People's Republic of Bangladesh
Ministry of Water Resources

Flood Plan Coordination Organisation

BANGLADESH FLOOD ACTION PLAN

JAMALPUR PRIORITY PROJECT

Caisse Francaise de Developpement

PRELIMINARY CONTRACT

HYDROLOGICAL SURVEY

FINAL REPORT

Volume I : Main Report

MARCH 1995

Consortium

SOGREAH - HALCROW - EPC - AQUA

People's Republic of Bangladesh
Ministry of Water Resources

Flood Plan Coordination Organisation

BANGLADESH FLOOD ACTION PLAN

JAMALPUR PRIORITY PROJECT

Caisse Francaise de Developpement

PRELIMINARY CONTRACT

HYDROLOGICAL SURVEY

FINAL REPORT

Volume I : Main Report

MARCH 1995

Consortium

SOGREAH Ingenierie
Sir William Halcrow & Partners Limited
Engineering & Planning Consultants Ltd.
AQUA Consultants and Associates Ltd.

HALCROW
Consulting Engineers

Sir William Halcrow & Partners Ltd

Asia Pacific Region 1
Regional Office
House No 36, Road No 100
Gulshan, Dhaka 1212
Bangladesh
Telephone 606737, 884629, 889198
International Fax + 88 02 883663
Telex 642578 Halbd BJ

Head Office
Vineyard House, 44 Brook Green,
London W6 7BY, England
International Telephone +44 171 602 7282
International Fax +44 171 603 0095

Mr M H Siddiqi
Chief Engineer
Flood Plan Co-ordination Organization
Green Road
Dhaka

15 March 1995 Our ref API/JPD/CONF Your ref

Dear Mr Siddiqi

JAMALPUR PROJECT : PRELIMINARY CONTRACT
Final Report

We are pleased to enclose 25 copies of the final version of the Final Report following the completion of the hydrological data collection programme for the monsoon period in 1994 from June to October. This includes necessary revisions to accommodate the comments received by FPCO on the draft Final Report submitted on 19 December 1994.

Data were collected from a network of 25 gauge station installed at selected locations within the project area. These data together with the data collected in 1992 during the FAP 3.1 study and by FAP 25 in 1993 will be invaluable for the hydraulic studies in the forthcoming Main Study Phase.

We wish to acknowledge the co-operation and assistance received from FPCO and CFD in Dhaka for the Preliminary Contract activities.

Yours sincerely

V R Baghirathan
Regional Director
Sir William Halcrow & Partners Ltd
on behalf of
Sogreah-Halcrow-EPC-Aqua Consultants

cc: Mr Pin Yathey, CFD, Dhaka
Mr C Lavorel, Sogreah, France

encl.

JAMALPUR PROJECT

FINAL REPORT

Contents

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

BWDB	Bangladesh Water Development Board
CFD	Caisse Francaise de Developpement (formerly CCCE)
EIA	Environmental Impact Assessment
FAP	Flood Action Plan
FPCO	Flood Plan Coordination Organisation
TBM	Temporary Bench Mark
TOR	Terms of Reference

SUMMARY

The Jamalpur Project area covers about 180,000 hectares, including the associated char land areas. It is located on the left bank of the Jamuna river, and is bounded by the Jamuna on the west, the Old Brahmaputra river to the east and the Jamalpur-Jagannathganj railway line to the south.

A feasibility study for flood control/drainage and agriculture development of the project area was completed in February 1993 as a component of the Flood Action Plan (FAP 3.1). This study was financed by the Caisse Francaise de Developpement of France (CFD), the Commission of the European Communities (CEC) and the Government of Bangladesh. The Flood Plan Co-ordination Organisation (FPCO) was the Executing Agency.

To improve the limited hydraulic and hydrological data available for the project area, a network of stations was established during the FAP 3.1 study and data collected during the 1992 monsoon period. These data were used in developing and calibrating a hydraulic mathematical model based on MIKE 11 software, which was used for the study of different development options. However, the model schematisation and accuracy were affected by the limitations in the hydrological and topographic data available.

The hydrological data collection was continued during the 1993 monsoon season by FAP 25 who installed a network of 13 gauging stations. The data collected has enhanced the available data base of hydrological data.

Following an agreement between GOB and CFD/CEC to proceed with detailed studies of the Jamalpur Project area, a decision was taken to undertake a monsoon data collection programme under a Preliminary Contract by the Consortium comprising Sogreah-Halcrow-Aqua-EPC. The programme was undertaken with FPCO as the Executing Agency. The main objectives of this assignment were as follows:

1. Establish a network of 25 hydrological stations for monitoring monsoon water level data (including at the 13 locations used by FAP 25 in 1993).

2. Undertake discharge measurements at 8 selected stations.

3. Prepare specified reports describing the data collection and basic analysis of the data.

The location of the stations were selected according to the requirements of future hydraulic studies and based on available topographical mapping and field surveys. The latest 1:20,000 FINNMAPS were also used together with available satellite images. The stations were established during May/June 1994 and field data collection continued up to end October. Levelling surveys were carried out for each station and TBM's established which were tied to FINNMAP bench marks.

This is the Final Report which describes the data collection and includes appendices of all data collected. These data and those collected during 1992 and 1993 will be used in the hydraulic studies under the forthcoming Main Study programme, including the development of a Flood Management Model for the project area.

The report includes an analysis and an interpretation of the data collected during 1994. Discharge rating curves were developed using data collected for the 3-year period 1992-94. Water levels and discharges were significantly lower than average and rainfall data obtained from 3 stations within the project area confirm that the monsoon was relatively dry. The monsoon water levels observed in the Jamuna and in the Old Brahmaputra are the lowest since observations began.

1. INTRODUCTION

1.1 Background

The disastrous 1987 and 1988 floods in Bangladesh raised considerable international interest in helping the country to find a long term plan and permanent solution to its flood problem. As a result the Flood Action Plan (FAP) was prepared which consists of regional and project oriented studies throughout the country. On a priority basis the Jamalpur Project was taken as the first project in the Flood Action Plan for feasibility study with wide range of disciplines to achieve an integrated development adopting required flood protection and drainage improvement works in the area.

The feasibility study of the Jamalpur Project was financed by the Caisse Francaise de Developpement (CFD), the Commission of the European Communities (CEC) jointly, with France taking the lead, and the Government of Bangladesh. The Flood Plan Co-ordination Organization (FPCO) was the executing agency. This first phase of the study was completed in February 1993, by submission of the final report. Location of the project area is shown in Figure-1.

During the first phase of the Jamalpur Priority Project Study which was completed in February 1993, a hydrodynamic mathematical model of the study area was constructed, based on MIKE-11 software, using only the data available at that time, which includes :

- topographical cross-sections and longitudinal profiles of the principal rivers, roads and embankments within the area,
- hydrological surveys (seven water level and four discharge measuring points) during the 1992 monsoon period,
- BWDB contour map (scale 4 inches to a mile) was used to obtain the area-elevation-storage curves for the various cells (compartments).

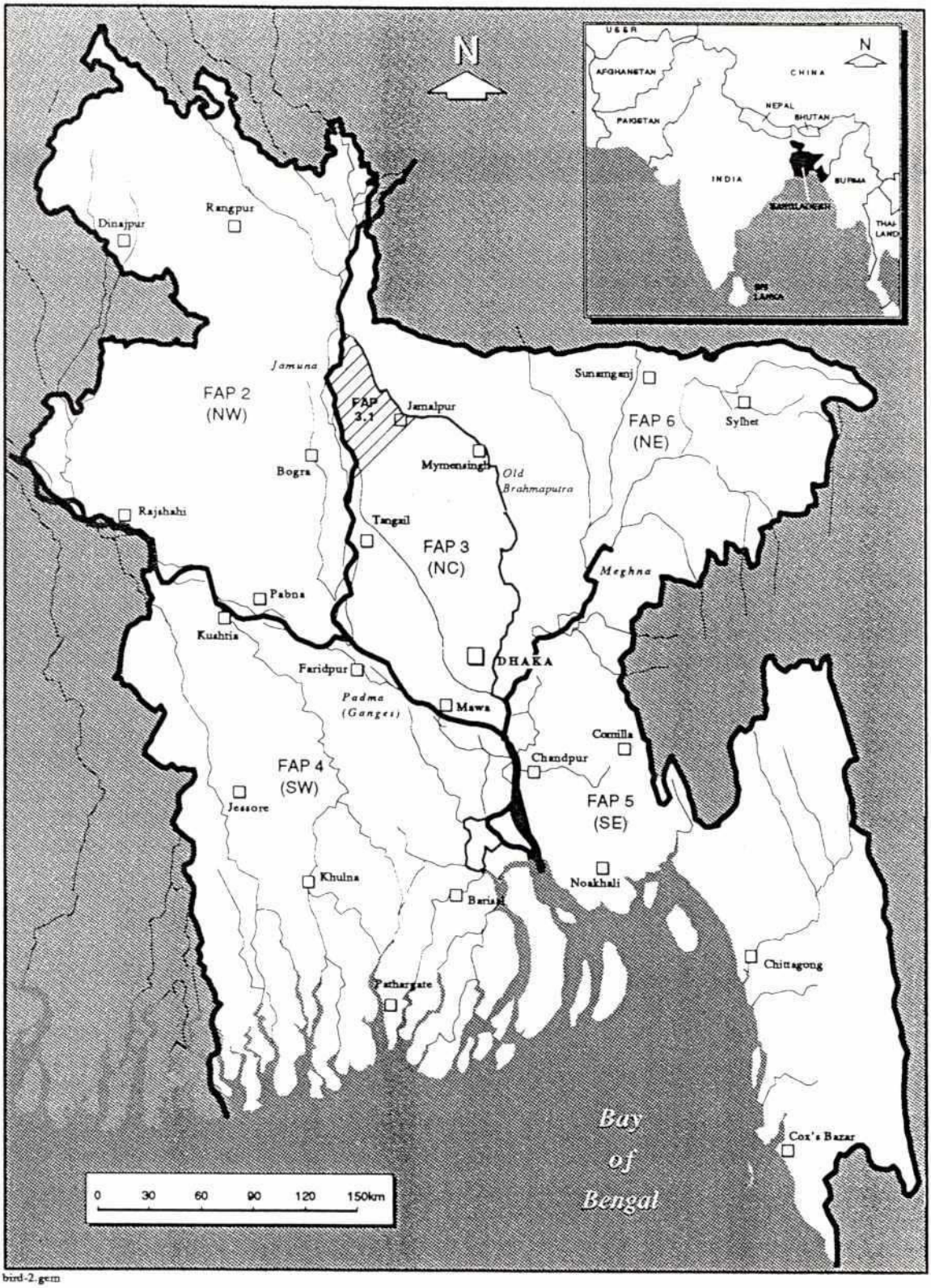
The aim of the previous mathematical model was to show the effects of different development scenarios, in terms of water level and discharges in the hydrographic network, flow rates through structures were studied at preliminary design level and water management procedures. But with the lack or the bad quality of available data, it was essential to interpret the simulation results with caution. Results were interpreted as only relative (and not absolute) values, between "with" and "without" project scenarios. Model accuracy was not sufficient for detailed design studies.

The second phase of the study is expected to commence shortly. It would comprise two components:

- Firm tranche :
  People's consultation, Environmental Impact Assessment (EIA) and Project refinement,
- Conditional tranche :
  Detailed planning and design studies.

During the firm tranche, a new mathematical model will be constructed on the basis of the new MIKE-11 GIS-ARC INFO software (which supports graphical representation like area-

LOCATION MAP



bird-2.gem

elevation curve, river network etc. of MIKE 11) which was recently developed by FAP-25 (Flood Management Model).

The following additional data which are now available :

- FINNMAP, the photo map of the Flood Action Plan area with contours in 1:20,000 scale

- 1993 hydrological surveys data (13 gauge stations were installed in the Jamalpur Project area by FAP-25/FMM)

To enhance these data and to establish a satisfactory data set for the forthcoming studies including the FMM development, a hydrological survey was carried out during 1994 monsoon. This was undertaken via a Preliminary Contract between CFD and the SOGREAH-HALCROW-AQUA-EPC consortium with FPCO as the executing agency.

1.2 Physical Description of Jamalpur Project area

The Jamalpur Project area comprising the mainland and char lands (attached & island) covers about 180,000 hectares shown in Figure-2.

It is located on the left bank of the Jamuna river and is bounded by the Jamuna to the west, the Old Brahmaputra river to the east and the Jamalpur-Jagannathganj ghat railway line to the south. The project area itself is crossed by two main water courses flowing southward. In the west the Chatal a distributary of the Jamuna and in the east the Jhenai a distributary of the Old Brahmaputra. A small part of the Jhenai flows joins the upper Bangsi and the other part flows to the south through the Bausi Railway Bridge (Figure-2). Both water course are seasonal and become almost dry during the winter season. In addition to these two main rivers, there also exists several roads and embankments which divides the area is covered with a dense network of little rivers, khals and beels.

The main part of the area goes under flood each monsoon by both rainfall and inflow from Jamuna and Old Brahmaputra through distributaries.

1.3 Project Scope

The main objective of the Preliminary Contract is the collection of additional hydrological data to calibrate the mathematical model to be used to evaluate the influence of the structures projected on the hydraulic regime of the area and to specify the size of these structures, by the installation of a selected network of gauging stations during the 1994 monsoon period within the project area.

The construction and operation of a mathematical model has three distinct phases :

- The construction phase : during which the topology of the flow is described and illustrated in diagram form. Topographical data such as cross sections, area - elevation - storage curves, particular structures etc. are introduced into the model. The data required come from maps (FINNMAP) and specific field surveys. No hydraulic data are used at this stage.

- The calibration phase : during which hydraulic simulations are carried out to reconstruct the hydraulic events observed as accurately as possible. The model is calibrated by empirically modifying the roughness coefficients. At this stage, the topological diagram can be modified as a function of the results obtained. This is the stage where the hydrological surveys are used. The methodology consists in simulating the whole hydraulic regime of a measurement campaign in order to come as close as possible to the levels and discharges observed. The more hydrological information is available, the better calibration will be and thus the greater the reliability of the model.

  For the future model, only a few data taken during the 1992 and 1993 monsoons were available. It was therefore very important to collect 1994 information.

- The operation phase : consists of carrying out simulations in order to evaluate the influence of constructing new structures on water levels, discharges and flooded areas.

However, it should be stressed that the 1994 monsoon was abnormally dry and from this point of view, the data collected cannot be used to calibrate the high flood levels reliably, but the 1993 data were more typical for a wet year and will also be used for calibration purposes.

The project scope from the Preliminary Contract are as follows :

- re-installation of 13 nos. of water level gauge stations at the same locations as in 1993 monsoon.

- additional 12 nos. of water level gauge stations to be installed at new locations (which merits) within the project area.

- discharge measurements from 8 locations (selected from the above 25 WL stations).

- at each gauge station a Temporary Bench Mark (TBM) to be established with reference to FINNMAP bench marks and connected to PWD datum and the accuracy of levelling checked with maximum closure errors (mm)$< 12\sqrt{K}$.

- monitoring of water level gauges at selected sites throughout the monsoon i.e. from June to October.

- execution of fortnightly discharge measurements at selected sites during the months of July, August and September.

- Preparation of following reports describing the data collection :
  - Inception report (following installation of stations)
  - Interim report (end of discharge measurement)
  - Final report (end of survey)

2. WATER LEVEL AND DISCHARGE STATION INSTALLATION

2.1 Selection of station network

The selection of locations of the additional 12 nos. water level gauge stations and 8 nos. discharge measurement stations was done mainly on the basis of obtaining data in areas where data is currently lacking and where the hydraulic drainage network merits the collection of additional data. This assessment was made with the experience gained from the modelling undertaken during the earlier feasibility study and also allowed for the requirements of the proposed FMM modelling study.

The location of all gauge stations were established by means of a Global Positioning System (GPS). The locations of all gauge stations are shown in Figure-2.

The gauge stations locations were initially identified using available mapping including the new 1:20,000 FINNMAP and Satellite images. The final locations were confirmed by field visits undertaken during May and June 1994.

The main reasons supporting the choice of stations are given in Table-1.

2.2 Installation of water level gauge station

2.2.1. Installation of gauge stations

The installation of the gauge stations were carried out on sub-contract by Hydroland Survey Ltd of Bangladesh. The same firm was responsible for the installation and data collection undertaken by FAP 25 in 1993.

All water level gauge stations have been installed according to BWDB standards as noted in the Preliminary Contract. The gauge posts were affixed to a suitable wooden post to which steel angles on two corner were affixed. The post and angles were driven into firm ground for a depth not less than 1.50 meter. The post were driven upright so that the gauge zero clearly visible. At each gauge station a Temporary Bench Mark (TBM) has been established with reference to FINNMAP bench mark and connected to PWD datum.

In general, a gauge station required 2 or 3 gauge posts depending on the variation between the high and low water levels during the monsoon period. Each gauge is 3 meters long. The gauge stations were sited such that observations can be made easily from the river bank.

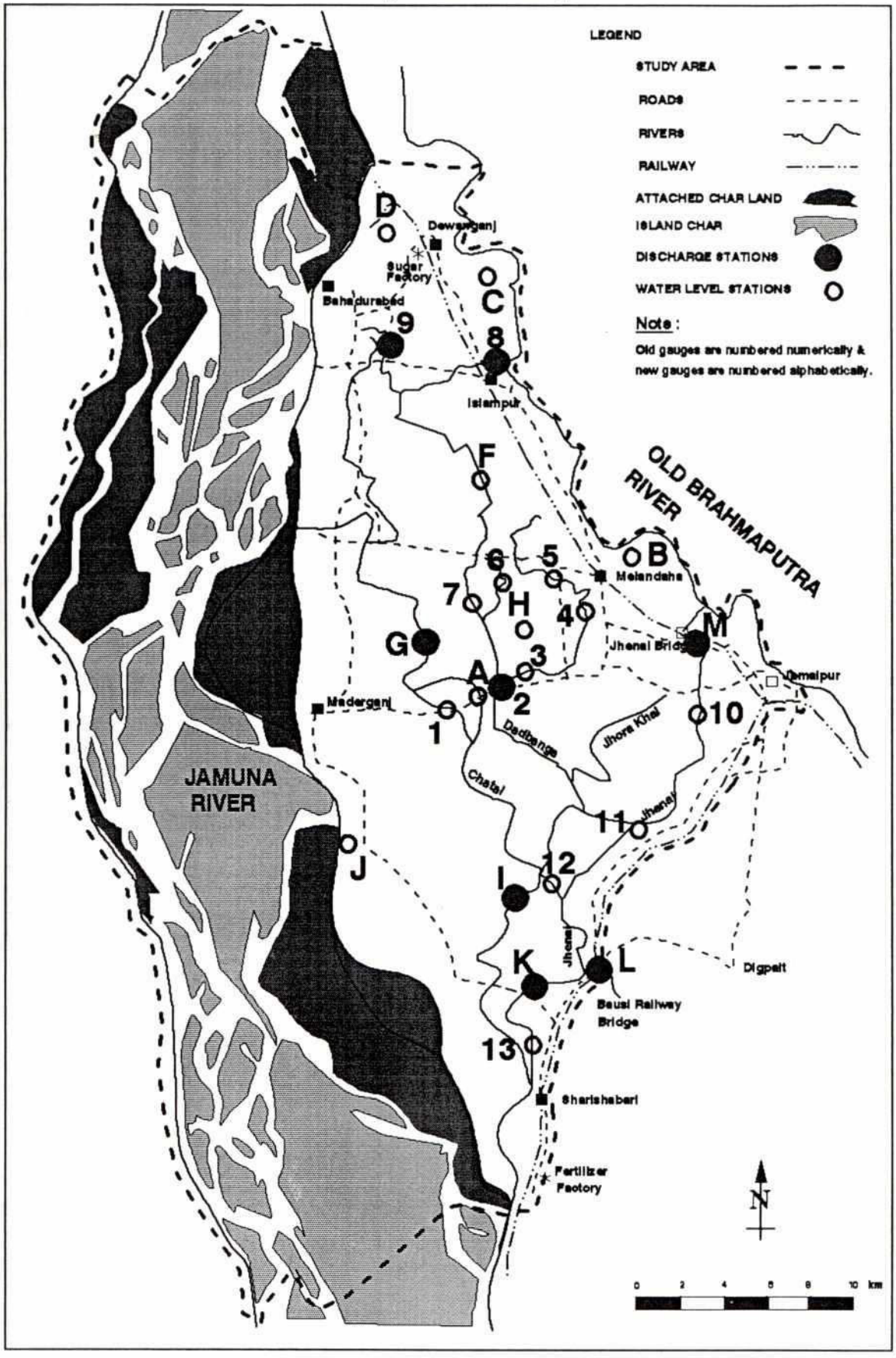
All gauge stations have been located by GPS, and their locations marked on topographic map at a scale 1:50,000 and on a sketch map showing surrounding details. These maps are included in Appendices A and B respectively. Color photographs of all the gauge stations are also presented in Appendix-A.

2.2.2 Levelling of gauge stations

Gauge levelling for all the 25 gauge stations was undertaken by survey teams of Hydroland Survey Ltd under the supervision of the Consultants. All TBM's established for the 1993 gauge stations were located and have been used again for this study.

Figure 2

Project Area Map



Jamalpur Project

Table 1

MAIN REASONS OF SELECTING LOCATIONS OF NEW GAUGE STATIONS

No of gauge station	Name of gauge station	River name	1994 Discharge measur.	Justification for selection of stations
A	Belamari	Chatal (East branch)	No	WL and discharge measurements were made in 1992 but not in 1993
B	Tupkar char	Old Brahmaputra	No	To observe the water level upstream of Jhenai inflow
C	Putdanga Rly. Br.	Branch of Old Brahm.	No	To observe quantum of inflow at that site
D	Bahadur Rly. Br.	Beel (connect Jamuna)	No	Lack of WL data in this area for the previous model
F	Khudur Kanda	Datbhanga	No	Lack of WL data in this area for the previous model
G	Mahishbatan	Chatal	Yes	1992 discharge measurements on gauges 1 and A were influenced by backwater effects. New location to minimize these effects
H	Naoghata Bridge	Satkuri beel	No	To observe drainage condition of of this area
I	Char Vatiani	Chatal Khal	Yes	To observe rate of outflow
J	Char Jorkhali	Jamuna	No	To observe Jamuna WL
K	Helenchabari	Chatal south	Yes	To observe outflow at the site of proposed structure at this location
L	Bausi Rly. bridge	Jhenai	Yes	To observe rate of outflow
M	Jhenai Rly. Bridge	Jhenai	Yes	To observe rate of inflow

Note :-
A station located at "E" in Figure-2 was initially selected to gauge a drainage water course shown in topo maps but later dropped following field surveys because the concerned water course was found to be abondoned.

TBM's for the new gauge stations have been installed and levelled based on the FINNMAP network of survey stations maintaining the accuracy of levelling closure errors (mm) within $12\sqrt{K}$, where K is the distance in km between FINNMAP bench mark and TBM. The distances between TBM's and FINNMAP network bench marks, are shown in Table-2. The table also includes the levelling tolerance.

Twelve stations had to be resited due to either the water levels dropping below the zero level or due to the water level exceeding the top of gauge. The resiting was done at the same location by either lowering the gauge zero or heightening it. The details of gauge stations which were resited are given in Table-3. It should be noted that, as a result of these shifting, the readings at these gauges will reflect different gauge zero values at different times. This explains the apparent discrepancies in observed water levels and gauge zeros. For example, gauge station L (Bausi Railway Bridge) on June & July gave the following readings :

	Water Level	Zero Value	Date
20th June	13.15 m,PWD	12.88 m,PWD	14-06-94
20th July	12.46 m,PWD	11.93 m,PWD	17-07-94

2.3. Water level measurement procedures

Water levels were monitored 5 times per day commencing at 6:00 a.m. and subsequently every 3 hours interval until 6:00 p.m. These data collection commenced from June 1994 and were completed at the end of October 1994.

Gauge readers were employed on the site after being trained by Hydroland Survey Ltd officials.

2.4 Discharge measurement procedures

BWDB guidelines were followed for discharge measurements. Cross-section markers on both banks at each section were established for identification of the sections. Two points of transit markers were also established on both banks across each gauging section to keep the measuring boat in transit line during the entire period of operation.

The Velocity - Area concept of computing discharge, passing through a cross-section of a river is computed by formula, $Q = V \times A$, where Q is the discharge in cumecs, V is the velocity (computed by Manning's formula) in m/sec and A is the cross-sectional area in sq. meter. Thus to measure discharge passing through a channel its cross-section was subdivided into adequate number of segments from the left edge of water (LEW) to the right edge of water (REW). Along measuring verticals, velocity and depth have been measured except at the first and the last verticals where depth and velocities are zero. The BWDB standard practice of subdividing the channel cross-section into adequate number of verticals were followed such that, discharge passing through any segment between successive verticals is not more than 10% of the total discharge. Magnetic water type current meter used for velocity measurement in discharge measurement exercises was calibrated on the 6th of June 1994 by the Calibration Laboratory of the BWDB.

At the start and end of the velocity measurement water levels with their time of occurrences were recorded in the discharge measurement sheets from the gauge of that station. Proceeding from LEW to the next vertical towards REW, measurement of surface

LEVELLING GAUGE STATION CHARACTERISTICS

No of gauge stations	Name of gauge stations	River name	1994 installation date	Coordonates		Gauge Zero (1994) (m PWD) (1)			FINNMAP BM (2)		TBM elevation (m PWD)	Distance FIN.-TBM (Km)	Permiss. error (3) (mm)	Closure error (4) (mm)
				Lat.(°N)	Lon.(°E)	Lower	Medium	Upper	BM No	Elevation (mPWD)				
1	Belamari	Chatal (W)	27-05-94	24 54 48	89 46 50	12 89	-	15.19	5211	18.370	19.271	7.815	34	19
2	Char Atiapara	Dadbhanga	27-05-94	24 55 06	89 48 08	11.90	-	14.70	5304	19.101	18.508	12.430	42	1
3	Dhaluabari	Lohajong	27-05-94	24 55 55	89 49 32	14.32	-	15.96	5304	19.101	18.782	8.465	35	9
4	Hat Gobindah	Nangla Khal	28-05-94	24 57 26	89 51 20	15.20	-	16.84	5304	19.101	19.263	3.701	23	10
5	Gobindapur	Nangla Khal	27-05-94	24 59 08	89 48 39	15.61	-	-	5304	19.101	18.645	5.949	29	8
6	Poyla Bridge	Madardah	30-05-94	24 59 17	89 47 23	12.77	-	15.25	5305	19.512	17.890	6.739	31	5
7	Khashimara	Madardah	28-05-94	24 58 37	89 46 38	12.79	-	15.41	5212	18.925	17.946	11.346	40	3
8	Islampur	Old Brahmap.	27-05-94	24 05 03	89 47 29	14.46	-	16.35	5309	19.774	20.485	1.929	17	4
9	Delirpar	Deli	27-05-94	25 05 23	89 44 15	14.13	-	15.88	5309	19.774	20.306	7.137	32	3
10	Madhyachar	Bhabkikhal	27-05-94	24 54 58	89 53 57	13.76	-	15.15	5301	17.888	17.854	4.575	26	1
11	Hazipur	Jhenai	29-05-94	24 51 14	89 52 59	11.69	-	14.07	5123	17.371	16.581	2.885	20	8
12	Benjail Rampur	Jhen./Chat.	28-05-94	24 49 36	89 49 37	12.04	13.61	14.30	5123	17.371	15.576	10.750	39	14
13	Jhalopara	Br of Jamuna	28-05-94	24 44 37	89 49 23	10.96	-	13.23	5118	16.676	16.591	1.835	16	1
A	Belamari	Chatal (E)	08-06-94	24 55 37	89 47 57	12.65	-	15.52	5304	19.101	20.252	12.043	42	8
B	Tupkar Char	Old Brahmap.	09-06-94	24 59 12	89 52 12	13.15	15.45	16.55	5305	19.512	18.731	1.895	17	1
C	Puddanga Br.	Br. of Old Br.	10-06-94	25 08 00	89 46 10	17.06	-	18.27	5311	20.422	20.295	1.306	14	2
D	Bahadur.Rlw.	Beel connect. with Jamuna	10-06-94	25 09 45	89 45 05	16.52	-	18.53	5219	20.546	21.112	0.987	12	5
F	Khudur Kanda	Dadbangha	13-06-94	25 02 22	89 47 37	14.14	-	14.66	5309	19.774	18.673	5.584	28	1
G	Mahishbatan	Chatal	10-06-94	24 57 11	89 46 19	12.96	-	14.69	5304	19.101	18.103	18.450	52	23
H	Naoghata Brg.	Satkuri Beel	09-06-94	24 57 14	89 49 36	14.61	-	16.63	5304	19.101	18.006	7.720	33	3
I	Char Bhaitiani	Chatal Khal	10-06-94	24 49 38	89 49 08	10.99	-	13.40	5121	16.165	16.029	6.353	30	11
J	Char Jorkhali	Jamuna	11-06-94	24 50 03	89 43 23	12.75	-	15.06	5208	17.171	17.034	5.330	28	2
K	Helenchabari	Chatal S.	09-06-94	24 46 07	89 49 13	12.05	-	14.63	5119	16.727	18.402	3.899	24	2
L	Bausi Bridge	Jhenai	09-06-94	24 47 18	89 51 30	11.97	-	14.69	5119	16.727	19.792	0.804	11	1
M	Jhenai Offtake	Jhenai	08-06-94	24 57 38	89 59 10	12.04	-	16.12	5302	18.974	20.382	1.375	14	0

Note :-

1. Each station has 2 or 3 gauge posts. They are referred to as Lower, Medium and Upper.
2. Closest FINNMAM BM to the gauge station.
3. Permissible error on the basis of _/12 K, where K is distance.
4. Actual closure error from field surveys.

Table 2

Table 3

CHANGE OF ZERO VALUES DURING DATA COLLECTION

GAUGE STATION	DATE	ZERO VALUES		
		LOWER	MIDDLE	UPPER
08	01-06-94	14.46		15.97
	29-06-94			16.35
11	01-06-94	11.68		14.07
	06-08-94	11.69		
12	01-06-94	10.86	13.61	
	13-07-94	13.05		
	17-07-94	12.25		
	07-08-94	12.04		
	19-08-94			14.03
13	01-06-94	10.27		13.23
	08-08-94	10.97		
	07-09-94	10.96		
B	14-06-94	15.06	15.45	16.55
	07-07-94	15.14		
	06-09-94	13.15		
F	14-06-94	14.66		15.98
	03-08-94	14.14		14.66
G	14-06-94	14.69		16.65
	19-07-94	12.96		14.69
I	14-06-94	12.87		13.40
	08-09-94	10.99		
J	14-06-94	14.04		15.06
	07-09-94	12.75		
K	14-06-94	12.93		14.63
	17-07-94	12.05		
	16-09-94	11.14		12.05
	10-10-94	11.13		
L	14-06-94	12.88		14.69
	17-07-94	11.93		
	20-07-94	11.97		
	22-10-94	11.44		
M	14-06-94	13.38		16.12
	19-07-94	13.04		
	01-08-94	13.38		
	02-08-94	13.32		
	06-09-94	12.04		

Note : The zero values were altered due to the gauge post being shifted to accommodate WL observations.

width was made from a boat at anchor position and its position was determined by a measuring line stretched across the section near the water surface. Depth at the same vertical was determined by taking sounding and the current meter was then lowered at 0.2 and 0.8 depths and the number of revolutions of the meter wheel was recorded for a fixed time period of 100 seconds at each point. These operations were repeated for each vertical of each cross-section.

From recorded revolutions and fixed time period, rate of revolution and the resulting point velocities at 0.2 and 0.8 depths have been computed from the current meter rating formula, using an electronic calculator in the field. The mean velocity in the segment was computed by averaging two successive vertical mean velocities. Similarly, mean depth in the segment was computed by averaging two successive vertical depths. The area of the segment was then derived from the segment depth and the corresponding width. Segment discharge was then computed by multiplying the segment area with the corresponding segment velocity. Total discharge and total area of the cross-section have been obtained through summation of all segment discharges and all segment areas respectively. The mean velocity then obtained from dividing total discharge by total area of the cross-section. Discharge measurement at gauge station No I shown in Figure-3.

Discharge measurement data have been stored in a computer format.

A summary of gauge stations for 1994 monsoon is shown in Table-4.

A summary of discharge measurements is shown in Table-5 and details are given in Appendix-D.

Figure 3

Discharge measurement at gauge station No. I

SUMMARY OF GAUGE STATIONS 1994 MONSOON

No of gauge stations	Name of gauge stations	River name	Instal. (1) (O)old (N)new	Date of installation	Coordonates		Gauge Zero (1994) (m PWD) (2)			WL (Y)yes (N)no	Disch. (Y)yes (N)no
					Lat.(°N)	Lon.(°E)	Lower	Medium	Upper		
1	Belamari	Chatal (W)	O	27-05-94	24 54 48	89 46 50	12.89	-	15.19	Y	N
2	Char Atiapara	Dadbhanga	O	27-05-94	24 55 06	89 48 08	11.90	-	14.70	Y	Y
3	Dhaluabari	Lohajong	O	27-05-94	24 55 55	89 49 32	14.32	-	15.96	Y	N
4	Hat Gobindah	Nangla Khal	O	28-05-94	24 57 26	89 51 20	15.20	-	16.84	Y	N
5	Gobindapur	Nangla Khal	O	27-05-94	24 59 08	89 48 39	15.61	-		Y	N
6	Poyla Bridge	Madardah	O	30-05-94	24 59 17	89 47 23	12.77	-	15.25	Y	N
7	Khashimara	Madardah	O	28-05-94	24 58 37	89 46 38	12.79	-	15.41	Y	N
8	Islampur	Br. of Old Brahmaputra	O	27-05-94	24 05 03	89 47 29	14.46	-	16.35	Y	Y
9	Delirpar	Deli	O	27-05-94	25 05 23	89 44 15	14.13	-	15.88	Y	Y
10	Madhyachar	Bhabki khal	O	27-05-94	24 54 58	89 53 57	13.76	-	15.15	Y	N
11	Hazipur	Jhenai	O	29-05-94	24 51 14	89 52 59	11.69	-	14.07	Y	N
12	Benjail Rampur	Jhenai / Chatal	O	28-05-94	24 49 36	89 49 37	12.04	13.61	14.30	Y	N
13	Jhalopara	Branch of Jamuna	O	28-05-94	24 44 37	89 49 23	10.96		13.23	Y	N
A	Belamari	Chatal (E)	N	08-06-94	24 54 58	89 47 34	12.65	-	15.52	Y	N
B	Tupkar Char	Old Brahmaputra	N	09-06-94	24 59 07	89 52 07	13.15	15.45	16.55	Y	N
C	Putdanga Rly. Br.	Branch of Old Brah.	N	10-06-94	25 07 36	89 46 06	17.06	-	18.27	Y	N
D	Bahadur Rly. Br.	Beel(connect Jamuna)	N	10-06-94	25 09 27	89 45 03	16.52	-	18.53	Y	N
F	Khudur Kanda	Datbhanga	N	13-06-94	25 02 13	89 46 52	14.14	-	14.66	Y	N
G	Mahishbatan	Chatal	N	10-06-94	24 56 43	89 45 47	12.96	-	14.69	Y	Y
H	Naoghata Bridge	Satkuri Beel	N	09-06-94	24 57 08	89 49 22	14.61	-	16.63	Y	N
I	Char Vatiani	Chatal Khal	N	10-06-94	24 49 23	89 48 41	10.99	-	13.40	Y	Y
J	Char Jorkhali	Jamuna	N	11-06-94	24 50 02	89 43 14	12.75	-	15.06	Y	N
K	Helenchabari	Chatal South	N	09-06-94	24 46 04	89 49 08	12.05	-	14.63	Y	Y
L	Bausi Rly. Bridge	Jhenai	O	09-06-94	24 46 47	89 51 18	11.97	-	14.69	Y	Y
M	Jhenai Rly. Bridge	Jhenai	O	08-06-94	24 56 59	89 59 06	12.04	-	16.12	Y	Y

Note :-

1. 'Old' stations - 1993 locations ; New stations - New 1994 locations.
2. Gauge zero refers to the zeros on upto three posts at each station.

Table 4

Summary of Discharge Measurement 1994

Gauge Station No.	Name of Gauge Station	Discharge m ^ 3/sec					
		July		August		September	
		1st week	3rd week	1st week	3rd week	1st week	3rd week
2	Char Atiapara	0.0	0.0	0.0	0.0	0.0	0.0
8	Islampur	0.0	0.0	0.0	0.0	0.0	0.0
9	Delirpar	9.2	0.0	1.2	9.0	0.0	0.0
G	Mohisbathan	56.0	1.1	17.5	46.3	4.2	0.9
I	Char Bhatiani	11.1	0.0	0.0	11.5	0.0	0.0
K	Helenchabari	137.2	56.1	63.8	139.1	63.0	30.6
L	Bausi Rly. Bridge	49.4	12.4	19.7	51.6	18.6	6.3
M	Jhenai Rly. Bridge	151.9	32.2	66.7	109.9	63.9	56.6

Table 5

3. FIELD DATA COLLECTION

3.1. Summary of data collected

A summary of the status of water level and discharge data collection carried out during 1994 monsoon is given in Table-6. Details of water level data from June to October are presented in Appendix-C and discharge data from July to September in Appendix-D.

Some gauge stations were found completely dry/stagnant-water with zero discharge during this Hydrological survey (gauges 2,3,4,5,8,C and H) denoted as "N" and in some other gauge stations (gauges 9,12,13,A, B,D,F,G,I,J,K,L and M) sometimes water level goes below the zero value so partial data available from these gauge stations denoted as "P" in Table-6.

3.2. Supervision and control

The data collection field activities were carried out by Hydroland Survey Ltd. based on procedures provided by the consultants. Consultants maintained close supervision and control during the full data collection period. This included the following :

1. Confirmation of location of stations in the field.
2. Check on satisfactory installation of all gauging stations.
3. Supervision of levelling surveys to establish TBM and gauge datums.
4. Levelling surveys at randomly selected stations to check accuracy of surveys carried out by Hydroland Survey Ltd.
5. Regular field visits to all stations to supervise and check the data collection activities.
6. Maintaining close co-ordination with Hydroland Surveys Ltd. in ensuing the data collection and reporting is maintained as per programme.
7. Checking of data obtained from the field for errors and inconsistencies.

No particular problems or difficulties were encountered and the performance of Hydroland Surveys Ltd. is considered satisfactory. Both the field data collection and reporting of data was carried out according to programme.

3.3 General characteristics of 1994 data

The reliability of a hydraulic model and its predictions depend to a large extent on satisfactory calibration of the model parameters. When a model is celebrated using data for a variety of flow conditions, its calibration is more robust. Hence it is useful to calibrate a model for both wet year and dry year conditions. The 1994 data reflect a dry year situation whereas data for 1993 reflects a wet year. Thus data currently available is useful to obtain a reasonable calibration of the hydraulic model to be developed for the Jamalpur Project area.

1992 and 1994 monsoon data will be useful to calibrate the reference model for relatively low flood discharges, and 1993 for normal flooding.

Table-7 shows the difference between maximum water levels for 1992, 1993 and 1994 monsoon for each gauge station where data are available. This illustrates the relatively dry 1994 monsoon where the minimum water levels recorded were significantly lower than in 1992 and 1993.

Comparative water level hydrographs for gauge station no. 7, 10 and 12 , which are representative locations within the project area, for 1993 and 1994 monsoon are shown in Figure-4.

Status of Data Collection 1994

Gauge Station No.	Name of Gauge Station	Water Level					Discharge			Remarks
		Jun	Jul	Aug	Sep	Oct	Jul	Aug	Sep	
1	Belamari	C	C	C	C	C				
2	Char Atiapara	C	C	C	C	C	N	N	N	Stagnant water no flow
3	Dhaluabari	N	N	N	N	N				
4	Hat Gobindha	N	N	N	N	N				
5	Gobindapur	N	N	N	N	N				
6	Poyla Bridge	C	C	C	C	C				
7	Khashimara	C	C	C	C	C				
8	Islampur	C	C	C	C	C	N	N	N	Stagnant water no flow
9	Delirpar	C	C	C	C	C	P	C	N	
10	Madhya Char	C	C	C	C	C				
11	Hazipur	C	C	C	C	C				
12	Benjail Rampur	C	C	C	C	P				
13	Jhalopara	C	C	C	C	P				
A	Jatirpar Bridge	P	C	C	C	C				
B	Tupkar Char	P	P	P	P	C				
C	Putdanga Rly. Bridg	N	N	N	N	N				
D	Guzimari Rly. Bridge	P	C	C	C	C				
F	Khudur Kanda	P	P	P	C	C				
G	Mohisbathan	P	P	C	C	C	C	C	C	
H	Naoghata Bridge	N	N	N	N	N				
I	Char Bhatiani	P	P	C	P	C	P	P	N	
J	Char Jorkhali	P	C	C	C	C				
K	Helenchabari	P	C	C	C	P	C	C	C	
L	Bausi Rly. Bridge	P	C	C	C	P	C	C	C	
M	Jhenai Rly. Bridge	P	C	C	C	C	C	C	C	

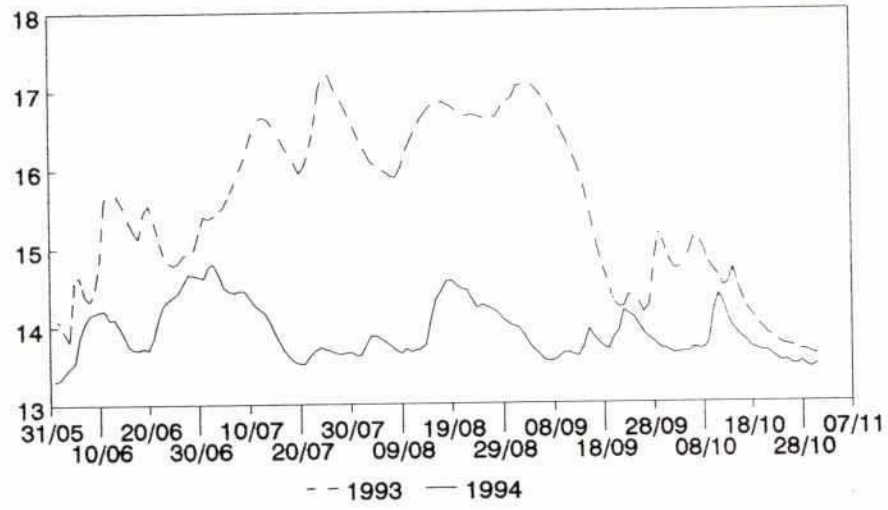
C = Complete
P = Partial (data available when WL are not below gauge zero and discharge is not zero)
N = Not Available (when gauge post is completely dry/stagnant water or WL goes below gauge zero and discharge is zero)

COMPARISON BETWEEN MAXIMUM WATER LEVELS 1992, 1993 and 1994 MONSOON

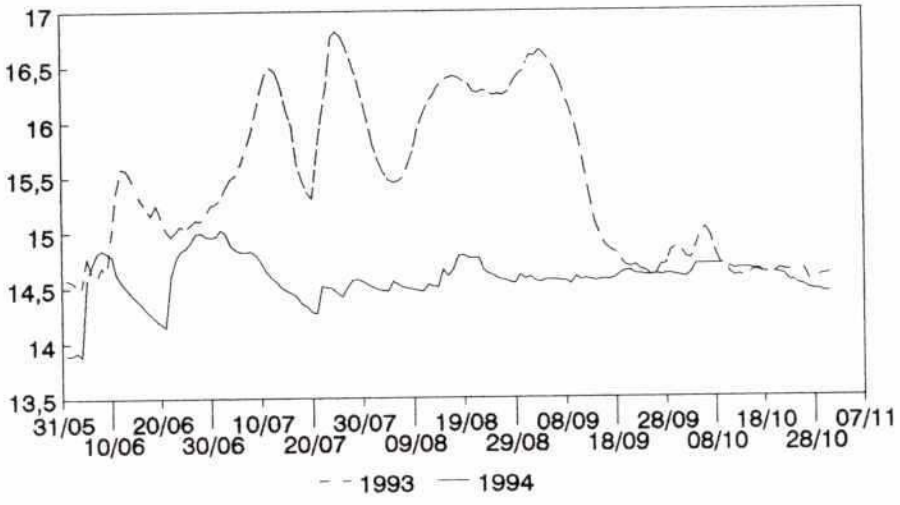
GAUGE No.	1992 Maximum Water level (PWD m)	1993 Maximum Water level (PWD m)	1994 Maximum Water level (PWD m)	Difference between 1992 and 1994	Difference between 1993 and 1994
1	15.49	16.85	14.87	0.62	1.98
2	15.48	16.83	14.53	0.95	2.30
3		16.93	dry		
4		16.91	dry		
5		17.64	dry		
6	17.14	17.43	14.85	2.29	2.58
7		17.20	14.80		2.40
8	18.89	18.79	16.74	2.15	2.05
9	17.61	18.60	16.73	0.88	1.87
10		16.81	15.02		1.79
11		16.45	14.65		1.80
12	15.44	16.22	14.25	1.195	1.97
13		15.32	13.90		1.42

WATER LEVEL COMPARISON BETWEEN 1993 AND 1994 MONSOON

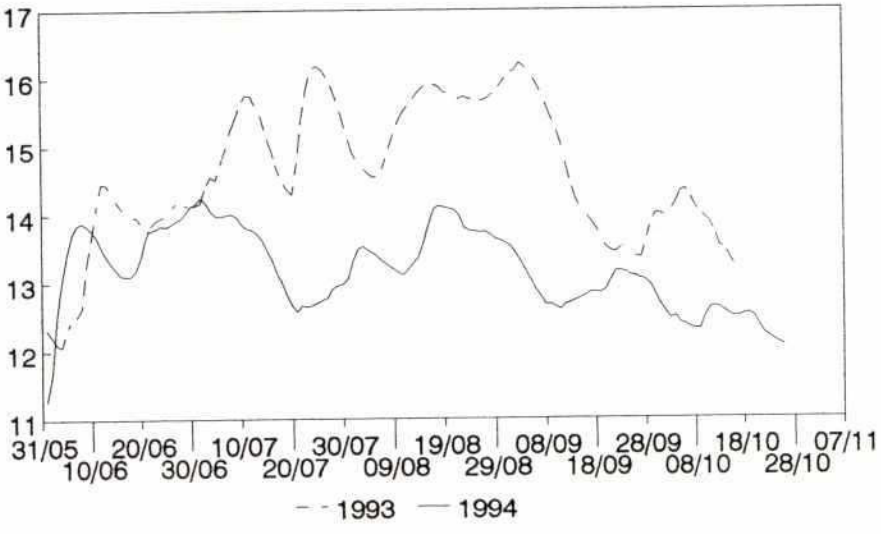
GAUGE 7
Water level (PWD m)



GAUGE 10
Water level (PWD m)



GAUGE 12
Water level (PWD m)



4. ANALYSIS AND INTERPRETATION OF DATA

4.1 General

The monsoon data collected during 1994 and in the previous two years will be used in the hydraulic studies in the forthcoming studies and design phase. The Hydraulic studies will be related to both engineering aspects of the proposed schemes as well as the socio-economic aspects of benefits and impacts. It is proposed a hydrodynamic Flood Management Model (FMM) will be developed to assist with the hydraulic studies based on the recently developed FAP 25 systems using Mike 11 connected with GIS.

The development of a reliable FMM will require, inter-alia, observed values level and discharge data adequately representing the flood flows in the project area. These data will be used to calibrate the model and to check the model calculations. The larger the available data set, the better the prospects of achieving more reliable model calibration.

Most of the data observed cover a three year period or less. Statistically reliable trend analysis is not feasible for such short periods. However statistical analysis was carried out for locations with more water level data (Bahadurabad, Jaganathganj, Jhenai Offtake, Jamalpur and Bausi Bridge) and for rainfall data (Dewanganj, Jamalpur and Sarishabari).

4.2 1994 monsoon characteristics

4.2.1 Rainfalls

The Jamalpur and Dewanganj rain gauge stations are located in the project area and provide a reasonable representation of the rainfall in the project area. Sarishabari is located at the extreme south of the Project area. These stations are monitored by the BWDB officials (see enclosed "Location of Hydrological Installation" map at the end).

The monsoon rainfall generally lasts from June to September. The mean annual rainfall on the project area is about 2200 mm.

The monthly rainfall for the 1994 monsoon period for the Dewanganj, Jamalpur and Sarishabari rainfall stations are shown in Table-8, Table-9 and Table-10 respectively.

1994 monsoon rainfalls were the lowest recorded since 1974 (starting of record). Table-11 shows the total rainfall and the estimated return periods of 1992, 1993 and 1994 for the three stations.

Figure-5 shows Cumulative Probability curves with observed values. Significant years are also indicated.

4.2.2 BWDB Water Level Stations

There are five water level measuring stations of BWDB surrounding the project area which are as follows:

- Jamuna at Bahadurabad since 1965
- Jamuna at Jagannathganj since 1965

DAILY RAINFALL (mm)
Station : R062 Dewanganj
Year : 1994

Date	Apr	May	Jun	Jul	Aug	Sep
1	1.50	0.00	1.00	0.60	0.00	3.50
2	0.20	0.00	2.00	12.00	1.00	0.50
3	2.00	0.00	32.00	0.00	0.50	0.00
4	0.00	0.00	0.50	0.00	2.20	0.00
5	0.00	0.00	9.00	0.00	6.00	0.00
6	52.00	0.00	22.00	22.00	19.50	0.00
7	0.00	0.00	0.00	2.00	2.20	0.00
8	0.00	5.50	0.00	0.00	10.00	0.00
9	0.00	5.30	0.00	0.00	5.00	25.00
10	0.00	0.00	7.00	0.00	1.00	14.00
11	0.00	12.00	32.00	0.00	1.50	0.00
12	0.00	0.00	6.00	0.50	5.00	0.00
13	0.00	0.00	28.00	0.00	0.50	0.50
14	0.00	1.60	0.20	5.50	2.50	72.50
15	0.00	8.20	0.00	0.30	73.00	0.00
16	0.00	25.00	0.00	0.00	0.00	0.00
17	0.00	3.00	15.50	0.00	0.00	14.00
18	0.00	21.00	11.00	0.00	0.00	0.30
19	0.00	0.00	4.00	0.00	0.00	1.30
20	4.80	0.00	0.00	0.00	0.00	58.00
21	3.80	0.00	1.00	3.00	0.00	18.00
22	0.00	0.00	6.30	39.00	0.00	7.50
23	3.50	1.50	0.00	17.00	1.50	0.00
24	0.00	1.00	0.00	0.50	48.00	89.00
25	0.00	3.00	6.50	7.50	3.00	0.00
26	0.00	57.50	0.00	2.70	0.00	0.00
27	0.10	0.00	0.00	14.00	0.00	0.00
28	0.00	73.50	4.00	2.00	0.00	0.00
29	0.00	0.00	9.00	0.00	2.00	0.00
30	8.00	42.00	10.50	5.00	1.00	0.00
31		1.00		0.00	0.00	

Decade	Apr	May	Jun	Jul	Aug	Sep
I	55.70	10.80	73.50	36.60	47.40	43.00
II	4.80	70.80	96.70	6.30	82.50	146.60
III	15.40	179.50	37.30	90.70	55.50	114.50
Total	75.90	261.10	207.50	133.60	185.40	304.10
Avg (1974-94)	134.30	338.50	419.20	518.20	326.80	329.70

DAILY RAINFALL (mm)
Station : R067 Jamalpur
Year : 1994

Date	Apr	May	Jun	Jul	Aug	Sep
1	0.00	0.00	0.00	0.00	0.00	16.20
2	4.20	0.00	10.80	16.40	1.50	2.30
3	1.40	0.00	23.50	0.00	14.20	0.00
4	0.00	0.00	0.00	9.40	3.90	2.50
5	0.00	0.00	0.00	0.00	27.50	0.00
6	0.00	0.00	47.60	0.00	2.10	0.00
7	0.00	0.00	0.00	4.80	0.00	22.50
8	0.00	9.80	0.00	0.00	0.00	0.00
9	0.00	12.60	0.00	0.00	6.40	62.30
10	0.00	0.00	0.00	0.00	0.00	3.70
11	0.00	0.00	31.30	0.00	1.50	0.00
12	0.00	0.00	13.40	0.00	8.20	33.20
13	0.00	0.00	6.20	0.00	0.80	22.30
14	0.00	8.40	0.00	3.10	3.90	16.40
15	0.00	16.20	5.40	1.50	83.20	0.00
16	0.00	51.80	8.90	1.00	0.00	0.00
17	0.00	7.80	6.50	0.00	0.00	3.40
18	0.00	18.20	7.30	0.00	0.00	3.80
19	0.00	0.00	12.80	1.60	0.00	10.40
20	0.80	0.00	0.00	1.00	0.00	25.30
21	17.40	0.00	3.40	19.60	0.00	18.70
22	3.60	0.00	4.20	32.30	33.40	10.20
23	9.80	0.00	0.00	0.00	1.60	0.00
24	0.00	8.50	10.40	18.30	45.00	0.00
25	6.70	0.00	11.50	2.30	0.00	0.00
26	11.20	4.90	0.00	11.20	0.00	0.00
27	13.70	0.00	1.30	36.40	0.00	0.00
28	0.00	0.00	9.10	46.80	4.30	0.00
29	0.00	0.00	26.30	21.30	0.00	0.00
30	2.90	24.20	33.50	20.90	76.80	0.00
31	0.00	0.00		0.00	0.00	

Decade	Apr	May	Jun	Jul	Aug	Sep
I	5.60	22.40	81.90	30.60	55.60	109.50
II	0.80	102.40	91.80	8.20	97.60	114.80
III	65.30	37.60	99.70	209.10	161.10	28.90
Total	71.70	162.40	273.40	247.90	314.30	253.20
Avg (1974-94)	114.70	328.10	474.70	546.20	366.20	356.80

DAILY RAINFALL (mm)
Station : R032 Sarishabari
Year : 1994

Date	Apr	May	Jun	Jul	Aug	Sep
1	0.00	0.00	0.00	9.30	0.00	0.00
2	2.20	0.00	0.00	5.30	0.00	0.00
3	2.30	0.00	6.60	0.00	7.20	0.00
4	0.00	0.00	0.00	0.00	5.60	0.00
5	0.00	0.00	46.70	1.60	21.80	0.00
6	10.30	0.00	0.00	0.00	0.00	0.00
7	0.00	1.20	0.00	12.50	7.40	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	6.20	0.00	3.20	0.00	0.00
10	0.00	22.10	6.50	0.00	0.00	0.00
11	0.00	0.00	12.60	9.50	6.60	0.00
12	0.00	0.00	4.60	3.60	18.50	0.00
13	0.00	0.00	0.00	0.00	8.30	0.00
14	0.00	2.30	12.80	1.20	21.40	0.00
15	0.00	25.30	6.30	5.60	0.00	0.00
16	0.00	28.10	8.20	0.00	0.00	0.00
17	0.00	36.80	6.20	0.00	0.00	0.00
18	0.00	0.00	21.90	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	1.60	0.00	0.00
21	9.10	0.00	0.00	3.50	13.20	0.00
22	17.40	0.00	0.00	75.60	4.40	0.00
23	38.80	0.00	11.40	26.40	13.20	0.00
24	0.00	11.30	1.30	12.20	12.30	0.00
25	10.20	5.20	3.50	0.00	2.20	0.00
26	2.40	1.60	0.00	0.00	0.00	0.00
27	0.00	0.00	0.80	42.60	2.50	0.00
28	0.00	0.00	9.20	7.60	0.00	0.00
29	0.00	0.00	20.70	29.50	24.20	0.00
30	0.00	35.10	37.50	0.00	0.00	0.00
31		0.00		0.00	5.50	

Decade	Apr	May	Jun	Jul	Aug	Sep
I	14.80	29.50	59.80	31.90	42.00	0.00
II	0.00	92.50	72.60	21.50	54.80	0.00
III	77.90	53.20	84.40	197.40	77.50	0.00
Total	92.70	175.20	216.80	250.80	174.30	0.00
Avg (1974-94)	102.70	337.70	461.30	513.60	253.50	296.70

Table 11

RAINFALL AND RETURN INTERVAL YEARS FROM APRIL TO SEPTEMBER

Station name	1974-94 Rainfall		1992		1993		1994	
	Mean (mm)	Standard Dev. (mm)	Total rainfall (mm)	Frequency (years)	Total rainfall (mm)	Frequency (years)	Total rainfall (mm)	Frequency (years)
Dewangang(RO62)	2066.7	470.0	1397.3	Dry 1:13	2254.0	Wet 1:3	1167.0	Dry 1:35
Jamalpur (RO67)	2186.7	532.7	1526.3	Dry 1:9	3141.6	Wet 1:27	1322.9	Dry 1:19
Sarishabari (RO32)	1965.6	810.6	1127.6	Dry 1:7	1977.5	1:2	909.8	Dry 1:10

Table 12

WATER LEVEL AND RETURN INTERVAL YEARS FOR BWDB STATIONS FROM APRIL TO SEPTEMBER

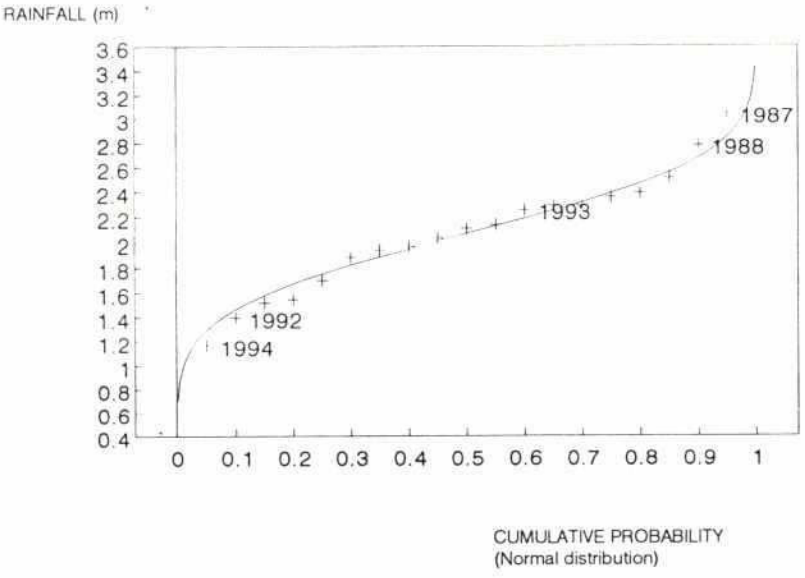
(using gumble's k factor)

Station Name	1965-94 WL		1992		1993		1994	
	Mean m, PWD	Standard Dev m, PWD	Water Level m, PWD	Recurence interval (Year)	Water Level m, PWD	Recurence interval (Year)	Water Level m, PWD	Recurence interval (Year)
Bahadurabad	19.74	0.37	19.17	Dry 1:10	19.90	Wet 1:4	18.75	Dry 1:34
Jagannathganj	15.10	0.42	14.75	Dry 1:5	15.32	Wet 1:4	14.12	Dry 1:24
Jamalpur	16.86	0.65	15.77	Dry 1:11			14.63	Dry 1:72
Jhenai offtake	17.42	0.67			17.48	Wet 1:3	15.39	Dry 1:43
Bausi bridge	15.75	0.71	14.92	Dry 1:7	15.88	Wet 1:3	14.12	Dry 1:20

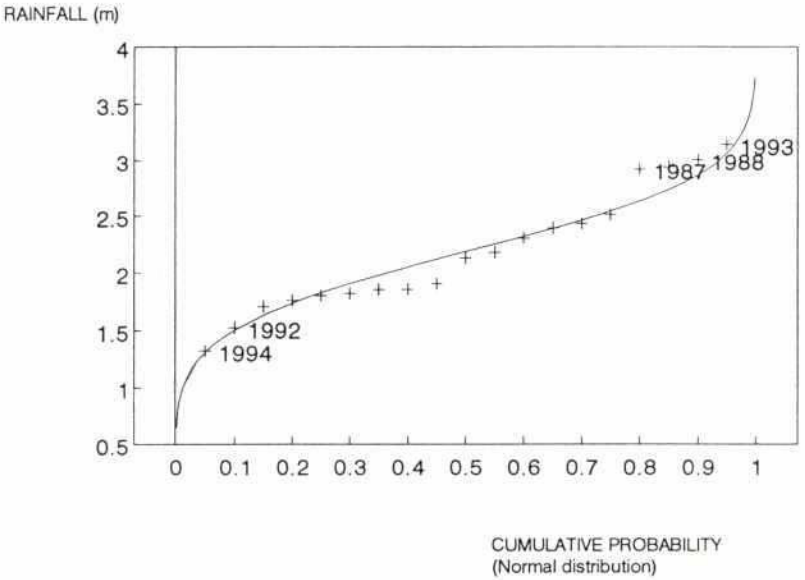
Figure 5

CUMULATIVE PROBABILITY OF RAINFALL
(FROM APRIL TO SEPTEMBER)

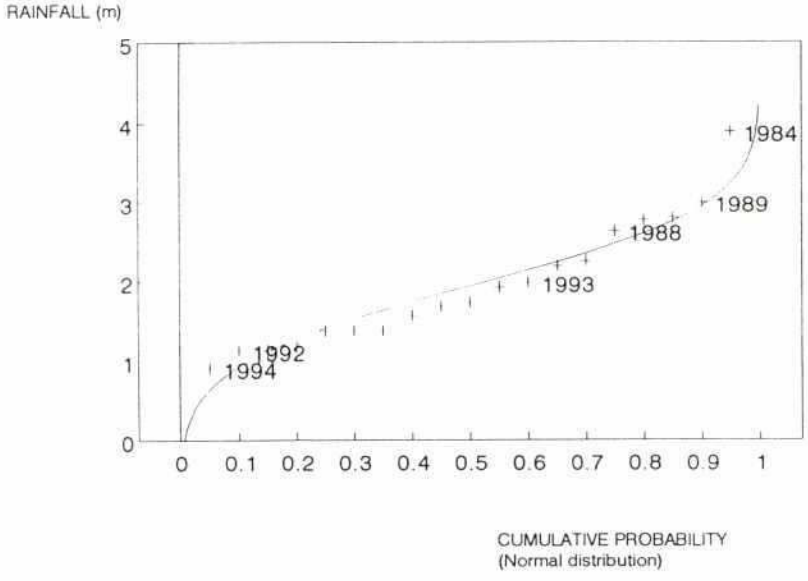
STATION : DEWANGANG



STATION : JAMALPUR



STATION : SARISHABARI



- Old Brahmaputra at Jamalpur since 1965
- Jhenai at Jhenai Offtake since 1974
- Jhenai at Bausi Rly. Bridge since 1975

Table-12 shows the flood water level and estimated recurrence interval (years) based on the Gumble method for these five stations.

1994 water levels are the lowest recorded since recording started for all the stations. Figure-6 shows Cumulative Probability curves with observed values. Significant years are also indicated.

Therefore, both rainfall and water level confirms that the 1994 monsoon was probably the driest year since data collection commenced.

4.3 Water level analysis

Table-13 and Table-14 shows 1994 monsoon water level analysis results for each decade for each gauge station :

- water level average
- water level maximum and minimum

4.4 Discharge interpretation and analysis

4.4.1 General

Where as water level observations can be made relatively easily, discharge measurements requires more expertise and measuring equipment. Discharge measurements at selected stations were undertaken fortnightly from July to September. The objective of the measurement is to obtain a representative range of monsoon discharges from which a rating curve could be established for each station. Discharge data are also available from measurements carried out in 1992 (FAP 3.1) and in 1993 (FAP 25).

The derivation of a reliable rating curve is also influenced by down stream influences and the hydraulic effects of flood rise and fall. These include :

- the slope of the river is mild and there is an independent downstream influence, like for example a tributary which flows independently of the river where measurements are performed. In this case the water level is more influenced by downstream phenomenon than effective discharge. An example is shown in Figure-7. A reliable rating curve cannot be derived for such cases.

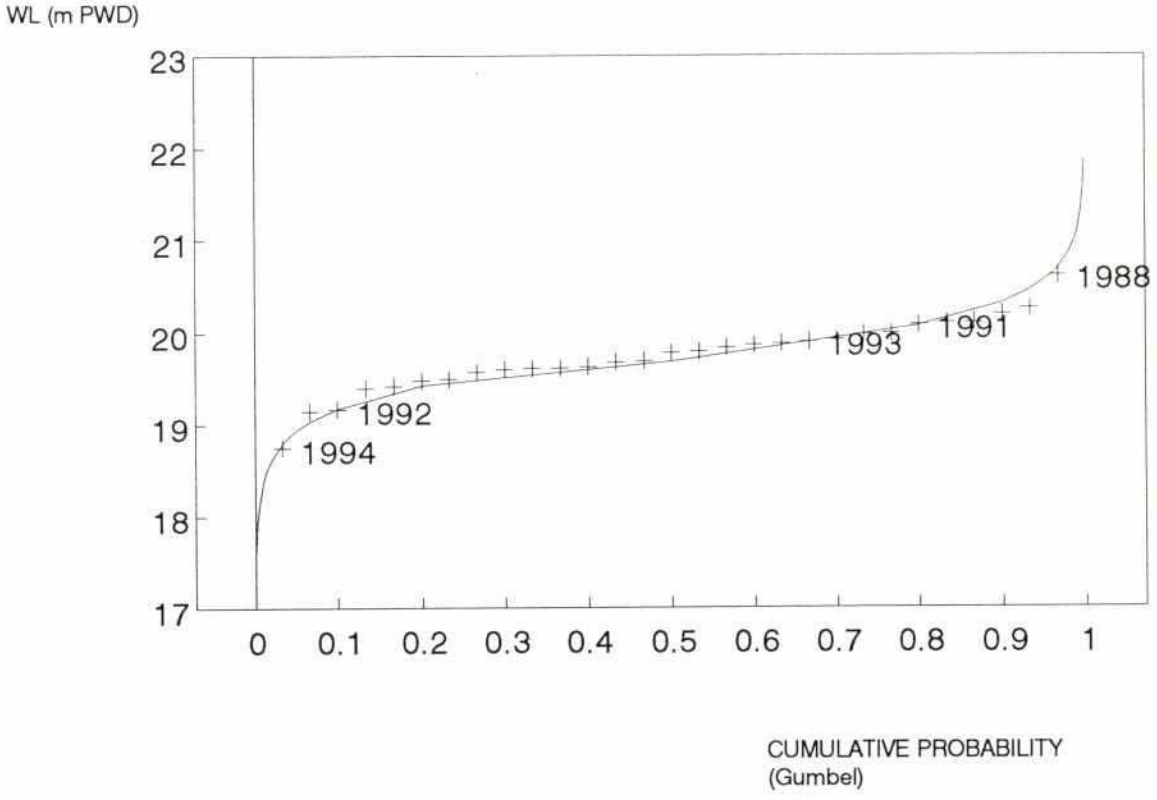
- the slope of the river is mild and the river has water storage area downstream as flood plains. An example is shown in Figure-8. The rating curve is looped due to dynamic effects (see Figure-9) and a single curve cannot be derived in such cases.

- In certain instances, the flow effects described above can have a combined influence at a single station.

Figure 6
(cont.)

Maximum Water Level vs Cumulative Probability

RIVER : JAMUNA
STATION : Bahadurabad



RIVER : JAMUNA
STATION : Jaganathganj

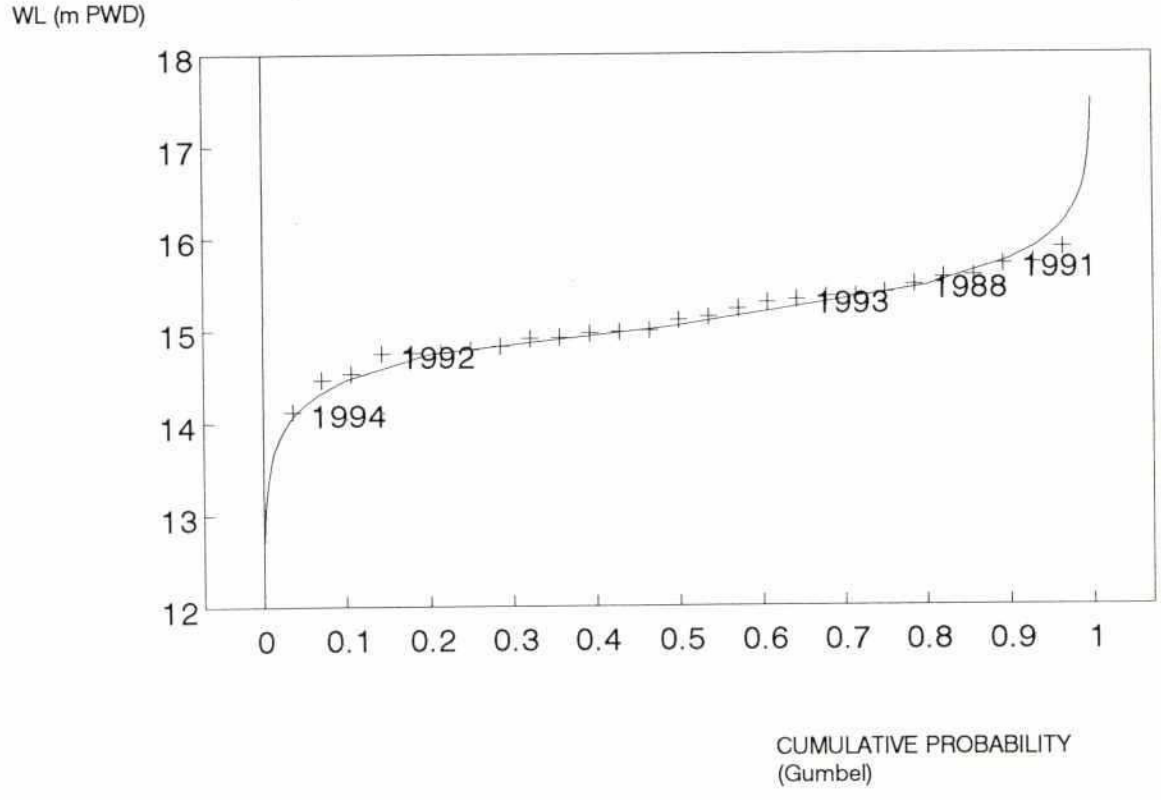
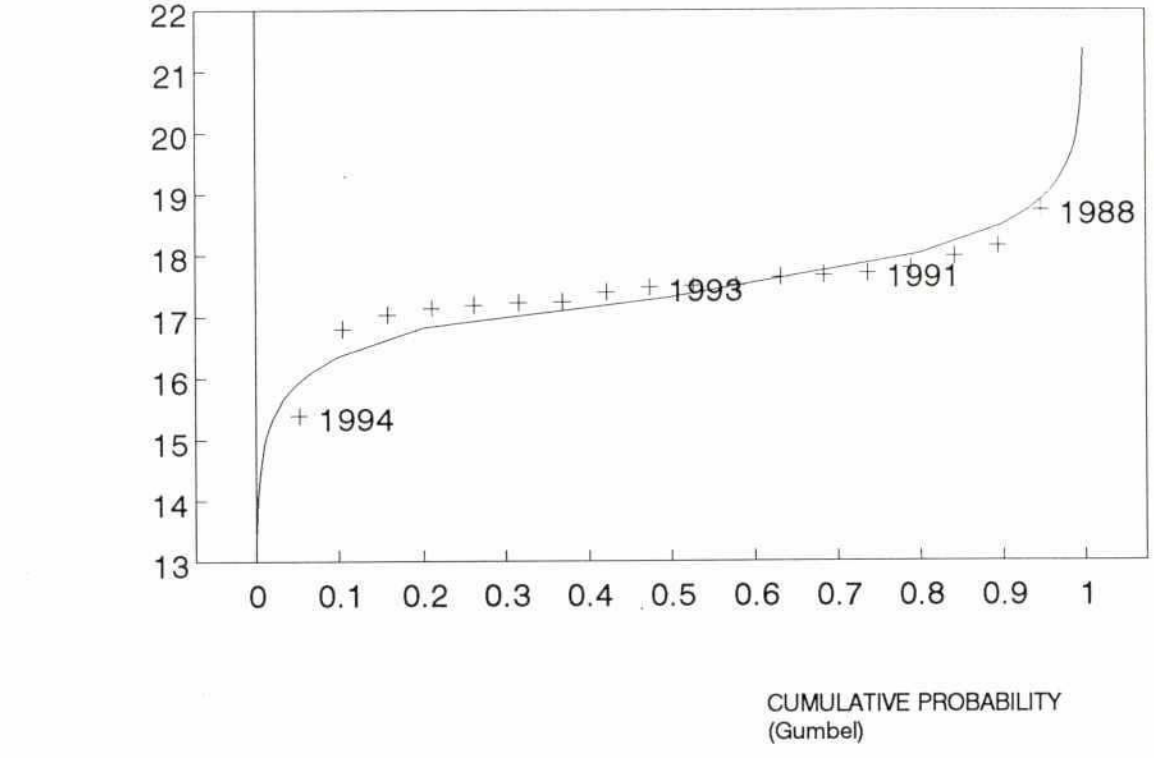


Figure 6
(cont.)

Maximum Water Level vs Cumulative Probability

RIVER : JHENAI
STATION : Jhenai Offtake



RIVER : OLD BRAHMAPUTRA
STATION : Jamalpur

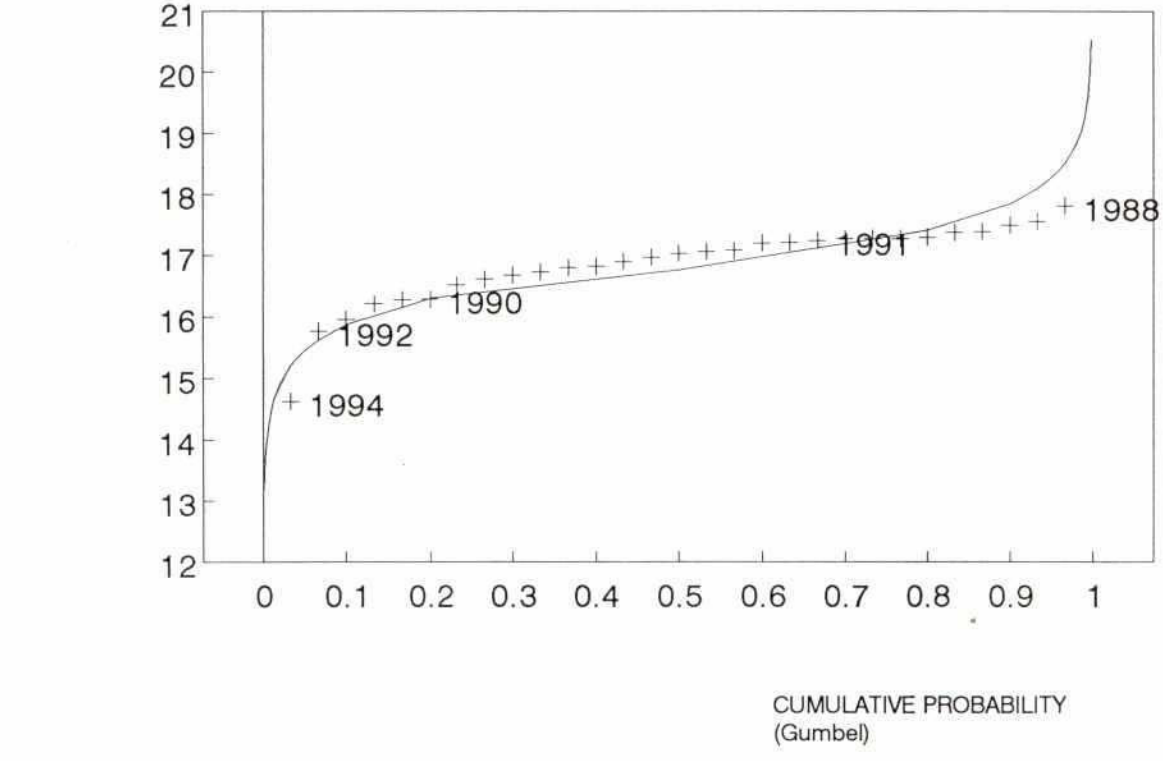
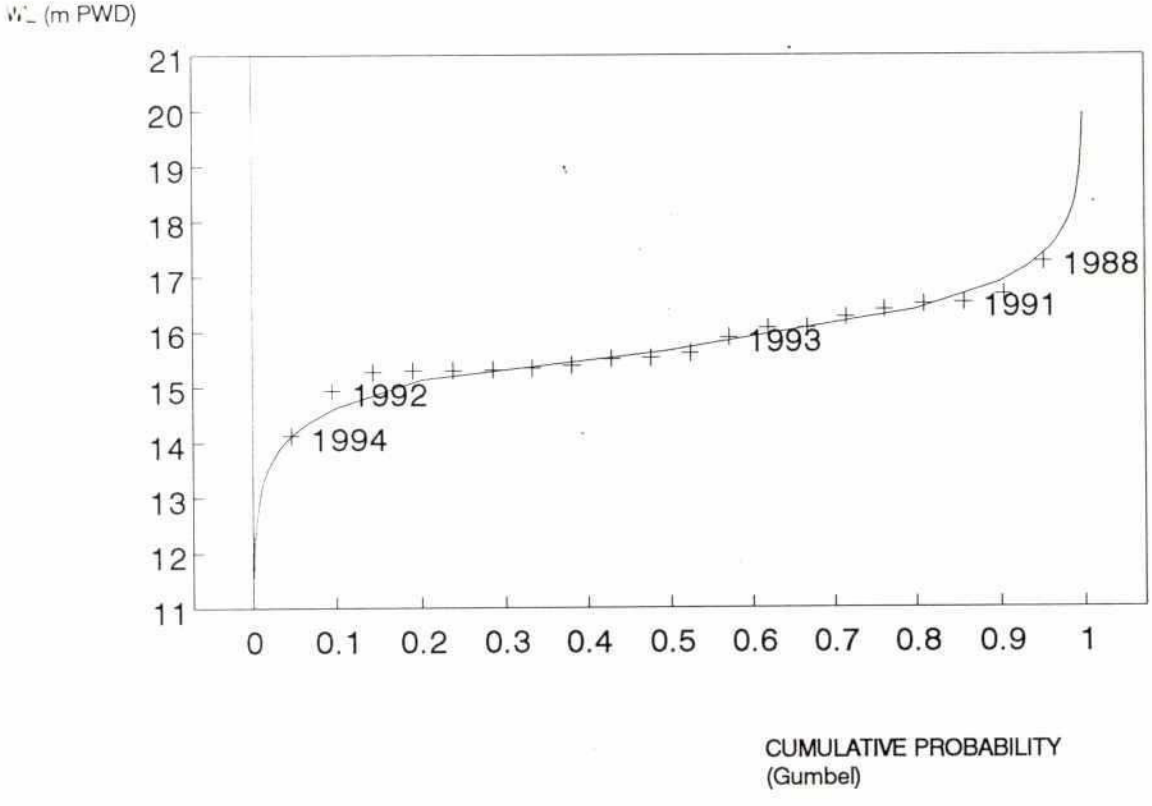


Figure 6

Maximum Water Level vs Cumulative Probability

RIVER : JHENAI
STATION : Baushi bridge



1994 MONSOON WATER LEVEL MAIN RESULTS

AVERAGE

Month	Decade	Gauge No.1	Gauge No.2	Gauge No.6	Gauge No.7	Gauge No.8	Gauge No.9	Gauge No.10	Gauge No.11	Gauge No.12	Gauge No.13
JUNE	I	13.76	13.40	13.76	13.85	15.01	15.60	14.38	13.70	13.08	12.84
	II	14.10	13.63	13.90	13.99	15.26	15.98	14.38	13.82	13.28	12.88
	III	14.45	14.25	14.41	14.49	15.36	16.50	14.79	14.44	13.99	13.56
JULY	I	14.64	14.35	14.59	14.66	15.91	16.52	14.87	14.48	14.04	13.59
	II	14.38	13.66	13.90	13.99	16.01	16.01	14.46	13.82	13.34	13.07
	III	14.31	13.13	13.66	13.76	16.02	15.86	14.48	13.34	12.78	12.68
AUGUST	I	14.31	13.60	13.77	13.86	16.01	15.99	14.49	13.80	13.34	13.19
	II	14.43	13.90	14.17	14.24	16.11	16.29	14.62	14.06	13.66	13.50
	III	14.48	14.02	14.25	14.33	16.19	16.22	14.62	14.13	13.75	13.54
SEPTEMB.	I	14.30	13.38	13.69	13.79	16.20	15.87	14.56	13.54	13.00	12.78
	II	14.27	13.20	13.76	13.85	16.23	15.88	14.58	13.37	12.77	12.60
	III	14.27	13.48	13.96	14.04	16.46	15.92	14.61	13.60	13.04	12.86
OCTOBER	I	14.32	13.03	13.75	13.72	16.41	15.89	14.67	13.08	12.43	12.13
	II	14.31	13.23	13.97	13.92	16.60	16.09	14.64	13.21	12.54	12.22
	III	14.24	12.69	13.54	13.52	16.30	15.87	14.51	12.51	12.17	11.41

MINIMUM

Month	Decade	Gauge No.1	Gauge No.2	Gauge No.6	Gauge No.7	Gauge No.8	Gauge No.9	Gauge No.10	Gauge No.11	Gauge No.12	Gauge No.13
JUNE	I	13.48	12.36	13.31	13.41	14.90	14.63	13.88	11.93	11.26	11.27
	II	14.01	13.42	13.72	13.81	15.21	15.88	14.18	13.63	13.10	12.73
	III	13.98	13.85	13.87	13.96	15.25	16.29	14.14	14.11	13.64	13.35
JULY	I	14.53	14.19	14.40	14.48	15.63	16.34	14.72	14.33	13.87	13.45
	II	14.26	13.04	13.54	13.62	15.98	15.81	14.28	13.21	12.66	12.49
	III	14.25	12.93	13.53	13.63	15.98	15.81	14.27	13.14	12.57	12.42
AUGUST	I	14.25	13.45	13.64	13.74	15.99	15.91	14.47	13.62	13.15	12.97
	II	14.29	13.40	13.68	13.77	16.04	15.90	14.46	13.59	13.11	12.97
	III	14.39	13.84	14.01	14.09	16.15	16.09	14.53	13.99	13.58	13.38
SEPTEMB.	I	14.26	13.04	13.54	13.64	16.18	15.79	14.52	13.25	12.63	12.36
	II	14.25	13.07	13.63	13.72	16.20	15.82	14.55	13.23	12.60	12.39
	III	14.24	13.25	13.71	13.80	16.34	15.87	14.60	13.38	12.81	12.62
OCTOBER	I	14.22	12.95	13.65	13.62	16.31	15.86	14.58	12.99	12.30	11.95
	II	14.28	12.98	13.69	13.65	16.35	15.94	14.62	13.13	12.47	12.16
	III	14.21	12.53	13.46	13.44	16.26	15.82	14.44	12.14	12.06	10.97

MAXIMUM

Month	Decade	Gauge No.1	Gauge No.2	Gauge No.6	Gauge No.7	Gauge No.8	Gauge No.9	Gauge No.10	Gauge No.11	Gauge No.12	Gauge No.13
JUNE	I	14.20	14.15	14.21	14.30	15.14	16.28	14.84	14.38	13.89	13.39
	II	14.20	14.04	14.22	14.31	15.28	16.12	14.63	14.21	13.67	13.15
	III	14.76	14.45	14.69	14.76	15.59	16.64	14.99	14.58	14.16	13.69
JULY	I	14.87	14.52	14.84	14.91	16.06	16.71	15.02	14.65	14.24	13.75
	II	14.50	14.12	14.30	14.38	16.05	16.31	14.65	14.26	13.81	13.44
	III	14.45	13.32	13.75	13.84	16.03	15.89	14.57	13.58	13.05	13.00
AUGUST	I	14.39	13.76	13.89	13.98	16.04	16.11	14.55	13.95	13.52	13.36
	II	14.65	14.35	14.62	14.68	16.16	16.61	14.79	14.43	14.11	13.90
	III	14.62	14.27	14.51	14.58	16.21	16.46	14.76	14.39	14.05	13.83
SEPTEMB.	I	14.38	13.81	13.99	14.07	16.23	16.04	14.59	13.97	13.53	13.32
	II	14.28	13.29	13.97	14.05	16.40	16.00	14.65	13.49	12.89	12.75
	III	14.29	13.64	14.22	14.29	16.56	16.00	14.64	13.70	13.15	12.99
OCTOBER	I	14.44	13.29	14.22	14.16	16.72	16.02	14.70	13.27	12.67	12.44
	II	14.36	13.58	14.46	14.38	16.74	16.46	14.67	13.32	12.63	12.29
	III	14.28	12.92	13.68	13.65	16.33	15.93	14.61	13.01	12.35	12.02

Note :
Gauge Stations No. 3, 4 & 5 are dry

1994 MONSOON WATER LEVEL MAIN RESULTS

AVERAGE

Month	Decade	Gauge A	Gauge B	Gauge D	Gauge F	Gauge G	Gauge I	Gauge J	Gauge K	Gauge L	Gauge M
JUNE	I	dry	dry	16.73	dry	dry	13.25	dry	dry	13.32	dry
	II	13.57	15.32	16.88	14.89	dry	13.05	14.66	13.29	12.99	14.36
	III	14.62	16.10	17.15	15.19	15.23	13.89	15.37	13.74	13.60	15.12
JULY	I	14.64	16.08	17.25	15.25	15.21	13.98	15.37	13.77	13.65	15.14
	II	13.73	15.67	17.25	14.94	13.92	13.48	14.80	13.20	13.08	14.49
	III	13.05	15.27	17.36	dry	13.55	13.01	14.39	12.75	12.65	13.96
AUGUST	I	13.66	15.47	17.39	14.59	14.15	13.30	14.82	13.31	13.17	14.38
	II	14.06	15.78	17.52	14.96	14.58	13.66	15.12	13.63	13.48	14.66
	III	14.14	15.73	17.60	14.95	14.59	13.76	15.11	13.67	13.53	14.73
SEPTEMB.	I	13.23	14.99	17.54	14.48	13.65	12.51	14.49	12.91	12.81	14.15
	II	12.94	14.99	17.66	14.66	13.42	11.65	14.44	12.72	12.62	14.01
	III	13.23	14.82	17.95	14.84	13.66	11.92	14.64	12.99	12.88	14.25
OCTOBER	I	12.87	14.62	17.97	14.80	13.39	11.53	14.01	12.27	12.22	13.66
	II	12.88	14.79	18.13	14.89	13.44	11.51	14.13	12.36	12.33	13.83
	III	12.74	13.89	17.86	14.66	13.45	11.49	13.48	11.62	12.26	12.94

MINIMUM

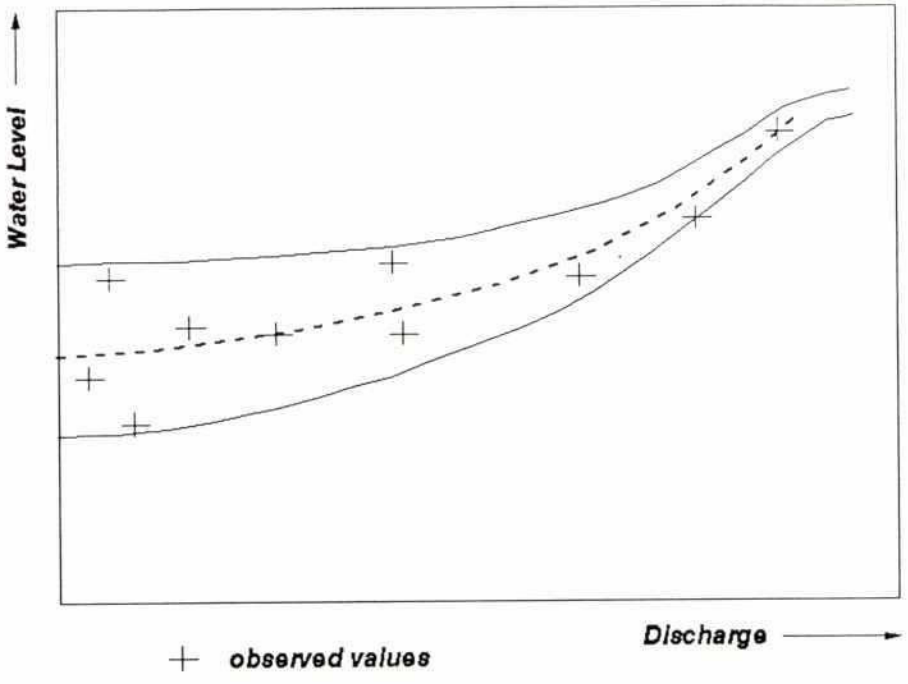
Month	Decade	Gauge A	Gauge B	Gauge D	Gauge F	Gauge G	Gauge I	Gauge J	Gauge K	Gauge L	Gauge M
JUNE	I	dry	dry	16.73	dry	dry	13.25	dry	dry	13.28	dry
	II	13.43	15.20	16.75	14.89	dry	12.93	14.53	13.29	12.87	14.24
	III	14.30	15.87	17.01	14.95	14.98	13.46	15.21	13.50	13.33	14.84
JULY	I	14.41	15.92	17.24	15.04	14.94	13.81	15.23	13.63	13.51	14.96
	II	12.95	15.37	17.23	14.91	13.40	13.07	14.22	12.57	12.49	13.76
	III	12.88	15.27	17.23	dry	13.38	13.01	14.17	12.49	12.41	13.69
AUGUST	I	13.40	15.38	17.38	14.44	13.85	13.08	14.62	13.10	12.97	14.20
	II	13.36	15.34	17.39	14.51	13.83	13.07	14.65	13.09	12.96	14.18
	III	13.92	15.64	17.55	14.75	14.37	13.58	15.00	13.50	13.38	14.61
SEPTEMB.	I	12.89	14.78	17.49	14.29	13.37	11.54	14.22	12.50	12.43	13.81
	II	12.85	14.83	17.56	14.46	13.36	11.51	14.29	12.51	12.44	13.83
	III	12.98	14.62	17.85	14.69	13.41	11.70	14.38	12.73	12.64	14.01
OCTOBER	I	12.80	14.48	17.87	14.65	13.33	11.50	13.86	12.09	12.00	13.51
	II	12.80	14.69	18.00	14.79	13.42	11.50	14.06	12.30	12.27	13.74
	III	12.71	13.41	17.77	14.46	13.42	11.48	13.29	11.19	11.56	12.40

MAXIMUM

Month	Decade	Gauge A	Gauge B	Gauge D	Gauge F	Gauge G	Gauge I	Gauge J	Gauge K	Gauge L	Gauge M
JUNE	I	dry	dry	16.73	dry	dry	13.25	dry	dry	13.37	dry
	II	13.93	15.64	16.97	14.89	dry	13.15	14.99	13.29	13.17	14.60
	III	14.83	16.25	17.23	15.36	15.44	14.10	15.48	13.88	13.73	15.26
JULY	I	14.93	16.23	17.26	15.52	15.52	14.21	15.57	13.93	13.82	15.32
	II	14.33	15.88	17.26	14.97	14.88	13.75	15.21	13.60	13.47	14.90
	III	13.29	15.27	17.43	dry	13.88	13.01	14.72	13.06	12.93	14.27
AUGUST	I	13.89	15.56	17.40	14.72	14.42	13.49	15.00	13.48	13.33	14.54
	II	14.60	16.01	17.61	15.31	15.11	14.15	15.46	14.03	13.87	15.01
	III	14.50	15.91	17.65	15.20	14.97	14.08	15.33	13.97	13.82	14.95
SEPTEMB.	I	13.85	15.59	17.59	14.74	14.27	13.52	14.94	13.45	13.31	14.63
	II	13.06	15.06	17.79	14.93	13.56	11.80	14.56	12.88	12.76	14.17
	III	13.35	14.89	18.01	15.01	13.81	12.03	14.75	13.11	12.99	14.35
OCTOBER	I	13.01	14.83	18.26	15.24	13.54	11.58	14.24	12.58	12.49	13.87
	II	12.97	14.85	18.26	15.25	13.49	11.52	14.22	12.42	12.38	13.93
	III	12.78	14.53	17.97	14.79	13.48	11.50	13.92	12.15	12.90	13.59

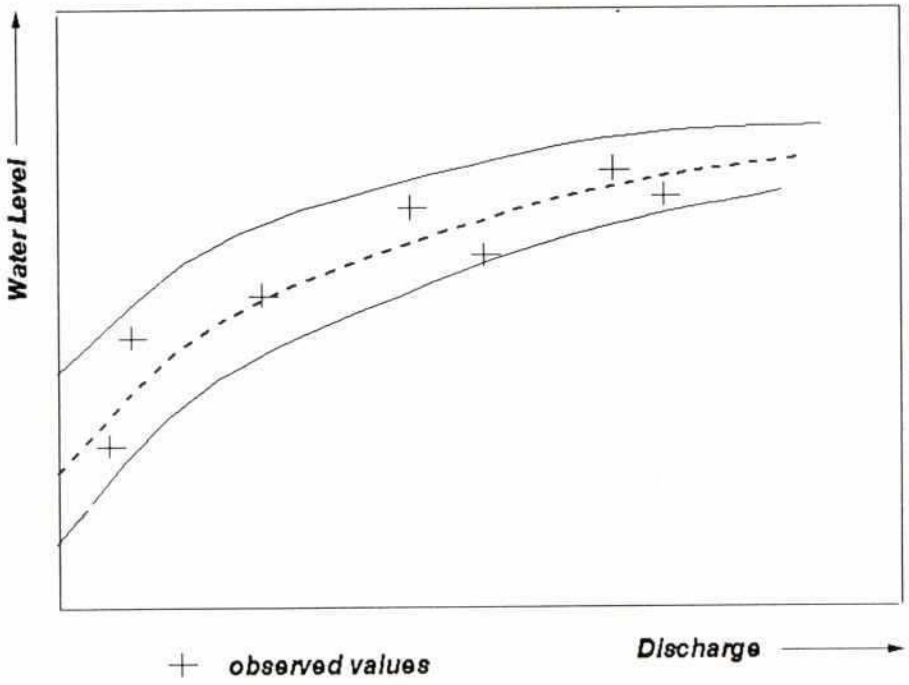
Note :
Gauge Stations C & H are dry

Figure 7



RATING CURVE WITH INDEPENDENT BACKWATER EFFECTS

Figure 8



RATING CURVE WITH DYNAMIC BACKWATER EFFECTS

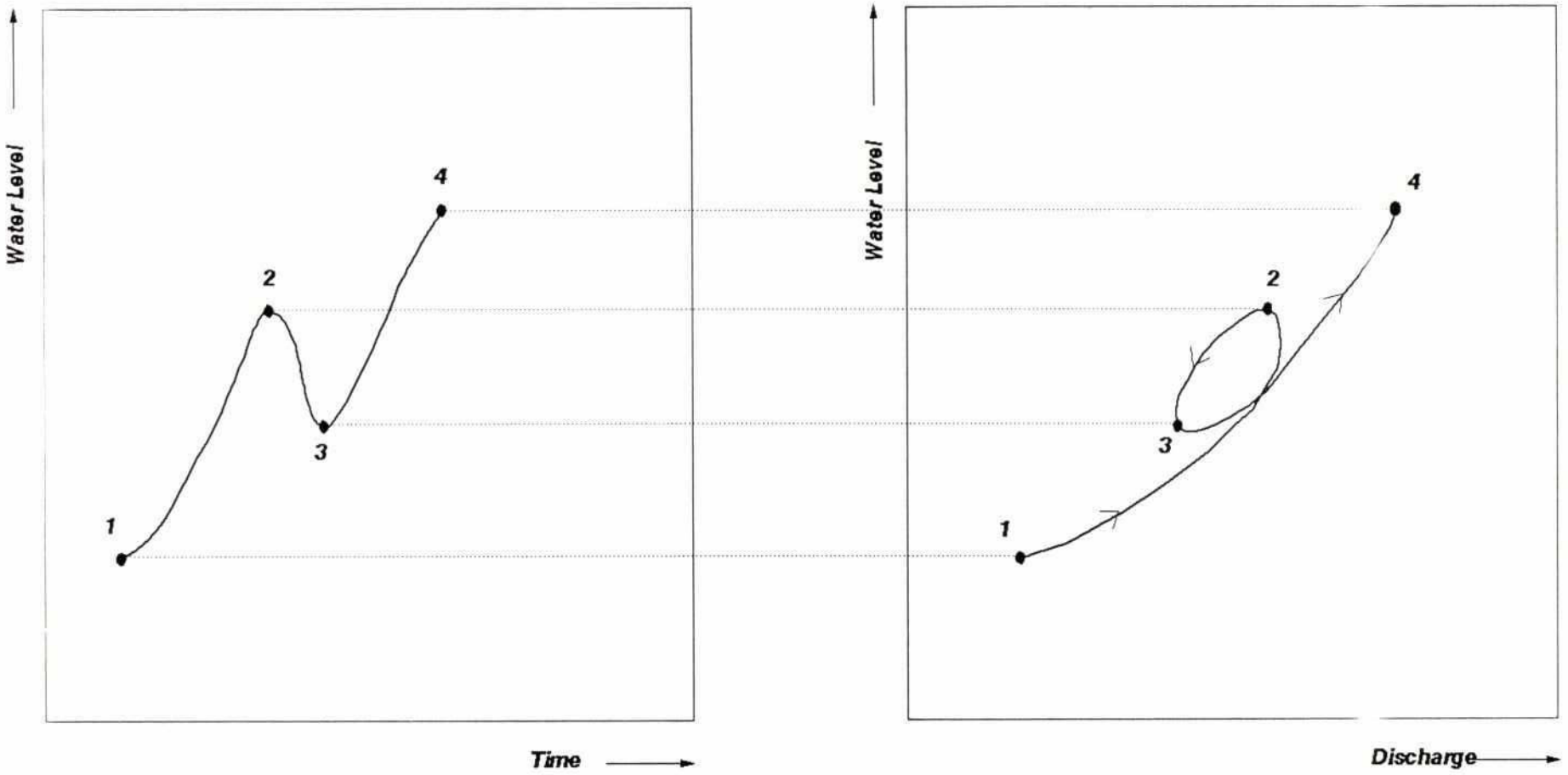

Water Level
1
2
3
4
Time
HYDROGRAPH
Water Level
1
2
3
4
Discharge
LOOPED RATING CURVE
DUE TO DYNAMIC EFFECTS

Figure 9

The Jamalpur project area is flat and has a dense and complex hydraulic network. Reliable rating curves at certain stages cannot be derived due to either insufficient discharge observations or due to one of the reasons described above.

4.4.2 Method used to calculate Stage-Discharge curve

The method used to determine the stage - discharge rating curve consists of a formula $Q = a (H - b)^c$, adjusted by a statistical method (least error squares method) where,

- Q is the discharge
- H is the level of the surface
- coefficients a , b , and c are constants determined in relation to available observations.

The above law is derived from the Manning-Strickler formula:

$$Q = K S R^{2/3} L^{1/2}$$

where,

- Q is the discharge
- K is Strickler coefficient
- S is wetted section
- R is hydraulic radius
- L is surface slope

If, in this formula, S and R are expressed as a function of the water depth, the following formulae are obtained as a function of the geometric shape of the river cross section :

Rectangular section, $Q = a (H - b)^{5/3}$ and

Triangular section, $Q = a (H - b)^{8/3}$

"a" being a constant expressed as a function of K, L and the opening of the triangular shape and "b" being a parameter constant at an altitude where the discharge is zero.

The coefficient "c" is 1.67 (5/3) for a rectangular section and 2.67 (8/3) for a triangular section. In reality, flow cross sections vary in size and this coefficient may thus vary noticeably between these points.

This entire approach is based on the following hypotheses :

- hydraulic operation in steady regime; the conditions for using the Manning-Strickler formula,

- constant surface slope regardless of the hydraulic regime, which is not always respected, especially when there are back water effects. This is why, for certain measurement sites such as gauge station nos. 1, 2, A and M, it is not possible to establish the rating curve, regardless of the method used.

In spite of this problem, on the latter sites the measurements taken will be useful for rating the mathematical model which is perfectly suitable for simulating unsteady hydraulic phenomena and the influence of back water effects.

In general, coefficients "c" obtained using this purely statistical method have a value between 1.67 and 2.67, except for certain stations where back-water effects are predominant and falsify the calculations.

This formula has used to derive the rating curves for stations where discharge observations are available for the monsoon periods 1992,1993 and 1994. The curves were fitted based on regration techniques using the Lotus 123 package. The details including the fitted curves are shown in Appendix-E. Comments on the rating curves are given in section 4.4.4.

4.4.3 Discharge hydrographs

Mean daily discharges at stations where rating curves have been derived were computed based on observed daily water levels. The discharge hydrographs shown in Appendix-F.

Due to the relatively small discharge data available for the derivation of the rating curves, the accuracy of the computed hydrographs is limited. Hence they should be used with caution.

4.4.4 Gauge station comments

Table-15 shows a summary of observed data from 1992 to 1994 within the project area and the main results of stage-discharge rating curve calculations.

Comments on each gauge stations are detailed below :

Gauge 1

Location	:	Belamari
River	:	Chatal (West branch)
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1992, 1993

Comments :

Chatal flow is divided in two branches: west branch and east branch. This gauge station is located on west branch, Gauge A on east branch.

The stage-discharge rating curve is not reliable and cannot be used because of strong backwater effects due to downstream floodplain fed by Jamuna and Dadbangha flows.

Gauge 2

Location	:	Char Atiapara
River	:	Dadbhanga
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1992, 1994

Comments :

The stage-discharge rating curve is not reliable because of strong backwater effects due to downstream floodplain. 1994 discharge measurements were all approximately nil discharge in spite of different water level values. This is due to the effect of independent downstream variations.

DISCHARGE OBSERVATION AND ANALYSIS SUMMARY

Gauge no	Discharge observation number			Discharge/ WL rating curve coef. Q = a (H - b) ^ c			Maximum observed discharge	Error standard deviation		Comments
	1992	1993	1994	a	b	c	(m3/s)	(m3/s)	%	
1	9	8	0	(12.20)	(14.08)	(1.78)	75.7	10.4	13.7%	Backwater effect
2	14	8	6 (zero:6)	(96.10)	(13.55)	(1.12)	363.1	33.6	9.3%	Backwater effect
3										
4										
5										
6	0	7	0	12.54	13.31	2.12	228	17.23	7.6%	
7										
8	0	8	dry	8.43	16.55	1	16.6	1.768	10.7%	
9	0	8	6 (zero : 3)	13.13	15.86	1.02	35.5	1.756	4.9%	
10	0	8	0	11.85	14.58	1.95	47.8	4.25	8.9%	
11										
12	0	8	0	21.4	11.19	2	482	29.85	6.2%	
13	0	8	0	132	11.85	2.01	1184	74.3	6.3%	
A	0	7	0	(2.20)	(13.28)	(1.99)	8.26	0.92	11.1%	Backwater effect
B										
C										
D										
E										
F										
G	0	0	6	11.68	13.15	2.16	55.98	2.55	4.6%	
H										
I	0	0	6 (zero:4)							Few points
J										
K	0	0	6	17.73	11.49	2.37	139.07	13.6	9.8%	
L	11	8	6	6.9	11.19	2.16	158	15.9	10.1%	
M	8	8	6	(7.75)	(12.48)	(2.85)	602.07	173	28.7%	Backwater effect and variation from year to year

( ) : cannot be used due to back water effect.

Table 15

Gauge 3

Location	:	Dhaluabari
River	:	Lohajong
WL observations	:	1993 , 1994
Discharge measurements	:	no

Comments :

This site remained dry during the 1994 monsoon.

Gauge 4

Location	:	Hat Gobindah
River	:	Nangla Khal
WL observations	:	1993, 1994
Discharge measurements	:	no

Comments :

This site remained dry during the 1994 monsoon.

Gauge 5

Location	:	Gobindapur
River	:	Nangla Khal
WL observations	:	1993, 1994
Discharge measurements	:	no

Comments :

This site remained dry during the 1994 monsoon.

Gauge 6

Location	:	Poyla bridge
River	:	Madardah
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1993

Comments :

At this point a bridge is under construction and water level and discharge characteristics were altered between 1993 and 1994.
The rating curve calculated with 1993 data cannot be used in 1994.

Gauge 7

Location	:	Khashimara
River	:	Madardah
WL observations	:	1993, 1994
Discharge measurements	:	no

Comments :

This site is in the main flow of Madardah (Dadbhanga) and just upstream of Gauge-2. In Gauge-2, stage-discharge was found less reliable due to strong backwater effects. So to get better result this station was chosen.

Gauge 8

Location	:	Islampur
River	:	Branch of Old Brahmaputra
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1993, 1994

Comments :

The 1994 water level hydrograph shows a gradual siltation of the Old Brahmaputra branch. Observing the previous hydrographs (1992 and 1993), it appears that the branch is silting up. Discharge measurements were made in the river which flows through the railway bridge.

The rating curve is not reliable because of the inadequate distribution of the observed values. Observed values are divided in two groups and there is no values between 2 and 12 m3/s. Moreover the divergence of the second group values shows an significant backwater effect. The site remained dry during the 1993 monsoon.

Gauge 9

Location	:	Delirpar
River	:	Deli
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1993, 1994

Comments :

The rating curve has relatively good accuracy as 1993 and 1994 discharge measurements are consistent. Rating curve can be used to reconstruct discharge hydrographs from water level hydrographs.

Gauge 10

Location	:	Madhyachar
River	:	Bhabki khal
WL observations	:	1993, 1994
Discharge measurements	:	1993

Comments :

The rating curve has relatively good accuracy. Rating curve can be used to reconstruct discharge hydrographs from water level hydrographs.

Gauge 11

Location	:	Hazipur
River	:	Jhenai
WL observations	:	1993, 1994
Discharge measurements	:	no

Gauge 12

Location	:	Benjail Rampur
River	:	Jhenai Chatal
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1993

Comments :

The rating curve has relatively good accuracy, and can be used to reconstruct discharge hydrographs from water level hydrographs.

Gauge 13

Location	:	Jholapara
River	:	Branch of Jamuna
WL observations	:	1993, 1994
Discharge measurements	:	1993

Comments :

The observed discharge values show a backwater effect for the low discharges, due to Jamuna. The accuracy of rating curve is better for larger discharges.

Gauge A

Location	:	Belamari
River	:	Chatal (East Branch)
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1992

Comments :

Chatal flow is divided in two branches, west branch and east branch. This gauge station is located on the east branch, whilst Gauge 1 is on the west branch.

The stage-discharge rating curve is non reliable and cannot be used because of strong backwater effects due to significant downstream floodplain fed by Jamuna and Dadbangha flows.

Gauge B

Location	:	Tupkar Char
River	:	Old Brahmaputra
WL observations	:	1994
Discharge measurements	:	no

Comments :

1994 records are incomplete due to the abnormal dry monsoon. Water level fell below the gauge zero and recording was not possible at that time.

Gauge C

Location	:	Putdanga Railway Bridge
River	:	Branch of old Brahmaputra
WL observations	:	1994
Discharge measurements	:	no

Comments :

This site remained dry during the 1994 monsoon.

Gauge D

Location	:	Bahadur Railway bridge
River	:	Beel (Connect Jamuna)
WL observations	:	1994
Discharge measurements	:	no

Comments :

Hydrograph shows the progressive filling of the beel during the monsoon.

Gauge E

Connection shown in Topo map but in field it was found closed. The station is canceled.

Gauge F

Location	:	Khudur Kanda
River	:	Datbhanga
WL observations	:	1994
Discharge measurements	:	no

Comments :

1994 records are incomplete due to the abnormal dry monsoon. Water level fell suddenly below the gauge zero and recording was not possible at that time.

Gauge G

Location	:	Mahishbatan
River	:	Chatal
WL observations	:	1994
Discharge measurements	:	1994

Comments :

The location of the discharge measurement station was selected upstream of the two branches of Chatal where gauge stations 1 and A are located. This each branches occurs significant backwater effects which should be avoided and then the rating curve derived will be considered reliable.

Gauge H

Location	:	Naoghata bridge
River	:	Satkuri Beel
WL observations	:	1994
Discharge measurements	:	no

Comments :

This site remained dry during the 1994 monsoon.

Gauge I

Location	:	Char Vatiani
River	:	Chatal Khal
WL observations	:	1994
Discharge measurements	:	1994

Comments :

All the discharge measurement were nil except during the 1st week of July and 3rd week of August during the 1994 monsoon. 1994 water level records are incomplete due to the abnormal dry monsoon. Water level fell suddenly below the gauge zero and recording was not possible at that time.

Gauge J

Location	:	Char Jorkhali
River	:	Jamuna
WL observations	:	1994
Discharge measurements	:	no

Comments :

Gauge K

Location	:	Helenchabari
River	:	Chatal south
WL observations	:	1994
Discharge measurements	:	1994

Comments :

Rating curve can be used but due to the dry 1994 monsoon extrapolations not recommended.

Gauge L

Location	:	Bausi railway bridge
River	:	Jhenai
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1992, 1993, 1994

Comments :

Bausi railway bridge will be a boundary condition of the hydraulic model. Rating curve will be used for a Q(H) boundary condition, for two reasons:

- data for H(t) boundaries are not available for the previous years,
- this outlet will be limited to 50 m3/s for the proposed option.

Discharge measurement data are available for three years. Stage-Discharge rating curve shows backwater effects due to dynamic phenomenon. The accuracy of the rating curve is sufficient to be used as boundary condition.

Gauge M

Location	:	Jhenai railway bridge
River	:	Jhenai
WL observations	:	1992, 1993, 1994
Discharge measurements	:	1992, 1993, 1994

Comments :

Rating curve cannot be used due to strong backwater effect and variations from year to years. For example, the water level is one meter higher in 1993 than 1992 for a discharge of about 300 m^3/s.

4.5 General observations

During the field visits the following things were noted in physical features within the project area which will affect hydraulic conditions. These observations will need to be included in the forthcoming hydraulic model studies:

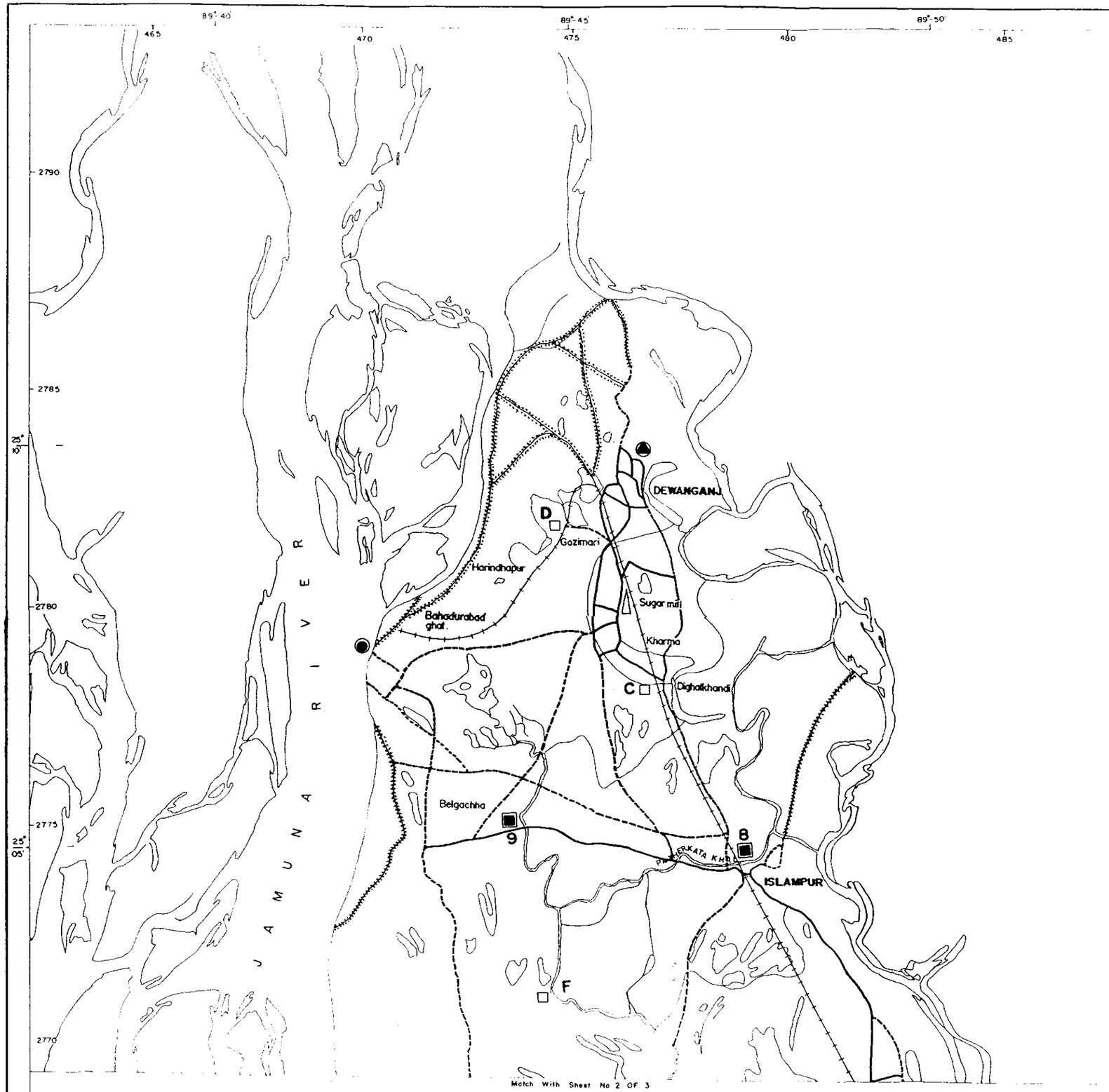
- The embankment which closed the Chatal intake has been washed away by the Jamuna during 1993 monsoon.

- Several new roads and bridges have been constructed since the earlier feasibility study.

- Some bridges, under construction, would temporarily alter hydraulic conditions of internal rivers. Likewise, temporary diversion roads used during construction works may have significant impacts on hydraulic flow patterns.

These observations exceed the strict frame defined in the terms of reference which include the collection of hydrological measurements from the 1994 monsoon. Nevertheless, they have been sumarized in the present report because it is essential for them to be taken into account in constructing the hydraulic model. These are qualitative and partial observations, made during field visits which were mainly to locate the hydrological measurement sites. These observations will have to be clarified by specefic field investigations during preparation of the mathematical model, especially to identify all new structures not marked on existing cartographical documents.

570



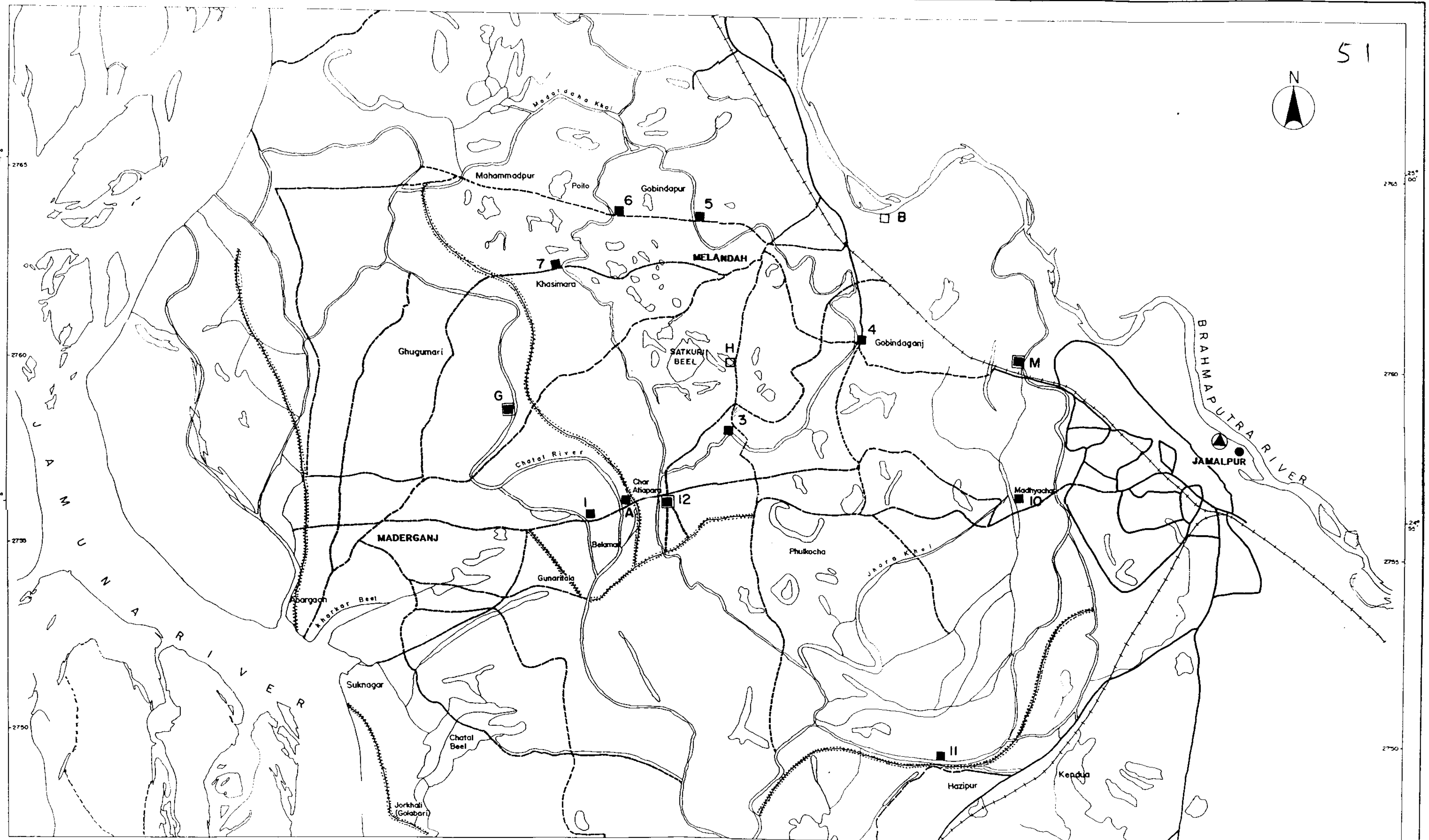
GOVERNMENT OF THE PEOPLES REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN CO-ORDINATION ORGANIZATION

JAMALPUR PRIORITY PROJECT

LOCATION OF HYDROLOGICAL INSTALLATION

DRAWING NO 2 (1 of 3)

DRAWN		SOGREAH-HALCROW-LAHMEYER WITH EPC & ADC
CHECK D		
APPRV D		
DATE	24-08-94	



Metres 1000 500 0 1000 2000 3000 4000 5000 Metres

SCALE 1 :

SHEET INDEX

1/3

2/3

3/3

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN CO-ORDINATION ORGANIZATION

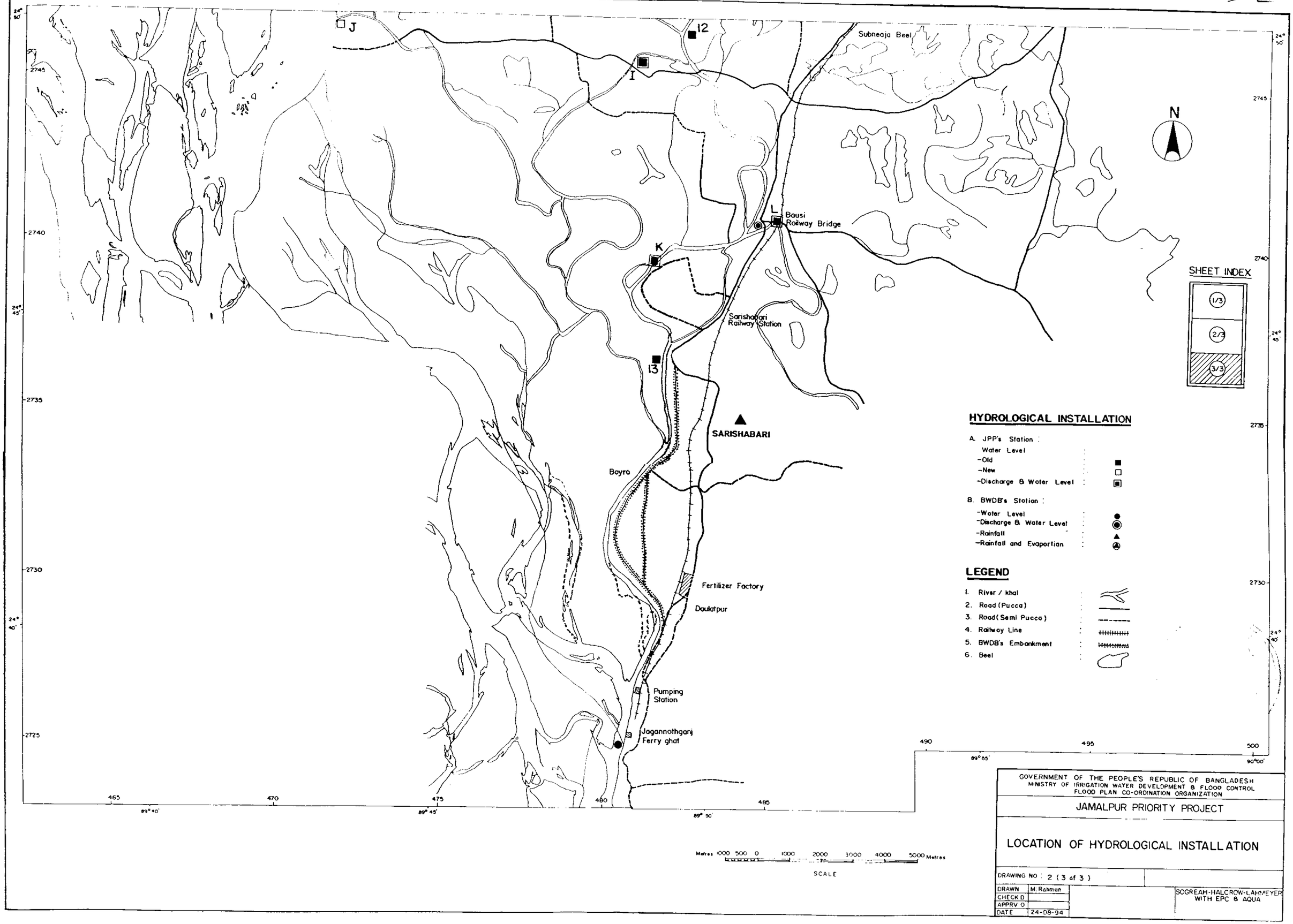
JAMALPUR PRIORITY PROJECT

LOCATION OF HYDROLOGICAL INSTALLATION

DRAWING NO : 2 (2 of 3)

DRAWN	M Rahman
CHECK'D	
APPR'V	
DATE	24-08-94

SOGREAH-HALCROW-LAHMEYER
WITH EPC & AQUA



GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN CO-ORDINATION ORGANIZATION

JAMALPUR PRIORITY PROJECT

LOCATION OF HYDROLOGICAL INSTALLATION

DRAWING NO : 2 (3 of 3)	
DRAWN	M. Rahman
CHECK D	
APPRV D	
DATE	24-08-94

SOGREAH-HALCROW-LAHMEYER
WITH EPC & AQUA