 850 m^3/s in a 20-year flood, a reduction of more than 50%. Flood discharges would decrease by 400 m^3/s or 30% in a 2-year flood which would have implications for sediment transport, deposition, and river regime throughout the lower Kangsha River.

5.6 Malijhee River Diversion

This intervention consists of a diversion channel that would carry flood peaks from an upstream point in the Malijhee River into the Old Brahmaputra River via the Mrigi River. The scheme was simulated in the model by a simple lateral outflow located slightly downstream of the model inflow boundary at Barakanda (the actual location would be some distance upstream). The diversion rate was assumed to be a maximum 200 m^3/s. The purpose of the modelling was to determine the effectiveness of this scheme on flood levels in the Malijhee River.

Simulation results indicate that flood levels would be reduced by 0.15 m at Balughata and 0.05 m at Urfa in a 2-year flood (Figure C.15). Flood levels would be lowered by 0.7 m at Barakanda which is located upstream of the flood-affected area.

5.7 Cumulative Effects

The cumulative effects of the flood control projects can be determined by comparing the final scenario with the simulation of existing conditions. This comparison is made in Table 1 at three key locations in the basin. The development scenario is Scenario 4 which

Table 5.1: Cumulative Effects of Flood Control Interventions

Location	Change from Existing Condition	
	20-Year Flood	2-Year Flood
Urfa	-0.45 m	-0.30 m
Sarchapur	-0.65 m	-0.35 m
Jaria water levels	-0.40 m	-0.55 m
Jaria discharges	-600 m3/s (-40%)	-350 m3/s (-25%)

includes the Dampara Project, the Konapara Embankment, the Bhogai Bypass channel, and the anticipated future changes in the Shibganjdhala and Atrakhali channels. The Malijhee diversion via the Mrigi River was not included as it is unlikely that it and the Bhogai Bypass would both be constructed, and the Bhogai Bypass has the prospect for making greater changes.

The results show that flood levels would be significantly reduced at all locations, typically by 0.3 m in a 2-year flood and 0.5 m in a 20-year flood. Peak discharges at Jaria would be reduced by about 25% in a 2-year flood and 40% in a 20-year flood, largely as a result of the avulsion into Atrakhali.

6. CONCLUSIONS AND RECOMMENDATIONS

The model is adequately calibrated to give a reasonable representation of the changes due to the various intervention scenarios. This statement has to be qualified, however, by the fact that there is little data with which to confirm the assumptions regarding the magnitude of overbank spills at several locations, especially over the left bank of the Bhogai River upstream of Sarchapur, over the south floodplain of the Kangsha River at Sarchapur, and over the right bank of the Kangsha River into the Dampara Project.

The impacts and effects of the various interventions are described above. In general it is found that the potential reduction in flood levels that can achieved through intervention in the upper basin (the Malijhee diversion and the Bhogai bypass) is quite small. However as the floodplain is so flat a large area is affected. Storage effects and local inflows are important factors in reducing the effectiveness of the alternative interventions.

The effects of the Dampara Project on flood levels outside the project will be negligible and will be far less than the natural changes which have already occurred and which are likely to occur in the future.

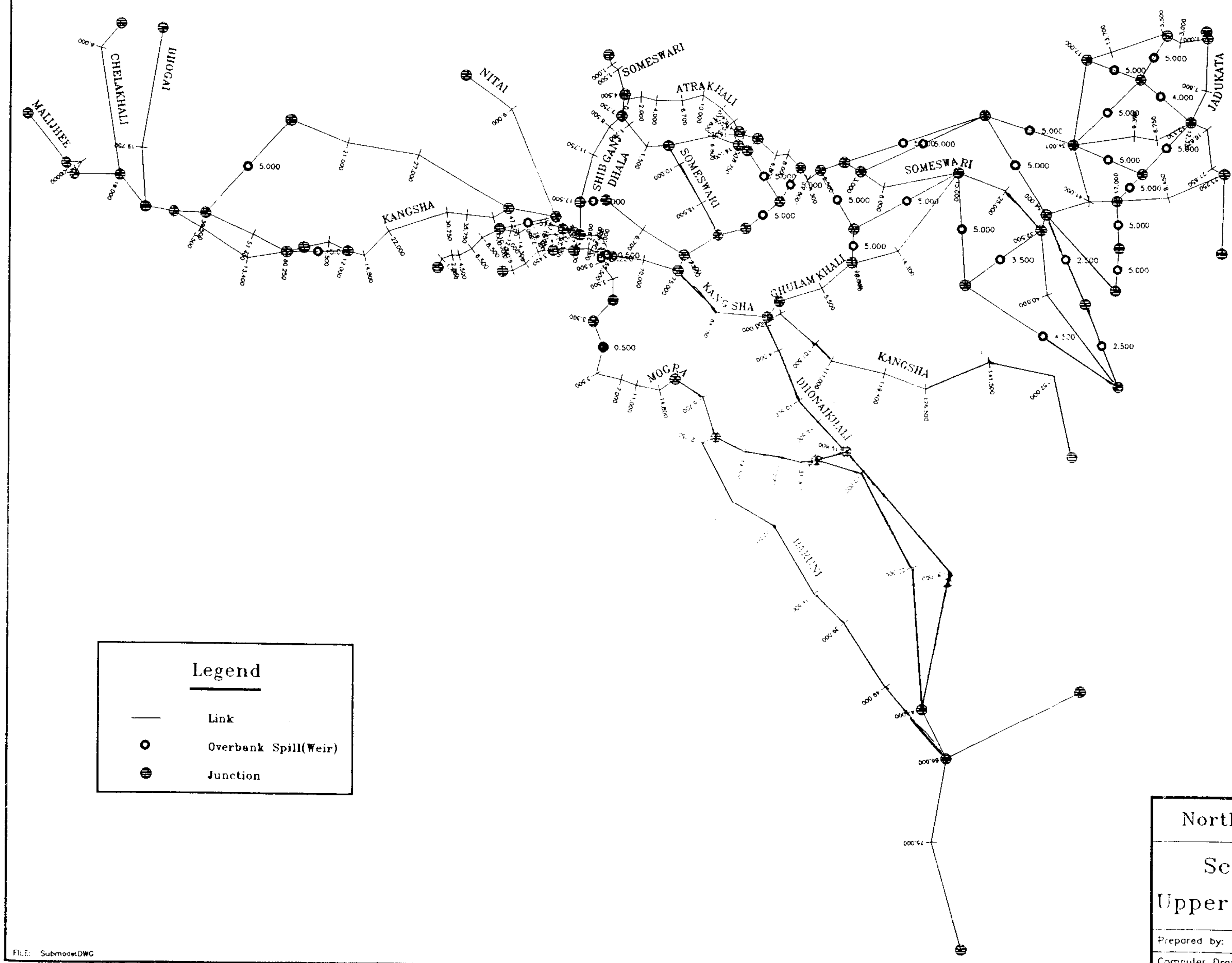
The proposed extension of the Konapara embankment could cause a significant rise in flood levels in the Bhogai/Malijhee floodplain, of the order of 0.3 m, if the existing closures haven't already done so. The reliability of this statement is tempered, however, by the fact that it is really no more than an educated guess as there are no data on the actual flow rates over the bank in this area. The assumptions are believed to be conservative. Discharge data in the spill path are required to confirm the key model assumptions in this area.

The on-going changes in the Shibganjdhala and Atrakhali Rivers have the potential for causing a significant impact on the Kangsha River. Flood levels will be reduced by as much as 0.7 m and flood discharges will be reduced by as much as 30 to 50 percent. Flood conditions along the Kangsha may be initially benefitted, but these changes will also affect the sediment transport characteristics and morphology of the river. The river cross-section will adjust to changes of this magnitude and these adjustments may offset any temporary reduction in flood levels. Simulation of the long-term morphological response is beyond the scope of the present exercise.

The cumulative impacts, including three possible flood control interventions and the anticipated future changes in the Atrakhali and Shibganjdhala Rivers, will be to lower the flood levels at all locations, typically by 0.3 m in a 2-year flood and 0.5 m in a 20-year flood. Peak discharges at Jaria would be reduced by about 25% in a 2-year flood and 40% in a 20-year flood, largely as a result of the avulsion into Atrakhali.

A program of data collection is recommended to acquire more discharge data at Barakanda, Jalapur, and Bathkuchi to improve the representation of boundary inflows at these locations. Additional water level data should be gathered at the same time at the locations which were monitored by NERP in 1994. The data collection program should extend for a period of three to five years.

Figure C.1

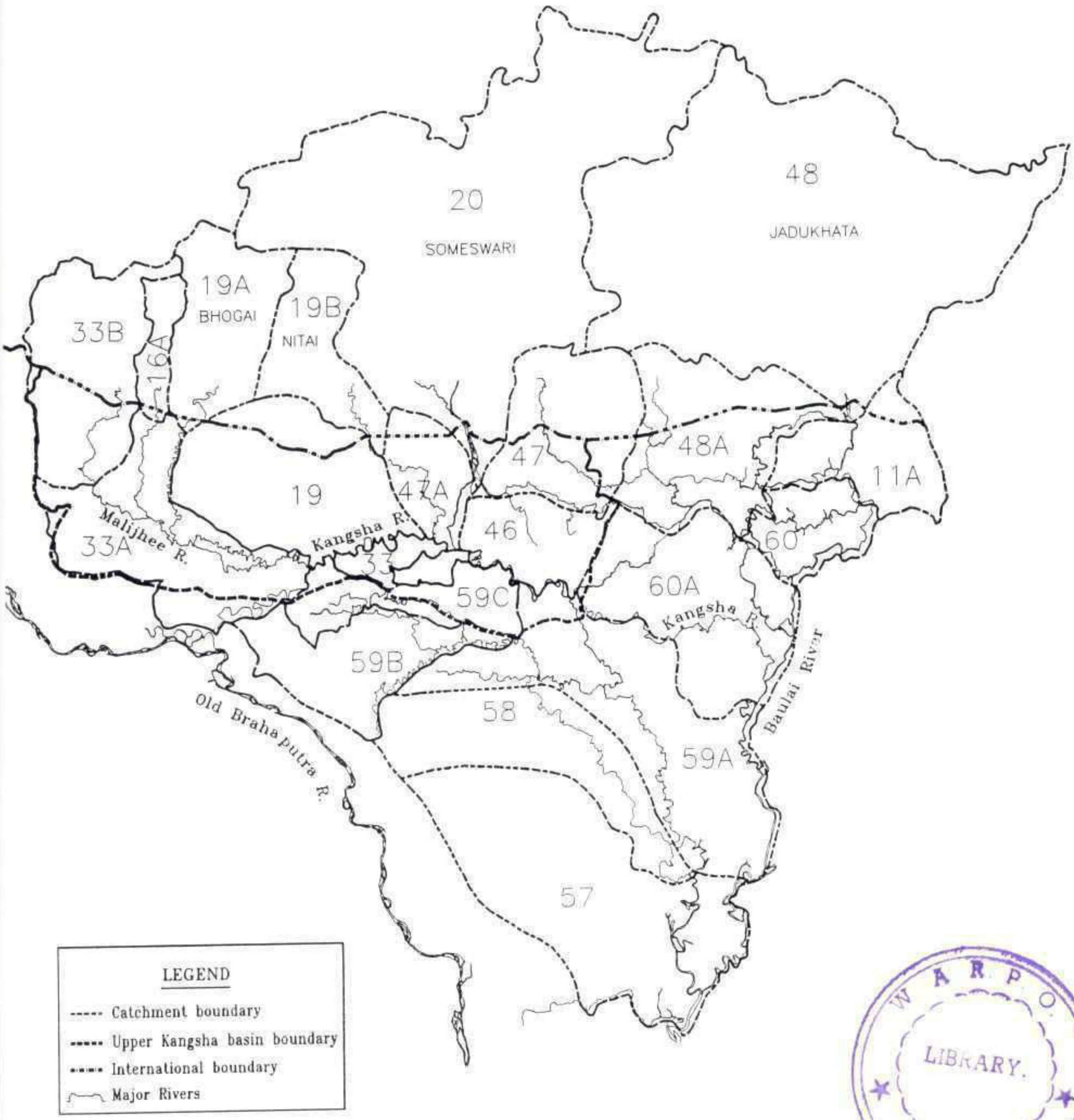


Northeast Regional Project

Schematic Map of Upper Kangsha Submodel

Prepared by: Saifuddin/Ashek	June, 1995
Computer Drafting by: Ashek	AutoCAD Drawing

Figure C.2



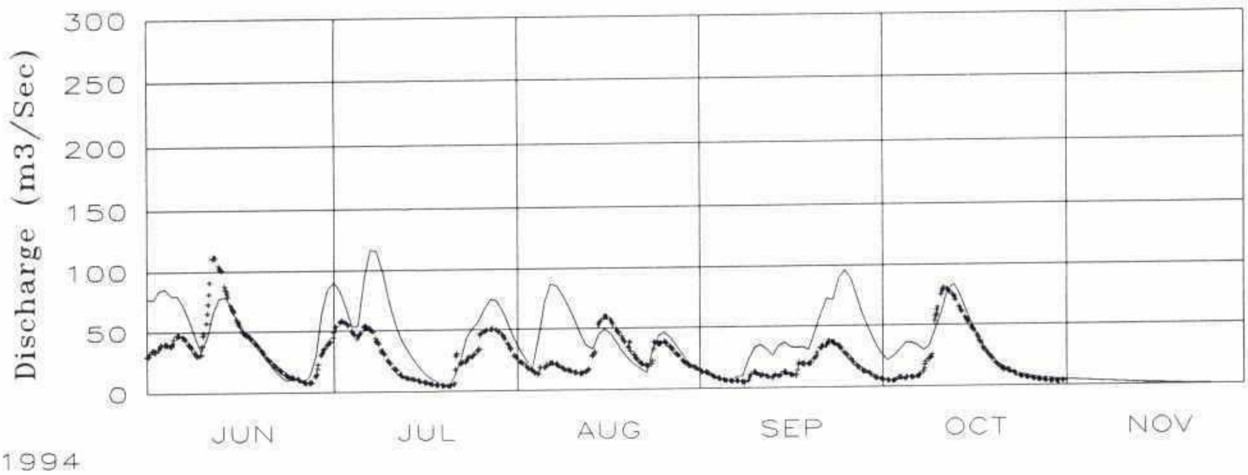
KANGSHA BASIN
CATCHMENT MAP

Northeast Regional Project

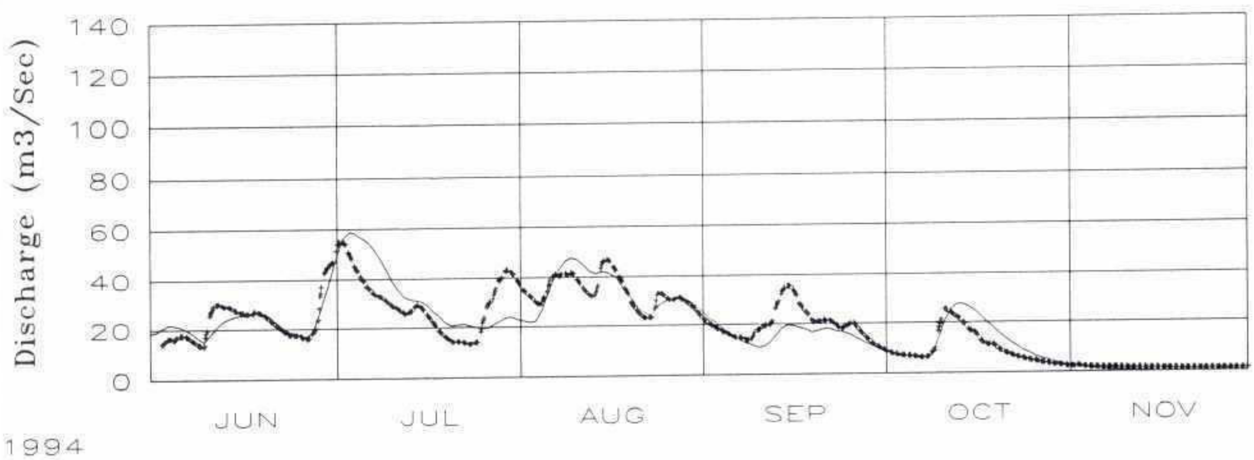
FILE: KANG-BAS.DWG

Figure C.3

Catchment NE-33B at Jalalpur



Catchment NE-59C at Barakanda



LEGEND

Recorded discharge

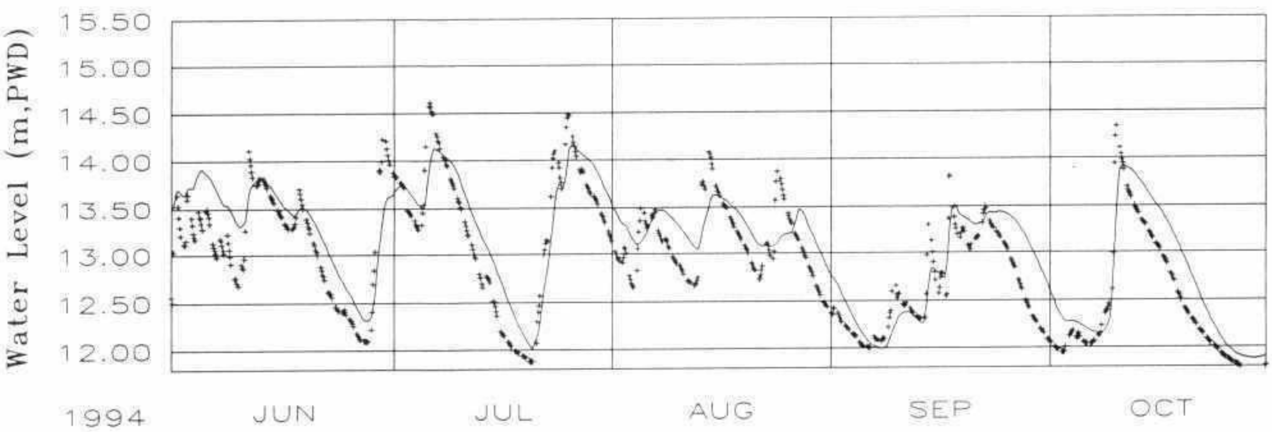
Simulated Runoff

NAM Calibration Results

Northeast Regional Project

FILE:MODL-803.DWG

Urfa (Bhogai River Km 25.75)



LEGEND

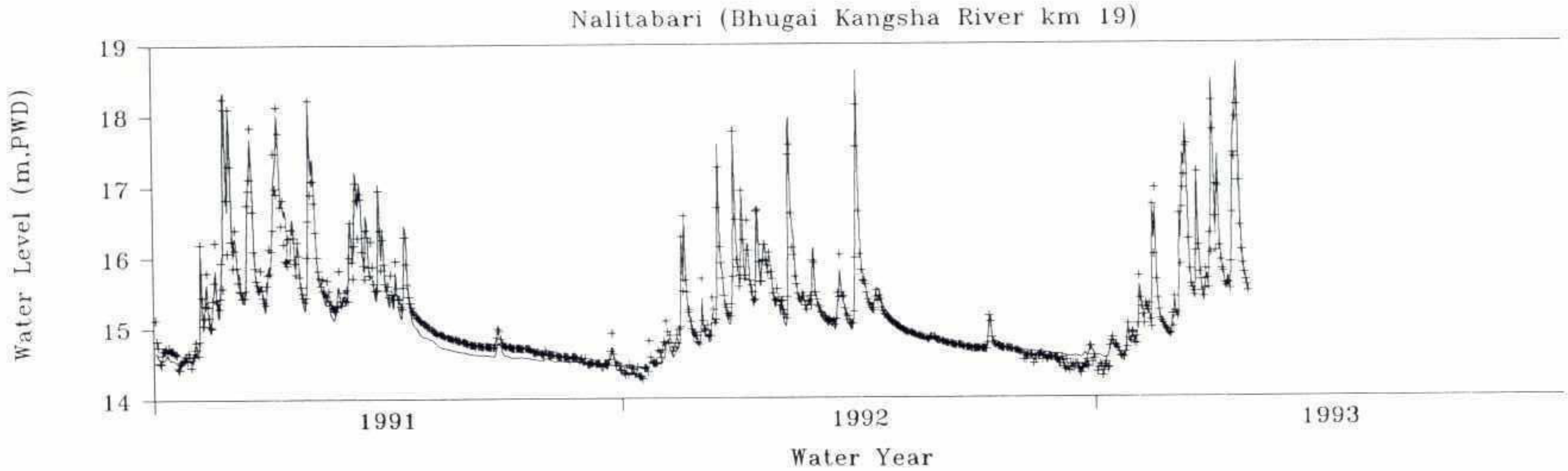
Recorded Water Level

Simulated Water Level

Calibration Results at Urfa

Northeast Regional Project

FILE: MODL-805.DWG



LEGEND

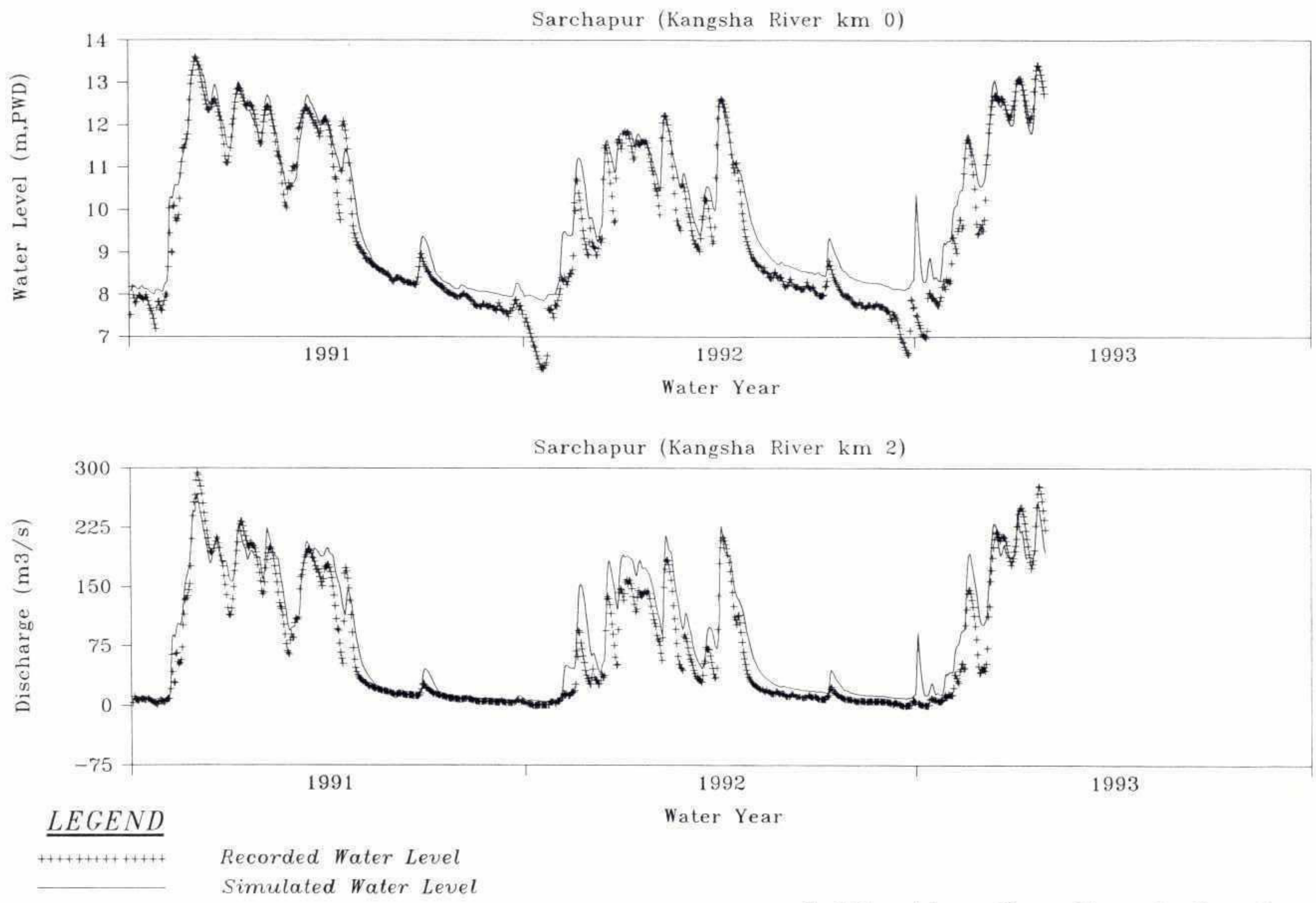
++++++++++++++ *Recorded Water Level*

———— *Simulated Water Level*

Calibration Result at Nalitabari

Northeast Regional Project

FILE: MODL–809.DWG



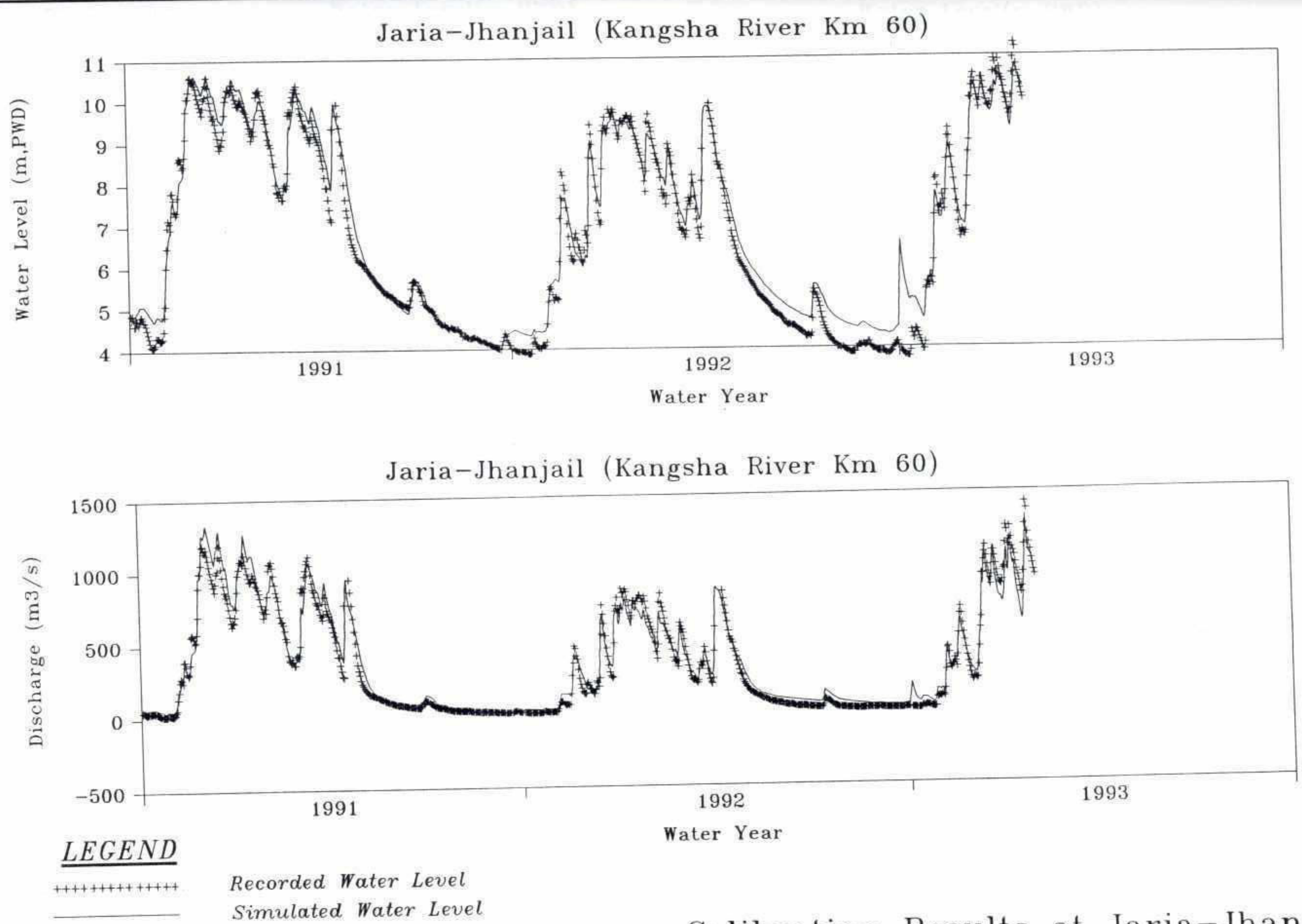
Northeast Regional Project

Calibration Results at Sarchapur

FILE: MODL−810.DWG

Figure C.6

FILE: MODL-810.DWG



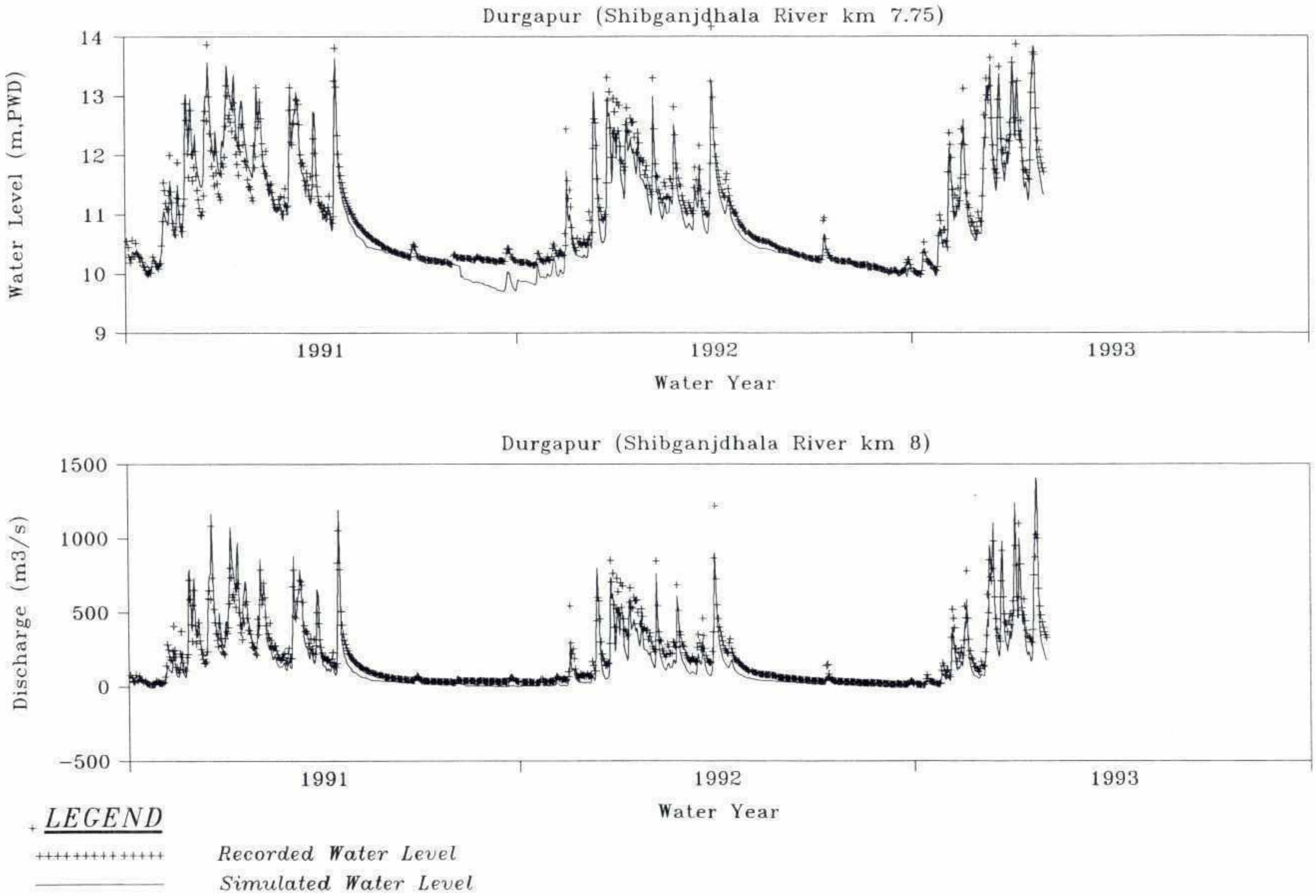
Calibration Results at Jaria-Jhanjail

Figure C.7

Northeast Regional Project

FILE: MODL-811 Prepared by:

Figure C.8



Northeast Regional Project

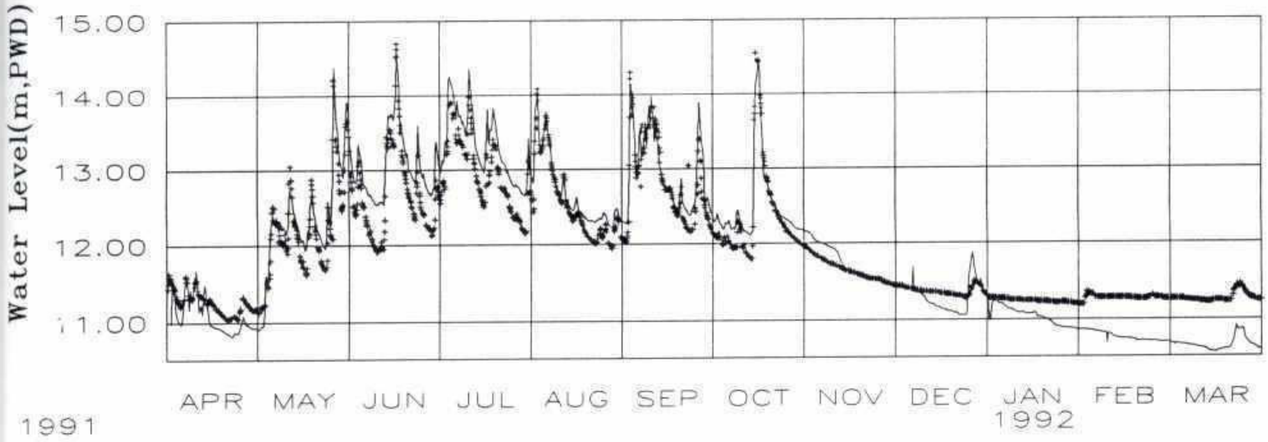
Calibration results at Durgapur

FILE: MODL-813.DWG

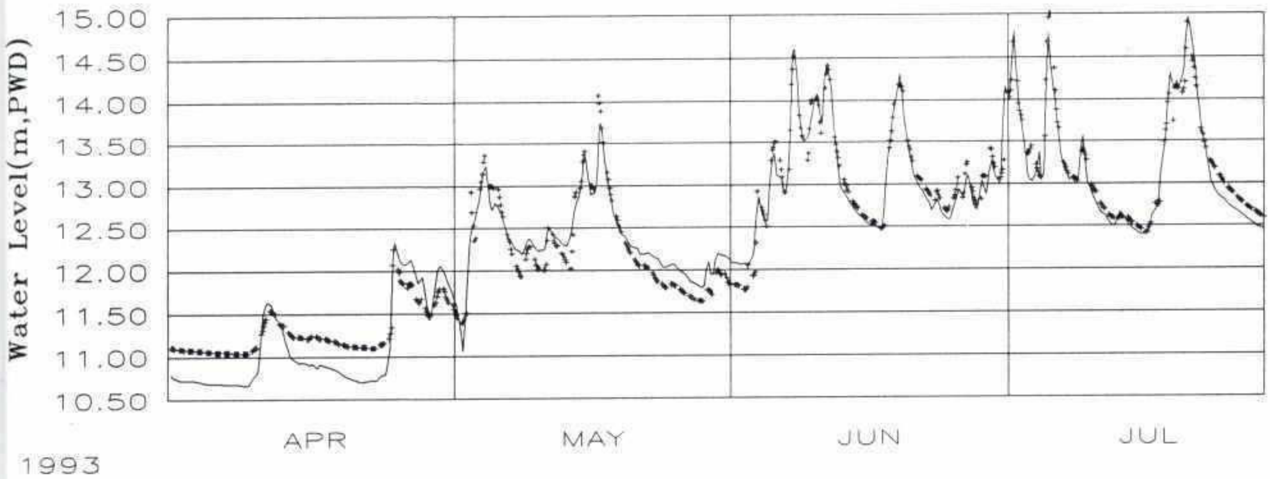
297

Figure C.9

Atrakhali Offtake (Atrakhali Km 0.5)



Atrakhali Offtake (Atrakhali Km 0.5)



LEGEND

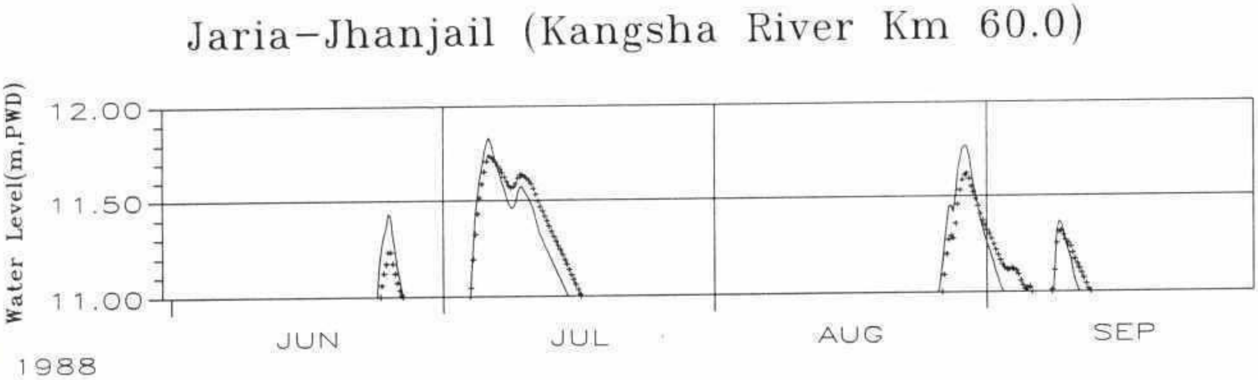
..............Water Level Generated by Correlation

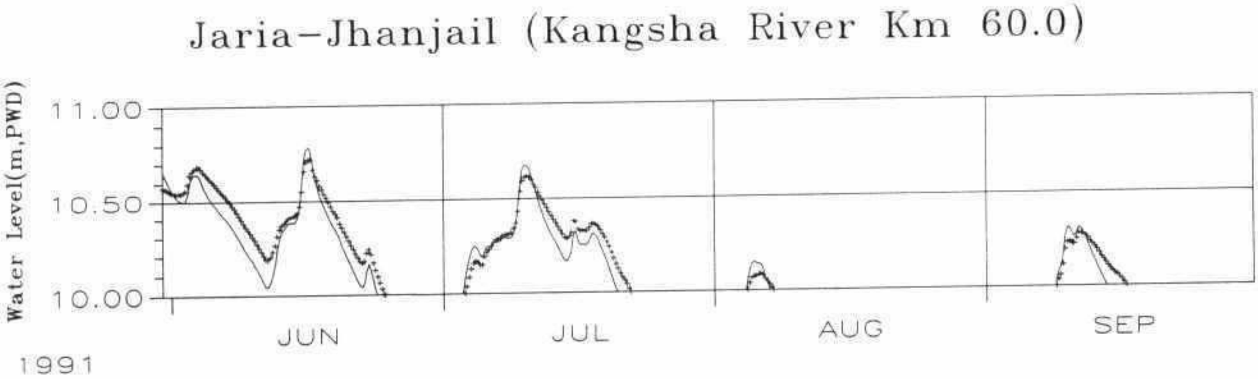
———— Water Level Hindcasted by Model

Calibration Results at Atrakhali Offtake

Northeast Regional Project

FILE:MODL-816.DWG





LEGEND

Existing Water Level

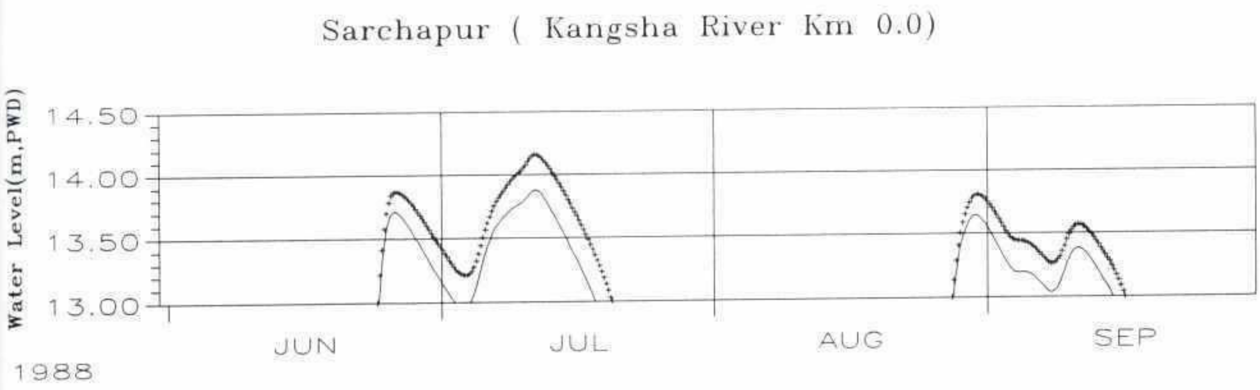
Post Dampara Project Water Level

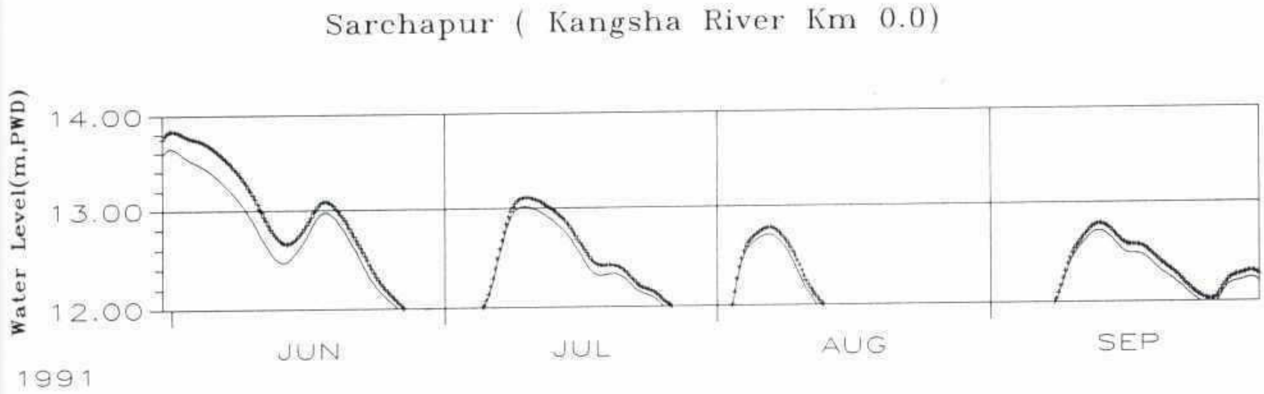
Effect of the Dampara Project on Water Levels at Jaria–Jhanjail

Northeast Regional Project

FILE: MODL-21 Prepared by:

Figure C.11





LEGEND

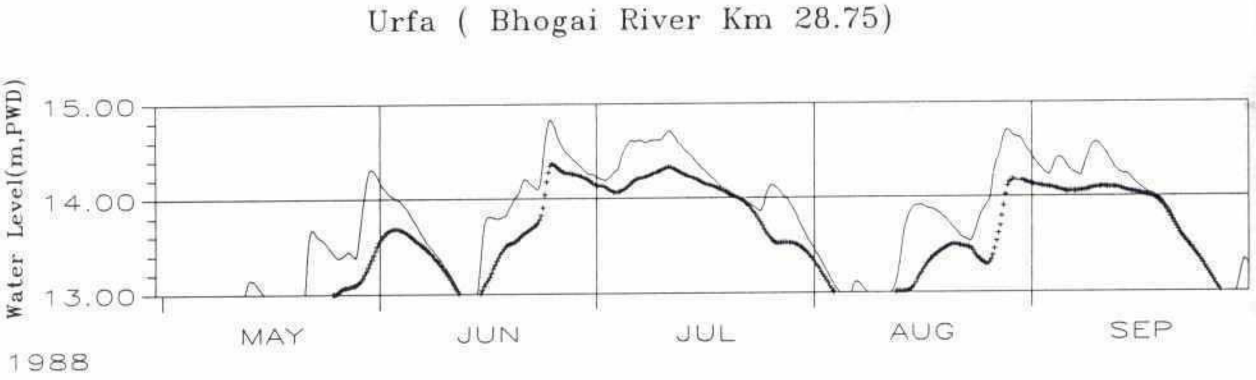
Post Project Water Level

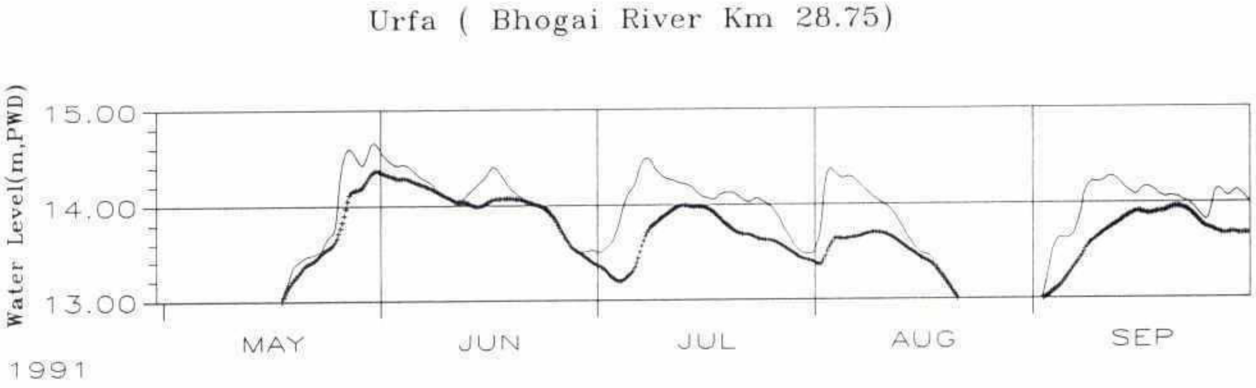
Pre Project Water Level

Effect of the Konapara Embankment on Water Levels at Sarchapur

Northeast Regional Project

FILE:MODL-22.DWG





LEGEND

.... Post Project Water Level

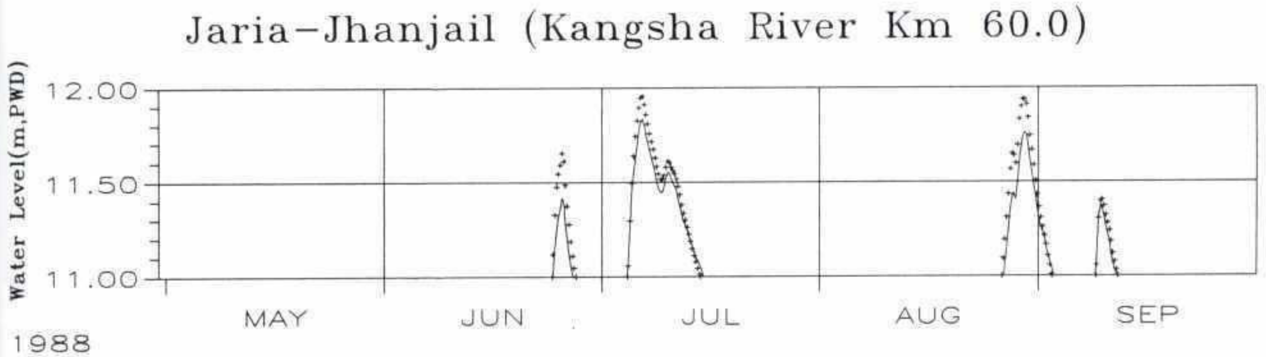
———— Pre Project Water Level

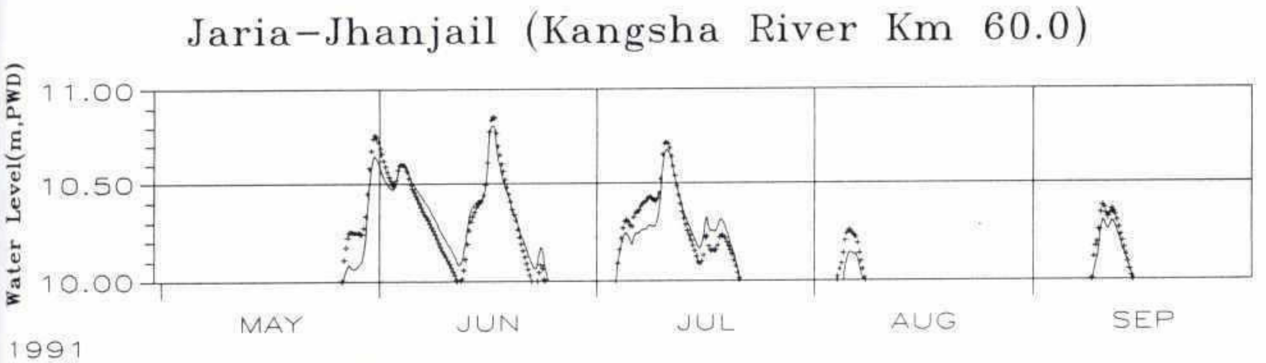
Effect of the Bhogai Bypass on Water Levels at Urfa

Northeast Regional Project

FILE:MODL-23.DWG

Figure C.13





LEGEND

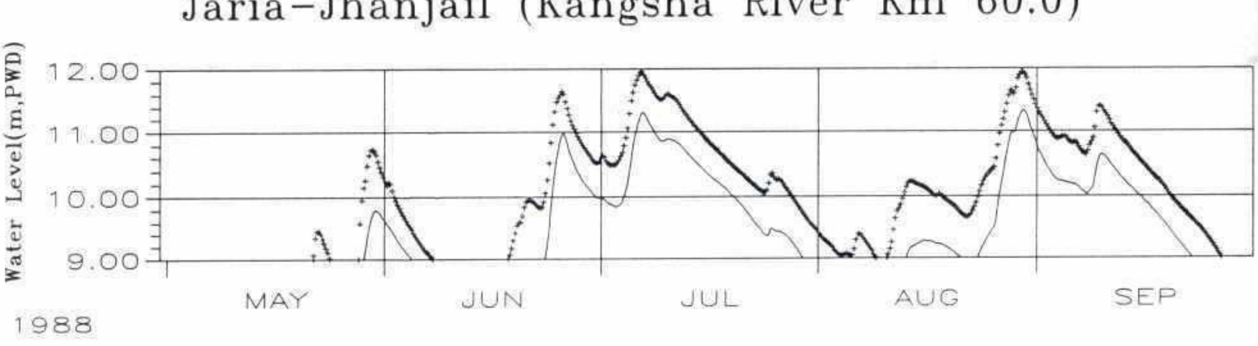
++++++++++++ Post Project Water Level

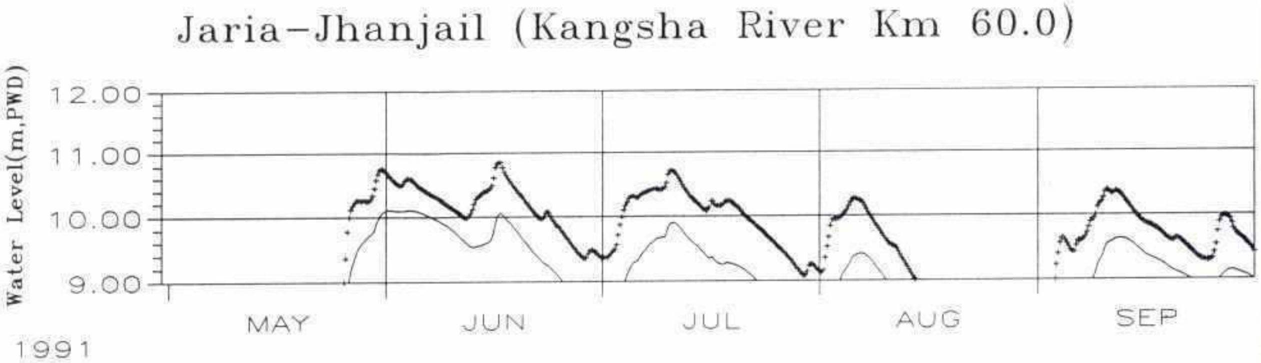
———— Pre Project Water Level

Effect of the Bhogai Bypass
on Water Levels at Jaria–Jhanjail

Northeast Regional Project

FILE: MODL-24 Prepared by:





LEGEND

Pre-Project Water Level

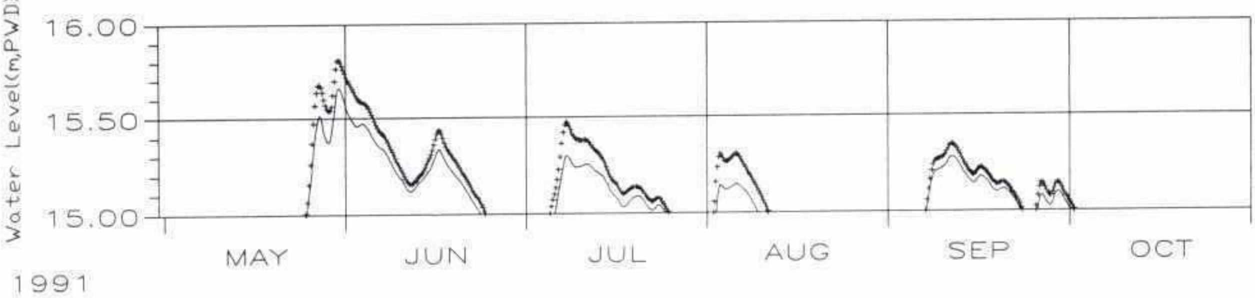
Post-Project Water Level

Effect of the Atrakhali Avulsion on Water Levels at Jaria-Jhanjail

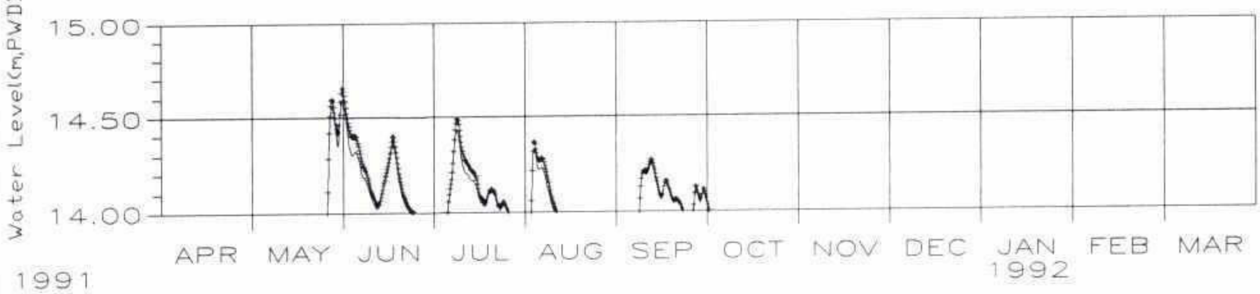
Northeast Regional Project

FILE: MODL-25 Prepared by:

Balughata (Malijhee River Km 11.70)



Urfa (Bhugai River Km 28.75)



LEGEND

.... Recorded Water Level

———— Simulated Water Level

Effect of the Malijhee Diversion on Water Levels in the Malijhee Lowlands

Northeast Regional Project

FILE:MODL-827.DWG

ANNEX D

Someswari River Stabilization Project

2b4

Annex D
Someswari River Stabilization Project

TABLE OF CONTENTS

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LIST OF FIGURES

1. INTRODUCTION

1.1 Background

Phase 1 of the Northeast Regional Water Management Project[1] prepared a Water Management Plan for the Northeast Region, including pre-feasibility level reports for various structural and non-structural initiatives. The pre-feasibility investigation "Upper Kangsha River Basin Development" included a proposal for controlling future instability on the Someswari River alluvial fan. In Phase 2, feasibility studies were initiated on several priority projects including the Someswari River. A detailed Water Management Plan for the Kangsha Basin (including the Someswari River) was also initiated.

Work commenced on the Someswari River feasibility study in January 1995 and progress on the investigation was reported to CIDA in June 1995. At that time it was indicated that a number of developments had taken place on the fan (including construction of embankments) since the pre-feasibility study. As a result, conditions on the fan had changed to the extent that the interventions proposed in the pre-feasibility study could no longer be recommended. Consequently, CIDA instructed that the feasibility study be terminated and alternative flood control concepts should be included as an element of the Kangsha Basin Water Management Plan[2]. This Annex has been prepared in accordance with these instructions.

1.2 Scope and Objectives

This Annex summarizes findings on hydrology, channel processes, and sediment transport on the fan and describes possible alternatives for controlling flooding and erosion. Findings on peoples' response to channel instability and flooding hazards are also documented. A recommended development alternative is presented, including a description of the institutional arrangements that are needed to manage flood and erosion hazards in an unstable river environment.

1.3 Description of the Project Area

Figure D.1 shows the Someswari River and the surrounding project area. The Someswari River enters Bangladesh from Meghalaya State in India near the town of Bagmara and flows for a distance of 20 km before entering the Kangsha River just upstream of Jaria Janjail. The Someswari alluvial fan encompasses portions of Durgapur, Kalmakanda, Pubadhala, Netrokona, and Barhatta thanas of Netrokona district. Figure D.2 shows the immediate area of the project in more detail.

The gross project area covers 306 km^2 and includes the town of Durgapur. The total estimated population in the project area was 169,900 in 1991.

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[1] "Northeast Regional Water Management Plan, Final Report", September, 1993, 212 pp.

[2] Canadian International Development Agency, "Report on Phase II Review Mission", Northeast Regional Water Management Project, NERP, Bangladesh (170/13339), June 1995

The Someswari River splits into three channels at Durgapur. In this report the following names are used for the various channels on the fan:

Someswari River:	the main branch that extends from the fan apex at the Indian border to the trifurcation near Durgapur.
Shibganjdhala River:	presently the main channel below Durgapur. It flows southward from Durgapur and enters the Kangsha River near Jaria.
Atrakhali River:	a new channel that has formed since 1988 upstream of Durgapur and heads eastward into the Baulai River system;
Old Someswari River:	formerly the main channel below Durgapur. It was abandoned after an avulsion in the 1960's but still continues to carry flood flows.

1.4 Previous Studies

The BWDB regional office in Mymensingh, under the responsibility of the Superintending Engineer, Mymensingh O&M Circle prepared a project proforma entitled "Someswari River Flood Control Project". This study presented a plan for closing the main course of the river and diverting it down a former channel.

In 1990, Snowy Mountains Engineering Corporation Ltd. (SMEC) in association with Bangladesh Consultants Ltd. prepared the report "Someswari River Flood Control Project" under the auspices of the Medium Scale Irrigation, Flood Control and Drainage Project, funded through Asian Development Bank, T.A. No. 1207-BAN. This report confirmed there is a serious need for flood protection in the project area and reviewed various alternatives for constructing full flood embankments. It also indicated that "*An understanding of the approximate quantity of sand carried annually and of its deposition pattern is needed in the planning of operations*".

The 1993 pre-feasibility study prepared by the Northeast Regional Management Project identified that a major channel shift on the river was imminent. The study reviewed various alternatives for stabilizing the river and advocated a combination of flood hazard zoning and river training.

2. PHYSICAL SETTING

2.1 Geomorphic Setting

2.1.1 Characteristics of Fans

Alluvial fans are formed when steep mountain streams exit from their canyons and spread over flatter, unconfined lowlands. The decrease in channel gradient and subsequent reduction in channel velocity causes deposition of sand and gravel in the form of a "fan-shaped" conical delta. Alluvial fans are characterized by sudden, irregular channel shifts which result in periodic abandonment of some channels and the creation of new channels across the fan surface. As a result, channel shifting on fans is usually unpredictable and erratic.

The main hazards on fans are associated with periodic channel erosion during avulsions and channel shifting, as well as flooding by channel spills, overland flow, and inundation. After an avulsion occurs, land adjacent to the newly formed channels will experience erosion as the new channel widens to accommodate the high velocity flows from upstream spills and overland flows. Large amounts of coarse sand may also be deposited overbank during subsequent floods over a zone of several kilometres in width as the river spills out of bank. Sand may also be deposited downstream in other river systems that receive flows from the newly formed channels. Consequently, sedimentation may take place far downstream from the site of the initial channel shift.

2.1.2 Watershed Characteristics

The Someswari River drains 2,135 km^2 of steep, mountainous terrain from the Tura Range in Meghalaya State, India. The overall relief in the watershed is 1,410 m and the average slope in the basin is around 2.6%. The watershed is composed primarily of sedimentary rocks such as sandstone and shale.

Tactical Pilotage Charts show the watershed to be sparsely settled with few major town centres. Due to access restrictions, it was not possible to visit the Indian portion of the watershed.

2.1.3 Alluvial Fan Characteristics

Figure D.3 shows an areal view of the alluvial fan and summarizes some aspects of its geomorphology. The fan covers an area of approximately 138 km2 and has a relatively low gradient (0.0005 between its apex at Bagmara and Durgapur and 0.00015 between Durgapur and Kangsha River confluence). Consequently, the land surface has built up only about 3 m above the surrounding lowland floodplain.

The lower portions of the fan are deeply inundated during the monsoon season by backwater from the Kangsha River, with this backwater extending to about 2 km downstream of Durgapur. The most aggressive channel shifting occurs at the upstream limit of this backwater where the flow velocities are suddenly reduced. Figure D.4 shows the extent of seasonal flooding in an average year and the locations of the major sand deposits.

The channels on the fan are composed of uniform fine sand, with a median size ranging between 0.25 - 0.40 mm and maximum sizes reaching up to 2 mm.

Figure D.5 shows past channel changes on the fan based on Rennell's map of 1768, topographic maps in 1952, and recent satellite images. Rennell's map of 1768 showed a single channel of the Someswari River flowing southward from its canyon mouth to the Kangsha River. East of the Someswari River Rennell's map showed a large "marshy lake". In 1952 the Someswari River flowed in a single braided channel which turned eastward into the Baulai River system. Subsequently, according to local inhabitants, a landslide occurred in the upper catchment in the early 1960's. Increased sediment supply to the river and channel deposition on the fan caused the river to shift back towards the west, excavating a new route (the Shibganjdhala channel) to the Kangsha River. Approximately 6 million m^3 of predominantly fine sand and silt sized sediment was eroded during the course of this avulsion. Much of this sediment has either been deposited in the old channel of the river or overbank into low lying areas on the fan such as Sitli Beel.

The present-day Shibganjdhala channel has an incised width at bankfull stage of about 100 m. However, the river spills out of bank in many locations and is depositing lobes of sediment over a 3 km wide zone. These broad sandy deposits extend as far east as the Jaria - Durgapur highway and as far west as the low lying haors near Sitli beel.

Information about past rates of channel changes on the fan can be inferred from the "specific gauge" plots for the Shibganjdhala channel and Old Someswari River channel which are shown in Figure D.6.[3] It can be seen that, after the avulsion occurred, degradation and channel enlargement have been taking place in the Shibganjdhala channel while sediment deposition has been occurring on the adjacent floodplain and in the Old Someswari channel. The plots suggest that as much as 1.0 to 1.5 m of erosion has occurred in the bed of the Shibganjdhala River while 1.5 to 2 m of deposition has occurred in the Old Someswari channel.

The shift from the Old Someswari River to the Shibganjdhala River has increased sediment loads in the Kangsha River and reduced sediment loads into the lower Someswari/Baulai River system. Deposition has occurred over the last 25 years along the lower Kangsha River as far downstream as Mohanganj. This deposition has virtually blocked off the original Kangsha channel and has resulted in the Kangsha River shifting into a former khal (Ghulamkhali channel). Impacts from the avulsion on Someswari River have extended over a distance of about 100 km. It should be noted that navigation channel depths have generally increased over the last 25 years on the Baulai River. It is believed that this change is partly due to the shift on the Someswari River system.

Two new avulsion paths have opened up since 1988 on the east side of the Someswari River, upstream of Durgapur near the fan apex. Local residents reported the Atrakhali channel developed after the 1988 flood when flow spilled eastward through a minor distributary into a former branch of the Old Someswari River. By 1995 the channel was 60 m wide with a cross sectional area of 200 m^2 at bankfull stage. The channel is continuing to enlarge and is depositing coarse sand on the floodplain over a length of several kilometres (sand deposits along the Atrakhali channel, in the area of the overbank spills, and along the Shibganjdhala channel are visible as light-coloured areas in Figure D.3). Continued enlargement of the Atrakhali River will

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[3] Specific gauge plots illustrate trends in water levels at specific discharges and provide a means for assessing long-term aggradation or degradation processes. A rise in water level on this graph indicates that the channel has aggraded or infilled while a fall in water level indicates that it has degraded or eroded.

pose a serious threat to the town of Durgapur from bank erosion and threatens to make the Atrakhali channel the main branch of the Someswari River.

2.1.4 Water Levels

The graph in Figure D.7 shows the water levels at Durgapur since the shift occurred from the Old Someswari River to the Shibganjdhala River. Flood levels fell from 1965 to 1975 and have subsequently risen again. Dry-season levels fell for the first 20 years or so and appear to be rising since 1988.

These features suggest that the newly-formed Shibganjdhala channel became incised between 1965 and 1975. Overbank deposition appears to have been occurring since 1975 and in-channel deposition has occurred since 1985.

The recent trend toward higher bed levels and higher water levels is a concern as it implies a greater tendency for channel shifting. Present conditions of water levels appear to be similar to those which existed prior to the major avulsion of 1963.

2.2 Hydrology

2.2.1 Observed Discharges

BWDB has measured river discharges and water levels on the two main branches of the Someswari River (Old Someswari channel, Shibganjdhala channel) since 1959 and on the Atrakhali channel since 1990. The highest recorded discharge on the Shibganjdhala River reached 1,380 m^3/s in 1988. Measurements have also been made periodically near the head of the fan at Bijoypur in 1992, 1993, and 1994. The highest observed discharge on the Someswari River was 3,063 m^3/s in 1993.

2.2.2 Flood Frequency Analysis - Someswari River

Estimates of the total inflowing flood discharge at the fan apex are required for designing flood protection works. Historic flood records at Durgapur are not suitable for design purposes since the data are truncated due to spills and are subject to long-term trends due to changing flow splits and channel aggradation.

An estimate of historic flood flows at Bijoypur was made using the recorded daily water level data and stage-discharge rating curves developed from BWDB measurements in 1993. Estimates of the annual maximum daily discharge were then made for the period 1965-1994. A flood frequency analysis was carried out on the synthesized flood discharge data. Results of the analysis (using a GEVIII frequency distribution) indicated that the 20-year flood at the fan apex is approximately 4,000 m3/s and a 2-year flood is around 2,300 m3/s. Using these results the 1988 flood would have had a return period of 20 years.

2.2.3 Flow Split on the Fan

Figure D.8 illustrates the flow distribution at the three channels at various discharge conditions and time periods based on actual discharge observations. It is apparent that the flow split has varied greatly over time depending on cycles of deposition and erosion. The Shibganjdhala channel enlarged during the 1960s and 1970s to capture an increasing proportion of the total flow. In recent years the Shibganjdhala has carried about 65 to 75% of the total flow during the monsoon months.

During the 1960s the Old Someswari channel carried up to 65% of the gauged flow; by 1988 the proportion had decreased to less than 50%. Data are scarce but suggest that the proportion of flood discharges carried by the Old Someswari River may have declined to 10 to 20%. The Old Someswari River carries no flow until the river stage exceeds 11.5 m, the elevation of the channel bed at the channel entrance. This stage is about 2 m above the bed of the Shibganjdhala channel.

The Atrakhali channel has increased in size since 1988 to the point where it carries between 10 and 15 per cent of the flow in the monsoon season. At lower stages it carries 20 - 50% of the total flow and this proportion seems to be increasing as the Shibganjdhala channel is filling in. Since the Atrakhali channel appears to be widening, it will probably carry more of the incoming flows in the future.

The following approximate flow distribution could be expected under present-day conditions during a 20 year flood event:

Upper Someswari River	4,000 m^3/s
Atrakhali River	600 m^3/s
Old Someswari River	600 m^3/s
Shibganjdhala River	2,800 m^3/s

2.3 Sediment Loads

Suspended sediment concentrations were measured in 1994 at Durgapur and Bijoypur[4]. The measurements were made once per week during the monsoon season (April - October). A suspended sediment rating curve was established to determine the correlation between sediment load and discharge (Figure D.9). The rating curve was then used with the daily discharge records to estimate annual suspended sediment loads.

The average suspended sediment load at the fan apex was estimated to be in the order of 700,000 tonnes/year which corresponds to a watershed sediment yield of around 330 tonnes/km^2. This value is comparable to sediment yields reported on other Meghalaya streams draining into India[5]. During a major flood such as occurred in 1988 the suspended load was estimated to be at around 1,200,000 tonnes/year. These loads include fine wash load (mainly silt) as well as the suspended bed material (very fine sand).

The suspended sediment measurements do not include the portion of the load moving as bed load.

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[4] Sediment samples were taken from a boat using a DH-77 depth integrated sampler attached to a standard USGS B-reel.

[5] Goswami, D. "Brahmaputra River, Assam India: Physiography, Basin Denudation and Channel Aggradation", Water Resources Research, Vol. 21, No. 7, pp. 959-978.

Observations with a depth sounder showed the channel bed was covered with shifting dunes and sand waves at most flow conditions. Efforts to estimate bed load rates from the rate of dune migration proved inconclusive. Consequently, the total bed material load was estimated from the Ackers-White equation using hydraulic properties measured during stream gauging. These computations were made near the fan apex (at Bijoypur on the main Someswari River), below the trifurcation (at Durgapur on the Shibganjdhala channel), and at in the Kangsha River at Jaria just downstream of the Shibganjdhala confluence. The average annual bed material load (for the period 1985-1993) was estimated for the three sites as follows:

Someswari River at Bijoypur	2,300,000 tonnes/year
Shibganjdhala River below Durgpur	700,000 tonnes/year
Kangsha River at Jaria	400,000 tonnes/year

These computations illustrate that most of the sand load is deposited on the upper portions of the fan. Furthermore, the sediment-carrying capacity of the Kangsha River is very small in comparison to that of the Someswari River. Therefore, much of the sand transported into the Kangsha River will be deposited near Jaria. Air photos taken in March 1995 show that sand deposition and bar formation has in fact occurred immediately downstream of the confluence.

3. SOCIAL PERSPECTIVE

3.1 Land Use and Land Use Constraints

3.1.1 Land Use

Field work for land use mapping was conducted from December 1994 to February 1995. A team of 4-to-8 field workers interviewed people and did ground truthing to determine areas under crop, homestead areas, types of crops, and areas flooded in 1991 and 1993, the most recent flood years. This information was marked on a series of *Mouza* maps which were prepared in the 1960's and were updated in the 1970's. The *Mouza* maps show the outline of individual plots of land. These maps are detailed, having a scale of 1:3,960 (16 inches = 1 mile). They are also reasonably current with respect to property boundaries although certain topographic features such as river locations have changed since the maps were originally drawn.

Field work for most of the project area was completed before the program was terminated. Principal results of the program representing the whole of the project area are shown in the following Figures:

- Figure D.10: settlement pattern
- Figure D.11: aus (pre-monsoon rice crop) area
- Figure D.12: aman (monsoon/post-monsoon crop) area
- Figure D.13: boro (dry season rice crop) area
- Figure D.14: dry season non-rice crop areas

Settlements and villages generally occupy the higher ground alongside existing and relic river channels[6]. Aside from settlements in villages and towns the land is used mostly for rice-crop agriculture. Most of the area has two crops per year. Transplanted aman is grown in most of the area during the monsoon season. The second crop varies depending on local soil conditions and availability of water for irrigation. Boro which is a dry season irrigated rice crop is grown where conditions permit, primarily in the lower areas, and aus is grown in highland areas where soils are sandy and have little moisture retention and where groundwater is not available.[7]

About one-half of the aman and three-quarters of the boro rice are high-yielding varieties.

Non-rice crops are primarily grown in small areas that are closely attached to homesteads. Some larger areas of wheat and vegetables are grown in the area between the Durgapur-Jhanjail road and the Shibganjdhala channel.

Land use is affected severely in places by channel shifting and overbank deposition of sandy bed material (see Figure D.3 and Figure D.4). Three areas of recent deposition are apparent:

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[6] River banks in the area are generally "perched" and are therefore higher than the main floodplain areas because they are constructed by overbank spills.

[7] Boro and aus cannot be grown on the same land area because their growing seasons overlap. Boro is more productive and is generally preferred by farmers if soils permit and if water is available for irrigation.

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- over the east bank of the Someswari River north of Durgapur, including the upstream reach of Atrakhali channel,
- east of the Shibganjdhala channel, along the Sakhait channel south of Durgapur which formed as an avulsion of the Shibganjdhala channel in 1988,
- small areas along the Nitai River channel.

Sand deposited on cropland renders it unusable for agriculture for many years. Channel shifting and overbank spills also directly damages homesteads and crops. A large area in the upstream reach of Atrakhali channel is affected. The problem is likely to increase with the increased flow in Atrakhali channel.

Deposition has also been occurring in Sitli Beel which was once a deep water body having depths of 2.5 m. It has largely infilled and is presently occupied by a network of shallow channels during the monsoon season. The beel presently acts as a wide floodway of the Shibganjdhala River, trapping some of the finer sediment and storing some of the peak flows.

3.1.2 Fishing

Fishing is done in the Shibganjdhala River and Atrakhali channels, in various beels, and in the floodplain areas. There are about 15 significant beels in the project area of which 3 or 4 are perennial and the remainder dry out in winter. There is considerable fishing activity in the Shibganjdhala and upper Someswari Rivers which are reportedly supplied, in this case, by downstream migration from *duars* (deeper areas) in India. The Old Someswari River channel goes dry except during higher flows and is less productive.

Areas on the east side of the project area are deeply flooded by backwater from the Sylhet Basin. Migration routes are good and this area is among the most productive in the Kangsha Basin.

Fisheries along Atrakhali channel have experienced somewhat of a resurgence with the growth of this channel and particularly the increase in winter flows, but it is early to tell what the magnitude and significance of this change will be.

Few of the beels are leased and therefore they are fished extensively during the monsoon season and in some places throughout the year. There are about 4,000 households of professional and semi-professional fishermen in the area.

3.1.3 Irrigation

Irrigation from STWs is found in the low areas to the north of Atrakhali channel. A number of small areas to the north of Atrakhali channel are also supplied from cross-dams in *chorras*, small streams that drain the base of the Meghalaya Hills. Irrigation use in the low-lying areas to the east of the Someswari has become more commonplace after Atrakhali channel was formed. Irrigation is almost exclusively used to grow dry-season crops.

Groundwater levels reach their lowest in the lean period from February to April. Demand for groundwater for irrigation and domestic purposes also increases as sources of surface water dry up during this period. Hand tube wells run dry in many areas where farmers use STWs for irrigation.

Table 1: Affected Villages on the Bank of the Atrakhali Channel

Village	Sand deposition	Erosion	Flooding	Avulsion
Left (north) side of Atrakhali channel:				
Chak Lengura	++	*	*	
Noapara	++	*	*	*
Chandrakona	++	*	*	
Mayanagar	++	*	*	*
Nandannagar	++	*	*	++
Dori Fechia	*		*	
Radhanagar	*		*	
Joynagar	*		*	
Rainagar	++		*	
Gouripur			*	
Bhabanipur			*	
Right (south) side of Atrakhali channel:				
Lengura	++	*		
Bogaikanda	++	*		
Maskanda	*		*	*
Charia	*		*	*
Bamapara	*		*	
Patharia	*		*	
Fechia	*	*	*	
Raghunathpur			*	
Lohargaon			*	
Uttarpara			*	
Atkapara			*	

* = Some Problem
++ = Major problem

3.1.4 Domestic Water Supply

Water for domestic purposes is generally supplied from HTWs although the use of surface water is still relatively common. People in the area of Old Someswari channel often have a shortage in the dry season when groundwater tables are low, and there are reports of people drawing water by digging pits in the sand bed of the river channel.

3.2 Effects of Atrakhali Avulsion

Fisheries of the Atrakhali area have been affected by the avulsion. Increased discharges and higher water levels have improved the migration for the Sylhet Basin. It has been reported that there has been a significant increase in the numbers of species and the abundance of fish in Atrakhali channel. Before 1988 only *koi, magur* and *shing* were found in the 15 km reach starting at the offtake of the Atrakhali River, and these were found in only small numbers. Now species such as *kalibaus, lachu*, and *boal* are available, and abundance has increased in the monsoon season.

However heavy sedimentation of sand and finer particles is degrading the aquatic environment and overwintering ground in the beels along the Atrakhali River, disrupting plankton, necton benthos, and other aquatic organisms. These changes may cause the fish production in this area to decrease. Some species such as Mohasol (Tor tor and Tor putitora) are becoming scarce. Other species such as prawn, turtles, and shellfish have become established.

Formation of the Atrakhali avulsion has improved water transportation in the area. Previously two earthen roads were the primary means of transport, one on the north side between Durgapur and Lengura and the other on the south side between Durgapur and Kalmakanda. Now boats carry freight and passengers along the Atrakhali channel during the monsoon season. People are less dependent on road transport than previously.

Major sand deposition has occurred along a stretch of 8 km from the offtake of the Atrakhali channel. Ground nut, sugarcane, linseed, chilies, wheat, and some rice are grown in these areas. Deposition has also occurred to a lesser degree further downstream. Locations which experience flooding, erosion, and deposition problems are summarized in Table 1.

3.3 Coping with Flood: Some Personal Perspectives

Following is a brief examination of the impacts of flooding and river changes on the daily lives of people living in the project area. It demonstrates their resilience and their methods of coping with disaster.

Dakshin Bhabanipur

The village of Dakshin Bhabanipur is located between the Someswari and Shibganjdhala Rivers, and is vulnerable to flooding.

Flood occurs almost every year. People stockpile firewood and food and make temporary cooking arrangements before the start of the monsoon season. Homestead platforms and courtyards are also raised. Sometimes flood levels rise up to the ceiling of the house and persist for up to 8 or

9 days. Other areas are flooded for 2 to 3 days. Crops are destroyed and houses fall. Livestock are carried away by the flood water.

Charia Mashkanda
The village of Charia Mashkanda, on the south bank of the river Atrakhali, is flooded after 2 to 3 days of heavy rain. Flood water washes away livestock and houses. The people say they would prefer continued flooding rather than flash flooding. No *boro* is grown on land due to sedimentation. Some farmers grow garlic on the degraded land.

Dasal
Half of the village of Dasal was affected by the flood of 1991. Many people are forced to borrow money to survive after the flood.

Nazirpur
This village, located toward the east end of the Atrakhali channel, was severely flooded in 1940, 1950, and 1991. Water rose to waist height and stayed for 3 to 4 days. Crops were affected and roads were submerged.

People moved firewood and rice to a higher place inside the room.

Khalisapara
The village of Khalisapara, on the southern side of the old Someswari, is flooded by flash floods several times each year. Flooding lasts for 2 to 3 days each time. During the floods of 1968 and 1988, people moved their livestock and materials to safer places. They cooked food on temporary cookers. Flood waters rose to a depth of two feet inside the houses during the 1992 flood and deposited sand inside the homes.

During the flood, people suffer from diarrhoea, fever, and skin diseases. Fortunately medical facilities are now available in Birishiri which is 7 km away. Veterinary health services are almost non-existent. After the Old Someswari was abandoned most fisher families have switched to farming.

Munshipara
In Munshipara village, flood water reaches the level of the homestead courtyard almost every year. Flood water entered all the houses during the 1988 flood and stayed for 3 to 4 days. Courtyards remained under water for 4 to 5 days and crop fields were under water for a longer period.

Latrines are submerged by flooding. There is no privacy and people are forced to use hidden places or to go out on the water by boat.

Poor people spend their savings and when these are exhausted they borrow money from money-lenders to survive. They also migrate to other places for work.

Naljora
The flood of 1988 rose very quickly. Many houses were washed away and the people took shelter in the school building. During floods, people usually cook larger quantities of rice to last for 2 to 3 days at a time. They stockpile fire wood in advance of the monsoon season. As a precaution for the coming monsoon they raise their belongings above the anticipated flood level.

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3.4 Local Initiatives for Flood Control

Local people have demonstrated considerable initiative in trying to contain the Someswari River floods and sediment deposition. It should be stated, however, that the scale of the problem far exceeds the capacity of the local people to make meaningful interventions. A number of projects have been undertaken by NGOs under local initiative in the Someswari Project area as will be described below.

Right Bank of Someswari
A road along the right bank of the Someswari River from the border to Durgapur serves as an embankment to protect the areas to the west. Some portions were raised by CARE in 1995. An avulsion of the Someswari River began to form formed in 1995 and breached the embankment. Deposition of sand occurred downstream but the avulsion has not yet developed to form a full channel.

Right Bank of Shibganjdhala
A dike was constructed by CARITAS along the right bank of the Shibganjdhala River for some 5 km downstream of Durgapur in 1980. More work was done in 1990 and 1983. The dike is 7-10 feet high, 8-10 feet wide at the crest level, 15-20 feet wide at the base, and is protected by banana and mulberry trees. It provides some protection against flash floods but is reportedly breached in high floods, causing crops to be damaged by sedimentation.

Left Bank of the Someswari
A road along the left (east) bank of the Someswari river serves as an embankment upstream of Durgapur. It was overtopped in 1984, 1988, and 1992, and two avulsion channels formed. The main avulsion, the Atrakhali, remains open while the second (more northerly) one, at Agar village, was closed in 1992 by a 2 km long embankment funded by CARITAS. The embankment is presently maintained under CARE's Rural Maintenance Programme (RMP).

Left Bank of Shibganjdhala
An embankment was constructed by the thana council before 1988, extending along the left bank from Durgapur to Janjail. Although it is set back some distance from the river it is nevertheless eroded by floods. It was breached in 1988 a short distance downstream of Durgapur and a large channel called the Sakhait River formed as an avulsion on the floodplain. The dike is not maintained and has been eroded and breached over about 25% of its length.

The Sakhait River formed as an avulsion of the Shibganjdhala River in 1988. It spilled across the Jaria-Durgapur Road and threatened the Jaria-Durgapur Road, the campus of the Cultural Academy, the Garo Baptist Mission, and part of Birishiri. Local people created a closure called Sakhait Bundt with help from Union Parishad, thana, local organizations, and an NGO (World Vision). The embankment is 1.5 km long, 3 m high, 3 to 4 m wide at the crest, and 9 m wide at ground level. It is built of sand and although it is strengthened with earth, grass, bamboo, sandbags, and pillars it remains vulnerable to river attack.

The Sakhait Bundt was built on fallow sandy land; hence there was no disagreement among the people about its alignment. A twelve-member committee was formed to look after the dyke. No plans have been made for its maintenance as yet.

Cross-Dams for Irrigation Water Supply

Many cross-dams are built under local initiative to store water for irrigation, primarily in the small streams that drain the base of the Meghalaya Hills. These structures are modest as they are built with local resources. Conflicts sometimes occur between upstream and downstream water users, but these conflicts are sometimes resolved through consultation and dialogue.

4. REVIEW OF RIVER STABILIZATION ALTERNATIVES

4.1 Description of the Problem

The major problems caused by the Someswari River include:

- channel shifting and erosion during avulsion,
- sand deposition on agricultural land and in beels,
- flood damage to crops and settlement due to spills and inundation.

Observation of past avulsion paths reveal that the river develops new courses through small spill channels. These minor distributaries can develop into a major channel even during a single flood. However, based on the experience of the Shibganjdhala and Atrakhali channels, it may take a decade or more for an avulsion to be fully established.

The avulsion into the Atrakhali River has been developing over the last seven years. The channel shift is initiating a major period of instability in the river, both to the biophysical environment and to the social conditions in the project area. Land adjacent to the newly formed channel has experienced bank erosion and high-velocity spills in recent years. Large amounts of coarse sand have been deposited over a zone that extends 6 km in length and at least 1 km in width.

Since the channel started enlarging, almost 100% of the *t. aman* crop adjacent to the channel is now damaged by flood spills. In addition, deposition of coarse sand on the agricultural land has made them unusable even for *boro* cultivation.

If the channel enlarges further, it will threaten to erode the northern part of Durgapur village. Eventually, Durgapur may have to be abandoned due to this instability.

Enlargement of the Atrakhali channel has had some benefit to certain areas on the fan, particularly on the lower reaches of the Atrakhali River downstream of the area of active sand deposition. For example fisheries on the lower Atrakhali River have increased as a result of the increased flow. Farmers in the lower reaches have also been able to use the water for *boro* irrigation in the dry season. It is likely that monsoon flood levels have been lower than they would have otherwise been in the Shibganjdhala channel.

Overall, the losses to agriculture have far outweighed these gains. Furthermore, as sediment deposition and channel instability progress downstream in Atrakhali channel most of the benefits will disappear. For example, newly created fisheries habitat will be damaged by sand deposition.

Sand deposition, bank erosion, and flooding have also been recurring problems along the Shibganjdhala River ever since the Old Someswari River was abandoned. For example, sand deposition has virtually infilled Sitli beel on the west side of the river. Sand deposition and spills have damaged agricultural land on the east side of the river and have breached the Durgapur - Janjail road.

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4.2 Past Proposals

Various proposals have been made to control the Someswari River. These include:

(1) constructing a sabo dam at the head of the fan to trap the incoming sediment,

(2) dredging the river to increase its conveyance,

(3) re-opening the Old Someswari channel and closing off existing channels,

(4) confining the river with full flood control embankments to prevent spills.

These proposals were reviewed in the pre-feasibility study and were found to be unsuitable for the situation on the Someswari Fan. In brief, there are no suitable locations for sabo dams to be constructed and no place to dispose of the large volumes of trapped sediment. Furthermore, sabo dams are used on much steeper channels where the bed load is usually gravel and boulders, not fine sand. Dredging is not practical since a huge amount of excavation would be required to lower flood levels, the work would have to be repeated annually due to recurring infilling, and there is no suitable place to dispose the spoil. Closing off the Shibganjdhala channel is impractical as it still carries the majority of flood discharges; furthermore there are problems of sandy fill and foundation soils which are subject to erosion and piping failure. Confining the river within conventional flood control embankments would require designing a stable channel that could accommodate sediment inflows of up to 6 million tonnes during a 20 year flood year and would have to convey a flood discharge of 4,000 m^3/s. The embankments would have to be protected with stone to prevent erosion. The confined channel would transport large amounts of sand into the Kangsha River, which would produce serious downstream impacts including channel aggradation, channel instability, and increased flood levels. There is ample experience on other rivers in the region, such as the Chelakhali River, to show that this approach would require an extraordinary amount of ongoing maintenance and re-excavation work.

4.3 Pre-Feasibility Proposal

The main components of the 1993 pre-feasibility project included:

- upgrading the existing local dikes and roads along the upper Someswari River to reduce the risk of new avulsion developing near the head of the fan;
- closing the Atrakhali channel to prevent the river capturing the entire Someswari flow;
- raising and strengthening the existing road between Jaria and Durgapur to provide a set-back dike that could contain spills from the Shibganjdhala channel.

It was recommended that a wide floodway be maintained along the Shibganjdhala River in order to provide adequate storage for sediment deposition and flood conveyance. It was recognized however that even this was not a permanent solution as eventually the proposed floodway would be filled in and a new outlet would have to be provided.

Subsequently, several developments have taken place that have altered the feasibility of this proposal. Local residents, with the assistance of the NGO CARITAS, constructed a full flood control embankment along the right bank of the Shibganjdhala River up to Durgapur. This embankment was constructed with minimal set-back from the river. A second embankment was constructed by local people along the left bank of the Shibganjdhala for a distance of 7 km downstream of Durgapur. This dike was set back around 400 m. Finally in 1994 the LGED constructed a closure (Sakhait Bundt) at the entrance to the major left bank distributary channel immediately downstream of Durgapur. This has eliminated a major spill and sand deposition zone.

While the objectives of these works are understandable they have confined the river and will have a significant impact on future sediment deposition on the fan. For example, constricting the flow in the Shibganjdhala River has forced more flow into the Atrakhali channel and the Old Someswari channel. This has accelerated the avulsion into Atrakhali River, causing further widening of this channel and producing an incised low-flow channel into the Atrakhali River. Consequently it is becoming increasingly difficult to close the Atrakhali channel.

Furthermore if the Atrakhali channel was closed the embanked Shibganjdhala channel would have to carry virtually all of the flood water and sediment flows from the Someswari River. With embankments on both sides the existing channel does not have the necessary hydraulic conveyance or sediment storage capacity. Furthermore, with the new local dike and spill closure along the left bank there is relatively little advantage in using the Durgapur - Jaria road as a set-back dike.

None of these local structures have been designed to withstand a major flood event, so it is expected that they will require ongoing repair and re-construction. It is likely that they have had a role in the increased deposition that appears to be occurring in the channel in this vicinity.

5. RECOMMENDED ALTERNATIVE

5.1 Project Concept

Because of the unstable nature of alluvial fans it is impossible to forecast the long-term behaviour of individual channels on the fan. Future developments that are predicted on one year's observations may be completely irrelevant after the next year's flood. Localized bank erosion and sedimentation at critical sites may trigger unexpected channel shifts and new avulsion. Consequently, flooding and erosion problems on fans generally require a higher degree of ongoing channel maintenance, local protective works, and monitoring than conventional flood control projects.

Emphasis also needs to be placed on proper floodplain management in order to guide future development into lower risk areas and prevent costly development in high hazard areas. The safety of lower risk areas may be enhanced further by constructing river training works, including embankments and spur dikes. Areas designated as high risk should be utilized as a floodway for passing floods and for storing sediment.

Finally, successful management of channel instability and flood problems on fans requires institutions that can coordinate and consult with the various stake-holders in the project area to avoid conflicting developments. This could prevent the recent situation where local embankments have been constructed without an appropriate feasibility study and may be defeating their own purpose.

In order to incorporate these concepts a phased development approach is recommended. This involves constructing certain river training works that are required immediately to prevent new channel shifting from occurring, followed by other work that could be carried out later on when conditions stabilize, combined with an effective monitoring program to ensure that corrective action can be taken as soon as new conditions develop.

An overall plan of the project concept is provided in Figure D.15. Details will be provided below.

5.2 Project Description

5.2.1 Phase 1 - Priority Works (local stabilization)

This high priority work is required immediately in order to prevent new channel instability and erosion from occurring. The works are largely remedial or preventative in nature since they are arresting new changes from occurring. Therefore they should have virtually no adverse impacts. The work could be carried out in one year.

- Upgrade the existing roads and local embankments on both banks of the Upper Someswari River, upstream of Durgapur. This work would extend for a distance of 5 km on the right bank, from the border downstream to a point opposite Durgapur. On the left bank the work would extend for 3 km from the border down to the Atrakhali channel. This work will reduce the risk of the river developing new avulsion paths across the fan;

- Construct a stone spur dike (a flood control dyke protected with stone pitching) between the south side of the Atrakhali channel and Durgapur to protect the town from future erosion by the Atrakhali River. This structure would tie-in to high ground near the Old Someswari channel;

- Construct a 2 km long stone revetment river training structure starting at the north end of the Durgapur - Janjail Road to prevent further eastward shifting and spills from the Shibganjdhala River. This structure would replace the temporary LGED spur dike that closes off the major east spill channel from the Shibganjdhala River (the Sakhait Bundt). It would protect the roadway from overtopping and breeching, reduce the risk of flooding and spills on the eastern side of the fan, and provide a lower hazard "safe area" for future development.

Approximate cost of this work are summarized in Table 2.

Table 2: Preliminary Quantity List

Item	Description	Quantity	Rate	Amount (million Taka)
Upper Someswari R.	Upgrade 8 km road/embankments	146,400 m3	17.1 Tk/m3	2.50
Atrakhali right bank training & town protection	1,500 m embankment	38,500	17.1 Tk/m3	0.66
	Land	6 ha	0.3 Mtk/ha	1.80
	Stone spur dike	8,640 m3	1,220 Tk/m3	10.54
Shibganjdhala left bank river training	2,000 m embankment	51,400 m3	17.1 Tk/m3	0.88
	Stone revetment	11,520 m3	1,220 Tk/m3	14.06
	Land	8 ha	0.3 Mtk/ha	2.40
Total				32.84

5.2.2 Phase 2: land use and water management planning

This work could start simultaneously with Phase 1 but would require three years for completion. It focuses on institutional strengthening and channel maintenance work.

- Develop, in conjunction with local government authorities, BWDB, and NGOs a water management committee to plan and coordinate future work on the fan. One task would involve implementation of land-use planning and promotion of future development in the designated "low hazard" area. Other tasks would be to coordinate and implement river maintenance work on the Someswari and Shibganjdhala River.

- Monitor conditions on the Atrakhali River and assist local people to re-locate from high risk areas in the floodway that will experience future erosion and flooding. Where warranted carry out local channel maintenance work to minimize adverse impacts from future widening and sedimentation.

5.2.3 Phase 3: long term monitoring and response as required

The start-up date would be phased with future developments on the fan. These are long-term actions:

- Evaluate the need for upgrading the local embankment on the left bank of the Shibganjdhala River. The work should be carried out only after conditions on the Shibganjdhala River have stabilized. It is expected that this will occur when the Atrakhali River captures more of the peak flows and sediment loads. In the meantime protect the Jaria-Durgapur roadway as the first line of defense against flooding and sedimentation from the Shibganjdhala River.

- Continue monitoring conditions on the Atrakhali River. If it eventually stabilizes then initiate river training work to provide a wide floodway for the channel. Until then protect the Durgapur-Kalmakanda roadway as the first line of defense against flooding and sedimentation from the Atrakhali River. Discourage further encroachment by local dikes or roads into the floodway;

- Upgrade the dike road on the south limit of the fan bordering the Kangsha River to control flood inundation from Shibganjdhala River spills and from backwater from the Kangsha River. This work is similar to that proposed in the pre-feasibility study;

- Upgrade existing roads-cum-embankments along the Old Someswari to protect the adjacent lands against overbank spills.

5.3 Project Benefits

The main benefits from this work include:

(1) increased security from flood spills and future avulsion on the Upper Someswari River,

(2) protection of Durgapur town against further erosion of the Atrakhali channel, and reduction of flood damage,

(3) reduced damage to agriculture on the east side of the fan between the

Shibganjdhala River and Old Someswari River,

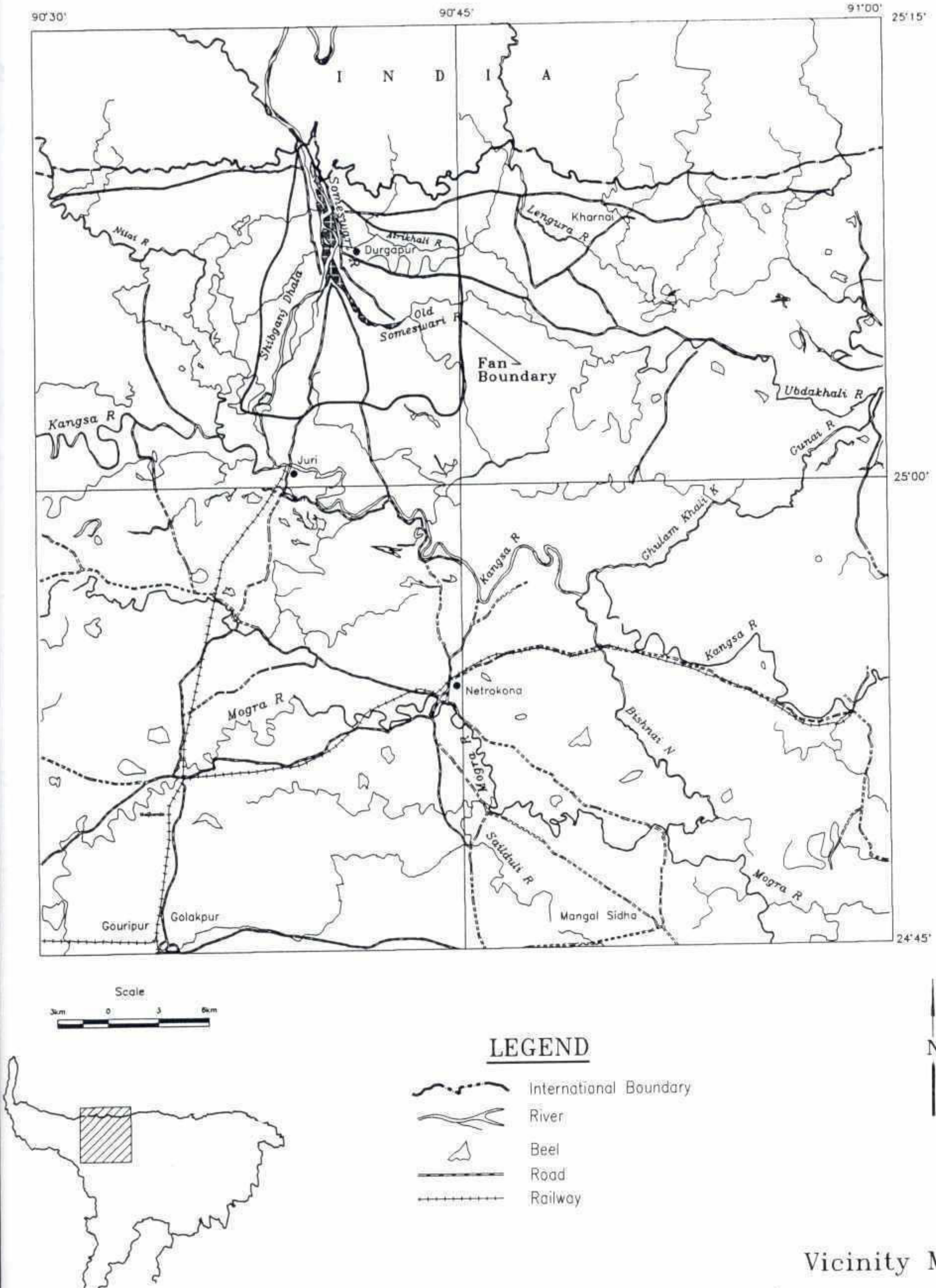
(4) reduced flooding and sediment deposition in the lower Kangsha River,

(5) land use planning that identifies and avoids the high-risk areas,

(6) an effective strategy for anticipating future changes and responding to them as they occur, before it is too late.

Negative and positive impacts will occur along the Atrakhali River as a result of the continuing expansion of the Atrakhali River. These changes will be a result of the natural evolution of the river, not as a result of the project. However, mitigation measures should be carried out to reduce the negative impacts of on-going changes in this area. These will be carried out as part of the long-term strategy for floodplain management.

Figure D.1

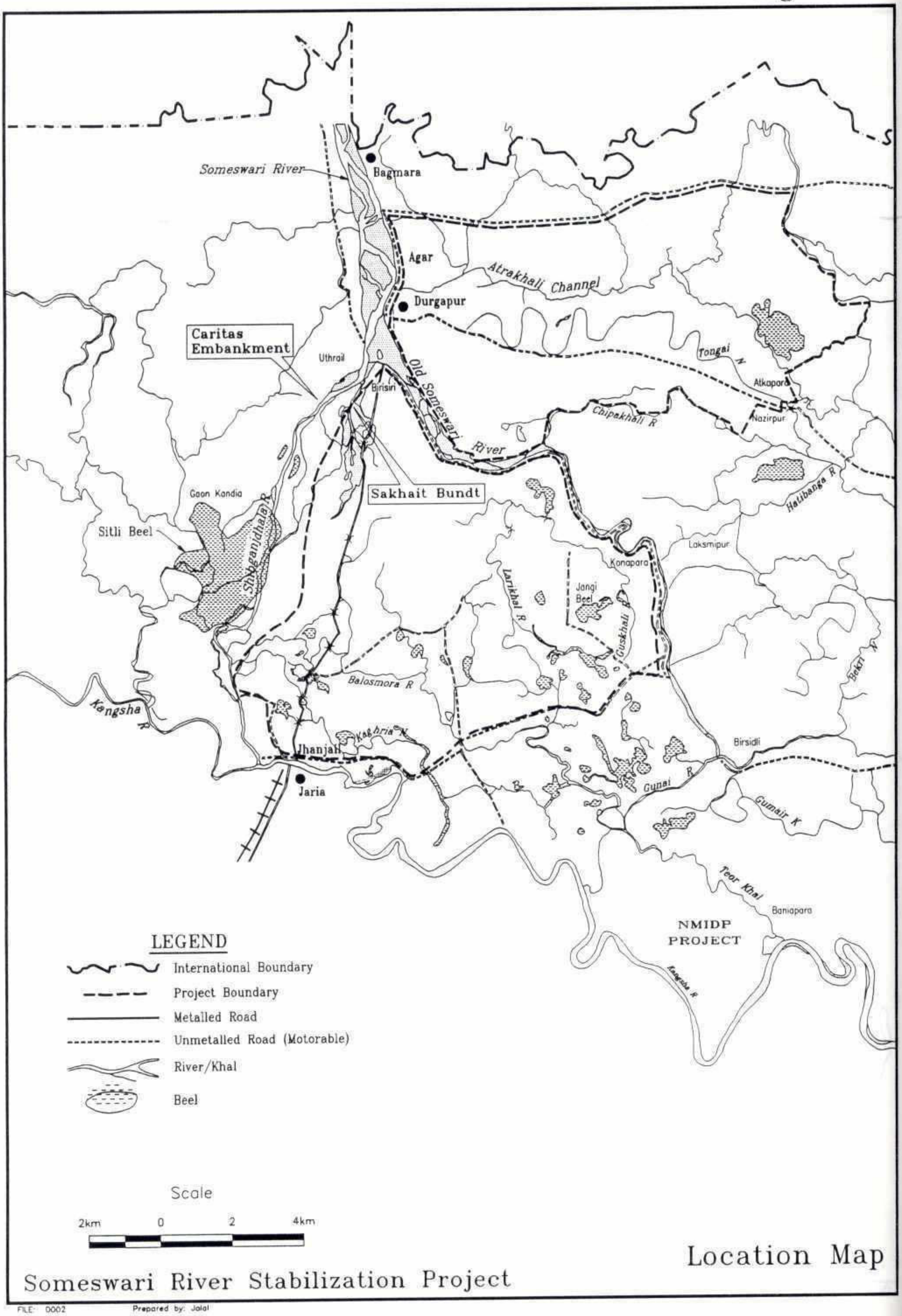


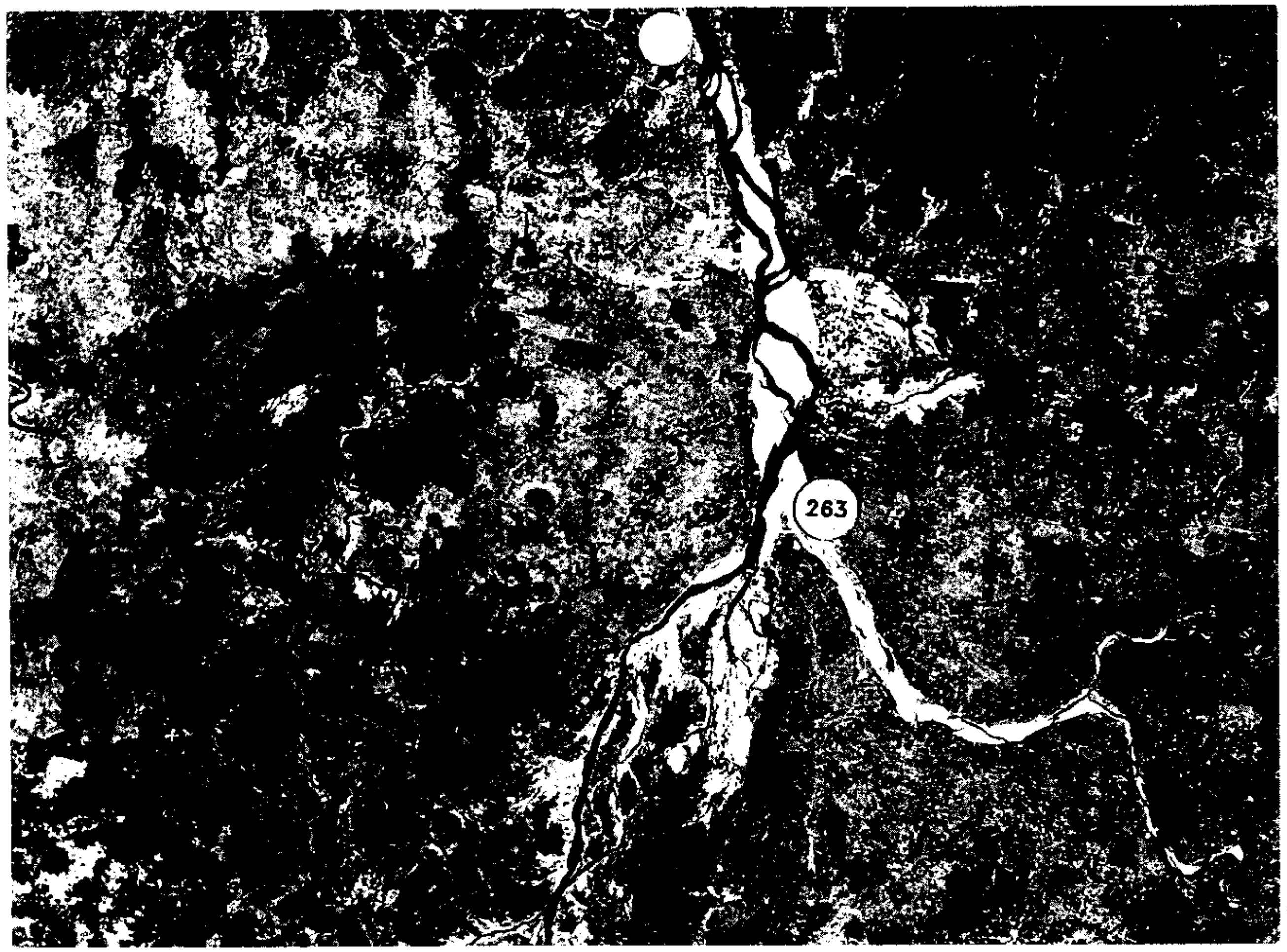
Vicinity Map

Someswari/Kangsha River

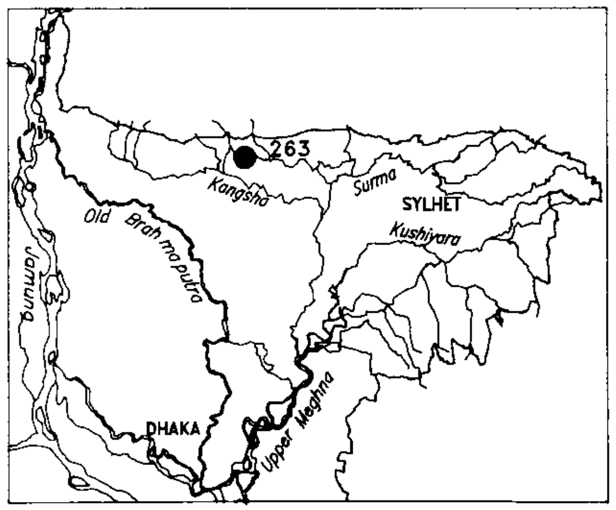
Someswari River Stabilization Project

FILE: 0001 Prepared by: Mamun


Someswari River
Bagmara
Agar
Atrakhali Channel
Durgapur
Caritas Embankment
Uthrail
Birisiri
Old Someswari River
Tongai N
Atkapara
Nazirpur
Chipakhali R
Sakhait Bundt
Gaon Kandia
Sitli Beel
Shibganjdhala R
Halibanga R
Laksmipur
Konapara
Jangi Beel
Larikhal R
Guskhali
Balosmora R
Bekri N
Kangsha R
Kaghria N
Jhanjail
Jaria
Birsidi
Gunai R
Gumair K
Teor Khal
Baniapara
NMIDP PROJECT
Kangsha R
LEGEND
International Boundary
Project Boundary
Metalled Road
Unmetalled Road (Motorable)
River/Khal
Beel
Scale
2km
0
2
4km
Location Map
Someswari River Stabilization Project
FILE: 0002
Prepared by: Jalal



Someswari R. near Durgapur



Site Location:

River Characteristics:

1. Gauge Number: 263

2. Location:
   Lat. 25 06'35"N
   Lon. 90 40'18"E

3. Available Data
   Water Level: 1964–93
   Discharge : 1964,1966–70,1972–78,1983–93
   Sediment: 1963–64,1992

4. Physical Setting:
   Physiographic Unit: Alluvial Fan
   Agro-ecologic Zone: Northern & Western Piedmont Plains
   Features: The Somewari R. exits from a mountainous canyon in India and develops a broad, low gradient alluvial fan over 138 km^2 of lowlying land. At present, the main channel (Shibganjdhala) heads south joining Kangsha R. just upstream of Jaria Janjail.
   Abandonment of the Old Someswari R. commenced in the mid-1960's.

5. Channel Pattern:
   Channel: Upper Someswari R. is braided; Shibganjdhala R. has a single straight channel.
   Bars: Mid-channel bars, sand waves, sand sheets.
   Sinuosity: 1.12

6. Sedimentology
   Channel: Mainly coarse-medium sand.
   Banks: Mainly silt and silty sand

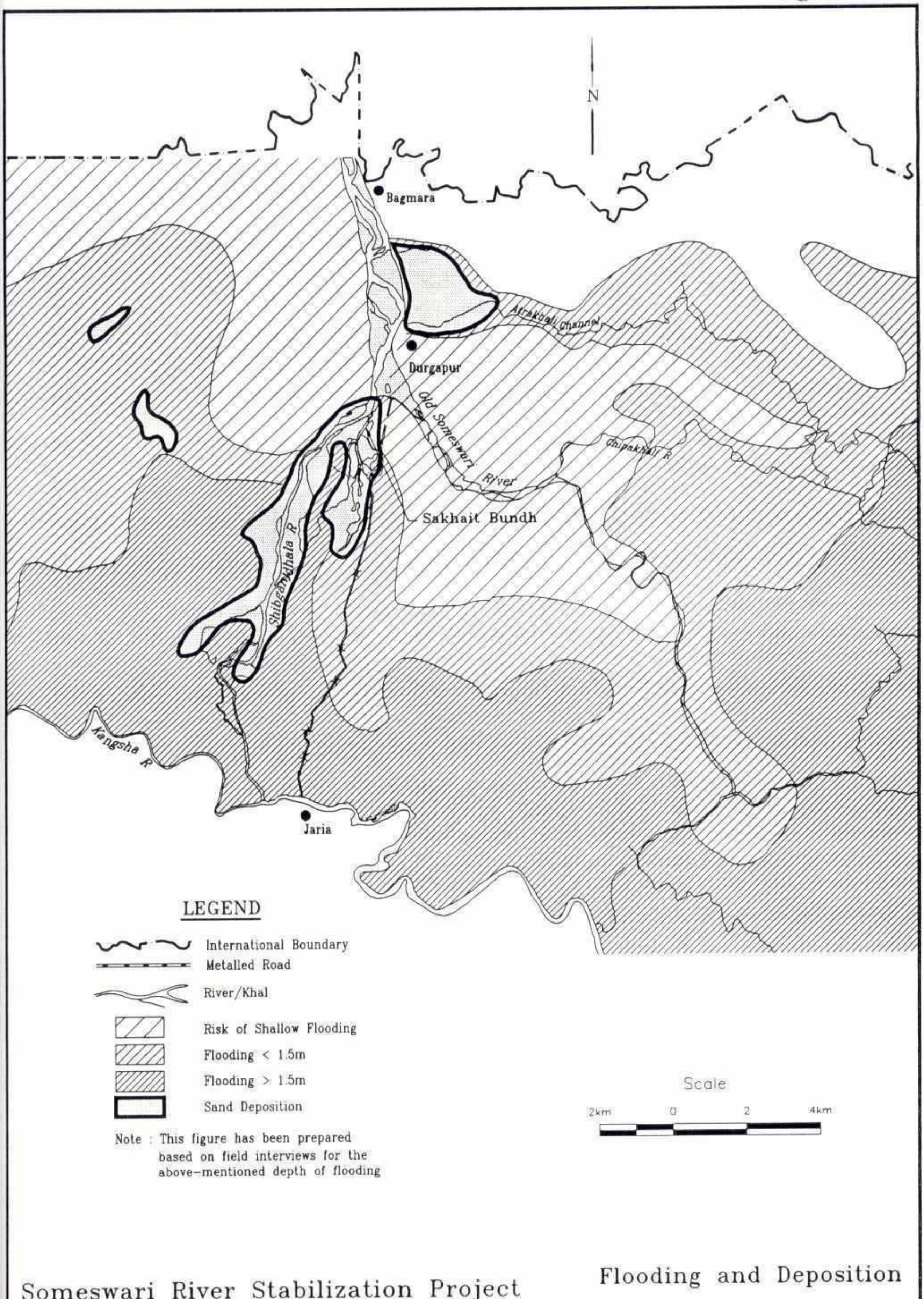
7. Pattern of Instability
   A major new avulsion is occurring upstream of Durgapur through the Atrikhali channel. Sand deposition is occurring on the floodplain of the Shibganj Dhala River causing channel shifting and bank erosion.

Northeast Regional Project

Someswari River at Durgapur

Prepared by: DMc | October 1994

FILE: M263-LDWG

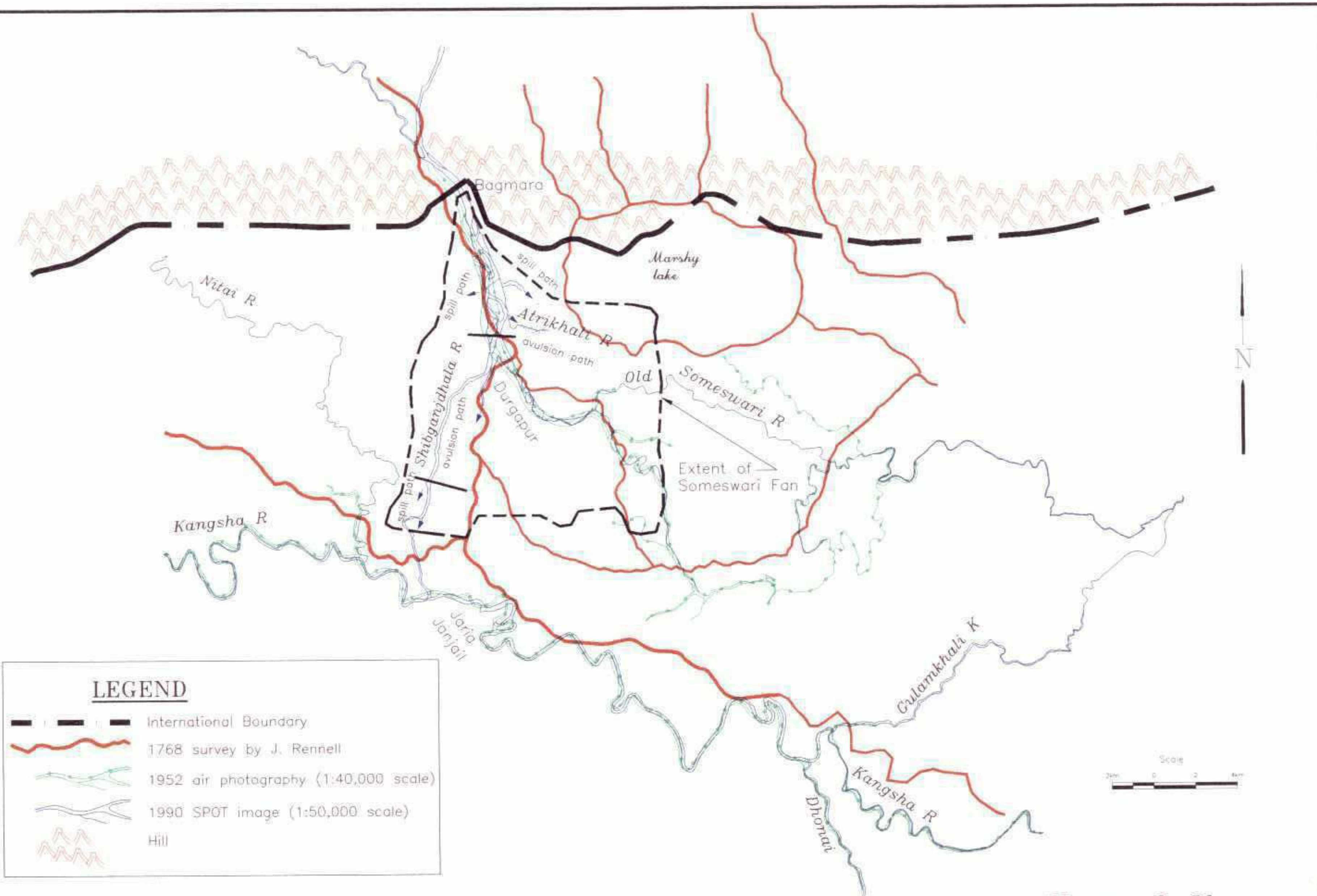


Flooding and Deposition

Someswari River Stabilization Project

FILE: D004 Prepared by: Jalal

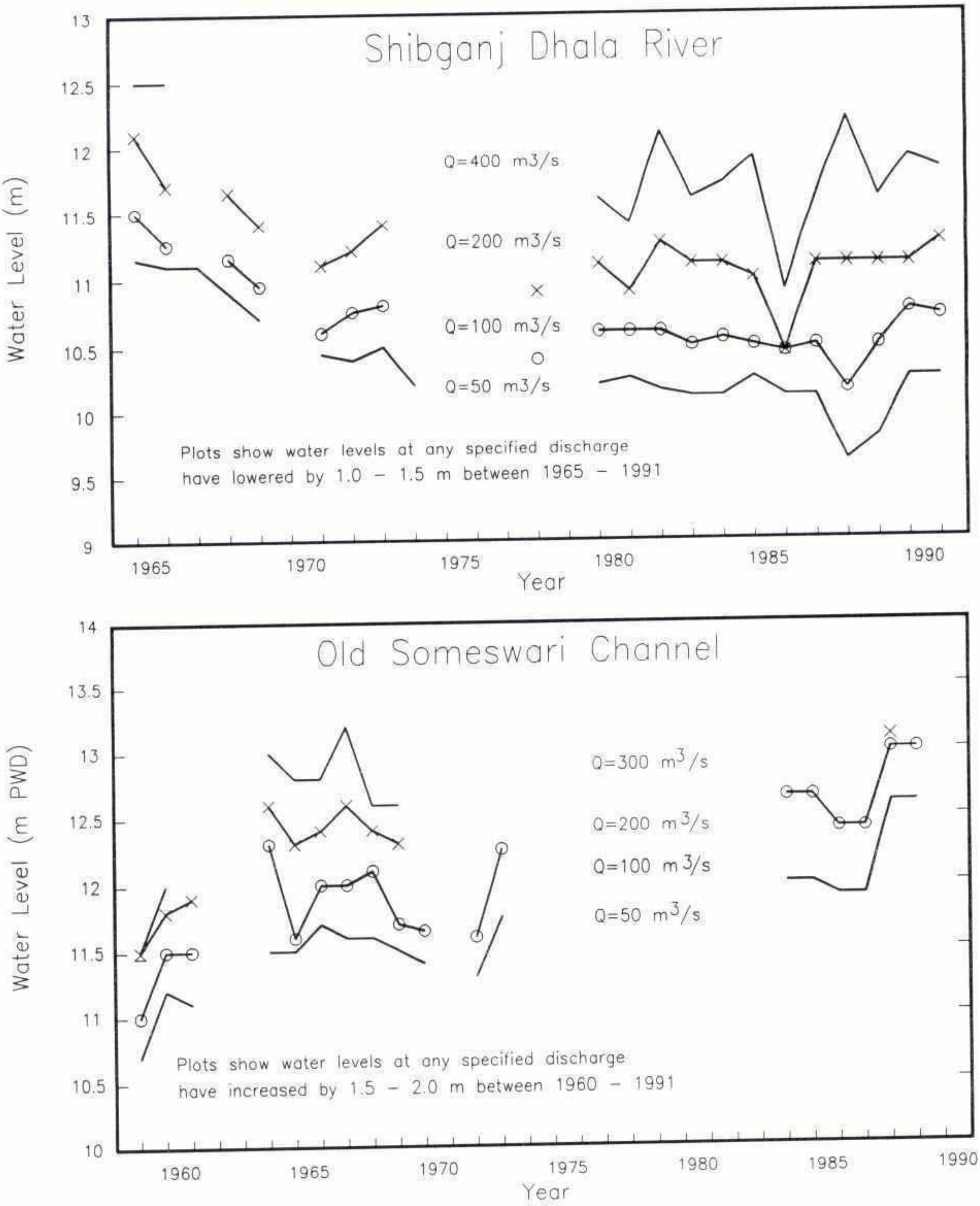
Figure D.5



Channel Changes

Someswari River Stabilization Project

FILE: D005 Prepared by: Mamun



Note :

1. Specific guare plots show long–term vatiations in water levels for four specific discharges.

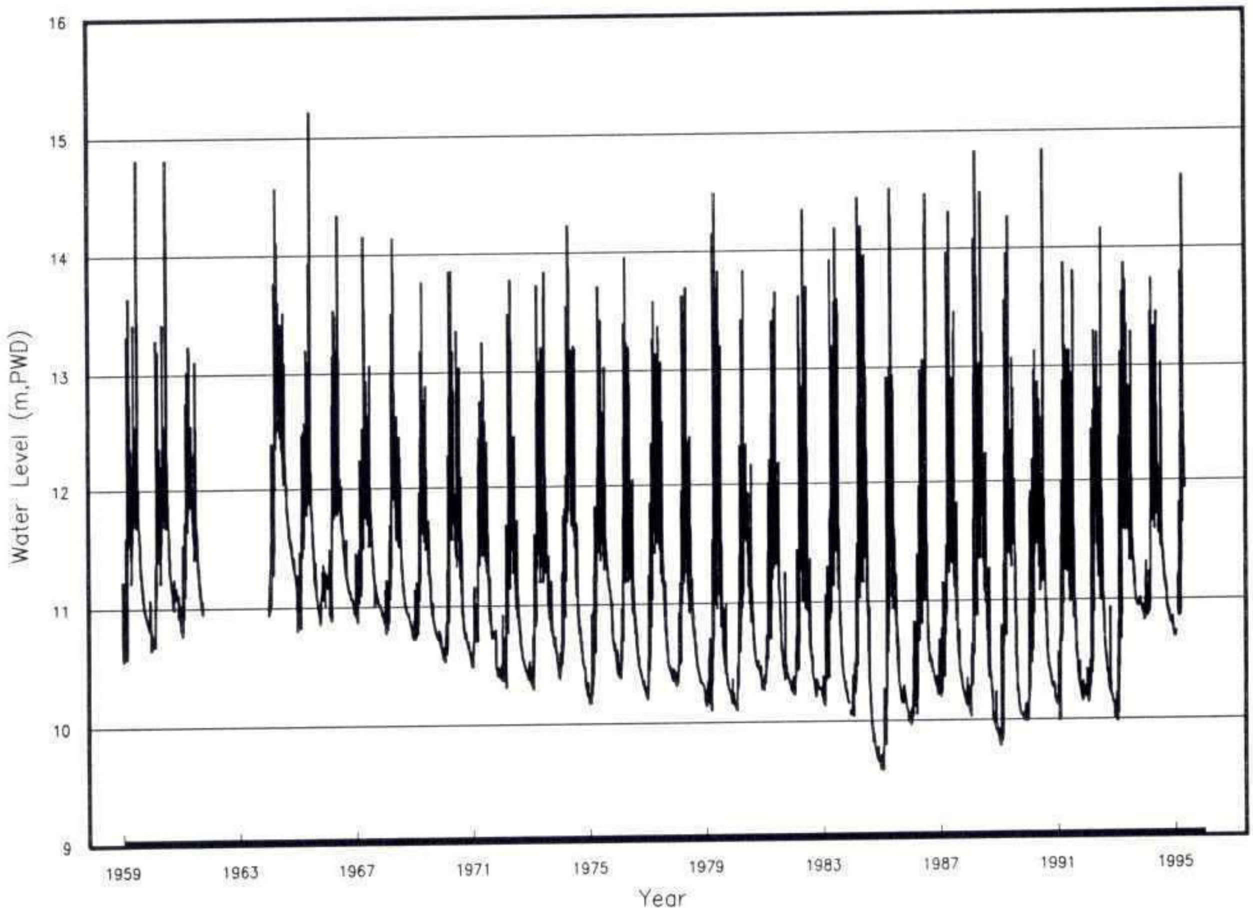
2. Plots wer constructed by comparing stage–discharge rating curves for each year of observation.

Specific Gauge Plots for the Someswari Fan

Someswari River Stabilization Project

FILE: D006 Prepared by: Mamun

Figure D.7

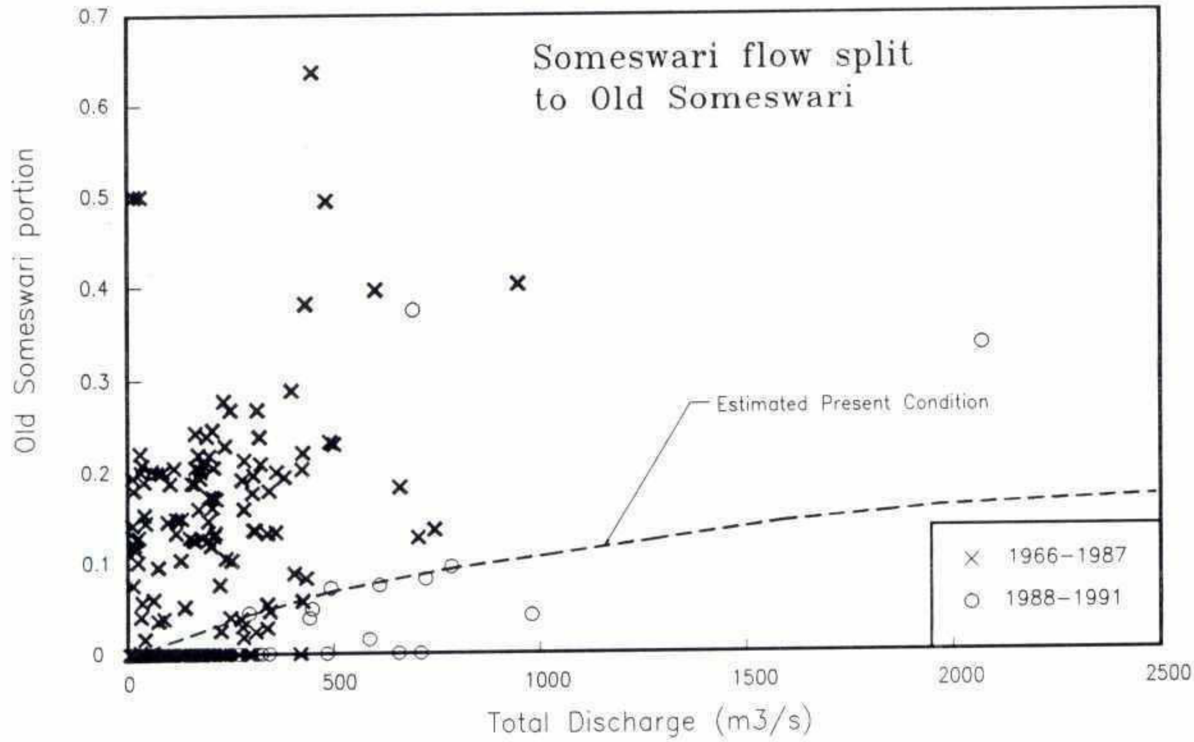


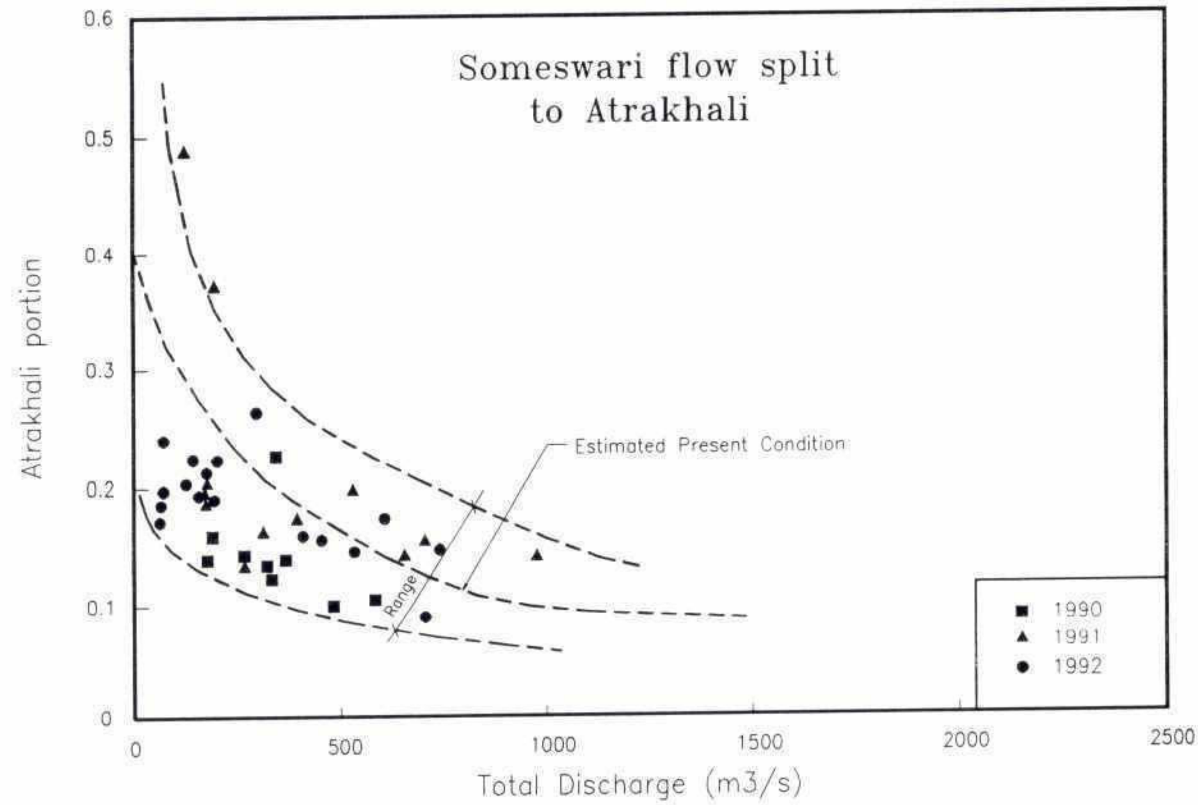
Historic Water Levels
Someswari River at Durgapur

Someswari River Stabilization Project

FILE: D007 Prepared by: Jalal

Figure D.8





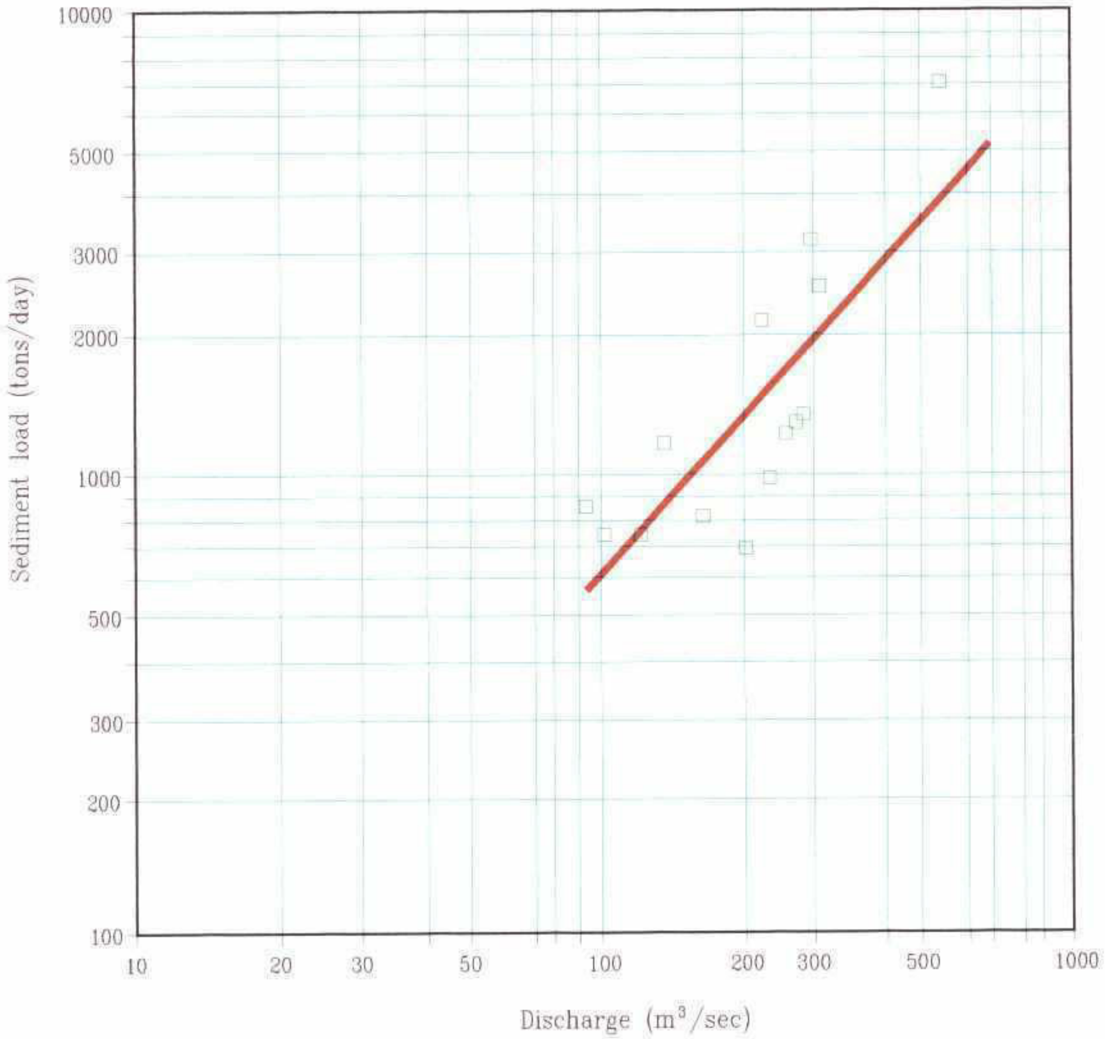
Flow Split

Old Someswari/Atrakhali

Someswari River Stabilization Project

FILE: D008 Prepared by: Mamun

Figure D.9

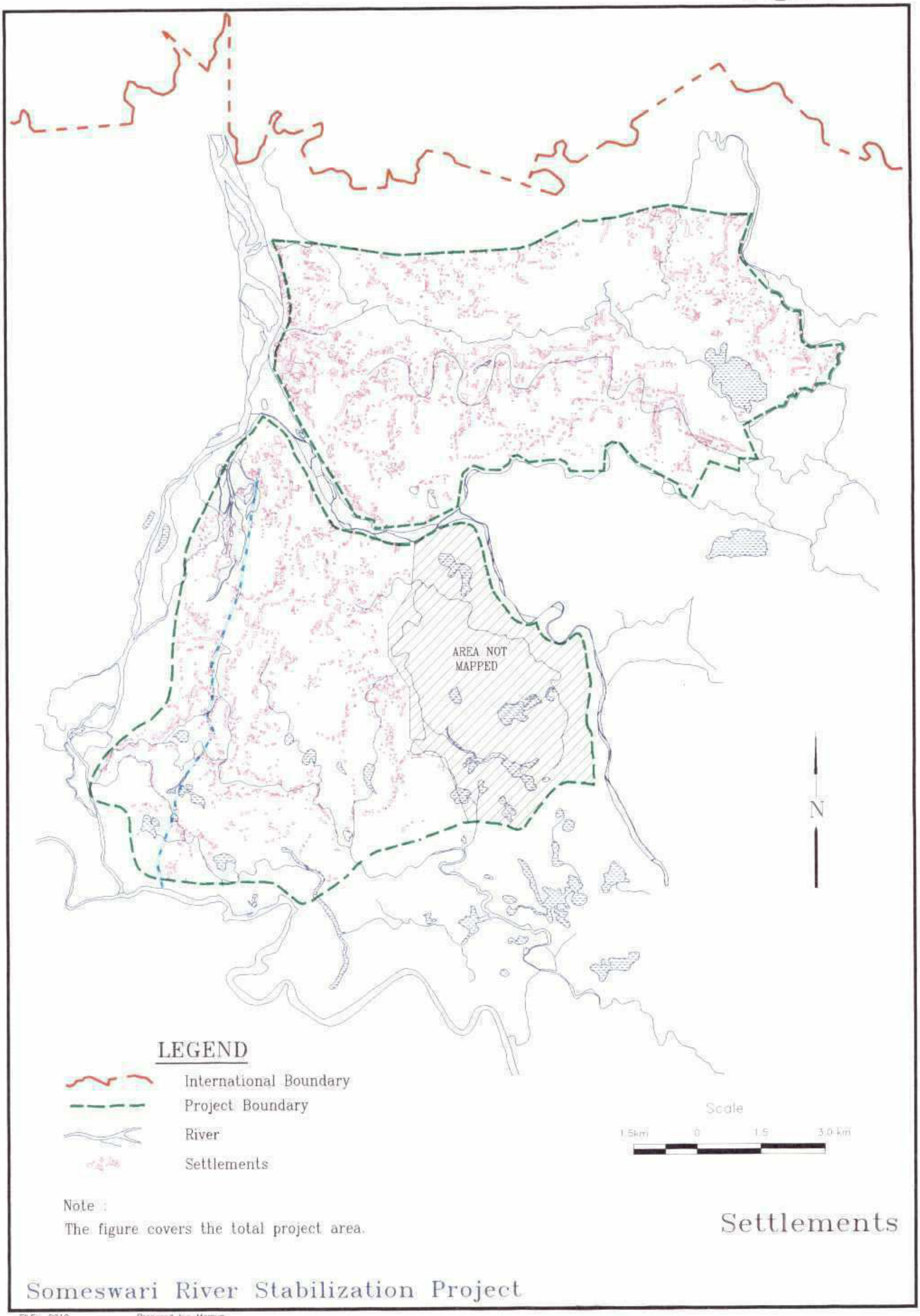


Sediment Rating Curve
Someswari River at Bijoypur

Someswari River Stabilization Project

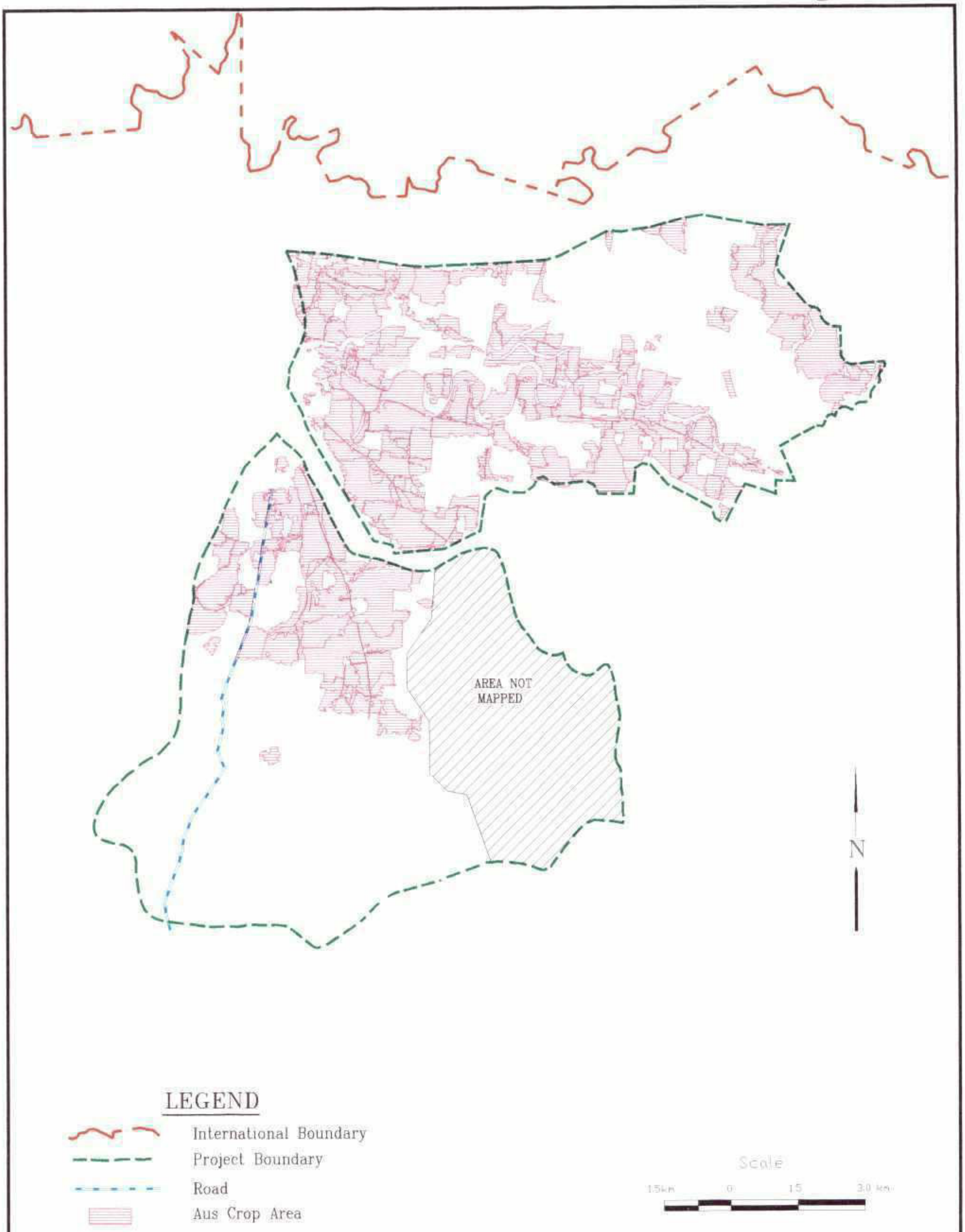
FILE: D009 Prepared by: Mamun

Figure D.10



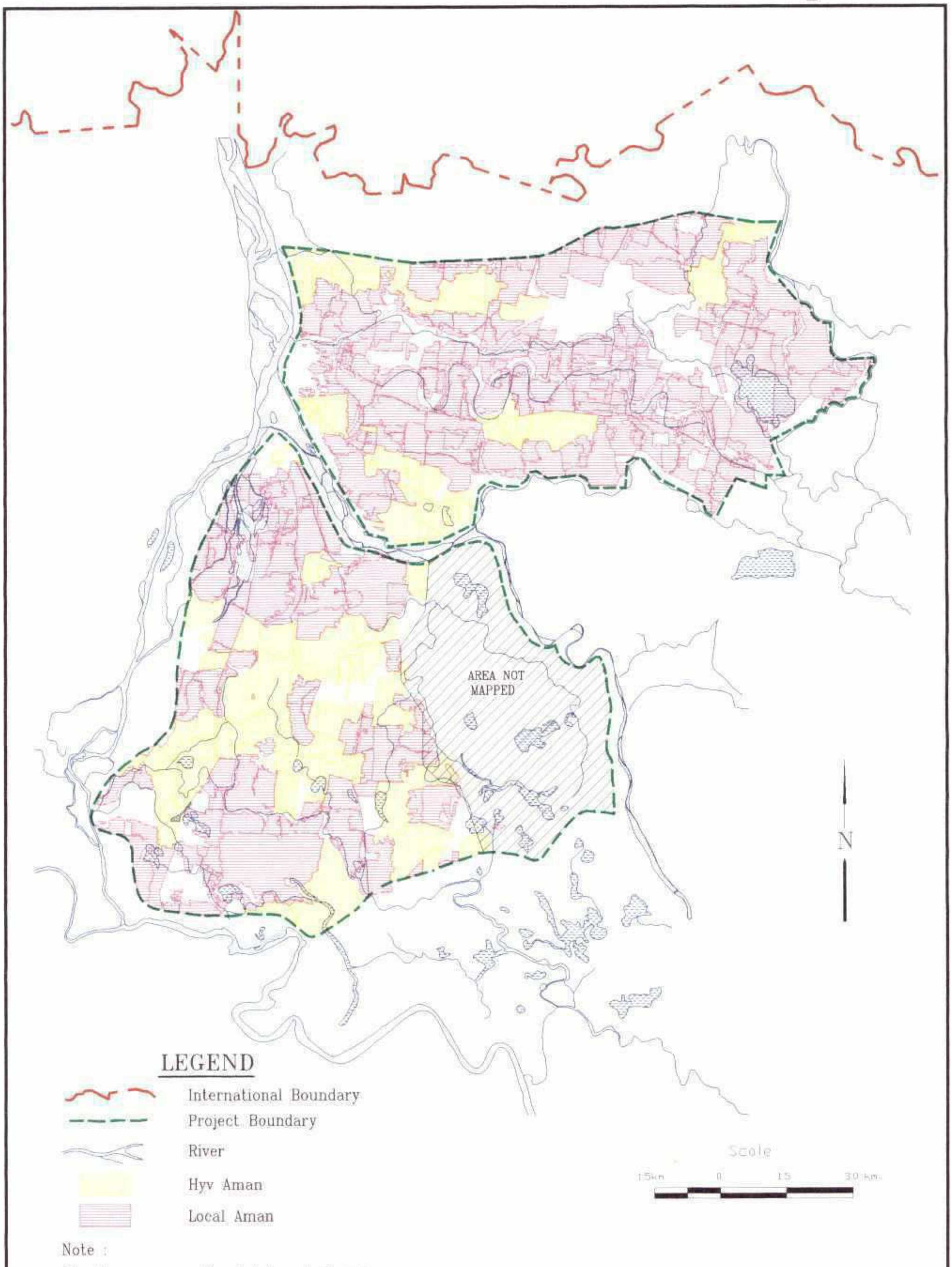
FILE: D010 Prepared by: Mamun

Figure D.11



FILE: D011 Prepared by: Mamun

Figure D.12

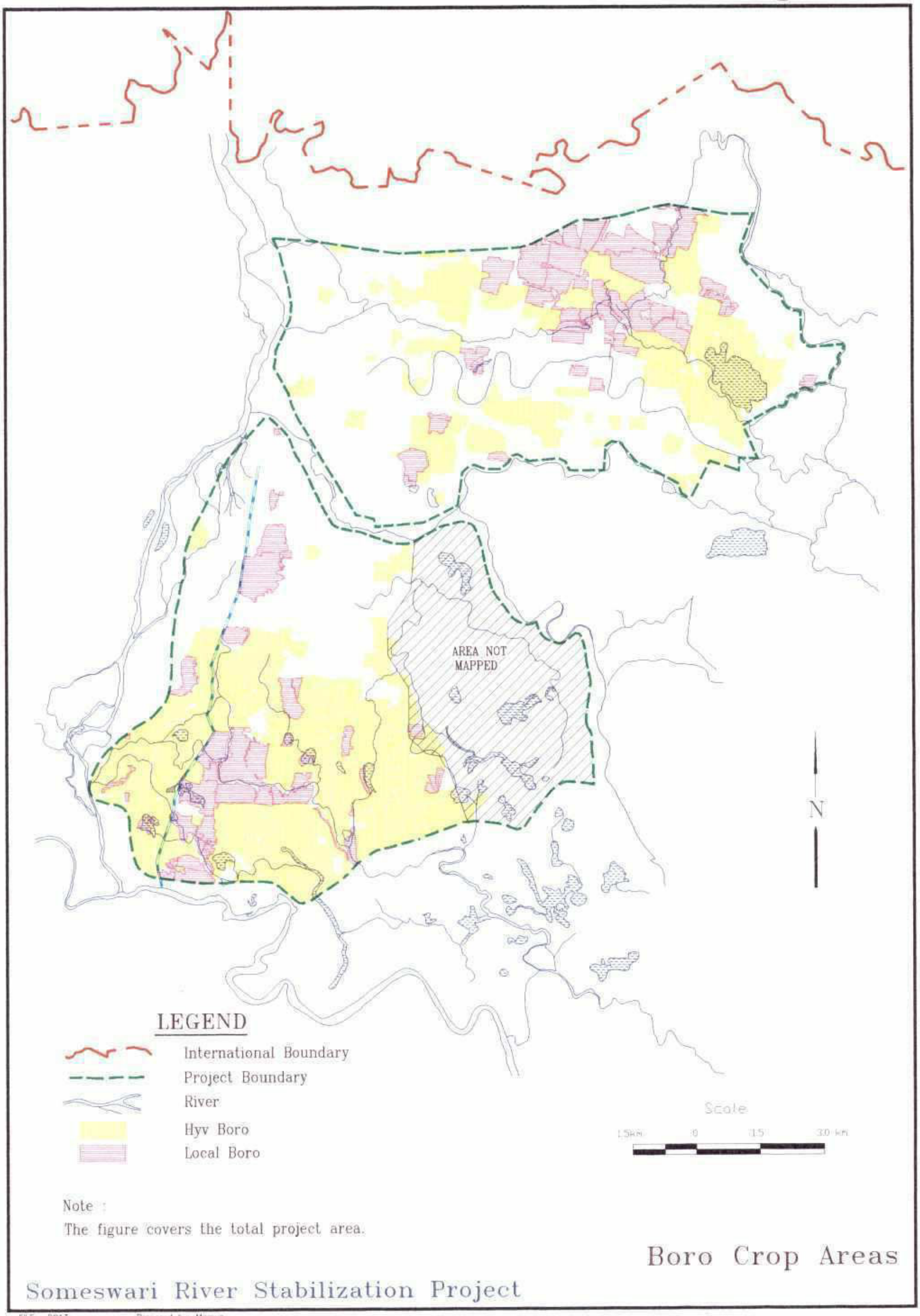


Aman Crop Areas

Someswari River Stabilization Project

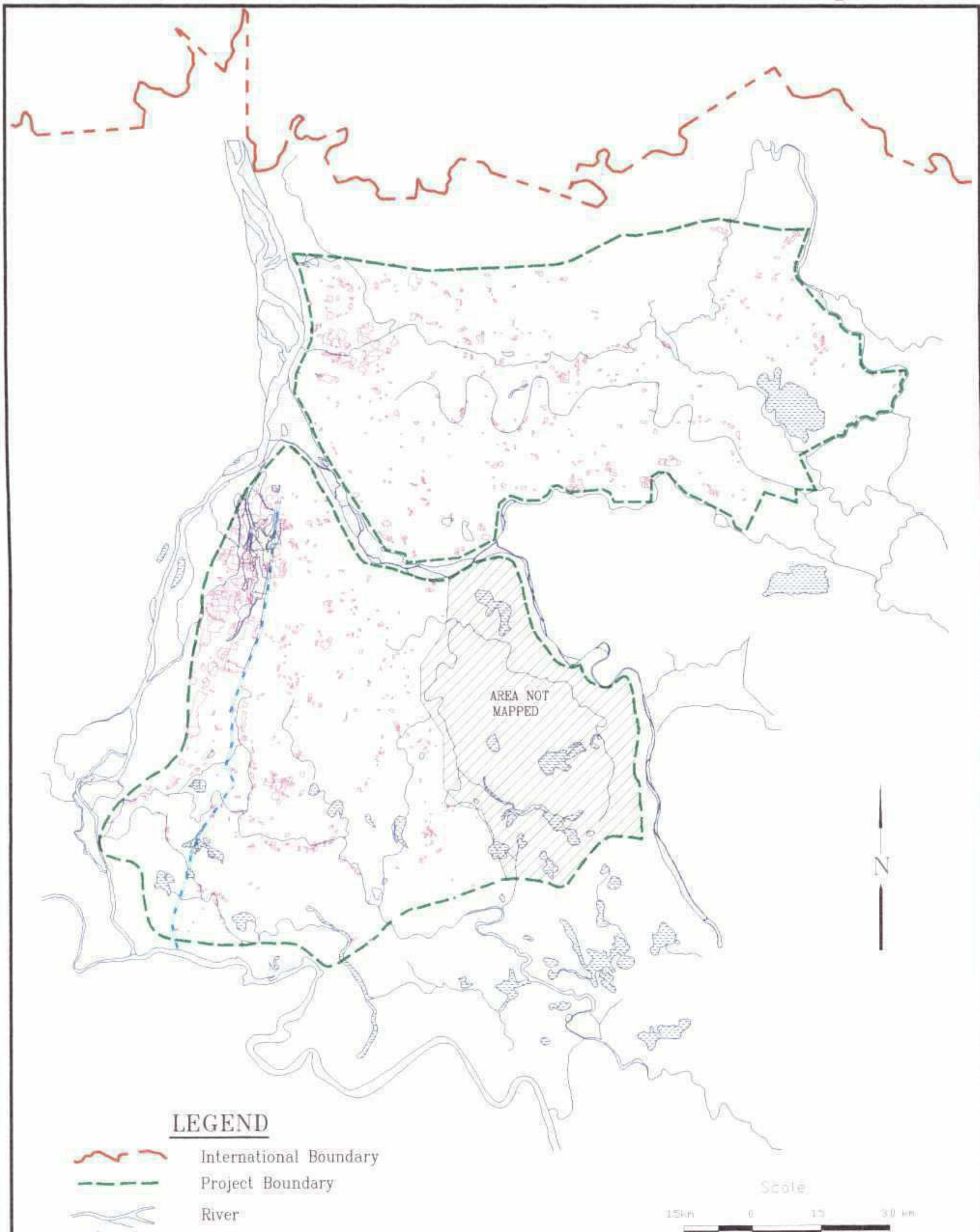
FILE: D012 Prepared by: Mamun

Figure D.13



FILE: D013 Prepared by: Mamun

Figure D.14



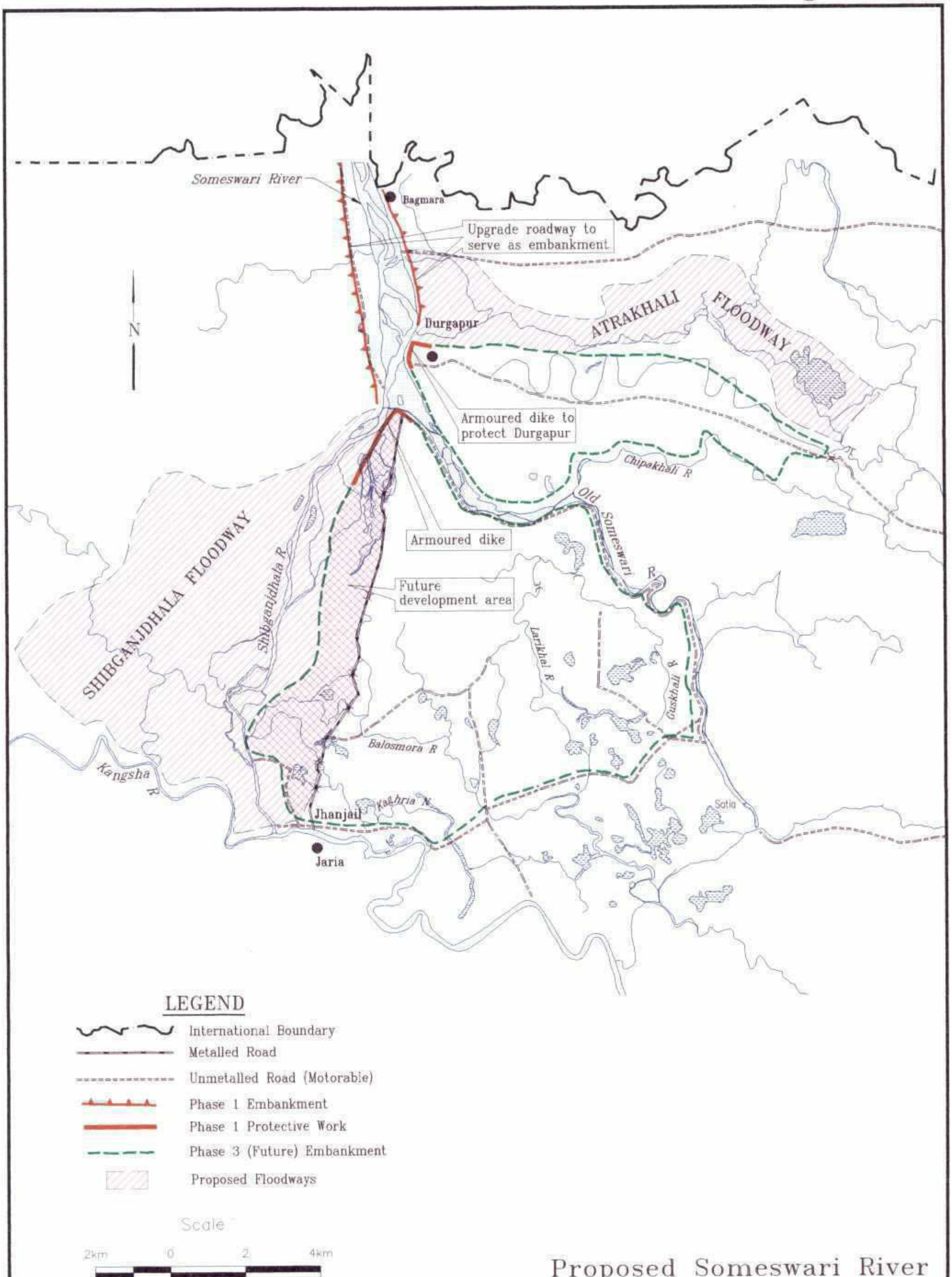
Note :
The figure covers the total project area.

Non–Rice Crop Areas

Someswari River Stabilization Project

FILE: D013 Prepared by: Mamun

Figure D.15



Proposed Someswari River Management Concept

Someswari River Stabilization Project

FILE: D015 Prepared by: Jalal

ANNEX E

GROUNDWATER RESOURCES

ACRONYMS AND ABBREVIATIONS

AST	Agricultural Sector Team
BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DPHE	Department of Public Health Engineering
DSSTW	Deep Set Shallow Tube Well
DTW	Deep Tube Well
EPCB	Environmental Pollution Control Board, Bangladesh
FAP	Flood Action Plan
FCD	Flood Control and Drainage
HTW	Hand Tube Well
HYV	High-yield variety
LLP	Low-lift Pump
MMI	Mott MacDonald International
MOA	Ministry of Agriculture
MPO	Master Plan Organization
MTW	Manual Tube Well
NERP	Northeast Regional Water Management Project
NMIDP	National Minor Irrigation Development Project
NWD	Net Water Demand
NWP	National Water Plan
PWD	Public Works Department
SAR	Sodium Absorption Ratio
SRDI	Soil Research and Drainage Institute
STW	Shallow Tube Well
TDS	Total dissolved solids
UNDP/FAO	United Development Programme/Food and Agriculture Organization
WARPO	Water Resources Planning Organization
WHO	World Health Organization

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1. INTRODUCTION

1.1 Background

This report is the result of a study of the groundwater resources in the Kangsha River Basin, a subregion of the Northeast Regional project area. The study was carried out over a period of three months and is to a large extent based on a review of existing data and information generated by a number of previous workers. Several field trips were made to verify the reported data, and whenever possible acquire new information. Investigations into groundwater irrigation practices by the farmers during the dry season and the impact that these may have on the future availability of groundwater were also carried out.

Data critical for the study were obtained from several sources, especially from reports issued by BADC, WARPO, MOA, BWBD, MMI and NMIDP.

1.2 Purpose

The purpose of this study was to assess the groundwater resources of the Kangsha River Basin, the location and of which is shown in figure 1. The specific objectives were as follows:

- describe the quantity and quality of the groundwater resource and if the resource is part of a larger aquifer. Note any evidence of overuse;
- describe the recharge patterns and their relationship to seasonal rainfall, river discharges and flooding;
- quantify the number of wells by type and uses for each type;
- analyse apparent trends in groundwater exploitation for the past decade and assumed trends in the future;
- examine linkages to changes in groundwater use in respect of socio-economic factors.

1.3 Previous Work

Different organizations have produced more than 50 regional and 27 country reports on various aspects of groundwater since 1961, when minor irrigation first began in Bangladesh. In this study, an emphasis has been placed on using the most recent reports (those prepared since 1990) as reference sources. These reports to a large degree reflect the experience and knowledge of the groundwater situation in Bangladesh gained over the past three decades. Digitized hydrographic data and observation wells, and also precipitation and flood level data from as far back as 1961 were used. Occasional paucity or lack of data resulted in diminished accuracy of the influenced parameters.

Under NERP, the groundwater resources of the Northeast Region, including the districts of Mymensingh and Netrakona (which partly lies within the Kangsha River Basin), were studied. A report on the findings and recommendations for further studies were issued in 1993 (NERP 1993, FAP 6).

Several important recommendations were made in this report. A summary of these are as follows:

- acquisition of all BWDB water supply papers;
- preparation of digitized files of all groundwater data;
- collection, review and selection of groundwater monitoring data obtained by BWDB and BADC;
- supplementing the 1:500,000 project map with Autocad-plotted locations of BADC groundwater monitoring sites;
- evaluation of groundwater monitoring data, leading to classification of the hydrographs by type and depth of well;
- preparation of maps showing the oldest recorded water table data in the unconfined surface aquifer and of the oldest potentiometric surface of the semi-confined or confined aquifers, both in terms of depth below ground and PWD data;
- attempt identification of the various groundwater flow systems and their recharge and discharge areas.

The report also makes recommendations on the assessment of groundwater development impacts, surveys of domestic water supplies and evaluation of hydrogeologic data. Many of the recommendations presented should be applied to the Kangsha River Basin.

In February 1994, DAE and the Ministry of Agriculture issued a report on the 1992-93 census of minor irrigation in Bangladesh, (DAE/ATIA Feb.94) under project BGD/89/039. This report contains the most recent district-wise statistical data on groundwater irrigation and the number and type of wells operating, including data from the three districts within which the project area is found. Numerical data with respect to number and type of wells in operation, equipment failures and command areas quoted in this report is based on these data.

The report demonstrates a rapid increase in STWs but stagnating developmental trends in DTWs, MTWs and LLPs, citing the high cost of DTWs as the main reason for the decline. The downward trend in the use of LLPs reflects a shift toward the use of STWs in place of low yield LLPs. This may be due to a decline in the stream water levels on which these pumps depend; because of the increased abstraction of groundwater by STWs.

The survey sampled about one percent of all minor irrigation systems and it was suggested that this may not be large enough for adjusting some district and thana totals. It was also suggested that the census, to be of greater use, should be expanded to include the hydrologic, engineering and socio-economic performance of minor irrigation.

In July 1993, a draft final report entitled: "Groundwater Resources Of Bangladesh," authored by L. R. Khan under project BGD/89/093, UNDP/FAO Technical Report 1 was issued. This report covers many of the aspects of groundwater exploration and exploitation in Bangladesh, including a review of present methodologies applied to abstraction, pumping tests, well drilling, hydrographs, groundwater modelling, groundwater flows and hydrogeology. In addition a number of environmental and ecological concerns are discussed. Under recommendations, specific corrective measures to improve the methodologies used are made. Although most of the recommendations are applicable to the Kangsha River Basin area, the advice with respect to the need for a comprehensive hydrogeological and groundwater monitoring programme is especially relevant, as are the recommendations for siting and spacing of tube wells that is currently uncontrolled.

In August 1993, the UNDP/FAO Technical Report no. 2 entitled "Potential For Minor Irrigation Development In Bangladesh," authored by M. A. Sattar, was issued. The report deals with a variety of groundwater irrigation aspects. Discussions on groundwater characteristics, recharges and limitations parallels those discussed in UNDP/FAO Technical Report 1. Comments with respect to under-utilisation of well capacities are of particular significance. Investigations in the Kangsha River Basin indicate similar problems, which ultimately may result in overuse and unnecessarily high abstraction rates from the aquifers.

In June 1992, BADC and Mott MacDonald International in association with Hunting Technical Services Ltd. issued a report entitled "Deep Tubewell II Project, Natural Resources;" final report supporting volume 2.1.

This report details the results of extensive studies carried out over a period of years, during the execution of a deep tube well development project.

The area covered by the report lies outside the Kangsha River Basin with the exception of the western part of Netrakona district, where it extended into the thanas of Barhatta and Kalmakanda.

A number of studies based on previously generated information did, however, cover much of the Basin except the district of Sherpur. These studies included geology, tectonics, hydrogeology, physiography, water quality, agroecology and several others related to agriculture and irrigation. This report is a valuable reference work for a general understanding of the groundwater situation in the Kangsha River Basin.

2. PHYSICAL SETTING

2.1 Location

The Kangsha River Basin is located in the northwestern corner of the Northeast Region (Fig. 1). The northern boundary is formed by the Megalaya Hills, which also delineate the international border between Bangladesh and India. The southern boundary is formed by the highway between Netrakona and Sherpur. The eastern Basin limit is delineated by a road leading northward from Dhonaikhali River to Kalmakanda, then along Lengura River and one of its tributaries up to Kharnai and the border with India. The Western boundary follows the road from Sherpur to Balijuri and northward to the international border with India.

The Basin area is approximately 89 by 26 km, comprising 2310.29 square kilometres and lying wholly within the districts of Netrakona, Mymensingh and Sherpur. The districts are divided into thanas, of which 13 lie partly or wholly within the Basin (Fig.2).

2.2 Topography

The highest elevations are found in the northwestern part of the project area, reaching 31 metres above sea level in the Megalaya Hills, just west of the Marisa River. Elsewhere along the northern boundary elevations are lower, ranging from 28 m to a low of 9.5 m, declining in an easterly direction. In the southern part of the area, elevations range from 16 m to 5 m above sea level, with the lowest elevations found in the eastern-most section. The lowest elevations are situated within small depressions ranging in size from about 8 km^2 to less than 1 km^2. The entire area is thus sloping east-southeasterly.

2.3 Hydrology

Drainage in the Kangsha River Basin is mainly through a series of rivers whose headwaters are located in the Megalaya Hills. In the eastern part of the Basin the Someswari, Marisi, Chelakhali and Bhogai Rivers and their tributaries form the major drainage network. The main rivers generally flow north to south. The Bhogai and Chelakhali Rivers joins at the village of Danakusha. The confluence turns easterly for some five km, where it splits into two smaller rivers, the Bhogai and Malijhee Rivers. These join again at Sarchapur where they form the headwaters of the Kangsha River.

The Kangsha River flows easterly with a strongly meandering course and leaves the Basin in its southeastern corner. Eastward from Sarchapur, all the rivers and their tributaries flow into the Kangsha River. The largest of these is the Shibganjdhala River which flows southward from the border with India, past Bagmara and Durgapur. At Birisiri, the river splits and the east - southeasterly flowing branch is named the Old Someswari River. The Shibganjdhala River flows into the Kangsha River just east of Jhanjail and the Old Someswari River joins the Kangsha Rivre through the Gunai River and Teor Khal at Baniapari.

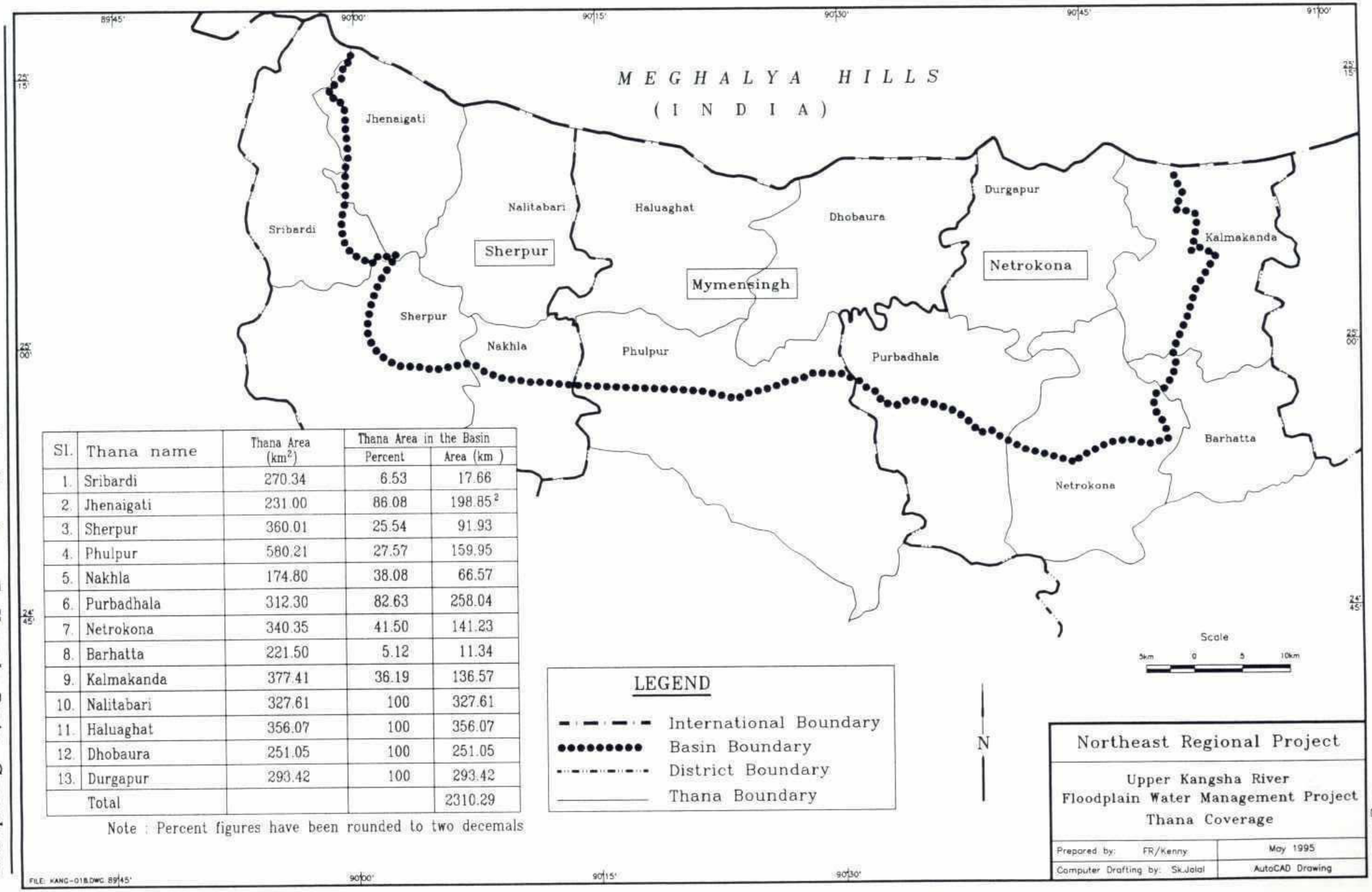
Flood control embankments have been constructed along both sides of the Chelakhali River between Nunni Bridge in the north and the highway between Sherpur and Nalitabari in the south. The Bhogai River has an embankment along its east side from near the border with India southward to the town of Danakusha and along its north side from Bahirsimul to Sarchapur. The same embankment continues along the north side of the Kangsha River from Sarchapur to Phutkai.

Figure 1

Sl.	Thana name	Thana Area (km²)	Thana Area in the Basin Percent	Thana Area in the Basin Area (km²)
1.	Sribardi	270.34	14.20	38.37
2.	Jhenaigati	231.00	87.50	202.13
3.	Sherpur	360.01	28.11	101.19
4.	Phulpur	580.21	24.27	140.79
5.	Nakla	174.80	40.06	70.02
6.	Purbadhala	312.30	55.94	174.71
7.	Netrokona	340.35	40.31	137.20
8.	Barhatta	221.50	14.36	31.81
9.	Kalmakanda	377.41	49.26	185.92
10.	Nalitabari	327.81	100	327.81
11.	Haluaghat	356.07	100	356.07
12.	Dhobaura	251.05	100	251.05
13.	Durgapur	293.42	100	293.42
	Total			2310.29

Note : Percent figures have been rounded to two decemals

Figure 2



Sl.	Thana name	Thana Area (km²)	Thana Area in the Basin	
			Percent	Area (km)
1.	Sribardi	270.34	6.53	17.66
2.	Jhenaigati	231.00	86.08	198.85 ²
3.	Sherpur	360.01	25.54	91.93
4.	Phulpur	580.21	27.57	159.95
5.	Nakhla	174.80	38.08	66.57
6.	Purbadhala	312.30	82.63	258.04
7.	Netrokona	340.35	41.50	141.23
8.	Barhatta	221.50	5.12	11.34
9.	Kalmakanda	377.41	36.19	136.57
10.	Nalitabari	327.61	100	327.61
11.	Haluaghat	356.07	100	356.07
12.	Dhobaura	251.05	100	251.05
13.	Durgapur	293.42	100	293.42
	Total			2310.29

Note : Percent figures have been rounded to two decemals

Major embankments also exists along the south side of the Kangsha River from Jaria, eastward to Batta and then south along the west side of Dhonaikhali River. Teor Khal has an embankment along both sides of its course, the northern part of which extends northeasterly along the Gunai River and the southern embankment southward along the Gunai River. The highway between Netrakona and Sherpur, in addition to being the southern boundary of the project area, also forms a major embankment.

2.4 Physiography

Classification of the physiographic units in Bangladesh is largely based on FAO/UNDP (1988) studies. The units recognized in the Kangsha River Basin are Piedmont Alluvium, Old Brahmaputra floodplain and Young Brahmaputra floodplain. The distinction between the latter two, both of which lie east of the Brahmaputra River, is somewhat biased. Coleman (1969) has recognized seven ancient courses of the Brahmaputra, thus the two units reflect the developmental history of the Brahmaputra River.

2.4.1 Piedmont Alluvium

The Piedmont Alluvium is confined to the area south of the Megalaya Hills along the border with India, from where it extends southward in a gentle slope for a distance of approximately 10 km. The dominant soil types are sandy to sandy silt with local minor clay contents. Due to the porous nature of these Piedmont soils, the area constitutes an important groundwater recharge zone. It is subject to shallow flooding during the monsoon season which substantially augments the recharge rates. Flash flooding from the rivers dissecting the area in a general north-south direction with headwaters in the Megalaya Hills is common and may cause considerable damage to crops and real property; except in areas protected by embankments. This is especially true of the early monsoon floods which cause damage to the boro rice crops before they are harvested. The Piedmont Alluvium corresponds geologically to the alluvial fan deposits of Young Gravelly Sand described in 4.1.

2.4.2 Old Brahmaputra Floodplain

The Old Brahmaputra Flood plain constitutes the largest physiographic unit in the Basin, occupying approximately sixty per cent of the area. The contact between this unit and the Piedmont Alluvium is subtly gradational and interfingering, reflecting the difference in their respective depositional environments. The soils vary from clay, clay silt to silt and sandy silt with highly varying permeabilities, giving rise to different rates of infiltration. A number of shallow ponds (beels) are located in small topographic lows within this unit. These, accompanied by surrounding marshy areas, cover as much as 10 percent of the area. The ponds are economically important to the local freshwater fishing industry.

2.4.3 Young Brahmaputra Floodplain

The Young Brahmaputra sequence forms the latest meander floodplain of the Old Brahmaputra River. Only a small tongue of this physiographic unit is present within the Kangsha River Basin. It extends northeasterly from Phuphur towards Dhobaura. The soils are less well-developed than those overlying the old Brahmaputra Floodplain but are generally texturally indistinguishable.

3. METEOROLOGY AND CLIMATE

3.1 Climate

The climate is tropical, monsoonal with characteristic high humidity which reaches its maximum level coincident with the arrival of the monsoon season in early to late May. The temperature ranges between 29 and 38 degrees centigrade between March and October, occasionally reaching 40 degrees for short periods of time. Between November and February the average temperatures vary between 16 and 20 degrees. There are no climatologic stations within the project area. The closest is located at Mymensingh, about 23 km south of Phuphur.

3.2 Rainfall

A total of six rain gauges are located within the project area with records going back to 1961. Although occasional paucity in the data is present, it provides a substantially good record of annual precipitation patterns in the Basin. Table 3.1 shows the minimum, mean and maximum rainfall for the six stations located within the project area. The most complete data bases are from the Durgapur and Jaria gauges, each with a 30-year record. The smallest data base is from the Phulphur gauge where no data is available for the years 1961, 1981,19 82, 1983 and only partial data only for the years 1962, 1971, 1974, 1980 and 1993. A somewhat similar situation is found for the gauge at Nalitabari. Fig. 3 shows the location of the rain gauges and a graphic illustration of the mean annual rainfall for each gauge with the data base in years as per Table 3.1.

Although the difference in data base length gives rise to some constraints with respect to comparison of total rainfall recorded by the gauges, it is clear that differences in the amount of precipitation exists. The gauge at Sherpur, with records dating back 28 years, shows 1367.8 mm less mean average rainfall than the gauge located at Durgapur, which recorded the highest mean annual rainfall. The data from the Phulphur and Nalitabari gauges can not be compared to the others in view of their shorter data base.

TABLE 3.1
KANGSHA RIVER BASIN RAINFALL DATA

STATION NUMBER	LOCATION	DATA BASE (YEARS)	MIN. (MM)	MEAN (MM)	MAX. (MM)
R - 063	DURGAPUR	30	2510.9	3568.6	4935.2
R - 068	JARIA	30	2296.4	3368.6	4951.6
R - 123	NETRAKONA	25	1899.8	3067.4	4320.8
R - 074	NALITABARI	21	1745.8	2588.1	3669.8
R - 077	PHULPHUR	20	1104.5	2658.8	5831.4
R - 078	SHERPUR	28	1322.9	2200.8	3339.2

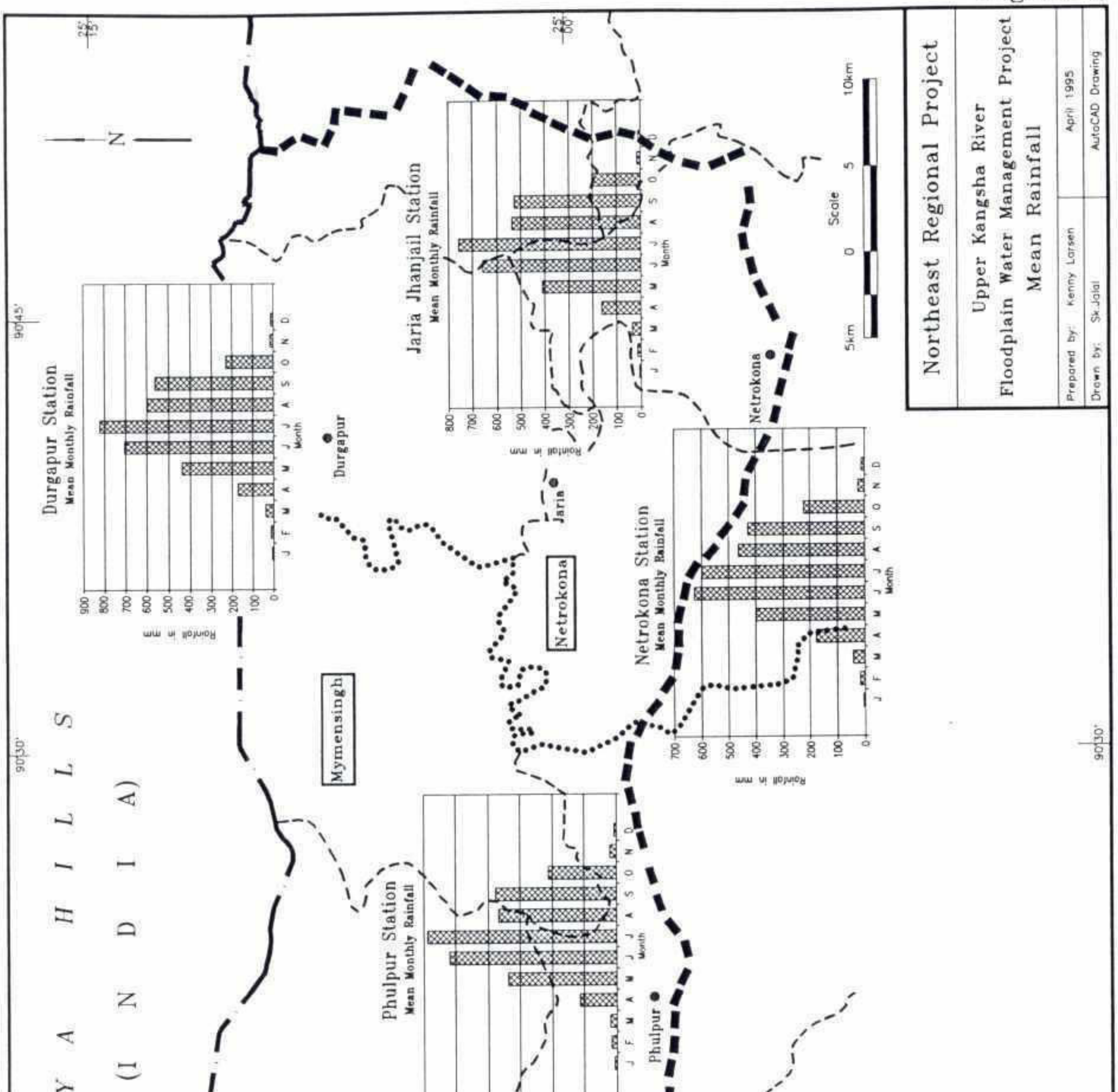
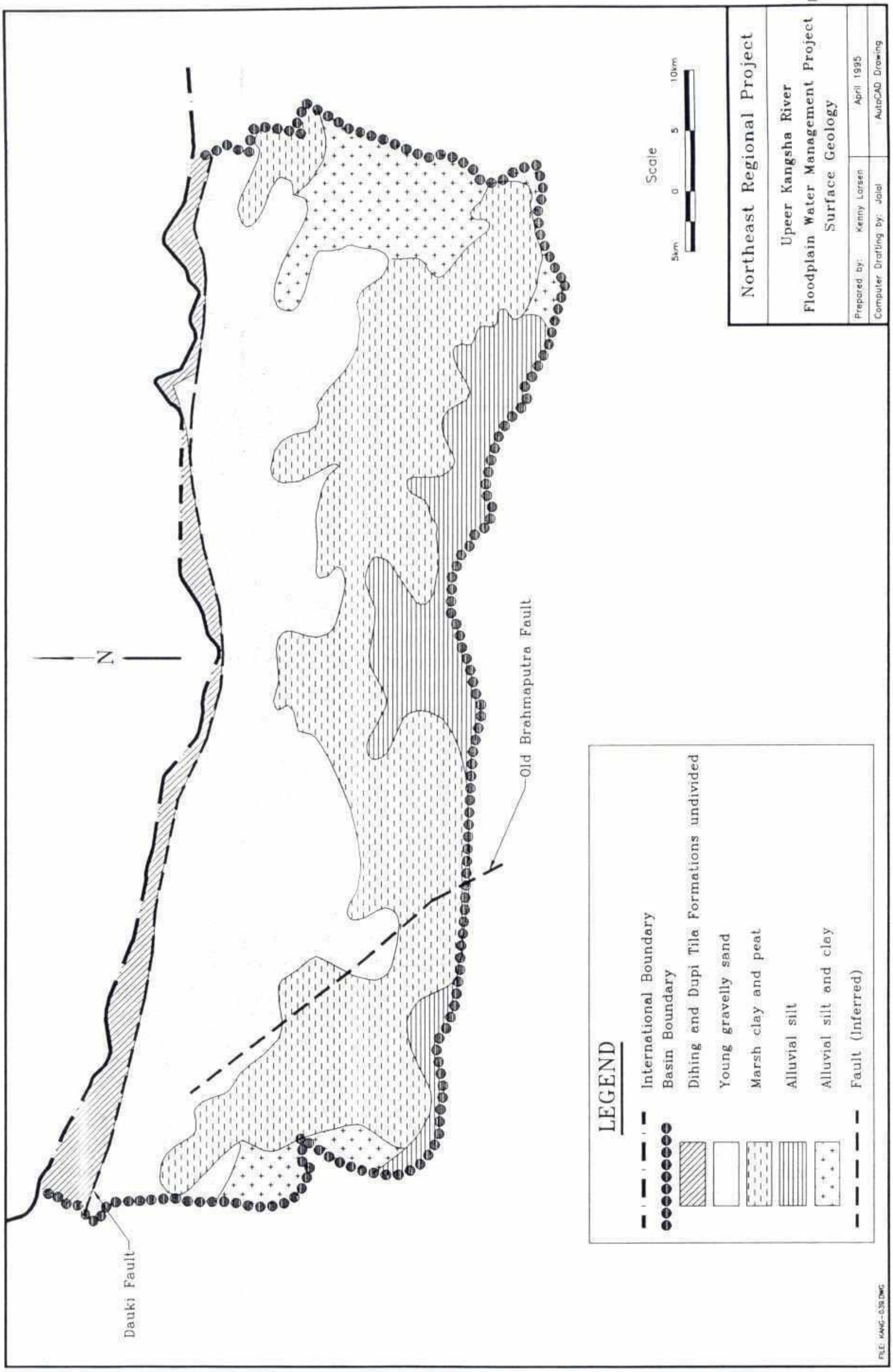

Northeast Regional Project
Upper Kangsha River
Floodplain Water Management Project
Mean Rainfall
Prepared by: Kenny Larsen
April 1995
Drawn by: Sk.Jalal
AutoCAD Drawing
Scale
5km 0 5 10km
N
MEGHALAYA HILLS
(INDIA)
Mymensingh
Netrokona
Sherpur
Durgapur Station
Mean Monthly Rainfall
Jaria Jhanjail Station
Mean Monthly Rainfall
Netrokona Station
Mean Monthly Rainfall
Phulpur Station
Mean Monthly Rainfall
Nalitabari Station
Mean Monthly Rainfall
Sherpur Station
Mean Monthly Rainfall
Rainfall in mm
Month
Durgapur
Jaria
Netrokona
Phulpur
Nalitabari
Sherpur
LEGEND
International Boundary
Upper Kangsha Floodplain Boundary
District Boundary
Thana Boundary
90°00'
90°15'
90°30'
90°45'
25°15'
25°00'
24°45'

Figure 4



Northeast Regional Project
Upeer Kangsha River
Floodplain Water Management Project
Surface Geology
Prepared by: Kenny Larsen
April 1995
Computer Drafting by: Jalal
AutoCAD Drawing
Scale
5km 0 5 10km
N
Old Brahmaputra Fault
Dauki Fault
LEGEND
International Boundary
Basin Boundary
Dihing and Dupi Tila Formations undivided
Young gravelly sand
Marsh clay and peat
Alluvial silt
Alluvial silt and clay
Fault (Inferred)

4.1.4 Paludal Deposits

Paludal deposits are grey to bluish-grey clay and commonly interbedded with peat, peaty clay and silt; especially in the small beels and marshy areas. Many of the ponds remain partially filled with water during the dry season and are often interlinked with small streams. The clay beds act as impermeable strata, preventing infiltration into the substrata. Some of the streams are small tributaries to nearby rivers, fed by base flows from the aquifers during the dry season, thus maintaining water levels in the beels. Paludal deposits covers about 10 per cent of the project area.

4.2 Bedrock

The Basin is underlain by rocks of the (Oligocene?) Bogra formation. In the north, along the border with India, the Bogra formation is overlain by Pleistocene and Pliocene rocks of the Dupi Tila formation composed of massive to thin-bedded grey sandstone, siltstone and conglomerate. The upper part is dominated by fine to medium-grained sandstone; subordinate thin beds of siltstone and claystone with intraformational siltstone breccia at top. The majority of this formation lies wholly within India.

4.3 Structural Geology

Folding has not been detected within the Basin. The evident east-southeasterly decline in elevations may reflect tilting of the basement rocks in the same direction. Tectonically, the sediments have been affected by faulting. The Dauki fault running east-west along the border with India has a vertical displacement of several kilometres. The only other fault is an inferred fault along the Old Brahmaputra River. Displacement of the unconsolidated sediments by subsidence can be difficult to distinguish from that which is caused by faulting, especially when only minor displacement has occurred. Erosion of the unconsolidated sediments quickly obliterates any visual traces of displacement. Fig. 4 shows the location of the two faults.

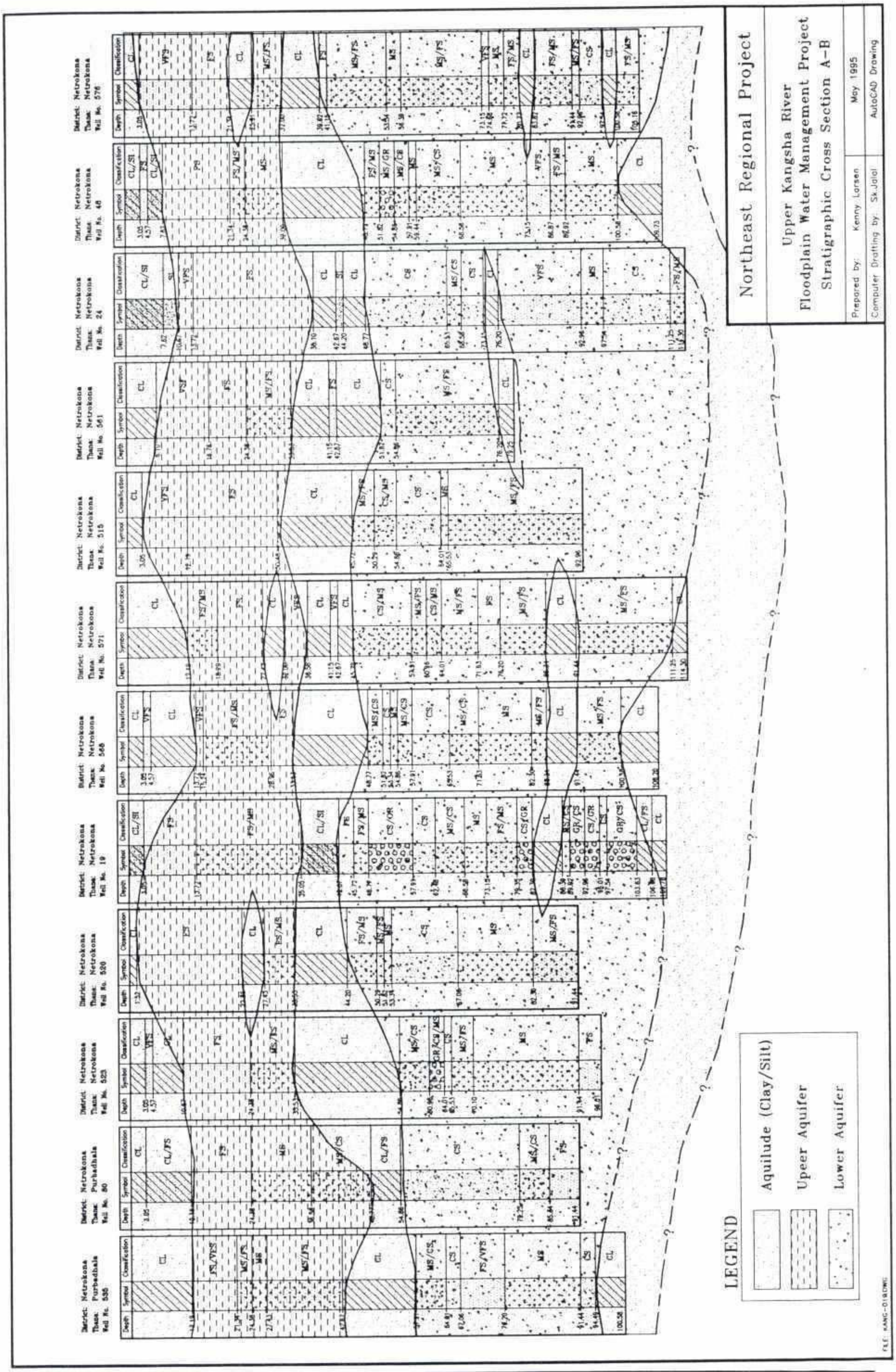
4.4 Stratigraphy

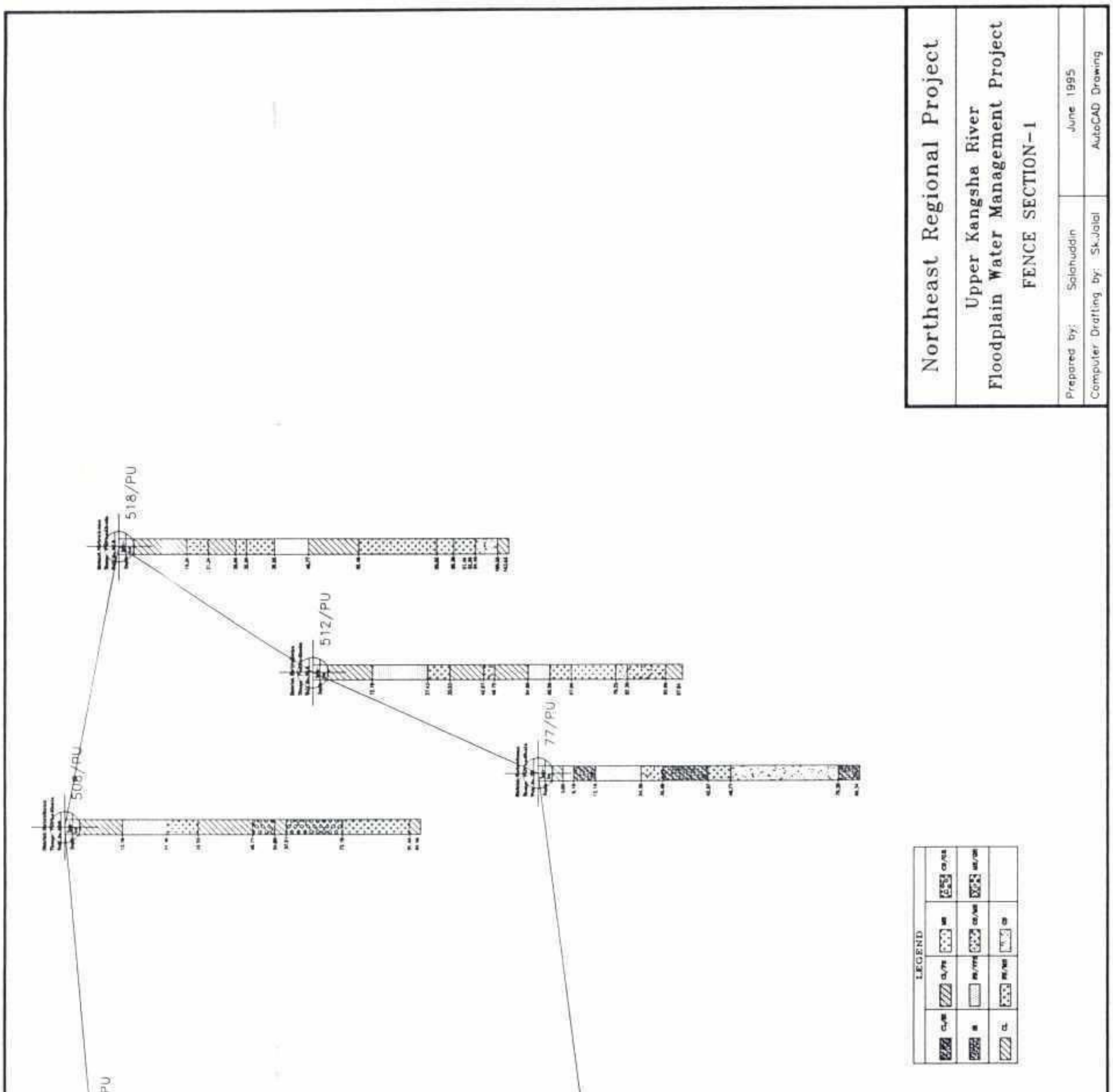
Lithologic logging of a considerable number of wells drilled within the Kangsha River Basin provides an excellent data base for interpreting the vertical stratigraphic sequences. The deeper bore holes which explores the unconsolidated sediments to depths of over 100 metres are of more interest than shallow bore holes, drilled for development of shallow tube wells. They provide a more complete picture of the complex series of alluvial sediments deposited over the last several thousand years.

The highly variable and constantly changing depositional environment has resulted in considerable vertical and horizontal variation in both type and grain size of the unconsolidated sediments. Individual beds may be horizontally contiguous for several kilometres with phase changes expressed only in terms of grain size. Vertical changes in stratigraphy appear to be more abrupt. Interpretation of these sudden changes should be discretionary since the samples on which the logging is based may be contaminated with material from overlying formations, depending on the drilling technique used to bore the well.

A generalized stratigraphic section (Section A-B) shows a vertical north-south oriented cross section through twelve bore holes ranging in depth from 91 to 114 metres. The section is 10.6 km long. The difference in elevation from bore hole to bore hole is plus or minus one metre. Stratigraphically, the section is composed of beds of clay and sand, each of which is further subdivided according to grain size and admixture of clay, silt and sand. While lateral continuity of the major units is quite pronounced, there are rapid phase changes in grain size and composition. This reflects the fluvial depositional mode of the sediments. The clay beds, especially those with large areal extents, indicate paucity in the rate of sedimentation, et. periods of quiescence.

The clay beds are undulating, forming wavy thin and thick sections along their strike. This may in part be a depositional phenomena but the plasticity of the clay renders the beds subject to plastic deformation due to differential load pressures from the overlying sandy beds. Subsidence in lower formations due to compaction may also be a contributing factor. A three-dimensional view of the stratigraphy is shown in Fence Section 1, which well illustrates the complexity of the stratigraphy.


Northeast Regional Project
Upper Kangsha River
Floodplain Water Management Project
Stratigraphic Cross Section A-B
Prepared by: Kenny Larsen
May 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
Aquilude (Clay/Silt)
Upeer Aquifer
Lower Aquifer


Northeast Regional Project
Upper Kangsha River
Floodplain Water Management Project
FENCE SECTION-1
Prepared by: Salahuddin
June 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
518/PU
512/PU
77/PU
508/PU
513/PU
517/PU
83/PU
507/PU
505/PU
72/PU

5. HYDROGEOLOGY

5.1 Aquifer Sequences

5.1.1 Old Brahmaputra Floodplain

The Old Brahmaputra constitutes the largest hydrostratigraphic unit within the Basin. Two aquifers are present within the unit. In this report, they are referred to as the upper and lower aquifers. Both aquifers are located within a depth of 100 metres from surface. Aquifers located at deeper elevations are not discussed in view of the economic constraints that groundwater abstraction from very deep aquifers poses. A basic view of the two aquifers can be seen on the stratigraphic section A - B. The hydrostratigraphic units have been classified according to particular characteristics such as the number or thickness of the aquitards/aquiludes and the colour of the sediments composing the aquifer sequence. (Mott MacDonald 1992) The Brahmaputra Floodplain subdivisions are listed in Table 5.1.

Unit Be is present in the Phulphur area. Units B2a and B2c are present in the district of Netrakona, with B2a probably extending into the district of Mymensingh north of unit Be at Phulphur. Unit B2b is present in Netrakona district, but southeast of the Basin boundary. Unit B3 has not been detected in the Basin to date. Since none of the units have been completely outlined, additional work is required before a meaningful map can be produced.

The aquitard above the lower aquifer is here referred to as the "Intermediate aquitard", since the aquitard below the lower aquifer may be overlying a third aquifer. None of the bore holes used in this study have penetrated this aquitard, therefore little is known about the lower stratigraphic horizons.

a) The Upper Aquifer

The upper aquifer is confined to semi-confined by an aquilude composed of clay to silty clay, ranging in thickness from less than one metre to twenty metres. The thickness of the aquifer on average varies between 20 and 40 metres, and is composed of a complex sequence of unweathered grey, very fine sand (VFS), fine sand (FS), medium sand (MS) and rarely coarse sand (CS). Admixtures of these units in any given bed are common.

The upper part of the aquifer is most frequently composed of very fine to fine sands, but may locally be composed of fine to medium sands. Underlying these formations are lens-shaped sequences of fine to medium sands, medium sands and rarely coarse sands which are the screenable parts of the aquifer, exploited by STWs, deepset shallow tube wells and manual tube wells (Treadle pumps).

The aquifer is confined or semi-confined at the bottom by a clay bed varying in thickness from less than one metre to twenty five metres. Smaller lenses of clay, three to six metres thick with a strike length of a few hundred metres are common within the aquifer itself.

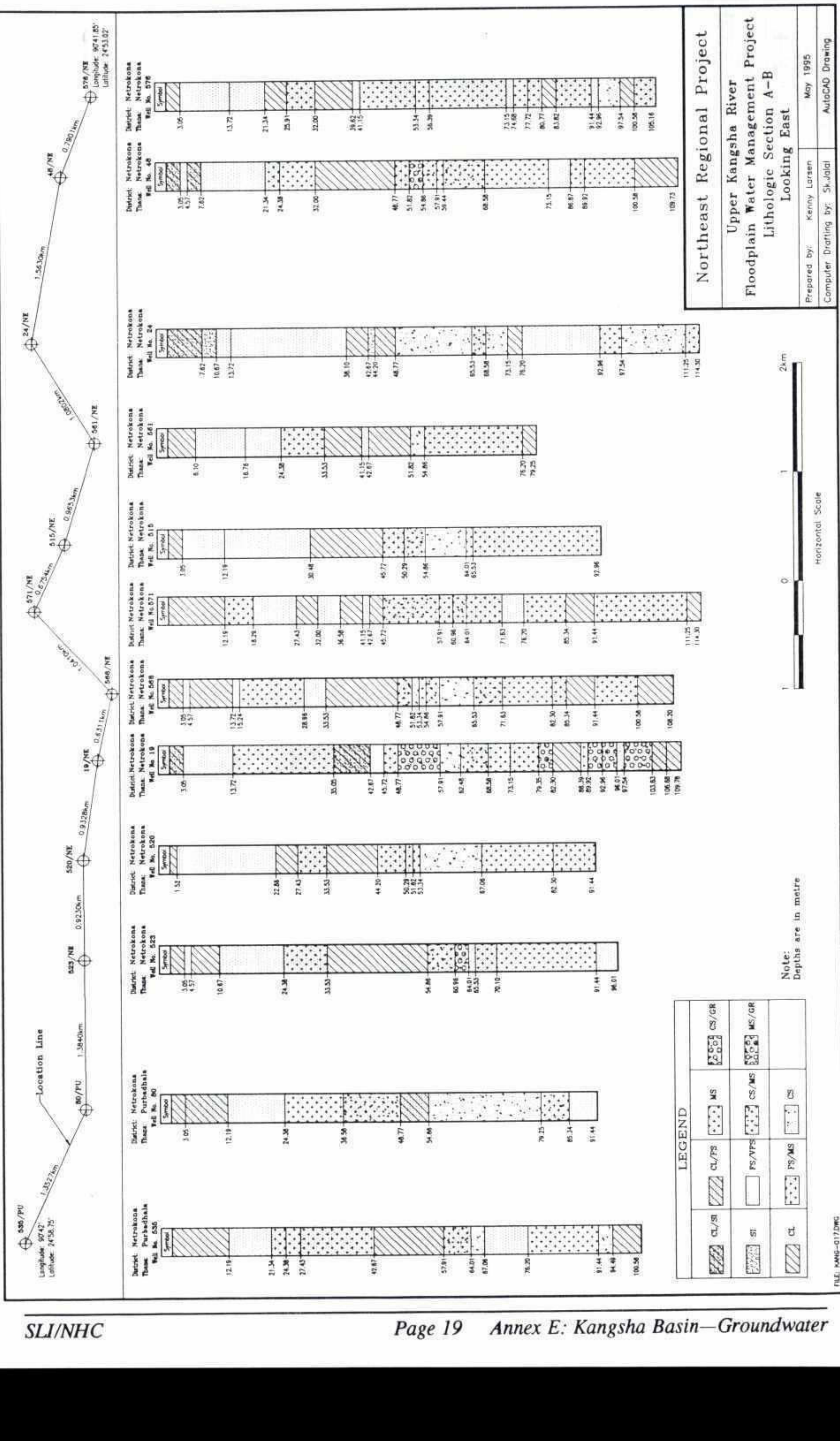
Table 5.1

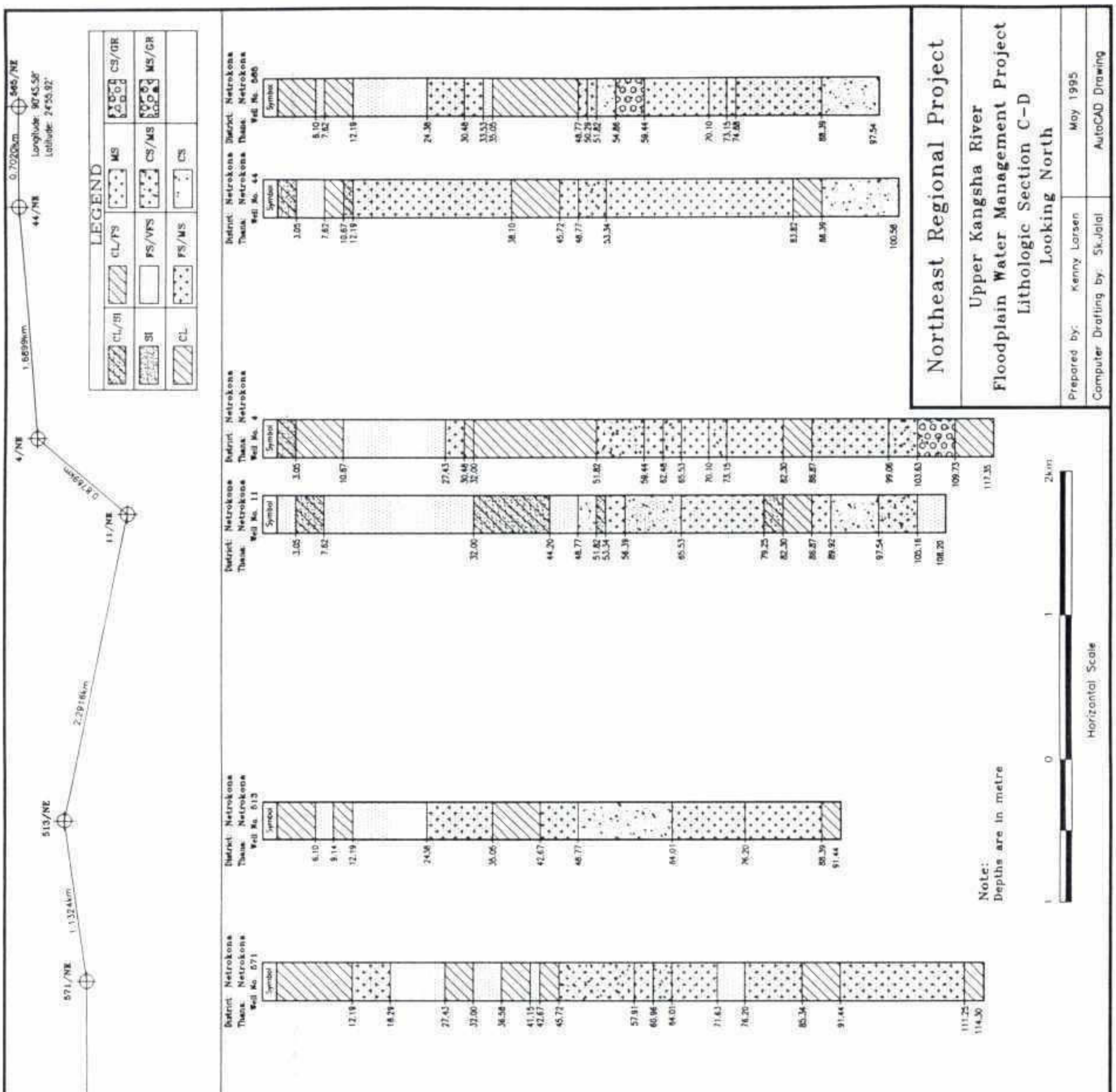
Aquifer Unit Classification
Old Brahmaputra Floodplain Sequence

Aquifer Unit	Characteristics
Be	**Surface aquilude only, lower aquifer sands brown, altered**
B2a	**Upper and intermediate aquilude is present. Lower aquifer sands brown, altered.**
B2B	**Upper and intermediate aquilude present. The latter is thick. Lower aquifer sands brown, altered.**
B2c	**Upper and intermediate aquilude present, but thin. The upper aquifer is thick. Lower aquifer sands are grey, unaltered.**
B3	**Upper aquilude is thick. Upper aquifer is thin and lower aquifer sands are grey, unaltered.**

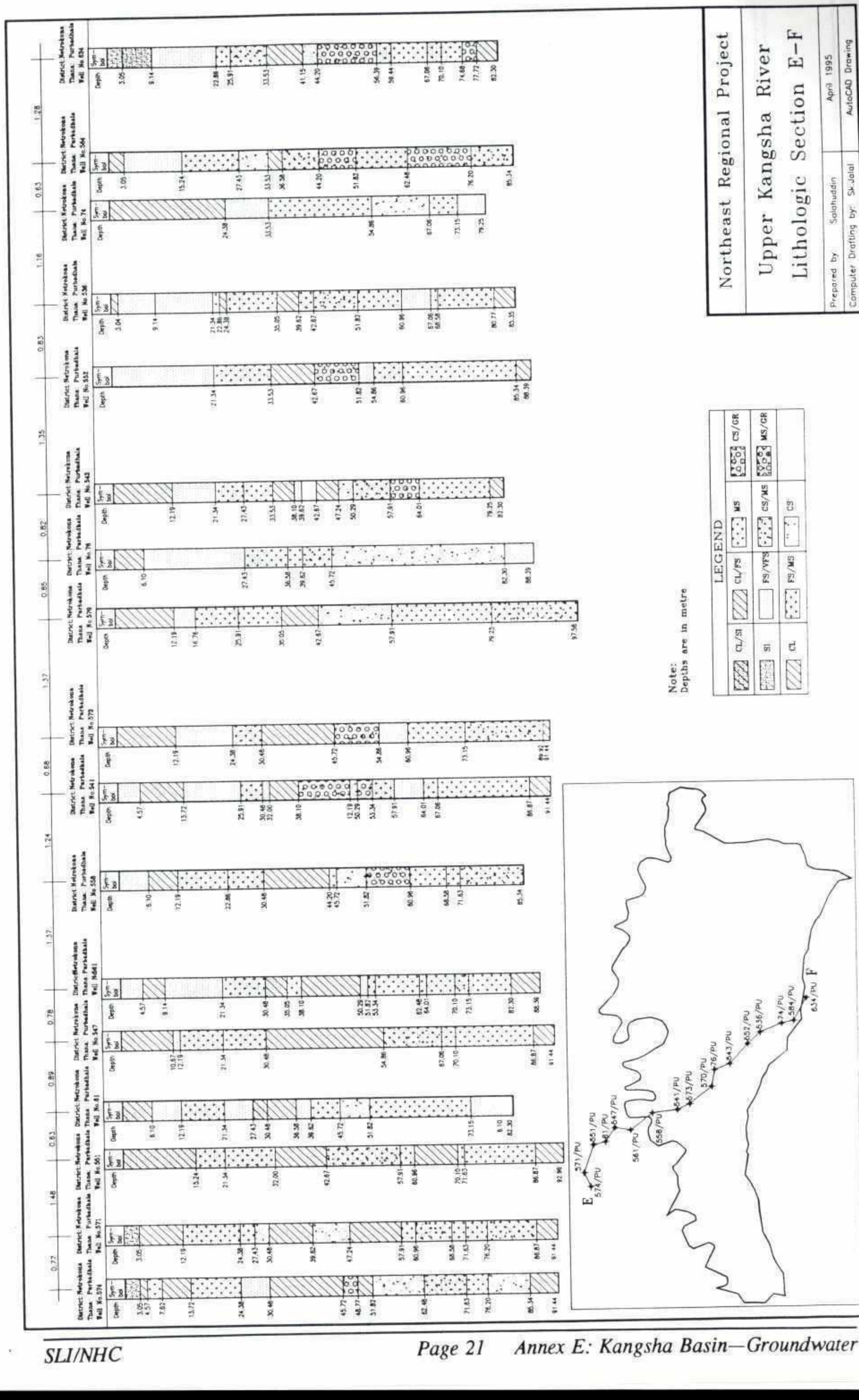
The surface clay layer may contain thin interbeds of silt or fine sand or be composed of admixtures of clay, silt or clay and fine sand. It should thus be viewed as an aquilude, rather than an aquitard. The upper aquifer is therefore semi-confined to locally unconfined. The degree of confinement is dependent on the composition, thickness and areal extent of both the overlying and the bottom clay layers. The potentiometric level (hydrostatic head) in a well is dependent upon the degree of confinement to which the aquifer is subjected; since confinement results in increased pressure within the aquifer. Under high pressure conditions, artician flows may occur. This has important implications for the development of STWs using suction pump technology for irrigation.

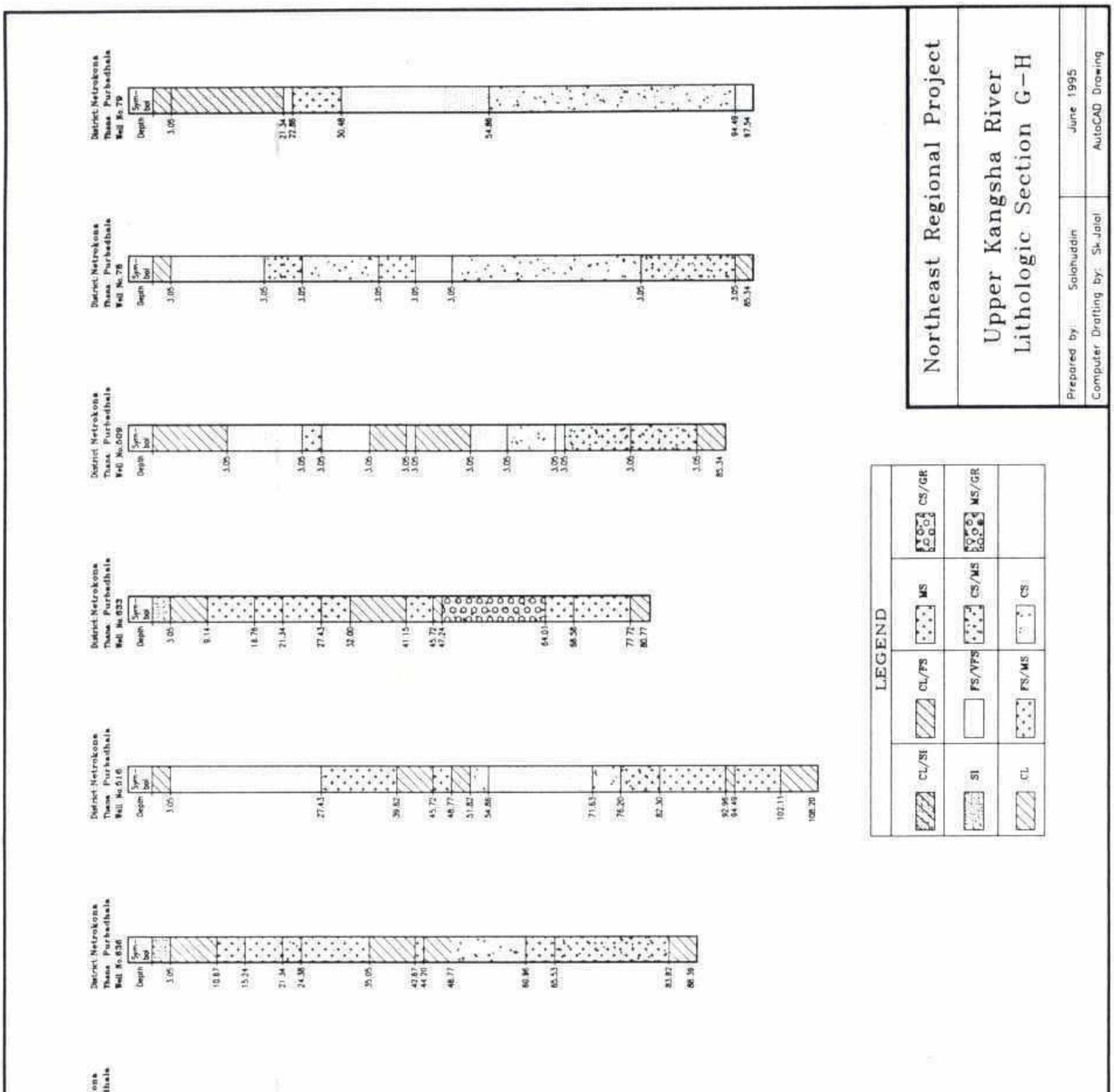
Lithologic sections A-B, C-D, E-F and G-H show the complex layering and interfingering of the sandy upper aquifer sequence. The apparent abrupt termination of some of the sand lenses should be interpreted with caution. Consideration should be given to the spacing between the points of information (bore holes), which varies from 0.63 to 1.56 kilometres, and the fact that the section line is staggered. Vertical shifting of the beds in response to local minor subsidence and varying degrees of compaction may also have played a role in compounding the complexity of the stratigraphy.


Northeast Regional Project
Upper Kangsha River
Floodplain Water Management Project
Lithologic Section A-B
Looking East
Prepared by: Kenny Larsen
May 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
Note:
Depths are in metre
Horizontal Scale
Location Line



Northeast Regional Project
Upper Kangsha River
Floodplain Water Management Project
Lithologic Section C-D
Looking North
Prepared by: Kenny Larsen
May 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
CL/SI
CL/FS
MS
CS/GR
SI
FS/VFS
CS/MS
MS/GR
CL
FS/MS
CS
Location Line
Note:
Depths are in metre
Horizontal Scale
FILE: KANG-022.DWG


Northeast Regional Project
Upper Kangsha River
Lithologic Section E–F
Prepared by Salahuddin
April 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
CL/SI
CL/FS
MS
CS/GR
SI
FS/VFS
CS/MS
MS/GR
CL
FS/MS
CS
Note:
Depths are in metre
FILE: KANG-D63.DWG


Northeast Regional Project
Upper Kangsha River
Lithologic Section G-H
Prepared by: Salahuddin
June 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
CL/SI
CL/FS
CS/GR
SI
FS/VFS
CS/MS
MS/GR
CL
FS/MS
MS
CS

b) The Lower Aquifer

The most basic difference between the upper and lower aquifer is one of grain-size. As can be seen on lithologic sections "A-B", "C-D" and "E-F" the lower aquifer contains a preponderance of medium and coarse sands with very few beds of fine sand. It is confined to semi-confined at the top by the intermediate clay/silt layer and at the bottom by another bed of clay that is not clearly defined on the section. Some wells did not reach it, and the remainder did not penetrate it. The thickness of the aquifer varies from 30 to 70 metres. In isolated instances it can be contiguous to the upper aquifer, when the intermediate clay/silt aquilude is absent.

The coarser grained sandy sediments of the lower aquifer suggest a depositional environment where stream flow gradients were higher than those found in the upper aquifer, or simply a series of point bar deposits. The finer grained material in the upper aquifer may represent floodplain deposits, covering the coarser point bar sediments as a result gradual lateral migration of stream meanders.

As with the upper aquifer, the degree of confinement is governed by the thickness of the clay beds and their porosity. The thickness of the intermediate clay bed (aquitard/aquilude) above the lower aquifer) is quite variable. It reaches 50 to 60 metres in the area around Haluaghat, below the alluvial fan deposits. The thinnest sections occur around Phulphur and Purbadhala, averaging 10 metres or less. Pumping from the lower aquifer in areas where the aquitard is thin will cause more rapid infiltration (deep percolation) of groundwater from the upper to the lower aquifer. This is in reaction to pressure reduction within the aquifer caused by pumping. Conversely, where the aquitard is thick, the rate of deep percolation is lower. It is critical to understand the interactive response between the upper and lower aquifer when planning groundwater development. The storage properties of the semi-pervious aquiludes as well as changes in the lithology, not only in depth but horizontally, must also be taken into consideration.

5.1.2 Piedmont Aquifer

The Piedmont aquifer unit (P1) extends southward from the Indian border where its boundary is formed by the Dauki fault. It is widest in the district of Sherpur and Mymensingh, becoming more narrow and less distinct east of Haluaghat. It is considered older than the Brahmaputra Floodplain sequence, which thus overlies this unit. The older course of the Brahmaputra River may have reworked some of the alluvial Piedmont sediments and made distinction between the two units difficult in some areas of the Basin. This is especially true in Kalmakanda thana, where the lithology from several bore holes near the border with India shows similarity to the Brahmaputra Floodplain sequence and have been classified as B2c. At present, however, the Piedmont Alluvial is being deposited over top of the old Brahmaputra sequence, mostly through flood stage reworking of the existing older deposits by rivers with headwaters in the Megalaya Hills.

In Haluaghat thana, the Piedmont sequence exhibits coarse grained sediments typical of alluvial fan deposits, including beds of angular fanglomerates resulting from erosion of the Dauki fault scarp. Boulders and gravel beds have also been noted. The coarse sediments are separated by numerous clay and silt beds in the case of unit P1, and by a thick surface aquitard in unit P2. The latter has not yet been identified within the Basin, but may be present in Sherpur district, where lithologic information from deep bore holes is largely absent.

The upper aquifer is poorly developed, consisting of thin beds of medium to coarse grey sands separated by thin beds of clay and silt. Only rarely and under local ideal conditions can this aquifer be exploited by shallow tube wells. The lower aquifer is composed of brown, altered, medium to coarse grained sands of greater thickness than those in the upper aquifer. Characteristically, the aquiludes of clay silt are thin. This aquifer is exploited through deep tube wells. especially between Haluaghat and Dhobaura.

5.2 Aquitards, Aquiludes

The use of these terms has been somewhat casual in many reports. By definition, an aquitard is a geologic formation, group of formations, or part of a formation through which virtually no water moves. Conversely, an aquilude is a saturated but poorly permeable bed, formation, or group of formations that does not yield water to a well or spring. However, an aquilude may transmit appreciable water to or from adjacent aquifers.

In the Kangsha River Basin aquifers, an aquitard would be composed of a thick layer of very plastic clay, the presence of which has not been precisely determined. Those clay beds to which knowledge has been acquired through lithologic sampling appears to be composed predominantly of varying admixtures of clay and silt, and should therefore be termed aquiludes since they are capable of transmitting water.

The rate at which the aquiludes transmits water to an underlying formation (aquifer) is a function of their composition. The percolation (transmission) rate increases proportionately to the grain size and will therefore be greater in aquiludes containing high proportions of silt. The amount of water the aquiludes can transmit to underlying formations is a function of thickness and grain size combined. Thick aquiludes with high proportions of clay may hold considerable amounts of water in storage, but are unable to release more than a small percentage of it due to high specific retention resulting from the fine grained texture of the formation. The reverse becomes true when the aquiludes contain high percentages of silt. Where the aquiludes are thin, the volume of water they store is reduced proportionately; but the time required for water to percolate through them is also diminished.

These principles have major significance, since they not only effect recharge to the aquifers but also impact on the overall scheme of groundwater development planning.

5.3 Specific Yield

5.3.1 Old Brahmaputra Floodplain Aquifer

The *specific yield* of an aquifer is the ratio of the water which will drain freely from the material to the total volume of the formation and generally expressed in percent of the total formation. High porosity does not necessarily indicate a productive aquifer, since much of the water may be retained in small pore spaces under capillary tension as the material is dewatered. Specific yield of a fine-grained aquifer will be small whereas coarse-grained material will yield a greater amount of its contained water. The specific yield for different lithologic units are given in Table 6.6.

Since specific yield is related to grain size and pore space, the stratigraphic complexity, variable grain size and pore space of the aquifer sequences must be considered. The term "specific yield" is only applicable to unconfined or semi-confined (leaky) aquifers. Under confined conditions, the aquifer is not de-watered, rather water is released from storage by compression of the aquifer.

The medium to coarse sands containing little or no clay (unaltered) have the highest specific yield and conversely the fine sands, silts and clays have the lowest. Porosities of unconsolidated sediments are highest in clays and lowest in the coarse sediments. The higher the porosity, the greater the specific retention and lower the specific yield. These characteristics play an important role in the Kangsha River Basin aquifers.

The upper aquifer contains high proportions of very fine to fine sands interbedded with fine to medium sands. Only the medium sands are screenable. The constantly changing fluvial environment in which these sediments were deposited has resulted in frequent reversals of normal upward fining sandy sequences. It is quite common to encounter coarser sandy beds on top of unscreenable fine sands or rapid lateral phase changes from medium to fine sands. Semi-impervious lenses of clay are also common.

The lower aquifer, separated from the upper by an aquilude composed of clay and silty clay, comprises a sequence of sandy sediments. It basically differs from the upper aquifer only in the sense that the sediments are predominantly coarser grained and the aquifer as a whole is thicker. Coarse and medium grained sands are complexly interbedded with fine to medium sands, forming a series of lens-shaped deposits.

Beds of fine to very fine sand are present, but much less common than in the upper aquifer. The frequency of three to six metre thick laterally discontinuous clay lenses parallels that of the upper aquifer.

Since higher specific yields are found in the coarser sediments where pore spaces are larger, it is clear the specific yield of the aquifers is depth dependent. The overall coarser grained sediments in the lower aquifer will have a higher specific yield than the finer grained sands in the upper aquifer.

Specific yield from an aquifer is most often determined from pumping test or regional water level responses. The complex composition of the aquifers, however, would require pumping tests to be continuous for a number of days in order to determine delayed release from storage.

5.3.2 Piedmont Aquifer

Few estimates are available with respect to specific yields from the Piedmont aquifers; at present only from the upper aquifer at an elevation of 10 metres below the surface. In the northwest corner of Mymensingh district, the specific yields are less than 3 percent, increasing southward to between four and five percent around Haluaghat. Since both the upper and lower aquifer in the Piedmont unit consist of medium to coarse sands, it is reasonable to assume that the specific yield is less depth-dependent in this sequence than in the Brahmaputra unit.

5.4 Permeability

By definition, permeability is the capacity of a porous media for transmitting fluid. It is expressed in metres per day. It is directly related to the porosity of the sediments; thus coarse grained, unaltered sands have a greater permeability than fine sands and silt or clay. Altered sands contain greater percentages of clay minerals which tend to clog the pores, thus effectively reducing the hydraulic conductivity of the media. The brown sands of the lower aquifer in the Brahmaputra unit are weathered and contain fractions of clay minerals. Chlorite, resulting from the breakdown of mafic minerals in the sands, is probably a major constituent. Kaolinite, from the breakdown

2a2

of potash feldspar grains, may also be present. Large percentages of mica such as biotite, muscovite or sericite also tend to reduce pore space since they are highly compressible and subject to rapid alteration.

Permeability in the lower aquifer has been determined for parts of the Kangsha River Basin. They range from 20 to 30 metres in Haluaghat and Kalmakanda thanas to more than 70 metres per day in Phulphur and Purbadhala thanas. The higher hydraulic conductivity in the latter two thanas may possibly be a reflection of the presence of ancient river channel deposits laid down by the Old Brahmaputra River.

The permeability of the upper aquifer has been estimated to range between 10 and 20 metres per day, reflecting the overall finer-grained composition of the sediments in this sequence. It may locally be higher, depending on the proportion of coarse grained sand present.

5.5 Transmissivitiy

By definition, transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. In the international system, it is expressed in cubic metres per day through a vertical section of an aquifer one metre wide and extending the full saturated height of an aquifer under a hydraulic gradient of 1 (100 percent) or in square metres per day.

The transmissivity (T) and storage coefficients (S) are two of the key parameters in well hydraulics. Transmissivity signifies how much water will move through a formation, and the coefficient of storage indicates how much water can be removed by pumping. Both hydraulic properties are determined from aquifer pumping tests and when known, a number of other significant predictions can be made.

In Bangladesh, thousands of pumping tests have been carried out over the past two decades. Considerable knowledge of the hydraulic properties of the aquifers has been gained from these. In most instances, the duration of the pumping tests has been too short to determine the true transmissivity. Other problems which seriously influence the pumping tests are partial penetration; that is, the well does not completely penetrate the full thickness of the aquifer. In the Old Brahmaputra aquifer sequences the effects of layering and leakage also gives rise to errors in the interpretation of observation well data. Thus a pumping test carried out in the lower aquifer is influenced by vertical leakage or infiltration from the overlying clay aquilude and the fine sands composing the upper aquifer.

Rapid horizontal changes in the geologic character of the aquifer material created by the depositional process also severely influences the flow of water towards a pumping well. The sudden changes in grain size and lithology within distances of a few hundred metres from a pumping well results in variable flow rates to the well and thus changes in the transmissivity. The effect is frequently a delayed response resulting from slower release of water from the finer grained sediments, where hydraulic conductivity is lower.

In spite of the difficulties encountered in obtaining adequate data from short pumping tests, average transmissivities for the thanas have been established. Table 5.2 shows the transmissivity values for each thana. It should here be borne in mind that only four of the thanas lies wholly within the Kangsha River Basin (See fig. 2).

The higher transmissivities probably reflect the presence of higher hydraulic conductivities in the ancient Brahmaputra river courses. The quoted tranmissivities are average for the thanas and consider vertical leakage from overlying aquiludes, since the pumping tests were conducted from wells screened in the lower aquifer. Locally, higher or lower values may be encountered depending on both vertical and horizontal variations in the lithology.

High transmissivities may be expected in beds of coarse-grained gravel and sand, such as is present just northwest of the town of Netrakona, (Fig. 5, example "C") even though the average transmissivity for the thana is only 1500 m^2/day. The coarse gravels represent river bed deposits.

Lower transmissivities in the range of 600 to 700 m^2/day, present in the eastern part of the Basin in the thanas of Kalmakanda and Barhatta, are due to strong stratification of the lower aquifer. On figure 5, example "D" shows the tightly interbedded composition of the aquifer. The narrow beds of coarse and medium sands results in low transmissivities. The aquilude/aquitard above the lower aquifer is thick, (32 m) and the upper aquifer is composed of non-screenable fine and very fine sand. In example "B" in figure 5, the upper and lower aquifer are contiguous, with no aquilude or aquitard separating them. Coarse sands are absent and lower tranmissivity is to be expected.

Transmissivities in the upper aquifer have not been studied in detail and are generally estimated.

Given the presence of the clay/silt surface aquilude and the low hydraulic conductivity of the very fine to fine sands overlying the fine to medium sands forming the screenable part of the aquifer, the values would on average be considerably less than those found in the lower aquifer. Sustainable well yields of 20 to 30 litres per second from turbine pump-equipped wells in the upper aquifer indicate that good transmissivities are present.

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Table 5.2

Transmissibilities by Thana in the Kangsha Basin

Thana	Percent of Thana in Basin	Average Transmissibilities m^2/Day
Sribardi	6.53	1500
Jhenaigati	86.08	1500
Sherpur	25.54	3000
Phulphur	27.57	1500
Nakhla	38.08	2000
Purbadhala	82.63	1500
Netrakona	41.50	1500
Barhatta	5.12	700
Kalmakanda	36.19	600
Nalitabari	100	1000
Haluaghat	100	1500
Dhobaura	100	700
Durgapur	100	1500

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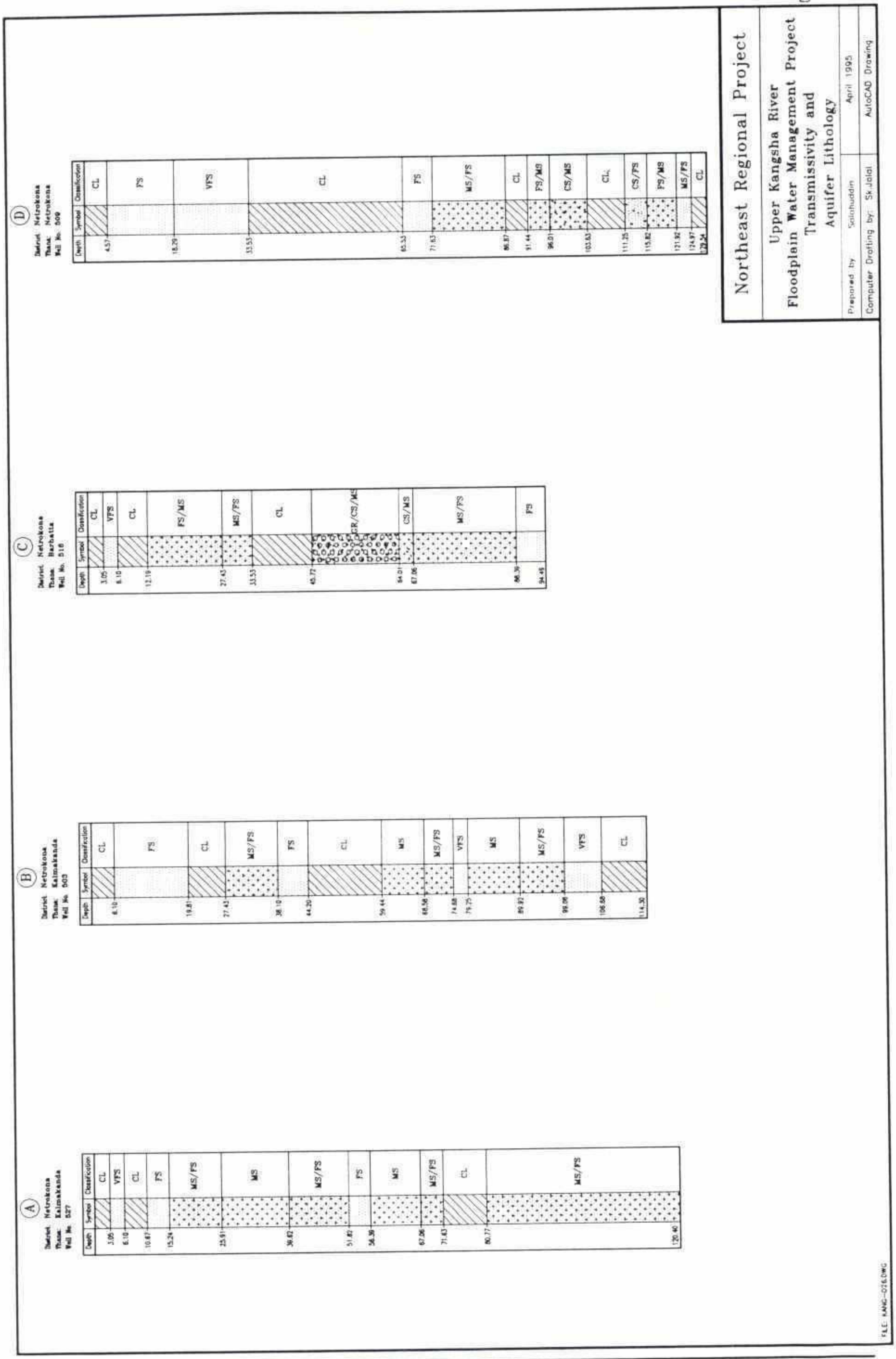
Figure 5


Northeast Regional Project
Upper Kangsha River
Floodplain Water Management Project
Transmissivity and
Aquifer Lithology
Prepared by Salahuddin
April 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
A
District: Netrokona
Thana: Kalmakanda
Well No. 527
B
District: Netrokona
Thana: Kalmakanda
Well No. 503
C
District: Netrokona
Thana: Barhatta
Well No. 518
D
District: Netrokona
Thana: Netrokona
Well No. 509
Depth
Symbol
Classification

6. GROUNDWATER RESOURCES ASSESSMENT

6.1 Objective

The objective of the study is to integrate the groundwater potential with the overall upper Kangsha River Water Management Plan for optimal, equitable and sustainable development with a view to enhance food production and maintain the natural environment.

Appraisal of the resources in the Upper Kangsha Basin is based primarily on databases generated during the National Water Plan (NWP-II, 1991) which is undergoing updating using models and recent data. The primary sources of data related to Hydrology, Hydrogeology, Agronomy and Soil are WARPO, BWDB, SRDI, BADC, BBS, DPHE, BMD, and NMIDP.

The approach is conceptually similar to the one developed in MPO during its two Phases, NWP-I, 1987 and NWP-II, 1991, which integrated aspects of earlier works and at the same time developed a new modelling technique compatible with others in Bangladesh.

Groundwater appraisal in the Kangsha River Basin covers the following;

- groundwater resources availability;
- present trend of its agricultural, domestic and industrial use;
- groundwater potential for future development options;
- groundwater development and environmental impacts;
- interventions in groundwater development.

6.2 Groundwater Models

Groundwater models are based on a number of simplifying assumptions related to geology, hydrogeology and water balances. It is always presented in the form of a set of mathematical equations, which in this case is Darcy's equation together with continuity concepts. The solution explains the behaviour of the system in terms of water level fluctuations and water balance components. Reappraisal of the groundwater estimates and sensitivity analysis has been done using a set of models which are conceptually similar to those listed below, developed in MPO;

- multi-cell groundwater model;
- recharge model;
- depth-storage model;
- Resource potential model.

6.2.1 Multi-cell Finite Difference Groundwater model

The model simulates groundwater behaviour in eight special areas in Bangladesh monitored by WARPO (MPO) in relation with the surface water environment. The objective of modelling in an area is to define those parameters which regulate the processes of recharge and discharge in the groundwater aquifers.

In the majority of the Kangsha Basin the modelled aquifer system is assumed to consist of a single aquifer of variable thickness. The hydrological characteristics of the aquifer and semi-confining layer shows significant variation. Since the water balance of the upper aquifer, which overlies the lower aquifer, is the main regulator of natural recharge processes in the Kangsha

Basin and elsewhere in Bangladesh, the model was constructed to simulate the behaviour in a four-layer system as follows:

- soil surface;
- soil profile;
- semi-pervious layers;
- upper composite and lower main aquifer.

A large number of parameters and data are involved in the model:

A) Physical parameters

- land type distribution;
- soil characteristics within each layer;
- surface storage or bund height.

B) Hydrological parameters

- rainfall;
- depth and duration of flood on each land phases.

C) Parameters related to agricultural practices

- reference evapotranspiration;
- crop coefficient;
- cropping pattern related to soil and land type;
- crop rooting depth;
- cultivable and gross area;
- crop statistics.

D) Hydrogeological parameters

- infiltration rate;
- soil specific deep percolation rate;
- vertical permeability;
- horizontal permeability;
- specific yield;
- storage co-efficient.

To model an aquifer, the area is sub-divided in to a regular square mesh of polygon elements of different shape and size. Surface and subsurface detail data, as described above, are used for each of the polygons and calibrated for groundwater table, piezometric levels and actual rate of abstraction.

Special groundwater study area in Phulpur

Groundwater Recharge estimates in the Upper Kangsha Basin are based on detailed calibration and verification of a "Multi-cell finite difference groundwater model" on a special study area at Phulpur and Haluaghat (Figure-6) during NWP-I and NWP-II. This area best represents the Physiographic and Geologic environment of the major part of the Kangsha River Basin.

The study area covers approximately 100 km^2 which is known as level-II area. Inside this, a smaller, hydraulically controlled area of 9 km^2 is designated as Level-III area. Detailed investigations were made through farm surveys on hydrology, agronomy and hydrogeology in the level-III area, while secondary data from various sources were used for the Level-II area. Rainfall was observed at five sites. Water level fluctuations and head gradients between the water Table and water level in the pumped aquifer were observed in 12 location using a pair of piezometric wells (Figure-6). Bore logs from these sites constitute the basis for lithologic descriptions of the modelled area. Climatological data was taken from the BMD station in Netrokona and Mymensingh.

The model simulation and groundwater level monitoring in the study area confirms that the upper soil profile is the main regulator of recharge processes during the rainy season from May through October. Because of discontinuous, low permeable clay/silt lenses in the underlying strata, there is considerable hydraulic head difference between the groundwater levels in the upper and lower pumped aquifer during the irrigation periods. This happens when the rate of abstraction is higher than the rate of leakage (recharge) through the overlying clay/silt layer(s) when pumping from the lower aquifer (Figure 7).

Groundwater model calibration (MPO, 1987,1991) in the Phulpur special study area generated an average relation between soil type and rate of infiltration shown in the Table 6.1. These values, commonly referred to as DP3 in MPO, were used to compute the Potential Recharge in the Basin. Given that most of the area is under paddy rice cultivation during both the aman and boro/aus seasons, the 'wet' values are governing the recharge processes.

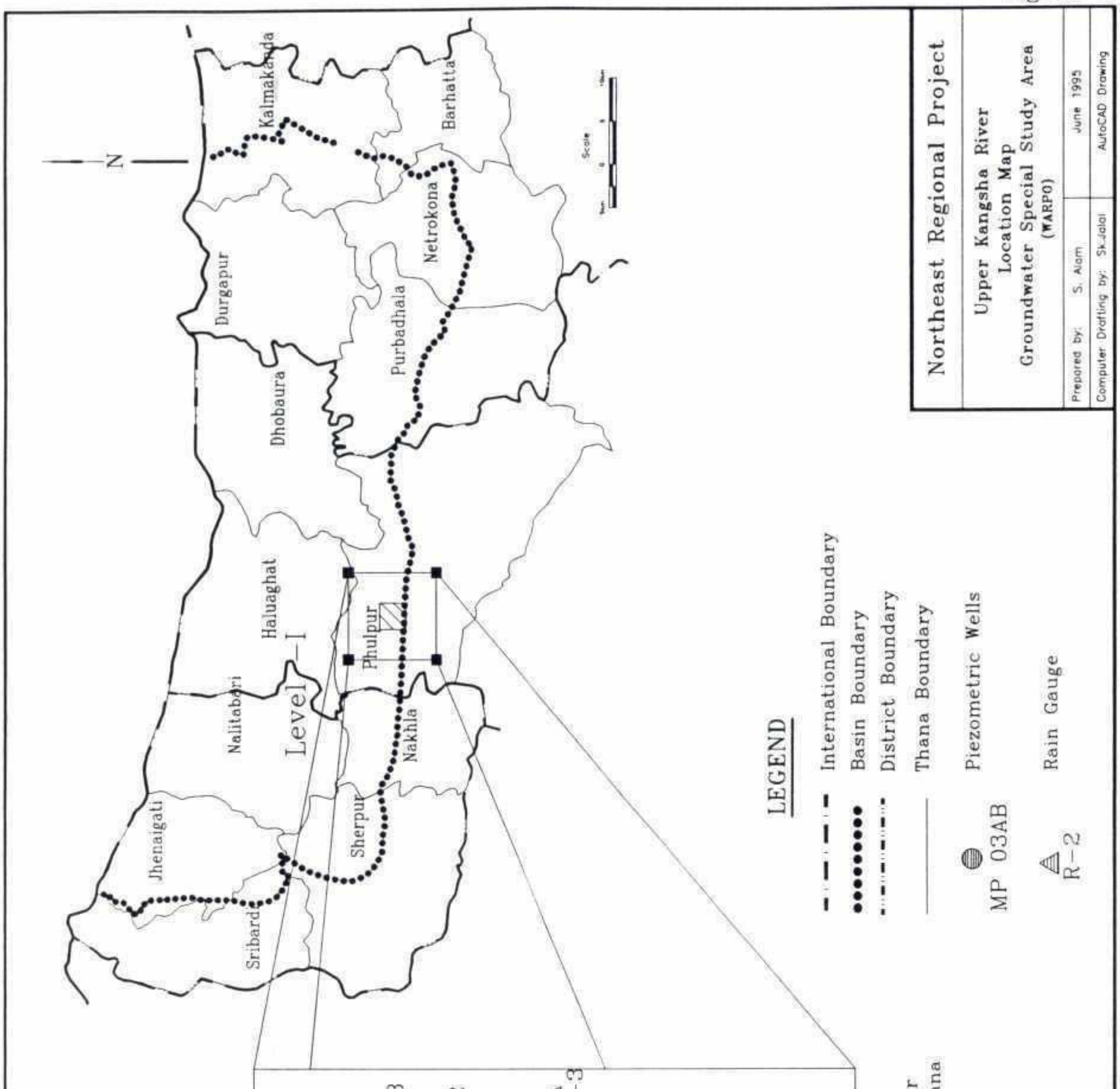
Table 6.1

Soil Specific Deep Percolation Rate

Soil Texture	Vertical Permeability (m/d)	
	Wet	Dry
Fine Sandy Loam	0.010	0.050
Silty Loam	0.006	0.020
Loam	0.010	0.030
Silty Clay Loam	0.006	0.030
Clay Loam	0.004	0.010
Silty Clay	0.002	0.010
Clay	0.002	0.010
Sandy Clay Loam	0.006	0.030

Source : WARPO, 1991

Figure 6



Northeast Regional Project
Upper Kangsha River
Location Map
Groundwater Special Study Area
(WARPO)
Prepared by: S. Alam
June 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
N
Scale
Kalmakanda
Barhatta
Durgapur
Netrokona
Purbadhala
Dhobaura
Haluaghat
Phulpur
Nalitabari
Level -I
Nakhla
Sherpur
Jhenaigati
Sribardi
LEGEND
International Boundary
Basin Boundary
District Boundary
Thana Boundary
MP 03AB
Piezometric Wells
R-2
Rain Gauge
MP 01AB
R-1
Level -II
MP 02AB
MP 12AB
R-2
MP 08AB
Level-III
R-5
MP 11AB
MP 09AB
MP 03AB
R-3
MP 10AB
MP 04AB
MP 07AB
MP 05AB
MP 06AB
R-4
Note: Groundwater model calibration parameter in level III & level II extrapaleted to thana level analysis (level I)
FILE: KANG-055.DWG

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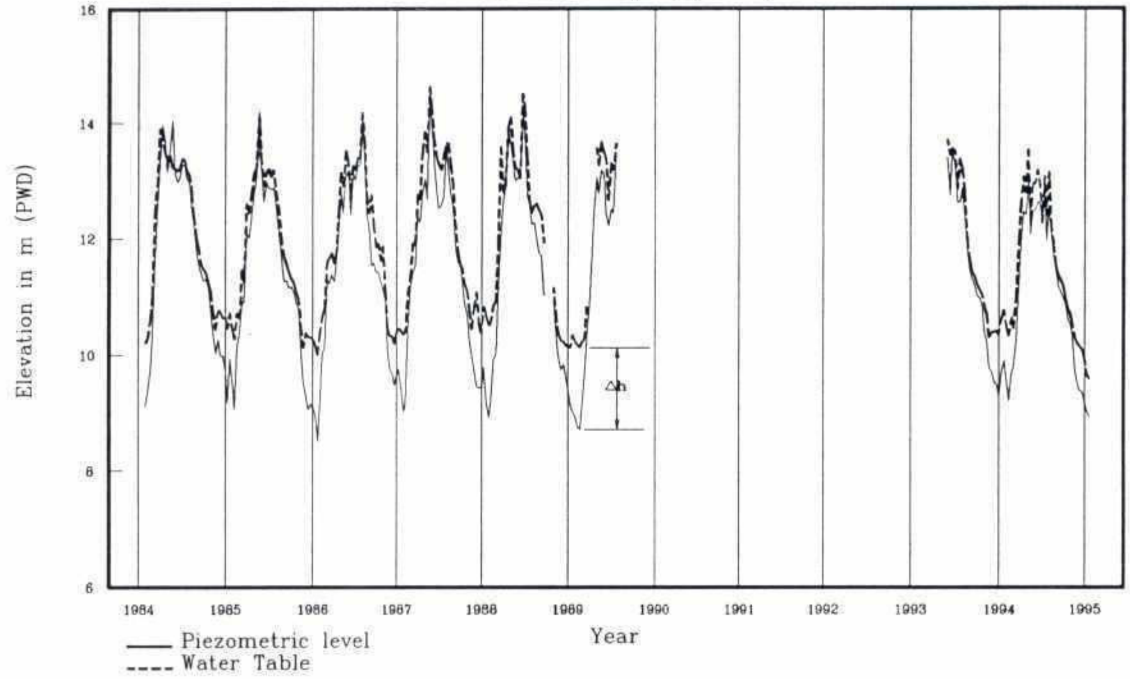
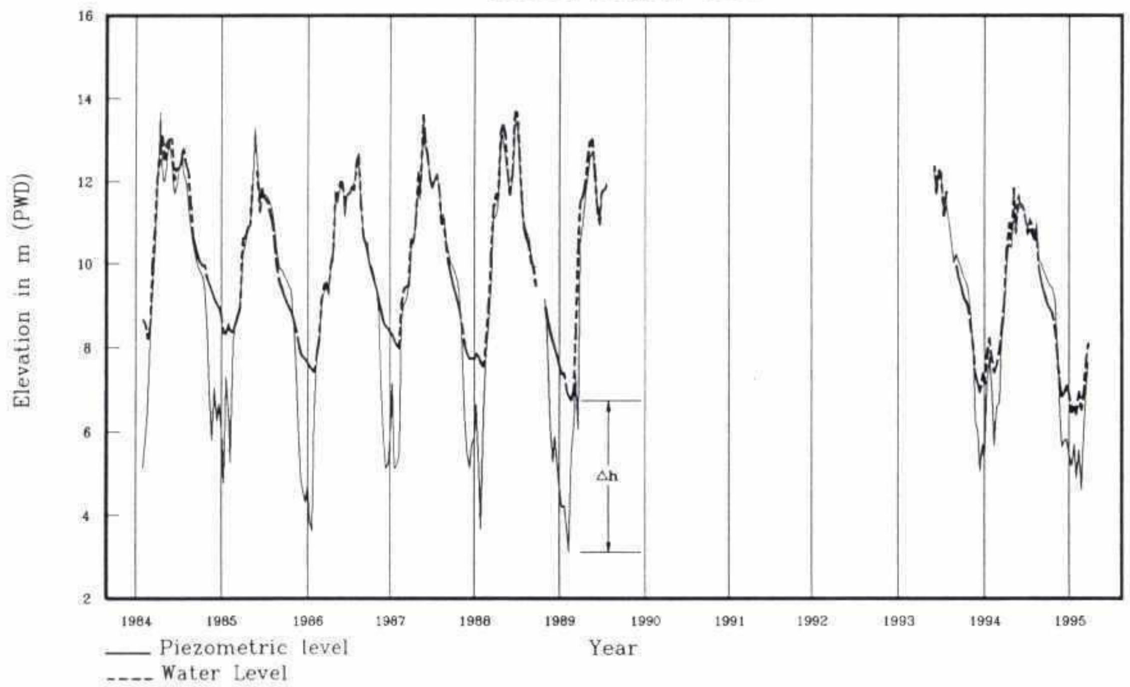
Figure 7

Groundwater Level Hydrograph
MP01AB, Phulpur, (WARPO)



Groundwater Level Hydrograph
MP12AB, Phulpur, WARPO



Northeast Regional Project	
Groundwater Hydrograph (Groundwater Special Study Area) (Phulpur, WARPO)	
Prepared by: S. Alam	September 1995
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: KANG-080.DWG

6.2.2 Recharge Model

The observed fluctuations of groundwater levels in the upper and lower aquifer in the area and model simulation (WARPO, 1991) justifies the use of a recharge model in the Basin, which assumes the infiltration and deep percolation rate of the upper soil profile to be the main regulator in the natural recharge processes, while return flows of irrigation water are considered at the later stage of computation.

The model used for recharge computation was identical to the model used for the special study area, except that in the recharge model the aquifers were assumed to have sufficient capacity to store all recharges passing through the land surface and underlying clay/silt aquiludes.

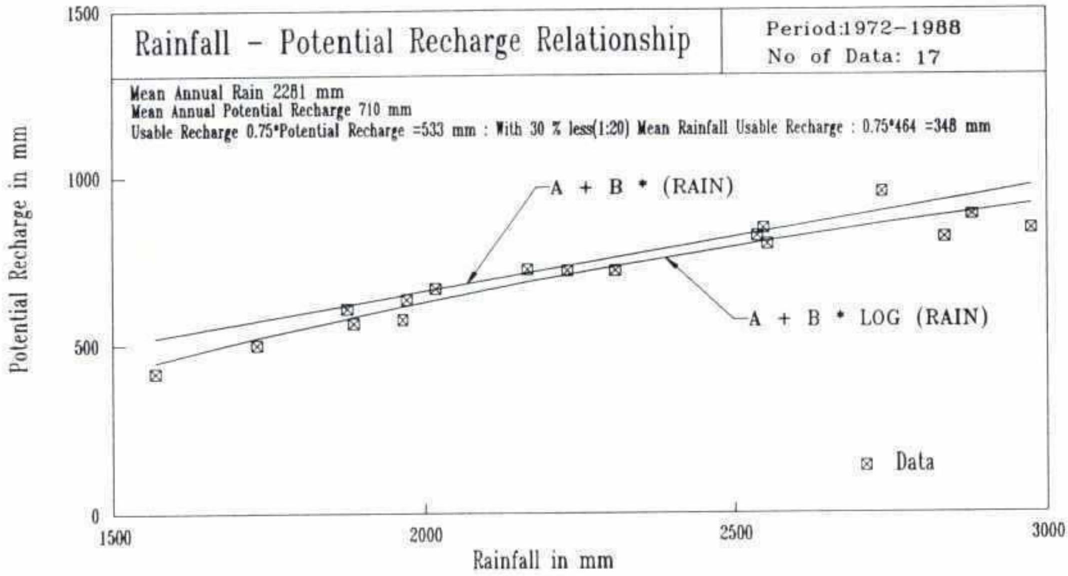
The analysis with this model showed that the large percentage of high and medium land (F0 through F2 land) and large annual rainfall in the area are both significant parameters influencing the annual recharge in Upper Kangsha Basin.

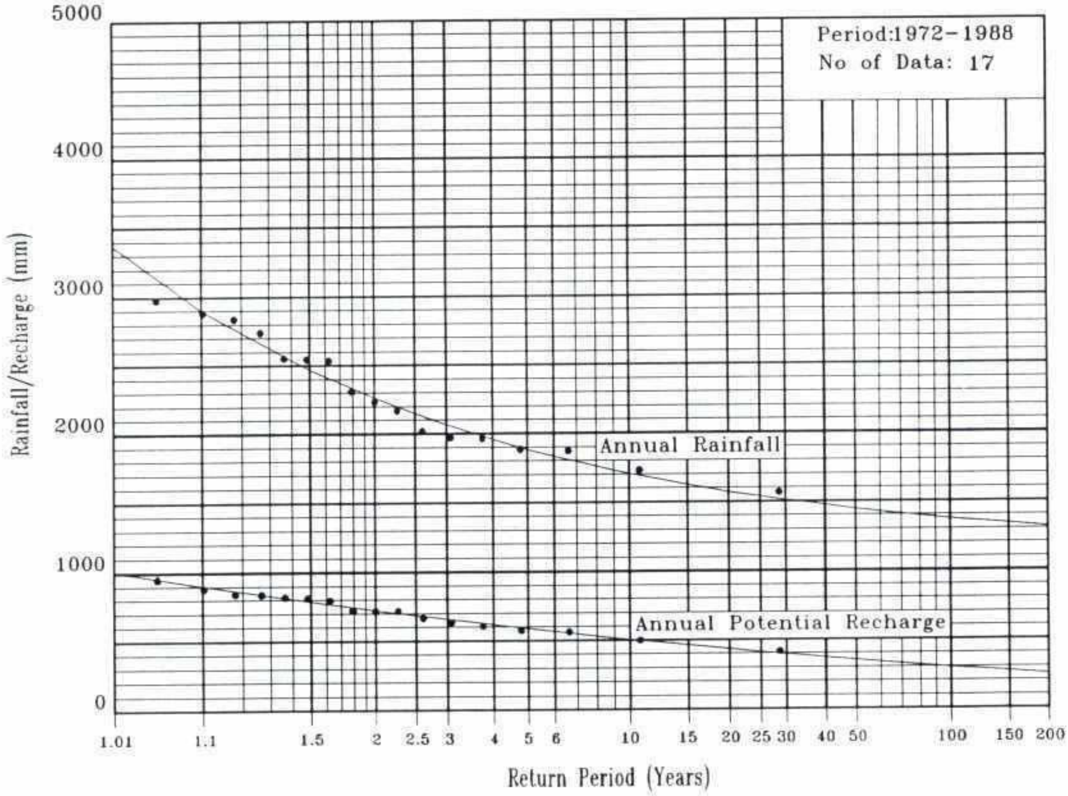
There are three major findings on the variability of Potential Recharge:

- the relation between annual Potential Recharge and Rainfall;
- change in land use may change Potential Recharge;
- flood control and drainage (FCD) development will reduce Potential Recharge estimates since this form of intervention reduces the depth of flooding.

In order to estimate the annual potential recharge for 1972 through 1989, the model was run using representative parameters related to hydrology, hydrogeology, agriculture etc. for each thana, as described in paragraph 6.2.1.

Rainfall and Recharge
Recharge modelling showed that the annual potential recharge is highly correlated with annual rainfall (Figure-8). Given the correlation between rainfall and potential recharge available for the following dry season, areas where groundwater withdrawal is likely to be affected by droughts can be forecast six month in advance. A sample of 17 years annual recharge simulation for Sherpur thana and monthly recharge distribution are given in the Table 6.2, Table 6.3 and Table 6.4.





FILE: KANG-020.DWG

Northeast Regional Project	
Upper Kangsha River Rainfall - Potential Recharge Relationship	
Thana: Sherpur, District: Sherpur	
Prepared by: S.Alam	May 1995
Computer Drafting by: Jalal	AutoCAD Drawing

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Table 6.2

Annual Rainfall and Recharge for Thana Sherpur, Sherpur

Year	Annual Recharge (mm)	Annual Rainfall (mm)
1972-73	499	1731
1973-74	884	2881
1974-75	952	2739
1975-76	416	1568
1976-77	719	2233
1977-78	845	2546
1978-79	607	1873
1979-80	563	1883
1980-81	575	1964
1981-82	666	2017
1982-83	723	2167
1983-84	710	2409
1984-85	822	2536
1985-86	633	1971
1986-87	797	2552
1987-88	816	2839
1988-89	840	2975

Source: WARPO, 1991

Table 6.3

Rainfall and Recharge Distribution (1983-1984), Sherpur

Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Rainfall (mm)											
8	66	262	173	428	488	424	434	100	17	6	2
Recharge (mm)											
1	1	5	45	108	166	161	149	65	15	1	1

Annual Rainfall and Recharge Relationship for Sherpur thana can be also represented by the following equation which is based on the recharge simulation of 17 year as listed above;

$$Annual\ \ Recharge = A + B * LOG * (Annual\ \ Rain\ )$$

A= -4924.82
B= 1681.72

The relation also shows that Recharge is reduced to zero if rainfall with the same distribution is less then 848 mm/year. Correlation coefficient is

R= 0.957

Frequency analysis of annual rainfall and recharge in Sherpur thana shows the following reduction in annual recharge.

Table 6.4

Sensitivity of Recharge with Rainfall in Thana Sherpur, Sherpur

Return Period	Annual Rainfall in mm	Annual Recharge in mm	Percent of mean Rainfall
Mean	2286	710	31
1 in 5	1900	600	26
1 in 10	1700	500	22
1 in 20	1580	430	19

The mean annual Potential Recharge for all the thanas in the Basin is summarised in Table 7.1. Equivalent depth of these recharges over the entire Basin is about 647 mm. A large value (> 850 mm) occurs in the northeast sandy soil areas of Dhuboura, Kalmakanda, Barhatta, Durgapur, Purbadhala, and Netrokona; smaller recharges (500-650 mm) occurs in Sherpur and Nakla in the southwest.

Dependable groundwater availability was taken as the mean value of potential recharge represented by the value of potential recharge that occurs with a return period of 1 year in 2.33 years. Groundwater availability with 1 in 5 year dependability was also estimated from probability analysis, and is 16% less than the availability with 1 in 2.33 year dependability.

Planning with the 1 in 5 year low available recharges would mean that average potential irrigation will be 10 to 20 percent below the mean value and expansion of crop production aided by groundwater irrigation would not be possible for one year out of four years.

Land Use and Recharge
Potential Recharge is also dependent upon future development in each area. A periodic reassessment is therefore required, based upon updated crop statistics and changes in land use.

Flood Control and Recharge in Kangsha
The effect of flood control on potential recharge was evaluated using a Recharge model which simulates recharge from natural sources. In this model synthesised flood hydrographs were used to represent two basic conditions no flood control and full flood control. The hydrographs, which are shown in Figure-9, were kept constant for each of the 17 years in the simulation period. Rainfall was allowed to vary and based on rainfall records for the historical period 1972 - 1989. Monthly distribution of the potential recharge in Sherpur, with full flood control, is shown in Table 6.5.

The difference between no flood control and full flood control is not very significant for average rainfall conditions. However, rainfall and recharge curves show a distinct steepening with a marked reduction of potential recharge in a dry year. A thana with large proportion of F1 land under full flood control would contribute to reduction in the total potential recharge.

Figure-9

Schematic Flood Hydrograph

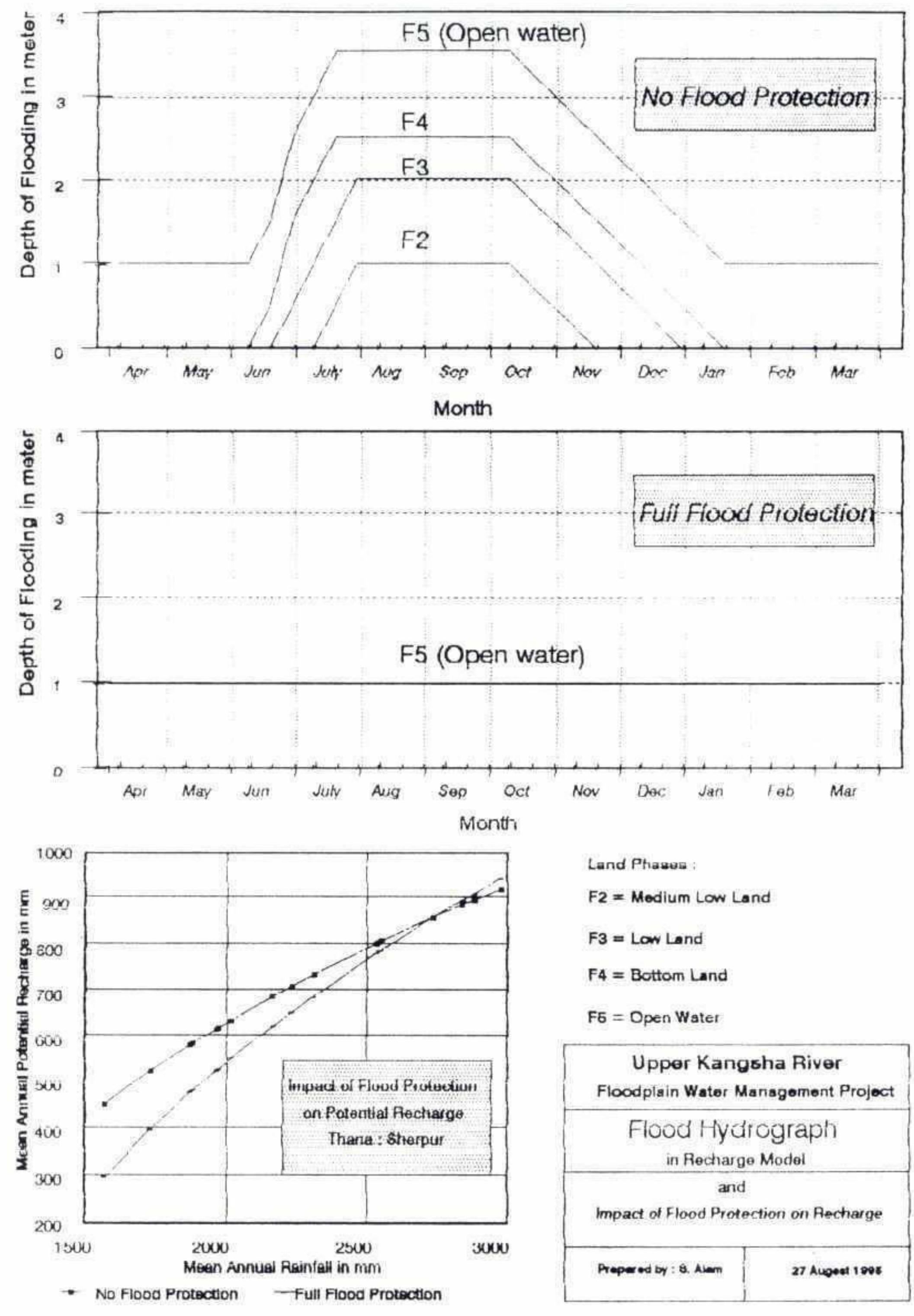

Table 6.5

Impact of Flood Control on Mean Annual Potential Recharge (mm) in Sherpur Thana

Month	M	A	M	J	J	A	S	O	N	D	J	F	Total
No Flood control	1	5	47	104	149	148	132	85	31	5	1	1	710
Flood control	1	5	47	87	121	118	108	71	24	4	1	1	589

6.2.3 Depth-Storage Model

Analysis of hydraulic and storage properties of the overlying soil strata for each thana is required for estimating the resources available to the various modes of abstraction, selection of the appropriate pump and annual abstraction costs.

Examination of a number of boreholes for the area show that:

- lithology varies considerably from borehole to borehole (see para. 5.1);
- lateral discontinuity of stratigraphic units is pronounced, giving rise to difficulty in cross sectional interpretation.

Therefore, statistical averages of borehole logs and hydrogeological data for the thana were used to compute the depth dependent storage variation for each thana, using the depth-storage model.

Lithology
For each thana, the lithologic composition of each 10 ft depth interval was derived from the well logs.

Specific yield
The lithologic units were assigned specific yield values to compute the composite specific yield for a given depth. The lithologic units used in the definition of depth-dependent specific yield and the likely range of their values are given in the Table 6.6.

Table 6.6

Lithologic Units and Specific Yield

Lithologic units	Specific-Yield (%)		
	Low	Mediu	High
Clay	1	2	3
Silt	3	5	07
Very Fine	5	8	11
Fine Sand	7	10	13
Medium Sand	10	15	20
Coarse Sand	15	20	25
Gravel	25	30	35

Source : WARPO, 1991

The composite specific yields are used to compute the net available storage, which is calculated as the difference between total storage release and natural losses from the aquifer system during the normal irrigation periods. A sample depth-storage relationship for Purbadhala thana used in the resource model is shown in Figure -10. This relationship was used to estimate the available resources to the various pumping technologies and to predict drawdown in the water level due to release from given aquifer storages.

The depth-dependent storage capacity (see para. 5.3) within the Kangsha area is quite variable; good in the southwestern and northeastern area and moderate to poor in the remainder of the Basin (Figure-11).

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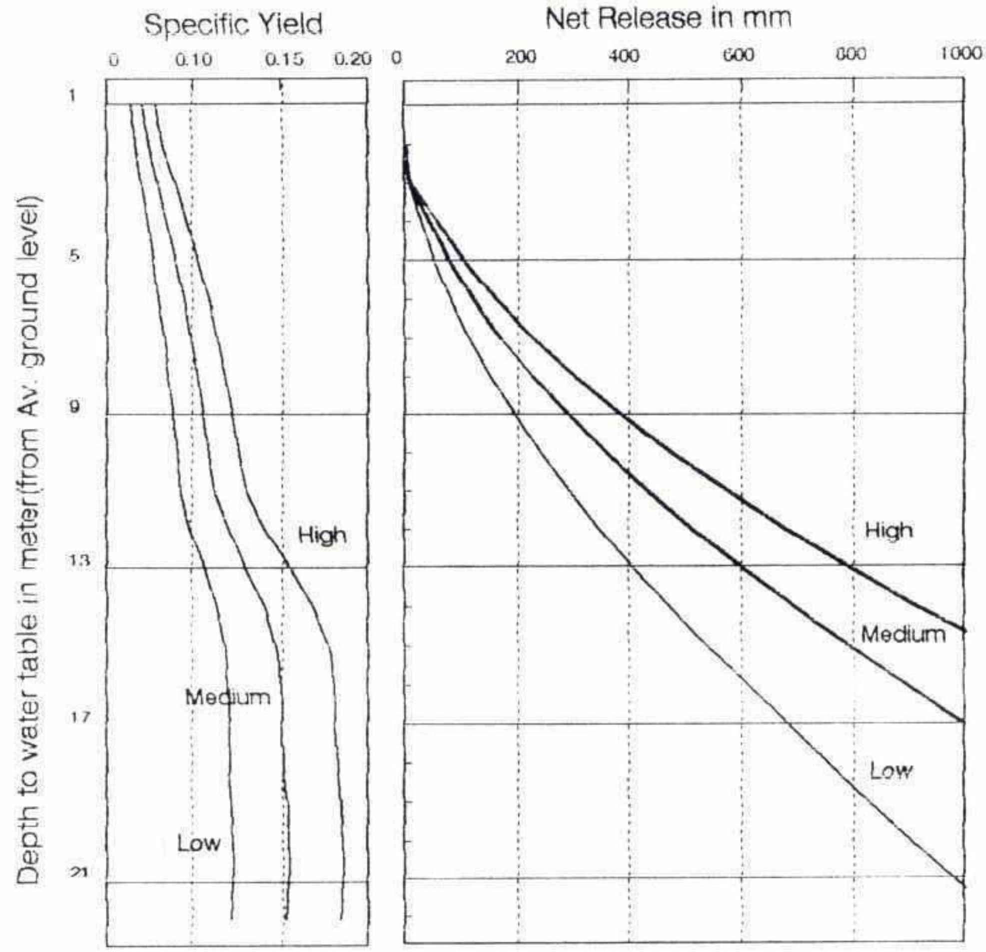
Figure-10

Depth and Net Storage Release



Thana Area : 347 km2

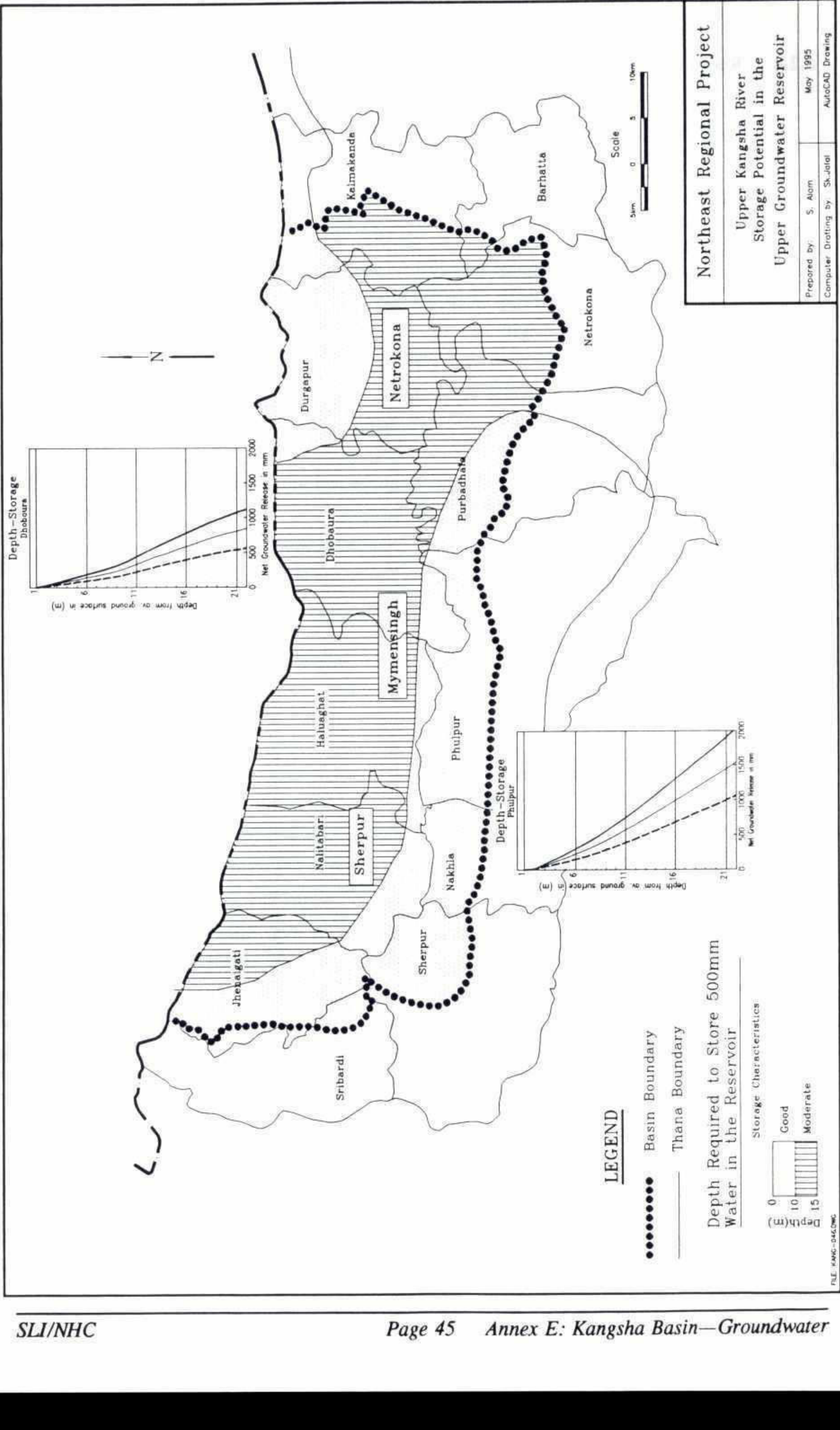
-Depth to water table prior to development (from village mound)

End of Year : 2.0 m (1 st Jan)
End of Dry Season : 2.90 m (1st May)

-Average ground level below village mound : 1.52 m

Upper Kangsha River *Floodplain Water Management Project*	
Thana : Purbadhala	
District : Netrokona	
Prepared by : S. Alam	15 August 1995

Figure 11


Northeast Regional Project
Upper Kangsha River
Storage Potential in the
Upper Groundwater Reservoir
Prepared by: S. Alam
May 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
Scale
5km 0 5 10km
N
LEGEND
Basin Boundary
Thana Boundary
Depth Required to Store 500mm
Water in the Reservoir
Storage Characteristics
Good
Moderate
Depth(m)
0
10
15
Depth-Storage
Dhobaura
Depth-Storage
Phulpur
Depth from av. ground surface in (m)
Net Groundwater Release in mm
Netrokona
Mymensingh
Sherpur
Kalmakanda
Barhatta
Durgapur
Netrokona
Purbadhala
Dhobaura
Haluaghat
Phulpur
Nalitabari
Nakhla
Sherpur
Jhenaigati
Sribardi

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6.2.4 Resource Potential Model

The model is used to assess the groundwater availability for STW, DSSTW and DTW technologies. The development limits to safeguard the water supply for current HTWs or the limit for the future modified HTW technology where also tested.

The groundwater development potential available to different technologies is constrained by the following criteria:

- critical pumping depths for various tubewell technologies;
- amount of usable recharge;
- depth dependent storage capacity of the upper aquifer;
- transmissivity;
- thickness of the aquiludes and their resistance to leakage.

6.2.5 Assumptions in Groundwater Appraisal

A number of assumptions are involved in the Resources Potential Model:

- water table in the upper aquifer and piezometric level in the pumped aquifer are horizontal over a thana;

- abstraction from the aquifer system is evenly distributed and aquifer characteristics do not vary over the area;

- flood phases are random and evenly distributed over the area;

- net abstraction = net release from aquifer storage = gross abstraction minus return flow.

Other assumptions related to the natural losses are:

- water levels and the natural losses under average conditions (before the irrigation starts) are considered;

- natural losses between the beginning and end of the irrigation season are considered to be inversely related to lowering of the water table;

- prior to irrigation development, natural losses during the normal irrigation season are equivalent to the storage release over the period. If the groundwater level is known at the beginning and end of the season, the storage released from the aquifers during the season can be computed;

- abstraction of groundwater by pumping from the aquifers will result in further reduction of the groundwater level, but decrease natural losses through base flows to rivers and streams and evaporation by reversal of the normal upward capillary action;

- a proportion of the abstracted irrigation water returns to the aquifer system through reinfiltration. In previous studies, the amount has been estimated to be between 20 % and 30%. In this study, a value of 20 % was adopted.

7.0 GROUNDWATER RESOURCES

7.1 Potential Recharge

Potential recharge is defined as the mean annual volume of surface water that can reach an infinite groundwater reservoir, limited only by the rate at which upper soil layers and sub-surface silt and clay aquiludes allow the water to infiltrate and percolate. It is a theoretical upper limit of recharge. The potential recharge estimate for the Upper Kangsha Basin is approximately **1495 Mm^3** or 647 mm if spread over the entire Basin area of 2310 km^2. Thana estimates of Potential Recharge are summarised in the Table 7.1 .

Table 7.1

Potential Recharge in Kangsha Basin

Thana	Potential Recharge in mm
Sribardi	663
Jhinaighati	523
Sherpur	710
Nalitabari	500
Nakla	675
Haluaghat	550
Phulpur	800
Durgapur	600
Duboura	725
Kalmakanda	729
Purbadhala	800
Netrokona	792
Barhatta	933

The weighted average over the Basin is, therefore, 647 mm. The figures reflect the difference in annual precipitation within the Basin and the potential recharge limitations resulting from different land classifications and infiltration rates of the soil and clay/silt aquiludes overlying the aquifers.

7.2 Usable Recharge

Seventy-five percent of the Potential recharge is designated "Usable Recharge" leaving 25 percent for uncertainties and errors involved in the model simulation and data collection. If the development limit of Usable recharge is not exceeded, and given average rain and flood conditions, the aquifer is replenished every year; thus keeping equilibrium between recharge and discharge conditions in the aquifer. Usable Recharge in the Kangsha Basin is 1121 Mm^3, equivalent to 485 mm if spread over the entire Basin.

7.3 Availability of Groundwater Recharge

The availability of the usable recharge to various pumping technologies is constrained by several factors:

Pump and well Technology
The main constraints for suction mode technology as used by STWs and DSSTWs is the maximum allowable or operational depth to pumping level. The depth was set to 7.0 m for STWs and 9.0 m for DSSTWs, assuming a 2.0 m deep pit for the latter. This is an average setting value and should be seen in the context of land classification (F0 through F3) and the efficiency of the pumping equipment. The total resource available to these two options is therefore a technology imposed limitation on exploitation of the upper aquifer, incapable of taking advantage of the full usable recharge.

For DTWs using force mode technology (turbine or submergible pumps) no lift constraints exists, but limits are based on a general setting of the pump intake at 20 m below ground surface (with well screens set in the lower aquifer). However, there is no reason to exclude greater depth settings for the pump intake. These, and a few DTWs which have their screens set in the upper aquifer, are able to take advantage of the full potential recharge.

Hydraulic constraints
The drawdown from a pumping well is related directly to the transmissivity in the aquifer. Thus low transmissivities will cause high drawdown in a well unless the pumping rate is adjusted to reflect the rate of transmissivity.

A high hydraulic resistance of the clay layers (aquitards) overlying both the upper and the lower aquifer in most of the Basin can constrain the vertical downward recharge. This causes a delayed response in the reinfiltration rate of irrigation water and a slowdown of the recharge from the upper to the lower aquifer when groundwater from the latter is being abstracted.

High hydraulic resistance can cause important hydraulic head differences between the water table and the piezometric level in the aquifer. In such instances, a deeper pumping level in the wells is required, adding to the pumping cost.

While in the majority of places the resources available to DTWs of 28 l/s and 56 l/s capacity seem neither to be restricted by the pumping limit, nor by aquifer constraints, but limited only by the Potential Recharge, it is clear that mixing the two technologies in the same area will increase the strain on the upper aquifer and thus potentially further reduce the amount of available resources to the STW pumps.

In order to ensure a safe domestic water supply for the foreseeable future by the Tara pumps, (improved hand tubewells with a pumping limit of 15 m), net available resources would be restricted in a few places. The pumps, as a rule, are located within the village mounds and elevated about 1.5-2.5 metres above average ground elevations. This reduces the effective abstraction limit of the pumps.

Lithology
Descriptions of the lithology and storage capacity of the upper aquifer within the Basin are derived from BWDB and BADC data. Aquifer hydraulic and storage properties (Figure-12) in the upper layer are used to determine the type of well and pumping technology (STW, DSSTW or DTW) best suited for abstracting groundwater economically. The storage capacity in the upper reservoir is based on statistical averages of lithologies in a thana, with adjustments for the data (lithologic samples) with under- or overestimation of fines in the sample.

7.3.1 Groundwater Occurrence

Available Recharge
Available recharge is the usable recharge without any physical constraints to the various mode of pumping technology, less stored groundwater naturally lost before it can be used for irrigation. Losses deducted include base flows to rivers and streams, capillary flux and evapotranspiration.

The estimated groundwater availability varies according to the type of aquifer (Figure-13) plus hydraulic and storage properties in the upper aquifer (Figure-12).

Eastern Piedmont
In the northern part of the Kangsha Basin the gently southward sloping, Piedmont alluvial plane is sandy near the hills but becomes clayey at lower grades. Surface clays 15-25 m thick are followed by silt lenses overlaying coarse sand and clay to a depth of 50 m. The aquifer is dominantly semi-confined, with sand deposit coarsening downwards from 40 to 75 m. Significant and extensive clay layers are present from 75 m to 110 m.

The area covers all of Jhenaighat , Duabaura, Northern Haluaghat and Nalitabari. Due to a sandy soil cover, the average annual recharge is good, but only a fraction (0-20 %) and (0-30%) of the usable recharge is available to the suction mode technology of STWs and DSSTWs respectively. This is due to the thick clay layers and greater depth of groundwater. Although the STW development potential is limited, DTW potential is moderate to good because of coarser aquifer material at depth and nearly 100 percent of the potential recharge may be exploited. Available Recharge to various pumping technologies in the area is summarised in Table -7.2

Figure 12

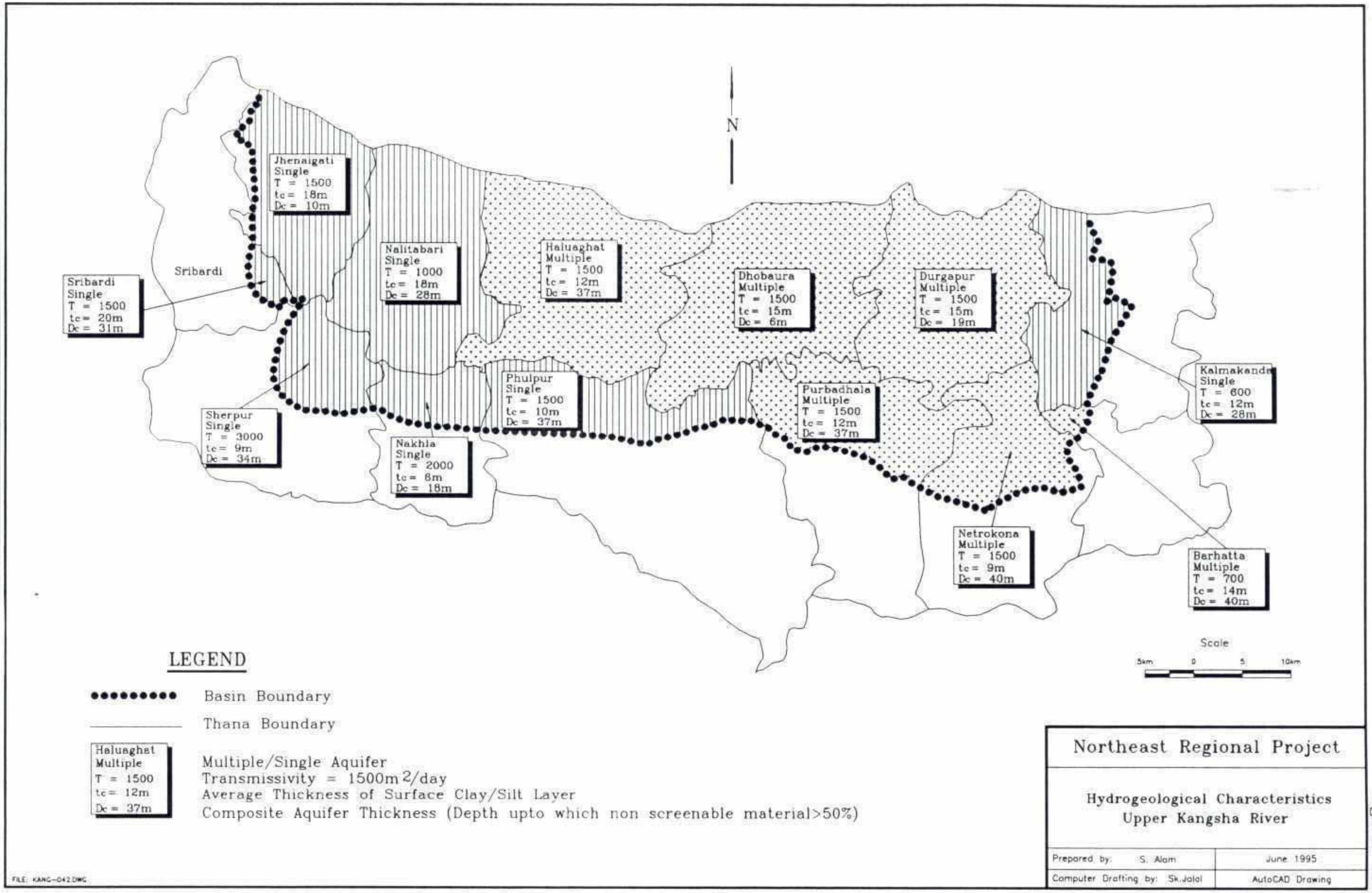
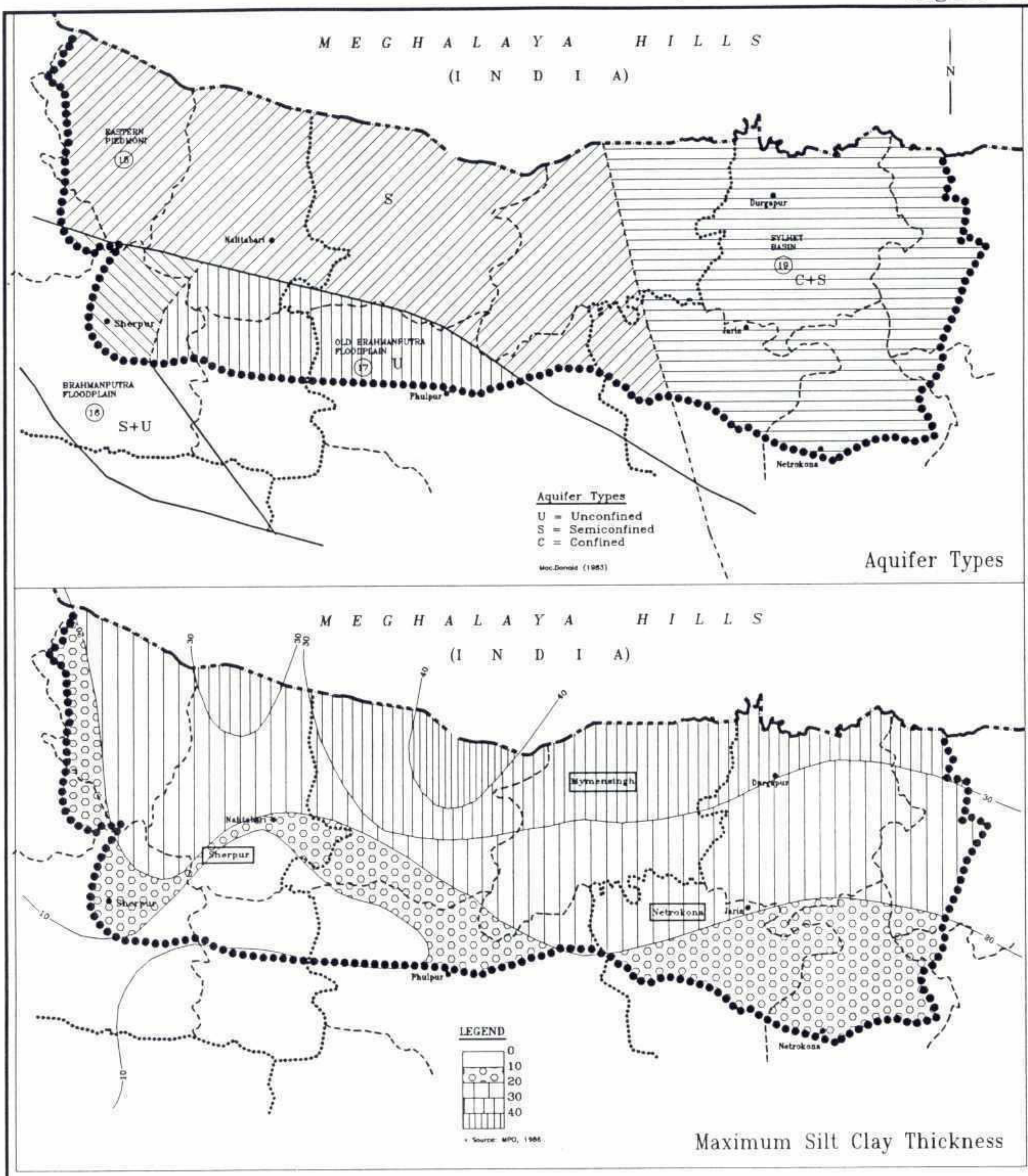

N
Jhenaigati
Single
T = 1500
tc= 18m
Dc = 10m
Sribardi
Sribardi
Single
T = 1500
tc= 20m
Dc = 31m
Nalitabari
Single
T = 1000
tc= 18m
Dc = 28m
Haluaghat
Multiple
T = 1500
tc= 12m
Dc = 37m
Dhobaura
Multiple
T = 1500
tc= 15m
Dc = 6m
Durgapur
Multiple
T = 1500
tc= 15m
Dc = 19m
Kalmakanda
Single
T = 600
tc= 12m
Dc = 28m
Sherpur
Single
T = 3000
tc= 9m
Dc = 34m
Nakhla
Single
T = 2000
tc= 6m
Dc = 18m
Phulpur
Single
T = 1500
tc= 10m
Dc = 37m
Purbadhala
Multiple
T = 1500
tc= 12m
Dc = 37m
Netrokona
Multiple
T = 1500
tc= 9m
Dc = 40m
Barhatta
Multiple
T = 700
tc= 14m
Dc = 40m
Scale
5km 0 5 10km
LEGEND
Basin Boundary
Thana Boundary
Haluaghat
Multiple
T = 1500
tc= 12m
Dc = 37m
Multiple/Single Aquifer
Transmissivity = 1500m 2/day
Average Thickness of Surface Clay/Silt Layer
Composite Aquifer Thickness (Depth upto which non screenable material>50%)
Northeast Regional Project
Hydrogeological Characteristics
Upper Kangsha River
Prepared by: S. Alam
June 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
FILE: KANG-042.DWG

Figure 13



LEGEND

- International Boundary
- Upper Kangsha Floodplain Boundary
- District Boundary
- Thana Boundary

FILE: KANG-060.DWG

Northeast Regional Project

Upper Kangsha River

Aquifer Type & Maximum Silt Clay Thickness

Prepared by: S. Alam	August 1995
Computer Drafting by: Jalal	AutoCAD Drawing

Table 7.2

Available Recharge to Different Option of Groundwater Development (Piedmont Alluvial)

Thana	Mean Annual Usable Recharge in mm	Available Recharge to the Technology in mm				HTW LIMIT (15 M)
		Only STW (14 l/s)	Only DSSTW (14 l/s)	Only DTW2 (56 l/s)	Only DTW1 (28 l/s)	
Jhenaighati	392	51	90	333	392	247
Nalitabari	375	71	113	368	375	375
Haluaghat	413	78	124	413	413	413
Dhobaura	544	49	98	256	468	375

Source : NERP, 1995

Old Brahmaputra Floodplain
Sribardi, Sherpur, Nakla, Phulpur thanas and part Purbadhala thana in Netrokona lie within the Old Brahmaputra floodplain with a good uniformity in lithology. A 3 m -10 m of surface clay/silt deposit overlies fine sands, which coarsens gradually downwards to uniform medium sands providing very good aquifer characteristics. The aquifer is in general unconfined to semi-confined with very good to good potentials for suction mode tubewell development. More than 70 percent of the usable recharge (390 mm -500 mm) can be exploited using DSSTW in Sherpur and Nakla, but only 30-45 percent (200 mm -250 mm) in Sribardi Phulpur, Purbadhala and Netrokona. The potential for DTW technology is also good. Northwestern phulpur has predominantly good potential for both STW and DTW development, while in the eastern part the potential for STWs is limited. Available recharges for various pumping technologies in the area are summarised in Table -7.3

Sylhet Basin
Durgapur, Barhatta, Kalmakanda and part of Netrokona and Dhubaura are located in the Sylhet Basin. They are subject to deep flooding and a possibility of large amounts of silt and clay being deposited. The aquifer within the area is semi-confined to confined in nature. Because of recharge conditions, storage capacity and depth to groundwater, development of STWs is not favourable. DTW development may be possible, although there is some indication of hard-packed formations of mixed gravel and clay in some places which may be inhibitory. Available Recharge to various pumping technologies in the area is summarised in tables 7.3 and 7.4.

Table 7.3

Available Recharge to Different Options of Groundwater Development (Old Brahmaputra Floodplain)

Thana	Mean Annual Usable Recharge	Available Recharge to Technology in mm				HTW LIMIT (15 M)
		Only STW (14 l/s)	Only DSSTW (14 l/s)	Only DTW2 (56 l/s)	Only DTW1 (28 l/s)	
Phulpur	600	120	192	600	600	600
Nakla	506	385	506	506	506	506
Sribardi	497	134	209	497	497	497
Sherpur	538	258	387	538	538	538
Purbadhala	600	126	240	600	600	600
Netrakona	594	95	190	594	594	594

Source : NERP, 1995

Table 7.4

Available Recharge to Different Options of Groundwater Development (Sylhet Basin)

Thana	Mean Annual Usable Recharge (mm)	Available recharge to Technology in mm				HTW LIMIT (15 M)
		Only STW (14 l/s)	Only DSSTW (14 l/s)	Only DTW2 (56 l/s)	Only DTW1 (28 l/s)	
Duboura	544	49	98	256	468	375
Durgapur	450	95	135	410	450	329
Kalmakanda	547	38	109	323	547	547
Barhatta	700	35	77	196	406	373
Netrokona	594	95	190	594	594	594

Source : NERP, 1995

Resources available to various options of tube well development in the whole Basin are summarised in the Table 7.5. The estimates are cumulative summations of the values for thana or fractions of thanas within the boundary of the project.

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Table 7.5

Groundwater Resources Development Options (Unconstrained) in Mm^3 for the Basin

Usable Recharge	Only STWs (14 l/s)	Only DSSTWs (14 l/s)	Only DTW2 (56 l/s)	Only DTW1 (28 l/s)	HTW Limit (15 m)
1121	220	364	965	1093	975

Source : NERP, 1995

7.3.2 Additional constraints to Groundwater Development

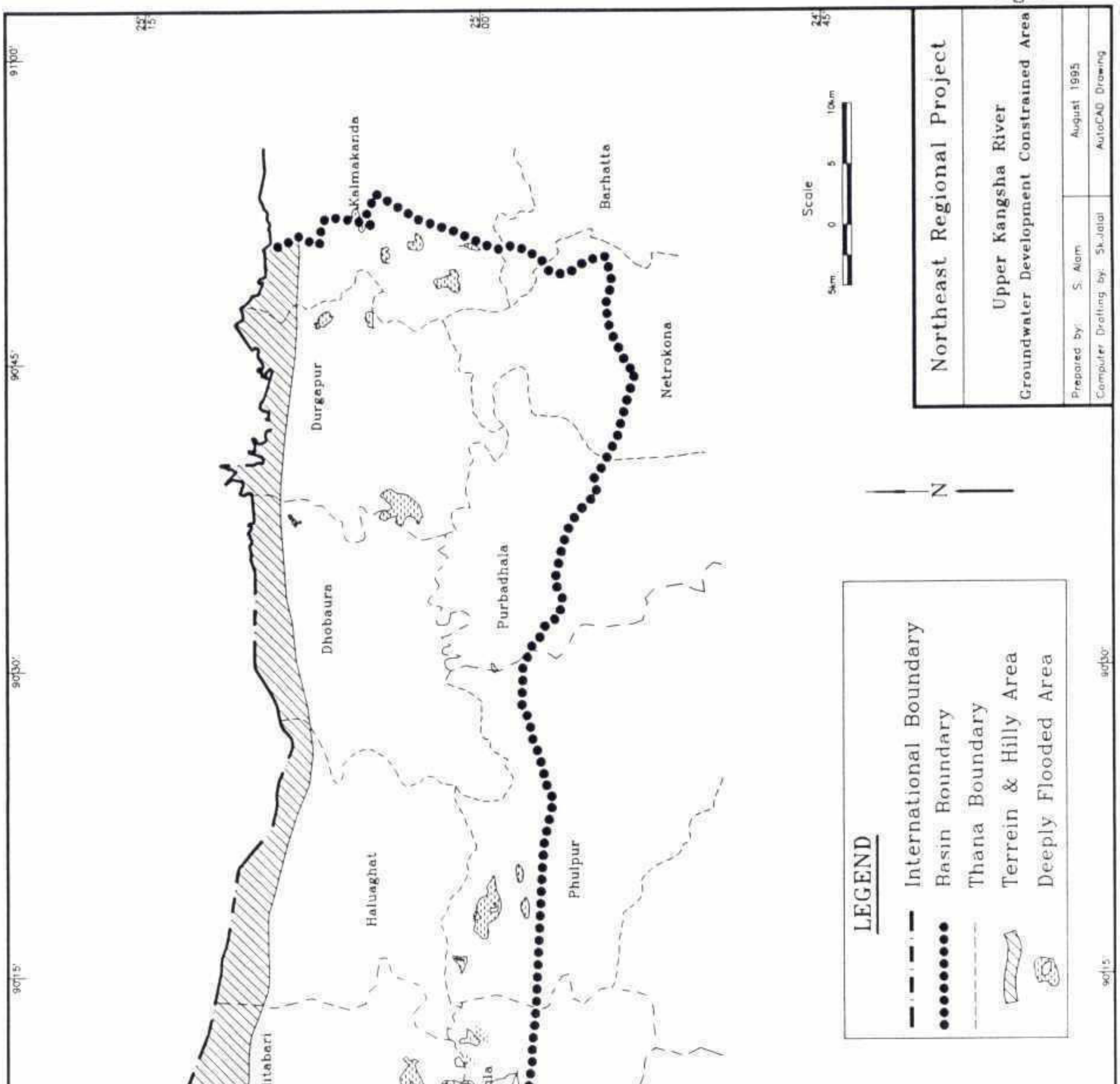
In the MPO process of planning, usable recharge was modified for several geographic constraints known as planning constraints. Only a few are found significant or relevant for the Kangsha Basin:

- difficult terrain and hilly areas;
- deeply flooded areas;
- spatial distribution of the terrain and hilly areas are shown in the Figure-14. Grouped together in one large contiguous area, groundwater development as well as resource availability may be assumed as non-existent in this area;
- unless drainage measures are effective, deeply flooded areas are considered unsuitable for groundwater development.

Constrained resources available to various options of technology are taken as areal modification of resources available. Because of hilly terrain, 17.8 percent of the gross area is not available for groundwater development. It is assumed that the constraint reduces available recharge and resources available to each well technology by the same amount. No allowances are made for horizontal flow of stored groundwater from the constraint areas to areas where groundwater is or can be developed.

Suction mode tubewells are unable to create large cones of depression to induce horizontal flow. Conversely, DTWs using force mode pumps can significantly lower the groundwater level and utilize more of the resource. Only the periphery wells, however, can draw the resources from areas of higher groundwater level. Therefore with the constraints in Table 7.6 the modified development limits are summarised in Table 7.7.

Figure 14



Northeast Regional Project
Upper Kangsha River
Groundwater Development Constrained Area
Prepared by: S. Alam
August 1995
Computer Drafting by: Sk. Jalal
AutoCAD Drawing
Scale
LEGEND
International Boundary
Basin Boundary
Thana Boundary
Terrain & Hilly Area
Deeply Flooded Area
N
Kalmakanda
Barhatta
Durgapur
Netrokona
Dhobaura
Purbadhala
Haluaghat
Phulpur
Nalitabari
Nakhla
Sherpur
Jhenaigati
Sribardi

Table 7.6

Groundwater Planning Constraints in Kangsha Basin Area

Thana	Percent of Thana Gross Area				
	Terrain	F4	W.b	F3	Total
Sribardi	31	0	0.15	1.1	32.25
Jhinaigati	28	0	0.26	0.12	28.38
Sherpur	0	0.58	0.19	0.1	0.87
Nalitabari	30	0	0.76	0.38	31.14
Nakla	0	2.25	0.31	0.15	2.71
Haluaghat	28	0	0.65	2.52	31.17
Phulpur	0	0	1.49	0.88	2.37
Durgapur	27	0	0	0.5	27.5
Dhubaura	9	0	0.55	2	11.55
Kalmakan	14	2	2.95	8.67	27.62
Purbadhal	0	0	0.88	1.82	2.7
Netrokona	12	0	1.01	6.31	19.32
Barhatta	0	0.31	1.71	10.16	12.18
Total in percent of	17.78	0.26	0.79	2.16	21

Source : MPO, 1991
Note: Wb. = Water Bodies

Table 7.7

Groundwater Resources Development Options (Constrained) in the Basin in Mm^3

Usable Recharge	Only STW (14 l/s)	Only DSSTW (14 l/s)	Only DTW2 (56 l/s)	Only DTW1 (28 l/s)	HTW Limit (15 m)
1121	184	303	777	879	790

Note: modified resources using recharge available in Tables-7.2, 7.3, 7.4 and constraints in Table 7.6

7.3.3 Sensitivity of Specific Yield on Available Resources

The specific yield, which is the aquifer's water yield per cubic metre of soil, is either poorly defined or has a large range of possible values because of rapid vertical and horizontal changes in the lithology; often within very short distances from a well (see lithologic sections E-F and G-H in Chapter 5). Sensitivity tests over the range of specific yield values for the given lithologic description in the area were undertaken to assess the effects of variable specific yield values on groundwater availability for each well type.

Table 7.8

Sensitivity of Specific Yield on Resources Available to Technology

Thana	Mean Annual Usable Recharge mm	Percent of Usable Recharge					
		DSSTW			DTW2		
		L	M	H	L	M	H
Jhenaighati	397	15	23	30	85	100	100
Nalitabari	375	22	30	38	70	98	100
Haluaghat	413	20	30	38	100	100	100
Dhoubaura	544	13	18	22	34	47	58
Phulpur	600	17	25	32	90	100	100
Nakla	506	61	67	98	100	100	100
Sribordi	497	25	34	42	76	100	100
Sherpur	538	38	56	72	100	100	100
Dhobaura	544	13	18	22	33	47	58
Durgapur	450	20	30	39	73	100	100
Kalmakan	547	16	20	24	44	59	71
Purbadhal	600	23	32	40	89	100	100
Barhatta	700	11	16	20	28	40	52
Netrokona	594	16	24	32	83	100	100

Note : L =Low value, M=Medium value, H=High value
Values in the cells with white background are considered approprite for resource appraisal
Source : NERP, 1995

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Table 7.9

Sensitivity of Specific Yield on Resources Available in the Basin

Specific Yield Range	Available Recharge by Technology in Mm³				
	STW	DSSTW	DTW2	DTW1	HTW
High	248	414	1025	1121	1066
Medium	196	322	981	1107	991
Low	135	230	816	1004	746

The change in resources available to suction pump-equipped wells varies in proportion to the yield change per cubic metre of soil, but with decreased sensitivity at higher pumping lift and specific yields. Higher values increase the recharge available to STWs and DSSTWs by 25-30 percent; lower values of available recharge decrease it by the same percentage. Force mode pumps used in DTWs have negligible effect on specific yields.

The above analysis suggests that the estimated resources available for suction pump equipped wells should be taken within a confidence limit of +/-25 percent. Higher values of specific yield are applicable for areas within the Brahmaputra plain formation and medium values in the northern areas (table 7.9).

7.4 Potential Irrigable Land for Groundwater Development

In the Kangsha Basin Land classifications F0 through F3 comprising 91 percent of the gross area are considered to be cultivable and 85 percent of this is considered irrigable by either surface or groundwater. Around 17.8 percent (table 7.6) of the gross area in the north is considered unsuitable for groundwater development due to the hilly topography. The potential irrigable area in the Basin is around 147,485 ha (64 % of gross area). Thana-wise Land type distributions in the Basin are summarised in the Table 7.10.

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Table 7.10

Flood Phases in Kangsha Basin Area

Thana	Flood Phases in % of Gross Area			
	F0	F1	F2	F3
Sribordi	50.97	34.59	6.57	3.16
Jhinaighati	56.4	34.9	3.9	0.4
Sherpur	44.43	35.45	11.8	0.2
Nalitabari	37	47.72	9.26	1
Nakla	36.58	41.72	13.05	0.43
Haluaghat	35.39	32.77	16.2	7.21
Phulpur	37.48	27.01	22.4	2.52
Durgapur	22.81	30.38	25.6	9.55
Dhubaura	27.62	37.68	19.65	5.85
Kalmakanda	9.45	24.2	32.03	24.78
Purbadhala	38.34	27.25	19.31	5.19
Netrokona	33	30.6	19	6.3
Barhatta	24.67	28.22	28.08	10.17
Percent of Gross area in the Basin	34	34	17	6

Note : Percent distribution of Land types in a thana within the Basin is the same as for the whole Thana.
Source : MPO, 1991

Sixty-eight percent of land phases fall within the categories F0 through F1, therefore the majority of the irrigable land lies on F0 through F1 land type. Relief differences of the F1 and F2 type lands range between 30-90cm and 90-180 cm respectively from datum F0 type land without flood.

Estimates of the net potential irrigable land within each thana, suitable for groundwater development, (Table 7.11) are based on the total irrigable land minus the surface water irrigated area during the period 1992-93. Surface water development prospects in the Basin are very small; therefore the remaining irrigable area may be taken as the potential area for groundwater development. The total irrigable area is 147,485 ha, of which 20,089 ha (13.7 percent of irrigable area) are irrigated with surface water. The net potential area for groundwater irrigation development is therefore 127,296 ha (86.3 percent of irrigable area).

Table 7.11

Potential Net Irrigable Land (ha) Available for Groundwater Resource Development

Thana	Gross Area in the Basin	Irrigable. Area in the Basin	Basin Surface water Irr.(1992-93)		Potential Irrigable Area by GW	
			LLP	TRD	(ha)	% of Col 2
1	2	3	4	5	6	7
Sribordi	3839	2145	10	69	2066	54
Jhenaighati	20213	11826	777	3153	7896	57
Sherpur	10120	7908	3	116	7785	77
Nalitabari	32761	18514	2507	577	15430	71
Nakla	7002	5463	81	243	5138	73
Haluaghat	35607	19954	1164	1148	17642	75
Phulpur	14082	10704	111	166	10427	74
Durgapur	29342	16084	932	970	14182	75
Dhubaura	25105	17632	1119	1724	14789	71
Kalmakanda	18591	12294	1557	311	10426	72
Purbadhala	17470	13378	1162	329	11886	68
Netrokona	13720	9123	909	524	7690	56
Barhatta	3181	2464	198	326	1939	61
Basin Total	231032	147485	10531	9658	127296	
Percent	100	63.8	8.7		55.1	

Note : col (2) Fraction of thana within the Basin in ha. col (3) Irrigable area = 85 percent of F0 through F3 land types (cultivable)(from Table 7.2) in fraction * col (2) * Terrain constraint (in Table 7.4) in fraction col (4) and col (5) are Thana census, 1992-93 times the fraction of thana within the Basin col (6) Net potential Irrigable area for GW development is col (3) minus col (4) and col (5).

7.5 Groundwater Use

7.5.1 Present use in Agriculture

Development of STWs and DSSTWs have undergone considerable expansion since the Government introduced a policy of privatisation of groundwater development. STW, DTW and LLP technologies have been widely used in the Kangsha Basin; with preference to STWs due to the lower cost of this technology. Although some thanas show marked declines in the number of DTWs, there is an overall annual increase of 5 percent in the area. STW development increased by 11 percent annually over the entire area, while there was a significant reduction of DSSTWs.

Table 7.12 gives an overview of the recent development trend in the Basin area in terms of modes of technology for groundwater abstraction from 1991 to 1993. Thana census are summarised in Tables 7.24 and 7.25.

Table 7.12

Development Trend of Minor Irrigation in Number

Census year	Number of wells			
	STWs	DSSTWs	DTWs	MTWs
1990-91	5155	86	795	3511
1992-93	6302	62	874	3158
Change in	1148	-24	79	-353
Change in %	+22	-28	+10	-10

Source : AST census 1991 and 1993

Net agricultural groundwater withdrawal during 1992-93 was about 301 Mm^3 based on thana duty and irrigated area census (Tables 7.13 & 7.14). According to the 1992-93 census the present use is not evenly distributed in the Basin. Five out of thirteen thanas have reached more than 50% of the maximum resource available to the technology.

Presently about 77,000 ha of land is under irrigation by groundwater or surface water in the Basin based on the projection of 1992-93 AST census. Nearly 57,000 ha (38.6 percent of the gross area) is presently under groundwater irrigation. In view of the limited scope for extensive low cost surface water development in the area, groundwater would be the prime source for future expansion within the remaining 70,485 ha (48 percent of the irrigable land) irrigable land in the area.

Spatially, groundwater development has expanded in the areas most favourable for STW and DSSTW development, ie, where recharge and storage capacity in the upper reservoir is good. Cheaper stream surface water available during the period March-April is being utilized in the northern part of the Basin, for the most part leaving insufficient flows for surface water irrigation in the southern part.

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Table 7.13

Net Abstraction in the Basin (Census 1992-93)

Thana	Abstraction	
	Mm^3	mm
Sribordi	7.4	193
Jhenaighati	20.4	101
Sherpur	22.0	217
Nalitabari	46.7	142
Nakla	19.6	279
Haluaghat	52.8	148
Phulpur	27.3	194
Durgapur	26.0	89
Dhubaura	19.9	79
Kalmakanda	13.8	74
Purbadhala	28.0	160
Netrokona	15.0	110
Barhatta	2.1	66

Note :Abstraction by STW, DSSTW, DTW & MTW based on irrigated land and duty.

Table 7.14

Abstraction by Mode During 1992-93 Period for Agriculture

Mode	STWs	DSSTWs	DTWs	MTWs	TOTAL
Mm3	193.4	1.87	101.5	4.1	301

The major part of this area lies in the southwestern part of the Basin within the Old Brahmaputra Floodplain, covering Sribordi, Jhenaigati, Sherpur, Nakla and Phulpur. Patches of intense STW development can also be found in the northeast corner of the Basin where good recharge and storage capacities are found..

7.5.2 Irrigation demand

Total irrigation water demand is described in Table 7.15 for thana cropping patterns, evapotranspiration and 1 in 5 year rainfall availability. Allowance is made for the application of field and conveyance efficiencies. The net withdrawal of groundwater equals the consumptive use plus 60% of losses which are not returned to groundwater. The estimated duty was checked on several thanas representative of cropping pattern and physiography in Bangladesh (MPO,1987).

The method used to estimate groundwater abstraction volumes (known as capacity utilization), which is the product of installed capacity times annual running hours, differs from the method used in this report, which is based on crop irrigation duty. Actual abstraction characteristics of the groundwater units depend on:

- rainfall characteristics;
- crop grown;
- working efficiency of the pumping units and well design;
- availability of fuel/power, and
- deep percolation rate of the sols, ie, the rate of recycling.

Table 7.15

Crop Irrigation Duty

Thana	Duty in Ha/	GW Requirement
Sribordi	163	613
Jhenaighati	170	588
Sherpur	154	649
Nalitabari	170	588
Nakla	160	625
Haluaghat	169	592
Phulpur	148	675
Durgapur	168	595
Dhubaura	168	595
Kalmakanda	165	606
Purbadhala	149	671
Netrokona	142	704
Barhatta	166	602

7.5.3 Irrigation in the Dampara Project

The Dampara project is a Flood control project within the Basin with a gross area of about 15,000 ha. The net cultivated area covers 90.5% of the project area. Presently 91% of the cultivable area (82 % of the gross area) i.e. 12,356 ha is irrigated (Table 7.16), the majority (95%) of which is under boro rice cultivation and irrigated by wells. Figure-15 shows the land use pattern within the Dampara project area.

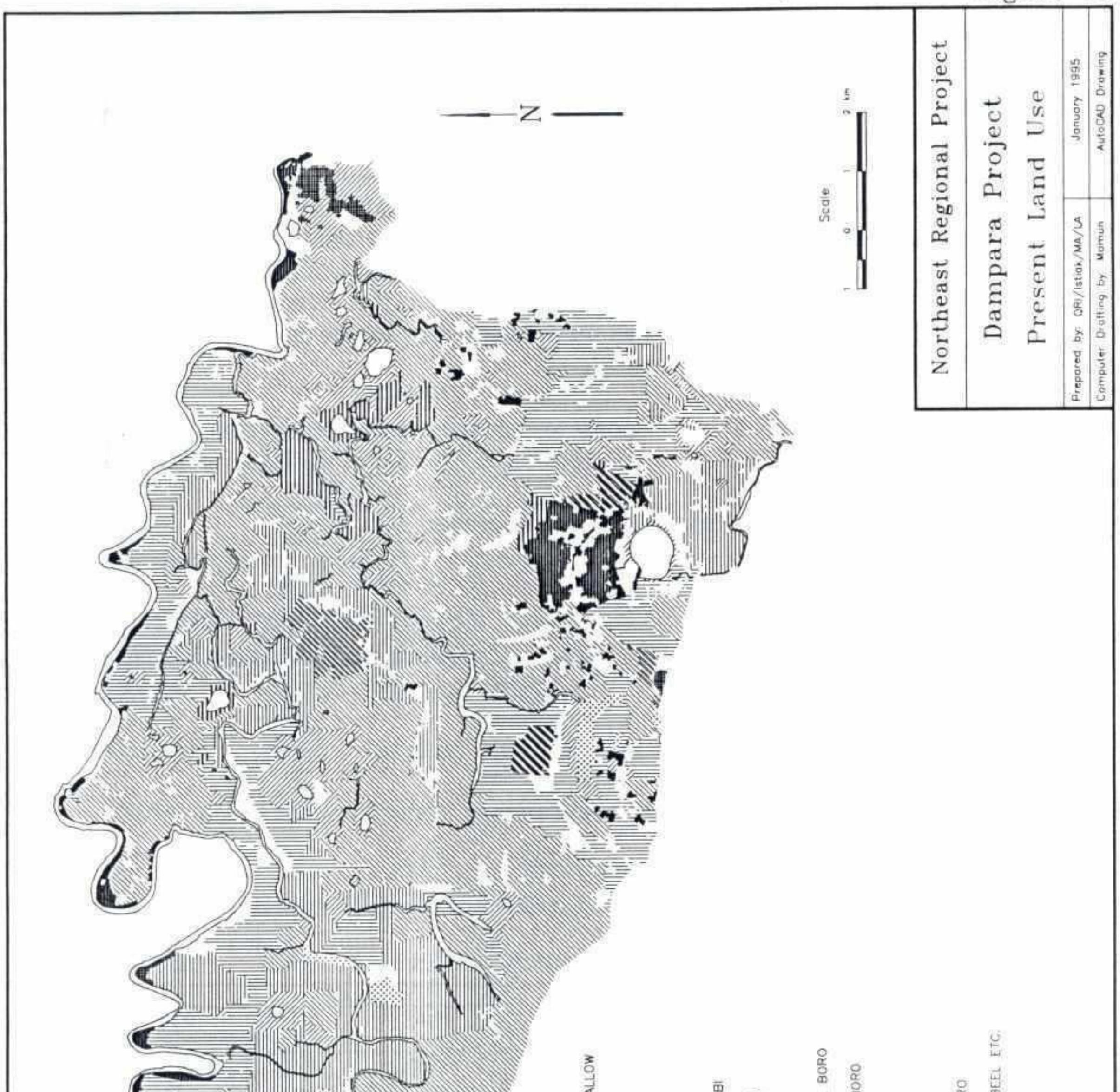
The project comprises 28% of Phulpur thana and 72% of Purbadhala thana. The estimated maximum usable recharge for the project is around 613 mm; irrigation demand for present cropping pattern is about 671 mm. Therefore 91 percent of the project area may be irrigated with the available groundwater resources. The maximum resources available to the suction mode technology is about 240 mm which can irrigate 39 percent of the gross project area. During 1995, a detailed survey was carried out to determine the extent of the groundwater irrigated area in the Basin. The survey showed that the present boro rice cropped area has almost reached saturation. This makes it possible to check the actual abstraction using the estimated limits of the resources to various technologies and the crop irrigation duty.

Table 7.16

Present Crop Area in Dampara Project

Crop	Area (ha)	Irrigated. Area (ha)
Broadcast Aus	1005	30
Broadcast Aman	69	-
local Transplanted Aman	7430	111
HYV Transplanted	4017	60
Local Boro	3398	3398
HYV Boro	8335	8335
Wheat	170	128
Jute	135	-
Rape and Mustard	912	182
Vegetables and Species	249	100
Sugarcanes	1	1
Sunn-hemp	8	-
Total	25729	12346

Sources: NERP, 1995


N
Scale
1 0 1 2 km
LEGEND
LOCAL/IMPROVED LOCAL BORO-FALLOW
LOCAL T. AMAN-FALLOW
HYV BORO-FALLOW
MIXED B. AUS AND B. AMAN
JUTE/B. AUS-LOCAL T. AMAN-RABI
B. AUS-RABI (OIL SEEDS/WHEAT)
HYV T. AUS-HYV T. AMAN-RABI
LOCAL T. AMAN-IMPROVED LOCAL BORO
HYV T. AMAN-IMPROVED LOCAL BORO
LOCAL T. AMAN-HYV BORO
HYV T. AMAN-HYV BORO
HYV T. AMAN-OILSEEDS-HYV BORO
HOMESTEADS, INFRASTRUCTURE, BEEL ETC.
RIVER/KHAL
Northeast Regional Project
Dampara Project
Present Land Use
Prepared by: QRI/Istiak/MA/LA
January 1995
Computer Drafting by: Mamun
AutoCAD Drawing

There is only one BWDB well monitoring the groundwater level in the lower aquifer, which is not sufficient to extrapolate lowering of the groundwater level over the entire Dampara project area. According to 1995 groundwater level measurements there was only a 3.5 m depletion in and around the observation well (MY-49) (BWDB) during the irrigation period , which suggest a high specific yield of the fine sand formations at depth and therefore a good storage capacity within 3.5 to 7 m from average ground surface. The recorded depletion of 3.5 m with medium to high specific yield for fine sand (Table 6.6) suggests that the net abstraction would be around 350 to 450 mm, which is lower than the estimated duty for the boro rice crop area of 11,733 ha, derived from the 1995 agricultural survey.

Monitoring of the groundwater response to recharge and discharge within the Dampara area needs to be improved to enhance resource appraisal in this part of the Kangsha River Basin.

7.5.4 Domestic and Industrial use and Future Reserves

Rural Water Supply
Due to the increasing population in the Basin, the number of HTWs, both No. 6 and modified HTWs (Tara) is expanding rapidly. Table 7.17 presents the 1992 census for No.6 HTWs, Tara (deep-set modified HTWs) and DTWs operating in the Basin for the purpose of supplying domestic water.

Table 7.17

Thana Census of Hand Pumps in the Kangsha Basin (1992)

Thana	No. 6	Tara	Deep
Sribordi	330	0	0
Jhenaighati	830	229	0
Sherpur	715	0	0
Nalitabari	1563	359	0
Nakla	520	0	0
Haluaghat	1625	402	2
Phulpur	800	182	0
Durgapur	1448	237	33
Dhobaura	-	-	-
Kalmakanda	944	4	0
Purbadhala	1044	236	0
Netrokona	773	146	0
Barhatta	156	30	0
Total	10,748	1825	35

Note : Estimates are based on Thana census times the fraction of thana within the Basin

The estimated number of hand tube wells in the Basin was 12,573 in the year 1992, 85 percent of which are No. 6 suction lift type; the rest are Tara HTWs.

Urban Water Supply

Population expansion in the urban areas is much higher than in the rural areas. The Thana headquarters of Sherpur and Netrokona, as well as others, will need to abstract large amounts of groundwater to meet future domestic needs in their municipalities. Based on 1991 census, urban population (8.6 percent of 1995 Basin population) is predicted to grow to a size of 361,970 by the year 2015 (15% of the total population by the year 2015 (Table 7.18).

Table 7.18

Projected Population in the Basin

Thana	Thana Census 1991			Basin Projection 2015		
	Urban	Rural	Total	Urban	Rural	Total
Sribordi	8802	219392	228194	4031	45807	49,838.0
Jhenaigahti	4304	135428	139732	12146	175905	188,051.
Sherpur	62828	358591	381419	56958	107947	164,905.
Nalitabari	25096	201234	226332	80944	267166	348,110.
Nakla	7332	155620	162962	9473	90929	100,402.
Haluaghat	9727	232612	242339	31371	341359	372,730.
Phulpur	12292	446754	459046	9621	161734	171,355.
Durgapur	12999	156136	169135	41923	218215	260,138.
Dhubaura	3027	154000	157027	9762	231753	241,515.
Kalmakanda	9385	199975	209360	14910	143710	158,620.
Purbadhala	15996	219679	235675	28859	173913	202,772.
Netrokona	45674	219969	265643	59378	105318	164,696.
Barhatta	5602	136572	142174	2594	28807	31,401.0
Total	225,05	2,835,9	3,019,0	363,985.	2,092,56	2,456,54

Note : population figures adjusted for Thanas lying fractionally in the Basin.

The projected domestic and industrial groundwater reserve for the future population (in the year 2015) is estimated to be 50 Mm^3 (Table 7.19).

Fourty-five percent of the urban population would be served by urban pipe supply systems, consuming an average of 130 l/p/d, while 85 percent of the rural population would be provided with safe water through HTWs with a combined consumption rate of 60 l/p/d. The rest of the population would remain underserved, consuming only 20 l/p/d (Table 7.20).

Table 7.19
Domestic and Industrial Groundwater Reserved for Future Use (Mm^3)

Thana	Year			
	1995	2000	2010	2015
Sribordi	0.49	0.61	0.92	1
Jhenaighati	1.86	2.28	3.44	3.77
Sherpur	0.61	2.05	3.21	3.55
Nalitabari	3.45	4.29	6.61	7.30
Nakla	0.99	1.22	1.85	2
Haluaghat	3.69	4.53	6.85	7.52
Phulpur	1.69	2.08	3.13	3.43
Durgapur	2.58	3.18	4.87	5.35
Dhubaura	2.39	2.92	4.40	4.82
Kalmakanda	1.57	1.93	2.92	3.21
Purbadhala	2	2.48	3.78	4.15
Netrokona	1.63	2.05	3.22	3.56
Barhatta	0.31	0.38	0.58	0.63
Total	23.3	30.01	45.78	50.3

Table 7.20
Consumption Rate for the Population Groups

Population	Percent of Population			
	1995	2000	2010	2015
Pipe supply for Urban	25	35	45	45
HTW for Rural	61	67	85	85
Under-served	Remaining			
Population	Consumptive use in l.p.c.d			
	1995	2000	2010	2015
Pipe supply for Urban	105	110	130	130
Rural supply	53	56	60	60
Under-served	18	19	20	20

Note : l.p.c.d = Litres per capita per day

Estimates are based on the fraction of urban and, separately, of rural populations to be served by piped water or target well density for the projected future consumption rates. The remaining population, not fully served, is assumed to use at lower rate.

7.6 Future Potential for Groundwater Development

The potential available groundwater resources for future development in a given area is based on the following criteria:

- present groundwater use;
- potential resources available to various abstraction technologies;
- future domestic and industrial needs;
- net irrigable land potentially available for groundwater development.

Table 7.21 shows the upper limits of the groundwater resources development potential (without planning constraints). The maximum development level is expressed as a percentage of the area available for irrigation in col- (7). For full irrigation coverage this percentage is 100. For partial development the constraint to full development is indicated in col- (8), which is the technological constraint limit (from Table 7.2, 7.3 and 7.4) in percent of col- (5) in col- (7). Constraints can relate to usable recharge, to pumping limits for force mode units (56 l/s) or to water table limits for village hand tubewells fitted with Tara pump (< =15 m). The limitation showed in Table 7.22, related to the DTW2 and HTWs, can be overcome by either choosing low capacity force mode units(< = 28 l/s) or in the case of HTWs, the super Tara (> 15m). Therefore serious resource limitations can occur in the thanas Nalitabari, Haluaghat and Durgapur where 75 to 93 percent of potential groundwater irrigable area can be developed.

The groundwater development options in Tables 7.2, 7.3, and 7.4 for "Only STWs" and "Only DSSTWs" assume that development ultimately would be in F1 through F3 land types. Using suction mode for the available recharge within the available land resources will result in suction lift units in F0 land type which covers nearly 30-45 percent of the gross area eventually to become inoperable at and above the full development level of suction lift limit.

On the other hand Options for "Only DTWs" in the Table 7.2, 7.3, and 7.4 means DTWs will operate in land types F0 through F3, while suction lift would become inoperable. As illustrated in Table 5.14 in almost all the thanas, full development would require DTWs.

However, in the thanas Nakla and Sherpur, suction lift units will remain operable in all land phases with some exceptions even at the development of potential available land. Table 7.22 illustrates the possibility of mixed pumping technology development in the Basin. In order to develop 100 percent of the potential irrigable area, mixed technology is possible in Sherpur thana, while suction mode STWs alone can develop 100 percent of the potential irrigable land available in Nakla. The assumption in the mixed mode development is that DTWs would not draw down the water table below the lifting limit of DSSTWs, in other words both the technologies are compatible in this area in view of the Net Water Demand (NWD) and availability of the resources to the DSSTW technology. For the remaining thanas in Table 7.23, potential irrigable land would not be covered marginally if the mixed mode development is chosen at full development.

Table 7.21

Upper Limit of Groundwater Resource Development in the Kangsha Basin (Without Planning Constraints)

Thana	Usable recharge (mm)	Irrigation demand (mm)	Potential Irrigable Area (% of Gross Area)	GW Requirement		Max Development (% of Col.4)	Constraint Limit
				mm	% of usable recharge		
1	2	3	4	5	6	7	8
Sribordi	497	613	54	330	66	100	None
Jhenaighat	392	588	57	334	84	74	HTW, DTW2
Sherpur	538	649	77	500	93	100	None
Nalitabari	375	588	71	417	111	90	UR, DTW2
Nakla	506	625	73	459	91	100	None
Haluaghat	413	592	75	445	108	93	UR
Phulpur	600	675	74	500	83	100	None
Durgapur	450	595	75	446	99	74	UR, HTW, DTW2
Dhubarra	544	595	71	424	78	60	DTW2,HTW
Kalmakanda	547	606	72	437	80	74	DTW2
Purbadhala	600	671	68	457	76	100	None
Netrokona	594	704	56	395	66	100	None
Barhatta	594	602	61	367	52	53	DTW2,HTW

Note: UR = Usable Recharge; Col-(3) :From Table 7.16; Col-(4) : Table 7.12; Col-(7) : Controlled by usable recharge, drawdown constraints on HTW fitted with Tara pump and DTW2. Constraint limits are derived from table- 7.2,7.3 and 7.4. No constraint exists if 100 percent of the GW area can be irrigated by the usable recharge and STW and DSSTW. col-(8) : List of constraints.

Table 7.22

Resources Availability to Suction Mode Units and Mixed Mode Development

Thana	Available recharge with DSSTW only from different land Phases in mm				Available recharge to DTW from F0 (56 l/s)	NWD for potential irrigable land development
	F0	F1	F2	F3		
1	2	3	4	5	6	7
Sribordi	154	169	194	267	497	330
Sherpur	387	436	522	538	538	500
Nakla	506	506	506	506	506	459
Phulpur	162	192	240	318	600	500
Purbadhala	172	198	240	300	600	457
Netrokona	125	149	190	255	594	395

Note : Figure in Tables 7.2, 7.3, 7.4 for these Thana are one of the figure selected from col (2) through col (5) in view of availability of irrigable land for only 'DSSTWs' option. Col (6) upper limit of recharge where DTW1 can operate on all land type.

Table 7.23

Net Groundwater Resources Available for Future Development (with Adjustment)

Resources	Mm3
a)Unconstrained maximum Groundwater Available	1093
b)Constrained maximum Groundwater Available	879
c)Reduction for areas where recharge limit exceeds agricultural potential	-100
d)Domestic and Industrial Reserve for yr. 2015	-50
e)Present use in Agriculture (1994-95)	-356
f)Net Available for Future Development	373

Note:
a) cummulative sum of Thana upper limit for 'DTW only'(28 l/s) without areal modification
b) cummulative sum of Thana upper limit with 'DTW only'(28 l/s) with areal modification
c) cummulative sum of Thana recharge which is excess of potential required for Thana agriculture
d) calculated for the year 2015 and put to reserve (Table 20).
e) crop demand for present irrigation coverage (24.7 % of gross area) under present cropping pattern.
f) surplus is the Available constrained groundwater resources minus Iteam (c),(d) and (e).

According to the projection of 1992-93 AST census, 38.6 percent of the irrigable area (24.7

percent of the gross area), ie. 57,000 ha, is under groundwater abstraction which accounts for about 356 Mm^3 (625 mm irrigation demand). This leaves a balance of about 373 Mm^3 available as a future development potential for agricultural purposes meaning that an additional 59,680 ha (40 percent of irrigable area, 26 percent of gross area) could be brought under irrigation to reach full recharge development using the available recharge with the option of "Only DTW1". With the option of "only DTW2", additional agricultural development would be around 50,400 ha (34 percent of the irrigable area, 22 percent of the gross area). However limiting groundwater level lowering by 15 m (Tara HTW limit) from village mound, future agricuture would be restricted o 51,520 ha of land development.

A few areas within the thanas Nakla, Sherpur, Purbadhala and Netrokona would be able to develop a significant share of the usable recharges through suction mode technology. Full development in the rest of the area by DTWs would depend on the financial resources of the developer and the economic viability of the technology. The unrestricted use of mixed technology in areas having a high potential for application of suction mode technology (Sherpur and Nakla), should be considered with some degree of care, especially in terms of irrigation cost per hectare.

Table 7.24: Number of Wells and Irrigated Area (Thana Census)(1990-1991)

THANA	IRRIGATED AREA AND NUMBER OF WELLS							
	STW		DSSTW		DTW		MTW	
	Ha	No.	Ha	No.	Ha	No.	Ha	No.
Sribordi	4113	1050	0	0	1673	117	705	5041
Jhinaigati	1856	305	0	0	1682	78	24	174
Sherpur	7534	1652	0	0	2542	128	1033	7061
Nalitabari	3551	581	0	0	4106	211	28	190
Nakla	4798	862	0	0	1425	88	72	436
Haluaghat	3355	686	235	39	4560	214	53	111
Phulpur	8450	2356	0	0	3105	245	107	419
Durgapur	3709	934	6	0	390	18	6	26
Dhubarra	0	0	0	0	0	0	0	0
Kalmakanda	3730	813	264	20	190	13	5	33
Purbadhala	4236	911	22	61	1882	138	7	32
Netrokona	2637	522	48	5	2283	110	25	46
Barhatta	1309	249	17	9	1043	60	5	13

Table 7.25: Number of Wells and Irrigated Area (Thana Census) (1992-1993)

THANA	IRRIGATED AREA AND NUMBER OF WELL							
	STW		DSSTW		DTW		MTW	
	Ha	No	Ha	No	Ha	No	Ha	No
Sribordi	5483	1131	0	0	2299	134	708	5500
Jhinaigati	2224	383	0	0	1709	84	23	172
Sherpur	9425	2522	0	0	1645	106	942	5561
Nalitabari	3710	532	0	0	4199	212	21	108
Nakla	5994	1133	0	0	1675	96	145	309
Haluaghat	4092	794	104	19	4599	223	130	248
Phulpur	13065	3221	4	2	3505	247	60	254
Durgapur	3996	869	53	15	317	20	4	16
Dhubarra	1979	356	20	4	1310	61	28	78
Kalmakanda	3940	737	183	33	482	14	6	29
Purbadhala	5237	1190	59	10	2166	150	2	5
Netrokona	3320	630	12	2	1962	95	6	21
Barhatta	1210	197	18	3	1197	60	4	14

Source :AST Census

8. ISSUES RELATED TO GROUNDWATER DEVELOPMENT

8.1 Groundwater Depletion

The groundwater table and piezometric surface in the area rise in response to recharge at the beginning of the monsoon season in May and generally reach their highest level in late July. The aquifer is assumed to be fully recharged if groundwater levels in October are comparable to historic levels. In areas where the water table reaches surface, further potential recharge is rejected.

On cessation of the monsoon in September, the water table begins to fall in response to evapotranspiration and rapid drainage via base flows to rivers and streams. The natural rate of fall is highest during October and November. Induced by groundwater abstraction, the water table reaches its maximum depth in March-April. The minor rivers and streams continue to exhibit small flows, sustained by groundwater discharges, as long as the difference between stream and groundwater levels are high.

8.2 Recharge and Discharge

Natural Discharge

As a result of evaporation, evapotranspiration and base flow to streams, there is considerable fluctuations in the level of the water table, both in the beginning and the end of the irrigation season; even without irrigation development. About 22 m^3/s of surface water is available during the dry season.

The recession curve fitted with the hydrography and related with the specific yield distribution in the upper aquifer can be used to estimate the natural drainage reduction with the development.

The mean annual losses, from cessation of the monsoon season to the beginning of the irrigation season, is roughly 30 mm over the Basin. These losses are not recoverable unless water conservation measures are implemented using supplemental irrigation or by starting the irrigation season in November rather than January.

Without groundwater abstraction, depth to the water level exceeds 4 m in the southeast and northwest, and 2 to 3.5 m in the rest of the Basin (Table 8.1). Abstraction of groundwater for irrigation results in reduced base flows to streams due to artificially induced lowering of the groundwater level caused by pumping . This amounts to the equivalent of 15 mm over the Basin. Availability of surface water for LLP irrigation may be reduced by about 4.5 m^3/s with full potential groundwater development. Surface water reduction will also negatively affect fisheries and wetlands.

Table 8.1

Groundwater Depth at Beginning and End of Irrigation Season (No Groundwater Abstraction)

Thana	Initial depth (m)	Final depth (m)	Av. ground depth from Village mound (m)
Sribordi	1.82	2.2	1.32
Jhinaigati	3.09	4.05	1.20
Sherpur	2.21	3.2	1.31
Nalitabari	1.98	3.38	1.38
Nakla	2.71	3.76	1.41
Haluaghat	3.16	4.49	1.56
Phulpur	3.51	4.34	1.51
Durgapur	1.89	2.24	1.69
Dhubarra	2.38	2.98	1.58
Kalmakanda	3.15	3.98	2.15
Purbadhala	3.52	4.43	1.52
Netrokona	3.32	4.34	1.52
Barhatta	3.21	4.21	1.71

Source: WARPO, 1991, data for the period 1964 - 1975

The assumptions related to the base flow reduction are:

- without irrigation development the losses are based on the average depth at the beginning and end of the season (Table 8.1) and specific yield;
- during irrigation natural loss occurs through base flow only, and
- the natural losses between the beginning and end of the season are considered to be inversely related with the groundwater drawdowns caused by pumping

Most of the BWDB observation wells are located on the village mounds which have an elevation 1.5 to 2.5 metres above the average surrounding land surface. Depth to the groundwater level is measured from the village mound elevation (Table 8.1).

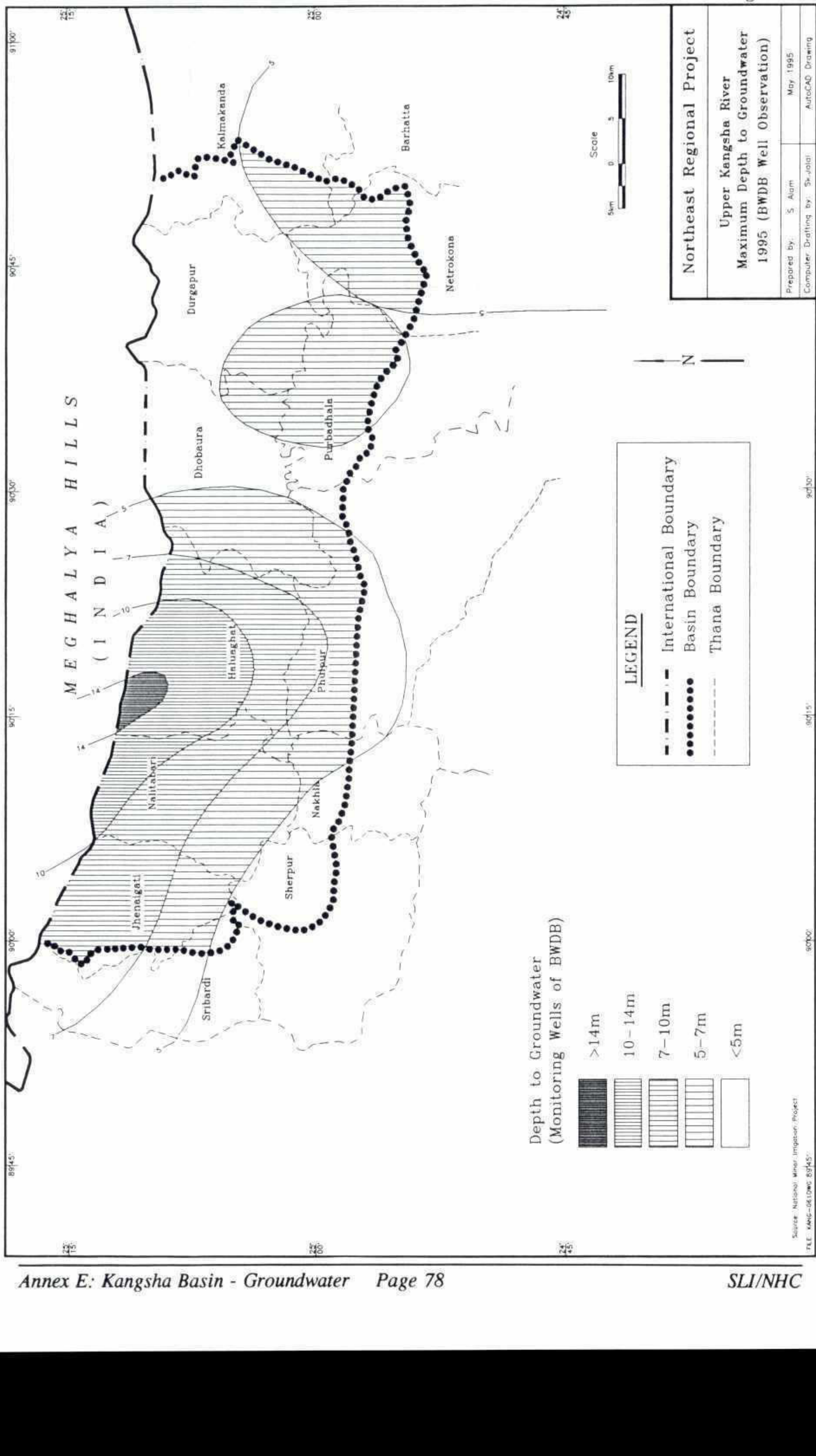
Seasonal Abstraction and Depletion

The seasonal groundwater depletion and recharge can best be presented in the form of a hydrograph covering entire cycle. There is, in general, a decline in the lowest annual water level in all the thanas because of extensive dry season irrigation with abstracted groundwater. The annual fluctuation ranges between 2.0 and 3.0 metres in Nakla, Phulpur and Sherpur thanas. Precise levels vary according to the flood and rainfall patterns in a given year, but so far there is no indication of over exploitation in the areas.

Most of the observation wells in the area are dug wells, converted to piezometric wells. There is considerable variation in the maximum depth to water level within the Basin area. Maximum draw down of the piezometric surface in the lower aquifer (from village mound elevations) following the drought years of 1988 and 1994 is shown in the Figures 15 and 16. The depths observed in Nalitabari, Jhinaigathi and Haluaghat thanas ranges between 6.5 and 14 metres. In Sribordi, Nakla, Sherpur, Phulpur, Durgapur and Dhoboura thanas, maximum depths varies between 3.0 m and 4.5 metres. Intermediate ranges of 4.5 to 6.5 metres are observed in Purbadhala, Netrokona and Kalmakanda thanas.

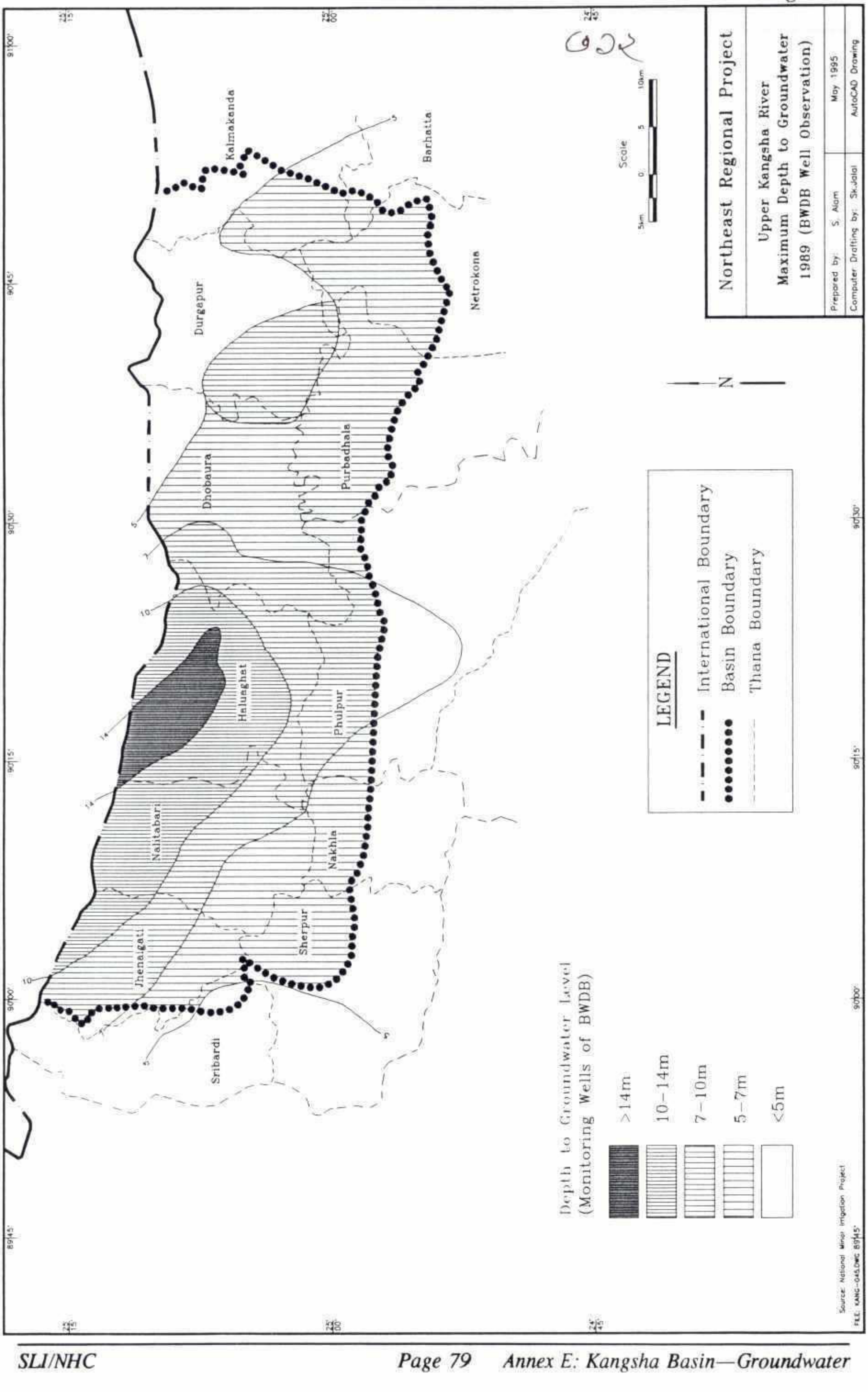
In general there is no apparent trend of continuous decline in the recovery of water levels. Temporary abnormal declines in the water levels were observed for the month of October in the years 1988 and 1994; due to the low rainfall.

Figure 16



Northeast Regional Project
Upper Kangsha River
Maximum Depth to Groundwater
1995 (BWDB Well Observation)
Prepared by: S. Alam
May 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
Scale
5km 0 5 10km
M E G H A L Y A H I L L S
(I N D I A)
Kalmakanda
Barhatta
Durgapur
Netrokona
Dhobaura
Purbadhala
Haluaghat
Phulpur
Nalitabari
Nakhla
Sherpur
Jhenaigati
Sribardi
LEGEND
International Boundary
Basin Boundary
Thana Boundary
Depth to Groundwater
(Monitoring Wells of BWDB)
>14m
10-14m
7-10m
5-7m
<5m
N
Source: National Minor Irrigation Project

Figure 17

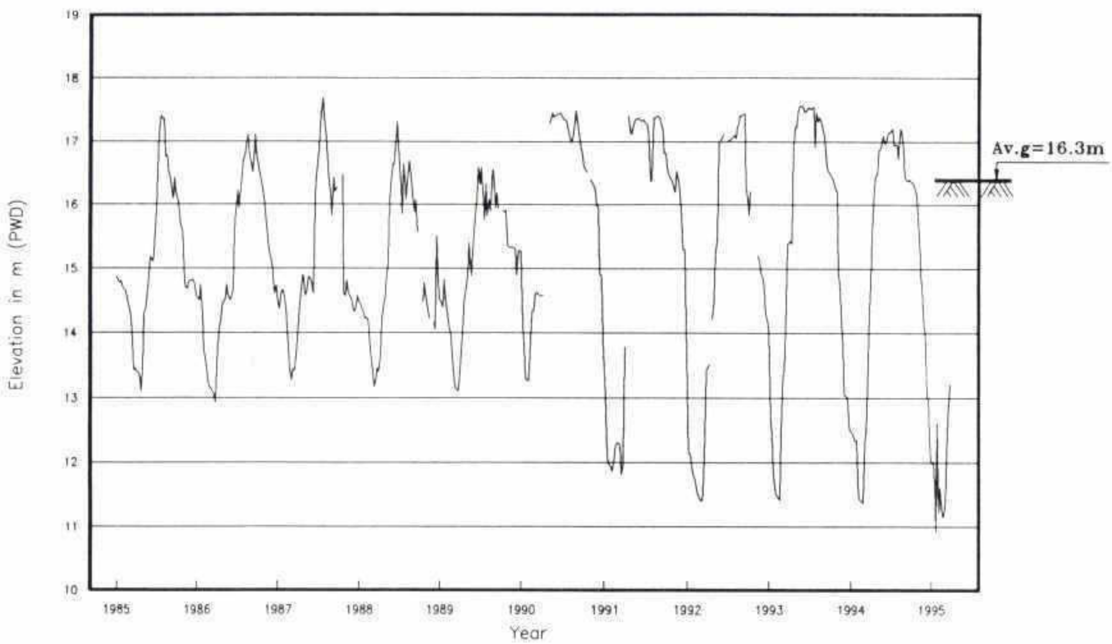


Northeast Regional Project
Upper Kangsha River
Maximum Depth to Groundwater
1989 (BWDB Well Observation)
Prepared by: S. Alam
May 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
LEGEND
International Boundary
Basin Boundary
Thana Boundary
Depth to Groundwater Level
(Monitoring Wells of BWDB)
>14m
10–14m
7–10m
5–7m
<5m
Scale
N
Kalmakanda
Barhatta
Durgapur
Netrokona
Dhobaura
Purbadhala
Haluaghat
Phulpur
Nalitabari
Nakhla
Jhenaigati
Sherpur
Sribardi
Source: National Minor Irrigation Project

Figure 18

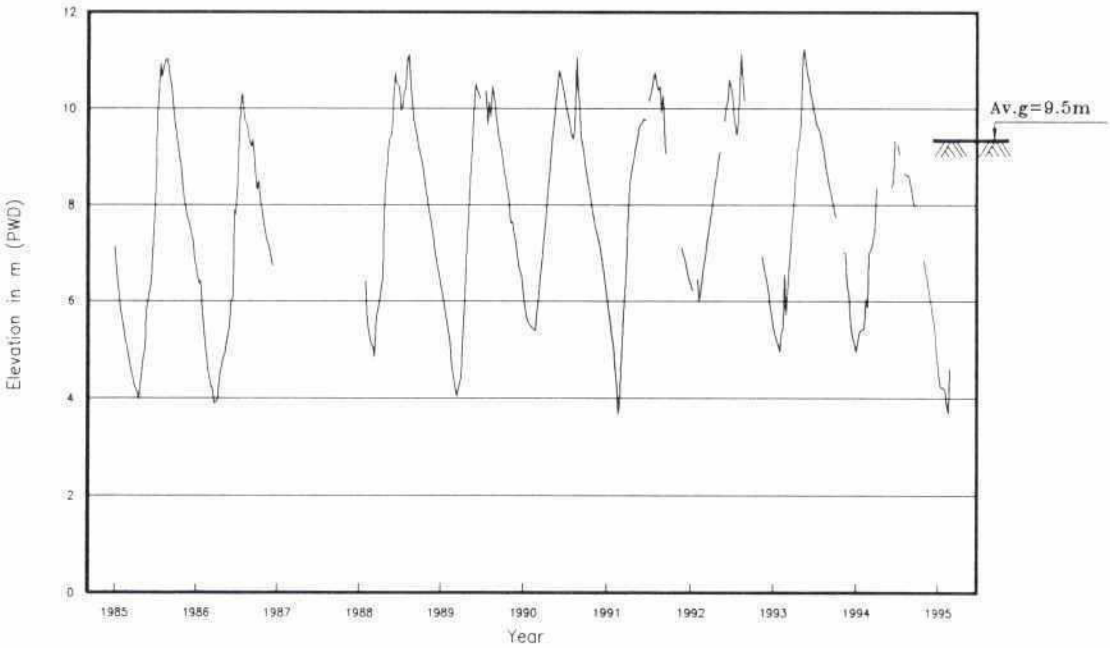
Groundwater Level Hydrograph

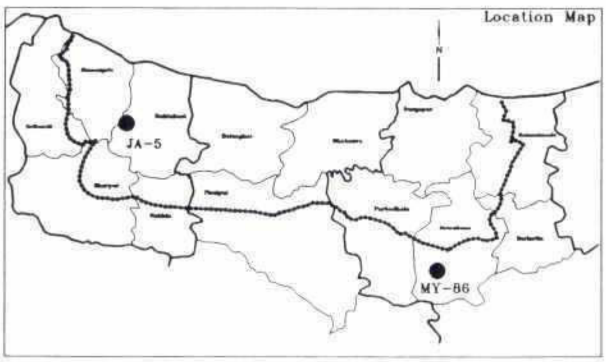
Nalitabari, Ja-5



Groundwater Level Hydrograph

Netrokona, MY-86



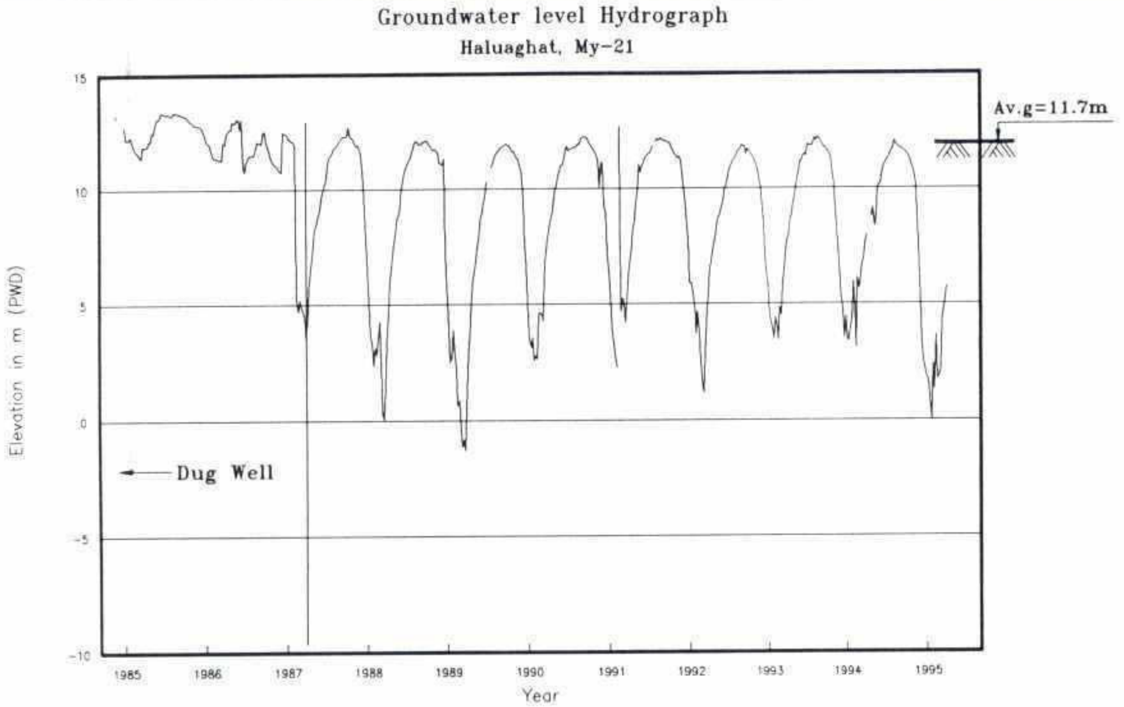


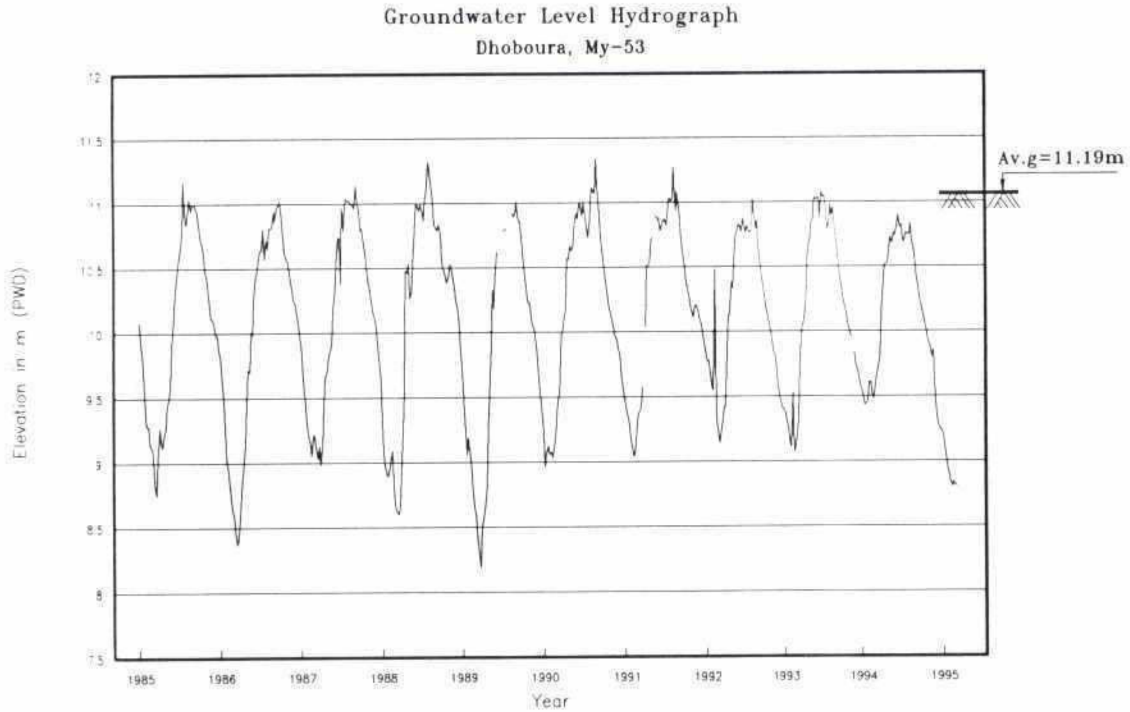
FILE: KANC-066.DWG

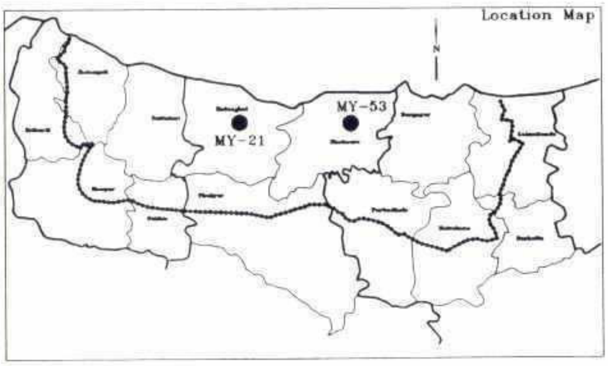
Northeast Regional Project	
Upper Kangsha River	
Groundwater Hydrograph	
Prepared by: S. Alam	August 1995
Computer Drafting by: Jalal	AutoCAD Drawing

028

Figure 19







Northeast Regional Project	
Upper Kangsha River Groundwater Hydrograph	
Prepared by: S. Alam	August 1995
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: KANG-067.DWG

The groundwater level in Haluaghat and Nalitabari exhibits large fluctuations (Figures 17 and 18). This is due to the presence of intercalated clay and silt beds of low specific yield, but normal recovery of the water level is achieved by the end of July.

Groundwater Level Drawdown and Abstraction in Dampara FCD Project

There is only one well monitoring groundwater levels, considered representative of groundwater level fluctuations in the area. The well, operated by BWDB, was converted from Dug well to Piezometric well in March, 1992. Since then the maximum depth to water level has shown a declining trend; implying increasing groundwater abstraction (Figure 20).

In the northwest of the project the reservoir capacity is reduced due to an increased presence of clay interbeds in the upper stratigraphy. Based on the net irrigation demand of 625 mm, the net groundwater irrigation use in 1995 was 513 mm over the project area which seems excessive in view of the small decrease in the water level during the irrigation season and the storage capacity in the upper aquifer.

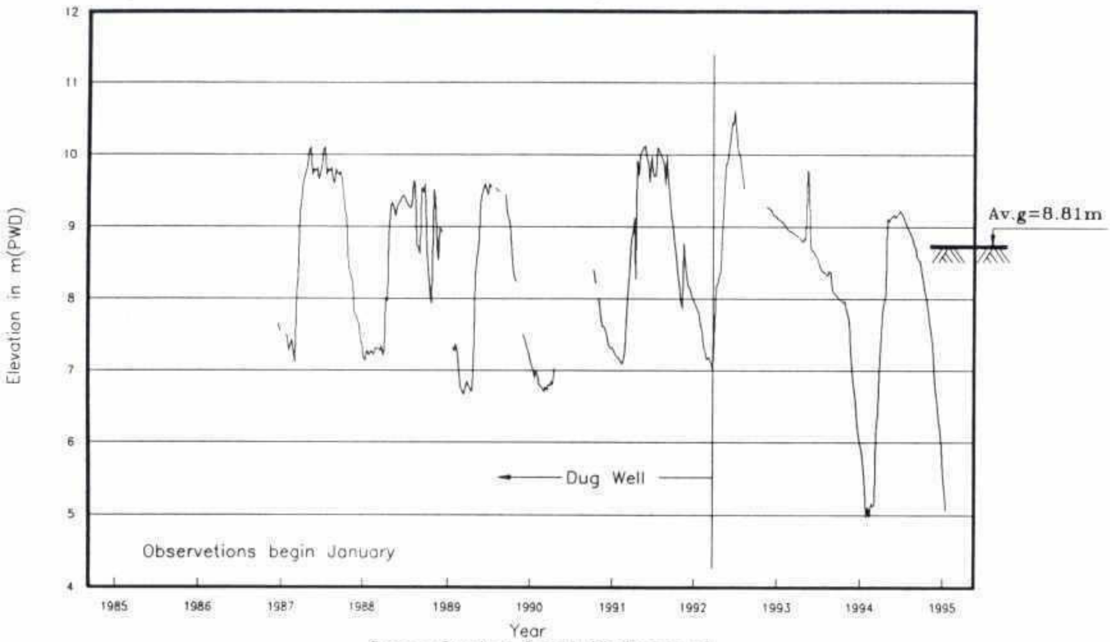
Overestimation in the actual abstraction is generally the result of cumulative errors from overestimation of the predominant fines in the drillers samples, lower actual irrigation demands (higher rates of irrigation water recycling), overestimation of the actual land use under boro cultivation (1995) or undefined external recharges during the irrigation season.

The estimated maximum usable recharge in the project is about 613 mm. Based on lithology and the estimated Potential Recharge, only 39 percent of the usable recharge (240 mm) may be utilized by DSSTW alone. From the NMIDP 1992-93 census, both the suction and force mode pumps are operating without encountering water shortages.

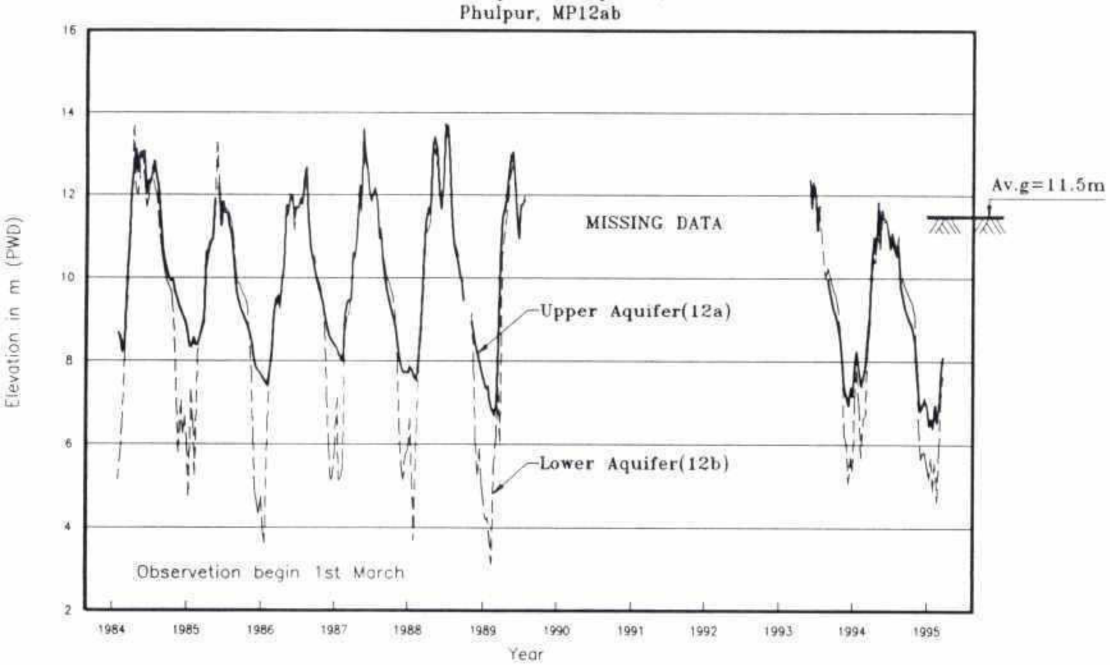
The annual rainfall available for recharge during 1994-95 was sufficient for the annual potential recharge conditions in the area. The maximum usable recharge is still sufficient to sustain any additional potential available land.

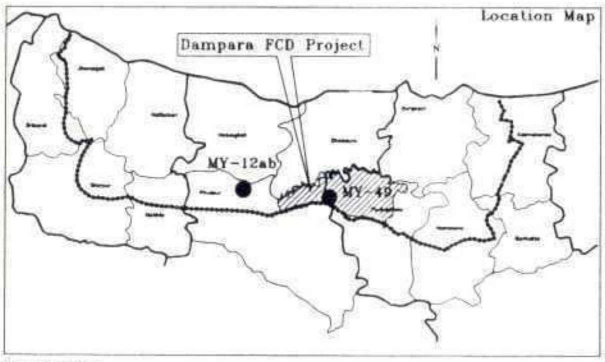
Figure 20

Groundwater level Hydrograph
Dampara FCD Project
Purbadhala, My-49



Groundwater Level Hydrograph
Groundwater Special Study Area, WARPO
Phulpur, MP12ab

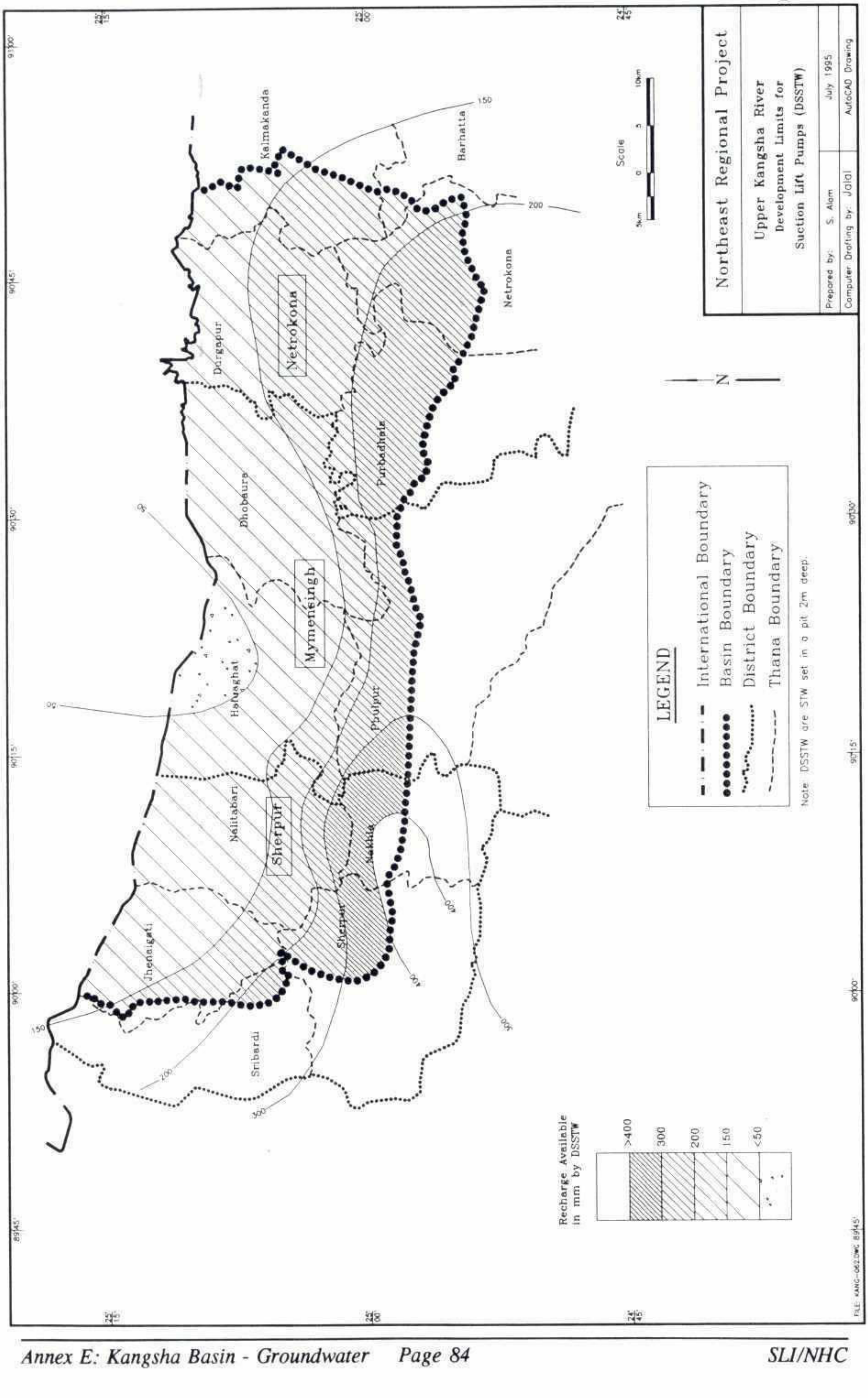




FILE: KANG-068.DWG

Northeast Regional Project	
Upper Kangsha River Dampara FCD Project Groundwater Hydrograph	
Prepared by: S. Alam	August 1995
Computer Drafting by: Jalal	AutoCAD Drawing

Figure 21



Northeast Regional Project
Upper Kangsha River
Development Limits for
Suction Lift Pumps (DSSTW)
Prepared by: S. Alam
July 1995
Computer Drafting by: Jalal
AutoCAD Drawing
Scale
LEGEND
International Boundary
Basin Boundary
District Boundary
Thana Boundary
Note: DSSTW are STW set in a pit 2m deep.
Recharge Available in mm by DSSTW
>400
300
200
150
<50
Netrokona
Mymensingh
Sherpur
Kalmakanda
Barhatta
Durgapur
Purbadhala
Dhobaura
Haluaghat
Phulpur
Nalitabari
Nakhla
Sherpur
Jhenaigati
Sribardi

Maximum depth to the water level in the part of Phulpur which lies inside the project area, as observed in a nearby WARPO well, is about 6.5 metres. Beyond the elevation 5.0 m PWD the water level response to pumping is sensitive, indicating a lower specific yield at this depth. Given average annual groundwater recharge conditions, however, there do not appear to be any serious shortfalls of groundwater. Drawdown during the irrigation period due to withdrawal is only about 3.0 m.

Future Groundwater Development and drawdown of water level
Predicted groundwater drawdown for future potential groundwater development is summarized in Table 8.2. Database for Net Groundwater Storage release for different depth to water level for each thana, calibrated for abstraction for agriculture in the year 1991, were used for the prediction. The range of specific yields (High, Medium or Low) are specified in Table 7.8. The depths to water level in the upper aquifer refers to the water table. Depths to the water level in the lower aquifer is thus the water table plus the maximum hydraulic head difference caused by pumping, which results in leakage through the upper saturated silt/clay formation. In areas where the aquifer is unconfined or areas where the water table is lowered below the upper clay/silt layer, there are no separate water levels. Confidence limits for predicted drawdown should be in the range of 10 - 15 percent.

Impact of Groundwater drawdown on Potable water supply
Present indications show that the No. 6 HTWs are being replaced by Tara pumps within the Kangsha Basin. With increased drawdown of the groundwater level there will be a need for an accelerated rate of replacement of the No. 6 HTWs in future. This handpump can only abstract water from a depth of 6 metres below the village mound. The modified HTW (Tara pump) can withdraw water from depths of 15 metres or more. Available resources to the various handpump technologies are tabulated in Table 8.4. In the areas where the water level remains at less than 5 metres below the Village mound, No. 6 HTW can comfortably operate. Where the level is deeper, modified Tara HTWs are required.

The future HTW replacements are not only based on future groundwater level drawdown due to increased agricultural and domestic water use, but also the type of aquifer, thickness of the upper clay/silt layer and the quality of water available in the upper and lower aquifer.

Based on the depletion in Table 8.2 and HTW criteria in Table 8.4, the probable future (dominant) HTW for potable water supply in the rural area is summarised in Table 8.3. However HTW No. 6 will still be operating in three of the municipalities under Netrokona district administration (Netrokona, Kalmakanda, Dhubuara) in the forceable future using either the upper aquifer or perched water tables. In other places Marginal Tara and Tara would be required to abstract water from the lower aquifer. In the northern part of the Basin, Tara, M.S. Tara and Super Tara would be the future HTW technology for rural domestic water supply. In the thanas Nakla and Sherpur HTW No.6 would remain dominant for rural water supply in the forseeable future.

Table 8.2

Water Level Depth from Village Mounds After Potential G.W. Irrigation Requirements

Net Pot. GW for Irri. in mm	Height of Village Mound	Thana	Depth to GW from Village Mound in m	
			Upper	Lower
2	3	1	4	5
330	1.32	Sribordi	8.58	11.21
334	1.20	Jhinaighati	15.87	16.56
500	1.31	Sherpur	9.71	9.80
417	1.38	Nalitabari	14.01	15.41
459	1.41	Nakla	7.27	7.35
445	1.56	Haluaghat	14.56	19.28
500	1.51	Phulpur	13.34	14.33
446	1.69	Durgapur	14.47	16.48
424	1.58	Dhubarra	14.3	15.70
437	2.15	Kalmakanda	12.15	12.70
457	1.52	Purbadhala	11.27	12.77
395	1.52	Netrokona	11.52	11.77
367	1.71	Barhatta	15.9	16.09

Note : col (2) Net water demand to irrigate the potential Irrigable land by groundwater (Table 7.7 and Table 7.6)

Table 8.3

Future Tubewell Requirements for Rural Potable Water Supply

Thana	Recommended Technology for Rural water supply	
	Upper Aquifer	Lower Aquifer
Sribordi	Tara	Tara
Jhinaigati	M.S. Tara	Tara
Sherpur	M.Tara	M. Tara
Nalitabari	Tara	Tara
Nakla	No. 6	No. 6
Haluaghat	Tara	S. Tara
Phulpur	Tara	Tara
Durgapur	Tara	S. Tara
Dhubarra	Tara	M. S.Tara
Kalmakanda	Tara	Tara
Purbadhala	Tara	Tara
Netrokona	Tara	Tara
Barhatta	Tara	Tara

Table 8.4

Criteria for Different Hand Pumps

	Hand Pump Type	Pumping Depth capacity
a)	No. 6	<=6 m
b)	Marginal Tara	6 m -8 m
c)	Tara	8 m - 15 m
d)	Mrg. Super Tara	15 m -16 m
e)	Super Tara	>16 m

Source : UNICEF, June 1994

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8.3 Impact of Flood Control and Drainage on Potential Recharge

The impact of flood control on the potential recharge was evaluated using a recharge model on each thana, which simulates recharges from natural sources.

In the recharge model, synthesized flood hydrography was used to represent two basic conditions: NO flood control and FULL flood control (see Figure 9); all other conditions remaining the same. Table 8.5 summarizes the results, which shows a reduction in the southwestern thanas of Sribordi, Sherpur and Nakla between 15 and 30% which may be too much to satisfy the net water demand for potential irrigation development. In other places, a recharge reduction of less than 10% would still satisfy the full development. Exception to this is in Nalitabari, Haluaghat and Durgapur thanas, where recharge without flood protection intervention is already too marginal to satisfy the full demand.

Table 8.5

Impact of Flood Control on Potential Recharge

Thana	No Flood Control (mm)	With Flood Control (mm)
Sribordi	663	435(34)
Jhinaigati	523	509(3)
Sherpur	710	589(17)
Nalitabari	500	492(2)
Nakla	675	505(25)
Haluaghat	550	544(1)
Phulpur	800	730(9)
Durgapur	600	524(13)
Duhboura	725	711(2)
Kalmakanda	729	714(2)
Purbadhala	800	744(7)
Netrokona	792	725(8)
Barhatta	933	904(3)

Note : Numbers in parentheses = percent reduction of recharge with flood control

8.4 Groundwater Quality

Groundwater quality monitoring in the area has been rather sporadic in the past, and few samples are available. Data for 1979 - 1983, published by BWDB in 1983 - 1984, included a few samples collected from the Kansha River Basin. These should be considered outdated. More recent samples of groundwater quality from BWDB include two sample collected in Netrakona and Sherpur thanas. Results of the analysis are shown in Tables 8.6 and 8.7. According to the drinking water standards (Table 8.8) of the Environmental Pollution Control Board, Bangladesh (EPCB), and World Health Organization (WHO), the quality of the two groundwater samples falls well within the acceptable range, and based on past analysis of groundwater from the Basin there do not appear to be any serious problems.

Preliminary information for the main aquifer shows pH values in the range of 6 to 7 in Mymensingh which is well within the prescribed limits.

Total dissolved solids are in the range of 100-200 mg/l; well below the WHO standard of 1500 mg/l.

Basin-wide measurements of iron content are generally not available. The reported data can only be regarded as indicative. The total iron content value of the groundwater is likely to vary in the ranges from the high value of 10 mg/l in Sherpur Thana, within the Brahmaputra Floodplain, to less then 1.5 mg/l in the rest of the Basin. The standard value is in the range of 1-5 mg/l.

Analysis for Nitrate shows traces to negligible values. The increased use of high nitrogen fertilizers for HYV boro rice crops may in the long run result in contamination of the groundwater. Although beneficial in terms of irrigation water, values higher than 50 mg/l may be detrimental to human health.

Hardness and chloride contents are within the standard ranges.

SAR values, essential for assessing the suitability or water for irrigation purposes are not available.

The presently available analytical data are insufficient to produce a comprehensive and meaningful picture of the groundwater quality in the Kangsha Basin.

Of major concern is the quality of drinking water, which in the rural areas often is drawn from hand dug or shallow hand tube wells situated in the water table in the vadose zone (surface aquilude). Due to poor sanitary conditions, the water in this zone is subject to bacterial contamination (E-Coli) and may present serious health hazards in some areas. The critical areas are those where the No. 6 HTW, with its limited 6-metre suction capacity, is unable to reach the upper aquifer due to the thickness of the upper aquilude. These same wells are also the first to run dry during the irrigation season due to lowering of the water level in the upper aquifer; caused by groundwater abstraction for irrigation. Remedial action for this situation is discussed in paragraph 8.1.1.

Table 8.6
Water Quality Investigation in Netrokona

Thana : Netrokona ST-NO : S-45, YEAR : 1993 Depth : 64.63 m							
pH	TDS	SiO_2	Ca	CO_2	Fe	Mg	Na
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
7.22	221	134	47.4	40	1.43	47.4	10.4
Cl	So_4	Co_3	HCO_3	NO_3	SAR	Mn	HD
16	0	0	172	3.3	0.22	0.2	118.5

Source : BWDB

Table 8.7
Water Quality Investigation in Sherpur

Thana : Sherpur ST-NO :S-42/A , YEAR : 1993 Depth :36.34 m							
pH	TDS	SiO_2	Ca	CO_2	Fe	Mg	Na
-	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
6.32	280	0.96	73.6	28	12.8	110.4	20.8
Cl	So_4	Co_3	HCO_3	NO_3	SAR	Mn	HD
32	0	0	160	1.6	0.35	0.6	184

Source : BWDB

Table 8.8
Drinking Water Standard of EPCB and WHO

Item	**Units**	**EPCB**	**WHO**
pH	-	**6.5-9.2**	**6.5-9.2**
TDS	**mg/l**	**1500**	**1500**
Iron	**mg/l**	**1.0(5)**	**1.0**
Nitrate (NO_3)	**mg/l**	**45(50)**	**45**
Total Hardness [1]	**Mg/l**	**250(45**	**500**
Chloride	**mg/l**	**600(10**	**600**

[1] Contents of soluble impurities

Note : Groundwater Survey, UNDP, 1982

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

WARPO's groundwater model takes into consideration many parameters which are required to generate the data. The output of the model is therefore critically dependent on the quality of the data it uses for the input. The key hydrogeologic parameters used in the appraisal of the groundwater situation in the Basin are based on results obtained from WARPO's special study area at Phulphur. While the aquifer characteristics of this particular area may be typical for parts of the Basin, it is too simplistic to assume that they are applicable to the majority of the area. The adaptation by WARPO of a "Usable Recharge", representing 75 percent of the Potential Recharge, no doubt cushions the margin of error and may in some instances actually result in rather conservative estimates of available resources. Greater reliability of the model will no doubt ensue as availability and quality of the required input data expands.

The expanding use of groundwater for irrigation in the Kangsha River Basin will continue to put additional strains on the aquifers. Following privatization of groundwater development in Bangladesh, the number of STWs have continued to expand in the Basin, whilst development of DTWs has sharply curtailed. The much higher cost of the latter, and difficulty in assembling enough land holdings to justify the use of higher capacity DTWs, may be part of the underlying reasons.

Socio-economic conditions and land ownership play a major role in the development pattern of STWs. Preliminary investigations indicate that as a result of this, the command area for each well is shrinking. Provided that abstraction rates for each well are matched to the required crop duty, this in itself does not give rise for concern. There are good indications, however, that the rate of groundwater abstraction increases within a given area, already having sufficient irrigation capacity, as the number of DTWs expands within the same. The result is overuse of irrigation water.

The growing population in the Basin's urban centres will necessitate expansion of potable water supplies at an accelerated rate. The rural domestic water supply, provided by HTWs, must be safeguarded. The change from the shallow capacity No. 6 HTW to Tara-type HTWs, with a 15 metre lift capacity, is currently under way; supported in part by UNICEF. Increasing drawdown of the water table resulting from expanding irrigation activities has caused domestic water shortages in some areas where the No. 6 HTW is used.

Hydrographic data from the Basin is limited and insufficient to give a clear picture of the interactive responses to groundwater abstraction between the upper and lower aquifer. Confined conditions in the lower aquifer would enable DTWs to operate in conjunction with STWs without detrimental effect on the upper aquifer. Where the lower aquifer is unconfined, the use of mixed abstraction technology is not compatible. Semi-confined conditions allows for limited mixed abstraction technology.

Continued lowering of the water level with expanding irrigation will result in water shortages for the STW technology. Introduction of alternative pumping technology which can take advantage of the full usable recharge will become necessary in some areas of the Basin in the foreseeable future. Expansion of the groundwater observation network in areas where groundwater irrigation is intense is therefore essential.

9.2 Recommendations

The inherent dependency on WARPO's groundwater model for assessing groundwater resource availability makes it essential that the required input data be as accurate as possible. Expansion of the groundwater monitoring network in the Kangsha Basin would render much needed assistance toward this. It is therefore recommended that NERP should design and execute a program which would insure that an adequate and functional groundwater monitoring program be established in the Basin.

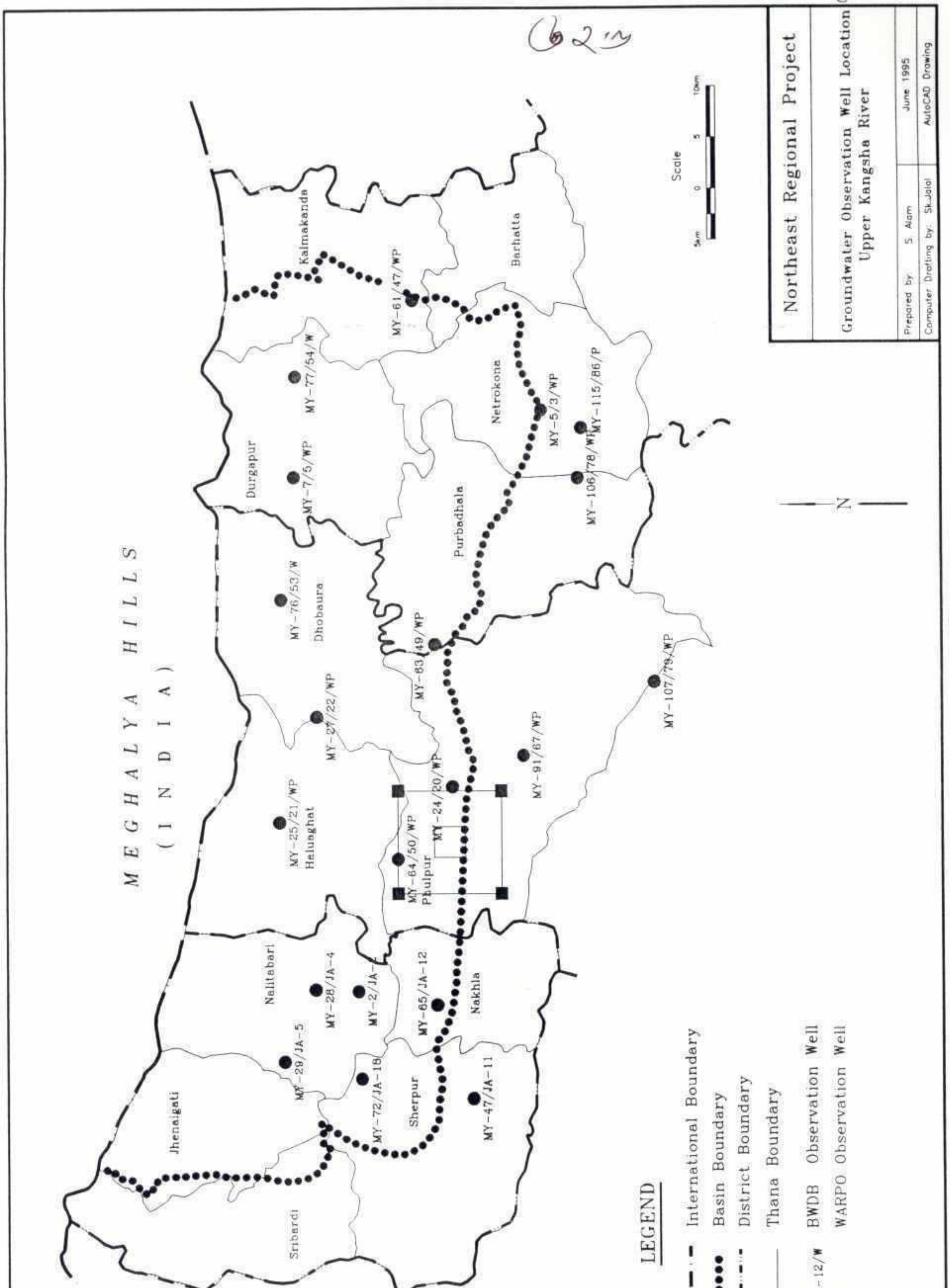
Many of the present observation wells are grouped near thana centres (Figure 22), and do not serve to monitor the effect of rapid expansion of agricultural irrigation on the groundwater. A number of the wells used in the present network measure either the water table fluctuations or the piezometric surface and fail to provide the type of data that a homogenous network would.

The design of a network should consider the following:

- density of observation points must be varied according to the geology, geomorphology and hydrogeology;
- the level of irrigation development should determine the location of the observation wells;
- the wells should be used only for monitoring purposes;
- each monitoring point should consist of two wells, monitoring separately the upper and lower aquifer, unless the intermediate aquilude/aquitard above the lower aquifer is absent;
- automatic water level recorders should be used as much as possible and set to record the groundwater level or piezometric surface weekly.

A thorough study of the existing network should be carried out. Those observation wells which meet the criteria required with respect to location and depth should be incorporated into the new network. Final design of the network should be carried out in consultation with WARPO to ensure that their requirements for groundwater model calibration are met. Hydrographic data obtained from the observation wells are essential to recalibrate and reassess the groundwater resource potential.

Figure 22


Northeast Regional Project
Groundwater Observation Well Location
Upper Kangsha River
Prepared by: S. Alam
June 1995
Computer Drafting by: Sk.Jalal
AutoCAD Drawing
Scale
5km
0
5
10km
N
M E G H A L A Y A H I L L S
(I N D I A)
Kalmakanda
Barhatta
Durgapur
Netrokona
Purbadhala
Dhobaura
Haluaghat
Phulpur
Nalitabari
Nakhla
Jhenaigati
Sherpur
Sribardi
MY-61/47/WP
MY-77/54/W
MY-7/5/WP
MY-5/3/WP
MY-115/86/P
MY-106/78/WP
MY-76/53/W
MY-63/49/WP
MY-107/79/WP
MY-27/22/WP
MY-91/67/WP
MY-24/20/WP
MY-25/21/WP
MY-64/50/WP
MY-28/JA-4
MY-2/JA-
MY-65/JA-12
MY-29/JA-5
MY-72/JA-18
MY-47/JA-11
LEGEND
International Boundary
Basin Boundary
District Boundary
Thana Boundary
MY-63/JA-12/W
BWDB Observation Well
WARPO Observation Well