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

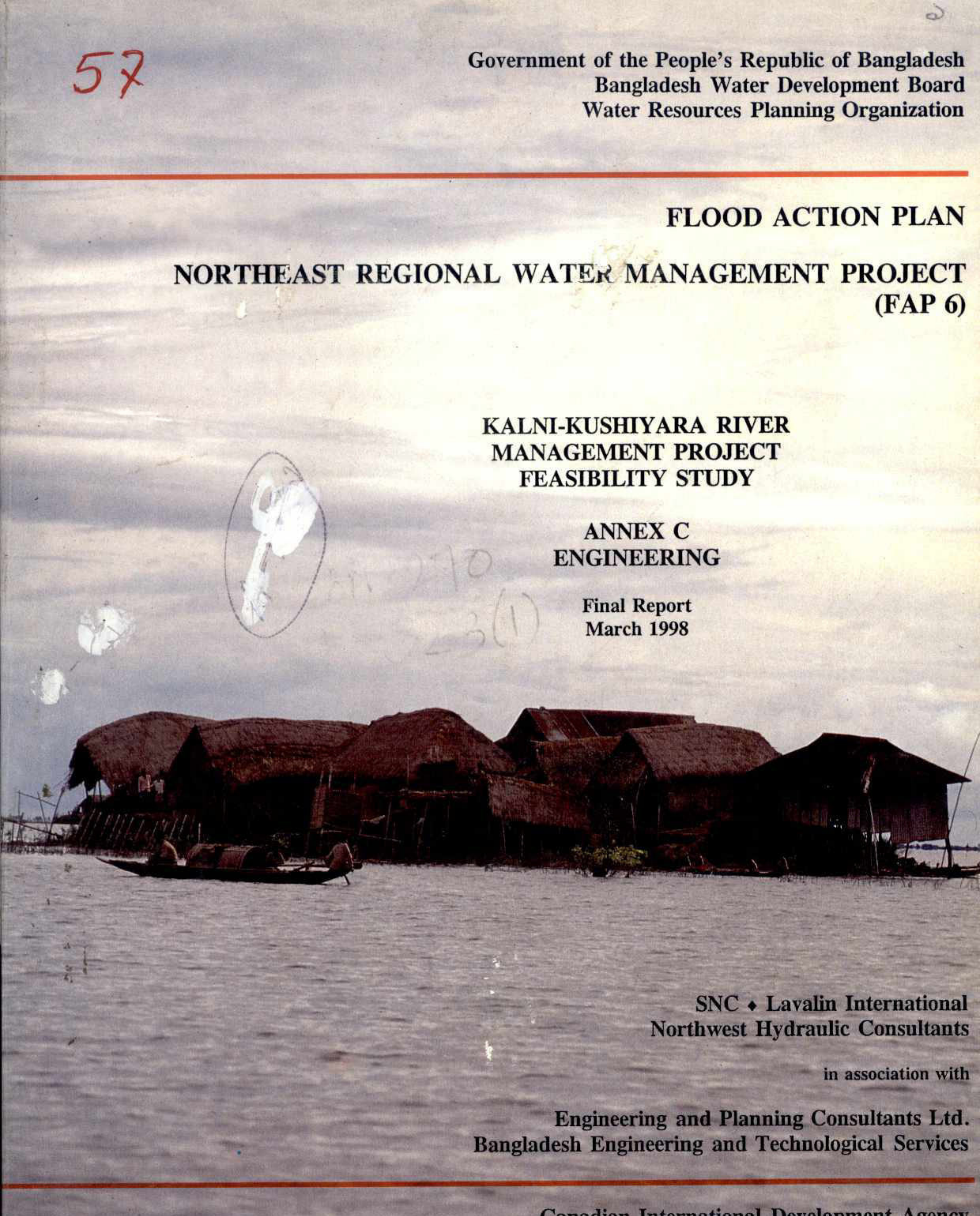
FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT FEASIBILITY STUDY

ANNEX C
ENGINEERING

Final Report
March 1998



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Bangladesh Engineering and Technological Services

Canadian International Development Agency

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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APPROVED BY BWDB
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ACRONYMS AND ABBREVIATIONS

AST	Agriculture Sector Team
BWDB	Bangladesh Water Development Board
CDN	Canadian
CIDA	Canadian International Development Agency
COE	Corps of Engineers (USA)
DSSTW	Deep Set Shallow Tube Well
DTM	Digital Terrain Model
DTW	Deep Tube Well
EMP	Environmental Management Plan
FAP	Flood Action Plan
FCDI	Flood Control Drainage and Irrigation
FPCO	Flood Plan Coordination Organization
GEV	General Extreme Value
GL	Ground Level
GOB	Government of Bangladesh
ha	hectare
hr	hour
kg	kilogram
km	kilometre
KK	Kalni-Kushiyara
KKCDMP	Kalni-Kushiyara Community Development and Monitoring Project
KKRMP	Kalni-Kushiyara River Management Project
LLP	Low Lift Pump
LLW	Low Level Water
m	metre
mm	millimetre
Mm^3	Million cubic metres
MPO	Master Plan Organization
mt	metric tonne
NERP	Northeast Regional Water Management Project
O&M	Operation and Maintenance
PWD	Public Works Department
RCC	Reinforced cement concrete
RTAC	Roads and Transport Association of Canada
TBM	Temporary benchmark
USA	United States of America

GLOSSARY

aman	monsoon rice crop
aus	pre-monsoon rice or rice grown in *kharif* I season.
ballah piles	wooden piles
beel	floodplain lake that may hold water perennially or dry up during the winter season
bhita	homestead
boro	rice grown during the winter season
chailla	a grass (Hemarthria protensa) grown in low-lying floodplains
dhala	breaches across river banks
dhaincha	a green manuring crop (sesbania sp.) also used as fuel
dry season	5 months: December-April inclusive
duar	scour hole in river bed which provides habitat for fish and river dolphins
haor	depression on floodplain located between two or more rivers
kanda	raised land surrounded by crop fields used for cattle grazing or rice threshing
khal	channel
khas	government owned land or water bodies
koroch	type of water tolerant tree
mandir	Hindu temple
salaballah	Harwood pile
taka (tk)	unit of currency, 1 US $ = 40 taka (approx.)
tarja	bamboo mat
thana	geo-administrative unit under a district comprising several unions
wet season	7 months: May-November inclusive

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1. INTRODUCTION

1.1 Scope of Work

This Annex presents hydro-meteorological and topographical conditions within the Project area, engineering surveys and analysis carried out in the course of this study, and feasibility level designs. The civil designs include quantity and cost estimates which were used in the preparation of the Project schedules, and in the economic analyses.

1.2 Project Goals and Objectives

The Kalni-Kushiyara River is one of the major rivers in Northeast Bangladesh. Over the last 30 years it has experienced ongoing channel instability and sedimentation problems, which have led to increased pre-monsoon flood damage, deteriorating river navigation and loss of productive lands and settlements. The purpose of the Kalni-Kushiyara River Management Project is:

- to improve the river's long-term stability and to create a more stable environment for development;
- to reduce damage to agriculture by controlling pre-monsoon floods and improving post-monsoon drainage;
- to improve people's living conditions by reducing erosion damage to villages and homesteads, and by creating new flood-protected village platforms, and
- to improve navigation during the dry season.

1.3 Report Outline

In addition to this brief introduction, the Annex contains 10 additional Chapters and 4 Appendices. These chapters are organized as follows:

- Chapter 2, *Project Area*, summarizes the main characteristics of the project area;
- Chapter 3, *Hydrology*, describes the pattern of runoff, magnitude and frequency of discharges, and the wave climate in the monsoon season;
- Chapter 4, *River Hydraulics*, summarizes information on the hydraulic behaviour of the river channel, including water surface profiles, velocities and depths;
- Chapter 5, *Present Infrastructure*, summarizes the status of FCDI works in the project area;
- Chapter 6, *Current Problems*, describes the key technical problems and issues that are addressed in this feasibility investigation;
- Chapter 7, *Project Concept*, describes the overall conceptual planning that was carried out during the project's formulation;
- Chapter 8, *Project Description - Alternative 1* summarizes the main components and the design aspects of Alternative 1;
- Chapter 9, *Quantity and Cost Estimates - Alternative 1*, provides a detailed cost summary of all physical works;
- Chapter 10, *Project Description - Alternative 2* summarizes the physical components and design of Alternative 2, and
- Chapter 11, *Quantity and Cost Estimates - Alternative 2* provides a summary of costs for Alternative 2.

In addition to this main text, 4 Appendices have been included:

- Appendix C.1, contains a summary of BWDB's hydrometric data at key stations along the Kalni-Kushiyara River;
- Appendix C.2, summarizes NERP's hydrometric measurements;
- Appendix C.3, presents a summary brief of partial flood control and drainage projects;
- Appendix C.4, summarizes monitoring of bank protection on the Kushiyara River, and
- Appendix C.5, provides results of soils investigations at various sites.

Additional supplementary information that is relevant to this Annex is contained in Annex A - Sedimentation and Annex B - Hydrodynamic Modelling.

2. PROJECT AREA

2.1 Location

The Kalni-Kushiyara River Management Project lies south of Sylhet and east of Bhairab Bazar between Latitude 24° 56' - 24° 15' and Longitude 92° 05' - 92° 55'. It is bounded by the Kushiyara-Bijna-Ratna-Sutang River system on the south, the Old Surma-Dahuka River system and Jagannathpur-Sylhet road on the north, Old Surma-Baulai River system on the west and the Sylhet-Kaktai village road on the east. The project covers a gross area of 335,600 ha and extends over the districts of Sylhet, Sunamganj, Moulvibazar, Habiganj, and Kishoreganj. Figure C.1 shows a general map of the project area and the surrounding river systems.

2.2 Accessibility

The project area is accessible by road from Dhaka via Bhairab Bazar and Habiganj. It is also accessible by boat via the river navigation network, through the Ashuganj-Bhairab Bazar-Ajmiriganj-Fenchuganj route.

2.3 Population

According to the 1991 census, the population in the project area was 1.77 million. The project area accounts for 2.27% of the country area and 1.58 % of the total population of Bangladesh. The average population density is $526/km^2$, which is much lower than the national figure of $755/km^2$. Although the population density is relatively low, in fact, large tracts of land are not suitable for dwelling, due to their low elevation and susceptibility to annual flooding. During the period 1981-1991 the population increased at an annual rate of 1.77%, which is lower than the national figure of 2.17%. This relatively lower rate may be due to net out migration.

2.4 Physical Setting

The landforms in the project area have formed as a result of alluvial sediment deposition in a slowly subsiding tectonic basin. Consequently, most of the area is underlain by Holocene-age alluvial and lacustrine deposits. The project area consists primarily of lowland floodplain and flood basins.

The project area encompasses 3 main physiographic sub-divisions (Figure C.2):

Eastern Surma-Kushiyara Floodplain
This land lies mainly east of Sherpur and consists of recent alluvial floodplain sediments. The rivers have formed prominent natural levees which reach 2 to 3 m above the surrounding lower lying back-basins.

Sylhet Basin
This land occupies the middle of the project area and consists mainly of low-lying flood basin land that is traversed by a maze of distributary channels, abandoned *khals* and ox-bow lakes. Virtually all of the land lies below El. 6 m, and becomes deeply flooded in the monsoon season. The area is characterized by large *haors* and permanently inundated *beels*. The "inter-riverine" *haor* areas consist of dish-shaped depressions that are confined within a perimeter of natural levees. The lowest portion of the *haor* is often occupied by a permanently inundated *beel*.

The *haors* comprise the prime agricultural land of the project area, but their seasonal inundation provides a serious constraint to agriculture. The main *haors* in the project area include Chanhai Hoar, Chaiar Haor, Baram Haor, Tangua Haor, Chaptir Haor and Naluar Haor.

Old Meghna Estuarine Floodplain
This land occupies the eastern part of Kishoreganj District and the western part of Habiganj District. This unit forms the right (western) bank of the Kalni River and Baida River between Kadamchal and Astagram. This land consists of almost level, floodplains or shallow basins, and ranges between El. 3 to 5 m PWD. The sediments consist of predominately silty material.

2.5 Topography

Figure C.3 shows a general topographic map of the project area and illustrates the low-lying character of the land. Figure C.4 summarizes the elevation-area and elevation-storage volume relation for the project area. These results were determined from land levels on the Survey of Bangladesh's 4 inch=1 mile topographic maps. These maps have 1 foot contour levels and were produced from ground surveys between 1965-1968. Approximately 80% of the land in the project lies below 7 m PWD and 50% lies below 5 m PWD. The land generally slopes down from east to west. The highest alluvial land lies along the main course of the river where natural levees extend up to 3 m above the adjacent flood basins.

2.6 Climate

Long-term climate stations are maintained at Sylhet, Habiganj (east of the project), at Sunamganj (north of the project area), and at Markuli (near the centre of the project). Figure C.5 summarizes average climate statistics at Sylhet. The area experiences the sub-tropical monsoon climate typical of Bangladesh, but with variations due to its location and topography. Figure C.6 shows the variation in mean annual rainfall over the Northeast Region (NERP, 1994). Mean annual rainfall increases from an average of 2,572 mm/year in the south (at Habiganj) to 5,641 mm/year (at Sunamganj) in the north, or by 119% across the project area. Table C.1 summarizes monthly rainfall totals at Habiganj, Markuli, Zakiganj and Sheola.

There are 4 more or less distinct seasons in the project area and they reflect the seasonal distribution of the annual rainfall (Table C.2). The most distinctive climatic events of the year are the onset and withdrawal of the monsoon. In the project area, onset occurs around 1 June plus or minus about 4 days. Withdrawal occurs around 7 October plus or minus about 14 days. The average duration of the monsoon is 122 days, but it has varied from 112 to 139 days.

Maximum temperatures vary from about 27.6°C to 35.0°C. The highest temperatures are experienced during the period of April to June. Daily minimum temperature can fluctuate significantly during the year, ranging from about 9°C to 23°C.

Table C.1: Monthly Rainfall Statistics

Month	Zakiganj			Sheola			Habiganj			Markuli		
	Max (mm)	Min (mm)	Mean (mm)	Max (mm)	Min (mm)	Mean (mm)	Max (mm)	Min (mm)	Mean (mm)	Max (mm)	Min (mm)	Mean (mm)
Jan	51.6	0.0	9.3	65.1	0.0	9.1	127.0	0.0	13.2	37.8	0.0	7.1
Feb	171.0	0.0	45.0	152.3	0.0	35.5	166.3	0.0	22.6	139.8	0.0	25.8
Mar	550.7	1.1	148.4	472.2	8.9	131.5	343.1	0.0	70.7	198.6	0.0	63.2
Apr	935.0	145.0	421.8	994.7	156.0	384.9	614.4	45.0	223.7	1,002.7	46.5	341.0
May	1,200.0	112.0	588.5	1,324.0	128.5	576.4	939.2	98.6	446.4	1,310.8	135.0	558.1
Jun	1,552.1	158.0	798.7	1,714.3	220.3	898.9	987.1	93.1	491.4	1,504.4	249.4	822.6
Jul	1,275.9	416.4	743.4	1,235.8	393.0	748.0	816.2	139.2	415.3	1,319.6	217.7	672.9
Aug	1,078.5	359.7	555.3	850.6	279.4	572.9	955.5	113.2	398.1	1,168.4	52.2	465.1
Sep	1,288.0	87.6	428.1	1,232.0	0.0	494.1	565.4	73.1	271.9	825.4	71.4	393.2
Oct	512.0	0.0	217.1	692.0	4.0	232.9	388.9	4.1	151.5	508.0	0.0	145.4
Nov	156.9	0.0	34.3	121.9	0.0	33.6	139.7	0.0	24.7	105.7	0.0	23.8
Dec	121.9	0.0	14.2	120.0	0.0	15.3	147.3	0.0	9.4	98.8	0.0	11.4
Annual	**5,484.0**	**2,816.6**	**4,011.9**	**5,207.0**	**3,046.5**	**4,089.4**	**4,152.8**	**1,519.5**	**2,542.3**	**5,355.2**	**2,116.7**	**3,500.6**

Table C.2: Seasonal Distribution of Annual Rainfall

Season	Nature of Runoff	Calendar Period	Percent of Annual Rainfall in Project Area (%)		
			South (Habiganj)	Middle (Markuli)	North (Sunamganj)
Dry	drought	Dec. - Mar.	4	3	2
Pre-monsoon	Flash Floods	Apr. and May	25	25	15
Monsoon	Flooding	June - Sept.	65	67	78
Post-monsoon	Drainage	Oct. and Nov.	6	5	5

2.7 River System

The Kalni-Kushiyara River system originates from the Barak River in India. The Barak River drains 25,260 km^2 of land in the states of Assam, Manipur and Mizoram. The Barak River enters Bangladesh near Amalshid and splits into the northward flowing Surma River and the southward flowing Kushiyara River. Below Amalshid, the river undergoes several name changes along its course (Table C.3). All locations along the river have been referenced to a chainage, measured along the river centreline and starting from the BWDB gauge on the Meghna River at Bhairab Bazar. Table C.4 summarizes the locations of key sites that are referenced in this text. A 1:10,000 map of the main study reach is included at the end of the report (Figure C.7).

The Sonai-Bardal River, Juri River and Manu River are the main left bank tributaries between Amalshid and Sherpur. North of the Kushiyara, the land slopes towards the low-lying Surma-Kushiyara Inter-basin. This flood basin is drained by distributary channels such as Sada Khal which eventually flow into the Kushiyara River through Damrir Haor near Fenchuganj. Other major distributary channels such as Barbhaganga Nadi and Itakhola Nadi flow into Sadipur Khal, a major distributary channel that parallels the Kalni River north of Sherpur. These flows eventually enter the Darain River north of Ajmiriganj.

Downstream of Sherpur, the Kushiyara River flows in a westerly direction through the Suriya channel until reaching Markuli. This channel has developed over the last 40 years from a minor *khal* into the main channel, after the river was accidently diverted from its former course (the Bibiyana channel). Before 1978, the upper Kalni River collected runoff from the Surma-Kushiyara inter-basin and drained southwards into the Kushiyara River at Markuli. In 1978, a closure was constructed across the Kalni River at Markuli and the flows from the inter-basin were diverted into the Darain River system (Figure C.1).

Table C.3: Kushiyara River System

River Name	Reference Chainage (Km)	Extent
Kushiyara River	313 -163	Amalshid bifurcation to Bibiyana offtake near Sherpur
Kushiyara River	163- 133	Suriya channel to Markuli
Kalni River	133 -66	Markuli to Ratna/Khowai River junction
Dhaleswari River	66 -20	Ratna River junction to Ghorautra River confluence
Upper Meghna River	< 20	downstream of Ghorautra River confluence

Downstream of Markuli, the river is called Kalni River. The Kalni River carries on in a southerly direction until reaching Issapur, where it bifurcates, with the shorter western branch called Baida River. The Kalni River heads eastward through a series of bends and is joined by the Ratna/Khowai River near Madna. This section of the Kalni River is also locally called Dhaleswari River. The Ratna River drains floodplain land south of Ajmiriganj, while the Khowai River is a major southward flowing Piedmont stream that drains the Tripura Hills in India. Downstream of this confluence, the Kalni River is called Dhaleswari River. This eastern branch has been gradually silting in over time, so that in the dry season most flow now is carried by the Baida channel. The Baida channel re-joins the Dhaleswari River south of Astagram. The river joins the Baulai River near Dilalpur and forms the Upper Meghna River.

Table C.4: Location of Key Sites

Feature	Kilometre	River	Comment
Bhairab Bazar	0	Meghna	BWDB gauge site
Madna	61.0	Dhaleswari	junction of Ratna R.
Issapur	72.4	Kalni	Kalni/Baida bifurcation
Abdullahpur	79.0	Kalni	village
Kadamchal	84.7	Kalni	NERP hydrometric station
Katkhal	93.5	Kalni	village
Shantipur	95.4	Kalni	NERP hydrometric station
Ajmiriganj	106.5	Kalni	BWDB hydrometric station
Koyer Dhala	115.4	Kalni	site of major spill/breach
Markuli	133.4	Kushiyara	closure blocks old Kalni R.
Sherpur	177.3	Kushiyara	BWDB gauge
Fenchuganj	217.0	Kushiyara	BWDB gauge
Sheola	269.0	Kushiyara	BWDB gauge

3. HYDROLOGY

3.1 Available Data

Table C.5 summarizes the period of record for BWDB's hydrometric stations on the Kalni-Kushiyara River system and adjacent rivers. The two key discharge measurement stations are situated at Sheola (upstream of Fenchuganj) and at Sherpur on the Kushiyara River. Due to backwater control and spilling during most of the monsoon season, discharges are not routinely measured downstream of Sherpur. However, discharge measurements were made by NERP on the Kalni River at Markuli, Ajmiriganj, Shantipur, Kadamchal and Issapur in 1995 and 1996. These measurement were generally made in the dry season and pre-monsoon flood season when the flow remained within its banks. The period of observations for these temporary stations are summarized in Table C.6.

BWDB has operated water level stations at several locations along the river, including Amalshid (at the Indian border), Sheola, Fenchuganj, Manumukh and Sherpur on the Kushiyara River and Markuli, Ajmiriganj and Madna on the Kalni River. Most of the available data from these stations starts around 1964, although in some cases data from the 1950's has been obtained.

Hydrometric data for the period 1991 to 1993 have been collected from SWMC (Table C.5).

3.2 Data Summary

NERP (1994) compiled all available hydrometric data in the NE Region. After reviewing the information to screen out possible errors, and correcting the data to SOB's Second Order Levelling Survey Datum, the records were entered into spreadsheet format to provide a convenient data base.

Basic statistics were computed and time series plots were prepared. Results of this analysis are summarized for key stations on the river in Appendix C.1 of this Annex.

3.3 Runoff

3.3.1 Annual Runoff

Discharge records on the Kushiyara River at Sheola extend 28 years (between 1964-1993), while records at Sherpur extend 10 years (1982-1993). Water balance studies were carried out by NERP (1995) to estimate the total contribution of the Kushiyara River system to the Meghna River at its junction near Dilalpur. The results of this analysis are summarized in Table C.7. The water balance shows that the Kushiyara River contributes 32% of the total runoff to the Upper Meghna River system. Figure C.8 shows a schematic distribution of the mean annual discharge throughout the Northeast Region. The figure shows that the long-term mean discharge on the Barak River at Amalshid has been estimated at 1,008 m^3/s, with the flow into the Kushiyara River branch amounting to 656 m^3/s. The long-term mean is 1,100 m^3/s at Sherpur and 1,535 m^3/s on the lower Dhaleswari River at its confluence with the Upper Meghna River near Dilalpur. The mean discharge on the Meghna River at Bhairab Bazar is 5,589 m^3/s.

Table C.5: Summary of BWDB Hydrometric Measurements

Station No.	Type	River	Station	Latitude (N)		Longitude (E)		Confirm	Date Installed	Water Year																													
				Deg	Min	Deg	Min			64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
33	Q	Bhattakhal	Gobindaganga	24	56.2000	91	41.5000		1958	H	H	H	H	H	H	H		H	H	H	H	H	H	H	H	H	H												
67	Q	Dhalai	Kamalganj	24	21.3579	91	51.0793	GPS	1957	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	H	C	C	C	C	C	C	C	C	C	S	S	S
71	T	Dhaleswari	Kalagachia	23	34.7684	90	32.5516	GPS	1945		H	H	H	H	H	H	H	H	H	H	H	H	C	C		C			C	C	C	C	C	C	C	C			
71 A	T	Dhaleswari	Rekabi Bazar	23	34.1856	90	30.2902	GPS	1965		H	H	H	H	H	H	H	H	H	H			H			H			C	C	C	C	C	C	C	C			
72	T	Baulai	Kaliajuri	24	41.3052	91	7.3302	GPS	1945	H	H	H	H	H	H	H	H	H	H	H		H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
72 B	Q	Baulai	Sukdevpur	24	52.7637	91	9.9385	GPS																				C	C	C	C	C	C	C	C	C	S	S	S
73	T	Baulai	Itna	24	31.8347	91	5.6318	GPS	1945	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
74	T	Ghorautra-Balulai	Dilalpur	24	11.2258	90	58.5953	GPS	1945	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
135	Q	Juri	Juri	24	36.4800	92	8.2200	GPS	1957	C	C	C	H	H	H	H	H	H	H	H	H	C	H											H					
135A	Q	Juri - Continala Branch	Juri(continala)	24	35.5983	92	6.7331	GPS	1967				H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	S	S	S
138	Q	Korangi	Sofiabad	24	17.5477	91	32.9787	GPS		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	S	S	S
157		Khowai	Ballah	24	5.0070	91	36.0154	GPS	1958	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	S	S	S
158		Khowai	Chunarghat	24	12.1010	91	31.8220	GPS	1957	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
158.1	Q	Khowai	Shaistaganj	24	16.3825	91	28.5790	GPS	1964	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
159		Khowai/Barak	Habiganj	24	22.1080	91	25.6750	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
172	Q	Kushiyara	Amalshid	24	52.1300	92	28.5400	GPS	1951	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
173	Q	Kushiyara	Sheola	24	53.3950	92	11.4460	GPS	1949	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
173A	Q	Sada Khal	Sheola	24	53.8055	92	10.7268	GPS	1947	H		H	H	H	H	H	H	H	H	H	H	H	H															S	S
174	Q	Kushiyara	Fenchuganj	24	42.1250	91	56.4800	GPS	1947	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	S	S	S
175	Q	Kushiyara	Monumukh	24	35.7000	91	43.5000	NERP	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	C	H				C											
175.5	Q	Kushiyara	Sherpur	24	37.6564	91	40.9657	GPS																				C	C	C	C	C	C	C	C	C	S	S	S
192	Q	Langla	Motiganj	24	18.2950	91	40.8870	GPS	1958	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	S	S	S
201	Q	Monu	Monu R.R. bridge	24	25.7133	91	56.5840	GPS	1958	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
202		Monu	Moulvi bazar	24	29.6476	91	46.4358	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	S	S	S
265	Q	Sonai-Bardal	Jaldhup	24	46.4370	92	10.3620	GPS	1957	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C		C	C	S	S	S
266	Q	Surma	Kanairghat	25	0.0000	92	15.5520	GPS	1951	H	H	H	H	H	C	C	H	C	C	C	C	C	C	C	C	C		C	C	C	C	C	C	C	C	C	S	S	S
267	Q	Surma	Sylhet	24	53.2413	91	52.2655	GPS	1938	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	S	S	S
268	Q	Surma	Chatak	25	2.1561	91	39.9331	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	H	H	C	C	C	C	C	C	C	C	C	S	S	S
269	Q	Surma-Meghna	Sunamganj	25	4.5307	91	24.8461	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	S	S	S
270	T	Kusiyara	Markuli	24	41.6220	91	22.8710	GPS	1947	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C		C		S	S	S
271	T	Kalni-Kushiyara	Ajmiriganj	24	33.2220	91	13.7290	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S
272	T	Kalni-Kushiyara	Madna	24	20.1410	91	14.2620	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H		C	C	C	H		C	C	C	C	C	C	C	C		S	S	S
272.1	T	Dhaleswari-Kushiyara	Astagram	24	16.3000	91	6.0000		1962		H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	C		C	S	S	S
273	TQ	Meghna	Bhairab bazar	24	2.6911	90	59.6681	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C	S	S	S
274	T	Meghna	Narsingdi	23	55.0915	90	43.7660	GPS	1949	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	H	H	C	C	C	C	C	C	C	C	C	C		
275	T	Meghna	Badyar Bazar	23	38.8833	90	37.5825	GPS	1958		H	H	H	H	H	H	H	H	H	H	H	H	C	H	H	H	C	C	C	C	C	C		C	C	C	C		
275.5	T	Meghna	Meghna Ferry Ghat	23	36.0757	90	37.3871	GPS	1965		H	H	H	H	H	H	H	H	H	H	H	H	C	H	H	H	C	C	C	C	C	C	C			C	C		
276	T	Meghna	Satnal	23	28.6911	90	35.7416	GPS	1951		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	C	C	C	C	C	C	C	C		
280	Q	Sutang	Sutang rly.br.	24	16.9890	91	24.1560	GPS	1957	H	H	H	H	H	H	H	H	H	H	H	H	H	C	C	C	H	H	C	C	C	C	C	C	C	C	C	S	S	S

Type: Q= Discharge, T= Water level (Tidal), TQ= Discharge (Tidal)
Observations: H= Hard copy, C= Computer copy, S= SWMC

Table C.6 : Summary of NERP Hydrometric Measurements

Stn No	Station Name	River	Latitude		Longitude		1995									1996							
			Deg	Min	Deg	Min	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
B175-5	Sherpur	Kushiyara	24	27.433	91	40.983	S	S	S	S	S	S	S										
B270	Markuli	Kalni	24	41.683	91	22.917		S	S	S	S	S	S										
B271	Ajmiriganj	Kalni	24	32.517	91	13.667	S	S	S	S	S	S	S		S	S	S	S	S	S			
1	Ajmiriganj (closure)	Bheramohona	24	34.4469	91	14.4026	w	w	w	w	w	w	w	w	w	w	w	w	w	w			
2	Aktar Bazar	Mahasingh	24	53.5895	91	28.7161	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w		
7	Durgapur	Bashira						w	w	w	w	w	w	w	w	w	w	w	w	w			
8	Ilaspur	F.P							w	w	w	w	w	w	w	w	w	w	w	w			
9	Jagannathpur	Naljur						w	w	w	w	w	w	w	w	w	w	w	w	w			
10	Khagapasha	Old Kushiyara	24	33.0590	91	26.2750	w	w	w	w	w	w	w	w	w	w	w	w	w	w			
13	Madhabpur	Singli	24	37.5323	91	32.5396	w	w	w	w	w	w	w	w	w	w	w	w	w	w			
15	Nilpur	Old Surma	24	59.7021	90	23.2693	w	w	w	w	w	w	w	w	w	w	w	w	w	w			
18	Ratna	Ratna Shatal						w	w	w	w	w	w	w	w	w	w	w	w	w			
19	Shadipur	Shadipur Khal						w	w	w	w	w	w	w	w	w	w	w	w	w			
20	Terapasha	Bijna	24	33.0907	91	36.5276		w	w	w	w	w	w	w	w	w	w	w	w	w			
21	Katakhali	Kalni	24	37.2683	91	18.2032	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	
22	Shantipur	Kalni	24	28.8550	91	11.1747	w	w	w	w	w	w	w	w	S	S	S	S	S	w	w		
23	Kadamchal	Kalni	24	25.7015	91	12.2070	w	w	w	w	w	w	w	w	S	S	S	S	S	S	w	w	
24	Dhanpur	Gachiduar											w	w	w	w	w	w	w	w			
25	Gazaria	Kalni	24	32.1	91	13.25												S	S	S	S	S	S
26	Kakailseo	Kalni	24	30.55	91	12.2										S	S	S	S				
27	Kaisar	Cherapul khal	24	27.167	91	9.467								Q	Q	Q	Q	Q	Q	Q			

Legend :
B = Station corresponding to BWDB
S= Suspended sediment station (including discharge and water level)
Q = Discharge and water level
W = Water level only
Note : Discharge at sherpur estimated from published rating curves.

2&

Table C.7: Contribution of Kushiyara River to Meghna River at Dilalpur

Component	Mean Annual Discharge (m^3/s)	Runoff ('000 m^3/year)
Flow at border (65% of Barak)	656	20.7
Inflows from Tripura Hills	322	10.1
Local Runoff	557	17.7
Total Contribution to Meghna	**1,535**	**48.5**
Baulai River at Dilalpur	3,247	102.4
Meghna River at Dilalpur	**4,782**	**150.9**

Source: NERP (1995)

3.3.2 Seasonal Distribution of Runoff

In Bangladesh, the "water year" (defined as beginning on 1 April) can be divided into 4 distinct seasons:

• pre-monsoon	(1 April - 15 May)
• monsoon	(16 May - 30 September)
• post-monsoon	(1 October - 30 November)
• dry season	(1 December - 31 March)

The pre-monsoon season is characterized by unstable weather conditions, including occurrences of intense tropical depressions and "Nor-Westers" which generate heavy localized rainfalls. Low magnitude pre-monsoon floods usually stay within the channel banks and enter the adjacent flood basins and haors through the open spill channels and distributaries. Larger pre-monsoon floods overtop river banks and flood the back basins and floodplain by overland flow and through breaches and spills. These floods are relatively "flashy" and may last from a few days to about two weeks. The flood volumes are sufficient to fill the *haor* depressions and they are the cause of major crop damage in the region.

Flooding in the monsoon season normally lasts from July to October. High water is a result of large runoff volumes and backwater from the Lower Meghna River. During extreme events, such as in 1988 and 1993, virtually all of the project area was inundated. Considerable damage may take place to village platforms at this time due to wave erosion. During the post-monsoon season, the water levels in the main rivers recedes and water drains off the floodplain back into the main channel through open khals and distributary channels. Water levels normally continue to recede over the dry season and discharges are very low. Occasional local flash floods may occur between December and February, caused by winter storms in the outlying hills. These floods rarely overtop the river banks but the water can readily enter the haors because at this time of year there are numerous openings along the river banks.

Table C.8 shows the long-term seasonal distribution of runoff and average discharges at Sherpur.

Table C.8: Seasonal Distribution of Runoff at Sherpur

Season	Mean Discharge (m^3/s)	Mean Runoff (million m^3)	% of Annual Runoff
Pre-monsoon	1,152	6,074	17.4
Monsoon	1,952	20,577	59.0
Post-Monsoon	1,175	6,196	17.8
Dry Season	197	2,058	5.8
Year	1,101	34,906	100

3.4 Trends

NERP (1995) compiled data from 51 rainfall stations in the NE Region of Bangladesh and India and examined long-term trends by comparing the rainfall between 1961-1990 with the average from 1901-1990. It was concluded that the 30 year (1961-1990) mean rainfall has increased by 10% over the 90 year period, and that the variability has doubled. No firm conclusions could be reached whether these changes represented a peak of some long-term climatic cycle or a monoclinal rise due to global climatic change.

Table C.9 summarizes average rainfalls and daily discharges in various seasons between 1964 and 1993. The two rainfall stations (Zakiganj and Sheola) are situated on the Upper Kushiyara River near the Indian border. Discharges at Amalshid were synthesized from measured water levels (Gauge 172) and stage-discharge rating curves as well as from a correlation using historic measurements on the Surma and Kushiyara River (NERP, 1995).

The period since 1982 has experienced greater rainfall and mean daily discharge, on average, than the period between 1964-1981. Furthermore, the percentage changes in rainfall and discharge are reasonably consistent (both around +10%). The published mean daily discharge at Sheola shows the same trend, however, the magnitude of the increase is substantially higher that the increase in rainfall or discharge on the Barak River. All data show very substantial increases in average rainfall and discharge during the dry season and pre-monsoon season. For example, the mean daily discharge in the dry season at Sheola increased from 95 m^3/s in 1964-1973 to 145 m^3/s in 1982-1993, while the dry season rainfall totals increased from 156 mm/year in 1964-1973 to 273 mm/year in 1982-1990. The corresponding percentage changes in discharge and rainfall amount to +43% and +41% respectively.

Much of the apparent increase can be accounted for by four unusually wet years (1986,1988,1991, 1993). This clustering of unusual wet and dry years is characteristic of monsoon-driven weather systems (Fein and Stephens, 1987).

Figure C.9 and Table C.10 shows the range of annual maximum discharges and pre-monsoon discharges at Sheola and Sherpur. The last decade has experienced an unusual sequence of high pre-monsoon floods and annual maximum floods. The average pre-monsoon flood discharge at Sheola was 804 m^3/s between 1964-1973 and 1,227 m^3/s between 1982-1993. The average annual maximum flood discharge increased from 1,816 m^3/s between 1964-1973 to 2,619 m^3/s between 1982-1993. The following comparisons illustrate the percentage changes in flood discharges in relation to the mean annual flood (1964-1993):

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Pre-monsoon flood at Sheola (gauge 173)

$\%\Delta Q_{1964\text{-}1973}$ = (804 -965)/965 or -17%
$\%\Delta Q_{1982\text{-}1993}$ = (1,227-965)/965 or +27%
$\%\Delta Q_{1964\text{-}1993}$ = (1,227-804)/965) or +44%

Annual maximum flood at Sheola (gauge 173)

$\%\Delta Q_{1964\text{-}1973}$ = (1,816-2,225)/2,225 or -18%
$\%\Delta Q_{1982\text{-}1993}$ = (2,619-2,225)/2,225 or +18%
$\%\Delta Q_{1964\text{-}1993}$ = (2,619-1,816)/2,225 or +36%

Two factors have contributed to this pattern. First, the unusual sequence of wet years between 1988-93 produced a clustering of extreme flows (1988, 1991, 1993). There is no evidence to suggest that this pattern will persist in the future. Second, the increase in flood discharges has coincided with reduced discharges in spill channels on the Upper Kushiyara floodplain (Figure C.10). This reduction in overbank flows and increased flow carried by the main channels is attributed mainly to construction of flood embankments and spill channel closures (NERP, 1995).

Figures C.11 and C.12 show the trend in maximum daily pre-monsoon and annual maximum water levels at Sherpur, Markuli, Ajmiriganj and Madna. Markuli, Ajmiriganj and Madna represent, respectively, the upper end, middle and lower end of the Kalni River. Pre-monsoon flood levels at Markuli and Ajmiriganj have increased by an average 1.2 m and 1.0 m respectively since 1975. At Markuli, the maximum daily pre-monsoon water levels have been increasing in a remarkably consistent fashion since the 1950's, at a rate of an average of 8.5 cm/year over the last 25 years. By comparison, pre-monsoon water levels at Madna show no consistent trend. The trend of increasing pre-monsoon flood levels has been attributed to three main factors:

- increased discharges in recent years on the Upper Kushiyara River;
- closure of distributary channels at and below Markuli, which effectively increased the discharges in the lower reach of the river, and
- sediment aggradation below Ajmiriganj causing reduced channel conveyance.

The minimum recorded water levels at Ajmiriganj and Markuli have also increased consistently since 1964. They rose an average of 1 m in 25 years (4 cm/year) until 1988, then rose abruptly by nearly 1 m since then. The corresponding minimum discharges showed no systematic change up until 1988, after which the flows have nearly doubled. The 4 cm/year rise between 1964-1988 is believed to reflect morphologic changes (since the discharge was approximately constant during this time), while the increase since 1988 is believed to be caused by both sedimentation and increased flows.

Table C.9: Variations in Rainfall and Runoff

Total Rainfall in Specified Periods

Period	Annual (mm)		Pre-monsoon (mm)		Dry Season (mm)	
	Zakiganj	Sheola	Zakiganj	Sheola	Zakiganj	Sheola
1964 - 1973	3,859	4,128	907	874	144	156
1974 - 1981	3,794	4,086	1,046	958	241	193
1982 - 1993	4,273	3,815	1,105	1050	252	237
1964 - 1993	3,958	4,467	1,024	967	212	197

Percentage change relative to long-term mean (1964-1993)

Period	Annual (%)		Pre-monsoon (%)		Dry Season (%)	
	Zakiganj	Sheola	Zakiganj	Sheola	Zakiganj	Sheola
1964 - 1973	-2.5	-1	-11.4	-9.6	-31.9	-21.0
1974 - 1980	-4.2	-7.6	+2.2	-0.9	+13.8	-1.8
1990 - 1993	+8.0	+8.2	+8.0	+8.6	+19.0	+20.4

Mean discharge in various periods

Period	Annual (m^3/s)		Pre-monsoon (m^3/s)		Dry Season (m^3/s)	
	Amalshid	Sheola	Amalshid	Sheola	Amalshid	Sheola
1964 - 1973	1,064	581	417	282	102	95
1974 - 1981	1,070	649	478	332	104	100
1982 - 1993	1,172	793	828	536	165	145
1964 - 1993	1,108	684	596	396	128	116

Percentage change relative to long-term mean (1964-1993)

Period	Annual (%)		Pre-monsoon (%)		Dry Season (%)	
	Amalshid	Sheola	Amalshid	Sheola	Amalshid	Sheola
1964 - 1973	-4	-15	-29.9	-28.8	-19.9	-17.9
1974 - 1981	-3.4	-5.1	-19.9	-16.2	-18.3	-14.0
1982 - 1993	+5.8	+16.0	+38.9	+35.3	+29.6	+24.8

Table C.10: Flood Discharges on the Kushiyara River

Pre-monsoon Flood Discharge

Period	Amalshid (172)[1]		Sheola (173)		Sherpur (175.5)	
	Average (m^3/s)	Maximum (m^3/s)	Average (m^3/s)	Maximum (m^3/s)	Average (m^3/s)	Maximum (m^3/s)
1964 - 1973	930	1,500	804	1,580	-	-
1974 - 1981	921	1,640	785	1,680	-	-
1982 - 1993	1,484	3,781	1227	3,250	1,790	3,471
1964 - 1993	1,145	3,781	965	3,250	-	-

Annual Maximum Flood Discharge

Period	Amalshid (172)[1]		Sheola (173)		Sherpur (175.5)	
	average (m^3/s)	maximum (m^3/s)	average (m^3/s)	maximum (m^3/s)	average (m^3/s)	maximum (m^3/s)
1964 - 1973	2,941	3,308	1,816	2,130	-	-
1974 - 1981	3,137	3,803	2,144	2,330	-	-
1982 - 1993	3,236	3,780	2,619	3,250	2,746	3,632
1964 - 1993	3,113	3,803	2,225	3,250	-	-

Note: 1. Discharges at Amalshid were estimated from synthesized records (NERP, 1994)

3.5 Flow-Duration Analysis

Dry Season

The dry season flows show a noticeable trend over the last 30 years. Therefore, the analysis was carried out using only measurements from 1982 - 1989 and 1991- 1993. The frequency and duration of levels was estimated for the period from December 1 to March 31. These levels were used to determine conditions during the construction season. The results are summarized in Table C.11. It should be noted that the proposed project will lower dry season water levels by approximately 1 m below existing conditions. Future levels should be closer to the conditions that were experienced in the 1980's than in the 1990's (1991 - 1993). Depending on the construction schedule, some of the erosion protection works may be completed before the loop cutting and dredging is completed. Therefore, the historic water levels have been used in this analysis, rather than the post-project conditions.

Table C.11: Historic Water Levels From December 1 to March 31

% of time water level is less than indicated value	# of days water level is less than indicated value	Madna (272) (m PWD)		Ajmiriganj (271) (m PWD)		Markuli (270) (m PWD)	
		1982-89	1991-93	1982-89	1991-93	1982-89	1991-93
0	0	0.63	0.94	1.38	2.38	2.13	2.88
10	12	1.16	1.2	1.84	2.91	2.41	3.26
20	24	1.27	1.31	1.98	3.09	2.53	3.47
30	36	1.38	1.44	2.11	3.24	2.65	3.65
40	48	1.46	1.54	2.24	3.39	2.8	3.76
50	60	1.53	1.62	2.38	3.52	2.99	3.87
60	72	1.61	1.7	2.52	3.66	3.19	4.05
70	84	1.72	1.78	2.68	3.8	3.38	4.24
80	96	1.85	1.91	2.87	3.96	3.59	4.53
90	108	2.07	2.08	3.15	4.21	4.04	5.11

3.6 Flood Frequency Analysis

The available data have certain limitations for frequency analysis.

1. At Sherpur and Sheola, the gauge discharge measurements represent the flow in the main channel only. However, the floodplain and secondary channels carry part of the total flood flow, which the data series do not take into account. As a result, the frequency curves tend towards upper asymptotes. In such cases, flood frequency predictions underestimate the true flood potential that could develop if the overbank spills are confined by embankments.

2. The data series are short, with the longest at Sheola covering only 30 years. This means that tests for statistical anomalies are very weak, and not very useful for assessing the data's homogeneity. Consequently, predictions for longer return periods tend to have low reliability.

3. Some data series, especially pre-monsoon water levels at Markuli and Ajmiriganj, are non-homogeneous and non-stationary - that is, the data do not reflect consistent physical conditions of flood generation. In such cases flood frequency estimates derived from the whole record represent an average of historic conditions and are not necessarily applicable to present or future conditions.

Given these limitations, the available data were analyzed to estimate flood frequencies by using the General Extreme Value (GEV) distribution. There are 30 years of records (1964-1993) available at Sheola and 14 years of records (1982-1995) at Sherpur. The analysis was made for the pre-monsoon season and the annual maximum flood. Some key results are summarized in Table C.12. A flood frequency plot is shown on Figure C.13. Based on the estimates at Sherpur, the largest recent floods (1993 and 1991) had annual return periods of 20 years and 14 years respectively.

Table C.13 summarizes flood frequency estimates of annual maximum water levels and pre-monsoon water levels at various locations along the river. It should be emphasized that the historic pre-monsoon flood levels at Markuli and Ajmiriganj show obvious trends over time and therefore, are not suitable for design purposes. These trends are not evident in the annual maximum water levels.

Table C.12: Flood Frequency Analysis of Discharges

Type	**Discharge (m^3/s)**			
	1:2 year	**1:5 year**	**1:10 year**	**1:20 year**
	Sherpur (175.5)			
Pre-Monsoon	1,694	2,398	2,834	3,228
Annual Maximum	2,579	2,977	3,225	3,451
	Sheola (173)			
Pre-monsoon	1,020	1,730	2,325	3,000
Annual Maximum	2,543	2,890	3,065	3,200

Note: GEV distribution, using data from 1980-1993

It should be noted that for extreme floods the pre-monsoon and monsoon floods converge. This may not be realistic and probably reflects the relatively short period of record.

Table C.13: Flood Frequency Analysis of Water Levels

Pre-monsoon Season

Location	Water Levels (m PWD)				
	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year
Sherpur (175.5)	7.45	8.42	8.80	9.04	9.24
Markuli (270)	6.18	6.89	7.22	7.45	7.67
Ajmiriganj (271)	4.5	5.10	5.45	5.75	6.11
Madna (272)	3.24	3.68	3.97	4.26	4.65

Note: GEV distribution, for the period 1980-1995

Annual Maximum

Location	Water Levels (m PWD)				
	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year
Sherpur (175.5)	8.97	9.16	9.31	9.39	9.50
Markuli (270)	7.43	7.80	7.90	8.05	8.32
Ajmiriganj (271)	7.12	7.49	7.78	7.95	8.20
Madna (272)	6.95	7.30	7.63	7.77	8.02

Source: NERP (1995), Table 11.2

3.7 Wave Climate

Wave erosion can seriously damage exposed structures, village platforms and embankments in the project area. Generation of high waves depends on the occurrence of extreme winds, the presence of long exposed fetches and deeply flooded conditions in the fetch zone. The most severe wave action occurs at sites bordering one of the major deeply flooded *haors*. Major damage occurs when severe winds coincide with extreme high water conditions, as in the disastrous flood of 1988. In that year, many of the villages in the project area lost 25 to 35 % of their platform from wave erosion.

Information on extreme wave conditions is difficult to document, with reports from local villagers ranging from 1 m to 1.5 m. Design wave heights and wave periods were estimated using hindecasting procedures recommended by the US Army Corps of Engineers for shallow lakes and reservoirs. The main input data that are required include a design wind speed, the representative fetch length and water depth.

Two severe weather disturbances can generate extreme high winds in the project area. "Nor-Wester" thunderstorm squalls usually occur between March and June and are caused by outbreaks of cold air from Central Asia. High winds, thunderstorms and even tornados are generated along the interface between the advancing cold air and the warm air already in the region. The passage of a Nor-Wester typically lasts only for an hour or two and the extent of extreme winds is usually localized. Furthermore, since these occur primarily in the pre-monsoon season when the depth of inundation over the floodplain is low, the occurrence of a "Nor-Wester" does not usually generate damaging waves.

Extreme winds can also be generated with the inland incursion of tropical cyclones from the Bay of Bengal. These events typically occur in the pre-monsoon (April-May) and post-monsoon (October-November) season. Once the cyclones cross over the mainland they degenerate into intense tropical depressions which can move into the NE Region and can generate heavy rainfalls and floods for periods of up to 2 or 3 weeks.

Monthly extreme wind speed and direction data from the anemometer at Sylhet were collected from the Bangladesh Meterological Department. This station operated for 23 years between 1966 and 1988. The published wind extremes are the maximum three minute average speeds, measured every 8 hours during the day. The monthly wind extremes were analyzed by computing the number of occurrences in each specified wind speed class and direction. The analysis was carried out for the months between May - October, since this is the time that the floodplain could be deeply flooded. The frequency of occurrence for winds exceeding 20 knots is shown in Figure C.14. The most frequent directions for extreme winds were from the east, north-east, south-east and south. The maximum observed wind speed reached 84 knots (from the north-east) in May 1979.

It was decided to combine all of the wind records and not to develop a separate wind frequency relation for different wind directions. The log-Pearson Type III distribution was used to fit a curve to the observations. The estimated extreme wind speeds for various return periods are summarized in Table C.14.

Table C.14: Adopted Design Wind Speeds

Return Period (Years)	Wind Speed (3 minute duration in knots)	Wind Speed (15 minute duration in m/s)
10	23	12.5
20	33	17
50	50	25

Wave hindecasting calculations showed a wind duration of at least 20 minutes would be required for the waves to become fully developed in the project area. Therefore, the three minute maximum wind speed estimates need to be reduced to account for the longer duration required for wave generation. Based on the analysis carried out for wave protection designs at Bhairab Bazar, a factor of 0.5 was applied to the 2 minute wind speed estimates (BWDB, 1990).

Table C.15 summarizes the significant wave heights (Hs) and wave periods (Ts) that will be generated for various fetch lengths and water depths.

Table C.15: Estimated Wave Heights in the Monsoon Season

1:2 Year Wind Storm

Fetch Length (km)	Depth = 1 m		Depth = 2 m		Depth = 3 m		Depth = 4 m	
	Hs (m)	T (sec)	Hs (m)	Ts (sec)	Hs (m)	Ts (sec)	Hs (m)	T (sec)
2	0.3	1.7	0.3	1.8	0.3	1.8	0.3	1.8
5	0.3	2.1	0.4	2.3	0.5	2.4	0.5	2.4
10	0.3	2.4	0.5	2.7	0.6	2.8	0.6	2.9
20	0.3	2.6	0.5	3	0.7	3.2	0.8	3.4

1:20 Year Storm

Fetch Length (km)	Depth = 1 m		Depth = 2 m		Depth = 3 m		Depth = 4 m	
	Hs (m)	T (sec)	Hs (m)	Ts (sec)	Hs (m)	Ts (sec)	Hs (m)	T (sec)
2	0.4	1.9	0.4	2.1	0.5	2.1	0.5	2.1
5	0.4	2.4	0.6	2.6	0.7	2.7	0.7	2.8
10	0.4	2.7	0.6	3	0.8	3.2	0.9	3.3
20	0.4	2.9	0.7	3.4	0.9	3.7	1	3.9

1:50 Year Storm

Fetch Length (km)	Depth = 1 m		Depth = 2 m		Depth = 3 m		Depth = 4 m	
	Hs (m)	T(sec)	Hs (m)	Ts (sec)	Hs (m)	Ts (sec)	Hs (m)	T (sec)
2	0.5	2.3	0.7	2.4	0.7	2.4	0.8	2.5
5	0.5	2.8	0.8	3	1	3.1	1.1	3.2
10	0.5	3.1	0.9	3.5	1.1	3.7	1.3	3.8
20	0.5	3.4	0.9	4	1.2	4.3	1.4	4.5

Hs = Significant wave height, T = wave period

This hindecasting analysis showed the wave heights are limited by the water depths in the fetch zone. However, even when the water depths reach up to 4 m, the wave height will not increase much after the fetch exceeds about 15 km in length. The calculations show that the incident wave heights are unlikely to exceed around 1 m except in very extreme conditions. The wave height at the time of breaking may be affected.

3.8 Groundwater Resources

Based on MPO (WARPO) data, the estimated usable ground water recharge within the project area is 406 million cubic metres (Mm^3). Out of this, about 269 Mm^3 are available within depths accessible by the force mode technology (DTW). Suction mode STW technologies could withdraw only about 7.0 Mm^3 which indicates STWs are probably not suitable due to aquifer constraints, but about 70 Mm^3 could be withdrawn by deep-set STW (DSSTW). The majority of the groundwater resource potential is located in Baniachang, Nabiganj, Astagram and Jagannathpur thanas (Table C.16).

Table C.16: Groundwater Availability

Thana	Usable Recharge (Mm^3)			Available Recharge (Mm^3)		
	STW	DSSTW	DTW	STW	DSSTW	DTW
Itna	0.0	4.0	16.1	0.0	0.8	3.1
Mitamain	0.0	4.7	19.8	0.0	2.6	11.1
Astagram	0.0	10.4	34.7	0.0	5.8	19.4
Nikli	0.0	0.2	0.7	0.0	0.1	0.2
Habiganj	1.8	4.0	12.0	1.3	2.9	8.7
Lakhai	0.0	1.6	17.2	0.0	0.9	9.4
Baniachang	1.1	16.7	53.2	0.9	14.3	45.8
Ajmiriganj	0.0	2.4	22.0	0.0	2.2	19.7
Nabiganj	0.0	21.3	84.6	0.0	13.3	53.0
Moulvibazar	0.0	0.3	1.5	0.0	0.1	0.6
Sylhet	0.0	7.5	26.4	0.0	4.1	14.5
Balaganj	0.0	3.3	23.8	0.0	1.8	13.2
Fenchuganj	0.0	0.0	11.3	0.0	0.0	6.8
Biswanath	0.0	2.2	8.9	0.0	1.9	7.7
Golabganj	0.0	3.6	10.6	0.0	2.7	8.0
Derai	1.6	5.5	14.3	1.2	4.0	10.5
Jagannathpur	2.4	10.1	32.2	2.0	8.4	26.8
Sullah	2.4	4.9	13.9	1.9	3.8	10.7
Total	**9.4**	**103.3**	**406.0**	**7.3**	**69.8**	**269.4**

Source: MPO (Currently WARPO)

4. RIVER HYDRAULICS

This section describes the flow distribution through the main channel branches downstream of Sherpur, estimates the present channel bankfull capacity along the river and describes the channel's geometry and hydraulic properties. Additional information on these topics may be found in Annex B - Hydrodynamic Modelling.

4.1 Data

4.1.1 Second Order Levelling Survey

A levelling program was conducted in 1993-94 to accurately check the elevation of existing water level gauges and to provide accurate benchmarks for future projects. The program involved high precision level surveys to second-order accuracy. The permissible tolerance (in mm) for second-order levelling was defined as $8.4\sqrt{L}$, where L is the distance in km to form a complete loop.

The Survey of Bangladesh (SOB) conducted the surveys, CIDA provided the funding and NERP provided a field monitor and administered the program. The program involved completing 2741 km of survey lines, connecting 397 permanent monuments and tying-in 77 BWDB hydrometric gauges. Level surveys were also conducted at 20 gauge locations to connect TBMs (temporary bench marks) to the permanent gauge benchmarks. These TBMs are generally used for day-to-day operation of the gauges and were used for establishing some of the channel cross section surveys.

During the feasibility study, all surveys by NERP were referenced to the updated benchmarks.

4.1.2 Hydrometric Measurements

Table C.6 summarizes the hydrometric data that was collected by NERP in 1995-1996 at various stations along the Kalni-Kushiyara River. The location of these stations are shown in Figure C.15. The water level stations were established by installing a staff gauge and hiring a gauge reader to measure the levels four times daily. Miscellaneous discharge measurements were made at several key stations (primarily Markuli, Ajmiriganj, Shantipur, Kadamchal and Cherapur Khal). These measurements were carried out during the dry season and continued into the pre-monsoon, while the flows were confined within the main channel. It was not possible to measure the total discharge during the monsoon season since much of the river's flow was carried on the floodplain.

The discharge measurements were made two or three times per week during the dry season and pre-monsoon seasons at established metering lines. The measurements were made using a standard USGS Price current meter and reel mounted on a country boat. Horizontal positioning was accomplished using a tag line. The velocity measurements were made at 5 m intervals across the channel, which resulted in 20 to 30 segments for each complete discharge measurement. The corresponding water level was determined by levelling from a NERP bench mark. In total, 157 discharge measurements were made during 1995 and 1996. The complete set of data has been tabulated in Annex A - Sedimentation.

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The basic data has been included in Appendix C.2 of this Annex. Figures C.16 to C.22 summarize the stage-discharge rating curves at each station as well as hydraulic geometry plots (velocity versus discharge, top width versus discharge).

4.1.3 River Surveys

NERP developed a fast, accurate method for producing hydrographic charts of the river by using a Global Positioning System (GPS), digital depth sounder and data logger mounted in a survey boat. A second GPS receiver was set-up as a base station so that the horizontal positions could be differentially corrected to improve the accuracy of the surveys. The water level at the time of the survey was measured from staff gauges that were established by NERP. All elevations were referenced to bench marks established from SOB's Second Order Levelling programme. In total, approximately 250 km of river was surveyed over the course of the project. The river topography was represented on 1:10,000 scale charts with 1 m contour lines. These data have been compiled under a separate cover as Annex M - Project Maps and Engineering Drawings.

Additional river cross sections were established to monitor annual and seasonal changes in bed levels on the Kushiyara and Kalni Rivers. Table C.17 and Figure C.23 summarize the location and frequency of these surveys. Where possible, the cross sections coincided with previous cross sections established by the Morphology Directorate, BWDB (Figure C.24). Cross sections were also established over the 120 km reach between Astagram and Sherpur for use in the hydraulic modelling analysis. These cross sections included the main channel and a 500 m wide portion of the floodplain on each bank. The location of these cross sections are shown in Figure C.23. Cross-section plots are summarized in Figure C.25.

Table C.17: Cross Section Monitoring on Kalni River, Markuli to Dilalpur

	Distance (km)	1980	1981	1982	1986	1987	1990	1991	May 93	Jun 93	Jul 93	Sep 93	Dec 93	1994
M-22	28.0						X	X						X
M-23	34.0						X	X						X
M-25	47.0						X	X						X
M-26	54.0						X	X						X
M-27	61.0						X	X						X
M-28	70.0						X	X						X
M-29	77.0						X	X						X
M-30	82.0						X	X						X
M-31	88.0						X	X						
M-32	94.2								X	X	X	X	X	
M-33	99.9		X		X	X	X	X				X	X	
M-34	105.3		X	X	X	X	X	X				X	X	
M-35	112.0	X	X		X	X	X	X	X	X	X	X	X	
M-36	117.7	X	X	X	X	X	X	X	X	X	X	X	X	
M-36A	121.7								X	X		X	X	
M-37	123.4	X	X		X	X	X	X	X	X	X	X	X	
M-37A	126.2								X	X	X	X	X	
M-38	129.5	X	X	X	X	X	X	X	X	X	X	X	X	
M-39	134.7													
M-41	152.0													

Sources: 1. Surveys from 1980-1987 by BWDB Morphology Directorate, 2. Surveys from 1990-1991 by SWMC, 3. Surveys from 1993 by NERP

4.1.4 Observations of Flood Conditions

NERP carried out ongoing reconnaissance studies and field trips along the Kalni-Kushiyara River between 1992 - 1996 to observe and monitor the hydraulic characteristics of the river. This included observing the major channel shift near Katkhal in 1994, and documenting the beginning of flooding between Madna and Raniganj in April 1996. Special observations were also made to assess the performance of bank protection works on the Kushiyara River. These observations are included as Appendix C.4 in this Annex.

4.2 Flow Distribution

The Manu River enters the Kushiyara River just upstream of Sherpur near Manumukh (Km 177). Downstream of Manumukh, there are no major tributary inflows until the Ratna/Khowai Rivers joins near Madna (Km 61). However, there are several points between Sherpur and Ajmiriganj where flow may be lost through various spill channels. These sites, which are identified on Figure C.7, include Markuli (Km 132), Fayjullapur (Km 129.5), near Tangua Haor (Km 119), Koyer Dhala (Km 15) and Pituakandi (Km 114.5). The location of spills may vary from year to year depending on the occurrence of localized erosion and the performance of temporary protective works. Based on past experience, and direct field observations, spills typically begin to develop at a discharge of around 1,600 m^3/s (at Sherpur).

Downstream of Ajmiriganj, the river branches between Rahala and Kadamchal (Km 97-92) into the active eastern channel and an inactive, silted-in western distributary. Shantipur gauge is situated on the active branch of the river. Just downstream of Katkhal, Cherapur Khal (Km 90) flows westwards and diverts water from the Kalni River into the Baulai River system. This *khal* has enlarged substantially since 1994 in response to upstream channel shifting on the Kalni River.

Table C.18 summarizes measured flow split in the dry season and pre-monsoon flood season at Cherapur Khal. The *khal* presently carried around 25% to 35% of the total discharge. Continued widening could eventually cause most of the dry season and pre-monsoon season flows to be diverted through the *khal* into the Baulai River system. This would cause a major disruption to both the lower Kalni-Dhaleswari River and the Baulai River.

Near Issapur (Km 72), the Kalni River splits into the westward flowing Baida River and the eastward flowing Kalni-Dhaleswari branch. The flow split at Issapur averages 52% Baida River, 48% Kalni River (Table C.19). These measurements were made in the pre-monsoon season. During the dry season, the flow split into the Kalni-Dhaleswari branch becomes virtually zero due to the presence of shoals and sand bars downstream of Issapur. Furthermore, hydraulic modelling computations show the Baida channel can carry more than 70% of the total discharge during flood conditions. Therefore, it appears the lower Kalni branch is becoming a silted-in distributary of the Baida channel.

4.3 Bankfull Flow Capacity

Field studies were made in April 1996 to determine the representative bankfull stage and bankfull discharge along the river between Raniganj (Km 153) and Madna. The observations were made on April 6th during a pre-monsoon flood with a return period of approximately 1.5 years at Sherpur, and whose water profile was at or near bankfull conditions downstream of Ajmiriganj.

The river's present bankfull discharge capacity was estimated as follows:

- the water level on April 6th was measured at each hydrometric station (8 in total) between Madna and Sherpur (Table C.20);
- the discharge at each station was either measured directly or estimated from stage-discharge rating curves;
- a reconnaissance survey was made by speed boat between Madna (Km 61) and Raniganj (Km 150). The vertical distance from the water level to the top of the bank was measured at various locations along the reach. In most cases this distance ranged between 0.5 and 1.0 m;
- A water surface profile was then plotted along with the adopted bankfull level, and
- The bankfull discharge capacity was then determined for each reach from the stage-discharge rating curves.

Table C.18: Flow Split Cherapur Khal

Date	Water Level (m)	Q(Obs) Kadamchal (m^3/s)	Q(Obs) Cherapur (m^3/s)	Q(Kadam) + Q(Chera) (m^3/s)	% flow Baida
19-Dec-95	2.57	250	71	320	22.1
02-Jan-96	2.24	180	50	230	21.6
15-Jan-96	2.06	152	50	202	24.7
26-Jan-96	1.92	122	42	164	25.5
06-Feb-96	2	120	39	159	24.7
13-Feb-96	1.89	101	32	133	24.2
27-Feb-96	2.31	167	56	223	25
08-Mar-96	2.22	156	46	202	23
12-Mar-96	2.1	129	43	172	25
19-Mar-96	3.5	624	142	766	18.6
30-Mar-96	3.65	821	243	1063	22.8
09-Apr-96	3.97	1001	349	1351	25.9
16-Apr-96	3.51	503	161	664	24.3
24-Apr-96	3.39	379	164	543	30.2
07-May-96	3.84	609	188	797	23.6

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Table C.19: Flow Split in Baida River near Issapur

Date	Q(Baida) (m^3/s)	Q(Kalni) (m^3/s)	Q(Baida) + Q(Kalni) (m^3/s)	% flow Baida	% flow Kalni
10-Apr-96	523	487	1,010	51.7	48.3
17-Apr-96	242	227	469	41.6	48.4
22-Apr-96	204	172	376	54.3	45.7
08-May-96	265	243	508	52.2	47.8
15-May-96	583	492	1,075	54.2	45.8

Table C.20: Observed Conditions April 6, 1996

Station	Distance (km)	Estimated Discharge (m^3/s)	Water Level (m PWD)
Sherpur	177.3	1,390	7.25
Markuli	133.4	1,350	6.82
Ajmiriganj	106.5	1,480	5.55
Shantipur	95.4	1,340	5.26
Kadamchal	84.7	1,100	4.11
Madna	61	530	3.15

Figure C.26 shows the water surface profile of the 1:20 year monsoon water level, the water level which occurred on 6th April 1996, low water level for the period 1991-93 and the bankfull level. Table C.21 summarizes the adopted bankfull flow capacities at various locations along the river. Bankfull discharge at Sherpur corresponds approximately to an annual flood (essentially a flood that occurs in the monsoon season) with a return period of 2 years. This condition is found on many alluvial rivers. Near Markuli, spills begin to develop when flows exceed 1,600 m^3/s, which is substantially less than the channel's discharge capacity at bankfull stage. These spills occur through low, localized weak spots in the bank or through open breaches or *khals*. Downstream of Markuli, bankfull discharge occurs well below the annual flood discharges. In fact, bankfull stage corresponds closely to the 2-year pre-monsoon flood.

Table C.21: Adopted Bankfull Discharge Capacity

Gauge	Location (Km)	Bankfull Level (m PWD)	Discharge (m^3/s)
Sherpur	177.28	8.8	2,500
Markuli	133.44	7.25	1,965
Ajmiriganj	106.45	5.85	1,750
Shantipur	95.4	5.5	1,500
Cherapur Khal	90	5.1	
Kadamchal	83.62	4.5	1,350

4.4 Water Surface Profiles

Figure C.27 (top) shows water surface profile in the pre-monsoon season (May), monsoon season (August) and dry season (February). Tables C.22 and C.23 summarize slope values in the pre-monsoon and monsoon season. These profiles are based on the average monthly levels recorded at BWDB gauges between 1964-1993.The plots show backwater from the Meghna River in the monsoon season produces a very flat slope downstream of Ajmiriganj (6 mm/Km) and is relatively uniform upstream of Sherpur (around 40 mm/Km). The slope in the dry season and pre-monsoon season is noticeably steeper downstream of Markuli. Figure C.27 (bottom) summarizes the pre-monsoon profiles in 1964, 1965, 1992 and 1993. The profiles in 1992 and 1993 show the slope steepens noticeably between Madna (Km 61) and Ajmiriganj (Km 107) in comparison to the profiles in 1964 and 1965.

Figure C.28 shows the water level difference between Ajmiriganj and Madna plotted as a function of time between 1964-1993. The water level difference has increased consistently on average by 0.043 m/year in the pre-monsoon season since 1964, which represents an increase of 1.3 m over the last 30 years. A multiple regression analysis showed that changes in discharge over this period could not explain the increase in water level. Therefore, it is believed that the rise in water level between Madna and Ajmiriganj is largely governed by ongoing morphologic changes.

Figure C.26 shows the pre-monsoon flood levels on April 6, 1996. The profile also shows the water surface profile steepens noticeably between Madna and Ajmiriganj. However, in 1996, the profile showed an unusually large drop (115 mm/Km) in the Katkhal reach between Shantipur and Kadamchal (Km 94 to Km 85). Field observations showed this was caused by a constriction that developed downstream of Shantipur as a result of recent channel shifting and sedimentation.

These changes in the water surface profile provide an indication of the magnitude of the water level lowering that might be expected from channel improvement work. For example, the head drop between Shantipur and Kadamchal in April 1996 amounts to around 1m, while in unconstricted reaches, the corresponding drop would be around 0.36 m, for a similar length of channel. Therefore, pre-monsoon flood levels might be lowered by up to 0.64 m upstream of Shantipur if this blockage was eliminated.

Table C.22: Average Pre-Monsoon Water Surface Profiles

River	Gauge	ID	Distance (Km)	May 1993		May 1992	
				Water Level (m)	Slope (mm/Km)	Water Level (m PWD)	Slope (mm/Km)
Meghna	Bhairab Bazar	273.0	0	3.30	---	2.40	--
Dhaleswari	Astagram	272.1	41	3.63	8	2.65	6
Dhaleswari	Madna	272.0	61	3.84	10	2.62	
Kalni	Ajmiriganj	271.0	105	5.40	35	4.02	32
Kushiyara	Markuli	270.0	132	6.97	58	5.73	63
Kushiyara	Sherpur	175.5	177	8.13	26	6.24	11
Kushiyara	Fenchuganj	174.0	218	9.16	37	7.00	19
Kushiyara	Sheola	173.0	269	12.05	47	8.94	38
Kushiyara	Amalshid	172.0	315	13.88	40	10.38	31

Table C.23: Average Monsoon Water Surface Profile

Gauge Name	ID	Distance (km)	August Water Level (m PWD)	Slope (mm/Km)
Meghna River at Bhairab Bazar	273.0	0	6.09	
Meghna River at Astagram	272.1	41	6.37	6.8
Kalni River at Madna	272.0	61	6.50	6.5
Kalni River at Ajmiriganj	271.0	105	6.74	5.5
Kalni River at Markuli	270.0	132	7.09	13.0
Kushiyara River at Sherpur	175.5	177	8.13	23.1
Kushiyara River at Fenchuganj	174.0	218	9.97	44.9
Kushiyara River at Sheola	173.0	269	12.71	53.7
Kushiyara River at Amalshid	172.0	315	14.93	48.3

4.5 Hydraulic Geometry

Figures C.16 to C.22 summarize measured hydraulic geometry at each hydrometric station. Channel parameters such as cross sectional area, top width and mean depth have been plotted as a function of discharge. Power-law relations were developed by regression to provide a means for estimating these parameters. These relations are also summarized in the figures.

Table C.24 summarizes the estimated bankfull channel geometry at various cross sections along the river between Sherpur and the Dhaleswari River. Figure C.29 plots these parameters as a function of distance along the channel. The plot shows the apparent decrease in cross sectional area downstream of Ajmiriganj due to past sedimentation.

Table C.25 summarizes the average channel characteristics in various reaches between Amalshid and Dilalpur at the junction of the Baulai River.

Table C.24: Bankfull Channel Characteristics

Section	Chainage (Km)	Bankfull Elevation (m PWD)	Area (m^2)	Top Width (m)	Mean Depth (m)
K-1	181.0	9.1	2,445.0	299.0	7.2
K-2	178.0	8.9	1,925.0	304.0	6.4
K-3	174.9	8.9	1,960.0	238.0	8.3
K-4	170.1	8.4	1,918.0	351.0	5.0
K-5	166.8	8.2	2,196.0	369.0	5.5
K-6	163.1	8.3	2,666.0	342.0	6.6
K-7	159.9	8.0	2,108.0	406.0	5.1
K-8	154.1	7.7	2,245.0	203.0	10.1
K-9	149.3	7.4	1,612.0	299.0	3.8
K-10	143.5	7.3	3,072.0	285.0	8.4
K-11	140.5	7.3	1,876.0	233.0	6.7
K-12	134.3	7.2	1,916.0	168.0	9.5
KL-1	126.4	7.0	1,509.0	201.0	5.7
KL-2	120.9	6.8	1,434.0	269.0	4.2
KL-5	111.0	6.4	1,304.0	206.0	4.4
KL-6	107.5	6.3	1,335.0	243.0	3.6
KL-6A	103.5	6.2	1,423.0	295.0	3.6
KL-7	100.0	6.0	1,102.0	297.0	3.1
KL-9	95.4	5.7	1,246.0	316.0	2.9
KL-11	85.2	4.6	1,071.0	385.0	2.0
KL-12	80.2	4.3	983.0	456.0	1.6
KL-13	76.0	4.1	848.0	414.0	1.5
KL-15	71.6	3.9	967.0	455.0	1.8
KL-16	71.4	3.8	858.8	417.3	1.6
KL-18	66.0	3.6	483.2	212.7	2.9
DH-1	65.5	3.6	787.3	289.5	2.8
DH-2	62.8	3.5	1,128.6	648.3	1.3

Table C.25: Morphologic Characteristics of Kushiyara/Kalni River

Extent of Reach	Physiographic Unit	Channel Pattern	Channel Confinement	Bars	Islands	Vertical Stability	Lateral Stability	Bed Material D_{65} (mm) D_{50} (mm) D_{35} (mm)	Bank Material	Sinuosity (Lc/Lv)	Slope (m/km) Average Pre-monsoon Monsoon	Bankfull dimensions Top Width Mean Depth Area
Amalshid-Fenchuganj Km 0 - Km 95	Kushiyara Floodplain	Single channel; Irregular meanders	Often deflects off uplands & inerodible materials	Point bars	Absent	Stable minor degradation	progressive meander migration channel widening	0.23 0.20 0.16	Silty Clay	1.42	0.040 0.070 0.060	166 9.76 1410
Fenchuganj-Manumukh Km 95 - Km 130	Kushiyara Floodplain	Single channel; Irregular/sinuous	Partly confined by embankments	Absent	Absent	Stable	progressing meander migration channel widening	0.18 0.16 0.13	Silty Clay	1.28	0.030 0.040 0.040	225 8.06 1810
Manumukh- Suriya River Km 130 - Km 152	Kushiyara Floodplain	Single channel; Irregular/straight due to loop cutting	Partly confined by embankments	Absent	Absent	Degrading	channel switching due to loop cutting, channel widening	0.10 0.095 0.08	Clay, organic clay and silt	1.25	0.020 0.040 0.040	240 9.1 2177
Suriya River- Markuli Km 152 - Km 180	Kushiyara Floodplain	Single channel; Irregular meanders	Unconfined	Absent	Absent	Degrading	major avulsion in 1960's ongoing widening and shifting due to loop cutting	0.11 0.10 0.086	Clay organic clay and silt	1.36	0.010 0.030 0.030	251 6.82 1711
Markuli- Dhaleswari River Km 180 - Km 235	Sylhetl Basin	Split channel; Irregular sinuous	Unconfined	Absent	Few	Aggrading rapidly	channel widening and irregular shifting due to loop cutting	0.11 0.10 0.086	Silty Clay	1.12	0.022 0.080 0.008	335 4.1 1365
Dhaleswari River Km 235 - Km 271	Sylhetl Basin	Single channel; Irregular meanders	Unconfined	Point bars	Common	Aggrading slowly	Irregular shifts and avulsion of distributary channels	0.11 0.10 0.086	Silty Clay	1.76	0.015 0.060 0.060	Na

4.6 Channel Velocities

Channel velocities were estimated using two different methods:

- from measured velocities at NERP and BWDB hydrometric gauges, and
- from hydraulic modelling computations.

4.6.1 Observed Velocities

Figures C.16 to C.22 summarize the relation between mean channel velocity and discharge at seven hydrometric stations along the Kalni-Kushiyara River. Figures C.18 to C.21 also show the gauge cross sections with plotted iso-velocity contours during flood conditions. The highest measured mean channel velocity is listed below in Table C.26.

At Ajmiriganj, the mean channel velocity reached up to 1.9 m/s at the maximum observed discharge of 2,040 m^3/s. During this time spilling was occurring at various locations along the river.

Table C.26: Highest Observed Channel Velocities

Station	Distance (Km)	Date	Discharge (m^3/s)	Mean Velocity (m/s)	Maximum Velocity (m/s)
Kushiyara River at Markuli	133.44	July 9 1995	2,587	1.12	1.36
Kalni R. at Ajmiriganj	106.45	May 20 1996	2,040	1.89	2.02
Kalni R. at Shantipur	95.4	April 4 1996	1,400	1.75	2.01
Cherapur Khal	90	April 9 1996	350	1.29	1.95
Kalni R. at Kadamchal	84.69	April 2 1996	1037	1.63	2.23

The hydraulic geometry regression relations were used to estimate the mean channel velocities under flood conditions. These results are summarized in Table C.27 for pre-monsoon flood conditions up to the point where substantial overbank spilling will occur. It is expected that the main channel velocities will not increase much after this overtopping occurs.

Table C.27: Estimated Mean Channel Velocities

Gauge	Distance (Km)	Mean Velocity (m/s)	
		1:2 year pre-monsoon	1:5 year pre-monsoon
Kushiyara R. at Markuli	133.44	0.9	1.12
Kalni R. at Ajmiriganj	106.45	1.49	1.9
Kalni R. at Shantipur	95.4	1.93	spilling
Kalni R. at Kadamchal	84.69	1.74	spilling

4.6.2 Estimated Velocities from Hydraulic Modelling

Mean velocities were computed for project conditions using the HEC-2 hydraulic model for 1:20 pre-monsoon and 1:20 annual maximum discharges. In the reach between Ajmiriganj and Markuli, the highest mean channel velocity were as follows:

- pre-monsoon flood : 1.80 m/s near Koyer Dhala
- annual maximum flood : 1.77 m/s near Markuli

At most locations, the velocities in the monsoon season were about 80% of the pre-monsoon values due to the higher tailwater level. However, further upstream of Markuli, velocities were highest in the monsoon season, since backwater effects from the Meghna River did not extend that far.

Actual maximum velocities through the bends will be substantially higher than the mean channel values due to curvature of the flow. The velocities along the concave (outer) banks were estimated from the method recommended by the US Corps of Engineers (EM-1110-2-1601). It was found that the velocities at the outer bank reached up to 1.8 times the mean velocity when the bend radius/channel width ratio was around 1.0. Table C.28 summarizes the estimated maximum velocities for various bend curvatures.

Table C.28: Maximum Velocity in Bends

Bend Curvature (R/W ratio)	V_{max}/V_{mean} Ratio	V_{max} (m/s)
2	1.58	2.85
4	1.43	2.57
6	1.34	2.4
8	1.27	2.29
10	1.22	2.2

Note: V_{mean} = 1.8 m/s

5. PRESENT INFRASTRUCTURE

This chapter summarizes the present status of the physical water-management infrastructure in the project area. The following components are described:

- partial flood control and drainage works;
- irrigation, and
- river closures.

Detailed description and analysis of the project area's transportation network is provided in Annex G - Navigation.

5.1 Flood Control and Drainage Works

Projects described in this chapter are categorized as partial flood control projects and drainage projects. Table C.29 summarizes the main features of these projects. A summary brief has been included for each project in Appendix C.3 of this Annex. These descriptions were abstracted from previous investigations (NERP, 1992).

Partial Flood Control Projects

The objective of partial flood control projects is to increase agricultural production by protecting the *boro* crop from early or pre-monsoon flooding. The protection is provided by constructing submersible embankments around the areas to be protected and placing regulators at strategic locations in the embankment. The regulators are designed to promote post-monsoon drainage and to allow water to enter the protected area immediately after the *boro* crop is harvested. The aim is to minimize the differential head between the water levels inside and outside the area, thereby reducing damage to the embankments when they are overtopped. Partial flood control infrastructure is not intended to alter conditions during the monsoon season.

There are 11 projects providing partial flood control in the project area: four on the left bank of the Kushiyara River and seven are on the right bank. The gross area of these projects is approximately 80,000 ha and the total length of submersible embankments amounts to about 208 km. Details about each projects are described in Appendix C.3.

Most of the projects were reported to have produced positive impacts. Negative impacts included: altered sediment deposition patterns, channel shifting, increased water levels in adjacent channels and deficient drainage. Sediment deposition delays post-monsoon drainage thereby delaying planting of *boro* and increasing the risk of pre-monsoon flood damage as well as reducing the area planted.

Often embankments were constructed with insufficient regulators to provide adequate drainage. Inadequate drainage facilities resulted in public cuts of the embankments. BWDB tends to repair breaches late in the construction season because financial support for repairs is not available any earlier. Breaches are often repaired with unsuitable sandy material because suitable material is not readily available. Breaches occur as a result of natural processes such as wave action, embankment overtopping and river erosion.

Table C.29: Summary of Water Resource Infrastructure in the Project Area

Project	BWDB Division	Type	Gross Area (ha)	Net Area (ha)	Population
Baram Haor	Sunamganj	PFCDI	5,500	4,800	25,800
Bashira R. Re-excavation	Habiganj	DI	7,150		32,100
Bhanda Beel	Sunamganj	PFCDI	4,000	3,600	17,200
Chaptir Haor	Sunamganj	PFC	4,453	3,642	22,700
Damrir Haor	Sylhet	D	18212	7,285	127,410
Jhingari Nadi	Habiganj	DI	4,260	3,600	18,960
Naluar Haor (I & II)	Sunamganj	PFCD	12141	10,724	57,600
Sutki R.	Habiganj	PFCD	1,417	810	4,740
Tangua Haor	Sunamganj	PFC	5,000	4,500	20,800
Udgal Beel	Sunamganj	PFC	5,900	4,700	21,800
Sutki River Embankment	Habiganj	FCD	12,146	9,710	54,940

Project Type:
PFC: Partial Flood Control Project
D: Drainage Project
I: Irrigation Project

Drainage Improvement Projects
The objective of these projects is to improve drainage so that *boro* crops can be planted earlier on low lands, thereby to reduce the pre-monsoon flood damage to this crop. They are also intended to expedite rainfall runoff from upland areas thereby reducing flood damage to standing crops.

There are three projects that are primarily drainage improvement projects - Bashira River Re-excavation Project" near Shantipur, "Damrir Haor Project" near Fenchuganj and "Jhingari Nadi Drainage and Irrigation Project" located east of Ajmiriganj . All of these projects are considered to have had some positive impacts and none have had any apparent negative impacts.

5.2 Irrigation

Surface Water irrigation coverage is about 125,000 ha by LLP's and traditional modes (AST, 1991). There are 3,200 LLP's of various discharge capacities irrigating an area of 55,000 ha. The majority of the surface water irrigated area is concentrated in Astagram, Nabiganj, Baniachang, Balaganj, Derai, Sullah, and Jagannathpur.

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Present groundwater abstraction for irrigation is not significant. According to AST (1991), there are 191 shallow tube wells and 77 deep tube wells in the project area. The reported groundwater irrigated area is 4,000 ha, of which 1,700 ha is from shallow tube well and 2,300 ha is from deep tube wells. Groundwater abstraction is about 17.33 million m^3 based on MPO's (currently WARPO) estimated groundwater irrigation duty. According to AST, groundwater irrigation is mainly concentrated in Ajmiriganj, Baniachang, Habiganj, Lakhai and Astagram Thana.

5.3 River Closures

Two major closures have been constructed along the river - the Markuli Closure in 1978 and the Bheramohona Closure opposite Ajmiriganj in 1993 (Figure C.1).

Markuli Closure
Pre-monsoon flooding problems increased throughout the 1960's and 1970's north of Markuli in response to major morphologic changes further upstream on the Suriya channel (Annex A - Sedimentation). In 1978, local officials decided to construct a closure across the Old Kalni River at Markuli to prevent spills from the Kushiyara River from entering into the lowlands. After several attempts were made a permanent closure was completed by 1982. The outlet of the Old Kalni River silted-in completely after the closure, which has disrupted post-monsoon drainage around the Baram Haor Project and Tangua Haor Project. After the closure was constructed, it was noticed that the water levels on the Kushiyara side (south) were up to 1.2 m higher than on the Kalni side (north). Although the structure reduced spills into the low-lying basins north of Markuli, it raised water levels on the Kushiyara River and significantly increased discharges further downstream on the Kalni River. It is believed that this closure has contributed significantly to the downstream progression of channel instability problems along the Kalni River.

Bheramohona Closure
This closure is situated on the right bank of the Kalni River opposite Ajmiriganj across the Old Surma River channel. The closure was constructed in 1993 in response to increasing pre-monsoon water levels on the Kalni River to prevent spills from entering the low-lying *haor* area.

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6. CURRENT PROBLEMS

This chapter describes the key technical problems and water management issues that can be addressed in this project. The following sections highlight the impacts of the river on people's lives. Past approaches to flood control and water management practices are then reviewed. Finally, conclusions are drawn on the key problems that need to be addressed in this project.

6.1 Impacts of the River on People Over the Year

Table C.30 summarize the hydrological events and their significance to people's lives through the year.

6.1.1 Pre-monsoon Flood Season

Pre-monsoon floods are the major cause of damage to the *boro* rice crop, the principal food grain grown in the project area. Low yields and complete loss of the *boro* crop leads to unstable food production and causes economic insecurity for the people. Recurring pre-monsoon flood damage has accelerated the process of pauperization among farm families.

Much of the pre-monsoon flood damage is caused by bank breaching along the outer bank in meander bends. The resulting spill channel (*dhala)*, may damage crops and cultivated land, even though the water level in the river does not exceed the top of the river bank. The breaches scour sediment from the floodplain and re-deposit the material in nearby *beels* and *haors*. These sediment "splays" can greatly accelerate overbank sedimentation and infill wetlands and permanent water-bodies. This damages valuable aquatic habitat and reduces the amount of water available for irrigation water supplies.

6.1.2 Monsoon Flood Season

Monsoon Floods
During the monsoon flood, most of the project area is deeply flooded and people's living space is restricted to their homestead platform (*bhita*) and the higher natural levees (*kanda*) along the river. Movement to schools, markets and neighbouring platforms is hampered by flooded low areas in the village. Earthen homestead platforms are usually not raised above extreme flood levels and up to 0.6 m of water may inundate the courtyard. In addition to the severe dislocation of people's lives, monsoon floods cause economic hardship when livestock, fodder and stored grain supplies are lost or damaged and have to be disposed of at distress sale.

Channel Shifting and Bank Erosion
Channel shifting and bank erosion is mainly governed by flows in the monsoon season, particularly in the reach upstream of Ajmiriganj. Bank erosion has destroyed several villages along the river and has turned many peasant families into day labourers.

Wave Erosion
Downstream of Ajmiriganj, village platforms, roads and embankments are subject to severe wave attack during the monsoon season. The most exposed sites are located adjacent to major *haors*. Damage to infrastructure such as roads and embankments entails annual replacement or re-

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construction. Local people may not have sufficient resources to adequately maintain and protect their platforms in all years. Furthermore, traditional methods of wave protection are not adequate to protect against a very severe storm event. Consequently, the size of the platforms may gradually decrease over time. Some villages, such as Shahebnagar, have been completely eroded by wave erosion.

6.1.3 Post-Monsoon Season

After October, water levels in the project area usually start to decrease, and the water drains from the floodplain back to the main river channels. The timing of this recession is very important, since it governs when *boro* rice cultivation can begin. If drainage is delayed or obstructed, farmers can not transplant *boro* seedlings. Furthermore, the longer the delay in planting, the greater the risk of incurring damage from pre-monsoon floods before the next harvest.

Many of the long-term drainage patterns on the floodplain have been disrupted or blocked as a result of channel shifting or construction of closures across open channels. Consequently, much of the post-monsoon drainage is now forced through other channels such as the Darain River, and Old Surma River which ultimately flow into the Baulai River system. As a result, problems of post-monsoon drainage congestion are perceived to have worsened over time.

6.1.4 Dry Season

Constraints to Navigation
Shoals and shallow reaches restrict navigation between January and March, particularly in the 40 km reach between Kalma and Ajmiriganj. The available depths have decreased by over 2 m since 1963 as a result of channel aggradation. Portions of the main river such as the Dhaleswari reach between Kalma and Madna, do not even meet a Class III navigation standard (1.8 m least available depth). This effectively isolates some communities from normal river transport routes. In the dry season, goods must be off-loaded onto smaller boats or transported at higher costs by roads.

Irrigation and Water Supplies
Surface water from *beels*, *haors* and the river are the main source of irrigation water supplies in the dry season. Overbank sedimentation has filled-in many of the *beels* and *haors* adjacent to the main channel. As a result, water for irrigation must be drawn from the main channel. This requires construction of long canals and additional pumping costs. Approximately 200 low lift pumps (LLP) have been installed in the last 2 years along the river and about 20% of the LLPs have canals more than 2.5 km in length.

6.2 The Impact of Channel Instability

The problems associated with flooding and sedimentation have been exacerbated by recurring channel instability along the river. Table C.31 summarizes the three main styles of channel instability that occur and their associated hydrological effects. Table C.32 summarizes the resulting impacts on people's livelihood in the region. Channel avulsions (such as the shift from the Bibiyana River to Suriya Khal) produce the greatest impacts to flooding and sedimentation patterns and the greatest disruption to people's lives. Although these events occur infrequently, their effects can persist for many years. Furthermore, they accelerate other kinds of channel instability such as meander shifting and bank breaching.

The following factors are believed to have contributed the most to de-stabilizing the Kalni River:

- the accidental diversion of the Bibiyana channel into Suriya *khal* by local authorities;
- construction of the closure across the Kalni River at Markuli, and
- the occurrence of an unusual number of large floods in the period between 1982 to 1993.

An example of damage from recent channel shifting was documented at Shahebnagar in 1994. Shahebnagar is located on the left bank of the Kalni, near Km 92 and across the river from Katkhal (Figure C.7). The destruction of Shahebnagar's homestead and agricultural land was caused by the abandonment of a former main channel and the subsequent enlargement and shifting of a former *khal*. In April 1994, 200 households became homeless overnight, when erosion along the Kalni's right bank eroded the last piece of land separating the Kalni and the Old Kalni Rivers. After this cutoff, the contiguous villages of Katkhal and Shahebnagar were separated, the homesteads of Taragazir Hati were submerged and Shahebnagar was lost to the river. Of the 200 Shahebnagar homesteads eroded in 1994, 100 families also lost their agricultural land. They now work as wage labour, living on others' homesteads in neighbouring villages during the dry season, and migrating during the monsoon to find work in Dhaka and Sylhet. The remaining 100 households live and work on their agricultural land during the dry season and shift to flood-secure living space during the monsoon.

In addition to the loss of their homesteads and agricultural land, Shahebnagar farmers report loss of yield and high production costs for *boro* rice, cultivated on silted fields.

Impact of Channel Changes on Flood Levels

The cumulative effect from past aggradation, and channel changes has been to increase the magnitude and frequency of pre-monsoon flood levels between Sherpur and Madna. Measurements at Ajmiriganj show that the pre-monsoon flood levels have risen by approximately 1.5 m over the last 20 years. As reported in Chapter 3 of this Annex, pre-monsoon floods are approaching the levels that occur during the monsoon season.

An example of how local channel instability and sedimentation can affect pre-monsoon flood damage was documented in 1994. In that year, significant crop damage was experienced throughout the project area. Furthermore, the pre-monsoon flood level at Ajmiriganj was the second highest on record, reaching nearly the level of the 1991 flood. However, the actual pre-monsoon flood discharge (measured at Sherpur) had a return period of only about three years. Field observations showed the unusually high water level occurred after a channel shift below Katkhal produced a channel constriction, which raised the water levels upstream.

Table C.30: Impacts of Hydrological Processes on Peoples Lives

	Season			
	Pre-monsoon	**Monsoon**	**Post-Monsoon**	**Dry Season**
Hydrological Processes	• flash-flooding • overbank spills • bank erosion • bank breaching	• deep flooding by backwater from Meghna River	• drainage from floodplain to river	• drought
Human Activities	• *boro* harvest • rice processing sale & storage • platform flood protection • household flood preparation (fuel, food)	• people confined to high land • fishing • distress sales of livestock	• planting non-cereal crops • preparation rice seed beds • fishing • repair of earthen platforms • sale of surplus crops • purchase of crop inputs	• plantation, weeding, irrigation of *boro* rice • harvest of non-cereal crops • fishing
Impact of river processes on Agriculture	• spills damage *boro* crop before harvest • overbank sand deposition reduces soil fertility	• *aus* and *aman* crops restricted to limited flood-free areas	• slower drainage delays planting *boro* crops	• surface irrigation supply dries up due to reduced storage capacity in *beels/ haors*
Impacts of river processes on Fishing	• spills and sediment deposition degrade habitat			• shallow depths restrict over-wintering ground
Impacts of river processes on Water Transport			• shoals restrict boat traffic	• shoals and shallow channel restricts boat traffic and increase cost of commodities
Impacts of river processes on Human Settlement	• economic loss of the year's main crop • economic loss of homestead land and buildings	• damage to homestead platform from bank & wave erosion • damage to grain, fodder & livestock when platforms are overtopped	• increased risk for economic loss of the following year's *boro* crop	• traders incur business losses

Table C.31: Types of Channel Instability on Kalni-Kushiyara River

Style of Channel Instability	Description	Physical Impacts	Hydrological Impacts
Avulsion	• Sudden channel shift resulting in abandonment of former channel and development of a new channel	• Channel widening and accelerated shifting along the new channel; • Degradation along the new channel; • Aggradation in lower reach; • Former channel silts-in	• Pre-monsoon flood levels may be increased during the development of the new channel system; • Post-monsoon drainage may be reduced due to disruption of the drainage system; • Increased magnitude of flows along new channel system.
Breach or *Dhala* Formation	• Breach at outside of bend causes spill channel to form	• Erosion along spill channel; • Increased overbank sedimentation in adjacent *beels* and *haors*	• Increased pre-monsoon flood spills • Reduced post-monsoon drainage due to local siltation of drainage channels.
Meander Shift	• Progressive migration of meander pattern	Bank erosion along concave (outer) bank, deposition along convex (inner) bank. May eventually lead to natural cutoff.	• Usually minor.

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Table C.32: Impacts of Channel Instability

Style of Channel Instability	Impact on Agriculture	Impact on Human Settlements	Impact on Aquatic Habitat	Impact on Navigation
Avulsion	• Increased frequency of pre-monsoon flood damage along entire new channel system; • Loss of cultivable land due to bank erosion; • Delayed *boro* plantation due to post-monsoon drainage congestion.	• Increased damage to homesteads along new channel route due to bank erosion and channel widening;	• Major displacement and / or alteration to habitat characteristics along river. • Former *duars* may be filled-in, new *duars* will be created in other locations.	• Navigation routes disrupted in dry season during formation of new channel; • Navigation routes along former main channel may be permanently obstructed.
Breach	• Frequency of pre-monsoon flood damage increases in localized areas affected by spills; • Reduced crop yields due to overbank sand deposition • Reduced irrigation water supply from *beels* due to over bank siltation	• Usually minor unless village is located along path of spill channel.	• Overbank sedimentation causes infilling of *beels* and *haors* which are important habitat for many species of fish and wildlife.	• Local sedimentation in *khals* blocks connector routes between main channel and floodplain areas.
Meander Shift	• Loss of cultivable land due to bank erosion;	• Erosion damage to villages and infrastructure	• Ongoing creation and destruction of habitat such as *duars* and *beels*	• Natural loop cuts may disrupt navigation routes

6.3 River Management Practice

To-date, the main priority of water management authorities has been to develop pre-monsoon flood protection schemes around individual *haors* on the floodplain. These *haor* development projects were constructed with the assumption that the areas could be treated in isolation from each other and from channel instability problems on the main river system. However, the recurring spills and breaches from the main river and the need for raising the submersible embankments to keep up with the constantly rising pre-monsoon flood levels show the limitations of this approach. So far, responsible agencies such as BWDB or BIWTA have not had the resources to carry out systematic channel maintenance or stabilization measures on the main river. As a result, some of the works that have had the greatest impact to the river system were carried out by local groups with virtually no detailed engineering investigation or planning.

Works carried out in this manner included:

- construction of the Quesba pilot channel which triggered the avulsion from the Bibiyana channel into the Suriya channel;
- closure of the Kalni River channel at Markuli, and
- construction of loop cuts between Markuli and Ajmiriganj.

Although these works may have benefitted some areas, they also produced substantial adverse impacts along other portions of the river system and have continued to affect the channel's overall stability to this day. They have certainly increased the need for maintenance work on the river and made it more difficult for local people to cope with the hydrological regime.

6.4 Future Threats

There is no indication that the instability problems and increasing pre-monsoon flood damage will cease in the near future. In fact, there is strong evidence that these problems are continuing to propagate downstream of Ajmiriganj. As a result, there is a significant risk that a substantial portion of the river's flow will be diverted through Cherapur Khal into the Baulai River system. This would cause substantial disruption along both the lower Kalni River and the lower Baulai system.

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7. PROJECT CONCEPT

7.1 Project Formulation

The Kalni-Kushiyara River has experienced ongoing instability and sedimentation problems over the last 30 years which have led to increased pre-monsoon flood damage to *boro* rice cultivation, deteriorating river navigation and loss of productive agricultural land and human settlements. The situation is expected to worsen over the next 30 years, particularly in the reach downstream of Ajmiriganj. Given the nature of the problems facing the region, the project must be formulated to meet multiple objectives, including:

- improving the river's stability and providing a more stable environment for development;
- reducing damage to agriculture by reducing pre-monsoon flood damage and improving post-monsoon drainage;
- improving living conditions along the river by reducing erosion damage to villages, and by creating new flood-free village platform, and
- improving navigation along the river during the dry season.

In order to meet all of the project's objectives, a coordinated river management strategy was developed. In this approach, river stabilization measures required for improving agricultural production, will also be used to benefit navigation, fisheries and human settlements. Waste spoil from channel re-excavation work is used for constructing new flood-protected village platforms. At the same time, using the spoil to build new platforms provides an effective means of solving a difficult waste material disposal problem that is commonly associated with channel excavation work.

The initial priority was to develop a workable plan to improve the river's overall stability, since the other project objectives can not be met without achieving a more stable channel configuration. Once a tentative set of works was developed, the additional requirements needed for flood control and navigation could be defined. Finally, plans for providing new village platforms and for enhancing village development were defined.

7.2 Development Concept

The 1993 pre-feasibility study proposed a combination of loop cuts (near Issapur and Katkhal), bank protection and channel re-excavation to develop a more stable channel configuration and to achieve the required flood control benefits. This basic approach was adopted for the feasibility investigation. However, as more field surveys and information became available, a number of modifications were made to the original concept. The general approach that was adopted is as follows.

1. All of the river stabilization work will be carried out downstream of Sherpur (starting near Raniganj at Km 153). Upstream of Raniganj, only improvements to the navigation are proposed;

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2. In the reach between Raniganj and Ajmiriganj, bank protection (stone revetments) and low levees are used to control pre-monsoon flood spills and bank breaches. Structures placed in this reach need to be planned so they will not confine the higher monsoon flood discharges and do not impede post-monsoon drainage. Regulators and fish-pass structures will be installed to improve post-monsoon drainage and fish migration above present conditions;

3. In the reach between Ajmiriganj and Astagram (Km 106.5 to Km 40), a combination of river re-alignments, re-excavation and low levees where required, will be used to provide a more stable channel alignment. There are two reaches that require particular attention - the Katkhal-Cherapur Khal reach, where the river is threatening to make a new avulsion towards the Baulai River, and the reach of the Kalni-Dhaleswari River from Issapur to Shibpur, which has been silting-in. These works should be planned to minimize the need for channel maintenance dredging since this will be critical to the project's sustainability, and

4. The spoil from the channel re-excavation work will be used to construct new flood-protected village platforms to improve human settlements and to improve infrastructure. These platforms should be designed to withstand floods and wave action during the monsoon season.

Figure C.30 shows a general layout of proposed works along the river.

The pre-feasibility study considered constructing a new loop cut near Issapur to shorten the river by about 16.5 km. The main purpose of this new channel was (1) to reduce upstream water levels, (2) to promote a more self-scouring channel upstream of the cut and (3) to reduce sediment deposition in the lower Dhaleswari branch, particularly around the junction of the Ratna/Khowai Rivers. During the early stages of the feasibility study, concerns were raised that the loop cut could adversely impact local communities whose cultivable land lay along the route of the new channel. As a result, an assessment was made to determine whether the Issapur loop cut could be eliminated and the same benefits could be achieved by additional channel re-excavation along the Dhaleswari River channel. Consequently, two alternatives were investigated:

Alternative 1: construct loop cuts at Katkhal and Issapur, along with other necessary channel re-excavation and bank stabilization work upstream of Kalma;

Alternative 2: construct only the Katkhal loop cut, along with other channel re-excavation and bank stabilization works in order to provide equivalent flood control benefits as in Alternative 1.

The main components for each alternative are summarized in Tables C.33 and C.34. The components in the two alternatives are virtually identical upstream of Issapur.

7.3 Design Criteria

The following criteria were used for planning and design of the proposed interventions:

Flood protection to agricultural crops:	1:5 year pre-monsoon flood
Flood protection to human settlements:	1:20 year monsoon flood
Protection against wave erosion:	1:20 year storm
Design of bank protection works:	1:20 year flood
Navigation channel improvements:	BIWTA Class II channel

Table C.33: Primary Flood Control and Channel Stabilization Works - Alternative 1

Kilometre	Name	Proposed Works	Purpose	Other Beneficiaries
53-72.5	Issapur loop cut	• excavate a new channel from Kalma to Issapur; • close entrance to old Kalni channel; • re-excavate Dhaleswari channel from Madna to Kalma	• reduce sediment deposition in Dhaleswari channel; • improve drainage in lower Ratna/Khowai system; • reduce pre-monsoon flood damage by lowering water levels and making the channel more self-scouring	navigation, community development
72.5-83.0	Issapur-Anwarpur re-excavation	• dredge Kalni River channel	• restore channel capacity to reduce pre-monsoon flood damage; • reduce risk of avulsion at Cherapur Khal,	navigation, community development
83.5-85.5	Kadamchal re-alignment	• excavate accretion on right floodplain	• re-align bend to reduce bank erosion near Kadamchal; • remove local constriction caused by floodplain accretion	community development
86.5-96.5	Katkhal loop cut	• shorten river by 5.5 km by excavating a new channel from Bisurakona to Shantipur	• stabilize the river and prevent avulsion through Cherapur Khal; • lower pre-monsoon flood damage by lowering upstream water levels and making the channel more self-scouring	navigation, fisheries, community development
96.5-107.0	Ajmiriganj re-excavation	• dredge Kalni River	• restore channel capacity to reduce pre-monsoon flood damage	navigation, community development
114.0-114.5	Pituakandi Revetment	• construct bank protection	• prevent bank breaching and pre-monsoon flood spills • stabilize meander bend	fisheries
114.5-115.5	Koyer Dhala Revetment	• construct bank protection and regulator	• prevent bank breaching and pre-monsoon flood spills; • stabilize meander bend • restore irrigation water supply and boat access	fisheries
125.0-142.0	Intermittent levees	• construct low levees along low sections of banks	• prevent pre-monsoon flood spills	
138.5-139.5	Akkilshah Revetment	• construct bank protection	• prevent bank breaching and pre-monsoon flood spills; • stabilize meander bend, reduce erosion damage	fisheries

Table C.34: Primary Flood Control and Channel Stabilization Works - Alternative 2

Kilometre	Name	Proposed Works	Purpose	Other Beneficiaries
55.0-72.0	Dhaleswari/Kalni re-excavation	• dredge channel	• improve drainage in lower Ratna/Khowai system • reduce pre-monsoon flood damage	navigation, community development
72.5-83.0	Issapur-Anwarpur re-excavation	• dredge Kalni River channel	• restore channel capacity to reduce pre-monsoon flood damage, • lower risk of avulsion at Cherapur Khal,	navigation, community development
83.5-85.5	Kadamchal re-alignment	• excavate accretion on right floodplain	• re-align bend to reduce bank erosion near Kadamchal • remove local constriction caused by floodplain accretion	community development
86.5-96.5	Katkhal loop cut	• excavate a new channel from Bisurakona to Shantipur	• stabilize river and prevent avulsion through Cherapur Khal • lower pre-monsoon flood levels at Ajmiriganj by shortening river's length 5.5 km to increase the slope and make the channel more self-scouring	navigation, fisheries, community development
96.5-107.0	Ajmiriganj re-excavation	• dredge Kalni River	• restore channel capacity to reduce pre-monsoon flood damage	navigation, community development
114.0-114.5	Pituakandi Revetment	• construct bank protection	• prevent bank breaching and pre-monsoon flood spills • stabilize meander bend	fisheries
114.5-115.5	Koyer Dhala Revetment	• construct bank protection and regulator	• prevent bank breaching and pre-monsoon flood spills • stabilize meander bend • restore irrigation water supply and boat access	fisheries
125.0-142.0	Intermittent levees	• construct low levees along low sections of banks	• prevent pre-monsoon flood spills	
138.5-139.5	Akkilshah Revetment	• construct bank protection	• prevent bank breaching and pre-monsoon flood spills • stabilize meander bend	fisheries

7.4 Design Methods

The following discussion describes the general procedures that were followed for the design of main physical works. The Pilot Project provided a substantial amount of prototype information for the design of the dredging operations and platform construction. That information is contained in Annex J - Pilot Dredging Project.

7.4.1 Channel Design

An iterative series of hydraulic design calculations were carried out to assess the effectiveness of the proposed channel works. Preliminary calculations were made using the standard step backwater program "HEC-2" developed by the US Army Corps of Engineers. The main advantage of using this program is that it has features for representing channel improvements such as dredging, levees and flood control embankments. This allows many different in-channel concepts and alternatives to be quickly screened and evaluated. Following this initial analysis, the designs were represented in the MIKE-11 hydrodynamic model of the Northeast Region. This model can simulate the complex interaction between the main Kalni-Kushiyara River and the surrounding network of channels and floodplain areas. As a result, the impacts of the project alternatives on the surrounding water levels can be assessed. Therefore, the hydrodynamic model was the key tool for evaluating the project's physical impacts and benefits.

The volume of channel re-excavation was determined from the available hydrographic surveys, using the digital terrain model (DTM) "Surfer". This analysis involved fitting a mathematical surface on a regular grid to the irregularly spaced surveyed elevations. The dredged channel was then plotted on the charts and represented in the DTM as a "mask" and the two surfaces were subtracted to compute the volumes of "cuts" and "fills".

7.4.2 Bank Protection

Requirements for bank stabilization against river attack include (1) providing adequate stone size in the revetment to resist the shear stresses from the river currents during extreme floods (2) providing sufficient stone volume in the revetment toe to provide a suitable launching apron that will prevent undermining of the slope by scour and (3) providing adequate slope preparation and grading to ensure the revetment will not be subject to geotechnical failures from sloughing or rotational slumping.

Prior to carrying out the bank protection design a review was made on the performance of existing bank protection along the Kushiyara River, from Amalshid to Sherpur. This involved undertaking field inspections (accompanied by BWDB engineers) and monitoring scour and erosion processes by carrying out repeat cross section surveys before and after floods. This monitoring included surveys of recently constructed protection at Amalshid and Zakiganj during and after the major flood of 1993. Methods for estimating the stone size and scour depth were tested against actual field measurements. Results of these studies are included in Appendix C.4 of this Annex. These observations provided additional confidence that standard design methods such as C. R. Neill (RTAC, 1975) and BWDB (1993) could be applied to the proposed works.

The depth of scour was estimated by direct observation using the results of the hydrographic charts as well as standard "Regime methods" (Blench, 1969).

7.4.3 Wave Erosion Protection

Requirements for protecting embankments against wave attack in the monsoon season were based on the design methods outlined in BWDB 1993 (Hudson's Formula) and the US Army Corps of Engineers "Shore Protection Manual" (COE, 1986). The wave climate was estimated from the analysis of winds and wave hindecasting outlined in Section 3.7 of this Annex.

7.4.4 Spoil Disposal Confinement Chambers

Dredge spoil will be pumped into confined disposal chambers on land. After filling, these disposal chambers will eventually be turned over to the communities and will be used as new village platforms. The disposal chambers must be designed properly so that virtually all of the sediment will be retained, while the clarified effluent is returned to the river. Design of the confinement chambers was based primarily on the methods outlined by the US Army Corps of Engineers Manual EM 1110-2-5027. The designs were tested during the Pilot Dredging Project by successfully constructing and operating disposal sites at Gazaria and Kakailseo. At these two sites, the confinement chambers were able to trap approximately 95% of the sediment, even when relatively fine grained materials were excavated from the river bed.

The trap efficiency of the disposal chambers was designed on the basis of a laboratory "Settling Tube" test, using procedures described in EM 1110-2-5027. A series of boreholes were drilled along the centreline of the channel to obtain representative samples of sub-surface river bed materials. Boring logs and sieve curves are included in Appendix C.5 of this Annex.

7.5 Hydraulic Design Parameters

This section summarizes key hydraulic and hydrologic design information. These results were based on the predictions from the MIKE-11 hydrodynamic model described in Annex B as well as on the hydrology investigations summarized in Chapter 3 of this Annex. This information was used for the hydraulic design of the flood protection works.

Table C.35 summarizes the estimated pre-monsoon flood discharges at key locations along the river. The discharges downstream of Sherpur were estimated by the MIKE-11 model for the 1991 flood condition. The flows below Cherapur Khal reflect the influence of local inflows which may vary from year to year. The effect is most apparent for the discharges below the Baida River junction which represents the total discharge from the Kalni River as well as the inflows from the Khowai-Ratna River systems.

Table C.35: Estimated Pre-monsoon Flood Discharges

Location	Pre-monsoon Flood Discharge (m^3/s)		
	1:2 year Flood	1:5 year Flood	1:10 year Flood
Sherpur	1,698	2,395	2,590
Markuli	1,653	2,313	2,563
Ajmiriganj	1,598	2,265	2,528
Katkhal Loop cut	1,530	2,250	2,489
Below Cherapur Khal	1,262	1,960	2,772
Issapur Loop Cut	940	1,284	1,616
Below Baida Junction	1,507	2,550	3,226

Note: flows based on 1991 flood year simulation. Discharges below Baida Junction reflect local inflows from Ratna/Khowai River systems.

Table C.36 summarizes the adopted 1:20 year annual maximum water levels at key locations. These values are based on historic flood frequency analysis, since the project will significantly affect the annual maximum levels in the pre-monsoon season. These results were used primarily for determining embankment and village platform flood construction levels.

Table C.36: Design Water Levels (1:20 year) Annual Maximum Flood

Location	Kilometre	1:20 Annual Maximum (m PWD)
Sherpur	177.28	9.39
Markuli	133.44	8.00
Ajmiriganj	106.45	7.90
Madna	61.00	7.77

Table C.37 summarizes the predicted pre-monsoon flood levels at each cross section along the river.

Table C.37: Predicted Pre-monsoon Flood Levels

Location	Chainage		Alternative - 1			Alternative - 2		
			1:2 year (m PWD)	1:5 year (m PWD)	1:10 year (m PWD)	1:2 year (m PWD)	1:5 year (m PWD)	1:10 year (m PWD)
	Mike-11	1995						
Sherpur	92.0	177.3	7.60	8.83	9.17	7.61	8.84	9.18
	97.0	172.5	7.23	8.43	8.80	7.24	8.44	8.8
	100	169.4	7.11	8.29	8.66	7.12	8.30	8.68
	104.0	165.9	7.02	8.17	8.53	7.03	8.18	8.54
	107.0	162.6	6.91	8.05	8.42	6.92	8.06	8.42
	110.0	159.4	6.82	7.94	8.31	6.84	7.95	8.31
	113.0	156.4	6.78	7.87	8.23	6.80	7.88	8.24
	116.5	153.2	6.75	7.82	8.18	6.77	7.83	8.18
	120.0	149.9	6.73	7.78	8.14	6.74	7.79	8.14
	123.5	146.4	6.71	7.76	8.11	6.72	7.77	8.11
	126.5	143.4	6.65	7.68	8.04	6.66	7.69	8.05
	129.5	140.4	6.56	7.56	7.92	6.57	7.57	7.92
	132.5	136.9	6.50	7.46	7.80	6.51	7.47	7.81
Markuli	136.0	133.3	6.38	7.34	7.69	6.40	7.35	7.70
	4.5	129.0	6.06	6.93	7.27	6.09	6.94	7.27
	7.3	126.2	5.93	6.74	7.06	5.95	6.75	7.07
	10.0	123.4	5.80	6.55	6.86	5.82	6.57	6.87
	12.8	120.6	5.65	6.35	6.65	5.68	6.37	6.66
	15.5	118.0	5.50	6.13	6.41	5.53	6.15	6.42
Koyer Dhala	20.0	113.5	5.30	5.88	6.16	5.34	5.91	6.18
Ajmiriganj	24.5	109.2	4.96	5.57	5.91	5.02	5.61	5.92
	28.0	105.2	4.70	5.32	5.71	4.78	5.37	5.74
	32.0	101.3	4.52	5.16	5.59	4.62	5.22	5.62
Rahala	36.5	97.1	4.34	5.04	5.49	4.47	5.09	5.53
Katkhal	37.75	95.9	4.28	4.97	5.47	4.42	5.08	5.51
loop cut	38.70	94.9	4.24	4.95	5.46	4.40	5.04	5.50
	39.86	92.5	4.15	4.90	5.45	4.34	5.00	5.49
	42.0	85.2	4.04	4.81	5.41	4.25	4.92	5.46
Cherapur	44.75	82.5	3.96	4.75	5.36	4.20	4.87	5.42
Abullahpur	47.5	81.1	3.90	4.69	5.31	4.16	4.82	5.37
	51.5	76.9	3.75	4.55	5.20	4.06	4.72	5.28
Issapur	55.5	72.6	3.38	4.15	4.97	3.83	4.47	5.07
	0.0	66.1	3.39	4.12	4.84	3.79	4.43	5.02
Madna	2.5	63.5	3.36	4.09	4.83	3.70	4.34	4.97
	5.0	60.6	3.32	4.05	4.83	3.56	4.20	4.90
	9.5	56.0	3.26	3.99	4.81			
Baida junction	14.0	52.0	3.25	3.98	4.81			
	17.5	48.5	3.12	3.82	4.73			

Note: Water levels are referenced to both Mike-11 & NERP (1995) Chainages

8. PROJECT DESCRIPTION - ALTERNATIVE 1

This chapter describes the main physical components of Alternative 1, including the river stabilization and flood control works, navigation improvements and new village platform construction. The description of each component includes a summary of the works that are planned, comments on the design and analysis that was carried out, and an outline of the construction activities and planning that will be required for implementation. This is followed by a breakdown of the estimated operation and maintenance requirements.

8.1 River Stabilization and Flood Control Works

Figures C.31 and C.32 show the overall location of the main components. The main flood control and river stabilization works include:

- constructing a 2.75 km long loop cut between Issapur and Kalma;
- re-excavating portions of the lower Kalni River between Issapur and Kadamchal;
- re-aligning a portion of the Kalni River opposite Kadamchal to remove a point bar deposit that encroaches the channel;
- constructing a 5.5 km long loop cut at Katkhal along with new bank protection works and a closure structure to re-align the entrance of Cherapur Khal;
- constructing bank protection works at three major breaches upstream of Ajmiriganj, and
- constructing low levees between Raniganj and Markuli to contain pre-monsoon spills.

The following comments describe the main works, proceeding in an upstream direction.

8.1.1 Issapur Loop Cut

Planned Works

This re-alignment involves making a 2.75 km long excavation from Issapur on the Kalni River to Kalma on the Dhaleswari River, which will reduce the river's length by 16.5 km. Embankments will be constructed on either side of the new channel to guide flood flows along the desired alignment in order to reduce the chance of future channel migration. The embankments will not be "tied-in" to high ground, and during the monsoon season flows will continue to be carried on the floodplain on both sides of the structures. As they will not confine monsoon season flood flows, water levels should not be raised. The embankments will be protected with concrete blocks to prevent wave erosion and scour.

After the new channel is opened, a closure will be constructed across the old channel entrance near Issapur. This closure will effectively block sediment laden water from the Kalni River from depositing material in the branch of the Dhaleswari channel between Madna and Kalma. The Dhaleswari channel will be re-excavated from the mouth of the Ratna/Khowai Rivers (Km 64) down to Shibpur (Km 56) near the junction with the new loop cut channel to improve drainage at the outlet of the Khowai/Ratna River systems. This will also provide a minimum Class II (2.4 m deep) navigation channel, which will allow water transport up to Adampur in the dry season. Initially, there was concern that serious deposition problems could develop over time near the junction of the Ratna/Khowai Rivers just upstream of Madna. Subsequent studies show the Khowai River deposits most of its sediment load on the broad, low-lying floodplain just below Habiganj (25 km upstream of the Kalni junction) when it spills overbank (Annex A-Sedimentation). Therefore, very little additional sedimentation is expected at the mouth of these tributaries. However, an allowance has been made for periodic maintenance dredging in the Dhaleswari channel. The two most likely reaches requiring maintenance dredging are (1) downstream of the Ratna/Khowai junction and (2) near Kalma where the new channel joins with the Dhaleswari River.

Design Considerations

The 2,750 m long new channel starts near Issapur near the Baida/Kalni-Dhaleswari bifurcation and has a gradually curved alignment, with a radius of curvature (R) of 3,000 m, a channel top width (W) of 270 m, and an R/W ratio of 11. The outlet of the new channel joins with the Dhaleswari River near the village of Kalma.

The land generally slopes from around El. 2.5-3.0 m PWD at the downstream end of the channel up to El. 4.5-5.0 m at the upstream end. Figure C.33 shows sub-surface soil characteristics at three test holes along the proposed route. The new channel will be constructed through primarily silty sandy floodplain sediments underlain by fine sand and silty sand.

Tentative design parameters of the new channel are summarized in Table C.38. A typical cross-section of the channel with the embankment is shown in Figure C.34. During final design, additional work should be carried out to optimize the geometry of the new channel in order to minimize excavation costs and maintenance requirements.

Table C.38: Channel Properties at Issapur Loop Cut

Parameter	Symbol	Top of Bank Elevation (m PWD)		
		3	3.5	4
Depth (m)	Y	6	6.5	7
Channel Area (m^2)	A	1,488	1,622	1,757
Top Width (m)	W	266	269	272
Hydraulic Radius(m)	R	5.6	6	6.4
Section Factor ($m^{5/3}$)	$AR^{2/3}$	4,666	5,344	6,060
Bankfull Capacity (m^3/s)	Q	1,255	1,440	1,630

Note: S_f=0.000035 n=.022

Table C.39 shows the expected hydraulic conditions in the new channel during pre-monsoon floods. The mean channel velocities reached up to about 1.1 m/s in a 1:5 year pre-monsoon flood.

The 1:2 year flood level in the monsoon season will reach El. 7 m PWD near Issapur. The mean velocities in the new channel will average around 0.6 m/s under these conditions.

Table C.39: Hydraulic Conditions in Issapur Loop Cut Channel

Location	Reference Distance (Km)	Pre-monsoon Flood Discharges (m^3/s)					
		1:2 year flood			1:5 year flood		
		Water Level (m PWD)	Vchan (m/s)	Shear Stress (N/m^2)	Water Level (m PWD)	Vchan (m/s)	Shear Stress (N/m^2)
Entrance	72.6	3.39	0.93	2.26	4.22	0.93	2.21
	54.5	3.38	0.6	0.92	4.19	0.71	1.28
	53.5	3.36	0.6	0.93	4.17	0.71	1.29
	52.5	3.3	1	2.59	4.1	1.12	3.5
Kalma	52	3.3	0.72	1.22	4.1	0.8	1.4

The channel will be provided with embankments set-back a minimum distance of 100 m from the new channel bank. The design cross section for these embankments are given below:

Flood Construction Level:	7.77 m + 0.9 m = 8.65 m PWD
Crest Width:	4.27 m
River Side Slope:	1V:3H
Country Side Slope:	1V:2H
Slope Protection:	Concrete Block

The embankments will be protected against wave erosion with concrete blocks on a geotextile filter over a layer of sand. Based on the wave climate hindecasting from Section 3.4 (Table C.15), the 1:20 year wave height will be around 0.9 m at this location. Based on Hudson's formula, the corresponding stable block size would be approximately 80 kg. Therefore, standard 40 cm x 40 cm x25 cm concrete blocks, (150 kg), placed on a slope of 1V:2.5H should provide adequate protection up to a 1:20 year storm.

Construction

The new channel will require excavating 4.12 million m^3 of material. The work will be carried out in two stages:

- first stage: surface excavation
- second stage: dredging

About 1 million m^3 of material will be excavated by manual methods and will be used for the construction of the embankments cum confinement dykes and the closure dam. The embankments have a total length of about 5 km and requires about 0.67 million m^3 of material. An additional 30,000 m^3 will be used for constructing the closure dam. The remaining volume will be used for infilling the two confinement chambers (for later use as village platforms) along the river side (Figure C.35). All the first stage surface excavation works should be completed in one dry season (from December to April), before the start of the pre-monsoon flood season. This operation includes excavation of the upper layer of the channel, above the ground water table to El. 1.70 m PWD (approximately), carriage of the spoil to the disposal sites and the construction of the confinement dykes. As manual methods of excavation are more economical than dredging, an attempt should be made to maximize the surface excavation component.

About 3.1 million m^3 of material will be excavated using hydraulic suction cutter dredges, with the spoil pumped into permanent disposal chambers on the floodplain. After the dredging is completed, the disposal chambers will be converted into village platforms or used for multi-purpose development to benefit the local communities. The dredging operations should start immediately after the surface excavation is completed. Therefore, all dredging preparatory work such as mobilization, assembling of pipelines and construction of confinement chambers should be carried out ahead of time to avoid delay. The dredging is planned to start by May and will continue through the monsoon until the work is completed in December. It is expected that all of this excavation may be completed in an eight month period, assuming four 18" dredgers can be used.

The closure on the Dhaleswari River will be constructed in the dry season (between January and March), after the new channel is opened. Flows through the Kalni-Dhaleswari channel will be virtually zero at this time of year. Figure C.36 shows details of the closure. It is proposed to construct the closure from a wooden piling core filled with alternating layers of earth-filled gunny bags and brush wood, and an outer embankment of gunny bags. Construction of the closure approaches should start simultaneously from both banks.

The Dhaleswari River will be re-excavated between Madna and Shibpur (Figure C.37). Approximately 740,000 m^3 of material will be excavated and the spoil will be used to infill a low-lying floodplain area opposite Madna (Site 5) and to construct 2 new village platforms at Shibpur (Sites 3 and 4; Figure C.37).

8.1.2 Channel Re-excavation - Issapur to Kadamchal

Planned Works

The Kalni River will be re-excavated from Issapur to Kadamchal (Km 72.39 to Km 86.5). The total volume of material that needs to be removed from the channel downstream of Katkhal amounts to 4.2 million m^3. However, it is anticipated that degradation will occur once the loop cuts are opened, which could reduce the need for excavation. Therefore, it is proposed to excavate only a portion of the material during the initial project construction phase, then monitor the response of the bed to the loop cuts and other works. Depending on the channel's response, additional excavation would be carried out to achieve the final design grade. In order to provide a conservative estimate of project costs, it has been assumed that all of the material in the channel will have to be removed by dredging.

Design Considerations

Figure C.30 shows the location of the proposed work. The volume of excavation, excluding any work associated with the construction of loop cuts is summarized in Table C.40. Design parameters for the main channel re-excavation work are as follows:

- bottom width: 100 m
- design grade varies, from El. -3 m near Issapur to El. -2.5 at Kadamchal
- bed material: very fine sand, silty-sand, sandy-silt, typical D_{50} size = 0.065 mm

Figure C.38 shows present channel cross sections with the proposed excavation superimposed. The average depth of excavation ranges between 2.5 to 5 m, and the increase in channel cross sectional area averages around 380 m^2 and ranges between 300 - 500 m^2 (Table C.40). This will increase the channel's cross sectional area at bankfull stage by around 20-30%.

Table C.40: Summary of Channel Re-excavation - Issapur to Kadamchal

Location	Reach (km)	Phase	Grade Level (m PWD)	Excavated Volume (m^3)	Average Increase in Area (m^2)	Increase in Bankfull Area (%)
Issapur	72.7-76.5	2	-3.0	1,370,000	370	44
	76.6-79.0	1	-3.0	710,000	280	33
Abullahpur	79.0-81.0	1	-3.0	951,000	480	48
Kalimpur	81.0-83.0	1	-3.0	764,000	380	38
Kadamchal	84.5-86.5	1	-2.5	426,000	210	20
Total				**4,221,000**		

Construction

Table C.41 summarizes the volumes of excavation by reach along the river and provides details on the number of disposal sites and platform areas that will be constructed. The location of these disposal sites are shown in Figure C.39.

Suction cutter dredgers will be used for the excavation, with the spoil pumped into permanent disposal chambers on the floodplain (Figure C.40). The dredging should start at the upstream end and proceed downstream. The excavation should be completed before the upstream loop cut is opened up. Phase 1 excavation could be completed by three dredgers working over a six month period. Phase 2 would require an additional eight months of work.

Table C.41: Summary of Channel Re-excavation and Village Platforms

Location	Reach (km)	Phase	Grade Level (m PWD)	Excavated Volume (m^3)	Village Platform Statistics		
					Total Platform	Disposal Sites	Area (ha)
Issapur	72.7-76.5	2	-3.0	1,370,000	8	6-13	28.0
	76.6-79.0	1	-3.0	710,000	4	14-17	16.0
Abdullahpur	79.0-81.0	1	-3.0	951,000	4	18-21	24.8
Kalimpur	81.0-83.0	1	-3.0	764,000	2	22-23	18.1
Kadamchal	84.5-86.5	1	-2.5	426,000	1	26	9.5
Total				**4,221,000**	**29**		**144.24**

8.1.3 Kadamchal Re-alignment

Planned Work

A channel constriction has developed in the large meander bend downstream of Katkhal as a result of land accretion along the right bank in the point bar opposite Kadamchal (Km 84). This accretion has reduced the width of the river from typically 250 m to only about 100 m which causes higher upstream water levels. This accretion has also deflected the river towards the left bank, causing bank erosion between Anwarpur (Km 82) and Kadamchal (Km 85). The proposed work involves removing part of the accreted land along the right bank to eliminate the constriction. Since the re-alignment is only a short distance downstream of the Katkhal loop cut, it is anticipated that some channel shifting will occur in this reach during the first years after the new channel is opened.

Construction

This work would involve manual excavation of 170,000 m^3 in the dry and dredging approximately 300,000 m^3. The material will be used to raise the existing ground on the right bank and for constructing platforms (Sites 24 and 25).

8.1.4 Katkhal Loop Cut

Planned Work

The Katkhal loop cut is intended to stabilize the channel near Shantipur and to reduce the risk of a major flow diversion into the Baulai River through Cherapur *Khal*. The loop cut will also shorten the channel length by around 5.5 km through the reach, which will reduce water levels in the pre-monsoon, post-monsoon and dry season. A closure will be constructed across the present channel that leads directly from Katkhal towards Cherapur Khal. This will effectively shift the entrance to the *khal* approximately four km downstream from its present location (Figure C.41). The *khal* will remain open through the channel leading to Nayakurar Kandi village, so it will still be accessible to navigation and will provide some post-monsoon drainage relief. A second closure will be constructed across the former main channel near Shantipur. The outlet of this old channel will be left open so that drainage will not be impeded.

The channel will be provided with guide bunds set-back at least 100 m from the new channel bank to prevent spills from causing bank erosion which could eventually cause the new channel to be out flanked. However, since the structures are not tied-in to high ground, they will not confine the flood flows and should not raise water levels in the monsoon season. The embankments will be protected with concrete blocks to protect against wave erosion in the monsoon season.

The reach is presently unstable, with active bank erosion occurring along the outer (concave) bank of the bend near Shantipur and along the entrance to Cherapur Khal. Figure C.42 shows an estimate of the future bank position near Shantipur. This estimate was based on measurements of historic rates of bank erosion in meander bends (Annex A - Sedimentation). This future development will reduce the amount of excavation that is required for the new channel. However, to provide a conservative estimate, the excavation volumes were calculated using the present channel alignment.

In order to reduce the risk of channel instability disrupting construction activities, or causing a new avulsion, temporary protection will be installed along the entrance to Cherapur Khal and the bend near Shantipur. At Cherapur Khal, a row of bamboo "porcupines" would be placed along both banks of the *khal* entrance. At Shantipur, a series of short temporary bamboo spurs would be constructed along the bank, and a spill channel would be dyked off.

Design Considerations

The channel has three main components. Proceeding from upstream to downstream, these include:

1. *Shantipur-Katkhal Section*
   A 1,465 m long new channel, having a radius of curvature (R) of 2943 m, an average top width (W) of around 280 and an R/W ratio of 10.5;

2. *Kaisar Section*
   A 1,420 m long channel that transitions from the bend into a straight alignment. This part of the loop cut follows an existing channel that will be re-excavated;

3. *Shahebnagar Section*
   A 1,200 m long new channel that follows a straight alignment until meeting the present channel near Bishorikona.

Downstream of the new entrance to Cherapur Khal, there is a short transition section into with a bend radius of 3,694 m that joins into the natural channel.

The land along the proposed route lies between El. 3.5 to 5.5 m PWD. Figure C.42 shows the sub-surface soil characteristics. The new channel will be constructed through primarily silty loam floodplain sediments. However, the materials show considerable variation in composition, ranging between fine sand, silt and silty clay. Detail descriptions of the soil characteristics are included in Appendix C.5.

Table C.42 summarizes tentative design parameters for the new channel. During final design, additional work should be carried out to optimize the geometry of the channel in order to minimize excavation costs and maintenance requirements.

Table C.42: Channel Properties at Lower Loop Cut

Bed Elevation =-2.5 m PWD; Side Slope 1V:3H					
Parameter	Symbol	**Top of Bank Elevation (m PWD)**			
		4.0	**4.5**	**5.0**	**5.5**
Depth (m)	Y	6.5	7.0	7.5	8.0
Channel Area (m^2)	A	1,622	1,757	1,894	2,032
Top Width (m)	W	269	272	275	281
Hydraulic Radius (m)	R	6	6.4	6.8	7.2
Section Factor ($m^{5/3}$)	$AR^{2/3}$	5,344	6,060	6,814	7,606
Bankfull Capacity (m^3/s)	Q	1,630	1,850	2,080	2,320

Note: $S_f=0.000045$ n=.022

It is anticipated that spoil from the excavation will be used to raise low-lying portions of the ground between the embankments and the new channel banks to around El. 5 m PWD and construction of 11 homestead platforms.

The new channels have a narrower, deeper cross section than the silted-in portion of the river below Kadamchal. It is expected that the channel will adjust somewhat after it is opened to the main flow. The "channel forming discharge" will be around a 1:5 year pre-monsoon flood (2,250 m^3/s), since this will be approximately the bankfull discharge on the river. Based on Regime Theory, the corresponding equilibrium dimensions would be as follows:

- Regime Width = 230 m;
- Regime depth = 8.2 m, and
- mean velocity = 1.2 m/s.

Table C.43 summarizes the initial hydraulic conditions in the new channel during pre-monsoon flood conditions. The initial hydraulic properties are close to the Regime estimates.

During the monsoon season, the mean velocities through the main channel were found to remain relatively high (around 1 m/s at a 1:2 year monsoon flood). Therefore, fine suspended sediments are unlikely to be deposited in this portion of the channel.

Table C.43: Hydraulic Conditions in New Channel

Location	Reference Distance (Km)	1:2 year Pre-monsoon Flood			1:5-year Pre-monsoon Flood		
		Water Level (m PWD)	Velocity (m/s)	Shear Stress (N/m^2)	Water Level (m PWD)	Velocity (m/s)	Shear Stress (N/m^2)
Entrance	91.3*	4.26	0.95	1.94	5.12	1.17	2.8
U	91.0*	4.25	0.95	1.94	5.11	1.17	2.81
U	90.0*	4.21	0.96	1.97	5.07	1.18	2.85
L	89.0*	4.18	0.96	1.97	5.03	1.18	2.87
L	88.0*	4.15	0.97	2.02	4.98	1.19	2.94
Outlet	87	4.11	0.97	2.04	4.93	1.2	2.98
Down-stream	85.9	3.96	1.6	3.48	4.75	1.86	4.43

Note: U = Upper loop cut channel
L= Lower loop cut channel
* = chainage measured along new channel
Section KM 85.9 is MIKE-11 cross section 42 at new Cherapur Khal bifurcation

Bank protection will be required along the right bank opposite Kaisar where the flow from the bend will enter into the existing channel (Figure C.41) and impinges along the existing bank. Bank protection will also be required at the downstream end of the loop cut near Nayakurar Kandi village. The bank protection will consist of a stone revetment placed over a geotextile filter. The stone can be placed on a graded 1V:2H slope excavated down to the dredged channel level. A launching apron will be provided at the bottom of this slope containing sufficient material so it can launch down to the anticipated scour level (Figure C.43). The volume of stone in the apron has been increased to account for losses during launching.

The estimated scour depth was estimated by Blench's Regime formula, as follows:

- Top of bank = 5.0 m
- d_r = 8.2 m
- Z_{factor} = 1.7 for moderate bend (R/W ratio = 10.5)
- Scour depth = 1.7* 8.2 = 14.0 m
- Scoured Bed Level = 5.0 -13.0 = El. -9.0 m PWD

The stone size and gradation were based on the US Army Corps of Engineers Design Manual EM1110-2970 and from results of the hydraulic modelling.

V_{mean} = 1.3 m/s (from Hydraulic model output)
V_{max} = 1.2*V_{mean} = 1.5 m/s (based on R/W ratio of 10.5 in bend)

The following size gradation and volume of stone was adopted for the bank protection:

- Gradation:
  254-305 mm 60% by weight
  153-254 mm 40% by weight
  nominal thickness: 600 mm
- side slope: 1V:2H
- nominal volume = 10.1 (revetment) + 12.1(apron) = 22.2 m^3/lineal m (total)
- total length of protection = 1,085 m

Revetments constructed to this specification were observed to perform satisfactorily during major floods in 1993 (Appendix C.5).

The channel will be provided with embankments set-back a minimum distance of 100 m from the new channel bank. The embankment's flood construction level is set at the 1:20 year annual maximum flood level with a freeboard of 0.9 m. The design cross section for these embankments are given below:

- Flood Construction Level: 7.9 m + 0.9 m = 8.8 m PWD
- Crest Width: 4.27 m
- River Side Slope: 1V:3H
- Country Side Slope: 1V:2H
- Slope Protection: Concrete Block

The embankments will be protected against wave erosion with concrete blocks on a geotextile filter over a layer of sand. Based on the wave climate hindecasting from Section 3.4 (Table C.15), the 1:20 year wave height will be around 0.9 m at this location. Based on Hudson's formula, the corresponding stable block size would be approximately 80 kg. Therefore, standard 40cm x 40cm x 25cm concrete blocks (150 kg) placed on a slope of 1V:2.5H should provide adequate protection up to a 1:20 year storm. A typical design for this protection is shown in Figure C.44. The same type of protection will be applied to both channel embankments and homestead platforms.

Construction

Constructing the new channel will require excavating approximately 4.4 million m^3 of material, of which about 3.22 million m^3 will be made by hydraulic dredges. About 1.25 million m^3 of earth will be excavated manually and the spoil will be used mainly for the construction of guide embankments and two closure dams. The total length of guide embankments is about 8.1 km and requires about 1.13 million m^3 of earth work including 0.28 million m^3 for the two closure dams. Approximately 195 ha of land will be required for constructing the Katkhal loop cut and its ancillary works. Eleven disposal sites (27 to 37) will be developed mainly from the dredged spoil (Figures C.45 and C.46).

8.1.5 Channel Re-excavation - Rahala to Ajmiriganj

Planned Work

Table C.44 summarizes the channel re-excavation volumes and grade levels in this reach upstream of the Katkhal loop cut. The total volume amounts to 2.23 million m^3. It is expected that some channel degradation will occur upstream of the loop cut after the new channel is opened, which could reduce the amount of dredging that is required. Therefore, it has been planned to dredge only about half of this volume in the first phase, and then monitor the channel's response for a period to assess whether additional excavation is required.

Design Considerations
Figure C.38 shows the location of the proposed work. The volume of excavation, excluding any work associated with the construction of loop cuts is summarized in Table C.44. Design parameters for the main channel re-excavation work are as follows:

- bottom width: 100 m;
- design grade: El. -2.0 m PWD, and
- bed material: varies from very fine sand, to sandy-silt, typical D_{50} size = 0.06 mm.

Figure C.38 shows channel cross sections with the proposed excavation superimposed. The average depth of excavation ranges between 2 m to 5 m, and the increase in channel cross sectional area averages around 280 m^2 and ranges between 180 - 515 m^2 (Table C.44). This will increase the channel's cross sectional area at bankfull stage by around 20-30%.

It should be emphasized that this reach is undergoing considerable changes at the time of this investigation, with apparent bed lowering occurring between Rahala and Kakailseo. Therefore, the requirements for dredging could be substantially different (lower) than these estimates. Updated surveys and quantity estimates will have to be prepared during final design.

Table C.44: Summary of Channel Re-excavation - Rahala to Ajmiriganj

Location	Reach (km)	Phase	Grade Level (m PWD)	Excavated Volume (m^3)	Average Increase in Area (m^2)	Increase in Bankfull Area (%)
Rahala	97.5-98.8	2	-2.0	670,000	515	44
Kakailseo	98.8-102.3	2	-2.0	543,000	160	15
Shahebnagar	102.3-104.5	1	-2.0	572,000	260	18
Ajmiriganj	104.5-107.0	1	-2.0	448,000	180	13
Total				**2,233,000**	**1,115**	

Construction
Table C.45 summarizes the dredging volumes, number of disposal sites required and total area of village platforms that will be constructed along this reach. Locations of these disposal sites are summarized on Figure C.39.

Suction cutter dredgers will be used for the excavation, with the spoil pumped into permanent disposal chambers on the floodplain (Figure C.40). The dredging should start at the upstream end and proceed downstream. The excavation should be completed before the upstream loop cut is opened up. Phase 1 excavation could be completed by three dredgers working over a six month period. Phase 2 would require an additional eight months of work.

Table C.45: Summary of Channel Re-excavation and Village Platforms - Rahala to Ajmiriganj

Location	Reach (km)	Phase	Grade Level (m PWD)	Excavated Volume (m^3)	Village Platform Statistics		
					Total Platform	Disposal Sites #	Area (ha)
Rahala	97.5-98.8	2	-2.0	670,000	2	38-39	18.6
Kakailseo	98.8-102.3	2	-2.0	543,000	2	40-41	6.4
Shahebnagar	102.3-104.5	1	-2.0	572,000	3	42-44	13.0
Ajmiriganj	104.5-107.0	1	-2.0	448000	3	45-47	9.8
Total				**2,233,000**			**47.8**

8.1.6 Bank Protection at Spill Channels

Planned Works
It is proposed to construct bank protection works at three major bank breaches (*dhalas*) to arrest further bank erosion and to control future pre-monsoon spills:

- Koyer Dhala (Km 114.5-115.5);
- Pituakandi revetment (Km 114.0-114.5), and
- Akkilshah revetment (Km 138.5-138.9)

Provision has been made for a regulator/fish pass at Koyer Dhala so that the protection will not obstruct irrigation water supplies, navigation or fisheries. Given the deep scour that occurs at these sites and high costs of suitable pipe piles for permeable groins, it was decided to use conventional rip rap revetments for the bank protection works. Since these sites are upstream of the deeply flooded area, they will not be subject to severe wave erosion. The height of the protection will extend only up to the bank level, and it will be submerged in the monsoon season.

Design Considerations
Hydraulic properties at the three sites are summarized in Table C.46. Figures C.47 and C.48 show the channel topography in each bend and the proposed riprap revetment designs. The estimated velocities were based on the 1:20 year design flood. It was found that the pre-monsoon floods produce the highest velocities in this reach.

Table C.46: Hydraulic Characteristics at Bends

Parameter	Unit	Pituakandi (Km 114.5)	Koyer Dhala (Km 115.4)	Akkilshah Bazar (Km 138)
Top of bank	m PWD	6	6	8
Flood level	m PWD	5.96	5.96	7.5
Thalweg level	m PWD	-12	-14	-16
Bend Radius	m	190	180.4	187
Top Width	m	190	194	217
Mean velocity	m	1.7	1.7	1.1
Maximum velocity	m	3.06	3.06	2.0

Based on these, a single size gradation and specification was adopted for the river bank protection.

- Gradation:
  - 254-305 mm 60% by weight
  - 153-254 mm 40% by weight
- nominal thickness: 600 mm
- side slope: 1V:2H

Layout of the revetments are shown in Figures C.47 and C.48. General specification are summarized in Table C.47.

Table C.47: Revetment Characteristics

Parameter	Unit	Pituakandi Km 114.5	Koyer Dhala Km 115.4	Akkilshah Bazar Km 138
Top of revetment	m PWD	6	6	8
Length of bank protected	m	500	850	640
Scour elevation	m PWD	-20	-16	-20
Unit volume of stone	m^3/ m	39.5	31	41.4
Total volume of stone	m^3	15,600	26,350	26,500
Unit volume of filter layer	m^3/ m	1.2	1.2	1.8
Volume of filter layer	m^3	600	1,020	1,170

Construction

The bank protection should be constructed in the dry season, when water levels are lowest. Table C.11 summarized historic low water levels at Markuli. After the channel improvements are completed, the low water levels will be approximately 1 m lower. Therefore, water level at the time of construction will be around El. 3 m PWD.

8.1.7 Levees

Planned Works

Low levees will be required in localized reaches between Markuli and Kakailseo to ensure the pre-monsoon flood flows can be confined with an adequate degree of security. In this reach, flood flows spill over local low portions of the banks even though the channel's average bankfull capacity has not been exceeded. It will be more practical to construct levees to provide a uniform bankfull level along the reach, rather than lowering the flood level by further channel re-excavation.

Design Considerations

Table C.37 summarizes the predicted 1:5 pre-monsoon water level along the river with Alternative 1. The levees can be less than one metre in height and will be able to confine a 1:5 year pre-monsoon flood with 0.3 m of freeboard. The levees will be set-back from the main channel by at least 100 m.

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8.2 Navigation Channel

The channel stabilization and flood control works also effectively improve the navigation channel to at least a Class II standard up to Ajmiriganj. However, the main water transportation routes on the Kalni-Kushiyara system extend up to Fenchuganj, 60 km upstream of Ajmiriganj. Therefore, in order to significantly improve navigation, additional dredging will be required upstream of Ajmiriganj. Based on the present channel topography, navigation dredging will be required at 5 locations between Ajmiriganj and Fenchuganj in order to achieve a Class II channel. These sites are located at local shoals that develop in straight reaches between major bends, primarily between Manumukh (near the mouth of the Manu River) and Fenchuganj. Although the total excavation required is relatively small (164,000 m^3), it is anticipated that the shoals will re-form after each monsoon, so that maintenance dredging will be required annually.

Five disposal sites (48 to 52) have been identified for the navigation dredging (Table C.48). Land at 4 sites has already been acquired by BIWTA, so that only land at the Galimpur site (50) needs to be acquired by the project. A provision for acquisition of 3 ha land for navigation dredging has been made in the capital cost.

Table C.48: Summary of Navigation Dredging and Disposal Sites

Location	Reach (km)	Excavated Volume (m^3)	Disposal Site Statistics	
			Number	Area (ha)
Nawanagar	107.5-110.8	31,000	48	3.6
Manumukh	182	19,000	49	8.6
Galimpur	188	9,000	50	3.0
Omarpur	202	59,000	51	3.0
Fenchuganj	215-216	46,000	52	4.0

8.3 Village Platforms

8.3.1 Planned Works

Spoil from the proposed channel excavation work can be used as a beneficial resource for constructing new village platforms or raising existing flood-prone ground. Figures C.40 and C.49 illustrate the general concept involved in constructing a new platform. Based on initial planning and analysis, up to 52 platforms can be constructed during the implementation period of the Kalni-Kushiyara River Management Project. Of these, 13 platforms will be constructed from the two Loop cuts, while the remaining 39 platforms will be constructed from the excavation of Kalni and Dhaleswari Rivers. Figures C.37, C.45, C.46 and C.50 to C.53 show the tentative location of these platforms. All of the sites are located within 1.5 km of proposed channel excavation work, in order to avoid the higher cost of using booster pumps. Initially, 44 sites will be used for constructing homestead platforms. The Issapur sites (1 and 2) have been identified for multi-purpose use, while the site near Madna (5) will be used for raising flood-prone land in order to grow non-cereal crops. The five navigation dredging disposal sites (48 to 52) will be used for annual disposal operations until they are eventually filled, at which point they could be used for other purposes. The platforms range between 2 to 7 ha in size and have a total area of about 247 ha. In most situations, the land for the homestead platforms will be dedicated by the villagers, and returned to them after the construction is completed. Therefore, land acquisition will not be required in these circumstances. At sites 6 to 17 and site 39, the land ownership believed to be mostly *khas* land and is not yet inhabited. However, a provision was made in the cost estimate to acquire this land and use it for settling landless families.

8.3.2 Design Considerations

Table C.49 summarizes the main civil works that are required at each village platform.

Confinement Chamber Size
The confinement chamber must be designed to provide effective settling of the dredged sediments and should have sufficient volume to store all of the excavated material. The trap efficiency of the chamber is a function of its surface area "A", ponding depth (Y), dredge discharge (Q) and the sediment's settling time (T). The settling time was determined from a laboratory settling test carried out on river bed sediments collected near Gazaria and Kakailseo. The minimum size of confinement chambers that are required to achieve a given trap efficiency are shown in Table C.50 for a range of dredger production rates. All of the calculations were based on a minimum ponding depth of 0.6 m in the confinement chamber.

Table C.49: Civil Works Associated With Village Platform Construction

Component	Component	Function	Comments
1	Confinement Dyke	• Provides settling basin for pumped dredged spoil	• Will be re-graded following the monsoon season to provide permanent platform slope
2	Effluent Outlet Structure	• Maintains adequate ponding level in settling basin during pumping, • Prevents erosion by return effluent	• Only required during platform filling
3	Effluent Outlet Channel	• Prevents dredge effluent return flows damaging adjacent crops and land	• Will be filled-in after platform filling is completed
4	Platform Top Grading	• Final levelling and grading of platform after filling completed	• Will be done in association with post-monsoon repairs of confinement dykes
5	Platform Drainage	• Safe disposal of rain and prevention of slope erosion	• Temporary drainage provision will be made in the first year. Permanent structure will be installed in year 2.
6	Platform Protection	• Prevents platform erosion from waves and river erosion	• Combination of "hard" and "soft" protection has been proposed, depending on exposure
7	Platform Access	• Prevents slope damage from people and livestock	• Permanent access facilities will be installed in year 2.
8	Green Manuring	• Improves structure and productivity of dredge spoil to enhance cultivation on the platforms	• Combination of short and long-term programs has been proposed. This includes top-soil, plantation of quick growing plants and research.

Platform Construction Level

The village platforms were designed on the basis of providing protection up to a 1:20 year annual flood, with a freeboard allowance for wave runup, and an additional allowance for settlement. In the absence of specific design criteria for homestead platforms, a freeboard allowance of 0.90 m has been adopted.

The long-term settlement was estimated to be 5% of the depth of fill. A sample calculation is illustrated below:

- flood elevation: 7.77 m PWD (1:20 year flood level)
- freeboard: 0.90 m
- flood construction level: 7.77+0.90 = 8.67 m PWD
- ground elevation: 3.0 m PWD
- depth of fill: 8.67 - 3.0 = 5.67 m
- allowance for settlement: 0.28 m
- required platform top elevation: 8.67 + 0.28 = 8.95 m PWD
- deduct top cover: 0.4 m
- dredge fill elevation: 8.55 m PWD

In this case, the platform would be filled with dredge material to El. 8.55 m PWD. With the addition of 0.4 m of top soil cover the construction platform elevation is 8.95 m PWD. Top soil cover ranges between 15 to 40 cm depending on the need and type of platform.

Table C.50: Kalni River Dredging Minimum Size of Confinement Chamber

Trap Efficiency 94% **Required Retention Time: 3.3 hours**	**Number of Dredges (18")**			
Number of Dredges (18")	1	2	3	4
Minimum Surface of Chamber (ha)	1.0	2.0	3.0	4.0
Trap Efficiency 96% **Required Retention Time 4.0 hours**				
Minimum Surface of Chamber (ha)	1.2	2.4	3.6	4.8
Trap Efficiency 98% **Required Retention Time 8.0 hours**				
Minimum Surface of Chamber (ha)	2.4	4.8	7.2	9.6

Confinement Dykes

Confinement dykes are earthen embankments enclosing the disposal chamber area. They must be designed to withstand the combined soil and water pressure from the dredged fill during the dry season and to remain stable during the monsoon season when the exterior slope is saturated. In many situations one side of the confinement chamber will be constructed along an existing village platform in order to eventually enlarge the village's overall extent. In these cases, the confinement dykes will have two different cross sections - one on the village side and another on the river side. This is illustrated in the typical cross section of village platform in Figure C.49. On the river side, the height of the confinement dykes may vary from 4.0 m to 7.0 m. Table C.51 shows the adopted parameters for the river-side confinement dykes. The design was based on experience gained from the pilot project and from additional slope stability analysis.

Table C.51: **Adopted Confinement Dyke Cross Section - River Side**

Dyke Height (m)	Crest Width (m)	Exterior Slope	Interior Slope
less than 5.0 m	3	1V:2.5H	1V:1.5H
greater than 5.0 m	4.27	1V:3H	1V:2H

Confinement dykes on the village-side of the chamber will not be exposed to wave action and will be lower in height. The following cross section was adopted for these embankments:

- Crest Width: 2.0 m
- Chamber Side Slope: 1V:1.5H
- Village Side Slope: 1V:2.0H

The crest elevation of a confinement dyke is determined by the platform design elevation plus the additional height required for the ponding depth in the chamber. A sample calculation is presented below:

- Design Flood Elevation: 7.77 m PWD
- Freeboard: 0.90 m
- Flood Construction Level: 8.67 m PWD
- Dredge Fill Elevation: 8.60 m PWD (refer platform construction level)
- Depth of Ponding: 0.60 m
- Dyke Freeboard: 0.30 m
- Required Crest Elevation: (8.60+0.60+0.3) = **9.50 m PWD**
- Ground Elevation: 3.0 m PWD
- Dyke Fill Height : 9.50 - 3.0 = 6.5 m
- Settlement: (10% of fill depth) = 0.65 m
- Construction Dyke Crest Elevation: 9.50+0.65 = **10.15 m PWD**

Effluent Outlet Structures

The purpose of the outlet structure is to regulate release of ponded water from the confinement chamber area. The location of the outlet should be on the extreme end of the confinement chamber (1) to increase distance and time of travel of slurry between the inlet and the outlet for maximum deposition of sediments and (2) to prevent blocking of the outlet with dredged material. Two types of outlet structures are used, weirs and pipe outlets. Pipe outlets used in Bangladesh have proven to be economical and easy to operate. On other landfill projects in Bangladesh, a ratio of two outlet pipes per one inlet pipe have been used. On the Pilot Project, a ratio of three to one has been used at Kakailseo chamber with a short outlet length of up to 18 m. At Gazaria, where the outlet length exceeded 18 m, four outlet pipes had to be used.

A ratio of four outlet to one inlet is proposed to be used in small chambers (less than 2 ha). In larger chambers three to one ratio can be used at the first stage of ponding, and more pipes added at consecutive drainage stages. The release of water is regulated by blocking the pipes at the inlet side with wooden boards.

For hydraulic energy dissipation of the falling water from the outlet pipes, an indigenous flexible bamboo rack constructed on *ballah* piles under the outlet pipes proved to be very successful on the Pilot Project. The same type of energy dissipators are proposed for the project.

Effluent Outlet Channel

An outlet channel should be designed to evacuate safely the effluent water from the confinement chamber back to the river without posing hazards or damage to agriculture, fisheries and environment in general. The cross-section of the channel should be designed for non-erodible flow velocity of less than 0.5 m/s, and it should not be overtopped by the design pre-monsoon flood with a 1:10 year return period. A minimum section with 1.00 m bed width and 1:1 side slopes for channels in excavation, and 1:1.5 slopes for channels in fill is recommended. The outlet channel width should be increased accordingly to the size (discharge capacity) and number of dredges used. However, when a channel is constructed in fill, to minimize the construction cost, the dyke fill material is borrowed from the inside area of the channel and its section is increased to balance the earthworks volume.

A minimum 0.50 m freeboard should be used for channel dykes up to 2.0 m high; for dykes above 2.0 m the construction crest elevation should be increased by 10% of the design dyke height.

The crest elevation of an outlet channel should include 0.50 m freeboard above the 1:10 year pre-monsoon flood elevation, added to a 10% increase of fill height for settlement.

As a general rule, outlet channels in fill (above ground surface) are to be avoided, and wherever possible the alignment of outlet channel should be in high ground so its section is in excavation.

Levelling Platform Surface

As observed on the Pilot Project, little ground levelling is required in areas where the chamber was filled under water, i.e., where the ponding depth was maintained the dredged material settled close to a horizontal surface. In case the dredge filling continued above water surface, mounds formed around the discharge pipe with the flowing slurry cutting irregular channels. (Extra works were needed to protect the dykes on the inside from undercutting currents). Small depressions, about 0.5 m deep with about 30 m radius formed at outlets where most of the finer materials (clay and silt) has settled.

To minimize the earthwork volume of the platform levelling, the platform ponding depth should be maintained until the dredging filling operation is completed.

Top Soil Cover

For protection of sandy platform surface against wind erosion a layer of top soil cover will be placed manually over the hydraulically deposited dredged material. The material for the platform cover will be taken from the exterior surface of confinement dykes, placed there in excess during the construction of the dykes. This operation should be carried out during the second dry season after the short-term settlement of the dyke section and the dredge fill material has taken place. The thickness of the top soil will range between 0.15 and 0.40 m.

Protection of Homestead Platform Slopes

In the first monsoon season the homestead platform slopes will be protected from erosion by rain cuts, and mainly from erosion by wave action using traditional methods, with bamboo, *tarja* and *chailla* grass matting. This type of work provides a one-season protection which will have to be rebuilt every year before the onset of the monsoon season.

A permanent protection of platform with concrete blocks placed over a geotextile filter over sand bed is proposed to be constructed in the second dry season, after the dyke fill material has attained sufficient degree of settlement. The concrete block protection has been selected as the most economic protection, compared to RCC retention wall and brick gravity wall.

This work will coincide with the execution of platform levelling and placement of top soil cover, as the top soil material will be taken from the side of the platform (exterior dyke).

The platform side surface, settled and partially eroded during the monsoon season, will be cut and resectioned to a 1V:2.5 H side slope.

Typical design of platform slope protection with concrete blocks, including the toe protection with brick wall is shown in Figure C.44.

Platform Drainage

Two types of drainage facilities are required to evacuate safely rainfall run-off from platform surface (1) temporary drains and (2) permanent drains.

The temporary drains will be needed during the first rainy season after the completion of the dredge filling operation and/or until a permanent protection of the platform slope is constructed. In properly designed confinement chamber with sufficient freeboard the risk of dyke overflow is reduced. With the internal drainage pastern towards the chamber outlet the outlet pipes can be utilized for drainage of local runoff. In case the steel outlet pipes are removed, and permanent drains are not constructed yet, PVC pipes with adequate capacity should be installed before the onset of the rainy season.

The permanent drains should be installed at the time of constructing permanent slope protection works with concrete blocks. The drains should be incorporated into the CC block platform slope protection by constructing a 0.30 m x 0.30 m gutters with sealed joints. These drains should be constructed perpendicular to the side slope at 200 m to 300 m interval. The cost of these drains has been included in the cost of platform protection works.

Platform Access Facilities

Concrete stairways and brick lined cattle access ramps, shown in Figure C.54, are proposed to be constructed at suitable locations.

8.4 Regulators

Two types of regulating structures are proposed to be constructed, (1) Drainage cum Flushing Pipe Sluice and (2) Multipurpose Regulators. Figures C.31 and C.32 show the location of these regulating structures.

8.4.1 Drainage cum Flushing Pipe Sluice

A drainage cum flushing sluices will be installed at the offtake of Barabaria Khal near Shantipur village to drain accumulated water from local depressions blocked by the Katkhal embankments (Figure C.31). The structure will also facilitate irrigation water supplies on both banks of the khal during the dry season. However, at the advent of the pre-monsoon floods the gate should be closed to prevent inflow of flood water into the protected area.

Typical preliminary design of Drainage cum Flushing Pipe Sluice at Barabaria Khal is shown in Figure C.55. Location of this pipe sluice has been identified from preliminary examination of local topography. Detail investigations are required for the preparation of final design and should be carried along with the investigation and design of Katkhal loop cut.

Pipe Sluice Design Parameters:

Maximum Hydraulic Head	3.0 m
Design Head in	
Drainage Mode	0.6 m
Flushing Mode	0.3 m
RCC Pipe Diameter	1.05 m
Pipe Length	27.5 m
Design Drainage Capacity	2.3 m^3/s
Design Flushing Capacity	1.7 m^3/s

8.4.2 Multi-purpose Regulator

A multi-purpose regulator will be installed at Koyer Dhala about 10 km upstream of Ajmiriganj in order to divert some Kalni River flow to the left bank (Figure C.56). The structure will facilitate irrigation water supplies to the existing projects and post-monsoon drainage from the adjacent floodplain, fish migration to the Kodalia fisheries and floodplain and will reopen traditional navigation route from Kalni to Habiganj.

The structure includes three main components:

- flushing cum drainage;
- fishpass, and
- navigation pass

Flushing cum Drainage Regulator

The Koyer Dhala regulator will provide flushing for irrigation during the dry season to the Old Kushiyara Irrigation Scheme, Jhingari Nadi Irrigation Scheme and some fallow lands along the Baniachang-Ajmiriganj road (Figure C.56). NERP case studies in 1996 show that the Old Kushiyara Irrigation Scheme, with a command area of about 2,500 ha, is almost ineffective due to offtake siltation of the Old Kushiyara River. The Jhingari Nadi Irrigation Scheme has a net area of about 3,600 ha and the Old Kushiyara River is the main source of irrigation water supplies for this scheme. This scheme has also been ineffective. The irrigation water provided by the Koyer Dhala regulator will restore the effectiveness of both the projects.

The regulator will also provide irrigation water to an area of 1,200 ha, located along the Southern side of Baniachang-Ajmiriganj road (Figure C.56). The area, which is currently fallow, remains-flood free even with 1:5 year pre-monsoon flood, and local people report that the land is suitable only for boro crop.

To secure uninterrupted inflow of water through the structure, the regulator invert elevation has been fixed below the expected "Future With Project" low water level in the Kalni River during the dry season. To provide a year-round access to the top of the structure, the operating decks are designed above the 1:20-year annual flood elevation. As the project provides protection from the pre-monsoon flood only, for hydraulic design, the river side design water level should correspond to 1:10 year pre-monsoon flood elevation plus 0.30 m for freeboard. The country side water levels are determined from field observations. Typical preliminary design of Koyer Dhala multi-purpose regulator is shown in Figure C.57.

Flushing cum Drainage Regulator Design Parameters:

Maximum Hydraulic Head (R/S to C/S)	3.0 m
Design Head:	
Drainage Mode	0.3 m
Flushing Mode	0.6 m
Regulator Size	2-vent 1.8 m x 2.4 m
Invert Elevation	0.00 m PWD
Operating Deck Elevation	8.78 m PWD
Design Drainage Capacity	16.8 m^3/s
Design Flushing Capacity	23.5 m^3/s

For flushing, the regulator gate will probably be opened in the month of February because it allows floodplain to drain out quickly and the initial irrigation will be made from the canal's storage volume. The gate should be closed before the onset of pre-monsoon floods to save *boro* crop from inundation. During the monsoon season, the regulator gates should remain open for free migration of fish. At the end of the monsoon season when water levels in the Kalni River fall below the floodplain level, the structure will operate in drainage mode and will remain open till the flow reverses. At this stage, the gates should be closed to facilitate quick drainage from the floodplain.

Fishpass

A single jet vertical slot RCC fishpass has been adopted as the suitable design for sites with varying upstream and downstream water levels. This design has been constructed and successfully operated by NERP in Bangladesh (Kashimpur Fishpass in Manu River Project). To allow free migration of fish the fishpass should remain open throughout the year. For emergency repairs it can be closed with wooden fall boards placed in the entrance slots (Figure C.57).

Fishpass Design Parameters:

Type	Single-Jet Vertical Slot
Length	41.00 m
Invert Elevation	2.00 m PWD at R/S; 0.00 m PWD at C/S
Number of Pools	13
Number of Baffles	12
Pool Dimensions	2.00 m Width and 3.00 m Length
Baffle Slot Width	0.30 m
Design Head	2.00 m
Baffle Velocity Head	0.17 m
Baffle Flow Velocity	1.3 m/s
Maximum Inflow Rate	1.5 m^3/s

Navigation Pass

A medium size country boat pass arrangement has been made in the multi-purpose regulator (Figure C.57). It features a 3.50 m wide opening with a single gate (steel fall boards) closure arrangement. This facility is designed for operation during dry and wet seasons when the difference in water levels between the river and the country side is small. However, at the advent of flash floods during the pre-monsoon, the gate should be closed to prevent flooding of the protected area.

Navigation Pass Design Parameters:

Boat passage width	3.50 m
Invert Elevation	1.00 m PWD
Operation Deck Elevation	Portable
Overhead Lift Elevation	12.00 m PWD
Closure Type	Steel Fall Boards with Gantry Crane & Lift

The provision of navigation pass has been made based on the local demand. However, there could be some social conflicts between the farmers and water transport users particularly for the opening and closing of the navigation gate. On the basis of local demand, a preliminary design and cost estimates have been made in order to keep the project's capital cost on the conservative side. The viability of navigation pass should be determined and finalized during the detailed design. Based on this consideration, benefits from navigation pass have not been taken into consideration during the evaluation of project benefits.

8.5 Schedule - Alternative 1

Successful implementation of this project will require careful planning and a flexible design approach so that plans can be adapted to varying river conditions as well as other social, economic and environmental factors. A minimum of seven years will be required for planning and construction of the main physical works. Some of issues that will complicate implementation are summarized below:

- construction of some components will not start until at least Year 5 of the project. Plans made in Year 1 need to be revised substantially by the time of implementation. Preliminary planning may be necessary in Year 1 for budgeting purposes. However, a design review and program of data collection needs to be carried out nearer the time of construction of these works;

- land acquisition requires at least one year to be carried out. This will limit the amount of flexibility in planning channel excavation work and in selecting disposal sites, and

- the risk of experiencing a major flood that could delay or disrupt construction activities is relatively high. For example, there is an 18 % chance of at least one major flood (1:25 year) event occurring during the five years of construction activities.

Furthermore, the project's implementation needs to be sequenced carefully to avoid adverse downstream impacts and to minimize channel maintenance costs. A tentative recommended sequence is as follows:

- construct emergency remedial works at Shantipur and Cherapur Khal;
- construct Issapur loop cut, Kadamchal re-alignment, Katkhal loop cut;
- complete Phase 1 channel re-excavation prior to opening of the loop cuts, and
- construct bank protection, spill closures and levees upstream of Ajmiriganj and commence navigation dredging.

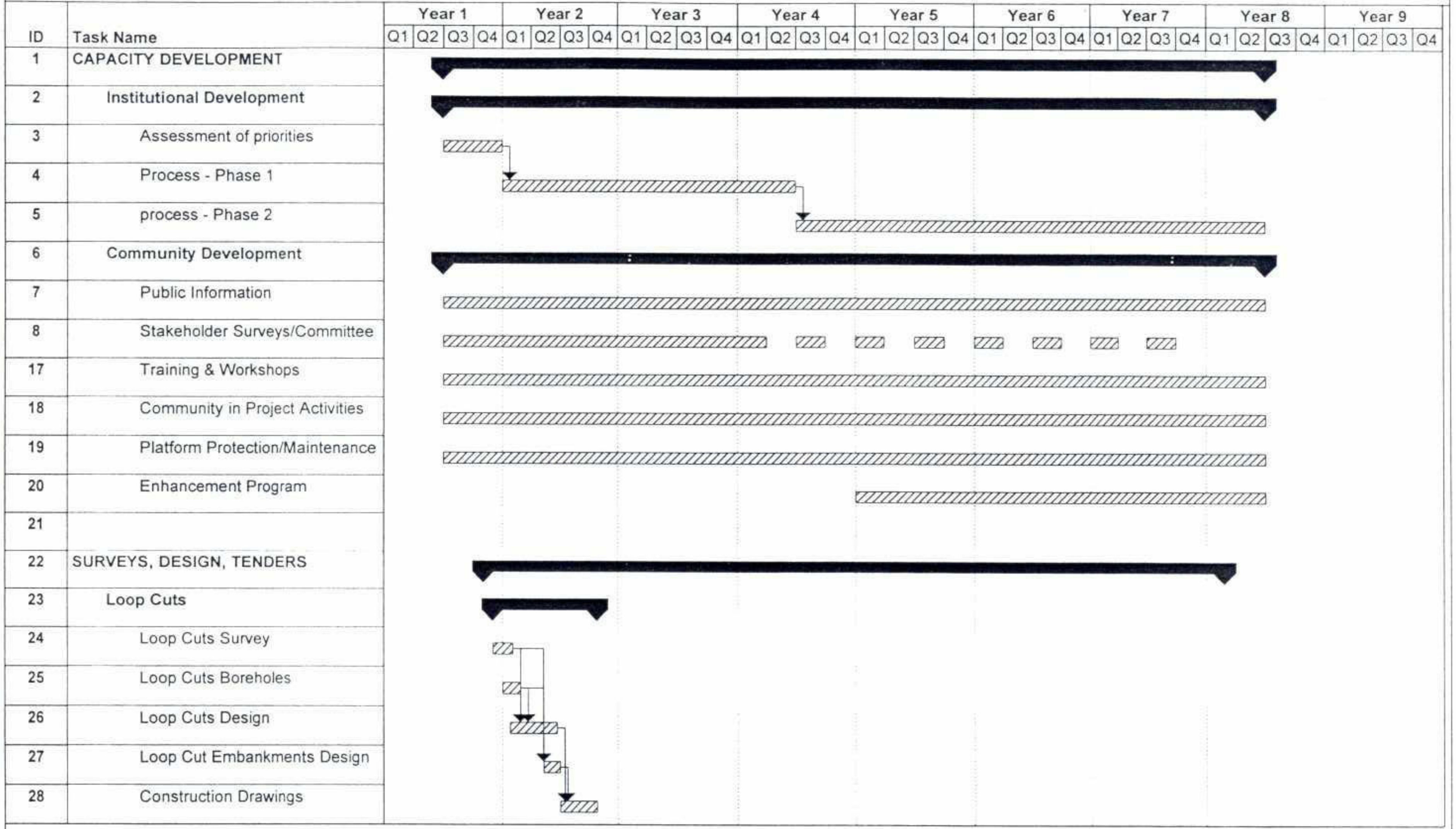
The spill closures and levees, which are mainly located in the upstream reach, have been delayed until after the works in the downstream reach are completed. This is necessary since the upstream works will increase the magnitude of pre-monsoon flood flows further downstream. If the closures were constructed first, then flood damages could be increased in the lower reach during the period when the loop cuts are being constructed. The navigation dredging upstream of Ajmiriganj can also be delayed until after the loop cuts and downstream channel re-excavation work is completed. This is because these downstream channel improvements must be completed in order to provide any benefit to navigation.

Table C.52 shows a tentative schedule that has been adopted for initial planning and costing purposes. In the project area, the construction season coincides with the dry season, which begins in November-December. Hence, it is proposed to start the construction time from October. Year 1 is assumed to start in November.

8.5.1 Pre-Construction

Two years have been assigned for initiating the main pre-construction activities, which include:

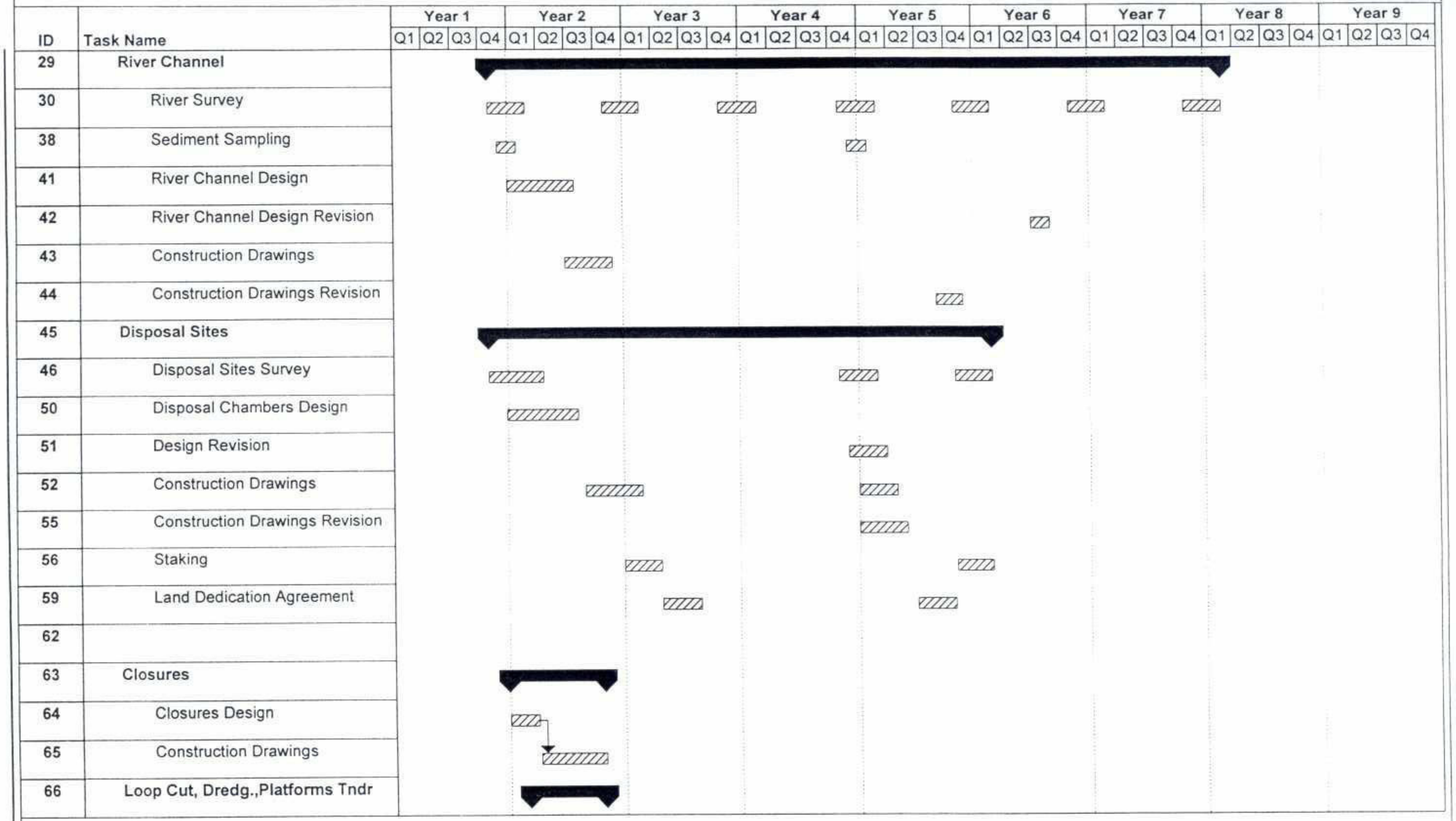
- institutional strengthening;
- surveys and investigation;
- engineering designs;
- preparation of implementation plan;
- preparation of tender documents;
- invitation and award of tender;
- land acquisition, and
- mobilization.



ID	Task Name
1	CAPACITY DEVELOPMENT
2	Institutional Development
3	Assessment of priorities
4	Process - Phase 1
5	process - Phase 2
6	Community Development
7	Public Information
8	Stakeholder Surveys/Committee
17	Training & Workshops
18	Community in Project Activities
19	Platform Protection/Maintenance
20	Enhancement Program
21	
22	SURVEYS, DESIGN, TENDERS
23	Loop Cuts
24	Loop Cuts Survey
25	Loop Cuts Boreholes
26	Loop Cuts Design
27	Loop Cut Embankments Design
28	Construction Drawings

Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

Task	▨	Summary	▬	Rolled Up Task	▨



ID	Task Name
29	**River Channel**
30	River Survey
38	Sediment Sampling
41	River Channel Design
42	River Channel Design Revision
43	Construction Drawings
44	Construction Drawings Revision
45	**Disposal Sites**
46	Disposal Sites Survey
50	Disposal Chambers Design
51	Design Revision
52	Construction Drawings
55	Construction Drawings Revision
56	Staking
59	Land Dedication Agreement
62	
63	**Closures**
64	Closures Design
65	Construction Drawings
66	**Loop Cut, Dredg.,Platforms Tndr**

Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

Task	▨	Summary	■	Rolled Up Task	▨

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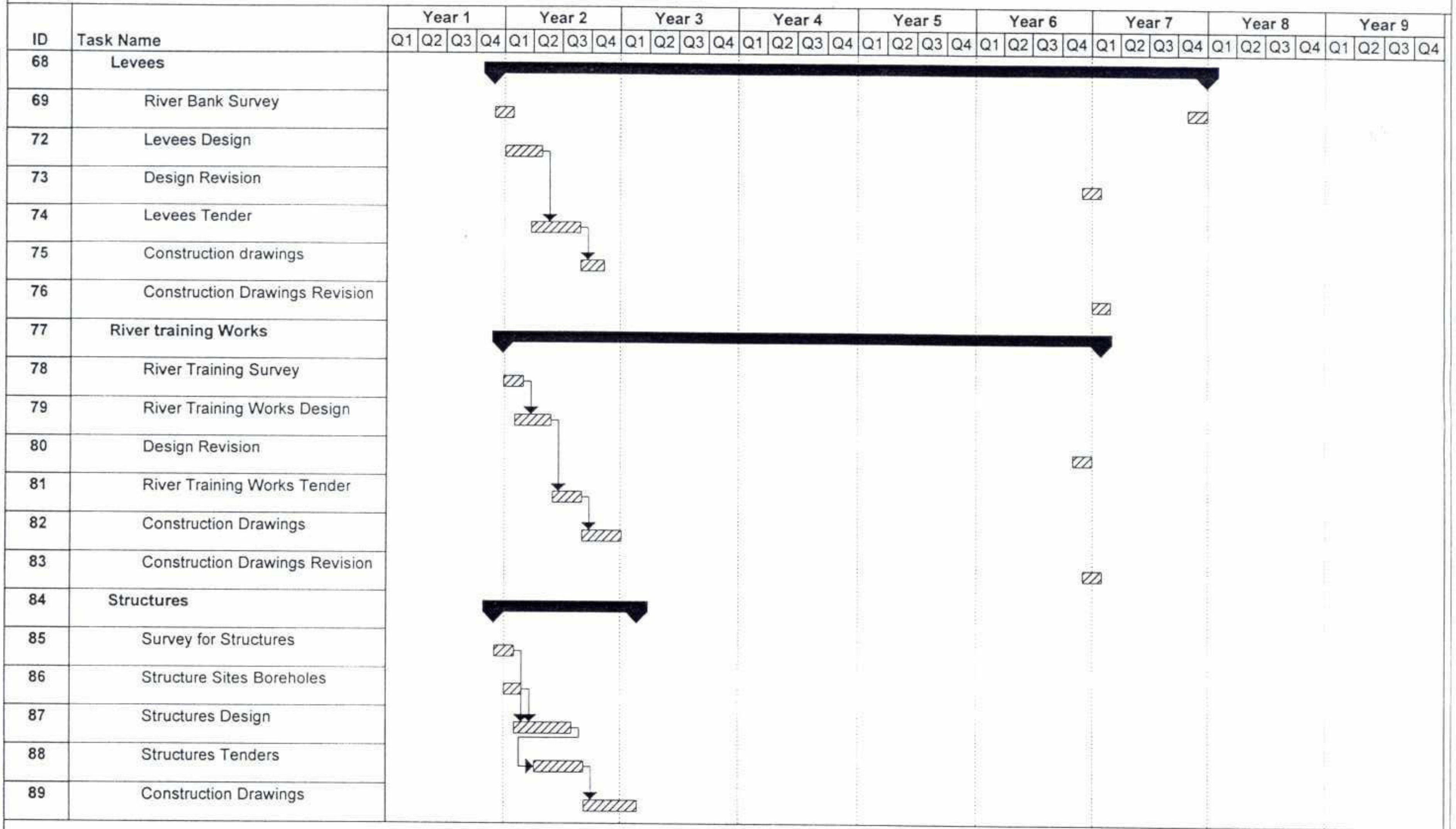

Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

Task ▨	Summary ▬	Rolled Up Task ▨

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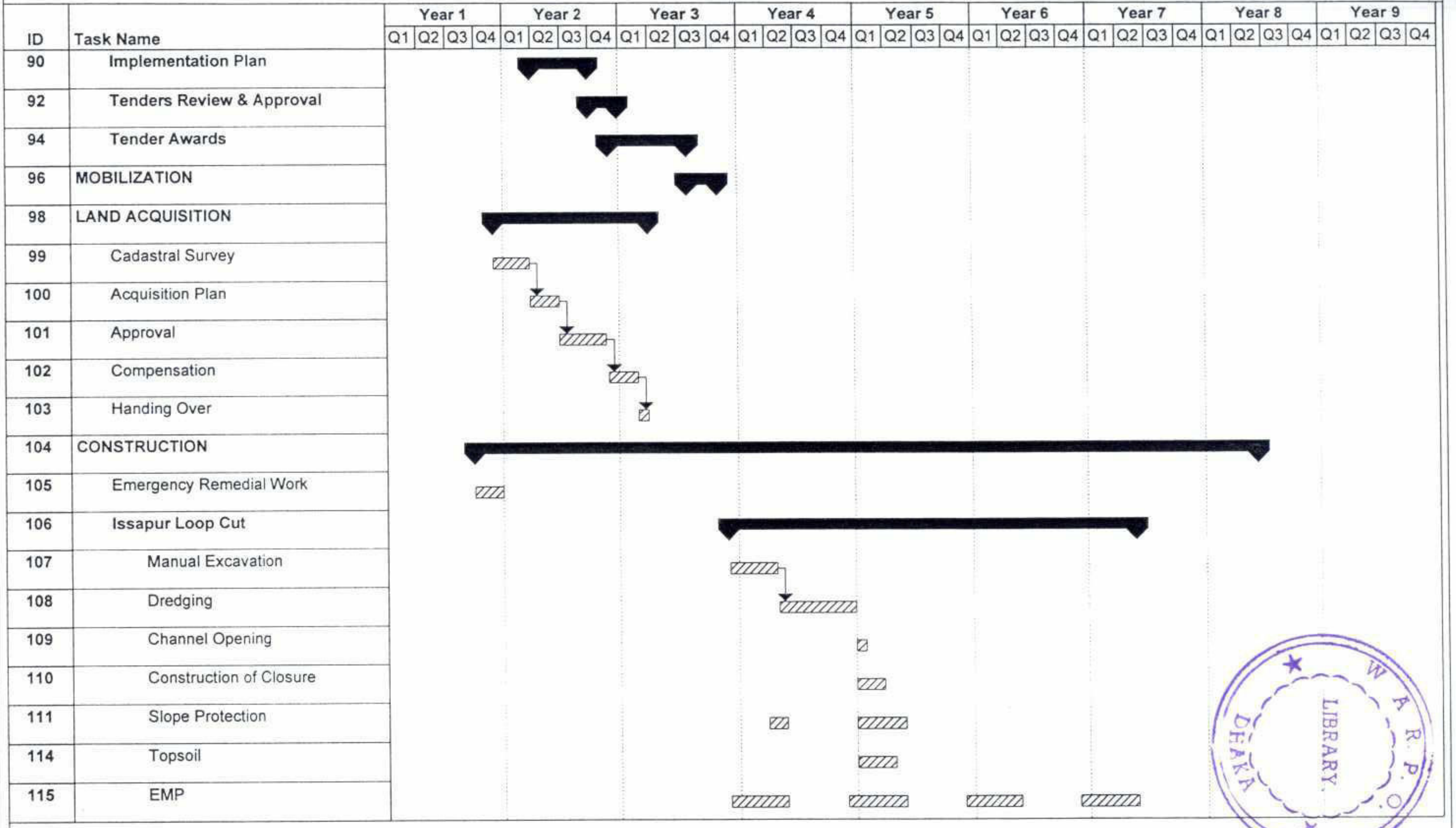
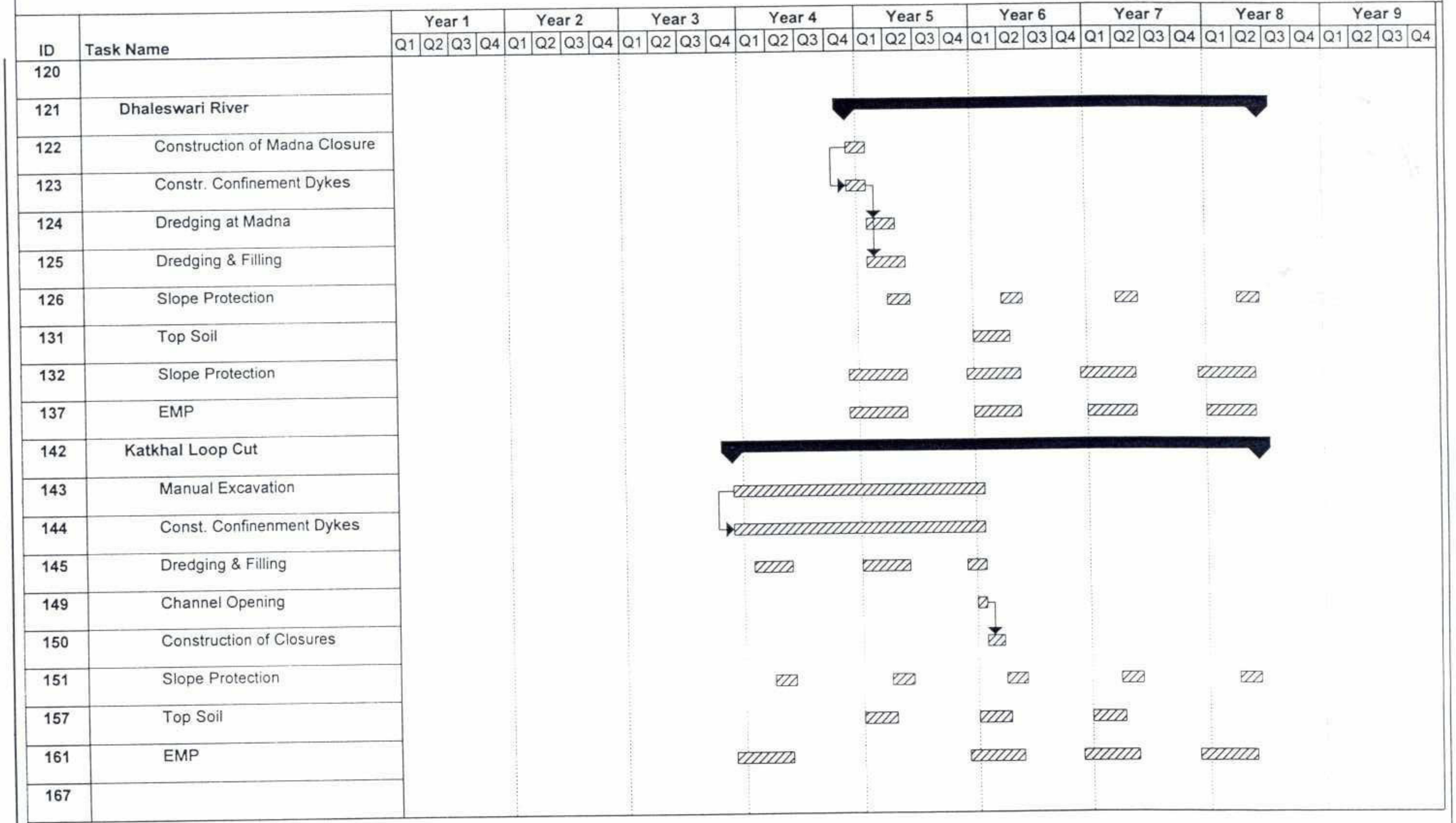


Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

ID	Task Name
90	**Implementation Plan**
92	**Tenders Review & Approval**
94	**Tender Awards**
96	**MOBILIZATION**
98	**LAND ACQUISITION**
99	Cadastral Survey
100	Acquisition Plan
101	Approval
102	Compensation
103	Handing Over
104	**CONSTRUCTION**
105	Emergency Remedial Work
106	**Issapur Loop Cut**
107	Manual Excavation
108	Dredging
109	Channel Opening
110	Construction of Closure
111	Slope Protection
114	Topsoil
115	EMP



ID	Task Name
120	
121	**Dhaleswari River**
122	Construction of Madna Closure
123	Constr. Confinement Dykes
124	Dredging at Madna
125	Dredging & Filling
126	Slope Protection
131	Top Soil
132	Slope Protection
137	EMP
142	**Katkhal Loop Cut**
143	Manual Excavation
144	Const. Confinement Dykes
145	Dredging & Filling
149	Channel Opening
150	Construction of Closures
151	Slope Protection
157	Top Soil
161	EMP
167	

Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

Task ▨ Summary ▬ Rolled Up Task ▨

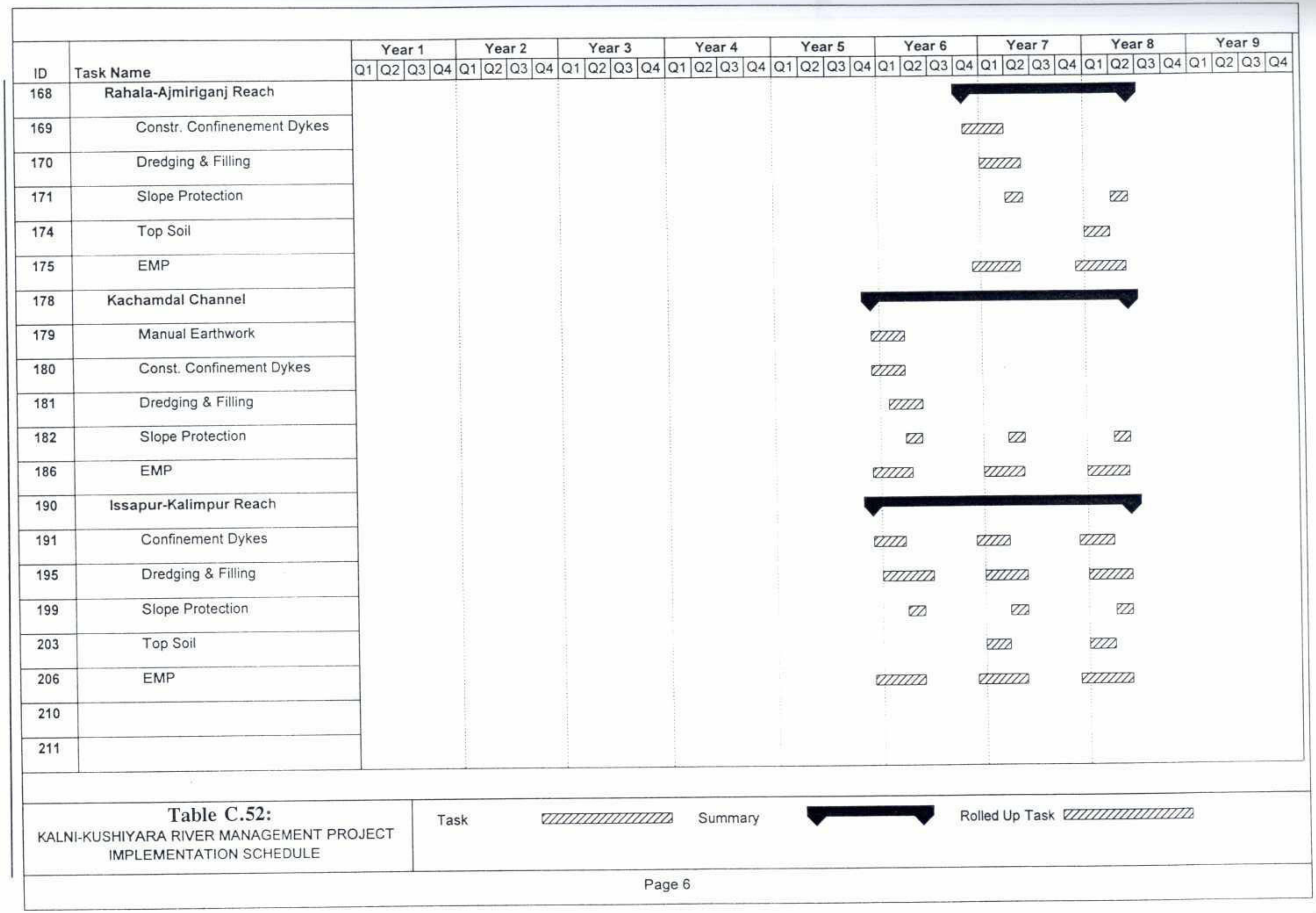


Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

ID	Task Name
212	**Navigation Dredging**
213	Confinement Dykes
214	Dredging & Filling
215	Slope Protection
218	EMP
221	**Construction of Levees**
223	**Construction of Structures**
226	**River Training Work**
228	
229	PERFORMANCE MONITORING
230	Establishment of Baseline Database
231	Crop Production & Losses
239	Fisheries-River Reaches & Beels
247	Koyer Dhala Fishpass
251	River Transportation
259	Employment & Income

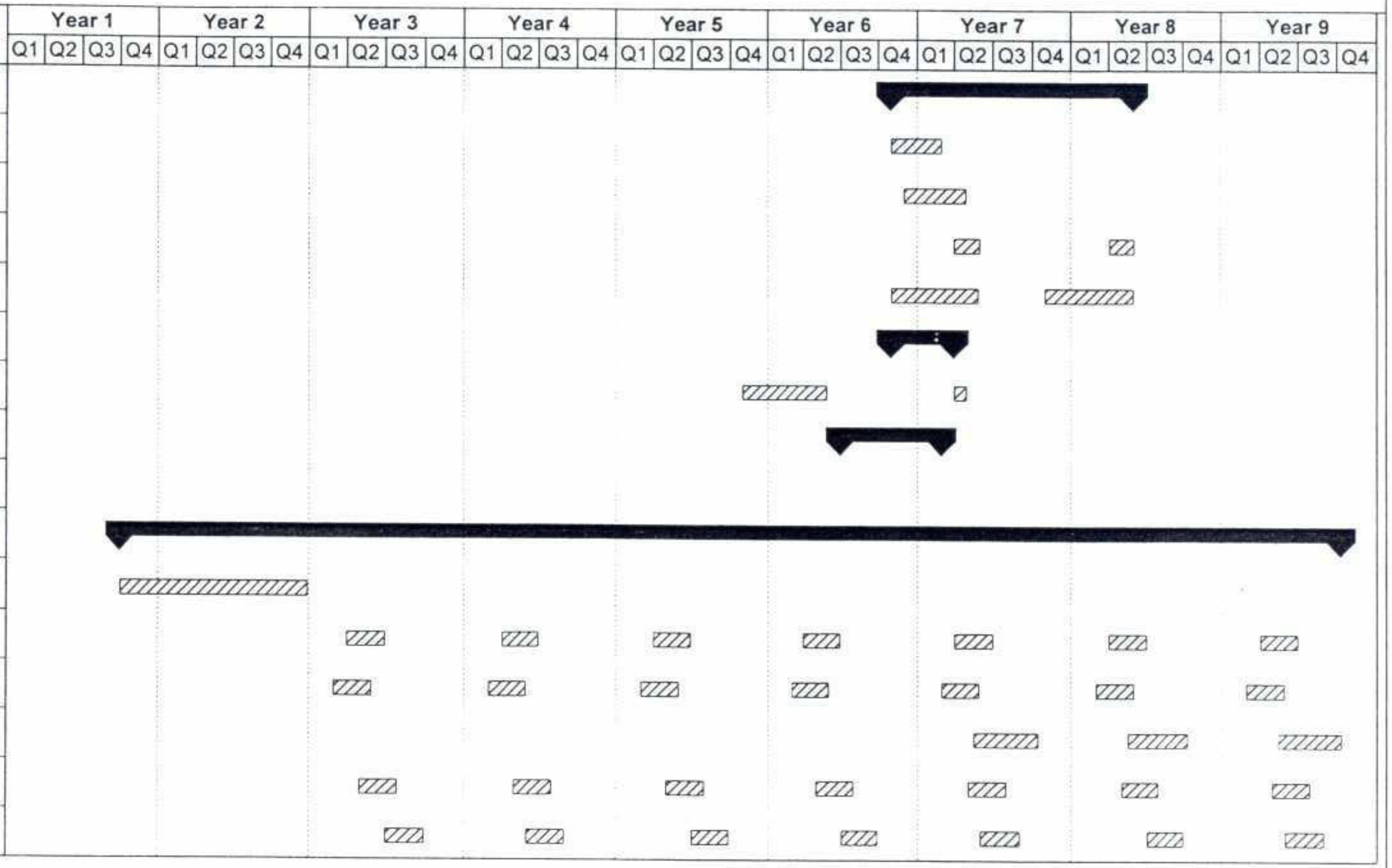


Table C.52:
KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT
IMPLEMENTATION SCHEDULE

Task ▨ Summary ▬ Rolled Up Task ▨

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Cadastral surveys for land acquisition and topographic surveys for planning and quantity estimates should be completed in the first dry season of Year 1. A hydrographic survey over the reach from Markuli to Madna should also be carried out during the first post-monsoon season. Identification, selection, and finalization of disposal sites should be completed in the working season of Year 1.

Land acquisition should start in Year 1 and should be completed in Year 2, prior to the start of construction.

Approval of the implementation plan and tender documents should be made at the beginning of Year 2. Invitation for tenders and contract award must be planned in relation to the time required for mobilization. For example, dredgers typically cannot be mobilized after November 15 due to inadequate draft along the river. Mobilization of manpower should be completed by the end of November so that earthwork could be started by the first week of December, Year 2.

8.5.2 Construction

The following comments highlight the tentative schedule for the main construction activities.

Issapur Loop Cut
Surface excavation and construction of confinement dykes will be carried out in Year 3 and will be completed during that year's dry season (April-May). Dredging will start in April-May of Year 3 and will be completed by December of Year 4. The opening of offtake is targeted in the month of January, Year 4. Construction of closure dam will commence from January, Year 4 and will be completed before the onset of pre-monsoon floods.

Excavation on the Dhaleswari channel will start in January, Year 4 and will be completed during that year's dry season (April-May). Construction of confinement dykes for dredge spoil disposal chambers will start in December-January, Year 4 and will be completed in the same year.

Kadamchal Dredging and Channel Re-alignment
Kadamchal channel dredging, channel re-alignment and construction of village platforms will start in Year 5 and will be completed in the same year.

Issapur-Ajmiriganj Channel Dredging
Construction of the dredge spoil confinement chambers and dredging between Issapur and Kadamchal will start in Year 5 and will be completed in Year 6. Excavation of the reach Rahala-Ajmiriganj will start in Year 6 and will be completed in the same year.

Katkhal Loop Cut
Surface excavation and construction of guide embankments will start in December-January, Year 3 and will be completed in Year 5 (January). Dredging is expected to start from February of Year 3 and will be completed including opening of the new channel's offtake in Year 5 (January).

Bank Protection
Construction of these components will commence in Year 4 (November). The work will be completed in Year 5, to coincide with the opening of Katkhal loop cut.

Navigation Dredging
Disposal chambers will be constructed in the dry season of Year 6 and channel excavation will be completed in the same year.

8.6 Operation and Maintenance

8.6.1 Channel Stabilization and Flood Control Works

The main types of maintenance involve channel re-excavation, and repair of bank protection, existing embankments and levees.

Solutions to problems associated with channel instability and sedimentation generally require a long-term management approach. ***A crucial aspect of river management involves carrying out ongoing channel maintenance.*** In this context, "maintenance" involves more than routine repair of existing structures. Instead, it entails a program of monitoring, diagnosing potential stability problems before they develop into major ones, and carrying out remedial works to maintain the river.

Bank Protection
There will be a need for ongoing monitoring of channel shifting and bank erosion, and construction of bank protection works at strategic locations, particularly during the first five years after the main capital works have been constructed. Table C.53 provides a preliminary list of sites where bank protection may be required in the future. Other, possibly different sites will be identified during the future monitoring program.

Channel Maintenance Dredging
Requirements for channel maintenance dredging were based on experience from the pilot project, results of long-term channel monitoring studies, and sediment transport modelling and analysis. The incoming coarse silt and sand load on the river presently amounts to around 3.5 million m^3/year (at Sherpur and Markuli). It is this bed material load that will create the primary need for ongoing maintenance dredging downstream of Ajmiriganj. At present, the reach below Katkhal can not transport all of the incoming sediment load. For example, morphologic studies showed that approximately 1.2 million m^3 of material was deposited between Kadamchal and Issapur during 1995. In order to achieve a long-term equilibrium in this reach, the channel would have to transport all of this silt and sand load into the Meghna River.

Results of the pilot project monitoring near Gazaria and Kakailseo villages showed that deep, local excavations in the river bed filled-in within a matter of weeks. Overall, with a total excavation of approximately 450,000 m^3, the average bed level in the dredged reaches filled in by about 50% by the end of the monsoon season. However, the extent of the pilot dredging was very limited (about 1 km at each location) and did not involve other measures to improve the self-scouring capacity of the river. The project's proposed channel improvements should reduce the need for future dredging along the river. For example, the loop cuts will shorten the river's length, which will initially steepen the river's gradient and increase the channel's transport capacity. Also, the closures and levees upstream of Ajmiriganj, will increase the pre-monsoon velocities in the lower reach, since spills and losses into the floodplain will be reduced. This will increase the lower reach's capacity to transport sediment which will promote channel scouring before the monsoon season. Furthermore, assuming a major new avulsion can be prevented, the river should begin to establish a more stable configuration than it has in the last 30 years, which will reduce sediment production from bank erosion.

Table C.53: Tentative Locations For Future Bank Protection

River Kilometre	Name	Bank	Comment
52.0-53.0	Kalma	LB	Bank will start eroding after loop cut is opened up. Monitor bank retreat and decide on final preferred bank alignment. Stabilize bank if necessary (ALTERNATIVE 1 only).
83.5-85.0	Anwarpur	LB	Monitor ongoing retreat. If erosion rate accelerates after Katkhal loop cut then add additional bank protection.
86.0-86.5	Bishorikona	LB-RB	Bank will start eroding after loop cut is opened up. Monitor bank retreat and decide on final preferred bank alignment. Stabilize bank if necessary.
114.0-115.0	Koyer Dhala	LB-RB	Monitor performance of closures at Pituakandi and Koyer Dhala, extend/repair if necessary.
119.0	Tangua Dhala	RB	Monitor/upgrade existing protection.
129.5	Fayjullapur	RB	Monitor/upgrade existing protection.
139.0	Akkilshah Bazar	LB	Monitor performance of new closure, extend, upgrade if necessary.
144.0		RB	Monitor/upgrade existing protection.
149.5	Balisri	LB	Upgrade spill closure.
153	Raniganj	RB	Monitor/repair/extend existing protection.
156-161		LB	Monitor future cutoff development, construct new bank protection if required.

Note: LB and RB are defined looking downstream of the river.

A series of morphologic modelling simulations and sediment transport calculations were made to provide preliminary estimates of the future channel maintenance requirements along the river (Annex A - Sedimentation). On the basis of this analysis it was concluded that annual channel maintenance dredging will have to be carried out on the river to preserve the improved channel conveyance. Given the inherent uncertainties with sediment transport predictions, these type of computations can provide indicative results only. It was decided to use the predictions as baseline estimates, then carry out a sensitivity analysis during the project's economic evaluation to assess the impact of variations in maintenance dredging on the overall project economics.

Table C.54 summarizes the estimated maintenance dredging volumes by reach after project completion. The greatest need for maintenance dredging will be in the 7 km reach downstream of the Issapur loop cut on the Dhaleswari River (Km 49-42), downstream of Katkhal loop cut between Bishorikona and Kadamchal (Km 87-85) and below Kalimpur (Km 82-79) on the lower Kalni River. Less excavation will be required immediately upstream of the loop cuts, since these reaches will degrade after the new channels are opened (for further details refer to Chapter 10 of Annex A - Sedimentation).

Table C.54: Maintenance Dredging after Project Completion - Alternative 1

Location	Reach (Km)	Maintenance dredging (m³/year)
		Alternative 1
Kalma	47-52	200,000
Shibpur	54-58	100,000
Adampur	63-66	100,000
Islampur	68-71	
Issapur	70-72.5	
Abdullahpur		475,000
Navigation Dredging		125,000
Total		**1,000,000**

Maintenance requirements are expected to decrease over time with Alternative 1 as the channel adjusts to the two loop cuts. Therefore, after Year 14 the volumes are reduced by 20%. Over a 30 year planning period, the total maintenance dredging quantities amounts to 19.3 million m^3. This work will create an ongoing need to find disposal sites along the river as well as an opportunity to continue developing new village platforms.

8.6.2 Navigation Channel Maintenance

The channel improvements for navigation are situated in the upper reach near Manumukh, Omarpur and Fenchuganj, far upstream from the main river channel stabilization works. The shoals that obstruct navigation in the upper reach are all located at "cross-overs" or "riffles" between major bends. It is proposed that additional maintenance dredging be carried out to ensure that adequate depths can be maintained in the dry season. Given the morphologic characteristics of these bends, it is expected that the dredging will have to be repeated each year. Based on the estimated excavation volume of 125,000 m^3 /year upstream of Sherpur, the total maintenance dredging volume that will be required over the 30 year planning period amounts to 3.7 million m^3.

Given the localized nature of the shoals in the upper reach, there may be some advantage in using alternate methods (such as spur dikes or groins) for maintaining portions of the navigation channel. For example, river training structures would not require constructing spoil disposal facilities on land. They would also eliminate the need to mobilize dredgers each year to this reach. However, provision would have to be made for installing new works periodically, since the location of the shoals could vary from year to year. If temporary structures (such as bamboo spur dikes) were utilized, they would probably have to be re-built virtually every year. As a result, maintenance costs could also be relatively high. At this time, it is not clear that these alternate measures would be more effective and less expensive than maintenance dredging.

The excavation volumes for navigation channel maintenance represent only 12.5 % of the total maintenance effort required along the river. Therefore, the choice between using river training works or dredging will have only a minor impact on the project's overall maintenance costs. The optimum combination of dredging and river training should be determined during the project's detailed design stage.

8.6.3 Village Platform Maintenance

The most critical aspect for village platform maintenance will be to ensure the slope protection is properly maintained. While "hard" protection should not require repair except possibly after major floods or storms, "soft" protection requires annual replacement and repair. Provision for "soft" protection has been included in the cost estimate, assuming annual replacement for 4 years following construction. In the last 3 years, the platform beneficiaries will be expected to contribute to the costs of platform protection through the contributions of material and labour. Community motivation practices will be carried out in platform communities. The enhanced production of *chailla* grass for use in traditional platform protection will be encouraged. Village-based nurseries will be established for the production and sale of adult-sized *koroch* saplings. Full protection and maintenance costs will be assumed by platform landowners after 3 years.

9. QUANTITY AND COST ESTIMATES
ALTERNATIVE 1

9.1 Capital Costs

Total project costs are estimated to be Tk 2,788 million including the cost of mitigative measures, compensation plan and enhancement program. A breakdown of costs by component is shown in Table C.55. These costs were estimated according to the *FPCO Guidelines* (FPCO, 1992).

Table C.55 to Table C.77 detail the estimated volumes and the direct costs of all civil works: earthworks, river improvement works, homestead protective works, hydraulic structures and EMP. The earthworks requirements are based on topographic surveys along both banks of the river conducted by NERP survey section from March to May 1996. The costs of structures are based on preliminary design drawings prepared for the existing field conditions and the hydrologic/hydraulic requirements.

Subsoil data were not available for the proposed hydraulic structures sites. A lump sum provision has been made for de-watering, based on comparative estimate of structures constructed in the area.

The estimates of the required channel dredging and the bank protective works are based on hydrographic surveys and channel cross sections carried out from September 1995 to September 1996.

Unit rates for earthwork, structures and other associated items have been taken from BWDB's 1996 Schedule of Rates for Moulvibazar O&M Circle. Future dredging costs have been estimated assuming a unit cost of Taka 82/m^3 equivalent US$ 2/m^3. Cost of mitigative measures, compensation and enhancement programs have been estimated on the basis of Kalni-Kushiyara Pilot Dredging Project experiences.

Land costs reflect the current prices obtained from field interviews. High agricultural land (*boro*) in Issapur area was assumed to be priced at Tk 180,000/ha, high agricultural land *boro* in Katkhal and upstream reaches was priced at Tk 125,000/ha and lowlands on the downstream of Abdullahpur was priced at Tk 80,000/ha.

Physical contingencies equal to 15% of base construction costs as per *FPCO Guidelines* were used to cover unforeseen costs. The engineering costs (survey, design, preparation of implementation plan and tender documents, supervision of construction and EMP, and administration) are estimated to be Tk 291.8 million. A breakdown of the costs by component is shown in Table C.76 (Annex L - Project Management Plan).

9.2 Operation and Maintenance Costs

The O&M costs are divided into 3 broad categories:

- annual maintenance dredging;
- physical components, and
- village platforms.

The O&M costs were estimated on the basis of *FPCO Guidelines* and pilot project experience. These costs will cover cost of technical staff, departmental overheads, maintenance of physical components and replacement of items subject to wear and tear.

Annual Maintenance Dredging

Cost of annual maintenance dredging associated with construction of disposal chambers and other related components including EMP has been estimated based on the adopted estimating procedure of capital costs. Estimated annual maintenance dredging and other associated costs are given in Table C.77.

Physical Components

Physical components mainly include: embankments, levees, closures structures, river bank protection and embankment slope protection (permanent) at Issapur and Katkhal. The O&M costs of these physical components have been calculated as a percentage of capital costs on the basis of FPCO *Guidelines*. The breakdown of these costs are given below:

- embankments, levees & closures: 6%;
- structures: 3%;
- river bank protection: 10%, and
- slope protection: 3%

Village Platforms

This activity mainly includes post-monsoon platform dyke repairs and protection against wave erosion through the traditional method which is termed as soft protection. Maintenance of village platforms has been placed under the following 2 categories:

- first year program; and
- three years program.

First year maintenance program will be carried out by the same contractor who constructed the confinement dykes. Costs of soft protection were estimated on the basis of the Pilot Dredging Project experience. These costs have been included in the capital costs as O&M during construction (Table C.55).

The concept of a subsequent 3 years program has been developed based on Kalni-Kushiyara Community Development and Monitoring Project (KKCDMP) experience. This program states that the village platforms will be maintained jointly by the project authority and the beneficiary households. Beneficiary households will assure their contribution of labour and materials for soft protection. After the 3 year program, the platforms will be maintained by the beneficiaries themselves (Annex D - Social).

The costs of the 3 year program has been estimated on the basis of the Pilot Dredging Project experience and is also included in the capital cost (Table C.55).

Physical contingencies equal to 15% of base costs (Table C.77) as per FPCO guidelines were used during the economic evaluation to cover unforeseen costs (Annex E - Economics).

Table C.55: Summary of Capital Costs - Alternative 1

Sl	Item	Quantity	Unit	Total Cost (million Tk)
1	Channel Dredging	7.358	m^3	603.36
2	Channel Re-alignment			
	Manual	0.14	m^3	10.78
	Dredging	0.3	m^3	24.60
3	Issapur Loop Cut			
	Dredging	3.1	m^3	254.00
	Manual Earthwork	1.02	m^3	105.61
	Slope Protection-Soft	52,450	m^2	5.25
	Slope Protection-Hard	83,920	m^2	84.03
	Drains-Stairs	6	Nos	0.95
	Levelling	61	ha	1.53
	Closure	1	No	3.96
4	Katkhal Loop Cut			
	Dredging	3.22	m^3	264.05
	Manual Earthwork	1.25	m^3	79.41
	Slope Protection-Soft	81,000	m^2	10.53
	Slope Protection-Hard	92,800	m^2	92.92
	Closure	2	Nos	17.47
	Temporary Bank Protection	2	Nos	6.62
	Permanent Bank Protection	1	No	42.39
5	Madna Closures	2	Nos	1.45
6	River Training	3	Nos	110.67
7	Levees	24	km	10.86
8	Homestead Platforms			
	Confinement Dyke	2.2	m^3	96.5
	Slope Protection-Soft			
	First Year	32,818	m	16.41
	Three Years	56,814	m	28.41
	Slope Protection-Hard	13,880	m	111.18
	Dyke Repair	96.5	m Tk	1.93
	Drains-Stairs	132	Nos	13.20
	Levelling	209	ha	5.23
	Topsoil	209	ha	22.99
	Effluent Outlet-Construction	52	Nos	1.30
	Effluent Outlet-Filling	52	Nos	1.30
9	Drainage Regulators			23.17
10	EMP			
	Mitigation			20.63
	Compensation			0.66
	Enhancement			28.91
	Training			0.50
	Monitoring			6.90
	BASE COST:			**2,109.66**
11	Physical Contingency			316.45
	(15% of Base Cost)			
	SUB-TOTAL			**2,426.11**

12	Study Cost			291.80
13	Land Acquisition			
	Issapur Loop Cut	216	ha	37.80
	Katkhal Loop Cut	195	ha	24.38
	Levees and Structures	20	ha	2.40
	Navigation	3	ha	0.36
	Anandapur	13	ha	1.56
	Abdullahpur	44	ha	3.52
	TOTAL:	**491**	**ha**	**2,787.93**

Table C.56: Earthworks at Issapur Loop Cut

Item	Qty	Unit	Rate (Tk)	Amount (Tk)
A. Left Bank Confinement Chamber				
Guide Embankment	12,990	m^3	64.12	832,919
Country Side Dykes	310,870	m^3	43.78	13,609,889
River Side Dykes	315,110	m^3	64.12	20,204,853
Cut and Fill 1	36,900	m^3	61.37	2,264,553
Cut and Fill 2	222,000	m^3	63.63	14,125,860
Top Soil Cover	116,116	m^3	36.80	4,273,069
			Total A:	**51,038,074**
B. Right Bank Confinement Chamber				
Guide Embankment	12,460	m^3	64.12	798,935
Country Side Dykes	338,800	m^3	43.78	14,832,664
River Side Dykes	323,860	m^3	64.12	20,765,903
Cut and Fill 1	34,800	m^3	61.37	2,135,676
Cut and Fill 2	252,000	m^3	63.63	16,034,760
Top Soil Cover	128,336	m^3	36.80	4,722,765
			Total B:	**54,567,938**
			Total Manual Earthworks:	**105,606,012**
Channel Manual Exc.	1,016,187	m^3	Included in above works	
C. Channel Dredging	3,097,629	m^3	82.00	**254,005,578**
			Total A+B+C:	**Tk 359,611,590**

Notes:

1. All material from manual excavation of loop cut channel is to be reused for the construction of river side confinement dykes, and guide embankments.

2. Cut and fill volumes represent excess material from the channel excavation placed inside chambers, with different lifts and leads depending on existing ground elevations.

3. Country side confinement dykes are to be constructed from local material borrowed from inside of confinement chambers.

4. To account for expansion, 10% has been added to the volume of manually excavated material reused for construction of confinement dykes and embankments.

Table C.57: Earthworks at Katkhal Loop Cut

Item	Qty	Unit	Rate (Tk)	Amount (Tk)
A. Shantipur-Katkhal Section				
Left Bank Guide Embankment (2000 m)	214,600	m^3	64.12	13,760,152
Right Bank Guide Embankment (2200 m)	236,060	m^3	64.12	15,136,167
Channel Manual Exc.	417,045	m^3	Included in above works	
Channel Dredging	1,657,805	m^3	82.00	135,940,010
			Total A:	**164,836,329**
B. Kaisar Section				
Right Bank Guide Embankment (1300 m)	118,859	m^3	64.12	7,621,239
Confinement Dyke (No. 32)	24,115	m^3	64.12	1,546,254
Stockpiled for Kaisar Closure	30,000	m^3	51.72	1,551,600
Channel Manual Exc.	161,088	m^3	Included in above works	
Channel Dredging	189,081	m^3	82.00	15,504,642
			Total B:	**26,223,375**
C. Shahebnagar Section				
Left Bank Guide Embankment (1450 m)	132,574	m^3	64.12	8,500,645
Right Bank Guide Embankment (1150 m)	145,130	m^3	64.12	9,305,736
Platform No. 31 R/S Dyke Chamber Fill	 91,000 253,897	 m^3 m^3	 64.12 63.63	 5,834,920 16,155,466
Channel Manual Excavation	594,827	m^3	Included in above works	
Channel Manual Excavation	594,827	m^3	Included in above works	
Channel Dredging	1,373,282	m^3	82.00	112,609,124
			Total C:	**152,405,891**
Total-Manual Excavation	**1,246,253**	**m^3**		**79,412,179**
Total-Dredging	**3,220,168**	**m^3**	**82.0**	**264,053,776**
Total Cost (Manual Excavation & Dredging)				**343,465,955**

Table C.58: Issapur Loop Cut and Homesteads
First Year - Temporary Protection of Slopes

Item	Protected Length (m)	Quantity	Unit	Rate (Tk)	Amount (Tk)
A. Left Bank Platform					
Guide Embankment	300	1,500	m^2	100.00	150,000
C/S Pl. Slope	2,225	11,125	m^2	100.00	1,112,500
R/S Pl. Slope	2,485	12,425	m^2	100.00	1,242,500
TOTAL A:		**25,050**	**m^2**		**2,505,000**
B. Right Bank Platform					
Guide Embankment	300	1,500	m^2	100.00	150,000
C/S Pl. Slope	2,720	13,600	m^2	100.00	1,360,000
R/S Pl. Slope	2,460	12,300	m^2	100.00	1,230,000
TOTAL B:		**27,400**	**m^2**		**2,740,000**
			Total 1st Year Protection:		5,245,000

Table C.59: Katkhal Loop Cut
First Year - Temporary Protection of Slopes

Item	Protected Length (m)	Quantity	Unit	Rate (Tk)	Amount (Tk)
A. Shantipur-Katkhal Section					
Left B. Embankment	4,000	20,000	m^2	100.00	2,000,000
Right B. Embankment	4,400	22,000	m^2	100.00	2,200,000
TOTAL A:		**42,000**	**m^2**		**4,200,000**
B. Kaisar Section					
Right B. Embankment	2,600	13,000	m^2	100.00	**1,300,000**
TOTAL B:		**13,000**	**m^2**		**1,300,000**
C. Shahebnagar Section					
Left B. Embankment	2,900	14,500	m^2	100.00	1,450,000
Right B. Embankment	2,300	11,500	m^2	100.00	1,150,000
TOTAL C:		**26,000**	**m^2**		**2,600,000**
			Total 1st Year Protection:		**10,528,140**

Table C.60: Issapur Loop-cut Permanent Protection of Slopes

Item	Protected Length (m)	Quantity	Unit	Rate (Tk)	Amount (Tk)
A. Left Bank Platform					
Guide Embankment	300	2,400	m^2	1,001.26	2,403,024
C/S Pl. Slope	2485	19,880	m^2	1,001.26	19,905,049
R/S Pl. Slope	2225	17,800	m^2	1,001.26	17,822,428
TOTAL A:		**40,080**	m^2		**40,130,501**
B. Right Bank Platform					
Guide Embankment	300	2400	m^2	1,001.26	2,403,024
C/S Pl. Slope	2,720	21,760	m^2	1,001.26	21,787,418
R/S Pl. Slope	2,460	19,680	m^2	1,001.26	19,704,797
TOTAL B:		**43,840**	m^2		**43,895,238**
Total Permanent Protection:					**84,025,739**

Table C.61: Katkhal Loop-cut Permanent Protection of Slopes

Item	Protected Length (m)	Quantity	Unit	Rate (Tk)	Amount (Tk)
A. Shantipur-Katkhal Section					
Left B. Embankment	2,200	17,600	m^2	1,001.26	17,622,176
Right B. Embankment	4,400	35,200	m^2	1,001.26	35,244,352
TOTAL A:		**8,400**	m^2		**52,866,528**
B. Dakhinhati-Pubhati Section					
Right B. Embankment	2,000	1,600	m^2	1,001.26	**16,020,160**
C. Shahebnagar Section					
Left B. Embankment	1,600	8,000	m^2	1,001.26	8,010,080
Right B. Embankment	2,000	16,000	m^2	1,001.26	16,020,164
TOTAL C:		**24,000**	m^2		**24,030,240**
Total Permanent Protection:					**92,916,928**

Table C.62: Volume and Cost Estimates of Confinement Dykes - Alternative 1

Disposal No	Location	Area (ha)	Length (m)		Unit (m^3/m)		Volume (m^3)		Total (m^3)
			Home	Free	Home	Free	Home	Free	
3	Shibpur	1.28	423	129	65	32	27,495	4,128	31,623
4	Shibpur	6.72	1,427	347	65	32	92,755	11,104	103,859
5	Madna	58.00	0	0	0	0	0	0	0
6	Issapur	3.50	0	752	65	32	0	24,064	24,064
7		3.50	0	752	65	32	0	24,064	24,064
8		3.50	0	752	65	32	0	24,064	24,064
9		3.50	0	752	65	32	0	24,064	24,064
10		3.50	0	752	65	32	0	24,064	24,064
11		3.50	0	752	65	32	0	24,064	24,064
12	To	3.50	0	752	65	32	0	24,064	24,064
13		3.50	0	752	65	32	0	24,064	24,064
14		4.00	0	752	65	32	0	24,064	24,064
15		4.00	0	752	65	32	0	24,064	24,064
16	Downstream of	4.00	0	752	65	32	0	24,064	24,064
17	Abdullahpur	4.00	0	752	65	32	0	24,064	24,064
18	Abdullahpur	7.24	645	923	65	32	41,925	29,536	71,461
19		9.14	1,292	290	65	32	83,980	9,280	93,260
20		8.06	847	564	65	32	55,055	18,048	73,103
21	To	1.56	140	360	65	32	9,100	11,520	20,620
22		2.94	210	490	65	32	13,650	15,680	29,330
23	Kalimpur	16.68	968	1,153	65	32	62,920	36,896	99,816
24		6.86	752	414	65	32	48,880	13,248	62,128
25	Kadamchal	2.82	619	277	65	32	40,235	8,864	49,099
26		9.50	0	1,939	65	32	73,970	62,048	136,018
27	Bishorikona	15.62	547	1,665	65	32	35,555	53,280	88,835
28		7.52	467	912	65	32	30,355	29,184	59,539
29		7.41	274	870	65	32	17,810	27,840	45,650
30		10.66	583	759	65	32	37,895	24,288	62,183
31		2.89	0	428	65	32	0	13,696	13,696
32	To	9.87	600	1,040	65	32	39,000	33,280	72,280
33		3.16	428	553	65	32	27,820	17,696	45,516
34		3.27	401	560	65	32	26,065	17,920	43,985
35		3.14	452	575	65	32	29,380	18,400	47,780
36		1.72	280	420	65	32	18,200	13,440	31,640
37	Shantipur	16.80	419	1,144	65	0	27,235	36,608	63,843
38	Rahala	5.83	0	0	0	0	29,250	16,000	45,250
39		12.77	0	1,688	65	32	0	54,016	54,016
40		3.00	0	0	0	32	19,500	15,936	35,436
41		3.43	111	511	65	32	7,215	16,352	23,567
42	To	2.50	402	402	65	32	26,130	12,864	38,994
43		7.00	533	933	65	32	34,645	29,856	64,501
44		3.50	305	586	65	32	19,825	18,752	38,577
45		3.83	225	574	65	32	14,625	18,368	32,993
46		3.00	293	491	65	32	19,045	15,712	34,757
47	Ajmiriganj	3.00	0	798	65	32	0	25,536	25,536
	Sub-Total:	**246.72**	**15,531**	**31,817**	**2,860**	**1,408**	**1,009,515**	**1,018,144**	**2,027,659**
48-52	Navigation	25.69	0	5,520	65	32	0	176,640	176,640
	Total:	**272**	**15,531**	**37,337**	**2,925**	**1,440**	**1,009,515**	**1,194,784**	**2,204,299**
	Unit Cost = 43.78 Tk/m3					**Total Cost (million Tk):**			97

Table C.63: Protection Type and Cost of Confinement Dykes - Alternative 1

Name	Dis No	Location	Area (ha)	Length (m)		Protection	Length (m)		PP (000'Tk)	SP (000'Tk)
				Home	Free	Ranking	PP	SP		
Dhaleswari Channel Dredging	3	Shibpur	1.28	423	129	PP+SP	76	53	608.77	26.50
	4	Shibpur	6.72	1427	347	PP	347	0	2,779.50	0.00
	5	Madna	58	0	0	None			0.00	0.00
Kalni River Dredging	6	Issapur	3.5	0	752	PP	752		6,023.58	0.00
	7		3.5	0	752	PP	752		6,023.58	0.00
	8		3.5	0	752	PP	752		6,023.58	0.00
	9		3.5	0	752	PP	752		6,023.58	0.00
	10	To	3.5	0	752	PP	752		6,023.58	0.00
	11		3.5	0	752	PP	752		6,023.58	0.00
	12		3.5	0	752	PP	752		6,023.58	0.00
	13		3.5	0	752	PP	752		6,023.58	0.00
	14		4	0	800	PP	800		6,408.06	0.00
	15		4	0	800	PP	800		6,408.06	0.00
	16	Downstream of	4	0	800	PP	800		6,408.06	0.00
	17	Abdullahpur	4	0	800	PP	800		6,408.06	0.00
Kalni River Dredging	18	Abdullahpur	7.52	645	923	PP+SP	137	786	1,097.38	393.00
	19		9.14	1,292	290	PP+SP	200	90	1,602.02	45.00
	20		8.06	847	565	SP		565	0.00	282.50
	21	To	1.56	140	360	SP*		360	0.00	180.00
	22		2.94	210	490	PP+SP	140	350	1,121.41	175.00
	23	Kalimpur	16.68	968	1153	PP+SP	876	277	7,016.83	138.50
Kadamchal Channel	24		6.86	752	414	PP+SP	118	296	945.19	148.00
Dredging and	25	Kadamchal	2.82	619	277	PP+SP	135	142	1,081.36	71.00
Realignment	26		9.5	1,138	1939	PP+SP	320	1619	2,563.23	809.50
Katkhal Loop Cut	27	Bishorikona	15.62	547	1655	PP+SP	473	1182	3,788.77	591.00
	28		7.52	467	912	PP+SP	248	664	1,986.50	332.00
	29		7.41	274	870	SP		870	0.00	435.00
	30		10.66	583	759	SP		759	0.00	379.50
	31	To	2.89	0	428	SP	0	428	0	214.00
	32		9.87	600	1040	SP		1040	0.00	520.00
	33		3.16	428	553	PP+SP		553	0.00	276.50
	34		3.27	401	550	None			0.00	0.00
	35		3.14	452	575	SP		575	0.00	287.50
	36		1.72	280	420	SP Part		150	0.00	75.00
	37	Shantipur	16.8	419	1144	SP		1144	0.00	572.00
Kalni River Dredging	38	Rahala	5.83	450	500	PP+SP	400	100	3,204.03	50.00
	39		12.77	0	1688	PP+SP	294	1394	2,354.96	697.00
	40		3	300	498	PP+SP	300	198	2,403.02	99.00
	41		3.43	111	511	PP+SP	300	211	2,403.02	105.50
	42	To	2.5	402	402	SP		402	0.00	201.00
	43		7	533	933	SP		933	0.00	466.50
	44		3.5	305	586	SP		586	0.00	293.00
	45		3.83	225	574	PP+SP	300	274	2,403.02	137.00
	46		3	293	491	SP		491	0.00	245.50
	47	Ajmiriganj	3	0	798	SP		798	0.00	399.00
		Sub-Total:	**247**	**15,531**	**31,990**	**0**	**13,880**	**17,290**	**111179.9**	**8645**
Navigation Dredging	48	Nawanagar	3.6							
	49	Manumukh	8							
	50	Galimpur	3		1648	SP	0	1,648	0	824.00
	51	Omarpur	7.09							
	52	Fenchuganj	4							
		Total:	**272.69**	**15,531**	**33,638**	**0**	**13,880**	**18,938**	**111179.9**	**9,469**
First Year Soft Protection						**SP**	**0.00**	**32,818**	**0**	**16,409**
Three Year Soft Protection						**SP**	**0.00**	**56814**	**0**	**28,407**

PP: Permanent Protection, SP: Soft Protection, Home: Dyke along the existing homestead, Free: Dyke along the free end (haor side).

Table C.64: Homestead Access Cattle Ramp and Stairway

Item	Quantity	Unit	Rate (Tk)	Amount (Tk)
Mobilization & Demobilization	L.S.			10,000
Earthworks	59.5	m^3	29	1,748
CC Work	2.2	m^3	2,435	5,358
RCC Work	19	m^3	2,944	55,938
Form Work	8.5	m^2	176	1,497
MS Reinforcement	802	kg	28	22,448
Brick Work	23	m^3	2,005	46,115
Carriage of Materials				15,000
			Total:	**158,102**

Table C.65: Homestead Platform and Embankment Slope Protection

Item	Qty	Unit	Rate (Tk)	Amount (Tk)
A. Toe Protection with Brick Wall				
Excavation	0.65	m^3	28.33	18.41
Earth Filling	0.50	m^3	131	10.85
CC Work (1:3:6)	0.07	m^3	2,435.23	170.47
Brick Work	0.22	m^3	2,004.98	442.10
			Unit Rate Tk/linear m:	**641.83**
B. Slope Protection with Concrete Blocks				
Fine Dressing of Slope	1.00	m^2	3.06	3.06
Sand Bed (50 mm)	0.05	m^3	217.51	10.88
Geotex. 3mm Filter	1.00	m^2	0.00	151.54
CC Blocks (45x45x30cm)	0.30	m^2	2,572.00	771.60
			Unit Rate Tk/m^2:	**937.08**
C. Slope Protection with Traditional Method				
Slope Protection	1	m^2	100.00	100.00
			Unit Rate Tk/m^2	**100.00**

Table C.66: Design and Cost Estimates of Shantipur Closure

Sl.#		
1.	Design Data	
	Design Water Level	7.87 m PWD*
	Return Period	1:20 year
	Freeboard	1.0 m
	Settlement	25 cm
	Design Crest Level	9.10 m PWD
	Side Slopes	1:3 both sides
	Top Width of Embankment	4.27 m
	Top Width at GL	41.87 m including 10 m berm
	Average GL	4.5 m PWD
	Average Depth at GL	3.0 m
	Length of Closure	176 m
	Water Level at January	3.0 m PWD
	Closure Length at January	94.15 m
2.	Estimated Volume for Closure	26,858 m^3
3.	Total Vol.(with 30% wastage)	34,915 m^3
	Earthwork for closure	1479 m^3
	Earthwork for final closing	33418 m^3
4.	Earthwork for Embankment	20,781 m^3
5.	Cost Estimates	
	Earthwork for the closure	Tk 1,652,186
	Earthwork for final closing	Tk 92,844
	Bamboo Piling (3372 nos)	Tk 233,241
	Bamboo Pin Driving (5058 m)	Tk 60,494
	Half Split Bamboos	Tk 12,915
	Packed Straw	Tk 8,394
	Brush Wood	Tk 6,635
	Earthwork for Embankment	Tk 1,131,083
	Turfing	Tk 43,500
6.	**Total Cost**	**Tk 3,241,291**

Note: * Water level is estimated on the basis of Ajmiriganj and Katkhal levels.

Table C.67: Design and Cost Estimates of Shahebnagar Closure

Sl.#		
1.	Design Data	
	Design Water Level	7.87 m PWD*
	Return Period	1:20 year
	Freeboard	1.0 m
	Settlement	25 cm
	Design Crest Level	9.10 m PWD
	Side Slopes	1:3 both sides
	Top Width of Embankment	4.27 m
	Top Width at GL	130.3 m including 110 m berm
	Average GL	5.1 m PWD
	Average Depth at GL	6.1 m
	Length of Closure	233.5 m
	Water Level at January	3.0 m PWD
	Closure Length at January	180 m
2.	Estimated Volume for Closure	
	Earthwork for closure	234780 m^3
	Earthwork Final Closing	1465 m^3
	Total Volume for Closure	235245 m^3
4.	Earthwork for Embankment	14500 m^3
5.	Cost Estimates	
	Earthwork for the closure	Tk 11.40 million
	Earthwork for final closing	Tk 0.09 million
	Earthwork for Embankment	Tk 0.36 million
	Supply and Laying Mata	Tk 0.46 million
	Supply *ballah* (2024 m)	Tk 0.69 million
	Supply Half Sawn *ballah*	Tk 0.15 million
	Ballah Driving	Tk 0.04 million
	Supply Bamboo (5340 nos)	Tk 0.34 million
	Bamboo Driving (5340 m)	Tk 0.06 million
	Half Split Bamboos	Tk 0.01 million
	Packed Straw	Tk 0.01 million
	Brush Wood	Tk 0.01 million
	Turfing	Tk 0.02 million
6.	**Total Cost**	**Tk 14.23 million**

Note: * Water level is estimated on the basis of Ajmiriganj and Katkhal levels.

Table C.68: Design and Cost Estimates of Issapur Closure

Sl.#		
1.	Design Data	
	Design Water Level	7.77 m PWD
	Return Period	1:20 year
	Freeboard	0.6 m
	Settlement	0.30 cm
	Design Crest Level	8.67 m PWD
	Side Slopes	1:3 both sides
	Top Width of Embankment	4.27 m
	Top Width at GL	51.03 m including 10 m berm
	Average GL	3.5 m PWD
	Average Depth at GL	2.67 m
	Length of Closure	208 m
	Water Level at January	2.1 m PWD
	Closure Length at January	183 m
2.	Estimated Volume for Closure	28,848 m^3
3.	Total Vol.(with 30% wastage)	37,502 m^3
	Earthwork for closure	36,393 m^3
	Earthwork for final closing	1,109 m^3
4.	Earthwork for Embankment	22,832 m^3
5.	Cost Estimates	
	Earthwork for the closure	Tk 1,538,332
	Earthwork for final closing	Tk 68,780
	Bamboo Piling	Tk 289,615
	Bamboo Pin Driving (6282 m)	Tk 75,133
	Half Split Bamboos	Tk 5,702
	Packed Straw	Tk 4,197
	Brush Wood	Tk 3,317
	Earthwork for Embankment	Tk 1,165,345
	Turfing	Tk 51,347
	Salballah	Tk 236,538
	Salballah Driving	Tk 17,758
	Half Split Ballah	Tk 130,244
	Royalty of Earth	Tk 306,193
	Mata Supply & Placing	Tk 70,831
6.	**Total Cost**	**Tk 3,963,332**

Table C.69: Summary Costs of Madna Channel Closures

Sl.#		X-Sec 1	X-Sec 2
1.	Design Data		
	Average Bed Level, m PWD	2.07	1.71
	Top Elev. of Closure, m PWD	4.0	4.0
	Crest Width of Closure, m	4.27	4.27
	Side Slopes	1:3 both	1:3 both sides
	Top Width of Channel, m	300	285
2.	Cost Estimates Tk		
	Earthwork for Closure	418,559	531,530
	Earthwork for Final Closing	7,132	7,566
	Royalty for Earth	37,984	48,236
	Packed Straw	2,099	2,099
	Supply Bamboo	138,963	138,963
	Bamboo Driving	24,028	24,028
	Half Split Bamboo	5,436	5,436
	Brush Wood:	3,317	3,317
3.	**Total Cost**	**637,518**	**761,175**
4.	**Total for two Sections**	**1.40 million Tk**	

Table C.70: Koyer Dhala Multipurpose Regulator

Item	Quantity	Unit	Rate (Tk)	Amount ('000 Tk)
Mob/Demob	L.S.	m^3		150.0
Excavation in foundation	0	m^3	39.02	699.1
Excavation (div.ch. 300m)	79,050	m^3	32.41	2,562.0
Back filling	0	m^3	21.70	94.1
Sand filling	2,600	m^3	0.00	471.3
Lean Concrete	70	m^3	3,144.06	220.1
RCC Work	1,040	m^3	3,941.49	4,099.1
Form Work	3,270	m^2	198.03	647.6
MS Reinforcement	110	tonne	27,990.00	3,078.9
Steel Gates (2.0.8x2.6 m)	2	Nos	126,000.00	252.0
Steel F.Boards (0.5x3.8 m)	12	Nos	96,000.00	1,152.0
MS Works	7,360	kg	56.55	416.2
Steel Sheet Piles (Supply)	21	tonne	71,238.71	1,496.0
Steel Sheet Piles (Driving)	160	m^2	320.84	51.3
CC/BI with sand/gr. filter	625	m^2	931.94	582.5
Rip Rap Protection Works	312	m^3	1,456.35	454.4
Dewatering	L.S.			1,000.0
Slide Gate Lift	2	Nos	43,875.06	87.8
Fall Board Lift	2	Nos	36,000.00	72.0
PVC water stop	88	m	777.26	68.4
Carriage of Materials				600.0
Fish Cage and Shed	L.S			2,460.0
			Total	**20,714.8**

Table C.71: Barabaria Khal Drainage/Flushing Pipe Sluice

Item	Quantity	Unit	Rate (Tk)	Amount ('000 Tk)
Mobilization & Demobilization	L.S.			100.0
Excavation in foundation	2,000	m^3	39.02	78.0
Excavation (div.ch. 200m)	6,120	m^3	32.41	198.3
Back filling	1,600	m^3	21.70	34.7
Sand filling	350	m^3	181.27	63.4
Lean Concrete	5	m^3	3,144.06	15.7
RCC Work	110	m^3	3,941.49	433.6
Form Work	360	m^2	198.03	71.3
MS Reinforcement	11	tonne	27,990.00	307.9
Steel Slide Gate	1	Nos	27,224.13	27.2
Hand Wheel Lifting Device	1	No	25,146.98	25.2
MS Works	500	kg	56.55	28.3
Steel Sheet Piles (Supply)	0	tonne	71,238.71	434.6
Steel Sheet Piles (Driving)	0	m^2	320.84	17.3
CC Blocks with Filter	209	m^2	931.94	194.8
Rip Rap Protection Works	6	m^3	1,456.35	8.7
Dewatering	L.S.			200.0
MS Railing	7	m^2	1,012.27	7.4
RCC Pipe 1050 mm Dia.	28	m	2,428.11	68.0
Carriage of Materials				150.0
			Total	**2,464.4**

Table C.72: River Bank Protection at Koyer Dhala (Km 115.4)

Sl.#	
1	Top of revetment = El. 6.0 m PWD.
2	Length of bank to be protected = 850 m.
3	Estimated scour level = El. -16.0 m PWD.
4	Side slope of revetment to be 1H:2V or flatter.
5	Gradation of rip-rap:
	at least 60 % between 254 mm - 305 mm
	40% between 153 mm - 254 mm
6	Nominal thickness of stone revetment should be not less than 600 mm.
7	Unit volume of placed stone should be not less than 31.0 m^3 per lineal metre of bank.
8	Total volume of placed stone should be not less than 26,350 m^3.
9	Filter layer should extend from LLW to top of bank and should consist of graded Khoa at least 150 mm thick.
10	Unit volume of filter should be at least 1.20 m^3 per lineal metre of bank.
11	Total volume of filter should be at least 1,20 m^3.

Table C.73: River Bank Protection at Pituakandi (Km 114.5)

Sl.#	
1	Top of revetment = El. 6.0 m PWD.
2	Length of bank to be protected = 500 m.
3	Estimated scour level = El. -20.0 m PWD.
4	Side slope of revetment to be 1H:2V or flatter.
5	Gradation of rip-rap:
	at least 60 % between 254 mm - 305 mm
	40% between 153 mm - 254 mm
6	Nominal thickness of stone revetment should be not less than 600 mm.
7	Unit volume of placed stone should be not less than 39.5 m^3 per lineal metre of bank.
8	Total volume of placed stone should be not less than 15,600 m^3
9	Filter layer should extend from LLW to top of bank and should consist of graded Khoa at least 150 mm thick.
10	Unit volume of filter should be at least 1.20 m^3 per lineal metre of bank.
11	Total volume of filter should be at least 600 m^3.

Table C.74: River Bank Protection at Akkilshah Bazar (Km 138)

Sl.#	
1	Top of revetment = El. 8.0 m PWD.
2	Length of bank to be protected = 640 m.
3	Estimated scour level = El. -20.0 m PWD.
4	Side slope of revetment to be 1H:2V or flatter.
5	Gradation of rip-rap:
	at least 60 % between 254 mm - 305 mm
	40% between 153 mm - 254 mm
6	Nominal thickness of stone revetment should be not less than 600 mm.
7	Unit volume of placed stone should be not less than 41.4 m^3 per lineal metre of bank.
8	Total volume of placed stone should be not less than 26,500 m^3
9	Filter layer should extend from LLW to top of bank and should consist of graded Khoa at least 150 mm thick.
10	Unit volume of filter should be at least 1.8 m^3 per lineal metre of bank.
11	Total volume of filter should be at least 1,70 m^3.

Table C.75: EMP Cost Estimates
Kalni-Kushiyara River Management Project - Alternative 1

Sl. #	Item	Quantity	Unit	Unit Price (Tk)	Total Cost (mTk)
1	**Mitigation**				
	Cash Grants				
	Issapur	216	ha	180,000	7.78
	Katkhal	195	ha	125,000	4.88
	Market		LS	-	1.48
	River Ghat	4	no	100,000	0.40
	Relocation	20	nos	80,000	1.60
	Drainage from Adj.		LS		2.00
	Road Shifting		LS		0.50
	House Shifting		LS		0.10
	Tubewell	100	nos	8,000	0.80
	Water Quality	52	nos	25,000	1.1
				Sub-Total:	**20.63**
2	**Compensation**				
	Crop Compensation				
	Outlets	51	nos	5,000	0.25
	Shore Pipelines	51	nos	5,000	0.25
	Homestead Loss	32	nos	5,000	0.16
				Sub-Total:	**0.66**
3	**Enhancement Program**				
	Plantation	20,000	nos	63	1.26
	Nursery	2	LS		0.85
	Saplings	0	nos	8	0.75
	Tree purchase	100,000	nos	0	1.00
	Tree care	30,000	nos	36	1.08
	Bamboo Basket	100,000	nos	10	1.00
	Green Manuring				
	Straw	148	ha	25,000	3.70
	Dhaincha	0	ha	0	0.20
	Navigation Sites	10	yrs	30,000	0.30
	Shrubs and Grasses	10	ha	5,000	0.05
	Chailla Production	138	ha	0	1.38
	Tubewells	135	nos	8,000	1.08
	Water Seal Latrines	6,275	nos	600	3.77
	Landless Settlement	1,250	nos	10,000	12.50
				Sub-Total:	**28.91**
4	**Monitoring Plan**				6.9
5	**Training Plan**				0.5
				TOTAL:	**57.60**

Table C.76: Costs of Personnel and Expenses

Item	Government of Bangladesh			Consultants		
	('000 Tk)	('000 CDN)	('000 US$)	('000 Tk)	('000 CDN)	('000 US$)
Management	4,532	146	111	28,039	904	684
Field Investigation	2,396	77	58	7,631	246	186
Land Acquisition	3,389	109	83	13,773	444	336
Detailed design	1,240	40	30	56,952	1,837	1,389
Tendering	364	12	9	8,707	281	212
Construction	13,162	425	321	74,873	2,415	1,826
EMP Process	3,768	122	92	73,185	2,361	1,785
	28,851	**931**	**704**	**263,160**	**8,488**	**6,418**

Table C.77: O&M and EMP Cost Estimates Kalni-Kushiyara River Management Project - Alternative 1

Year	Dredged Volume (Mm3/yr)	Total No Dip. Sites	Total Area (ha)	Dyke (M Tk)	Dredg. (M Tk)	Protec-tion (M Tk)	Dyke O&M (M Tk)	Topsoil (M Tk)	Drains (M Tk)	1st Yr (M Tk)	3 Year (M Tk)	Outlet Both (M Tk)	EMP			Annual Dredg-ing O&M (M Tk)	Other Compo-nent (M Tk)	TOTAL O&M (M Tk)
													Mitiga-tion (M Tk)	Compens a-tion (M Tk)	Enhance (M Tk)			
8	1.00	4	22.22	4.17	82.0	2.14	0.08	2.44	0.89	0.15	0.35	0.22	0.566	0.055	1.13	94.19	22.76	116.95
9	1.00	4	22.22	4.17	82.0	2.14	0.08	2.44	0.89	0.15	0.35	0.22	0.566	0.055	1.13	94.19	22.76	116.95
10	1.00	4	22.22	4.17	82.0	2.14	0.08	2.44	0.89	0.15	0.35	0.22	0.566	0.055	1.13	94.19	22.76	116.95
11	0.90	4	20.00	3.75	73.8	1.92	0.08	2.20	0.80	0.13	0.31	0.20	0.509	0.049	1.017	84.77	22.76	107.53
12	0.90	4	20.00	3.75	73.8	1.92	0.08	2.20	0.80	0.13	0.31	0.20	0.509	0.049	1.017	84.77	22.76	107.53
13	0.90	4	20.00	3.75	73.8	1.92	0.08	2.20	0.80	0.13	0.31	0.20	0.509	0.049	1.017	84.77	22.76	107.53
14	0.80	4	17.78	3.33	65.6	1.71	0.07	1.96	0.71	0.12	0.28	0.18	0.453	0.044	0.904	75.35	22.76	98.11
15	0.80	4	17.78	3.33	65.6	1.71	0.07	1.96	0.71	0.12	0.28	0.18	0.453	0.044	0.904	75.35	22.76	98.11
16	0.80	4	17.78	3.33	65.6	1.71	0.07	1.96	0.71	0.12	0.28	0.18	0.453	0.044	0.904	75.35	22.76	98.11
17	0.80	4	17.78	3.33	65.6	1.71	0.07	1.96	0.71	0.12	0.28	0.18	0.453	0.044	0.904	75.35	22.76	98.11
18	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
19	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
20	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
21	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
22	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
23	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
24	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
25	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
26	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
27	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
28	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
29	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
30	0.80	4	17.78	0.73	65.6	0.00	0.01	0	0	0	0	0.04	0.453	0.044	0.904	67.78	22.76	90.54
TOTAL	19.3	85.78	428.89	46.57	1582.6	19.02	0.93	21.76	7.91	1.33	3.09	2.44	10.92	1.06	21.81	1719.44		

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10. PROJECT DESCRIPTION - ALTERNATIVE 2

10.1 Project Description

Figure C.58 shows the general arrangement of works in Alternative 2. With this alternative, the Issapur loop cut was eliminated and in its place, additional channel re-excavation was carried out along the Kalni River and Dhaleswari River.

A hydraulic analysis demonstrated that it would not be practical to achieve the same degree of channel improvements as Alternative 1 with Alternative 2. Additional dredging downstream of the Baida-Kalni bifurcation simply caused more flow to be diverted from the Baida channel back into the Kalni channel, which maintained the high water levels near Madna. In order to achieve approximately similar water levels at Issapur during a 1:2 year pre-monsoon flood, at least 9 million m^3 of material would have to be removed from the Dhaleswari channel, which would lower the bed levels by around 5 m. It was judged this magnitude of over-dredging would require excessive maintenance dredging in order to sustain the increased conveyance. Therefore, it was decided to re-excavate the channel only to the typical bed level that existed in this reach during the 1960's prior to sediment infilling. This also ensured that a Class II navigation channel would be maintained in this reach during the dry season.

Table C.34 summarizes the main components of Alternative 2. All improvements upstream of Issapur are identical to Alternative 1. Therefore, in this chapter only those components that have been modified from Alternative 1 are described.

10.2 River Re-excavation on Dhaleswari River

The adopted dredge grade for the Dhaleswari Reach was as follows:

- bed width 100 m, and
- design grade: El. -3.0 m.

Figure C.58 summarizes the location and extent of the channel excavation work and the disposal sites for Alternative 2. Based on a review of the hydrographic survey data, additional channel re-excavation will be required on 3 reaches of the Dhaleswari River:

- Km 55-59 on Dhaleswari River near Shibpur;
- Km 61-65 on Dhaleswari River near Madna, and
- Km 67-71 on Kalni River near Islampur.

Table C.78 summarizes the channel re-excavation that is proposed on the Dhaleswari channel. Alternative II will require an additional of about 1.0 million m^3 of channel re-excavation along the lower Kalni/Dhaleswari River between Kalma and Issapur. This will increase the average cross sectional area by approximately 400 m^2.

Table C.78: Channel Re-excavation on Dhaleswari River

Location	Reach (km)	Grade Level (m PWD)	Excavated Volume (m³)
Shibpur	55.0-59.0	-3	650,000
Madna	61.0-65.0	-3	700,000
Islampur	67.0-71.0	-3	300,000
Total			**1,650,000**

Figures C.58 and C.59 show tentative locations for new village platforms associated with excavating the reach between Kalma and Issapur. Table C.79 summarizes information on the platform characteristics in each reach. With this alternative six additional platforms will be constructed. Of these, one platform will be constructed near Shibpur (Site 3) and the remaining five platforms will be constructed between Madna and Issapur (Sites 5 to 9, Figure C.59). The 6 new village platforms in this reach will cover an additional area of 19.0 ha.

Table C.79: Summary of Channel Re-excavation and Village Platforms - Alternative 2

Location	Reach (km)	Grade Level (m PWD)	Excavated Volume (m³)	Village Platform Statistics		
				Total Platform	Disposal Sites	Area (ha)
Shibpur	55-59	-3	650,000	3	3-5	15.3
Madna	61-65	-3	700,000	3	6-9	8.3
Islampur	67-71	-3	300,000	2	10-11	7.1
Issapur	72.7-76.5	-3.0	1,370,000	8	6-13*	28.0
	76.6-79.0	-3.0	710,000	4	14-17	16.0
Abdullahpur	79.0-81.0	-3.0	951,000	4	18-21	24.8
Kalimpur	81.0-83.0	-3.0	764,000	2	22-23	18.1
Kadamchal	84.5-86.5	-2.5	426,000	1	26	9.5
Rahala	97.5-98.8	-2.0	670,000	2	38-39	18.6
Kakailseo	98.8-102.3	-2.0	543,000	2	40-41	6.4
Shahebnagar	102.3-104.5	-2.0	572,000	3	42-44	13.0
Ajmiriganj	104.5-107.0	-2.0	448,000	3	45-47	9.83
Total			**8,104,000**	**34**		**174.3**

Note: * indicated the nos from Alternative 1.

In Alternative 1, it was proposed to defer channel excavation upstream of Issapur between Km 72.5 - Km 77. This was done to allow upstream degradation from the Issapur loop cut to partially lower the bed levels and reduce the excavation volumes that are required to achieve the design grade. In Alternative 2, the reach between Km 72.5-77 will have to be dredged in order to achieve the required design grade.

10.3 Schedule - Alternative 2

Alternative 2 will require a minimum of 7 years to complete construction of the main physical components. Therefore, eliminating the Issapur loop cut will not shorten the project's overall duration from Alternative 1.

10.4 Operations and Maintenance - Alternative 2

With Alternative 2, continuous maintenance dredging will be required along the Dhaleswari River between Kalma and Issapur (Km 52-72) on the Dhaleswari River, from downstream of Abdullahpur to Kalimpur on the lower Kalni River (Km 76-82) and downstream of Katkhal loop cut from Bishorikona to Kadamchal (Km 87-85). Table C.80 provides estimates of maintenance dredging requirements along the river. Over the 30 year period the total maintenance dredging will amount to 34.8 million m^3.

Table C.80: Maintenance Dredging After Project Completion

Location	**Reach (Km)**	**Maintenance dredging (m^3/year)**
		Alternative 2
Kalma	47-52	
Shibpur	54-58	200,000
Adampur	63-66	300,000
Islampur	68-71	275,000
Issapur	70-72.5	300,000
Abdullahpur		680,000
Navigation Dredging		125,000
Total		**1,800,000**

11. QUANTITY AND COST ESTIMATES ALTERNATIVE 2

11.1 Capital Costs

Total project costs are estimated to be Tk 2,366.46 million for Alternative 2, including costs of mitigative measures, compensation plan and enhancement program. A breakdown of the costs by component is shown in Table C.81. These costs were estimated on the basis of *FPCO Guidelines*. Detailed quantity and cost estimates have been provided in Tables C.82 and C.83.

Unit rates for earthwork, structures and other associated items have been taken from BWDB's 1995 Schedule of Rates for Moulvibazar O&M Circle. Future dredging costs have been estimated assuming a unit cost of Tk 82/m^3 equivalent US$ 2/m^3. Cost of mitigative measures, compensation and enhancement program has been estimated on the basis of pilot project experiences.

Land costs reflect the current prices obtained from field interviews. High agricultural land *(boro)* in Issapur area was assumed to be priced at Tk 180,000/ha, high agricultural land *boro* in Katkhal and upstream reaches was priced at Tk 125,000/ha and lowlands on the downstream of Abdullahpur was priced at Tk 80,000/ha.

Physical contingencies equal to 15% of base construction costs as per *FPCO Guidelines* were used to cover unforeseen costs. Engineering costs (survey, design, preparation of implementation plan and tender documents, supervision of construction and administration) were estimated to be Tk. 291.8 million which is about 12% of base construction costs plus physical contingencies.

11.2 Operation and Maintenance Costs

The O&M costs are divided into 3 broad categories:

- annual maintenance dredging;
- physical components; and
- village platforms

The O&M costs were estimated on the basis of *FPCO Guidelines* and pilot project experience. These costs will cover cost of technical staff, departmental overheads, maintenance of physical components and replacement of items subject to normal wear and tear.

Annual Maintenance Dredging

Costs of annual maintenance dredging associated with construction of disposal chambers and other related components including EMP have been estimated based on the adopted estimating procedure of capital costs. Estimated annual maintenance dredging and other associated costs are given in Table C.84.

Physical Components

Physical components mainly include: embankments, levees, closures structures, river bank protection and embankment slope protection (permanent) at Issapur and Katkhal. The O&M costs of these physical components have been calculated as a percentage of capital costs on the basis of FPCO *Guidelines*. The breakdown of these costs is given below:

- embankments, levees & closures: 6%;
- structure: 3%;
- river bank protection: 10%, and
- slope protection: 3%.

Village Platforms

This activity mainly includes post-monsoon platform dyke repairs and protection against wave erosion through the traditional methods which is termed as soft protection. Maintenance of village platforms has been placed under the following 2 categories:

- first year program; and
- three years program.

The first year maintenance program will be carried out by the contractor who constructed the confinement dykes. Cost of soft protection was estimated on the basis of Pilot Project experience. Costs of soft protection during the implementation stage have been included in the capital costs as O&M during construction.

The concept of a subsequent 3 year program has been developed based on the Pilot Dredging Project experience. This program states that the village platforms will be maintained jointly by the project authority and the beneficiary households. Beneficiary households will assure their contribution of labour and materials for soft protection. After the 3 year program, the platforms will be maintained by the beneficiaries themselves (Annex D - Social).

The costs of a 3 year program during the implementation stage have been estimated on the basis of the Pilot Dredging Project experience and is also included in the capital cost.

The costs of first year and three year programs associated with the annual maintenance dredging have been included in the annual O&M costs.

Physical contingencies equal to 15% of base costs as per FPCO Guidelines were used during the economic evaluation to cover unforeseen costs.

Table C.81: Summary of Capital Costs - Alternative 2

Sl #	Item	Quantity	Unit	Total Cost (M Tk)
1	Channel Dredging	8.268	Mm3	677.98
2	Channel Re-alignment			
	Manual	0.14	Mm3	10.78
	Dredging	0.3	Mm3	24.6
3	Katkhal Loop Cut			
	Dredging	3.22	Mm3	264.05
	Manual Earthwork	1.25	Mm3	79.41
	Slope Protection-Soft	81000	m2	10.53
	Slope Protection-Hard	92800	m2	92.92
	Closure	2	Nos	17.47
	Temporary Bank Protection	2	Nos	6.62
	Permanent Bank Protection	1	No	42.39
4	Madna Closures	2	Nos	1.45
5	River Training	3	Nos	110.67
6	Levees	24	km	10.86
7	Homestead Platforms			
	Confinement Dyke	2.49	m^3	109.2
	Slope Protection-Soft			
	First Year	37593	m	18.94
	Three Years	60846	m	30.70
	Slope Protection-Hard	17257	m	138.23
	Dyke Repair	109.2	M Tk	2.07
	Drains-Stairs	183	Nos	18.3
	Levelling	232	ha	5.80
	Topsoil	232	ha	25.52
	Effluent Outlet-Constr.	58	Nos	1.45
	Effluent Outlet-Filling	58	Nos	1.45
8	Drainage Regulator			23.17
9	EMP			
	Mitigation			11.56
	Compensation			0.71
	Enhancement			29.93
	Training			0.5
	Monitoring			6.9
	BASE COST:			**1,774.16**
10	Physical Contingency			266.12
	(15% of Base Cost)			
	SUB-TOTAL:			**2,040.28**

Table C.81: Summary of Capital Costs - Alternative 2 (Contd.)

11	Study Cost			291.80
12	Land Acquisition			
	Issapur Loop Cut	0	ha	0.00
	Katkhal Loop Cut	195	ha	24.38
	Levees and Structures	35	ha	4.20
	Navigation	3	ha	0.72
	Anandapur	13	ha	1.56
	Abdullahpur	44	ha	3.52
	TOTAL:	**290**	**ha**	**2,366.46**

Table C.82: Volume and Cost Estimates of Confinement Dykes - Alternative-2

Dis-posal No	Name	Area (ha)	Length (m)		Unit (m^3/m)		Volume (m3)		Total (m^3)
			Home	Free	Home	Free	Home	Free	
3	Shibpur	5.43	614	750	65	32	39,910	24,000	63,910
4	Shibpur	6.72	1,427	347	65	32	92,755	11,104	103,859
5	Shibpur	3.03	460	610	65	32	29,900	19,520	49,420
6	Madna	58.00	0	0	0	0	0	0	0
7	Sharifakandi	2.00	0	458	65	32	18,330	14,656	32,986
8	Dargahati	3.87	425	598	65	32	27,625	19,136	46,761
9	Adampur	2.38	991	215	65	32	64,415	6,880	71,295
10	Laura	3.50	139	687	0	32	0	0	31,019
11	Islampur	0.00	319	501	65	32	20,735	16,032	36,767
12	Issapur	3.50	0	752	65	32	0	24,064	24,064
13		0.00	0	752	65	32	0	24,064	24,064
14		3.50	0	752	65	32	0	24,064	24,064
15		3.50	0	752	0	32	0	24,064	24,064
16		3.50	0	752	65	32	0	24,064	24,064
17	To	3.50	0	0	65	0	0	24,064	24,064
18		3.50	0	752	65	32	0	24,064	24,064
19		3.50	0	752	65	32	0	24,064	24,064
20		4.00	0	752	65	32	0	24,064	24,064
21		4.00	0	752	65	0	0	0	24,064
22	Downstream of	0.00	0	752	65	32	0	0	0
23	Abdullahpur	0.00	0	752	65	32	0	24,064	24,064
24	Abdullahpur	7.52	636	927	65	32	0	0	0
25		9.14	1,224	292	65	32	79,560	9,344	88,904
26		8.06	996	549	65	32	64,740	17,568	82,308
27	To	1.56	148	362	65	0	0	11,584	21,204
28		0.00	211	489	65	32	13,715	15,648	29,363
29		8.08	634	695	65	32	41,210	22,240	63,450
30	Kalimpur	5.59	0	666	0	32	28,600	21,312	49,912
21		6.86	752	408	65	32	48,880	13,056	61,936
32	Kadamchal	2.82	619	303	65	32	40,235	9,696	49,931
33		9.50	0	1,263	65	32	47,710	40,416	88,126
35	Bishorikona	15.62	547	1,101	65	32	35,555	35,232	70,787
34		7.52	0	0	65	32	30,355	31,328	61,683
36		7.41	274	0	0	32	17,810	28,480	46,290
37		0.00	583	1,334	65	32	37,895	0	0
38	To	9.87	0	0	65	32	35,945	34,976	0
39		3.16	350	428	65	32	22,750	13,696	36,446
40		3.27	401	550	65	32	26,065	17,600	43,665
41		0.00	452	575	65	32	29,380	18,400	47,780
42		1.72	280	272	65	32	18,200	8,704	26,904
43	Shantipur	16.80	358	1,675	65	0	23,270	53,600	0
44	Rahala	0.00	0	674	0	32	24,505	21,568	46,073
45		12.77	0	1,694	65	32	0	54,208	54,208
46		3.00	300	500	0	0	19,500	16,000	35,500
47		3.43	0	785	65	32	0	25,120	32,335
48	To	2.50	393	393	65	32	25,545	12,576	38,121

Dis-posal No	Name	Area (ha)	Length (m)		Unit (m^3/m)		Volume (m3)		Total (m^3)
			Home	Free	Home	Free	Home	Free	
49		0.00	533	1,006	65	32	34,645	32,192	66,837
50		3.50	305	619	0	0	19,825	19,808	39,633
51		3.83	0	786	65	32	15,990	25,152	41,142
52		3.00	300	0	65	32	19,500	16,000	35,500
53	Ajmiriganj	3.00	300	500	65	32	19,500	16,000	35,500
	Sub-Total:	263.63	18,181	35,498	0	1,600	1,181,765	1,135,936	2,317,701
54-58	Navigation	25.69	0	5,520	65	32	0	176,640	176,640
	Total:	**289.32**	**18,181**	**41,018**	**3,315**	**1,632**	**1,181,765**	**1,312,576**	**0**
	Unit Cost = 43.78 Tk/m3					**Total Cost (million Tk):**			**109.20**

Notes: Home: Confinement dyke along the homestead
Free: Confinement dyke along the *haor*

Table C.83: Protection Type and Costs of Disposal Sites - Alternative 2

Dis-posal No	Name	Length (m)		Protection Ranking	Length (m)		PP	SP
		Home	Free		PP	SP	(000' Tk)	(000' Tk)
3	Shibpur	614	750	PP+SP	691	59	5,534.97	29.50
4	Shibpur	1,427	348	PP	348		2,787.51	0.00
5	Shibpur	460	610	PP	610		4,886.15	0.00
6	Madna	0	0	0	0	0	0.00	0.00
7	Sharifakandi	282	458	SP		458	0.00	229.00
8	Dargahati	425	598	PP+SP	93	505	744.94	252.50
9	Adampur	991	215	SP		215	0.00	107.50
10	Laura	139	687	PP	687		5,502.92	0.00
11	Islampur	0	501	PP+SP	300	201	2,403.02	100.50
12	Issapur	0	824	PP	824		6,600.31	0.00
13		0	824	PP	824		6,600.31	0.00
14		0	824	PP	824		6,600.31	0.00
15		0	824	PP	824		6,600.31	0.00
16		0	824	PP	824		6,600.31	0.00
17	To	0	824	PP	824		6,600.31	0.00
18		0	824	PP	824		6,600.31	0.00
19		0	824	PP	824		6,600.31	0.00
20		0	824	PP	824		6,600.31	0.00
21		0	824	PP	824		6,600.31	0.00
22	Downstream of	0	824	PP	824		6,600.31	0.00
23	Abdullahpur	0	824	PP	824		6,600.31	0.00
24	Abdullahpur	636	927	PP+SP	140	740	1,121.41	370.00
25		1,224	292	PP+SP	200	92	1,602.02	46.00
26		0	549	SP		549	0.00	274.50
27	To	148	362	SP		362	0.00	181.00
28		0	489	PP+SP	140	349	1,121.41	174.50
29		0	695	PP+SP	280	415	2,242.82	207.50
30	Kalimpur	440	666	PP+SP	425	241	3,404.28	120.50
21		0	408	PP+SP	100	308	801.01	154.00
32	Kadamchal	619	303	PP+SP	120	183	961.21	91.50
33		734	1,263	PP+SP	250	1,013	2,002.52	506.50
35	Bishorikona	547	1,640	PP+SP	470	1,170	3,764.74	585.00
34		467	979	PP+SP	250	729	2,002.52	364.50
36		274	890	SP		890	0.00	445.00
37		583	1,334	SP		1,334	0.00	667.00
38	To	553	1,093	SP		1,093	0.00	546.50
39		350	428	PP+SP*		428	0.00	214.00
40		401	550	None			0.00	0.00
41		0	575	SP		575	0.00	287.50
42		280	272	SP		272	0.00	136.00
43	Shantipur	0	1,675	SP		1,675	0.00	837.50
44	Rahala	0	674	PP+SP	400	274	3,204.03	137.00
45		0	1,694	PP+SP	630	650	5,046.35	325.00
46		300	500	PP+SP	300	200	2,403.02	100.00
47		111	785	PP+SP	585	200	4,685.90	100.00

Dis-posal No	Name	Length (m)		Protection Ranking	Length (m)		PP	SP
		Home	Free		PP	SP	(000' Tk)	(000' Tk)
48	To	393	393	SP		393	0.00	196.50
49		533	1,006	SP		1,006	0.00	503.00
50		305	619	SP		619	0.00	309.50
51		246	786	PP+SP	350	436	2,803.53	218.00
52		300	500	SP		500	0.00	250.00
53	Ajmiriganj	300	500	SP		500	0.00	250.00
	Sub-Total:	**18,181**	**36,902**		**17257**	**1,8634**	**138,229.951**	**9,317.00**
54-58	Navigation	0	1,648	SP		1,648	0.00	824.00
	Total:	**18,181**	**38,550**		**17257**	**2,0282**	**138,229.951**	**10,141.00**
First Year Soft Protection				**SP**		**3,7539**	**0**	**189,384.26**
Three Year Soft Protection				**SP**		**6,0846**	**0**	**306,968.07**

Notes: PP = Permanent Protection ("Hard")
SP = Soft Protection

Table C.84: O&M and EMP Costs Analysis Kalni-Kushiyara River Management Project
Alternative 2

Year	Volume Mm3/yr	No Dipos. Sites	Total Area (ha)	Cost Dyke (M Tk)	Cost Dredg. (M Tk)	Cost Protec-tion (M Tk)	Dyke O&M (M Tk)	Topsoil (M Tk)	Stairs Drains (M Tk)	Soft Ist Yr (M Tk)	Soft 3 Year (M Tk)	Outlet Both (M Tk)	EMP Cost			Other Component (M Tk)	Total O&M (M Tk)
													Mitig. (M Tk)	Compens (M Tk)	Enhance. (M Tk)		
8	1.80	8	40.00	7.50	147.6	3.85	0.38	4.40	2.40	0.27	0.63	0.40	0.92	0.10	2.01	20.25	190.71
9	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
10	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
11	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
12	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
13	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
14	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
15	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
16	1.50	7	33.33	6.25	123.0	3.21	0.31	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
17	1.50	7	33.33	1.37	123.0	0	0.07	3.67	2.00	0.22	0.52	0.33	0.77	0.08	1.68	20.25	162.29
18	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
19	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
20	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
21	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
22	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
23	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
24	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
25	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
26	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
27	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
28	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
29	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
30	1.50	7	33.33	1.37	123.0	0	0.07	0				0.07	0.77	0.08	1.68	20.25	147.28
TOTAL	34.8	154.67	773.33	76.65	2853.60	29.50	3.83	37.40	20.40	2.28	5.32	4.27	17.81	1.89	38.90	20.25	

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FIGURES

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Figure C.1

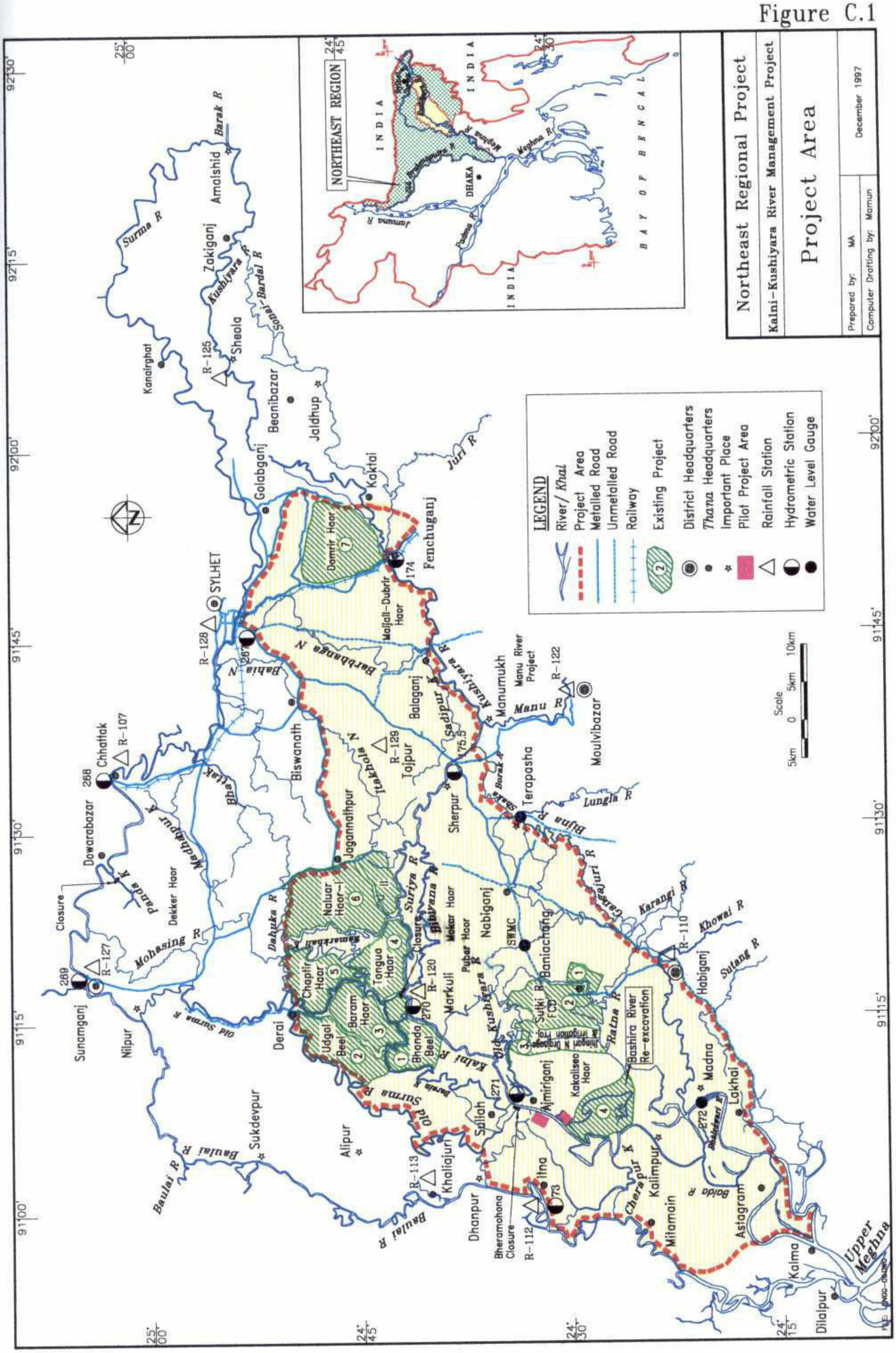
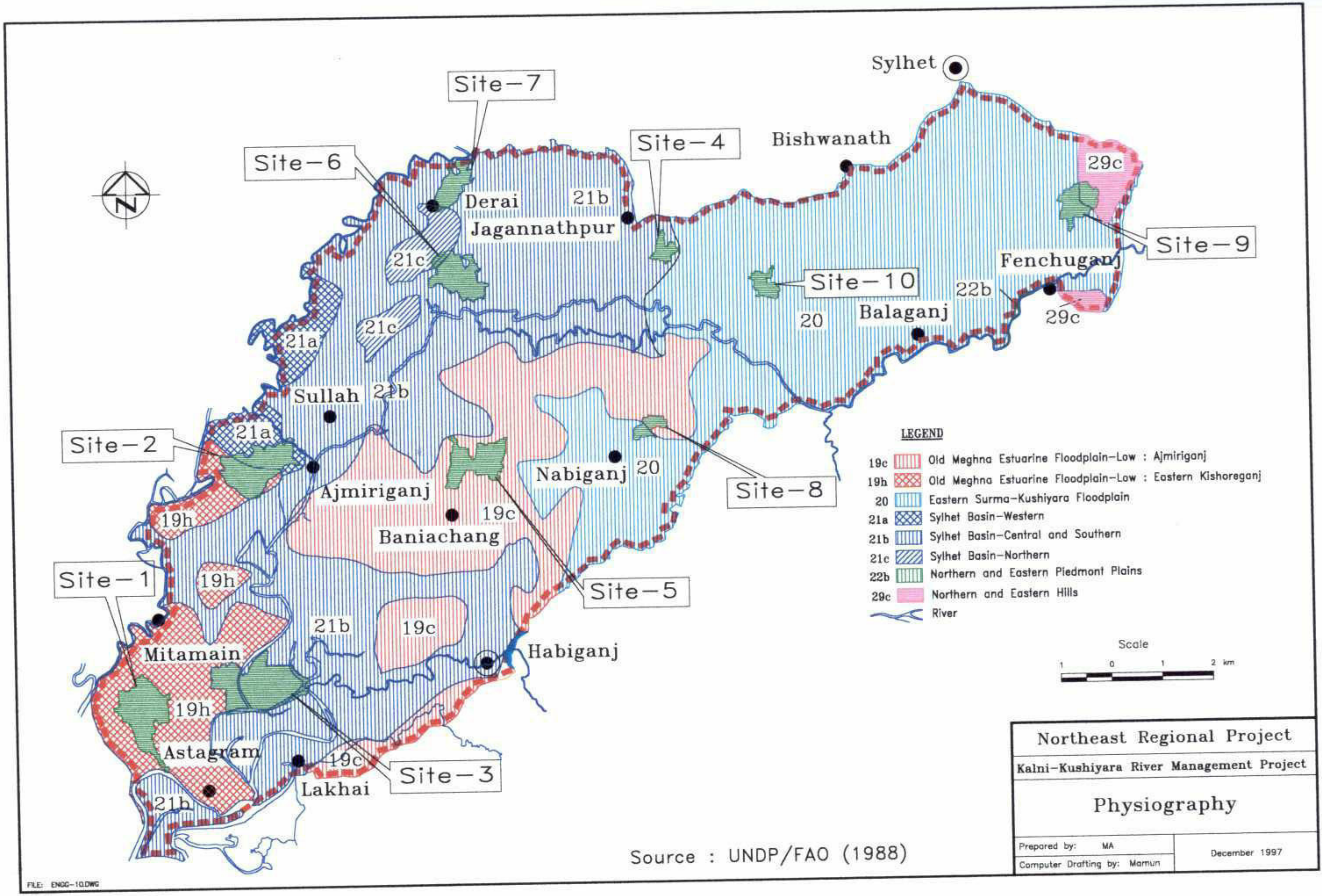


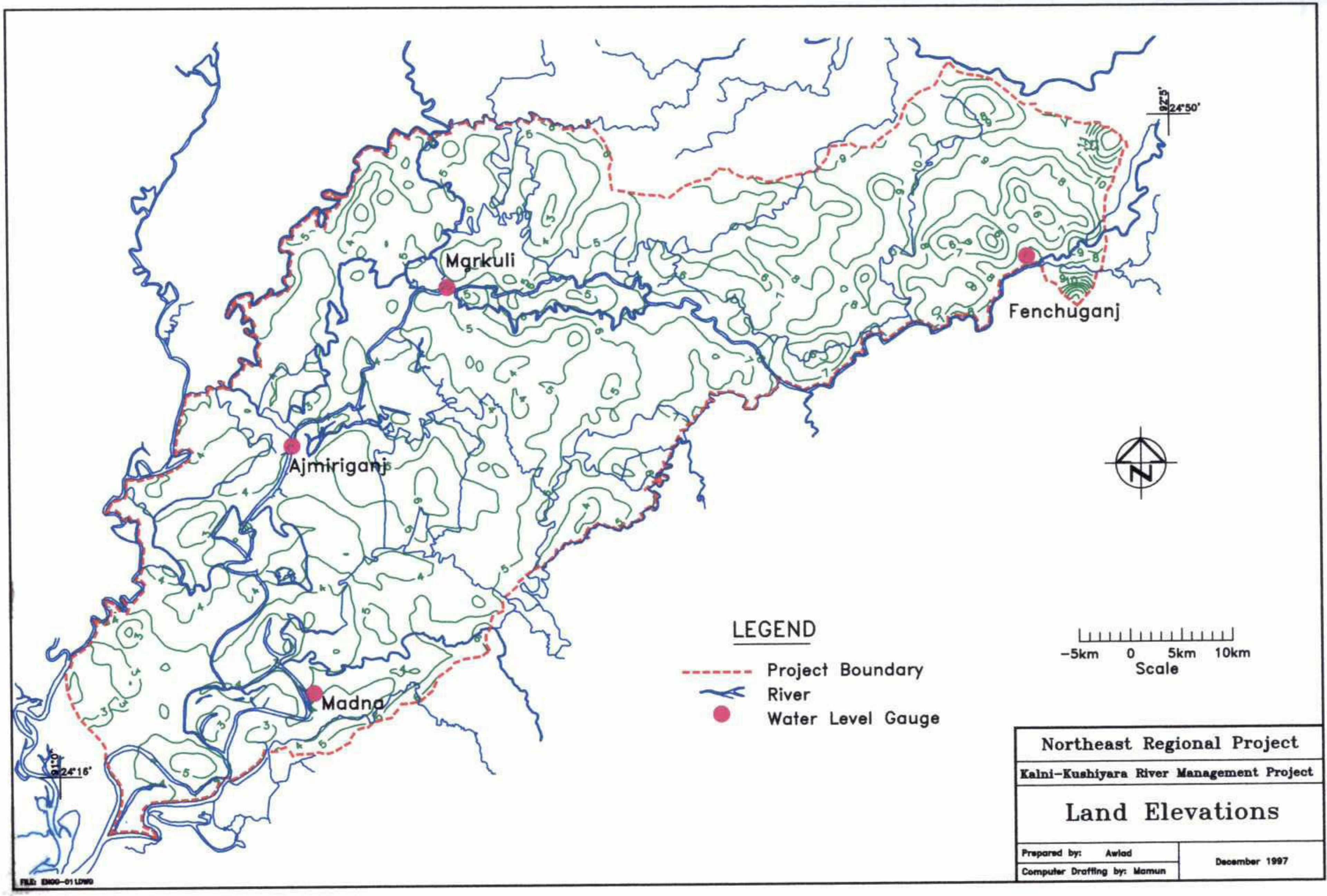
Figure C.2



Source : UNDP/FAO (1988)

Northeast Regional Project
Kalni−Kushiyara River Management Project
Physiography
Prepared by: MA
Computer Drafting by: Mamun
December 1997

Figure C.3



Northeast Regional Project

Kalni–Kushiyara River Management Project

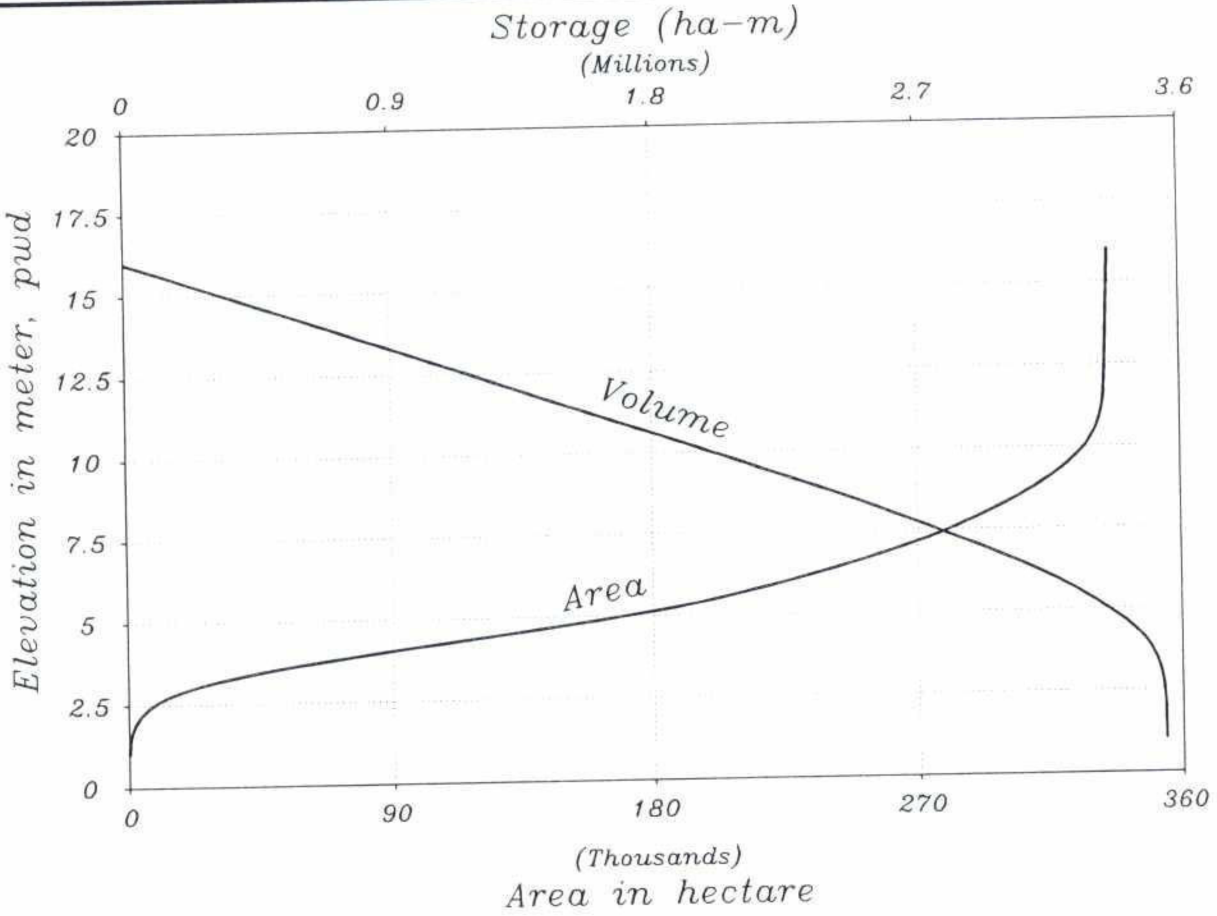
Land Elevations

Prepared by: Awlad

Computer Drafting by: Mamun

December 1997

Figure C.4



EL(m,PWD)	Area(ha)	Storage(ha−m)
1	0	0
2	202	101
3	8592	4498
4	80836	49212
5	178400	178830
6	228206	382133
7	267297	629885
8	294841	910954
9	314096	1215422
10	328297	1536619
11	333301	1867418
12	334033	2201085
13	334438	2535320
14	334791	2869935
15	335297	3204979
16	335600	3540427

Northeast Regional Project

Kalni−Kushiyara River Management Project

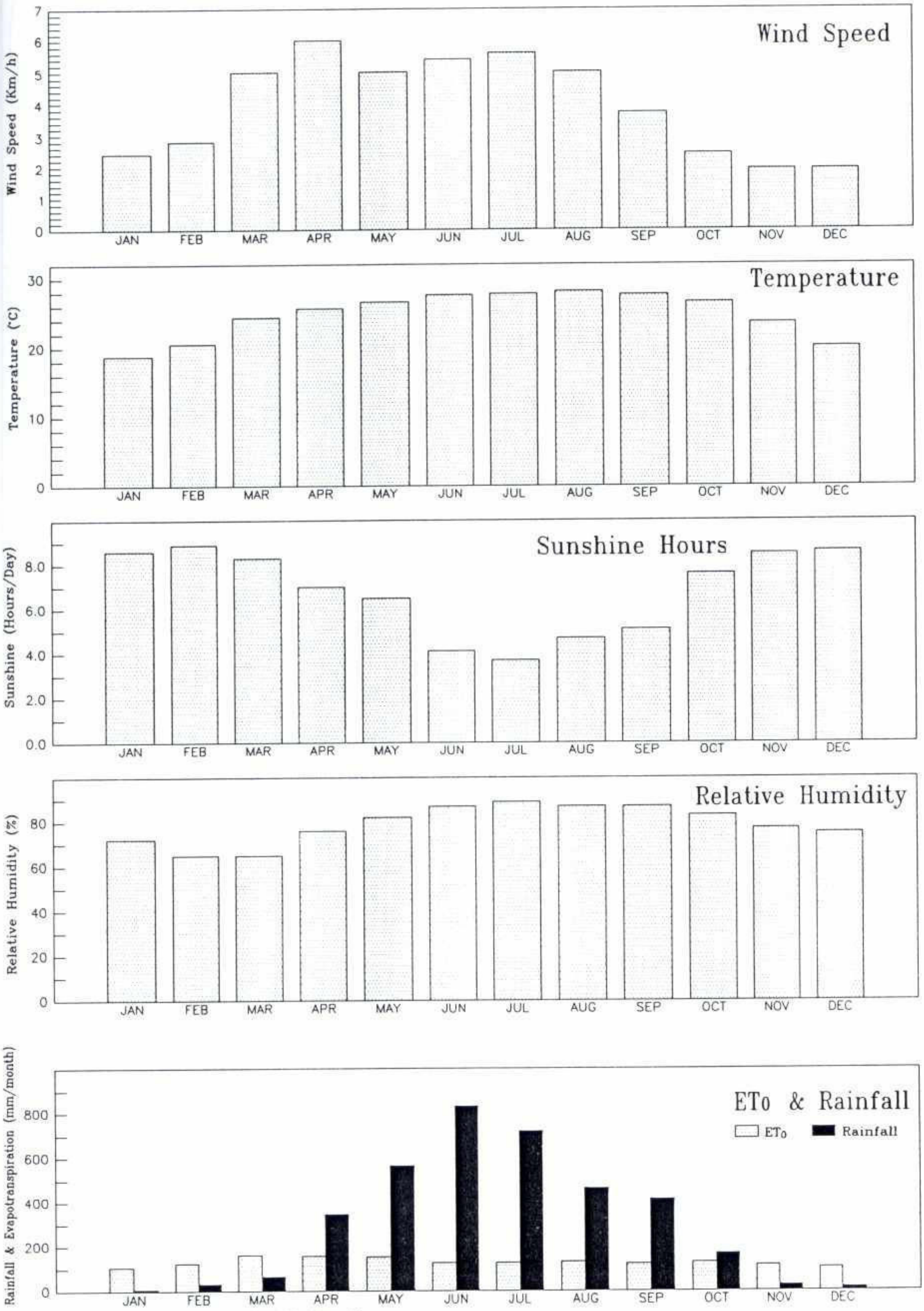
Elevation−Area−Storage

Prepared by: Tarek
Computer Drafting by: Tarek

December 1997

FILE: ENCC−12.DWG

Figure C.5



Rainfall Station No. R-120 (Markuli)

Climatic Conditions at Sylhet

Kalni-Kushiyara River Management Project

FILE: ENGG-13.DWG

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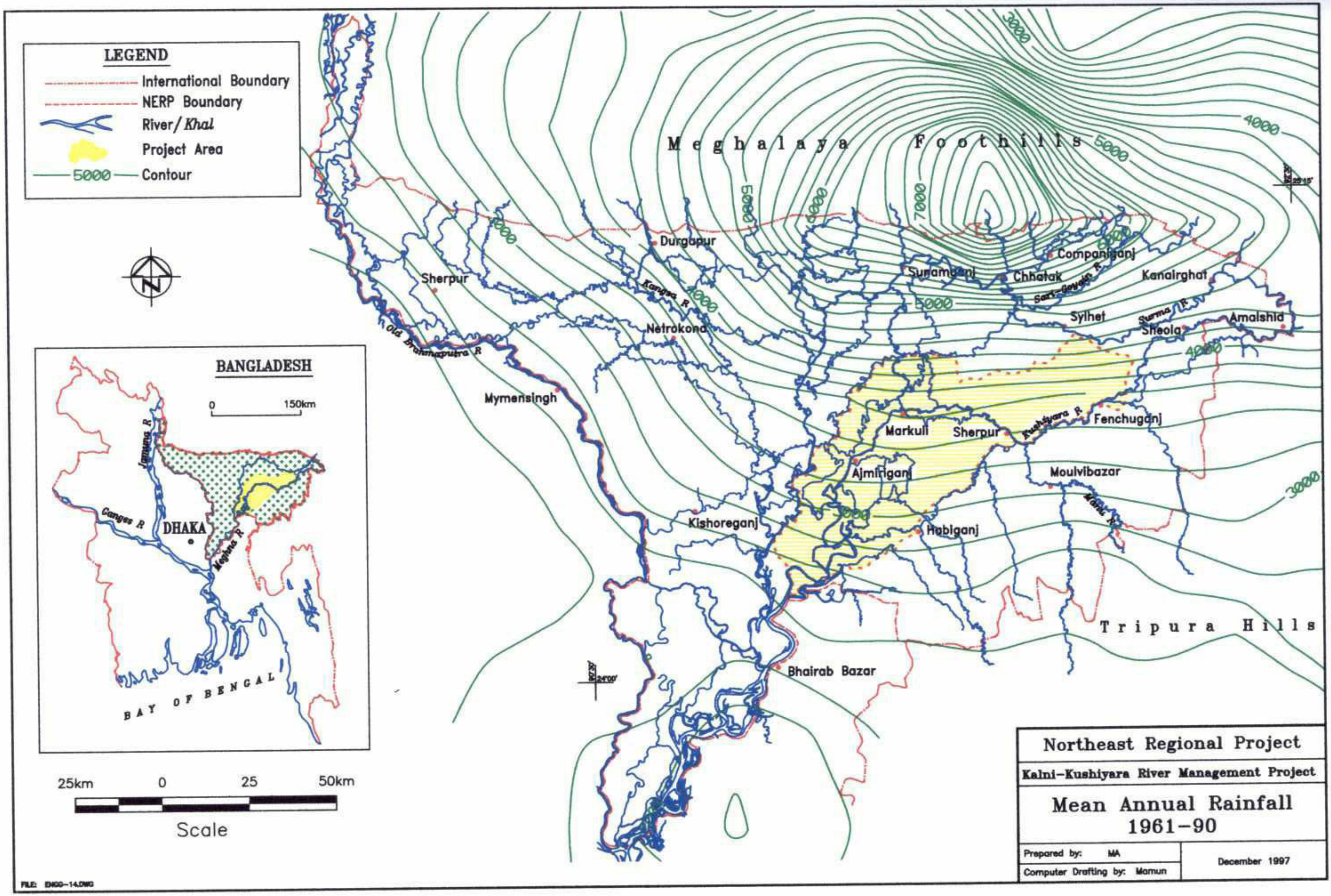
Figure C.6



Northeast Regional Project

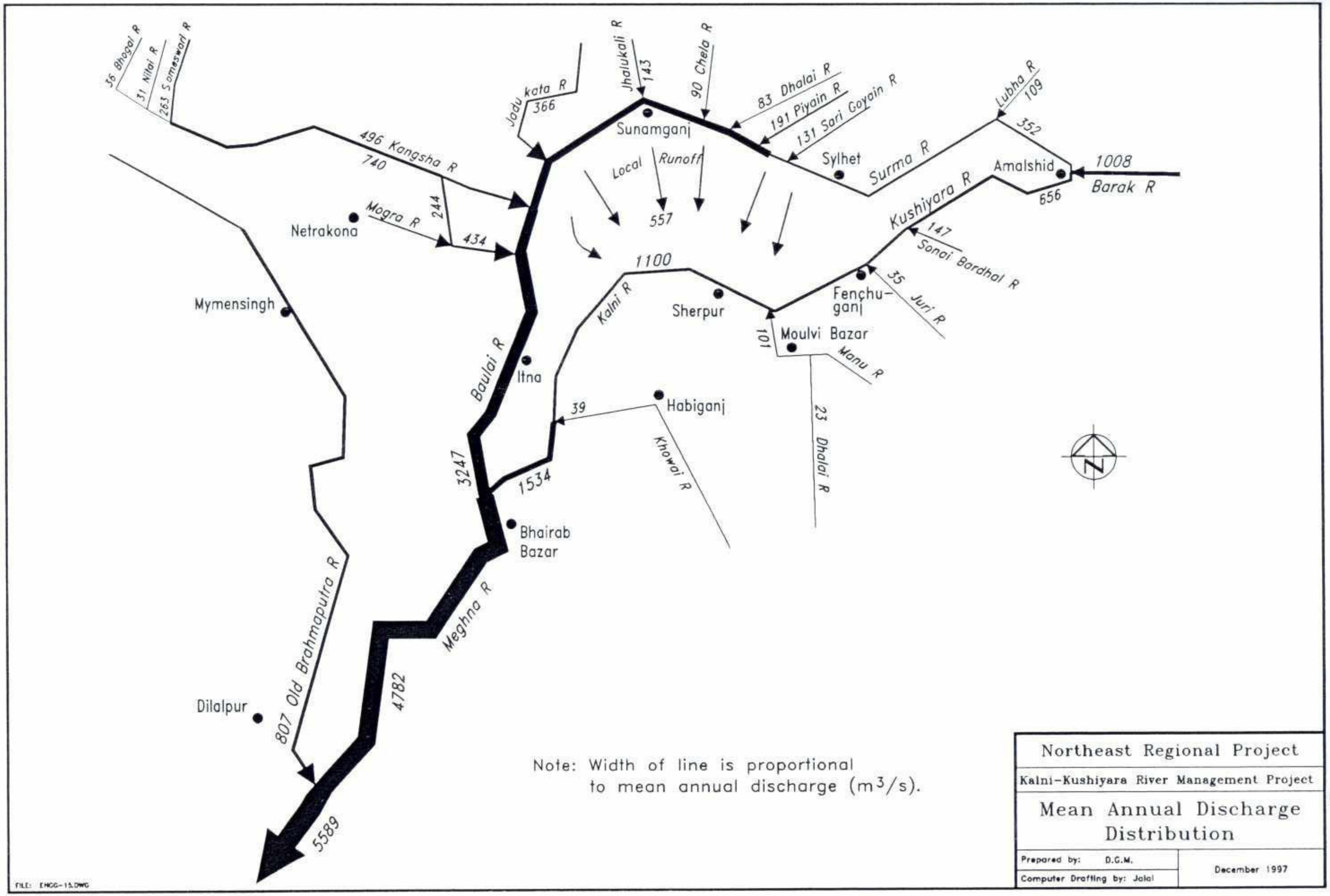
Kalni-Kushiyara River Management Project

Mean Annual Rainfall
1961–90

Prepared by: MA
Computer Drafting by: Mamun
December 1997

D84

Figure C.8



Note: Width of line is proportional to mean annual discharge (m^3/s).

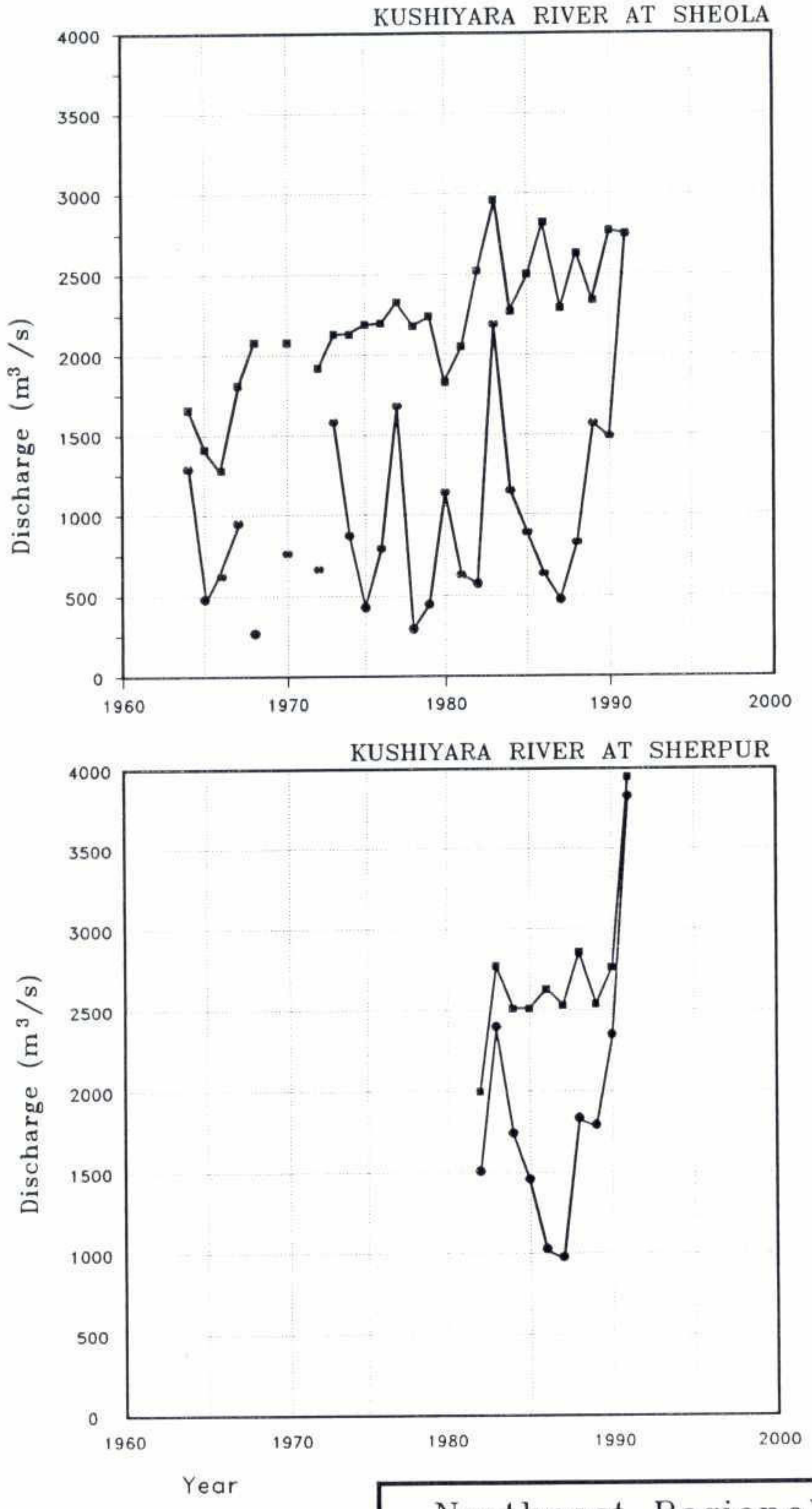
Northeast Regional Project

Kalni-Kushiyara River Management Project

Mean Annual Discharge Distribution

Prepared by: D.G.M.	December 1997
Computer Drafting by: Jalal	

Figure C.9



LEGEND
- ■ Annual Maximum
- ● Maximum in Pre-monsoon

Note:
Pre-monsoon season is period from March 1 – May 15

Northeast Regional Project

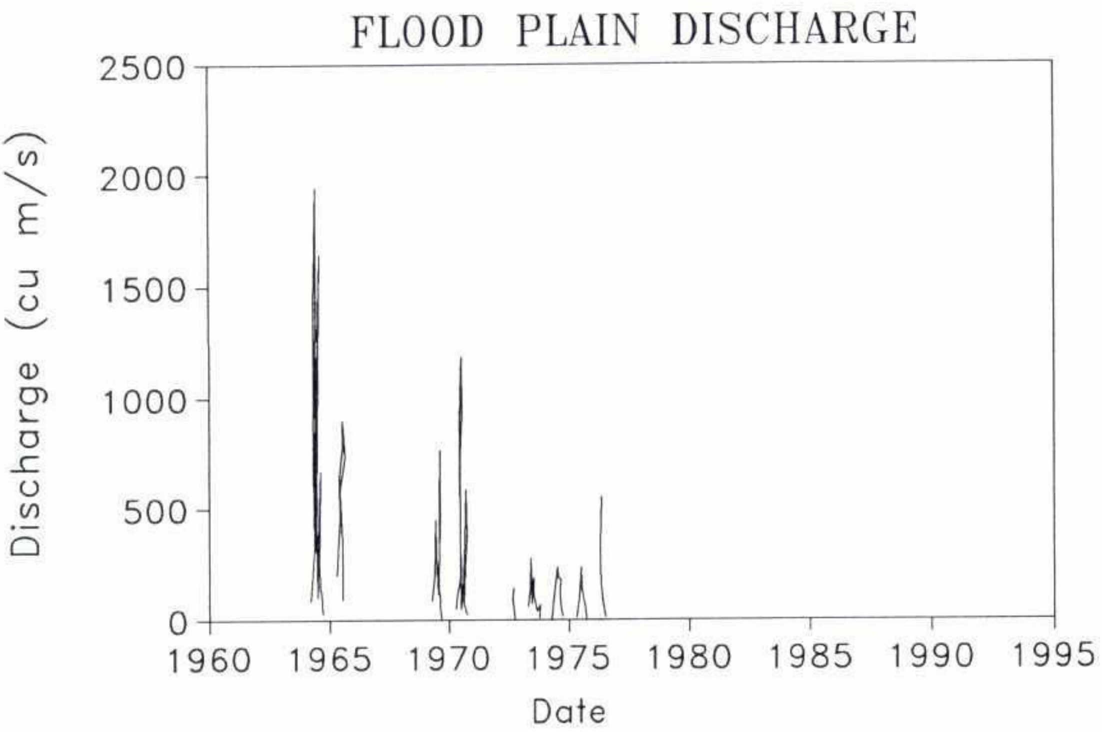
Kalni-Kushiyara River Management Project

Maximum Daily Discharges
Kushiyara River

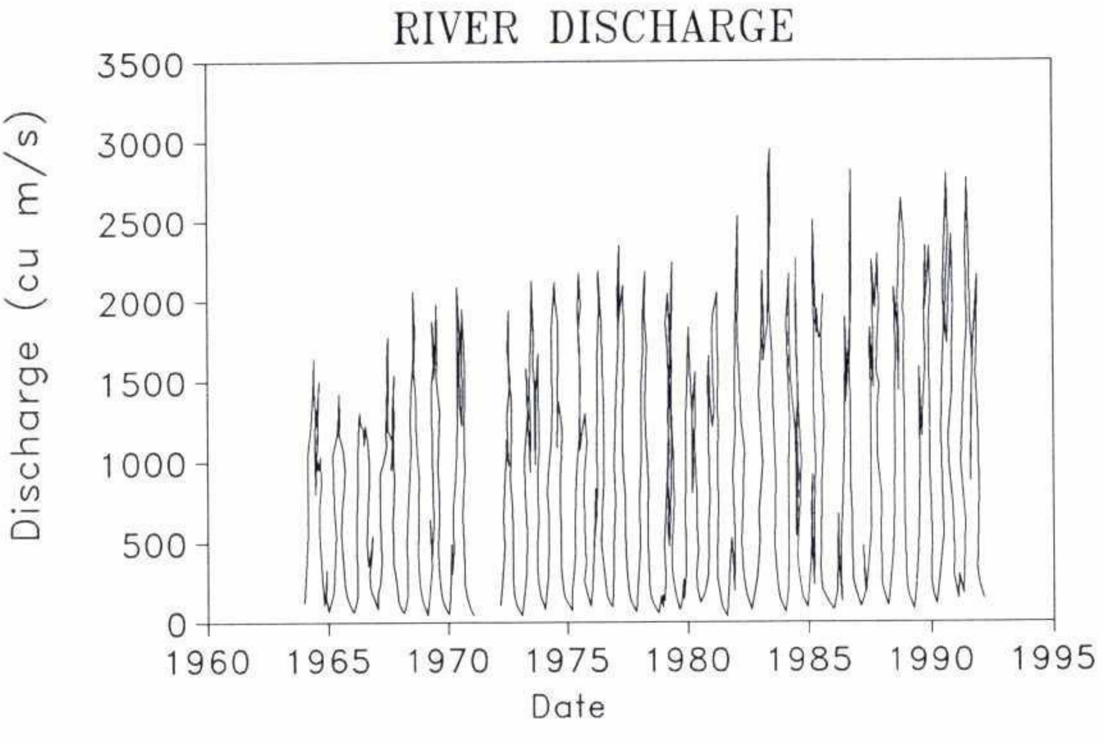
Prepared by: D.G.M.
Computer Drafting by: Mamun
December 1997

FILE: ENGG-16.DWG

Figure C.10



FLOOD PLAIN DISCHARGE



RIVER DISCHARGE

Northeast Regional Project

Kalni–Kushiyara River Management Project

Changing Flood Plain and Channel Flows Kushiyara River at Sheola

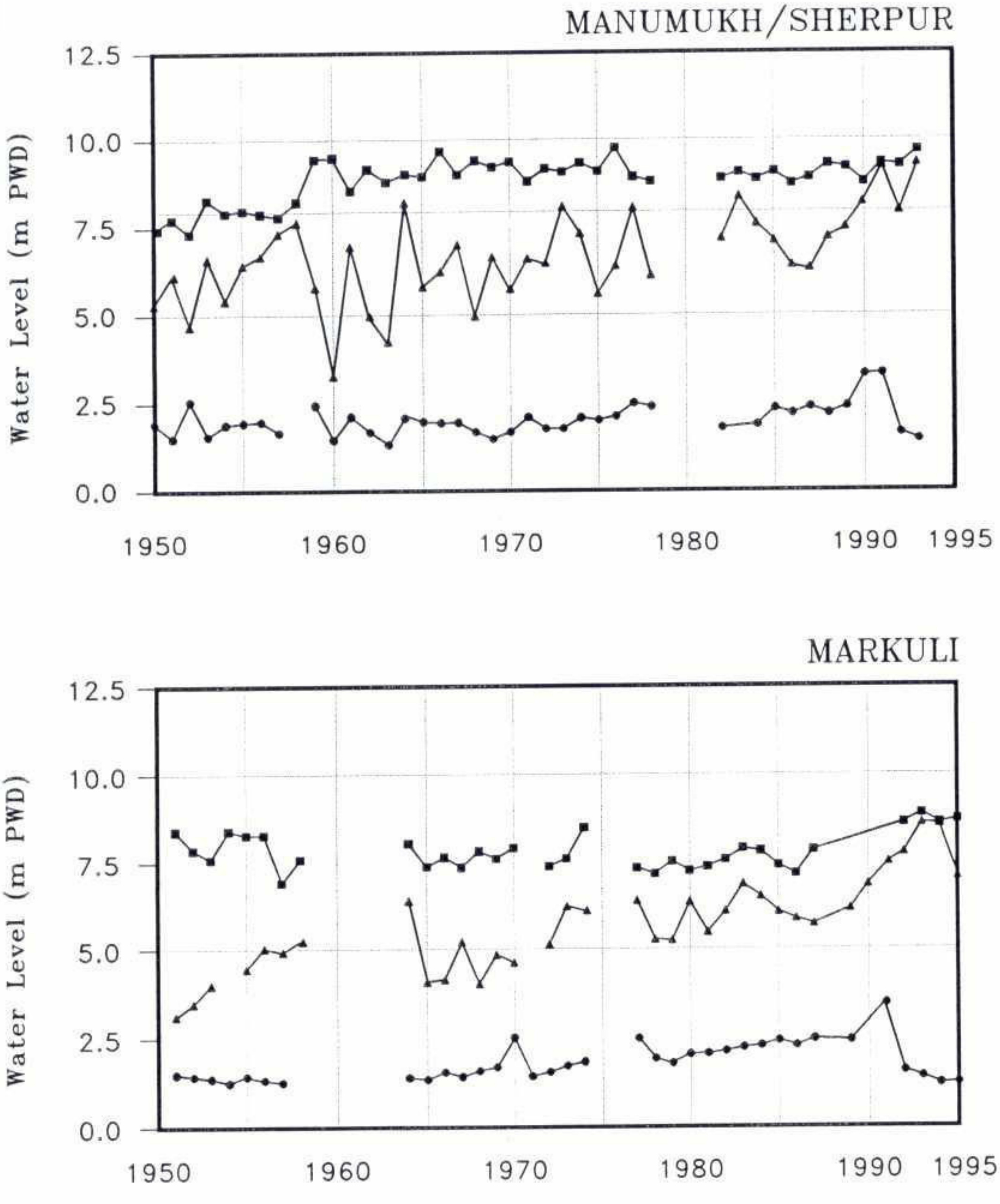
Prepared by: D.G.M.

Computer Drafting by: Mamun

December 1997

FILE: ENGG-59.DWG

Figure C.11



LEGEND

- ■ Annual Maximum
- ▲ Pre-Monsoon
- ● Minimum

Northeast Regional Project

Kalni-Kushiyara River Management Project

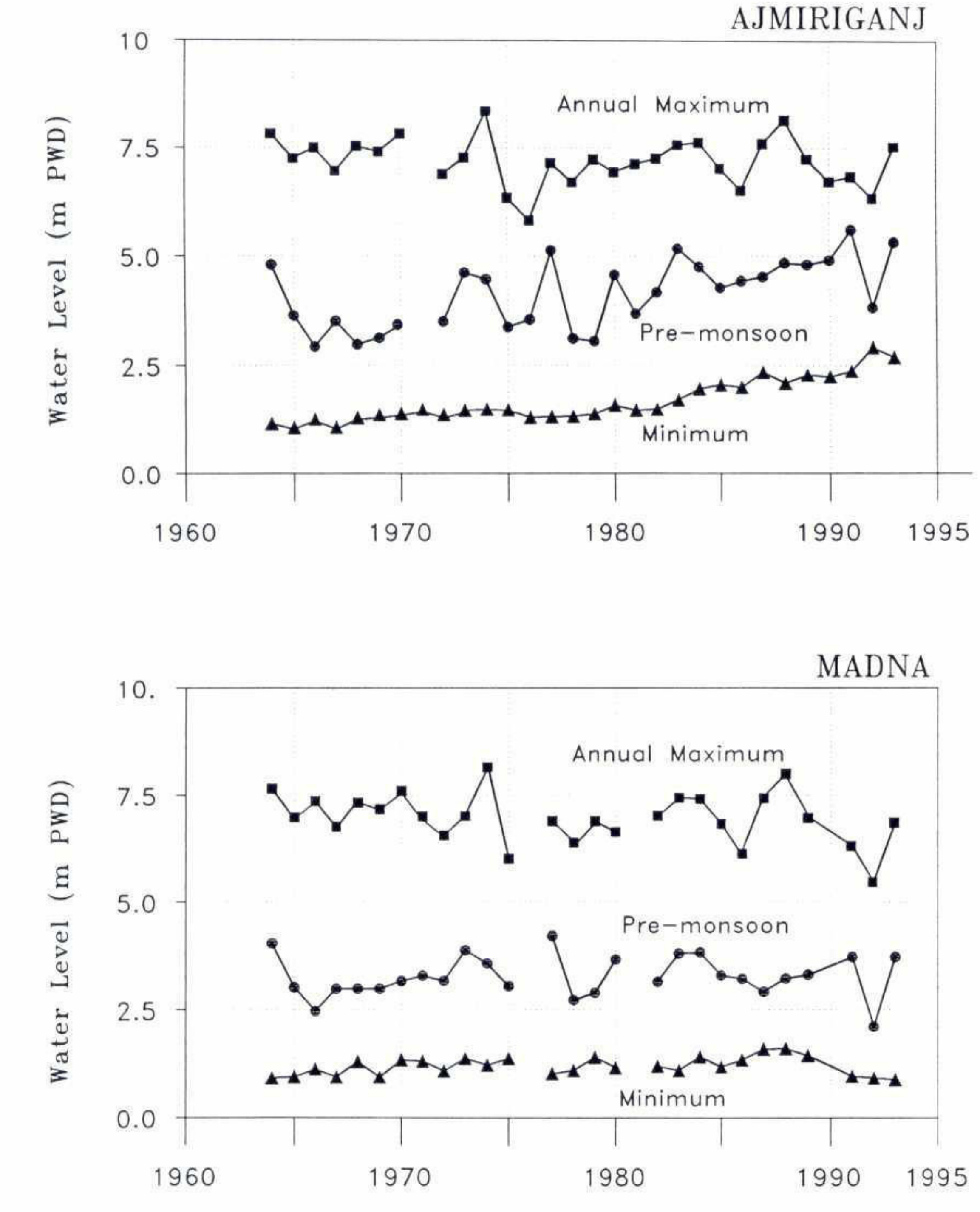
Annual Water Levels
Kushiyara River

Prepared by: D.G.M.
Computer Drafting by: Mamun

December 1997

FILE: ENGG-17.DWG

Figure C.12



LEGEND
- ■ Annual Maximum
- ● Pre-monsoon
- ▲ Minimum

Northeast Regional Project

Kalni-Kushiyara River Management Project

Annual Water Levels
Kalni River

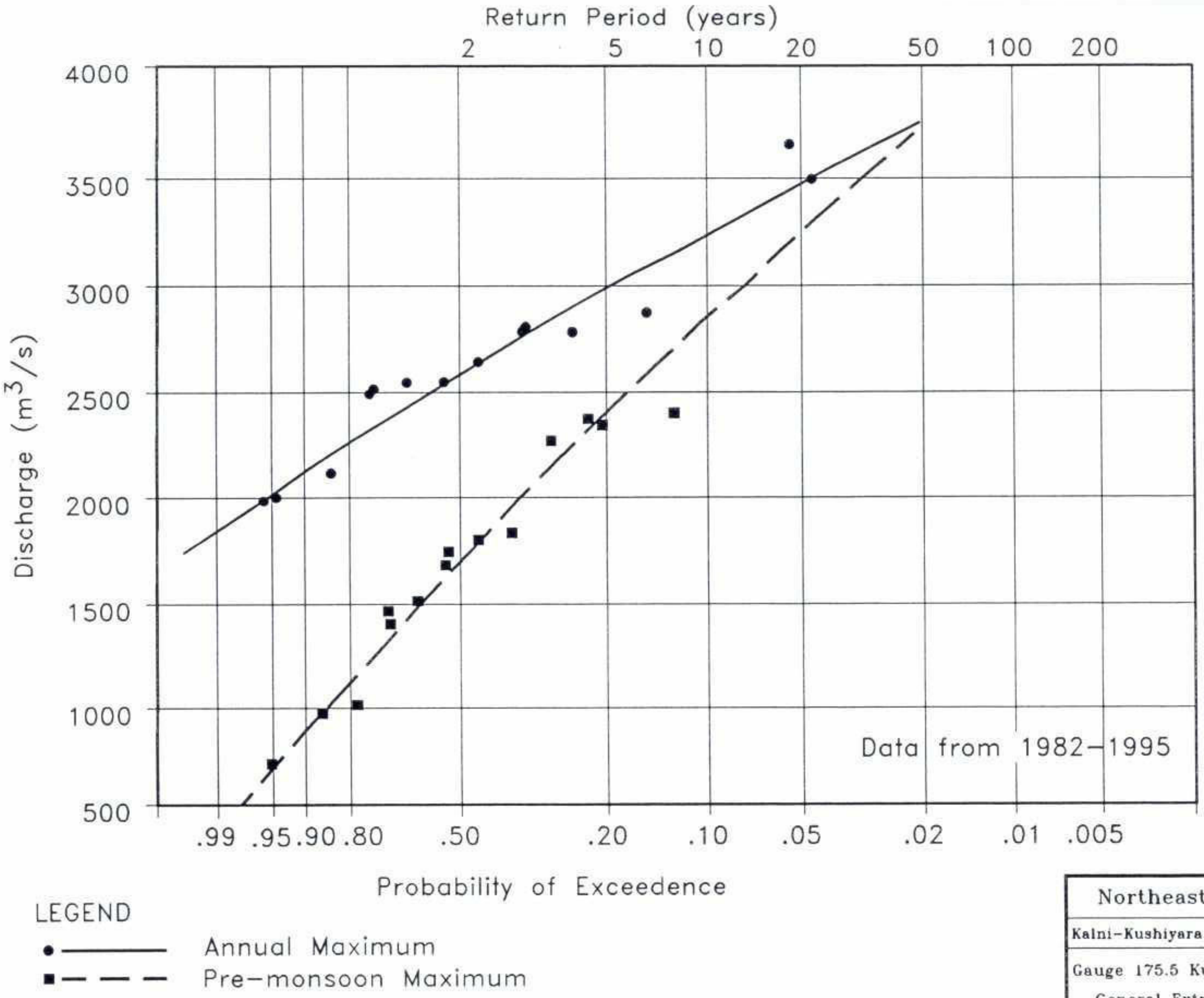
Prepared by: D.G.M.

Computer Drafting by: Mamun

December 1997

FILE: ENGG-18.DWG

Figure C.13



Northeast Regional Project

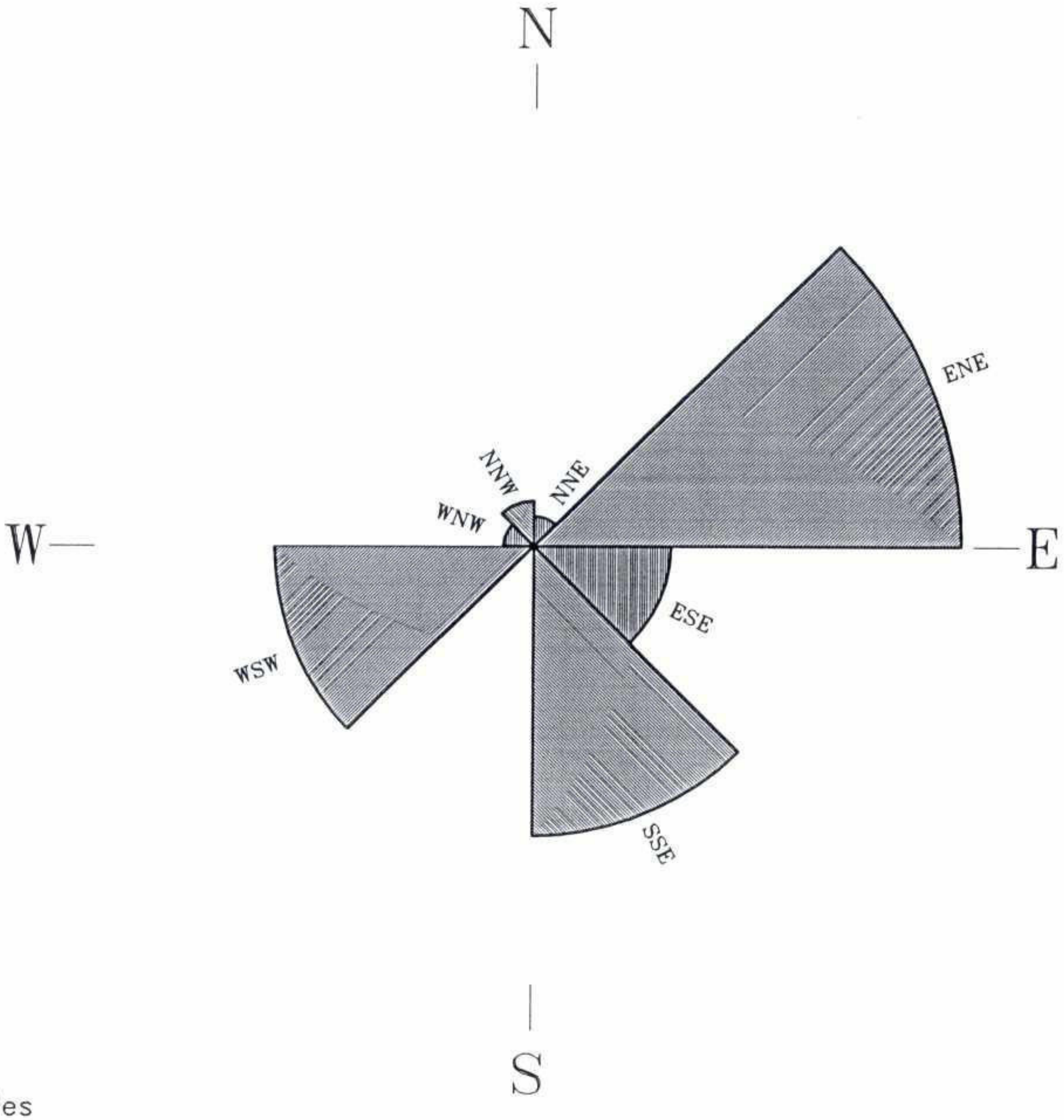
Kalni-Kushiyara River Management Project

Gauge 175.5 Kushiyara River at Sherpur
General Extreme Value Distribution

Prepared by: Tarek
Computer Drafting by: Mamun
December 1997

FILE: ENGG-19.DWG

202



Notes

1. Frequency of occurrence estimated from monthly maximum wind speed and direction measurement at Sylhet, 1966–1988.
2. Frequencies are computed for all occurrences exceeding 20 knots, for the months June–October.
3. Data provided by the Bangladesh Meteorological Department, Climate Division.

Northeast Regional Project

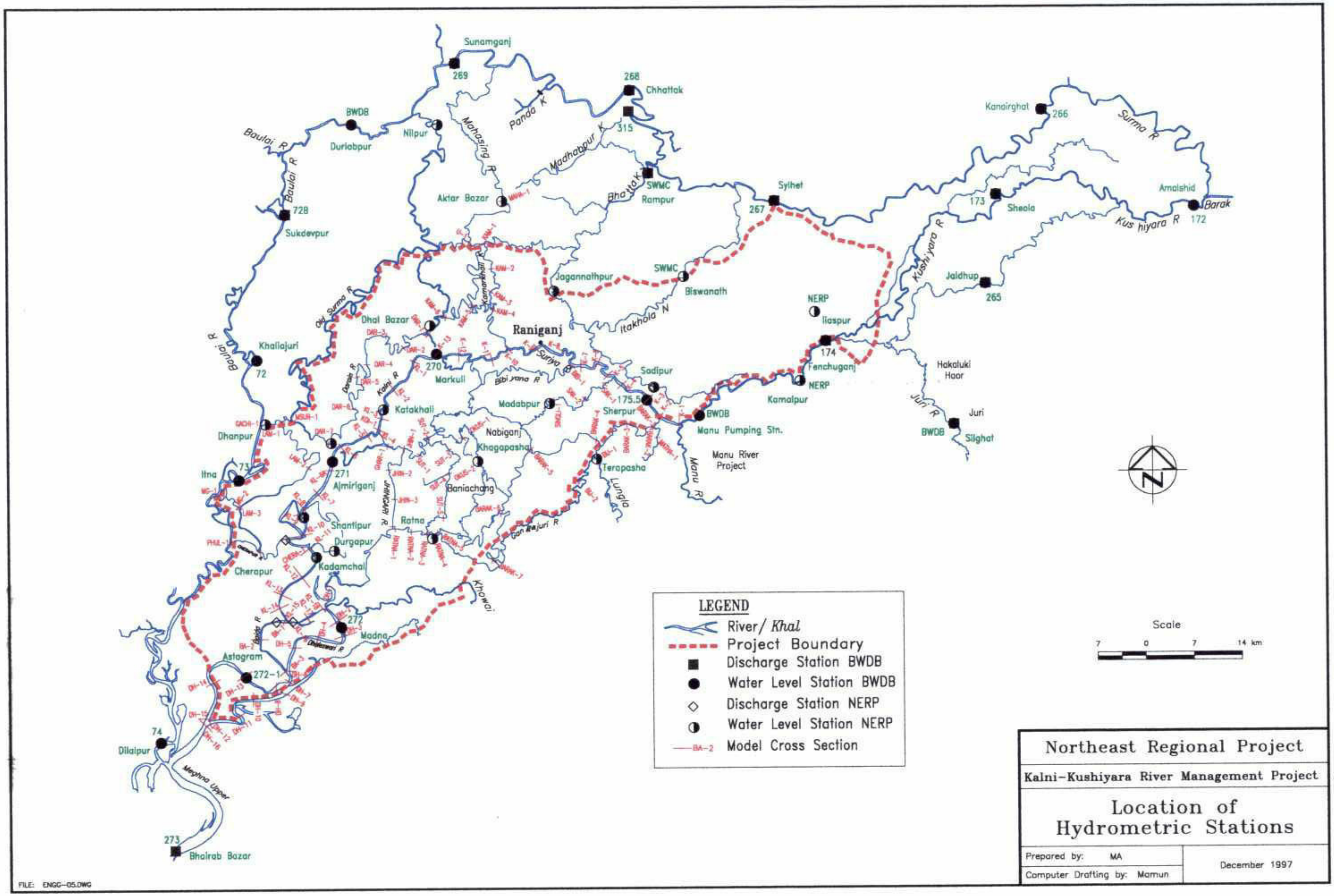
Kalni–Kushiyara River Management Project

Frequency of Extreme Winds at Sylhet

Prepared by: D.G.M.
Computer Drafting by: Jalal
December 1997

FILE: ENGG–20.DWG

Figure C.15



Northeast Regional Project

Kalni-Kushiyara River Management Project

Location of
Hydrometric Stations

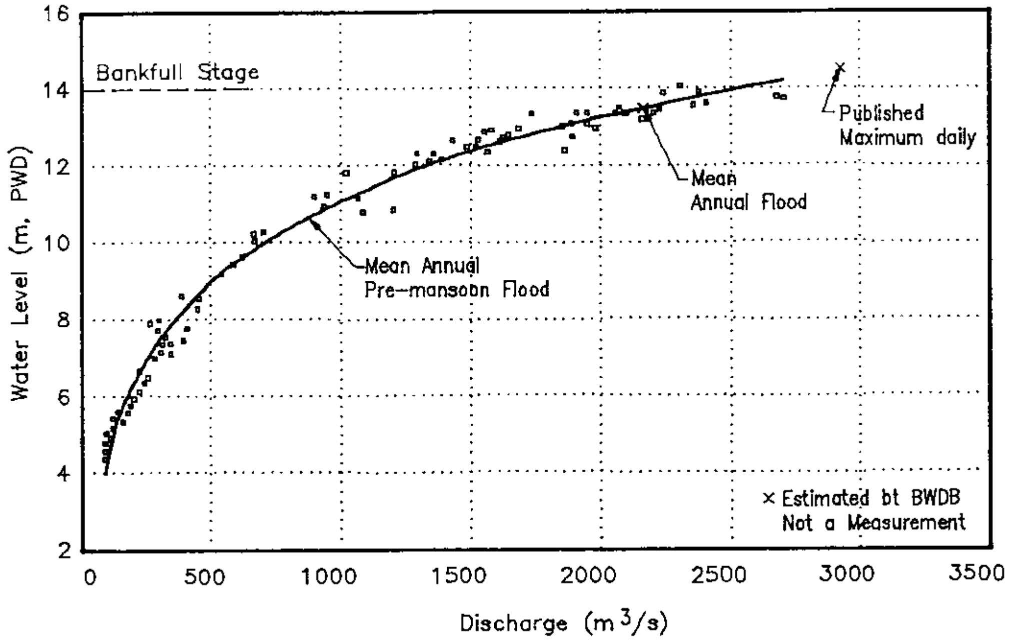
Prepared by: MA
Computer Drafting by: Mamun

December 1997

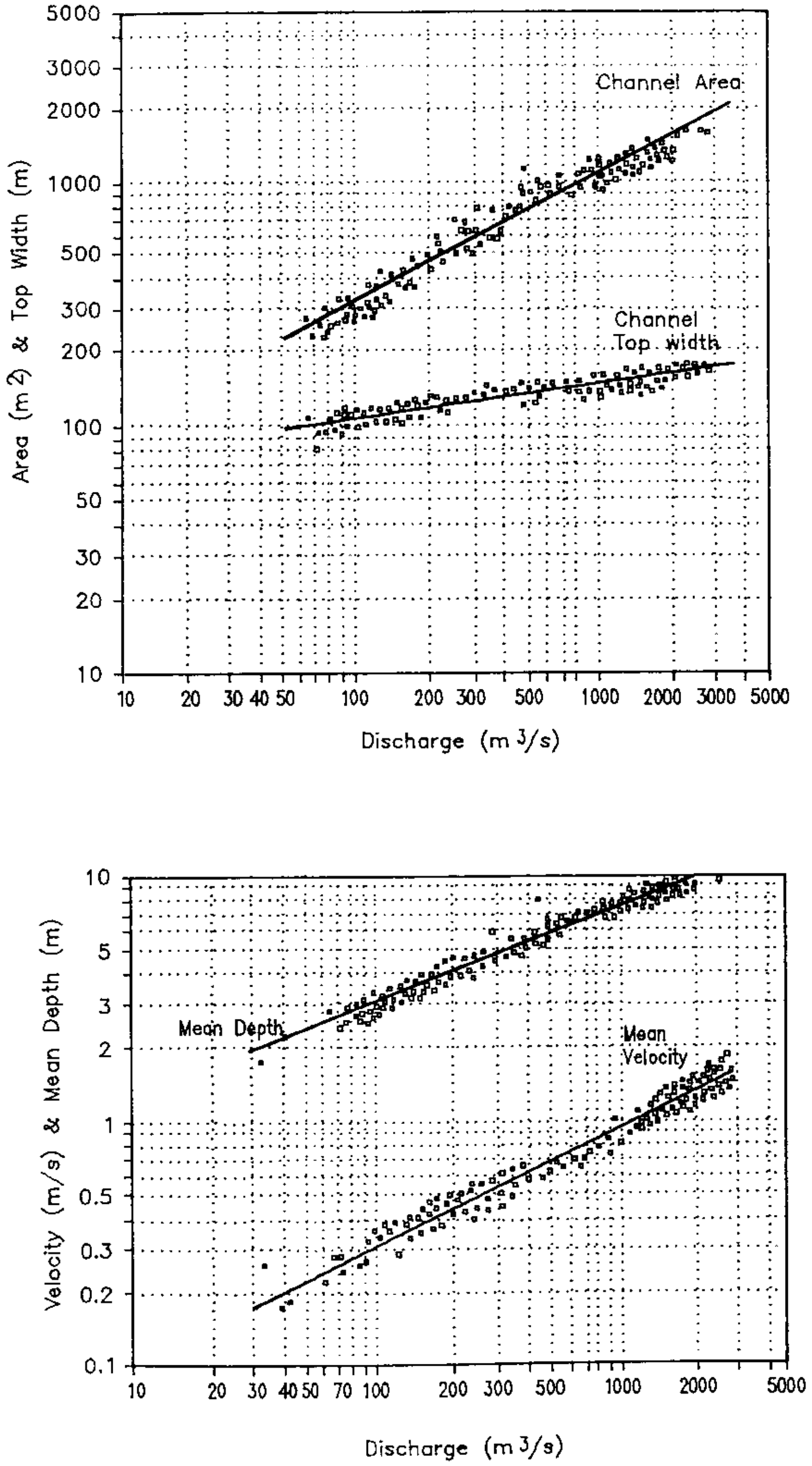
228

Figure C.16

Rating Curve (1988–1991)



Hydraulic Geometry



COMMENTS

1. $\frac{QMAXpub}{QMAXobs} = 1.08$

   Rating curve must be extrapolated to estimate monsoon flood flows.

2. Specific gauge plot shows rating curves have lowered between 0.5 – 1.0m since 1961.

3. Hydraulic Geomety Relatians

   $A = 29.34\ Q^{0.52}$

   $W = 56.7\ Q^{0.14}$

   $d = 0.52\ Q^{0.39}$

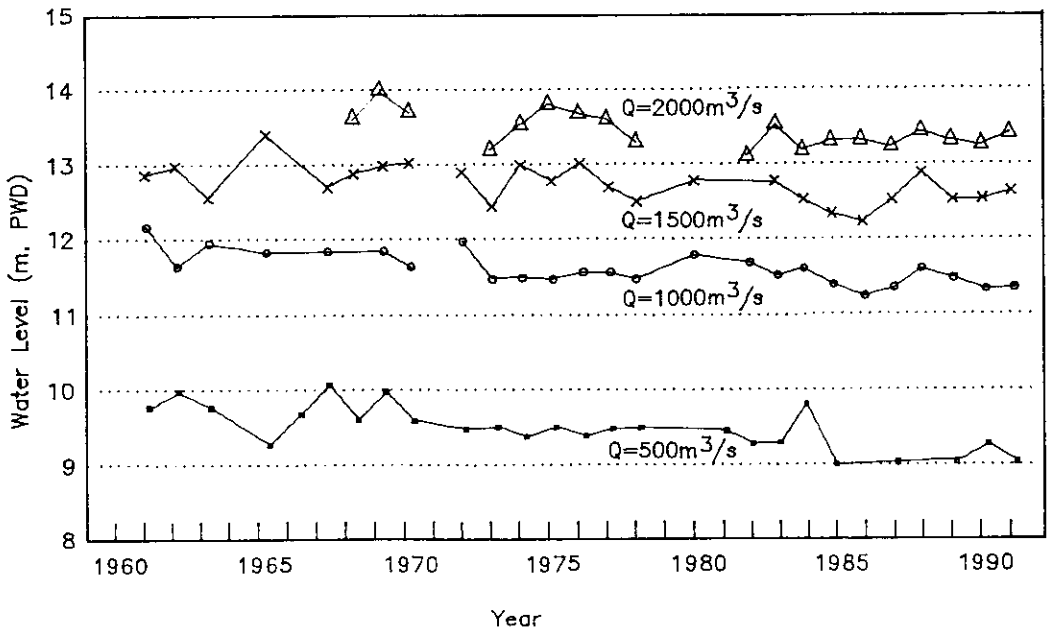
   $v = 0.034\ Q^{0.48}$

Condition	Q	A	W	d	v
1.	966	1066	145	7.3	0.91
2.	2198	1638	163	10.1	1.34

1. Mean annual pre–monsoon flood
2. mean annual Flood

Q= Discharge (m^3/s)
A= Area (m^2)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)

Historic Variation in Stage Discharge Relations
(Specific Gauge Analysis)



Northeast Regional Project

Kalni–Kushiyara River Management Project

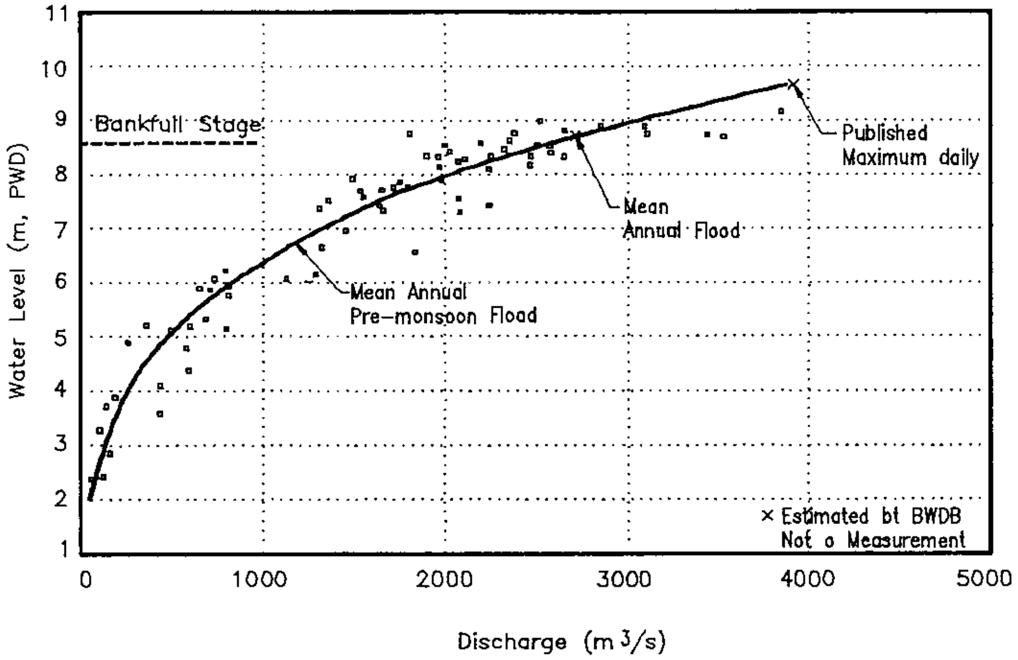
Kushiyara River
at Sheola

Prepared by: D.G.M.	December 1997
Computer Drafting by: Mamun	

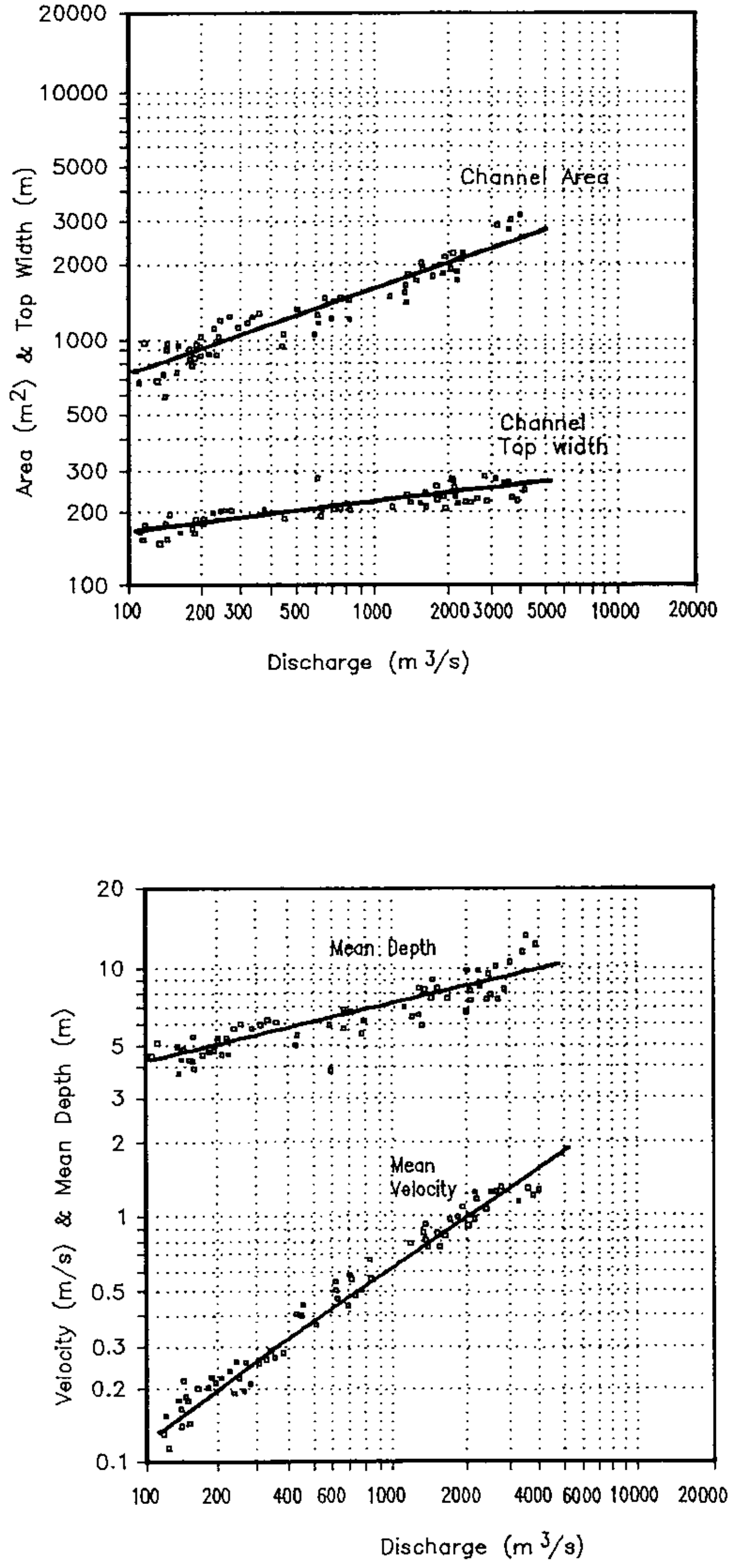
FILE: ENGG–60.DWG

Figure C.17

Rating Curve (1988–1991)



Hydraulic Geometry



COMMENTS

1. $\frac{QMAXpub}{QMAXobs} = 1.02$

   Rating curve must be extrapolated to estimate monsoon flood flows.
2. Specific gauge plot shows rating curves have lowered 0.5m on average between 1970–1990.
3. Hydraulic Geometry Relations

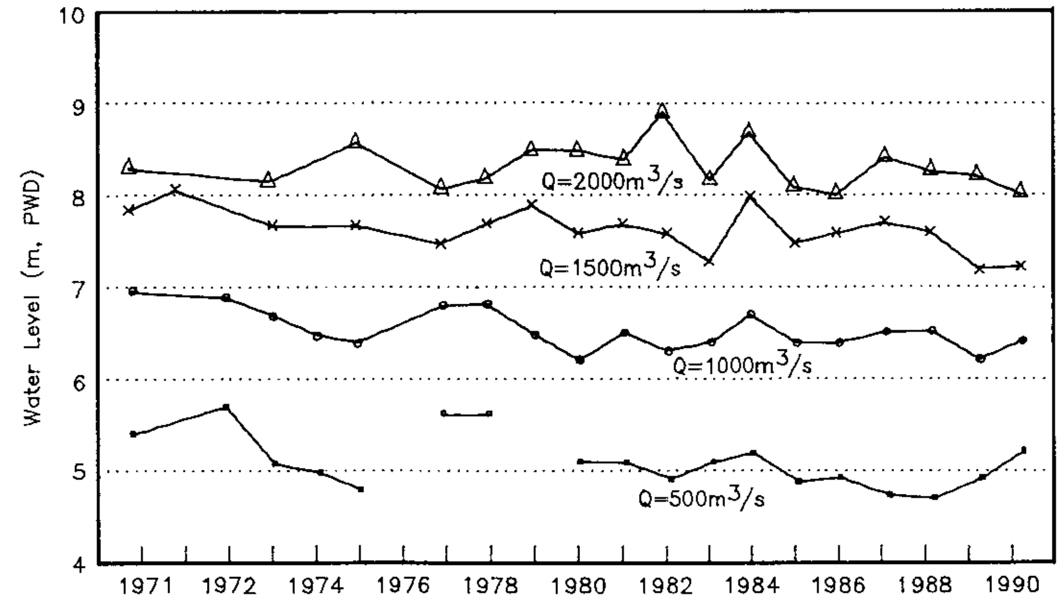
   $A = 162.07\ Q^{0.329}$
   $W = 103.68\ Q^{0.109}$
   $d = 1.563\ Q^{0.219}$
   $v = 0.006\ Q^{0.671}$

Condition	Q	A	W	d	v
1.	1884	1933	236.7	8.17	0.97
2.	2708	2178	246.3	8.84	1.24

1. Mean annual pre-monsoon flood
2. mean annual Flood

Q= Discharge (m 3/s)
A= Area (m 2)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)

Historic Variation in Stage Discharge Relations
(Specific Gauge Analysis)



FILE: ENGG-61.DWG

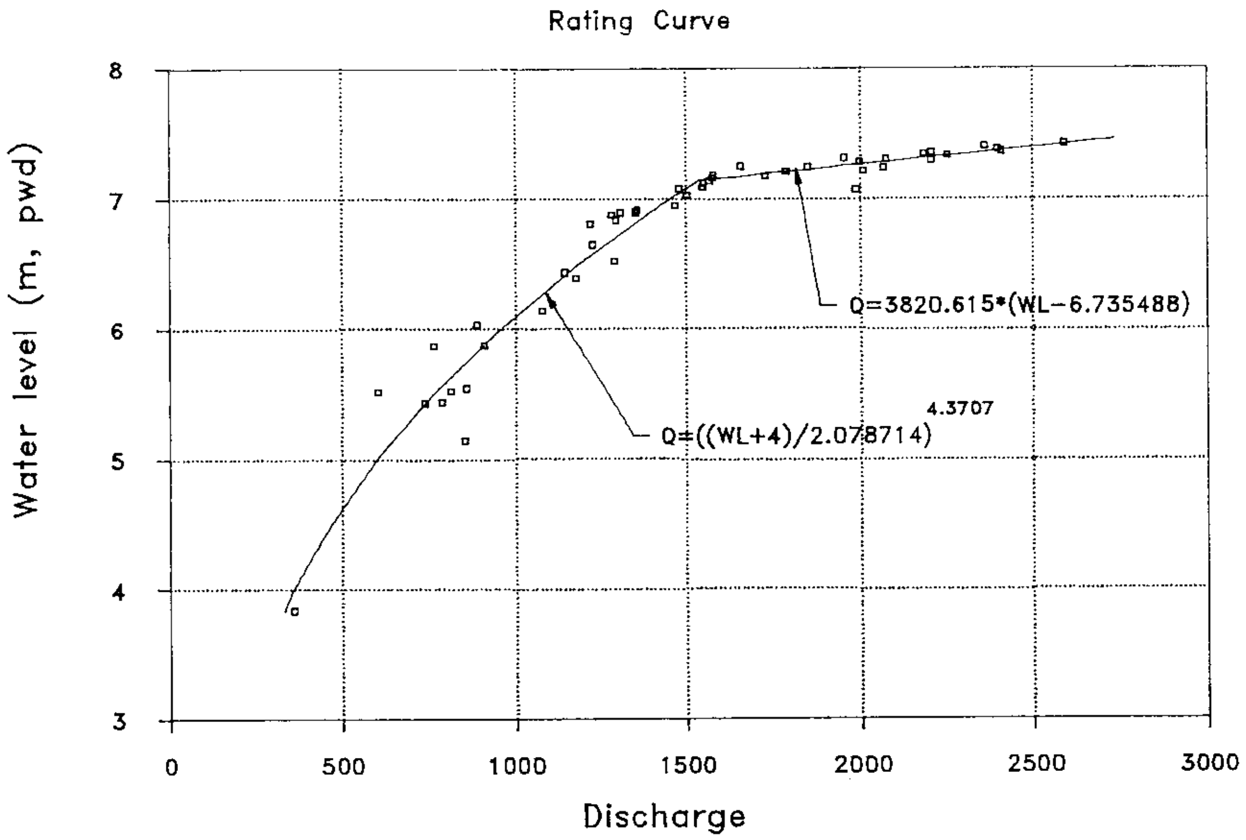
Northeast Regional Project

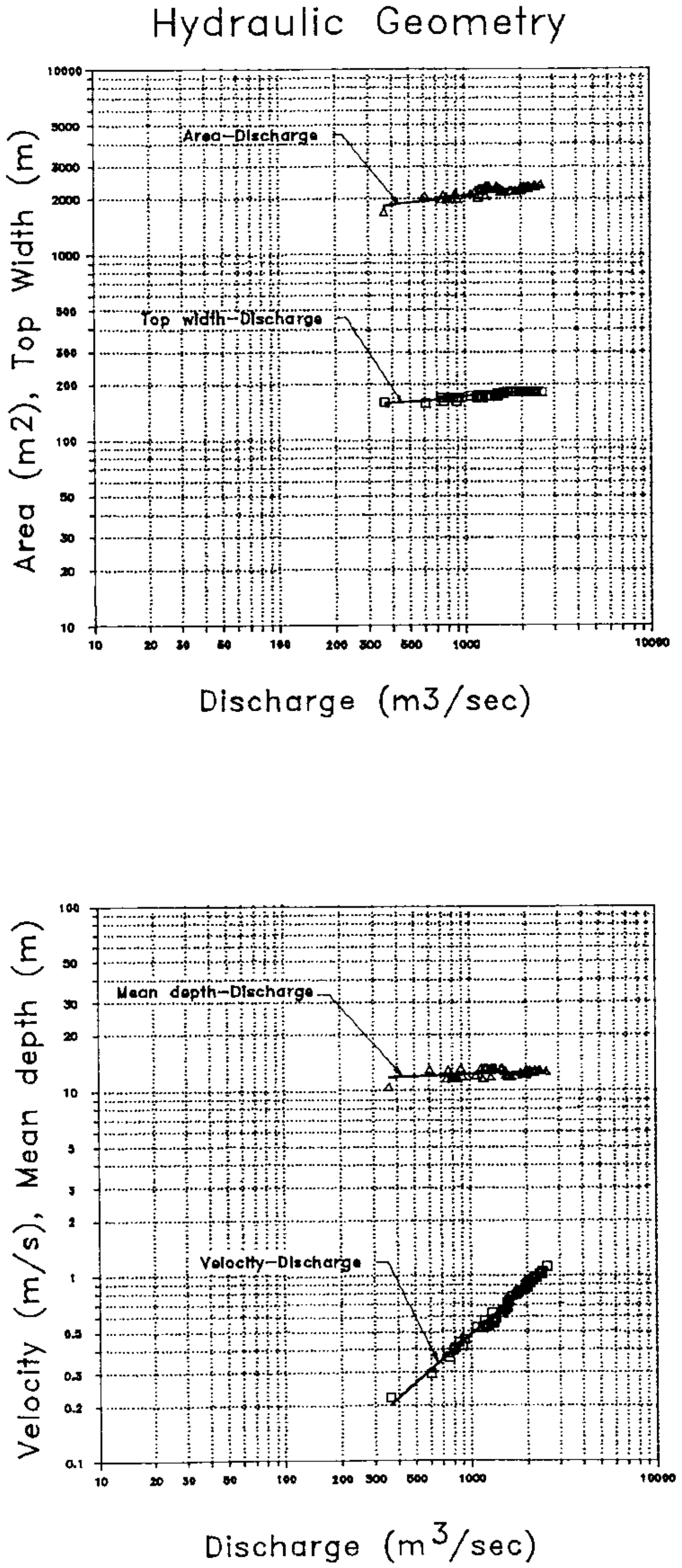
Kalni–Kushiyara River Management Project

Kushiyara River
at Sherpur

Prepared by: D.G.M.
Computer Drafting by: Mamun
December 1997

Figure C.18





COMMENTS

1. Temporary station 1995-96
   Opereted by SWMC 1988-92 & NERP1995

2. Hydraulic Geometry Relations

$A = 832.3\ Q^{0.132}$

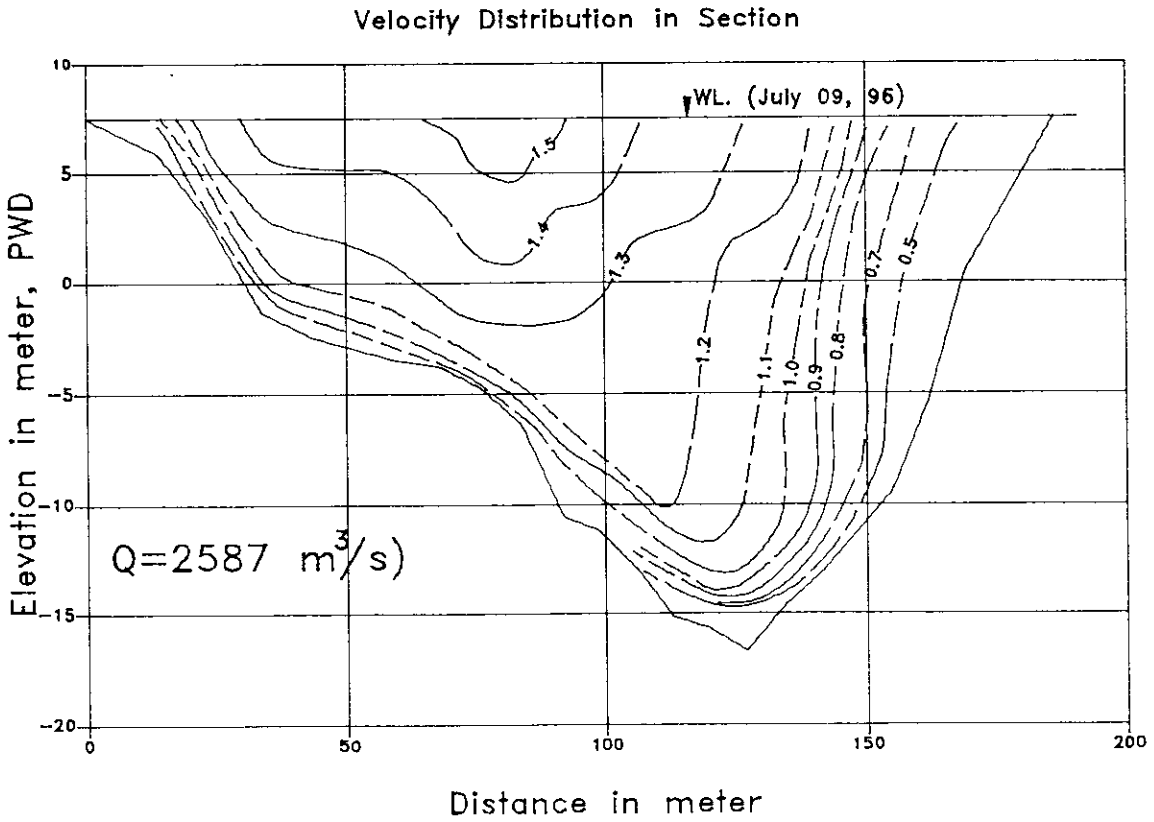
$W = 90.5\ Q^{0.091}$

$d = 9.20\ Q^{0.041}$

$v = 0.0012\ Q^{0.868}$

Condition	Q	A	W	d	v
Avg. monthly March	226	1704	149	11.5	0.13
Avg. monthly April	663	1965	164	12.0	0.34
Avg. monthly May	1438	2177	176	12.4	0.66
Pre-monsoon 2 Year	1630	2213	178	12.4	0.74
Pre-monsoon 5 Year	2330	2320	184	12.6	1.00
Pre-monsoon 10 Year	2700	2366	186	12.7	1.14
Annual 2 Year					
Annul 5 Year					
Annual 10 Year					
Bankfull (existing)	1965	2268	181	12.5	0.87
April 6/96	1350	2158	175	12.3	0.63

Q= Discharge (m^3/s)
A= Area (m^2)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)



Northeast Regional Project

Kalni-Kushiyara River Management Project

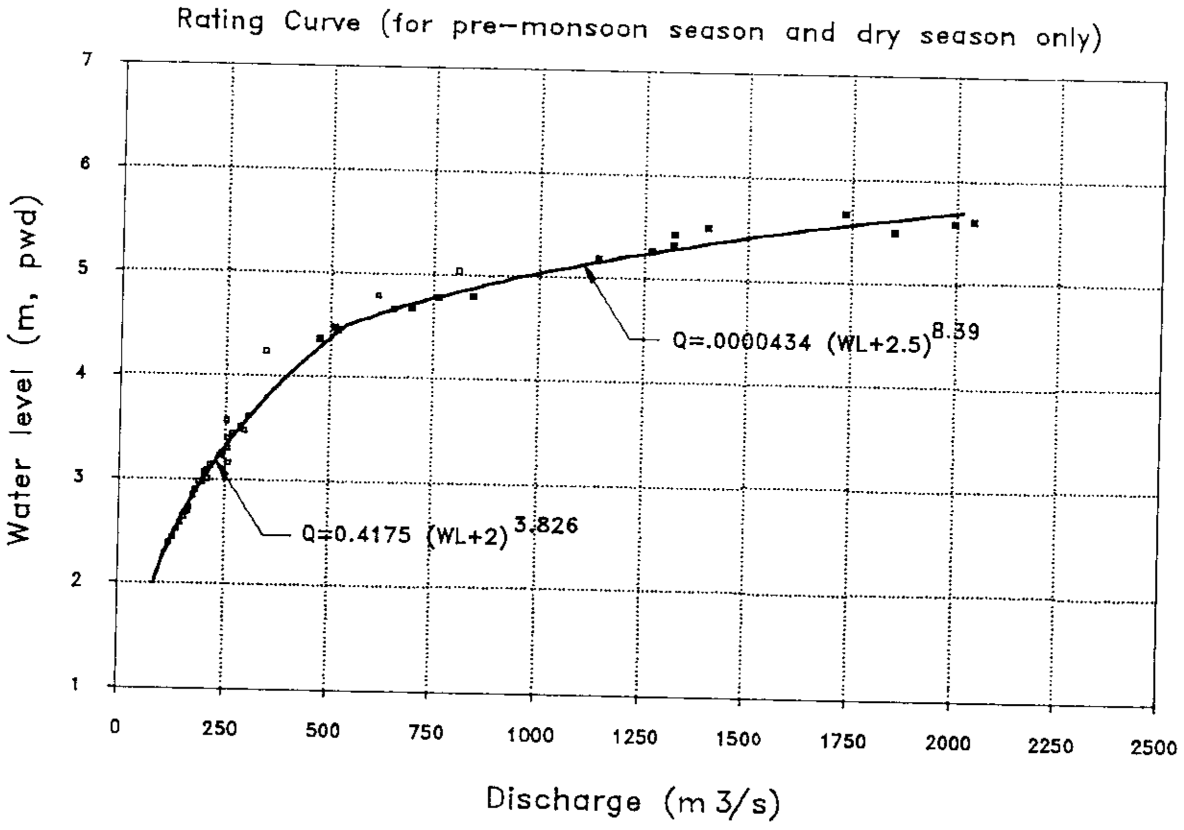
Kalni River
at Markuli

Prepared by: Tarek
Computer Drafting by: Jalal

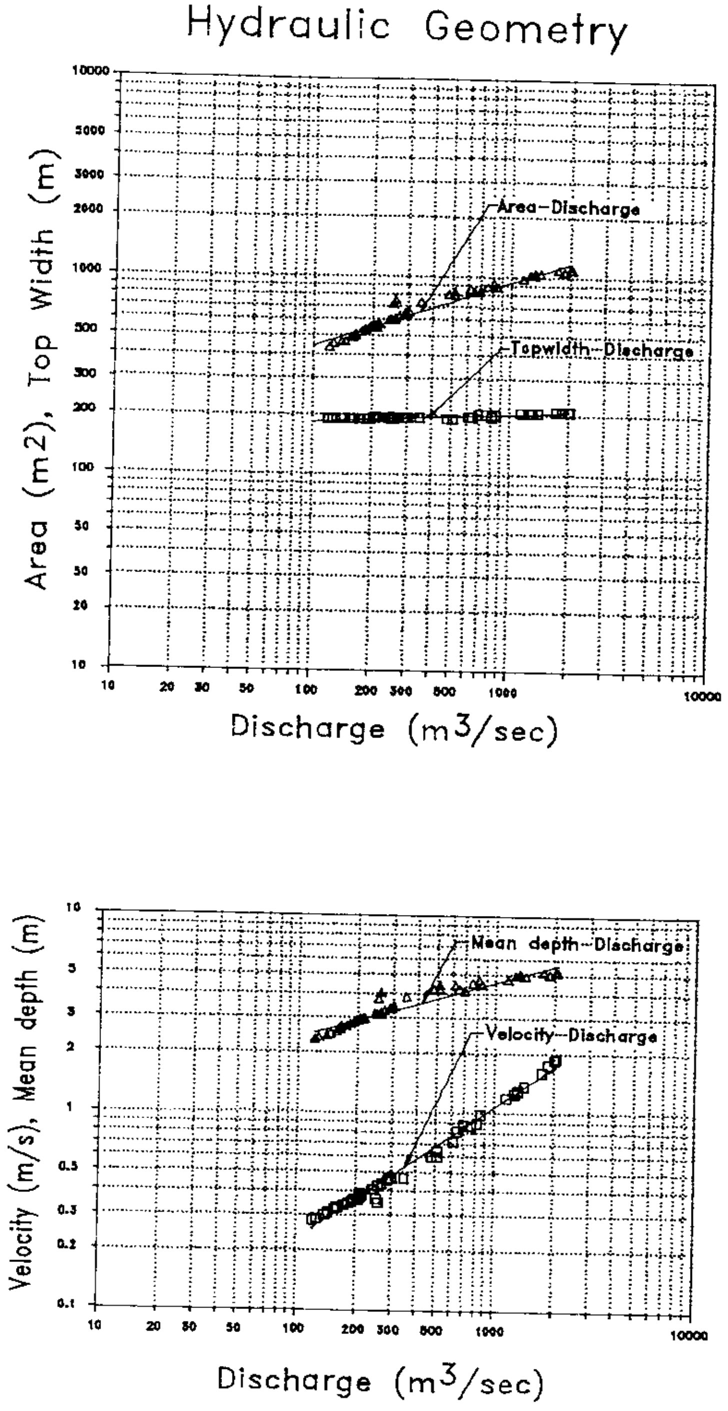
December 1997

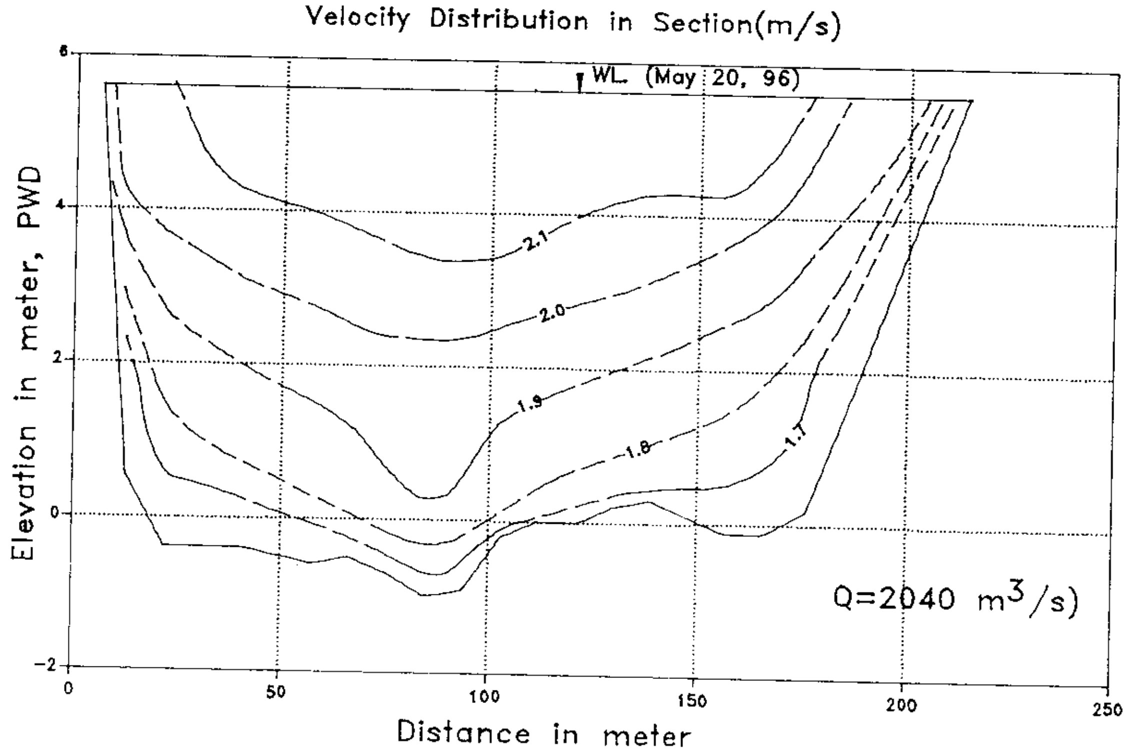
FILE: ENGG-21.DWG

Figure C.19



Hydraulic Geometry





COMMENTS

1. At BWDB gauge 271
2. Rating curve not valid in Monsoon season.
3. Hydraulic Geometry Relations

$A = 97.975 Q^{0.326}$
$W = 152.173 Q^{0.0401}$
$d = 0.644 Q^{0.286}$
$v = 0.0102 Q^{0.674}$

Condition	Q	A	W	d	v
Avg. monthly March	226	573	189	3.04	0.39
Avg. monthly April	663	814	197	4.13	0.81
Avg. monthly May	1438	1048	203	5.15	1.37
Pre-monsoon 2 Year	1630	1092	204	5.34	1.49
Pre-monsoon 5 Year	2330	1227	207	5.91	1.90
Pre-monsoon 10 Year	2700				
Annual 2 Year					
Annul 5 Year					
Annual 10 Year					
Bankfull (existing)	1750	1118	205	5.45	1.57
April 6/96	1485	1059	204	5.20	1.40

1. Mean annual pre-monsoon flood
2. mean annual Flood

Q= Discharge (m3/s)
A= Area (m^2)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)

FILE: ENGG-22.DWG

Northeast Regional Project

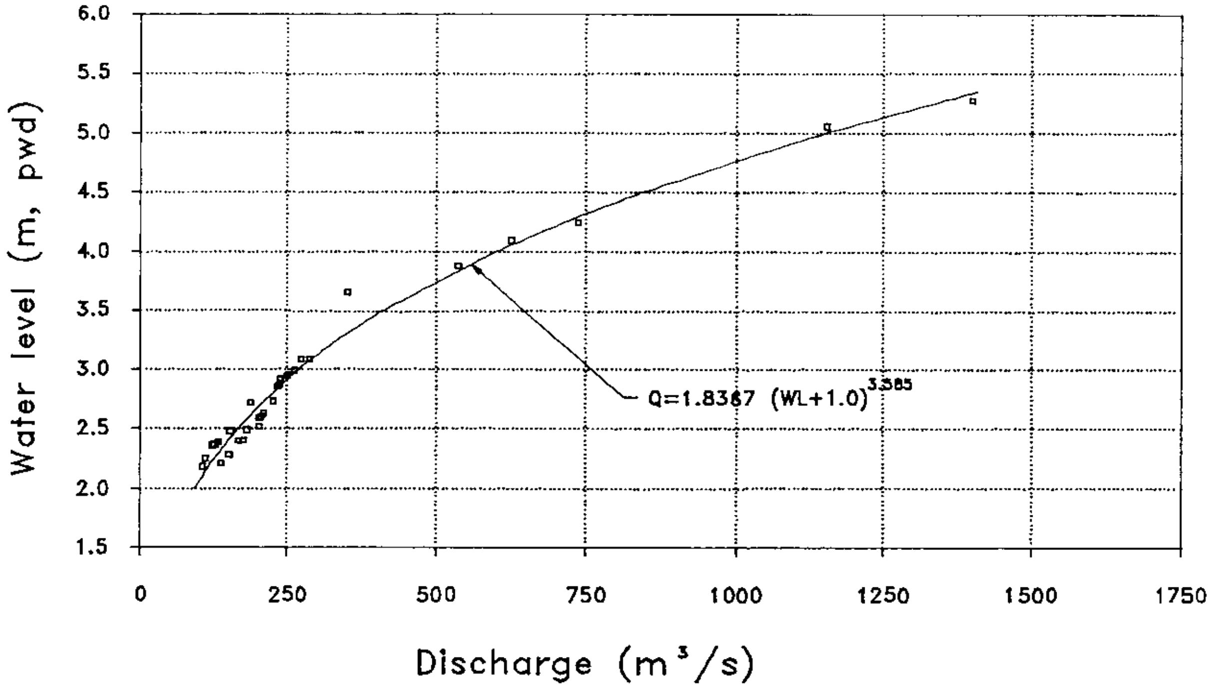
Kalni-Kushiyara River Management Project

Kalni River
at Ajmiriganj

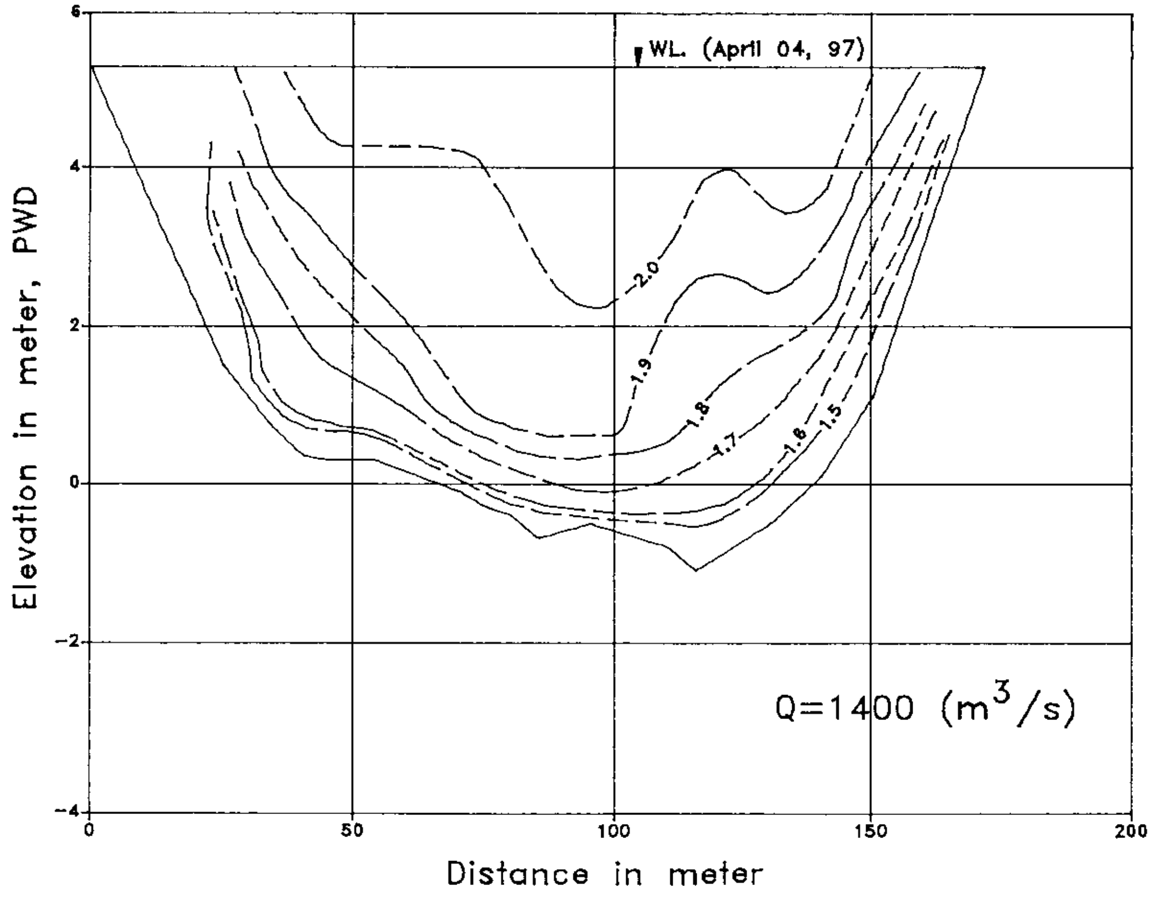
Prepared by: Tarek
Computer Drafting by: Jalal
December 1997

D-81

Figure C.20

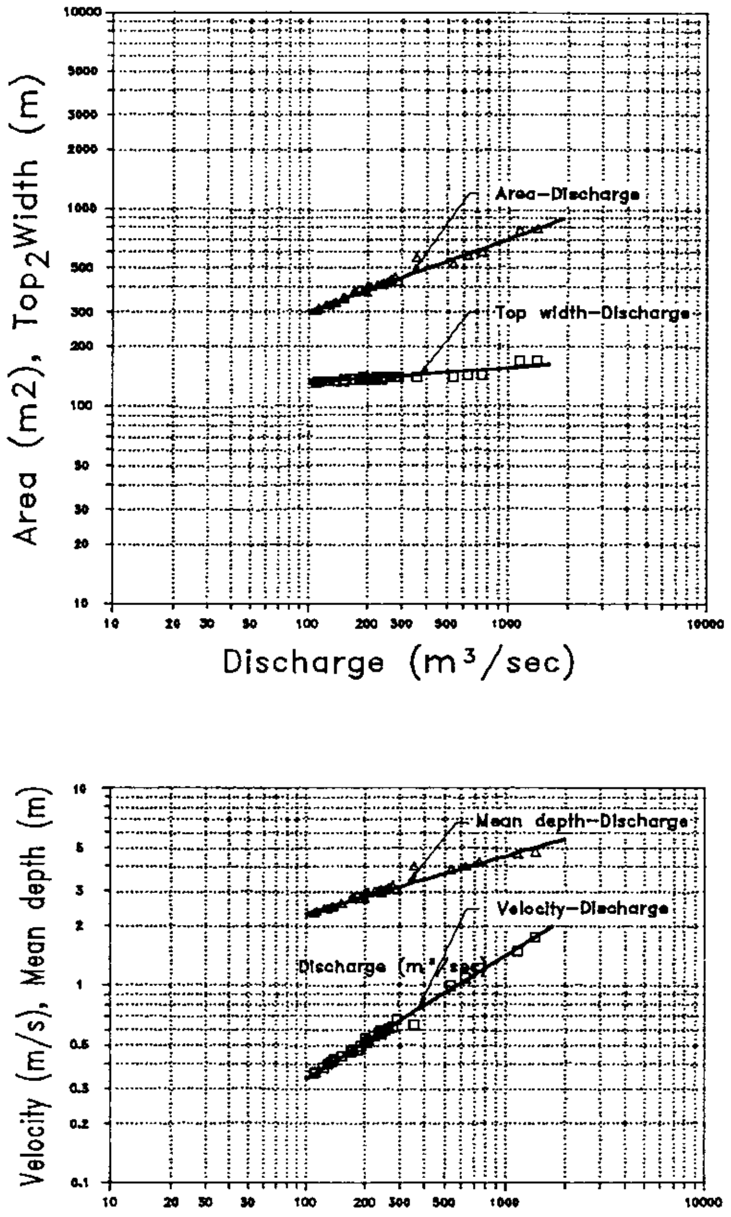


Rating Curve (for pre-monsoon season and dry season only)



Velocity Distribution in Section

Hydraulic Geometry



COMMENTS

1. Temporary gauge 1995-96
2. Rating curve not valid in Monsoon season.
3. Hydraulic Geometry Relations

$A = 54.033\,Q^{0.372}$
$W = 92.82\,Q^{0.0752}$
$d = 0.5821\,Q^{0.2972}$
$v = 0.0185\,Q^{0.626}$

Condition	Q	A	W	d	v
Avg. monthly March	226	406	140	2.91	0.56
Avg. monthly April	663	606	151	4.01	1.10
Avg. monthly May	1438	809	160	5.04	1.78
Pre-monsoon 2 Year	1630	847	162	5.23	1.93
Pre-monsoon 5 Year					
Pre-monsoon 10 Year					
Annual 2 Year					
Annul 5 Year					
Annual 10 Year					
Bankfull (existing)	1500	821	161	5.11	1.83
April 6/96	1337	787	159	4.94	1.70

1. Mean annual pre-monsoon flood
2. mean annual Flood
Q= Discharge (m³/s)
A= Area (m²)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)

Northeast Regional Project
Kalni-Kushiyara River Management Project

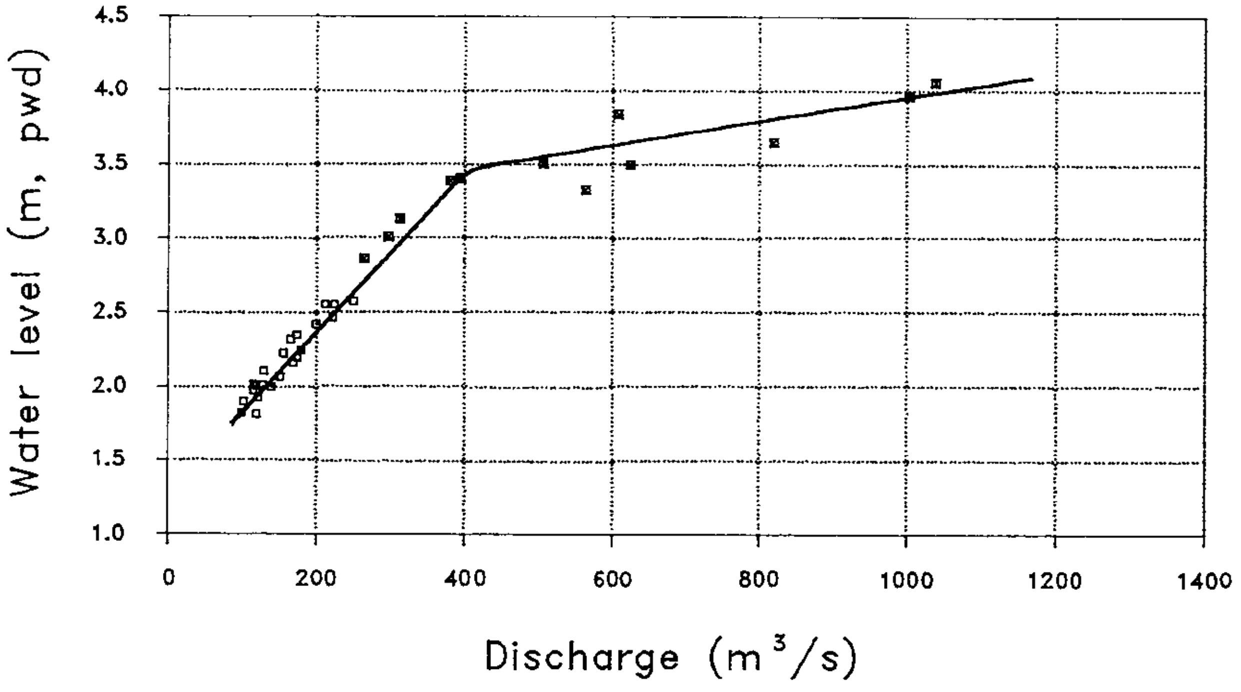
Kalni River at Shantipur

Prepared by: Tarek
Computer Drafting by: Jalal
December 1997

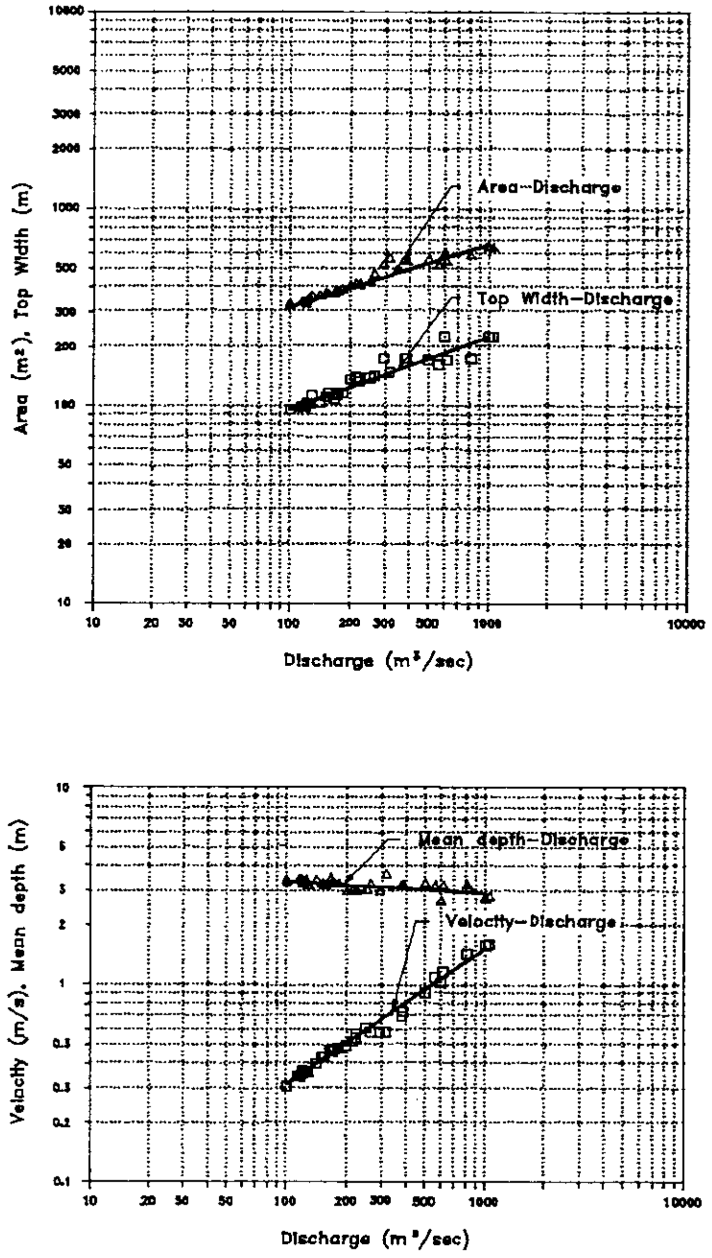
FILE: ENGG-23.DWG

Figure C.21

Rating Curve (for pre-monsoon and dry season only)



Hydraulic Geometry



COMMENTS

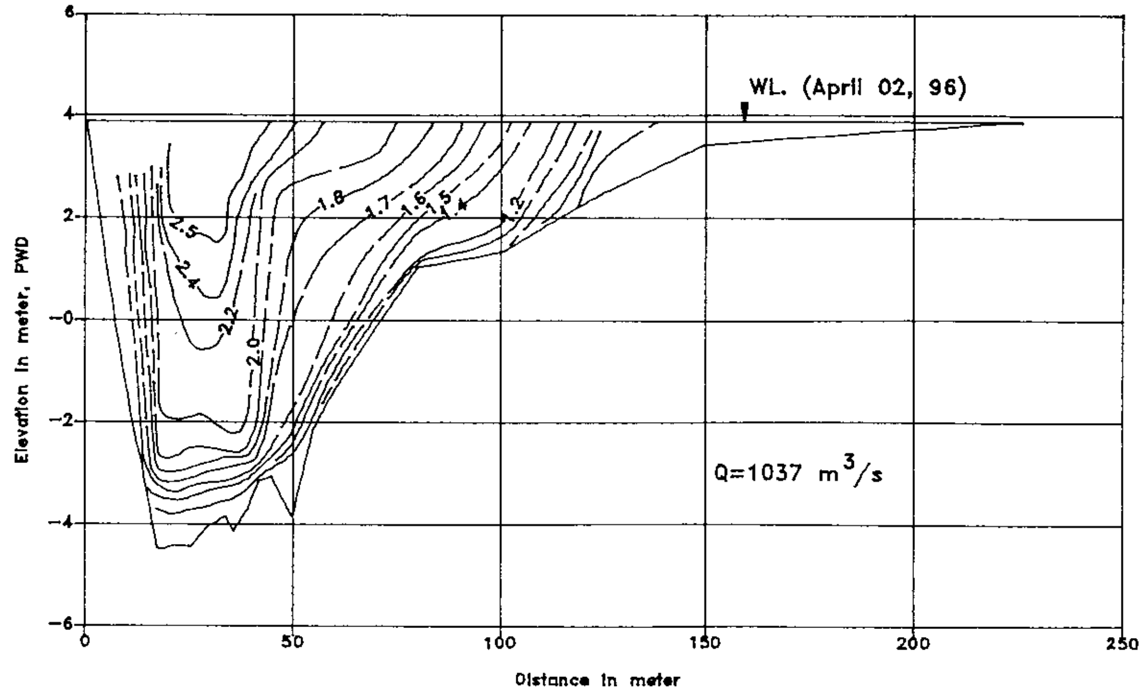
1. Temporary gauge 1995–96
2. Rating curve not valid in Monsoon season.
3. Hydraulic Geometry Relations

$A = 76.06\,Q^{0.313}$
$W = 17.506\,Q^{0.37}$
$d = 4.34\,Q^{-0.057}$
$v = 0.01315\,Q^{0.687}$

Condition	Q	A	W	d	v
Avg. monthly March	170	379	117	3.24	0.45
Avg. monthly April	497	531	174	3.54	0.94
Avg. monthly May	1079	677	232	4.51	1.59
Pre–monsoon 2 Year	1223	704	243	4.69	1.74
Pre–monsoon 5 Year					
Pre–monsoon 10 Year					
Annual 2 Year					
Annul 5 Year					
Annual 10 Year					
Bankfull (existing)	1350	726	252	4.84	1.86
April 6/96	1100	681	234	4.54	1.62

1. Mean annual pre–monsoon flood
2. mean annual Flood
Q= Discharge (m³/s)
A= Area (m²)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)

Velocity Distribution in Section



FILE: EN00-24.DWG

Northeast Regional Project

Kalni–Kushiyara River Management Project

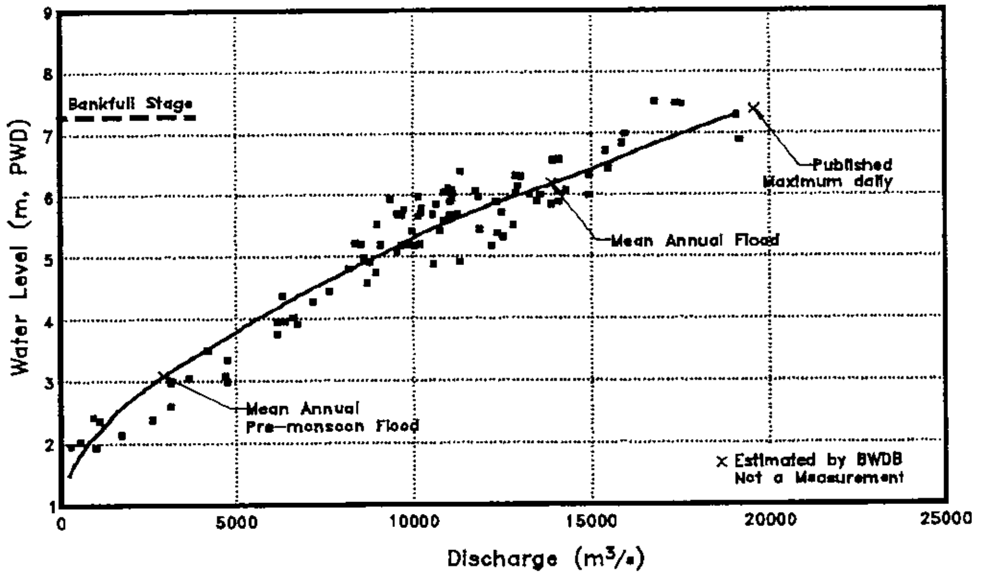
Kalni River
at Kadamchal

Prepared by: Torek
Computer Drafting by: Jalal

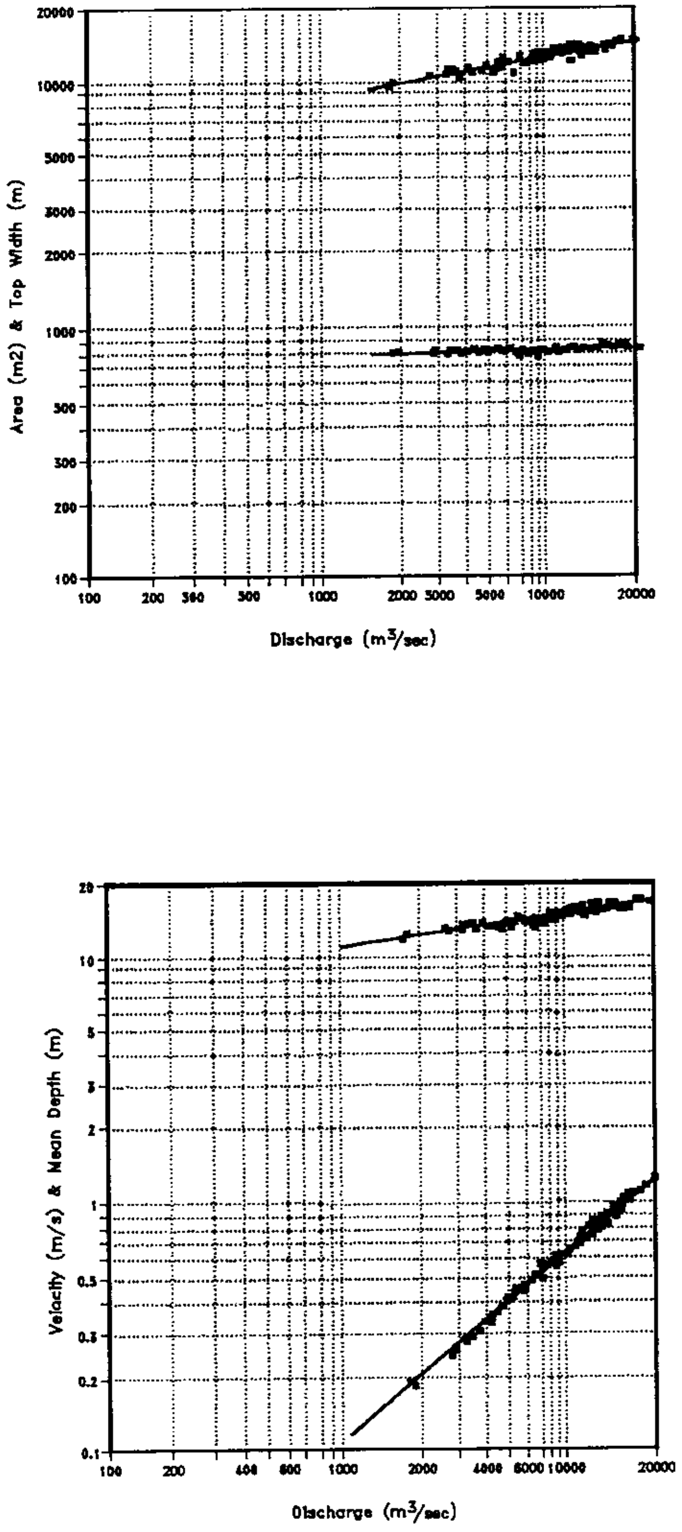
December 1997

Figure C.22

Rating Curve (1988-1992)



Hydraulic Geometry



COMMENTS

1. $\frac{\text{QMAXpub}}{\text{QMAXobs}} = 1.02$

   Rating curve must be extrapolated to estimate monsoon flood flows.

2. Water levels are affected by backwater at all flows, Rating curves after 1975 show looping and hysteresis. The specific gauge plot show ratings curves have lowered by nearly 1m since 1981.

3. Hydraulic Geometry Relations

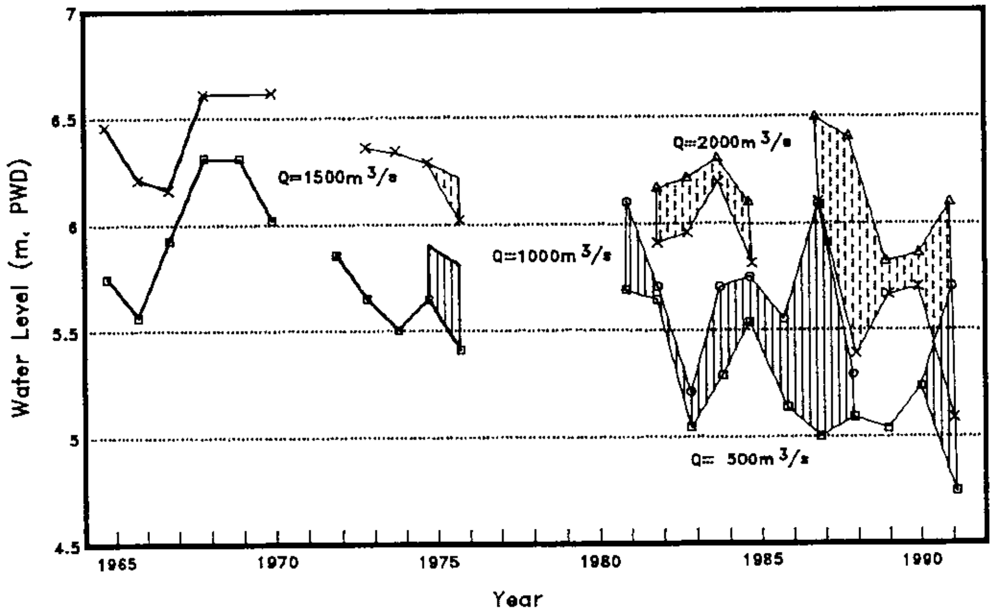
   $A = 2491.4Q^{0.18}$
   $W = 642.45Q^{0.029}$
   $d = 3.902Q^{0.15}$
   $v = 0.0004Q^{0.82}$

Condition	Q	A	W	d	v
1.	3003	10552	806	13.1	0.28
2.	13883	13906	842.5	16.51	1.0

1. Mean annual pre-monsoon flood
2. mean annual Flood

Q= Discharge (m3/s)
A= Area (m²)
W= Top Width (m)
d= Mean Depth (m)
v= Velocity (m/s)

Historic Variation in Stage Discharge Relations (Specific Gauge Analysis)



Note: After 1975, stage discharge relations show a seasonal hysteresis due to backwater condition from the lower Meghna River.

FILE: BD-173.DWG

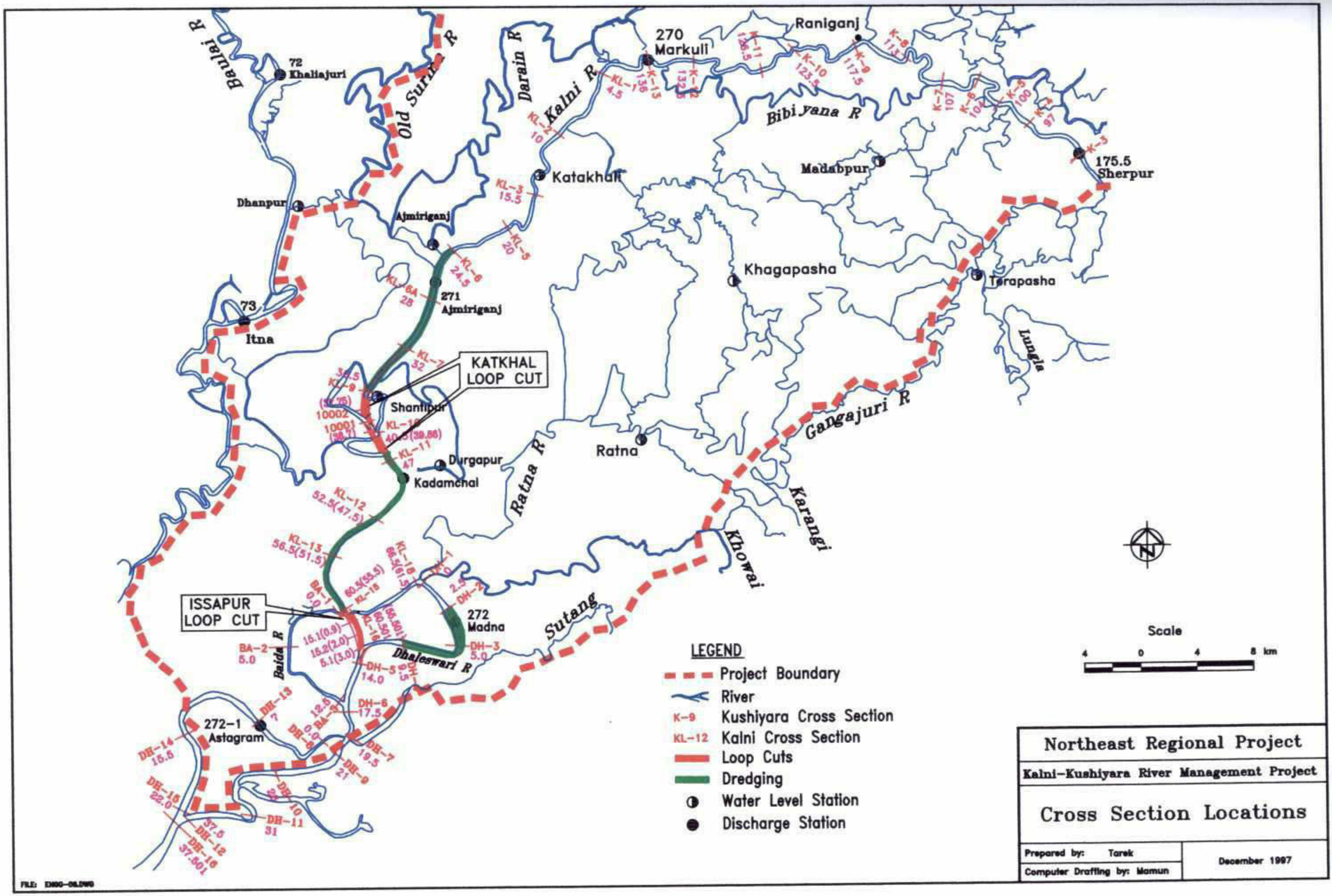
Northeast Regional Project

Kalni-Kushiyara River Management Project

Meghna River
at Bhairab Bazar

Prepared by: D.G.M./Tarek
Computer Drafting by: Jalal
December 1997

Figure C.23



Northeast Regional Project

Kalni-Kushiyara River Management Project

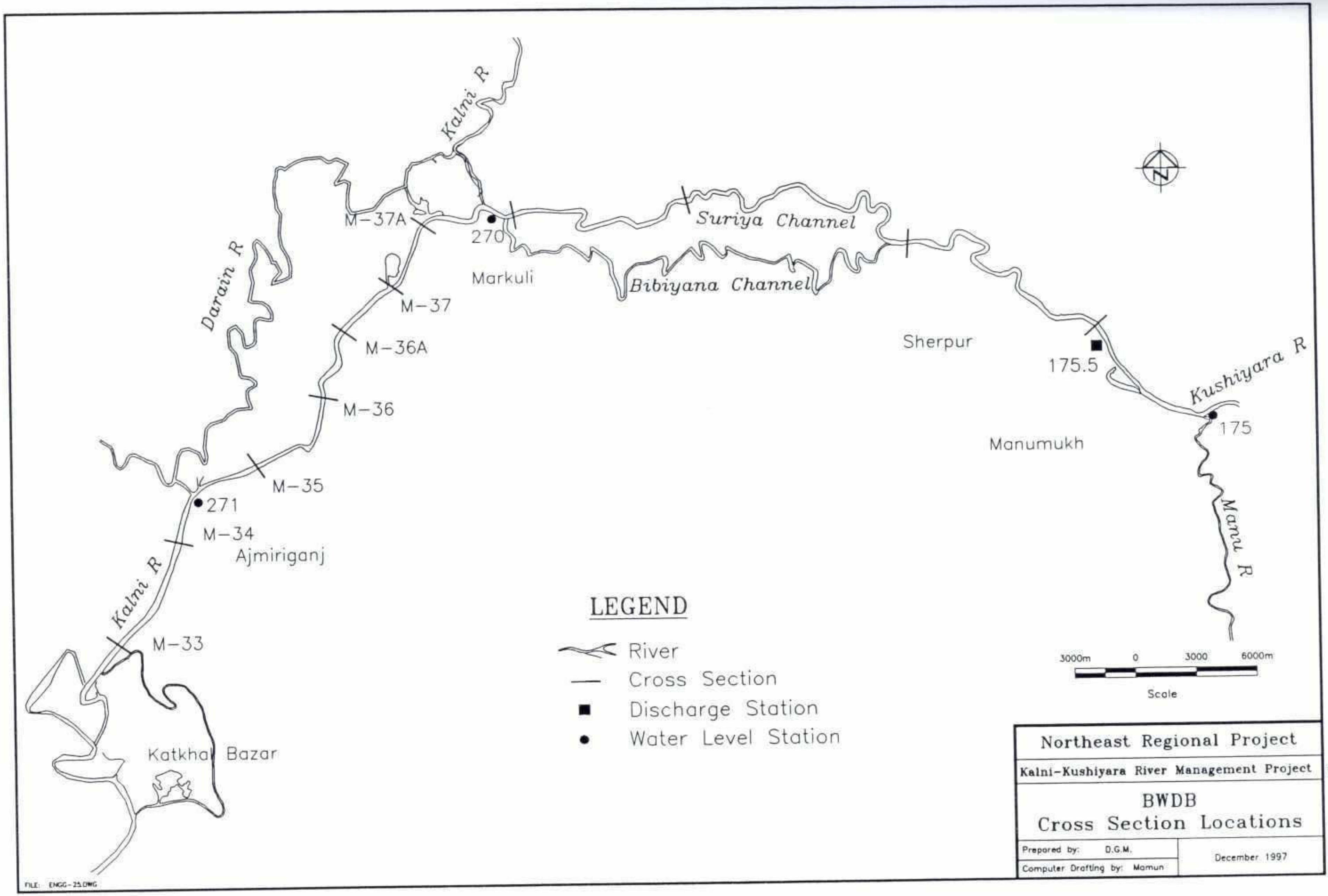
Cross Section Locations

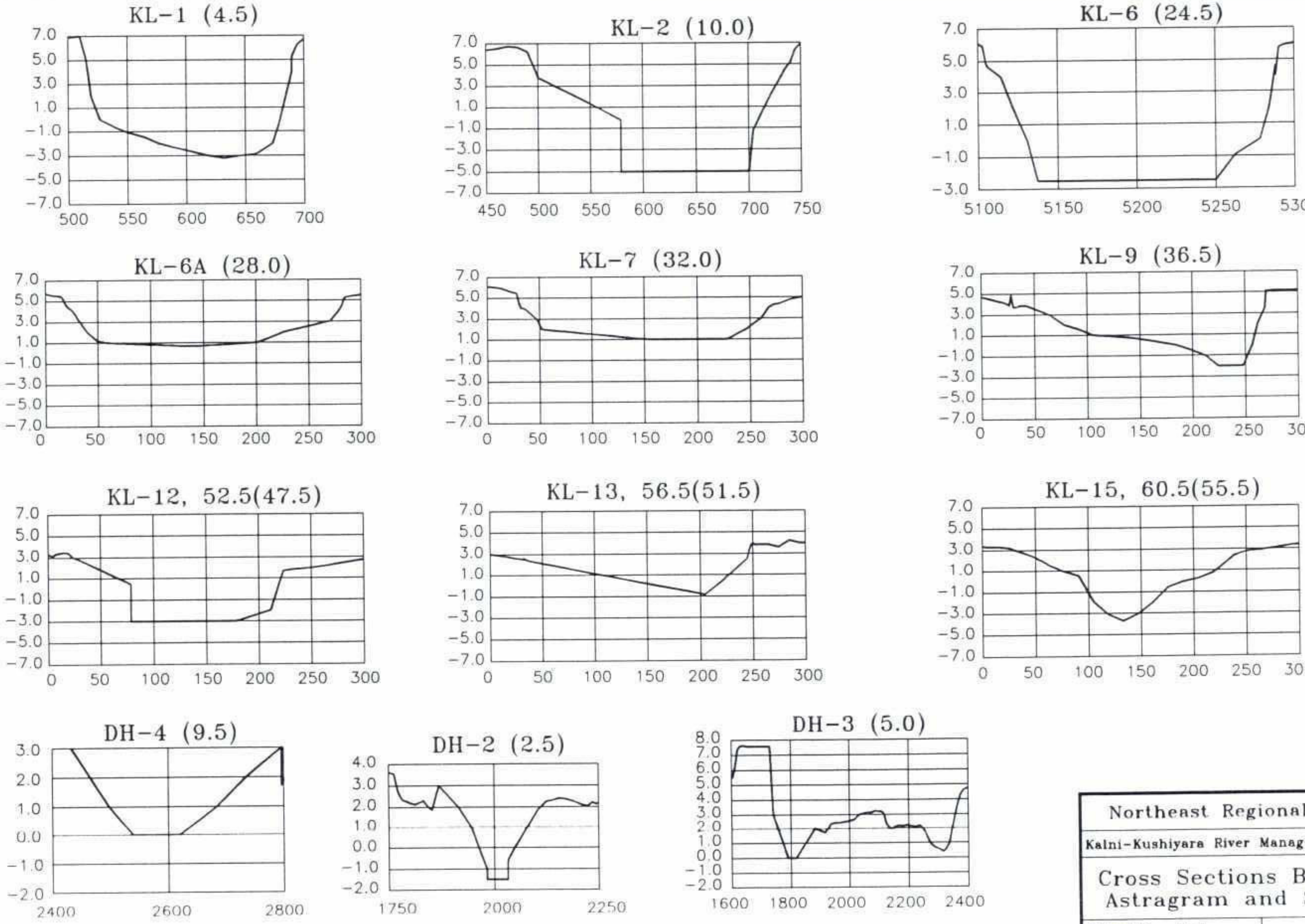
Prepared by: Tarek

Computer Drafting by: Mamun

December 1997

Figure C.24


Kalni R
M−37A
270
Suriya Channel
Bibiyana Channel
Markuli
Darain R
M−37
M−36A
M−36
M−35
271
M−34
Ajmiriganj
Kalni R
M−33
Katkhal Bazar
Sherpur
175.5
Kushiyara R
175
Manumukh
Manu R
N
LEGEND
River
Cross Section
■ Discharge Station
● Water Level Station
3000m
0
3000
6000m
Scale
Northeast Regional Project
Kalni-Kushiyara River Management Project
BWDB
Cross Section Locations
Prepared by: D.G.M.
Computer Drafting by: Mamun
December 1997
FILE: ENGG-25.DWG



FILE: ENGG-04.DWG

Northeast Regional Project

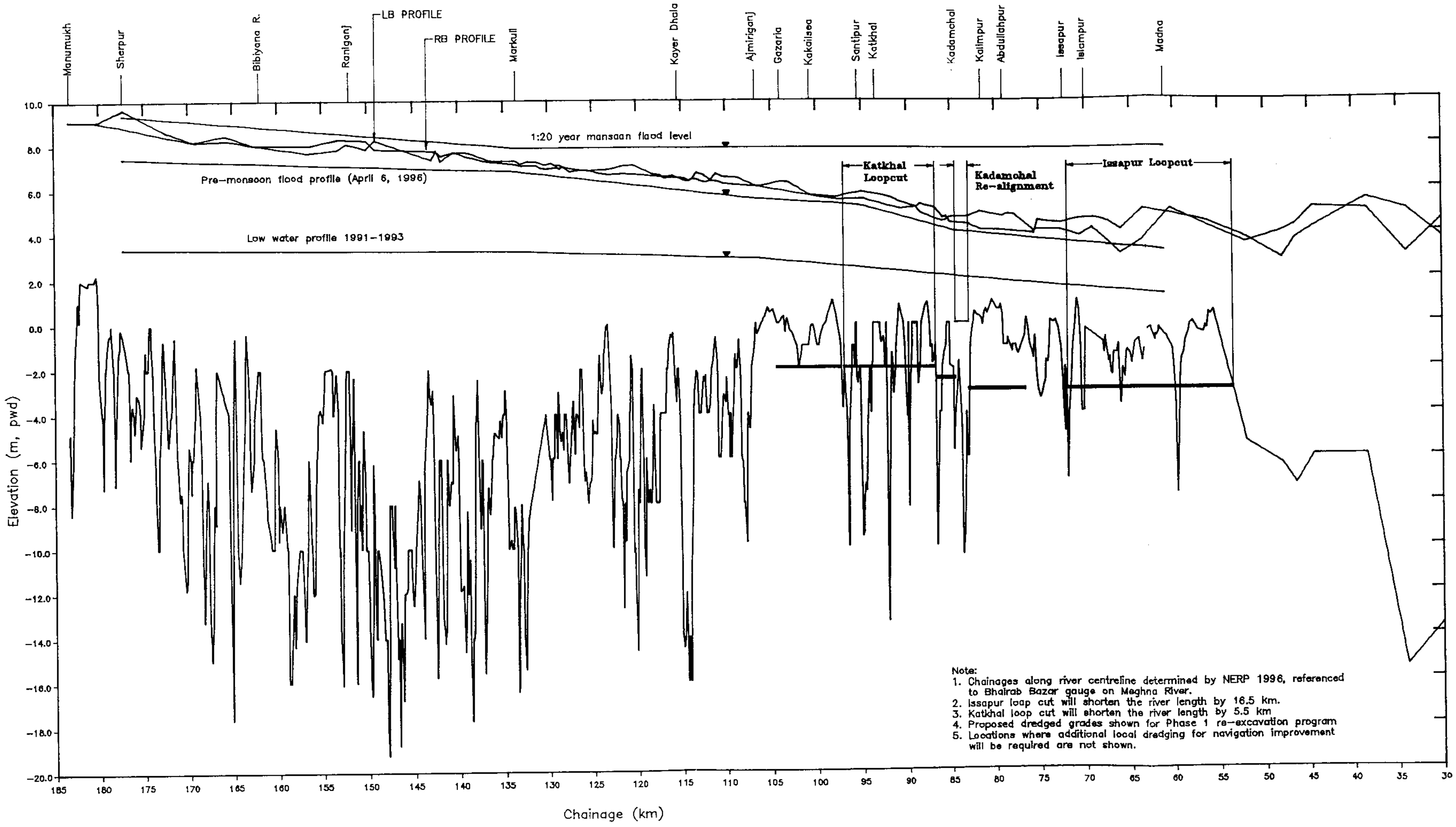
Kalni-Kushiyara River Management Project

Cross Sections Between
Astragram and Sherpur

Prepared by: Tarek	December 1997
Computer Drafting by: Mamun	

Figure C.25

Figure C.26



Note:
1. Chainages along river centreline determined by NERP 1996, referenced to Bhairab Bazar gauge on Meghna River.
2. Issapur loop cut will shorten the river length by 16.5 km.
3. Katkhal loop cut will shorten the river length by 5.5 km
4. Proposed dredged grades shown for Phase 1 re-excavation program
5. Locations where additional local dredging for navigation improvement will be required are not shown.

Northeast Regional Project

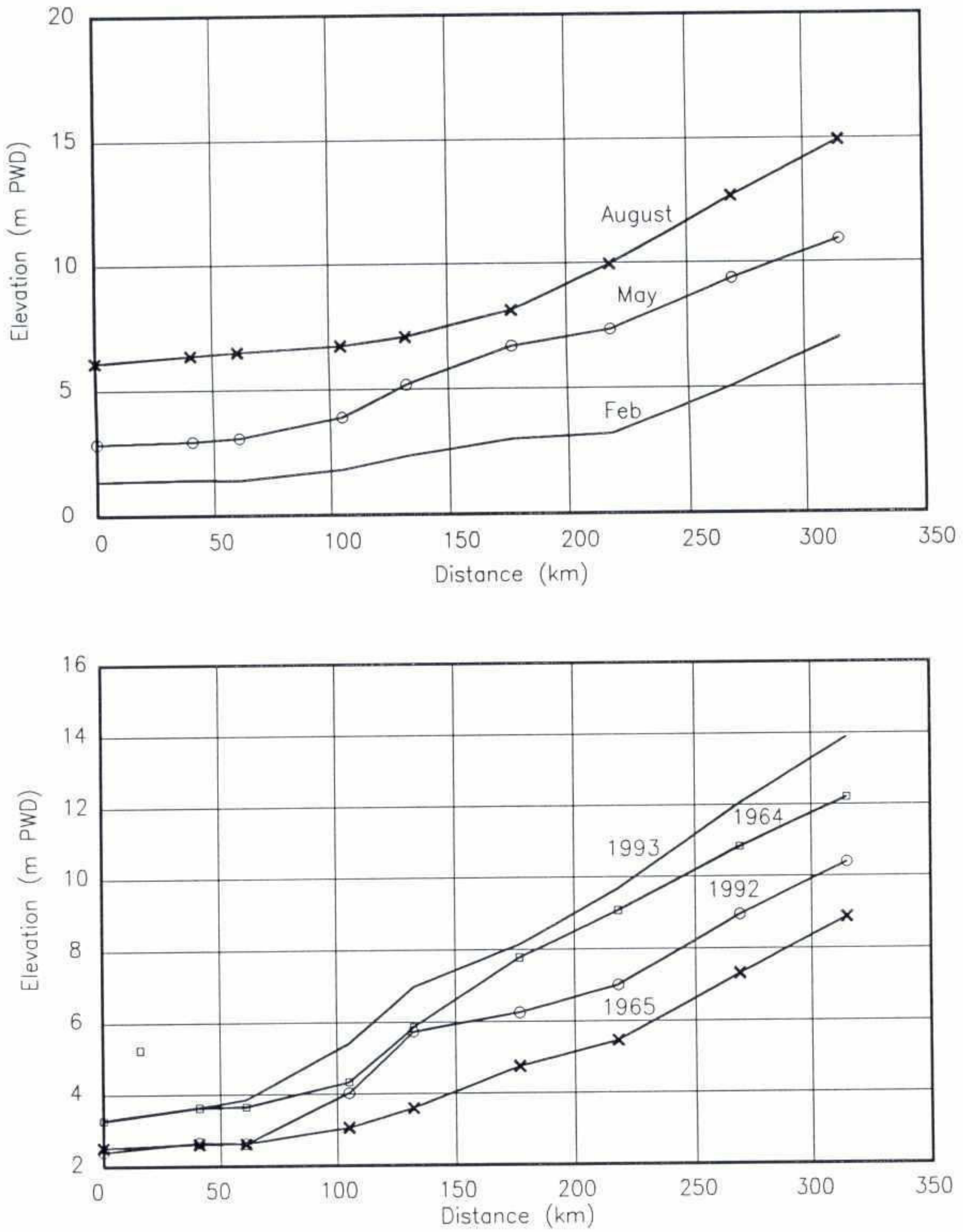
Kalni-Kushiyara River Management Project

Longitudinal Profile of Kalni-Kushiyara River

Prepared by: D.G.M.
Computer Drafting by: Jalal
December 1997

FILE: ENGG-26.DWG

১৬৫ Figure C.27



Northeast Regional Project

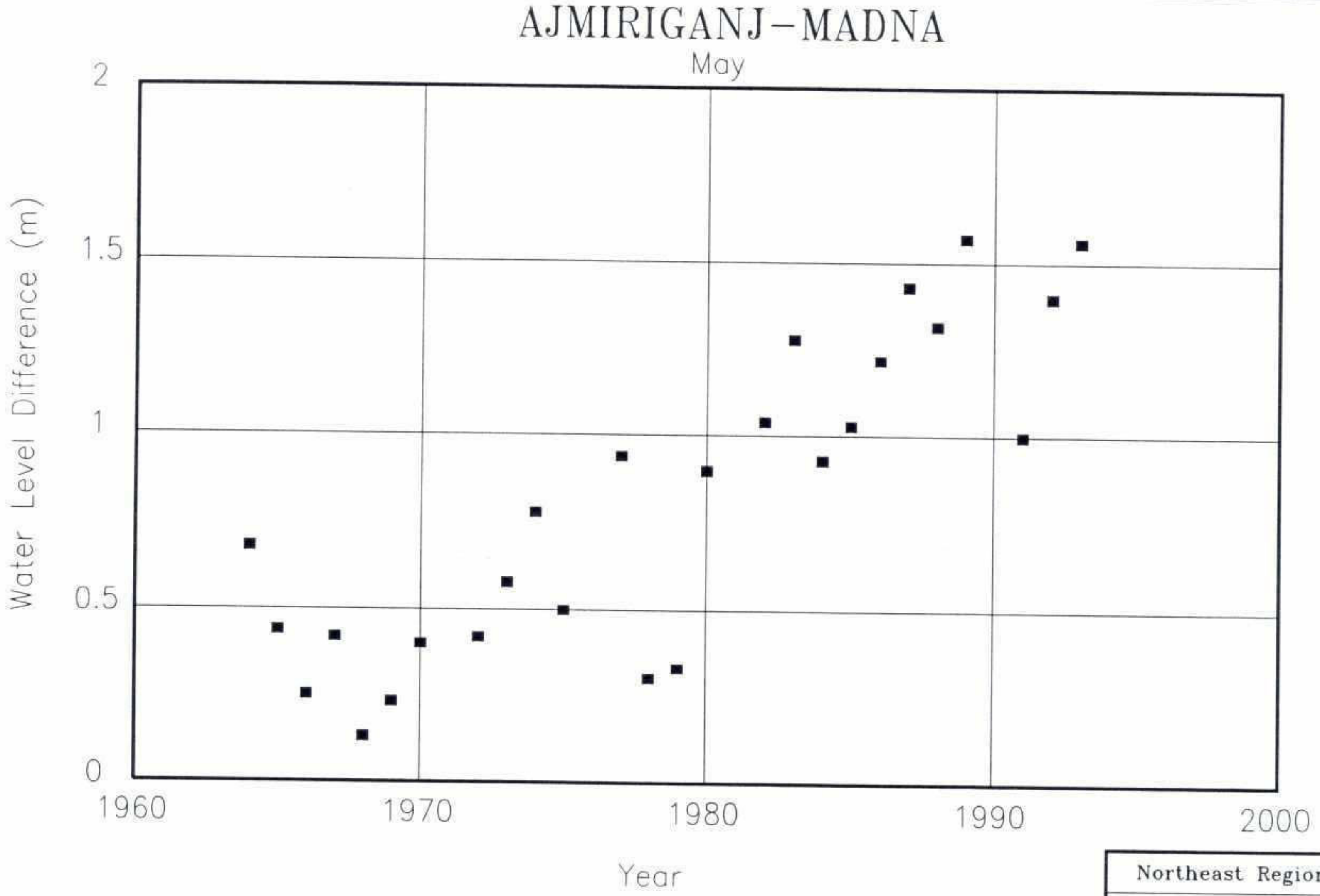
Kalni-Kushiyara River Management Project

Water Surface Profile
Meghna-Kalni-Kushiyara River

Prepared by: Tarek	December 1997
Computer Drafting by: Mamun	

FILE: ENGG-07.DWG

270



Northeast Regional Project

Kalni-Kushiyara River Management Project

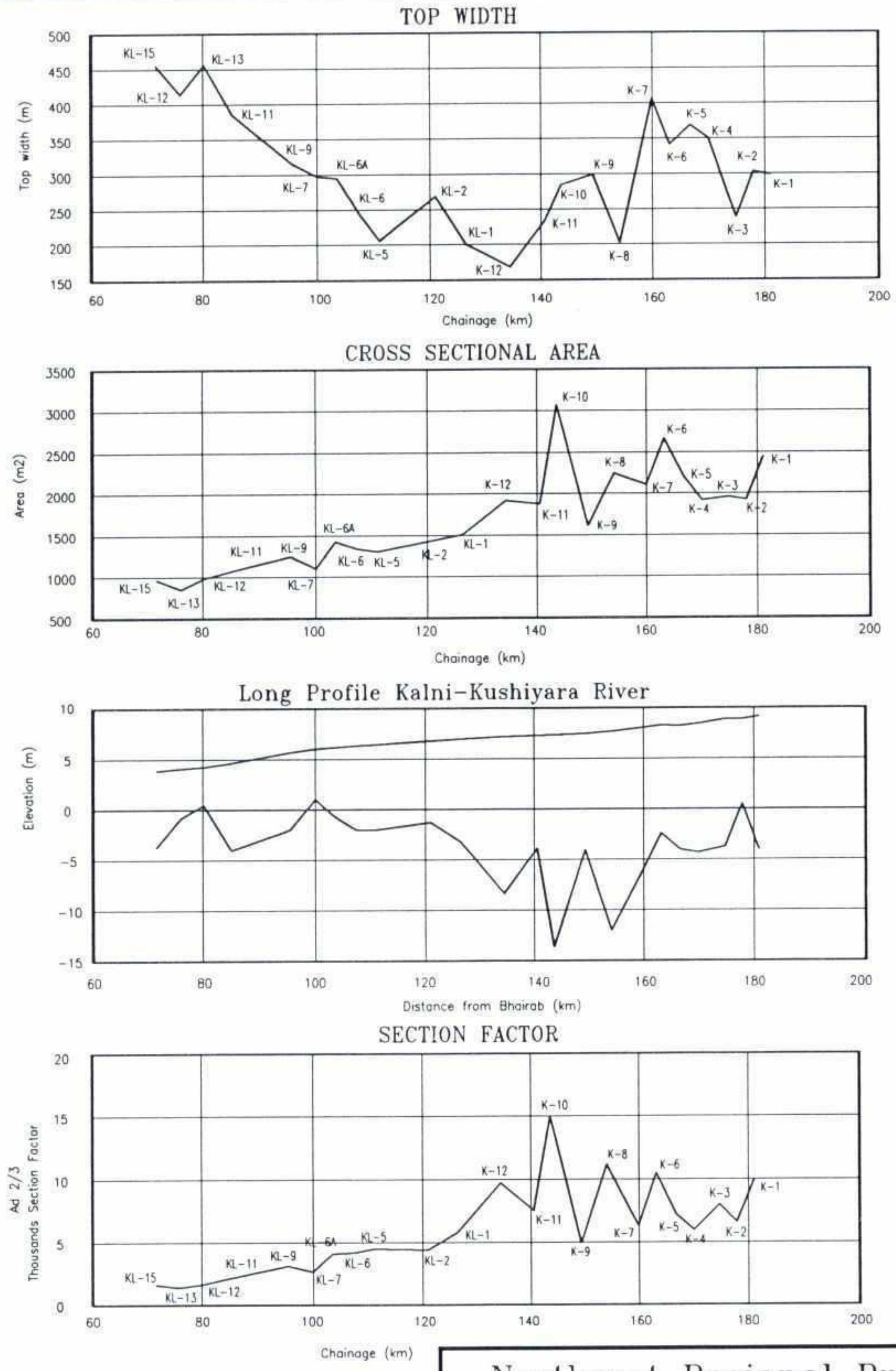
Water Level Difference 1964-93
Between Ajmiriganj and Madna

Prepared by: Tarek
Computer Drafting by: Mamun
December 1997

Figure C.28

FILE: ENGG-08.DWG

Figure C.29



TOP WIDTH

CROSS SECTIONAL AREA

Long Profile Kalni–Kushiyara River

SECTION FACTOR

Northeast Regional Project

Kalni–Kushiyara River Management Project

Kalni–Kushiyara River Bankfull Properties

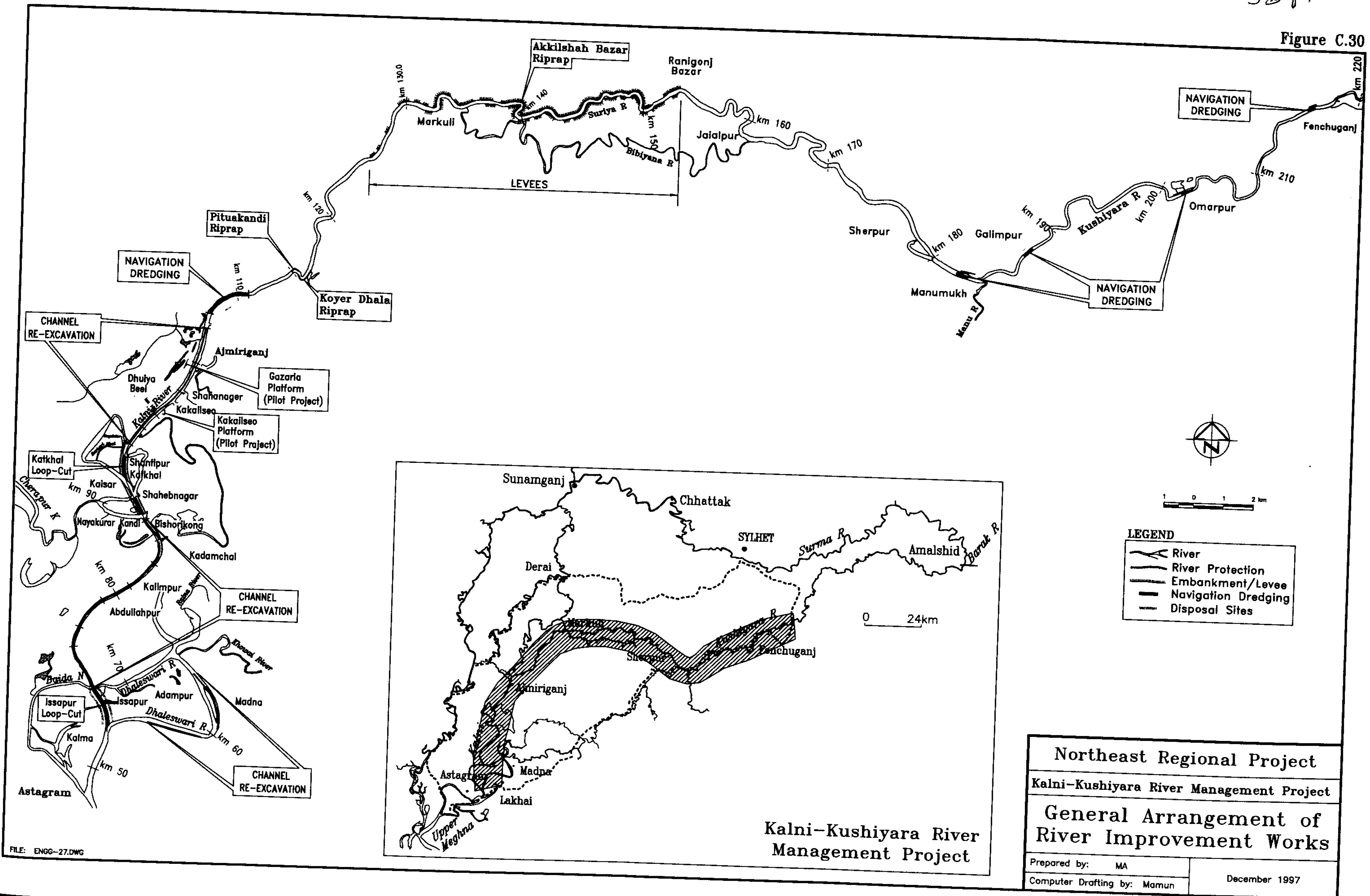
Prepared by: Tarek

Computer Drafting by: Mamun

December 1997

FILE: ENGG-03.DWG

Figure C.30



Northeast Regional Project

Kalni-Kushiyara River Management Project

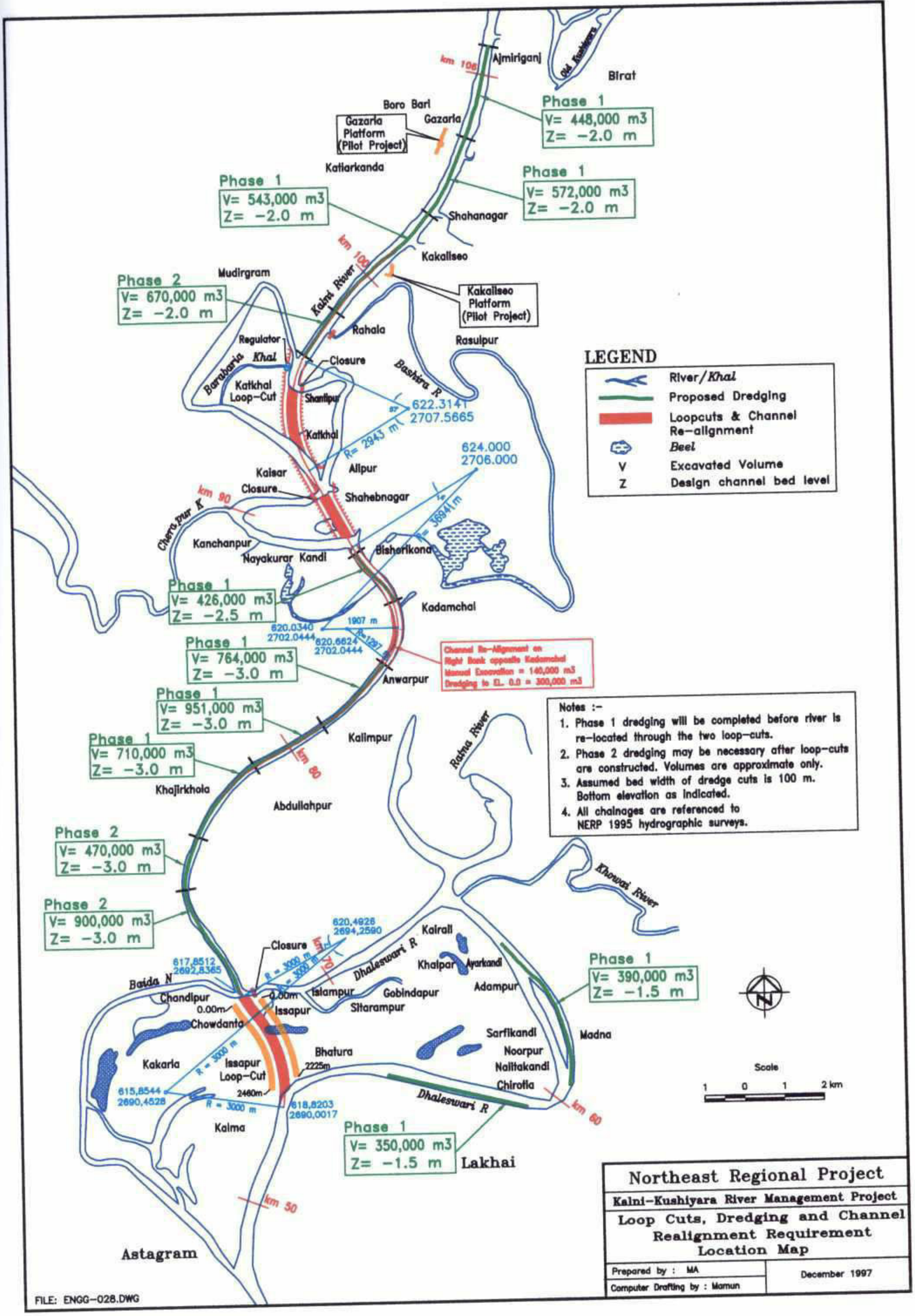
General Arrangement of River Improvement Works

Prepared by: MA

Computer Drafting by: Mamun

December 1997

Figure C.31



LEGEND

	River/*Khal*
	Proposed Dredging
	Loopcuts & Channel Re-alignment
	Beel
V	Excavated Volume
Z	Design channel bed level

Notes :-

1. Phase 1 dredging will be completed before river is re-located through the two loop-cuts.
2. Phase 2 dredging may be necessary after loop-cuts are constructed. Volumes are approximate only.
3. Assumed bed width of dredge cuts is 100 m. Bottom elevation as indicated.
4. All chainages are referenced to NERP 1995 hydrographic surveys.

Northeast Regional Project

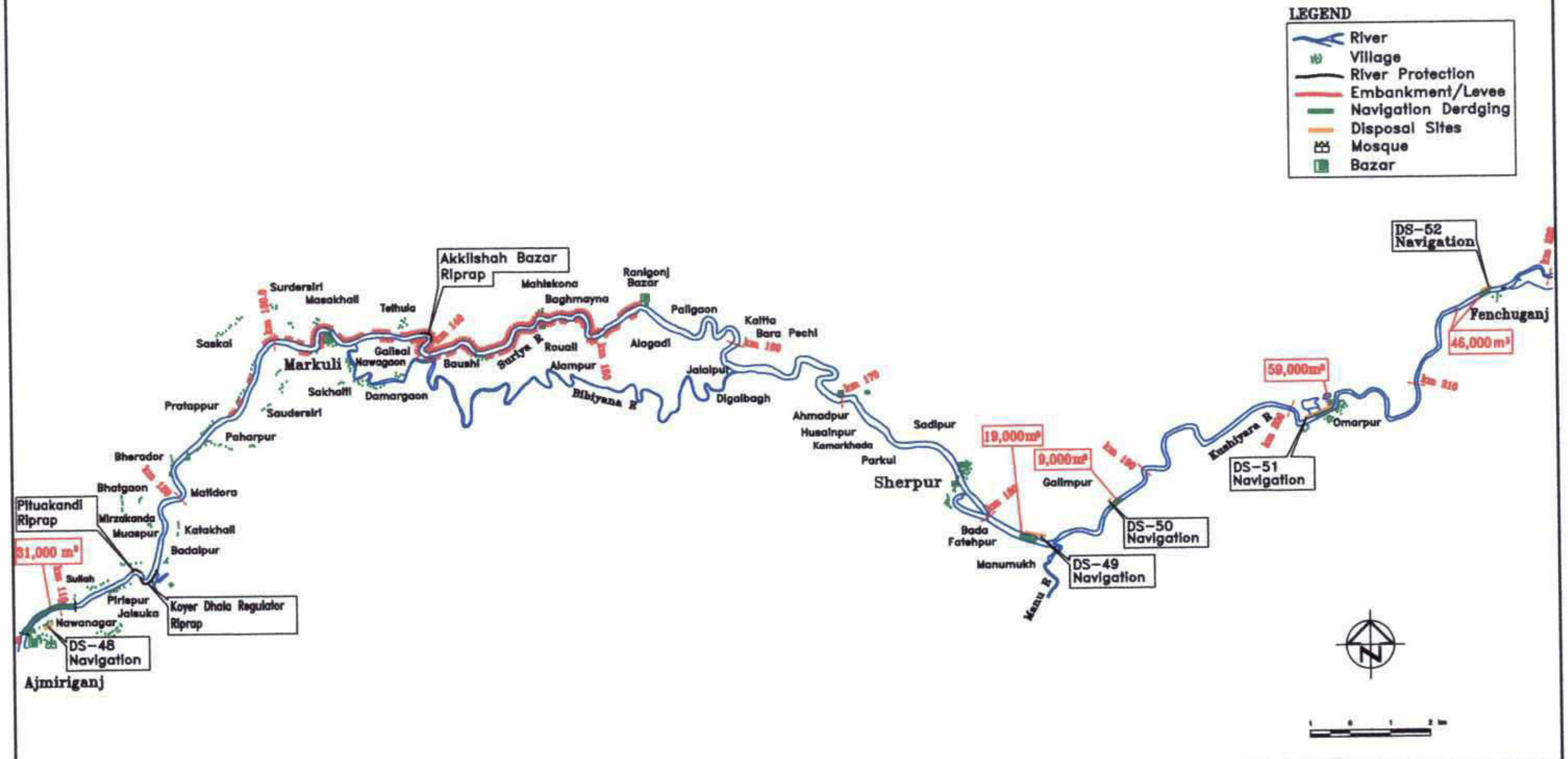
Kalni-Kushiyara River Management Project

Loop Cuts, Dredging and Channel Realignment Requirement Location Map

Prepared by : MA
Computer Drafting by : Mamun
December 1997

D9D

Figure C.32



Northeast Regional Project

Kalni-Kushiyara River Management Project

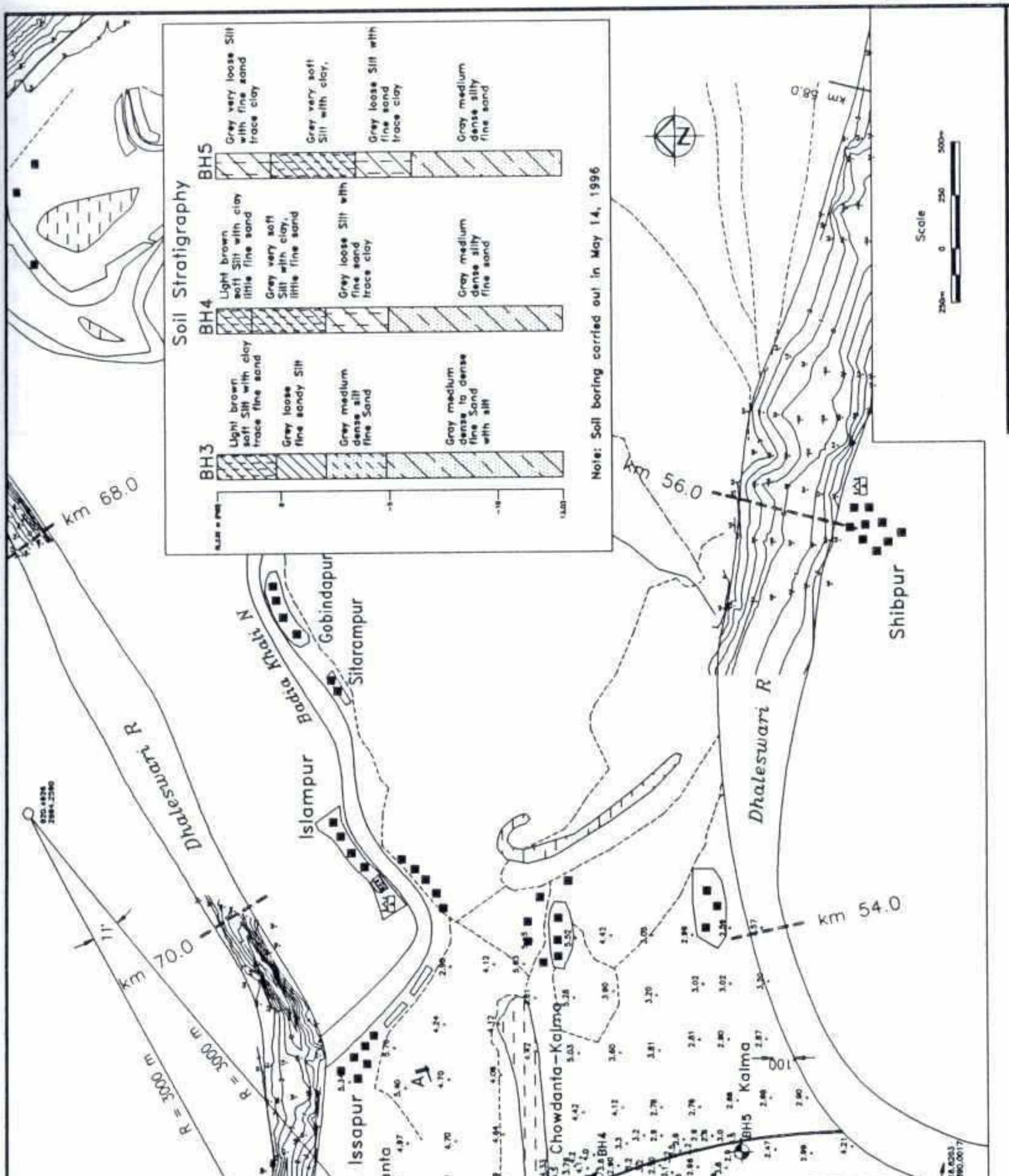
River Training, Levees & Navigation Dredging

Location Plan

Prepared by: MA	December 1997
Computer Drafting by: Mamun	

FILE: EN00-29.DWG

Figure C.33



Northeast Regional Project

Kalni-Kushiyara River Management Project

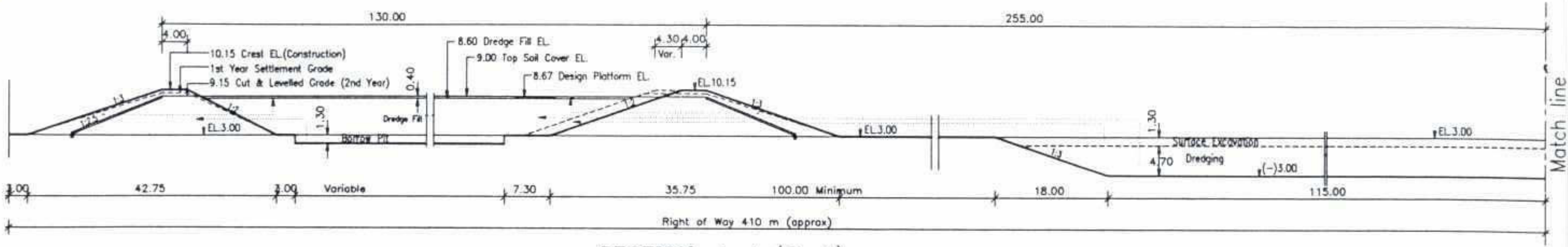
Issapur Loop Cut
Site Condition

Prepared by: D.G.M.

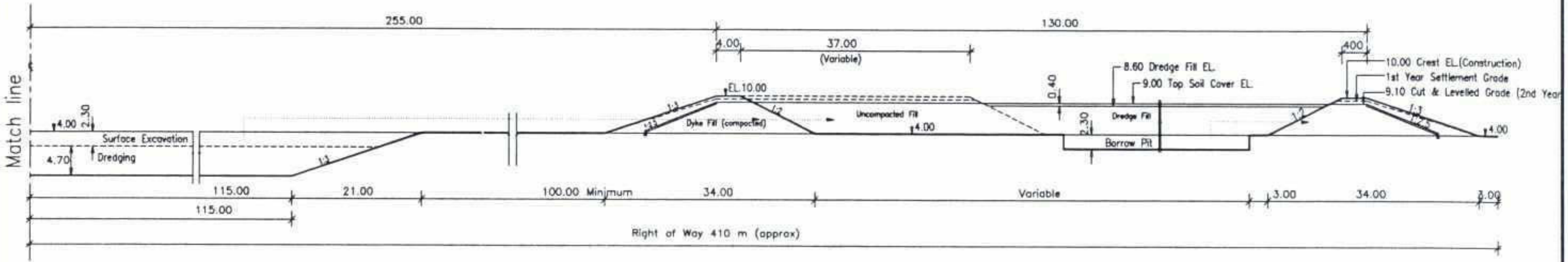
Computer Drafting by: Jalal

December 1997

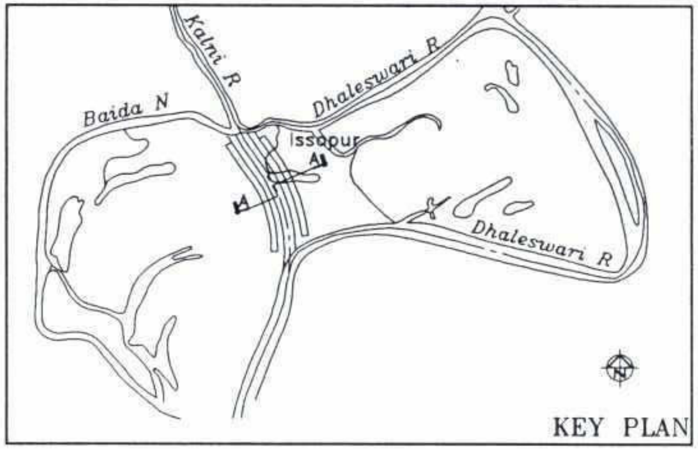
FILE: ENGG-302.DWG



SECTION: A-A (Part)



SECTION: A-A (Part)



KEY PLAN

FILE: ENGG-31DWG

Northeast Regional Project

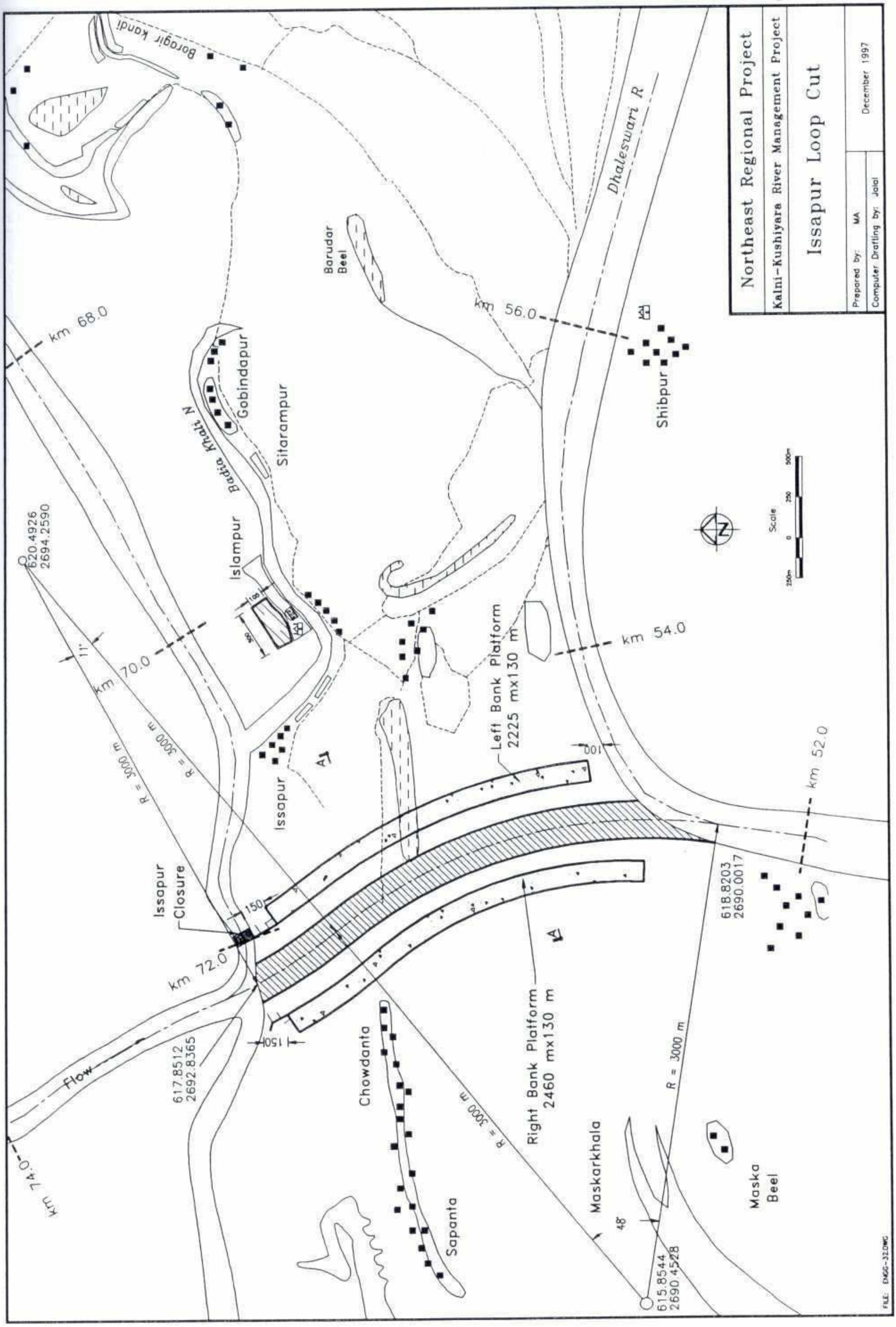
Kalni-Kushiyara River Management Project

Issapur Loop Cut
Section A-A

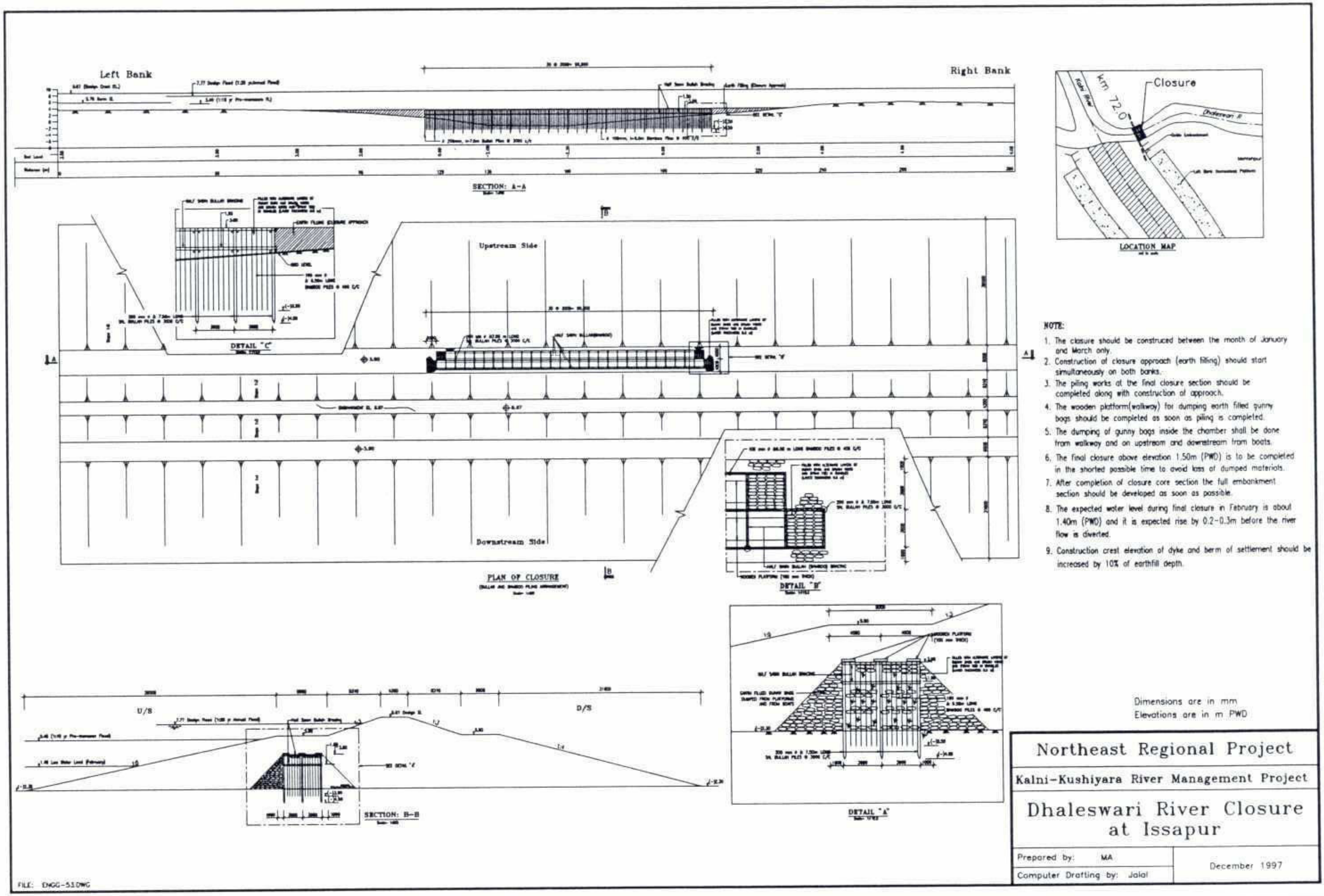
Prepared by: MA	December 1997
Computer Drafting by: Jalal	

Figure C.34

Figure C.35



Northeast Regional Project
Kalni-Kushiyara River Management Project
Issapur Loop Cut
Prepared by: MA
Computer Drafting by: Jalal
December 1997



NOTE:

1. The closure should be construced between the month of January and March only.
2. Construction of closure approach (earth filling) should start simultaneously on both banks.
3. The piling works at the final closure section should be completed along with construction of approach.
4. The wooden platform(walkway) for dumping earth filled gunny bags should be completed as soon as piling is completed.
5. The dumping of gunny bags inside the chamber shall be done from walkway and on upstream and downstream from boats.
6. The final closure above elevation 1.50m (PWD) is to be completed in the shorted possible time to avoid loss of dumped materials.
7. After completion of closure core section the full embankment section should be developed as soon as possible.
8. The expected water level during final closure in February is about 1.40m (PWD) and it is expected rise by 0.2-0.3m before the river flow is diverted.
9. Construction crest elevation of dyke and berm of settlement should be increased by 10% of earthfill depth.

Dimensions are in mm
Elevations are in m PWD

Northeast Regional Project

Kalni-Kushiyara River Management Project

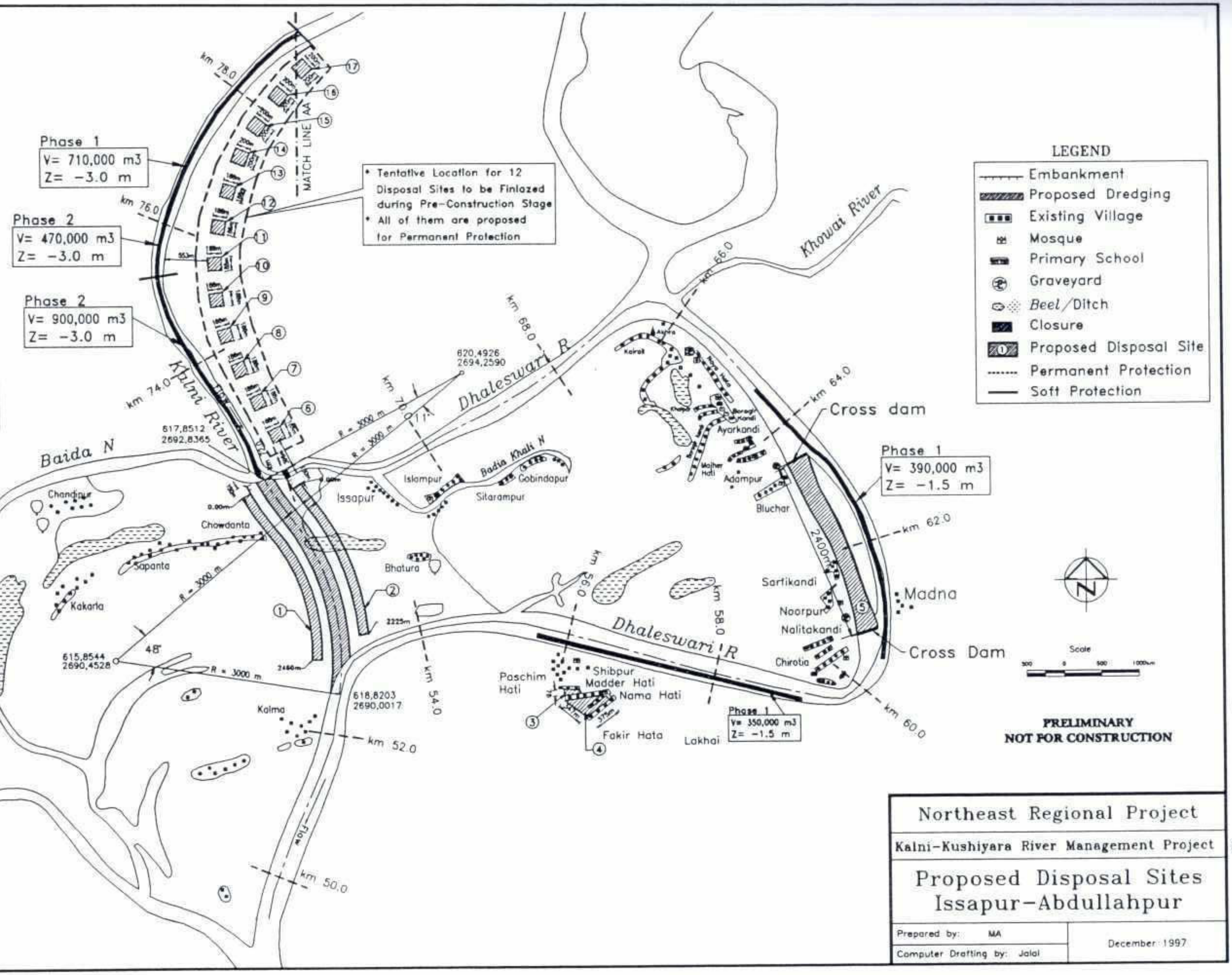
Dhaleswari River Closure
at Issapur

Prepared by: MA
Computer Drafting by: Jalal
December 1997

Figure C.36

Figure C.37

Site No	Length (m)	Length (m)
1	2460	130
2	2225	130
3	207	76
4	347	375
5	2400	300
6	188	188
7	188	188
8	188	188
9	188	188
10	188	188
11	188	188
12	188	188
13	188	188
14	200	200
15	200	200
16	200	200
17	200	200



Northeast Regional Project

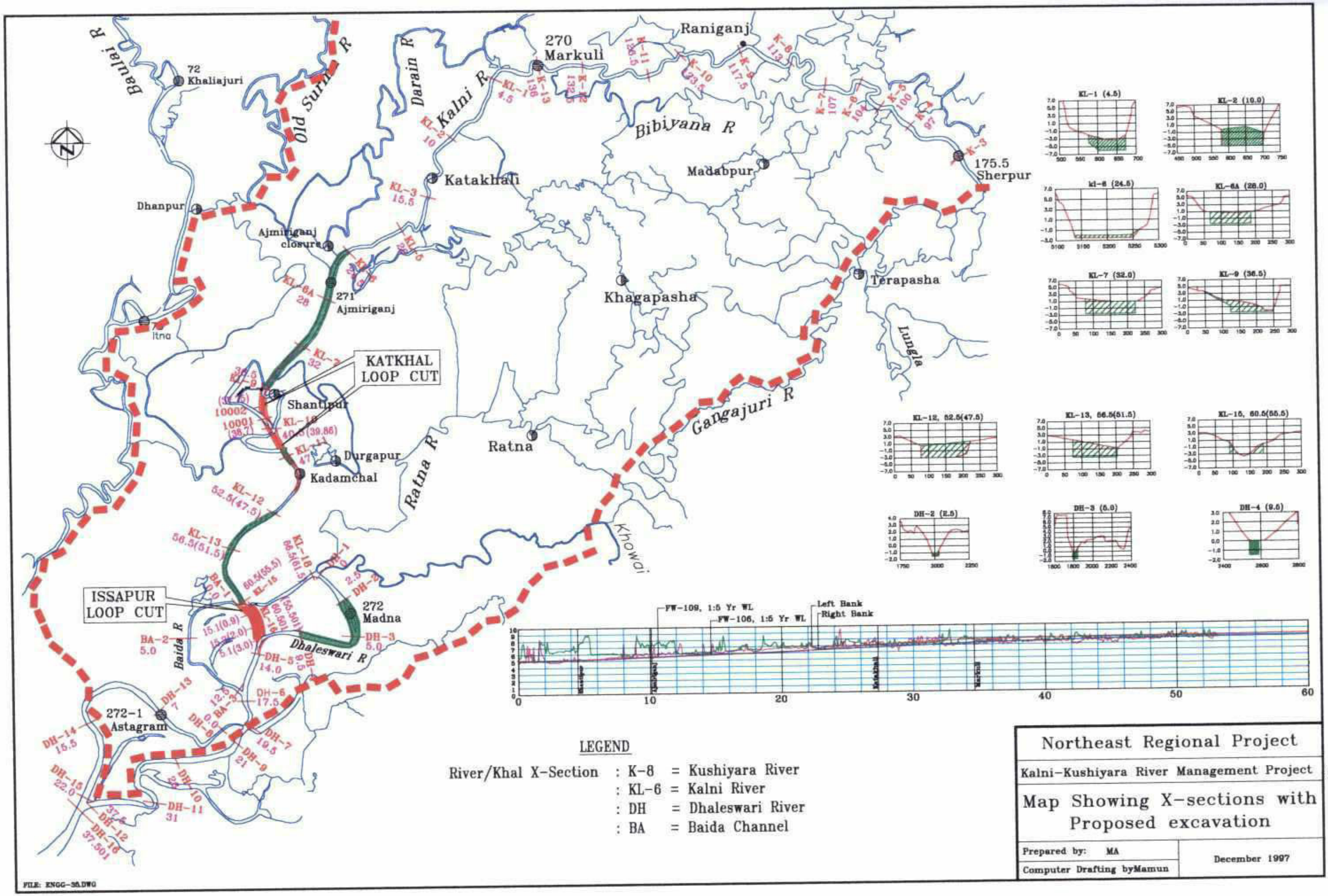
Kalni-Kushiyara River Management Project

Proposed Disposal Sites
Issapur-Abdullahpur

Prepared by: MA
Computer Drafting by: Jalal
December 1997

D95

Figure C.38



LEGEND

River/Khal X-Section
: K-8 = Kushiyara River
: KL-6 = Kalni River
: DH = Dhaleswari River
: BA = Baida Channel

Northeast Regional Project

Kalni-Kushiyara River Management Project

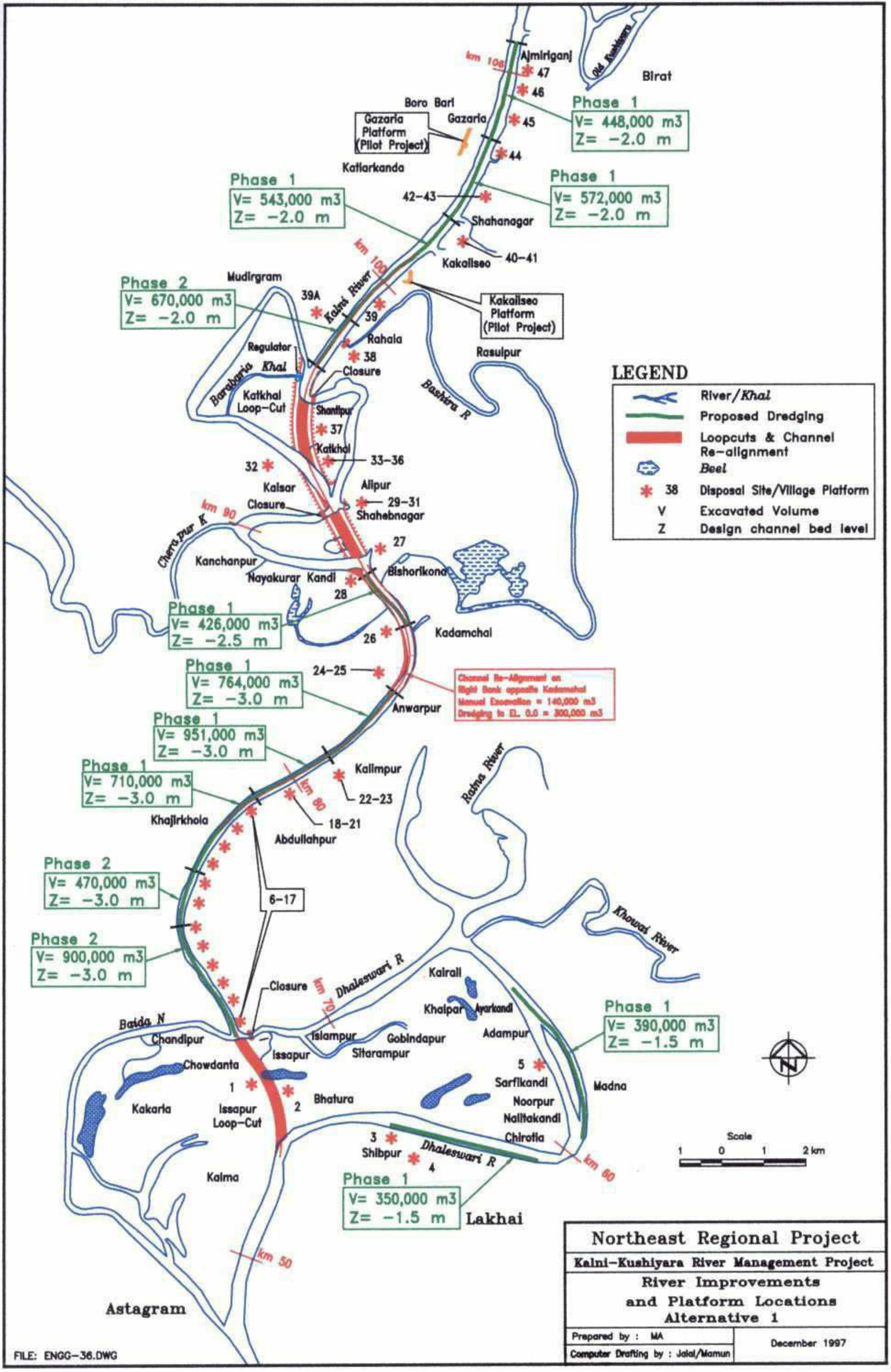
Map Showing X-sections with Proposed excavation

Prepared by: MA

Computer Drafting byMamun

December 1997

Figure C.39



LEGEND

	River/*Khal*
🟩	Proposed Dredging
🟥	Loopcuts & Channel Re-alignment
	Beel
* 38	Disposal Site/Village Platform
V	Excavated Volume
Z	Design channel bed level

Northeast Regional Project

Kalni-Kushiyara River Management Project

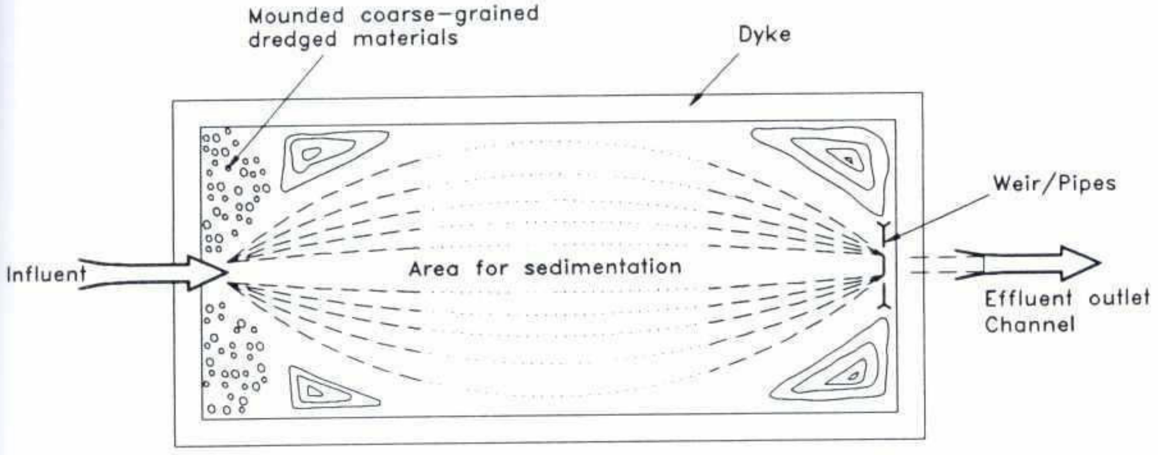
River Improvements
and Platform Locations
Alternative 1

Prepared by : MA

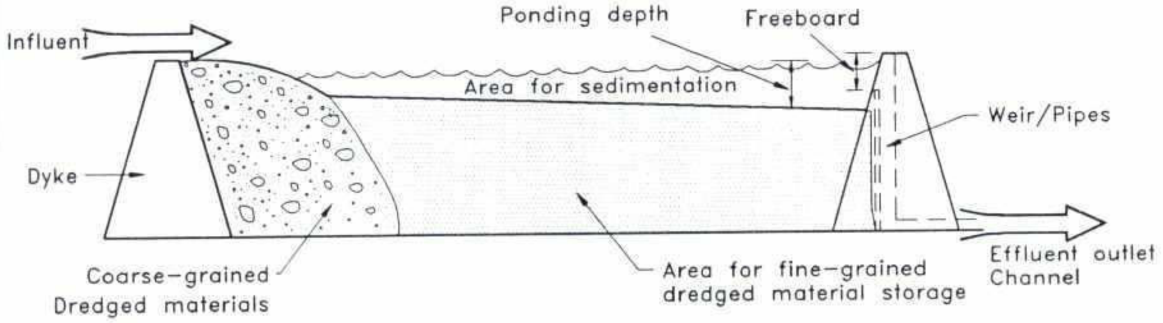
Computer Drafting by : Jalal/Mamun

December 1997

Figure C.40



(a) PLAN



(b) CROSS SECTION

Northeast Regional Project

Kalni-Kushiyara River Management Project

Main Features of Confined Disposal Chamber

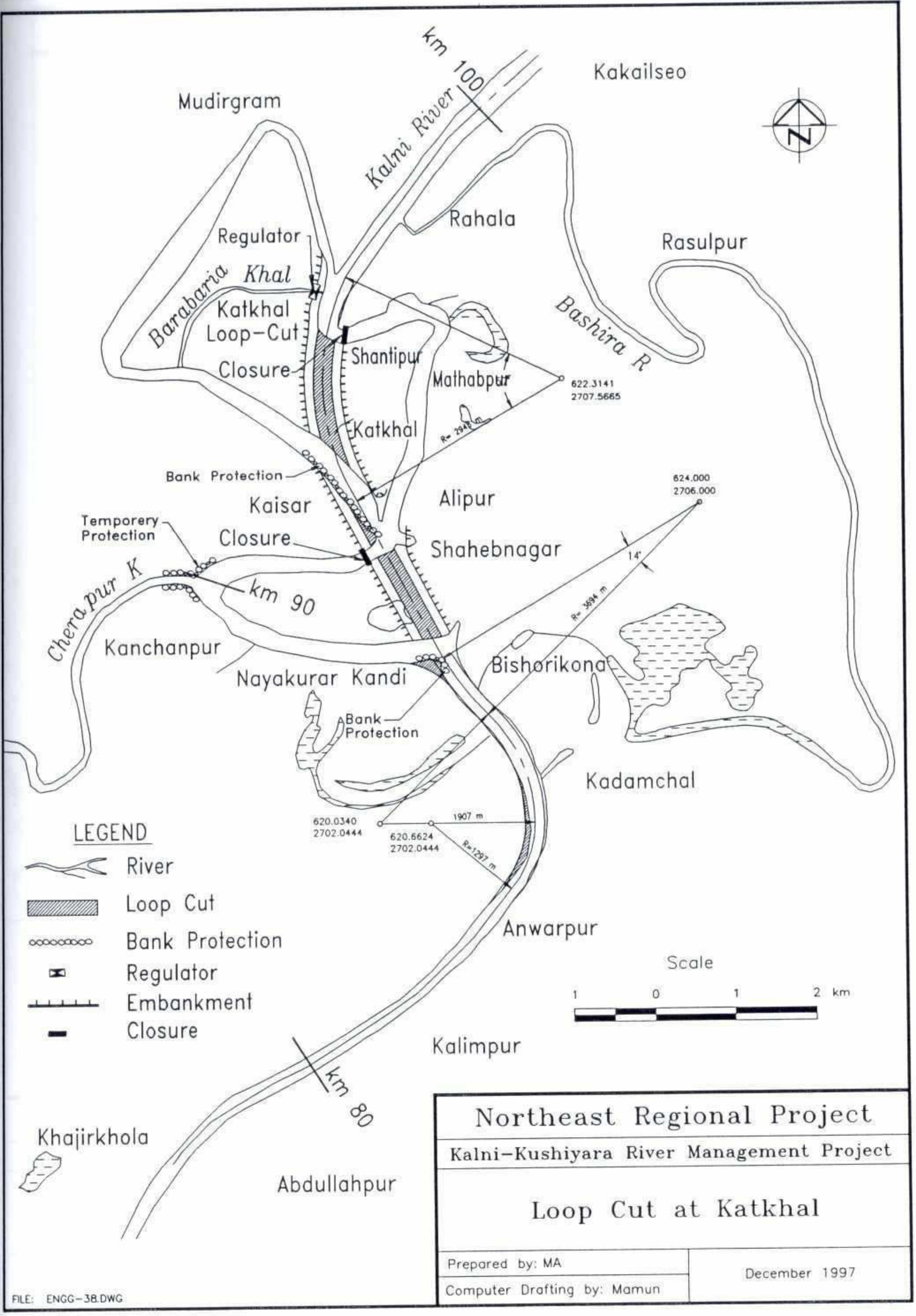
Prepared by: D.G.M.

Computer Drafting by: Jalal

December 1997

FILE: ENGG-37.DWG

Figure C.41



Northeast Regional Project

Kalni-Kushiyara River Management Project

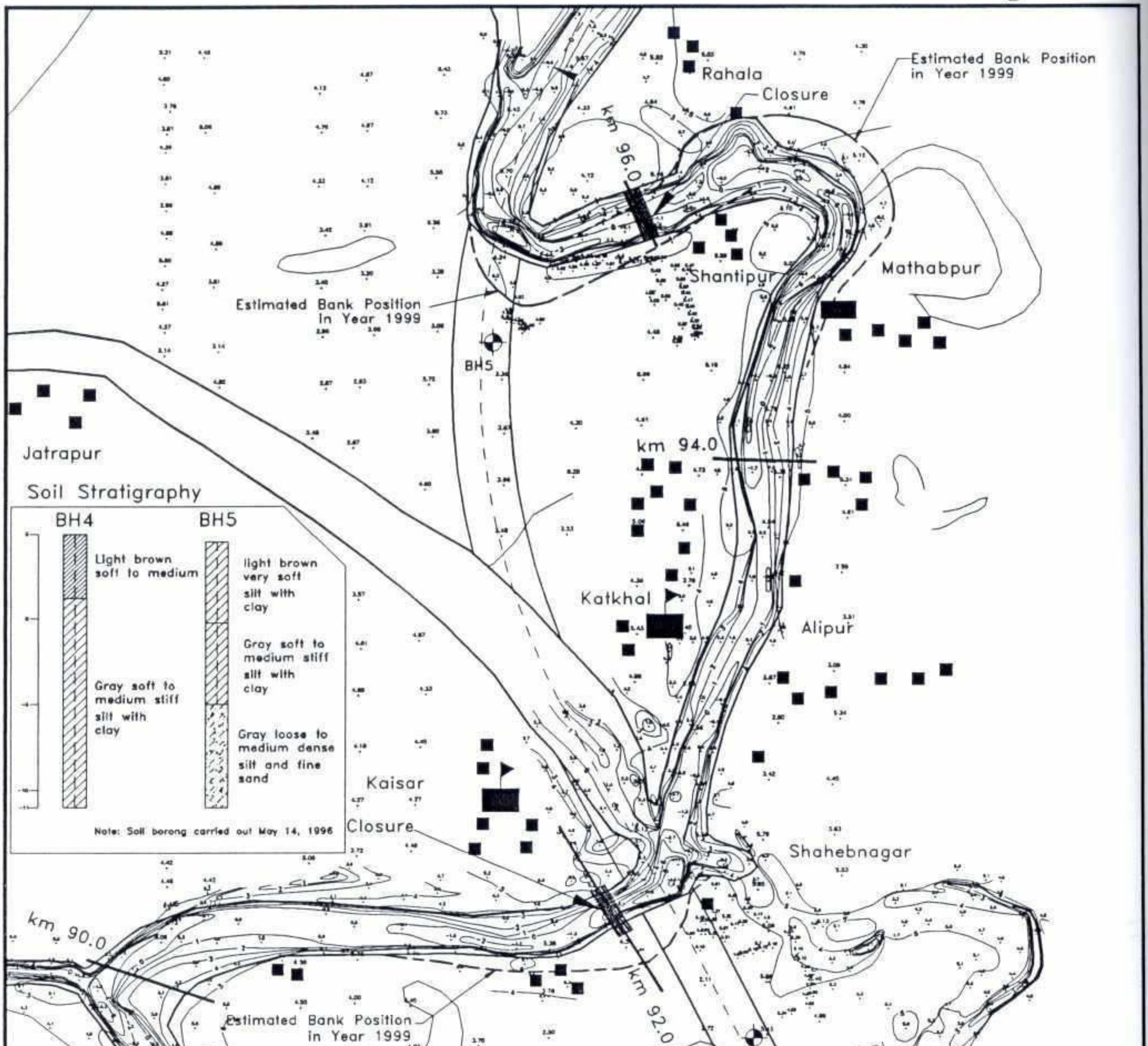
Loop Cut at Katkhal

Prepared by: MA

Computer Drafting by: Mamun

December 1997

Figure C.42



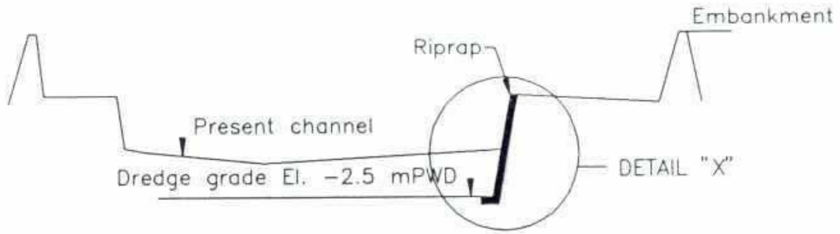
Northeast Regional Project

Kalni–Kushiyara River Management Project

Katkhal Loop Cut
Site Condition

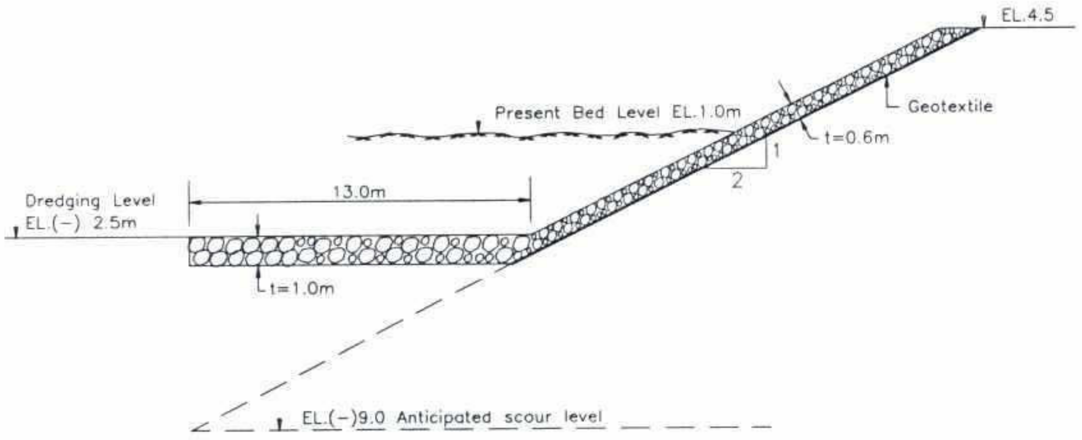
Prepared by: D.G.M.
Computer Drafting by: Jalal
December 1997

Figure C.43

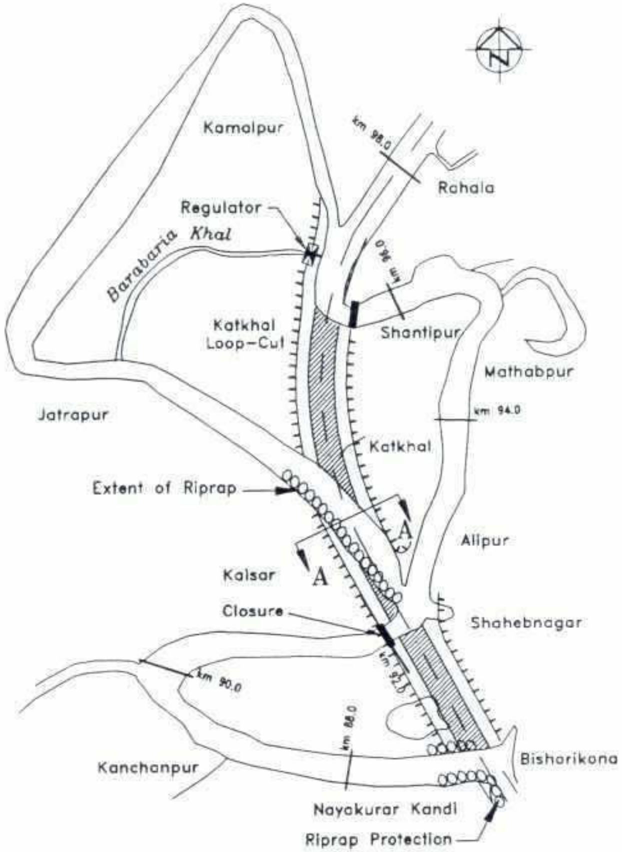


Distance from Left bank (m)

SECTION A-A
Viewing downstriem



DETAIL "X"



LOCATION MAP

Northeast Regional Project

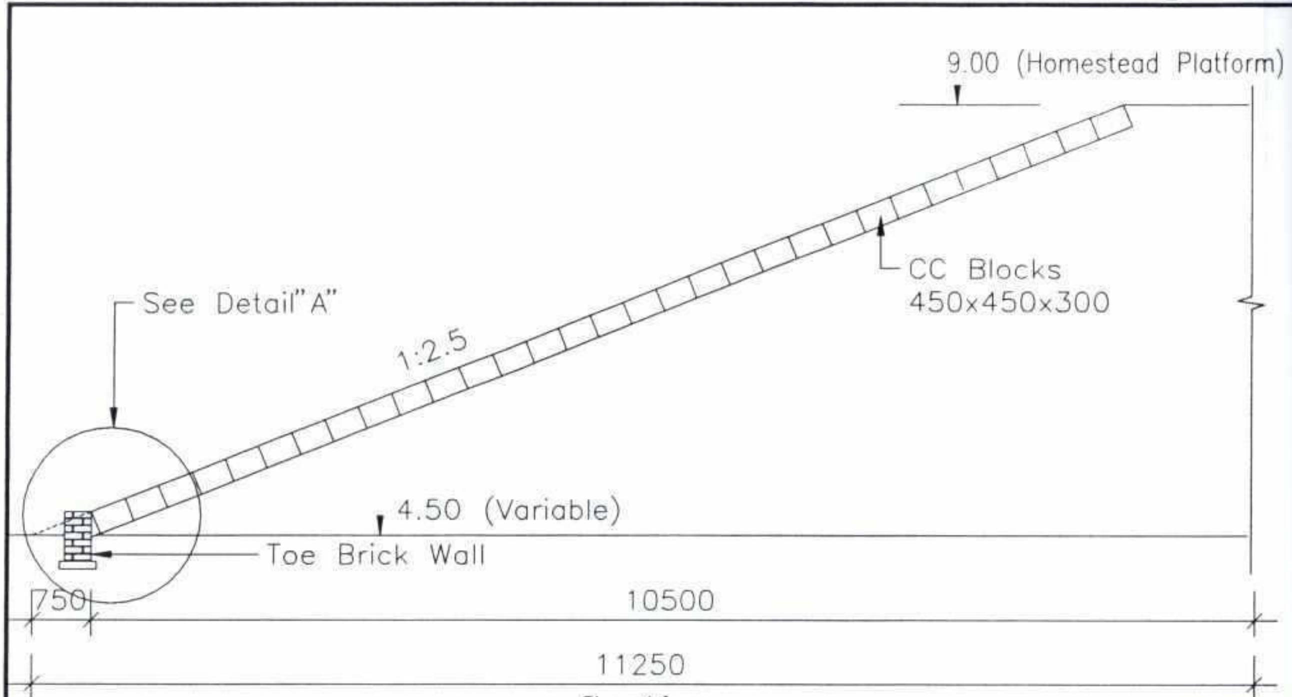
Kalni-Kushiyara River Management Project

Bank Protection
in Katkhal Loop Cut

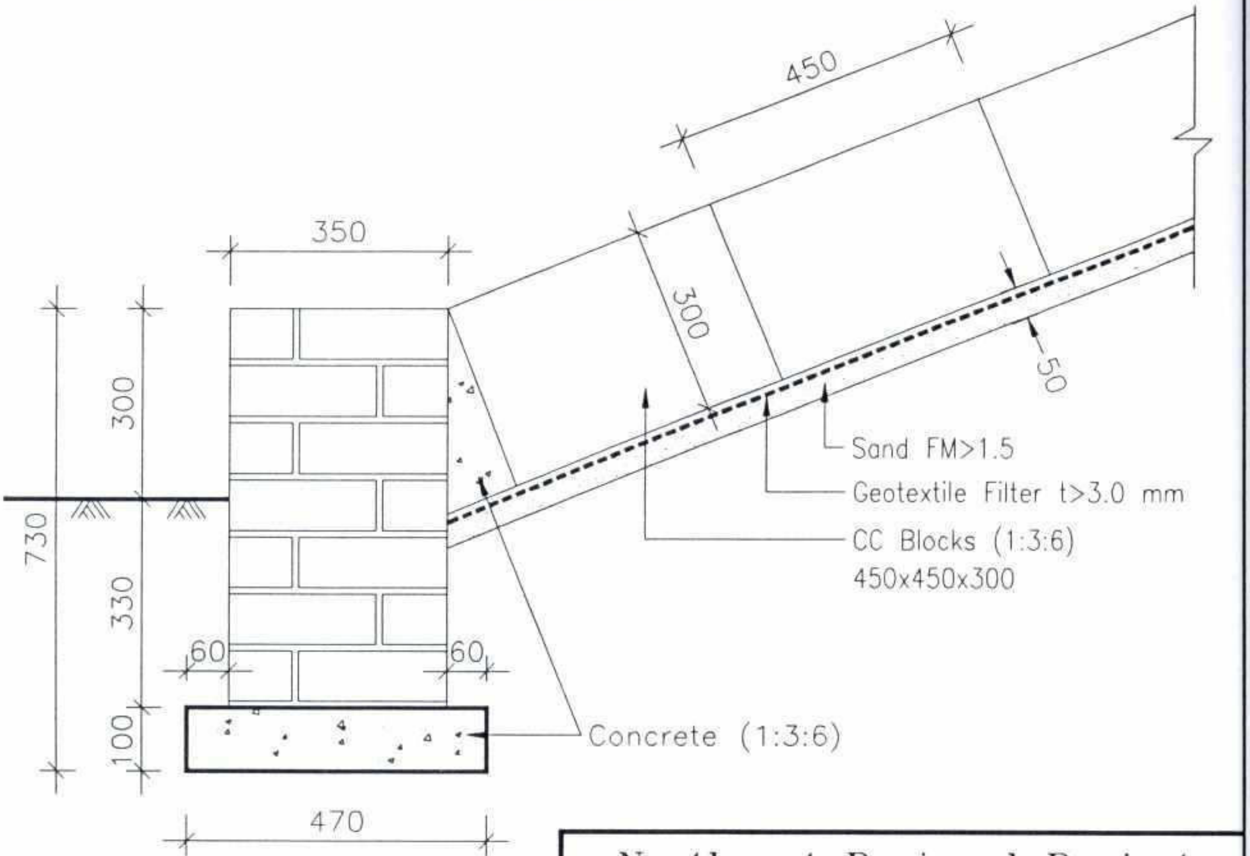
Prepared by: D.G.M.
Computer Drafting by: Mamun
December 1997

FILE: ENGG-02.DWG

Figure C.44



Section



Detail "A"

FILE: ENGG-40.DWG

Northeast Regional Project

Kalni-Kushiyara River Management Project

Protection of Homestead Platform
with Concrete Blocks

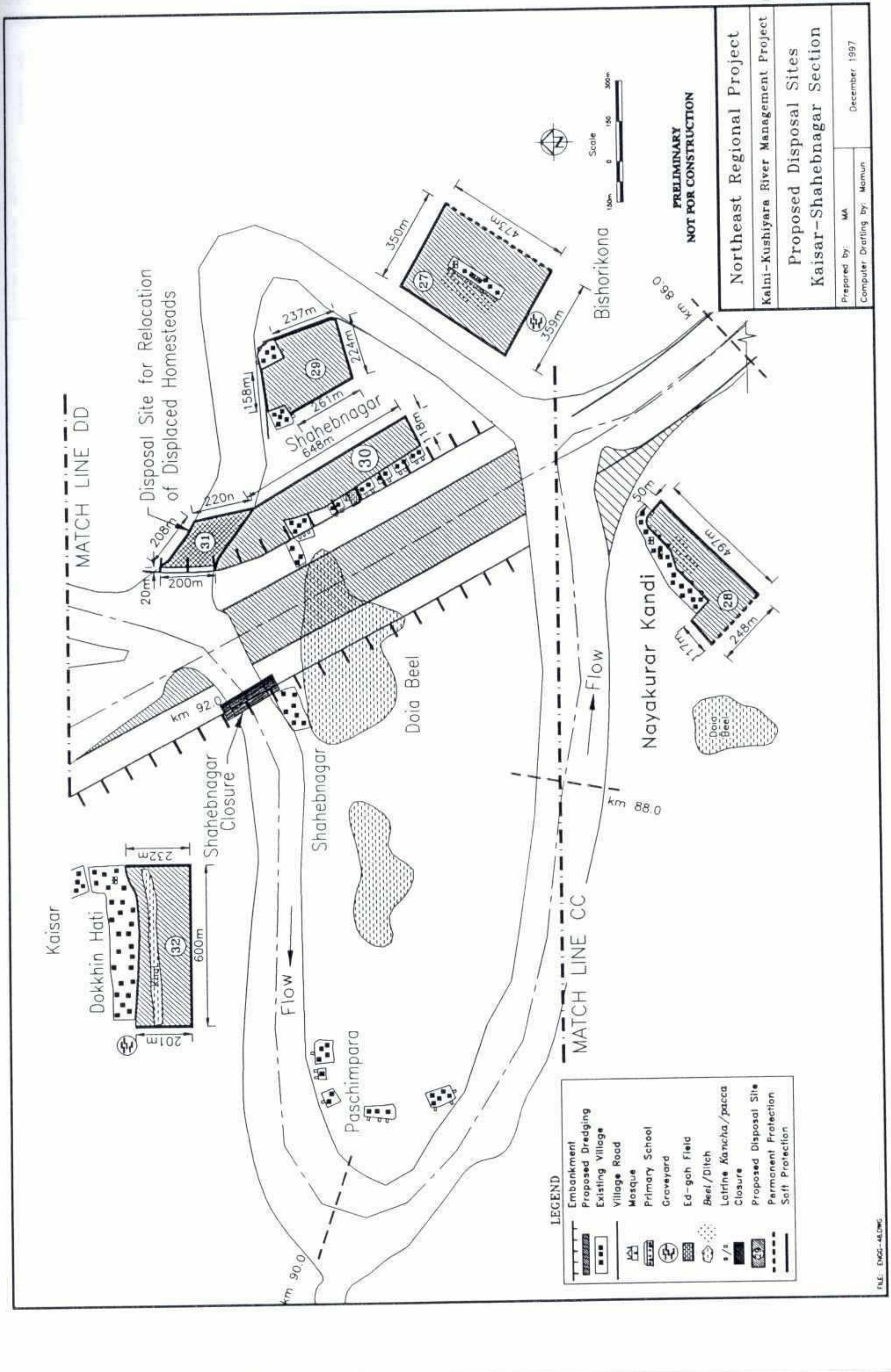
Prepared by: MA

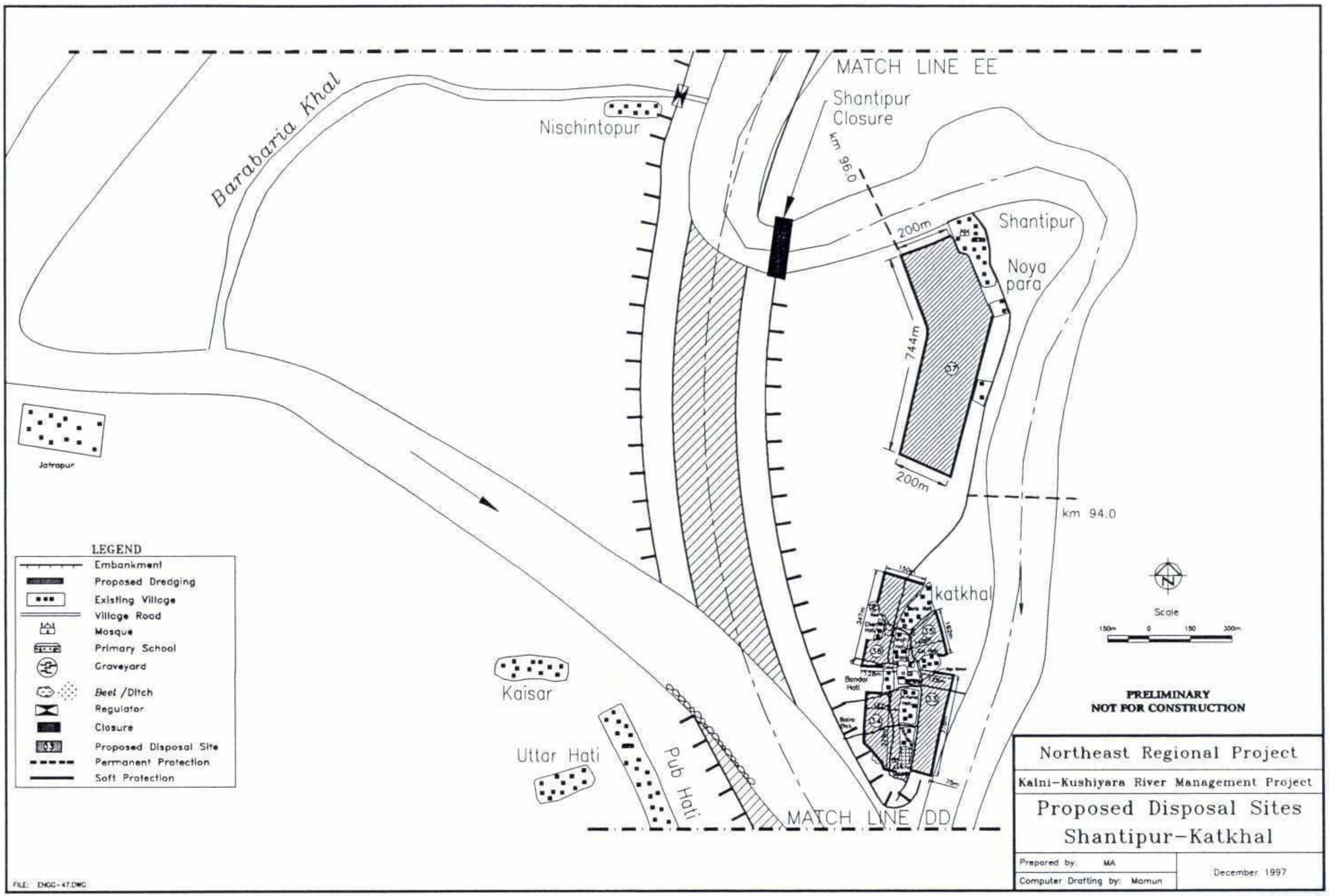
Computer Drafting by: Jalal

December 1997

268

Figure C.45





Northeast Regional Project

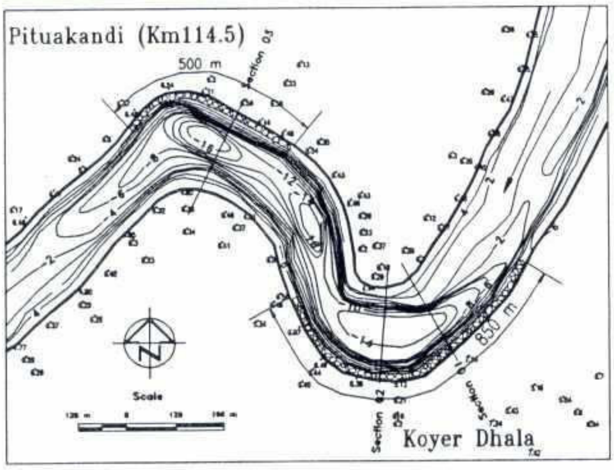
Kalni-Kushiyara River Management Project

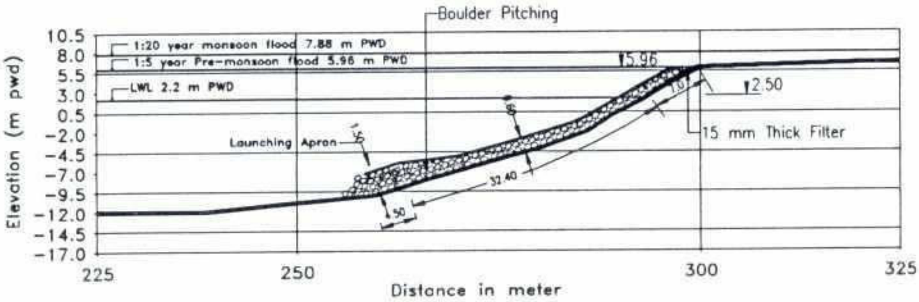
Proposed Disposal Sites
Shantipur-Katkhal

Prepared by: MA
Computer Drafting by: Mamun
December 1997

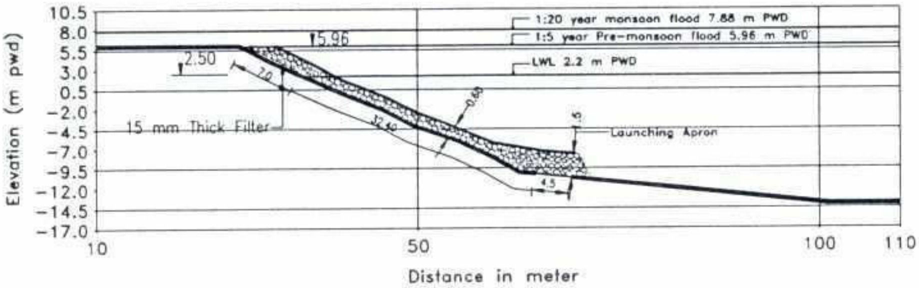
Figure C.46

Figure C.47

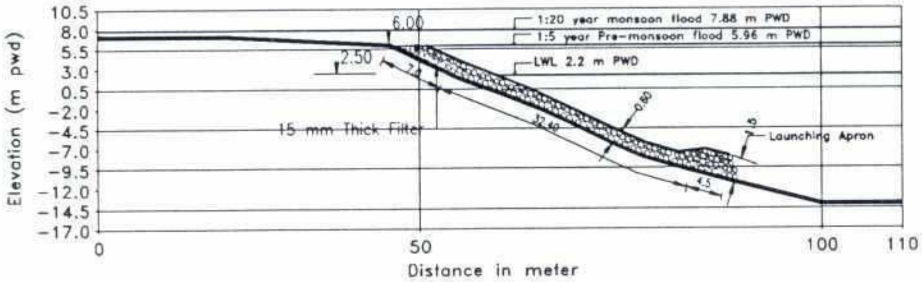




Section−3



Section−2



Section−1

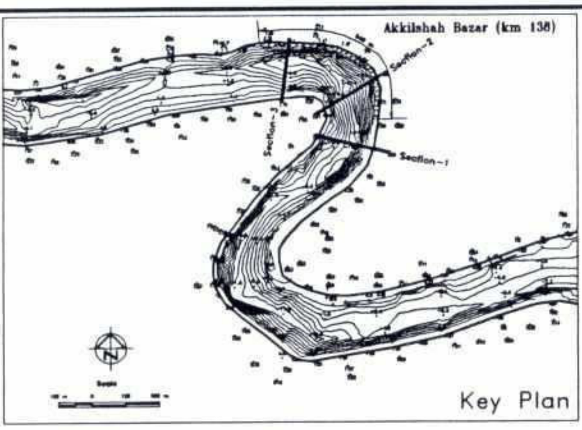
Northeast Regional Project

Kalni–Kushiyara River Management Project

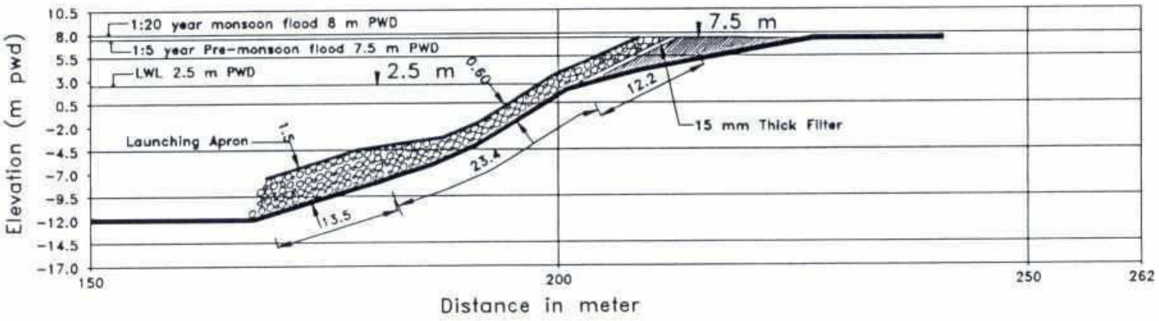
Erosion Protection at
Koyer Dhala and Pituakandi

Prepared by: Tarek	December 1997
Computer Drafting by: Jalal	

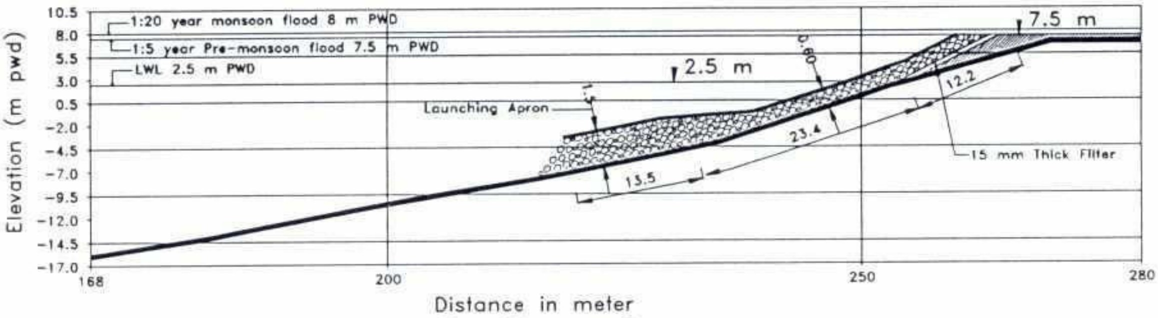
FILE: ENGG-41.DWG



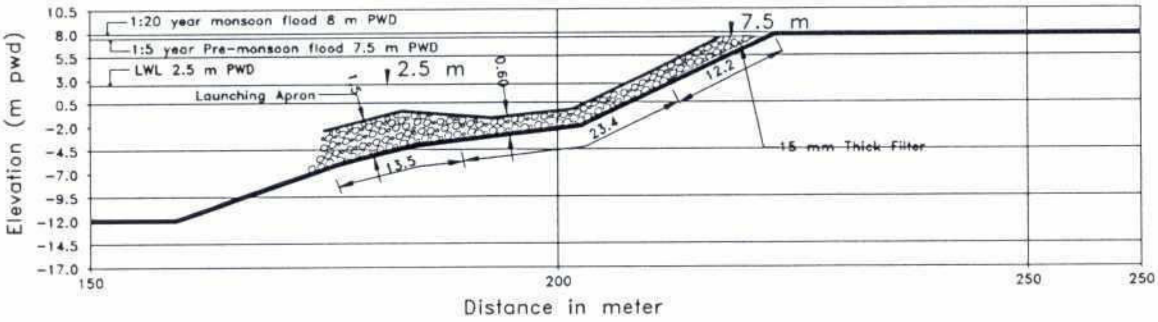
Key Plan



Section -3



Scetion -2



Section -1

Northeast Regional Project

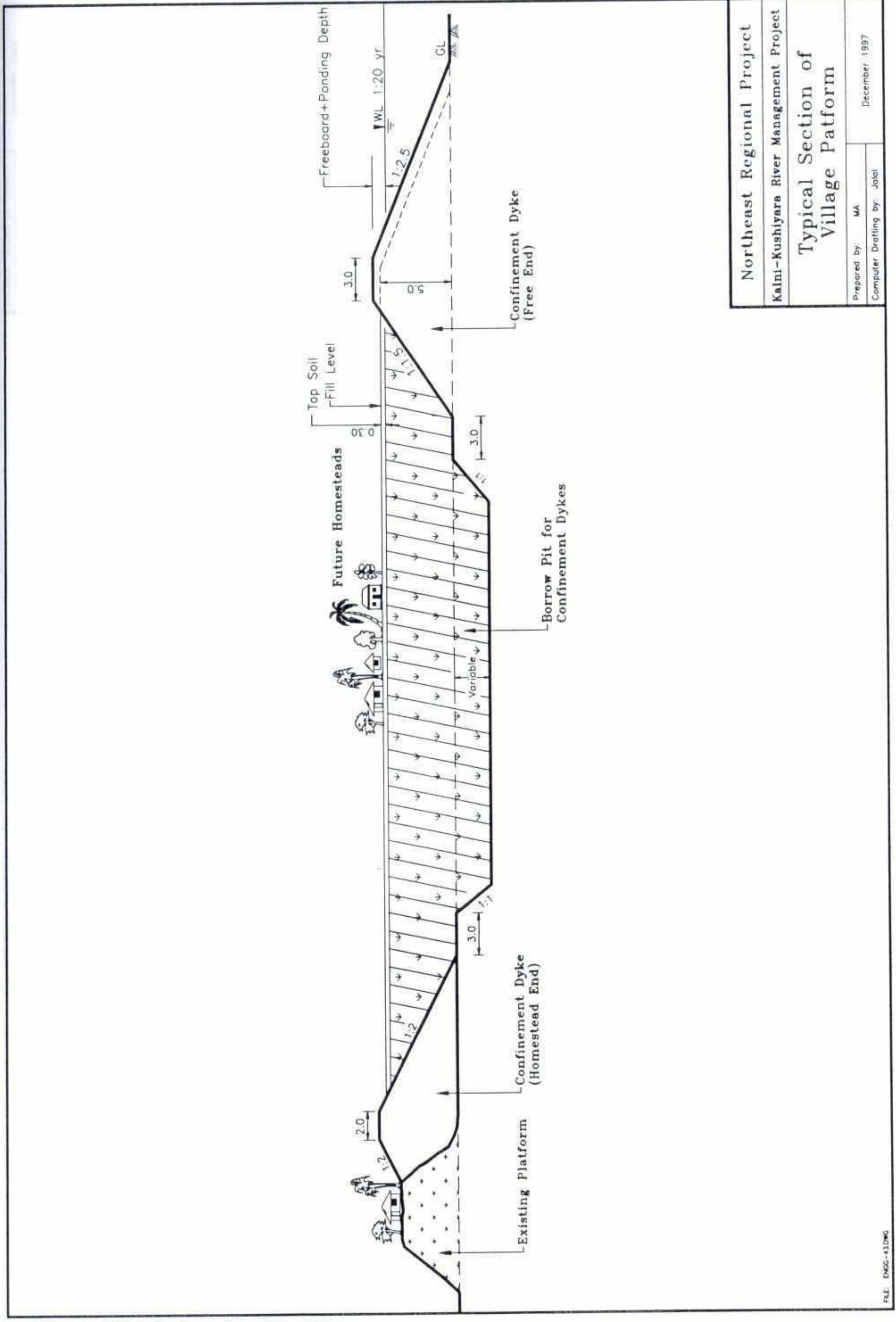
Kalni-Kushiyara River Management Project

Erosion Protection at
Akkilshah Bazar, km 138

Prepared by: Tarek	December 1997
Computer Drafting by: Jalal	

FILE: ENGG-42.DWG

Figuer C.49



Northeast Regional Project

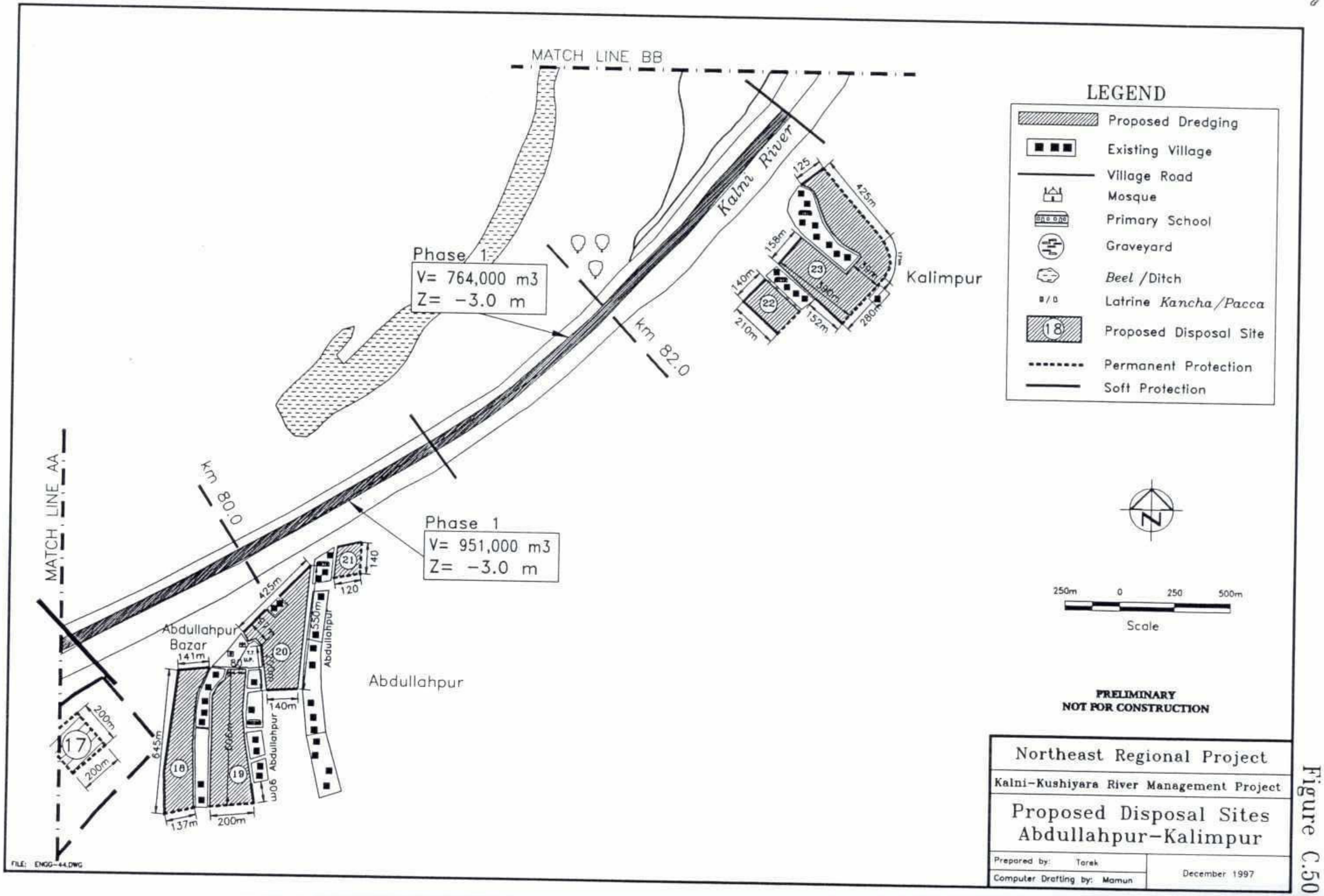
Kalni-Kushiyara River Management Project

Typical Section of Village Patform

Prepared by: MA

Computer Drafting by: Jalal

December 1997



Northeast Regional Project

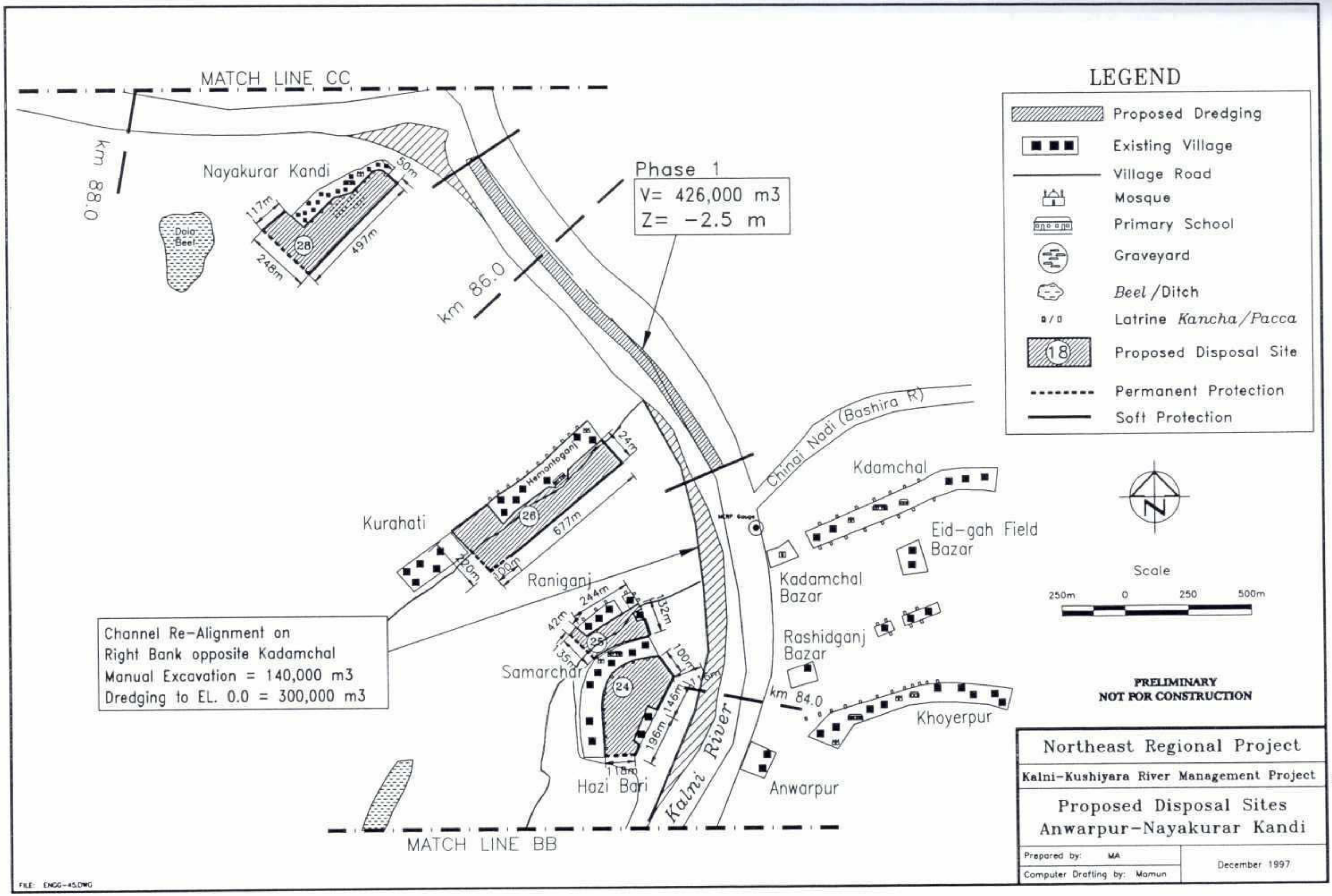
Kalni-Kushiyara River Management Project

Proposed Disposal Sites
Abdullahpur-Kalimpur

Prepared by: Tarek
Computer Drafting by: Mamun
December 1997

Figure C.50

Figure C.51



Channel Re-Alignment on
Right Bank opposite Kadamchal
Manual Excavation = 140,000 m3
Dredging to EL. 0.0 = 300,000 m3

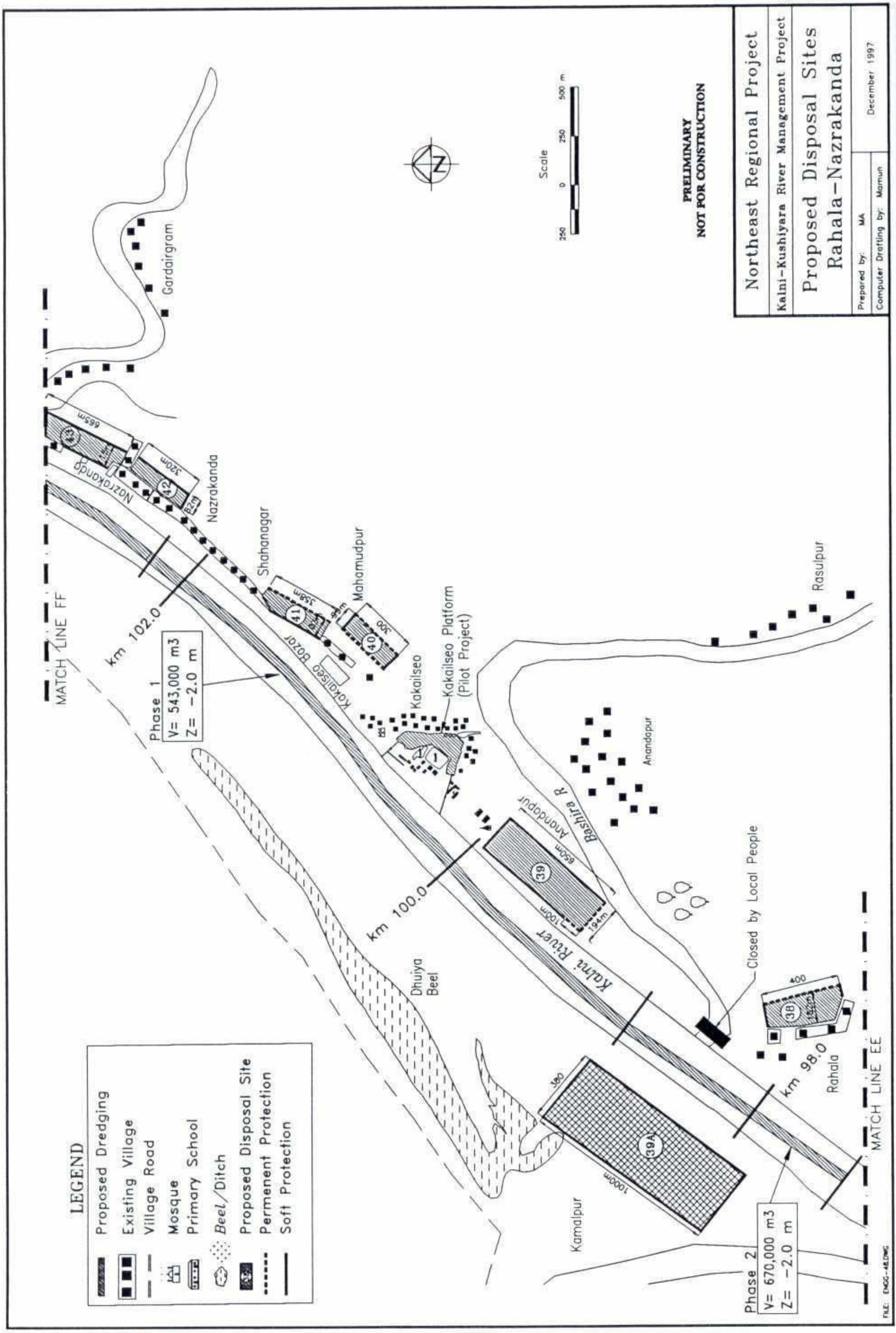
Northeast Regional Project

Kalni-Kushiyara River Management Project

Proposed Disposal Sites
Anwarpur-Nayakurar Kandi

Prepared by: MA
Computer Drafting by: Mamun
December 1997

Figure C.52



Northeast Regional Project

Kalni-Kushiyara River Management Project

Proposed Disposal Sites
Rahala-Nazrakanda

Prepared by: MA

Computer Drafting by: Mamun

December 1997

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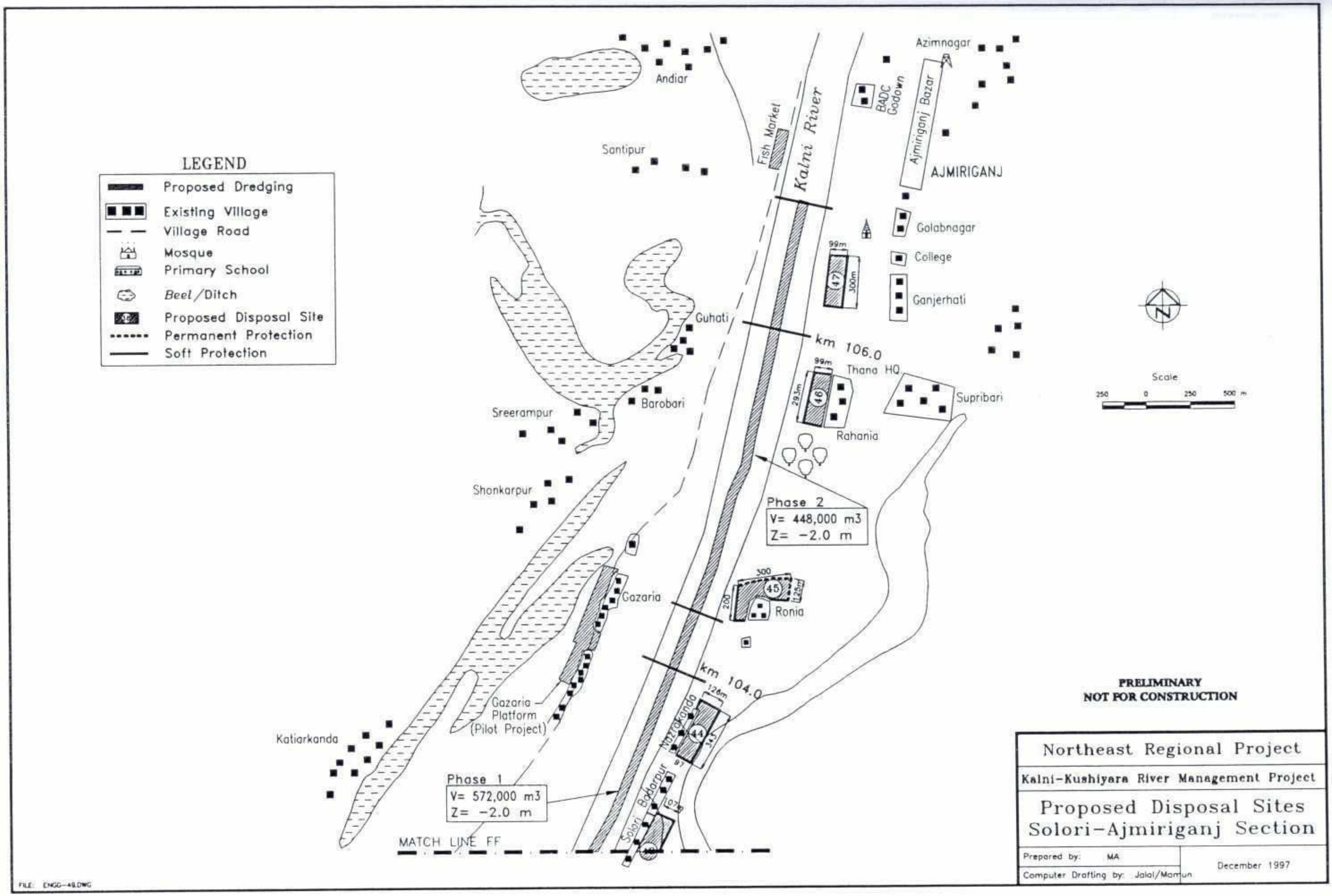
Figure C.53

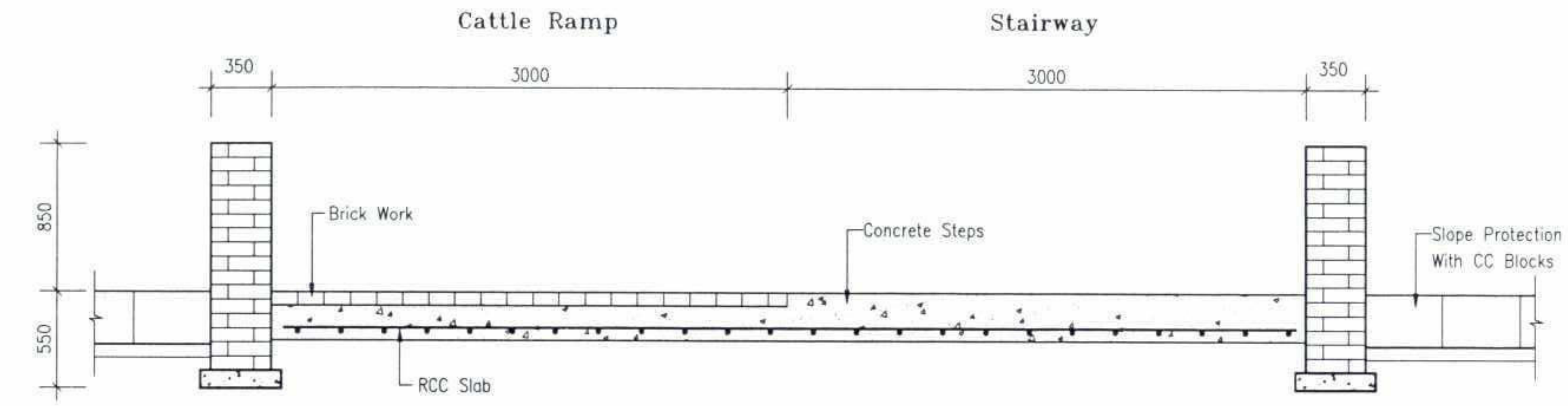


Northeast Regional Project

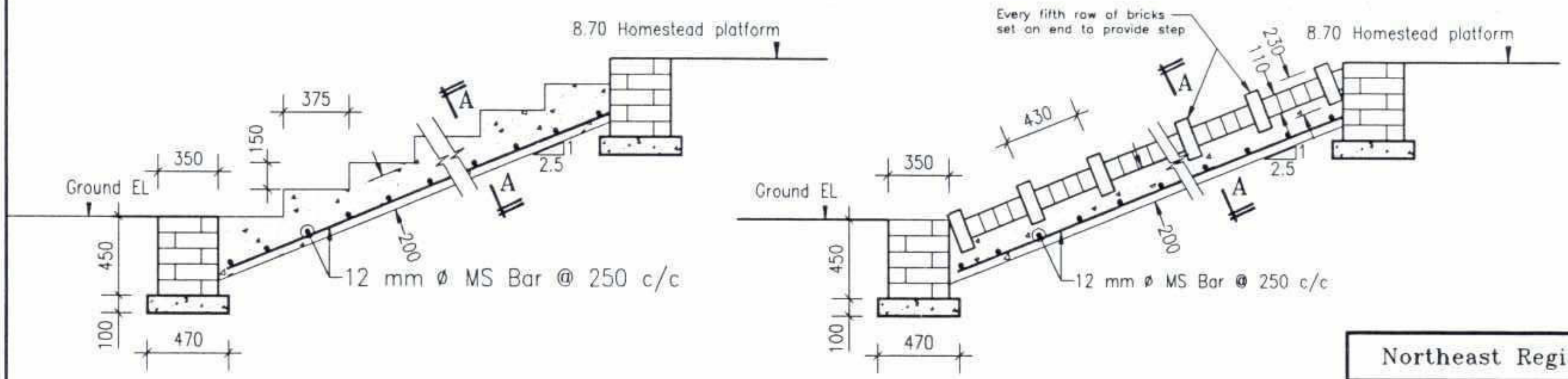
Kalni-Kushiyara River Management Project

Proposed Disposal Sites
Solori-Ajmiriganj Section

Prepared by: MA
Computer Drafting by: Jalal/Mamun
December 1997



Section: A-A



Section through Stairway

Section through Cattle Ramp

FILE: ENGG-50.DWG

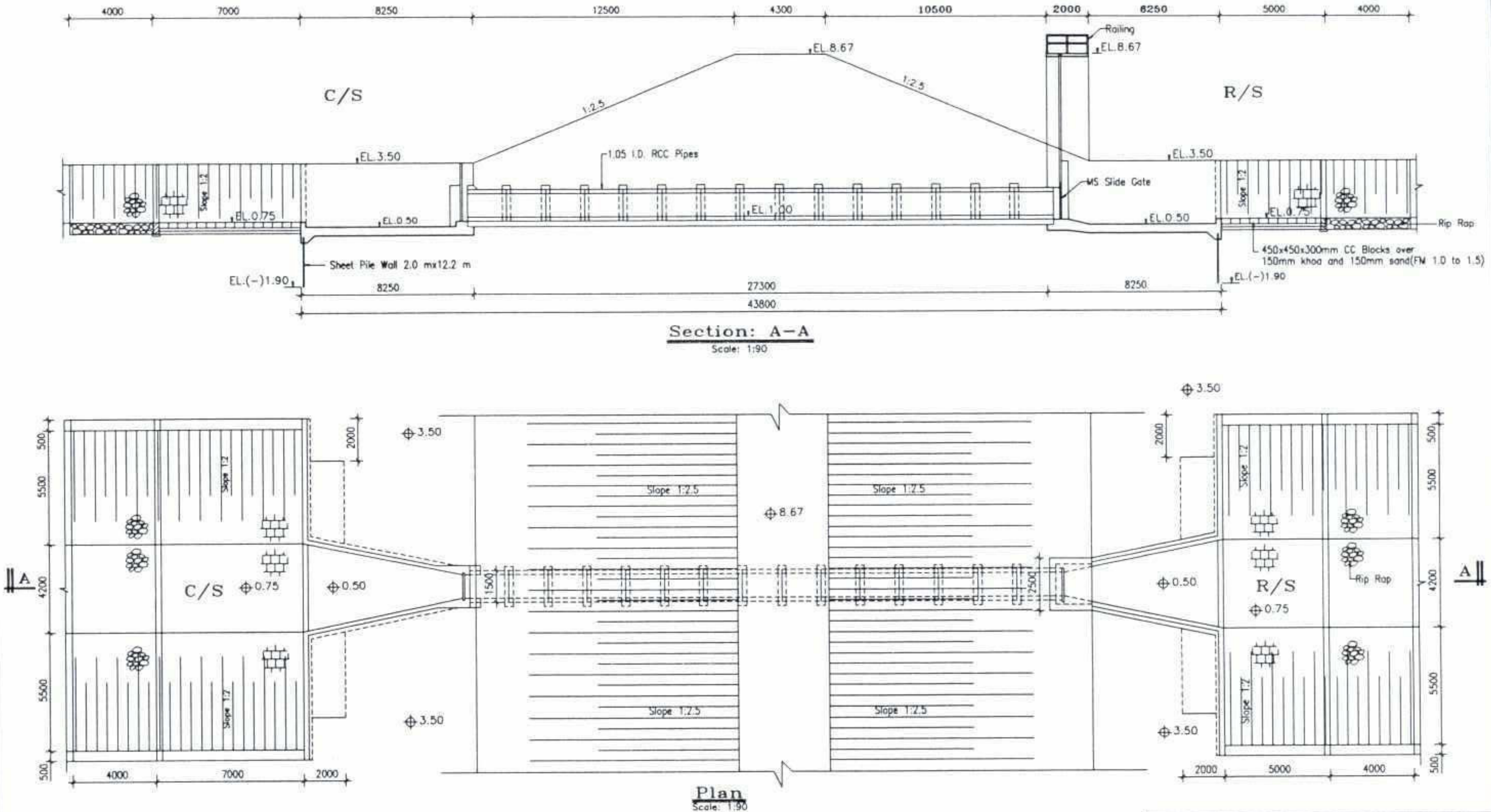
Northeast Regional Project

Kalni-Kushiyara River Management Project

Homestead Platform Cattle Access Ramp
and Pedestrian Stairway

Prepared by: MA
Computer Drafting by: Jalal
December 1997

Figure C.54



Note: Dimensions are in mm
Elevations are in m PWD

FILE: ENGG-55.DWG

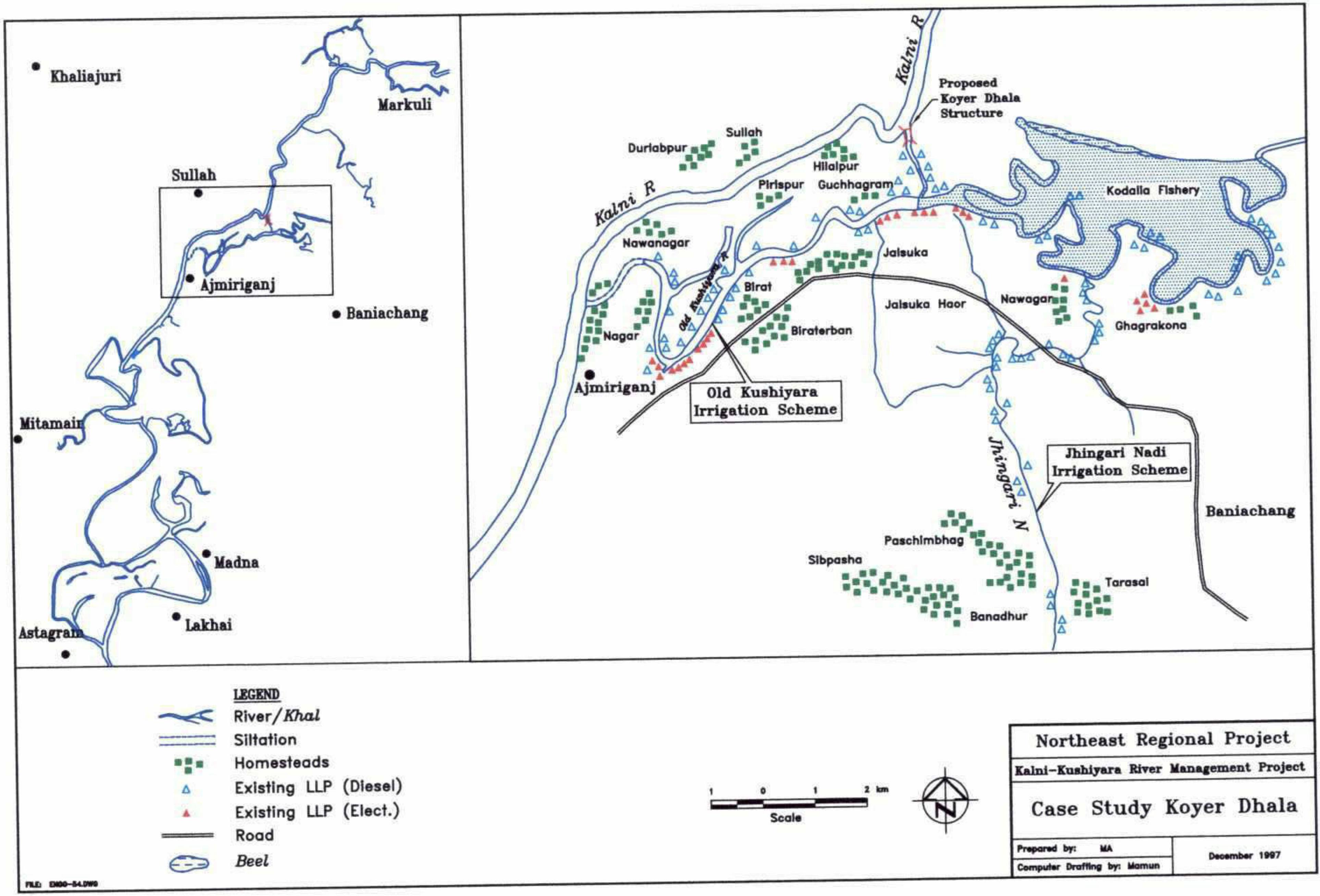
Northeast Regional Project

Kalni-Kushiyara River Management Project

Drainage/Flushing Sluice
Barabaria Khal at Shantipur

Prepared by: MA
Computer Drafting by: Jalal
December 1997

Figure C.55



Northeast Regional Project

Kalni-Kushiyara River Management Project

Case Study Koyer Dhala

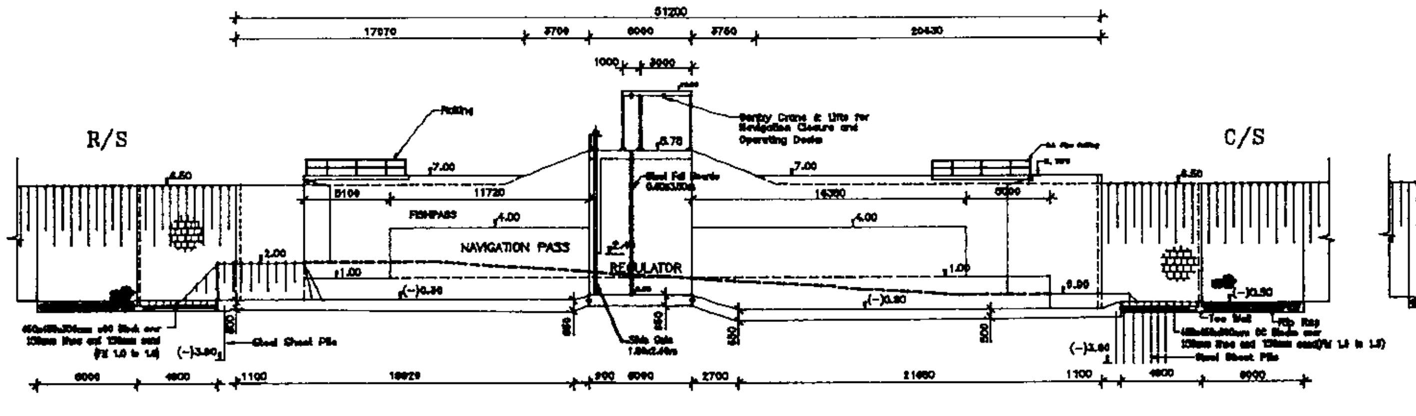
Prepared by: MA

Computer Drafting by: Mamun

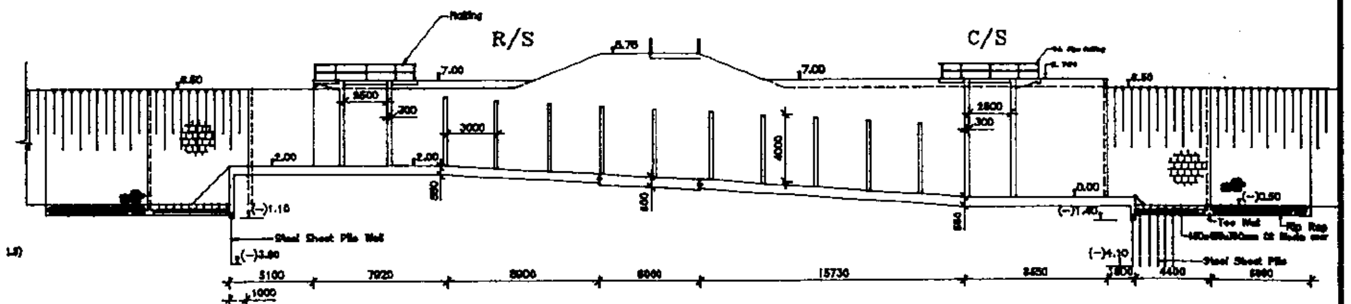
December 1997

Figure C.56

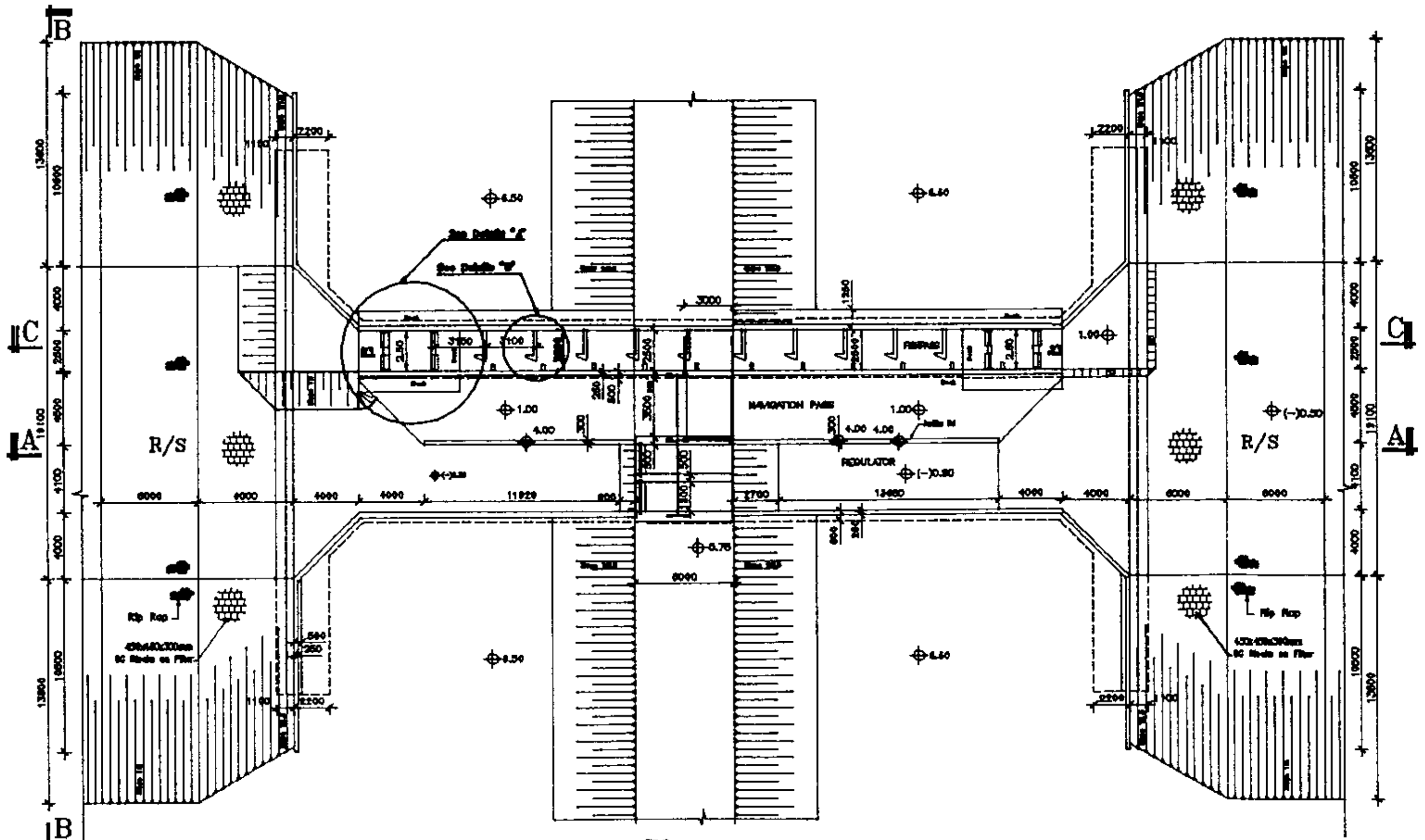
Figure C.57



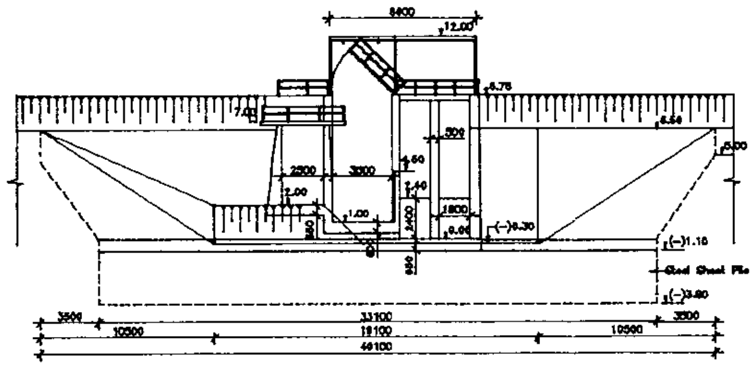
Section: A-A
Scale: 1:150



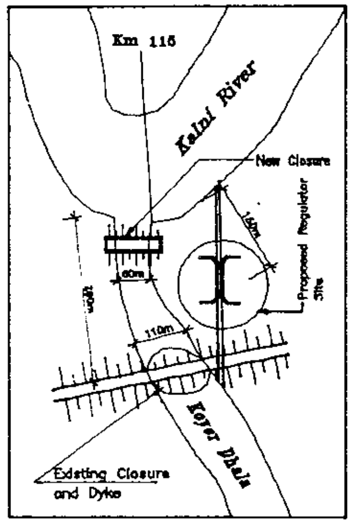
Section: C-C (Fishpass)
Scale: 1:150



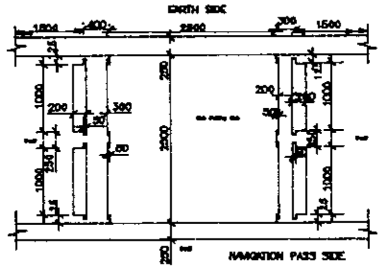
Plan
Scale: 1:150



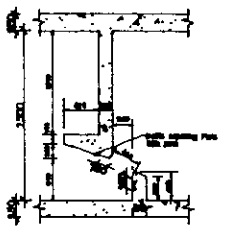
Section: B-B
Scale: 1:150



Location Map
Not to Scale



Detail "A"



Baffle and Pilaster Detail "B"

Note: Dimensions are in mm
Elevations are in m PWD

FILE: ENGG-56.DWG

Northeast Regional Project

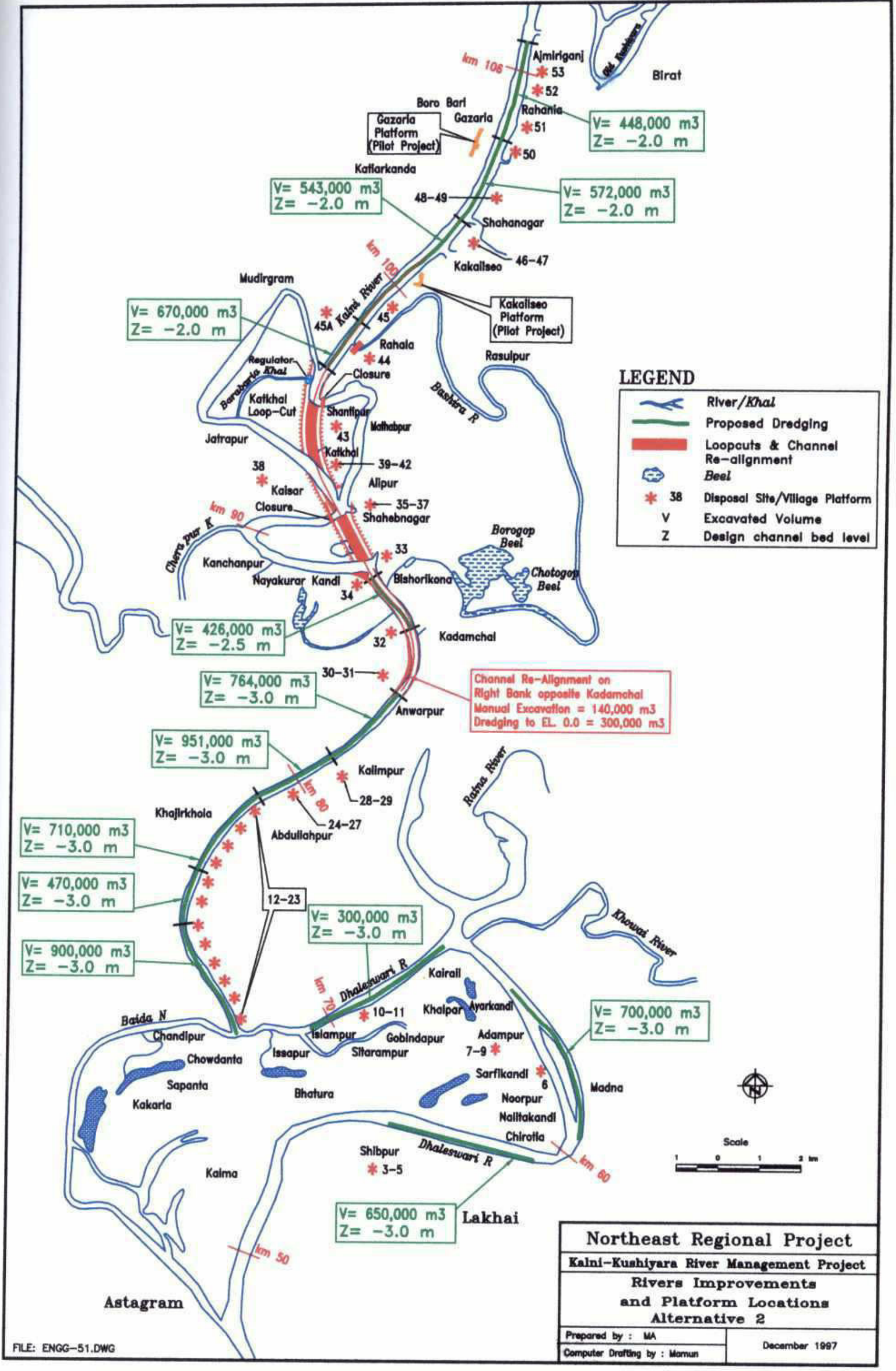
Kalni-Kushiyara River Management Project

Koyer Dhala Multipurpose Regulator
FL/DR Regulator-Fishpass-Navigation Pass

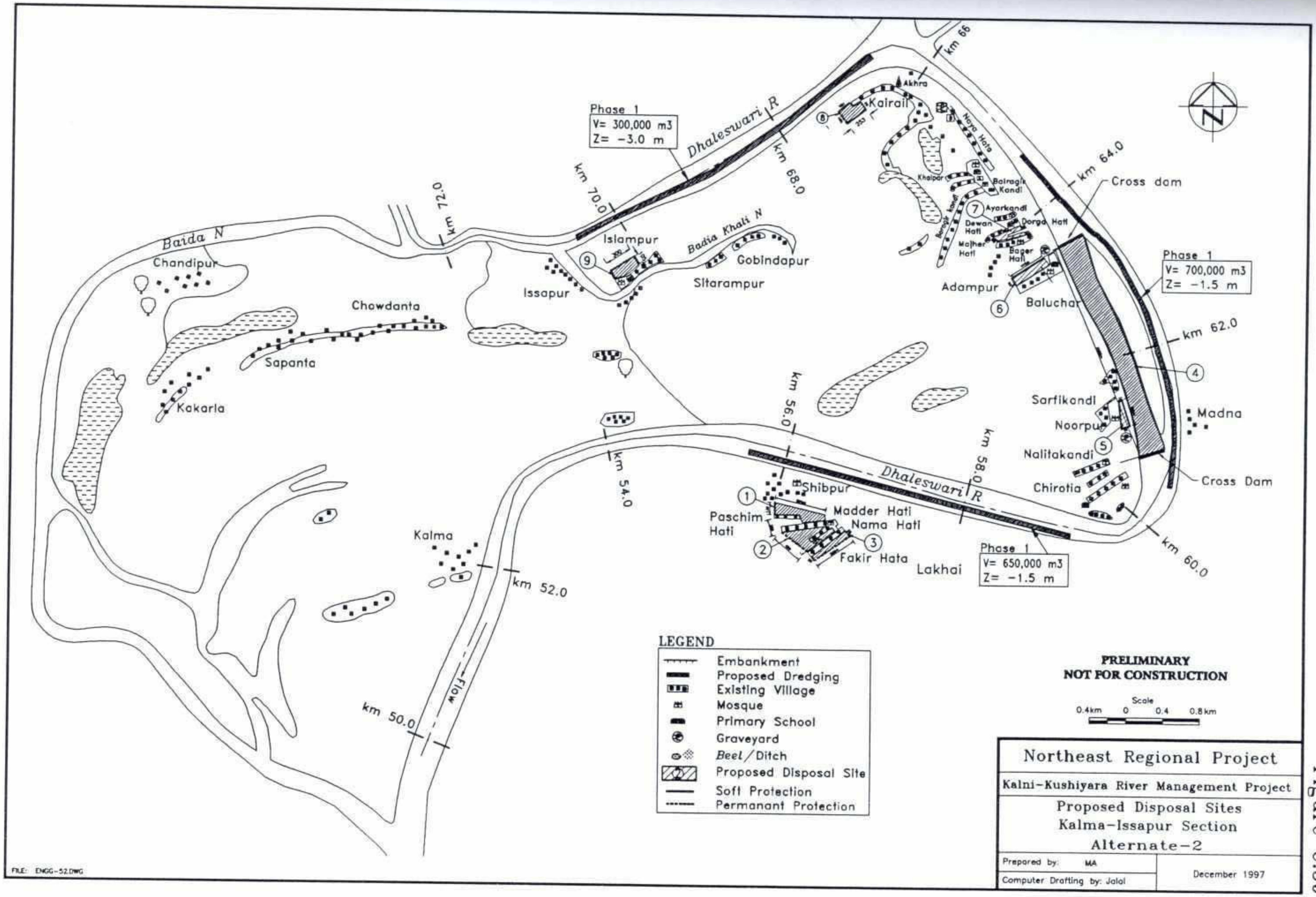
Prepared by: MA
Computer Drafting by: Jalal

December 1997

Figure C.58


Ajmiriganj
km 106
53
52
Birat
Boro Bari
Gazaria
Rahania
Gazaria Platform (Pilot Project)
51
50
V= 448,000 m3 Z= -2.0 m
Katiarkanda
V= 543,000 m3 Z= -2.0 m
48-49
V= 572,000 m3 Z= -2.0 m
Shahanagar
km 100
46-47
Kakailseo
Mudirgram
Kalni River
Kakailseo Platform (Pilot Project)
V= 670,000 m3 Z= -2.0 m
45A
45
Rahala
44
Rasulpur
Regulator
Barabaria Khal
Closure
Katkhal Loop-Cut
Shantipur
Mathabpur
Bashira R
Jatrapur
43
Katkhal
39-42
38
Alipur
Kaisar
Closure
35-37
km 90
Shahebnagar
Cherapur K
Borogop Beel
33
Kanchanpur
Nayakurar Kandi
Bishorikona
Chotogop Beel
34
V= 426,000 m3 Z= -2.5 m
32
Kadamchal
30-31
V= 764,000 m3 Z= -3.0 m
Channel Re-Alignment on Right Bank opposite Kadamchal Manual Excavation = 140,000 m3 Dredging to EL. 0.0 = 300,000 m3
Anwarpur
V= 951,000 m3 Z= -3.0 m
Kalimpur
Ratna River
km 80
28-29
Khajirkhola
24-27
Abdullahpur
V= 710,000 m3 Z= -3.0 m
V= 470,000 m3 Z= -3.0 m
12-23
V= 300,000 m3 Z= -3.0 m
Khowai River
V= 900,000 m3 Z= -3.0 m
Dhaleswari R
Kairail
km 70
Khalpar
Ayarkandi
10-11
V= 700,000 m3 Z= -3.0 m
Baida N
Chandipur
Islampur
Gobindapur
Adampur
Chowdanta
Issapur
Sitarampur
7-9
Sarfikandi
6
Madna
Sapanta
Kakaria
Bhatura
Noorpur
Nalitakandi
Chirotia
Shibpur
Dhaleswari R
3-5
km 60
Kalma
V= 650,000 m3 Z= -3.0 m
Lakhai
km 50
Astagram
LEGEND
River/Khal
Proposed Dredging
Loopcuts & Channel Re-alignment
Beel
38 Disposal Site/Village Platform
V Excavated Volume
Z Design channel bed level
N
Scale
1 0 1 2 km
Northeast Regional Project
Kalni-Kushiyara River Management Project
Rivers Improvements and Platform Locations Alternative 2
Prepared by : MA
Computer Drafting by : Mamun
December 1997
FILE: ENGG-51.DWG

209



Northeast Regional Project

Kalni-Kushiyara River Management Project

Proposed Disposal Sites
Kalma-Issapur Section
Alternate-2

Prepared by: MA
Computer Drafting by: Jalal

December 1997

Figure C.59

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT

ANNEX C
ENGINEERING
APPENDIX C.1

BWDB HYDROMETRIC DATA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Gauge 172 Kushiyara R. at Amalshid
MEAN DAILY DISCHARGE (m3/s)

Year	Number	Minimum	Mean	Maximum
1964	0			
1965	0			
1966	0			
1967	0			
1968	0			
1969	0			
1970	0			
1971	0			
1972	0			
1973	0			
1974	0			
1975	0			
1976	0			
1977	0			
1978	0			
1979	0			
1980	0			
1981	0			
1982	0			
1983	0			
1984	0			
1985	0			
1986	0			
1987	0			
1988	0			
1989	0			
1990	0			
1991	366	123.58	1008.8	3781
1992	365	106.04	645.8	2550
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
106.04	871.8	3781

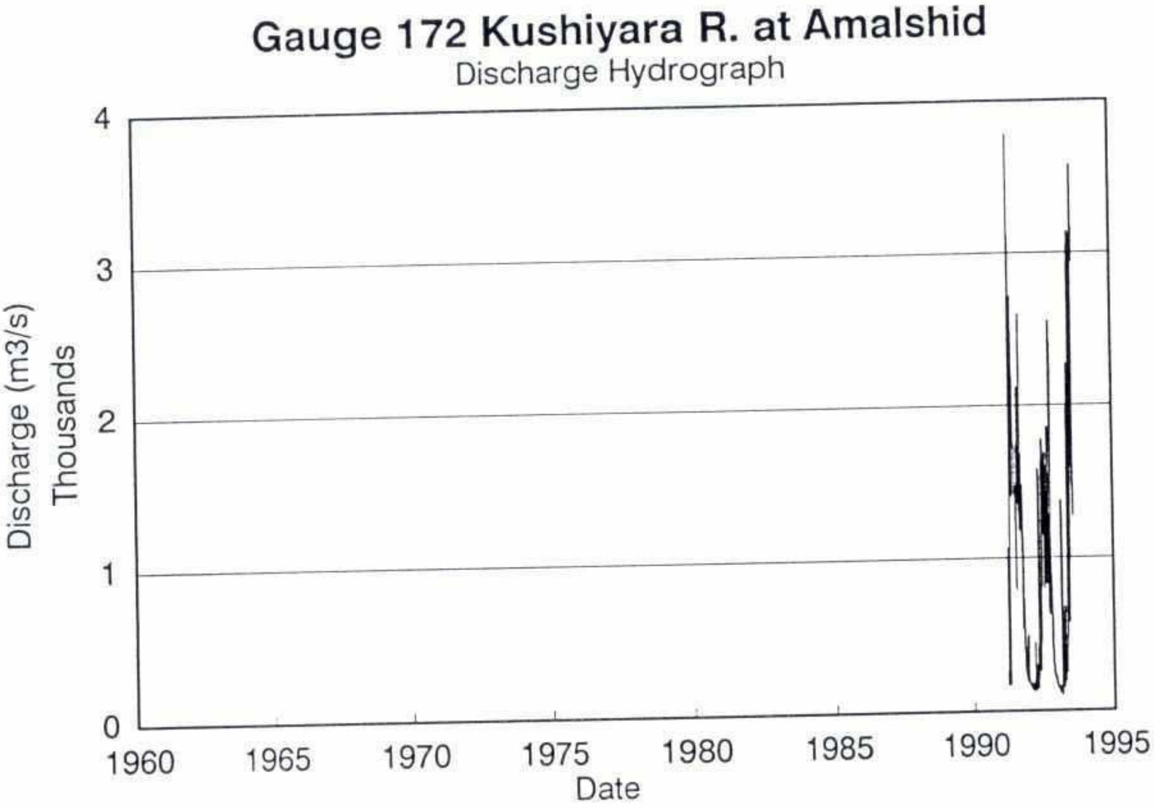
PRINTED 09-Aug-95

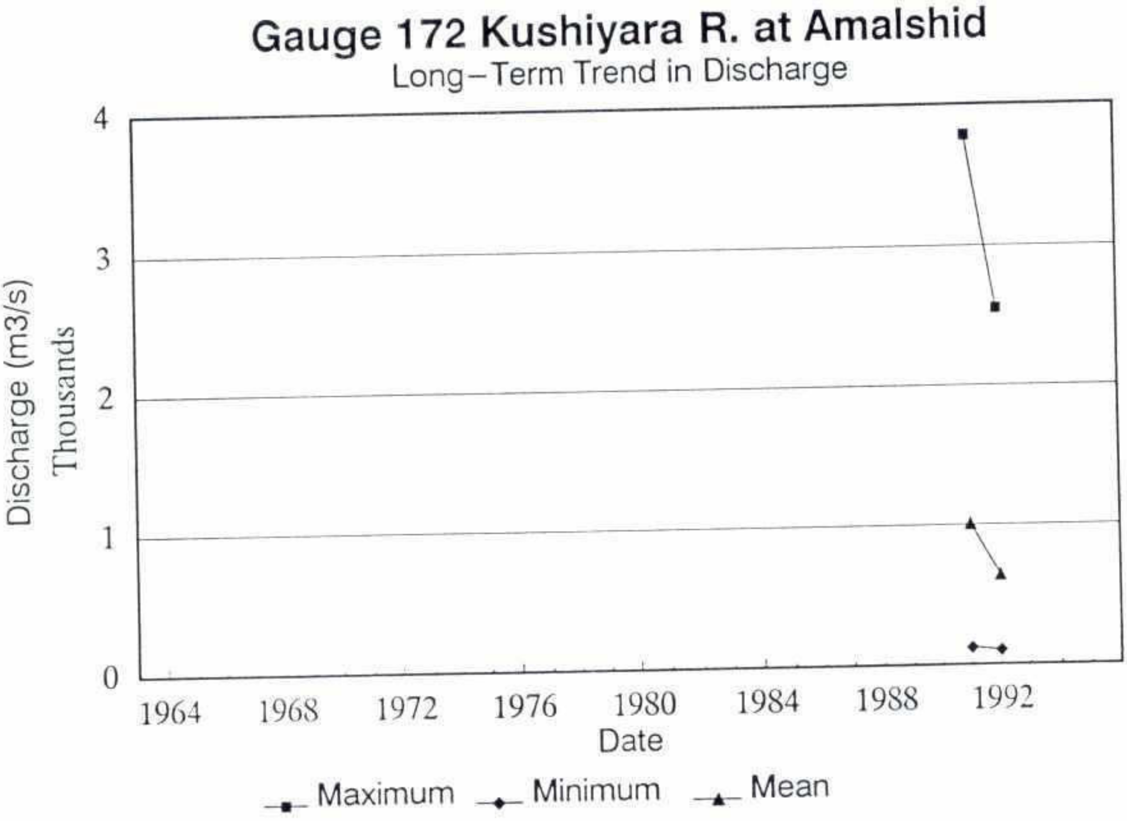
Gauge 172 Kushiyara R. at Amalshid

MEAN MONTHLY DISCHARGE (m3/s)

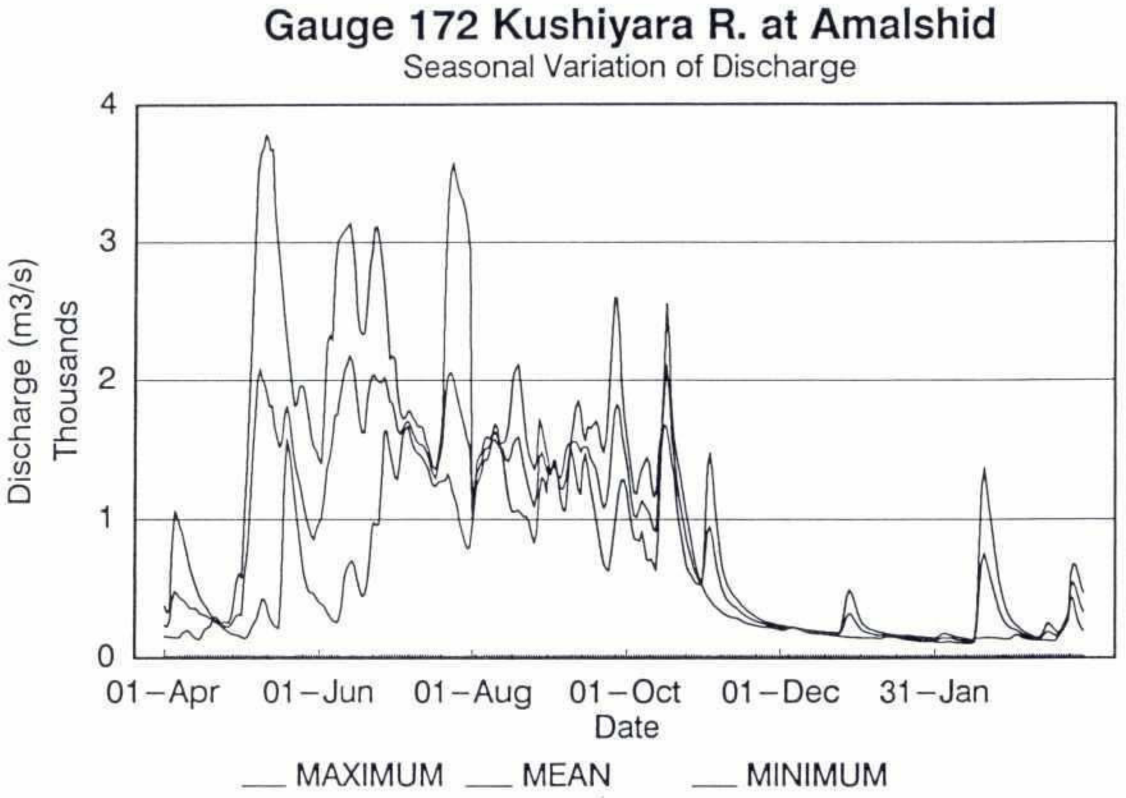
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964												
1965												
1966												
1967												
1968												
1969												
1970												
1971												
1972												
1973												
1974												
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991	457.9	2378.5	2182.9	1354.7	1572.0	1636.6	1151.6	544.9	247.5	181.7	152.1	187.3
1992	188.2	557.0	699.8	1400.7	1236.2	1220.4	1099.3	291.6	182.0	138.6	416.2	291.0
1993	309.2	1262.0	2481.0	2165.5								
1994												
1995												

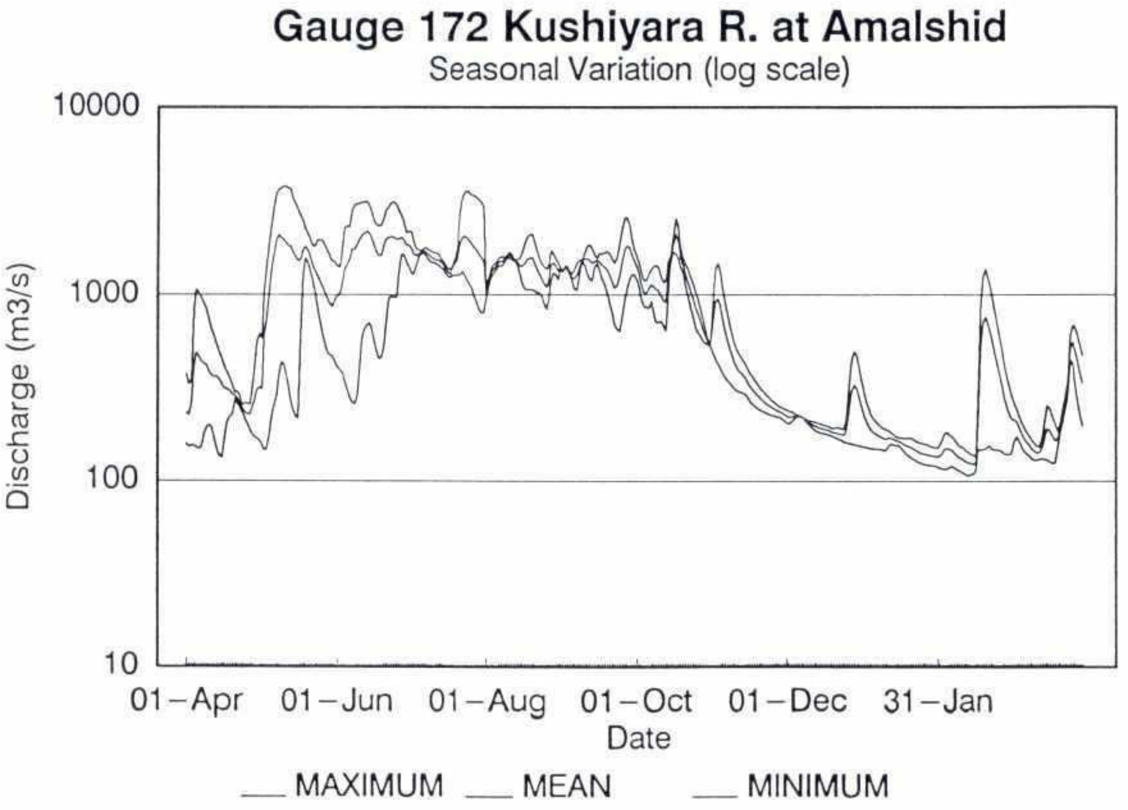
Number	3	3	3	3	2	2	2	2	2	2	2	2
Minimum	188.2	557.0	699.8	1354.7	1236.2	1220.4	1099.3	291.6	182.0	138.6	152.1	187.3
Mean	318.5	1399.1	1787.9	1640.3	1404.1	1428.5	1125.5	418.2	214.7	160.1	284.1	239.2
Maximum	457.9	2378.5	2481.0	2165.5	1572.0	1636.6	1151.6	544.9	247.5	181.7	416.2	291.0





PRINTED 09-Aug-95


Gauge 172 Kushiyara R. at Amalshid
Seasonal Variation of Discharge
Discharge (m3/s)
Thousands
4
3
2
1
0
01-Apr
01-Jun
01-Aug
01-Oct
01-Dec
31-Jan
Date
MAXIMUM
MEAN
MINIMUM


Gauge 172 Kushiyara R. at Amalshid
Seasonal Variation (log scale)
Discharge (m3/s)
10000
1000
100
10
01-Apr
01-Jun
01-Aug
01-Oct
01-Dec
31-Jan
Date
MAXIMUM
MEAN
MINIMUM

Gauge 173 KUSHIYARA R. at SHEOLA
MEAN DAILY DISCHARGE (m3/s)

Year	Number	Minimum	Mean	Maximum
1964	365	48.10	638.4	1660
1965	365	50.40	512.2	1410
1966	365	38.90	568.7	1280
1967	366	36.80	505.4	1810
1968	365	38.50	586.6	2080
1969	365	36.81	549.2	1977
1970	358		643.7	2080
1971	0			
1972	365	28.90	468.6	1920
1973	365	28.00	745.6	2130
1974	365	52.90	760.6	2130
1975	366	49.00	665.0	2190
1976	365	66.80	692.4	2200
1977	365	43.90	740.4	2330
1978	365	29.70	605.1	2180
1979	366	53.50	471.7	2240
1980	365	73.20	691.5	1830
1981	365	27.70	563.8	2050
1982	365	34.30	607.0	2520
1983	366	38.90	913.6	2960
1984	365	38.50	640.4	2270
1985	365	61.70	790.6	2500
1986	365	63.40	600.1	2820
1987	366	79.90	709.2	2290
1988	365	62.80	834.2	2630
1989	365	93.80	882.1	2340
1990	365	95.40	1008.3	2770
1991	366	106.70	1039.1	3250
1992	365	86.86	695.0	2457
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
27.70	690.0	3250

PRINTED 02–Jul–95

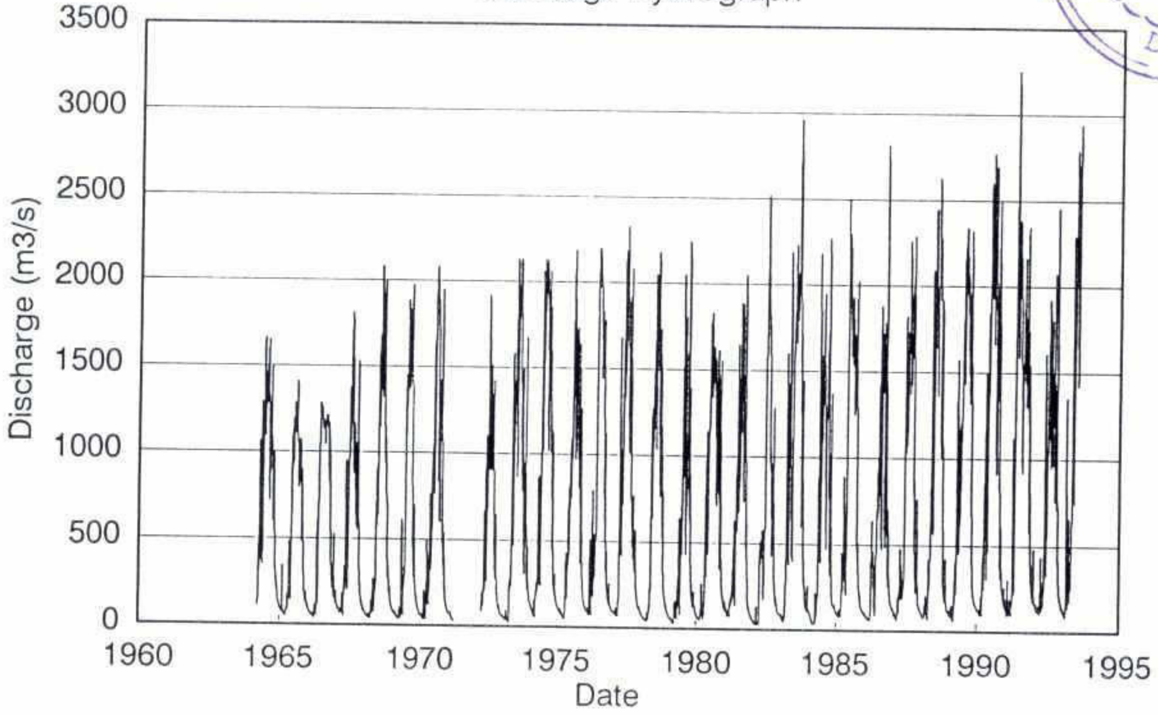
Gauge 173 KUSHIYARA R. at SHEOLA
MEAN MONTHLY DISCHARGE (m3/s)

Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	524.7	720.4	1248.5	1383.2	1112.2	1146.0	754.6	296.7	152.5	92.0	145.9	58.3
1965	111.3	277.5	914.7	1146.8	1201.7	950.5	789.1	345.7	147.9	100.1	69.4	57.7
1966	69.3	312.2	1160.8	1197.7	1138.1	1154.7	901.5	299.3	233.7	133.8	91.1	98.5
1967	165.0	440.0	806.2	1551.9	1012.3	744.7	817.6	185.8	103.5	68.9	51.6	69.2
1968	138.9	306.3	1048.2	1730.6	1684.5	1079.0	498.5	207.3	108.8	73.4	61.1	56.3
1969	222.7	165.7	1186.5	1624.1	1754.4	784.8	355.9	155.6	89.3	64.7	60.8	83.3
1970	224.4	418.9	982.2	1633.2	1517.1	1144.7	1104.5	337.1	132.6	79.8	68.1	
1971												
1972	188.0	544.1	977.5	1303.4	1164.7	708.3	330.0	127.9	83.2	59.2	45.0	55.3
1973	161.6	746.9	1523.7	1456.1	1938.7	1128.5	651.6	721.3	249.1	136.7	89.3	98.5
1974	321.0	476.4	1498.3	2003.5	1539.7	1560.3	941.4	285.7	183.0	111.2	92.1	69.9
1975	165.7	392.1	812.8	1554.0	1341.9	1396.9	1041.1	651.8	174.9	111.9	97.4	196.9
1976	317.9	352.4	1751.0	2021.3	1611.0	1196.0	445.5	172.1	140.3	95.0	86.8	82.1
1977	803.5	961.3	1779.7	1818.1	1560.6	811.4	456.7	309.4	130.8	96.5	66.5	49.5
1978	69.6	493.1	1267.5	1561.0	1617.8	1227.1	535.2	165.3	100.2	65.4	51.4	64.0
1979	89.4	272.1	419.3	1318.7	904.8	1438.0	610.1	162.5	136.9	74.6	63.8	137.7
1980	262.5	721.4	1536.9	1545.8	1274.9	1221.2	915.3	283.8	131.9	107.8	95.0	161.7
1981	362.8	497.8	956.1	1536.1	1322.0	1415.2	328.2	112.1	70.6	45.5	51.4	37.0
1982	422.9	401.5	1137.0	2029.0	1247.1	678.7	475.3	151.6	96.5	83.7	61.8	445.1
1983	870.4	1204.5	1192.1	1992.3	2188.1	1903.0	915.2	264.6	133.7	126.5	69.7	40.4
1984	107.9	1038.8	951.8	1601.3	974.2	1558.5	646.4	217.4	136.3	99.1	101.8	208.2
1985	545.1	577.7	2134.7	1722.3	1554.2	1678.3	663.5	210.0	125.5	102.2	83.8	67.1
1986	298.7	291.0	465.3	1250.8	1256.5	1229.1	1486.9	376.2	166.6	119.2	87.3	122.6
1987	289.8	268.4	1254.5	1512.3	1678.1	1858.0	747.0	393.4	149.2	108.2	84.5	138.2
1988	174.5	977.9	1147.1	1946.1	2146.5	1688.0	1139.5	213.4	201.5	109.3	109.1	83.6
1989	376.3	808.3	951.4	1800.3	2170.3	1753.0	1705.6	346.1	167.0	131.7	114.7	183.1
1990	857.4	832.9	2126.0	2140.6	2268.4	1403.7	1436.1	367.4	198.5	134.5	153.5	120.8
1991	493.5	2322.4	2200.9	1470.5	1667.7	1696.9	1259.4	571.0	238.2	177.7	137.0	173.0
1992	182.5	614.8	772.4	1540.5	1354.2	1355.0	1206.3	304.9	162.3	121.1	407.6	285.7
1993	301.5	1389.7	2343.2	2090.9								
1994												
1995												

Number	29	29	29	29	28	28	28	28	28	28	28	27
Minimum	69.3	165.7	419.3	1146.8	904.8	678.7	328.2	112.1	70.6	45.5	45.0	37.0
Mean	314.4	649.2	1260.2	1637.3	1507.2	1282.5	827.1	294.1	148.0	101.1	96.3	120.1
Maximum	870.4	2322.4	2343.2	2140.6	2268.4	1903.0	1705.6	721.3	249.1	177.7	407.6	445.1

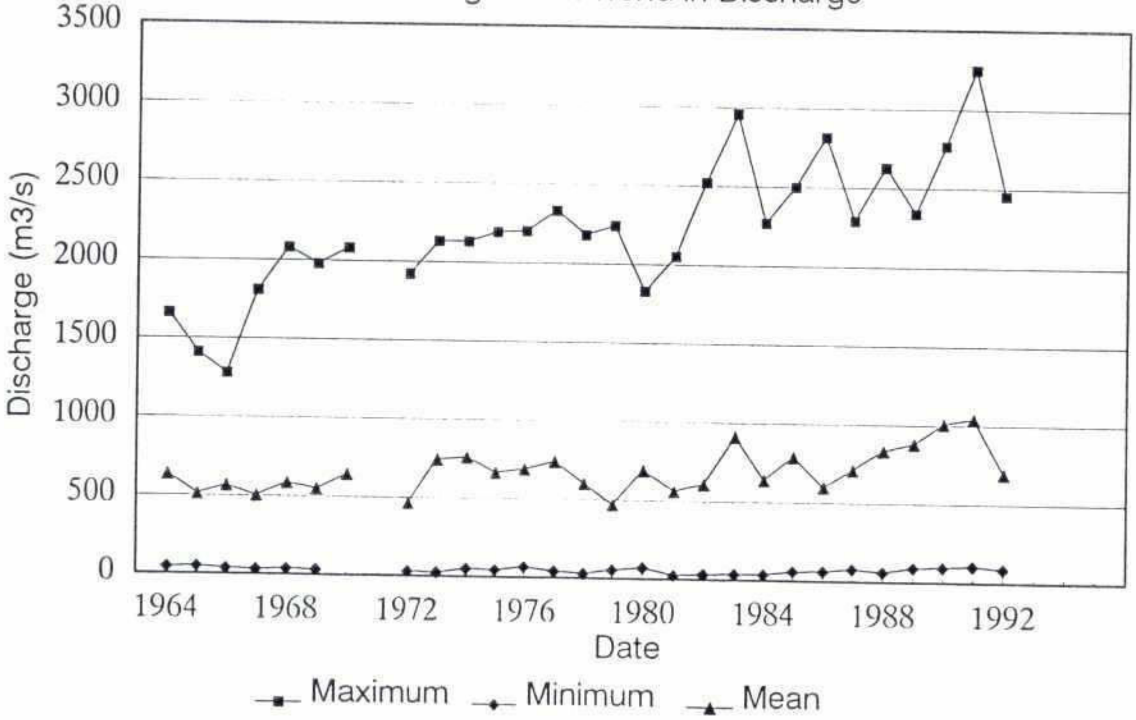
Gauge 173 KUSHIYARA R. at SHEOLA

Discharge Hydrograph



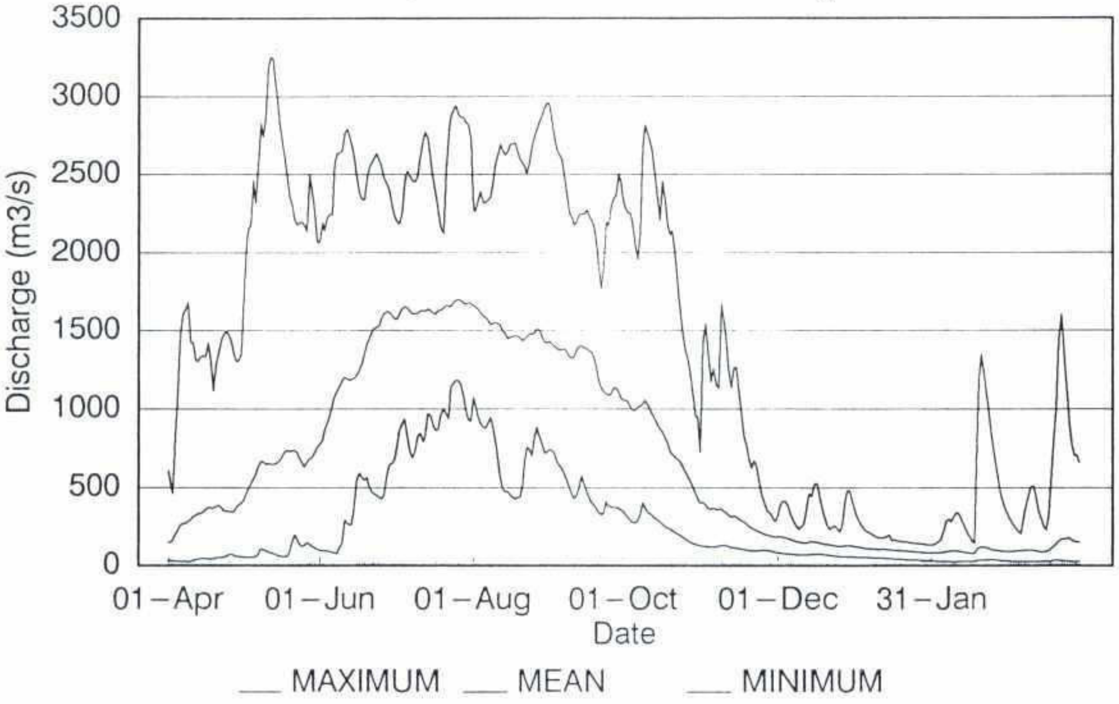
Gauge 173 KUSHIYARA R. at SHEOLA

Long-Term Trend in Discharge



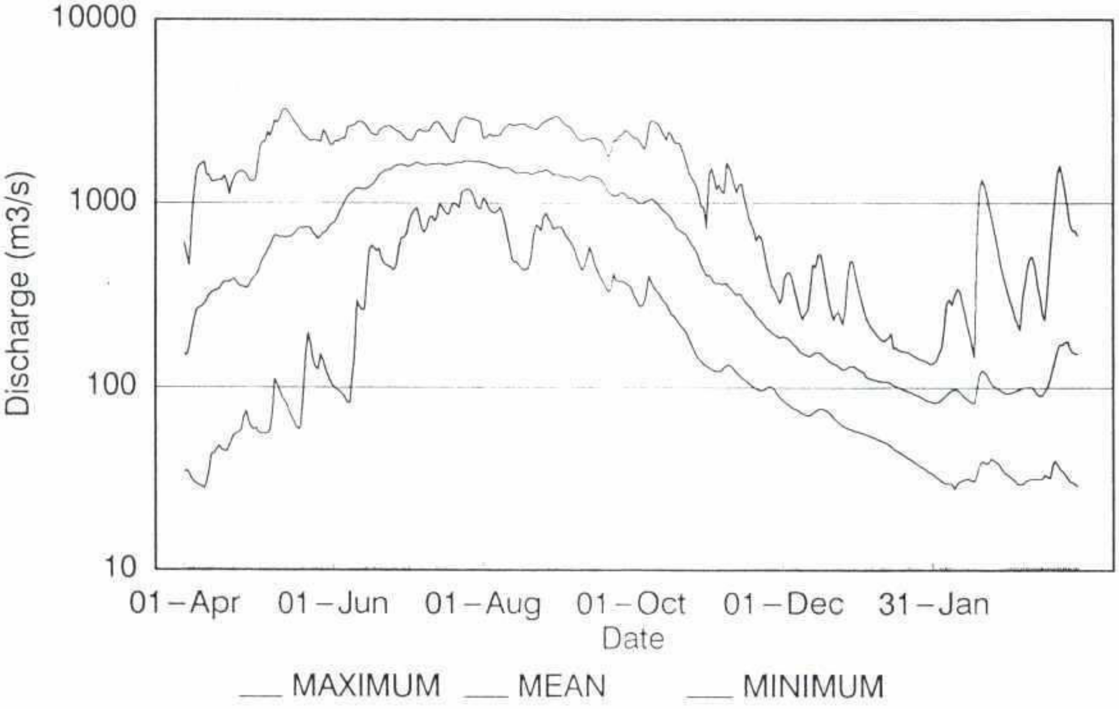
Gauge 173 KUSHIYARA R. at SHEOLA

Seasonal Variation of Discharge



Gauge 173 KUSHIYARA R. at SHEOLA

Seasonal Variation (log scale)



PRINTED 02-Jul-95

Gauge 174 Kushiyara R. at Fenchuganj
MEAN DAILY DISCHARGE (m3/s)

Year	Number	Minimum	Mean	Maximum
1964	0			
1965	0			
1966	0			
1967	0			
1968	0			
1969	0			
1970	0			
1971	0			
1972	0			
1973	0			
1974	0			
1975	0			
1976	0			
1977	0			
1978	0			
1979	0			
1980	0			
1981	0			
1982	0			
1983	0			
1984	0			
1985	0			
1986	0			
1987	0			
1988	0			
1989	0			
1990	0			
1991	366	46.62	1121.2	2376
1992	365	33.45	840.3	1827
1993	122			
1994	0			
1995	0			

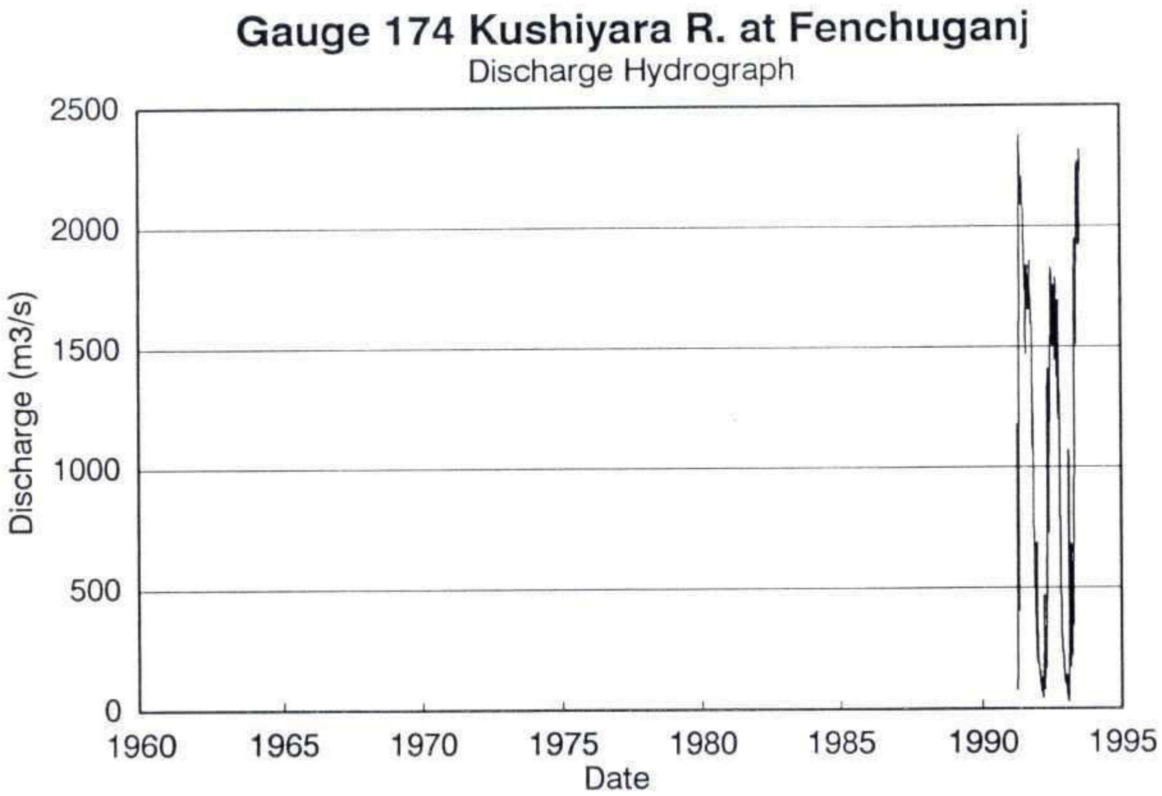
SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
33.45	1010.6	2376

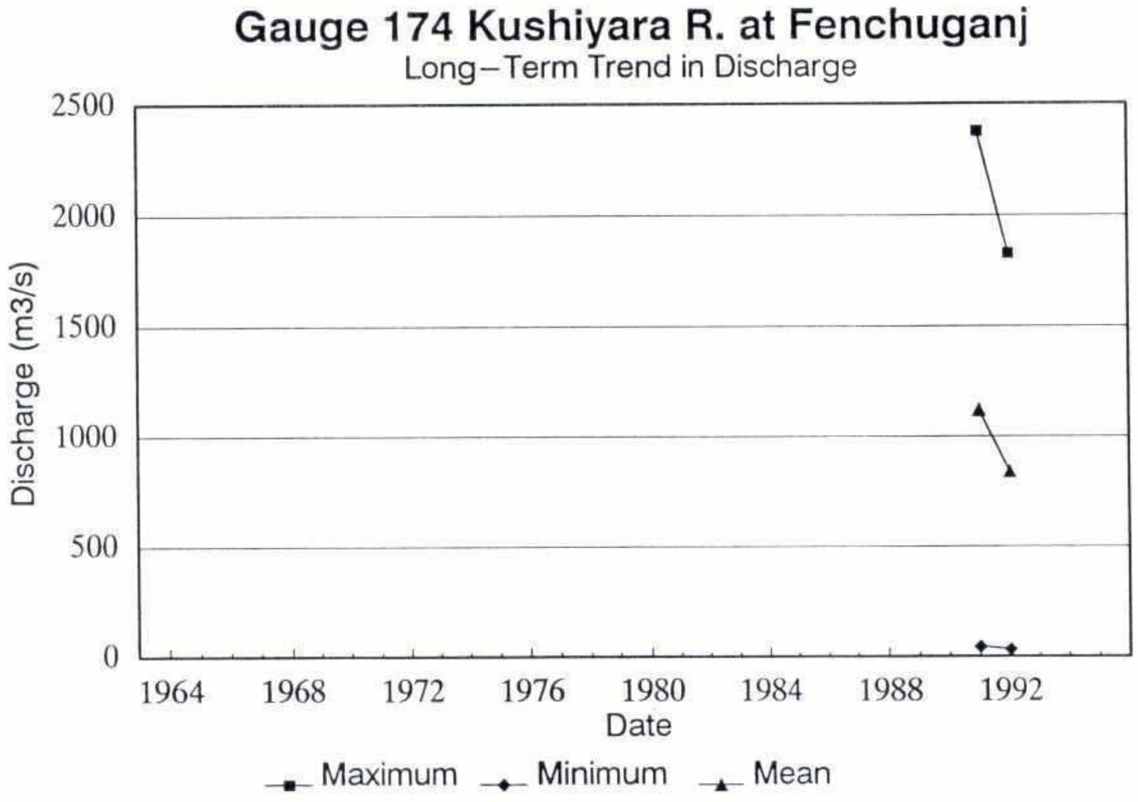
PRINTED 19-Jul-95

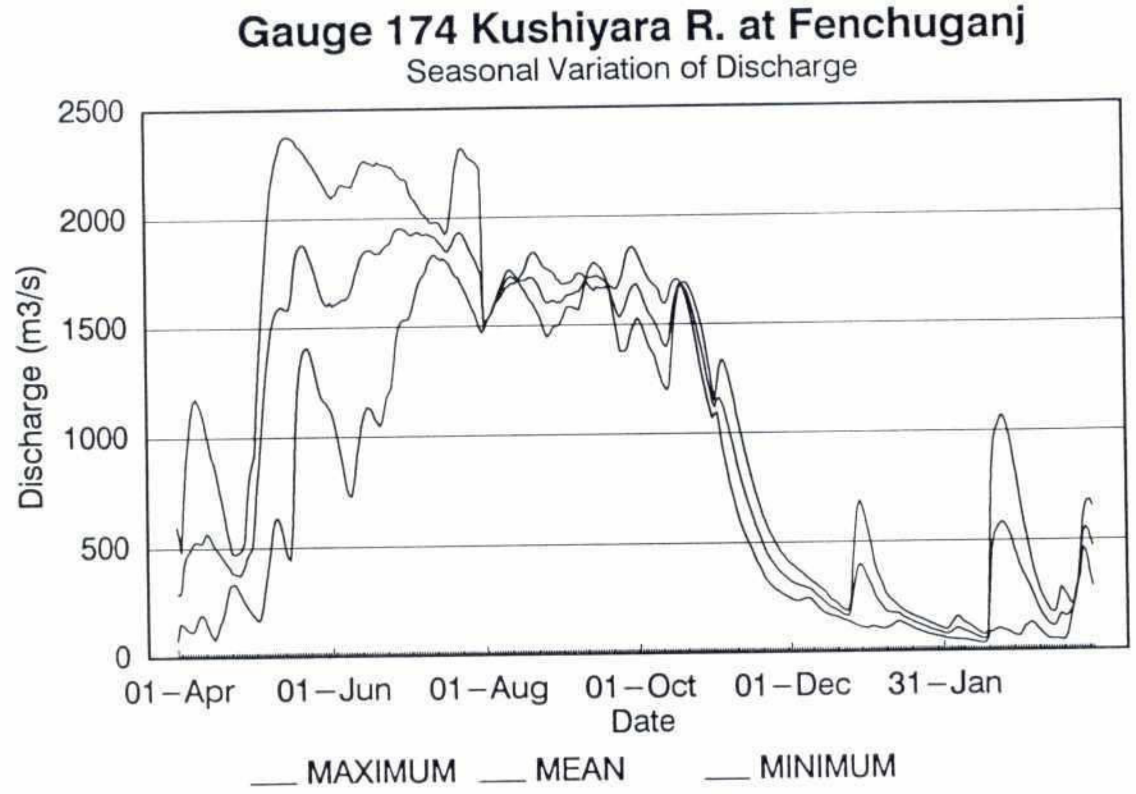
Gauge 174 Kushiyara R. at Fenchuganj
MEAN MONTHLY DISCHARGE (m3/s)

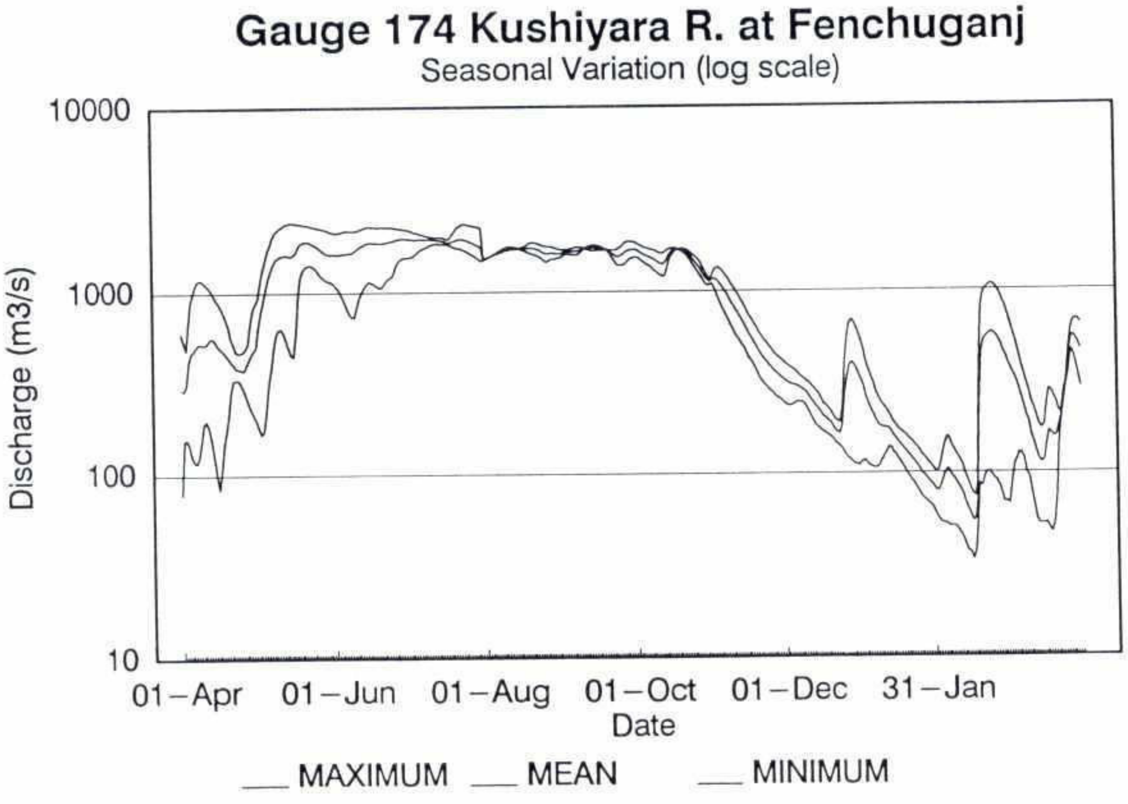
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964												
1965												
1966												
1967												
1968												
1969												
1970												
1971												
1972												
1973												
1974												
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991	715.0	2031.5	2156.1	1833.9	1696.9	1712.0	1566.0	840.5	348.1	227.5	102.2	156.6
1992	194.5	797.2	1089.6	1715.0	1596.6	1590.4	1451.2	541.4	180.2	101.5	390.7	393.1
1993	440.9	1676.6	2104.1	2114.4								
1994												
1995												

Number	3	3	3	3	2	2	2	2	2	2	2	2
Minimum	194.5	797.2	1089.6	1715.0	1596.6	1590.4	1451.2	541.4	180.2	101.5	102.2	156.6
Mean	450.1	1501.8	1783.3	1887.8	1646.8	1651.2	1508.6	691.0	264.2	164.5	246.5	274.9
Maximum	715.0	2031.5	2156.1	2114.4	1696.9	1712.0	1566.0	840.5	348.1	227.5	390.7	393.1


Gauge 174 Kushiyara R. at Fenchuganj
Discharge Hydrograph
Discharge (m3/s)
0
500
1000
1500
2000
2500
1960
1965
1970
1975
1980
1985
1990
1995
Date


Gauge 174 Kushiyara R. at Fenchuganj
Long−Term Trend in Discharge
Discharge (m3/s)
0
500
1000
1500
2000
2500
1964
1968
1972
1976
1980
1984
1988
1992
Date
Maximum
Minimum
Mean


Gauge 174 Kushiyara R. at Fenchuganj
Seasonal Variation of Discharge
2500
2000
1500
1000
500
0
Discharge (m3/s)
01-Apr
01-Jun
01-Aug
01-Oct
01-Dec
31-Jan
Date
MAXIMUM
MEAN
MINIMUM


Gauge 174 Kushiyara R. at Fenchuganj
Seasonal Variation (log scale)
10000
1000
100
10
Discharge (m3/s)
01-Apr
01-Jun
01-Aug
01-Oct
01-Dec
31-Jan
Date
MAXIMUM
MEAN
MINIMUM

Gauge 175-5 KUSHIYARA R. at SHERPUR
MEAN DAILY DISCHARGE (m3/s)

Year	Number	Minimum	Mean	Maximum
1964	0			
1965	0			
1966	0			
1967	0			
1968	0			
1969	0			
1970	0			
1971	0			
1972	0			
1973	0			
1974	0			
1975	0			
1976	0			
1977	0			
1978	0			
1979	0			
1980	0			
1981	0			
1982	365	55.10	822.8	2000
1983	366	43.30	1281.7	2770
1984	365	50.70	902.4	2510
1985	325	68.30		
1986	365	62.30	872.1	2630
1987	366	98.40	963.6	2530
1988	365	53.20	1189.7	2860
1989	365	68.40	1193.1	2540
1990	365	74.50	1402.3	2770
1991	366	103.60	1320.6	3632
1992	365	94.09	932.1	2116
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
45.60	1090.3	3843

PRINTED 02-Jul-95

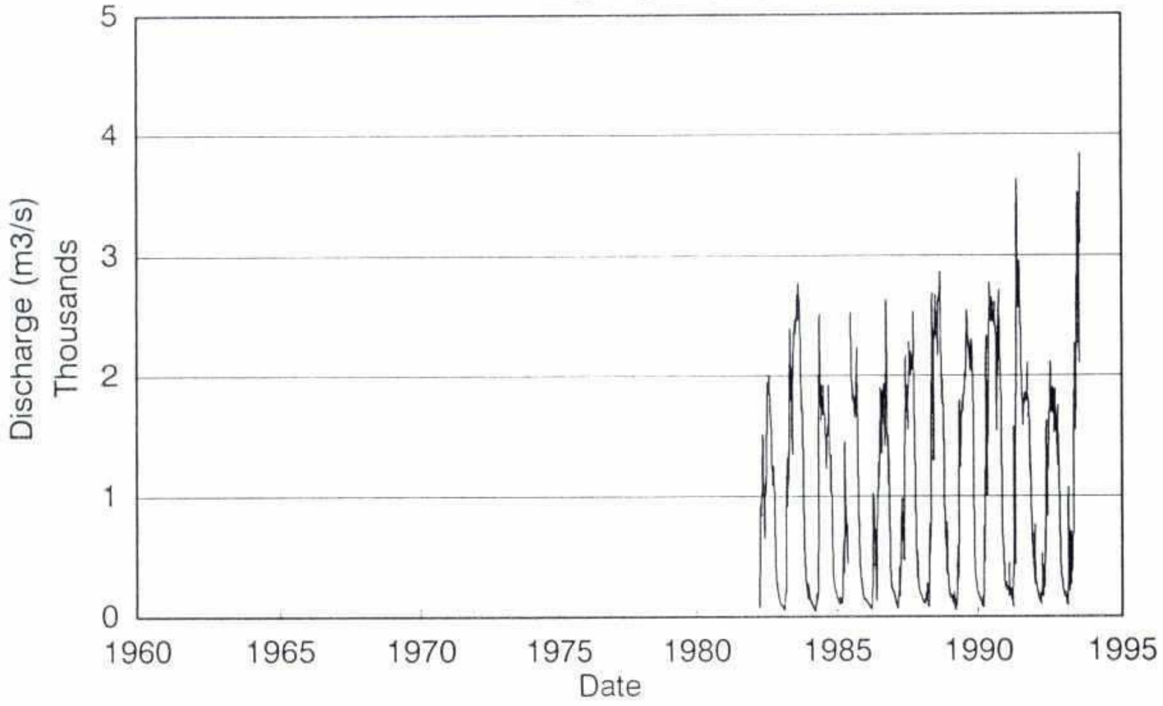
Gauge 175-5 KUSHIYARA R. at SHERPUR
MEAN MONTHLY DISCHARGE (m3/s)

Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964												
1965												
1966												
1967												
1968												
1969												
1970												
1971												
1972												
1973												
1974												
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982	811.8	1177.4	930.6	1803.5	1822.6	1241.3	890.5	247.9	133.3	88.8	71.3	579.4
1983	1202.3	2123.9	1773.3	2383.9	2593.9	2511.7	1628.4	557.8	197.9	158.1	103.2	61.5
1984	139.5	1545.4	1846.0	1778.7	1386.5	1676.3	1209.0	452.9	203.7	131.2	123.5	276.4
1985	991.3				1759.4	1902.0	1050.2	331.3	166.7	136.4	110.0	81.6
1986	479.4	627.0	573.2	1387.1	1599.7	1643.0	2180.3	1143.2	280.3	183.7	105.6	199.6
1987	583.9	654.0	1620.0	1774.8	2129.0	2176.0	1498.2	432.3	204.5	142.3	117.9	179.0
1988	290.8	1681.6	1844.7	2449.0	2462.6	2409.3	1668.4	582.8	401.7	168.3	139.3	88.2
1989	464.5	1452.3	1693.3	1952.3	2431.3	2182.7	2210.3	1044.0	269.3	165.9	122.5	244.6
1990	1340.4	1549.0	2557.0	2525.5	2464.5	1917.3	2386.5	1046.7	331.3	230.1	255.3	153.6
1991	910.4	2836.4	2726.1	1990.0	1752.5	1854.0	1646.5	924.1	441.9	309.3	164.5	216.8
1992	261.6	944.0	1253.2	1916.0	1731.4	1683.7	1503.7	612.9	240.0	163.8	418.0	409.4
1993	485.9	1846.7	2908.0	2825.6								
1994												
1995												

Number	12	11	11	11	11	11	11	11	11	11	11	11
Minimum	139.5	627.0	573.2	1387.1	1386.5	1241.3	890.5	247.9	133.3	88.8	71.3	61.5
Mean	663.5	1494.3	1793.2	2071.5	2012.1	1927.0	1624.7	670.5	261.0	170.7	157.4	226.4
Maximum	1340.4	2836.4	2908.0	2825.6	2593.9	2511.7	2386.5	1143.2	441.9	309.3	418.0	579.4

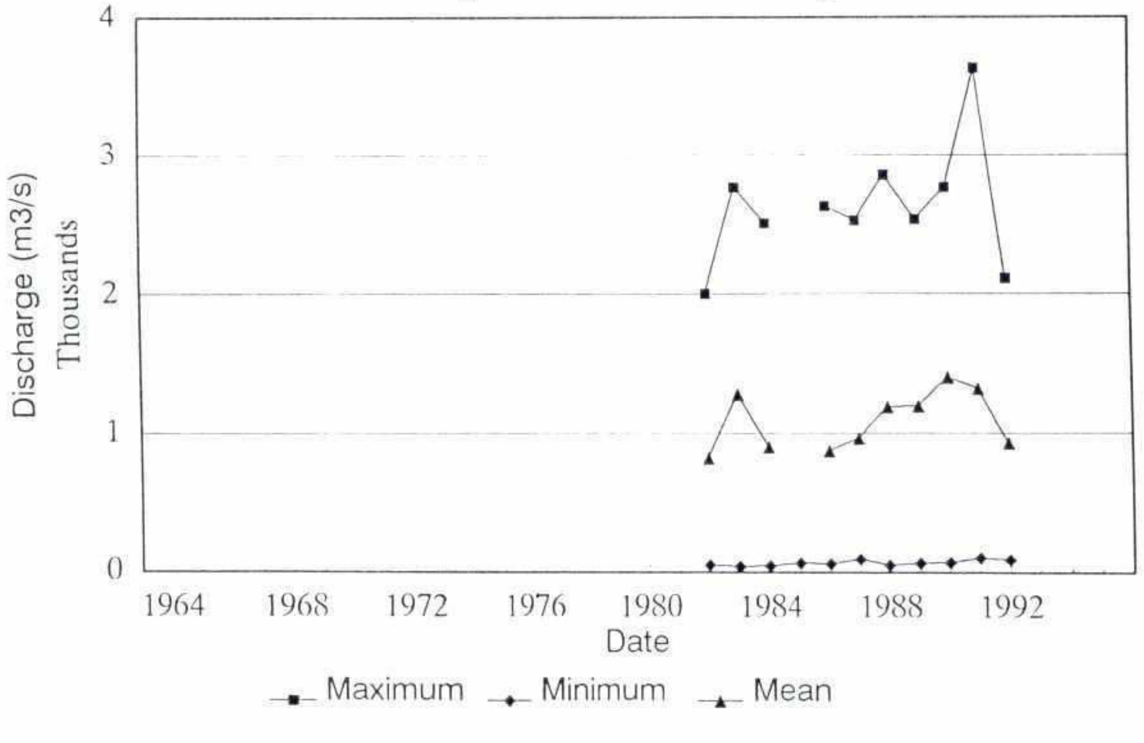
Gauge 175–5 KUSHIYARA R. at SHERPUR

Discharge Hydrograph



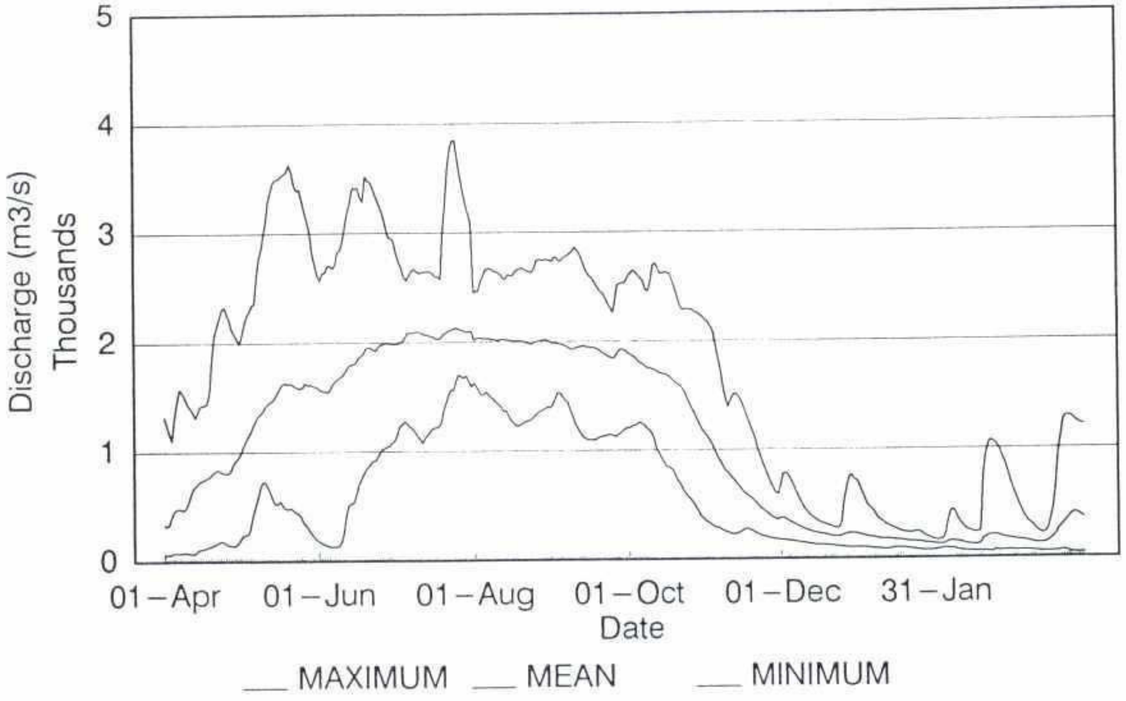
Gauge 175–5 KUSHIYARA R. at SHERPUR

Long–Term Trend in Discharge



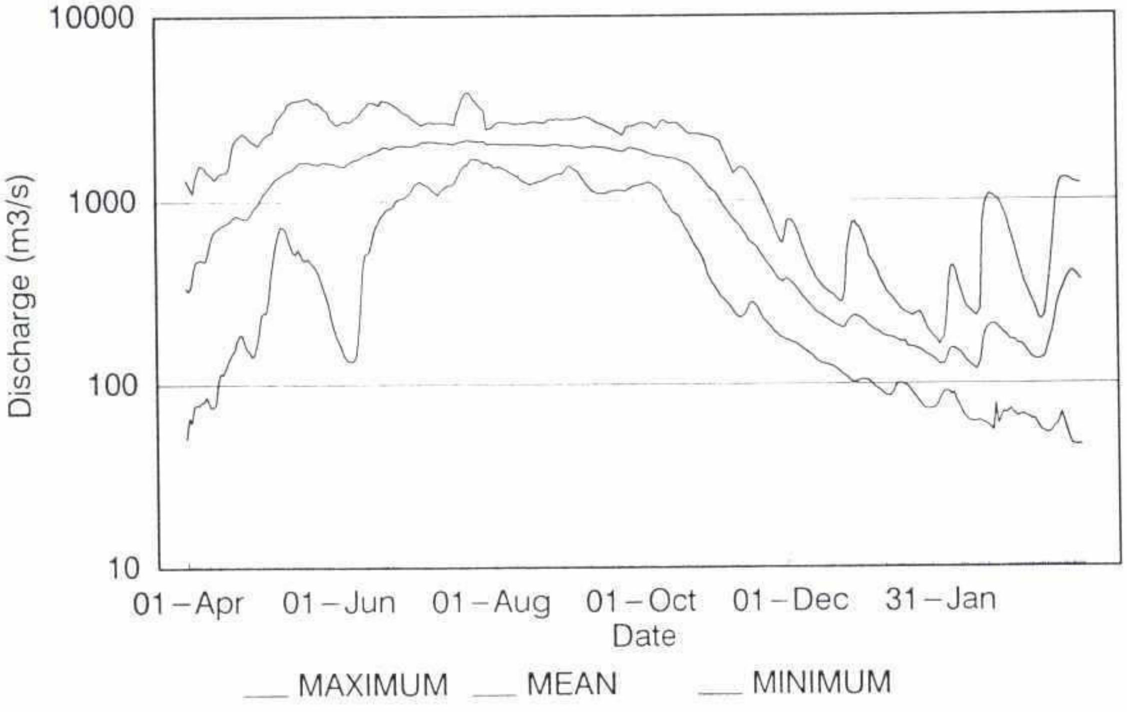
Gauge 175-5 KUSHIYARA R. at SHERPUR

Seasonal Variation of Discharge



Gauge 175-5 KUSHIYARA R. at SHERPUR

Seasonal Variation (log scale)



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Gauge 273 MEGHNA R. at BHAIRAB BAZAR
MEAN DAILY DISCHARGE (m3/s)

Year	Number	Minimum	Mean	Maximum
1964	195			
1965	365	37.40	4305.5	12100
1966	365	101.00	5083.0	14400
1967	366	67.90	3688.9	12700
1968	365	73.60	4127.4	13300
1969	363	79.20	3722.0	11500
1970	353		5038.4	13800
1971	0			
1972	365	87.20	3561.9	11500
1973	365	102.00	5343.0	12400
1974	365	130.00	6042.8	19500
1975	153			
1976	153			
1977	0			
1978	0			
1979	0			
1980	0			
1981	144			
1982	139			
1983	164			
1984	365	8.00	5094.2	13600
1985	365	3.00	4411.3	14300
1986	365	10.00	3984.2	11100
1987	366	2.00	4961.5	15200
1988	231		6347.9	19800
1989	162			
1990	198			
1991	196			
1992	28			
1993	9			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
2.00	4818.3	19800

PRINTED 03-Jul-95

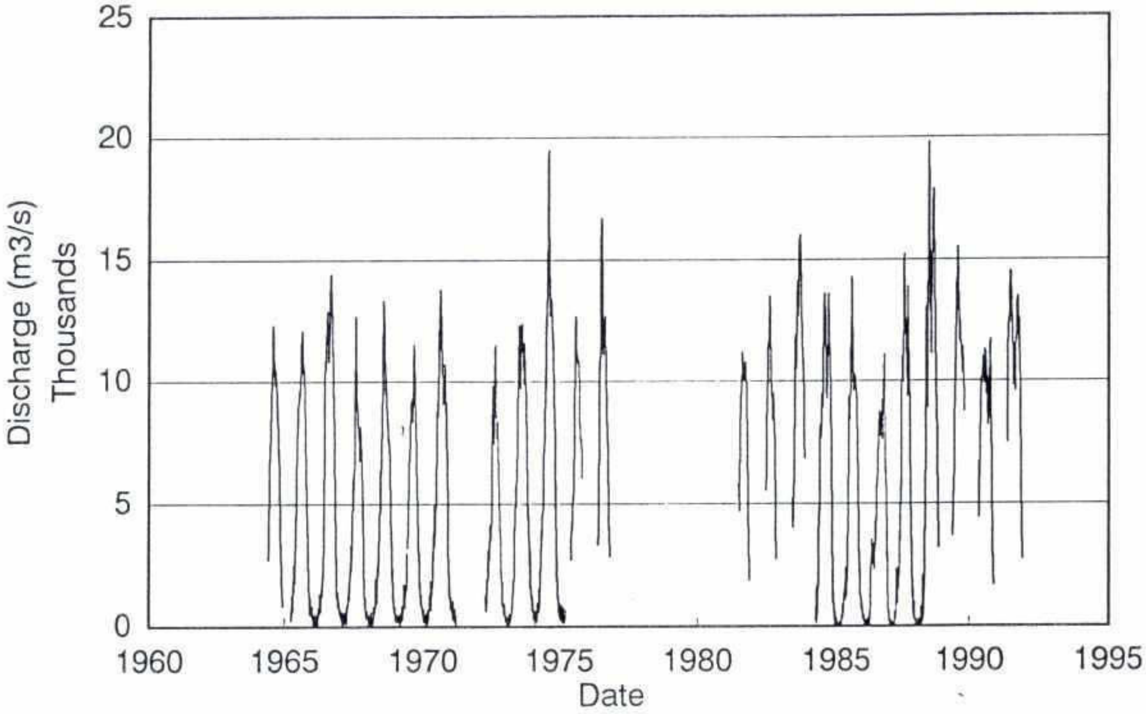
Gauge 273 MEGHNA R. at BHAIRAB BAZAR
MEAN MONTHLY DISCHARGE (m3/s)

Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964				9161.3	11351.6	9978.7	7728.7	3775.7				
1965	758.9	2116.8	6030.7	9049.0	11108.1	10679.0	7028.4	2861.3	725.3	407.4	244.6	364.4
1966	886.1	1600.7	7751.0	12080.6	11954.8	13363.3	8350.3	2547.3	871.2	465.3	354.3	449.8
1967	875.6	2271.0	4343.7	9202.3	9301.6	7423.3	6502.9	2415.9	625.3	325.9	292.9	368.2
1968	1089.2	2077.4	5208.7	10361.9	11060.0	8496.7	6474.2	2632.0	732.3	376.4	305.3	374.1
1969	948.2	1520.7	4759.6	8271.6	9460.6	9873.7	5429.0	2335.7	873.3	407.5	332.0	529.2
1970	1307.0	3355.8	5519.3	10120.6	12793.5	9867.7	9272.6	5119.7	1341.3	721.7	451.5	
1971												
1972	1280.9	2899.0	4812.3	8644.5	10125.5	7387.7	4236.8	1606.2	637.4	271.4	245.4	302.4
1973	1265.1	4321.0	7839.3	11046.1	11909.7	10823.0	8718.7	4265.7	1836.1	720.8	394.9	587.9
1974	1477.7	3971.6	7760.7	12961.0	16187.1	12756.7	10030.3	4407.7	1180.5	517.3	396.6	391.5
1975			3947.3	7853.9	11687.1	10148.3	7481.3					
1976			7752.3	15219.4	11812.9	9867.7	5004.2					
1977												
1978												
1979												
1980												
1981				8458.7	10571.0	10309.0	6372.6					
1982				10897.7	11870.3	9145.3	6369.4					
1983			5159.3	10606.5	13719.4	15206.7	11275.8					
1984	694.8	3903.2	8457.7	11603.9	11426.1	11730.0	9732.3	2312.0	352.8	75.3	80.6	367.7
1985	1192.5	1691.6	7048.7	11203.9	11375.8	9907.3	6823.5	2097.7	703.7	221.3	124.5	213.8
1986	1843.6	3058.7	3197.0	6018.4	8244.5	8395.7	9621.3	5510.0	1239.4	144.3	96.7	161.9
1987	1193.0	1812.3	4629.0	10509.4	13748.4	11041.3	10846.1	4015.0	831.8	149.1	112.3	214.0
1988	665.2	4290.6	11313.3	16900.0	13238.7	16483.3	9984.5					
1989			7145.7	12809.7	14006.5	11530.0	10607.7					
1990			9098.7	10634.2	10530.6	8805.0	10481.9	3792.1				
1991			13326.7	12430.3	10472.6	12646.7	11561.3	4944.6				
1992												
1993												
1994												
1995												

Number	14	14	20	23	23	23	23	16	13	13	13	12
Minimum	665.2	1520.7	3197.0	6018.4	8244.5	7387.7	4236.8	1606.2	352.8	75.3	80.6	161.9
Mean	1105.6	2777.9	6755.0	10697.6	11650.3	10689.8	8258.0	3414.9	919.3	369.5	263.9	360.4
Maximum	1843.6	4321.0	13326.7	16900.0	16187.1	16483.3	11561.3	5510.0	1836.1	721.7	451.5	587.9

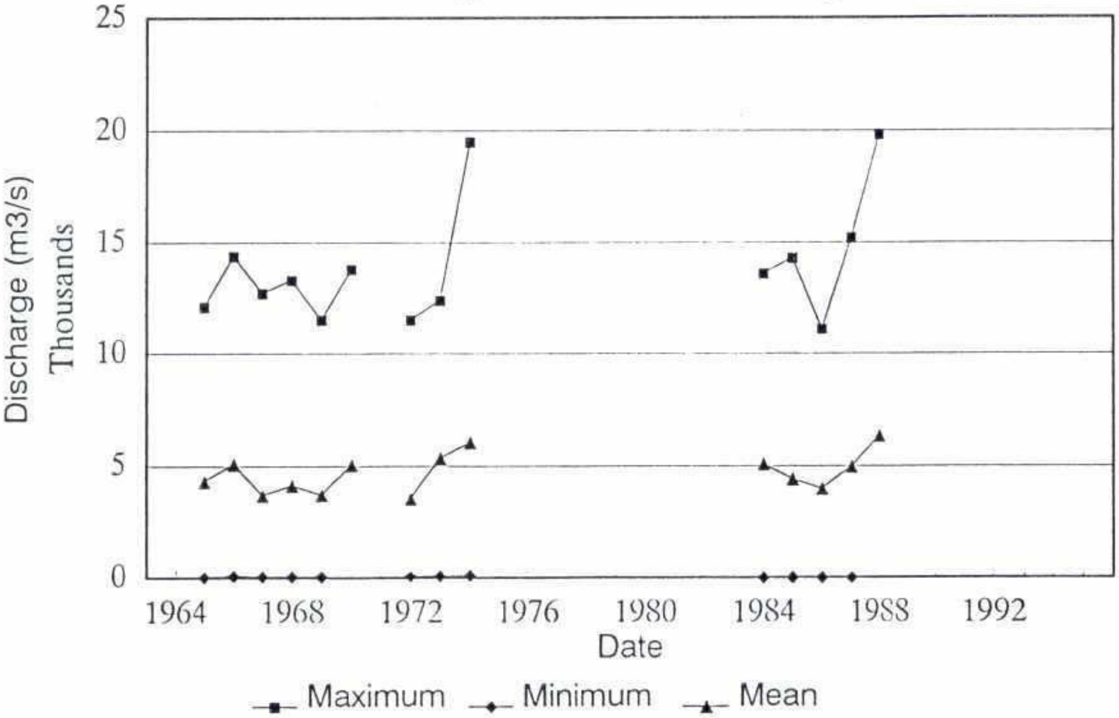
Gauge 273 MEGHNA R. at BHAIRAB BAZAR

Discharge Hydrograph



Gauge 273 MEGHNA R. at BHAIRAB BAZAR

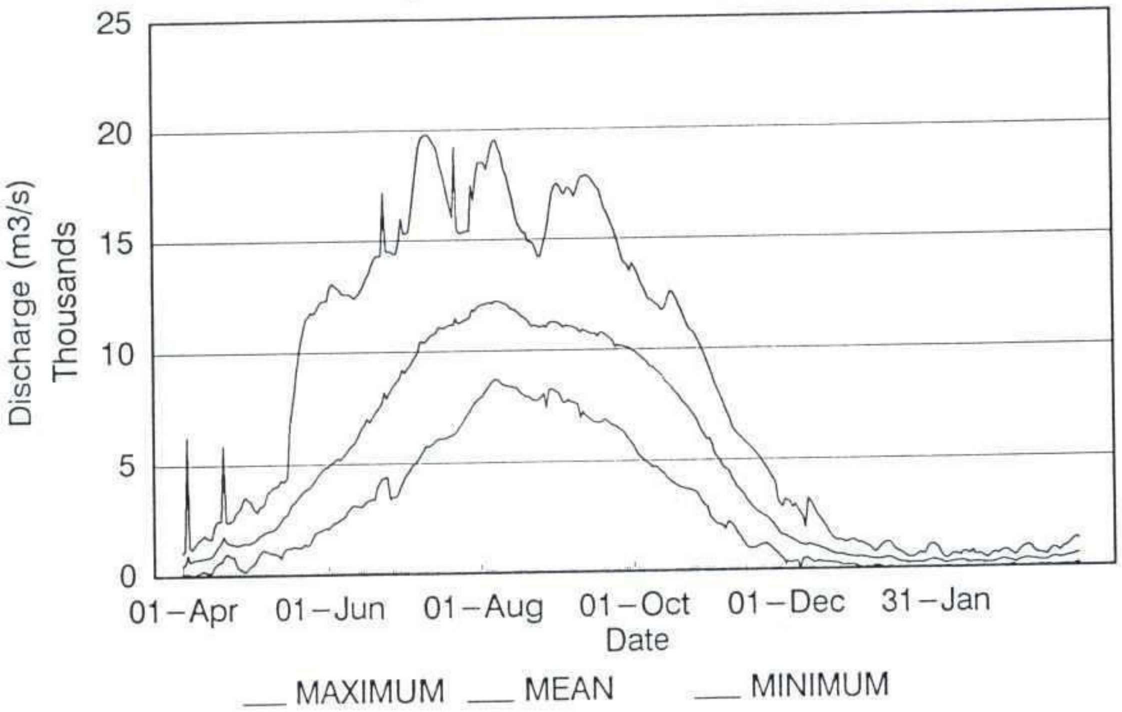
Long-Term Trend in Discharge



PRINTED 03-Jul-95

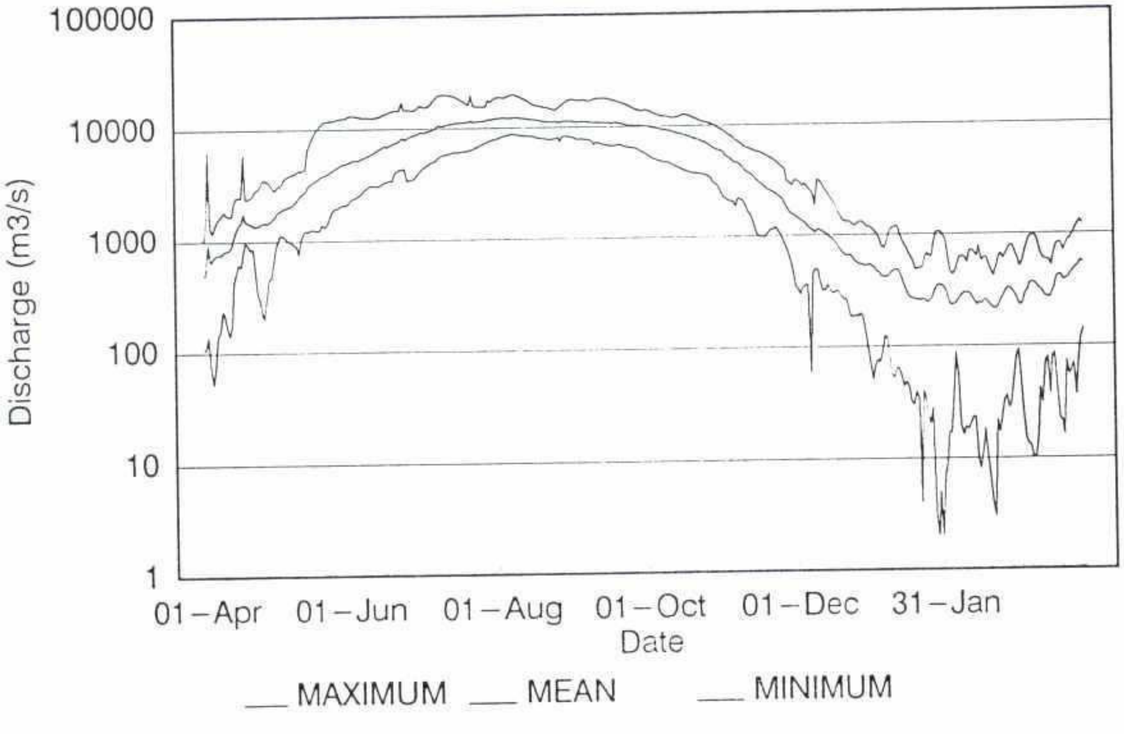
Gauge 273 MEGHNA R. at BHAIRAB BAZAR

Seasonal Variation of Discharge



Gauge 273 MEGHNA R. at BHAIRAB BAZAR

Seasonal Variation (log scale)



Gauge 172 KUSHIYARA R. at AMALSHID
MEAN DAILY WATER LEVEL (m, PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	6.64	11.23	17.01
1965	365	6.57	10.23	16.34
1966	365	6.52	11.21	17.42
1967	366	6.43	10.27	17.16
1968	365	6.34	10.45	17.18
1969	365	6.48	10.23	17.47
1970	334			17.33
1971	76			
1972	365	6.00	9.72	16.97
1973	365	5.94	11.14	17.23
1974	365	6.45	11.15	17.91
1975	337	6.34	10.84	
1976	365	6.31	10.59	17.77
1977	365	6.11	10.96	17.19
1978	365	6.02	9.96	16.49
1979	366	6.22	9.65	17.39
1980	365	6.33	11.07	16.71
1981	365	6.37	10.35	17.57
1982	365	6.20	10.36	17.11
1983	366	6.24	11.82	17.37
1984	365	6.31	10.50	17.00
1985	365	6.37	10.69	17.76
1986	365	6.42	10.13	17.68
1987	366	6.75	10.58	17.10
1988	365	6.53	10.98	17.50
1989	365	6.69	11.27	17.89
1990	365	6.68	11.60	17.29
1991	366	7.02	11.87	17.87
1992	365	6.74	10.60	16.76
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
5.94	10.74	17.91

(Corrected for second order survey datum adjustment)

PRINTED 18–Jun–95

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Gauge 172 KUSHIYARA R. at AMALSHID

MEAN MONTHLY WATER LEVEL (m, PWD)

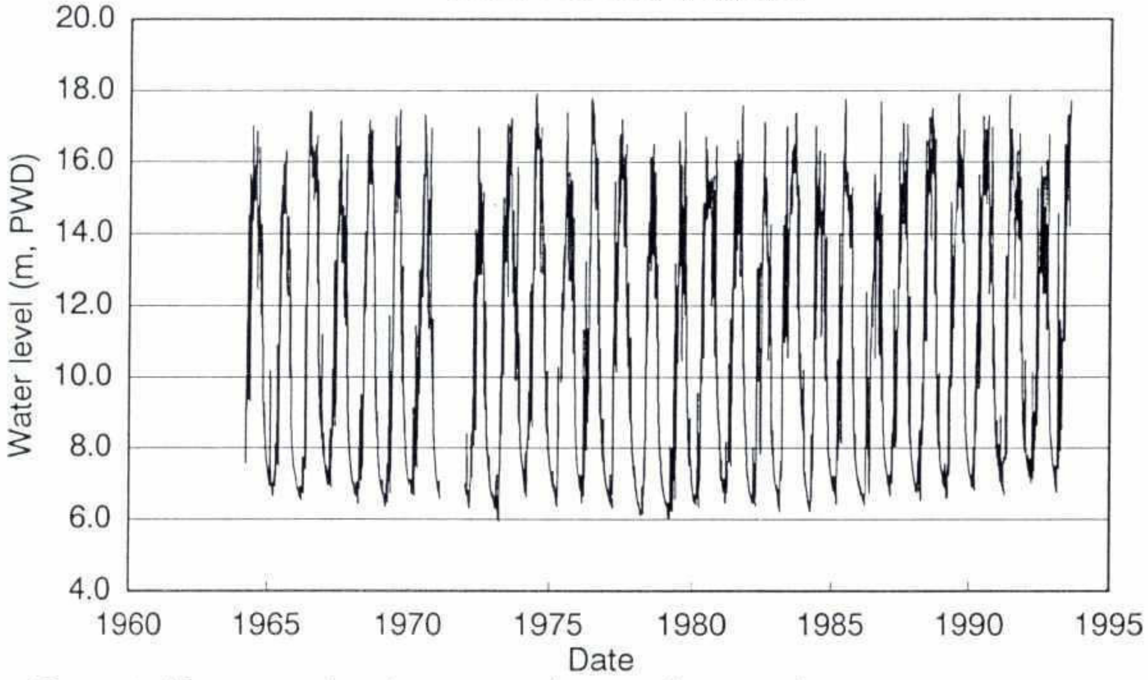
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	10.96	12.20	14.94	15.64	14.26	14.69	12.80	9.31	7.94	7.19	7.86	6.82
1965	7.33	8.86	13.44	14.90	14.98	13.50	12.35	8.89	7.54	7.15	6.79	6.75
1966	7.03	9.18	16.09	16.40	15.59	15.84	13.53	9.31	8.78	7.78	7.26	7.39
1967	8.17	10.27	12.63	15.97	14.05	12.86	12.63	8.38	7.41	6.97	6.73	6.98
1968	7.88	9.51	14.01	16.23	16.28	14.19	10.83	8.62	7.39	6.86	6.67	6.72
1969	8.38	7.92	13.99	15.61	16.13	12.65	10.63	8.44	7.38	7.06	7.06	7.34
1970	8.70	10.54	13.25	15.52	14.94	13.91	13.45	9.85	7.81	7.04	6.81	
1971											7.08	6.49
1972	8.39	11.11	12.66	14.42	14.00	11.82	9.61	7.74	7.06	6.64	6.41	6.49
1973	7.87	11.52	14.92	14.53	16.39	13.40	11.68	12.13	9.10	7.66	7.03	7.16
1974	9.53	10.45	15.04	16.73	15.05	15.15	12.79	9.31	8.34	7.34	7.05	6.70
1975			12.28	15.13	14.19	14.47	13.10	11.48	8.00	7.15	6.88	8.25
1976	9.35	9.54	15.83	17.10	15.38	13.82	10.10	8.10	7.58	6.86	6.68	6.55
1977	12.24	13.16	15.74	15.90	15.20	12.44	10.40	9.08	7.50	6.96	6.48	6.20
1978	6.62	9.88	13.66	14.71	14.78	13.92	10.96	8.07	7.12	6.60	6.36	6.60
1979	6.71	9.10	10.22	14.43	12.80	14.71	11.33	7.91	7.58	6.66	6.60	7.58
1980	8.39	12.37	15.46	15.14	14.42	14.09	13.22	9.92	8.26	7.15	6.82	7.31
1981	9.26	10.13	13.86	15.17	14.84	15.12	10.29	8.23	7.10	6.66	6.81	6.54
1982	11.02	10.60	12.17	15.43	14.11	12.05	10.87	7.85	7.07	6.68	6.57	9.57
1983	12.94	14.03	13.75	15.85	16.46	15.81	13.27	9.98	8.92	7.55	6.78	6.36
1984	7.22	12.77	13.38	15.40	13.17	14.46	11.28	8.72	7.50	7.01	6.91	7.93
1985	10.57	9.92	16.72	15.33	14.58	14.51	10.90	8.09	7.30	6.97	6.74	6.55
1986	8.80	8.59	9.60	13.61	13.29	13.36	14.13	10.39	7.94	7.31	6.95	7.33
1987	9.64	9.03	13.56	14.50	15.19	15.30	11.78	9.02	7.60	7.08	6.84	7.41
1988	7.59	12.54	13.05	15.84	16.17	15.14	13.21	8.58	8.17	7.18	7.13	6.79
1989	9.03	11.40	12.57	15.59	16.66	15.27	14.80	9.54	7.90	7.30	7.08	7.74
1990	12.00	11.95	15.82	15.62	16.09	13.97	13.57	9.96	8.04	7.49	7.45	6.99
1991	9.92	15.84	16.31	14.39	15.14	15.21	13.56	10.45	8.45	7.79	7.43	7.77
1992	7.85	10.38	11.34	14.58	14.00	13.89	13.22	8.90	7.80	7.24	9.09	8.75
1993	9.03	13.88	16.49	15.98								
1994												
1995												

Number	28	28	29	29	28	28	28	28	28	28	29	28
Minimum	6.62	7.92	9.60	13.61	12.80	11.82	9.61	7.74	7.06	6.60	6.36	6.20
Mean	9.02	10.95	13.89	15.37	14.93	14.13	12.15	9.15	7.81	7.12	6.98	7.18
Maximum	12.94	15.84	16.72	17.10	16.66	15.84	14.80	12.13	9.10	7.79	9.09	9.57

(Corrected for second order survey datum adjustment)

Gauge 172 KUSHIYARA R. at AMALSHID

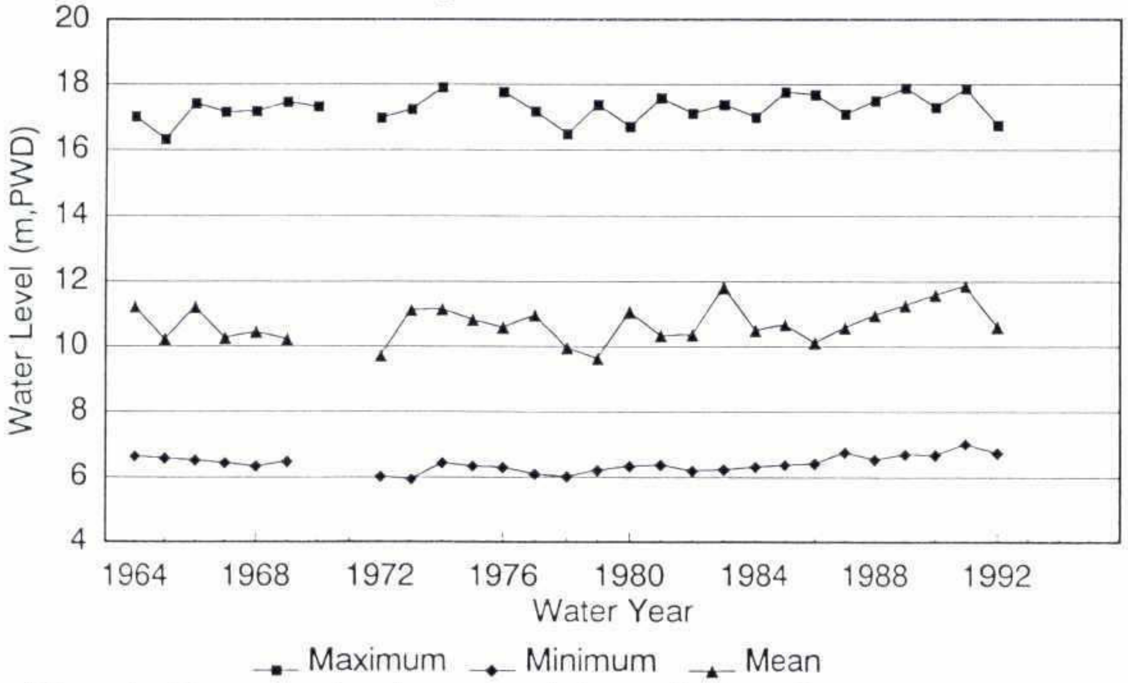
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 172 KUSHIYARA R. at AMALSHID

Long Term Trend in Water Level

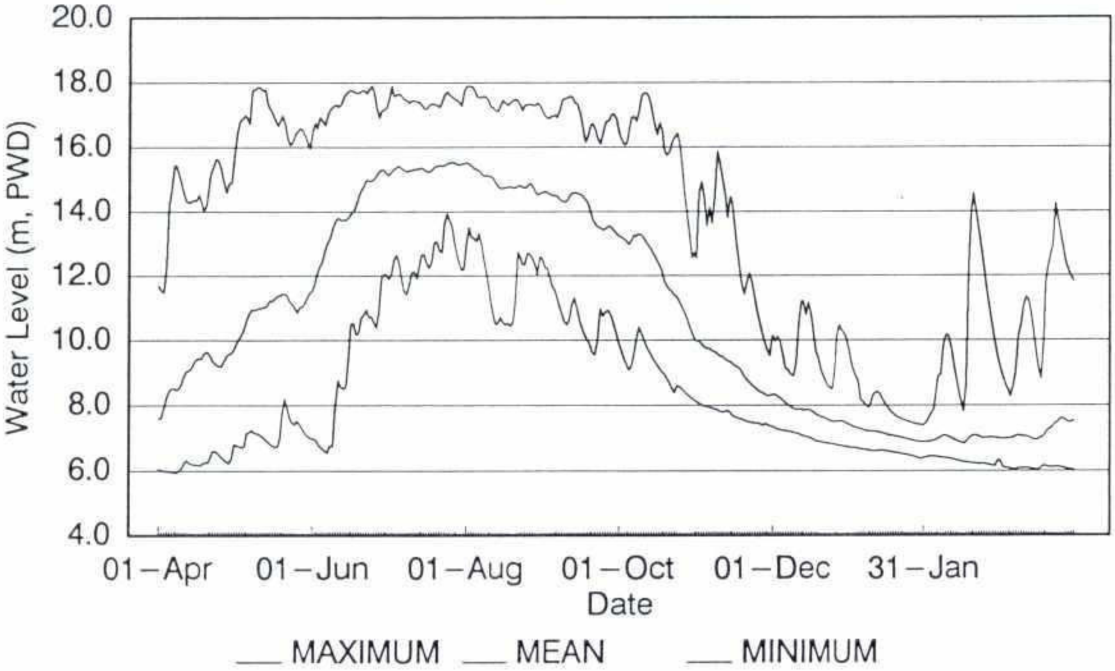


(Corrected for second order survey datum adjustment)

PRINTED 18-Jun-95

Gauge 172 KUSHIYARA R. at AMALSHID

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

Gauge 173 KUSHIYARA R. at SHEOLA
MEAN DAILY WATER LEVEL (m, PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	4.54	9.32	13.58
1965	365	4.59	8.44	13.40
1966	365	4.53	9.10	13.73
1967	366	4.79	8.49	13.60
1968	365	4.56	8.57	13.66
1969	365	4.65	8.33	13.77
1970	365	4.41	8.96	13.84
1971	349	4.46	8.76	
1972	365	4.13	7.98	13.92
1973	365	3.98	9.24	13.90
1974	365	4.18	9.13	13.90
1975	366	4.08	8.92	14.20
1976	365	4.33	8.61	14.20
1977	365	4.18	9.16	13.99
1978	365	3.99	8.13	13.66
1979	366	4.27	7.83	14.01
1980	365	4.46	9.01	13.65
1981	365	4.15	8.24	13.88
1982	365	4.06	8.45	13.97
1983	366	4.05	9.59	14.15
1984	365	4.04	8.59	13.93
1985	365	4.38	8.75	14.10
1986	365	4.38	8.35	14.09
1987	366	4.65	8.70	14.08
1988	365	4.37	9.02	14.15
1989	365	4.80	9.39	14.19
1990	365	5.08	9.81	14.16
1991	366	5.27	9.97	14.28
1992	365	4.90	8.93	13.88
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
3.98	8.84	14.28

(Corrected for second order survey datum adjustment)

PRINTED 13-Jun-95

Gauge 173 KUSHIYARA R. at SHEOLA

MEAN MONTHLY WATER LEVEL (m, PWD)

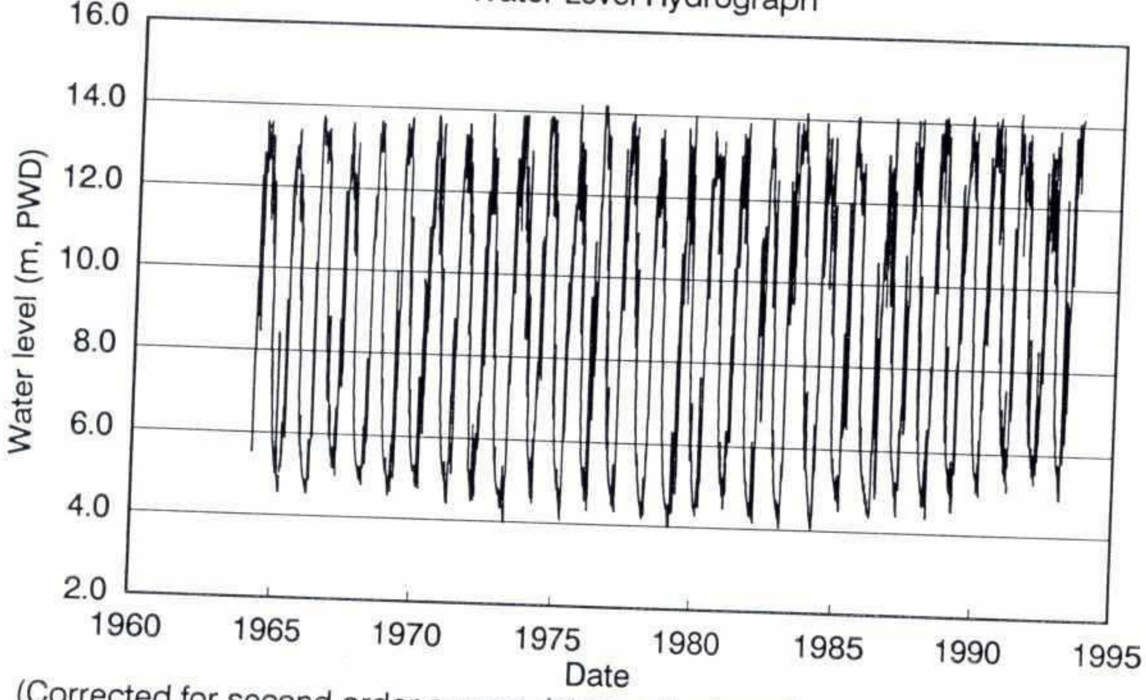
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	9.49	10.82	12.50	13.01	12.30	12.43	11.22	7.85	6.11	5.28	5.97	4.72
1965	5.44	7.31	11.42	12.55	12.71	11.80	10.97	7.95	5.90	5.31	4.89	4.72
1966	5.08	7.50	13.14	13.35	13.04	13.13	11.73	7.72	7.25	6.04	5.45	5.53
1967	6.54	9.21	10.66	13.13	12.02	11.15	10.97	6.84	5.68	5.23	4.98	5.23
1968	6.19	7.82	12.01	13.33	13.32	12.30	9.61	7.12	5.81	5.24	4.98	4.91
1969	6.72	6.39	11.59	13.12	13.37	11.25	9.19	6.65	5.61	5.23	5.16	5.52
1970	7.32	9.08	11.47	13.04	12.83	12.10	11.68	8.54	6.20	5.36	5.15	4.54
1971	6.91		11.70	12.95	13.00	12.47		8.88	5.91	4.85	5.10	4.79
1972	6.63	9.71	10.96	12.52	12.18	10.42	8.30	5.84	5.12	4.71	4.45	4.63
1973	6.14	10.28	12.68	12.50	13.57	11.79	10.12	10.34	7.47	5.67	4.97	5.13
1974	7.99	9.16	12.53	13.72	12.81	12.88	11.15	7.77	6.48	5.30	4.97	4.53
1975	5.90	8.47	10.72	12.77	12.36	12.51	11.41	9.84	6.31	5.26	5.00	6.31
1976	7.42	8.22	13.15	13.89	13.07	11.95	8.82	6.42	5.82	4.94	4.75	4.66
1977	10.57	11.46	13.25	13.30	12.87	10.92	9.37	8.00	5.82	5.22	4.64	4.29
1978	4.74	8.47	11.94	12.58	12.66	11.89	9.53	6.47	5.30	4.66	4.40	4.62
1979	4.92	7.47	8.67	12.38	11.24	12.53	9.80	6.18	5.75	4.65	4.47	5.73
1980	6.48	10.81	12.96	12.82	12.34	12.07	11.34	7.72	5.70	5.28	4.86	5.47
1981	7.87	8.52	11.50	12.70	12.44	12.54	8.48	5.94	5.08	4.58	4.71	4.36
1982	9.34	9.29	10.25	13.22	12.33	10.45	9.08	5.89	4.89	4.51	4.26	7.55
1983	10.67	12.15	11.96	13.56	13.69	13.31	11.44	7.59	5.98	5.56	4.79	4.23
1984	5.18	10.65	11.70	13.02	11.45	12.44	9.95	6.71	5.51	5.02	5.03	6.08
1985	9.17	8.26	13.76	13.03	12.49	12.39	9.49	6.43	5.49	5.09	4.75	4.47
1986	7.07	7.23	7.85	11.72	11.59	11.66	12.14	9.03	6.08	5.37	4.87	5.30
1987	8.02	7.55	11.60	12.45	12.97	12.96	10.41	7.30	5.72	5.09	4.73	5.52
1988	5.62	10.53	11.46	13.36	13.48	12.95	11.46	6.96	6.54	5.39	5.29	4.85
1989	7.19	10.02	11.13	13.19	13.79	13.08	12.72	8.22	6.22	5.54	5.27	6.04
1990	10.24	10.59	13.41	13.30	13.57	12.20	11.95	8.27	6.56	6.02	6.01	5.41
1991	8.47	13.48	13.64	12.41	12.91	12.94	11.79	8.91	6.86	6.26	5.75	6.09
1992	6.31	8.94	9.95	12.61	12.16	12.08	11.51	7.45	6.09	5.51	7.23	7.18
1993	7.45	12.05	13.67	13.39								
1994												
1995												

Number	30	29	30	30	29	29	28	29	29	29	29	29
Minimum	4.74	6.39	7.85	11.72	11.24	10.42	8.30	5.84	4.89	4.51	4.26	4.23
Mean	7.24	9.36	11.77	12.96	12.71	12.16	10.56	7.55	5.97	5.25	5.06	5.25
Maximum	10.67	13.48	13.76	13.89	13.79	13.31	12.72	10.34	7.47	6.26	7.23	7.55

(Corrected for second order survey datum adjustment)

Gauge 173 KUSHIYARA R. at SHEOLA

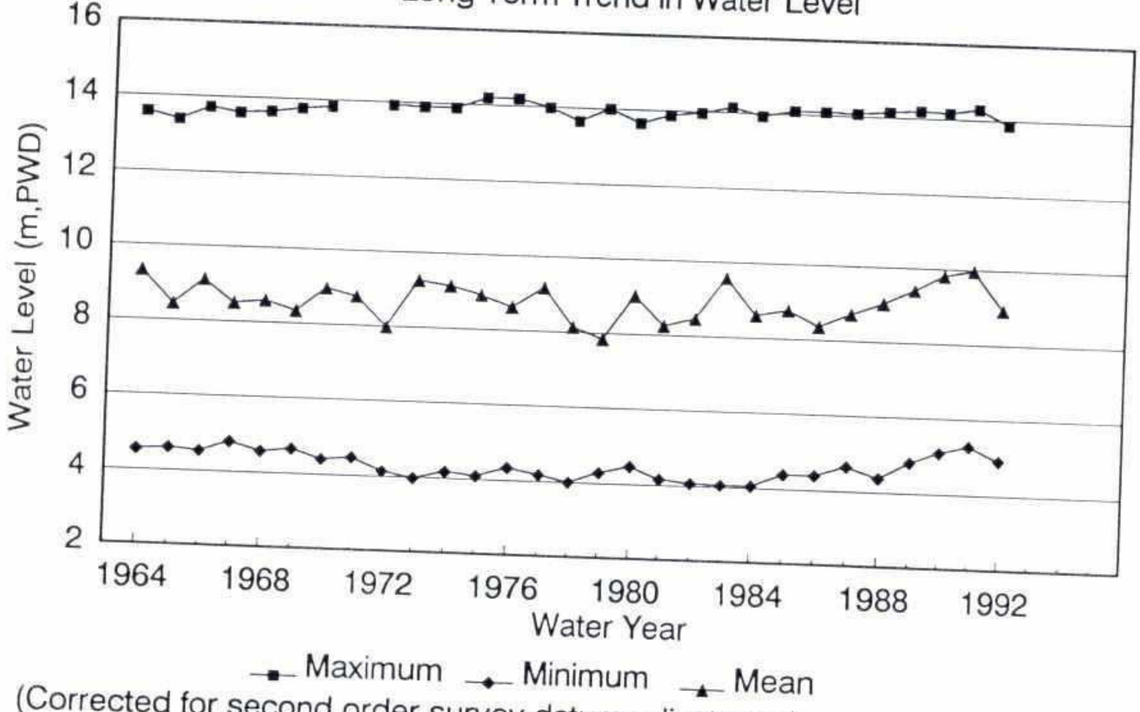
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 173 KUSHIYARA R. at SHEOLA

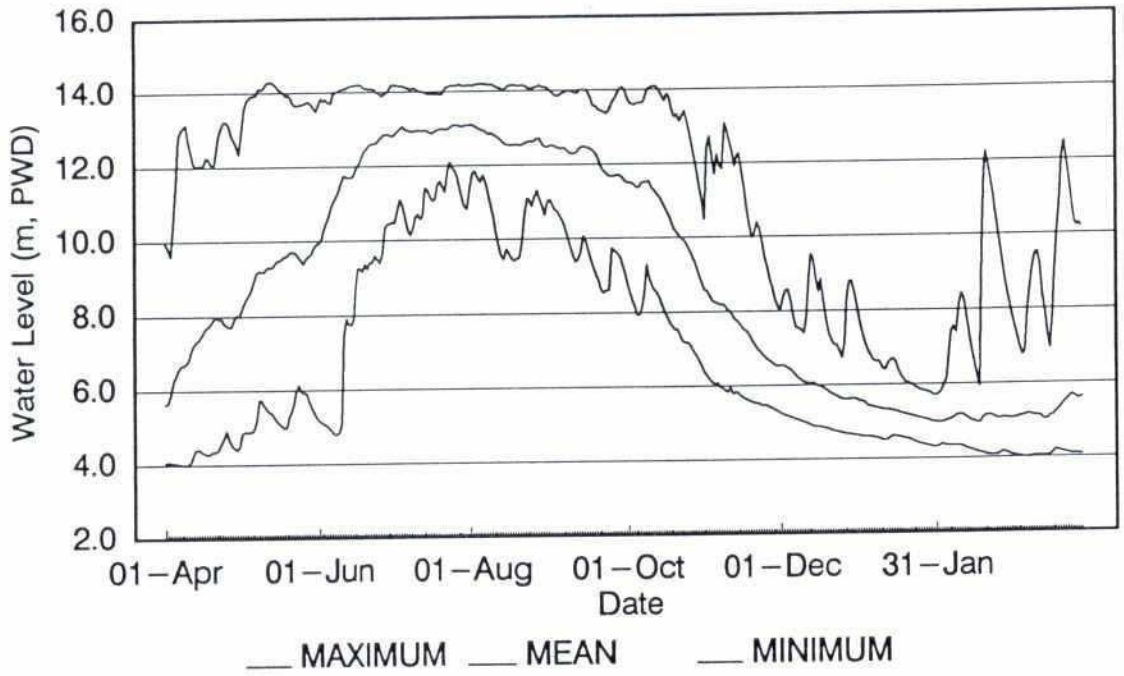
Long Term Trend in Water Level



(Corrected for second order survey datum adjustment)

Gauge 173 KUSHIYARA R. at SHEOLA

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

Gauge 174 KUSHIYARA R. at FENCHUGANJ
MEAN DAILY WATER LEVEL (m, PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	2.48	7.16	10.63
1965	365	2.51	6.23	10.48
1966	365	2.46	6.55	10.96
1967	366	2.44	6.29	10.45
1968	365	2.20	6.24	10.78
1969	365	2.40	5.99	10.77
1970	365	2.16	6.58	10.75
1971	366	2.57	6.51	10.50
1972	365	2.13	5.92	10.74
1973	365	2.11	7.04	10.57
1974	365	2.51	6.96	10.60
1975	366	2.44	6.68	10.51
1976	365	2.48	6.45	11.06
1977	365	2.64	7.04	10.45
1978	365	2.71	6.25	10.25
1979	366	2.70	5.90	10.42
1980	365	2.82	6.93	10.22
1981	365	2.69	6.23	10.40
1982	365	2.56	6.43	10.54
1983	366	2.45	7.28	10.88
1984	365	2.49	6.53	10.76
1985	365	2.67	6.60	11.06
1986	365	2.67	6.33	10.54
1987	366	2.93	6.70	10.52
1988	365	2.84	6.91	10.78
1989	365	3.00	7.24	11.14
1990	365	3.72	7.69	10.65
1991	366	3.69	7.77	11.35
1992	365	3.56	6.95	10.07
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
2.11	6.69	11.35

(Corrected for second order survey datum adjustment)

PRINTED 13–Jun–95

Gauge 174 KUSHIYARA R. at FENCHUGANJ
MEAN MONTHLY WATER LEVEL (m, PWD)

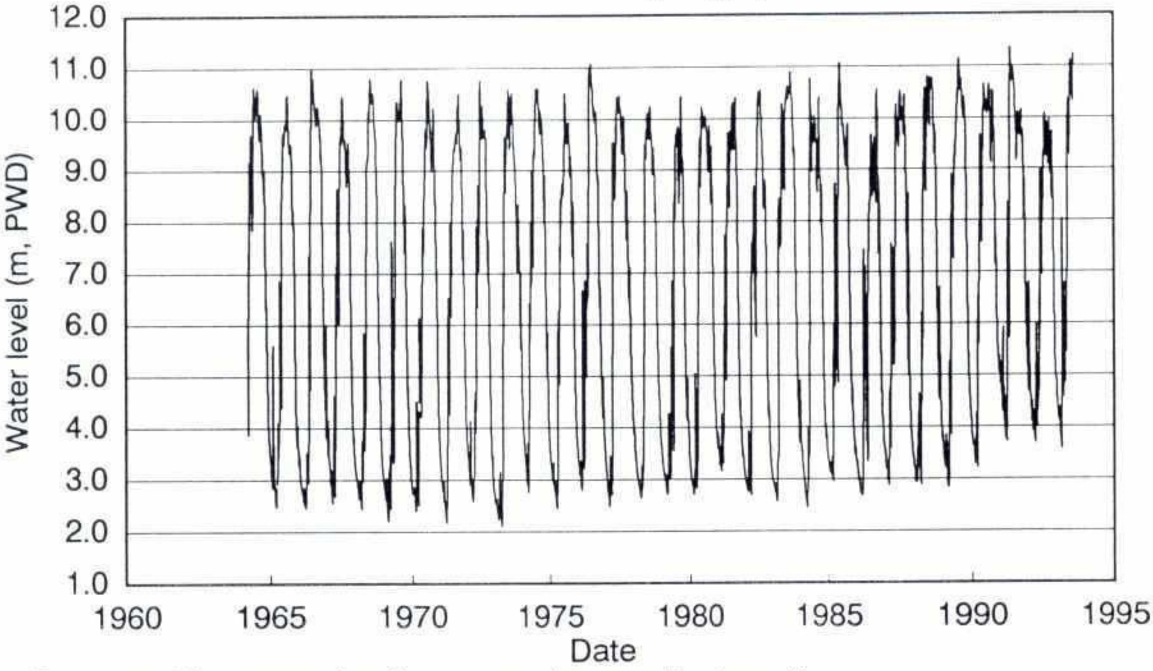
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	7.57	9.06	9.81	10.25	10.08	9.82	8.91	6.68	4.09	3.14	3.72	2.66
1965	3.50	5.46	8.66	9.76	10.16	9.48	8.73	6.47	3.76	3.19	2.75	2.65
1966	3.12	5.36	10.05	10.50	10.05	10.08	9.21	5.95	4.45	3.57	2.95	3.10
1967	4.57	7.61	8.25	10.11	9.65	8.91	8.82	5.17	3.52	3.01	2.71	2.89
1968	4.11	5.53	9.46	10.48	10.42	9.89	8.04	5.15	3.39	2.80	2.60	2.78
1969	4.83	4.71	8.41	10.12	10.29	9.45	7.46	4.64	3.23	2.79	2.69	3.07
1970	5.02	6.63	8.85	10.06	10.27	9.41	9.44	6.86	4.01	3.04	2.77	2.32
1971	4.98	6.30	8.27	9.45	9.84	10.13	8.98	6.84	4.12	3.23	3.21	2.73
1972	4.47	7.65	8.81	10.03	9.80	8.78	6.80	3.97	2.94	2.55	2.33	2.60
1973	4.19	8.47	9.73	9.95	10.28	9.49	7.97	7.83	5.88	3.92	3.22	3.23
1974	6.46	7.87	9.36	10.51	10.15	9.98	8.90	6.50	4.42	3.30	3.04	2.74
1975	3.94	6.39	8.45	9.21	9.99	9.73	8.96	7.61	4.62	3.40	3.11	4.64
1976	5.37	6.49	9.96	10.76	10.12	9.55	7.36	4.91	3.99	3.05	2.71	2.91
1977	8.39	9.26	10.28	10.22	9.72	8.91	7.63	6.14	4.34	3.56	3.02	2.76
1978	3.14	6.73	9.62	9.88	9.88	9.19	7.81	5.25	3.88	3.24	2.98	3.14
1979	3.44	5.33	6.72	9.53	9.07	9.78	8.33	4.90	4.01	3.07	2.82	3.70
1980	4.42	8.79	9.87	9.98	9.74	9.38	9.12	6.63	4.24	3.63	3.41	3.67
1981	5.95	6.60	9.06	9.58	9.91	9.93	7.09	4.23	3.41	2.98	3.03	2.84
1982	6.87	7.73	7.83	10.34	10.08	8.64	7.28	4.19	3.21	2.88	2.70	5.17
1983	7.93	9.80	9.27	10.42	10.60	10.51	9.22	6.01	4.10	3.74	3.04	2.60
1984	3.34	8.16	9.53	9.82	9.19	9.77	8.43	5.43	3.83	3.32	3.19	4.05
1985	7.19	6.34	10.59	10.20	9.57	9.39	7.96	4.86	3.77	3.36	3.02	2.74
1986	5.08	5.85	5.51	8.67	9.05	9.26	9.74	7.66	4.55	3.57	3.17	3.64
1987	6.06	6.14	9.18	9.74	10.30	9.94	8.99	5.93	3.98	3.31	2.98	3.77
1988	4.09	7.98	9.57	10.52	10.37	10.38	9.17	5.50	4.99	3.60	3.43	3.07
1989	4.77	8.04	9.12	10.19	10.88	10.39	10.08	6.98	4.60	3.79	3.49	4.29
1990	7.65	8.62	10.36	10.19	10.39	9.59	9.81	6.85	5.23	4.74	4.69	3.98
1991	6.79	10.49	10.85	10.07	9.74	9.78	9.39	7.24	5.42	4.83	4.13	4.39
1992	4.68	7.00	8.06	9.78	9.48	9.46	9.09	6.18	4.61	4.12	5.21	5.59
1993	5.83	9.66	10.72	10.75								
1994												
1995												

Number	30	30	30	30	29	29	29	29	29	29	29	29
Minimum	3.12	4.71	5.51	8.67	9.05	8.64	6.80	3.97	2.94	2.55	2.33	2.32
Mean	5.26	7.33	9.14	10.04	9.97	9.62	8.58	5.95	4.16	3.40	3.18	3.37
Maximum	8.39	10.49	10.85	10.76	10.88	10.51	10.08	7.83	5.88	4.83	5.21	5.59

(Corrected for second order survey datum adjustment)

Gauge 174 KUSHIYARA R. at FENCHUGANJ

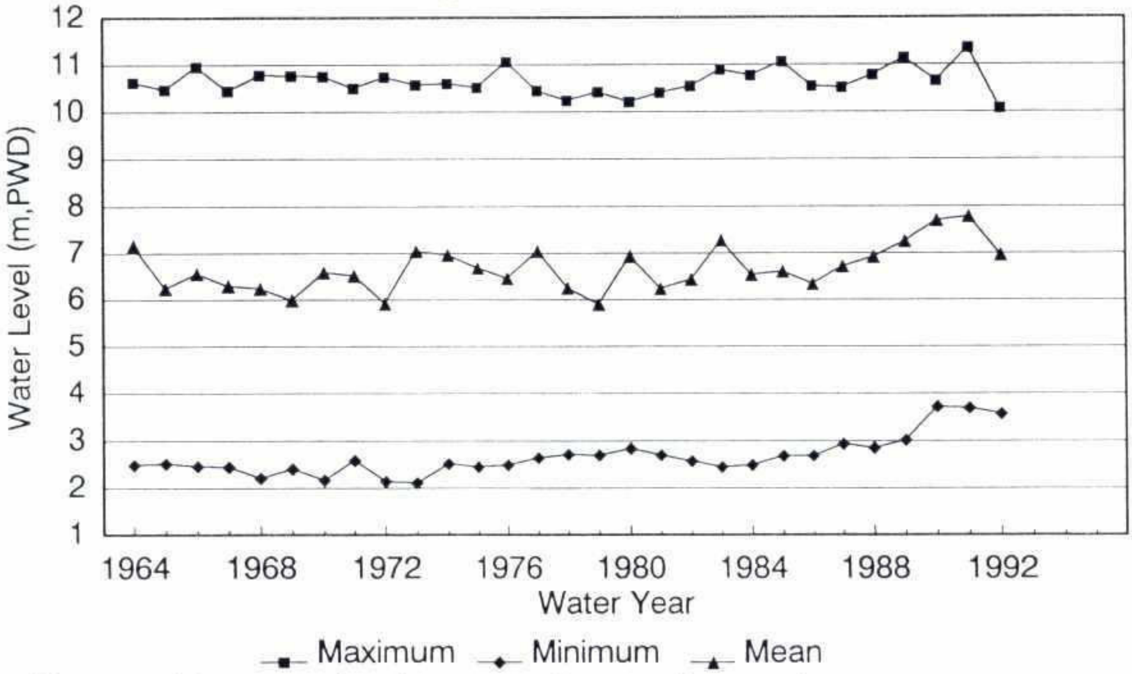
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 174 KUSHIYARA R. at FENCHUGANJ

Long Term Trend in Water Level

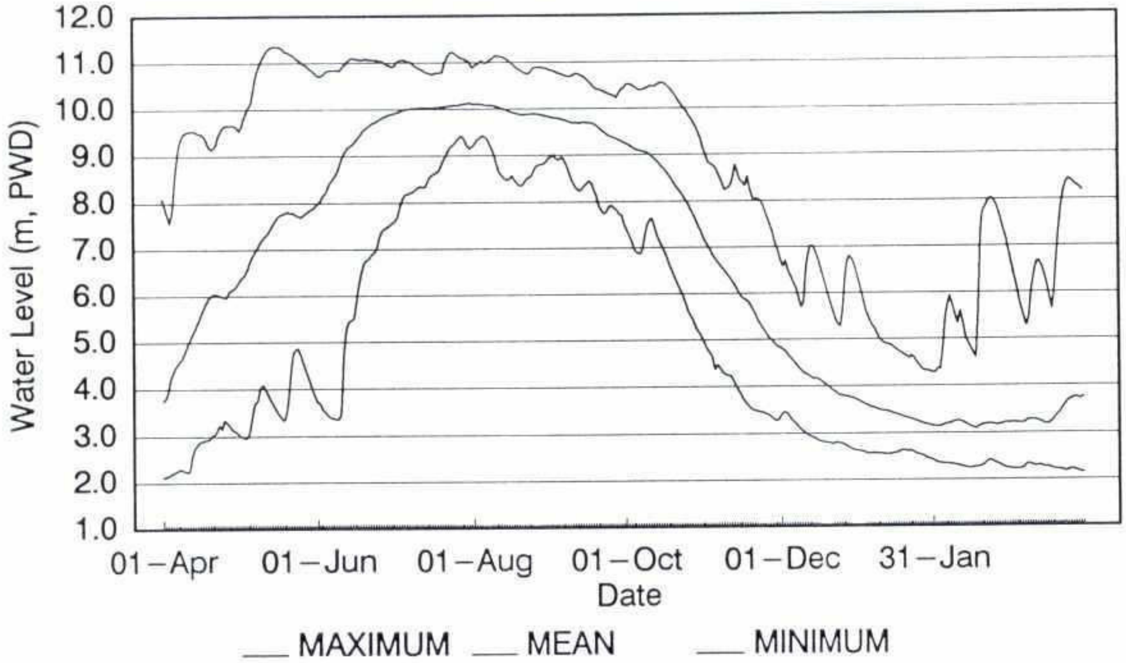


(Corrected for second order survey datum adjustment)

PRINTED 13-Jun-95

Gauge 174 KUSHIYARA R. at FENCHUGANJ

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

Gauge 175.5 KUSHIYARA R. at SHERPUR
MEAN DAILY WATER LEVEL (m, PWD)

Year	Number	Minimum	Mean	Maximum
1964	0			
1965	0			
1966	0			
1967	0			
1968	0			
1969	0			
1970	0			
1971	0			
1972	0			
1973	0			
1974	0			
1975	0			
1976	0			
1977	0			
1978	0			
1979	0			
1980	0			
1981	0			
1982	365	1.75	5.27	8.85
1983	366	1.75	5.97	9.02
1984	365	1.84	5.43	8.83
1985	365	2.29	5.53	9.03
1986	365	2.15	5.32	8.70
1987	366	2.33	5.55	8.87
1988	365	2.15	5.81	9.25
1989	365	2.34	6.11	9.16
1990	365	3.25	6.57	8.73
1991	366	3.35	6.64	9.26
1992	365	3.28	6.02	8.51
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
1.75	5.87	9.34

(Corrected for second order survey datum adjustment)

PRINTED 13-Jun-95

Gauge 175.5 KUSHIYARA R. at SHERPUR
MEAN MONTHLY WATER LEVEL (m, PWD)

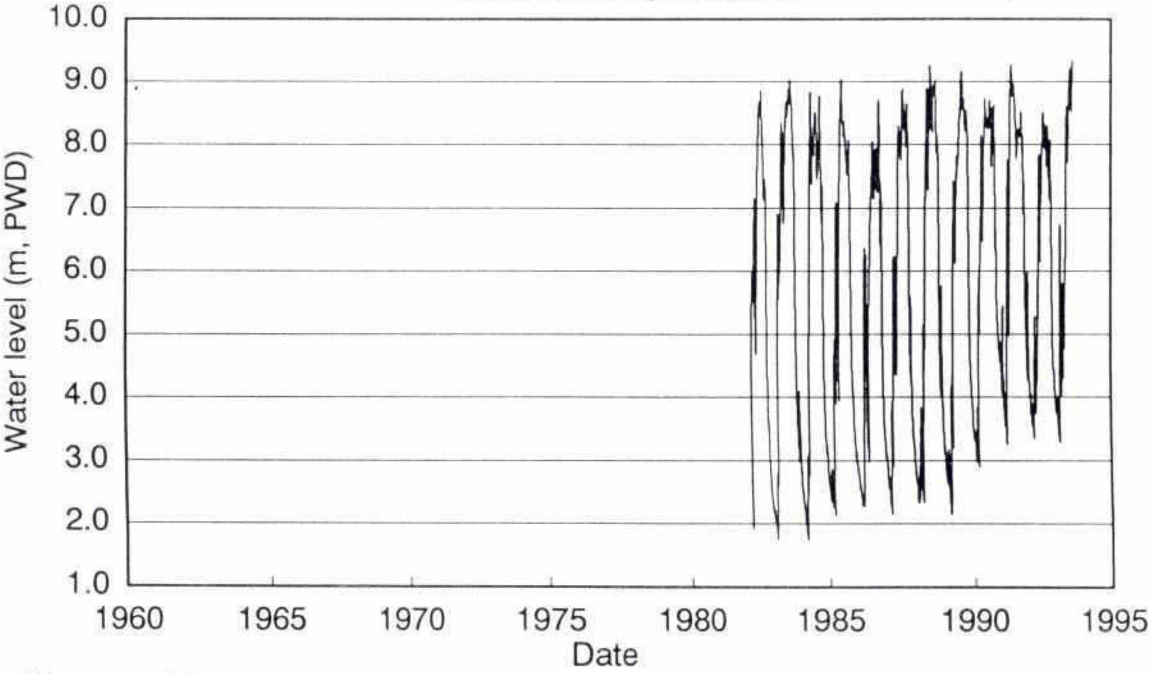
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964												
1965												
1966												
1967												
1968												
1969												
1970												
1971												
1972												
1973												
1974												
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982	5.40	6.22	6.43	8.52	8.43	7.42	6.27	3.53	2.52	2.14	1.93	4.15
1983	6.26	7.95	7.51	8.51	8.79	8.73	7.76	5.29	3.41	3.04	2.35	1.95
1984	2.70	6.80	7.84	8.23	7.84	8.24	7.20	4.68	3.12	2.55	2.47	3.21
1985	5.86	5.34	8.66	8.33	7.99	7.78	6.73	4.39	3.30	2.91	2.58	2.36
1986	4.31	5.06	4.63	7.27	7.61	7.73	8.12	6.61	3.89	2.98	2.55	2.90
1987	5.01	5.08	7.45	8.02	8.61	8.22	7.53	4.93	3.39	2.74	2.41	3.14
1988	3.37	6.78	8.07	8.84	8.63	8.66	7.69	4.87	4.33	2.99	2.82	2.44
1989	3.85	6.72	7.53	8.34	8.93	8.46	8.27	6.15	4.23	3.46	3.18	3.92
1990	6.61	7.33	8.49	8.32	8.51	7.97	8.10	6.06	4.88	4.48	4.35	3.62
1991	6.20	8.69	8.85	8.32	8.07	8.23	7.87	6.32	4.95	4.42	3.75	3.96
1992	4.23	6.24	7.10	8.31	8.03	7.94	7.61	5.47	4.15	3.75	4.52	4.81
1993	5.11	8.13	8.89	8.88								
1994												
1995												

Number	12	12	12	12	11	11	11	11	11	11	11	11
Minimum	2.70	5.06	4.63	7.27	7.61	7.42	6.27	3.53	2.52	2.14	1.93	1.95
Mean	4.91	6.69	7.62	8.33	8.31	8.13	7.56	5.30	3.83	3.22	2.99	3.31
Maximum	6.61	8.69	8.89	8.88	8.93	8.73	8.27	6.61	4.95	4.48	4.52	4.81

(Corrected for second order survey datum adjustment)

Gauge 175.5 KUSHIYARA R. at SHERPUR

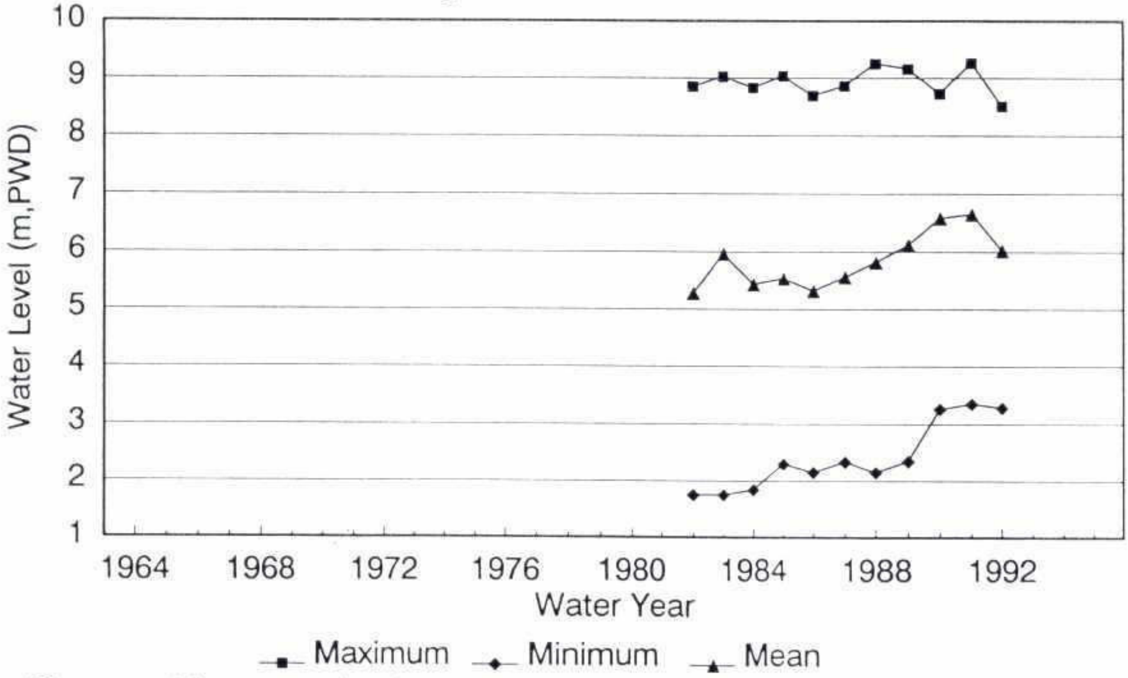
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 175.5 KUSHIYARA R. at SHERPUR

Long Term Trend in Water Level

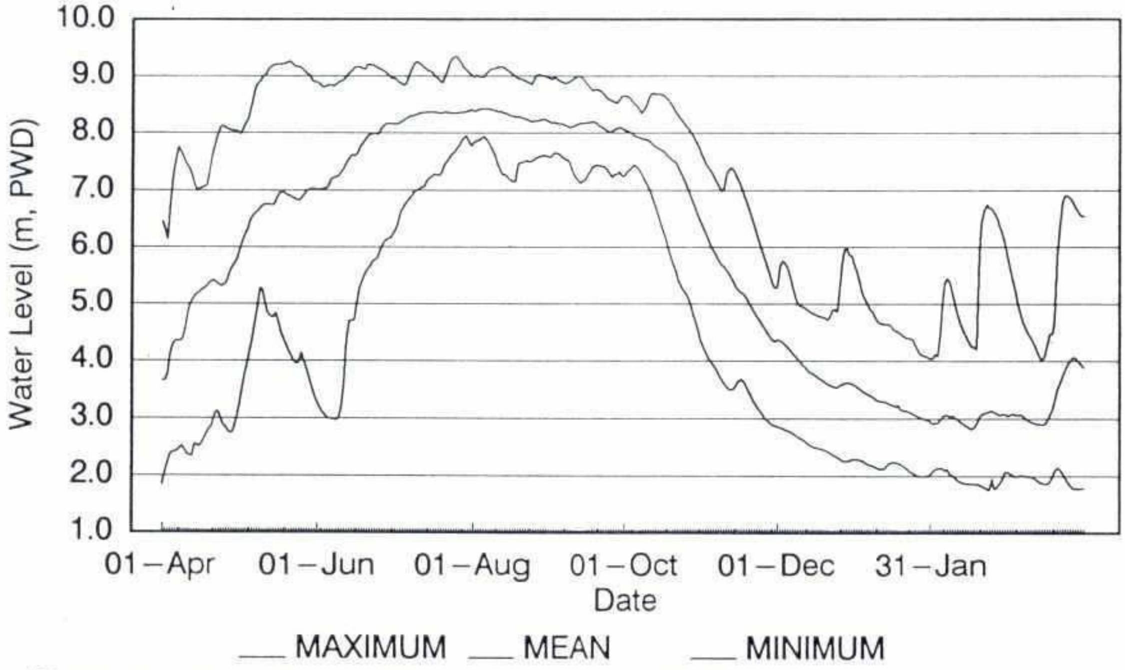


(Corrected for second order survey datum adjustment)

PRINTED 13-Jun-95

Gauge 175.5 KUSHIYARA R. at SHERPUR

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

Gauge 270 KUSIYARA R. at MARKULI
MEAN DAILY WATER LEVEL (m,PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	1.28	4.77	7.94
1965	365	1.23	4.11	7.27
1966	173			
1967	366	1.31	4.27	7.25
1968	365	1.47	4.33	7.71
1969	365	1.57	4.25	7.50
1970	312			7.81
1971	90			
1972	365	1.44	4.20	7.27
1973	364	1.58	4.95	7.49
1974	358		5.09	8.39
1975	61			
1976	61			
1977	365	2.36	5.26	7.23
1978	365	1.80	4.72	7.05
1979	366	1.68	4.51	7.41
1980	365	1.93	4.95	7.14
1981	365	1.93	4.49	7.26
1982	365	2.01	4.85	7.46
1983	359		5.34	7.78
1984	365	2.15	4.89	7.71
1985	365	2.30	4.86	7.29
1986	365	2.16	4.83	7.05
1987	365	2.35	5.02	7.73
1988	0			
1989	365	2.37	5.39	7.43
1990	0			
1991	366	3.34	5.89	7.38
1992	365	3.16	5.44	7.25
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
1.23	4.83	8.39

(Corrected for second order survey datum adjustment)

PRINTED 13–Jul–95

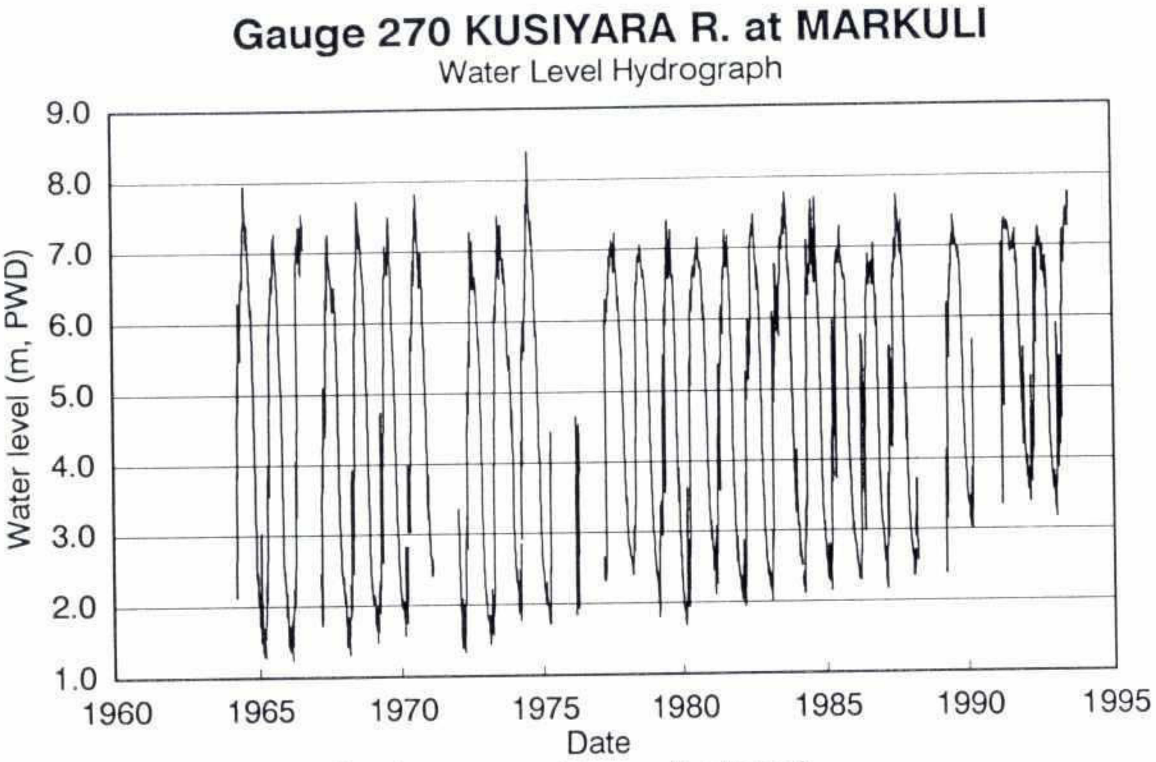
Gauge 270 KUSIYARA R. at MARKULI

MEAN MONTHLY WATER LEVEL

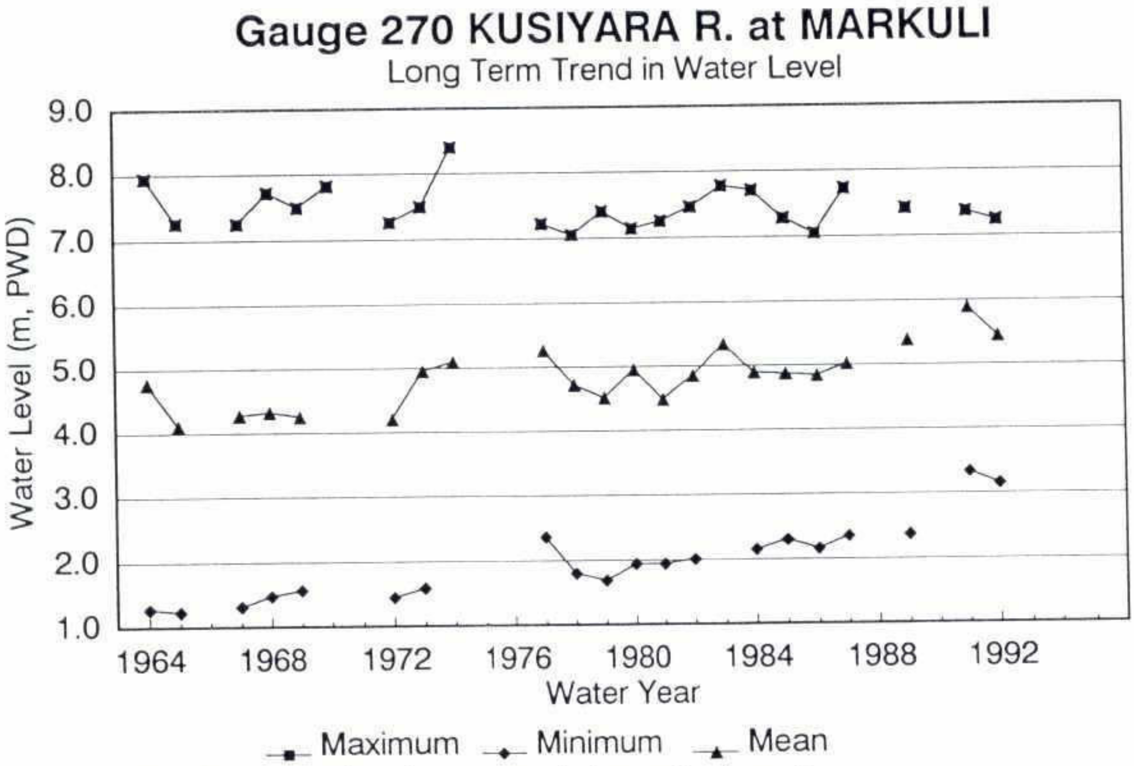
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	4.12	5.83	6.22	7.09	7.54	7.07	6.25	4.88	2.65	1.84	2.08	1.50
1965	2.01	3.59	5.59	6.47	7.06	6.82	5.85	4.44	2.38	1.84	1.51	1.58
1966	2.06	3.23	6.40	7.16	6.99							
1967	2.77	4.70	5.44	6.88	6.74	6.30	6.15	4.13	2.58	2.14	1.60	1.71
1968	2.73	3.52	6.07	7.30	7.24	6.81	5.88	4.05	2.39	2.04	1.83	1.91
1969	3.22	3.43	5.70	6.89	7.03	6.90	5.48	3.69	2.47	2.01	1.86	2.16
1970	3.45	4.77	6.15	7.06	7.51	6.78	6.53	5.01	3.45	2.66		
1971										2.41	1.73	1.58
1972	3.08	5.07	6.14	6.77	6.68	6.27	5.45	3.31	2.18	1.76	1.62	1.87
1973	3.08	5.74	6.65	7.05	7.21	6.73	6.00	5.40	4.40	2.61	2.09	2.10
1974	4.48	5.78	6.34	7.66	7.81	7.17	6.28	4.97	3.31	2.38	2.13	
1975	2.95											3.27
1976	3.47											2.47
1977	5.71	6.29	6.78	7.00	6.94	6.69	6.07	5.27	3.95	3.11	2.70	2.53
1978	2.92	4.94	6.57	6.90	6.88	6.61	6.11	4.75	3.36	2.62	2.26	2.48
1979	3.22	4.61	5.27	6.89	6.85	6.98	6.29	4.26	3.06	2.09	1.82	2.67
1980	3.14	6.00	6.59	6.73	7.02	6.79	6.29	5.20	3.52	2.85	2.44	2.64
1981	4.38	4.65	6.00	6.65	6.98	6.93	5.49	3.40	2.64	2.27	2.23	2.09
1982	4.79	5.51	6.07	7.22	7.17	6.61	5.72	3.63	2.69	2.37	2.21	3.98
1983	5.48	6.37	6.13	6.99	7.35	7.52	6.69	5.10	3.59	3.23	2.66	
1984	3.00	5.81	6.58	7.20	6.92	7.05	6.37	4.48	3.04	2.51	2.45	3.08
1985	5.08	4.70	6.78	6.94	6.90	6.60	5.93	4.23	3.25	2.89	2.57	2.38
1986	4.07	4.73	4.36	6.44	6.67	6.67	6.81	5.87	3.81	2.99	2.55	2.86
1987	4.61	4.70	6.28	7.01	7.50	7.08	6.60	4.70	3.32	2.73	2.42	3.11
1988												
1989	3.71	5.79	6.46	7.05	7.21	6.98	6.84	5.63	4.15	3.49	3.23	3.92
1990												
1991	5.71	7.14	7.27	7.13	6.97	7.10	6.76	5.72	4.77	4.31	3.75	3.94
1992	4.19	5.73	6.36	7.16	6.93	6.83	6.65	5.10	3.94	3.59	4.16	4.54
1993	4.82	6.97	7.30	7.47								
1994												
1995												

Number	27	25	25	25	24	23	23	23	23	24	23	23
Minimum	2.01	3.23	4.36	6.44	6.67	6.27	5.45	3.31	2.18	1.76	1.51	1.50
Mean	3.79	5.18	6.22	7.00	7.09	6.84	6.19	4.66	3.26	2.61	2.34	2.63
Maximum	5.71	7.14	7.30	7.66	7.81	7.52	6.84	5.87	4.77	4.31	4.16	4.54

(Corrected for second order survey datum adjustment)



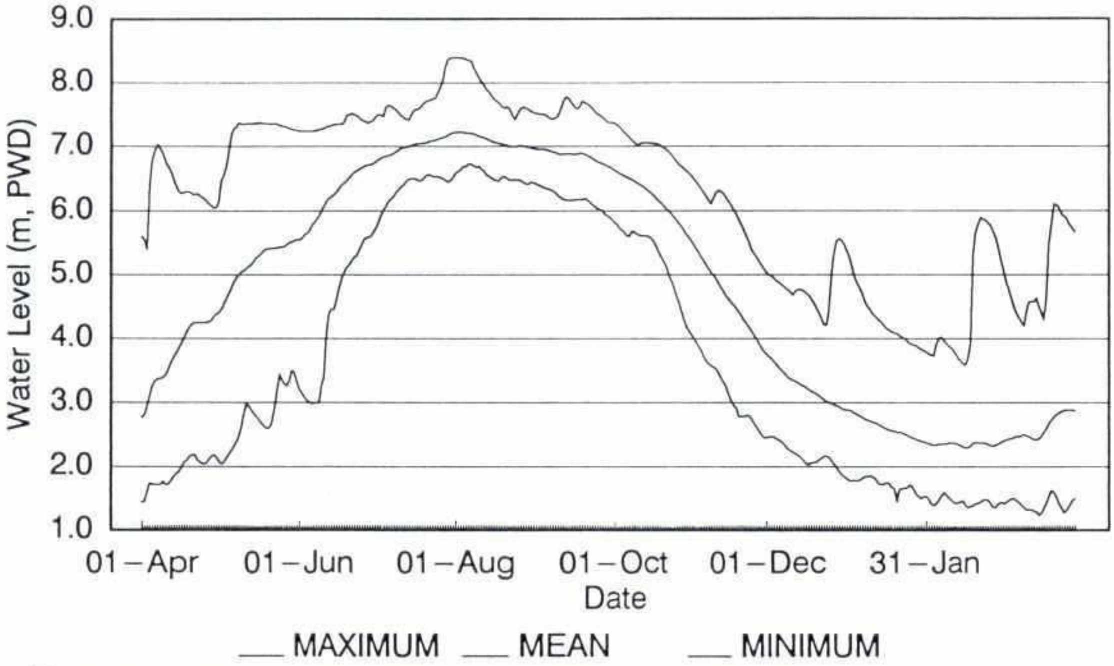
(Corrected for second order survey datum adjustment)



(Corrected for second order survey datum adjustment)

Gauge 270 KUSIYARA R. at MARKULI

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

Gauge 271 KALNI–KUSHIYARA R. at AJMIRIGANJ
MEAN DAILY WATER LEVEL (m,PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	1.02	4.20	7.68
1965	365	0.93	3.70	7.11
1966	365	1.12	3.89	7.36
1967	366	0.94	3.55	6.82
1968	365	0.90	3.77	7.40
1969	365	1.03	3.69	7.27
1970	354		4.28	7.68
1971	85			
1972	365	1.05	3.61	6.75
1973	365	1.17	4.27	7.13
1974	365	1.20	4.34	8.21
1975	244	1.16		
1976	243	1.05		
1977	365	1.06	4.23	7.01
1978	365	1.03	3.66	6.57
1979	366	1.08	3.67	7.09
1980	365	1.28	4.05	6.79
1981	365	1.17	3.80	6.99
1982	365	1.28	3.93	7.11
1983	366	1.54	4.51	7.44
1984	365	1.79	4.37	7.50
1985	365	1.89	4.18	6.89
1986	365	1.84	4.20	6.38
1987	366	2.18	4.53	7.47
1988	365	1.94	4.74	8.02
1989	365	2.09	4.56	7.11
1990	365	2.09	4.58	6.58
1991	366	2.39	4.92	6.84
1992	365	2.93	4.59	6.38
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
0.90	4.14	8.21

(Corrected for second order survey datum adjustment)

PRINTED 13–Jul–95

Gauge 271 KALNI–KUSHIYARA R. at AJMIRIGANJ
MEAN MONTHLY WATER LEVEL

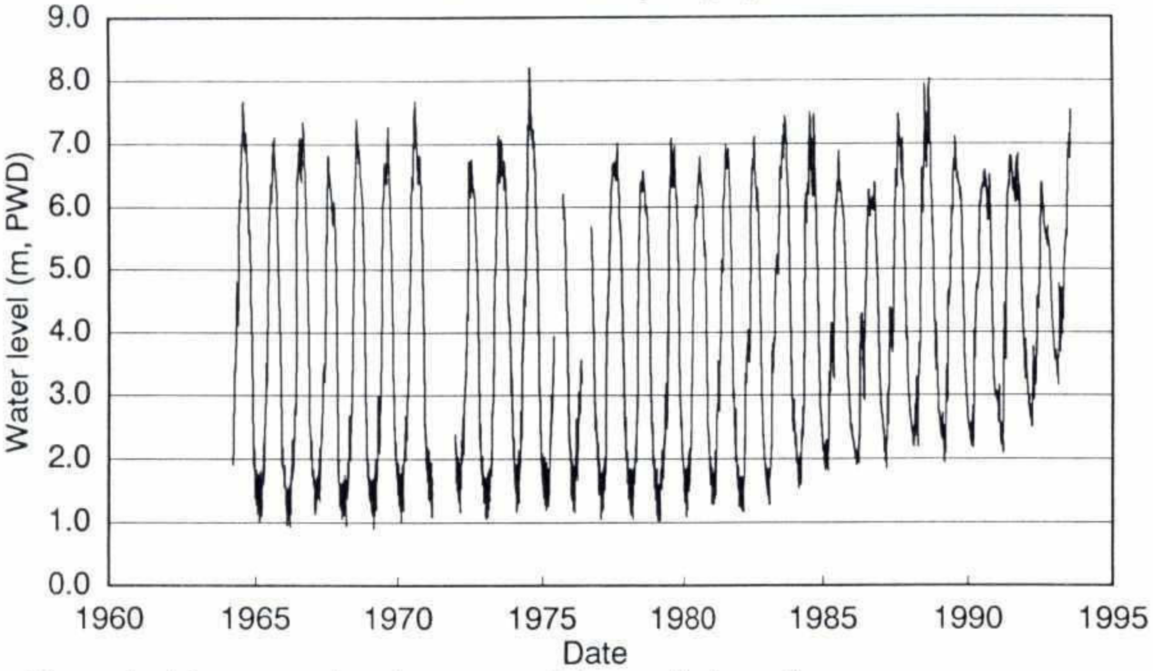
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	2.91	4.33	5.28	6.76	7.34	6.88	5.82	4.26	2.16	1.48	1.52	1.43
1965	1.84	3.06	4.85	6.12	6.84	6.57	5.34	3.53	1.93	1.53	1.26	1.38
1966	1.92	2.60	5.58	6.91	6.76	6.98	5.56	3.35	2.06	1.61	1.46	1.68
1967	1.91	3.15	4.27	6.33	6.39	5.90	5.65	3.17	1.48	1.38	1.42	1.44
1968	2.10	2.67	5.00	6.94	6.92	6.47	5.58	3.21	1.81	1.50	1.39	1.51
1969	2.17	2.53	4.74	6.49	6.75	6.75	5.07	2.90	1.93	1.59	1.49	1.68
1970	2.43	3.53	5.32	6.82	7.39	6.58	6.38	4.46	2.34	1.82	1.62	
1971										1.95	1.65	
1972	2.36	3.38	5.04	6.42	6.49	5.93	4.72	2.61	1.80	1.45	1.42	1.55
1973	2.36	4.28	5.94	6.75	6.91	6.55	5.72	4.18	3.05	1.99	1.60	1.76
1974	2.82	4.25	5.35	7.33	7.65	7.00	6.06	4.21	2.33	1.71	1.57	1.55
1975	2.22	3.17					5.83	4.35	2.55	1.71	1.52	2.04
1976	2.44	3.15					4.75	2.85	2.15	1.60	1.45	1.68
1977	3.72	5.02	6.22	6.64	6.65	6.40	5.36	3.59	2.32	1.69	1.50	1.52
1978	1.89	3.16	5.68	6.38	6.38	5.93	5.02	2.97	1.96	1.54	1.35	1.52
1979	1.89	2.74	3.64	6.31	6.55	6.61	5.77	3.36	2.24	1.59	1.45	1.81
1980	2.28	4.37	5.67	6.06	6.66	6.36	5.59	4.18	2.30	1.73	1.53	1.67
1981	2.87	3.38	4.98	6.22	6.78	6.67	5.07	2.87	2.06	1.56	1.50	1.47
1982	3.13	3.81	4.70	6.61	6.74	6.13	5.04	2.93	2.03	1.64	1.54	2.61
1983	3.73	4.95	5.24	6.48	7.01	7.25	6.31	4.36	2.66	2.37	1.88	1.75
1984	2.42	4.51	6.06	6.90	6.72	6.80	5.87	3.84	2.57	2.06	2.00	2.48
1985	3.75	3.75	5.66	6.37	6.47	6.01	5.22	3.63	2.72	2.37	2.09	2.01
1986	3.21	3.96	3.81	5.54	6.06	6.04	6.11	4.92	3.32	2.62	2.17	2.43
1987	3.72	3.95	5.14	6.51	7.29	6.74	6.17	4.17	3.01	2.53	2.27	2.80
1988	2.89	4.72	6.30	7.46	7.04	7.52	5.90	4.10	3.51	2.58	2.47	2.21
1989	3.14	4.59	5.57	6.59	6.79	6.38	6.06	4.43	3.13	2.58	2.38	2.86
1990	4.18	4.83	5.98	6.33	6.47	5.95	6.11	4.15	3.07	2.87	2.61	2.29
1991	3.96	5.55	6.55	6.59	6.26	6.64	6.15	4.63	3.63	3.27	2.81	2.93
1992	3.25	4.02	4.82	6.22	5.81	5.51	5.44	4.61	3.84	3.54	3.80	4.14
1993	4.33	5.40	6.33	7.14								
1994												
1995												

Number	29	29	27	27	26	26	28	28	28	29	29	27
Minimum	1.84	2.53	3.64	5.54	5.81	5.51	4.72	2.61	1.48	1.38	1.26	1.38
Mean	2.82	3.89	5.32	6.56	6.74	6.48	5.63	3.78	2.50	2.00	1.82	2.01
Maximum	4.33	5.55	6.55	7.46	7.65	7.52	6.38	4.92	3.84	3.54	3.80	4.14

(Corrected for second order survey datum adjustment)

Gauge 271 KALNI–KUSHIYARA R. at AJMIRIGANJ

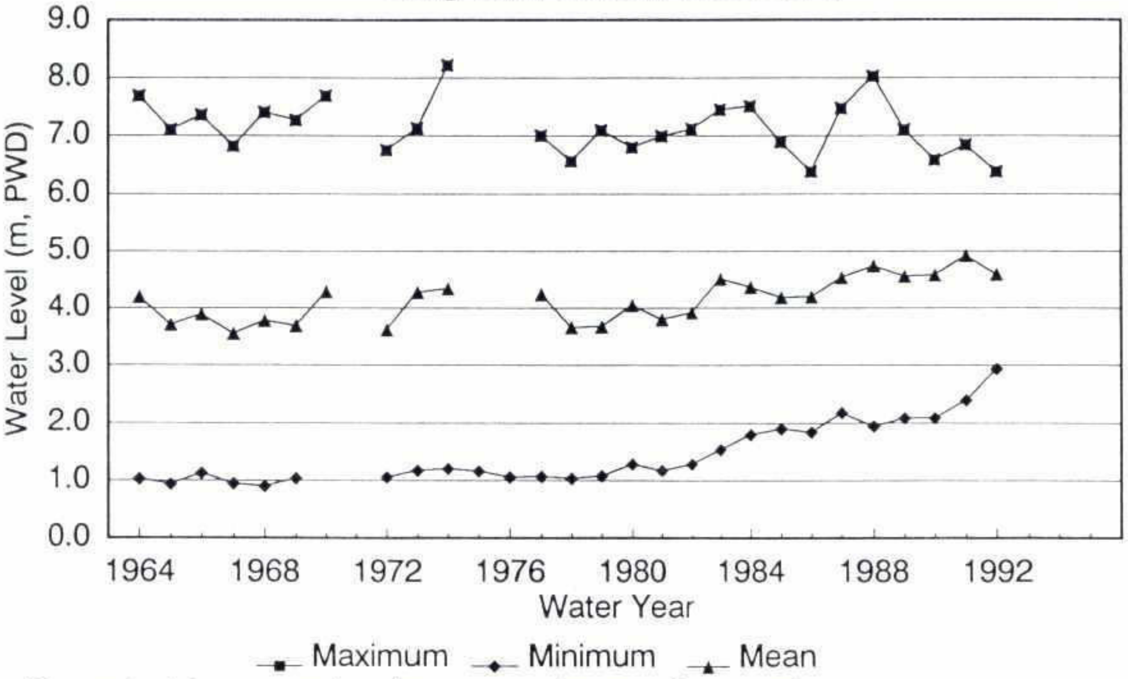
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 271 KALNI–KUSHIYARA R. at AJMIRIGANJ

Long Term Trend in Water Level

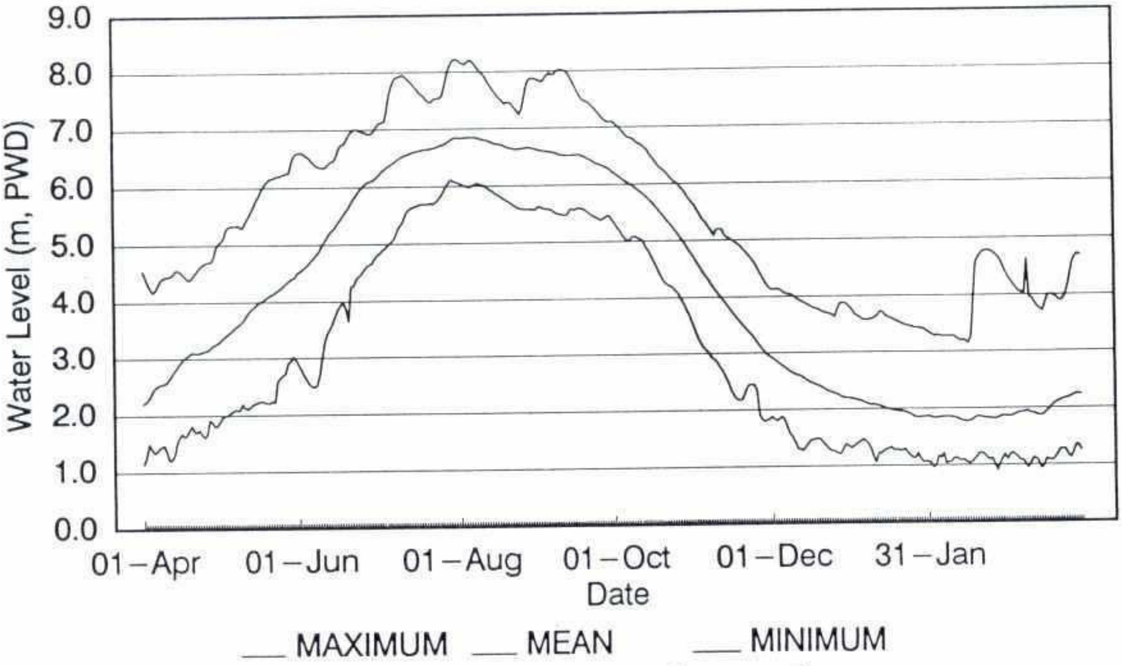


(Corrected for second order survey datum adjustment)

288

Gauge 271 KALNI–KUSHIYARA R. at AJMIRIGANJ

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

PRINTED 13-Jul-95

Gauge 272 KALNI–KUSHIYARA R. at MADNA
MEAN DAILY WATER LEVEL (m,PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	0.79	3.96	7.53
1965	365	0.82	3.47	6.86
1966	365	1.01	3.68	7.24
1967	366	0.82	3.34	6.65
1968	365	0.89	3.58	7.20
1969	365	0.56	3.42	7.05
1970	347		4.04	7.48
1971	271			
1972	365	0.87	3.29	6.44
1973	364	0.95	3.93	6.89
1974	365	0.90	3.98	8.03
1975	244	0.98		
1976	0			
1977	365	0.57	3.79	6.77
1978	365	0.73	3.39	6.28
1979	183			
1980	365	0.95	3.61	6.53
1981	0			
1982	365	0.74	3.38	6.90
1983	366	0.59	3.92	7.32
1984	365	0.92	3.81	7.29
1985	365	0.68	3.54	6.71
1986	365	0.86	3.34	6.01
1987	319			7.30
1988	365	1.23	4.19	7.87
1989	365	1.13	3.77	6.85
1990	0			
1991	366	1.14	4.04	6.66
1992	365	1.08	3.28	6.06
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
0.56	3.66	8.03

(Corrected for second order survey datum adjustment)

PRINTED 13–Jul–95

Gauge 272 KALNI–KUSHIYARA R. at MADNA

MEAN MONTHLY WATER LEVEL

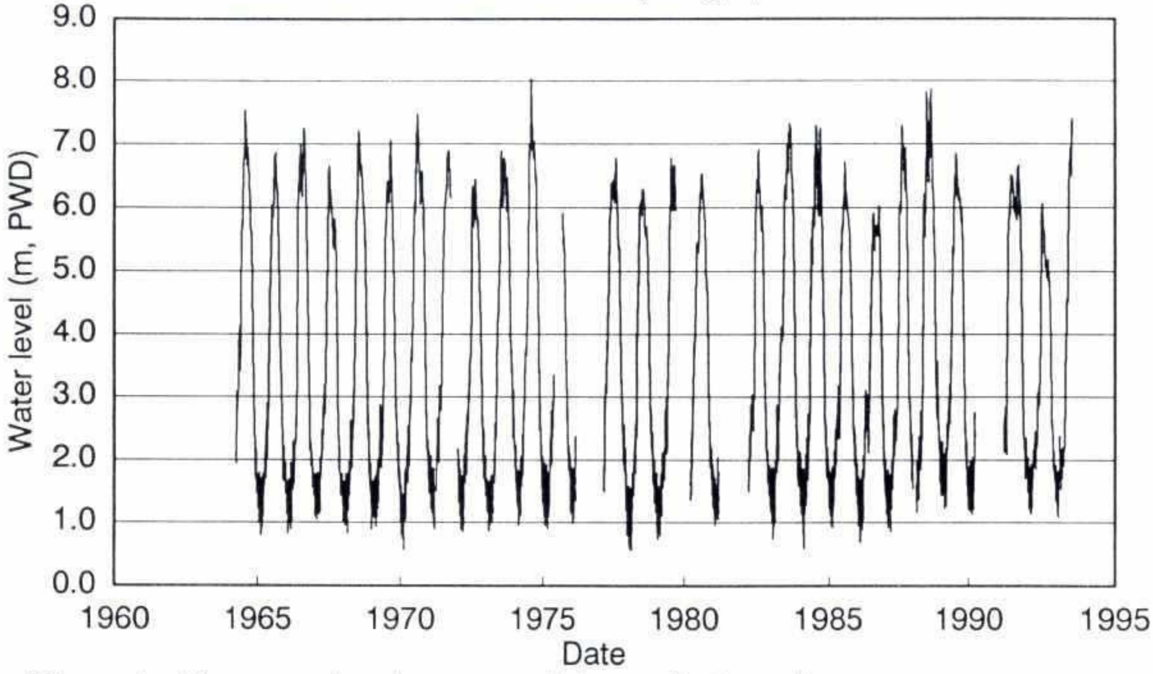
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	2.58	3.65	4.64	6.45	7.19	6.72	5.85	3.99	2.00	1.47	1.40	1.42
1965	1.83	2.62	4.24	5.79	6.55	6.35	4.91	3.02	1.84	1.52	1.26	1.48
1966	1.85	2.35	5.09	6.71	6.56	6.92	5.27	2.90	1.88	1.54	1.44	1.54
1967	1.87	2.73	3.75	5.99	6.14	5.59	5.30	2.78	1.68	1.39	1.33	1.45
1968	2.00	2.54	4.40	6.67	6.75	6.21	5.27	2.90	1.70	1.41	1.39	1.50
1969	2.15	2.30	4.23	6.14	6.48	6.52	4.67	2.65	1.82	1.20	1.13	1.57
1970	2.16	3.13	4.63	6.44	7.17	6.31	6.19	3.97	2.13	1.70	1.49	
1971	2.16	2.75	4.01	5.84	6.53	6.66				1.70	1.41	1.53
1972	2.11	2.96	4.33	6.01	6.18	5.54	4.12	2.30	1.69	1.36	1.33	1.43
1973	2.16	3.70	5.29	6.46	6.64	6.28	5.45	3.58	2.50	1.78	1.46	1.62
1974	2.28	3.47	4.61	7.00	7.49	6.83	5.79	3.65	2.02	1.53	1.42	1.42
1975	2.01	2.67					5.39	3.63	2.15	1.58	1.43	1.72
1976												
1977	2.90	4.08	5.72	6.32	6.39	6.18	4.97	3.04	2.11	1.32	1.11	1.19
1978	1.75	2.86	5.09	6.06	6.13	5.62	4.56	2.60	1.81	1.43	1.20	1.39
1979	1.75	2.41	2.99	5.74	6.25	6.30						
1980	1.99	3.47	4.85	5.57	6.36	6.10	5.15	3.48	1.94	1.46	1.35	1.47
1981												
1982	2.24	2.77	3.83	6.25	6.50	5.87	4.45	2.29	1.68	1.40	1.25	1.82
1983	2.36	3.67	4.30	6.08	6.83	7.15	6.22	3.77	1.98	1.66	1.37	1.52
1984	2.06	3.58	5.54	6.55	6.48	6.54	5.47	2.86	1.85	1.42	1.39	1.84
1985	2.43	2.72	4.99	6.08	6.29	5.82	4.91	2.93	1.97	1.48	1.31	1.44
1986	2.21	2.74	2.93	4.82	5.65	5.63	5.72	3.89	2.02	1.48	1.40	1.47
1987	2.25	2.52	3.79	6.05	7.13	6.57	5.91	3.21	2.12			1.71
1988	2.17	3.40	5.97	7.26	6.84	7.38	5.80	3.39	2.58	1.80	1.84	1.64
1989	2.38	3.02	4.67	6.21	6.54	6.12	5.75	3.51	1.91	1.54	1.52	1.86
1990												
1991	2.51	4.55	6.15	6.31	5.99	6.43	5.92	3.48	2.08	1.72	1.55	1.74
1992	2.14	2.62	3.41	5.81	5.40	5.01	4.81	3.04	1.90	1.52	1.72	1.87
1993	2.06	3.84	5.76	6.93								
1994												
1995												

Number	27	27	26	26	25	25	24	24	24	24	24	24
Minimum	1.75	2.30	2.93	4.82	5.40	5.01	4.12	2.29	1.68	1.20	1.11	1.19
Mean	2.16	3.08	4.58	6.21	6.50	6.26	5.33	3.20	1.97	1.52	1.40	1.57
Maximum	2.90	4.55	6.15	7.26	7.49	7.38	6.22	3.99	2.58	1.80	1.84	1.87

(Corrected for second order survey datum adjustment)

Gauge 272 KALNI–KUSHIYARA R. at MADNA

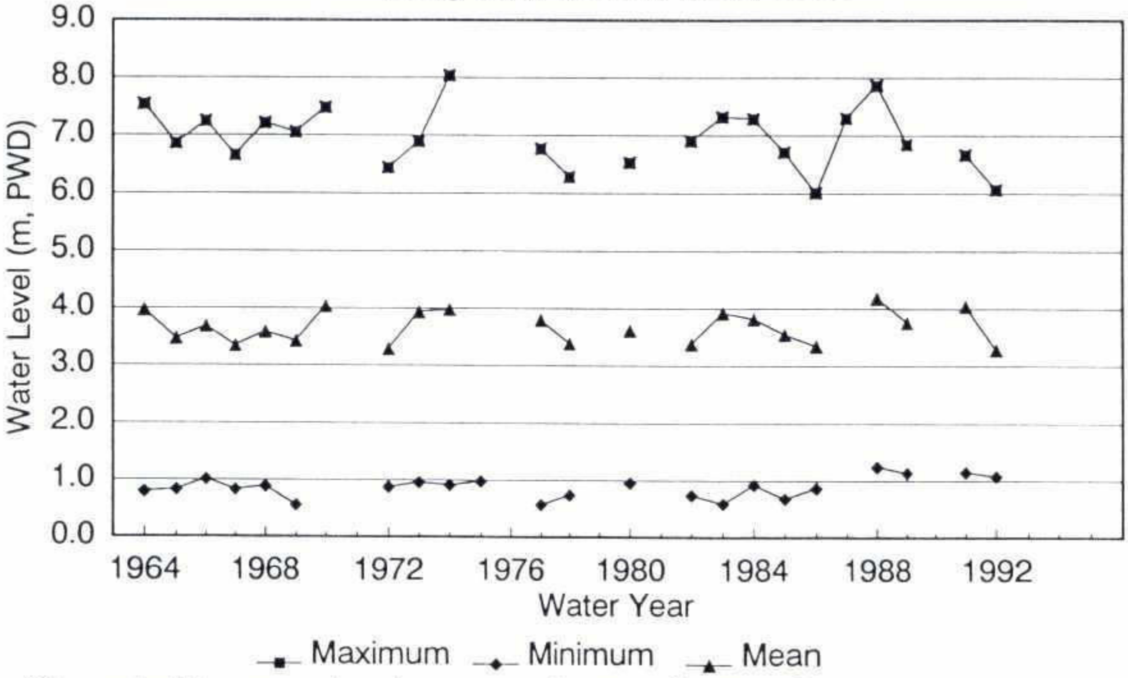
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 272 KALNI–KUSHIYARA R. at MADNA

Long Term Trend in Water Level

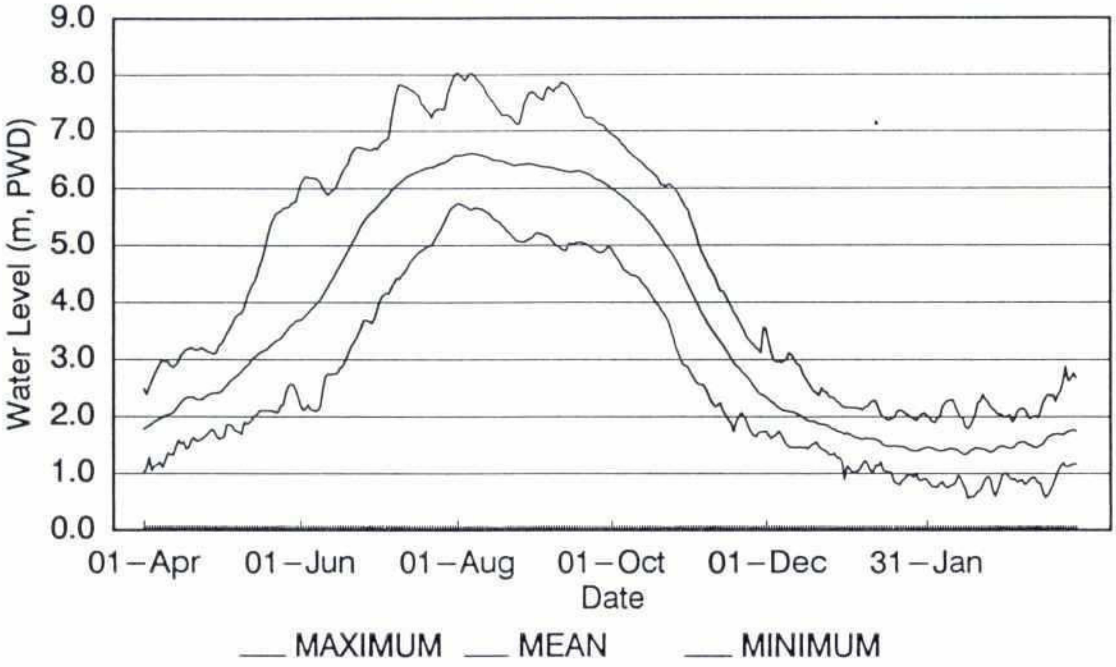


(Corrected for second order survey datum adjustment)

288

Gauge 272 KALNI–KUSHIYARA R. at MADNA

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

Gauge 272-1 DHALESWARI-KUSHIYARA at ASTAGRAM
MEAN DAILY WATER LEVEL (m,PWD)

Year	Number	Minimum	Mean	Maximum
1964	0			
1965	364	0.94	3.39	6.75
1966	365	1.06	3.56	7.17
1967	366	0.97	3.21	6.58
1968	365	0.98	3.54	7.14
1969	365	1.03	3.65	7.00
1970	365	0.95	3.86	7.40
1971	287			
1972	365	1.08	3.27	6.37
1973	364	0.92	3.86	6.84
1974	365	0.91	3.95	8.01
1975	213	0.89		
1976	205			
1977	365	0.94	3.73	6.72
1978	365	0.86	3.37	6.28
1979	366	0.95	3.29	6.67
1980	365	0.91	3.59	6.61
1981	365	0.32	3.25	6.72
1982	365	0.91	2.98	6.12
1983	366	0.78	3.78	7.16
1984	365	0.96	3.77	7.29
1985	365	0.87	3.45	6.65
1986	365	1.08	3.27	5.91
1987	366	1.06	3.67	7.24
1988	365	1.30	4.09	7.89
1989	0			
1990	365	1.27	3.78	6.36
1991	366	1.39	4.00	6.63
1992	365	1.31	3.29	6.07
1993	122			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
0.32	3.57	8.01

(Corrected for second order survey datum adjustment)

PRINTED 27-Aug-95

Gauge 272-1 DHALESWARI-KUSHIYARA at ASTAGRAM
MEAN MONTHLY WATER LEVEL

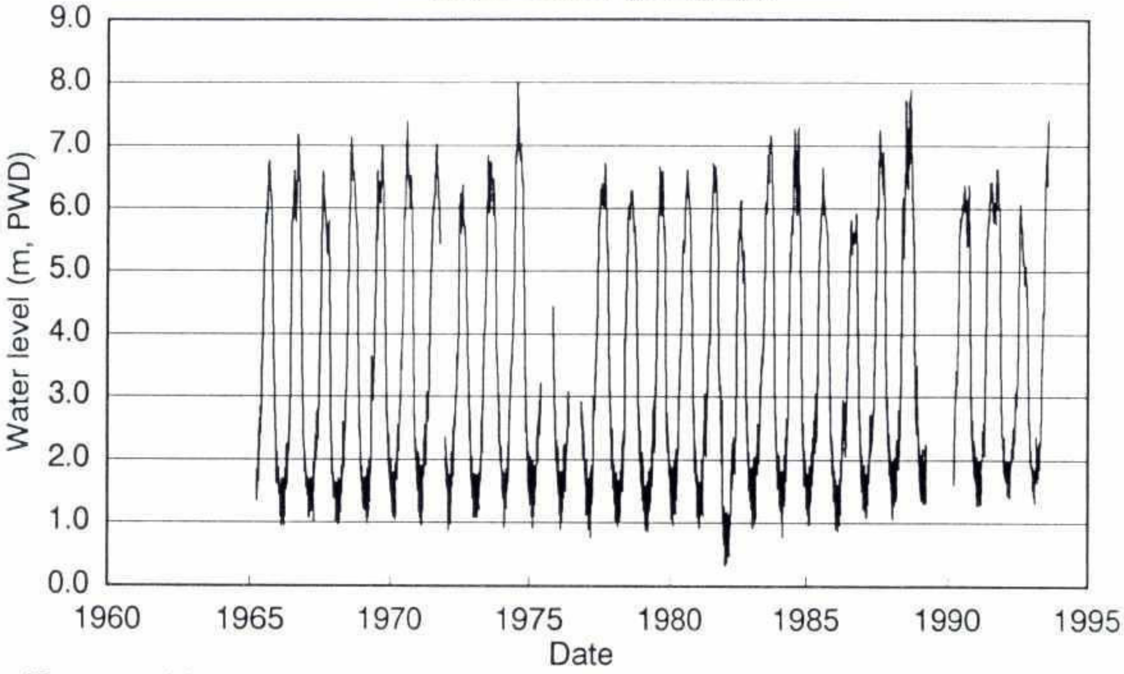
Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964												
1965	1.76	2.61	4.11	5.67	6.45	6.26	4.77	2.88	1.78	1.46	1.30	1.44
1966	1.82	2.27	4.79	6.33	6.22	6.85	5.17	2.82	1.85	1.52	1.47	1.54
1967	1.80	2.39	3.31	5.73	6.06	5.50	5.18	2.62	1.65	1.36	1.35	1.40
1968	1.98	2.52	4.25	6.62	6.69	6.12	5.19	2.80	1.73	1.46	1.41	1.52
1969	2.38	3.40	5.18	6.07	6.43	6.49	4.56	2.64	1.86	1.54	1.47	1.62
1970	2.19	3.09	4.49	6.34	7.12	6.24	6.06	3.79	2.13	1.71	1.50	1.48
1971	2.16	2.64	3.89	5.73	6.46	6.62				1.87		1.57
1972	2.09	2.91	4.19	5.90	6.10	5.43	3.99	2.54	1.71	1.43	1.34	1.44
1973	2.09	3.47	5.12	6.38	6.61	6.23	5.42	3.47	2.41	1.79	1.46	1.57
1974	2.19	3.33	4.41	6.94	7.48	6.81	5.75	3.56	2.08	1.67	1.51	1.52
1975	2.03	2.66						3.38	2.15	1.63	1.43	1.61
1976	1.73	2.63						2.46	1.90	1.49	1.34	
1977	2.64	3.73	5.60	6.27	6.28	6.18	4.85	2.87	1.95	1.48	1.38	1.43
1978	1.77	2.75	4.95	6.02	6.15	5.64	4.54	2.61	1.81	1.49	1.21	1.35
1979	1.58	2.41	2.92	5.58	6.20	6.22	5.25	2.72	2.00	1.47	1.39	1.63
1980	1.87	3.30	4.75	5.60	6.43	6.19	5.16	3.34	1.96	1.41	1.26	1.59
1981	2.30	2.69	3.72	5.64	6.48	6.41	4.74	2.90	1.58	0.83	0.72	0.85
1982	1.71	2.04	3.05	5.46	5.75	5.15	3.97	2.27	1.62	1.43	1.40	1.81
1983	2.25	3.28	3.98	5.87	6.69	7.04	6.06	3.53	1.98	1.61	1.39	1.52
1984	2.03	3.38	5.41	6.48	6.49	6.60	5.51	2.76	1.79	1.42	1.40	1.83
1985	2.30	2.61	4.78	5.97	6.22	5.78	4.89	2.84	1.86	1.41	1.26	1.39
1986	2.10	2.59	2.80	4.68	5.58	5.53	5.62	3.67	2.05	1.53	1.44	1.52
1987	2.24	2.49	3.60	5.95	7.06	6.52	5.93	3.12	2.15	1.64	1.56	1.73
1988	2.21	3.37	5.80	7.18	6.78	7.37	5.59	3.16	2.41	1.65	1.70	1.70
1989												
1990	2.54	3.36	5.37	5.94	6.21	5.62	5.88	3.14	2.10	1.71	1.61	1.67
1991	2.33	4.35	6.04	6.24	5.92	6.39	5.93	3.33	2.12	1.77	1.68	1.80
1992	2.22	2.65	3.36	5.77	5.46	4.93	4.68	2.98	1.99	1.60	1.82	1.93
1993	2.11	3.63	5.72	6.86								
1994												
1995												

Number	28	28	26	26	25	25	24	26	26	27	26	26
Minimum	1.58	2.04	2.80	4.68	5.46	4.93	3.97	2.27	1.58	0.83	0.72	0.85
Mean	2.09	2.95	4.45	6.05	6.37	6.16	5.20	3.01	1.95	1.53	1.42	1.56
Maximum	2.64	4.35	6.04	7.18	7.48	7.37	6.06	3.79	2.41	1.87	1.82	1.93

(Corrected for second order survey datum adjustment)

Gauge 272–1 DHALESWARI–KUSHIYARA at ASTAGRAM

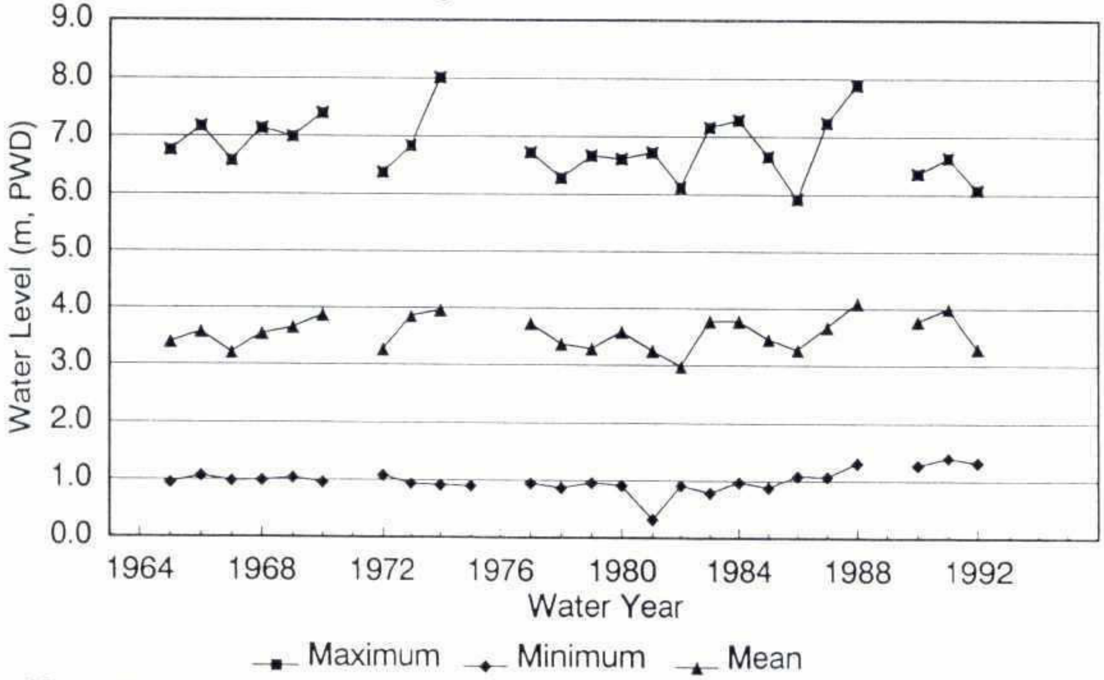
Water Level Hydrograph



(Corrected for second order survey datum adjustment)

Gauge 272–1 DHALESWARI–KUSHIYARA at AUSTAGM.

Long Term Trend in Water Level



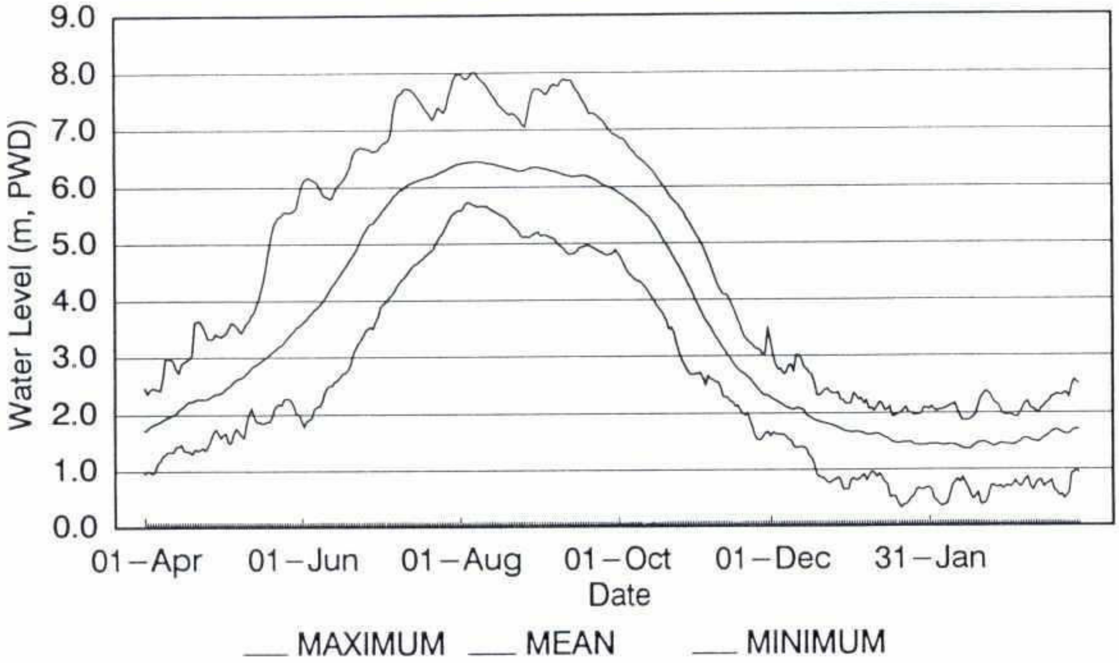
(Corrected for second order survey datum adjustment)

PRINTED 27-Aug-95

$2d^2$

Gauge 272−1 DHALESWARI−KUSHIYARA at ASTAGRAM

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

PRINTED 27-Aug-95

Gauge 273 Meghna R. at Bhairab bazar
MEAN DAILY WATER LEVEL (m,PWD)

Year	Number	Minimum	Mean	Maximum
1964	365	0.82	3.69	7.06
1965	365	0.88	3.24	6.42
1966	365	1.09	3.45	6.84
1967	366	0.98	3.15	6.18
1968	365	0.89	3.40	6.70
1969	365	0.91	3.28	6.64
1970	354		3.75	7.03
1971	90			
1972	365	0.91	3.10	6.02
1973	357	1.00	3.67	
1974	365	1.07	3.77	7.58
1975	213	0.97		
1976	365	0.88	3.35	6.95
1977	365	0.87	3.62	6.50
1978	365	0.81	3.22	5.92
1979	366	0.85	3.16	6.26
1980	365	1.03	3.45	6.34
1981	365	0.93	3.23	6.39
1982	365	0.81	3.15	6.36
1983	366	0.67	3.60	6.72
1984	365	1.02	3.61	6.82
1985	365	0.75	3.33	6.31
1986	365	0.95	3.11	5.60
1987	366	0.92	3.44	6.84
1988	365	1.02	3.78	7.59
1989	365	0.99	3.45	6.34
1990	365	1.01	3.46	5.97
1991	366	0.98	3.67	6.33
1992	363	1.05	2.97	5.48
1993	123			
1994	0			
1995	0			

SUMMARY FOR PERIOD OF RECORD		
MIN	MEAN	MAX
0.67	3.42	7.59

(Corrected for second order survey datum adjustment)

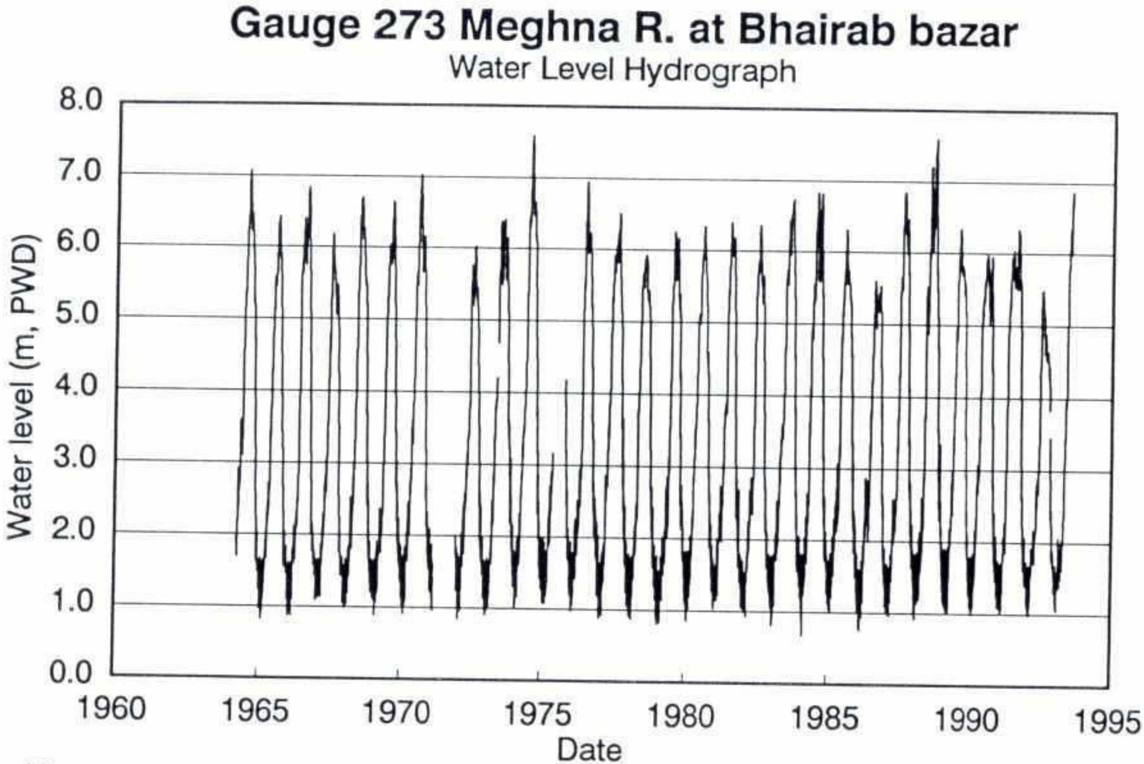
PRINTED 13-Jul-95

Gauge 273 Meghna R. at Bhairab bazar
MEAN MONTHLY WATER LEVEL

Year	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1964	2.35	3.27	4.24	5.98	6.75	6.28	5.46	3.66	1.95	1.42	1.36	1.36
1965	1.76	2.51	3.91	5.34	6.08	5.93	4.50	2.79	1.74	1.46	1.28	1.41
1966	1.83	2.25	4.61	6.14	6.10	6.52	4.86	2.65	1.84	1.52	1.43	1.51
1967	1.80	2.57	3.53	5.50	5.73	5.26	4.89	2.57	1.66	1.39	1.35	1.42
1968	1.95	2.47	4.05	6.19	6.38	5.80	4.98	2.77	1.74	1.46	1.37	1.44
1969	1.87	2.20	3.93	5.71	6.10	6.20	4.40	2.60	1.84	1.49	1.39	1.55
1970	2.10	3.00	4.28	5.95	6.76	5.89	5.69	3.60	2.11	1.73	1.52	
1971										1.62	1.31	1.52
1972	2.07	2.83	3.97	5.50	5.78	5.18	3.82	2.25	1.67	1.34	1.30	1.38
1973	2.06	3.35		5.96	6.24	5.88	5.14	3.34	2.37	1.73	1.47	1.62
1974	2.17	3.24	4.23	6.48	7.13	6.49	5.43	3.37	2.00	1.58	1.46	1.46
1975	2.00	2.63						3.31	2.06	1.54	1.39	1.65
1976	1.97	2.58	4.48	6.64	6.08	5.64	3.99	2.43	1.93	1.45	1.33	1.51
1977	2.64	3.65	5.26	5.90	6.12	5.92	4.71	2.92	2.00	1.46	1.35	1.38
1978	1.73	2.73	4.68	5.67	5.83	5.34	4.29	2.52	1.77	1.40	1.20	1.37
1979	1.69	2.34	2.84	5.26	5.87	5.86	4.98	2.71	1.97	1.45	1.30	1.52
1980	1.96	3.22	4.45	5.27	6.10	5.88	4.85	3.26	1.97	1.48	1.33	1.51
1981	2.20	2.56	3.73	5.41	6.16	6.00	4.25	2.44	1.84	1.41	1.33	1.28
1982	2.09	2.61	3.57	5.67	6.01	5.48	4.05	2.20	1.63	1.35	1.22	1.78
1983	2.22	3.24	3.81	5.48	6.26	6.59	5.71	3.39	1.91	1.60	1.35	1.51
1984	2.04	3.30	5.10	6.09	6.15	6.20	5.15	2.72	1.82	1.40	1.38	1.78
1985	2.26	2.57	4.54	5.63	5.89	5.50	4.65	2.80	1.90	1.41	1.25	1.39
1986	2.05	2.54	2.73	4.54	5.30	5.29	5.28	3.49	1.89	1.38	1.31	1.37
1987	2.09	2.34	3.42	5.56	6.71	6.22	5.46	2.93	1.98	1.47	1.42	1.57
1988	1.99	3.13	5.28	6.71	6.43	7.05	5.23	2.98	2.18	1.44	1.41	1.42
1989	1.95	2.81	4.29	5.72	6.09	5.73	5.38	3.19	1.76	1.41	1.34	1.51
1990	2.24	3.05	4.87	5.55	5.87	5.25	5.49	2.97	1.85	1.46	1.35	1.39
1991	2.01	3.93	5.54	5.87	5.65	6.09	5.53	3.10	1.87	1.49	1.38	1.53
1992	1.91	2.40	3.11	5.23	4.96	4.65	4.35	2.65	1.75	1.37	1.54	1.62
1993	1.84	3.30	5.15	6.37								
1994												
1995												

Number	29	29	27	28	27	27	27	28	28	29	29	28
Minimum	1.69	2.20	2.73	4.54	4.96	4.65	3.82	2.20	1.63	1.34	1.20	1.28
Mean	2.03	2.85	4.21	5.76	6.09	5.86	4.91	2.91	1.89	1.47	1.36	1.49
Maximum	2.64	3.93	5.54	6.71	7.13	7.05	5.71	3.66	2.37	1.73	1.54	1.78

(Corrected for second order survey datum adjustment)



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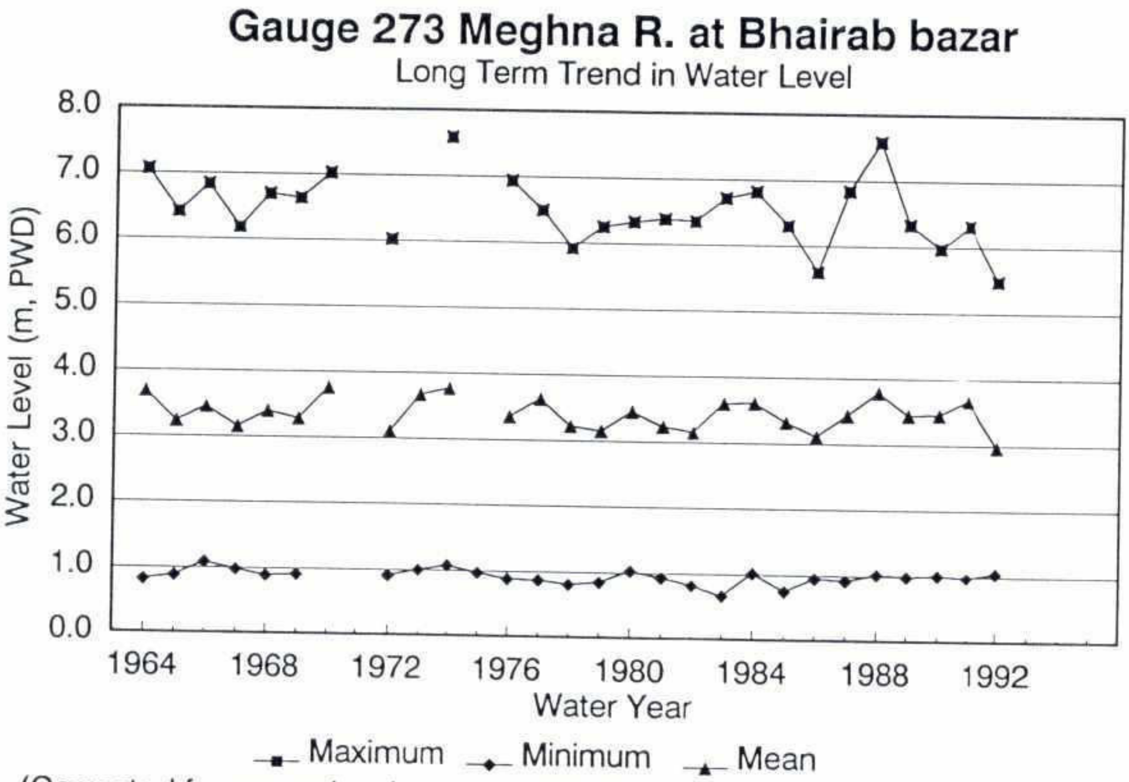
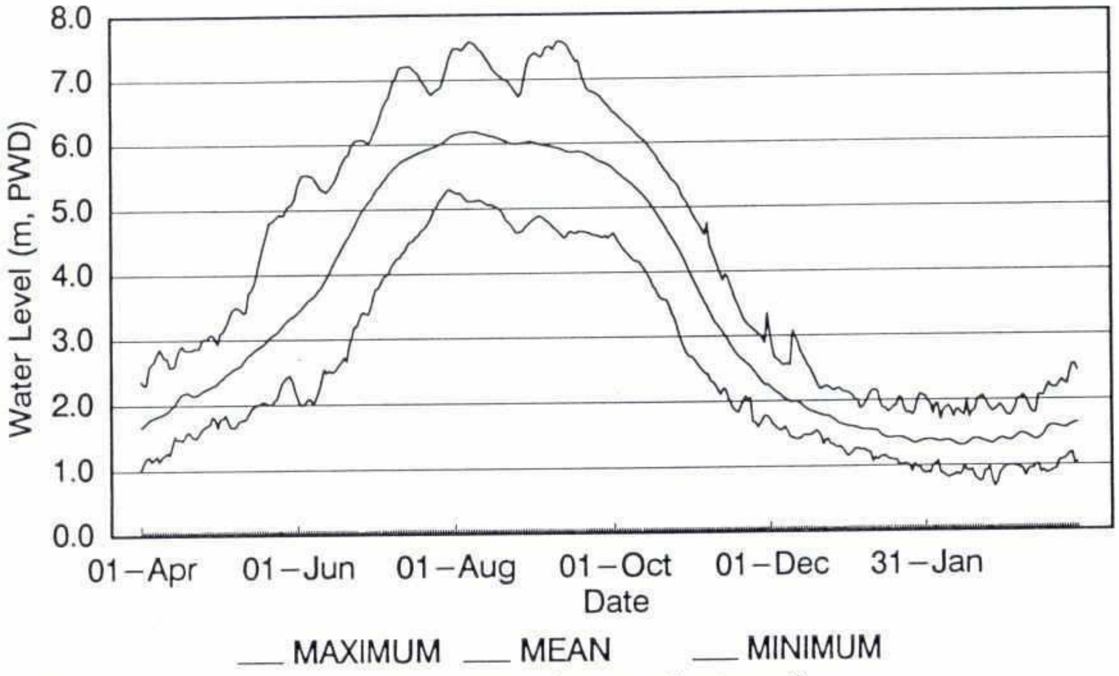


(Corrected for second order survey datum adjustment)

Gauge 273 Meghna R. at Bhairab bazar

Seasonal Variation of Water Level



(Corrected for second order survey datum adjustment)

PRINTED 13-Jul-95

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT

ANNEX C
ENGINEERING
APPENDIX C.2

NERP HYDROMETRIC MEASUREMENTS

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Kalni River at Markuli

Date	Water Level (m PWD)	Discharge (cumec)	Top width (m)	Area (m²)	Mean Depth (m)	Mean Velocity (m/s)
24-May-95	6.38	1174	175.3	2018	11.51	0.58
21-May-95	6.51	1287	175.5	2062	11.75	0.62
18-May-95	5.13	852.5	168.7	1960	11.62	0.43
07-May-95	3.83	359	159	1641	10.32	0.22
28-May-95	5.87	909	169.3	1970	11.64	0.46
31-May-95	5.53	856	169.4	1964	11.59	0.44
04-Jun-95	5.43	786.4	169	1960	11.60	0.40
07-Jun-95	5.42	738	169.2	1959	11.58	0.38
10-Jun-95	5.51	812	169.5	1972	11.63	0.41
14-Jun-95	6.135	1075.371	172.5	2071	12.01	0.52
26-Jul-95	7.18	1578.266	180	2123.05	11.79	0.74
30-Jul-95	7.14	1567.432	179.5	2114.35	11.78	0.74
02-Aug-95	7.12	1550.874	179.5	2138.35	11.91	0.73
06-Aug-95	7.09	1547.819	178	2263.65	12.72	0.68
09-Aug-95	7.025	1500.988	177.5	2249.57	12.67	0.67
13-Aug-95	7.09	1548.676	178	2245.5	12.62	0.69
10-Sep-95	7.155	1576.561	180	2169.9	12.06	0.73
13-Sep-95	7.08	1479.343	176	2245.65	12.76	0.66
17-Sep-95	6.95	1468.513	174	2307.11	13.26	0.64
20-Sep-95	6.885	1353.122	173.3	2308.9	13.32	0.59
24-Sep-95	6.89	1351.517	173.3	2308.75	13.32	0.59
27-Sep-95	6.89	1305.78	173.3	2295.8	13.25	0.57
01-Oct-95	6.91	1355.833	173.8	2308.76	13.28	0.59
04-Oct-95	6.87	1279.042	173	2286.2	13.22	0.56
08-Oct-95	6.8	1215.073	172.7	2263.25	13.11	0.54
11-Oct-95	6.83	1292.394	172.8	2271.34	13.14	0.57
15-Oct-95	6.64	1224.156	169	2231.98	13.21	0.55
18-Oct-95	6.43	1141.536	168	2197.15	13.08	0.52
22-Oct-95	6.03	888.153	161	2119.05	13.16	0.42
25-Oct-95	5.855	762.219	160.5	2087.33	13.01	0.37
29-Oct-95	5.505	603.361	158	2023.45	12.81	0.30

Kalni River at Ajmiriganj

DATE	Water Level (m PWD)	Discharge (cumec)	Top Width (m)	Area (m²)	Mean Depth (m)	Mean Velocity (m/s)
06-May-95	3.574	253.046	186.5	700.74	3.76	0.36
15-May-95	3.164	257.9	186.5	737.13	3.95	0.35
18-Dec-95	3.62	304.638	191	651.25	3.41	0.47
21-Dec-95	3.52	287.065	190.4	628.07	3.30	0.46
25-Dec-95	3.45	267.779	190.4	612.51	3.22	0.44
28-Dec-95	3.4	254.491	190.2	601.43	3.16	0.42
01-Jan-96	3.24	238.91	189.5	583.23	3.08	0.41
04-Jan-96	3.14	213.823	189	562.85	2.98	0.38
08-Jan-96	3.09	207.152	188.9	557.05	2.95	0.37
11-Jan-96	3.07	203.344	188.9	554.65	2.94	0.37
14-Jan-96	2.98	190.099	188.3	536.66	2.85	0.35
17-Jan-96	2.9	180.569	188	520.35	2.77	0.35
22-Jan-96	2.845	173.767	187.5	508.78	2.71	0.34
25-Jan-96	2.73	163.797	186.9	499.58	2.67	0.33
29-Jan-96	2.68	157.828	187.5	479.95	2.56	0.33
01-Feb-96	2.64	153.229	187.7	475.67	2.53	0.32
05-Feb-96	2.58	143.985	187.7	461.22	2.46	0.31
08-Feb-96	2.52	137.155	187.7	453.21	2.41	0.30
12-Feb-96	2.44	127.043	187	441.65	2.36	0.29
15-Feb-96	2.39	120.005	186.5	427.9	2.29	0.28
26-Feb-96	3.01	209.706	189.5	541.05	2.86	0.39
01-Mar-96	3.48	295.729	191	631.45	3.31	0.47
04-Mar-96	3.26	242.993	190	593.68	3.12	0.41
07-Mar-96	2.98	196.386	188.3	538.26	2.86	0.36
11-Mar-96	2.7	161.89	187.7	484.44	2.58	0.33
14-Mar-96	3.31	254.976	190.5	595.43	3.13	0.43
18-Mar-96	5.05	809.692	194	912.55	4.70	0.89
21-Mar-96	4.8	615.503	193	851.5	4.41	0.72
25-Mar-96	4.25	344.583	191	729.35	3.82	0.47
28-Mar-96	4.67	653.112	192.9	805.54	4.18	0.81
01-Apr-96	5.44	1321.388	205	997.95	4.87	1.32
04-Apr-96	5.67	1732.67	209	1074.5	5.14	1.61
08-Apr-96	5.51	1403.06	206.2	1017.57	4.93	1.38
11-Apr-96	5.19	1139.292	204	949.8	4.66	1.20
15-Apr-96	4.69	698.502	200	811	4.06	0.86
18-Apr-96	4.49	508.977	192	838.25	4.37	0.61
23-Apr-96	4.37	474.075	190	795.55	4.19	0.60
25-Apr-96	4.46	518.298	192	798.7	4.16	0.65
06-May-96	4.79	762.713	198	878.5	4.44	0.87
10-May-96	4.8	845.664	198	861.6	4.35	0.98
13-May-96	5.27	1268.295	204	1004.65	4.92	1.26
16-May-96	5.58	1993.921	208	1069.85	5.14	1.86
20-May-96	5.6	2040.155	208	1077.25	5.18	1.89
23-May-96	5.5	1849.964	208	1051.1	5.05	1.76
27-May-96	5.33	1320.13	204	1020.65	5.00	1.29

Kalni River at Shantipur

DATE	Water level (m PWD)	Discharge (cumec)	Top Width (m)	Area (m²)	Mean Depth (m)	Mean Velocity (m/S)
18-Dec-95	3.085	274.692	140.5	446.55	3.18	0.62
21-Dec-95	2.99	261.138	140.3	434.77	3.10	0.60
25-Dec-95	2.95	250.307	141.5	429.63	3.04	0.58
28-Dec-95	2.88	238.007	140.9	421.2	2.99	0.57
01-Jan-96	2.73	226.181	140.4	409.94	2.92	0.55
04-Jan-96	2.63	209.723	138	395.95	2.87	0.53
08-Jan-96	2.6	205.627	137.8	398.873	2.89	0.52
11-Jan-96	2.59	201.706	137.8	394.78	2.86	0.51
14-Jan-96	2.49	181.1	137.2	385	2.81	0.47
17-Jan-96	2.4	175.042	136.8	375.14	2.74	0.47
22-Jan-96	2.395	168.565	136.8	368.74	2.70	0.46
25-Jan-96	2.275	151.379	135.9	348.68	2.57	0.43
29-Jan-96	2.21	138.284	135.5	332.28	2.45	0.42
01-Feb-96	2.39	133.672	135	330.25	2.45	0.40
05-Feb-96	2.37	128.954	135.2	326.97	2.42	0.39
08-Feb-96	2.36	123.801	135	324.35	2.40	0.38
12-Feb-96	2.25	111.936	134	311.86	2.33	0.36
15-Feb-96	2.18	108.865	133	303.5	2.28	0.36
26-Feb-96	2.52	201.18	137	370.7	2.71	0.54
01-Mar-96	3.09	287.775	140.5	426.95	3.04	0.67
04-Mar-96	2.92	237.74	141	405.85	2.88	0.59
07-Mar-96	2.72	188.457	140.2	380.43	2.71	0.50
11-Mar-96	2.48	153.027	137	352.85	2.58	0.43
14-Mar-96	2.86	233.749	139	406.45	2.92	0.58
18-Mar-96	4.25	735.743	143	596.1	4.17	1.23
21-Mar-96	4.1	625.763	143	572.55	4.00	1.09
25-Mar-96	3.66	351.856	140.8	563.33	4.00	0.62
28-Mar-96	3.88	536.239	141	530.3	3.76	1.01
01-Apr-96	5.06	1153.856	170	773.6	4.55	1.49
04-Apr-96	5.28	1399.657	170	801.1	4.71	1.75

Kalni River at Kadamchal

DATE	Water Level (m PWD)	Discharge (cms)	Top Width (m)	Area (m^2)	Mean Depth (m)	Mean Velocity (m/s)
19-Dec-95	2.57	249.703	136.7	414.63	3.03	0.60
22-Dec-95	2.55	223.145	136.7	411.57	3.01	0.54
26-Dec-95	2.55	212.067	136.7	410.37	3.00	0.52
29-Dec-95	2.41	199.193	136.3	402.37	2.95	0.50
02-Jan-96	2.24	180.28	115.5	377.4	3.27	0.48
09-Jan-96	2.19	174.243	114.5	372.13	3.25	0.47
12-Jan-96	2.15	169.726	112.5	369.73	3.29	0.46
15-Jan-96	2.06	152.332	110.2	358.94	3.26	0.42
18-Jan-96	1.99	140.936	103	350.9	3.41	0.40
23-Jan-96	1.995	127.198	102.5	348.68	3.40	0.36
26-Jan-96	1.92	122.393	101.9	340.39	3.34	0.36
30-Jan-96	1.81	119.756	99.3	324.71	3.27	0.37
03-Feb-96	1.97	115.964	98.3	330.73	3.36	0.35
06-Feb-96	1.995	119.577	98.5	333.35	3.38	0.36
09-Feb-96	2.005	116.432	98.7	334.32	3.39	0.35
13-Feb-96	1.885	101.076	96.5	326.2	3.38	0.31
16-Feb-96	1.82	99.28	96	319.05	3.32	0.31
27-Feb-96	2.31	166.809	106	365.5	3.45	0.46
02-Mar-96	2.46	222.984	132.5	393.9	2.97	0.57
05-Mar-96	2.34	174.081	115.9	373.75	3.22	0.47
08-Mar-96	2.22	155.608	115	363.75	3.16	0.43
12-Mar-96	2.1	129.215	111.9	352.99	3.15	0.37
16-Mar-96	3.33	561.128	163	516.8	3.17	1.09
19-Mar-96	3.5	623.706	168.5	532.88	3.16	1.17
24-Mar-96	3.13	312.859	149	543.65	3.65	0.58
27-Mar-96	2.86	263.038	142	459.9	3.24	0.57
30-Mar-96	3.65	820.624	174.5	569.2	3.26	1.44
02-Apr-96	4.06	1037.287	226	637.8	2.82	1.63
09-Apr-96	3.97	1001.211	226	628.9	2.78	1.59
16-Apr-96	3.51	503.013	170	553.1	3.25	0.91
20-Apr-96	3.01	296.959	172	511.9	2.98	0.58
24-Apr-96	3.39	379.033	173	543.4	3.14	0.70
26-Apr-96	3.41	393.47	173	541.8	3.13	0.73
07-May-96	3.84	608.963	225	594.4	2.64	1.02

Cherapur Khal at Kaisar

Date	Water Level (m PWD)	DISCHARGE (cumec)	Top Width (m)	Area (m^2)	Mean Depth (m)	Mean Velocity (m/s)
08-Nov-95	3.815	129	55.2	202.8	3.67	0.64
22-Nov-95	3.68	100	54.2	195.4	3.60	0.51
05-Dec-95	3.44	106	52.9	186.5	3.52	0.57
19-Dec-95	2.74	71	48.5	146.6	3.02	0.48
02-Jan-96	2.38	50	46	120.6	2.62	0.41
15-Jan-96	2.1	50	45	122.9	2.73	0.41
26-Jan-96	1.94	42	44	118.4	2.69	0.35
06-Feb-96	1.83	39	43	114.6	2.67	0.34
13-Feb-96	1.68	32	41	107.3	2.62	0.30
27-Feb-96	2.18	56	44.5	137.0	3.08	0.41
08-Mar-96	2.06	46	43	132.6	3.08	0.35
12-Mar-96	1.9	43	44.8	125.4	2.80	0.34
19-Mar-96	3.8	142	48	169.7	3.53	0.84
30-Mar-96	3.94	242.5	57	234.97	4.12	1.03
09-Apr-96	4.56	349.454	59	271.7	4.61	1.29
16-Apr-96	3.73	161.296	50	204.7	4.09	0.79
24-Apr-96	3.88	164.193	50	206.8	4.14	0.79
07-May-96	4.19	187.659	56	238.9	4.27	0.79
14-May-96	4.6	330.45	60	262.95	4.38	1.26

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Kalni River at Issapur

DATE	Water Level (m PWD)	DISCHARGE (cumec)	TOP WIDTH (m)	AREA (m²)	Mean Depth (m)	Mean Velocity (m/s)
10-Apr-96	3.43	523	87	367.4	4.22	1.42
17-Apr-96	2.98	242	86	333.4	3.88	0.73
22-Apr-96	2.93	204	87	332.2	3.82	0.61
08-May-96	3.49	265	92	401.6	4.37	0.66
25-Dec-95	3.92	583	102	444.8	4.36	1.31

Baida River at Issapur

DATE	Water Level (m PWD)	DISCHARGE (cumec)	TOP WIDTH (m)	AREA (m²)	Mean Depth (m)	Mean Velocity (m/s)
10-Apr-96	3.37	487.141	78	428.3	5.49	1.14
17-Apr-96	2.96	226.705	72.5	389.45	5.37	0.58
22-Apr-96	2.91	171.817	72.5	388.15	5.35	0.44
08-May-96	3.46	242.537	84	430.3	5.12	0.56
25-Dec-95	3.86	491.789	119	497.75	4.18	0.99

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT

ANNEX C
ENGINEERING
APPENDIX C.3

SUMMARY BRIEF OF PARTIAL FLOOD CONTROL AND DRAINAGE PROJECTS

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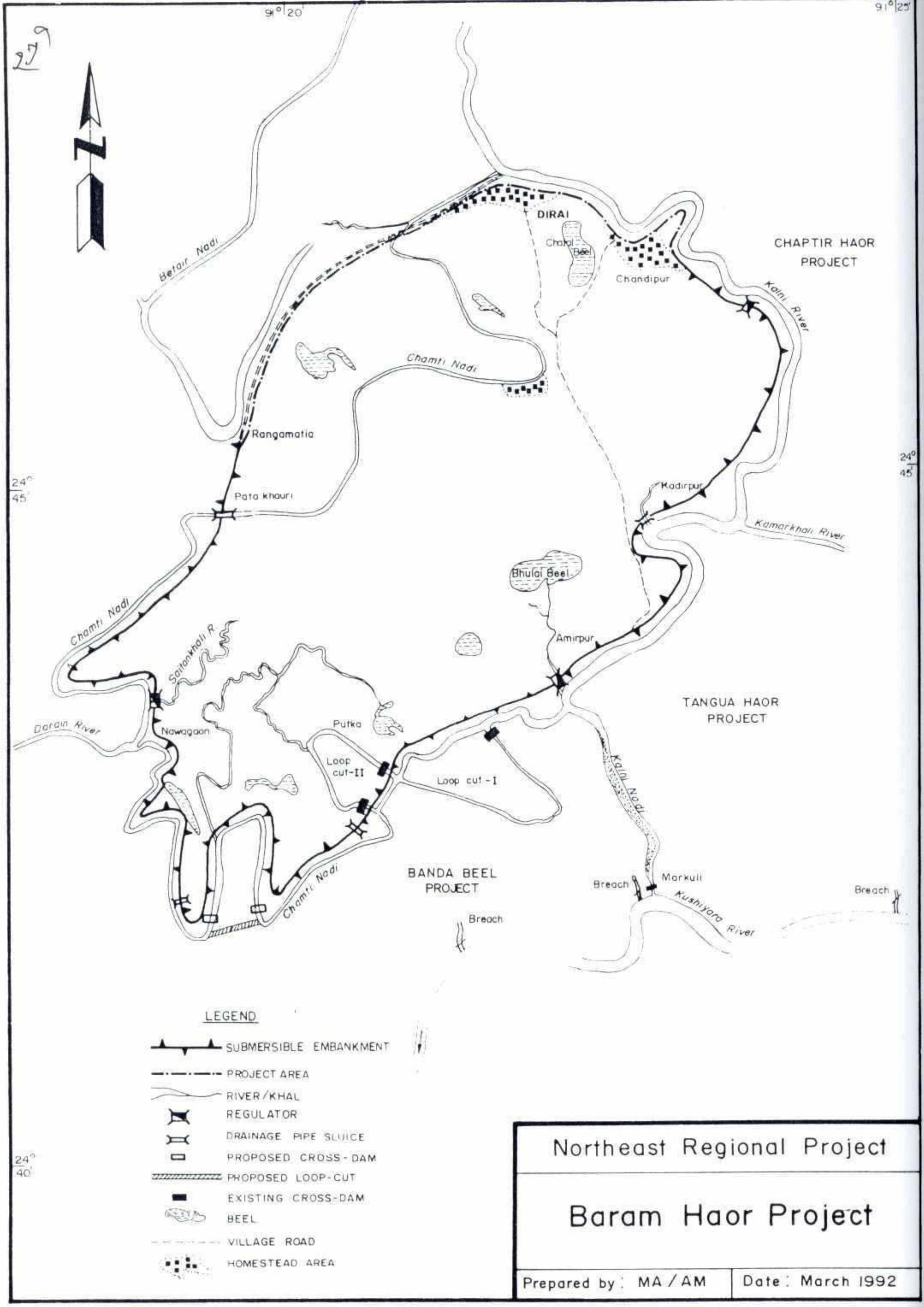
LIST OF PROJECTS



Northeast Regional Project

Baram Haor Project

Prepared by : MA / AM
Date : March 1992

BARAM HAOR PROJECT

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Sunamganj Water Development Division
District:	Sunamganj
Upazila:	Dirai

1.2 General Project Data

Project Type:	Partial Flood Protection, Drainage and Irrigation
Status:	Under Construction
Gross Area:	5,500 ha
Net Area:	4,800 ha
Population:	25,800

1.3 Project Concept

The Project was intended to protect *boro* crops in the area from early monsoon flash flooding resulting from massive early rainfall in the Meghalya Plateau. The identified infrastructure consisted of submersible embankments, compartmental bunds, three regulators, three pipe sluices, and irrigation inlets. The regulators were needed for post-monsoon drainage and to introduce water into the protected area — thereby reducing flows over the embankment. In addition, two major loops in the Kalni River were cut to improve river conveyance capacity and to reduce overall embankment lengths.

During the summer months, *Baram Haor* floods to depths ranging from 1.5 metres to 6 metres. This permits production of broadcast *aman* in the more shallowly flooded areas around the Project's periphery but the more deeply flooded areas within the haor remain fallow. Project infrastructure was not designed to alter the summer flood regime.

1.4 Project History

The project was identified by the BWDB, Sylhet O & M Division, in March 1986. An Early Implementation Project (EIP) appraisal mission recommended that the project be included in their 1987 EIP Program. Submersible embankment construction was subsequently initiated in 1987 and was completed in 1989-90. Construction of one box regulator and three drainage pipe sluices were also completed during this time period with the remaining two regulators and other miscellaneous works scheduled for completion in 1991-92 construction season.

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The Kalni River, which branches from the Old Surma River about 4 kilometres upstream of Dirai, drained south-east towards the Kushiyara River in the early and mid-1970's. The Kalni River was subsequently closed near Markuli (1978) and since then it drains into the Chamti Nadi which in turn flows into the Darain River and finally into the Kushiyara River below Ajmirganj. The Chamti River, which branches from the Kalni River near Dal Bazar, has been the main drainage channel in the project area since the Kalni was closed at Markuli. Reportedly, the main sources of Chamti flows are the Old Surma River and the Bhatta Khal. However, sediment deposition has taken place in these rivers in recent years which presumably is affecting flows.

All these river are seasonal but they maintain navigable depths probably due to backwater from the Kushiyara River. The Kushiyara River, a few kilometres downstream of the Sherpur gauging station (175), bifurcates into the Bibiyana and Suriya Rivers. These two rivers again merge near Markuli just upstream of the closure across the Kalni River. BWDB officials and local people believe that substantial sediment deposition has occurred in the Bibiyana River. As a result, most of the flow is currently passing through the Suriya River. It is also believed that sediment deposition has taken place recently in the Kushiyara River below Ajmiriganj. This sedimentation may be causing an increase in Kushiyara River water levels.

2.2 Engineering Works

Submersible Embankment. Much of the Baram Haor embankment is in good condition and only requires routine maintenance work. However, a breach was observed near the second loop-cut (see location map). It was generally reported that the breach occurred during a flash flood in May 1991. People living near the Saitankhali Regulator reported increased water levels in the peripheral rivers in recent years. They further reported sediment deposition during the past five years at Bera Mona Beel, the outfall of the Chamti-Darain River system. This, it is believed, delays drainage and may also be resulting in increased water levels. They requested that an additional loop of the Champti Nadi be cut. Chandipur villagers indicated that the embankment at their location — the Project's northern most side — is susceptible to damage by wave action and substantial erosion occurs most years. Area farmers are generally in agreement that the embankments are regularly overtopping prior to the *boro* harvest. They request that the embankments be raised. There is also another problem. The embankments along this reach are breaching regularly. BWDB officials indicate that a combination of increased flows in the Kushiyara River and sediment deposition in the river downstream of Ajmiriganj are responsible for these problems.

Regulators/Pipe Sluices. The project plan calls for three regulators and three pipe sluices. Of these, one regulator and three pipe sluices have been constructed and the remaining two regulators are expected to be completed during 1991-92. The single vent Naya Khal regulator is in good condition but the stop logs need replacing. The pipe sluices are generally in good condition but water is leaking into the project area through the Patakhauri pipe sluice.

Irrigation Inlets. About 34 irrigation inlets have already been installed. Local people have reported that many of the irrigation inlets are not used since they have not been installed at the right location.

2.3 Agriculture.

Agricultural concerns varied throughout the Project area. One theme, however, was dominant. Sedimentation in the peripheral rivers is impeding post-monsoon drainage. As a result the *boro* crops are being planted later and become more susceptible to flood damage.

At Chandipur village, mostly local *boro* is grown. Farmers report that the embankment overtopped in 1990 before the *boro* harvest, and that in 1991 it very nearly overtopped. Farmers around Boalia Regulator stated that more than 90 percent of the *haor* area is still (January 1992) under water due to high water levels in the peripheral rivers. They also say that last year (1990-91) they had been able to plant more than 60 percent of the cultivable area by January. Farmers at Boalia and Saitankhali Regulators have stated that the beds of the peripheral rivers have silted up significantly resulting in delayed post-monsoon drainage. They proposed that the peripheral rivers be re-excavated. At Saitankhali Regulator, farmers have complained that recently planted *boro* crops and about 50 percent of the seed beds have already been inundated due to inflow from the Chamti River. It appears that the planting of the entire *haor* area will be difficult because of the damage to the seed beds. The delay in planting will make the crops more susceptible to the early flash floods.

2.4 Navigation

Local people have stated that the project does not disturb any classified navigational channels but that the installation of drainage structures may affect internal water transportation. Reportedly, the Nayakhal drainage structure has been provided with a boat transfer to facilitate internal water transportation.

2.5 Fishery

Local people have stated that ten *beels* exist within the boundaries of the haor and that three are permanent water bodies. These *beels* mainly produce small fish and reportedly, the project has negligible impact on this existing fishery resource. However, there is a perception that the resource is diminishing because of sediment deposition within the *haor* area.

2.6 Siltation

As indicated above, sediment deposition is taking place in the Chamti-Darain River, especially around Nawagaon and Harinagar villages. Reportedly, the silt load of the Kushiyara River is very high and over bank spilling leaves behind heavy silt deposits every year. This has resulted in reduced conveyance capacity of all the minor drainage channels in the south. This combined with the closure dam at Markuli has shifted the main drainage system westwards towards the Darain River through the Chamti River. Local people also say that recently sediment deposition has occurred at the outfall of Darain River.

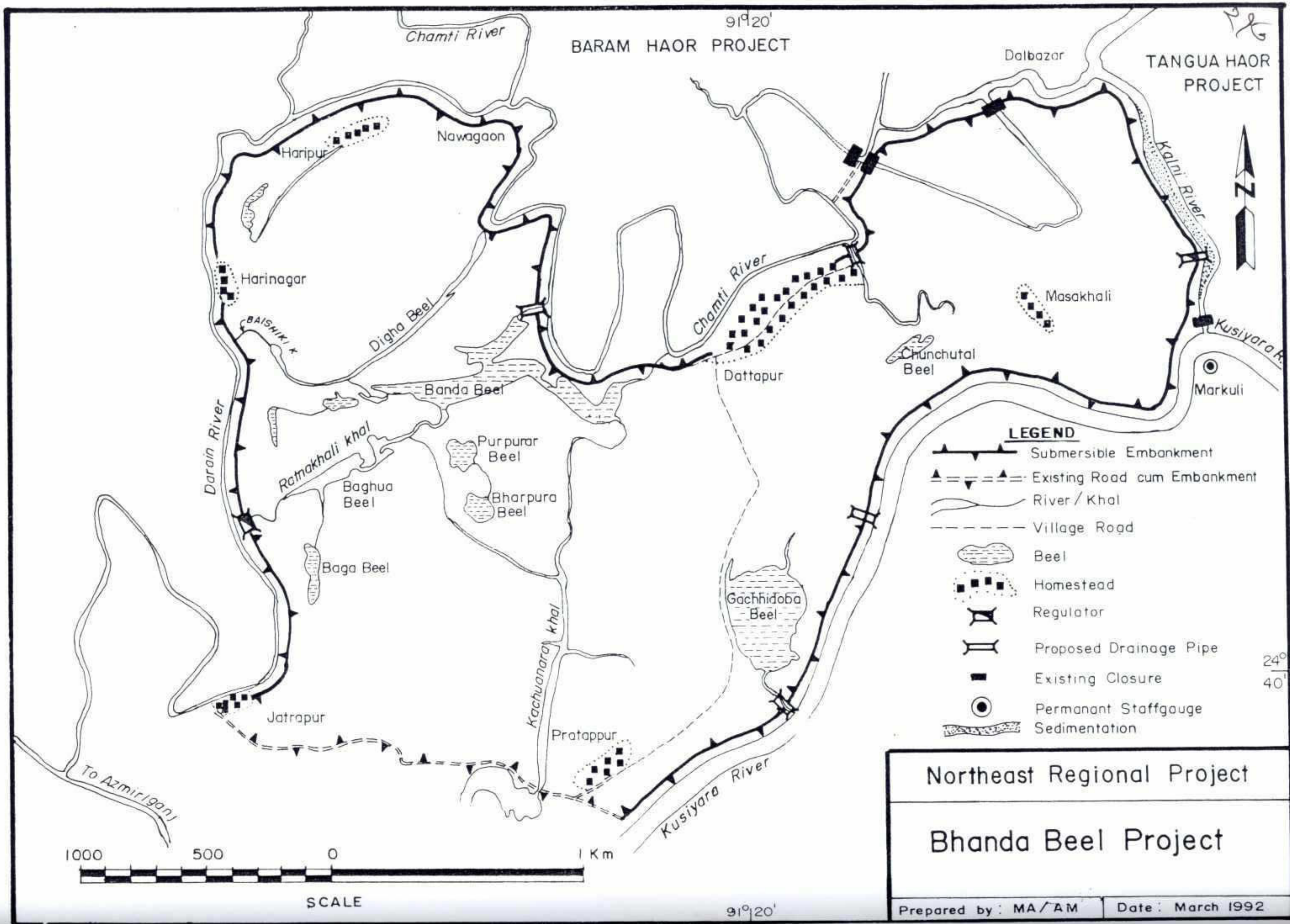
Mr. Saleh Ahmed, master of the ML FARHAD, a passenger launch having a draught of 1.8 meters, has been navigating the Sherpur-Madna route for the last 19 years. He states the Kushiyara River is gradually silting up. The reach between Sherpur and Markuli is still in fairly good condition, but navigation between Markuli and Ajmiriganj is difficult and the reach between Ajmiriganj and Madna has not been navigable by his launch for the last five years. He also indicated that no dredging work has been done since the independence of Bangladesh. However, a dredger fleet came to Madna in 1991, stayed three months, and then left without doing any work.

3.0 PROJECT EVALUATION

The Project concept was valid in so far as it identified the need to provide early monsoon flood protection to the *boro* crop. *Boro* cultivation increased following completion of the infrastructure which indicates some benefit. Three issues of major concern, however, are:

- the apparent substantial increases in sediment rates which coincide with project infrastructure development;
- the need to increase embankment crest levels to accommodate ever higher pre-monsoon flood levels; and,
- increasing Kushiyara flows.

These three phenomena are in all likelihood associated with the development of several similar projects in the vicinity of Baram Haor and all reflect the impact of confining surrounding rivers within their banks. The implication of excluding water from the flood plain — even if only for the pre-monsoon period — is the need to consider substantial recurrent costs associated with maintaining drainage systems and the need to ensure that the infrastructure, particularly earthworks, is sufficiently robust to withstand the higher discharges associated with confining a river within its banks.



Northeast Regional Project

Bhanda Beel Project

Prepared by : MA/AM

Date : March 1992

Prepared by : MA/AM | Date : March 1992

91°20'

BHANDA BEEL PROJECT

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB District:	Sunamganj WD
District:	Sunamganj
Upazila:	Sullah

1.2 General Project Data

Project Type:	Partial flood control, drainage, and irrigation
Status:	Began 1987, completion scheduled for 1993
Gross area:	4,000 ha
Net area:	3,600 ha
Population:	17,200

1.3 Project Concept

The project objective is to provide rapid post-monsoon drainage to allow early planting of *boro* crops and to protect *boro* crops from pre-monsoon flash floods. Pre-monsoon flash floods occur in April and May whenever heavy rains fall in the area and in Meghalaya State in India. The area is deeply flooded to 1.5-6 meters in the monsoon season. Most of the area is single-cropped: *boro* in the lower areas and *aman* on the higher land along the project boundary.

Project infrastructure consist of: 32 kilometres of submersible embankment; compartmental bunds; one regulator; five pipe sluices; and 20 low lift pump irrigation inlets. The regulator will be provided with a boat transfer facility.

1.4 Project History

The project was identified by the BWDB (Sylhet O & M Division) in 1987 and, after an EIP appraisal mission, included in the 1987-8 EIP program.

Project completion is scheduled for 1992-93. The submersible embankment is complete (constructed during the 1987-8 through 1990-91 construction seasons). All 20 irrigation inlets have been installed. Construction of the regulator and two pipe sluices has begun; completion is scheduled for 1991-92.

2.0 FIELD NOTES

2.1 Hydrology

The project area is bordered by the Kalni River to the east, Chamti River to the north, Darain River to the west, and Kushiyara River to the south.

The Kalni branches off from the Old Surma River (not shown - off map to the northeast). The Kalni drains southwest into the Chamti River; previously (before the Kalni was closed near Markuli), the Kalni drained south-east into the Kushiyara River.

The Chamti is the main drainage channel for the project area. It flows into the Darain which, in turn, flows into the Kushiyara below Ajmiriganj. Chamti flow is seasonal but it has navigable depth due to backwater from the Kushiyara River. According to the SDE Hydrology, Sylhet, the main sources of Chamti flow are Bhatta Khal (not shown on map) and the Old Surma River. Flow in these channels, which are silted up, is seasonal, but backwater from the Kushiyara fills most sections.

In the Kushiyara adjacent to the project, most of the flow comes from the Suriya River (off map to the east). Upstream of the project (and a few kilometres downstream from Sherpur gauging station [175]), the Kushiyara bifurcates into the Bibiyana and Suriya Rivers. These rejoin just upstream of Markuli closure. BWDB officials and local people say that most of the flow currently passes through the Suriya since the Bibiyana is silted up.

People involved in breach repair (see below) say that in recent years Kushiyara water levels have increased substantially. In 1990, the submersible embankment (completed 1990-1) was overtopped before the *boro* harvest. The design crest level is 6.93 m PWD at Dal Bazar, 6.70m PWD at Nawagaon and 6.57 m PWD at Jatrapur. After the 1990 event, EIP reviewed the levels and has revised them to 7.40 m PWD for the entire embankment.

2.2 Engineering Works

Submersible embankment. Generally the embankment is in good condition and requires only routine maintenance work. One public cut was observed near Harinagar village. Local people say the cut was made to drain the area. They request provision of a drainage structure at this location.

In the 1991 monsoon season, a breach occurred near Kachuanara Khal in the Jatrapur-Protappur road embankment, which forms the southernmost part of the project embankment. The breach was enlarged by floodwater from the Kushiyara after intense rainfall beginning on 25 Dec 1991. Local people tried to close the breach to save *boro* seed beds and recently planted crops. They state that the embankment was not constructed to proper section and request an immediate repair. They also indicate that breaches are a regular occurrence.

Another breach was observed during the field visit just downstream of the Markuli closure. Silt from the Kushiyara entering the project area caused severe sediment deposition 1.0-1.5 m thick, particularly in the drainage basin of the pipe sluice near the Markuli closure. The pipe sluice itself is completely blocked by silt.

BWDB officials state that the embankment on the Kushiyara right bank near Markuli should be raised because of increased Kushiyara water levels. They say that the increased flow caused a new channel to develop (location unknown), which they had to close. And they say that water levels have increased due to siltation of the Kushiyara below Ajmiriganj, and by the construction of a low embankment along the Kushiyara left bank.

Regulators and pipe sluices. The project plan calls for one regulator and five pipe sluices. During the field visit to Ratnakhali Regulator the contractor's representative said that more than 50% of the work has been completed and that the remainder should be completed in 1991-92. BWDB officials say that EIP has approved only four of the five planned pipe sluices, and that two will be completed in 1991-92.

Irrigation inlets. About 20 irrigation inlets have already been installed. During field enquiries local people said these inlets are mostly installed at locations where low lift pumps are to be used. Some of the inlets are in use.

2.3 Agriculture

Farmers around Harinagar village state that they mostly grow local *boro* and that in 1990 the embankment overtopped before harvest, damaging about 75% of the crop. Farmers request installation of a pipe sluice near the village.

Farmers along the Jatrapur-Protappur road report that they mostly grow local *boro* crops and that in early 1991 crop damage due to flash flooding was negligible (around 5%). Post-harvest losses due to insufficient sunlight associated with heavy rainfall were significant, however.

On 28 December 1991, the entire cultivable area along the Jatrapur-Protappur road was observed to be under 0.6-1.0 m or more of water, and that water from the Kushiyara was still flowing into the area. This damaged *boro* seed beds and recently planted fields. Farmers report that much of the cultivable area will lie fallow this season due to the shortage of seedlings.

The farmers around Markuli and Mosakhali villages say that over bank spilling and breaches along the Kushiyara occur each year, causing severe crop damage.

Farmers throughout the area request that the breaches be repaired to secure their crops. Farmers also complain that *jalmohal* lease-holders drain out water from the *beels* in December-January causing a shortage of water.

2.4 Navigation

Local people state that the project does not affect any classified navigational routes, but that installation of the regulator may hamper internal water transportation. However, BWDB officials say that the regulator will be provided with a boat transfer facility.

2.5 Fisheries

Local people say that the project has several *beels* but most become dry during the winter. These *beels* are now leased under open auction and the public are generally forbidden to fish in them.

Subsistence fishermen around Protappur village say that lease-holders sometimes permit them to catch fish in the *beels* but that 50% of their catch must be given to the lease-holder. They also say that these *beels* mainly produce small fishes and that the project will have negligible impact on the fishery.

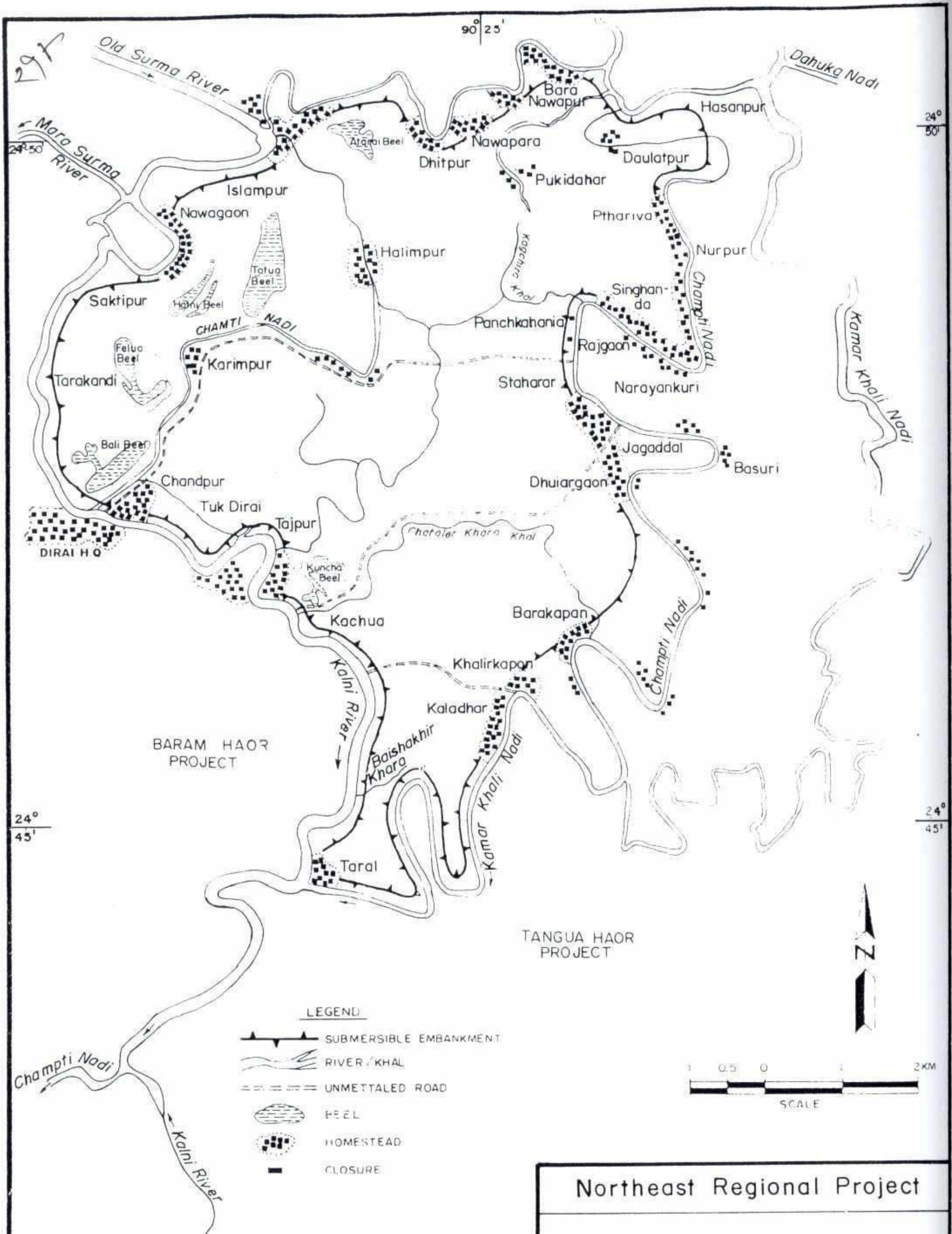
3.0 PROJECT EVALUATION

The project concept can be only partly evaluated as the project is still under construction (structures incomplete). The project objective is to protect *boro* crops from pre-monsoon flash floods, with provision for rapid post-monsoon drainage and entry of irrigation surface water. The embankment seems to be too low: in 1990, around the time the embankment was completed, it was overtopped; EIP is now recommending a higher crest level. There are drainage problems: in Dec 91, late drainage was a problem due to very slow recession of Kushiyara water levels; localized drainage congestion has led to one public cut; and there are conflicts over drainage between farming and fishing interests.

Submersible embankment with irrigation inlets is complete. Structures are scheduled for completion 1991-2.

Embankment may need to be heightened: crest level should be reviewed with reference to water levels and sedimentation in the regional river system.

The regulator is to be provided with a boat transfer facility to mitigate negative navigation impacts. Infrastructure may exacerbate fishing-farming conflicts over drainage.



Northeast Regional Project

Chaptir Haor Project

Prepared by : MA/AM | Date : March 1992

CHAPTIR HAOR PROJECT

1.0 PROJECT DESCRIPTION

1.1 Location

BWDB Division:	Sunamganj WD
District:	Sylhet
Upazila:	Dirai

1.2 General Data

Project Type:	Partial Flood Control
Status:	Under Construction
Gross Area:	4,453 ha
Net Are:	3,642 ha
Population:	22,700

1.3 Project Concept

The Project concept was to protect the *boro* crop from early flash floods through the construction of embankments and to provide adequate drainage facilities by constructing regulators. About 35 kilometres of submersible embankment have been constructed but no hydraulic structures have been built to date.

Chaptir Haor floods during the monsoon to depths ranging from 1.5 metres to 4.5 metres. The main crop grown is local *boro*.

1.4 Project History

Originally a low embankment was constructed by the Thana council under the Food For Work program. In 1976, the project was handed over to BWDB to be included as a part of the Haor Development Program in Sunamganj District. Embankment re-sectioning started in 1977 with GOB financing but work was suspended in 1978 after completion of 35 kilometres of embankment due to financial constraints. However, the project was declared complete. To date, no hydraulic structures have been constructed. The project is to rehabilitated and upgraded under the System Rehabilitation Project, Cycle-B (Credit No 2099/BD), with IDA and EEC financing. Since 1980, maintenance of the embankment is being carried out under the Food For Work program.

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The Dahuka Nadi, which is called Bhatka Khal at its upstream end bifurcates into the Kamar Khali Nadi and the Champti Nadi. The Dahuka Nadi is a distributary of the Surma River and sediment deposition has taken place at its off-take. The Kamar Khali Nadi, which formerly drained to the Kushiyara River in the south, silted up near its outfall and is currently flowing into the Kalni River.

The Kalni River was closed near Markuli in 1978. The closure induced sediment deposition in the river channel. The flow direction of the Kalni River subsequently reversed and currently the flow is through the Champti Nadi which has a smaller cross-section than the Kalni River.

The Sub-Divisional Engineer, BWDB, Sylhet has stated that sediment deposition has occurred at the off-take of the Bhatta Khal and Old Surma River. The rivers now do not have perennial flow though water remains in most sections due to backwater from the Kushiyara River.

2.2 Engineering Works

BWDB reported that the embankment of Chaptir Haor mostly follows the original alignment set by local authorities with the result that the set-back distance from the peripheral rivers is inadequate. The original alignment was maintained to minimize land acquisition costs. The embankments will likely need to be retired at some locations. BWDB also indicated that the design crest elevation of 7.30 metres PWD requires re-evaluation as it was overtopped in April 1990. However, it was decided to continue with the present embankment design until the results of the North East Regional Project studies are available.

From Tuk Dirai to Taral, local people and BWDB official have reported that the embankment along this section is subjected to severe wave action. Several breaches or public cuts were observed along this section. Reportedly the project has about 18 cuts mostly made to drain out standing water. Farmers throughout the project have requested the construction of drainage structures.

2.3 Agriculture

Farmers at Chandpur village have stated that they mostly grow local *boro*. Transplanted *aman* is also grown on the higher lands but over a smaller area.The farmers have also reported that the submersible embankment in their area never overtops before the *boro* harvest, but it requires regular maintenance. They have requested that a regulating structure be constructed at the outfall of Champti Nadi which they presently have to close every year to stop the entry of flash floods.

Farmers along Chataler Khara and near Baishakhir Khara believe that water levels in the peripheral rivers have increased significantly in the recent years. They have requested that the embankment height be increased and want immediate construction of drainage structures at the existing drainage outlets which they have to open and close every year. They have also requested that compartmental bunds be constructed in their area to retain water for irrigation during the dry season.

Taral farmers say the embankment almost overtopped in 1991, and that it was overtopped in 1990, causing damage to more than 80 percent of the standing crops. Five low lift pumps were observed working along the bank of Kamar Khali River. A farmer, Mr. Ahsan Ali, who was irrigating his lands using a low lift pump, said people mostly grow HYV *boro* crops along the banks of Kamar Khali River using pumped river water, but these crops are subject to flood damage due to the low height of the embankment.

2.4 Navigation

Local people have reported that the project does not disrupt any commercial navigation in the area, but installation of regulating structures may affect the internal waterways during the monsoon season, particularly the transportation of *boro* rice.

2.5 Fisheries

Fishermen around Chataler Khara have stated that most of the project area becomes dry during the winter, and there are no large permanent water bodies. Mainly small fish varieties are available in the area. They think the project does not have any adverse impact on the existing fish resources.

3.0 PROJECT EVALUATION

Even without the drainage structures, the Chaptir Haor Project appears to provide a positive impact on agriculture by protecting *boro* crops from early flash floods. Under the present system, without the drainage structures, area farmers are playing a significant role in manually opening and closing drainage channels through the embankment to effect drainage. This level of effort would not be evident were there no benefits.

Field visits revealed that the submersible embankment overtopped in 1990 before the *boro* harvest, and the design level of the embankment crest should be reviewed. A comprehensive review of the region's flood levels and sedimentation process is required.

Recently constructed village roads divide the project area into three smaller units. The units need to be taken into consideration in future drainage planning. The village roads should also be considered for use as compartmental bunds to retain post-monsoon water for irrigation during the dry season.

Consideration should be given to cutting off the meander loop of the Kamar Khali Nadi at Taral village. This would enhance drainage and may reduce sediment deposition in that reach of the river. It would also create an opportunity for a closed water culture fishery in the resulting oxbow lake.

Cropping patterns of the project area have not changed significantly. There is a trend to changing cropping patterns from local *boro* to HYV *boro* which may continue further but on a limited scale only along the river banks. However, more area is now under *boro* cultivation and this has generated additional employment in the project area.

DAMRIR HAOR PROJECT

1.0 PROJECT DESCRIPTION

1.1 Location:

BWDB Division:	Sylhet O & M
District:	Sylhet
Upazila:	Fenchuganj, Golabganj, Sylhet

1.2 General Data:

Project Type:	Drainage
Status:	Ongoing
Gross area:	18,212 ha
Net area:	7,285 ha
Population:	127,410

1.3 Project Concept

The project purpose is to reduce damage to *boro* and *t. aman* crops by improving pre- and post-monsoon drainage. Re-excavating the Kurkuchi Khal will allow earlier planting of *boro* so that it can be harvested before pre-monsoon flash floods; and will relieve pre-monsoon rainfall flooding.

1.4 Project History

In 1982, the re-excavation of Kurkuchi Khal was proposed by BWDB (Sylhet O&M Division). In 1983, the project was recommended for inclusion in the 1984 EIP program by an EIP appraisal mission. In 1984-6, it was implemented.

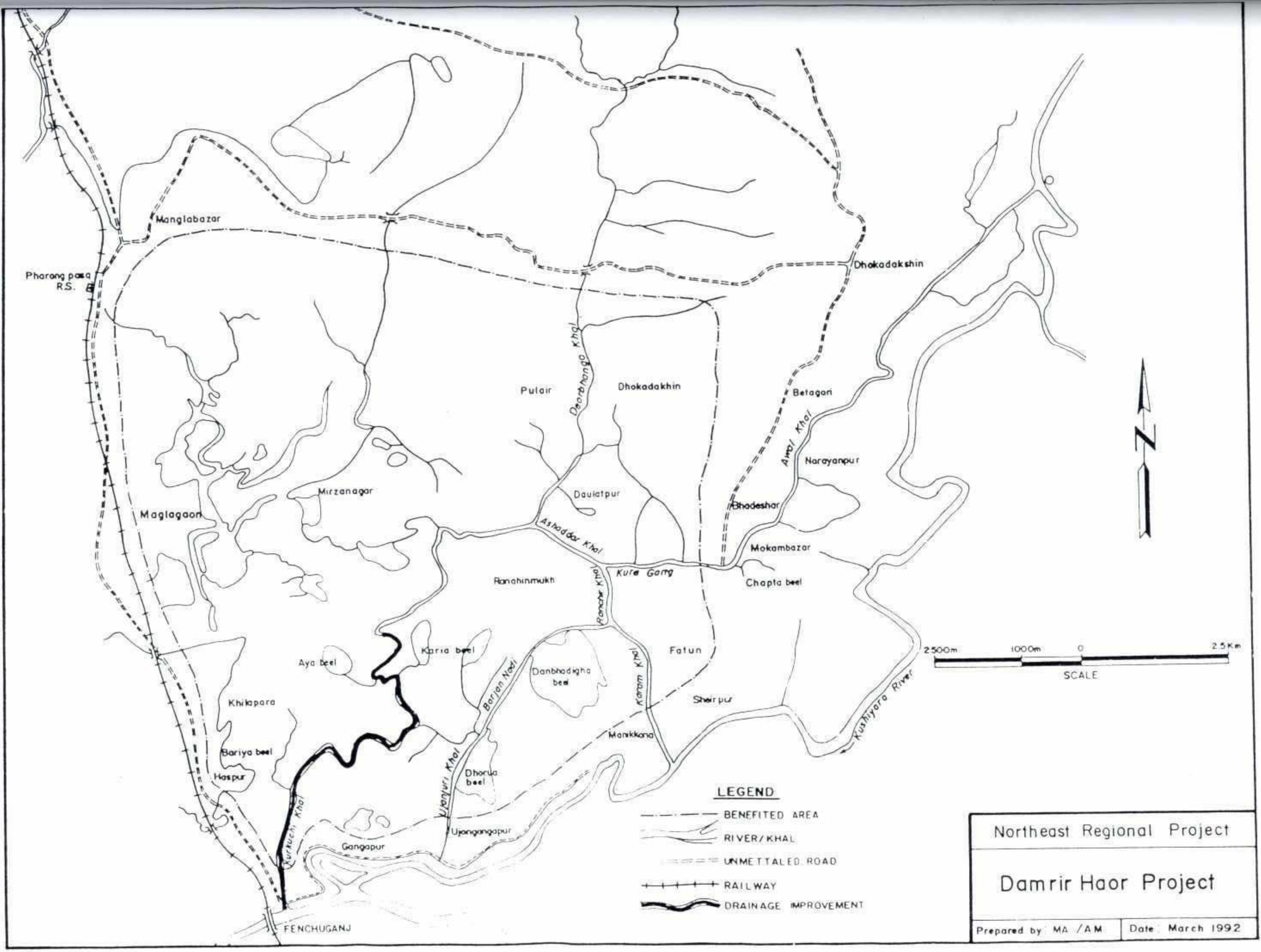
Initial re-excavation of 5.4 kilometres was completed in 1986. In 1990-1, FFW again re-excavated 3 kilometres of the original 5.4 kilometres and extended the excavated reach of the Khal by 0.85 kilometres to 6.25 kilometres in total. This was excavated only to 15 metre bed width, not the full 26 metre design bed width due to limited FFW wheat allocation. In the (1991-2) construction season, BWDB is re-excavating the 6.25 kilometres and extending the excavated reach of the Khal by 0.75 kilometres for a total excavated length of 7kilometres. This excavated width will again be 15 meters.

2.0 FIELD NOTES

2.1 Hydrology

The benefitted area is not well defined; roughly, it occupies the southwest part of Damrir Haor, and consists of the Kurkuchi Khal drainage basin, and part of the Ujanjuri Khal, Awal Khal, and Karam Khal basins. The area is bounded by the banks of the Kushiyara to the south and by high land, road and railway embankments elsewhere.

Kurkuchi and Ujanjuri *khals* are open to the Kushiyara. Pre-monsoon flood water enters through the Kurkuchi before the *boro* harvest but does not cause significant damage. Flood water enters through the Ujanjuri after the harvest. Karam Khal is closed each year by a temporary cross-dam built by local people. These khals serve as high water spill channels of the Kushiyara River during


Manglabazar
Pharong pasa R.S.
Dhokadakshin
Pulair
Daorbhanga Khal
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Awal Khal
Narayanpur
Bhadeshar
Mokambazar
Chapta beel
Daulatpur
Ashaddar Khal
Kure Gang
Ranchi Khal
Mirzanagar
Maglagaon
Ranahinmukh
Karia beel
Aya beel
Borjan Nadi
Danbhadigha beel
Karam Khal
Fatun
Sherpur
Manikkona
Khilapara
Bariya beel
Haspur
Ujanjuri Khal
Dhorua beel
Ujangangapur
Kurkuchi Khal
Gangapur
FENCHUGANJ
Kushiyara River
N
2500m
1000m
0
2.5Km
SCALE
LEGEND
BENEFITED AREA
RIVER/KHAL
UNMETTALED ROAD
RAILWAY
DRAINAGE IMPROVEMENT
Northeast Regional Project
Damrir Haor Project
Prepared by: MA /AM
Date: March 1992

the monsoon season. Any future development that changes Kushiyara water levels (e.g. confinement of Kushiyara River) will have a direct impact on internal water levels. The project area slopes generally to the southeast and drainage is effected through the Karam, Ujanjuri, and Kurkuchi Khals.

2.2 Engineering Works

The Kurkuchi Khal banks are mostly formed of clayey material. As such they are stable (little side-caving), and maintenance consists of straight-forward silt clearance.

Farmers say that Karam Khal and Ashadur Khal (an internal *khal* northwest of Karam Khal) have silted up and request that they be re-excavated.

2.3 Agriculture

Farmers from Khilapara, Mirzanagar, and Moglagaon villages request that Kurkuchi Khal be re-excavated annually. Farmers along the *khal* say that transplanted *aman* and *rabi* crops are planted on both its banks. In 1991, transplanted *aman* was re-planted three times due to abnormal monsoon flooding. Local *boro* is grown in the lower areas. In 1991, it was partially damaged.

At Haspur village, farmers report that *boro* crops were partially damaged by flash floods in 1991. Hail and drought also damage crops *boro* crops occasionally.

2.4 Navigation

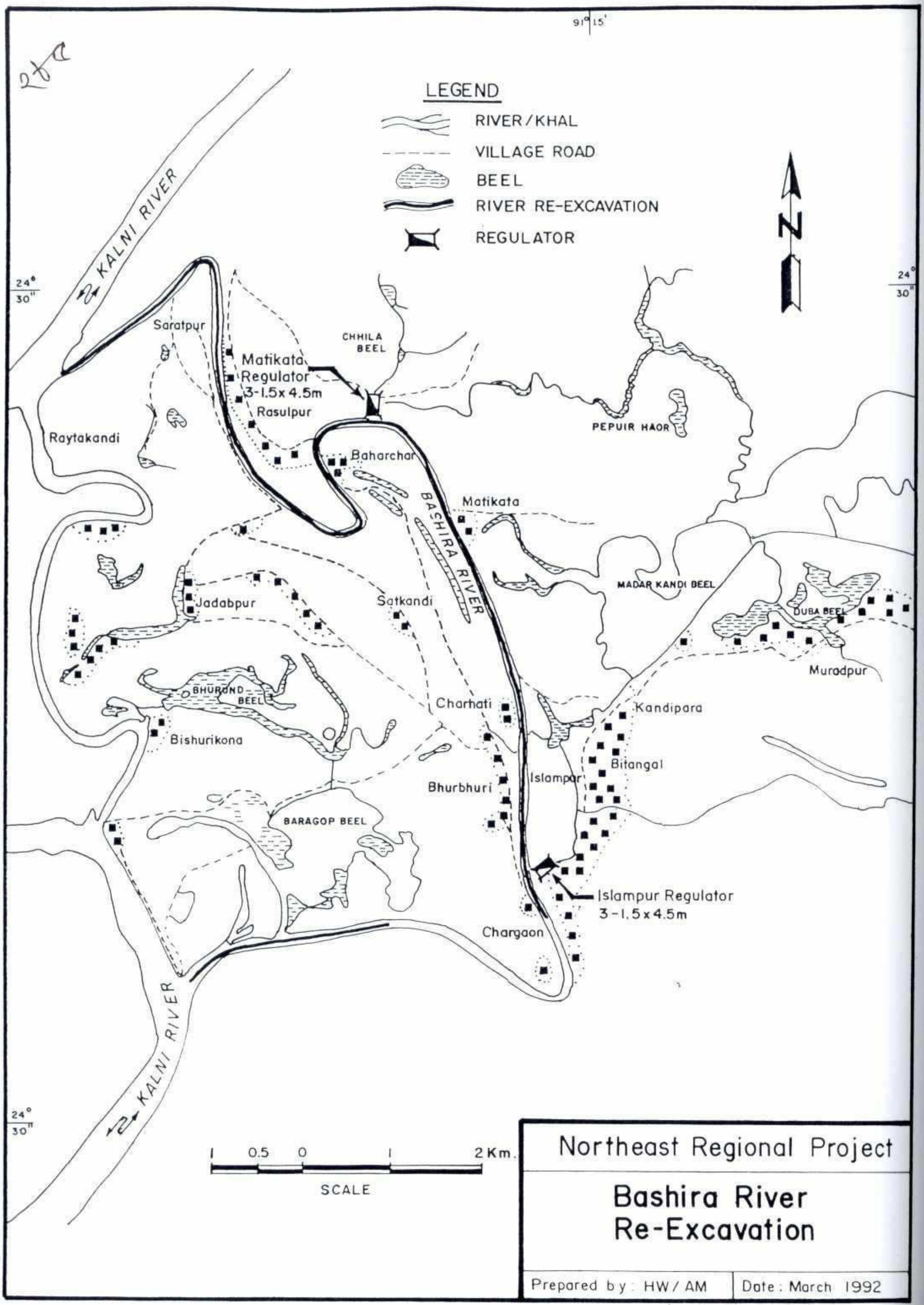
Local people state that the re-excavation has slightly improved water transportation on the *khal*.

2.5 Fisheries

Fishermen in the area say there has been no change in the fishery.

3.0 PROJECT EVALUATION

The project is achieving its objective of improved drainage in both pre- and post-monsoon seasons and has been of benefit to agriculture. Of concern is the projects sustainability. Specifically, the cost involved in providing the annually recurring maintenance to keep the Khal functioning effectively. There is no local "beneficiary" contribution to this project and because of inadequate funds, BWDB is compelled to re-excavate to a less than adequate section.



Northeast Regional Project

Bashira River Re-Excavation

Prepared by: HW/AM | Date: March 1992

BASHIRA RIVER RE-EXCAVATION

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Habiganj O & M
District:	Habiganj
Upazila:	Ajmiriganj and Baniachong

1.2 General Project Data

Type:	Flood Control Drainage and Irrigation
Status:	Completed
Gross Area:	7,150 ha
Flood Control area:	1,900 ha
Irrigation area:	1,600 ha
Population:	32,310

1.3 Project Concept

The Project was conceived to prevent pre-monsoon flooding, to provide efficient controlled post-monsoon drainage and water retention for irrigation. The project area is low-lying with several *beels* and *haors* and is bordered to the south and west by the Kalni and Bashira Rivers. These rivers have high banks which do not overtop but deliver water into the Project area by smaller channels; namely, the Matikata and Islampur Khals. Water enters the Project area via these *khals* and damages the standing *boro* crop. Two regulators, each having three vents, were constructed across these khals to prevent entry of pre-monsoon floods and to retain water at the end of the monsoon as required, and the khals were re-excavated to improve drainage.

1.4 Project History

The need for improved drainage was recognized by BWDB in the early 1980's. Matikata and Islampur Khals were re-excavated in 1981-82 as part of the Food-For-Work program. With the completion of this initial work, it was apparent that additional work would be required. BWDB proposed that regulators be installed at Islampur and Matikata Khals under IDA (Credit 955-BD). Construction started in 1984 and the regulators were completed in 1988. Also during this time period (1983-1988), re-excavation of the Bashira River was carried out through the Food-For-Work program.

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The Bashira River is a left bank loop channel of the Kalni River which is the lower reach of the Kushiyara River. It is located near the Barak-Khowai Rivers outfall into the Kalni River. During the pre-monsoon season, the flood regime of the Bashira is governed by the Kushiyara River. During the monsoon season, the Bashira River area is also flooded from overbank spill of the Barak-Khowai River. Hydrology in the area is also influenced by backflows from the lower Meghna and it remains inundated through August and September.

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2.2 Engineering Works

There are no flood embankments in the project area. The Kalni and Bashira River banks contain most of the pre-monsoon floods. The banks along the interior *khals* have also been raised by re-excavated spoil material.

Matikata Regulator has three vents, each 1.5 meters wide by 4.5 meters high. This structure is out of operation. Farmers use earth to retain water in place of the wooden fall-boards which are missing. The Islampur Regulator is the same size and design as the Matikata Regulator. There are no wooden fall-boards at the site and this structure too is out of operation. The closure on Islampur *khal* was breached in 1989 and has not yet been repaired.

Regulators of the type found in the Bashira Project are commonly used within many of the *haor* projects. They are designed to prevent inflow of pre-monsoon floods and following *boro* harvest the fall-boards are removed and water is allowed to enter the basin. This is to equalize water levels on both sides of the embankment before it is overtopped by the pre-monsoon flood. During the monsoon, the regulator remains open. In the post-monsoon season, after the basin water has drained to a desired level, the fall-boards are installed to retain water for winter irrigation. The hydraulic and the structural designs are adequate but the operation of the fall-boards is difficult. It is relatively easy to install fall-boards at the end of the monsoon season for water retention, because water depths are low. However, to remove them during the early monsoon when water depths can exceed several meters is generally not possible. Hence the design flushing capacity of the regulator is not fully utilized.

2.3 Agriculture

Broadcast *aman* and *boro* are the main crops grown in the project. The area under high yielding varieties of *boro*, which is irrigated with low lift pumps, has increased in recent years.

2.4 Navigation

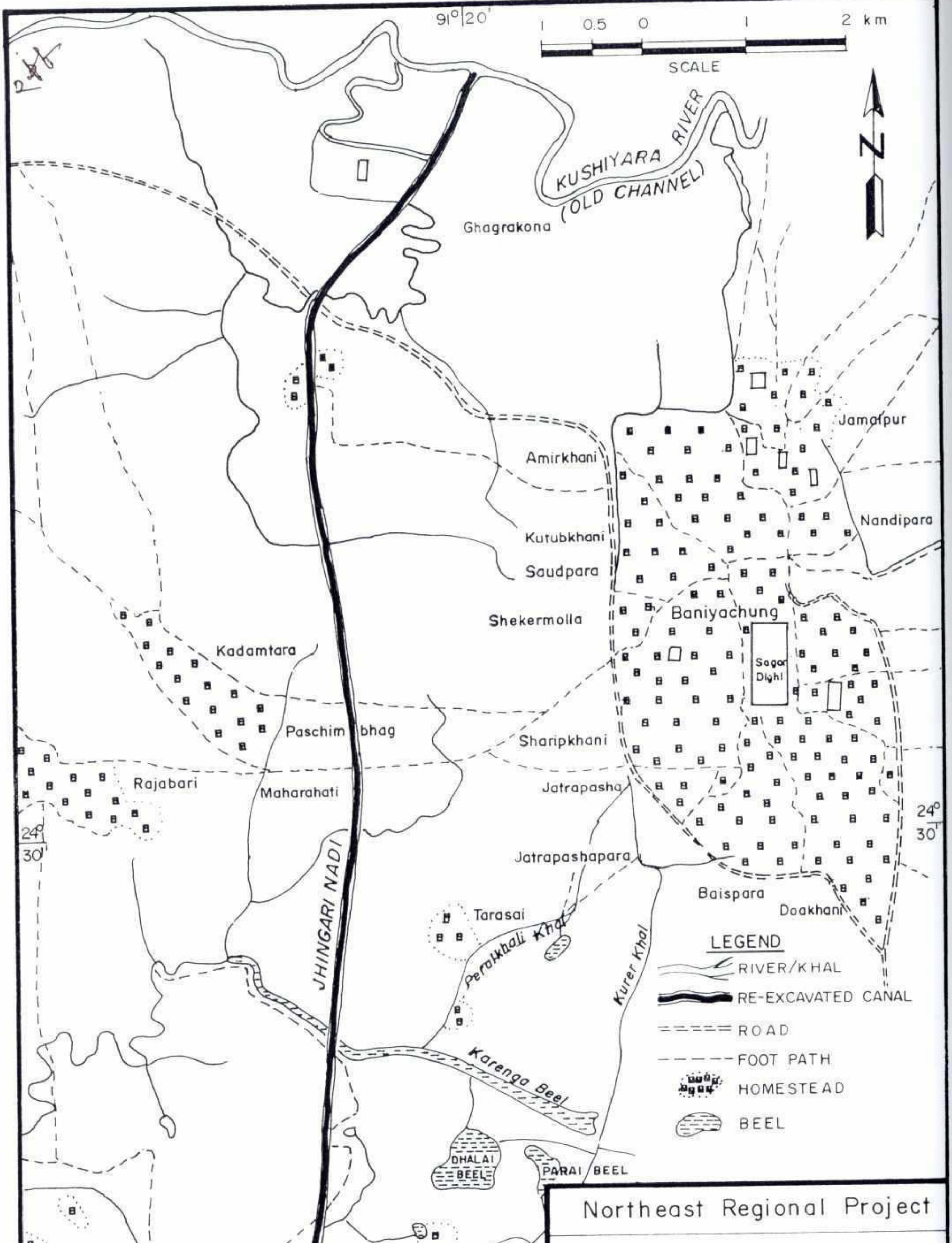
Country boats are the most important form of transportation in the area. Re-excavation of the Bashira River and the other *khals* has improved dry season navigation.

2.5 Fisheries

Fishermen have reported that there has been a decline in the fish catch from the *beels*; possibly a 50% decline over the last three years. They stated that fish disease is the main cause for the decline.

3.0 PROJECT EVALUATION

The Project concept appears valid. However, with the exception of improved navigation which inadvertently resulted from *khal* re-excavation, Project infrastructure has seemingly had very little impact on the "benefitted area". The main problem would appear to be the inoperability of the wooden fall-board arrangement on the regulators. This design needs to be re-assessed and replaced by a more practical arrangement — possibly steel vertical lift gates need to be considered.



Northeast Regional Project

Jhingari Nadi Drainage and Irrigation System

Prepared by: HW/AA Date: March 1992

JHINGARI NADI DRAINAGE AND IRRIGATION SYSTEM

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Habiganj O & M
District:	Habiganj
Upazila:	Baniachung

1.2 General Project Data

Type:	Drainage and Irrigation
Status:	Completed
Gross Area:	4,260 ha
Net area:	3,600 ha
Population:	18,960

1.3 Project Concept

The project was conceived to improve the drainage of low lying *beels* in the area and to enhance surface water availability for winter season irrigation. This was to be accomplished by re-excavating the Jhingari Nadi.

This is a small project and consists of the area on both banks of the Jhingari Nadi which is about 11 kilometers in length and which passes adjacent to or through *beels* such as *Karenga Beel*, *Dhalai Beel*, and *Parai Beel*. The Jhingari Nadi connects the old Kushiyara River channel in the north with Ratna River in the south (please see location map). The channel is also a source of water for low lift pumps irrigating *boro* paddy along the channel banks.

1.4 Project History

The Jhingari Nadi canal was first excavated with Food For Work assistance in 1974-78 under the then Government's Canal Digging Program. Neither feasibility studies nor planning reports are available, even at the offices of the Habiganj Water Development Division.

Re-excavation of Jhingari Nadi is being studied with a view to including it under the Systems Rehabilitation Project.

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The Jhingari Nadi canal is about 30 meters wide and 11 kilometers long. Historically, the old Kushiyara and the Ratna Rivers had separate drainage basins, divided by slightly higher land near Kadamtara village. Two drainage systems still exist: the *khals* which drain the *beels* in the northern part to the Kushiyara River; and the *beels* in the southern part which drain to the Ratna River. At present, Jhingari canal flows in one direction: to the south.

During the monsoon period the whole area, with the exception of Baniachung town, is deeply flooded.

2.2 Engineering Works

Local people claim that the canal is silted at both ends and hence, post-monsoon drainage from the area is slow.

2.3 Agriculture

Irrigated *boro* and broadcast *aman* are grown in the area. Traditional methods and low lift pumps are used for irrigating the *boro* crops.

The Jhingari canal has improved irrigation water availability, although it is reported that in recent years, the *boro* crops have been affected by water shortages due to sediment deposition at both ends of the channel and also because the irrigated *boro* area has expanded.

2.4 Navigation

The Jhingari Nadi channel improves water transportation in the area. Country boats use this water way during the early and late monsoon periods.

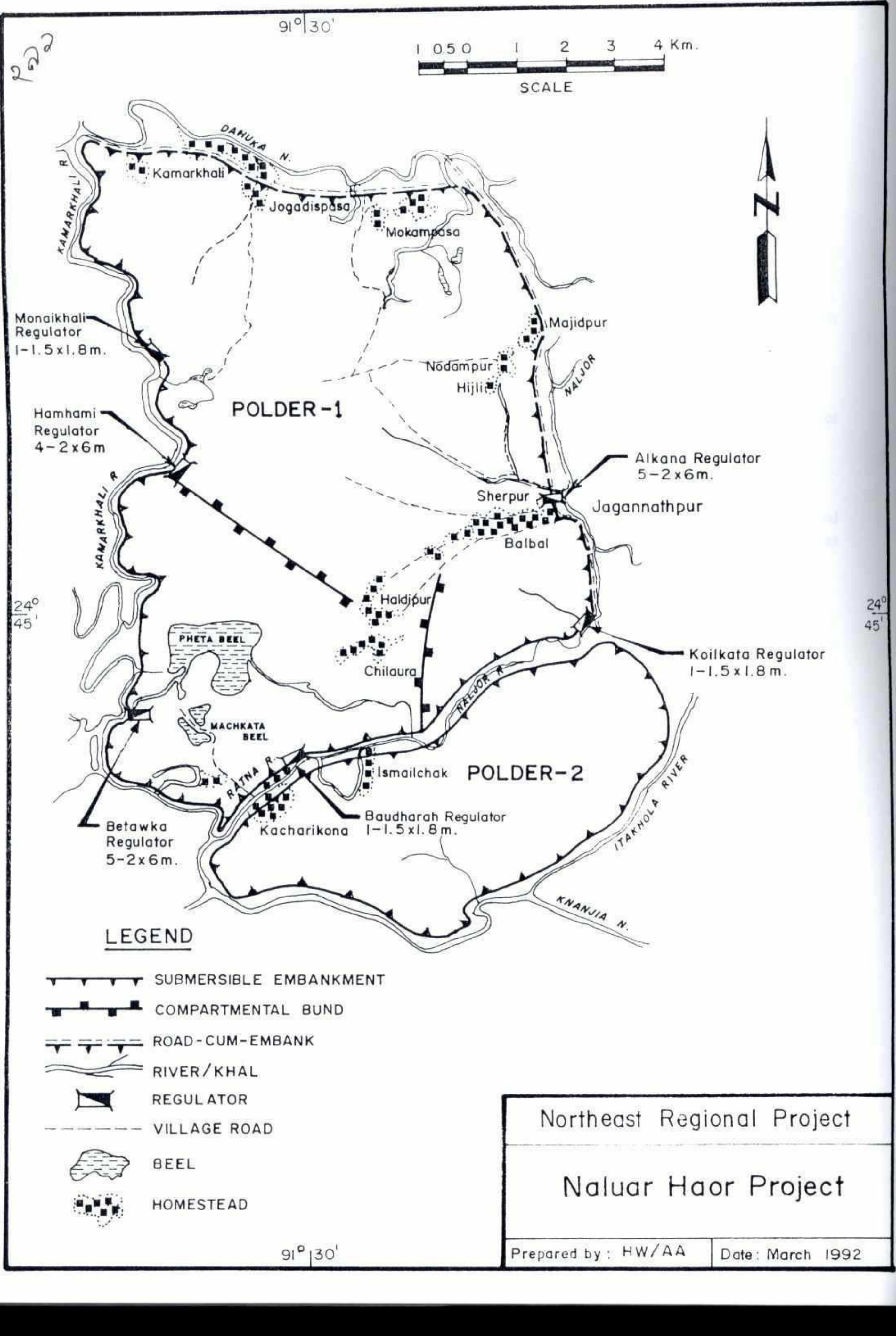
2.5 Fisheries

There are no major fisheries in the project area. A few of the perennial *beels* in the area are leased out by the local government authorities. While fishermen at the *beels* have stated that there has been a decline in the fish population they attribute it mainly to fish disease.

3.0 PROJECT EVALUATION

The Project has served the purpose for which it was intended. However, there is little evidence that any engineering planning was carried out, and possibly for this reason the channel alignment does not take advantage of the natural drainage system. The natural drainage system consists of existing channels running mostly parallel to the man-made Jhingari Nadi. Utilizing this system may have reduced the volume of earthwork; abrogated the need to acquire land; and may have resulted in more effective drainage and irrigation.

Prior to re-excavating the channel, a complete survey of the canal and a thorough study of flood levels in the region should be undertaken.



Northeast Regional Project

Naluar Haor Project

Prepared by : HW/AA

Date: March 1992

NALUAR HAOR PROJECT

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Sunamganj WD
District:	Sunamganj
Upazila:	Jagannathpur

1.2 General Project Data

Project Type:	Partial flood control and drainage
Status:	Begun 1983, completion expected 1993
Gross area:	12,141 ha
Net area:	10,724 ha
Population:	57,600

1.3 Project Concept

The project objectives are (i) to reduce pre-monsoon damage to nearly mature *boro* and young *aman* crops; and (ii) to encourage HYV *boro* cultivation on lower lands by improving post-monsoon drainage and providing protection from pre-monsoon floods.

Currently, the project consists of two polders. Polder 1 is the larger of the two, with a gross area of 9,840 hectares. Its planning and implementation began in 1983-4. Works in this polder will consist of 52 kilometres of submersible flood/road embankment, 8 kilometres of compartmental bund dividing the polder into three drainage basins, and six regulators (one five-vent flushing regulator and one five-vent, one four-vent, and three one-vent flushing/drainage regulators). Polder2 has a gross area of about 2300 hectare. Works are limited to 26 kilometres of submersible embankment built in 1990-1 and 1991-2; no structures are planned as yet.

The area includes Naluar Haor and other low lying *beels*. The area is deeply flooded during the monsoon season.

1.4 Project History

Before 1983, the northern part of the area where elevations are relatively high was partially protected from flooding by road embankments in the east and north-east. The rest of the area was flooded for most of the year and was not used for agricultural production. Flood protection was requested by the local population.

In 1983, BWDB proposed, and IDA and FFW agreed to finance, construction of a single polder with six structures in the Naluar Haor basin. In 1984, FFW completed the submersible embankments but structure construction under IDA Credit 955-BD was deferred due to fund shortages.

In 1987, a proposal under IDA Credit 1870-BD to complete the project was submitted and accepted. In 1989-90, an updated feasibility study report was prepared.

In 1990-1 and 1991-2, the Polder 2 embankments (not included in the feasibility study) were constructed under FFW. In 1991-2, re-sectioning of 60% of damaged Polder 1 embankments and construction of the three multiple-vent regulators was begun and compartmental bunds (not included in the feasibility study) were constructed. In 1992-3, the re-sectioning of the remaining 40% of damaged Polder 1 embankments and construction of the three one-vent regulators is scheduled, with which the project should be complete. Since 1984, earthwork maintenance has been carried out under FFW.

2.0 FIELD NOTES

2.1 Hydrology

The area lies in the Surma-Kushiyara floodplain. It is surrounded by Surma spill channels that flow from northeast to southwest, draining into the Kushiyara; in winter, inflow from the Surma drops to zero and water levels are controlled by the Kushiyara. The spill channels are: the Kamarkhali to the west of Polder 1, the Dahuka to the north, the Naljor to the east, and the Naljor and Ratna to the south; the Itakhola lies south of Polder 2.

During the pre-monsoon and monsoon seasons, Surma water levels are about 2 meters above Kushiyara levels. The Surma distributaries carry high velocity flash floods that erode the channels and their flood embankments. Towards the end of the monsoon, Surma levels fall and the flow is confined to the channel.

2.2 Engineering Works

Polder 1: The earthworks currently required in Polder 1 include twelve breach closures, six *khal* closures, and re-sectioning of 27 kilometres of flood embankment and 3 kilometres of road embankment that were damaged mainly by wave action. The remaining 16 kilometres of peripheral roads and 6 kilometres of embankments are in good condition and are above design crest elevation.

Construction of compartmental bunds is also underway. (See above, Project History, for 1991-2 work program.) The bunds will not be provided with cross-drainage facilities (culverts) and will divide the polder into three separate drainage basins; the implications for drainage requirements and regulator design should be investigated.

The embankment's crest elevation is higher than and the cross-section different from those specified in the feasibility report. The design crest level corresponded to 0.3 meters freeboard above the 1:10 year flood level expected before 15 May. Crest elevations varied from 7.5 meters PWD in the north to 7.1 meters PWD in the south. The design crest elevation of embankments currently under construction is 7.9 meters PWD.

Polder 2. FFW constructed 26 kilometres of submersible embankment in 1990-1. The design crest level is 7.9 meters PWD and the formation level is 8.9 meters PWD, including 1 meter for settlement. About 1.2 kilometres of embankment was eroded during the 1991 flood season and is scheduled for re-sectioning in 1991-2. Six *khals* drain through openings in the embankment. No hydraulic structures have been constructed and none are planned.

2.3 Agriculture

Construction of the Polder 1 embankment in 1984 provided some flood protection, even without water control structures, and present cropping patterns already reflect some shifting from local *boro* to HYV *boro* in response to the reduced risk of pre-monsoon flooding. Local *boro* is still the main crop, however, occupying about 60% of the project area. Broadcast *aman* and HYV *boro* each occupy about 20%. Oil seeds occupy about 10%.

With completion of the project and further reduction in pre-monsoon flood risk, some further shifting from local *boro* to HYV *boro* is expected.

2.4 Navigation

Villages located along the west and south boundaries of the project are accessible only by boat in the monsoon season. The north and east part of the area is served by the peripheral roads.

2.5 Fisheries

Most of the project's many *beels* become dry in winter. *Beels* are leased under open auction for a three year period. Fishing in them is prohibited to the general public.

The *khals* have not yet been closed and as yet the fishery is unaffected by the project. Once the regulators are installed, fish migration will be blocked from around 1 April to 15 May. The *khals* will still be open during the monsoon. Improved drainage and some increase in the winter irrigation for HYV *boro* will reduce the dry season water area, which will have a negative effect on the overwintering fish brood stock.

To offset the negative effects of the project development on fisheries, the NHC feasibility study proposed measures for rehabilitation and improvement of selected fisheries on a pilot basis. No action has been taken on this to date.

3.0 PROJECT EVALUATION

The project concept seems reasonable, but it cannot be reviewed against performance since implementation is not yet complete. Completion is expected 1993.

The completion in 1984 of the Polder 1 submersible embankments seems to have provided a degree of flood protection such that some shifting from local to HYV *boro* occurred. Navigation and fisheries impacts are possible, once the regulators are installed.

Drainage requirements and regulator designs should be reviewed to incorporate any changes made necessary by the division of Polder 1 into three drainage basins by the compartmental bunds.

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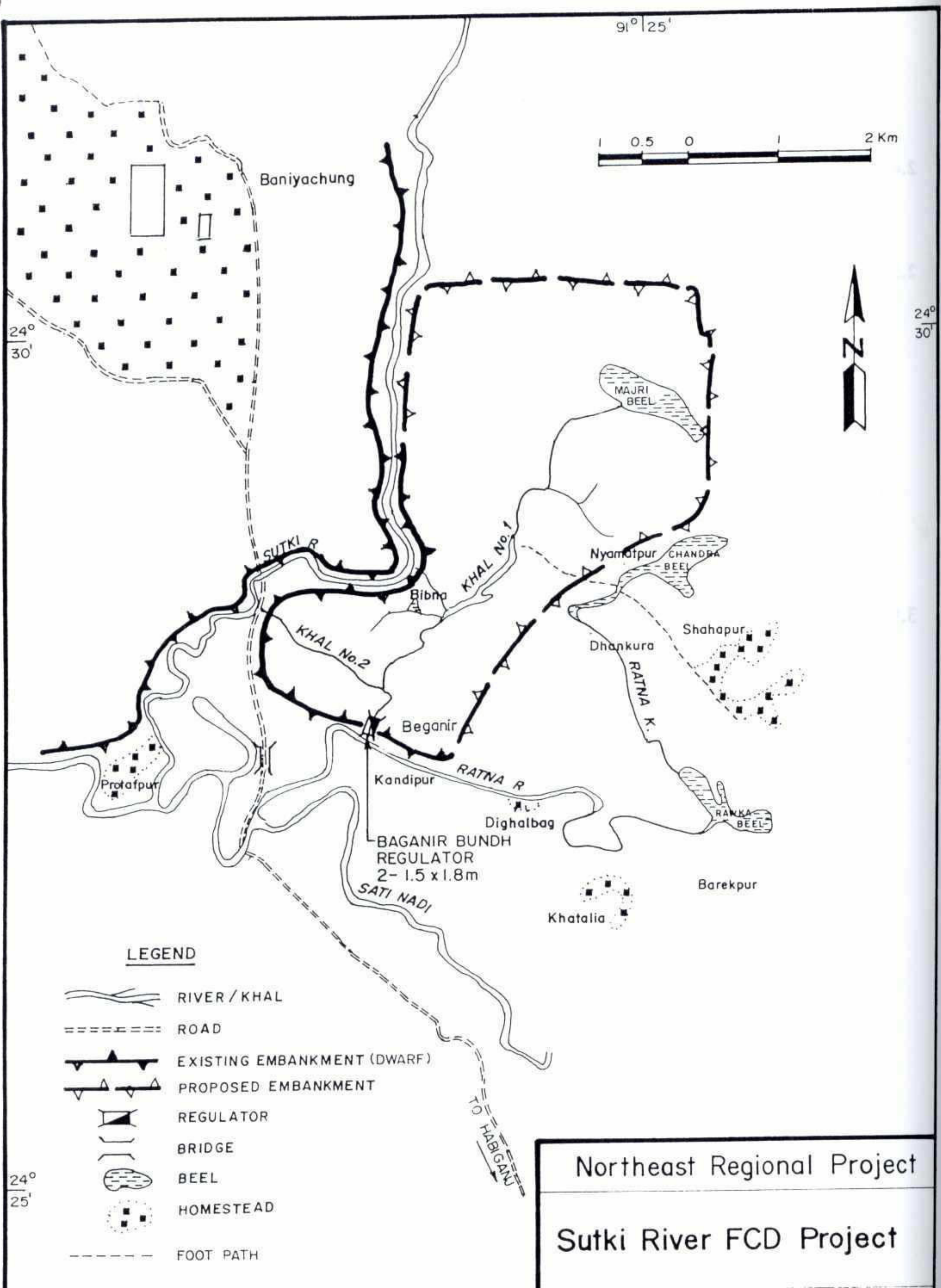


Northeast Regional Project

Sutki River FCD Project

Prepared by: HW / AA | Date: March 1992

SUTKI RIVER FCD PROJECT

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Habiganj O & M
District:	Habiganj
Upazila:	Baniachung

1.2 General Project Data

Project Type:	Partial flood control, drainage, water retention
Status:	Begun 1985, halted 1987; ongoing
Gross Area:	1,417 ha
Net Area:	810 ha
Population:	4,740

1.3 Project Concept

The project objectives are to protect the area from flooding from the Ratna and Sutki Rivers to the south and west, and to provide irrigation water for the *boro* crop by retaining water in the *khals* and *beels*. BWDB works consist of a two-vent flood control/water retention regulator, and re-excavation of 58 kilometres of channels to improve drainage. Locally constructed works consist of 9 kilometres of 0.5 meter-high submersible embankments and field irrigation channels.

Farmers state that pre-monsoon floods also enter the area overland from the north and east, and as such, the project concept for flood control is incomplete.

1.4 Project History

Before 1983 (date unknown), local farmers constructed 9 kilometres of submersible embankments. In 1983, a feasibility report and detailed engineering designs were prepared. During Nov 85 to Jun 86, the regulator was constructed under an IDA- financed Small Schemes Project. In 1985, re-excavation of drainage channels began, but in 1987, with work half complete, a dispute over earthwork measurement halted the program.

Currently, BWDB, Habiganj Division, proposes additional works: upgrading the existing submersible embankment; construction of a submersible embankment around the rest of the project boundary; *khal* re-excavation; improving the existing regulator with installation of country-side slide gates. Earthworks would be undertaken in phases under FFW, and regulator modification would be financed from the Project O&M fund.

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The project is bounded by the Sutki River to the west and the Ratna to the south. The area is composed mainly of low-lying *beels*. The poorly-defined north and east boundaries follow slightly higher land.

The area is deeply flooded throughout the monsoon. The main drainage channel, Khal #1, originates in Majri Beel, drains through other *beels*, and finally discharges into the Ratna at Baganir.

Before the project, pre-monsoon flood water entered the area through Khal #1, damaging mature *boro* crops; to prevent this, farmers constructed an earth dam every year at the *khal* outfall. Local farmers state that pre-monsoon floods also enter the area overland from the north and east.

2.2 Engineering Works

The flushing/drainage regulator (vent size 1.5 meters x 1.8 meters) is in good condition and the hydraulic design appears adequate. Two slide gates on the river-side prevent inflow from the river. Wooden stop logs on the country-side are supposed to retain water during the post-monsoon season, but they leak profusely and farmers fill the regulator with earth on the countryside instead.

The low submersible embankments constructed by local farmers need to be upgraded.

Supposedly Khals No. 1 and 2 were re-excavated in 1985-7 under FFW, but there is little evidence of spoil material from a sizable earthworks program. At the time of inspection (15 Jan 92) water levels were high and the condition of drainage channels could not be assessed.

2.3 Agriculture

The main crops are local *boro* and HYV *boro*; some broadcast *aman* is grown. Local *boro* is grown at lower elevations around the beels, using residual moisture and manual irrigation. HYV *boro* is grown under low lift pump irrigation on higher elevations and along the rivers. Numerous 2 cfs low lift pumps are operating along the Ratna and Sutki Rivers.

HYV *boro* is replacing local *boro* on higher land as more low lift pump irrigation becomes available. Farmers are reluctant to grow HYV *boro* in lower areas due to the risk of pre-monsoon flood damage.

Broadcast *aman* is grown on a small area. Yields are very low, and water hyacinth damages some crops.

2.4 Navigation

During the monsoon, local people use country boats to reach the Habiganj - Baniachung road; during peak floods, the road is submerged. In the dry season, people use local footpaths.

2.5 Fisheries

Local people fish in all area *beels*; these are not leased out.

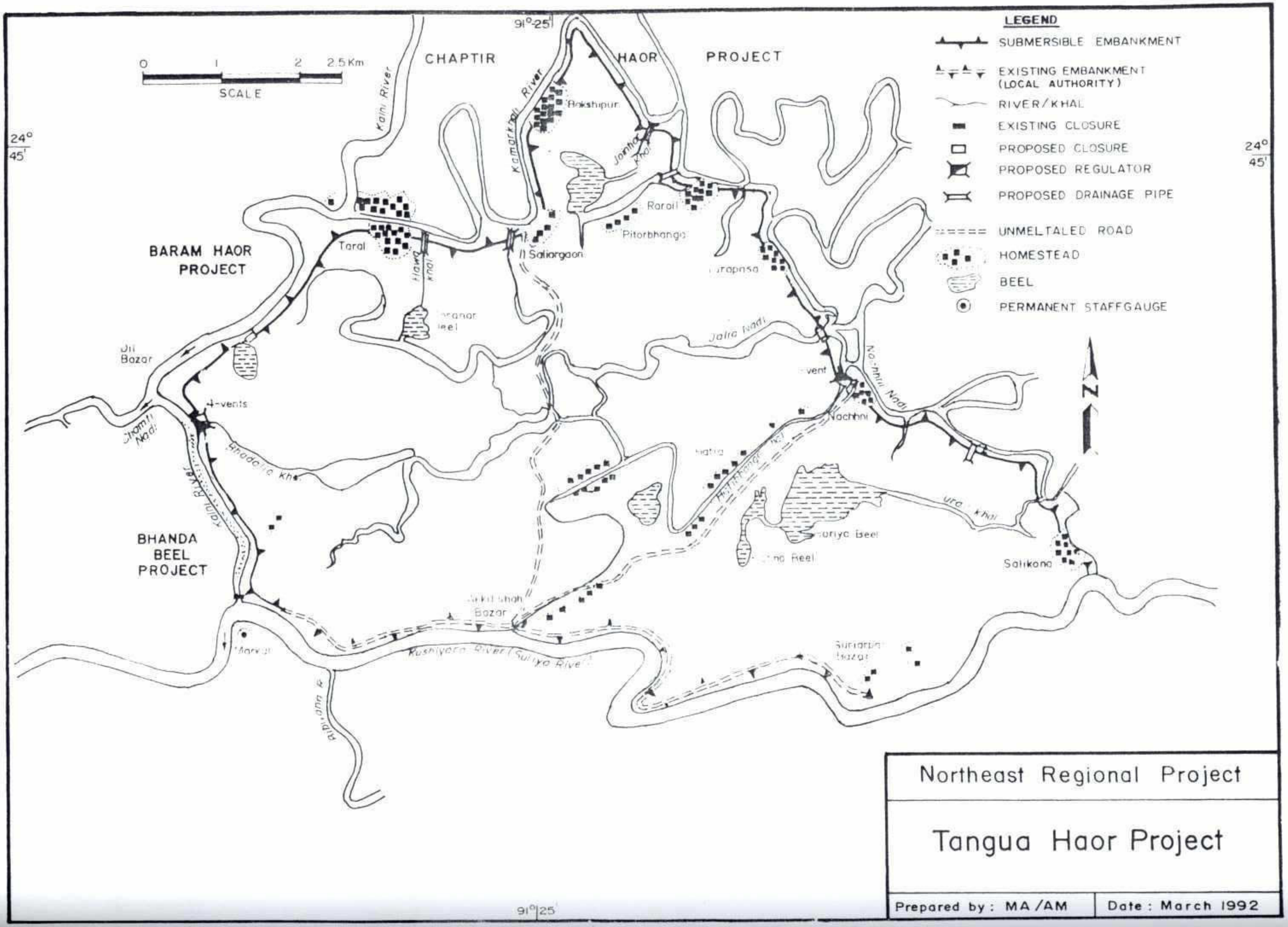
3.0 PROJECT EVALUATION

Project objectives are:

- to provide pre-monsoon flood protection. The project concept currently under implementation is incomplete, as flood water still enters from the north and east. The additional works proposed by BWDB Habiganj Division (see Project History, Sect. 1.4) would address this.
- to retain irrigation surface water. Concept is sound but stop logs are leaking and farmers fill with earth instead.
- to improve drainage. Not evaluated.

Flood control is ineffective as the project does not protect from floodwater entering from the north and east. The condition of the existing embankment needs to be upgraded. The regulator must be filled with earth on the country side for water retention. Condition of drainage channels is not known.

The additional interventions suggested by BWDB Habiganj appear to be reasonable.



Northeast Regional Project

Tangua Haor Project

Prepared by: MA/AM | Date: March 1992

TANGUA HAOR PROJECT

1. PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Sunamganj WD
District:	Sylhet
Upazila:	Dirai

1.2 General Data

Project Type:	Partial Flood Control
Status:	Under Construction
Gross Area:	5,000 ha
Net Area:	4,500 ha
Population:	20,800

1.3 Project Concept

The project objective is to protect *boro* crops from the pre-monsoon flash floods. This will be accomplished by constructing 20 kilometres of submersible embankment; two regulators for post-monsoon drainage and pre-monsoon flushing; six pipe sluices for post-monsoon drainage; and about 30 irrigation inlets.

Tangua Haor is deeply flooded between June and October with depths ranging from 1.5 to 6.0 metres. Flash floods occur in April and May as a result of heavy rainfall in the catchment. Because of the hydrology, the area is mostly single cropped to local *boro*. Some broadcast *aus* is grown on the southern fringe of the haor.

1.4 Project History

The project was identified and proposed for implementation by BWDBs Sylhet O & M Circle in 1987. An EIP appraisal mission recommended the project for inclusion in their 1987-88 program. Construction of the submersible embankment started in 1988-89 and is expected to be completed during 1991-92. Construction of three drainage pipe sluices has started and recently work orders were issued for the construction of two regulators. Twenty irrigation inlets have been installed and the remaining 10 are expected to be completed during 1991-92

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The project area is bordered by the Kalni River in the west, Kamar Khali Nadi in the north, and Kushiyara River in the south. There are significant recent changes to the flow patterns:

- The Kalni River, which is a branch channel of the Old Surma River, historically emptied into the Kushyiara at Markuli. A closure was constructed at Markuli in 1978 and the Kalni River now flows westward into the Champti Nadi, then into the Darain River before finally flowing into the Kushiyara River below Azmiriganj.
- The Kamar Khali Nadi is a distributary of the Dahuka Nadi. The off-take of the Kamar Khali Nadi has filled with sediment and as a consequence has become seasonal.

Historically, the Kamar Khali Nadi drained south to the Kushiyara River but sediment deposition near its outfall has forced it to flow into the Kalni River.

The Kushiyara River, a few kilometres downstream of the Sherpur gauging station (175), bifurcates into the Bibiyana and Suriya Rivers which join each other again near Markuli just upstream of the Kalni closure dam. BWDB officials and local people have stated that the Bibiyana River has been silted and that most of the flow is currently passing through the Suriya River. This may be resulting in increased water levels in the Kushiyara River.

2.2 Engineering Works

Submersible Embankment: The BWDB Tangua Haor embankment does not include the embankment along Kushiyara River which was constructed earlier by local officials under a FFW program. During the field visit around Taral village, people stated that in 1990 the embankment overtopped causing severe damage to *boro* crops and that in 1991 it almost overtopped. There is a public cut near Saliargaon village and the embankment crest has eroded around Bakshipur village. Local people around Bhadalia Khal have stated that the embankment in their area is most vulnerable to wave action, particularly the section about one kilometre upstream of the *khal*, and that it breaches almost every year.

About 1,000 metres of the Kushiyara embankment, upstream of Akkil Shah Bazar, has been eroded extensively by waves generated within the project area. Local people have reported that in 1990 the section was repaired by local authorities but not to the design section. They have asked for this critical reach to be repaired by BWDB and that special protective works be installed.

A breach in the Kushiyara embankment was observed at Suriarpar, further upstream of Akkil Shah Bazar. The breach occurred in May 1991 while the embankments were being overtopped. The breach has been further enlarged by a flood from the Kushiyara River which occurred as a result of heavy rainfall which started on 25 December 1991. Local people who tried to close the breach in order to save their *boro* crops stated that this was the first time the embankment had overtopped since its construction. They also observed that the Kushiyara River bank had not overtopped prior to the harvest of *boro* crops until recently. They mentioned that there is another breach at Tentulia Bhanga, downstream of Akkil Shah Bazar, which occurred about the same time as that at Suriarpar.

BWDB officials have reported that projects located on the right bank of the Kushiyara River around Markuli require higher embankments, ostensibly due to increased flows in the Kushiyara River.

Regulators: The project plan includes the construction of two regulators. Work orders have been issued but their construction has not started. Local people have stated that the regulator could be used to drain out all the water from Hatibhanga Khal which is presently used for *boro* irrigation around Hatibhanga village. They think that the regulator would better be placed at Kurar Khal where it would operate more efficiently. During the field visit around Hatibhanga Regulator site it was observed that the Hatibhanga canal had filled with sediment for a distance of about 2 kilometres.

Irrigation Inlets: About 20 irrigation inlets have been installed and another 10 are planned for completion during 1991-92. People report that the inlets were mostly installed at those locations where low lift pumps are to be used. Some inlets were observed to be in use.

2.3 Agriculture

Farmers at Taral village stated that the embankment was overtopped before the *boro* was harvested in 1990 destroying about 75 per cent of the crop. Bakshipur village farmers have stated that they cultivate HYV *boro* along the bank of Kamar Khali Nadi as well as some Shail Dhan (local *boro*). Farmers around Jalia Nadi requested that the river be closed immediately since it is the entry point for early floods.

Farmers around Hatibhanga village and Hatibhanga Khal, locally called Alongi Nadi, expressed concern that the regulator at the outfall of Alongi Nadi may drain out all the water that is now stored in the low lying *beels*. They have been using this stored water for the cultivation of HYV *boro*. Improper operation of the regulator would result in a shift back to a local variety. The lease-holders of the Jalmohals prefer to drain *beels* by the end of December-January to catch fish with the result that regulator operation will be contentious.

2.4 Navigation

Local people have stated that the project does not disturb any classified navigation but the construction of drainage structures may hamper internal water transportation. The drainage structures, however, will be provided with boat transfer facilities.

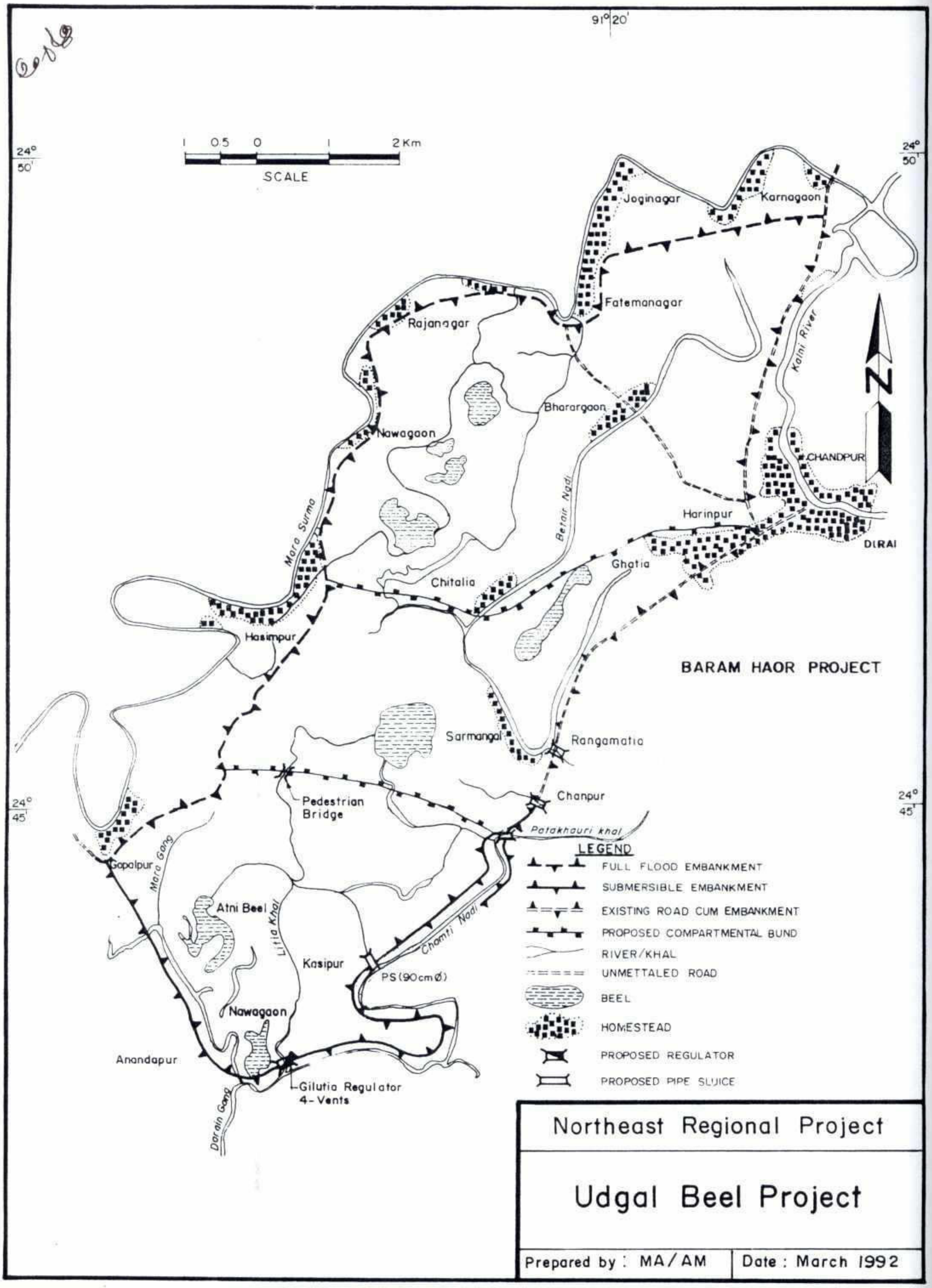
2.5 Fisheries

The project has several *beels* of which Hariya *beel* and Boranor Beel are the largest and have permanent water bodies. A representative of the Hariya Beel lease-holder association stated that the project has affected the migration of fish during the spawning period. The Hariya Beel has been leased for a period of three years under direct auction.

Subsistence fishermen around Bhadalia Beel have complained that, although the lease is given for a particular limited area, the lease-holders prevent them from fishing any of the *beels*. They state that the project has not had any apparent impact on the existing fish resources.

3.0 PROJECT EVALUATION

The Project is yet to be completed. EIP is adjusting embankment crest levels which reportedly are overtopping too early. In addition, it should be considered that there are potential conflict between farmers and jalmohal lease-holders in operating the Hatibhanga regulator. The conflict stems from the desire of the jalmohal lease-holders to drain water immediately after the monsoon to facilitate fish catch while farmers require that water be retained for irrigation. This conflict may well result in damage to the infrastructure and may only be solvable through appropriate policing. Nevertheless, given that extensive re-excavation is required to operationalize the Hatibhanga Khal as a drainage channel, the internal drainage should be reviewed considering the option of utilizing the Kurar Khal.



Northeast Regional Project

Udgal Beel Project

Prepared by : MA/AM | Date : March 1992

UDGAL BEEL PROJECT

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Sunamganj WD
District:	Sunamganj
Upazila:	Dirai and Sylhet

1.2 General Project Data

Project Type:	Partial Flood Protection
Status:	Under Construction
Gross Area:	5,900 ha
Net Area:	4,700 ha
Population:	21,800

1.3 Project Concept

The project was conceived to protect *boro* crops in the area from pre-monsoon flash floods. This is to be accomplished by constructing 16 kilometers of submersible embankments; 18 kilometers of full flood embankment cum road; one regulator to provide post-monsoon drainage and pre-monsoon flushing; three pipe sluices to provide post monsoon drainage; irrigation inlets; and, ancillary structures.

The project area is deeply flooded during the monsoon season to depths ranging from 1.0 to 6.0 meters. The area is mostly single cropped with local *boro* being the main crop while some broadcast *boro* is grown on the higher lands along the project boundary. The *boro* crop is damaged by pre-monsoon flash floods in most years.

1.4 Project History

The project was proposed by BWDB (Sunamganj Water Development Division) in March 1990 and an EIP appraisal mission recommended the project be included in their 1990-91 program. Construction of the embankment commenced in 1991 and the embankment work is scheduled for completion in 1992-93. Work on the regulator is scheduled to start in 1992-93 and the project is scheduled to be completed in 1993-94.

2.0 FIELD OBSERVATIONS

2.1 Hydrology

The project is bordered by the Kalni River and Chamti River in the east, Mara (old) Surma in the north and west and Darain River in the south. The Kalni River was closed near Markuli in 1978 and since then the Chamti River has become the main drainage channel for the project area. The Chamti River flows into the Darain River which, in turn, flows into the Kushiyara River below Ajmirganj. It has a navigable depth because of backwater from the Kushiyara River. The main sources of flow for Chamti River are the Old Surma River and the Bhatta Khal. The latter has recently silted.

2.2 Engineering Works

Full Flood Embankments: The proposed full flood embankment extends from Karangaon to Gopalpur village and follows the present village road alignment. The embankment is primarily intended to improve communications as the existing village road is under water during the rainy season.

Submersible Embankment: The proposed submersible embankment is from Gopalpur village to Patakhauri pipe sluice. The embankment from Patakhauri pipe sluice to Dirai upazila center shares a common boundary with Baram Haor embankment and mainly follows the existing village road.

A low embankment has been constructed along the southern project boundary by the local authorities using Food for Work. Some sections of this embankment are along the river and are well constructed but the embankment is not continuous. Local farmers request that the embankment crest level be raised to ensure that their *boro* crop is secure. They maintain that water levels in the peripheral rivers are higher than in the past.

Structures: The project plan includes one regulator, three pipe sluices, two culverts, one pedestrian bridge, 20 irrigation inlets and compartmental bunds. Construction of Gilutia Regulator is scheduled to start in late 1992.

2.3 Agriculture.

Local farmers have confirmed that local *boro* is their main crop, with some HYV *boro* grown along the river banks. Outside the project, transplanted *boro* and HYV *boro* are grown using irrigation water from Old Surma River.

Crop damage from the pre-monsoon floods in 1991 was not significant but post harvest losses were high because of continuous rain and cloud in May.

Intense storms in late December 1991 inundated the project area, damaging the newly planted *boro* crops and the seed beds. On 28 December 1991 water was entering the project area from Darain River though Gilutia Khal. Local farmers have reported that they will not be able to cultivate much of the project area, due to seedling damage and hence the 1991-92 harvest is expected to be low.

2.4 Navigation

Local people have stated that the project will not disrupt any classified navigation routes but that installation of the drainage regulator may disrupt their internal water transportation.

2.5 Fisheries

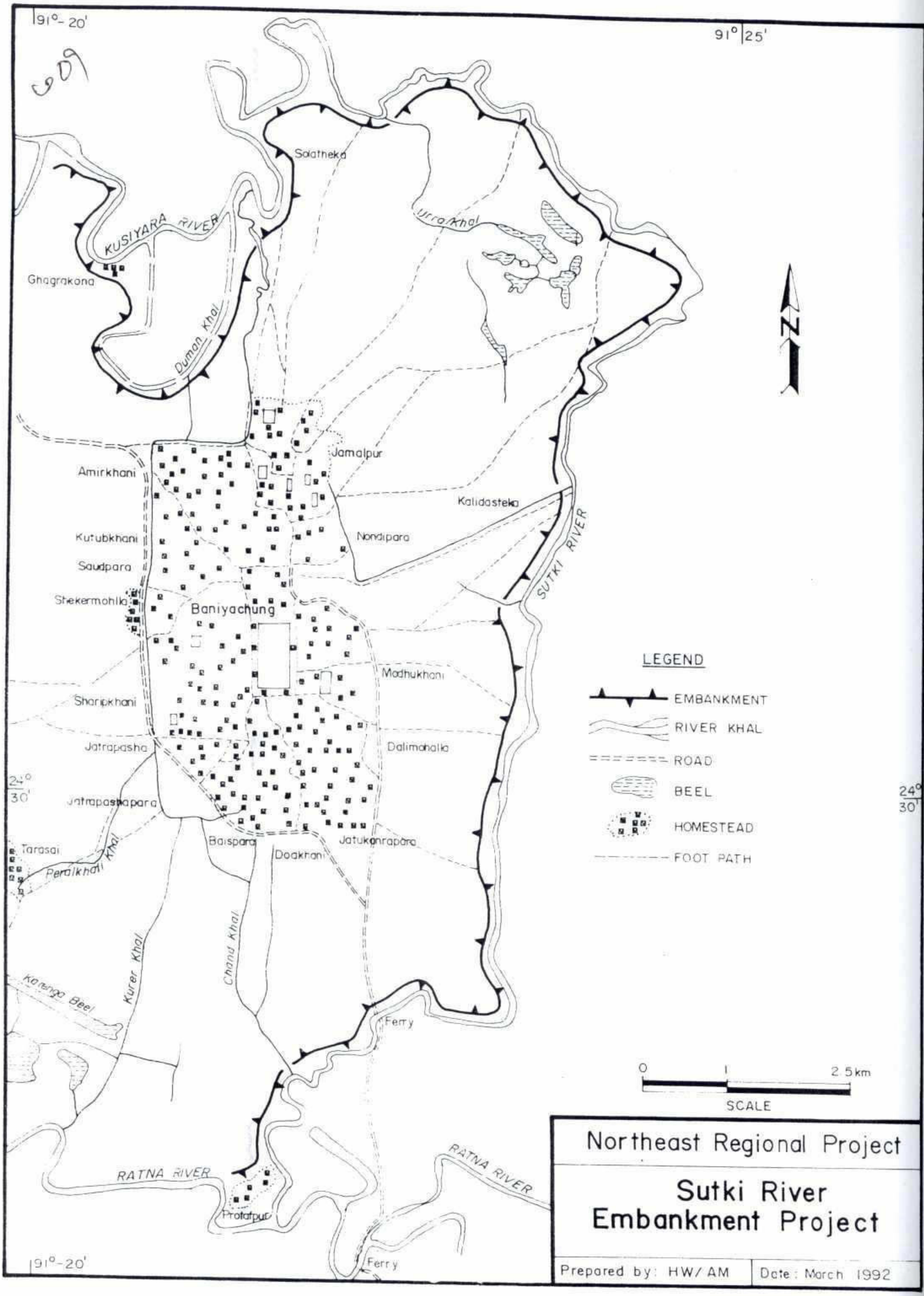
Most of the *beels* in the project dry out during the winter season. The *beels* are now leased by open auction and local people are generally not permitted to fish in them. Subsistence fishermen at Darain River have stated that the lease-holder sometimes permits them to catch fish in the *beels* but more than 50 percent of the catch must be given to the lease-holder. The *beels* mainly produce small fish.

3.0 PROJECT EVALUATION

Project infrastructure has not been completed.

Local people and BWDB officials have reported that the water levels in the peripheral rivers have increased in recent years.

It is expected that the project once completed will have a positive impact on agricultural production and little impact on navigation.



Northeast Regional Project

Sutki River Embankment Project

Prepared by: HW/AM | Date: March 1992

SUTKI RIVER EMBANKMENT PROJECT

1.0 PROJECT DESCRIPTION

1.1 Project Location

BWDB Division:	Habiganj O & M
District:	Habiganj
Upazila:	Baniachung and Ajmiriganj

1.2 General Project Data

Project Type:	Submersible flood protection
Status:	Begun 1957, completed 1959
Gross area:	12,146 ha
Population:	54,940

1.3 Project Concept

The project concept is to protect the *boro* crop from pre-monsoon flooding by constructing an embankment along the Sutki River and Duman Khal right banks. Project works consist of 33.8 kilometres of submersible embankment with a design crest elevation of 9.15 meters PWD.

1.4 Project History

During 1957-59, the Sutki River right embankment was constructed. Additional planned flood control and drainage works were never constructed. Over the years, various embankment reaches have been re-sectioned under FFW from time to time.

2.0 FIELD NOTES

2.1 Hydrology

The project area is bounded in the north, east and south by the Sutki River, a tributary of the Kushiyara River, in the northwest by Duman Khal, and in the west by high land in the Baniachung town area.

During the pre-monsoon period, Kushiyara flood water backs up into the Sutki. The embankment delays the inflow of early Sutki/Duman Khal overbank spill, but floodwaters still enter the project area through the open *khals* that drain into the Sutki.

Throughout the monsoon season, the project area is mostly deeply flooded, partly due to backwater effects from the Meghna.

2.2 Engineering Works

The average embankment height is about 4 m. Embankment reaches along Duman Khal and the Sutki on the northern project boundary are in poor condition. The embankment along the Sutki on the eastern project boundary is in good condition. The embankment design crest level (9.15 PWD) seems high for pre-monsoon protection.

2.3 Agriculture

Deep flooding restricts monsoon season cropping to broadcast *aman*. In winter, HYV *boro* is grown on higher land with shallow tube well irrigation. Local *boro* is grown around the *beels* and *khals*.

Farmers state that *boro* crops are not damaged in some years, and experience minor damage in others. Agricultural inputs and yields are low.

2.4 Navigation

The project has not affected water transportation because all the *khals* remain open. In the monsoon season, a regular launch service operates between Habiganj and Baniachung via the Ratna and Sutki Rivers. In August and September, boats are the only means of transport as all project area roads are submerged.

2.5 Fisheries

Local people are permitted to fish in the few shallow *beels* within the project, as these are not leased out under government auction even though they are government-owned (*khas*).

3.0 PROJECT EVALUATION

The project is partly achieving its objective of protecting *boro* crops from pre-monsoon flooding, as the embankment (though in poor condition on the project northern boundary) is slowing the entry of floodwater. The flooding that still enters through the open *khals* is reportedly causing minor flood damage.

Provision of regulators on the *khals* would likely further reduce flood damage.

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT

ANNEX C
ENGINEERING
APPENDIX C.4

MONITORING EROSION AND CHANNEL SCOUR ON UPPER KUSHIYARA RIVER

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Memorandum

By: D. McLean
Date: April 14, 1994
Subject: Monitoring Erosion and Channel Scour - Upper Kushiyara River

1.0 INTRODUCTION

This field trip report summarizes findings from a reconnaissance along the Upper Kushiyara River between Zakiganj and Bhuiyamura (Figure 1). The purpose of the trip was to observe conditions of bank protection works that were constructed by BWDB in 1992 and to monitor the channel in Bhuiyamura before protective works were constructed. A previous site inspection in the area was carried out in October 1992 and results from those observations were summarized in DM-TEC17 (1992). The purpose of these observations is to improve the level of information about scour conditions and erosion processes along major rivers in the Northeast Region. This should assist the NERP team in planning future developments in the region. The field trip to Zakiganj was carried out at the request of the Chief Engineer, Design I, BWDB.

The river surveys were made with a depth sounder mounted in a motorized country boat, with horizontal positioning carried out by topofil line. The work was intended to provide general reconnaissance level information.

2.0 GENERAL SITE CHARACTERISTICS

Near Zakiganj, the Upper Kushiyara River flows in an incised, irregularly meandering channel. Bed-material between Amalshid and Sheola varies from medium sand (D_{50} typically 0.15 mm) to mud (fine sand and silt). Bank materials are typically silty, and often containing substantial amounts of clay.

The Kushiyara River marks the border between India and Bangladesh in this reach. According to EPWPDA (1966), the Indian government had constructed a continuous flood control embankment along the left bank of the river and closed the Sonai Bardhal spill channel by the mid-1960's. In recent years, a major dock facility has been constructed on the Indian side, just opposite Zakiganj. On the Bangladesh side, the right bank has been embanked from Amalshid to Sheola with local embankments.

A comparison of 1952 maps and 1993 SPOT photos (1:50,000 scale) indicated bank erosion rates are generally very low at most sections of the river (channel changes were less than the resolution provided from the mapping). On the basis of site inspections, it appears progressive bank erosion is occurring slowly along the outer (concave) sides of most bends and slow accretion is occurring on the inner (convex) sides, in the form of point bar deposition.

Figure 2a shows discharges and water levels recorded between 1964-1991 at Sheola, about 25 km downstream of Zakiganj. The annual maximum discharges has increased substantially over the last 30 years, from typically 1,500-2,000 m^3/s in the 1960's up to 2,500-3,000 m^3/s in the 1980's. This increase is thought to have occurred primarily as a result of channel confinement from embankment construction and from closure of spill channels. Other factors, such as changes in basin rainfall may also have contributed to the trend. The highest flood on record reached 2,960 m^3/s in 1983, while the flood of 1991 and 1993 reached 2,750 m^3/s.

Figure 2b shows that the range in annual peak water levels at Sheola has been very small - the difference between the average annual peak water level and the highest recorded water level (in 1991) amounts to only 0.3 m. This is partly due to the nature of the stage-discharge relation at the site. Figure 3 shows the rating curve flattens out considerably once discharges exceed about 2,000 m^3/s. Furthermore, a review of all historic stage-discharge rating curves between 1964-1991 showed there has been a gradual downward trend in the rating curves over time. It appears that the river has enlarged its channel cross section in response to the increased flood flows that has been experienced in recent years. In fact, a comparison of historic and recent cross sections along the Upper Kushiyara River indicates that the channel top width and bankfull area has increased over time.

Figure 4 shows a preliminary hydrograph for Sheola during 1993. Four peaks occurred between May and July, with the highest flow reaching 2,750 m^3/s in July. Using the flood frequency analysis of annual maximum daily discharges recorded between 1964-1991 (NERP, 1993), the 1993 flood would have a recurrence interval of about 20 years. However, given the upward trend in discharges at Sheola, this frequency analysis may not be too useful for predicting future flood magnitudes.

3.0 ZAKIGANJ BEND

The bend at Zakiganj has a moderate curvature, with a bend radius (Rc) of 580 m and an average channel width (W) of around 170 m (Rc/W = 3). The Zakiganj revetment was reportedly constructed in early 1992. The extent of the revetment was not continuous, with protection placed in two 180 m (approx.) strips (along the upstream approach to the bend and along the downstream portion of the bend). No stone was placed at that time in the middle part (apex) of the bend, which left an unprotected section approximately 200 m in length.

Information about the revetment were obtained from BWDB design drawings 271-1, 311-1-6 and from discussions with BWDB:

> nominal stone size: 40 % consisting of 6-9 inch rock and 60 % between 9-12 inch.
> nominal stone thickness: 760 mm
> stone side slope: 1V:2H

Based on information provided by BWDB it is understood that a launching apron was proposed below EL. 5.1 m PWD, with a length of 11 m and a thickness varying between 1.0 - 1.75 m. The corresponding stone volume in the apron would be approximately 14 m^3/lineal metre. No information on the actual "as constructed" conditions are available.

3.1 Conditions in October 1992

Photos 1 and 2 show the condition of the revetment in 1992. At the time of the site visit, the protection had experienced one monsoon flood.

The channel cross sections showed the thalweg of the river was approximately in mid-stream at Zakiganj and shifted towards the right bank (Bangladesh side) in the entrance to the bend. The thalweg remained along the base of the right bank throughout the bend and then shifted back to mid-stream downstream of the bend where the channel flows in a straight reach. The lowest bed levels varied from around El. 0 m PWD at the entrance to the bend to El. -9 m near the bend apex. In the deepest part of the bend, the side slopes along the right bank were steep, typically 1V:1.3 H and occasionally formed near vertical scarps at the toe of the slope. These steep slopes were considered to be unstable although they may have indicated the presence of cohesive sediments in the bed and lower banks of the river.

Conditions in 1994

The water level at Zakiganj was estimated to be 12.7 m PWD at the time of the survey on March 28, 1994.[1] The water level was typically 3 - 4 m below the top of bank and stream velocities were very low. Figure 5 shows the location of the cross section lines while Figure 6 - 10 show plots of channel cross sections.

A description of the sections from upstream to downstream follow:

Section 1 is located at a Mosque in the bend approach (Photo 3). This section is situated in a slight indentation in the bank which partially protects it from direct flow impingement. The stone protection was intact, and there was a shallow bar at the base of the slope. Approximately 25 m offshore, the bank steepened, reaching a slope of 1V:1.3H near the toe.

Section 2.5 is located in the unprotected middle part of the bend where the bank is actively slumping. The bank slopes at approximately 1V:2H down to a thalweg level of -7.6 m. In this part of the bend, the thalweg is located on the Bangladesh side of river, at the base of the right bank.

Section 2 is also located in the unstable, unprotected middle part of the bend. The right bank slopes at around 1V:1.7 H to a minimum bed level of EL. -8.3 m. At this point the thalweg is located in approximately mid-stream.

Section 3 is located on the stone revetment towards the downstream end of the bend. The bank slopes uniformly at 1V:1.7H to around El. -5 m, and then remains flat in the middle of the channel.

Section 4 is located at the downstream end of the bend on the stone revetment. This section is situated at a collapsed building that has been undermined by past bank erosion (Photo 6). BWDB staff reported the collapse took place around the time of the 1988 flood. Since then the bank has eroded about 3 m. The channel has a shallow parabolic shape, with the thalweg level at +3 m in the middle of the river.

4.0 BHUIYAMURA BEND

The Bhuiyamura site is located about 4 km downstream of Zakiganj. At the time of survey, the slopes of the bank were being prepared for placement of stone protection and some stone was in-place along the upstream end. It was reported that the revetment will be placed over a length of 140 m in 1994.

The river has a long, narrow straight approach, and then turns abruptly 160 degrees through a highly sinuous bend. The channel widens as the flow enters the upstream half of the bend, mainly as a result of past bank retreat along the outer (concave) river bank. This has produced an irregular bank alignment, reducing the present-day flow impingement on the upstream part of the bend and causing the greatest flow

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[1] This level was established from the BWDB bench mark at the Custom's Ghat. The elevation of this BM was reported to be 16.23 m PWD.

impingement to occur near the middle and downstream portion. It was also noticed that a small point bar was forming along the left (convex) bank of the river (the Indian side). This shoal extended out into the river approximately 50 - 70 m in the upper-middle portion of the bend, where the channel was widest. Future growth of this point bar will also tend to shift the locus of greatest bank erosion further downstream. However, at the time of the site inspection there was little evidence of rapid bank erosion at the site and it appears the meander pattern is shifting very slowly in this location.

Figure 11-13 show cross sections at three locations in the bend:

- the upstream end of the proposed revetment
- downstream end of the proposed revetment
- downstream of the revetment approximately at the bend apex.

The thalweg level deepens from El. +1.0 m at Section 5 to El. -5.2 m at Section 7. Side slopes in the bend average about 1V:2H and reach up to 1V:1.6H.

5.0 DISCUSSION

The overall condition of the banks near Zakiganj have not changed significantly from 1992, although some additional slumping has occurred in the unprotected middle part of the bend. The location of the 1992 and 1994 Zakiganj cross sections did not coincide exactly, so only qualitative comparisons can be made between surveys. However, the minimum bed levels measured in 1994 are similar to those observed in 1992. Side slopes appeared to be flatter than in 1992, generally averaging 1V:2H and steepening to typically 1V:1.5H in the apex of the bend. This suggests the locally oversteepened slopes in 1992 were flattened back by subsequent undermining at the toe of the slope. When the revetment toe was undermined, the stone placed near the top of the bank rolled down the slope into the scour hole at the toe of the slope. It appears the stone volume was sufficient to protect the bank against the 1993 flood.

The launched stone may still be providing some protection against erosion along the base of the slope. It is not clear whether there is sufficient stone remaining in the launched apron to provide adequate protection against future floods.

Estimates of minimum scour levels during the 1993 flood were made using empirical "Regime Theory" equations of Lacey and Blench[2].

---

[2] Henderson, F. M. 1966 Chapter 10 "Sediment Transport" in *Open Channel Flow*, The Macmillan Company, p. 405-463.

$$d_r = 0.47\sqrt[3]{\frac{Q}{f}}\,(LaceyEquation)$$

$$d_r = \sqrt[3]{\frac{q^2}{f}}\,(Blench)$$

where Q is the discharge, q is the discharge/ unit width and f is a bed factor (0.7 for a D_{50} of 0.15 mm).

The peak 1993 discharge at Sheola was approximately 2750 m^3/s while the peak water level at Zakiganj was estimated to be around EL. 15.6 m. Computed hydraulic properties at each of the surveyed cross sections are summarized in Table 1. This shows the maximum depth reached 23.9 m in the Zakiganj bend and 20.8 m in the surveyed portion of the Bhuiyamura bend. The ratio of d_{max}/d_{av} averaged about 1.6 and reached a maximum of 2.1 at Section 6. However, these cross sections were surveyed during low water conditions and bed levels may have been lower at the time of peak flow conditions. Predicted average depths at the 1993 flood condition are as follows:

Blench Formula: d_r = 10.4 m
Lacey Formula: d_r = 7.5 m

(computed for a bed material D_{50} size of 0.15 mm and a top width of 180 m)

As shown in Table 1, the surveyed average depths ranged between 9.9 - 15.2 m for the assumed 1993 flood condition. Scour multiplying factors (Z-factors) for eroding bends with high curvature are often reported to range between 2.0 - 2.5 on incised sand-bed rivers. Based on these values, the estimated minimum bed levels in the bends would be as follows:

Blench Formula:

for Z=2.0, d_{max} = 20.8 m, minimum bed elevation = -5.2 PWD
for Z=2.5, d_{max} = 26.0 m, minimum bed elevation = -10.4 m PWD

Lacey Formula:

for Z= 2.0, d_{max} = 15 m, minimum bed elevation = +0.6 m PWD
for Z= 2.5, d_{max} = 18.7 m, minimum bed elevation = -3.1 m PWD

(based on an assumed water level of 15.6 m PWD)

The predicted minimum bed levels from Blench's equation are in the same range as the lowest bed levels surveyed after the 1993 flood (El. -8.3 m at Section 2.5). The predictions from Lacey's formula underestimated the scour depths, probably because the actual channel width is considerably narrower than the corresponding regime width predicted from Regime theory. These simple calculations and the surveys from 1992 and 1994 indicate that maximum scoured depths in the bends of the Kushiyara River can exceed 26 m during a flood such as 1993. It should be realized that the observed bed levels were surveyed at low water and that scour levels could have been lower at the time of the peak flows.

The volume of stone in the apron that would be required to provide protection against scour and undermining can be estimated using the Corps of Engineers criteria as follows:

- difference in elevation from apron to toe of scoured bed = +5.1 - -10.4 m = 15.5 m
- length of apron after launching on a slope of 1V:1.5H = 28 m (35 m on 1V:2.0H)
- thickness of apron = 1.5^*D_{50} or about 0.35 m
- minimum volume of stone in launched apron (including 50% allowance for losses and stone displacement) = 14 m^3/lineal metre assuming a launching slope of 1V:1.5H or 18 m^3/lineal metre at a slope of 1V:2H.

The estimated apron volumes are in the range of the volumes shown on BWDB design drawing. However, no "as constructed" information was available and it is not possible to verify the actual quantities that were placed.

These results indicate that the requirements for providing adequate protection against scour and undermining are substantial. In terms of arresting further bank erosion, the toe of the slope is probably the most critical portion of the bank requiring protection due to the high depths and high shear stresses from secondary currents in the bend. Near the top of the bank, the main source of erosion is probably from wave action or from geotechnical failure during the flood recession.

The situation at Zakiganj illustrates the difficulty of trying to stabilize bends by constructing revetments on meandering sand-bed rivers subject to deep scour. Instead of attempting to eliminate future channel migration along agricultural land, an alternative would be to provide an appropriate set-back for future developments to allow for future channel erosion along the outside of the meander bends. In general, the set-back should be greatest along the outside (concave side) of the bend where erosion rates are greatest and can be less on the inner (concave) side where deposition will occur. An example aligning embankments to account for future channel shifting is illustrated in Figure 14 (from "River Engineering" by M. Petersen, 1986).

Table 1: Hydraulic geometry of channel cross sections near Zakiganj

Section	Area (m^2)	Top Width (m)	Mean Depth (m)	Maximum Depth (m)	Thalweg El. (m PWD)
1	1760	178	9.9	16.6	-1.0
2	2447	161	15.2	23.4	-7.8
2.5	2352	155	15.2	23.9	-8.3
3	2163	150	14.5	20.8	-5.2
4	1756	175	10.0	12.3	+3.3
5	1794	202	8.9	14.6	+1.0
6	1742	196	8.9	18.6	-3.0
7	2744	188	14.6	20.8	-5.2

Note: Area and depths computed for a reference elevation of 15.6 m PWD.

Photo 1: October 1992 View from Indian side towards stone protection in bend approach.

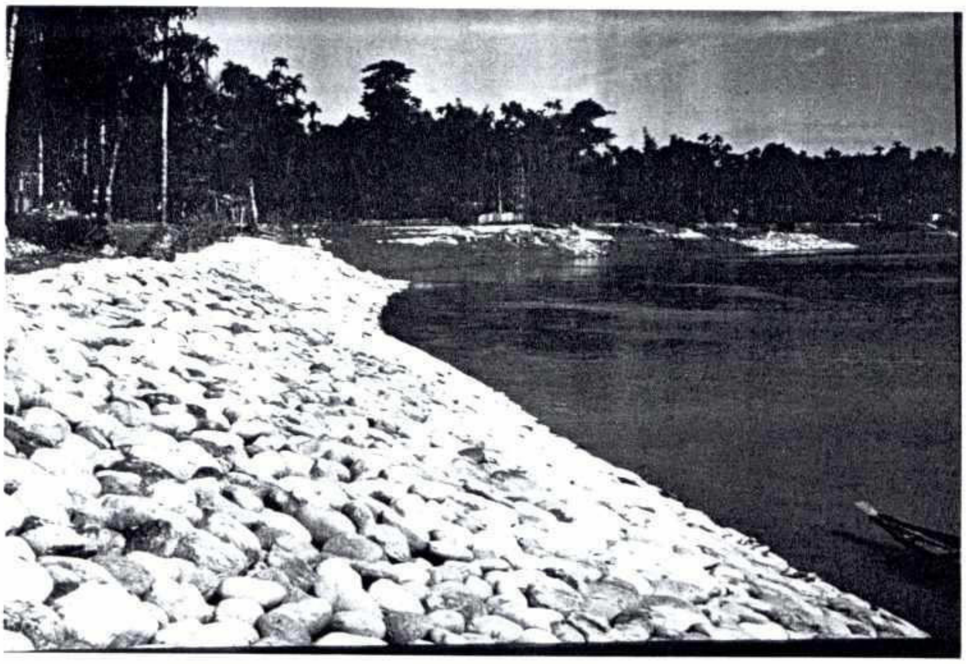


Photo 2: October 1992: View upstream from downstream end of bend showing condition of revetment and unprotected middle portion of bend.

Photo 3: March 28 1994: View of right bank revetment at section 94-1 near Zakiganj

Photo 4: March 28 1994: View of cross section 94-1 from Indian side of river.

Photo 5: March 28 1994: Condition of bank protection along downstream portion of Zakiganj bend.

Photo 6: March 28 1994: Collapsed building on right bank at Section 94-4

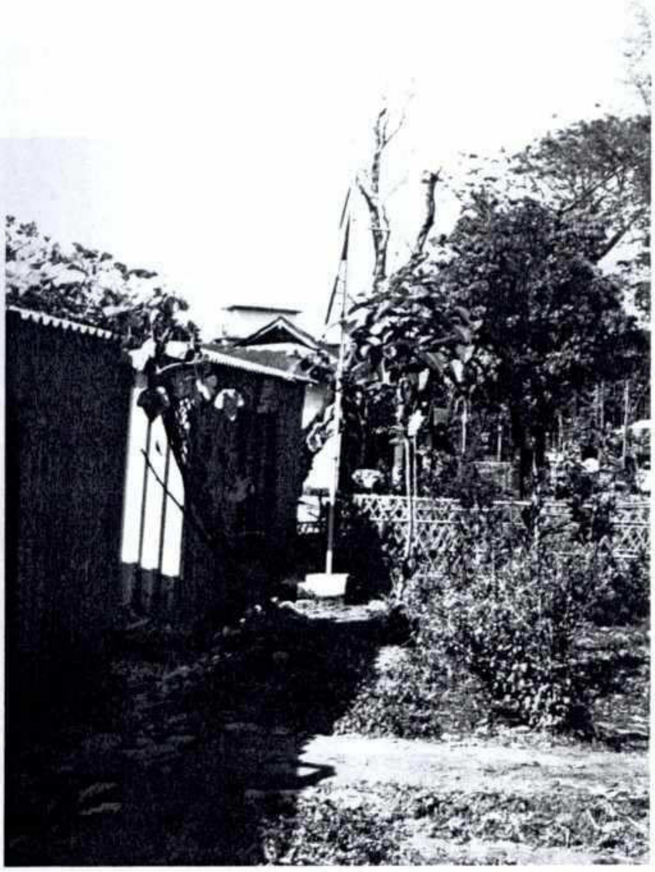


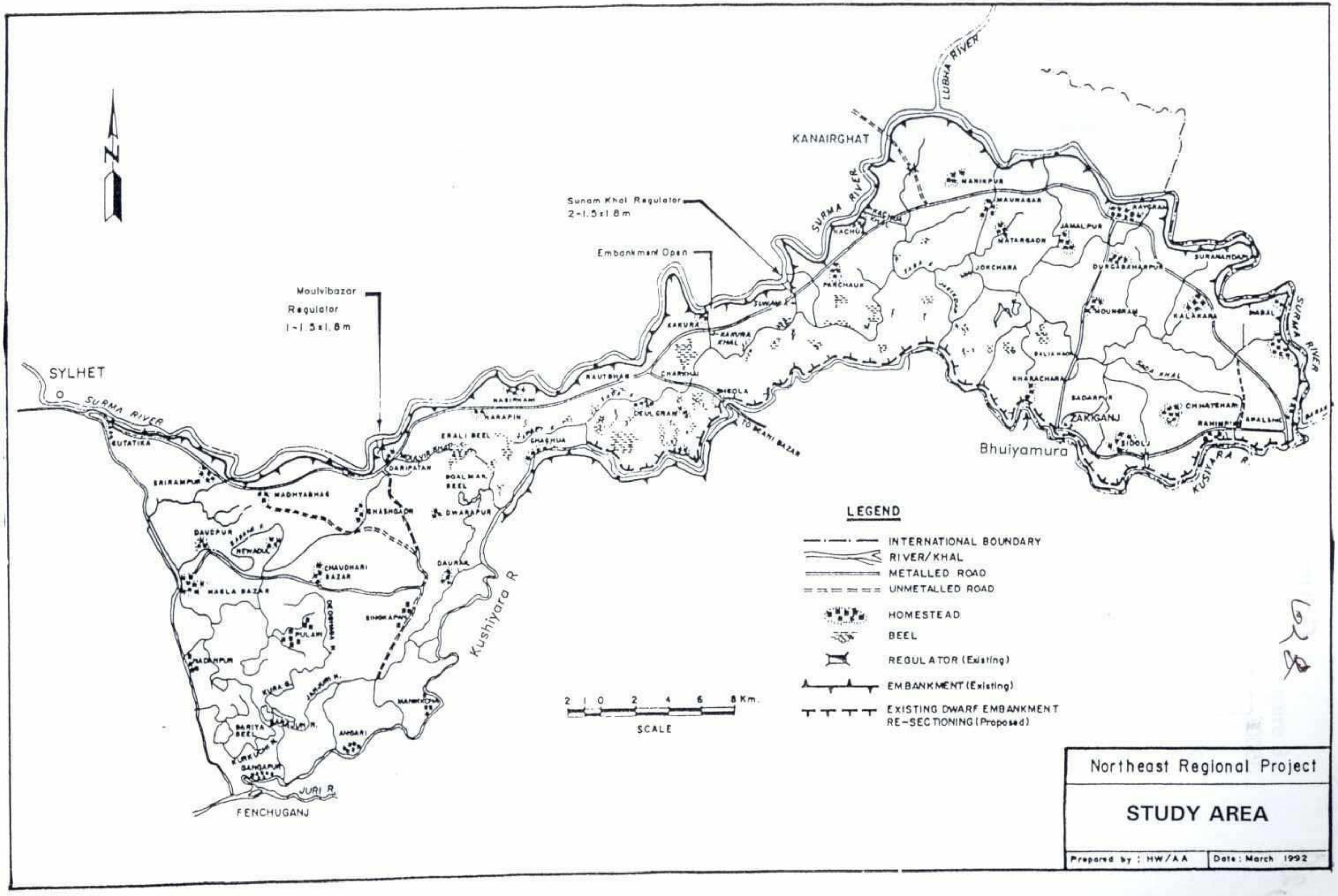
Photo 7: March 28, 1994: BWDB bench mark at base of flagpole at Zakiganj Ferry ghat. Elevation of hub was reported to be EL. 16.23 m PWD. This level has not been corrected or verified from the Second Order Levelling Program.

Photo 8: March 28, 1994: Section 94-5 at Bhuiyamura Bend. BWDB reports this is upstream end of planned protective works in 1994.

Photo 9: March 28, 1994: Bhuiyamura Bend, view towards mid-portion of bend. BWDB reported protection would be placed here in 1994.

Photo 10: March 28, 1994: Bhuiyamura Bend, view to Section 94-6 at downstream end of proposed 1994 bank protection.

(Figure 1


N
SYLHET
SURMA RIVER
KUTATIKA
SRIRAMPUR
MADHYABHAG
DAUDPUR
NEWAOUL
MAGLA BAZAR
CHAUDHARI BAZAR
PULAM
NADANPUR
BARIYA BEEL
KURA R.
JAKARI R.
KURKUCHI R.
GANGAPUR
JURI R.
FENCHUGANJ
ANGARI
MANIKKONA
SINGKAPAN
DAURA
DWARAPUR
BHASHGAON
DARIPATAN
KAVIR KHAL
ERALI BEEL
GOALMARA BEEL
Moulvibazar Regulator 1-1.5x1.8m
NARAPIN
NASIRNAM
CHAGHUA
Kushiyara R
KAUTBHAR
DEULGRAM
CHARKHAI
SHEOLA
TO BEANI BAZAR
KAKURA
KAKURA KHAL
Embankment Open
Sunam Khal Regulator 2-1.5x1.8m
SUNAM
KANAIRGHAT
SURMA RIVER
LUBHA RIVER
KACHU
PARCHAUR
MANIKPUR
MAUNAGAR
MATARGAON
JOKCHARA
JAMALPUR
KHARACHARA
BALIA
SADARPUR
ZAKIGANJ
Bhuiyamura
SIDOLI
DURGABAHARPUR
MOUNGRAM
KALAKARA
KAYGRAM
SURANANDAM
BABAL
SADA KHAL
CHHAYEHAM
RAHIMPUR
SURMA RIVER
KUSIYARA R.
LEGEND
INTERNATIONAL BOUNDARY
RIVER/KHAL
METALLED ROAD
UNMETALLED ROAD
HOMESTEAD
BEEL
REGULATOR (Existing)
EMBANKMENT (Existing)
EXISTING DWARF EMBANKMENT RE-SECTIONING (Proposed)
2 1 0 2 4 6 8 Km.
SCALE
Northeast Regional Project
STUDY AREA
Prepared by : HW/AA
Date: March 1992

628

02d

Figure 1 A

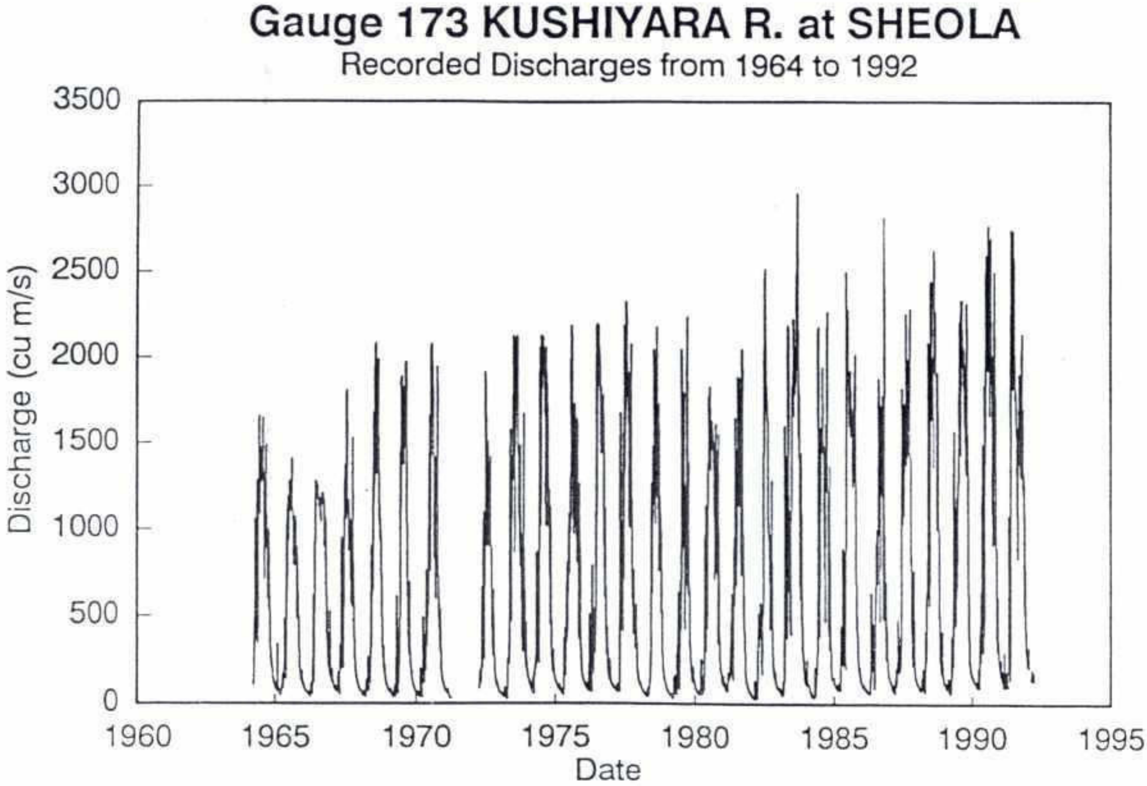
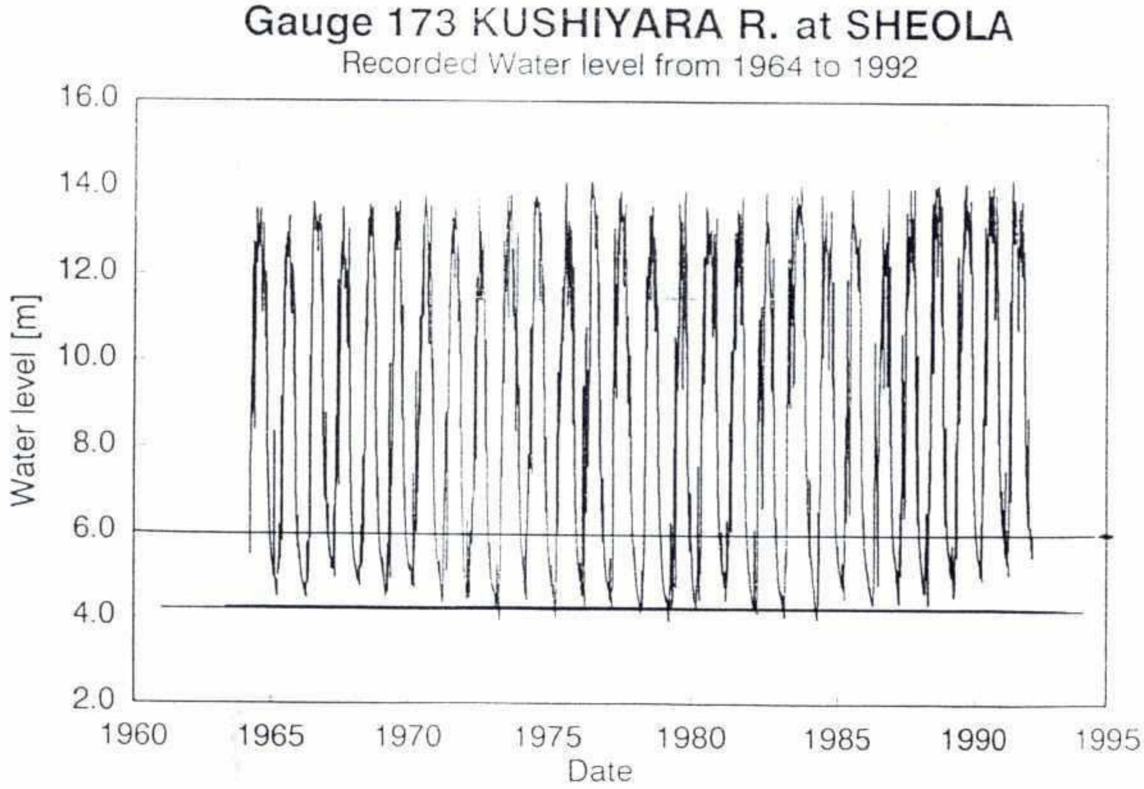
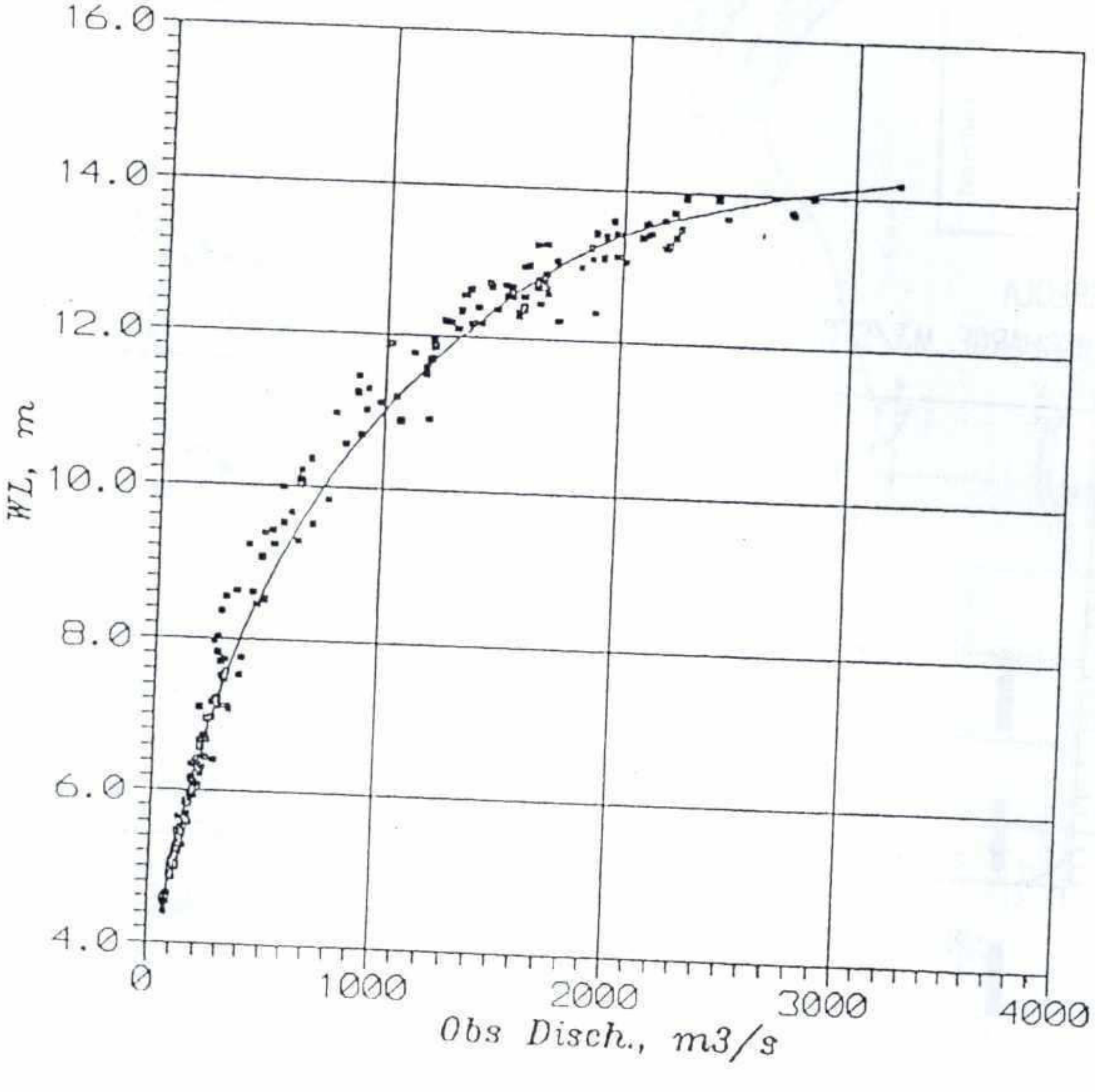


Figure 2



0 2 7

Figure 3:



Rating Curve Of 173 Sheola

$Q=0.133(H+1.40)^{3.54}$, $H \leq 12.6$

For $H > 12.6$, *Manually Fitted Curve*

Figure 4:

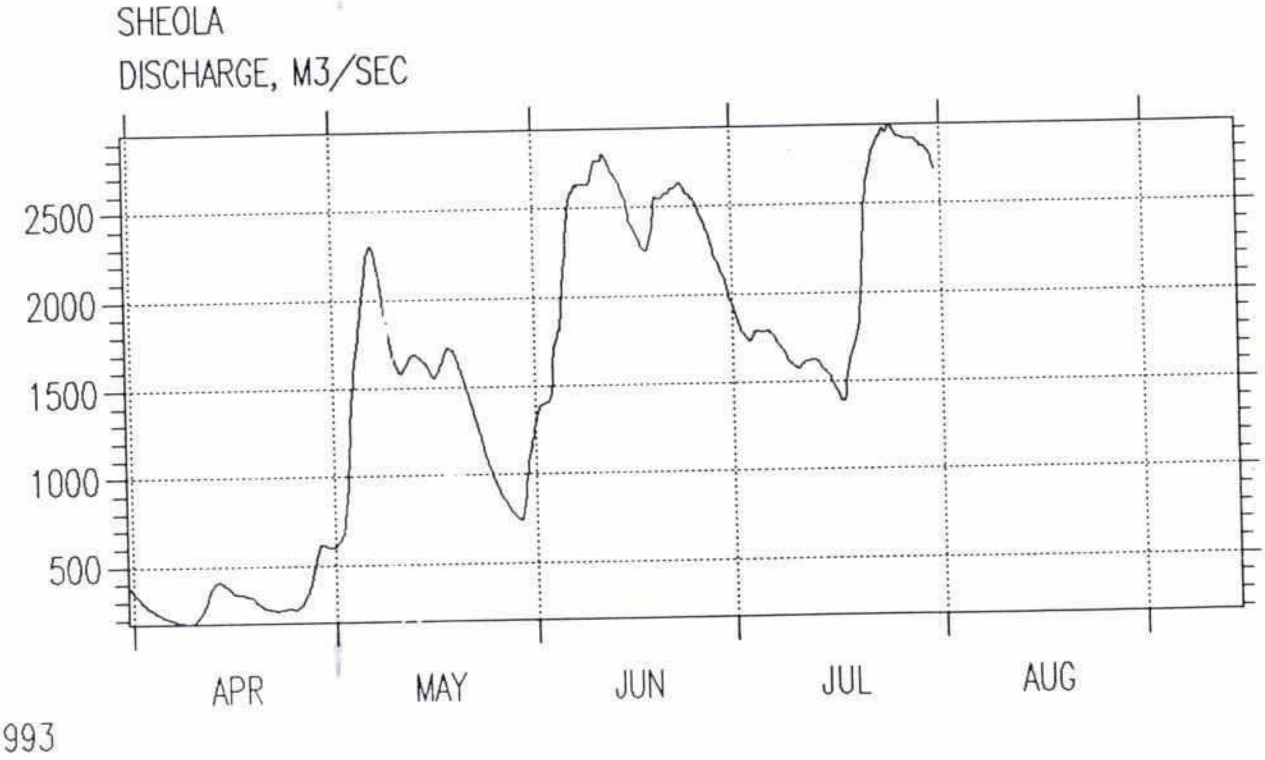
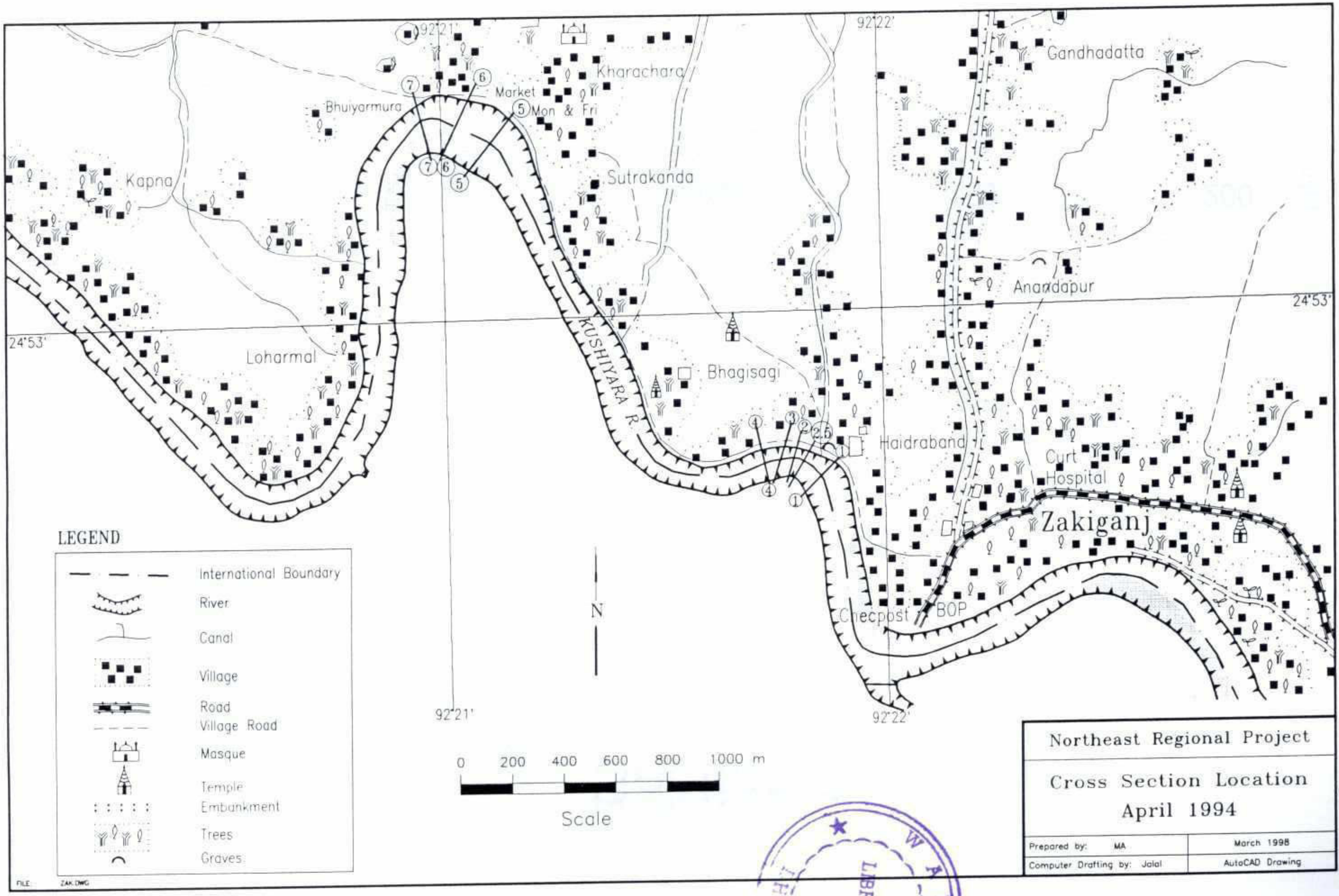

SHEOLA
DISCHARGE, M3/SEC
2500
2000
1500
1000
500
APR
MAY
JUN
JUL
AUG
1993

Figure 5



Northeast Regional Project

Cross Section Location
April 1994

Prepared by: MA	March 1998
Computer Drafting by: Jalal	AutoCAD Drawing

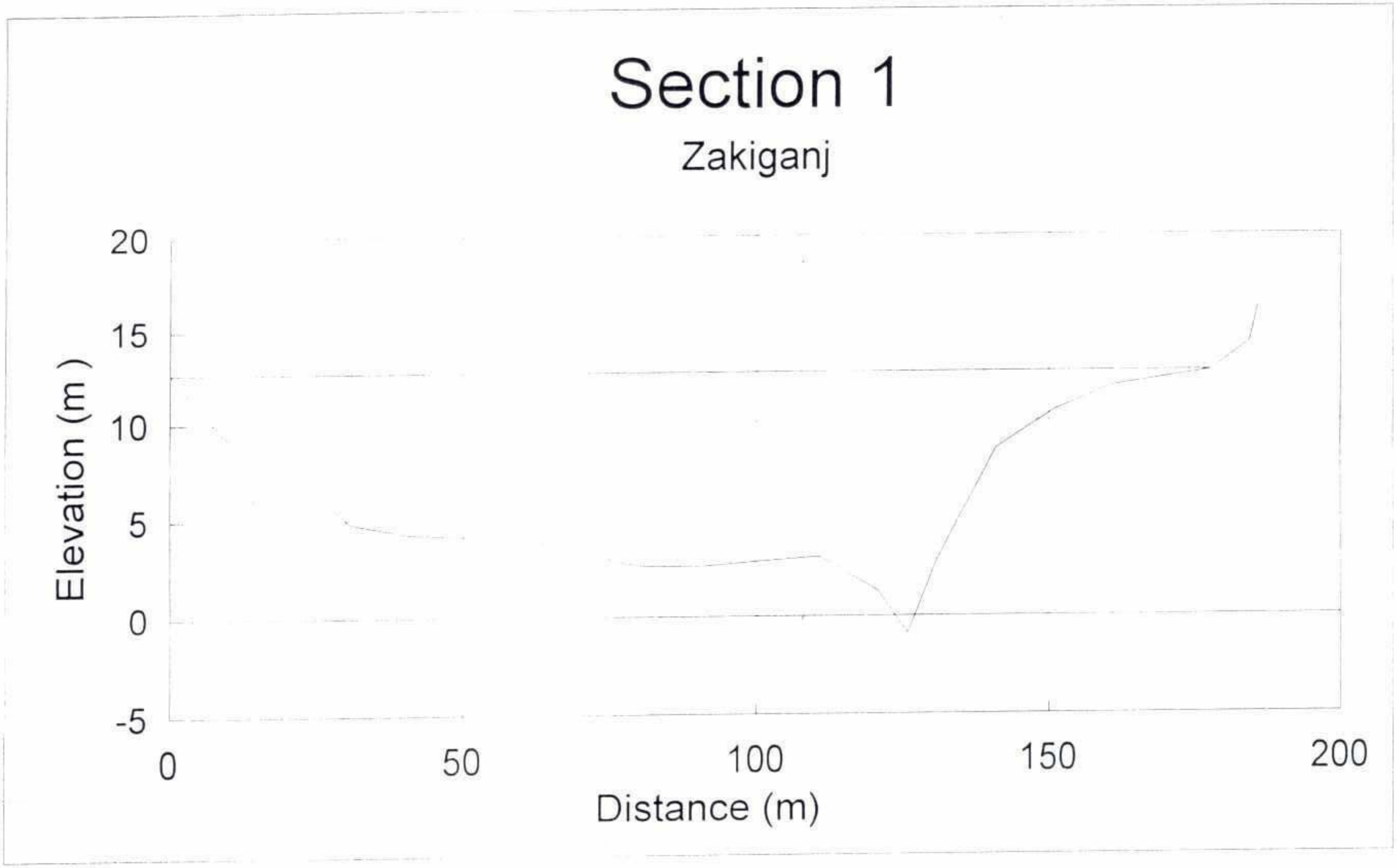

Section 1
Zakiganj
Elevation (m)
20
15
10
5
0
-5
0
50
100
150
200
Distance (m)

Figure 6:

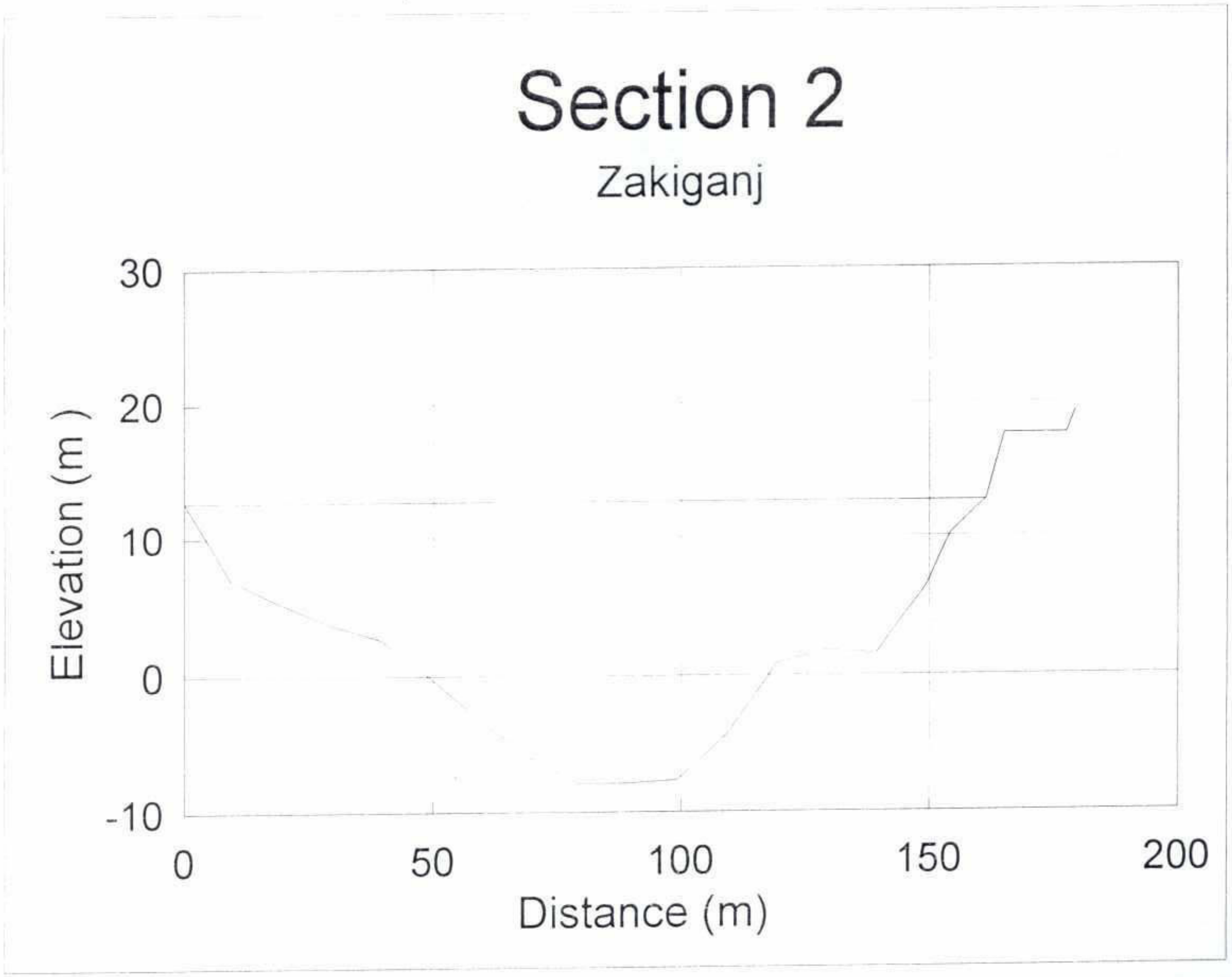

Section 2
Zakiganj
Elevation (m)
30
20
10
0
-10
0
50
100
150
200
Distance (m)

Figure 7:

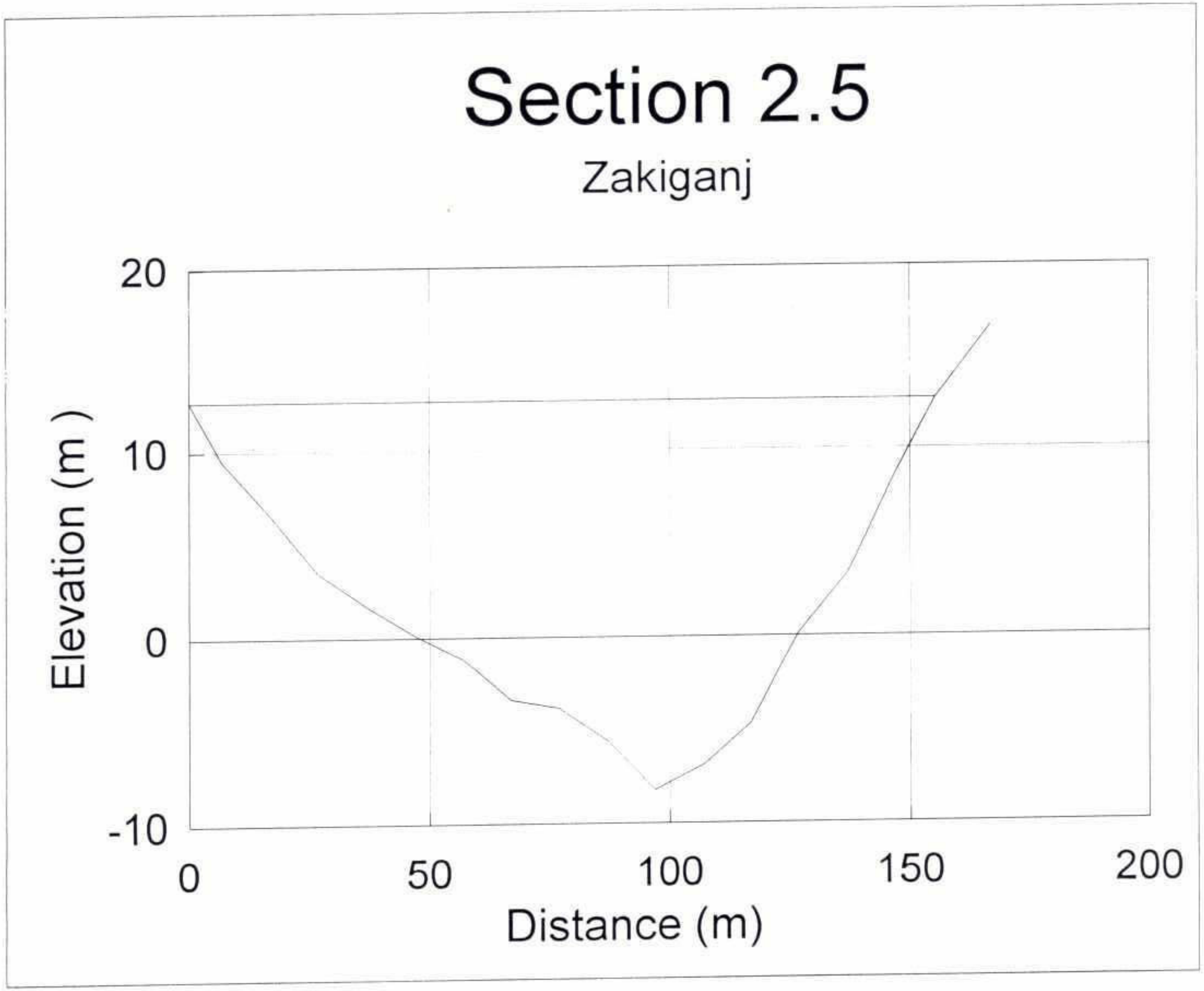
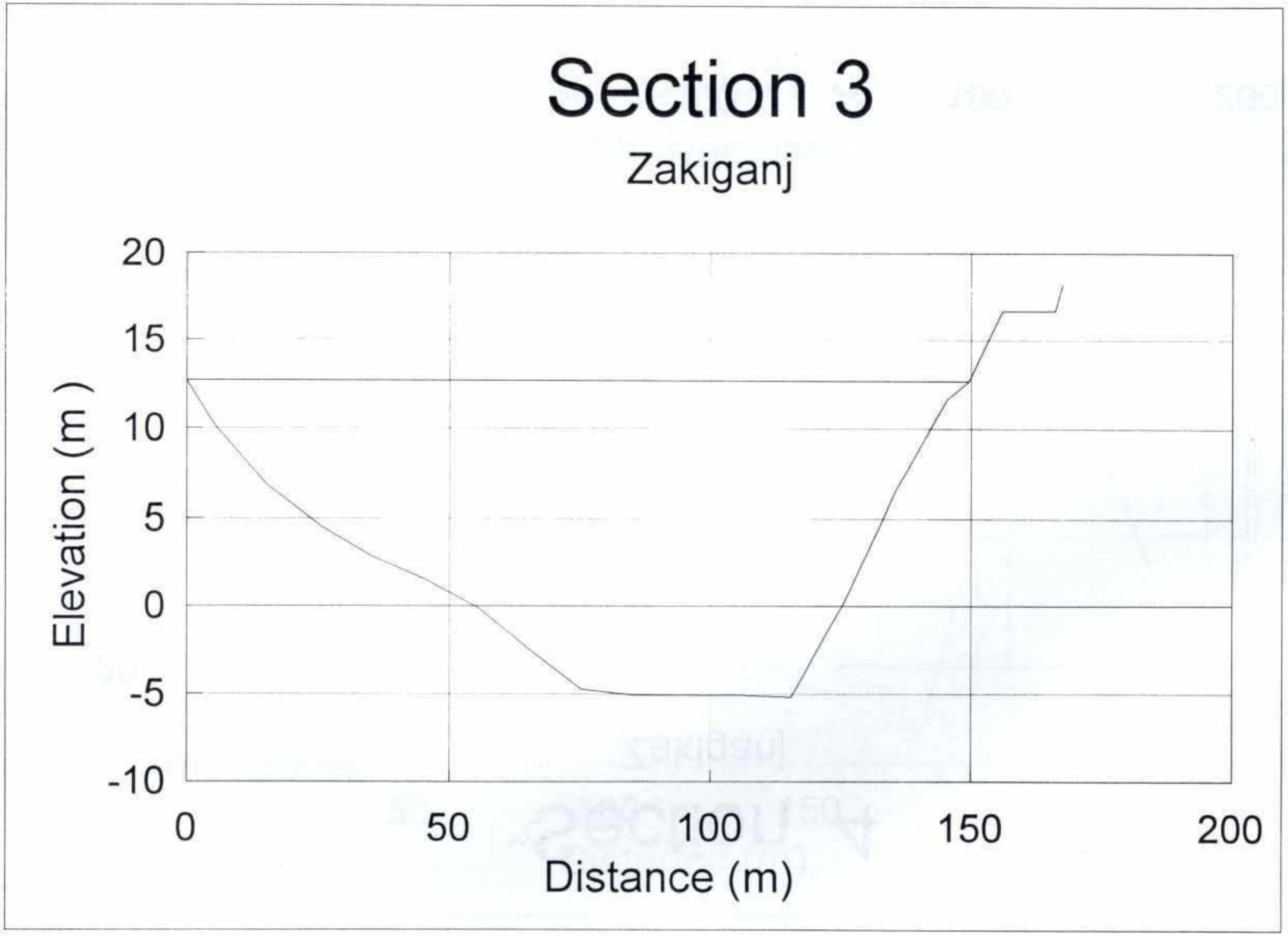

Section 2.5
Zakiganj
Elevation (m)
20
10
0
-10
0
50
100
150
200
Distance (m)

Figure 8:

Figure 9:


Section 3
Zakiganj
Elevation (m)
20
15
10
5
0
-5
-10
0
50
100
150
200
Distance (m)

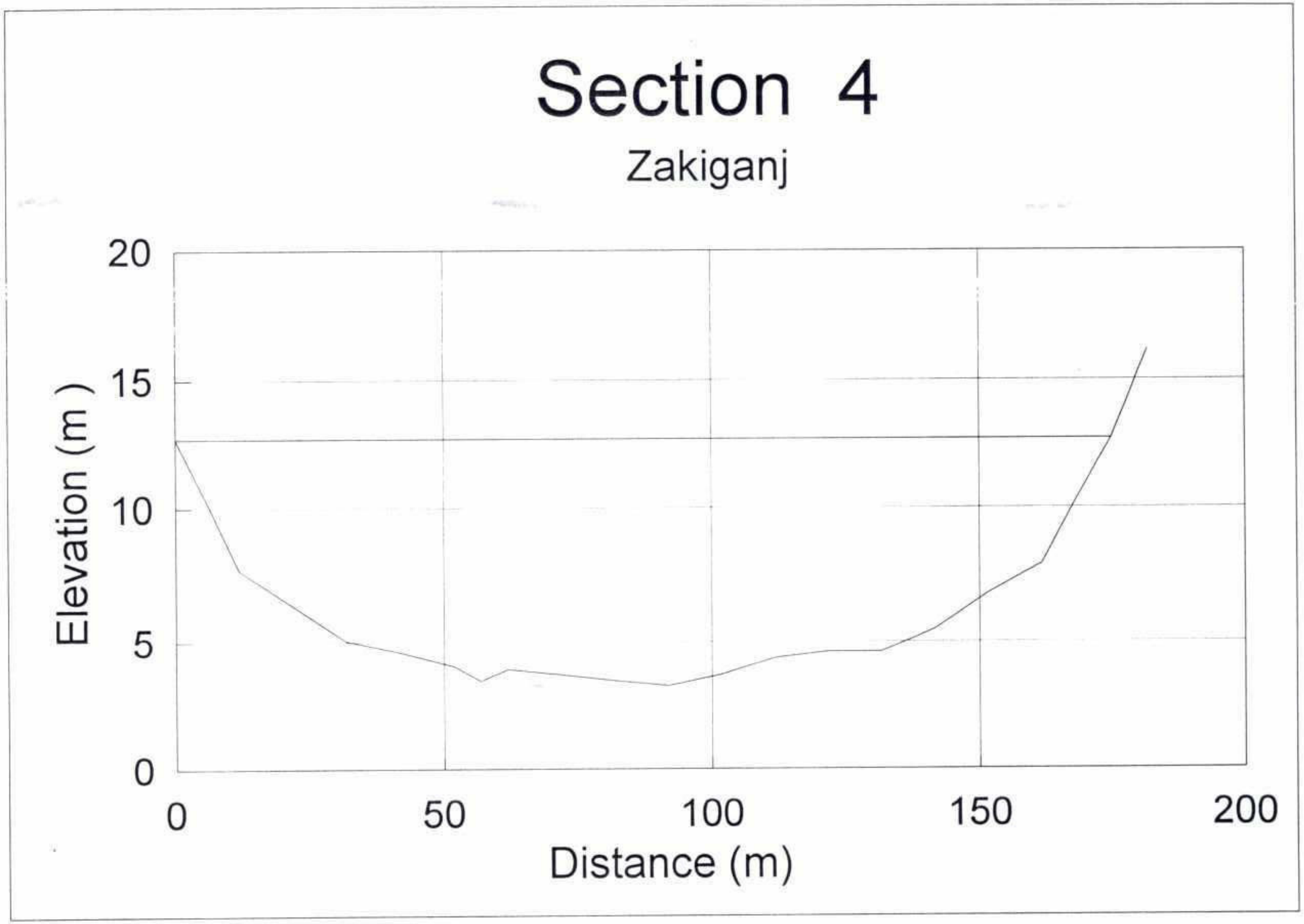

Section 4
Zakiganj
Elevation (m)
Distance (m)
0
5
10
15
20
0
50
100
150
200

Figure 10:

Figure 11:


Section 5
Bhuiyamura
Elevation (m)
20
15
10
5
0
0
50
100
150
200
250
Distance (m)

Figure 12:

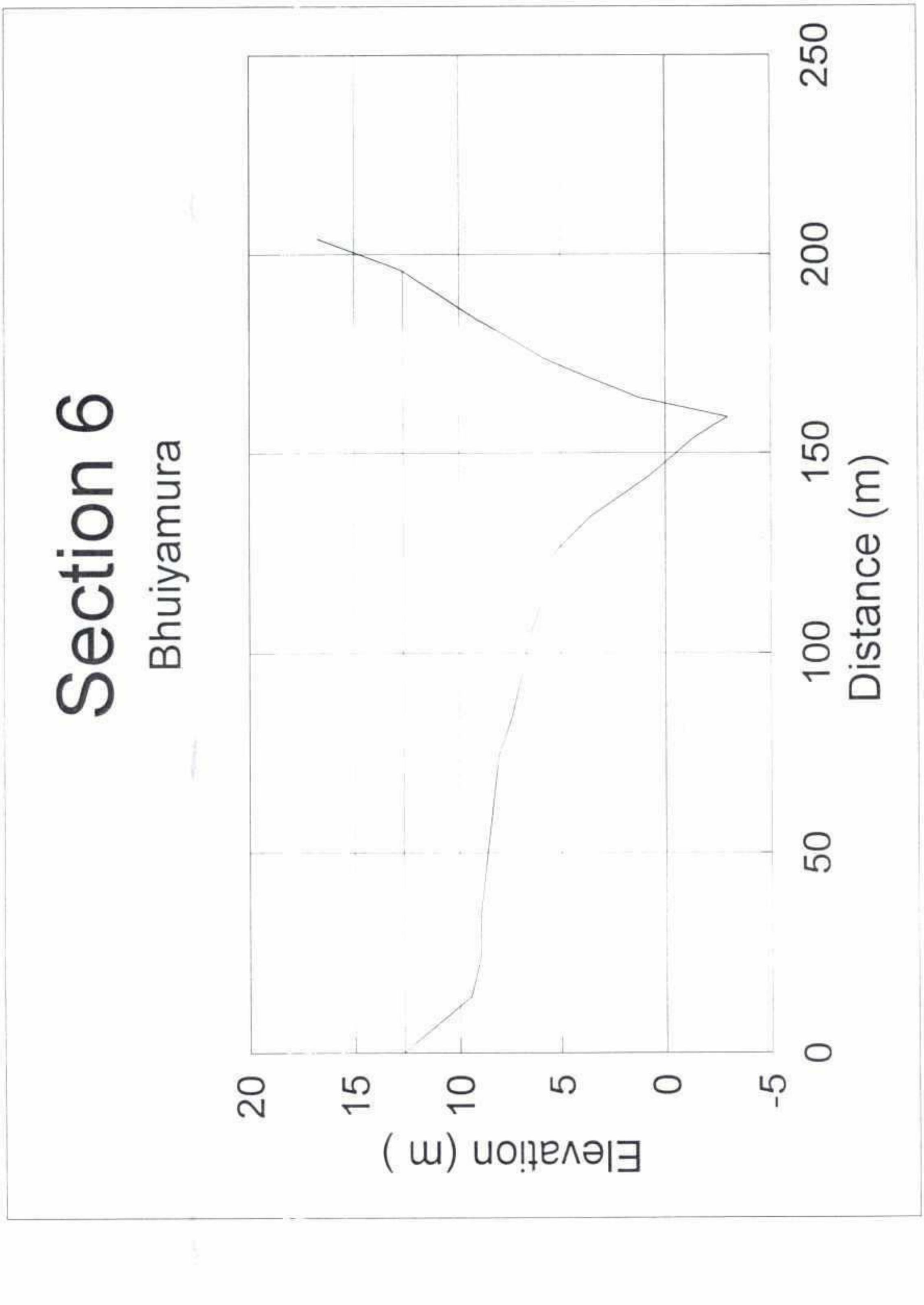
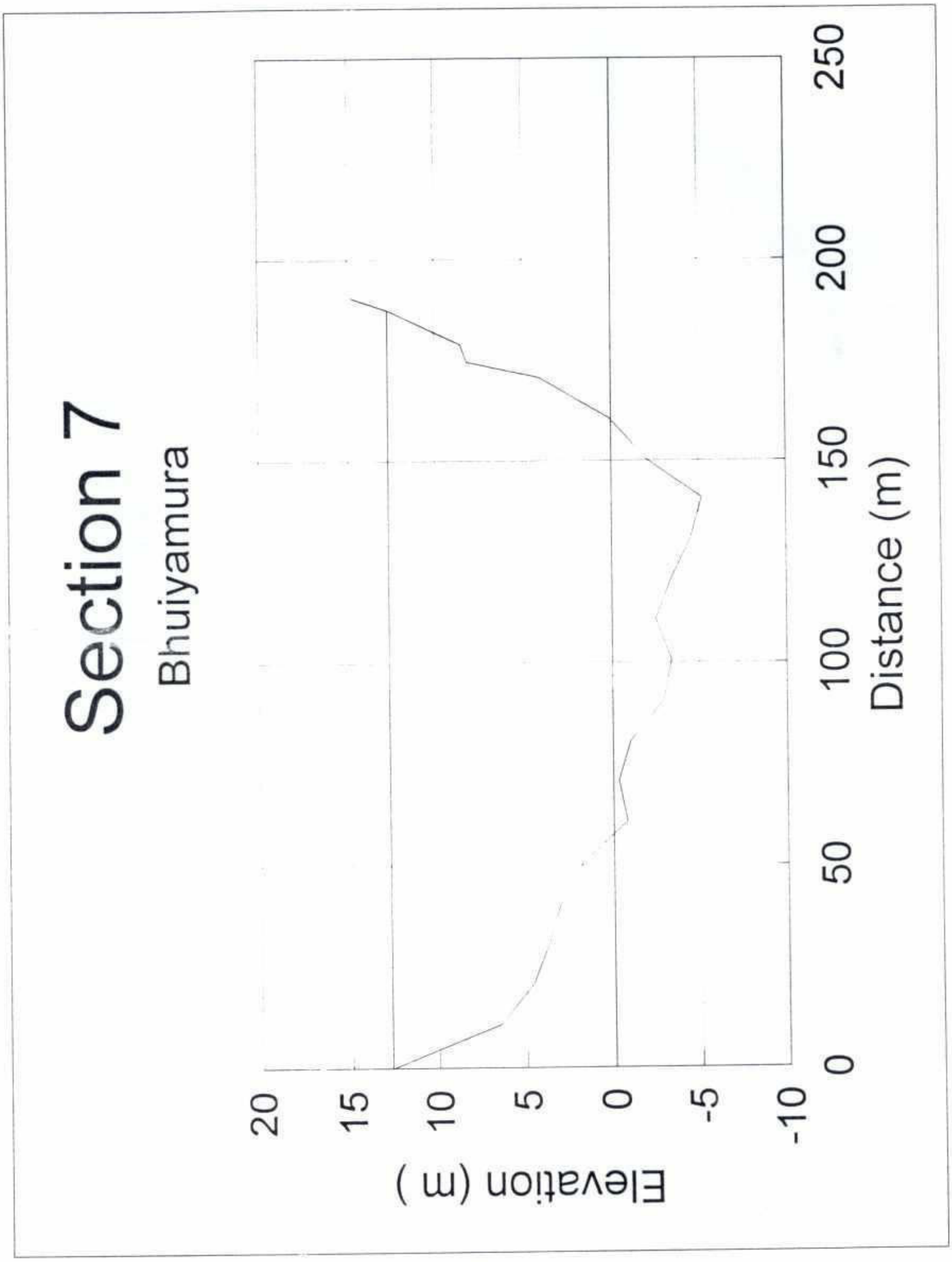

Section 6
Bhuiyamura
Elevation (m)
20
15
10
5
0
-5
0
50
100
150
200
250
Distance (m)

Figure 13:


Section 7
Bhuiyamura
Elevation (m)
20
15
10
5
0
-5
-10
Distance (m)
0
50
100
150
200
250

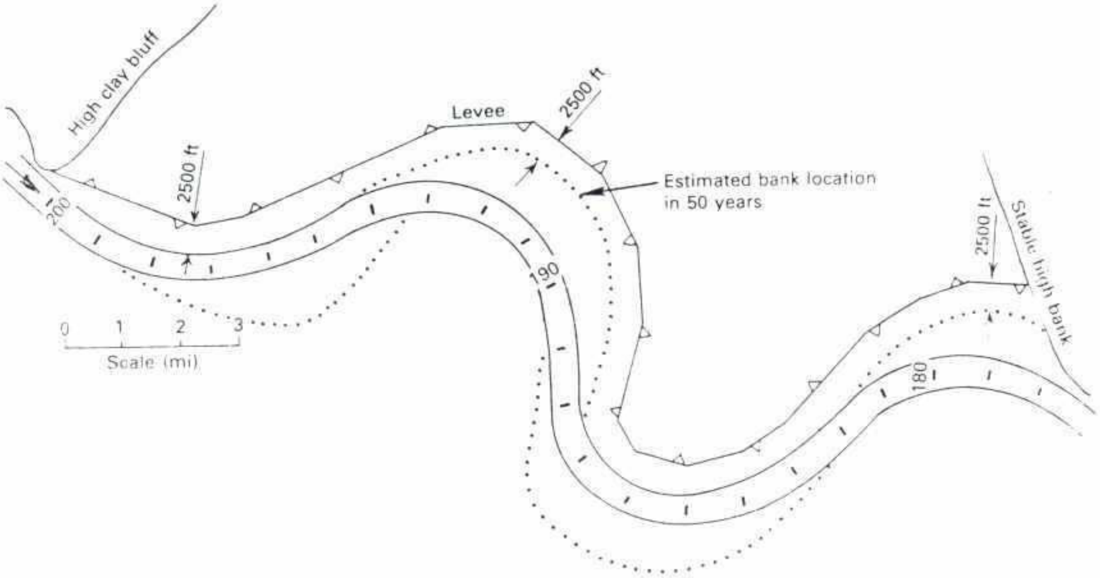


Figure 14: Providing Embankment Set-backs on a Meandering River (from Petersen, 1986)

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT

ANNEX C
ENGINEERING
APPENDIX C.5

REPORT ON GEOTECHNICAL INVESTIGATION WORKS AT THE PROPOSED ISSAPUR, SHAHEBNAGAR AND SHANTIPUR SITES FOR KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT

TABLE OF CONTENTS

REPORT

1. INTRODUCTION:

Messrs Subsoil Engineering & Construction Co. Ltd. was entrusted with the Geotechnical investigation works at *Ichapur, Shahebnagar and Shantipur* site for Kalni-Kushiyara River Improvement Project under Northeast Regional Project (Fap-6).

2. SCOPE OF WORK:

The scope of work is comprised of exploratory borings, in-situ testing, collection of disturbed soil samples, recording of River Water Level, laboratory tests, evaluation of test results and preparation of report.

3. FIELD WORKS:

Field works consists of exploratory borings, Standard Penetration Tests (SPT), collection of disturbed soil samples and recording of River Water Level.

3.1 Exploratory Borings:

A total of 5 nos. 100 mm.dia exploratory borings were performed at site for the proposed projects. The location of boring points are shown in the site plan attached in this report for reference. The name of location, Number and depth of borings performed at site have been furnished below:

3.2 Standard Penetration Test (SPT):

Standard Penetration Tests (SPT) have been executed in each bore hole at 1.0m intervals upto 5.0m depth below the existing ground level and 1.5m intervals upto the final depth of exploration (15.95 m).

The tests were made by using a split spoon of 50mm outer dia. and 35mm.inner dia.attached to the lower end of drill rod.A 63.50 Kg. hammer was allowed to fall freely from a height of 0.76m. on a socket attached to the drill rod. The blows of the hammer drove the spoon into the soil upto 45mm. The number of blows required for each 150mm.of penetration of spoon was recorded. The blows required for last 300mm of penetration of the spoon was entered into the bore chart as being the standard penetration test results. The disturbed samples collected in the spoon during the tests were kept in polythene bags and marked with bore hole number and blows recorded and stored in the godown of *M/S. SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD.*

3.3 Disturbed Soil Samples:

Disturbed soil samples were extracted at every 1.0m /1.5m intervals or at every change of strata and examine the changes in the colour and type of drill water returned with cutting of soil from the bore holes during operation.

Location	Boring number	Depth of boring performed
Ichapur	3	15.95 metre each
Shahebnagar	1	15.95 metre
Shantipur	1	15.95 metre

The boring holes were drilled by percussion method with the help of a manually operated rig and using a 125mm dia. casing pipe.The casing pipes were extended to the top of the deepest undisturbed sample. Seamless 50mm dia. m.s. drill rod in sections of 3.05m. length connected to each other by means of coupling with threaded joints were used for drilling. A chopping bit was attached to lower end of the drill rod and put to the bore hole fitted with the swivel head which was connected to the water pump through a high pressure hose pipe. When the pumping was started, water circulated through the swivel head into the drill rod and then to the soil through opening of the chopping bit under high pressure.

On the top of the swivel head manila rope was attached which passed through the pulley block of the tripod into the hand of the crawler who chopped up-down and rotated to disintegrate the soil. The disintegrated loose soil was thus forced out of the bore hole with circulation of water and the drilling was advanced to the desired elevation.

The samples were collected by means of split spoon sampler. This sampler was attached to the bottom of the drilling rod in place of the cutting bit and lowered into the hole at the desired depth. It was then driven into the soil upto a measured depth by means of hammering in a prescribed manner and then removed from the hole. The samples were then preserved in polythene bags, properly labelled and shifted to the laboratory for testing.

3.4 Ground Water Table (GWT):

The ground water table was recorded in each bore hole. Measurement for ground water table was taken after an overnight stabilization on completion of boring of that hole and followed by the another measurement after 24 hours.The last measurement was taken as final for ground water table and recorded.During this period, the bore hole was protected from any physical disturbance or caving. The recorded ground water table are shown on the bore logs attached in this report.

4. LABORATORY TESTS:

39 nos. of grainsize analysis have been performed in the soil testing laboratory tc determine the size of the soil grains and the percentage by weight of soil particles of different particle size comprising a soil sample. The process consists of either sieve analysis or hydrometer analysis or both. The percentage of sand, silt and clay of the testing samples have been furnished in the summary of test results for necessary utilization.

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5. ICHAPUR SITE

5.1 ENGINEERING PROPERTIES OF SOIL :

Investigation into the engineering properties of soil samples obtained from 3 nos. of bore holes drilled down to a maximum depth of 15.95m below the existing ground level indicates the following :

Hole No.	*RL in metre From*	*To*	*Strata encountered*	*Engineering properties of soil samples.*
1 (RL2.92M)	2.92	0.22	Clayey silt of soft consistency with trace fine sand.	N=3 to 4, Sand=4 to 8%, Silt = 77 to 79 % & Clay=15 to 17%.
	0.22	-2.08	Loose silt-sand deposit	N=9 to 10, Sand=44 to 49% & Silt=51 to 56%.
	-2.08	-4.88	Medium dense sand-silt deposit.	N=16 to 20, Sand=51 to 63% & Silt =37 to 49%.
	-4.88	-13.03	Medium dense to dense sand-silt deposit.	N=24 to 37, Sand=61 to 76% & Silt =24 to 39%.
2 (RL3.965M)	3.965	2.365	Clayey silt of soft consistency with little fine sand.	N= 4, Sand =17 %, Silt =70 % & Clay = 13 %.
	2.365	-1.035	Clayey silt of very soft consistency with little fine sand.	N=1 to 2, Sand=11 to 15%, Silt=71 to 72% & Clay = 14 to 17%.
	-1.035	-3.935	Loose silt-sand deposit with trace clay.	N=7 to 8,Sand= 10 %, Silt = 71 % & Clay = 19 %.
	-3.935	-11.985	Medium dense sand-silt deposit.	N=10 to24,Sand=71to80 Silt = 20 to 28% & Clay = 1%.
3 (RL4.23M)	4.23	1.73	Very loose silt-sand deposit with trace clay.	N= 2,Sand= 17 to 19%, Silt = 70 to 71 %, & Clay = 11 to 12%.
	1.73	-2.17	Clayey silt of very soft consistency.	N= 2,Sand= 1 to 6 % Silt= 75 to 81 % & Clay = 18 to 19%.
	-2.17	-4.77	Loose silt-sand deposit with trace clay.	N= 6 to 7,Sand=17 %, Silt=73% & Clay=10%.
	-4.77	-11.72	Medium dense to dense sand-silt deposit.	N=10 to 33, Sand=81 to 89% & Silt =11 to 19%.

M. C. Rudra

(MANIK CHANDRA RUDRA)
B. Sc. Engg. (Civil), MIEB.
Foundation & Structural Engineer

SUBSOIL ENGINEERING
& CONSTRUCTION CO. LTD.
DHAKA

client:- NORTHEAST REGIONAL PROJECT (FAP-6)
Project:- KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT
Site :- ICHAPUR SITE

Bore chart of Boring No. BH-1.

RL. 2·92 m. (PWD)

GROUND WATER LEVEL=RL.3·07m.(above)

DATE	REDUCED ELEVATION	DEPTH IN METRE	THICKNESS IN METRE	STRATA ENCOUNTERED	LOG	DIA. OF BORING	STANDARD PENETRATION TESTS BLOWS/0·305m. 10 20 30 40 50 60 70 80 90	REMARKS (G.W.T. SOIL SAMPLES) VANE SHEAR TESTS kg/cm²	SAMPLE
12 . 5 . 96			2·7	Light brown soft SILT with clay, trace fine sand		15·95 m., 0·10m. ∅ Percussion method	4	RL. 1·92m.	▨ D1
	0·22	2·7					3	" 0·92 "	▨ D2
			2·3	Grey loose fine sandy SILT			10	" (-)0·08 "	▨ D3
	(-)2·08	5·0					9	" (-)1·08 "	▨ D4
			2·8	Grey medium dense silty fine SAND			16	" (-)2·08 "	▨ D5
	(-)4·88	7·8					20	" (-)3·58 "	▨ D6
			8·15	Grey medium dense to dense fine SAND with silt			24	" (-)5·08 "	▨ D7
							30	" (-)6·58 "	▨ D8
							33	" (-)8·08 "	▨ D9
							34	" (-)9·58 "	▨ D10
							36	" (-)11·08 "	▨ D11
	(-)13·03	15·95					37	" (-)12·58 "	▨ D12

DISTURBED SAMPLE... ▨ UNDISTURBED SAMPLE... ■

DRN: A. Hashem DATE: 14 · 5 · 96 SCALE: 1:100 PLAN NO.

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SUBSOIL ENGINEERING
& CONSTRUCTION CO. LTD.
DHAKA

client:- NORTHEAST REGIONAL PROJECT(FAP-6)
Project:- KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT.
Site :- ICHAPUR SITE.

Bore chart of Boring No. BH-2.

RL.3·965m. (PWD)

DATE	REDUCED ELEVATION	DEPTH IN METRE	THICKNESS IN METRE	STRATA ENCOUNTERED	LOG	DIA. OF BORING	STANDARD PENETRATION TESTS BLOWS/0·305m. 10 20 30 40 50 60 70 80 90	REMARKS (G.W.T. SOIL SAMPLES) VANE SHEAR TESTS Kg/cm²	SAMPLE
11·5·96						15·95 m., 0·10m. ø Percussion method		▼RL.3·665m.	
	2·365	1·6	1·6	Light brown soft SILT with clay, little fine sand			4	RL.2·965 m.	▨ D1
			3·4	Grey very soft SILT with clay, little fine sand			1	" 1·965 "	▨ D2
							1	" 0·965 "	▨ D3
	(-) 1·035	5·0					2	"(-)0·035 "	▨ D4
			2·9	Grey loose SILT with fine sand, trace clay			7	"(-)1·035 "	▨ D5
	(-) 3·935	7·9					8	"(-)2·535 "	▨ D6
			8·05	Grey medium dense silty fine SAND			10	"(-)4·035 "	▨ D7
							13	"(-)5·535"	▨ D8
							17	"(-)7·035"	▨ D9
							19	"(-)8·535"	▨ D10
							22	"(-)10·035"	▨ D11
	(-) 11·985	15·95					24	"(-)11·535"	▨ D12

DISTURBED SAMPLE... ▨ UNDISTURBED SAMPLE... ■

DRN: A. Hashem DATE: 15·5·96 SCALE: 1:100 PLAN NO.

C 88

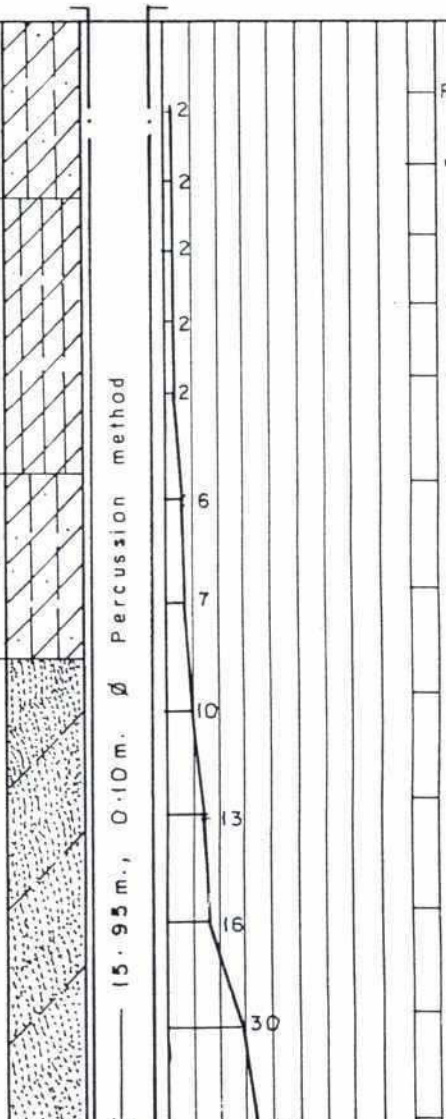
SUBSOIL ENGINEERING
& CONSTRUCTION CO. LTD.
DHAKA

client:- NORTHEAST REGIONAL PROJECT (FAP-6)
Project:- KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT
Site :- ICHAPUR SITE.

Bore chart of Boring No. BH-3.

RL. 4·23 m. (PWD)

DATE	REDUCED ELEVATION	DEPTH IN METRE	THICKNESS IN METRE	STRATA ENCOUNTERED	DIA. OF BORING
19 · 5 · 96	1·73	2·5	2·5	Grey very loose SILT with fine sand, trace clay	15·95 m., 0·10 m. ø Percussion method
	(–) 2·17	6·4	3·9	Grey very soft SILT with clay	
	(–) 4·77	9·0	2·6	Grey loose SILT with fine sand, trace clay	
	(–) 11·72	15·95	6·95	Grey medium dense to dense fine SAND with silt	



STANDARD PENETRATION TESTS BLOWS/0·305 m.	REMARKS (G.W.T. SOIL SAMPLES) VANE SHEAR TESTS kg/cm²	SAMPLE
	▼RL. 3·98 m.	
2	RL 3·23 m.	▨ D1
2	" 2·23 "	▨ D2
2	" 1·23 "	▨ D3
2	" 0·23 "	▨ D4
2	" (–)0·77 "	▨ D5
6	"(–)2·27 "	▨ D6
7	"(–)3·77 "	▨ D7
10	"(–)5·27 "	▨ D8
13	"(–)6·77 "	▨ D9
16	"(–)8·27 "	▨ D10
30	"(–)9·77 "	▨ D11
33	"(–)11·27 "	▨ D12

DISTURBED SAMPLE... ▨ UNDISTURBED SAMPLE... ■

DRN: A. Hashem DATE: 15 · 5 · 96 SCALE: 1:100 PLAN NO.

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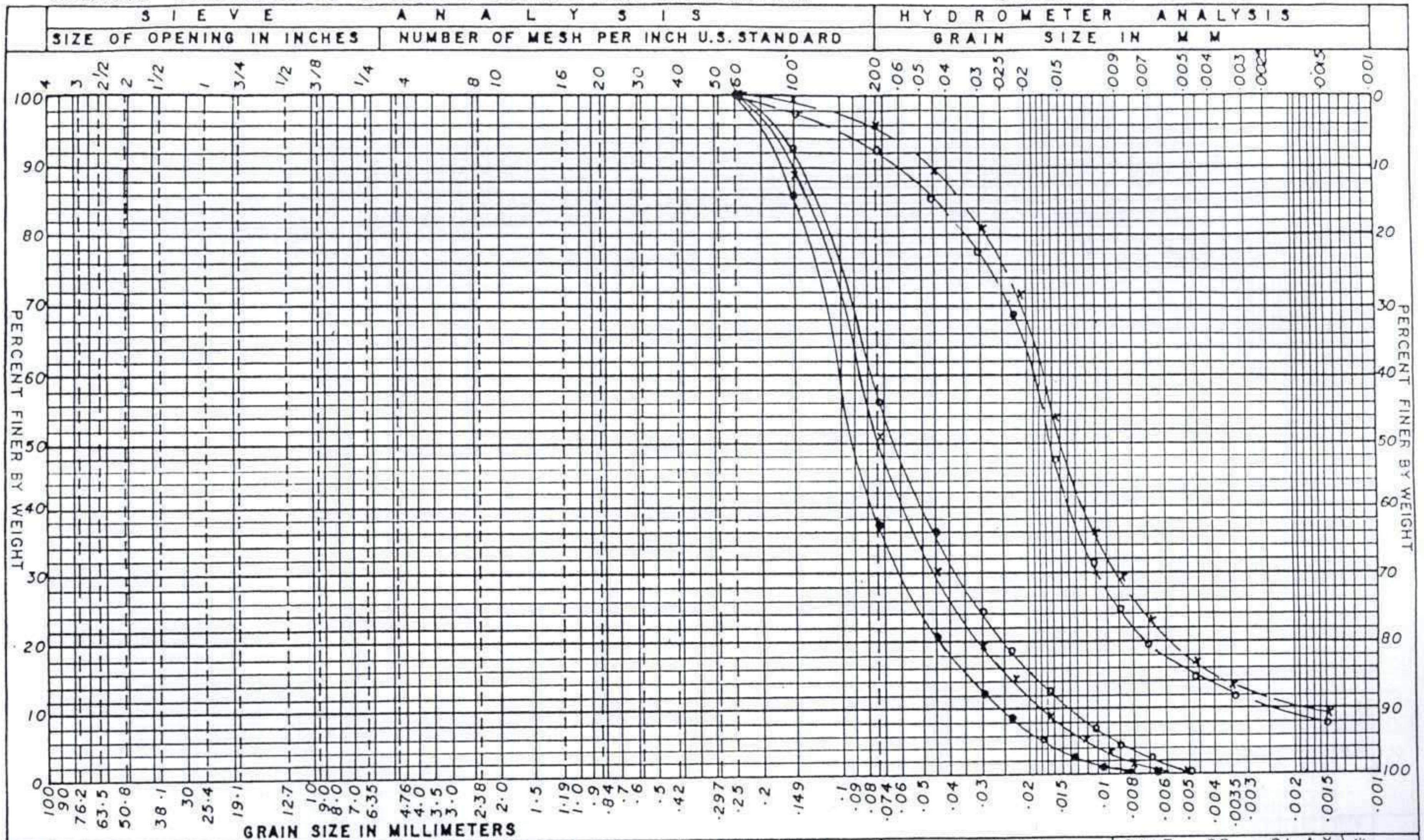
SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA. GRADATION CURVE



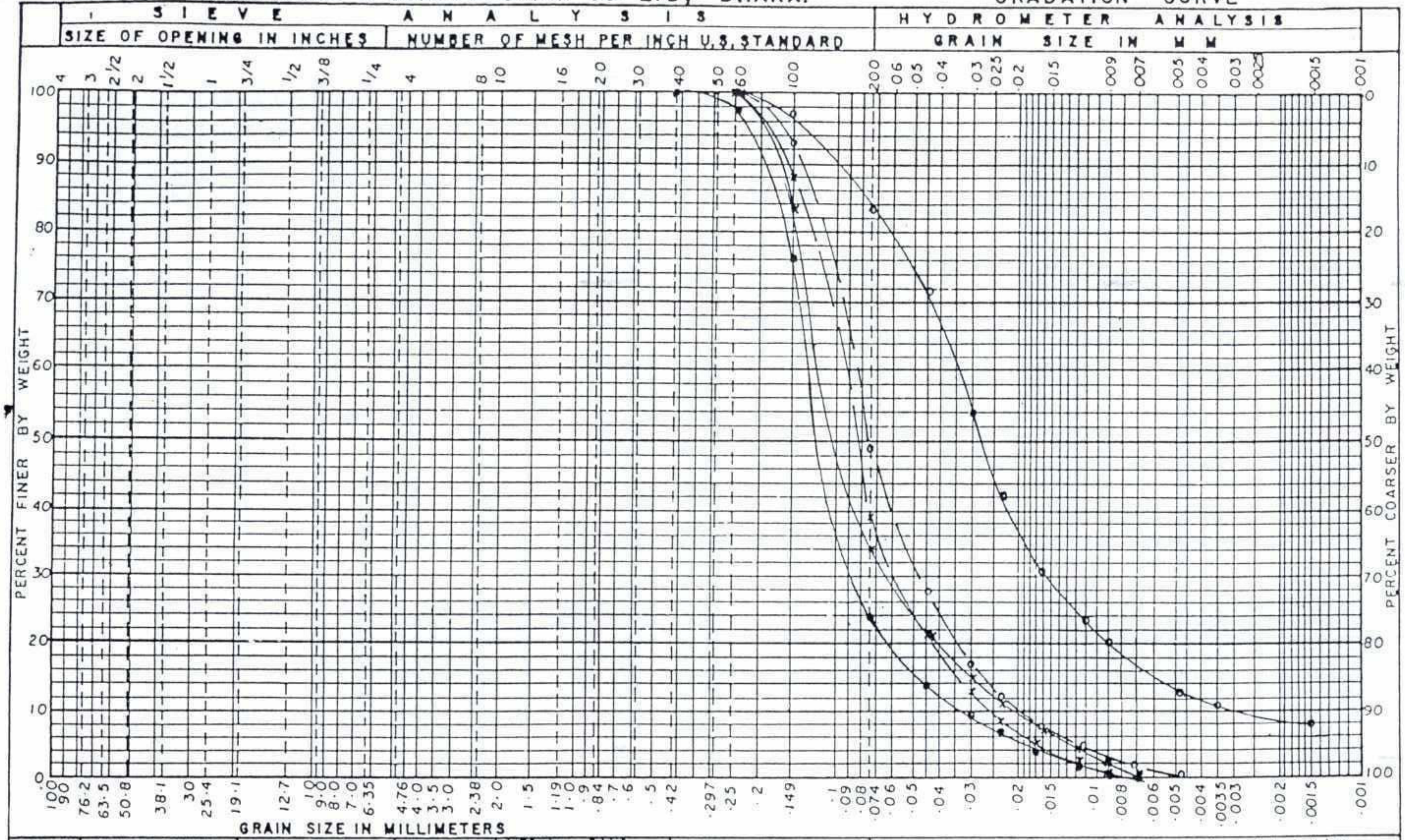
COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	FINES (SILT OR CLAY) *	
GRAVEL				COARSE SAND	FINE SAND	SILT	CLAY **

LOCATION	SYMB.	BORE	SAMP.	DEPTH IN RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
NORTHEAST REGIONAL PROJECT(FAP-6) KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT ICHAPUR SITE.	-o-o-o-	I.	D-1	1·92 to 1·47	SILT trace fine sand		8	77	15					
	-x-x-x-	"	D-2	0·92 to 0·47	——DO——		4	79	17					
	-o-o-o-	"	D-3	-0·08 to -0·53	SILT some fine sand		44	56	–					
	-×-×-×-	"	D-4	-1·08 to -1·53	——DO——		49	51	–					
	-●-●-●-	"	D-5	-2·08 to -2·53	FINE SAND some silt		63	37	–					

* Unified Soil Classification
** A.S.T.M. Soil Classification

DRN. DATE. PLAN No.

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD, DHAKA. GRADATION CURVE



COBBLES | COARSE GRAVEL | FINE GRAVEL | COARSE SAND | MEDIUM SAND | FINE SAND | FINES (SILT OR CLAY) *

GRAVEL | COARSE SAND | FINE SAND | SILT | CLAY **

LOCATION	SYMB.	BORE	SAMP.	Depth in RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
NORTHEAST REGIONAL PROJECT(FAP-6)	-o-o-o-	1	D-6	-3·58 to -4·03	FINE SAND some silt		51	49	—					
	-x-x-x-	"	D-7	-5·08 to -5·53	——— DO ———		61	39	—					
KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT.	-●-●-●-	"	D-8	-6·58 to -7·03	——— DO ———		76	24	—					
ICHAPUR SITE.	-x-*-*-	"	D-11	-11·08 to -11·53	——— DO ———		66	34	—					
	-o-o-o-	2	D-1	2·965 to 2·515	SILT ||||| fine sand		17	70	13					

* Unified Soil Classification
** A.S.T.M. Soil Classification

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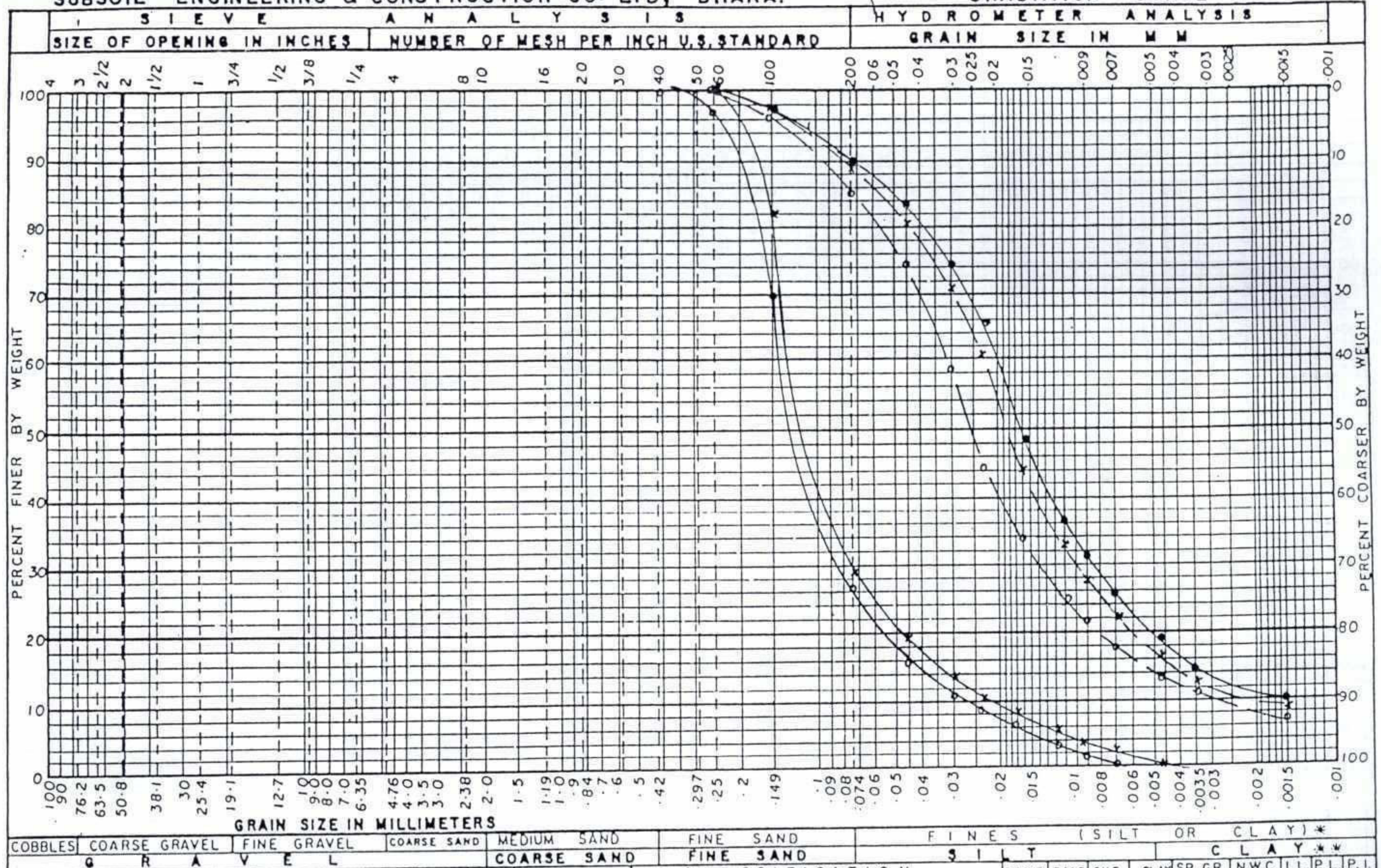
SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD, DHAKA. GRADATION CURVE

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD, DHAKA.

GRADATION CURVE

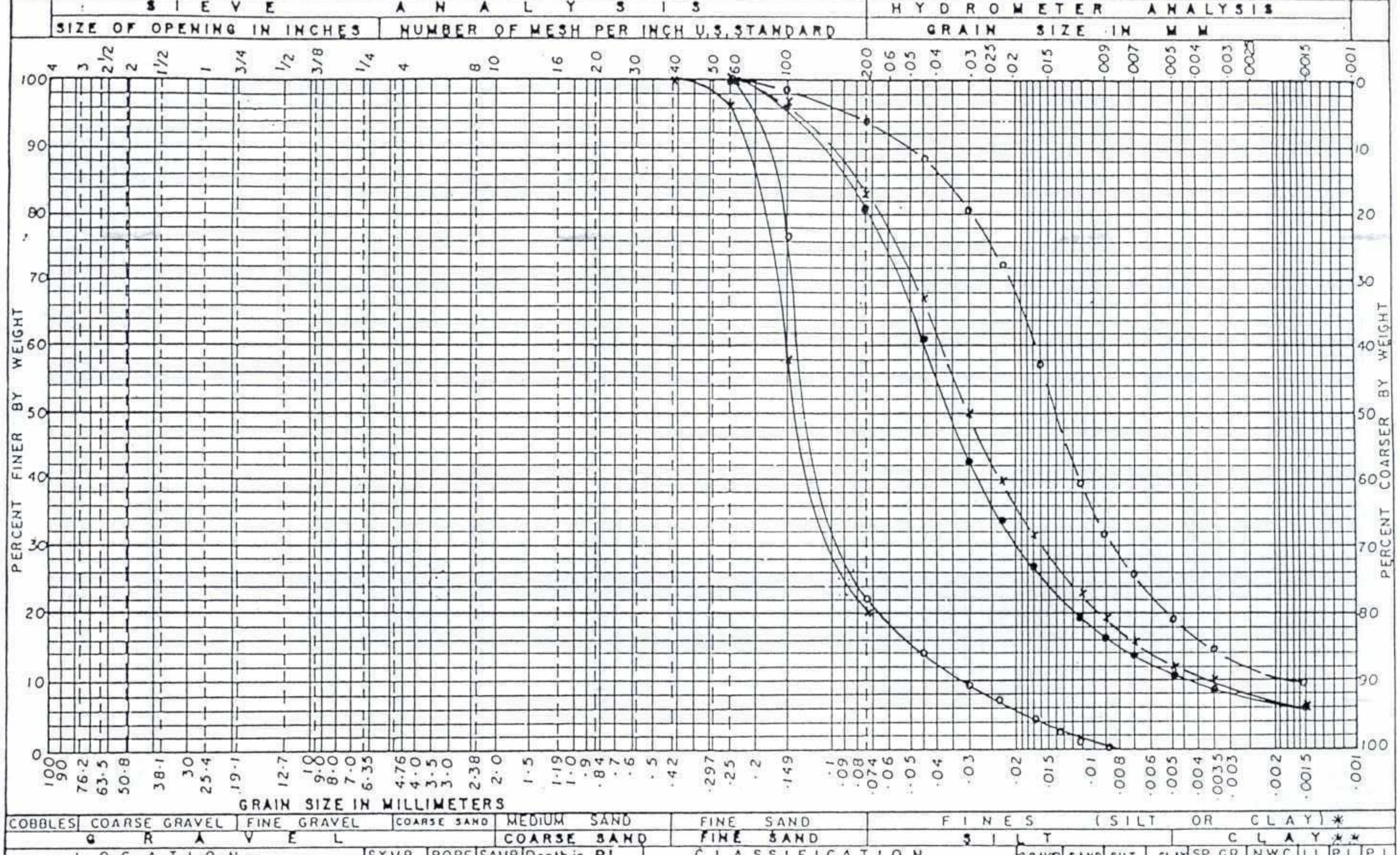


LOCATION	SYMB.	BORE	SAMP.	Depth in RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
	-o-o-o-	2	D-2	1·965 to 1·515	SILT little fine sand		15	71	14					
NORTHEAST REGIONAL PROJECT(FAP-6)	-x-x-x-	"	D-4	-0·035 to -0·485	——DO——		11	72	17					
KALNI-KUSHIYARA RIVER IMPROVEMENT	-●-●-●-	"	D-5	-1·035 to -1·485	——DO——		10	71	19					
PROJECT.	-*-*-*-	"	D-7	-4·035 to -4·485	FINE SAND some silt		71	28	1					
ICHAPUR SITE.	-o-o-o-	"	D-8	-5·535 to -5·985	——DO——		74	26	—					

* Unified Soil Classification
* * A.S.T.M. Soil Classification

DRN. DATE. PLAN No.

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD, DHAKA. GRADATION CURVE



LOCATION	SYMB.	BORE	SAMP.	Depth in RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
NORTHEAST REGIONAL PROJECT(FAP-6)	-o-o-o-	2	D-10	-8.535 to -8.985	FINE SAND some silt		78	22	—					
	-x-x-x-	"	D-11	-10.035 to -10.485	——DO——		80	20	—					
KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT.	-●-●-●-	3	D-1	3.23 to 2.78	SILT little fine sand		19	70	11					
ICHAPUR SITE.	-x-x-x-	"	D-2	2.23 to 1.78	——DO——		17	71	12					
	-o-o-o-	"	D-3	1.23 to 0.78	SILT trace fine sand		6	75	19					

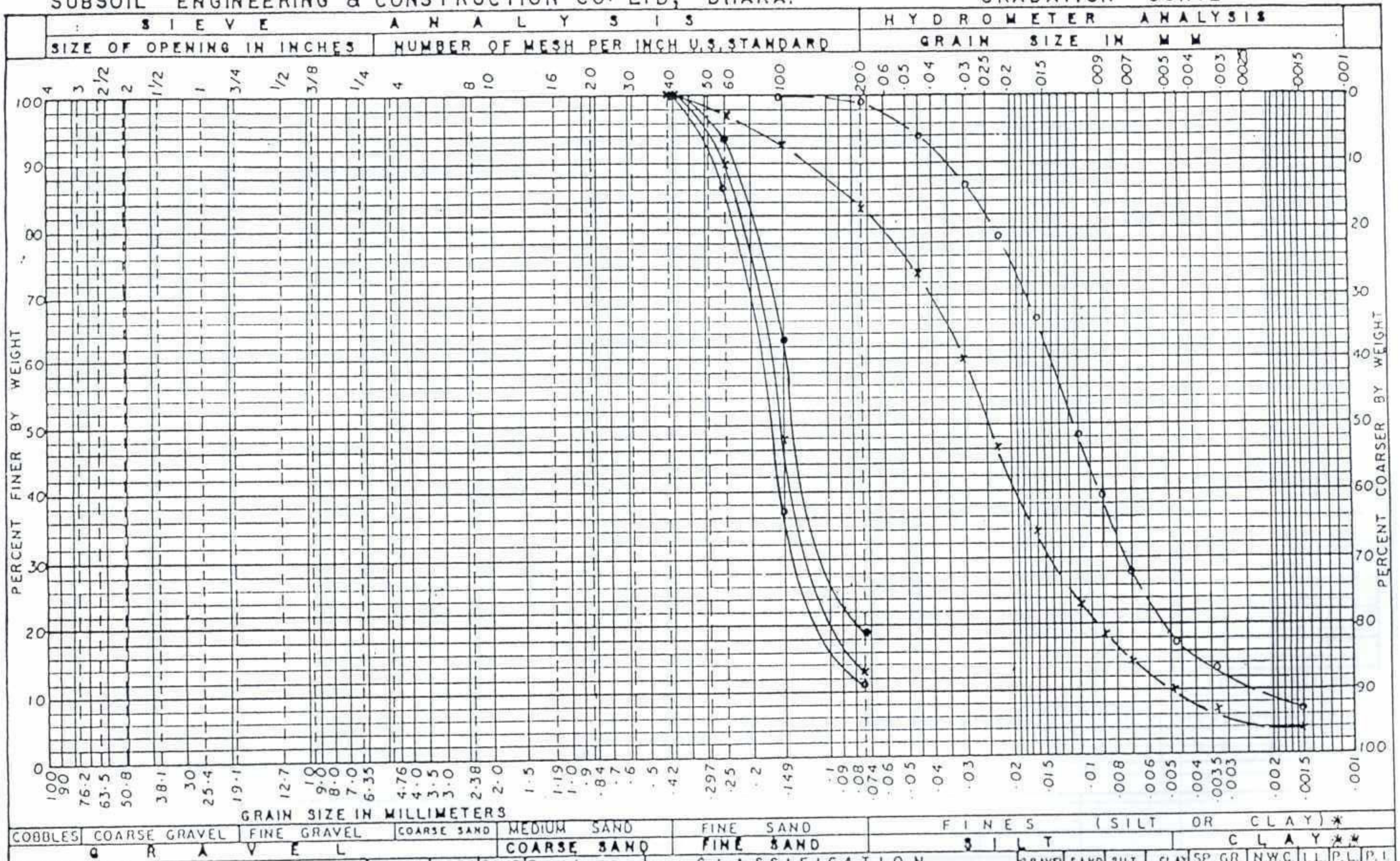
* Unified Soil Classification
** A.S.T.M. Soil Classification

DRN. DATE. PLAN No.

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD, DHAKA. GRADATION CURVE

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD, DHAKA.

GRADATION CURVE



LOCATION	SYMB.	BORE	SAMP.	Depth in RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
NORTHEAST REGIONAL PROJECT(FAP-6) KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT ICHAPUR SITE	-o-o-o-	3	D-5	-0.77 to -1.22	SILT trace fine sand		1	81	18					
	-x-x-x-	"	D-7	-3.77 to -4.22	SILT little fine sand		17	73	10					
	●-●-●	"	D-8	-5.27 to -5.72	FINE SAND little silt		81	19	—					
	✶-✶-✶	"	D-10	-8.27 to -8.72	——— DO ———		87	13	—					
	○-○-○	"	D-12	-11.27 to -11.72	——— DO ———		89	11	—					

* Unified Soil Classification
** A.S.T.M. Soil Classification

DRN.

DATE.

PLAN No.

SUB SOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA.	SUMMARY OF LABORATORY TEST RESULTS	Client : NORTHEAST REGIONAL PROJECT (FAP-6) Project : KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT. Site : ICHAPUR SITE.

Bore hole No.		BH-1								
Sample No.		D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-11
RL. in metre		1·92 to 1·47	0·92 to 0·47	−0·08 to −0·53	−1·08 to −1·53	−2·08 to −2·53	−3·58 to −4·03	−5·08 to −5·53	−6·58 to −7·03	−11·08 to −11·53
Natural moisture content (%)										
Specific gravity										
Atterberg limits	Liquid limit, LW									
	Plastic limit, PW									
Density	Wet (gm/cc)									
	Dry (gm/cc)									
Grain size analysis	Gravel (%)									
	Sand (%)	8	4	44	49	63	51	61	76	66
	Silt (%)	77	79	56	51	37	49	39	24	34
	Clay (%)	15	17	—	—	—	—	—	—	—
Consolidation tests	Natural void ratio, eo									
	Compression Index, Cc									
Unconfined Compression tests	Strain at failure (%)									
	Stress undist. (Kg/cm^2)									
	Stress remould. (Kg/cm^2)									
	Sensitivity									
Direct shear tests	Ø (degree)									
	C (kg/cm^2)									
Triaxial shear tests	Ø (degree)									
	C (kg/cm^2)									

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DRN. DATE. PLAN No.

SUB SOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA.	SUMMARY OF LABORATORY TEST RESULTS	Client :NORTHEAST REGIONAL PROJECT (FAP-6) Project :KALNI- KUSHIYARA RIVER IMPROVEMENT PROJECT Site : ICHAPUR SITE.

Bore hole No.		BH-2								BH-3	
Sample No.		D-1	D-2	D-4	D-5	D-7	D-8	D-10	D-11	D-1	D-2
RL. in metre		2·965 to 2·515	1·965 to 1·515	−0·035 to −0·485	−1·035 to −1·485	−4·035 to −4·485	−5·535 to −5·985	−8·535 to −8·985	−10·035 to −10·485	3·23 to 2·78	2·23 to 1·78
Natural moisture content (%)											
Specific gravity											
Atterberg limits	Liquid limit, LW										
	Plastic limit, PW										
Density	Wet (gm/cc)										
	Dry (gm/cc)										
Grain size analysis	Gravel (%)										
	Sand (%)	17	15	11	10	71	74	78	80	19	17
	Silt (%)	70	71	72	71	28	26	22	20	70	71
	Clay (%)	13	14	17	19	1	—	—	—	11	12
Consolidation tests	Natural void ratio, eo										
	Compression Index, Cc										
Unconfined Compression tests	Strain at failure (%)										
	Stress undist. (Kg/cm^2)										
	Stress remould. (Kg/cm^2)										
	Sensitivity										
Direct shear tests	Ø (degree)										
	C (kg/cm^2)										
Triaxial shear tests	Ø (degree)										
	C (kg/cm^2)										

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DRN. DATE. PLAN No.

SUB SOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA.	SUMMARY OF LABORATORY TEST RESULTS	Client : NORTHEAST REGIONAL PROJECT (FAP-6) Project: KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT. Site : ICHAPUR SITE.

Bore hole No.		BH-3					
Sample No.		D-3	D-5	D-7	D-8	D-10	D-12
RL. in metre		1·23 to 0·78	-0·77 to -1·22	-3·77 to -4·22	-5·27 to -5·72	-8·27 to -8·72	-11·27 to -11·72
Natural moisture content (%)							
Specific gravity							
Atterberg limits	Liquid limit, LW						
	Plastic limit, PW						
Density	Wet (gm/cc)						
	Dry (gm/cc)						
Grain size analysis	Gravel (%)						
	Sand (%)	6	1	17	81	87	89
	Silt (%)	75	81	73	19	13	11
	Clay (%)	19	18	10	–	–	–
Consolidation tests	Natural void ratio, eo						
	Compression Index, Cc						
Unconfined Compression tests	Strain at failure (%)						
	Stress undist. (Kg/cm²)						
	Stress remould. (Kg/cm²)						
	Sensitivity						
Direct shear tests	ø (degree)						
	C (kg/cm²)						
Triaxial shear tests	ø (degree)						
	C (kg/cm²)						

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DRN. DATE. PLAN No.

6. SHAHEBNAGAR SITE

6.1 *ENGINEERING PROPERTIES OF SOIL :*

*Investigation into the engineering properties of soil samples obtained from **Single** no. of bore hole drilled down to a maximum depth of **15.95m** below the existing ground level indicates the following :*

Hole No.	*RL in metre From*	*To*	*Strata encountered*	*Engineering properties of soil samples.*
4 (RL4.98M)	4.98	1.18	Clayey silt of soft to medium stiff consistency.	N=4 to 7,Sand=1 to 2%, Silt = 79 to 80 % & Clay = 18 to 20%.
	1.18	-1.00	Clayey silt of soft consistency.	N=4 , Sand= 4 %, Silt=79% & Clay=17%.
	-1.00	-10.97	Clayey silt of medium stiff consistency.	N=5 to 7, Sand=3 to 8% Silt = 77 to 84% & Clay = 12 to 18 %.

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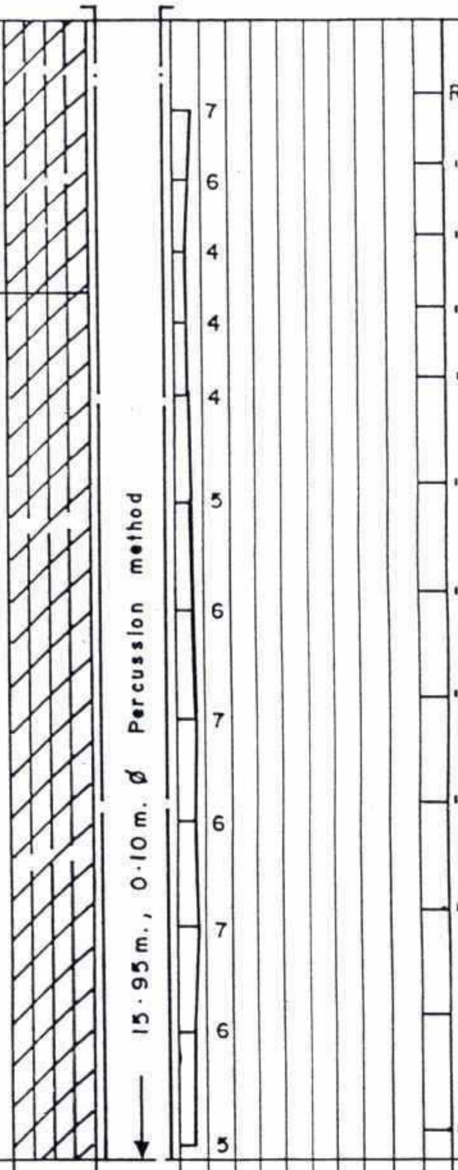
client:- NORTHEAST REGIONAL PROJECT (FAP-6)
Project:- KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT.
Site :- SHAHEBNAGAR SITE.

Bore chart of Boring No. BH-4.

RL. 4·980m. (PWD)

DATE	REDUCED ELEVATION	DEPTH IN METRE	THICKNESS IN METRE	STRATA ENCOUNTERED	DIA. OF BORING
8-5-96	1·18	3·8	3·8	Light brown soft to medium stiff SILT with clay	15·95m., 0·10 m. ø Percussion method
	(–) 10·97	15·95	12·15	Grey soft to medium stiff SILT with clay	

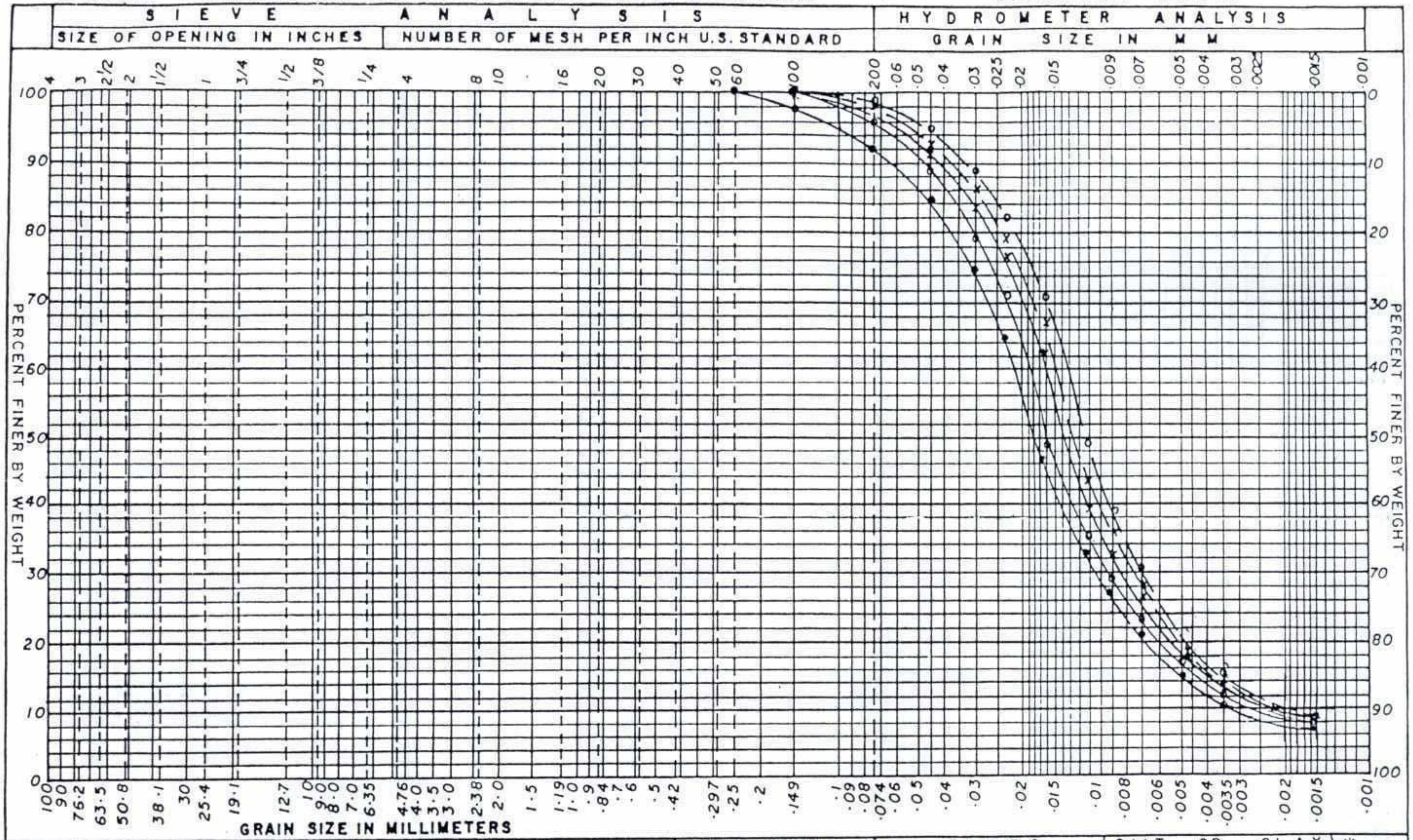


STANDARD PENETRATION TESTS BLOWS/0·305m.	REMARKS (G.W.T. SOIL SAMPLES) VANE SHEAR TESTS kg/cm²	SAMPLE
	▼RL. 4·63m.	
7	RL. 3·98 m.	▨ D1
6	" 2·98 "	▨ D2
4	" 1·98 "	▨ D3
4	" 0·98 "	▨ D4
4	"(–)0·02"	▨ D5
5	"(–) 1·52"	▨ D6
6	"(–)3·02"	▨ D7
7	"(–) 4·52"	▨ D8
6	"(–)6·02"	▨ D9
7	"(–)7·52"	▨ D10
6	"(–)9·02"	▨ D11
5	"(–)10·52"	▨ D12

DISTURBED SAMPLE... ▨ UNDISTURBED SAMPLE... ■

DRN: M. S. Ali. DATE: 15-5-96 SCALE: 1:100 PLAN NO.

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA. **GRADATION CURVE**



COBBLES | COARSE GRAVEL | FINE GRAVEL | COARSE SAND | MEDIUM SAND | FINE SAND | FINES (SILT OR CLAY) *

GRAVEL | COARSE SAND | FINE SAND | SILT | CLAY * *

LOCATION	SYMB.	BORE	SAMP.	DEPTH IN RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
NORTHEAST REGIONAL PROJECT(FAP-6)	-o-o-o-	4	D-1	3.98 to 3.53	SILT trace fine sand		1	79	20					
	-x-x-x-	"	D-3	1.98 to 1.53	——— DO ———		2	80	18					
KALNI-KUSHIYARA RIVER IMPROVEMENT PRØJECT	-•-•-•-	"	D-4	0.98 to 0.53	——— DO ———		4	79	17					
SHAHEBNAGAR SITE.	-*-*-*-	"	D-6	-1.52to-1.97	——— DO ———		3	79	18					
	-●-●-●-	"	D-8	-4.52to-4.97	——— DO ———		8	77	15					

* Unified Soil Classification
* * A.S.T.M. Soil Classification

DRN. DATE. PLAN No.

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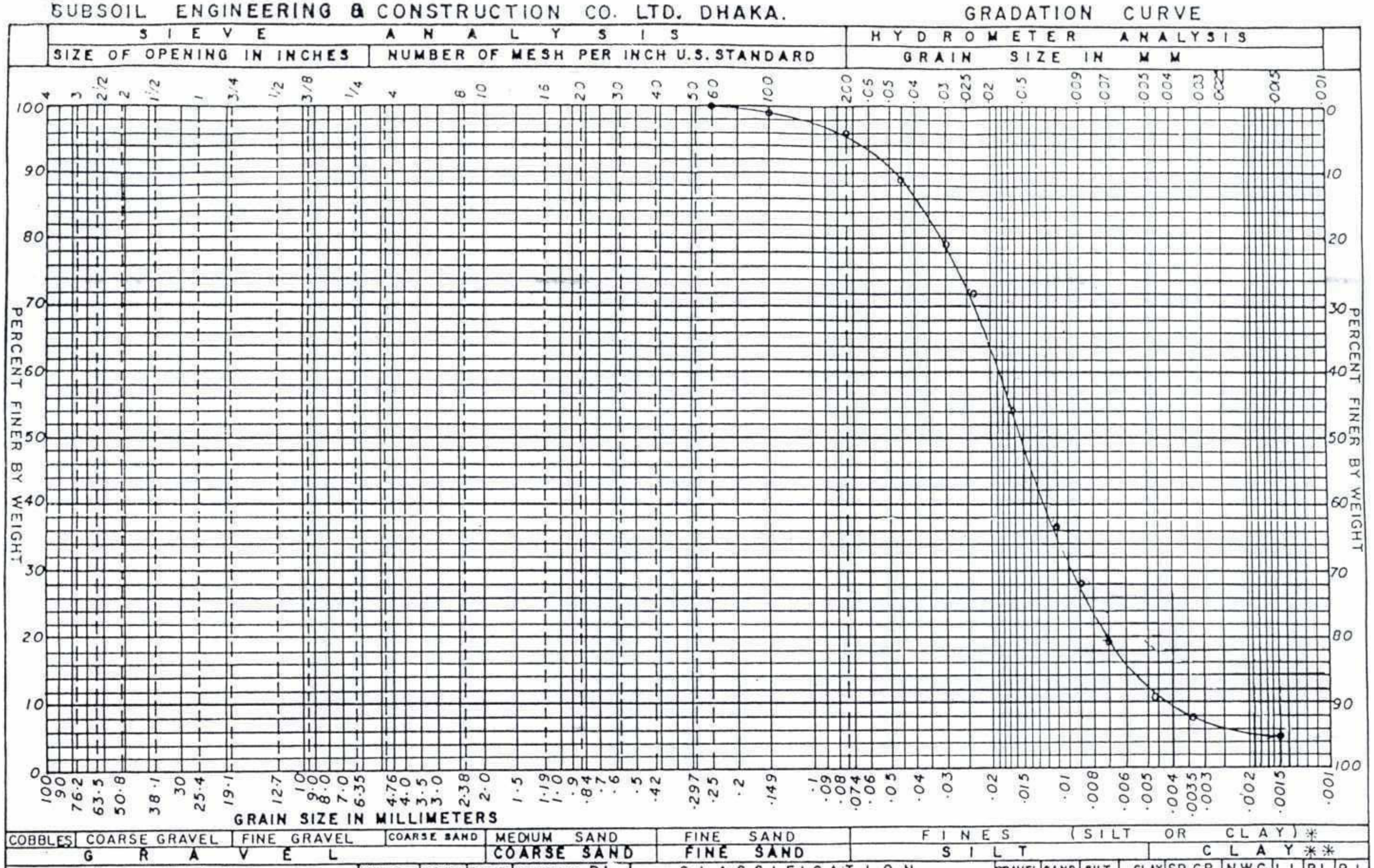
SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA. GRADATION CURVE



LOCATION	SYMB.	BORE	SAMP.	DEPTH IN RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
NORTHEAST REGIONAL PROJECT(FAP-6) KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT. SHAHEBNAGAR SITE	-o-o-o-	4	D-11	-9.02 to 9.47	SILT, trace fine sand		4	84	12·					

* Unified Soil Classification
** A.S.T.M. Soil Classification

DRN. DATE. PLAN No.

SUB SOIL ENGINEERING
& CONSTRUCTION CO. LTD.
DHAKA.

SUMMARY OF LABORATORY TEST RESULTS

Client : NORTHEAST REGIONA PROJECT (FAP-6)
Project: KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT.
Site : SHAHEBNAGAR SITE.

Bore hole No.		BH-4					
Sample No.		D-I	D-3	D-4	D-6	D-8	D-II
RL. in metre		3·98 to 3·53	1·98 to 1·53	0·98 to 0·53	−1·52 to −1·97	−4·52 to −4·97	−9·02 to −9·47
Natural moisture content (%)							
Specific gravity							
Atterberg limits	Liquid limit, LW						
	Plastic limit, PW						
Density	Wet (gm/cc)						
	Dry (gm/cc)						
Grain size analysis	Gravel (%)						
	Sand (%)	I	2	4	3	8	4
	Silt (%)	79	80	79	79	77	84
	Clay (%)	20	18	17	18	15	12
Consolidation tests	Natural void ratio, eo						
	Compression Index, Cc						
Unconfined Compression tests	Strain at failure (%)						
	Stress undist. (Kg/cm²)						
	Stress remould. (Kg/cm²)						
	Sensitivity						
Direct shear tests	Ø (degree)						
	C (kg/cm²)						
Triaxial shear tests	Ø (degree)						
	C (kg/cm²)						

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DRN. DATE. PLAN No.

7. SHANTIPUR SITE

7.1 ENGINEERING PROPERTIES OF SOIL :

*Investigation into the engineering properties of soil samples obtained from **Single** no. of bore hole drilled down to a maximum depth of 15.95m below the existing ground level indicates the following :*

Hole No.	*RL in metre From*	*To*	*Strata encountered .*	*Engineering properties of soil samples.*
5 (RL4.44M)	4.44	-0.56	Clayey silt of very soft consistency.	N=1 to 2,Sand=1 to 7%, Silt = 78 to 80 % & Clay = 15 to 19%.
	-0.56	-5.06	Clayey silt of soft to medium stiff consistency with trace fine sand.	N=3 to 5,Sand=2 to 13% Silt=72 to 82% & Clay=15 to 16 %.
	-5.06	-11.51	Loose to medium dense silt-sand deposit.	N=7 to 14,Sand=15 to 20%, Silt = 74 to 77% & Clay = 6 to 8 %.

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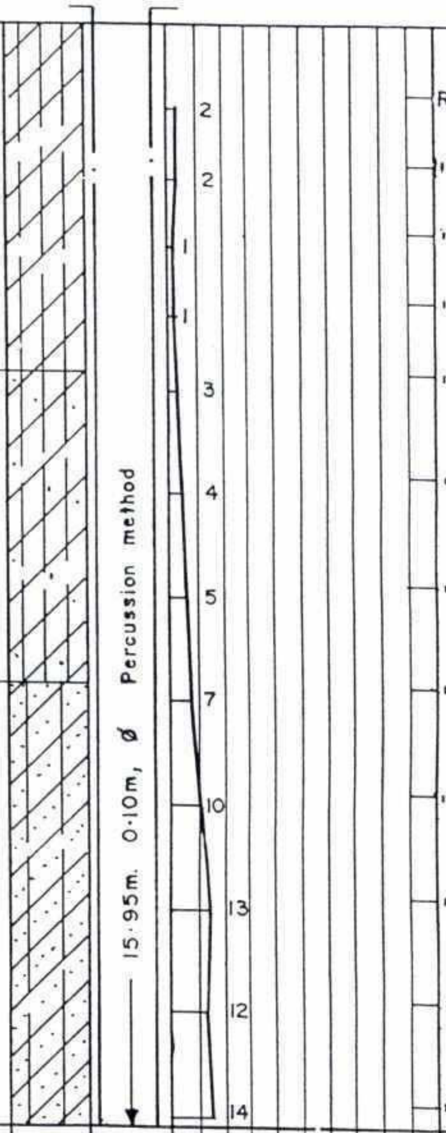
SUBSOIL ENGINEERING
& CONSTRUCTION CO. LTD.
DHAKA

client:- NORTHEAST REGIONAL PROJECT(FAP-6)
Project:-KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT.
Site :- SHANTIPUR SITE.

Bore chart of Boring No. BH-5

RL. 4.440 m. (PWD)



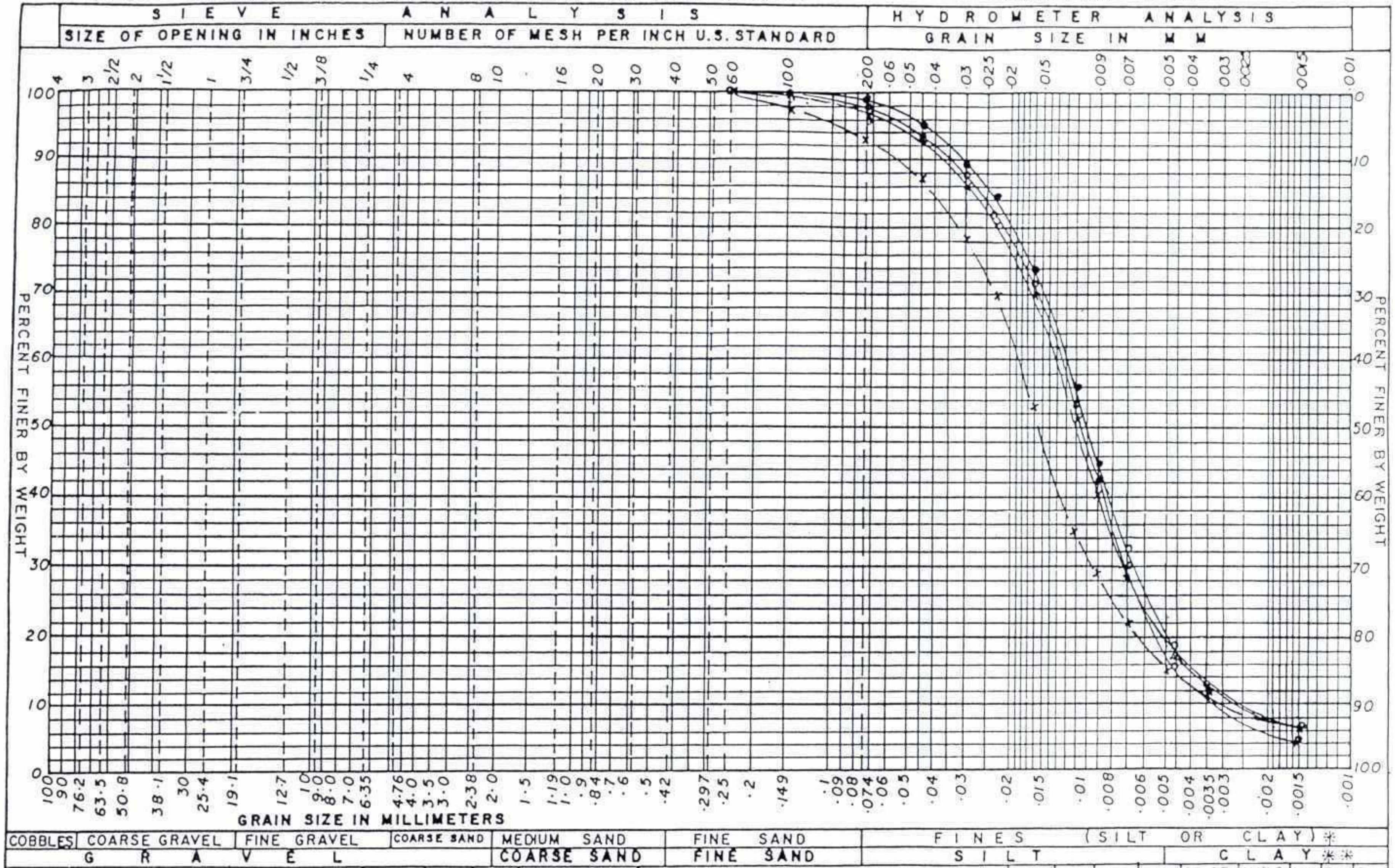
DATE	REDUCED ELEVATION	DEPTH IN METRE	THICKNESS IN METRE	STRATA ENCOUNTERED	DIA. OF BORING	STANDARD PENETRATION TESTS BLOWS/0.305 m.	REMARKS (G.W.T. SOIL SAMPLES) VANE SHEAR TESTS Kg/cm²	SAMPLE
(9 - 5 - 96)			5.0	Light brown very soft SILT with clay	15.95m. 0.10m, ø Percussion method		▼RL. 3.89 m.	
						2	RL. 3.44 m.	▨ D1
						2	" 2.44 "	▨ D2
						1	" 1.44 "	▨ D3
						1	" 0.44 "	▨ D4
	(−) 0.56	5.0						
			4.5	Grey soft to medium stiff SILT with clay, trace fine sand		3	"(−)0.56"	▨ D5
						4	"(−) 2.06"	▨ D6
						5	"(−) 3.56 "	▨ D7
	(−) 5.06	9.5						
			6.45	Grey loose to medium dense SILT with fine sand, trace clay		7	"(−)5.06"	▨ D8
						10	"(−) 6.56"	▨ D9
						13	"(−)8.06"	▨ D10
						12	"(−) 9.56"	▨ D11
	(−) 11.51	15.95				14	"(−)11.06"	▨ D12

DISTURBED SAMPLE... ▨ UNDISTURBED SAMPLE... ■

DRN: MAMOON DATE: 14-5-96 SCALE: 1:100 PLAN NO.

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA.

GRADATION CURVE



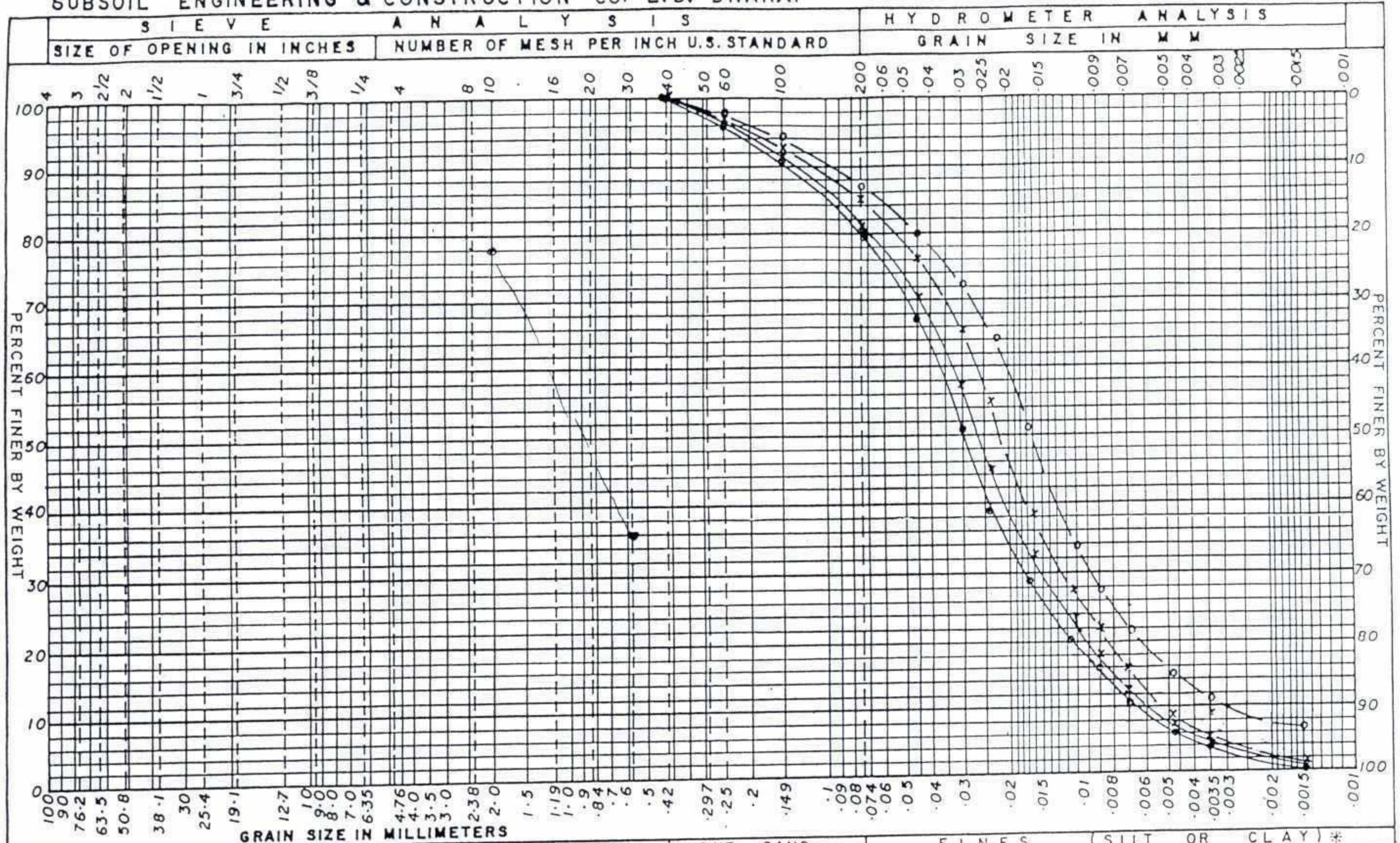
LOCATION	SYMB.	BORE	SAMP.	DEPTH IN RL.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
SHAHEBNAGAR														
NORTHEAST REGIONAL PROJECT (FAP-6)	-x-x-x-	5	D-1	3·44 to 2·99	SILT, trace fine sand		7	78	15					
KALNI-KUSHIYARA RIVER IMPROVEMENT	-●-●-●-	"	D-3	1·44 to 0·99	—:DO:—		1	80	19					
PROJECT SHANTIPUR SITE.	-x-x-x-	"	D-4	0·44 to -0·01	—:DO:—		3	79	18					
	-o-o-o-	"	D-5	-0·56 to -1·01	—:DO:—		2	82	16					

* Unified Soil Classification
** A.S.T.M. Soil Classification

DRN. DATE. PLAN No.

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DHAKA.

GRADATION CURVE



COBBLES | COARSE GRAVEL | FINE GRAVEL | COARSE SAND | MEDIUM SAND | FINE SAND | FINES (SILT OR CLAY) *

GRAVEL | COARSE SAND | FINE SAND | SILT | CLAY **

LOCATION	SYMB.	BORE	SAMP.	DEPTH IN R.L.	CLASSIFICATION	GRAVEL	SAND	SILT	CLAY	SP. GR.	N.W.C.	L.L.	P.L.	P.I.
	-o-o-o-	5	D-7	-3.56 to -4.01	SILT little fine sand		13	72	15					
NORTHEAST REGIONAL PROJECT (FAP-6)	-x-x-x-	"	D-8	-5.06 to -5.51	——— DO ———		15	77	8					
KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT	-●-●-●-	"	D-9	-6.56 to -7.01	——— DO ———		20	74	6					
SHANTIPUR SITE.	-✱-✱-✱-	"	D-11	-9.56 to -10.01	——— DO ———		19	74	7					

DRN. DATE. PLAN No.

* Unified Soil Classification
** A.S.T.M. Soil Classification

SUB SOIL ENGINEERING
& CONSTRUCTION CO. LTD.
DHAKA.

SUMMARY OF LABORATORY TEST RESULTS

Client : NORTHEAST REGIONAL PROJECT(FAP-6)
Project : KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT
Site : SHANTIPUR SITE.

Bore hole No.		BH-5							
Sample No.		D-1	D-3	D-4	D-5	D-7	D-8	D-9	D-11
RL. in metre		3·44 to 2·99	1·44 to 0·99	0·44 to -0·01	-0·56 to -1·01	-3·56 to -4·01	-5·06 to -5·51	-6·56 to -7·01	-9·56 to -10·01
Natural moisture content (%)									
Specific gravity									
Atterberg limits	Liquid limit, LW								
	Plastic limit, PW								
Density	Wet (gm/cc)								
	Dry (gm/cc)								
Grain size analysis	Gravel (%)								
	Sand (%)	7	1	3	2	13	15	20	19
	Silt (%)	78	80	79	82	72	77	74	74
	Clay (%)	15	19	18	16	15	8	6	7
Consolidation tests	Natural void ratio, eo								
	Compression Index, Cc								
Unconfined Compression tests	Strain at failure (%)								
	Stress undist. (Kg/cm^2)								
	Stress remould. (Kg/cm^2)								
	Sensitivity								
Direct shear tests	Ø (degree)								
	C (kg/cm^2)								
Triaxial shear tests	Ø (degree)								
	C (kg/cm^2)								

SUBSOIL ENGINEERING & CONSTRUCTION CO. LTD. DRN. DATE. PLAN No.