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FAP 24 RIVER SURVEY PROJECT

Phase 2,
2° Interim Report

June 1994 - May 1995

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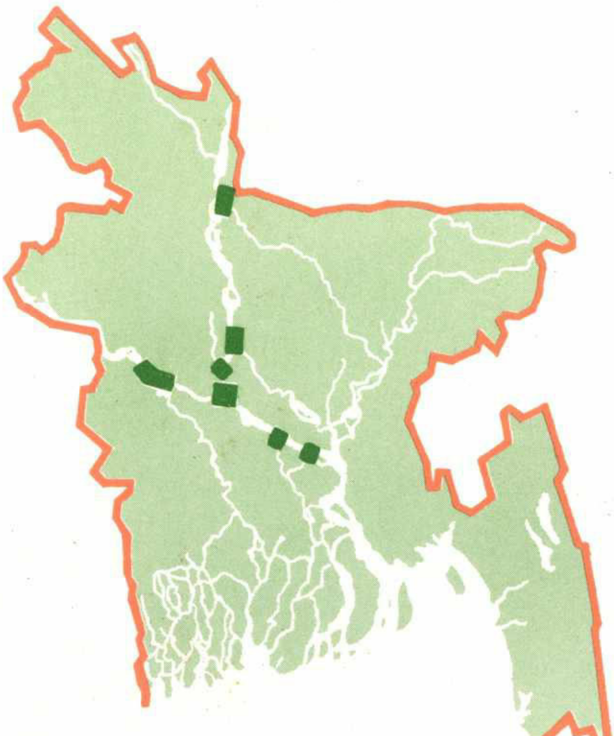

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Project ALA/90/04 — Commission of the European Communities

Phase 2,
2° Interim Report

June 1994 - May 1995

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Acronyms and abbreviations

ADCP	:	acoustic Doppler current profiler
ASCII	:	(a computer data format)
AWLR	:	automatic water level recorder
BIWTA	:	Bangladesh Inland Water Transport Authority
BTM	:	Bangladesh Transverse Mercator (a geodetic grid)
BUET	:	Bangladesh University of Engineering and Technology
BWDB	:	Bangladesh Water Development Board
CEC	:	Commission of the European Communities
CD	:	compact disk (for data storage)
DAT	:	digital audio tape (for data storage)
DELFT	:	Delft Hydraulics
DGPS	:	Differential Global Positioning System (a high-accuracy satellite-based positioning system)
DHA ... DHE	:	(names of the survey vessels of the RSP)
DHI	:	Danish Hydraulic Institute
DOS	:	(a computer operating system)
EG&G	:	(a specific electromagnetic flow meter)
EMF	:	electromagnetic flow meter
FAP	:	Flood Action Plan
FAP24	:	FAP project 24 = The River Survey Project
FPCO	:	Flood Plan Coordination Organization
Gb	:	Gigabyte (= 1,000 Mb)
GPS	:	Global Positioning System
HYMOS	:	(a hydrological software package)
IFCDR	:	Institute of Flood Control and Drainage Research, BUET
IHE	:	International Institute for Infrastructural, Hydraulic and Environmental Engineering (The Netherlands)
ISO	:	International Standard Organisation
LAN	:	local area (computer) network
Mb	:	Megabyte (= 1,000,000 bytes)
MEX	:	(a specific turbidity meter)
O&M	:	operation and maintenance
PA	:	Project Advisor (of the RSP)
PC	:	personal computer
PSD24	:	Processed Survey Data from FAP 24 (name of a FAP 24 database)
PWD	:	Public Works Department (also the name of a reference level)
RAM	:	random access (computer) memory
ROM	:	read-only (computer) memory
RRI	:	River Research Institute (Faridphur, Bangaldesh)
RSP	:	River Survey Project (= FAP 24)
RSPMU	:	River Survey Project Management Unit
SLW	:	Standard Low Water (a reference level)
SWMC	:	Surface Water Modelling Centre
S4	:	(a specific electromagnetic flow meter)

sb	:	Survey Bulletin
UNIX	:	(a computer operating system)
UoL	:	University of Leeds, UK
UoN	:	University of Nottingham, UK
US BM-54	:	(a specific bed material sampler)
VHF	:	very high frequency
VIMS	:	Virginia Institute of Marine Science
WHOI	:	Woods Hole Oceanographic Institution
WL	:	water level

1 Introduction

1.1 Rationale

The present Second Interim Report for Phase 2 of the River Survey Project presents a summary of progress and findings in the third year of that project.

However, while the third project year is the period from June 8, 1994 to June 7, 1995, the reporting period has been adjusted to the period from June 1, 1994 to May 31, 1995. Hereby, the report covers the entire 1994 flood season and the entire 1994/1995 lean season. The same period is covered by Quarterly Progress Reports 8 through 11.

The report is part of the series of General Project Reports, which includes

- Final Report Phase 1, covering the period till the end of 1993
- First Interim Report for Phase 2, covering the first half of 1994

The objective of the report is to inform FPCO, CEC, RSPMU, and relevant external parties about the progress made and about the planned future activities. For details, reference is made to the Quarterly Progress Reports, the Survey Reports, the Study reports, and other submissions that have been made or are under preparation.

1.2 Structure of this report

In Chapter 2 is given a short review of the various activities, which are then described in more detail in the following chapters:

Chapter 3 Mobilisation, describing the completion of the Phase 2 mobilisation

Chapter 4 Surveys, dealing with the various types of measurements (water level gauging, the routine gauging programme, bathymetry, and special surveys)

Chapter 5 Data processing, describing the processing of survey data and the implementation of the engineering database PSD24

Chapter 6 Studies, presenting the various study topics and some results

Chapter 7 Training, describing the various training activities

Finally, a review is given of the reporting (Chapter 8), and the work programme for the fourth and final project year is presented in Chapter 9.

2 Review of activities

In the present chapter is given a summary of proceedings of the River Survey Project in the period from June 1, 1994 to May 31, 1995.

2.1 Introduction

Main activities in the period are presented in Figure 2.1, while milestones are listed in Table 2.1.

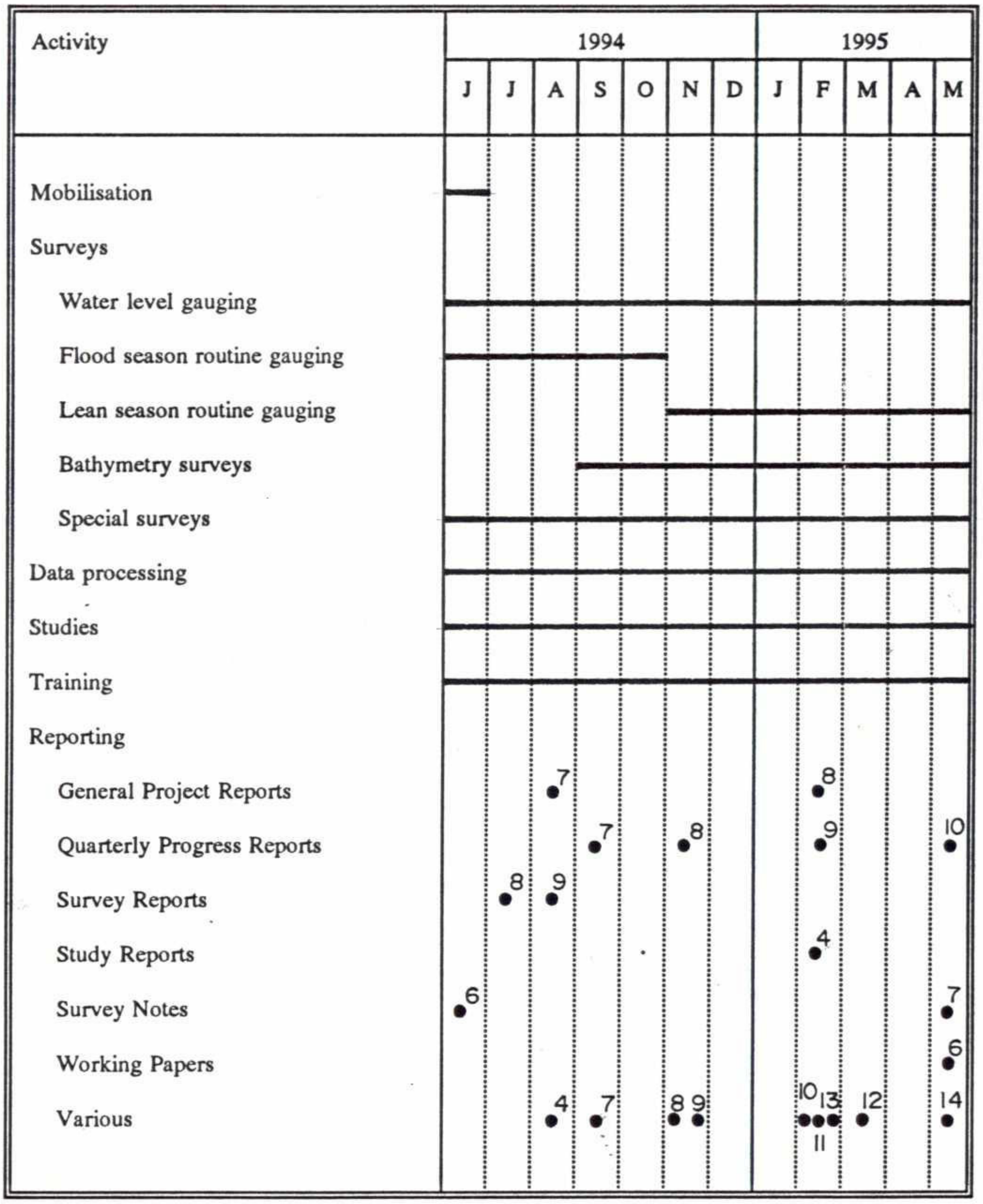

Figure 2.1: Main activities

June 1, 1994	Start of 1994 flood season programme
June 30, 1994	Completion of Phase 2 mobilisation
October 31, 1994	End of 1994 flood season programme
November 1, 1994	Start of 1994/95 lean season programme
May 31, 1995	End of 1994/95 lean season programme

Table 2.1: Milestones of the River Survey Project June 1994 - May 1995

2.2 Mobilisation

The mobilisation for Phase 2 of the project was completed by end of June, 1994, at which time 2 additional survey vessels became operational. Hereby, the full survey spread comprised 5 vessels.

2.3 Surveys

Water level gauging
In the period from June to July, 1994, 5 new water level stations were established. In April, 1995, 1 station (Gobindi, near Fulchari) was abandoned, while one additional station (Mir Char, 20 km downstream of Bhairab Bazar) was established in May, 1995. Hereby, by end of May, 1995, a total of 19 stations was operated by the River Survey Project. At that time, between them, the water level stations had been in operation for 257 months.

Flood season routine gauging
The flood season routine gauging took place from June through October, 1994, where a total of 50 gaugings was completed. Results are reported in Survey Bulletins 60-115.

Lean season routine gauging
The lean season routine gauging took place from November, 1994, through May, 1995, where a total of 42 gaugings was completed. Results are reported in Survey Bulletins 117-158.

Bathymetry surveys
A total of 16 bathymetry surveys was carried out in the period from September, 1994 through May, 1995. Results are reported in Survey Bulletins 8008-8022 and 9038.

Special surveys
The special surveys serve a variety of specific purposes that are identified in connection with the study activities. A total of 65 special surveys was completed from June, 1994 through May, 1995. Of these, 23 were additional flow recordings at Bahadurabad. Results are reported in Survey Bulletins 9001-9062.

2.4 Data processing

An improved survey bulletin format was introduced with Survey Bulletin 48, and the engineering database PSD24 (Processed Survey Data of FAP 24) was implemented in late 1994. At the same time, the LAN (Local Area Network) of the project office was extended to comprise the data users as well as the data processing unit. Two new series of survey bulletins were initiated: The 8000 series for bathymetry surveys and the 9000 series for the special surveys.

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The sediment laboratory completed 2691 analyses of sediment concentration, 2164 analyses of particle size by wet or dry sieving, and 190 settling tube analyses.

2.5 Studies

One of the objectives of the River Survey project is to undertake studies of the behaviour of the river system in Bangladesh based on (1) the new data that are collected during the routine surveys of the project, (2) existing data and (3) through the supplementary special surveys. The activities are listed below for the different study components during the reporting period.

Hydrology
The work comprised an examination of rating curves for Bahadurabad as established by BWDB and by FAP 24, and continued studies of the flow conditions at Bahadurabad. Rating curves were prepared for all FAP 24 routine gauging stations. The tidal influence at Mawa and at Bhairab Bazar was analyzed on the basis of special field surveys in February and March, 1995, respectively. The overland flow measurements were prepared to be executed in the monsoon 1995.

Sediment transport
The work concentrated on sediment transport rating curves for Bahadurabad, Hardinge Bridge, and Baruria, and on different factors affecting the rating curves. The study of the selection of suitable sediment transport predictors for the main rivers has started.

Planform characteristics
The flood plain levels, water level profiles, and the bankfull discharges were examined for the Jamuna, Ganges, and Padma rivers, and an analysis was made of applicable regime equations.

Off-takes and bifurcations
The work addressed flow and sediment transport characteristics at bifurcations, exemplified by the Gorai off-take and the bifurcation at Roy's bar near Bahadurabad. A 2-dimensional model was established for the area around the Gorai off-take. Good progress was made with the study of UoN of the secondary flow field around a bar near Bahadurabad.

Confluences
1-dimensional modelling of conditions at the Ganges/Jamuna confluence has been initiated and is in progress.

Bars and bedforms
This activity, which is carried out by UoL, comprises a study of bar and bedform development in the Bahadurabad area. In addition, some special surveys were carried out in order to measure bed forms in Jamuna River.

Measuring techniques
Special surveys were carried out of detailed flow characteristics (as a basis for optimisation of flow measurements), and of tidal and backwater effects at Mawa and Bhairab Bazar. Comparative field measurements were made with different sediment samplers: Delft bottle, Helley-Smith sampler, and the pump bottle technique, and with different flow measuring techniques for the near-bed sediment transport and the suspended bed material transport.

2.6 Training

Mr. Joynal Abedin Mollah, Executive Engineer, BWDB, joined the River Survey Project as a trainee on July 23, 1994. Mr. Minhaj Uddin Ahmed, the River Survey Project, was granted a 1-year fellowship at IHE, The Netherlands.

Dedicated in-house training programmes were conducted on the following issues:

- presentation techniques
- Autocad and Fortran 77 application
- database (PSD24) application
- river dynamics

River Survey Project staff held several external lectures and participated in a number of external conferences, seminars and professional meetings.

3. Mobilization and survey spread

The present chapter gives a short summary of the final mobilisation for Phase 2 of the River Survey Project, together with a listing of the survey vessel fleet and an outline of its instrumentation and capacity.

3.1 Phase 2 mobilisation

The mobilisation for the extended Phase 2 field programme was completed by the commissioning of two additional, fully equipped survey vessels, DHB and DHE, by end of June, 1994.

The DHB vessel
DHB is a "Sea Truck" type of glass fibre boat built for shallow water navigation. It is able to perform specialized survey operations (like the DHA and the DHC vessels) comprising bathymetry, depth integrated current and suspended sediment measurements, bed load sediment transport measurements and river bed sampling. The vessel features are:

- o positioning by DGPS
- o single frequency echo sounding including sand dune tracking
- o discharge measurements by moving boat method using EMF and/or ADCP
- o current velocity profiling
- o suspended sediment transport measurements by depth integrated sampling
- o bed load transport sampling
- o bed material sampling

The DHE vessel
DHE is a standard glass fibre boat built for shallow waters and with a small front cabin making it very suitable for bathymetric surveying, as well as for other special measurements in shallow areas requiring a small boat. The vessel features are:

- o positioning by DGPS
- o single frequency echo sounding including sand dune tracking
- o current velocity profiling in shallow waters

3.2 Survey vessels

A listing of the vessels operated by the River Survey Project is given in Table 3.1 below.

Name	DHA	DHB	DHC	DHD	DHE
Length over-all	20.2 m	11.2 m	8.7 m	4.9 m	5,2 m
Beam	4.7 m	3.2 m	6.3 m	1.9 m	2,2 m
Draft	1.2 m	0.9 m	0.8 m	0.8 m	0,8 m
Operational speed	12 knots	15 knots	12 knots	12 knots	20 knots

Table 3.1: Survey vessels

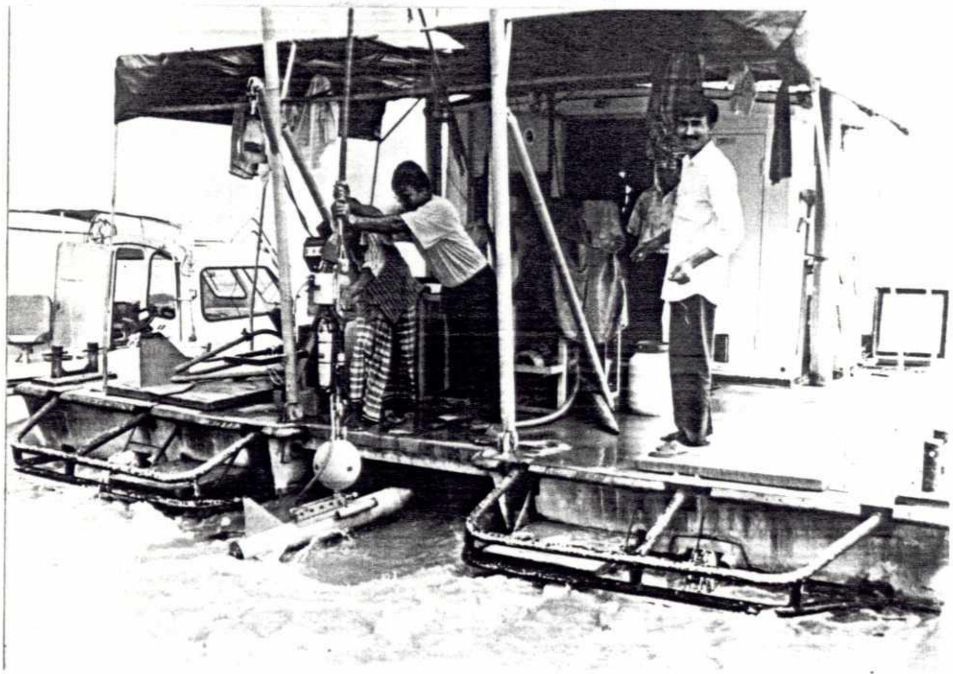

Figure 3.1: The DHC vessel

3.3 Survey equipment

The survey vessel and equipment configuration deployed by the River Survey Project as per end of June, 1994, is listed in Table 3.2 below.

Key characteristics of the positioning equipment and the applied recorders are listed in Table 3.3, while normal operational speed intervals are listed in Table 3.4 for different survey activities.

Equipment		DHA	DHB	DHC	DHD	DHE
DGPS positioning system:						
Trimble 4000, 9 channel		X	X	X		
Trimble Navtrac, 6 channel					X	X
Bathymetric survey:						
Elac Laz 4420 (echo sounding)		X				
Simrad EA 300 P (echo sounding)			X	X	X	
Atlas Deso 14						X
Point current measurement:						
Ott meter (mechanical)		X				
S4 InterOcean (electromagnetic)		X		X	X	
Braystoke propeller velocity meter					X	X
Integrated current measurement:						
300 kHz ADCP	(vertical)	X				
600 kHz ADCP	(vertical)		X			
EMF	(horizontal)	X	X	X		
Float tracking	(horizontal)	X	X	X	X	X
Suspended sediment measurement:						
Pump bottle sampling		X		X	X	
Depth integrated susp. sediment sampler		X	X			
MEX 3 turbidity recorder		X				
Bed load sediment transport measurement:						
Helley-Smith trap sampler		X	X	X	X	
Sand-dune tracking by echo sounding		X	X	X	X	X
Delft Bottle		X				
River bed sediment sampling:						
Van Veen grab		X		X		
USBM-54		X				
Drag sampler					X	X
Side scan sonar:						
EG&G Model 260		X				
Communication:						
VHF radios		X	X	X	X	X
Walkie talkies		X	X	X	X	X

Table 3.2: Capabilities and instrumentation of the survey vessels

Instrument		accuracy 1)	resolution 2)	sampling duration/ averaging period	sampling interval
DGPS		3 - 5 m	< 1 m	< 1 s / < 1 s	1 s
AWLR (pressure cell)	3)	1 cm	< 1 cm	< 1 s / 1 min	30 min
AWLR (acoustic)	3)	1 cm	< 1 cm	< 1 s / 1 min	30 min
Echo sounder		5 cm + 1 %	< 1 cm	<< 1 s / << 1 s	1 s
ADCP		5 - 10 cm/s	5 - 10 cm/s	<< 1 s / 6 s	1 s 4)
EMF	5)	2 %	1 cm/s	<< 1 s / 6 s	1 s 4)
S4	6)	2 %	1 cm/s	<< 1 s / 3 x 50 s	-
Ott current meter		3 - 10 % 7)	1 - 2 cm/s	50 s / 3 x 50 s	-

Note: All values are approximate. The values relate to the specific deployment, procedures, and application conditions during the River Survey Project, and do not directly reflect the potential capability of each instrument. The over-all accuracy of a recording can be different from the listed values due to for example repeated measurements (which can improve the over-all accuracy), or validity and time scale effects (which can reduce the over-all accuracy)

< = 'less than', << = 'much less than'

1): Standard deviation between true value and registered value
2): Smallest increment of the true value that can be registered by the instrument
3): 1 sample every 5 s, average for 12 samples (1 min) is stored
4): 6 s average value is updated every s
5): When used for cross-sectional transects or 'moving boat method'
6): When used for individual vertical current profiles
7): Mainly depending on the mooring of the vessel

Table 3.3: Characteristics of some instruments applied by the project

Operation	Speed	
Routine transect gauging	2 - 4 knots	1 - 2 m/s
Bathymetry and longitudinal transects during routine gauging	3 - 5 knots	1.5 - 3 m/s
Bedform inventory (longitudinal depth contours between stations)	10 - 15 knots	5 - 8 m/s

Values are indicative

Table 3.4: Operational speed during surveys

A particular feature of the River Survey Project is the application of the combined DGPS positioning and flow recording by ADCP, which makes it possible to measure flow distribution and integrated flow rates over a cross-section with a better accuracy and in a much shorter time (and hereby with a better validity) as compared with traditional velocity-area standard methods.

Further, the DGPS-ADCP approach does not require anchoring of the vessel while doing the measurements; on the contrary, the method is intended for flow recordings while transversing the river. This is a particular advantage in the large Bangladeshi rivers, where mooring in the main flow channels is not only risky from a safety point of view, but can also be unpractical, because the anchor can sometimes be buried so deep in the river bed that it cannot be retrieved. For example, during the initial pilot survey with *R/V Anwesha,* mooring in the main flow channels at Bahadurabad was not practical (please refer to RSP/FAP 24 Survey Report 1). The routine flow gauging at that location carried out by BWDB (by the velocity-area method using Ott propeller current meters) has to be carried out without mooring.

The ADCP instrument records the instantaneous vertical current profile by an acoustic Doppler technique. The velocity is registered by 3 orthogonal components over a series of depth intervals (that are called 'bins'). The bin height depends on the selected mode of operation and is 0.5 m. The uppermost 1.7 - 2.7 m of the water column are not covered(for DHB and DHA, respectively). Therefore, a supplementary single point EMF current meter is used for near-surface recordings. The measuring depth of this current meter is 0.5 m. Also, the deepest 6 percent of the water column are not covered by the instrument.

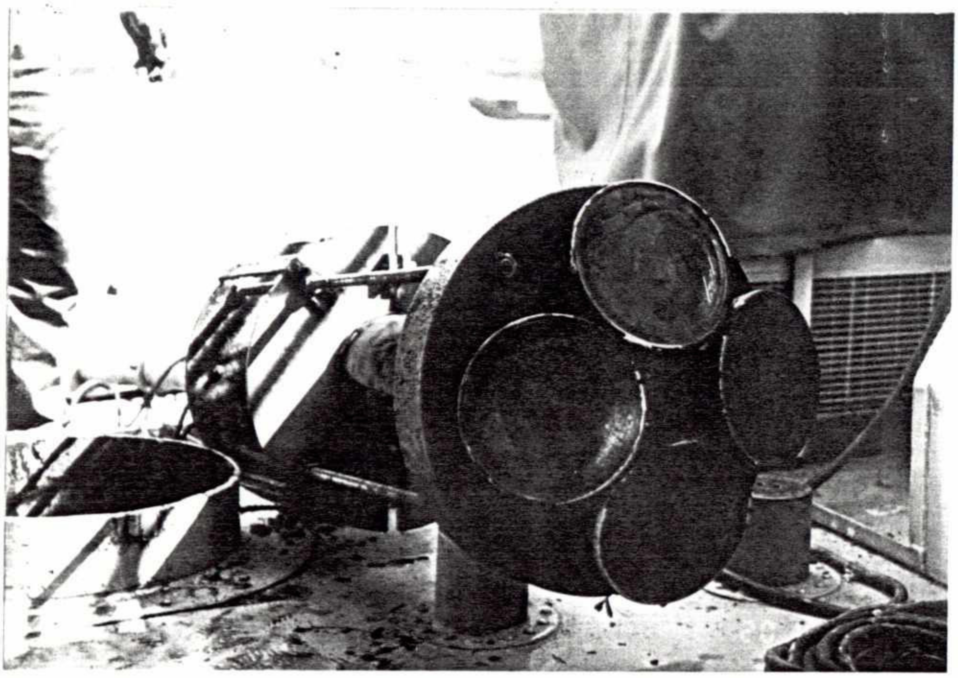

Figure 3.2: The ADCP lifted from its tube well on the DHA vessel

In addition to the vertical current profile, the ADCP can measure the movement of the vessel relative to the river bed by so-called bottom tracking. However, in case of a strong current, the river bed itself can move, whereby the bottom tracking does not provide a correct description of the boat's movement over the ground.

The coordinate system of the ADCP and the EMF (and hereby the speed and direction of the recorded current) is relative to the instrument, and hereby to the vessel. The current speed and direction relative to a fixed coordinate system (such as BTM) can be obtained in two ways: (1) by ADCP bottom tracking, or (2) by registration of the position and the orientation of the vessel (by DGPS and by a flux gate compass). The former method is applied for the ADCP under favourable measuring conditions (typically in the lean season), whereas the latter method is applied in case of a strong current, where the river bed moves, and also (in any case) for the EMF recordings. The required coordinate transformation is done in connection with the on-line data processing for the purpose of monitoring, and also, separately, as a part of the post-processing.

The performance of the DGPS-ADCP method was validated during comprehensive field trials that were carried out as a part of the project in late 1992 and in the 1993 flood season. The results of these trials are presented in Survey Reports 3 and 4. In brief, the method has fully proven its expected accuracy and capacity.

3.4 Horizontal and vertical reference

In the River Survey Project, all positions are relative to the BTM (Bangladesh transverse Mercator) grid.

During routine gauging of transects, stages and bed contour levels are referred to PWD (Public Works Department) datum. Depths are relative to the stage. However, for convenience, 'final' presentations of transect data in the Survey Bulletins are made in coordinate systems that are aligned along each transect.

Bathymetric surveys are referred to SLW (= Standard Low Water Level) datum.

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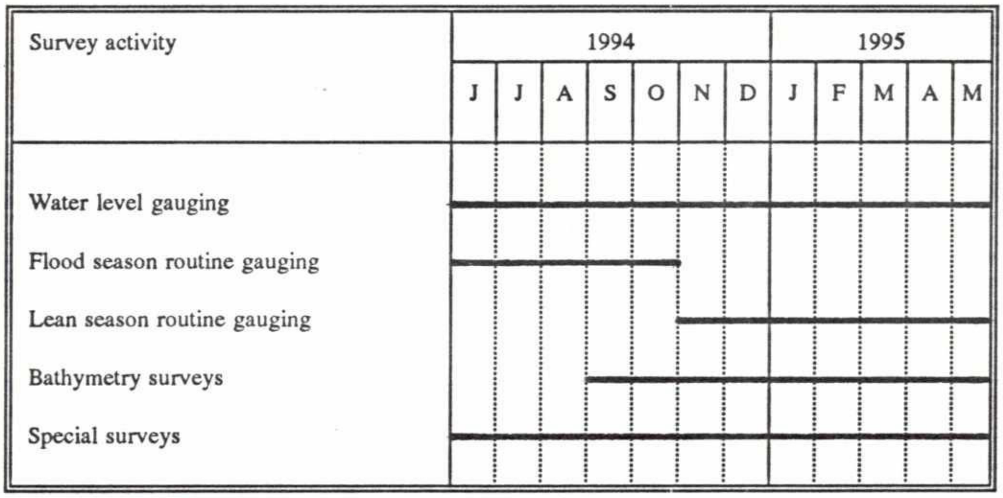
4 Surveys

This chapter describes the survey activities of the River Survey Project in the period from June, 1994 through May, 1995. First, a summary is given. Thereafter, each main activity is described in more detail.

4.1 Summary of activities

The survey activities are summarised in Figure 4.1.



Survey activity	No. of gaugings	Survey Bulletin nos.
Water level gauging	20	-
Flood season routine gauging	50	60-115
Lean season routine gauging	42	117-158
Bathymetry surveys	17	8008-8022, 9038, and 9044
Special surveys	63	9001-9062

Figure 4.1 : Main survey activities

4.2 Water level gauges

In the period from June to July, 1994, 5 new water level stations were established. In April, 1995, 1 station (Gobindi, near Fulchari) was abandoned due to poor data quality, while one additional station (Mir Char, 20 km downstream of Bhairab Bazar) was established in May, 1995 with the objective of monitoring backwater effects at Bhairab Bazar.

Hereby, by end of May, 1995, a total of 19 stations was operated by the River Survey Project. At that time, between them, the water level stations had been in operation for 257 months.

Two AWLR gauges (Baruria and Tilly) were damaged as they were hit by vessels, while two other AWLR gauges (Gabgachi and Bhuyanpur) had to be removed due to scour. Three AWLR gauges (Bahadurabad, Aricha, and Arial Khan) became dry during November. In all these cases, the 1/2-hourly AWLR readings were substituted by 3-hourly staff gauge readings. (All AWLR stations are supplied with staff gauges which are read all the time, irrespective of whether the AWLR is functioning or not).

The stations established or abandoned in the period from June, 1994 through May, 1995, are shown in Table 4.1. A list of the water level stations operated by the River Survey Project is given in Table 4.2. This table excludes 3 abandoned stations: Char Parul, Thanthania Para, and Gobindi.

The AWLR locations are shown in Figure 4.2.

Location	Change		Type
Arial Khan	Operational	3/6 94	P
Mymensingh	Operational	29/6 94	A
Hardinge Bridge	Operational	21/7 94	A
Gorai	Operational	22/7 94	A
Bhairab Bazar	Operational	24/7 94	A
Gobindi	Abandoned	1/5 95	S
Mir Char	Operational	31/5 95	S

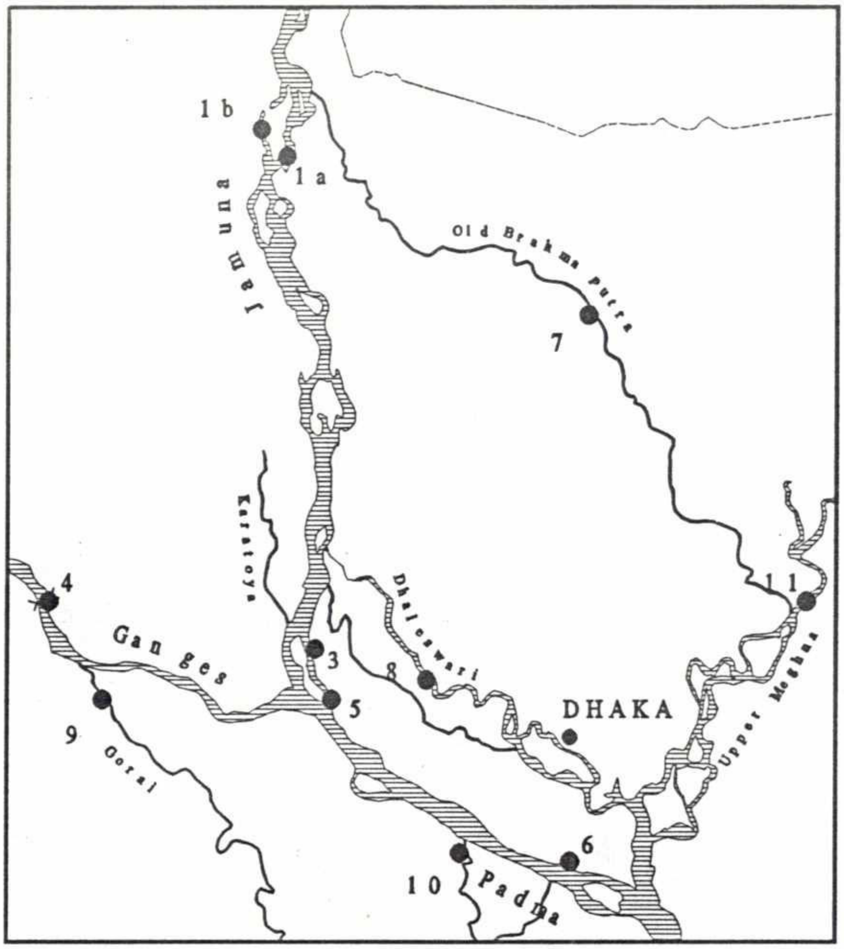
A: Acoustic AWLR
P: Pressure cell AWLR
S: Staff gauge

Table 4.1: New and abandoned water level stations (June 1994-May 1995)

Station	River	Appr. location	Operation period	Type
North Katiamari	Jamuna	Left channel, 7.5 km upstream of Bahadurabad	21/6/93 - 12/2/94 01/6/94 -	S
Uttor Horindhora	Jamuna	Left channel, 1.5 km upstream of Bahadurabad	1/6/94 -	S
Belgacha	Jamuna	Left channel, 3.5 km downstream of Bahadurabad	1/6/94 -	S
Bhagir Chow	Jamuna	Right channel, 4.5 km downstream of Fulchari	1/6/94 -	S
Shanki Bhangha	Jamuna	Right channel, 1 km upstream of Fulchari	1/6/94 -	S
Kabilpur	Jamuna	Right channel, 7.5 km upstream of Fulchari	1/6/94 -	S
Bahadurabad	Jamuna	700 m upstream of Bahadurabad Ghat	6/6/93 -	P
Gabgachi	Jamuna	Mid char opposite of Fulchari	15/7/93 -	P
Mawa	Padma	Near ferry ghat	10/5/94 -	P
Aricha (Teota)	Jamuna	2 km upstream of Aricha Ghat	13/5/94 -	P
Tilly	Dhaleswhari	10 km upstream of bridge	28/5/94 -	P
Baruria	Padma	6 km downstream of Aricha	28/5/94 -	P
Bhuyanpur	Jamuna	Left channel, opposite of Sirajganj	29/5/94 -	P
Arial Khan	Off-take of Arial Khan	Koshabhaya, 3 km downstream of off-take	3/6/94 -	P
Mymensingh	Old Brahmaputra	At railway bridge	29/6/94 -	A
Hardinge Bridge	Ganges	At bridge	21/7/94 -	A
Gorai	Gorai	At railway bridge	22/7/94 -	A
Bhairab Bazar	Meghna	At railway bridge	24/7/94 -	A
Mir Char	Meghna	20 km downstream of Bhairab Bazar	31/5/95 -	S

A: Acoustic AWLR
P: Pressure cell AWLR
S: Staff gauge

Table 4.2: Water level gauges in operation by end of May, 1995



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1a	Bahadurabad	Jamuna	6	Mawa	Padma
1b	Gabgachi	Jamuna	7	Mymensingh	Old Brahmaputra
2	Bhuyanpur	Jamuna	8	Tilly	Dhaleswari
3	Aricha (Teota)	Jamuna	9	Gorai off-take	Gorai
4	Hardinge Bridge	Ganges	10	Arial Khan off-take	Arial Khan
5	Baruria	Padma	11	Bhairab Bazar	Meghna

Figure 4.2: Water level gauge locations

Once per month, all stations are visited for inspection, down-loading of AWLR data, and collection of staff gauge data. Gauge data are compared and if any discrepancy is found, zero levels of the gauges are checked through levelling, and the data are corrected accordingly. In this way, the project has been able to collect reliable and continuous series of water levels, with the exception of the Gobindi station, which was abandoned because of insufficient reliability of the data.

The validation of water level data collected until end of December, 1994 is completed. The expert mr. Blok visited the project in April and May, 1995, in order to scrutinize the data quality, and all AWLR stations were checked in the field.

The readings of the staff gauges for slope measurements have also been validated, taking into account the results presented by the PA in Annexure IV of his 7th Mission Report of June 1994.

Conclusions of the water-level gauging so far can be summarized as follows:

- The applied logger-sensor system is working well, both in the case of a pressure cell sensor and an acoustic sensor

- The main advantage of the acoustic sensor is that all parts are above the river surface, which means that repairs and maintenance can be done also during high river stages

- The main problem is the appropriate selection of the platform location. Catching the full range of water-levels implies a deep water platform and a risk of scouring and exposure to collision by vessels

- A reasonable solution is to construct shallow water platforms at safe locations, from where the upper half of the hydrograph is measured. The lower, easier part can then be measured by staff gauges

For details about the AWLR measurements, please refer to *Survey Report 6: AWLR stations - site selection, installation and O&M (under preparation).*

4.3 Flood season routine gauging

In the 1994 flood season, routine gauging of flow, suspended sediment transport, and bed load was executed as presented in Table 4.3. The location of the transects is shown in Figure 4.3.

Station	1994					Total no.
	J	J	A	S	O	
1 Bahadurabad	60 69	80	89	95 98	107	7
2 Sirajganj	62	72 82	94		99 111	6
3 Aricha		74		97		2
4 Hardinge Bridge	61 67	79 87			104 115 108	7
5 Baruria	63	77 86	92	96	102 114	7
6 Mawa		84	93			2
7 Mymensingh	64	83			103 112	4
8 Tilly	65	85			105 113	4
9 Gorai Rlw. Bridge	66		88	106 109		4
10 Arial Khan		75	90		101 110	4
11 Bhairab Bazar		73	91		100	3
	Numbers are Survey Bulletin numbers					50

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Table 4.3: Flood season routine gauging 1994

The measurements were carried out by the recommended method, which is described in the Phase 1 Interim Report (Volume II, Annexure 4). A listing of the main components of the method is given in Table 4.4.

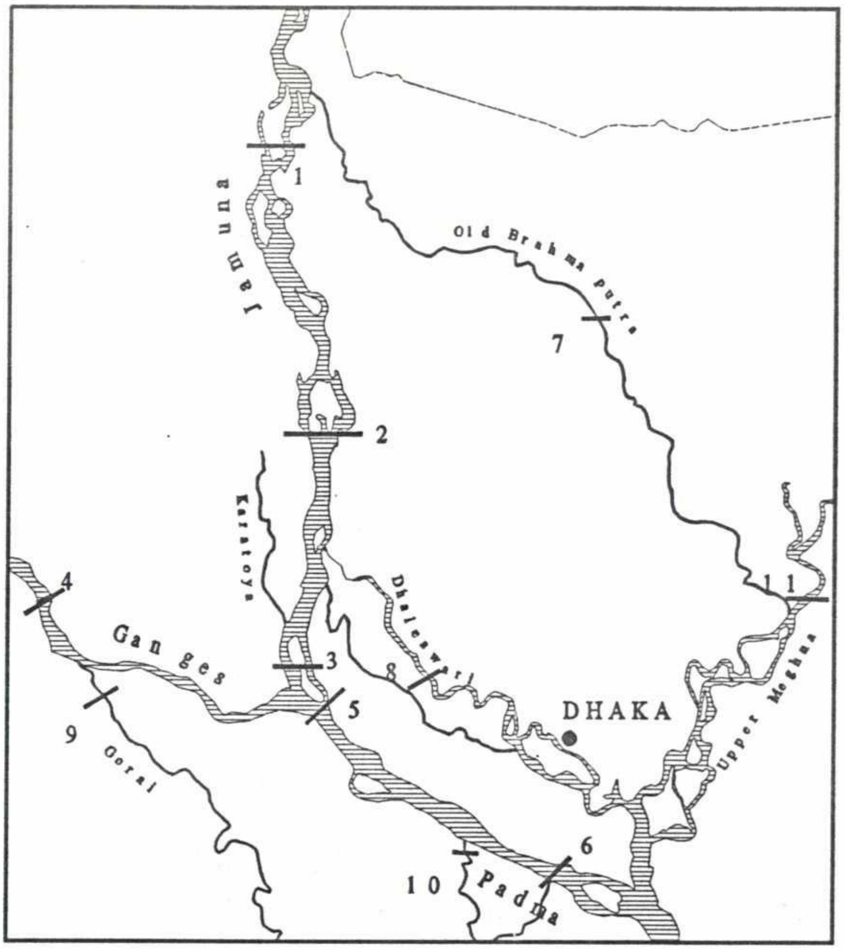
1	Longitudinal echo sounder reconnaissance of river bed features
2	Initial transects in each direction by ADCP, EMF, and echo sounder
3	Vertical profiles: (a) Current by ADCP and/or S4 (b) sediment concentration by pump bottle, turbidity meter, integrated bottle, and/or collapsible bag (c) pump bottle sampling for settling velocity
4	Bed load: (a) Helley-Smith sampler (b) Delft Bottle (c) dune tracking (where practical)
5	Bed material by US BM-54 sampler and/or van Veen sampler (Since June, 1995, a drag sampler has been applied from the smallest RSP vessels and from country boats)
6	Concluding transects in each direction by ADCP, EMF, and echo sounder

Table 4.4: Components of the recommended method

Please refer to the Survey Bulletins for additional information about the extent of the data collection, as well as for an outlook of the results and their storage in the PSD24 database.

Additional flow gaugings were carried out at Bahadurabad as a part of the special surveys programme (which is described in Section 4.6 below).

A listing of the flow regimes for the gaugings is given in Table 4.5 below. This table is intended as an information about the measuring conditions, rather than a presentation of the results. In the table, the stages are roughly listed as 12-hours average values (within channels) and as area-weighed 12-hours average values (between channels). In some cases, the stage has changed markedly during the gauging, and a more detailed analysis is required before using the data for rating curves and other purposes.



LEGEND

1	Bahadurabad	Jamuna	7	Mymensingh	Old Brahmaputra
2	Sirajganj	Jamuna	8	Tilly	Dhaleswari
3	Aricha (Teota)	Jamuna	9	Gorai off-take	Gorai
4	Hardinge Bridge	Ganges	10	Arial Khan off-take	Arial Khan
5	Baruria	Padma	11	Bhairab Bazar	Megna
6	Mawa	Padma			

Figure 4.3: Location of transects for routine gauging

Location		Date	Water level (mean value) m+PWD	Discharge m³/s	Suspended sediment transport kg/s
1	Bahadurabad	3-5/6 94	18.14	28329	23377
		24-26/6 94	18.58	34200	18989
		14-16/7 94	18.01	26738	13965
		6-8/8 94	17.82	23144	19370
		1-5/9 94	17.80	23812	12738
		21-27/9 94	17.73	25706	11081
		18-21/10 94	17.13	22089	7829
2	Sirajganj	10-11/6 94	11.46	27925	16249
		1-2/7 94	12.14	33670	21508
		18-19/7 94	11.37	21588	9053
		25-29/8 94	12.20	29910	15685
		3-4/10 94	10.89	19451	8616
		27-28/10 94	9.61	13737	6533
3	Aricha	6-8/7 94	7.65	32779	18237
		11-13/9 94	7.88	21467	8335
4	Hardinge Bridge	5-6/6 94	6.91	455	7
		20/6 94	7.88	1326	85
		14/7 94	11.77	14411	18196
		1/8 94	12.84	34667	138726
		11/10 94	10.98	11786	6204
		20/10 94	10.05	7810	3152
		1/11 94	8.82	3370	652
5	Baruria	14/6 94	6.11	30393	15113
		9/7 94	6.92	43585	21768
		29/7 94	7.45	52769	60786
		21/8 94	8.03	76553	140289
		9/9 94	7.18	54603	60393
		8/10 94	6.26	31135	13743
		28/10 94	5.01	19443	5251
6	Mawa	25/7 94	4.77	34550	23821
		25/8 94	5.87	70291	95119
7	Mymensingh	15/6 94	9.04	320	115
		19/7 94	8.65	271	83
		11/10 94	8.22	223	69
		27/10 94	7.32	95	5
8	Tilly	16/6 94	6.66	213	114
		25/7 94	6.91	258	122
		13/10 94	6.72	320	124
		28/10 94	5.66	174	43

Table 4.5: Stage-discharge-sediment transport results, 1994 flood season routine gauging

(continued)

Location		Date	Water level (mean value) m+PWD	Discharge m³/s	Suspended sediment transport kg/s
9	Gorai Railway Bridge	19/6 94	5.56	33	2
		5/8 94	11.34	3103	6019
		16/10 94	8.50	544	333
		24/10 94	6.95	225	83
10	Arial Khan	8/7 94	5.23	2026	1743
		10/8 94	5.89	2738	4381
		7/10 94	4.48	1534	943
		25/10 94	3.89	1156	270
11	Bhairab Bazar	5/7 94	4.83	6889	2182
		13/8 94	5.22	5980	184
		5/10 94	4.32	5543	125

Table 4.5 (continued): Stage-discharge-sediment transport results, 1994 flood season routine gauging

4.4 Lean season routine gauging

In the 1994/95 lean season, routine gauging of flow, suspended sediment transport and bed load was executed as presented in Table 4.6. The location of the transects is shown in Figure 4.3.

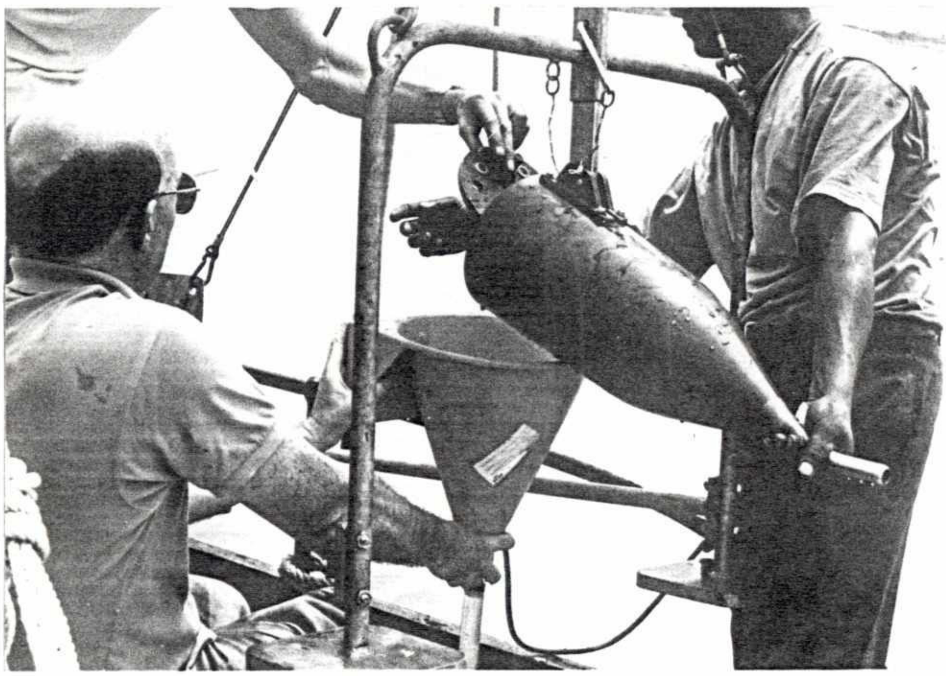


Figure 4.4: View from the field work: The Delft bottle in its frame

Station	1994		1995					Total no.
	N	D	J	F	M	A	M	
1 Bahadurabad	117 122			132	138 144	151		6
2 Sirajganj	118	127		133	142	146	152 154	7
3 Aricha								-
4 Hardinge Bridge		125	129	131	143	150	157	6
5 Baruria	119	128		137	140	147	153	6
6 Mawa				134				1
7 Mymensingh	124					145	156	3
8 Tilly	123				141		155	3
9 Gorai Rlw. Bridge		126	130				158	3
10 Arial Khan	120			136		148		3
11 Bhairab Bazar	121			135	139	149		4
	Numbers are Survey Bulletin numbers							42

Table 4.6: Lean season routine gauging 1994/95

The measurements were carried out by the recommended method, which is described in the Phase 1 Interim Report (Volume II, Annexure 4), and which is briefly summarized in Table 4.4. One survey at Mawa (No. 134) and one at Bhairab Bazar (No. 139) were extended in order to describe the tidal effect.

Additional flow gaugings were carried out at Bahadurabad as a part of the special surveys programme (which is described in Section 4.6 below).

A listing of the flow regimes for the gaugings is given in Table 4.7 below. Like Table 4.5, also this table is intended as an information about the measuring conditions, rather than a presentation of the results.

Location		Date	Water level (mean value) m+PWD	Discharge m³/s	Suspended sediment transport kg/s
1	Bahadurabad	7-8/11 94	15.08	8707	2050
		26-27/11 94	14.23	6342	1212
		8-9/2 95	12.90	3540	354
		2) sb 138			
		sb 144			
		sb 151			
2	Sirajganj	11/11 94	8.49	7729	1822
		15/12 94	7.23	5260	1041
		13/2 95	6.27	3683	544
		sb 142			
		sb 146			
		sb 152			
		sb 154			
3	Aricha				
4	Hardinge Bridge	3/12 94	7.66	1839	140
		3/1 95	6.52	1679	45
		3/2 95	5.87	548	9
		sb 143			
		sb 150			
		sb 157			
5	Baruria	14/11 94	3.80	11661	1897
		18/12 94	2.66	7477	760
		25/2 95	1.59	4001	107
		sb 140			
		sb 147			
		sb 153			
6	Mawa 1)	17-18/2 95	1.20-1.69	8-6539	
7	Mymensingh	sb 124	6.54	16	-
		sb 145			
		sb 156			
8	Tilly	sb 123	3.81	20	1
		sb 141			
		sb 155			
9	Gorai Railway Bridge	sb 126	3.66	5	-
		sb 130	4.38	-	0
		sb 158			

Notes: 1): Influenced by the tide
2): sb (survey bulletin) number is shown for measurements under processing

Table 4.7: Stage-discharge-sediment transport results, 1994/95 lean season routine gauging

(continued)

Location		Date	Water level (mean value) m+PWD	Discharge m³/s	Suspended sediment transport kg/s
10	Arial Khan	17/11 94 2) sb 136 sb 148	2.49	585	60
11	Bhairab Bazar	20/11 94 21/2 95 sb 139 sb 149	2.16 1.49	1865 1618	44 4

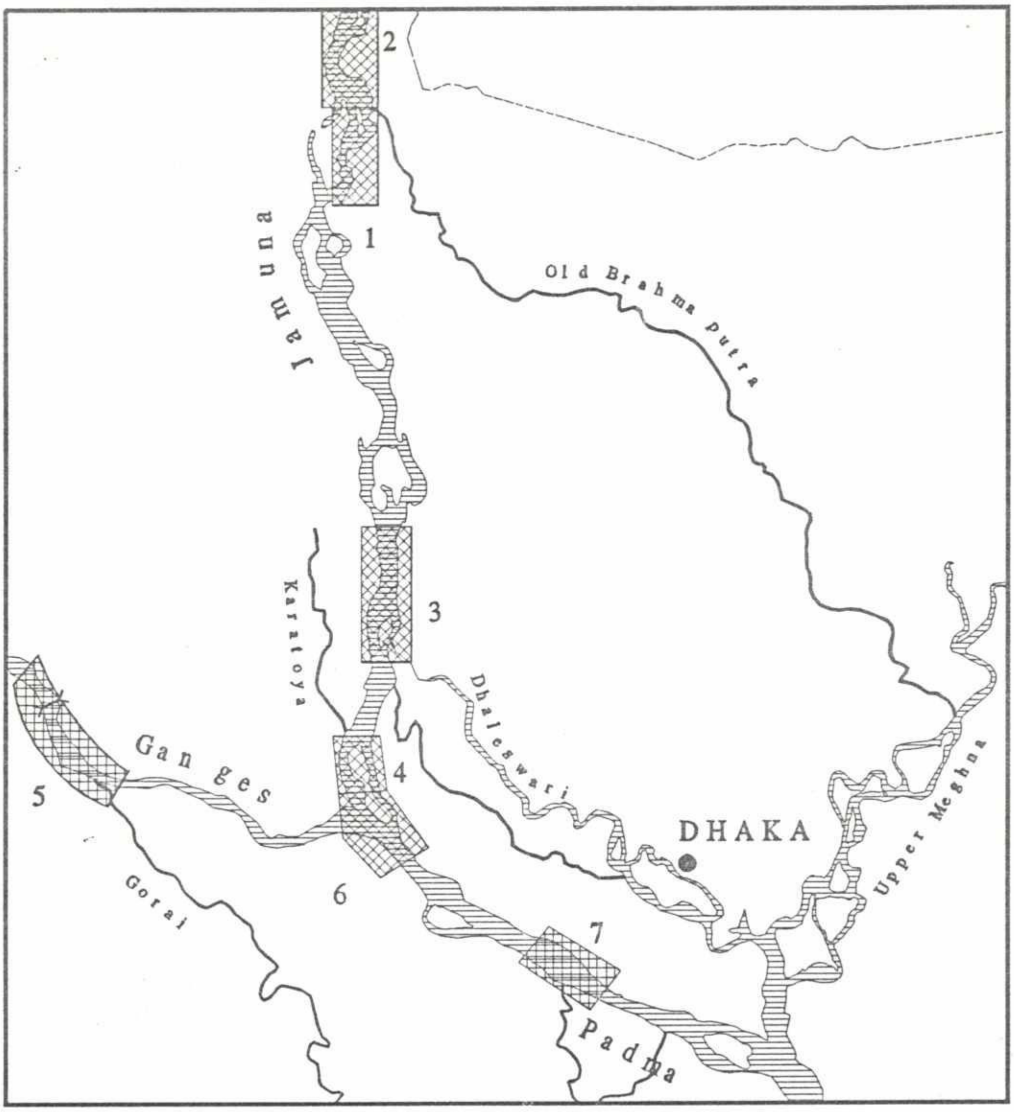
Note: 1): sb (survey bulletin) number is shown for measurements under processing

Table 4.7 (continued): Stage-discharge-sediment transport results, 1994/95 lean season routine gauging

4.5 Bathymetry

Bathymetry surveys are made in 7 areas, which are shown in Figure 4.5.

A listing of the bathymetry surveys completed in the reporting period is given in Table 4.8.



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1	Bahadurabad	Jamuna	4	Hurasagar outlet	Jamuna
2	Karmarjani (extension of the Bahadurabad survey area)	Jamuna	5	Gorai off-take	Ganges
3	Dhaleswari off-take	Jamuna	6	Jamuna/Ganges confluence	Padma
			7	Arial Khan off-take	Padma

Figure 4.5: Bathymetry survey areas

Area	Period	Survey Bulletin
Kamarjani	2-26 Sept 1994 10-20 Nov 1994 6-13 Mar 1995	8008 9038 8017
Bahadurabad	1-11 Nov 1994 24-27 Feb 1995	8010 8016
Dhaleswhari off-take	24 Nov-11 Dec 1994 29 Mar-4 Apr 1995	8011 8018
Hurasagar outlet	25-29 Dec 1994 18-20 Apr 1995	8013 8020
Gorai off-take	13-23 Oct 1994 6-18 Jan 1995 18 May-12 Jun 1995	8009 8014 8022
Jamuna/Ganges confluence	13-25 Dec 1994 8-15 Apr 1995	8012 8019
Arial Khan off-take	4-13 Feb 1995 27 Apr - 7 May 1995	8015 8021

Table 4.8: Bathymetry surveys from June 1994 through May 1995

Charts for morphological studies are made to the following scales:

interdistance of survey lines: 200 m → scale 1 : 20.000
interdistance of survey lines: 100 m → scale 1 : 10.000

The results of the bathymetric surveys are presented in the new 8000 series of Survey Bulletins, and will be summarised in a separate Survey Report (presently under preparation).

4.6 Special surveys

The special surveys serve a variety of specific purposes that are identified in connection with the study activities. A total of 65 special surveys was completed from June, 1994 through May, 1995. Results of the special surveys are reported in the new 9000 series of Survey Bulletins.

The special surveys may be divided into three categories:

- o additional flow measurements at Bahadurabad (carried out on 23 occasions in the reporting period)
- o a so-called bedform inventory programme, comprising repeated recordings of longitudinal depth contour profiles (carried out on 22 occasions in the reporting period)
- o a topographic (land) survey, carried out on one occasion in the reporting period
- o a variety of other purposes (carried out on 19 occasions in the reporting period)

Many of the special surveys support several study activities at the same time, while most of the study activities are based not only on the special surveys, but also on the results of the routine gauging programme (as well as on data produced or acquired by BWDB).

Flow measurements at Bahadurabad
The objective of the additional flow measurements at Bahadurabad is to improve the data coverage of the routine gauging, for several good reasons, one being to allow for a detailed inter-calibration and a mutual validation of the BWDB and the FAP 24 rating curves at that key location.

These flow recordings are being carried out by the same procedure as that of the routine gauging, except that sediment transport measurements are omitted. The special surveys are scheduled so that they, together with the routine gauging, provide a good coverage of the hydrograph, and, as far as practical, the measurements are made on the same days as the ones of BWDB.

The additional flow recordings at Bahadurabad are listed in Table 4.9. Please note that the table is intended as an information about the measuring conditions, rather than a presentation of the results. In the table, the stages are roughly listed as 12-hours average values (within channels) and as area-weighed 12-hours average values (between channels). In some cases, the stage has changed markedly during the gauging, and a more detailed analysis is required before using the data for rating curves and other purposes.

Date	Water level (m+PWD)	Discharge (m³/s)
23 Jun 94	18.54	33929
27 Jun 94	18.66	38473
28 Jun 94	18.59	34131
13 Jul 94	18.19	28799
16 Jul 94	17.86	26737
2 Aug 94	18.09	29884
5 Aug 94	18.39	25581
18 Aug 94	18.44	31710
31 Aug 94	18.09	24575
1 Sep 94	17.98	26304
6 Sep 94	17.42	20204
17 Sep 94	17.52	19305
28 Sep 94	17.62	22688
30 Sep 94	17.42	21581
17 Oct 94	17.24	22265
23 Oct 94	16.61	15749
26 Nov 94	14.25	6345
13 Dec 94	13.77	5416
8 Feb 95		1) sb 9045
11 Mar 95		sb 9049
28 Mar 95		sb 9052
4 Apr 95		sb 9054
30 Apr 95		sb 9057

1): Survey bullletin (sb) no. is indicated for measurements presently under processing

Table 4.9: Additional flow measurements at Bahadurabad

Bedform inventory programme
The bedform inventory programme comprises repeated recordings of longitudinal depth contour profiles, mainly in Jamuna. Hereby, a supplement is provided to the information about the time and space variation of bedforms that is produced by the bathymetry surveys. As compared with these surveys, the bedform inventory programme covers the entire reach between Bahadurabad and Aricha, and the measurements are more frequent, but only one longitudinal line is recorded, and the positioning (by ordinary, or 'non-differential' GPS) is less accurate than for the bathymetry surveys.

The recordings are made while transferring between routine gauging transects. The programme supplies data to study topics 6.2 and 7.4 (which are briefly described in Chapter 6 of the present report). A list of the recordings is given in Table 4.10.

Date	Route	Survey Bulletin no.
4 Jul 94	Sirajganj → Aricha	-
11 Jul 94	Aricha → Sirajganj	9005
28 Jul 94	Padma	9008
31 Jul-1 Aug 94	Aricha → Bahadurabad	9009
19-20 Aug 94	Bahadurabad → Aricha	9020
28-29 Aug 94	Aricha → Bahadurabad	9021
7-8 Sep 94	Bahadurabad → Aricha	9024
16 Sep 94	Sirajganj → Bahadurabad	9025
15 Oct 94	Aricha → Sirajganj	9030
16 Oct 94	Sirajganj → Bahadurabad	9031
25 Oct 94	Bahadurabad → Sirajganj	9036
14 Dec 94	Bahadurabad → Sirajganj	9042
17 Dec 94	Sirajganj → Aricha	9043
11 Feb 95	Bahadurabad → Sirajganj	9046
14 Feb 95	Sirajganj → Aricha	9047
14 Mar 95	Bahadurabad → Sirajganj	9050
27 Apr 95	Aricha → Sirajganj	9055
28 Apr 95	Sirajganj → Bahadurabad	9056
1 May 95	Bahadurabad → Sirajganj	9058
3 May 95	Sirajganj → Aricha	9059
18 May 95	Aricha → Sirajganj	9060
21 May 95	Sirajganj → Bahadurabad	9061

Table 4.10: Bedform inventory programme

Topographic surveys
Two topographic surveys were carried out in the reporting period:

- o Gorai off-take, in January, 1995, as a basis for the morphological modelling of that area (study topics 4.1 and 4.3). The activity is reported in Survey Bulletin 9044
- o Jim's Bar (at Bahadurabad), March 27-29, 1995, for the morphological investigations carried out by UoL (study topics 6.1, 6.2, and 7.4). Results are included in Survey Bullein 9051

Other special surveys
The programme of special surveys, in addition to the activities mentioned above, is described in Table 4.11 below. In this table, the scope of each activity is given by a few key words only, together with a reference to the related study topic, while a short outline of the scope of each survey is given in Table 4.12. Please refer to Chapter 6 for an elaboration of the different activities of the study programme.

It has become a good practice to discuss the programme of special surveys in detail with RSPMU prior to execution.

Date	Place	Scope and study topic 1)	Survey Bulletin no.
8 Jul 94	Arial Khan	Off-take dynamics (4)	9004
2 Aug 94	Upstr. of Hardinge Bridge	Effect of contraction (2)	9010
3-4 Aug 94	Bahadurabad	Near bed transport (9.3)	9012
4-5 Aug 94	Kushtia/Gorai	Off-take dynamics (4)	9013
6 Aug 94	Kushtia → Aricha	Bed material (3.2)	9014
9-20 Aug 94	Old Brahmaputra	Bed material (3.2)	9016
10-14 Aug 94	Bahadurabad	Bifurcation flow (4)	9017
15-18 Aug 94	Bahadurabad	Flow near bedforms (6.1, 6.2, 7.4)	9018
18 Sep 94	Bahadurabad	Bifurcation flow (4)	9026B
19-20 Sep 94	Bahadurabad	Flow near bedforms (6.1, 6.2, 7.4)	9026C
29 Sep 94	Bahadurabad	Slope measurements (1)	9028
1-6 Oct 94	Bahadurabad → Aricha	Bedform inventory, detailed flow near bedforms (6.1, 6.2, 7.4)	9029
19 Oct 94	Hardinge Bridge	Bridge constriction (2)	9033
21 Oct 94	Hardinge Bridge	Bridge constriction (2)	9034
4 Nov 94	Bahadurabad	Bifurcation flow (4.1)	9037
6 Nov 94	Bahadurabad	Turbulence measurements (9.2)	9037B
4-12 Dec 94	Bahadurabad	Sediment transport and morphology (2, 6, 9)	9040
6-10 Mar 95	Bahadurabad	Char topography (6, 7)	9048
24-27 Mar 95	Bahadurabad	Joint measurements with BWDB-Morphology (3)	9051
31 Mar-4 Apr 95	Bahadurabad	Optimization of survey methods (9.2, 9.3)	9053
22-31 May 95	Bahadurabad	Sediment plumes (2.2)	9062

1): Study topics are given in brackets; please refer to Chapter 6 for additional information

Table 4.11: Other special surveys

9004
Seasonal variation of bed forms. Measurements around Jim's Bar of bed forms and flow, and (a few) suspended sediment measurements

9010
Effect of constriction on sediment transport and discharge rating curve. Measurements at a cross-section upstream of the Hardinge Bridge constriction

9012
Near-bed sediment transport over dunes. Measurements of flow and sediment transport over stoss, crest, and trough of selected dunes

9013
(same as 9004)

9014
Bed material sampling in Jamuna in order to study the variability of bed material composition

9016
Bed material sampling in Old Brahmaputra in order to study the variability of bed material composition

9017, 9026B
Bifurcation flow patterns. Measurement of the flow division at a bar in order to determine secondary flow patterns

9026C
Seasonal variation of bed forms/bar topography. Measurements around Jim's bar of bed forms, flow, and (a few) suspended sediment measurements. Longitudinal profile of bed levels between Sirajganj and Aricha. Also, over-bar measurements of flow and bed levels

9028
Discharge rating curve by slope-area method. Measurements of local water level slopes and discharges

9029
Bedform inventory. Measurements of bed levels in order to map the spatial distribution of bars

9033
Effect of a constriction on the sediment transport and discharge rating curves. Measurements at a cross-section at the upstream end of the Ganges bathymetric survey area

9034
Sediment transport and discharge at the downstream boundary of the Ganges bathymetric survey area, and near Gorai mouth

9037
(same as 9017 and 9026B)

Table 4.12: Scope of special surveys (continued)

9037B
Time series measurements of flow profile, for optimization of the flow measuring period based on analysis of the turbulent flow structure

9040
Optimization of sediment measuring techniques, and bar topography and dune inventory. Measurements of sediment transport near eroding banks, and mapping of bed levels

9048
Bar topography. Land survey of bar, and bed level survey of dunes. Also flow measurements. Side scan sonar survey of bed form variation across the channel

9051
Cross-section survey. Joint measurements with BWDB-Morphology of one cross-section in Jamuna (J13-1). Echo soundings and topographical survey

9053
Optimization of number of verticals in a cross-section and number of measuring points in a vertical. Flow and sediment profiles

9062
High sediment concentrations. Measurements of flow, sediment, and local bathymetry in areas with sediment plumes

Table 4.12 (continued): Scope of special surveys

5 Data processing

5.1 Introduction

Most of the field measurements generate computer data, which are called raw data and which need supplementary off-line data-processing. The off-line data processing takes place in the River Survey Project's office in Dhaka. It comprises file conversion, plotting for quality check, subsequent data reporting and listing of files in the data catalogue. After processing, the water level data are stored within the framework of the HYMOS software system, while all other data are stored in a database called PSD24 (Processed Survey Data of FAP 24).

The processing of each type of data is carried out by a dedicated combination of standard methods and techniques that have been developed for the specific purpose as a part of the River Survey Project. An outline of the data flow is presented in Figure 5.1.

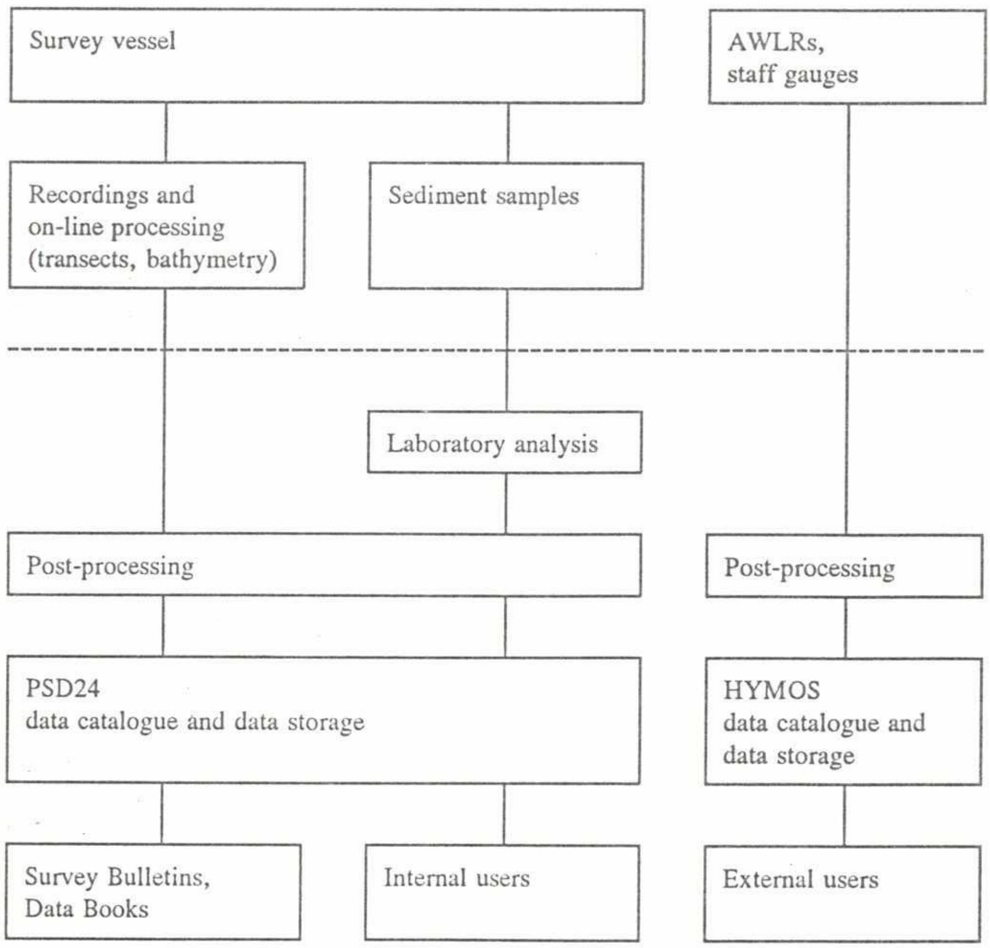

Figure 5.1: Data flow summary

The current rate of data production is equivalent with approximately 3 gigabytes per year of raw data and one gigabyte per year of processed data.

The following types of survey activities produce data to the RSP data processing office:

- o Water level recordings (Section 5.3)
- o Flow recordings for routine transect surveys (Section 5.4)
- o Sediment sampling for routine transect surveys (Section 5.5)
- o Bathymetric surveys (Section 5.6)
- o Special (non-routine) surveys (Section 5.7)

The PSD24 database is described in Section 5.8, and the quality control and the data reporting of the project is described in Section 5.9.

5.2 The RSP data processing office

The data processing office of the River Survey Project comprises two sections. One section undertakes off-line data processing and production of Survey Bulletins, while another operates the PSD24 and the LAN network. The former section employs 5 persons and the latter 3 persons (one of these half time).

Hardware facilities for data processing are listed in Table 5.1. All internal users are connected with the HYMOS package and the PSD24 by the LAN network in the RSP project office, for convenient downloading of data for secondary analysis in connection with the different study activities.

Off-line data processing and survey bulletins

- 1 UNIX server, 33 MHz, 16 Mb RAM, 1 Gb harddisk, 1 DAT tape drive, 1 external CD ROM drive
- 1 UNIX work station, 33 MHz, 16 Mb RAM, 200 Mb harddisk
- 2 486 PCs, 16 Mb RAM, 200 MB harddisk, and 1 486 notebook PC
- 2 DOS tape stations
- 1 A3 digitizing table
- 1 A0 plotter, 1 A3 plotter, and 1 laser printer

PSD24 operation

- 1 UNIX server, 66 MHz, 16 Mb RAM, 2x1 Gb harddisk
- 3 486 PCs

Table 5.1: Hardware for data processing

5.3 Water level recordings

The processing of the water level data is illustrated in Figure 5.2.

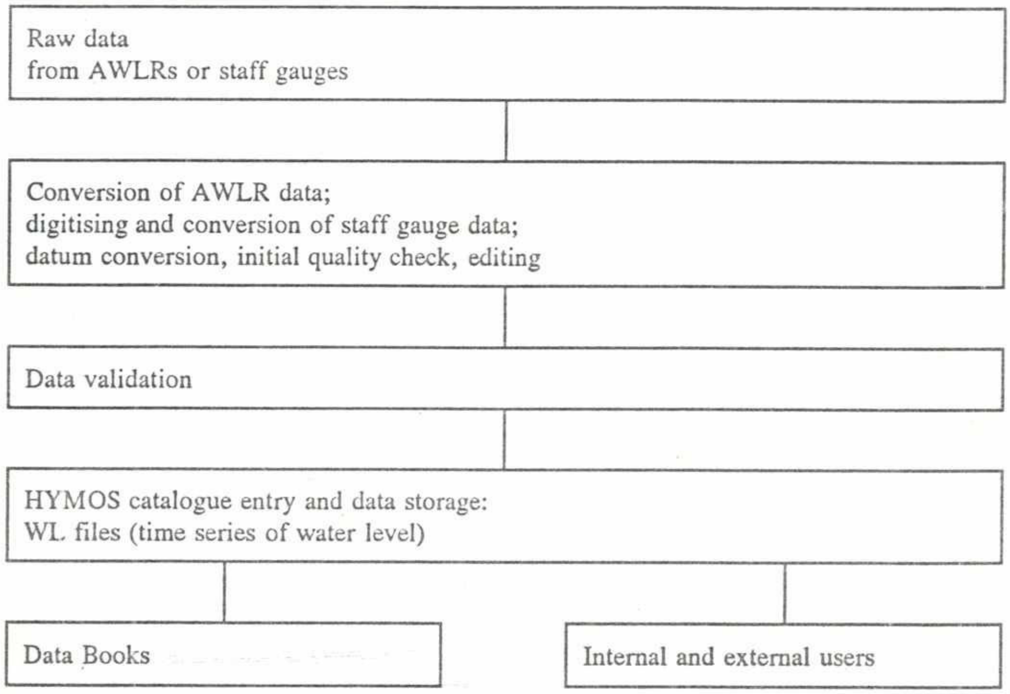

Figure 5.2: Processing of water level data

Following conversion and initial processing, the data are validated by consistency analysis, which involves examination of hydrographs, stage-discharge relationships and inter-station comparison. The water level data are catalogued and stored in HYMOS, which is a hydrological software system for analysis and management of hydrological data.

5.4 Flow recordings for routine transect surveys

The routine transect surveys comprise recordings of flow and sediment transport. These recordings form an integrated activity, but the data processing procedures are different. Therefore, the flow recordings are described in the present Section 5.4, whereas the processing of sediment data is described in the subsequent Section 5.5.

Each single transect produces around 1 Mb of raw data, and each individual vertical profile produces around 0.1 Mb of raw data. Hence, a typical routine gauging will produce somewhere around 10-15 Mb of raw data for each survey at each location, and sometimes more.

The on-line data processing comprises time and position control, data collection from the different sensors, data storage, and on-line monitoring of the measurements. The applied software is the Hydropac software package and dedicated software developed for the purpose of the project. All raw data are catalogued and stored at the data processing office.

The off-line data processing comprises file conversion and a drastic data reduction. Selected cross-section transects and all individual profiles are plotted for quality check and subsequent data reporting. All processed data are entered into the PSD24.

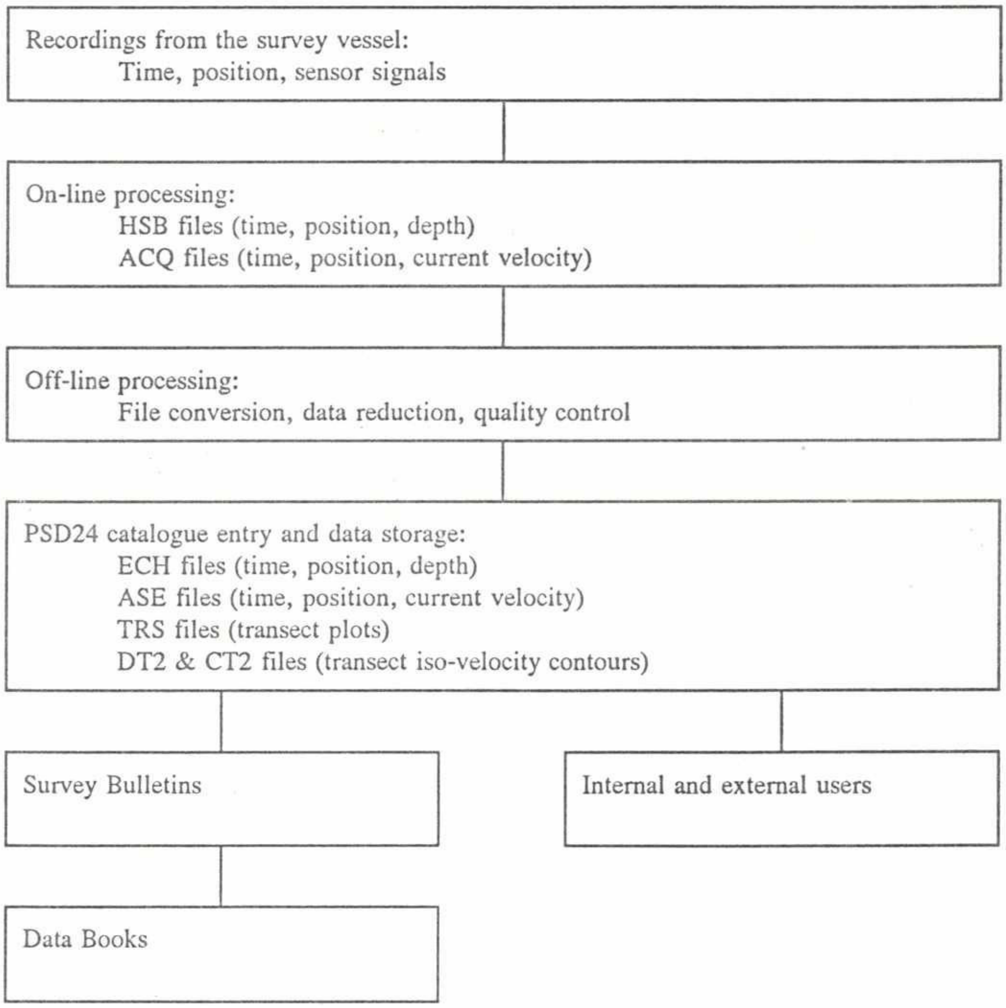

Figure 5.3: Processing of flow data of routine transect surveys

The software used for the routine post-processing comprises a standard (Quattro Pro) spreadsheet, modules from the Mike21 Pre- and Post-processing

80

software package, and utility programmes developed at the River Survey Project.

The processing of the flow recordings for the routine transect gauging is shown in Figure 5.3.

5.5 Sediment sampling for routine transect surveys

In addition to the flow recordings, the routine transect surveys comprise determination of suspended sediment transport and bed load transport, as well as sediment grain size distributions, and vertical distributions of sediment concentration and settling velocity. For these purposes, the routine gauging comprises collection of a variety of sediment samples, as briefly described in Chapter 4, Section 4.3. The different types of samples are analyzed in the sediment laboratory of the River Survey Project. This laboratory is located in the RSP project office in Dhaka. It has equipment for standard analyses of concentration, settling velocity distribution, and grain size distribution. Results are digitized, whereafter transport rates are calculated by application of the flow data from the survey. Data files are generated, checked, and stored in separate data files in the PSD24. From June, 1994 to through May, 1995, the sediment laboratory completed 2691 analyses of sediment concentration, 2164 analyses of particle size by wet or dry sieving, and 190 settling tube analyses. The processing of the sediment data of the routine transect surveys is shown in Figure 5.5.

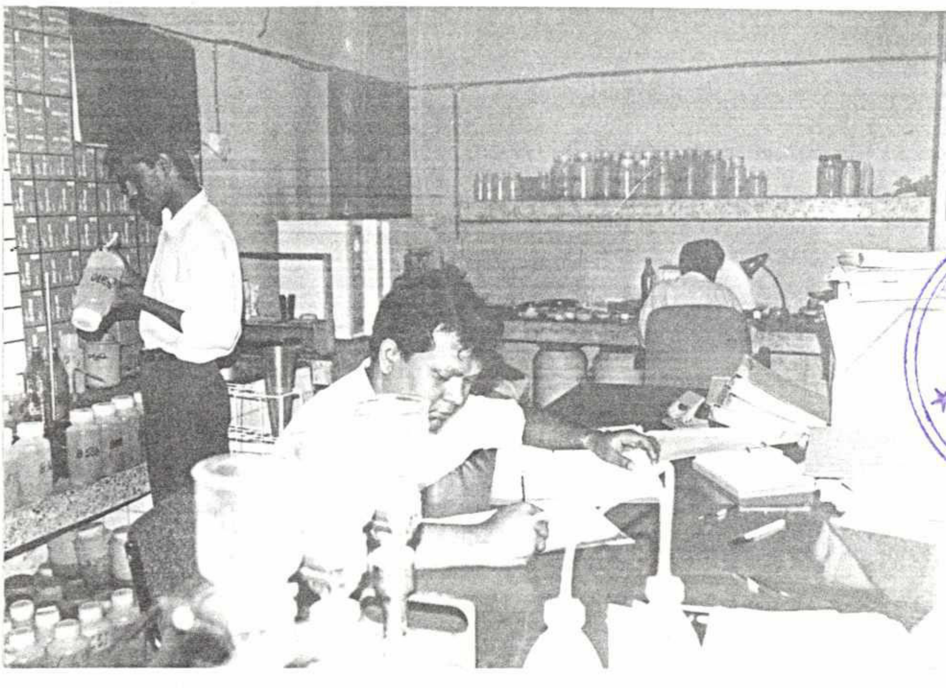

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Figure 5.4: View from the sediment laboratory

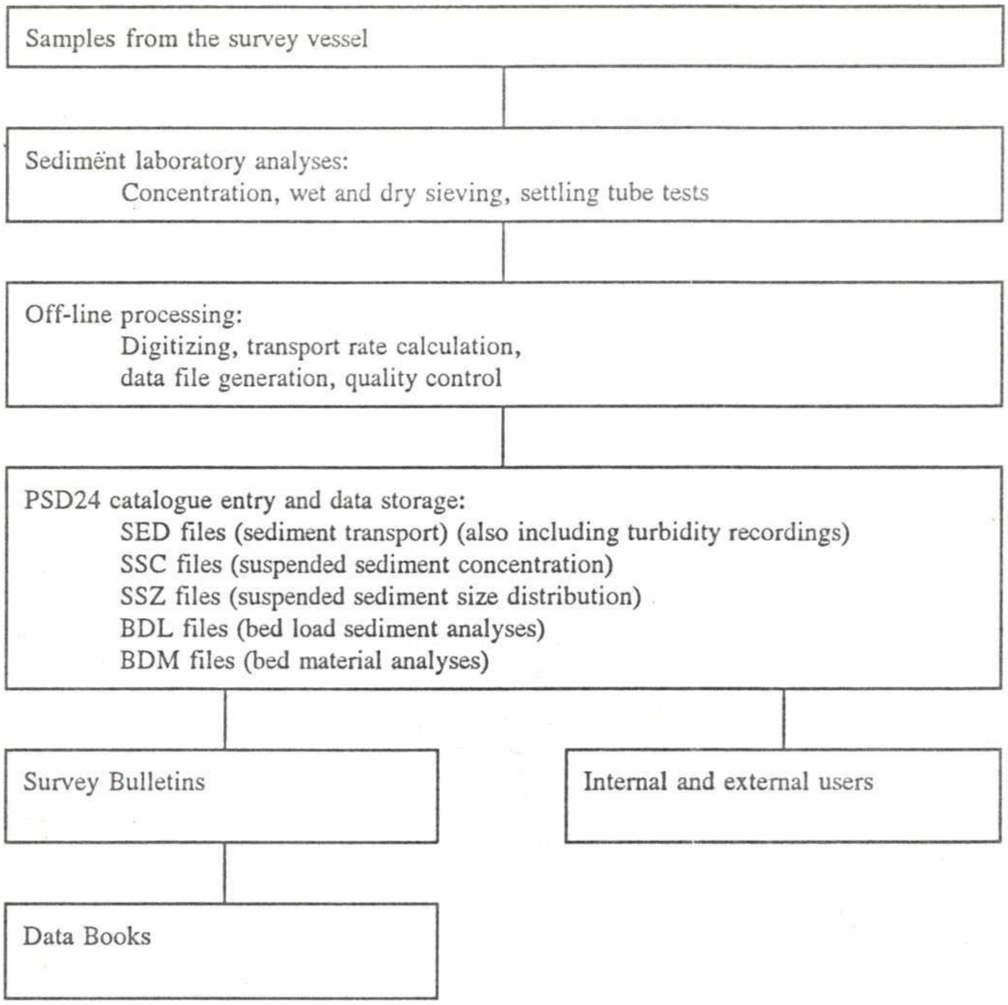

Figure 5.5: Processing of sediment data of routine transect surveys

5.6 Bathymetric surveys

The bathymetric surveys produce as much as up to around 30 Mb of raw data per km^2 of survey (which is 10 km survey line at a line spacing of 100 m).

The on-line control comprises position control and area coverage (by plotting and monitoring the survey lines). Occasional DGPS instabilities, which result in an apparent abrupt position shift, are labelled for correction later on. Also, the depth recordings are monitored on-line, and irregularities, if any, are identified and labelled.

The raw data are prepared for interpolation by applying error checking and datum reference conversion procedures. Error checking is done partly automatically and partly manually. Error checking software routines, which have been developed at FAP 24, are used to locate data spikes and other suspicious data, characterised by for example abrupt depth changes or completely constant depths. While some data items can be automatically discarded or edited, or at least automatically identified and labelled for subsequent manual checking, other data must be visually inspected to determine whether they make sense or not.

The raw data files are converted into processed data files at the data processing office. Hereby, the recorded depths are converted into river bed levels relative to the applied datum. The conversion is a function of time and space, as determined by water level recordings from the survey area relative to the datum. The bank line is specified, and the data are inspected once again for position and river bed level irregularities by plots or on the computer screen.

Bathymetric plots are produced in the data processing office using 3 software routines:

- The Consultant's utility program SCAN is used to produce maps of the echosoundings. This program serves a dual purpose in that it is used for the visual inspection of the data for quality checking procedures and it also produces the final sounding chart after quality checking
- M21digi (from the Mike 21 software package) is used for the conversion (by interpolation) of the prepared raw data into a fixed grid
- T2plot (also from the Mike 21 software package) is used for contour plots based on the fixed grid data

Results are presented as follows:

- Bathymetry charts, which show survey lines and soundings along the lines to the extent possible at the selected scale
- contour plots, based on interpolated arrays of river bed levels, by application of an arbitrary smoothing of the contours

The two types of presentations are exemplified in Figure 5.6.

The workload required for post-processing is 8 working days for a large survey, such as a flood season survey at Bahadurabad, and 4 working days for a small survey.

The processed bathymetry data are stored in two types of data files: One file type, the so-called XYZ file, contains sets of position and river bed level along the survey lines. Another file type (which is generated by the M21digi routine) contains river bed levels for the entire survey area in a fixed grid, which is established by bilinear interpolation of the measured values. The former file type is big, and one survey area will normally comprise a large number of files. The latter file type is convenient for certain types of analyses, such as contour plots, 3-D plots, and calculation of volumetric differences between successive soundings.

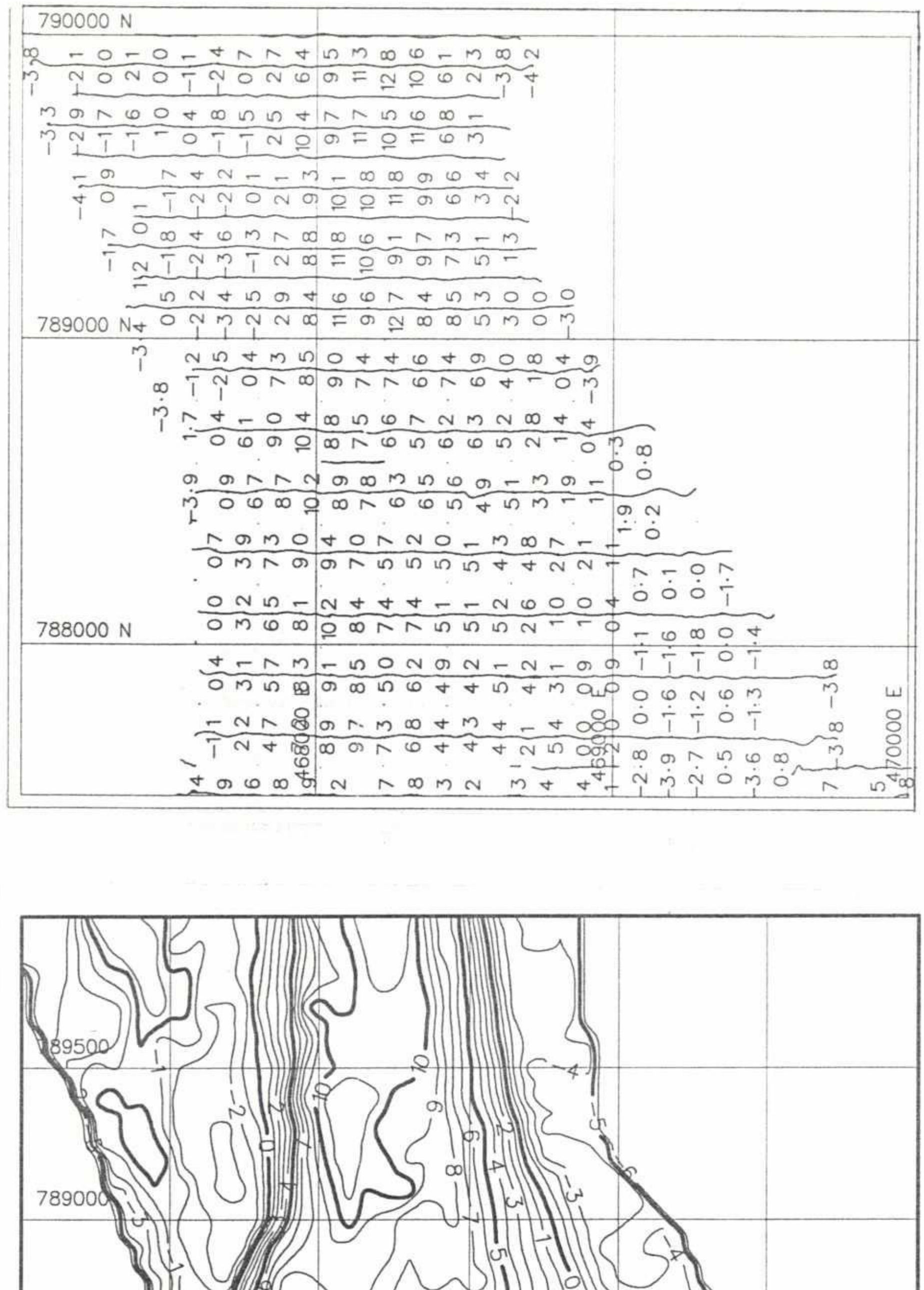

Figure 5.6: Bathymetry chart and contour plot (example, Bahadurabad, flood season 1993)

The processing of bathymetry data is illustrated in Figure 5.7. For details, please refer to *Survey Report 9: 'Bathymetric pilot surveys on Jamuna River at Bahadurabad'*.

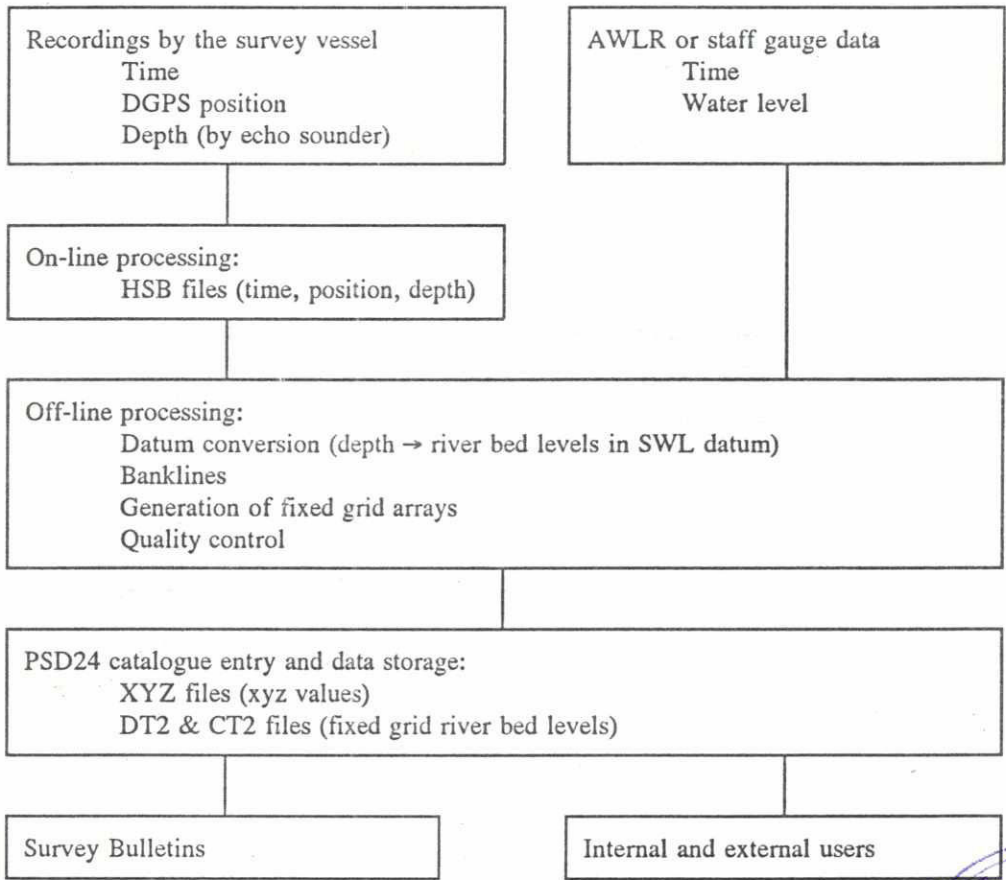

Figure 5.7: Processing of bathymetry data

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5.7 Special (non-routine) surveys

Many of the special surveys consist of elements of the routine gauging. This is for example the case with the additional flow measurements at Bahadurabad, which are carried out in exactly the same way as the flow measurements that are made during the routine gauging. In such cases, the data processing follows the routine procedures as described above.

When a special survey comprises activities that are different from the ones of the routine gauging, dedicated procedures for the data processing are established in a dialogue with the study team and applied in accordance with the objective of that survey.

5.8 PSD24

Specifications for the PSD24 were drafted in April-May 1994, and were reviewed in a dialogue with the PA, BWDB, and internal users in the following months. Some consideration was given to the choice of the basic operating system, weighing the performance requirements against the convenience to the users. The UNIX-based (Oracle) database that was established in Phase 1 of the project had performed well, but had never been effectively implemented, because it was not readily accessible by the users; another aspect was the highly increased performance of DOS software that appeared in the period since the planning of the project. On the other hand, still, certain bulky data processing operations must necessarily be made in a UNIX environment due to capacity requirements.

Hence, it was decided to implement a DOS database, and Paradox 4.5 for Windows was selected for the purpose. Wherever possible, preference was given to an ASCII or a DOS spreadsheet file format. At the same time, the Ethernet LAN network of the data processing office was extended to cover all internal data users. Certain processing operations, such as conversion of raw transect data and all bathymetry data processing, remained within the UNIX environment.

PSD24 comprises

- o a data catalogue (Paradox)
- o data files

The data catalogue comprises all data files of the River Survey Project. The catalogue is accessible via the LAN network.

Regarding the data files, the processed transect data are directly accessible via the network, while the raw transect data and the bathymetry data are not (because these files are too bulky and are therefore not well suited for the DOS environment). The former categories of data are stored in Quattro Pro spreadsheet format (which can easily be converted into ASCII format, if so desired). Hereby, these data files can be downloaded from the PSD24 directly into a Quattro Pro spreadsheet, where many types of analyses and presentations can be made.

The catalogue structure and the different software routines were gradually established and implemented in August-September, 1994, and the system became operational in October, 1994. Debugging and adjustments of plotting routines were made till May, 1995.

By end of May, 1995, it was the impression that the PSD24 complied well with the requirements of the users, and that it represented a good practical compromise between performance and accessibility.

5.9 Quality control, data reporting, and data storage

Quality control
The data quality control comprises

- o on-line control
- o off-line control
- o user control

In the three stages, different types of errors and deficiencies are monitored, according to the increased aggregation of information.

The on-line control is an integrated part of the survey procedure. It comprises the survey documentation, the basic data coverage, the immediate data consistency, and obvious measurement errors. Errors and deficiencies to be detected can be for example improper performance of instruments or of the on-line data processing system; inconsistent recordings, such as for example instantaneous position shifts; or identification of unusual recordings, where values are outside of an anticipated range. The on-line control results in reporting of actual or potential deviations, and can result in an immediate decision to repeat a suspect measurement.

The off-line control is a more deep examination of the results, which normally involves examination of a graphic presentation of data from one or more sources. Inter-station comparison is a common tool, where it for example is checked whether some unusual flow fluctuation occurs at one station only, or whether the pattern appears in several independent records.

This exercise can be quite time-consuming. For example, a bathymetric survey may display an unusual steep slope between two successive soundings. This may be due to either an error, or due to a true, but extreme bed level variation. An evaluation can involve an examination of the specific survey line, whereby for example erroneous spikes can be identified, or adjacent survey lines have to be compared in order to find out whether an unusual feature is reflected in independent recordings.

The data quality control is a process that continues for as long as the data are being used, and some errors or deficiencies will inevitably remain after post-processing and data reporting. For example, during a calibration of a hydrodynamic model, small errors within stage levels or phase lags can be detected that could not have been identified in any other way.

Data reporting

The ordinary data reporting comprises the following:

- o Survey Bulletins, basic series (routine transect gauging)
- o Survey Bulletins, 8000-series (bathymetric surveys)
- o Survey Bulletins, 9000-series (special surveys)
- o Data Books (water level data and extracts of routine transect gauging)

One Survey Bulletin is issued for each survey.

At the initiative of the PA, the format of the basic series of Survey Bulletins was changed by end of March, 1994 (Survey Bulletin 48 being the first one in the new format). The reason was that the bulletins had become too bulky. At the same time, the new format was made compatible with the PSD24. Hereby, the new bulletins provide an outlook of the gauging conditions, provide an extract of the findings, and supply a catalogue reference to the data files, rather that presenting the detailed results in their entity.

The data will be published in two data books, one for the period till April 1, 1995, and one for the period after that date.

Data storage

Water level data are stored in the HYMOS sytem, while all other categories of processed data are stored in the PSD24.

Security against loss of data is pursued by storing all data on DAT tapes. Raw data are stored in duplicate, whereas one copy is stored of the processed data.

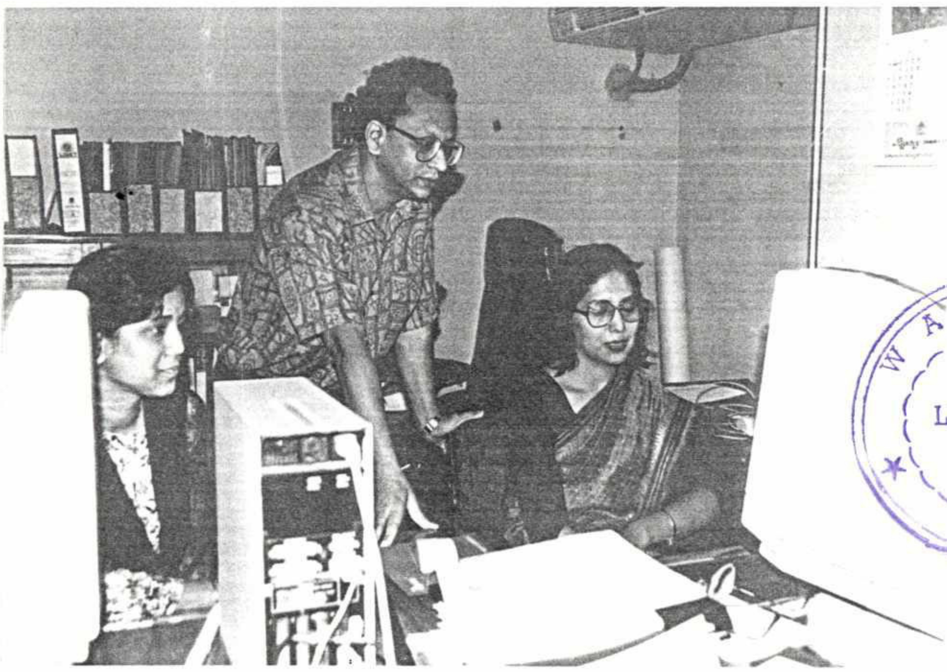

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Figure 5.8: View from the data processing office

6 Studies

6.1 Introduction

Scope of the programme

The objective of the study programme is *'to investigate key characteristics of the behaviour of the river system. The river studies would address aspects of the main river system that are essential for the planning of projects under the Flood Action Plan. ... The studies will be undertaken in response both to the demands of ongoing FAP studies and to the possible effects of planned Flood Action Plan projects on river regimes' (Terms of Reference of the River Survey project).*

A tentative outline of the study activities was presented in Study Report 1 (September 1993). The programme was briefly discussed in connection with an International Workshop arranged by FPCO in Dhaka in November, 1993, and has subsequently been elaborated and amended in a dialogue with PA/RSPMU. Proceedings of Phase 1 were presented in Study Report 2 (hydrology) and Study Report 3 (morphology).

The study programme for Phase 2 was presented in the Final Report Phase 1, and, in more detail, in Study Report 4, Study Programme. Progress of the work, and adjustments of the scope and the time schedule, have been discussed with the PA throughout the project.

Study activities in the period June 1994 - May 1995 are summarised in Figure 6.1.

Staffing

The study programme is undertaken partly by a team of Bangladeshi professionals who are full-time attached to the River Survey Project, partly by a number of expatriate specialists, and partly by external institutions in Bangladesh and abroad.

The Bangladeshi professional project staff members are dr. Dilib K. Barua, mr. Maminul Haque Sarker, mr. Zahirul Haque Khan, mr. Saleem Mahmood, mr. Krishna C. Dey, and mr. Khalid H. Rahman. Please refer to Study Report 4 for information about the work allocation within the study team.

External organisations participating in the study programme are:

- BUET (topics 2.4, 3.2, 3.3, 5, 7.1, and 7.2)
- UoN (topic 4.1)
- UoL (topics 6.1, 6.2, 7.3, and 7.4)

Subject		Topic
1 Hydrology	1.1	Improved discharges and rating curves
	1.2	Improved historic discharge time series
	1.3	Water balances and overland flow
	1.4	Water level profiles and slopes
	1.5	Phase 2 updating
2 Sediment transport and river aggradation and degradation	2.1	Rating curves and balances
	2.2	Sediment transport predictors
	2.3	Integration of existing knowledge
	2.4	Long-term development of distributaries
	2.5	Flood plain subsidence
	2.6	Phase 2 updating
	2.7	High sediment concentrations
	2.8	Fine sediments
3 Planform characteristics and channel dimensions	3.1	Planform classification
	3.2	Channel dimensions (regime equations)
	3.3	Bank erosion rates
	3.5	Channel cut-offs
	3.8	Local slopes and their importance for planform changes
	3.9	Prediction of medium-term planform changes
	3.10	Long-term changes of river locations
4 Off-takes and bifurcations	4.1	Discharges and sediment distribution
	4.3	Influence of bars
5 Confluences	5	Confluences
6 Sand bars	6.1	Dimensions and dynamics of bars
	6.2	Time dependence of bars
7 Bed forms	7.1	Occurrence, dimensions, and dynamics
	7.2	Time dependency of bed forms
	7.3	3-dimensionality of bed forms
	7.4	Roughness and bed forms
9 Measuring techniques	9.1	Selection of measurement sites
	9.2	Optimization of hydraulic measurements
	9.3	Optimization of sediment measurements
	9.4	Bed load transport by dune tracking
	9.5	Bathymetry and radar imagery
	9.6	Sustainable survey techniques

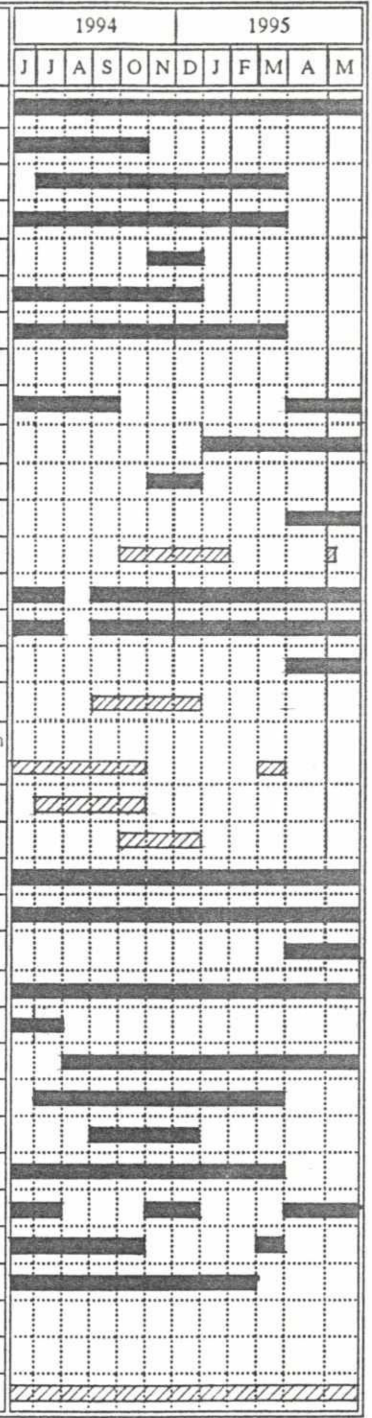

Figure 6.1: Study activities June 1994 - May 1995

An outline of the progress in the reporting period may be given as follows:

Subject 1: Hydrology
The work comprised an examination of rating curves for Bahadurabad as established by BWDB and by FAP 24, and continued studies of the flow conditions at Bahadurabad. Rating curves were prepared for all FAP 24 routine gauging stations. The tidal influence at Mawa and at Bhairab Bazar was analyzed on the basis of special field surveys in February and March, 1995, respectively. The overland flow measurements were prepared to be executed in the monsoon 1995.

Subject 2: Sediment transport
The work concentrated on sediment transport rating curves for Bahadurabad, Hardinge Bridge, and Baruria, and on different factors affecting the rating curves. To study the influence of these factors a 1-d model of the Ganges River with Hardinge Bridge was made. The study of the selection of suitable sediment transport predictors for the main rivers has started.

Subject 3: Planform characteristics and channel dimensions
The flood plain levels, water level profiles, and the bankfull discharges were examined for the Jamuna, Ganges, and Padma rivers, and an analysis was made of applicable regime equations.

Subject 4: Off-takes and bifurcations
The work addressed flow and sediment transport characteristics at bifurcations, exemplified by the Gorai off-take and the bifurcation at Roy's bar near Bahadurabad. A 2-dimensional model was established for the area around the Gorai off-take. Good progress was made with the study of UoN of the secondary flow field around a bar near Bahadurabad.

Subject 5: Confluences
1-dimensional modelling of conditions at the Ganges/Jamuna confluence has been initiated and is in progress.

Subjects 6 and 7: Bars and bedforms
This activity, which is carried out by UoL, comprises a study of bar and bedform development in the Bahadurabad area. In addition, some special surveys were carried out in order to measure bed forms in Jamuna River.

Subject 9: Measuring techniques
Special surveys were carried out of detailed flow characteristics (as a basis for optimisation of flow measurements), and of tidal and backwater effects at Mawa and Bhairab Bazar. Comparative field measurements were made with different sediment samplers: Delft bottle, Helley-Smith sampler, and the pump bottle technique, and with different flow measuring techniques for the near-bed sediment transport and the suspended bed material transport.

Selected interim results of the study programme are summarized in the subsequent sections.

6.2 Water level data validation (study topic 1.1)

6.2.1 Introduction

The River Survey Project is presently operating 22 staff gauges and 12 automatic water level recorders (AWLRs) in the main rivers. Some of these are routine stations, and others are for special study purposes. The recording interval of the AWLRs is 30 minutes, while the staff gauges are read 5 times in a day, starting at 0600h and ending at 1800h. The main objective of the measurements is to collect reliable all-season water level data for studying the hydrological and morphological characteristics of the rivers and to examine gauging strategies for water levels.

	Hydrological year	1994-95												1995-96		
Station	River	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Bahadurabad	Jamuna	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Gabgachi	Jamuna	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mawa	Padma			x	x	x	x	x	x	x	x	x	x	x	x	x
Aricha (Teota)	Dhaleswhari		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tilly	Jamuna			x	x	x	x	x	x	x	x	x	x	x	x	x
Baruria	Padma		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bhuapur	Jamuna			x	x	x	x	x	x	x	x	x	x	x		
Sirajganj	Jamuna													x	x	x
Arial Khan off-take	Arial Khan			x	x	x	x	x	x	x	x	x	x	x	x	x
Mymensingh	Old Brahmaputra			x	x	x	x	x	x	x	x	x	x	x	x	x
Hardinge Bridge	Ganges				x	x	x	x	x	x	x	x	x	x	x	x
Gorai Railway Bridge	Gorai				x	x	x	x	x	x	x	x	x	x	x	x
Bhairab Bazar Bridge	Megna					x	x	x	x	x	x	x	x	x	x	x
North Harindhara	Jamuna			x	x	x	x	x	x	x	x	x	x	x	x	x
Belgacha	Jamuna			x	x	x	x	x	x	x	x	x	x	x	x	x
North Khatiamari	Jamuna			x	x	x	x	x	x	x	x	x	x	x	x	x
Bhagirchaw	Jamuna			x	x	x	x	x	x	x	x	x	x	x	x	x
Shankibhanga	Jamuna		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kabilpur	Jamuna			x	x	x	x	x	x	x	x	x	x	x	x	x
Bheramara	Ganges															x
Kushtia	Gorai															x
Shelaidha	Ganges															x
Mirzachar	Meghna															x

Table 6.1: Water level stations and data collection period

Data quality checks are required in order to asses the quality of the data and to make the necessary corrections. A variety of data error sources exists. In Jamuna, Ganges and Padma Rivers, due to rapid changes in the location of channels and banks, it is sometimes necessary to shift the gauges along and across the channel in order to cover the entire stage variation. The collected data could be erroneous, if the zero level of the gauge is not properly transferred while shifting the gauge.

Another possible source of error in the gauged data is when the datum of the gauge is connected with an unreliable bench mark.

The data validation includes the following procedures:

(a) plotting of time series for comparison of hydrographs and annual extremes with neighbouring upstream and downstream stations
(b) correlating the station with a reference station in order to investigate the stability of the relation and to detect possible gauge shifts
(c) plotting of the water level difference between the two stations against time

In 1993, water level data were collected in the left channel of Jamuna River at Bahadurabad reach. A plot of these data and their correlation is presented as Figure 6.2. By comparing the similarity of the hydrographs and the relations between the stations, it seems that in November, there is a shift of the Thanthanipara gauge. From the gauge history, it is found that this error coincides with a shift of the gauge. The result was also found by Peters (1994) in his analysis of these water level data.

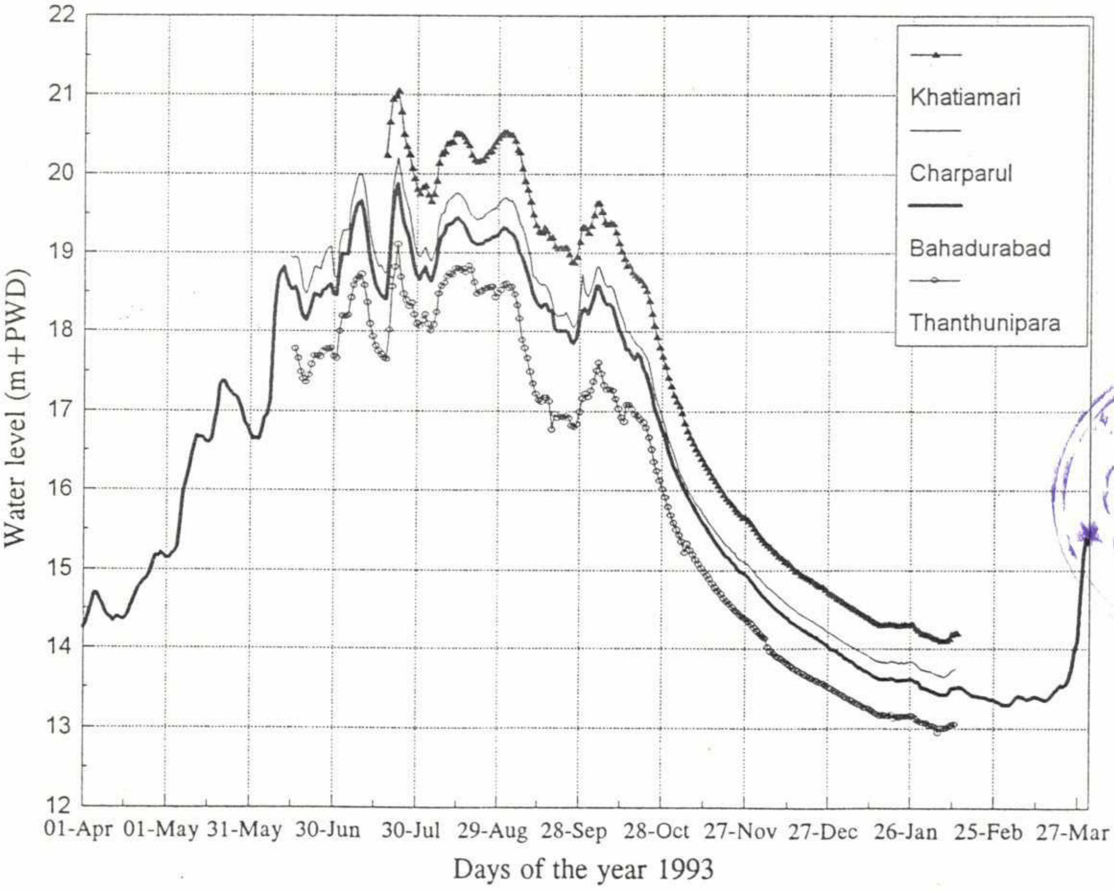

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Figure 6.2: Hydrographs, Jamuna, left channel at Bahadurabad

The mean daily water level data from North Khatiamari, North Harindhara and Belgacha have been correlated with data from Bahadurabad, see Figure 6.3. These stations are along the left channel of Jamuna River at Bahadurabad. A shift of a segment of the plot from the general trend in the correlations indicates an error. Such errors occur during shifting operations, and are corrected by adjusting the shift on the basis of an interpolation of the difference between the station and a reference station. An example of a different type of error appears on the figure: The river branch used for the gauge at North Harindhara has died off, and the staff gauge was misread.

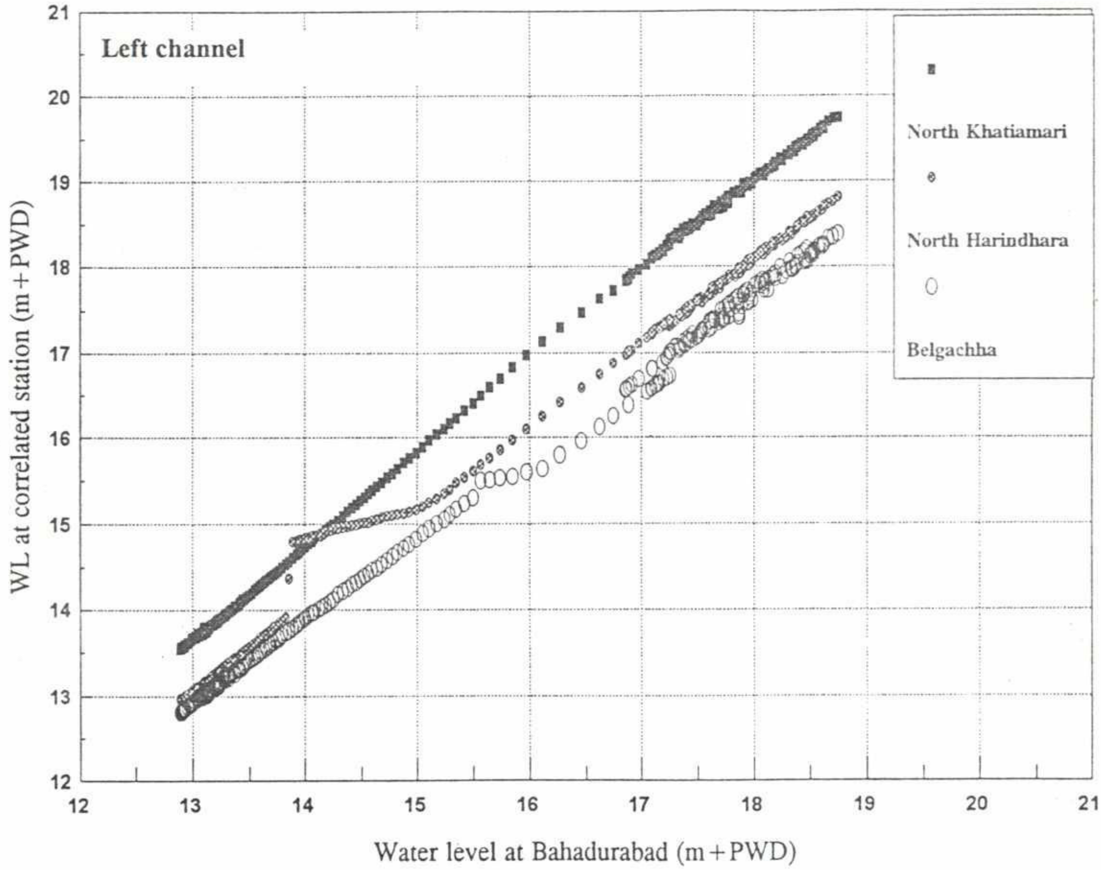


Figure 6.3: Correlations between water level stations

In case of an AWLR, the validity of the collected data is assessed in a number of steps. Upon downloading in the field, the data are visualized as a time series plot. Hereby, distinct errors, such as sensor over-range, recording of error codes, and spikes in the data, can be recognized, which allows the operator to take immediate action, if technically possible.

The validation process is strictly formalised..In general terms, the process is executed as follows: Staff gauge and AWLR data are retrieved from their dedicated files. From a third file, the reference file, reference levels of staff gauge and

AWLR are read, as well as the pre-set margin of the acceptance of the differences between staff gauge and AWLR readings. In case that data from both sources pass the test, they are subjected to the difference test. If the difference falls within the margin as set in the reference file, the AWLR level is regarded as valid, otherwise the staff gauge level is adopted.

6.2.2 Conclusions

At the end of every month, data are received from the field and are checked. The data of the hydrological years 1993 and 1994 were validated for almost all stations of FAP 24. The validated data are organised in a spread sheet and in the HYMOS data base, and for all stations, these data are reliable within a few cm.

6.3 Stage-discharge relationship for Jamuna River at Bahadurabad (study topic 1.1)

6.3.1 Introduction

In the hydrological year 1994 (April to March), a good number of discharge measurements were made by the River Survey Project in Jamuna River at Bahadurabad, see Figure 6.4. Stage-discharge relationships based on the combined observed discharges from the two main channels and on the observed discharges per channel were compared. The accuracies of these methods for the extrapolation of the stage-discharge relation have been investigated. The theoretical aspects of the stage-discharge relation and of past work on the stage-discharge data from Bahadurabad have also been reviewed.

The consistency of the discharge data has been checked by plotting water levels as well as discharges as a function of cross sectional area and of cross-section averaged flow velocity for the left and the right channel, separately. Uncertainties due to measurement errors have not been addressed in detail in this study. The relationships between the water surface width, the hydraulic depth, the hydraulic radius, the Chezy and the Manning conveyance factors, the Chezy and the Manning slope-roughness factors, the Froude numbers, and the flow distributions with the water level were investigated separately for the left and the right channel.

These analyses indicate differences between the dynamic behaviour of flood flows in these two channels. The discharge in the left channel is about three to five times that of the discharge in the right channel. The percentage of the total discharge passing through the right channel increases with increasing stage.

The relationship between the Chezy and the Manning roughness coefficients and the water level was examined by utilizing data on the local water surface slope, discharge and conveyance factors, see Figure 6.5. Results are summarised in Table 6.2.

		Left channel	Right channel
Stage: 17.0 m+PWD	Chezy coefficient	35-47 $m^{1/2}/s$	36 $m^{1/2}/s$
	Manning number n	0.027-0.035 $s/m^{1/3}$	0.032-0.042 $s/m^{1/3}$
Stage 18.5 m+PWD	Chezy coefficient	45-60 $m^{1/2}/s$	37-45 $m^{1/2}/s$
	Manning number n	0.023-0.029 $s/m^{1/3}$	0.029-0.035 $s/m^{1/3}$

Table 6.2: Variation intervals of roughness coefficients

A dividing point for segmenting the stage-discharge relationship seems to be appropriate at stages close to the beginning of the receding limb of the annual stage hydrograph. This breakpoint was established by investigating the relationship between the local water surface slope, the slope-roughness factor, the Froude number, and the stage. There is no significant difference in the standard error of the computed discharge when the upper segment is fitted to the combined observed discharges from the two channels, and when fitted separately to the discharges in the separate channels. However, this may not be the case at very high flood stages, since the percentage of the total discharge shared by the right channel increases with the increase in stage.

The channel specific approach can reduce the uncertainty in the survey results because of the long time required for a discharge measurement, which is for example about two days in the BWDB procedure, during which time the discharge and the water level can change considerably.

Five methods for the extrapolation of the stage-discharge relationship have been investigated. These are:

(1) a direct extrapolation of the fitted upper segment of the rating curve
(2) Stevens' method based on conveyance factors
(3) the conveyance-slope method
(4) the slope-area method of peak discharge determination, and
(5) application of a steady flow formula

Method (1) is used by BWDB. The accuracies of the five methods have been assessed by comparing the computed discharges with the measured discharges in 1994, as exemplified in Table 6.3.

6.3.2 Conclusion

The conclusions of this study are based on an analysis of discharge data measured by FAP 24 for the period April 1994 to March 1995. It is noted that this period does not include a severe flooding.

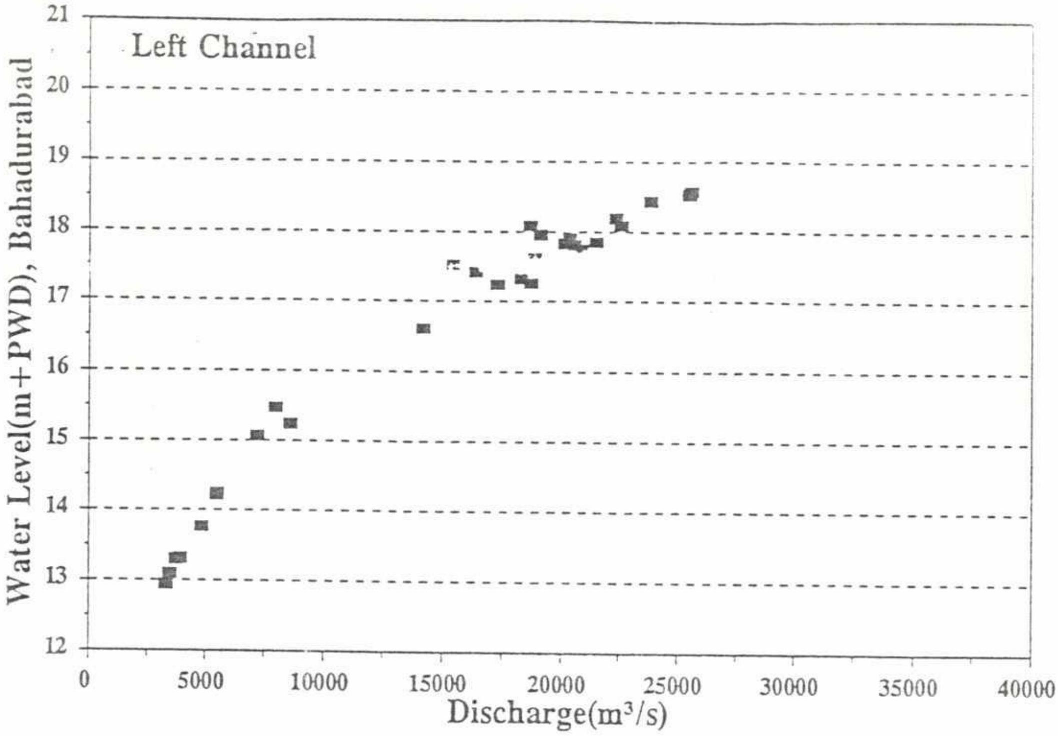
Standard errors in the fitted upper segment of the rating curves for the left and the right channels are 7.5 and 16.2 % respectively, which are on the high side. However, there is no significant difference in the standard errors of the computed discharges of the Jamuna river at Bahadurabad when the single stage-discharge relationship is used or when the channel specific stage-discharge relationship is used.

Channel	Date	Khatiamari		Belgachha		S_W cm/km	Upper C $m^{1/2}/s$	Q_s m^3/s	Q_s m^3/s
		Width m	Area m^2	Width m	Area m				
Left channel	27/6/94	2480	16000	2780	18600	9.34	57	25600	>25587
	2/8/94	2500	16000	3470	20100	10.00	56	24800	22596
	18/8/94	2481	15300	3770	21000	9.80	60	26000	23848
Channel	Date	Shankibhanga		Bagirchaow		S_W cm/km	Upper C $m^{1/2}/s$	Q_s m^3/s	Q_s m^3/s
		Width m	Area m^2	Width m^2	Area m^2				
Right channel	27/6/94	1690	9600	2700	13100	9.01	41	10400	10460
	2/8/94	1680	7200	2100	9400	7.31	44	6700	7288

Table 6.3: Input data for the slope-area method, along with computed and observed peak discharges

Among the five methods for the extrapolation of a stage-discharge relationship, the conveyance-slope method has the best performance, with an average relative deviation of 5.0%. The performance of methods (1) and (2) is poor, with an average relative deviation of 10.9 and 11.4%, respectively.
The measured maximum discharge during the year of 1994 was approximately 37,700 m^3/s, which was very low as compared with the annual maximum discharges of the previous years, and the maximum flood level was substantially below the bank level. Therefore, it is recommended that this study be extended, so that the stage-discharge data for 1995 can be included in the analysis.

This study was executed jointly with Institute of Flood Control and Drainage Research (IFCDR), BUET, with whom an excellent cooperation has been established.



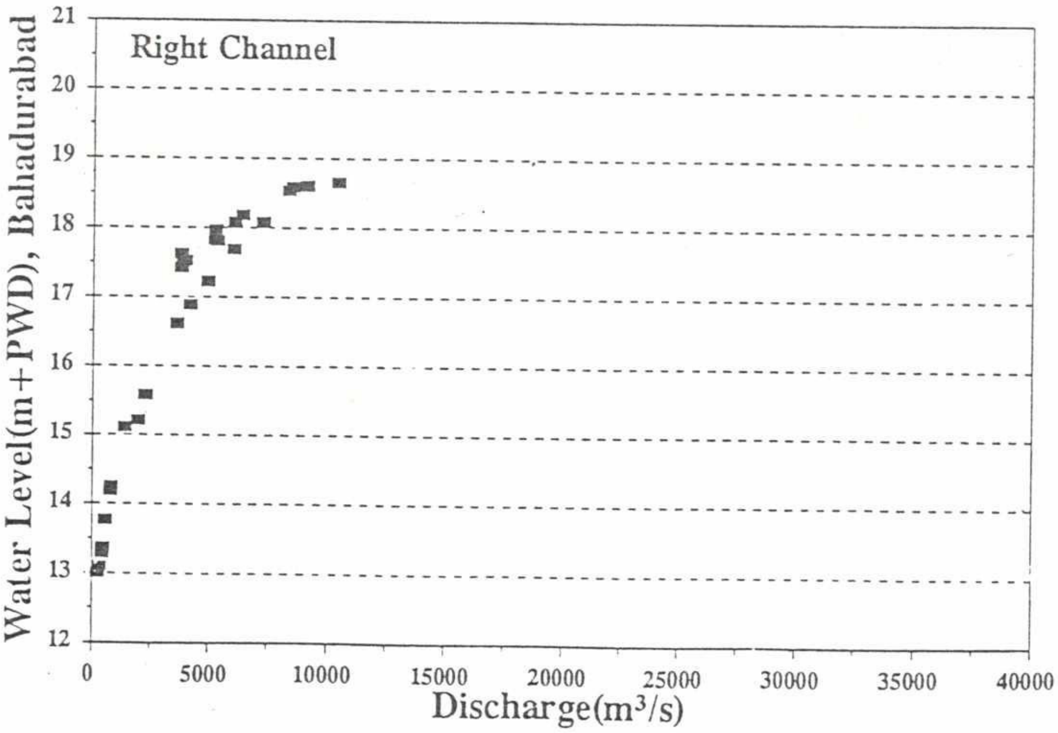


Figure 6.4: Plot of stage versus discharge

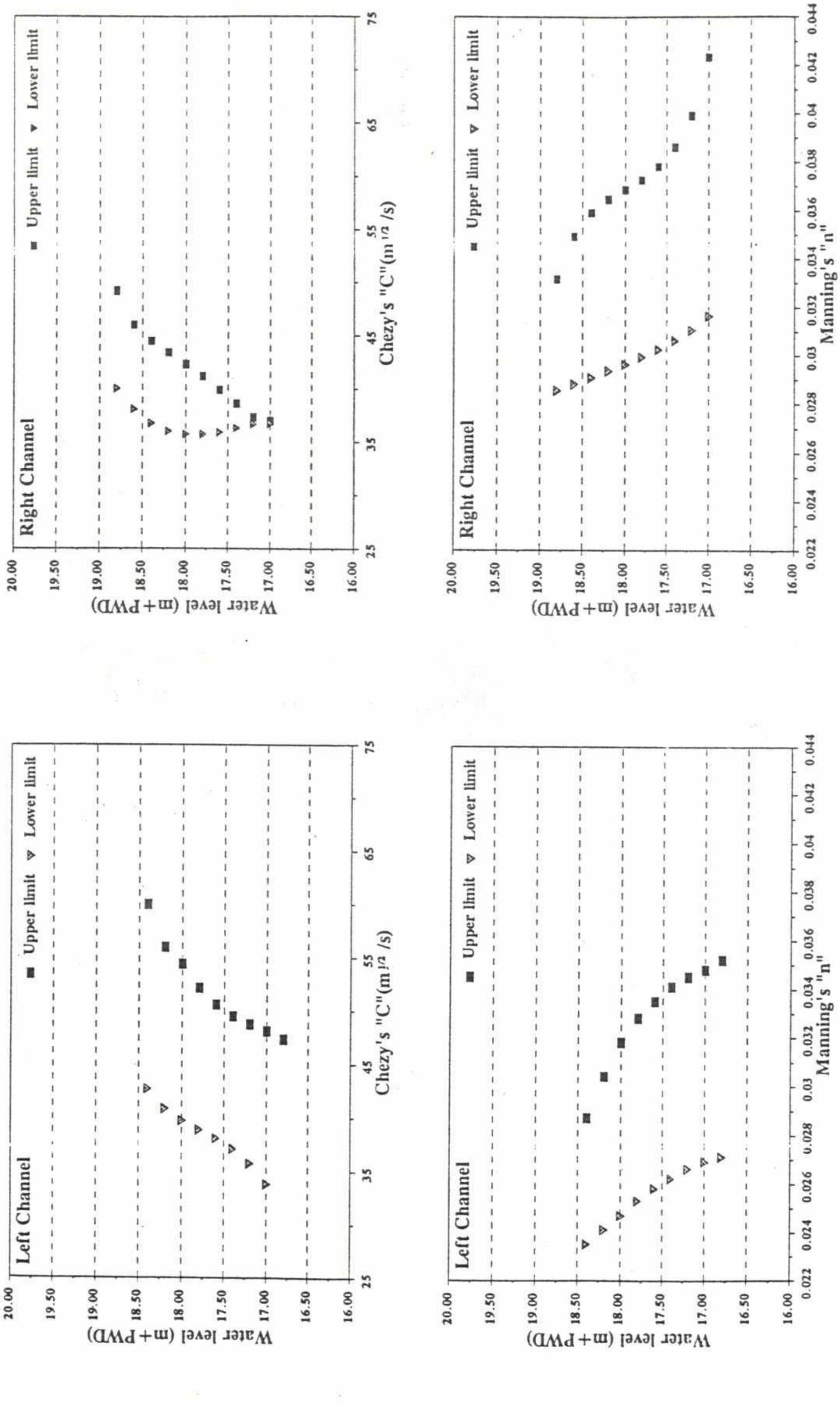


Figure 6.5: Variation of roughness coefficient with discharge

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6.4 Local slopes (study topic 1.4)

6.4.1 Introduction

Six water level gauges were installed in the Bahadurabad reach of Jamuna River in 1994: Three gauges are at North Khatiamari, North Harindhara, and Belgacha along the left channel, and another three are at Kabilpur, Shankibhanga, and Bagirchaow in the right channel, see Figure 6.6. The main objective of this deployment is to determine the local water level slopes and to study the hydraulic behaviour of the two channels. The operation of these staff gauges started in the first week of June, 1994, and the water level has been read daily every 3 hours from 06:00hrs to 18:00hrs.

The water level of all six stations was checked and corrected for errors. The water surface fall was computed from the corrected data, by the difference between mean daily water levels at the different stations.

The difference between the daily water level data at North Harindhara and those at North Khatiamari (upstream) and Belgacha (downstream) has been plotted as a function of stage at North Harindhara, as shown in Figure 6.7.a and b for the left and the right channel, respectively. It is difficult to convert the water level difference between two stations to a water surface slope, because of the uncertainty with respect to the length of flow axis. Still, these data can serve as an approximate indicator of the variation in the water level slope.

Figures 6.7.a and b indicate a similarity in the water level variation in the left and the right channel reaches. The local water surface slope fluctuates during the flood season (June to September). Thereafter, the slope gradually decreases with the fall of the water level during the receding phase, see also the analysis of Peters (1994). Data are not available for the period April, May, and the first week of June, 1994, when the water level rises. Therefore, a comparison between the rising stage slopes in the beginning of flood season and the receding post monsoon stage slopes cannot be made.

The rate of daily change of the water level has been determined by subtracting the daily water level data for one day from that of the previous day. Hereby, a remarkable similarity appears in the behaviour of the flood stages in the left and the right channel. The maximum rate of rise from June 1994 through March 1995 was 0.26 m in one day, while the maximum rate of fall was 0.15 m in one day. This is low as compared with the data from previous years.

6.4.2 Conclusion

There is a remarkable similarity between the left and the right channel with respect to the rate of change of water level with time, and also with respect to the stage variation of the local surface slope. The surface slope fluctuates during the flood season. Thereafter, the slope gradually decreases with the fall of the water level during the receding phase of the annual hydrograph.

The detailed analysis of the local slopes at Bahadurabad and the over-all slopes in the main rivers is still in progress.

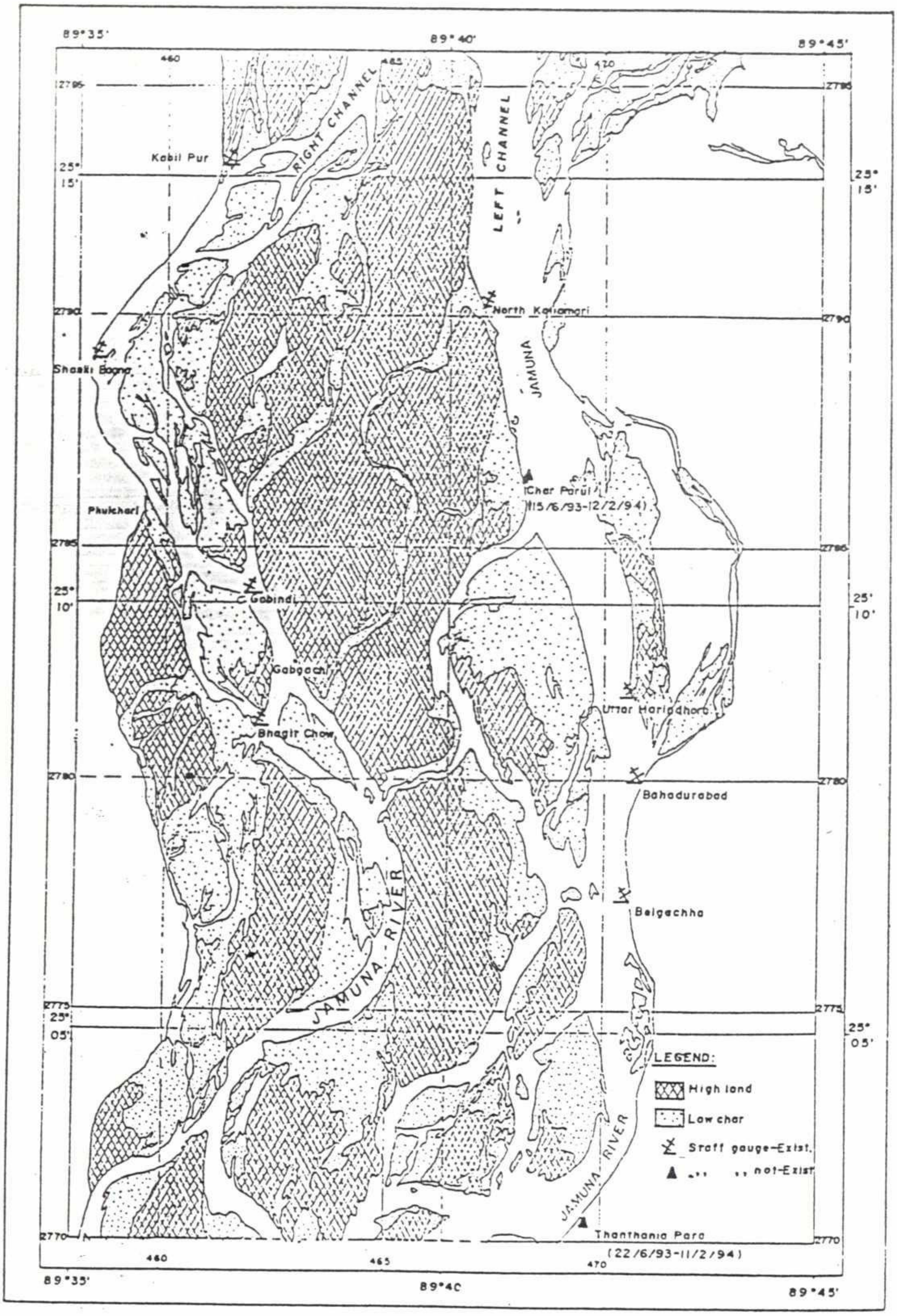

Figure 6.6: Gauge locations in the Bahadurabad area

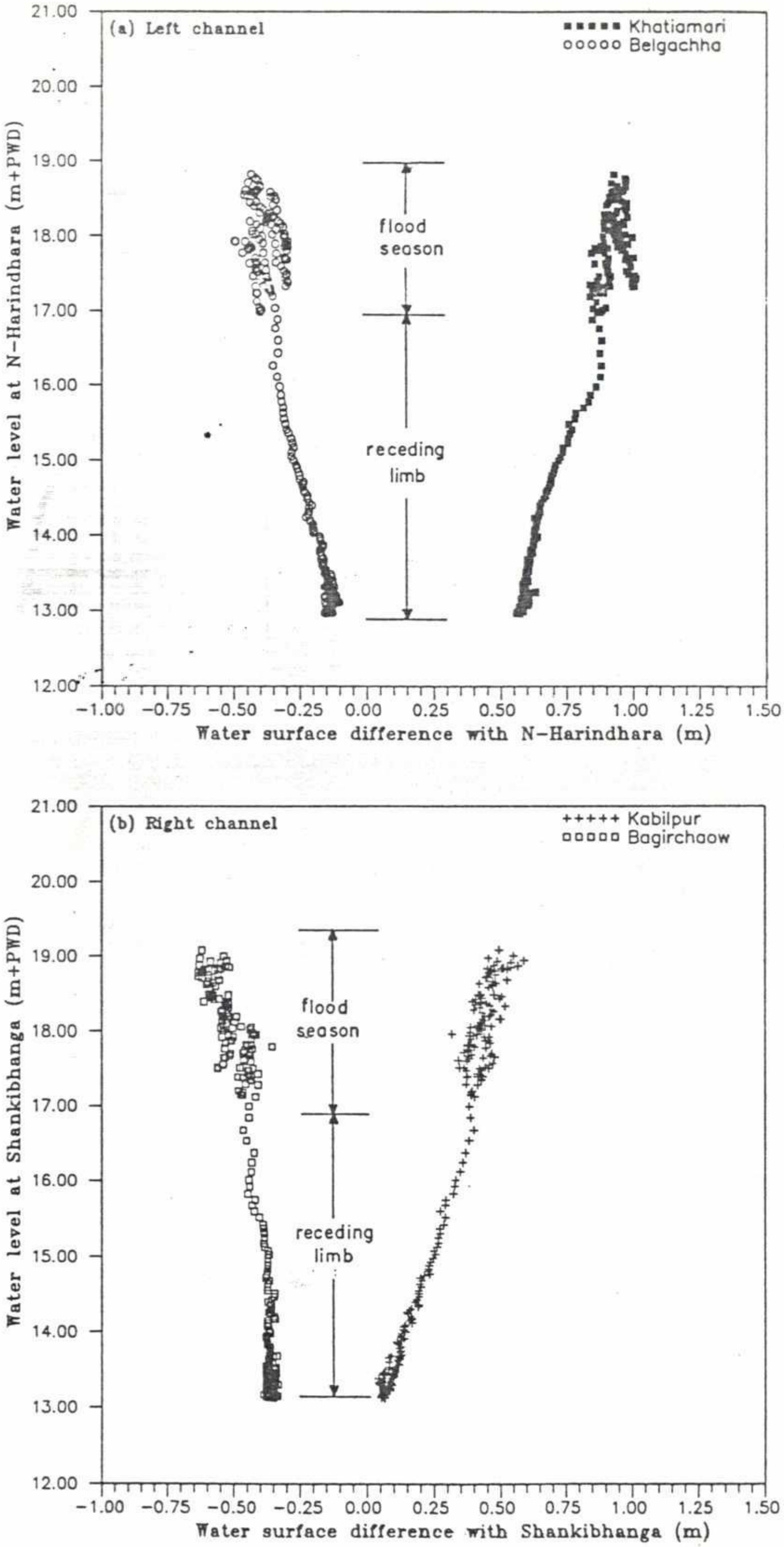

Figure 6.7: Water level differences: (a) left channel, and (b) right channel

6.5 Sediment rating curves (study topic 2.1)

6.5.1 Introduction

Background
During Phase 1 of the River Survey Project, a detailed analysis of BWDB sediment transport data from the major rivers was carried out (Study Report 3, 1994). Certain inconsistencies were observed in the sediment rating curves at Bahadurabad, Hardinge Bridge, and Baruria, and some of these inconsistencies were also reported during previous studies. In Phase 2, an attempt has been made to explain those inconsistencies by a more detailed data analysis, comprising for example seasonal effects, and using a 1-D mathematical model.

Objective
The objective of the study is to verify the inconsistencies in the BWDB sediment transport data, and to produce suitable sediment rating curves for the major gauging stations.

Observed inconsistencies
The following inconsistencies were noted in Phase I of the River Survey Project:

- o A significant scatter in the sediment transport data at Hardinge Bridge, and an extremely wide scatter at Baruria
- o a decreasing trend in the suspended sediment transport data at the major gauging stations. Suspended sediment transport data from 1966-1970 show a significantly (2 times) higher sediment transport as compared with data from 1976-1988
- o a steep suspended sediment rating curve at Hardinge Bridge and Baruria, i.e. a high exponent 'B' in equation (1):

$$S = A \cdot Q^B \qquad (1)$$

where
S = suspended bed material transport in tons/day
Q = discharge in m^3/s
A and B are not dimensionless coefficients.

6.5.2 Study of inconsistencies

The inconsistencies which were observed can possibly be explained as follows:

- o The scatter is due to seasonal effects
- o The steep rating curves at Hardinge Bridge and Baruria could be due to effects of the constriction and the confluence, respectively
- o The decreasing trend in the sediment transport can be explained by upstream storage

Seasonal effects

The flow in the river changes with the changes in the hydrological conditions. A rising flood has different hydraulic parameters as compared with the receding flood, and again as compared with the dry season flow. The suspended sediment transport data from different seasons have been separated (into rising, falling, and lean flow conditions), and the sediment rating curves have been produced for each season. This analysis shows that the seasonal effect is not pronounced at Bahadurabad, while it is significant at Hardinge Bridge and Baruria. Sediment transport data from specific seasons have less scatter than the data taken as an entity.

Steep slope and scatter in the rating curves
It is difficult to explain the inconsistencies mentioned above. The morphological environment of the river system was different in the past as compared with present conditions. Also, the sediment measurement procedures of the past cannot be checked. Therefore, it was decided to establish a mathematical model as a tool for a qualitative investigation of the inconsistencies that were noticed during FAP 24 and other studies.

A 1-D mathematical model has been used. The software package consists of a comprehensive set of application software for the simulation of water flow, sediment transport, and morphology, as well as water quality in open channel networks.

The Ganges, Jamuna and Padma rivers system was included in the model, which is therefore called the GJP-Model. The network of the model is shown in Figure 6.8. The three rivers meet at Aricha, a node, which is the confluence of the Jamuna and the Ganges river. The model has three boundaries: Discharges at the upstream boundaries of Ganges and Jamuna, and tidal elevation at the downstream boundary of Padma. For the sediment transport boundaries, an equilibrium sediment transport condition has been selected.

In this section, only the results of the model are described. Details of the analysis will be given in the final report.

<u>Hardinge Bridge</u>
For the sake of comparison, two cases are being studied: one case 'without constriction' and another one 'with constriction' by the river training works to protect the bridge. A presentation of the sediment transport for both cases is given in Figure 6.9. In this figure, the power law sediment rating curves are also plotted in a logarithmic scale. Within the same range of discharges, the sediment rating curve is steeper at the constricted section (B = 3.82) than at the unconstricted one (B = 1.65). It is also seen that the sediment transport is more scattered at the constricted than at the unconstricted section.

The segment of a transport curve can be approximated by a power relation of the form of equation (1). The exponent B is the slope of the curve in a logarithmic scale. When the equation is fitted to segments of a transport curve, the exponent B will diminish as the segments cover a gradually higher range of water discharge.

Baruria
Sediment transport data (1-D model output) at different sections of Padma River from confluence and downstream are plotted in Figure 6.10. A clear picture of the scatter near the confluence is seen. In the downstream sections, the scatter is greatly reduced, while the data are forming a concave shape. At low discharges, the sediment transport is moderately low and more scattered, while, at higher discharges, the sediment transport is high and less scattered, but the overall picture shows a scatter in the data. A sediment rating curve from all these data will have a steeper slope. In reality, there are two slopes: One at the low discharges (which may in fact not be a slope, since the data are very scattered), and another at higher discharges.

Regarding Figure 6.10.a, the higher sediment transport during the rising stage is the result of a high supply of sediment from Jamuna due to scouring of its bed in the reach near the confluence. The low sediment transport during falling stage is the result of a reduced supply of sediment from the upstream branches. The reaches upstream of the confluence are continuously adjusting, but do at the same time fluctuate around an average bed level (See Study Report 1, Selection of study topic for Phase 2, FAP 24, 1993). Hence, the system is in a dynamic equilibrium: In Figure 6.11, during the rising stage, the river bed is degrading, and during falling stage bed it is aggrading. This aggrading in Jamuna is typical of the back water effect in this river due to the late flood in the Ganges River. It can be seen that, downstream of the confluence, alternating aggradation and degradation occur. This causes the generation of sand waves, which travel through the downstream reach. These changes of bed levels in different branches near the confluence are the main reason of the scatter in the Padma River. At the confluence, the fluctuation of the bed is high, in the order of 1.5 to 2 m, while it becomes gradually insignificant in the downstream direction (Figure 6.12).

Bahadurabad
Similar inconsistencies in the scatter and the coefficient B of the BWDB data were not noticed during the analysis of FAP 24. Nevertheless, a few analyses were made of the results of the 1-D mathematical modelling for comparison with the measurements. Results from the model are plotted in Figure 6.13, which shows that data are less scattered and have approximately a single slope. The value of the coefficient B for this curve is 1.73, which is little higher than the value 1.5 derived from the BWDB measurements.

Decreasing trend in sediment transport
A storage was introduced in the far upstream reach of a single branch 1-D model. The results show the scatter of the sediment transport, and demonstrate the decrease from an initial level of maximum transport in the first year towards the equilibrium transport in the subsequent years.

6.5.3 Conclusions and recommendation

FAP 24 performed a detailed analysis based on almost all available sediment transport data of BWDB.

The seasonal effect in the sediment transport is not pronounced at Bahadurabad, moderately pronounced at Hardinge Bridge, and more pronounced at Baruria.

The scatter in the sediment transport data at Hardinge Bridge and Baruria can be explained by the constriction and the confluence, respectively. At low flow, the transport is irregular and scattered, and these data cause the sediment rating curve to become concave downward. The bed level changes at the confluence, due to the backwater effect in the upstream channels, cause an irregular sediment transport near Baruria. The analysis also shows that the sediment rating curves at different sections in the Padma River have a steep slope.

The analysis also reveals that the storage at the upstream in a river system could be the reason for a decreasing trend in the sediment transport.

The recommendations of the study activity will be presented in the Final Report.

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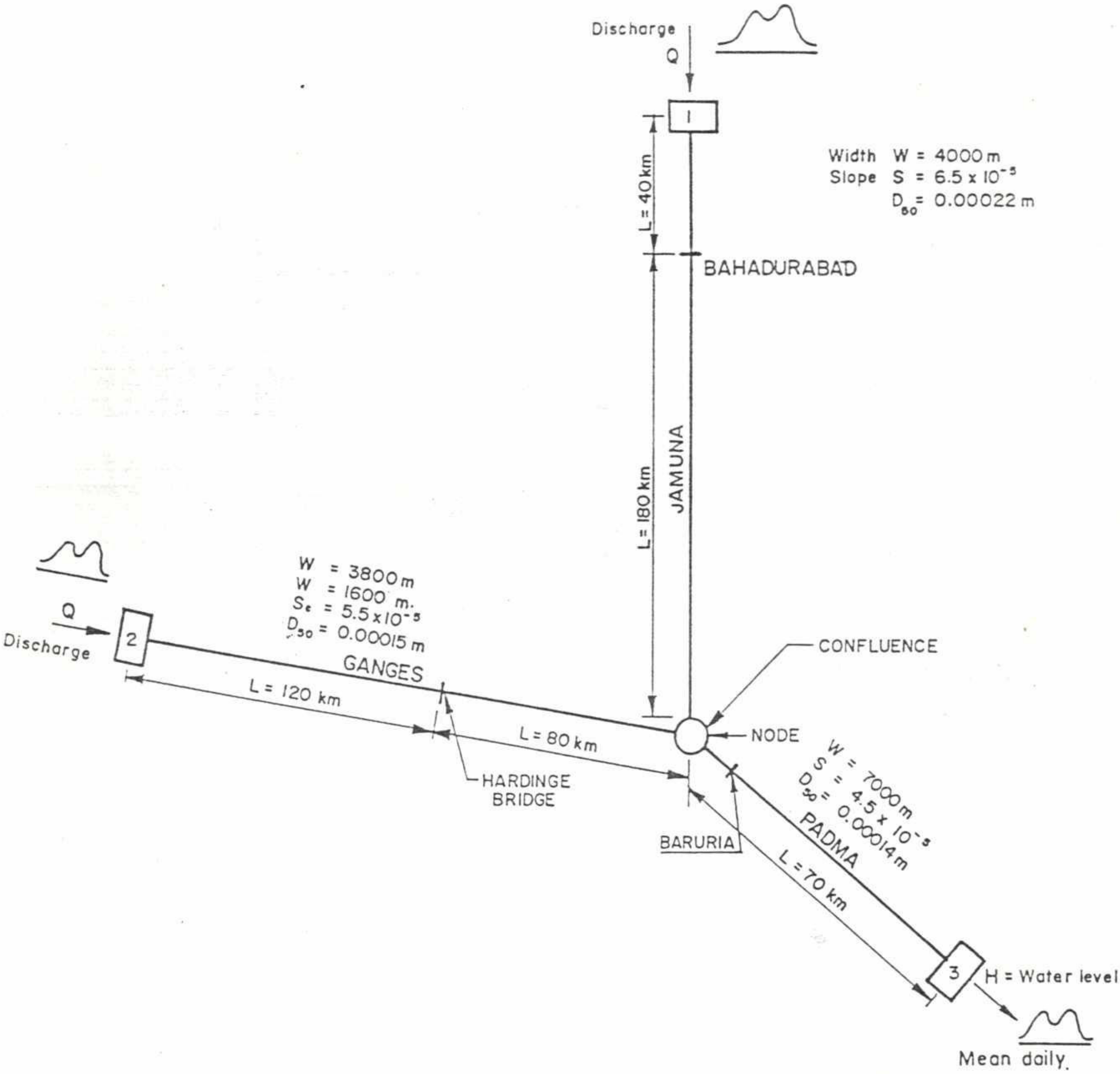

Figure 6.8: Schematization of the GJP model

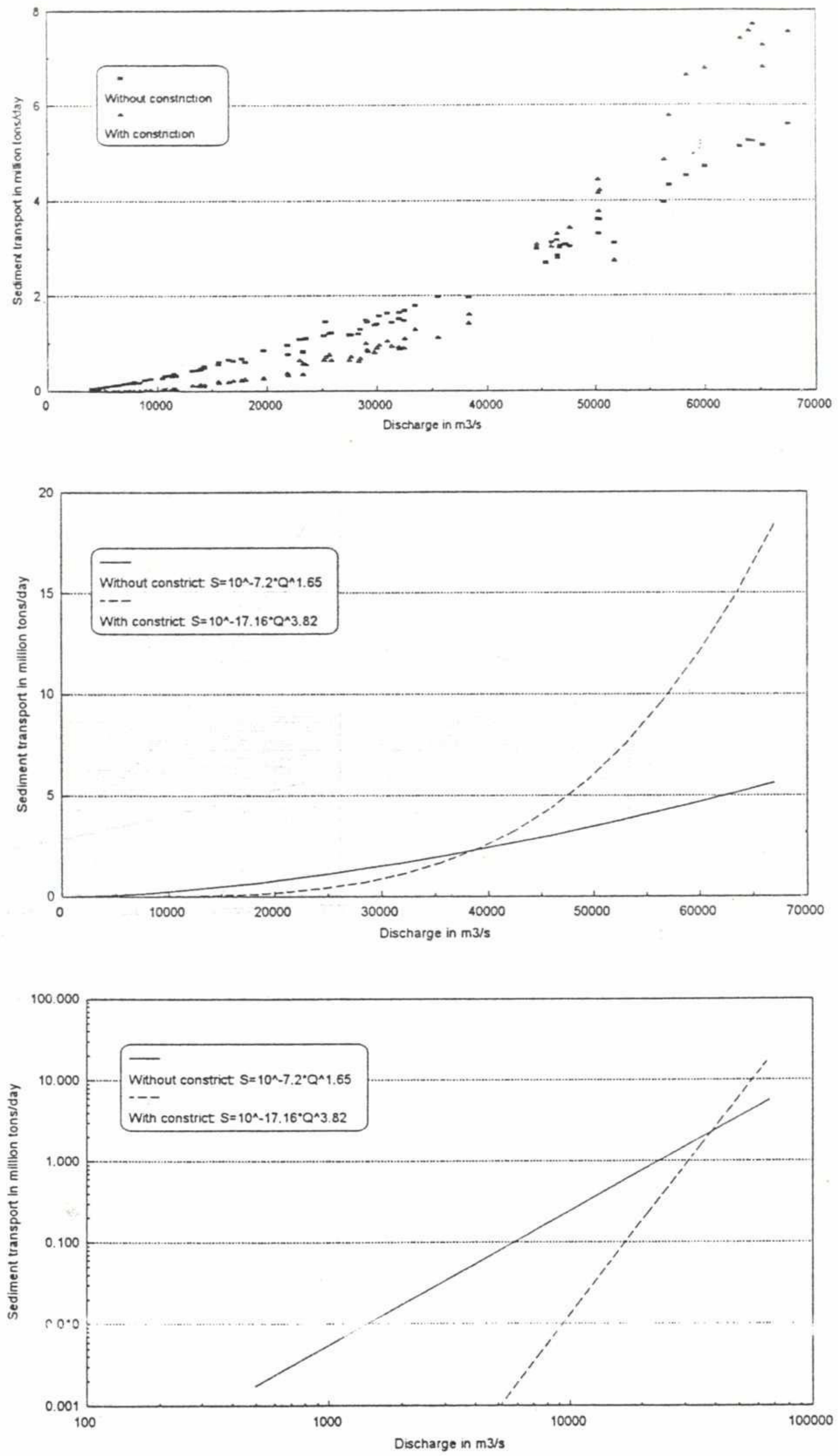

Figure 6.9: Calculated sediment transport in Ganges, with and without constriction

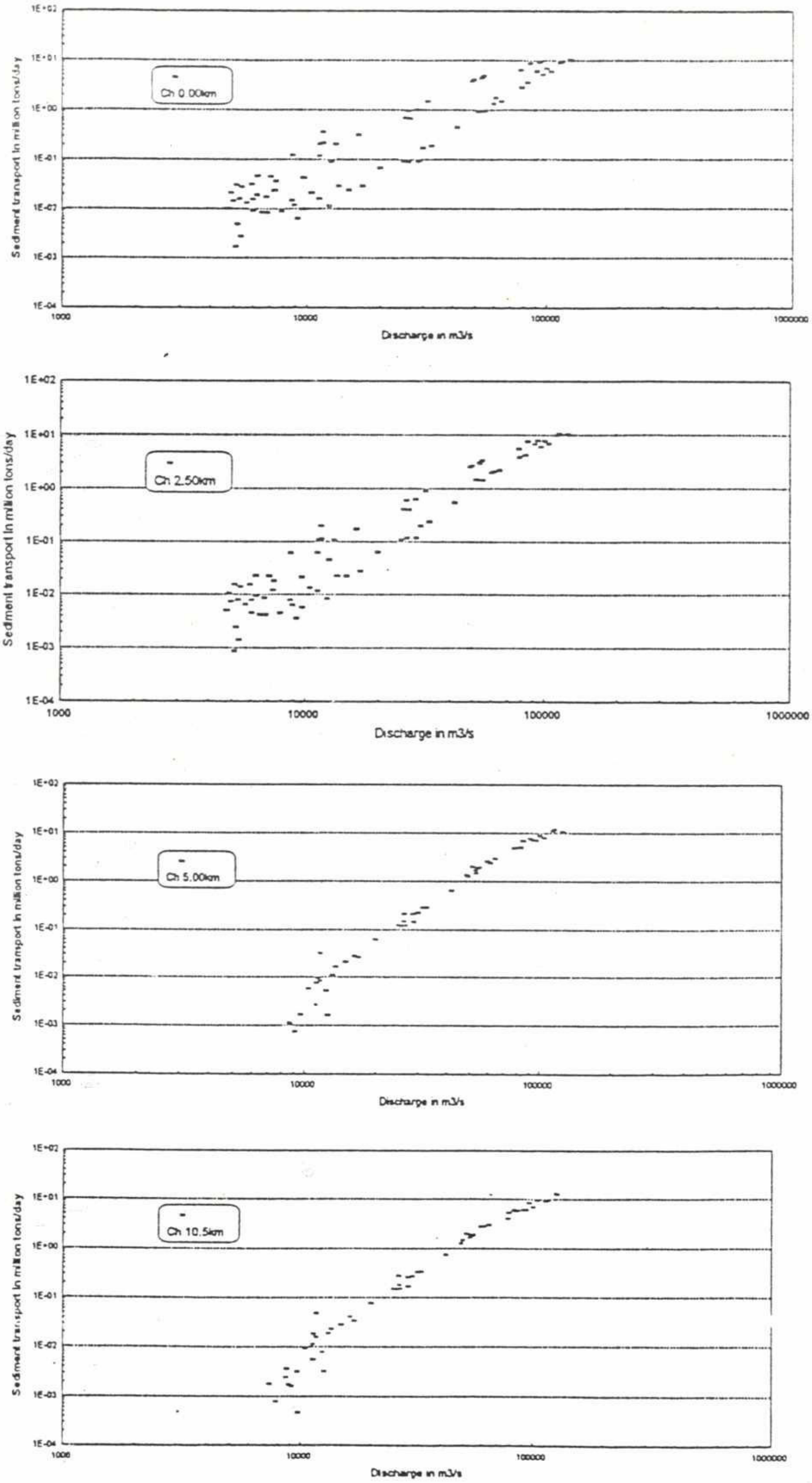

Figure 6.10: Calculated sediment transport, Padma River

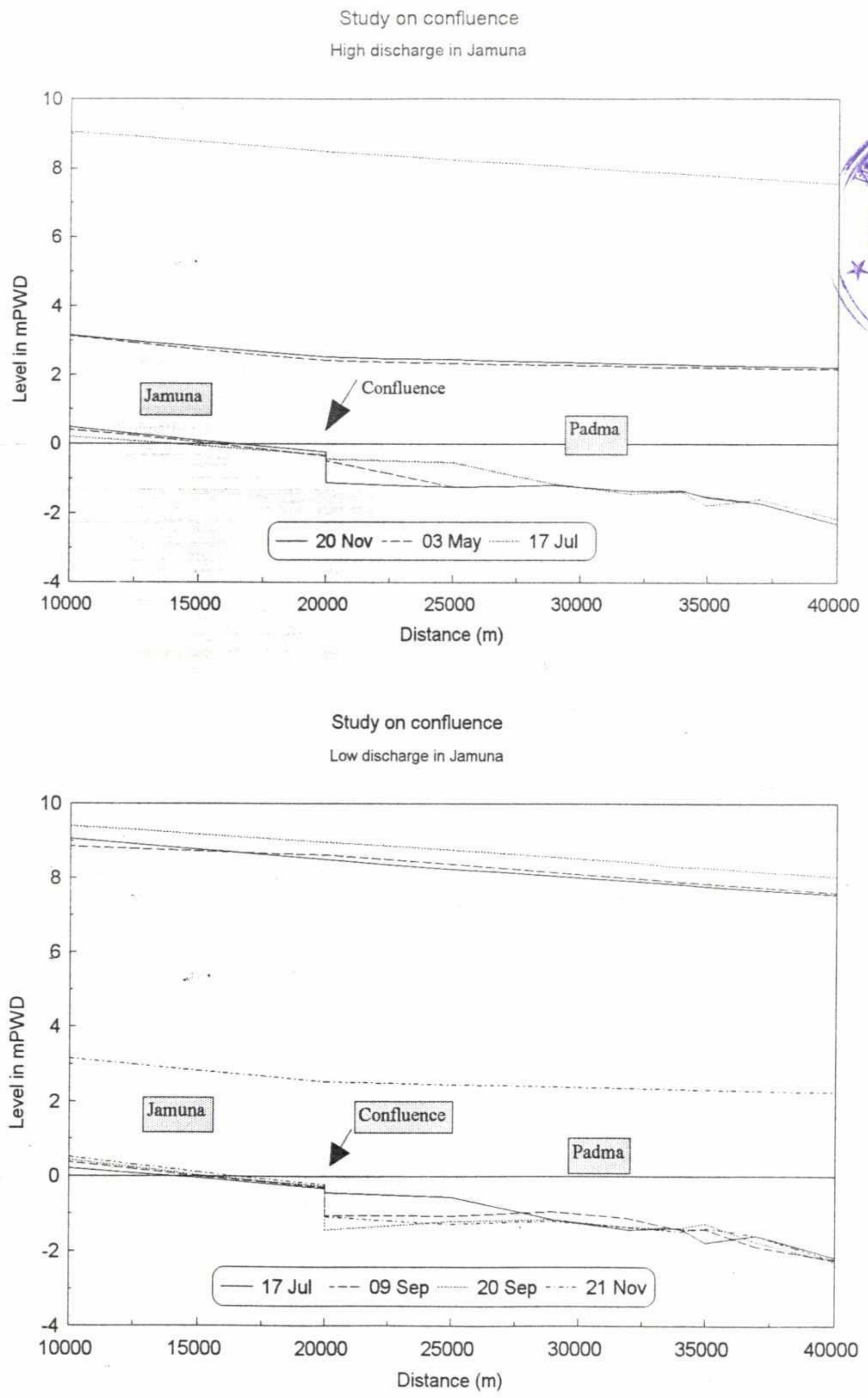

Figure 6.11: Dynamic equilibrium around a confluence

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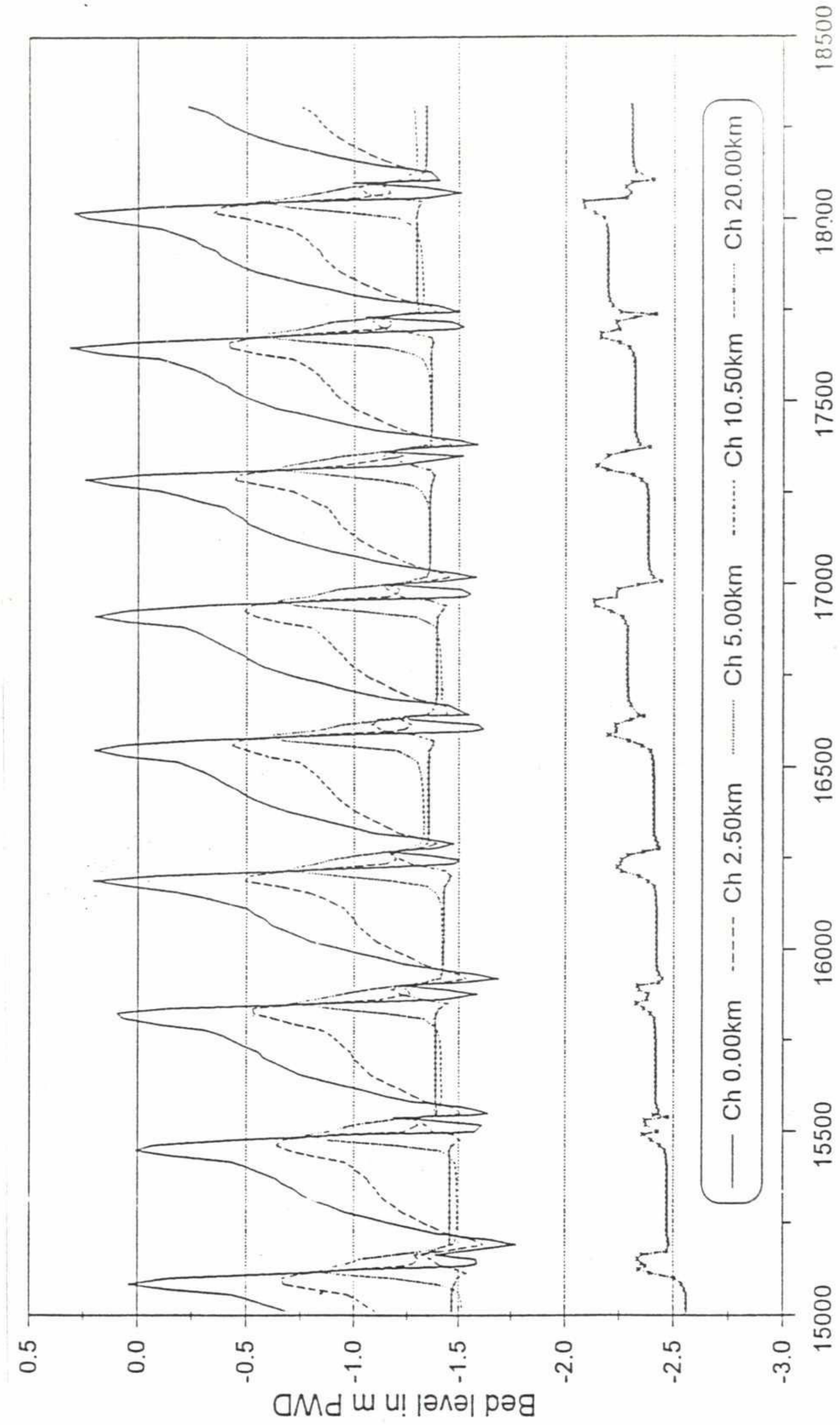


Figure 6.12: Time series of bed level changes, Padma River

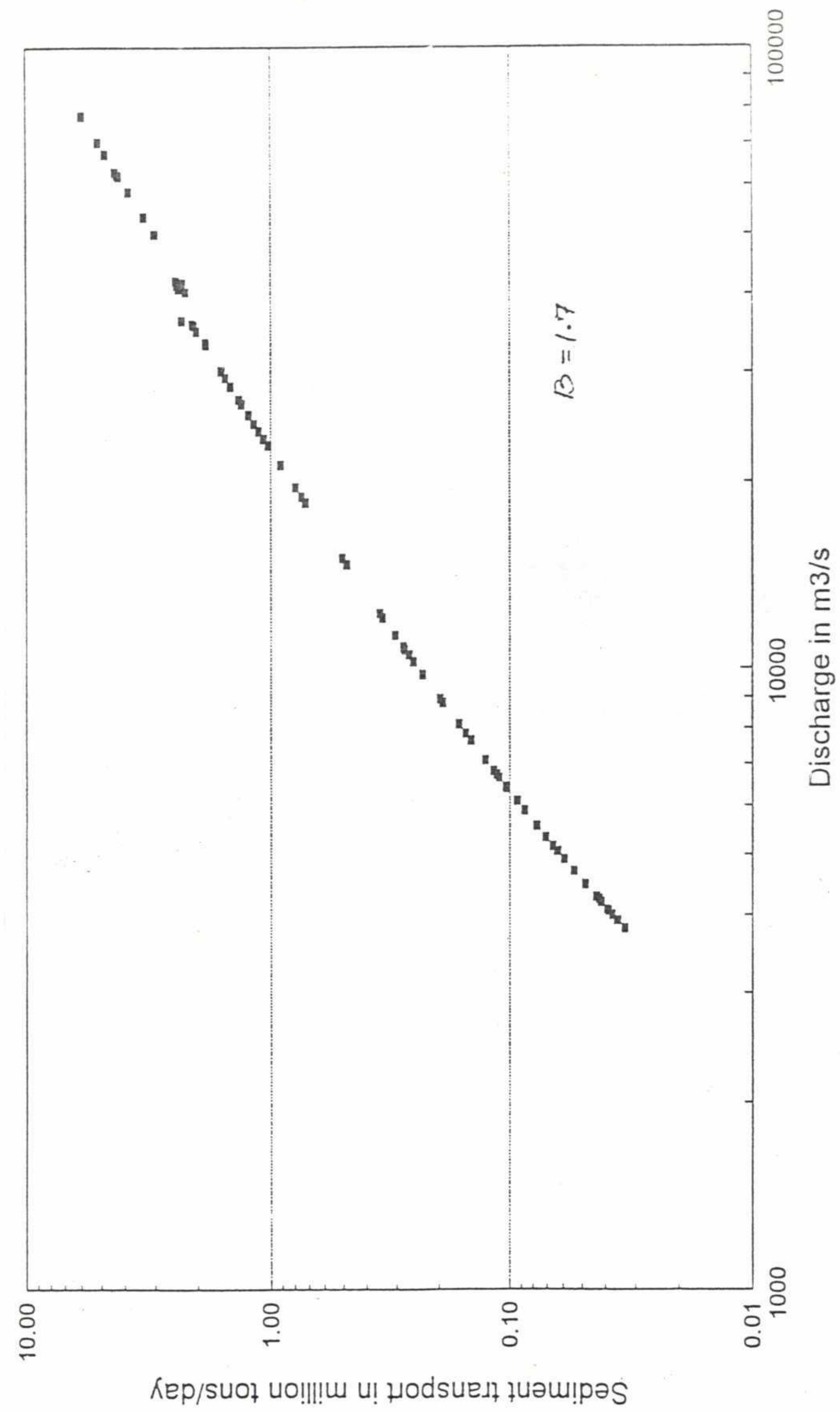


Figure 6.13: Sediment rating curve, Bahadurabad 1987

6.6 Sediment transport predictors (study topic 2.2)

6.6.1 Introduction

Various theoretical and semi-empirical approaches have been developed for the calculation of sediment transport rates (for example Einstein 1950, Bagnold 1966; Ackers & White 1973, Van Rijn 1984; Engelund-Hansen 1967; Yang 1973, Parker and Klingeman 1983; Paintal 1971). These relationships are mainly based on observations in laboratory experimental flumes and small streams. However, few attempts have been made to test their applicability in large sand bed rivers. Some recent projects, such as FAP 1 and the Jamuna Bridge Project, have used Engelund-Hansen and van Rijn predictors for estimation of sediment transport in the Jamuna River.

In the present study, field sheets collected from BWDB on sediment and discharge measurement have been analyzed. The quality of these has been assessed relative to the morphology and the hydraulic conditions at the gauging stations. Performance of the few selected sediment predictors has been investigated on the basis of measured sediment transport data at Bahadurabad, Hardinge Bridge and Baruria, on Jamuna, Ganges, and Padma Rivers, respectively. The selection of the predictors was based on experience from other research and study projects in Bangladesh and abroad.

It is shown that measurements at the constriction at Hardinge Bridge on the Ganges River exhibit a scatter in the data and predict a different sediment transport at the upstream of the bridge.

A student from BUET is working on this topic as a research work for a M.Sc. degree. The analysis will be presented in the Final Report of the River Survey Project.

6.6.2 Dimensionless sediment transport

The relation between the dimensionless sediment transport parameter and the dimensionless Shields parameter considers the bed shear stress as an important variable for sediment transport.

The analysis is based on the suspended bed material transport and discharge data collected by BWDB. A total of 582 sets of data for Jamuna River at Bahadurabad, 196 sets of data for Ganges River at Hardinge Bridge, and 541 sets of data for Padma River at Baruria were used in the analysis.

Most of the existing sediment transport predictors can easily be transformed into a dimensionless sediment transport parameter. This form can explain acceleration and deceleration modes of transport. None of the prediction formulae can explain sediment plumes, i.e avalanches of bulk of sediment due to erosion of the river bank or the river bed into the main stream of the river.

In Figure 6.14, the dimensionless sediment rating curve is produced for Bahadurabad for the monsoon period of 1983-1987. It can be seen that samples nos. 195, 196, 200, 202, and 203 are outlier, i.e behaving different from the cloud of the sediment samples. By verifying the position of those outlier samples in Figure 6.15, it is seen that these sampling verticals are from high eroding chars.

In Figure 6.16, all the sediment samples at Bahadurabad are shown according to their Chezy roughness in the dimensionless graph. The higher Chezy's value samples belong to the upper layer of the sediment cloud, while the lower Chezy's value samples are from the lower layer. There are distinct bundles of sediment samples from distinct roughness group, which is an indication of the accuracy of the sediment measurements. It explains that at a certain Shields value, the sediment transport will be higher if the Chezy roughness increases, i.e the river bed becomes smoother. The analysis shows that the sediment measurements at Bahadurabad are of a good quality.

A similar analysis has been made for the stations Hardinge Bridge and Baruria. The analysis shows that, at Hardinge Bridge, the Chezy's roughness bundles are fairly distinct, while at Baruria, the pattern is completely mixed. These inconsistencies could be due to the constriction of the Ganges at Hardinge Bridge and the confluence at Baruria. Hence, at those gauging stations, the local hydraulic and morphological parameters are governing the mode of sediment transport.

Comparison with prediction formulae

The selected five predictors have been compared with the measured sediment transport data. Results are shown in Figure 6.17. The Bagnold, Engelund-Hansen and Van Rijn predictors fit quite well with the measured regression line. Among these, the Bagnold and Van Rijn estimates are closer to the measured distribution, whereas the Engelund-Hansen predictor prediction formula needs slight orientation to fit the measured regression line. The Ackers and White prediction is not far from the measured line, but requires a little more realignment relative the measured data. An estimate based on Yang is lower than the measured values.

The Engelund-Hansen predictor is adopted for modification to the measured line because of the simplicity of its equation, which reads as:

$$\psi - 0.05 \frac{C^2}{g} \theta^{2.5} \qquad (2)$$

ψ = sediment transport parameter (-)
C = chery roughness coefficient ($m^{0.5}/s$)
g = aeceleration by gravity (m/s^2)
Ú = Shields parameter (-)

By shifting and rotating the equation towards the measured line, the modified Engelund-Hansen reads as:

$$\psi = 0.036 \frac{C^2}{g} \theta^{1.83} \tag{3}$$

Equation 3 is a modified Engelund-Hansen formula for the Jamuna River.

6.6.3 Analysis of the inconsistencies

The analysis of BWDB sediment transport data showed the same inconsistencies as discussed in section 6.5 sediment rating curves:

At Hardinge Bridge
- o Scatter in the measured suspended sediment data,
- o The dimensionless sediment rating curves show a high value of the power coefficient n of the flow velocity.

At Baruria
- o The dimensionless sediment rating curve could not be produced because of a wide scatter in the data.

1-dimensional mathematical modelling
A mathematical model is a tool which can simulate or generate the local hydraulic and morphological parameters in order to explore inconsistencies in the measured values. In combination with a sediment transport prediction model, it is possible to calculate the sediment transport at a section together with other relevant parameters. This analysis is an exercise in order to explore the inconsistencies, rather than to simulate the real conditions of the rivers.

The description and schematization of the model is mentioned in a study report presently under preparation. In the following, only the results are discussed.

At Hardinge Bridge
The sediment rating curves show that at the constriction, the exponent n is 9.2, whereas at the upstream section, n is 3.7. These results are consistent with the analytical analysis.

At the confluence
Dimensionless sediment transport rates at different sections of the Padma River are plotted in Figure 6.18. In this figure, the sediment transport data are scattered at all sections, particularly near the confluence. The exponent n varies significantly, from 7 to 18.

6.6.4 Observations and recommendations

The analysis of the sediment data from Bahadurabad shows as a distinct feature the increase in sediment transport with an increase in the Chezy roughness at a given Shields parameter. This indicates that the data quality is reliable with respect to the site of the gauging station and the measurement.

Based on the 582 sets of river data from Jamuna, the overall accuracy of the sediment predictors is, in descending order: Bagnold, Engelund-Hansen, Yang, Van Rijn and Ackers and White.

The use of the local slope in the dimensionless rating curve may reduce the scatter. The local slope can be extracted from the 1-D modelling.

A further analysis should be carried out of the suitability of each sediment gauging station.

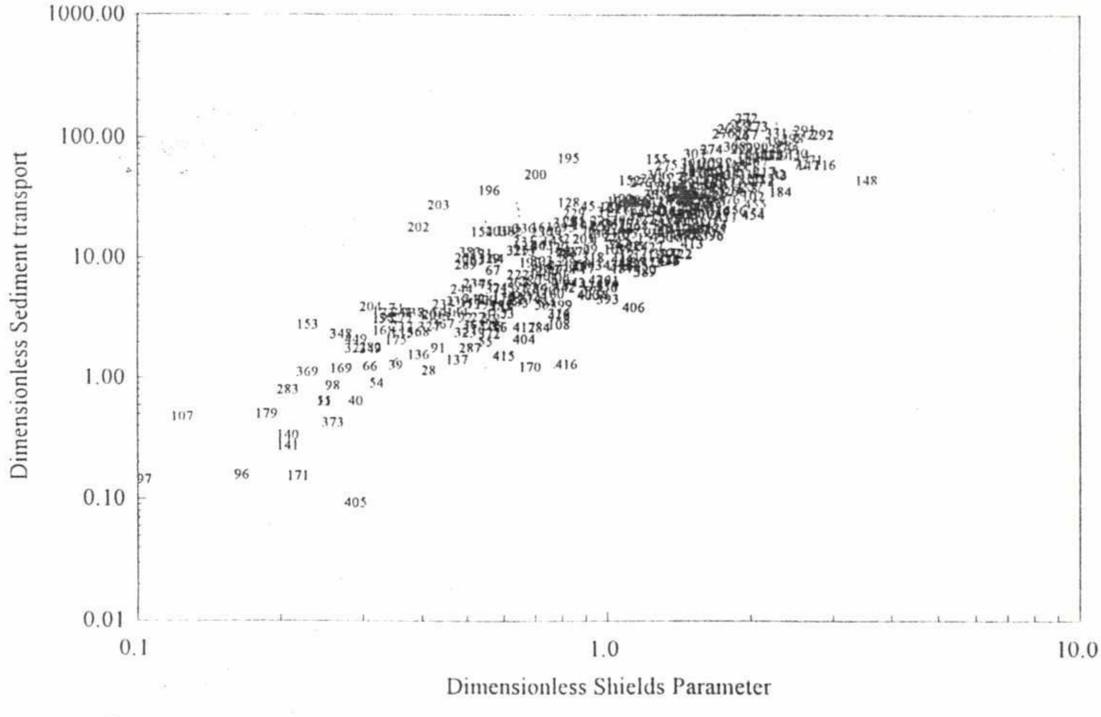


Figure 6.14: Dimensionless sediment rating curve, Bahadurabad

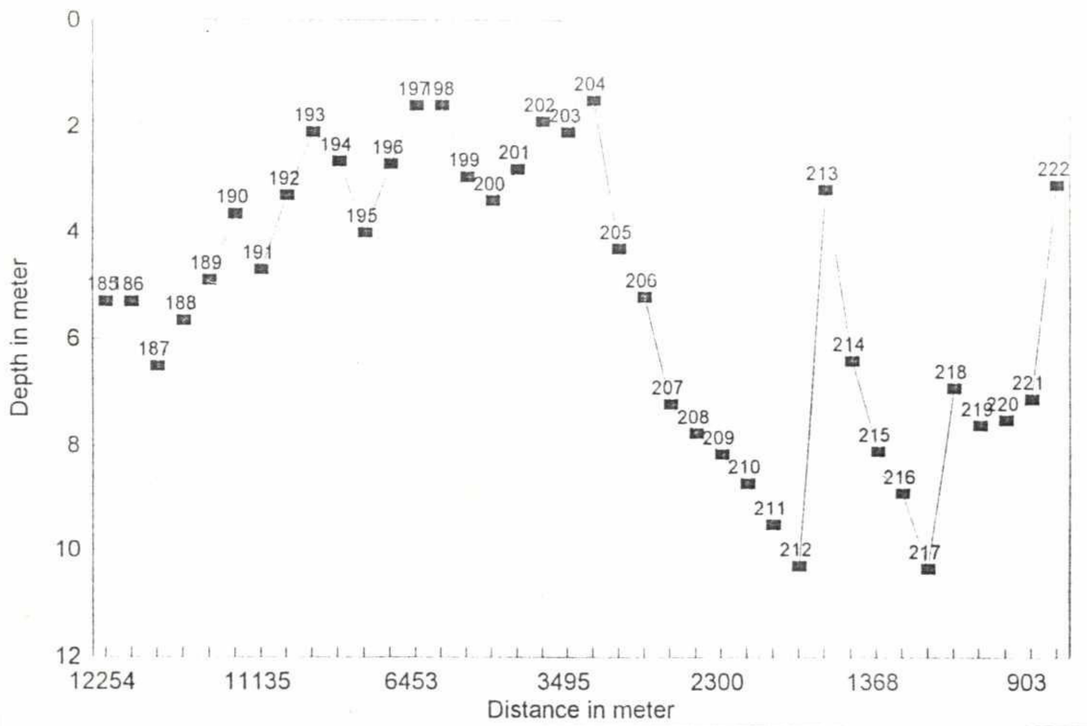


Figure 6.15: Location of sampling verticals, Bahadurabad

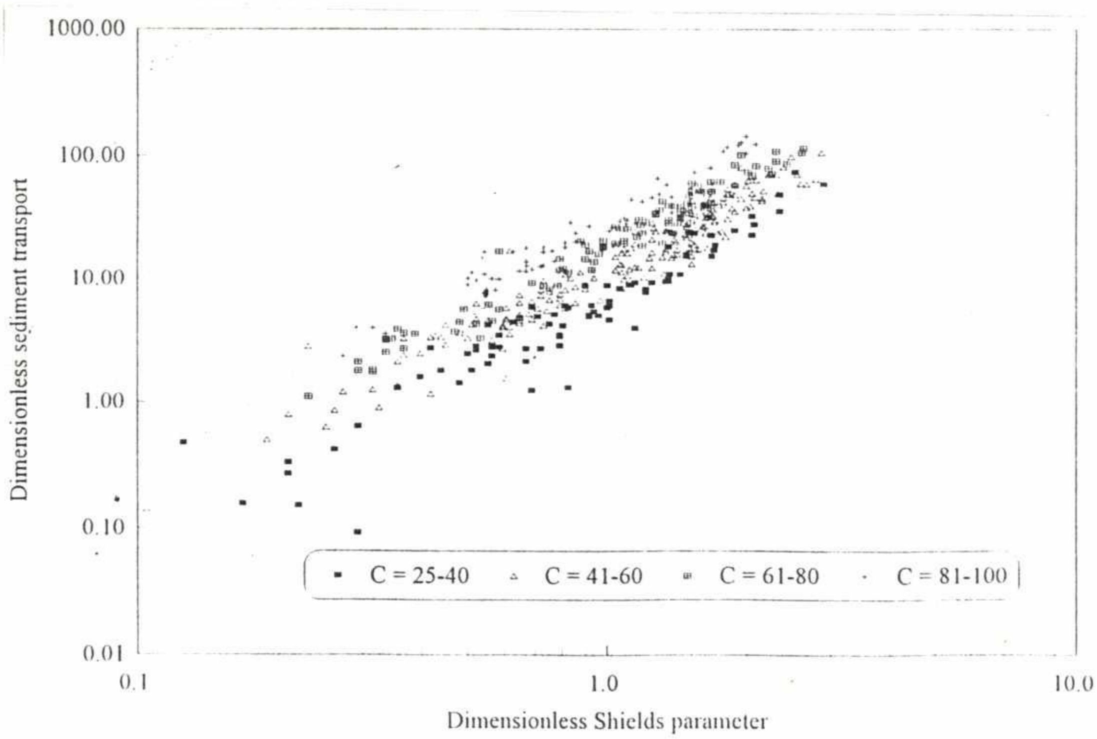


Figure 6.16: Sediment transport and roughness (Chezy) coefficient, Bahadurabad

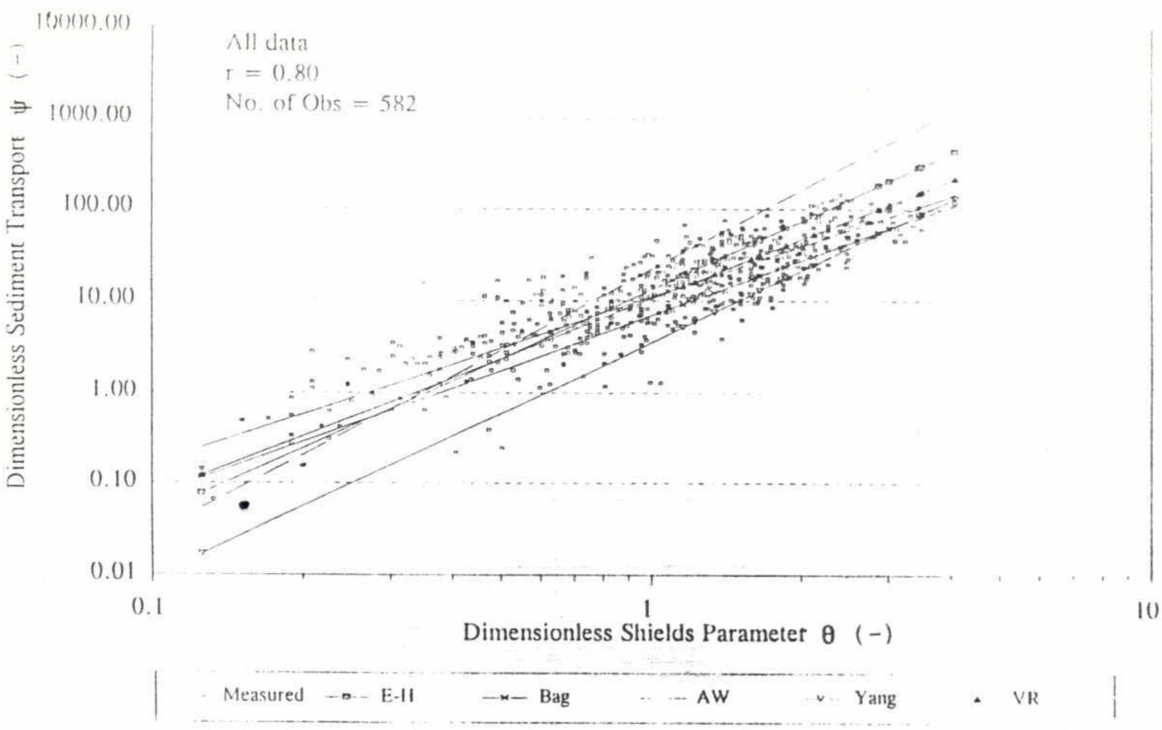


Figure 6.17: Comparison between predictors and measured transport

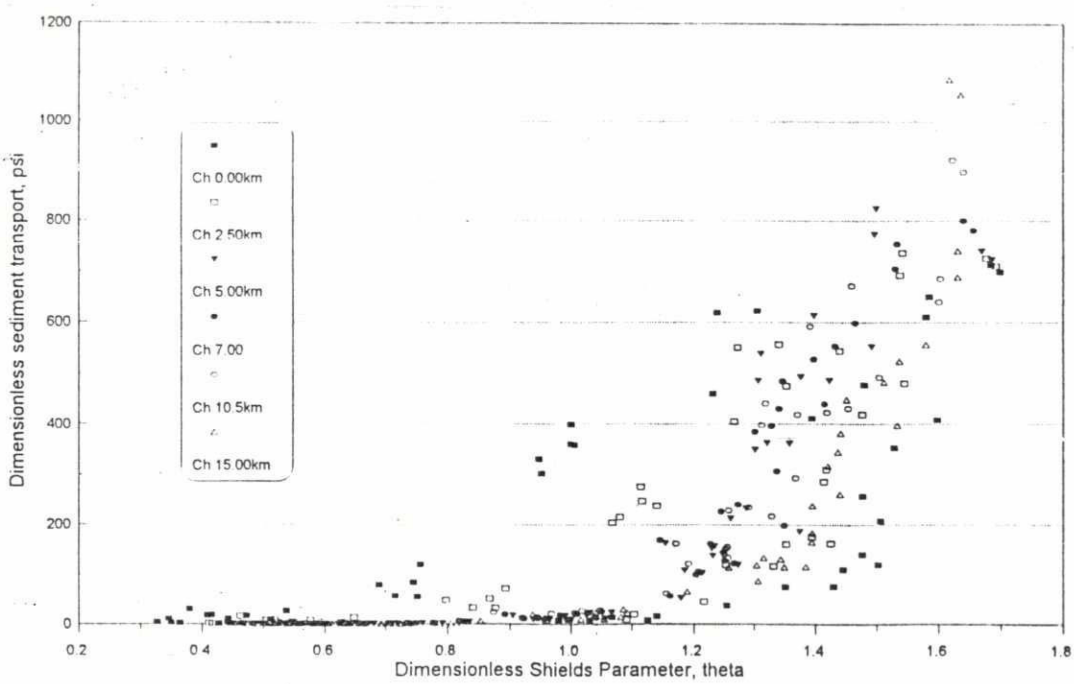


Figure 6.18: Sediment rating curves, Padma River

6.7 Floodplain level and bankfull discharge of the Jamuna, Ganges and Padma Rivers (study subject 3)

6.7.1 Introduction

In general, natural rivers are characterised by a wide variation of discharges and sediment load. Channel formation is the result of continuous changes of the discharge and the sediment load. To determine the channel dimension and the planform characteristics on the basis of a single discharge, the bankfull discharge is often applied. The bankfull discharge is defined by Richards (1980) as 'the flow which just fills the range of the section of the alluvial channel without overtopping the banks'. Further, he notes that it 'has often been... treated as a dominant or formative event controlling the channel form'.

After overtopping the banks of the river, the flow extends to the adjacent land, which is hereby defined as a floodplain. Due to the shallow depth and the vegetate surface of the floodplain, the flow often loses its sediment carrying capacity, whereby a sedimentation occurs. In the course of time, sedimentation can raise the flood plain, as well as the banks of the river. Not only the floodplain sedimentation, but also other phenomena: Bank erosion, tectonic movements, and flood spills, are determining the floodplain level adjacent to the river bank. The tectonic effects are beyond the scope of this study.

The present study considers floodplain areas that are covered by the BWDB standard cross-section surveys. These extend from a few km to a few decameters from the existing banks of the rivers.

There are mutual relationships between the channel form, the floodplain development, and the bankfull capacity of a section of the river (Keith Richards, 1980). Hence, the flood-plain level is studied in connection with the study of the bankfull discharge of the Jamuna, Ganges and Padma rivers.

6.7.2 Objective

The floodplain level is related to the bankfull discharge, which is utilised as a parameter for the prediction of the channel dimensions and plan-form characteristics of the major rivers in Bangladesh. The objectives of this study are as follows:

- To have an impression of the variability of the floodplain level and any changes of floodplain level during last few decades
- To determine the bankfull discharge of the Jamuna, the Ganges and the Padma Rivers
- In different studies of the Jamuna River, different values of the bankfull discharge are given. One objective of the present study is to estimate the range of the variation of the bankfull discharge of the Jamuna River relative to the applied definition of the bank level

6.7.3 Data

Three types of data are required: (1) floodplain level or bank level data, (2) hydrological data, and (3) the chainage line along the river, in order to link the two former types of data. For the present study activity, the data sources are BWDB, FAP 1, FAP 21/22, and FAP 24.

6.7.4 Data quality checking

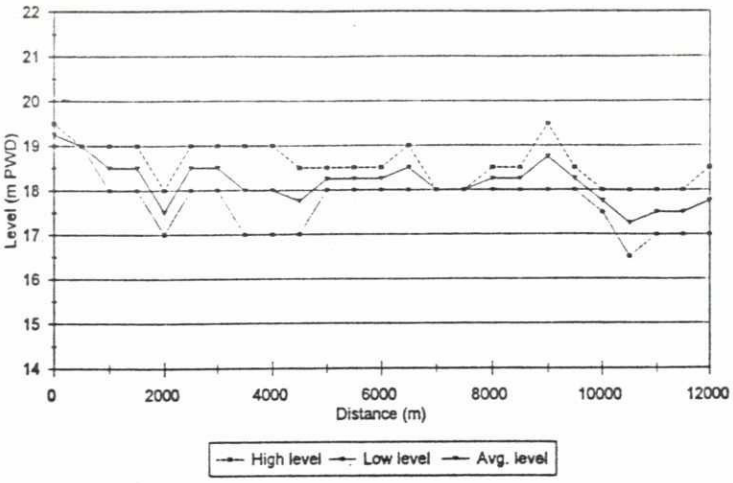
The quality of the BWDB cross-section surveys was discussed in FAP 24, Study Report 3 (1994), and by FAP 1 (1993), Annex 2. Though a lot of discrepancies and inconsistencies in the data have been detected, it is the only available description of the channel, the banks and the floodplain, both in time and space. Before analysing the BWDB data, a quality checking was made, as briefly discussed below. The data used in this study after quality checking are shown in Table 6.4. FAP 1 and FAP 21/22 data were assumed to be reliable and no checking was made before analysis of those data.

River	Type of data	No.	Period	Utilised
Jamuna	Cross-sections	34	1966-1993	16
	Water level	13	1966-1993	8
	Discharge	1	1966-1993	1
Ganges	Cross-sections	20	1966-1993	18
	Water level	7	1966-1993	6
	Discharge	1	1966-1993	1
Padma	Cross-sections	15	1966-1993	11
	Water level	5	1966-1993	3
	Discharge	2	1966-1993	1

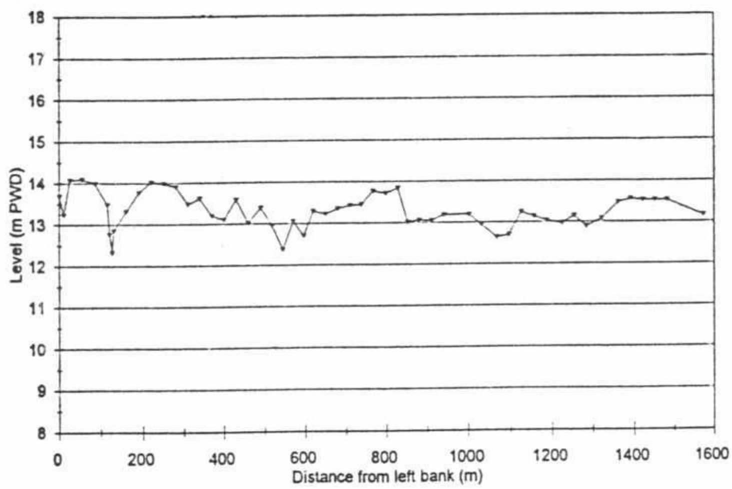
Table 6.4: BWDB data available and utilised in the study

6.7.5 Floodplain level: Data analysis and discussion

An analysis of FAP 21/22 and FAP 1 floodplain level survey data shows the local variation of the floodplain level, both along the river and in the transverse direction of the river, see Figure 6.19. The reason for the local irregularities may be crevasse splays influencing the boundary of the toe of the natural levee (cf. Colmen 1969). Formation and decaying of spill flood channels and irregular flow over the floodplain may also contribute to these irregularities.



a. Floodplain level along the river bank at Bahadurabad, width of the strip is 500 m.



b. Perpendicular section of floodplain at the left bank near Jamuna Bridge.

Figure 6.19: Floodplain level variability along and perpendicular to the river, based on FAP 21/22 and FAP 1 surveys

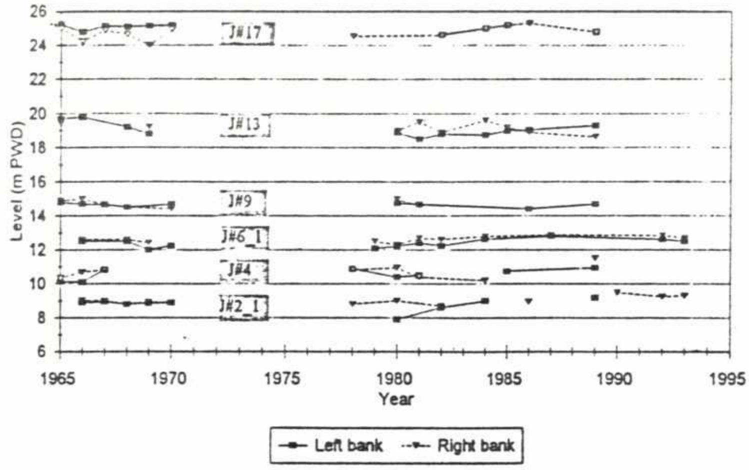
In Figure 6.20, the floodplain/bank level changes with time are shown for different BWDB cross-sections of Jamuna, Ganges, and Padma Rivers. No significant changes of floodplain/bank level are observed in this figure, though the year-to-year variation is considerable, especially at sections G#7 and G#10 (at the left bank of the Ganges) and at sections P#3_1 and P#7 (at the right bank) and at section P# 1 (at both banks of the Padma). The changes of the floodplain/bank level within two to four years are in range of 0.5-1 m.

These changes are often associated with either bank erosion or bank recedence. For the former case, see for example Figure 6.21.a, where, at section P#3_1, erosion of the right bank proceeds from 1975 until 1984. Erosion of the higher part of the natural levee shifted the bank at the toe of the previous levee from 1975 to 1979, and the right bank level continues to decrease as the erosion proceeds, see Figure 6.21.a. The section of 1984 shows that, after cessation of the erosion, the right bank raised nearly up to the level of 1975.

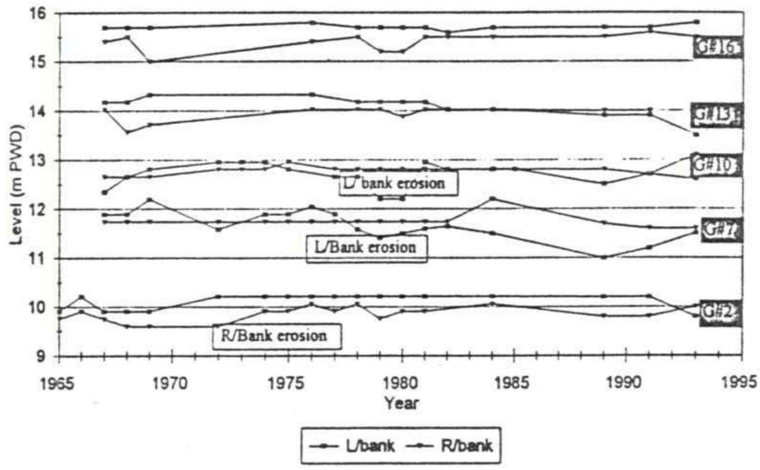
For the later case, see for example Figure 6.21.b, where, at section P#7, the right bank receded towards the river. A rise of the attached bar from 1974 continued up to 1989, where the level nearly reached the bank level of 1974. Figures 6.20 and 6.21 indicate that bank erosion or deposition into the river may change the level of the near-bank floodplain, but within a few years, the level raised again, nearly up to its previous level. More often, overtopping of flood water result in rapid sedimentation on the low laying floodplain.

One additional reason for apparent small year-to-year variations of the floodplain (as seen in Figure 6.20) may be the survey procedure, as the distances of the floodplain surveys are not the same, and also the applied levelling points are not same for every year. This may influence the apparent level of the highly irregular floodplain.

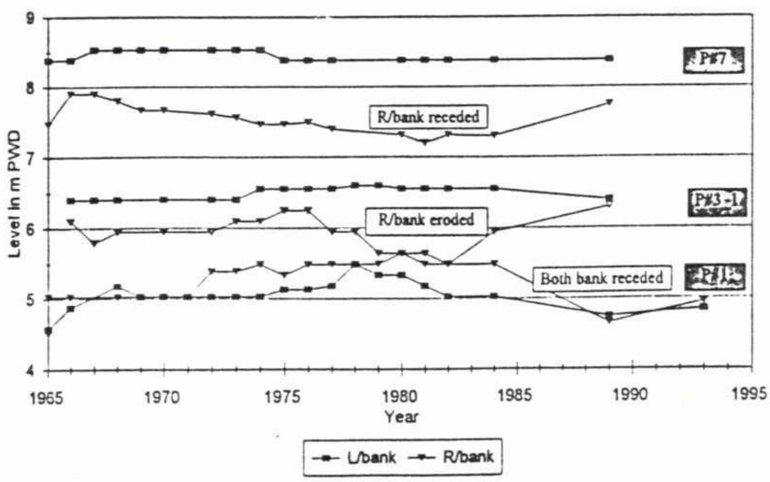
For those banks that are free from erosion or deposition for a long time, almost no change in level is observed in Figures 6.20 and 6.21. This suggests that any net aggradation or degradation occurring on the matured floodplain cannot be detected by this type of data, due to the time scale and the quality. The analysis shows that lateral deposition and erosion processes are more significant in rivers without net floodplain aggradation or degradation trends.



a. Jamuna river

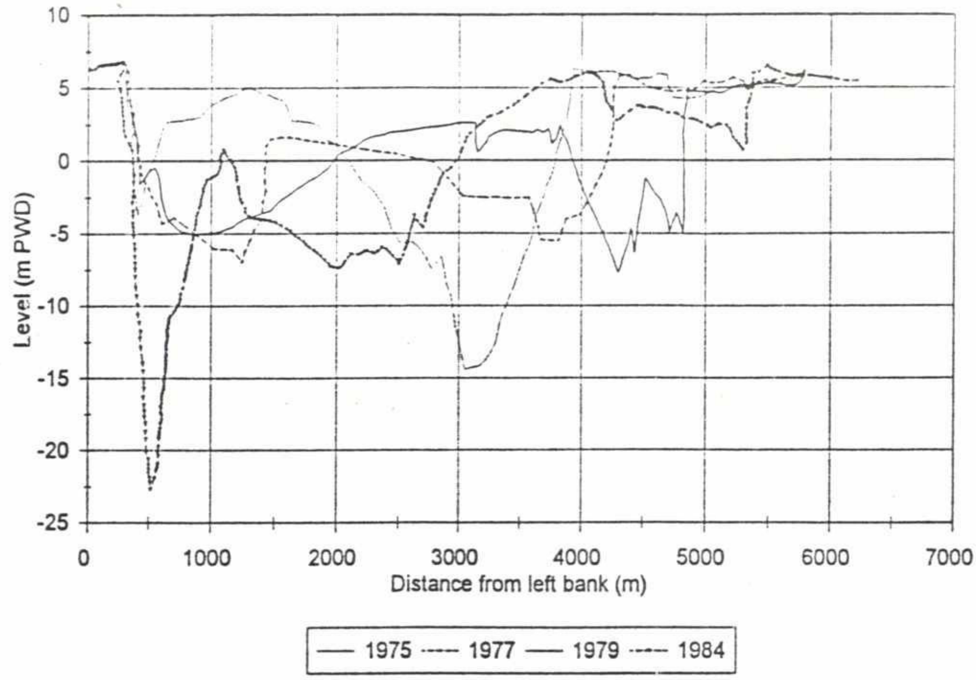


b. Ganges river

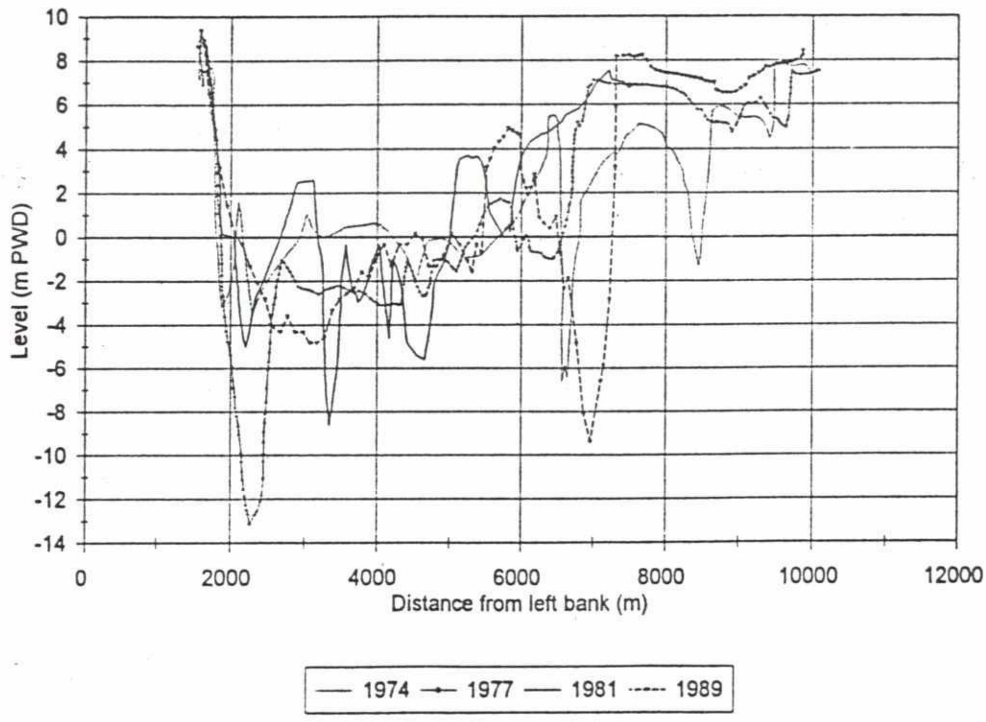


c. Padma river

Figure 6.20: Changes of floodplain levels with time



a. BWDB standard cross-section: P#3_1, Padma river.



b. BWDB standard cross-section: P#7, Padma river.

Figure 6.21: Bank level change due to bank erosion and bank recedence

6.7.6 Bankfull discharge

Determination of the bankfull discharge

The bankfull discharge can be estimated by an indirect method using the breaking point of the rating curve at higher discharges. This method is best for initial estimation. A drawback of this method is that the breaking point of the rating curve may reflect the 'char' level rather than the bank level; the range of variation of the breaking point is quite high, which may reflect both the local morphological changes, and changes of the char level. A bankfull discharge estimated by this method can be representative only for the section of the discharge gauging station for which the rating curve was made, as the bank level profile may not comply with the water level profile for the whole river reach.

In the present study, the bankfull discharge has been determined by estimating the bank level over a certain river stretch and by comparing the bank level with the water level profile at different discharges. The estimation of the bank level is made by considering the bank elevation at a number of fixed locations spread over a fixed distance along the river, and for the estimation of the water level profile, the same procedure has been applied. Drawbacks of this method are as follows: The bank level along the river is not a regular feature, and the water level profile, though less irregular than the bank level, still does not maintain a fixed slope profile for a long distance, but varies with time and space. A bankfull discharge derived by this method is sensitive to the estimation of the bank level and the water level. Still, this method can estimate the bankfull discharge in a better way than the first method, which is highly influenced by the local morphological features.

Definition of the parameters

To determine the bankfull discharge, two parameters are significant: One is the bank level, and another is the longitudinal water level profile at different discharges. In the present study, the bank level is defined as the average of the bank levels as estimated from BWDB survey data for about the last three decades.

Within the studied reaches of the rivers, the discharge is not the same, due to the presence of tributaries and distributaries. For simplicity, it has been assumed that the discharge at Bahadurabad represents the studied reaches of Jamuna River, the discharge from Hardinge Bridge the reaches of Ganges, and the discharge from Baruria the reaches of Padma River.

The water level profile for each discharge is not a constant line. It varies from year to year, and also within the same year due to hydrological and local morphological phenomena. To obtain an average impression of the stage for the same discharge, two years were selected for each river, where the stage variations were above and below the average and with almost the same magnitude for the higher discharges. The years 1990 and 1991 were selected for Ganges and Padma Rivers, while 1984, 1985, and 1990 were selected for Jamuna River.

Data analysis, Jamuna River
The mean bank level of Jamuna River was compared with the discharge profiles of 45,000 m^3/s and 50,000 m^3/s for the years 1984, 1985 and 1990. The comparison indicates that the bankfull discharge varies with time and chainage, and also that the average bankfull discharge is somewhere between 45,000 m^3/s and 50,000 m^3/s, so a characteristic value of 48,000 m^3/s would be reasonable, if the mean bank level is considered. It is noted that the mean bank level estimated from the BWDB cross-section surveys is in good agreement with the mean elevation derived from the FAP 21/22 and FAP 1 data.

Data analysis, Ganges River
In order to determine the bankfull discharge of Ganges River, the bank level profile was compared with the discharge profiles of 40,000 m^3/s, 45,000 m^3/s, and 50,000 m^3/s for the years 1990 and 1991. Two features were noted: (1) from chainage -20 km to 40 km, the bank levels are relatively high, and (2) downstream of chainage 40 km, the bank level is inundated even at a discharge of 40,000 m^3/s, for both years. The backwater effect of the confluence of Ganges and Jamuna Rivers at least partly accounts for this inundation. The average bankfull discharge of the Ganges is within the range from 40,000 m^3/s to 45,000 m^3/s. In between, any value could be selected.

Data analysis, Padma River
For determining the bankfull discharge of Padma River, 70,000 m^3/s, 75,000 m^3/s and 80,000 m^3/s discharge profiles for the years 1990 and 1991 were compared with the bank level profile. It was observed that the bank level at the mid portion of the river is relatively elevated. The reason for this phenomenon has not been examined, but it may be an effect of the local geology or of the plan-form of the river. However, the average bankfull discharge of Padma River can be estimated at around 75,000 m^3/s.

6.7.7 Conclusions

- The floodplain level near the bank of the river is quite variable, the typical variation being 1 to 2 m over a short distance. This may be explained by the presence of crevasse splay, or natural formation and decaying of flood spill channels. Because of the agricultural use of the flood plain, many anthropogenous elevation variations are found (drainage, footpaths, levees, housing on small hills).

- In order to study the changes of the floodplain with time, a long and reliable series of data with a good coverage of the floodplain is required. The present analysis has not detected any major change or any trend of the floodplain level over the last three decades. The erosion of the floodplain near an outflanking or meandering river channel is often compensated by sedimentation within a few years.

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- o The bankfull discharge of Jamuna River is about 48,000 m^3/s (between 45,000 m^3/s and 50,000 m^3/s), for the Ganges it is about 43,000 m^3/s (between 40,000 m^3/s and 45,000 m^3/s), and for Padma River it is about 75,000 m^3/s.

6.8 Bed material sampling, Ganges River (study subject 3)

6.8.1 Introduction

A bed material sampling campaign was carried out by FAP 24 in Ganges River on 6 August, 1994. Also, a number of bed material samples were collected during the routine gauging and the study surveys. The grain size analysis of those bed material samples were performed in the FAP 24 sediment laboratory. It was observed that a few samples contained 40 % to 99 % percent of silt. In this analysis, an attempt is made to locate those high silt contents samples in the river and to provide an explanation for the high silt contents.

6.8.2 Objective

The main objectives of the collection and analysis of the bed material samples are as follows:

- o To determine the characteristic bed material sizes of Ganges River (e.g. for sediment transport predictors or for modelling)
- o To estimate the grain size variation along the chainage of the river (grain sorting) during the monsoon
- o To improve the understanding of the role of fine sediment in the river system

6.8.3 Bed material sampling

Previous bed material sampling
NEDECO (1963-1967) collected ten bed material samples from Ganges River. Their findings were presented in Vol. III, Hydrology and Morphology, part B, NEDECO, 1967. NEDECO (1983) analyzed 180 bed material samples, which were collected in the period of August-December, 1970. They also collected and analyzed 5 bed material samples in April, 1982. Results of this previous work are shown in Table 6.5.

Previous work	Year of sampling	No. of samples	Findings, D_{50}mm
NEDECO, 1967	1963-1967	10	0.01-0.20
NEDECO, 1983	1970	180	0.12
	1982	5	0.18

Table 6.5: D_{50} of samples from Ganges River as determined by different studies

The results of the 1967 study show that d_{50} varies from 0.01 mm to 0.20 mm (NEDECO, 1967). The average d_{50} differs considerably for samples from 1970 and from 1982 (NEDECO, 1983), see Table 6.5. The samples from 1982 are biased by the sample size and cannot be representative for the Ganges River. No further bed material analyses from Ganges River are known.

Bed material sampling of the River Survey Project

To get a reliable picture of the bed material, FAP 24 made a sampling campaign on 6 August, 1994 in the Ganges. A total of 33 samples was collected in 11 cross-sections of the river, and the position and the water depth were registered. At each section, two near-bank and one mid-river sample were collected. Additional 17 bed material samples were collected during routine gauging in 1993 and during study surveys in 1994. In total, 50 bed material samples were collected during the period from September 1993 to October 1994. The locations of the bed material samples are shown in Figure 6.22.

Positioning was done by DGPS. Samples were collected by US-BM 54 sampler and by Van Veen (grab) sampler.

The grain size analysis was carried out in the FAP 24 sediment laboratory. The characteristic grain sizes were determined by sieve analysis for $D_{10} > 0.063$ mm, while for $D_{10} < 0.063$ mm, both sieving and Andreasen settling tube analysis were applied.

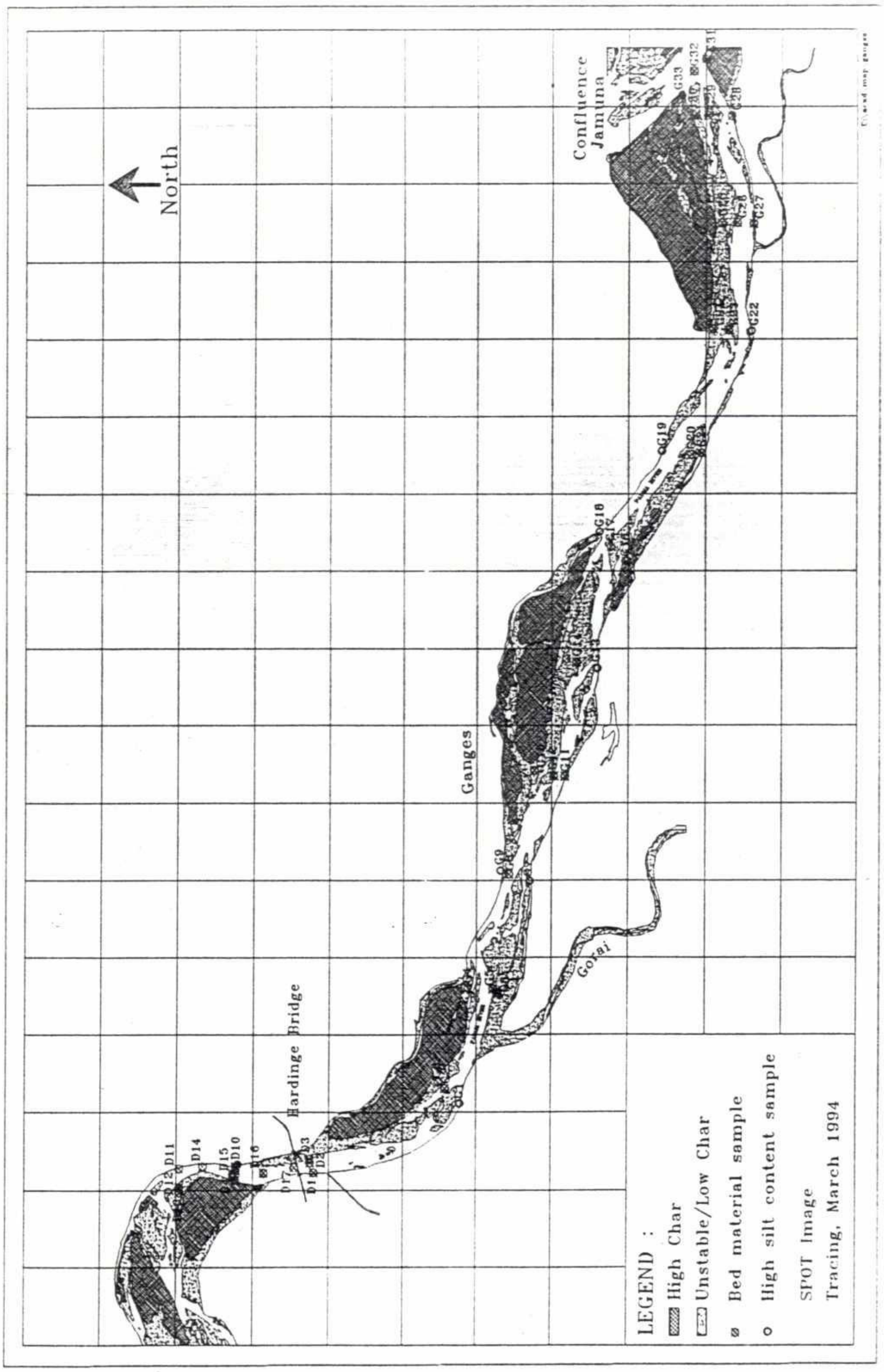

Figure 6.22: Bed material sampling locations

6.8.4 Analysis and results

It was found that 10 of the bed material samples contained 40-100% of silt. Also, the geometric standard deviation of those samples was higher than for the other samples, see Table 6.6. After placing the position of the samples over the tracing of SPOT images of March, 1994, and the FAP 24 bathymetric survey of October, 1994, it was found that out of those 10 bed material samples, 8 were from near the bank, and 2 samples were from the lee side of bars. The positions of these samples indicate the probable reason of their higher contents of silt. The 8 near-bank samples are probably containing bank material (which generally contains a higher percentage of silt and clay grains than the river bed materials). Some of the samples were collected near eroding banks.

No. of samples	Percent by weight		D_{50} (mm)	Standard deviation
	Silt	Sand		
50	19.56	80.44	0.123	1.63
40	5.77	94.23	0.144	1.46
10	74.72	25.28	0.039	2.33

Table 6.6: Average silt contents, grain sizes and standard deviations of 50 samples

Slack water generally prevails at the lee side of bars, which facilitates deposition of the finer portion of the suspended load. 2 samples at the lee side of bars were from such depositioning environment of the river bed. It appears from the analysis that the 10 samples with a high silt contents were not from the active river bed, which transports its incoming sediment in the form of bed load and suspended load.

For modelling the morphological behaviour of a river, the sand fraction of the bed material is of interest. Therefore, the 40 bed materials samples identified in Table 6.6 were analyzed further. The average D_{50} of those samples is 0.14 mm and the average geometric standard deviation is 1.46.

The grain size generally varies in the downstream direction due to abrasion or selective transport. The average characteristics grain sizes D_{16}, D_{50} and D_{84} of are plotted against the chainage in Figure 6.23. Though the sectional average grain sizes varies from section to section, a clear trend of finer grain sizes in the downstream direction is observed. As per the regression line, D_{50} at the upstream part of the sampling reach is 0.155 mm, decreasing to 0.132 mm within a 92 km stretch downstream of the river. The rate of decrease of the grain size in the downstream direction is about 0.025 mm per 100 km.

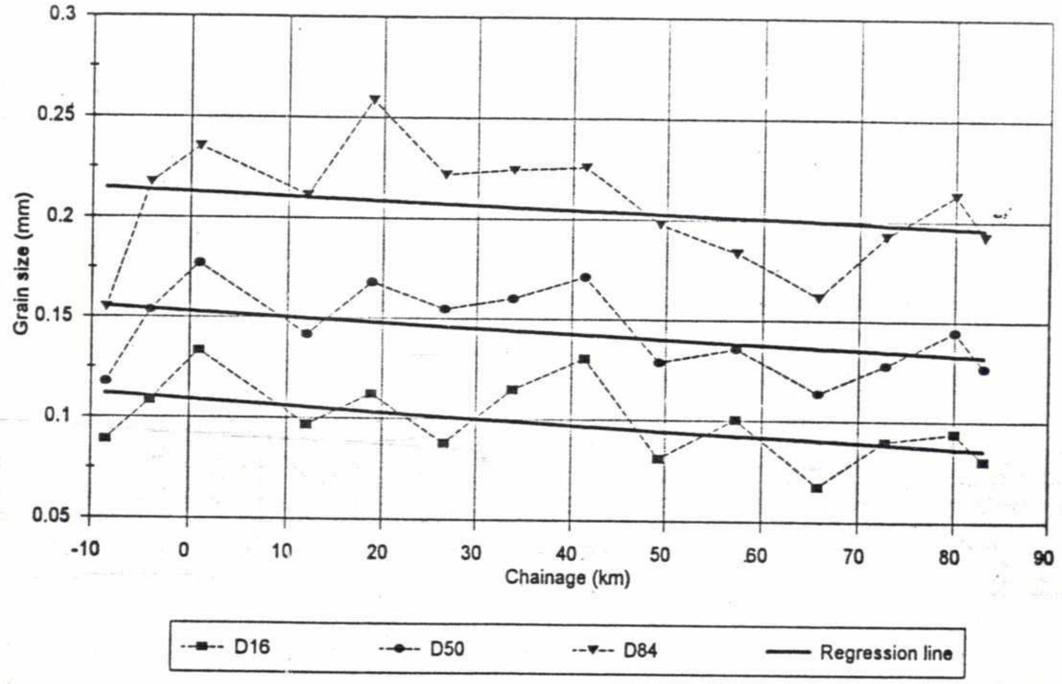

Figure 6.23: Characteristic grain size variation along Ganges River

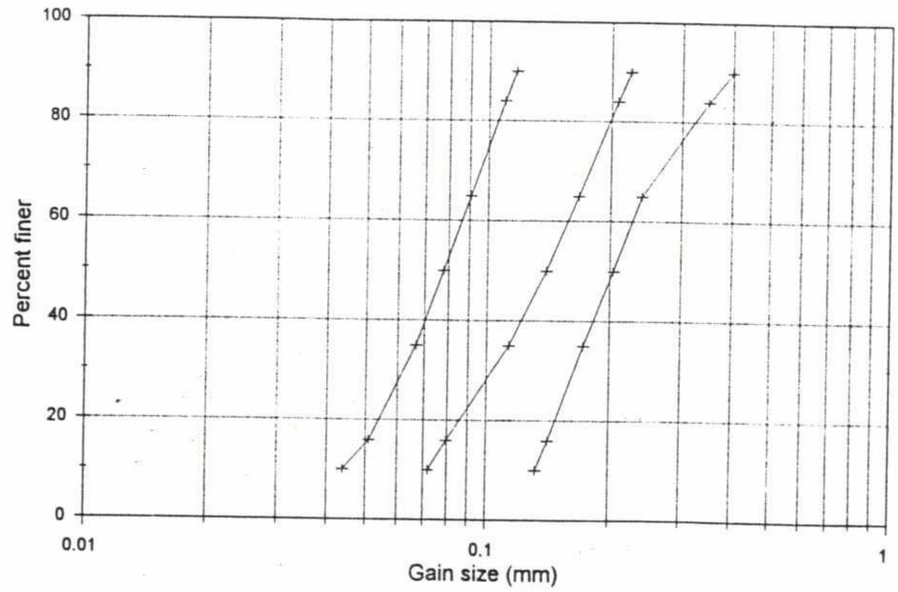

Figure 6.24: Grain size distribution

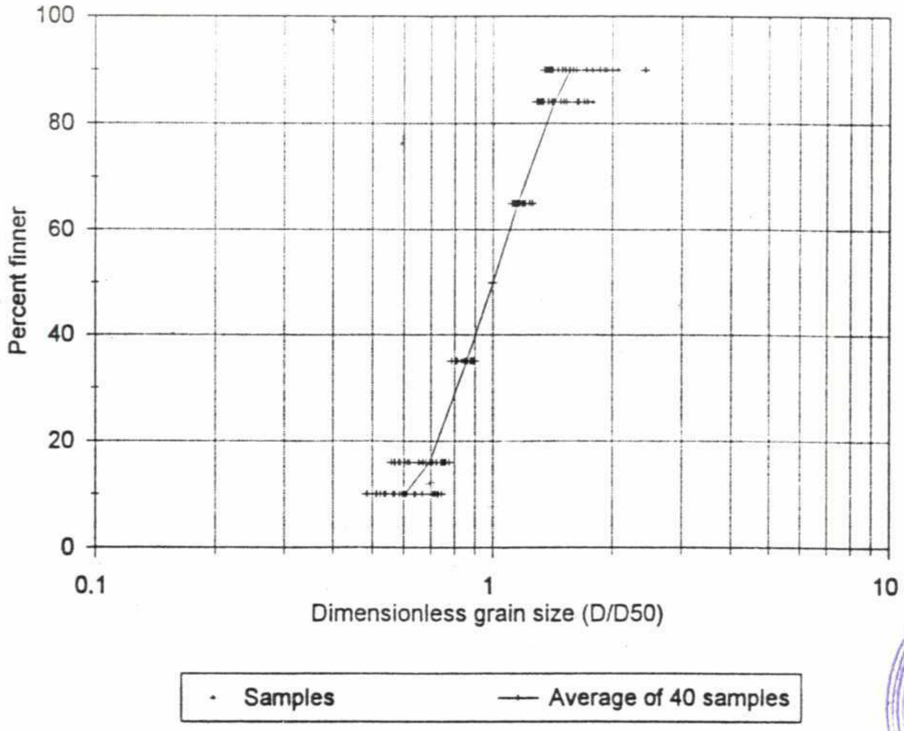

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Figure 6.25: Dimensionless grain size distribution

The typical grain size distribution curves for the bed material of the Ganges are shown in Figure 6.24. The variation of D_{50} ranges from 0.8 mm to 0.20 mm. The grains show an almost uniform distribution and are predominantly fine sand. The accumulated dimensionless grain sizes (D/D_{50}) of the 40 samples are plotted in Figure 6.25. For a single value of D_{50}, the range of variation of other characteristic sizes of the samples can be observed from this figure, which is a function of the geometric standard deviation of the samples. The average geometric standard deviation of the forty samples is only 1.46, see Table 6.6.

6.8.5 Conclusions

1. The bed material of Ganges River is fine and almost uniform sand. The average D_{50} is about 0.14 mm and the average geometric standard deviation is 1.46 in the stretch from Hardinge Bridge to the Confluence.

2. The rate of downstream fining is about 0.025 mm/100 km, slightly less than the fining rate in Jamuna River, and the gradation of grains in the Ganges is fairly similar to the gradation of grains in Jamuna.

3. Apart from the variation of grain size in the downstream direction, the bed material size distribution can vary with the depth of flow and in the transverse direction of the flow; due to the flow field. No such relations have been observed in the present analysis. However, from the analysis it appears that three different environments can de identified in the river system, namely eroding banks, settling areas, and an active river bed. For each environment, the bed material size and the silt contents are probably different.

6.9 Development of hydraulic conditions and bed levels at Gorai mouth (study topic 4.1)

6.9.1 Introduction

The total seclusion of the Gorai at its offtake from the Ganges every dry season in recent years is a matter of great concern. Several factors have been mentioned as being entirely or partly responsible for this development. These factors may be categorised according to their geographical origin:

- o the overall morphological development of the Ganges
- o the local morphological developments of the Ganges, such as changes of the curvature at Talbaria and bar formation patterns
- o local morphological conditions of the Gorai at or near the offtake
- o the morphological developments downstream in the Gorai such as increased sinusoidity

The present study deals with what we can learn from existing data and may be regarded as an extension of the comprehensive study of the Gorai already performed as part of FAP 4. These analyses shall not be repeated by the FAP 24 study, but are taken as a basis. The present analysis focuses on the local conditions at the Gorai mouth but considers also the character of the Ganges flow.

There is only little direct information about the bathymetry of the Gorai mouth from the past. Instead, existing water level and discharge data are applied to obtain information about the change in hydraulic conditions, and it is attempted to interpret the observed changes in terms of bed level changes.

Long time series of water level data from Hardinge Bridge, Talbaria and Sengram were applied in the analysis, together with time series of water levels and discharges from Gorai Railway Bridge.

The objectives of the analysis were:

- o To obtain information on bed level changes and changes in hydraulic conditions at Gorai mouth over the last 30 years by analysing existing water level and discharge data. The results will be compared with existing bed level data

- o to obtain information on changes in the Ganges water levels and, if possible, to establish correlations with the performance of Gorai Offtake

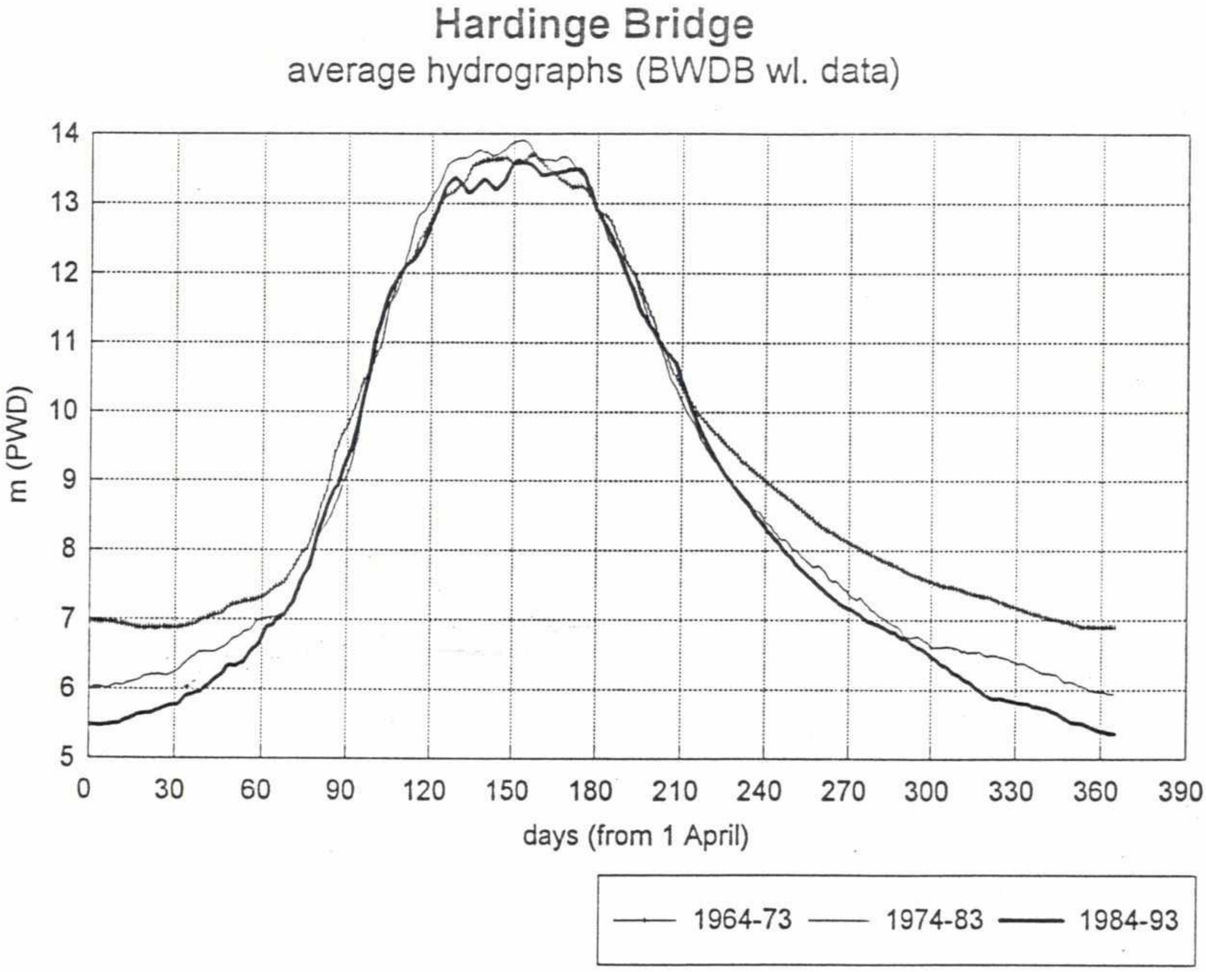

Figure 6.26: Average hydrographs, Hardinge Bridge

6.9.2 Conclusions

The conclusions are :

- o Since 1964, the minimum water level of the Ganges has clearly fallen by more than 2.5 m (Figure 6.27). The drop has been particularly sharp after 1987, but seems to have been going on gradually over the entire period. A clear decrease in minimum water level took place in the second half of the 1970'es - which coincides with the beginning of operation of the Farakka Barrage. The maximum water level does not show any decreasing or increasing trends.

- o On average, the water level of the Ganges at the end of the monsoon period is clearly dropping much faster during the latest 10-years period (1984-93) than it did in 1964-73 (Figure 6.26). The decrease from 11 m+PWD to 7 m+PWD now takes only half the time as compared with 20 years ago. This implies that a dry season flow channel on the average has roughly only half the time to develop by erosion than it had 20 years ago. The maximum water level drop in the Ganges over a 2 weeks period after the peak of the monsoon does seem to have changed after 1980, although the trend is not very clear due to high variations from year to year: The variability becomes less and low values of maximum decrease do no longer occur. The relative stage of the Ganges at the time when a steep drop occurs should, however, also be taken into account in more detailed future analyses.

- o The threshold bed level at the Gorai mouth (represented by the 10 $m^{8/3}$ conveyance factor level) has been varying by up to more than 3 m from 4.0 m+PWD in 1966 (estimated, because the minimum water level was 5.6 m+PWD) to 7.2 m+PWD in 1989 (Figure 6.27). A sharp increase appears to have taken place in connection with the high floods of 1987 and 1988. Before 1987, the bed level varied by approximately 1.5 m in a seemingly periodic way (period 6 to 12 years).

- o Two factors may, separately or in combination, cause the closure of the Gorai offtake: Dropping dry season water levels in the Ganges, and increasing threshold bed levels at the Gorai mouth. It was found that both factors have been effective (Figure 6.27)

- o Closure or near-closure of the offtake during the dry season has occurred now and again during the 30 years period. The tendency to close every year was initiated by a sharp bed level rise at the Gorai mouth in 1987 which continued in 1988. The sharp drop in the minimum water level in the Ganges after 1988 has made it increasingly likely that closure in the future will take place every year.

- o The increasing bed level after 1987 seems to have reduced the conveyance factor for all stages of the flow.

- o There is a tendency of narrowing of the lower part of the cross section, initially in 1982 and, more pronounced, from 1989. This may be due to the dredging of narrow channels. The intermediate part of the cross section and, to some extent, also the upper part, show a tendency to widen since 1987.

The assumption that the hydraulics of the Gorai Offtake is governed mainly by local conditions rather than by conditions further downstream need to be checked, before proceeding with more detailed analyses along this line.

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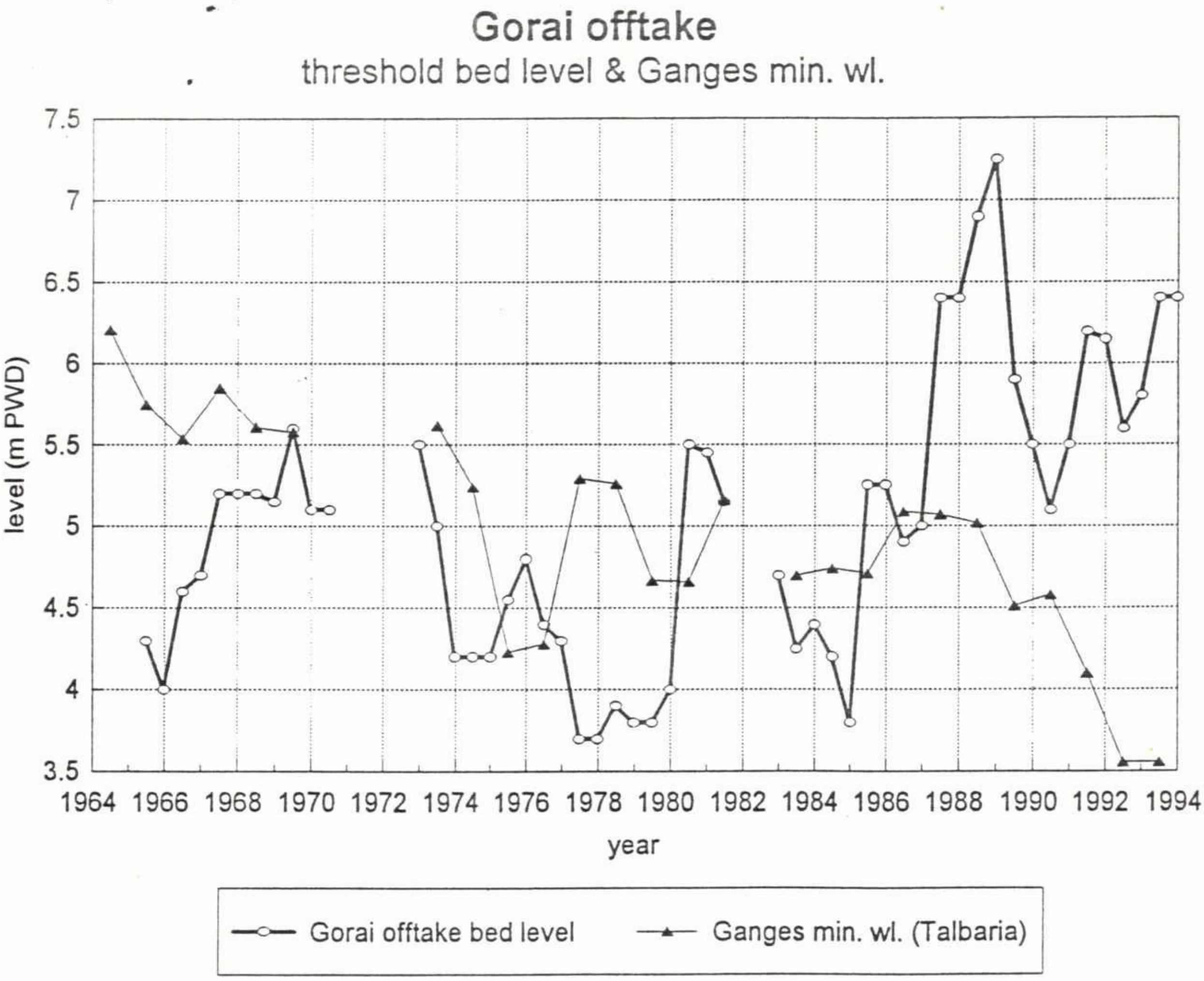

Figure 6.27: Gorai offtake, threshold bed level and minimum water level in the Ganges River

6.10 2-D morphological modelling of Gorai Offtake (study topic 4.1)

Introduction

The development of offtakes is one of the study topics of FAP 24. The Gorai Offtake was selected for a detailed study using 2-D morphological modelling. The reason for this choice was the importance of Gorai River for the water balance of the South-West Region.

Objectives

The objectives of the study are as follows:

- o To improve the understanding of factors that are important for the sediment transport distribution at bifurcations, and thereby enable a prediction of some overall trends in the morphological development at the offtake o To improve the understanding of the sediment transport distribution and the processes of erosion and deposition at an offtake channel, thereby gaining insight in the influence of bar formation in front of the offtake

Model set-up and initial results

The MIKE21-Curvilinear (M21-C) modelling system of DHI is used. It is an updated version of the SYSTEM21-Curvilinear system which was previously used for Brahmaputra River in connection with FAP 1. M21-C comprises computational modules to describe:

- Flow hydrodynamics, water levels, and flows over a curvilinear or a rectangular computational grid covering the area of interest by solving vertically integrated equations of continuity and conservation of momentum

- Helical flow (secondary currents) due to curving stream lines. Time and space lags in the development of helical flow are included

- Sediment transport, based on different model types (van Rijn, Engelund Hansen, or Engelund-Fredsoe). The effects of helical flow, gravity on a sloping river bed, and the shape of the velocity and concentration profiles are taken into account. The time and space lags in the development of sediment concentrations for given hydraulic conditions are included

- Hydraulic resistance due to bed material and bed forms (calculation of skin friction due to grain sizes and from drag friction due to bed forms). The model is based on the bed form model developed by Fredsoe (1979).

- Large-scale movement of bed material due to scour or deposition causing changes to the bathymetry. The continuity equation for sediment is solved in order to find changes in bed elevations at each grid cell and at every time step. The effect of bank erosion can be included.

The modules can be run interactively, incorporating feedback from variations in the hydraulic resistance and bed topography to the flow hydrodynamics and sediment transport.

The model covers approximately 30 km of the Ganges and Gorai Rivers (see Figure 6.28). So far, only a rough calibration has been made. Results of dedicated special surveys in the 1995 monsoon period will be used for calibration and validation.

Examples of preliminary results are shown in Figures 6.29 and 6.30.

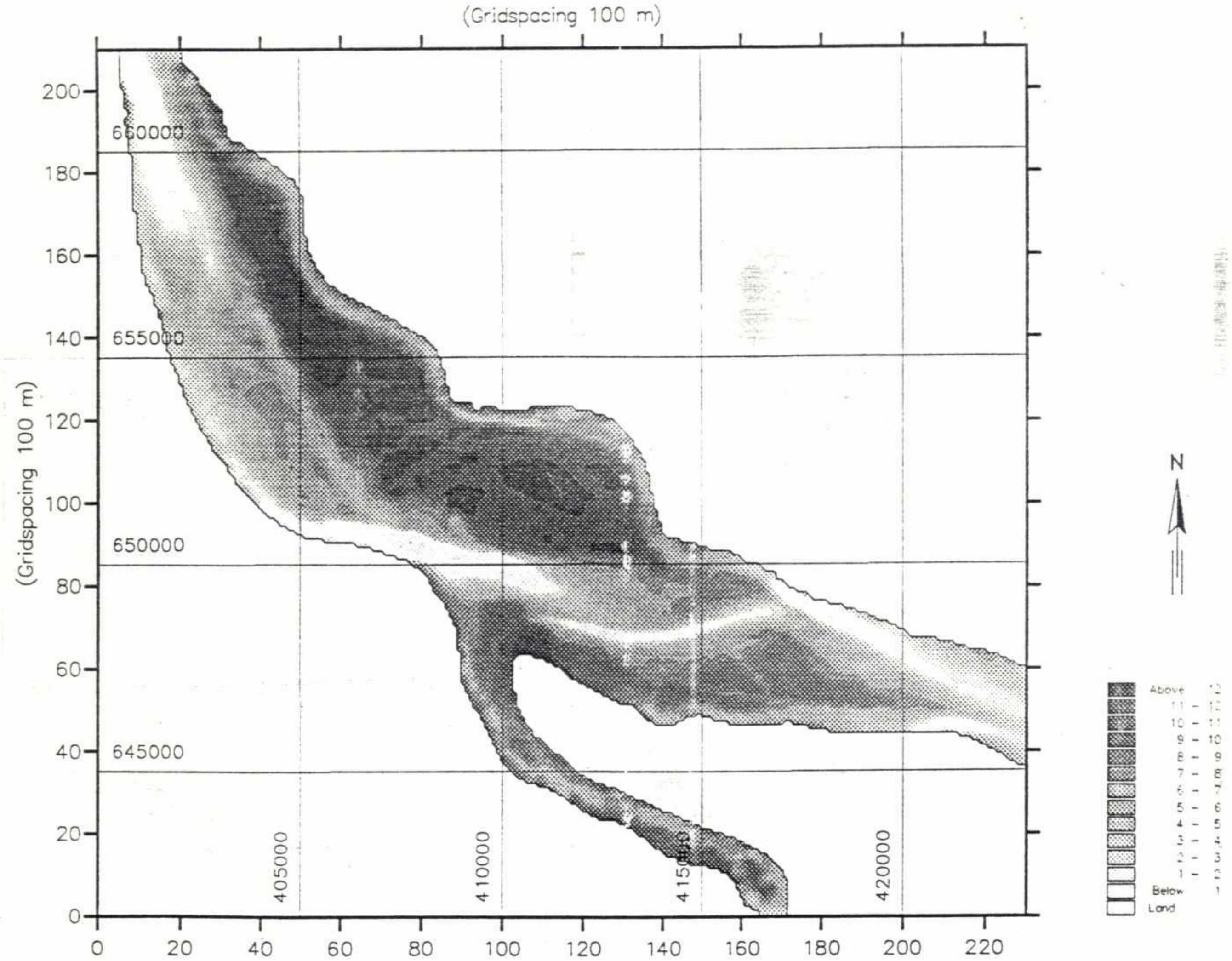

Figure 6.28: Model bathymetry of the Gorai model

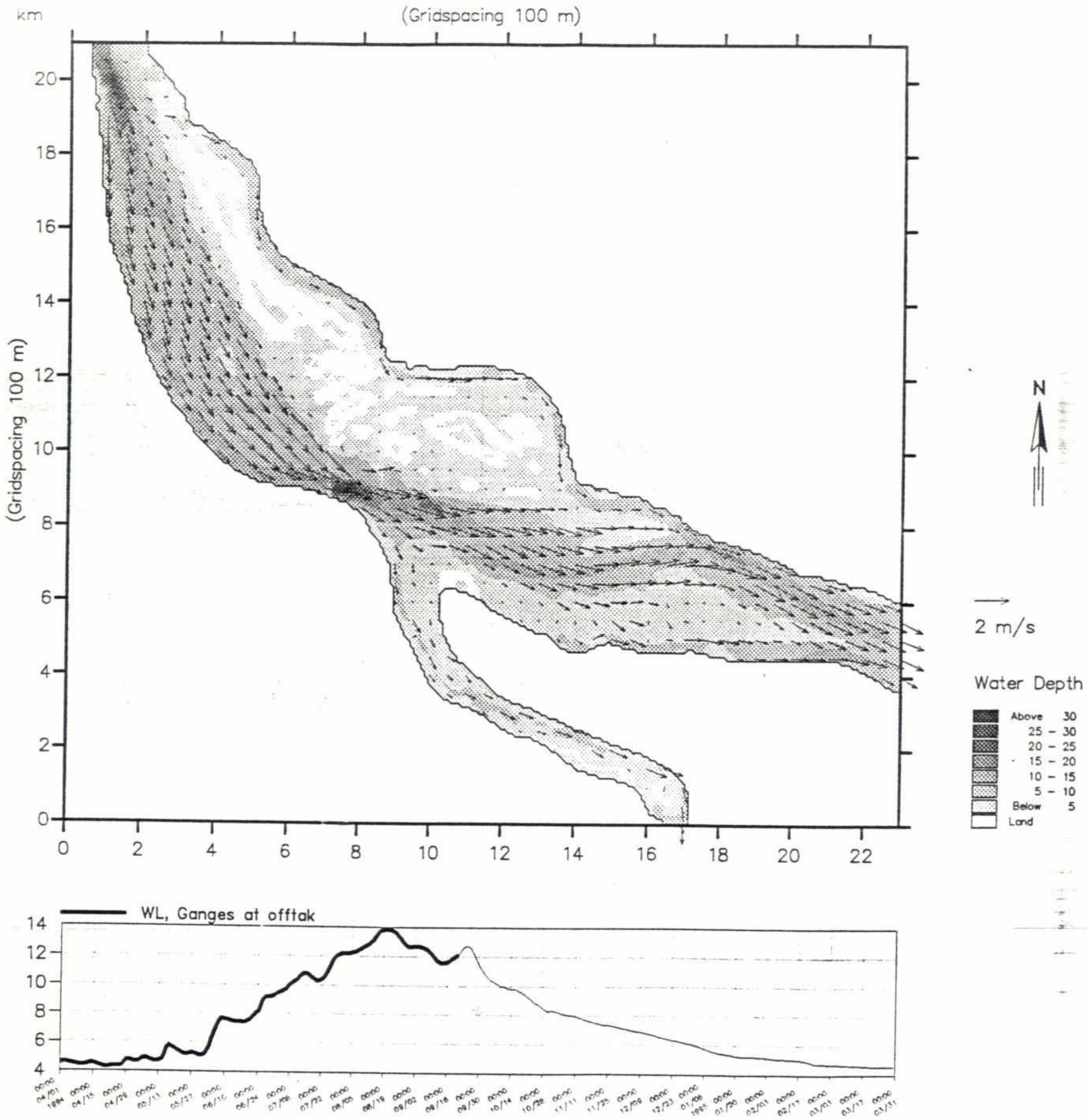

Figure 6.29: Calculated velocity field (example)

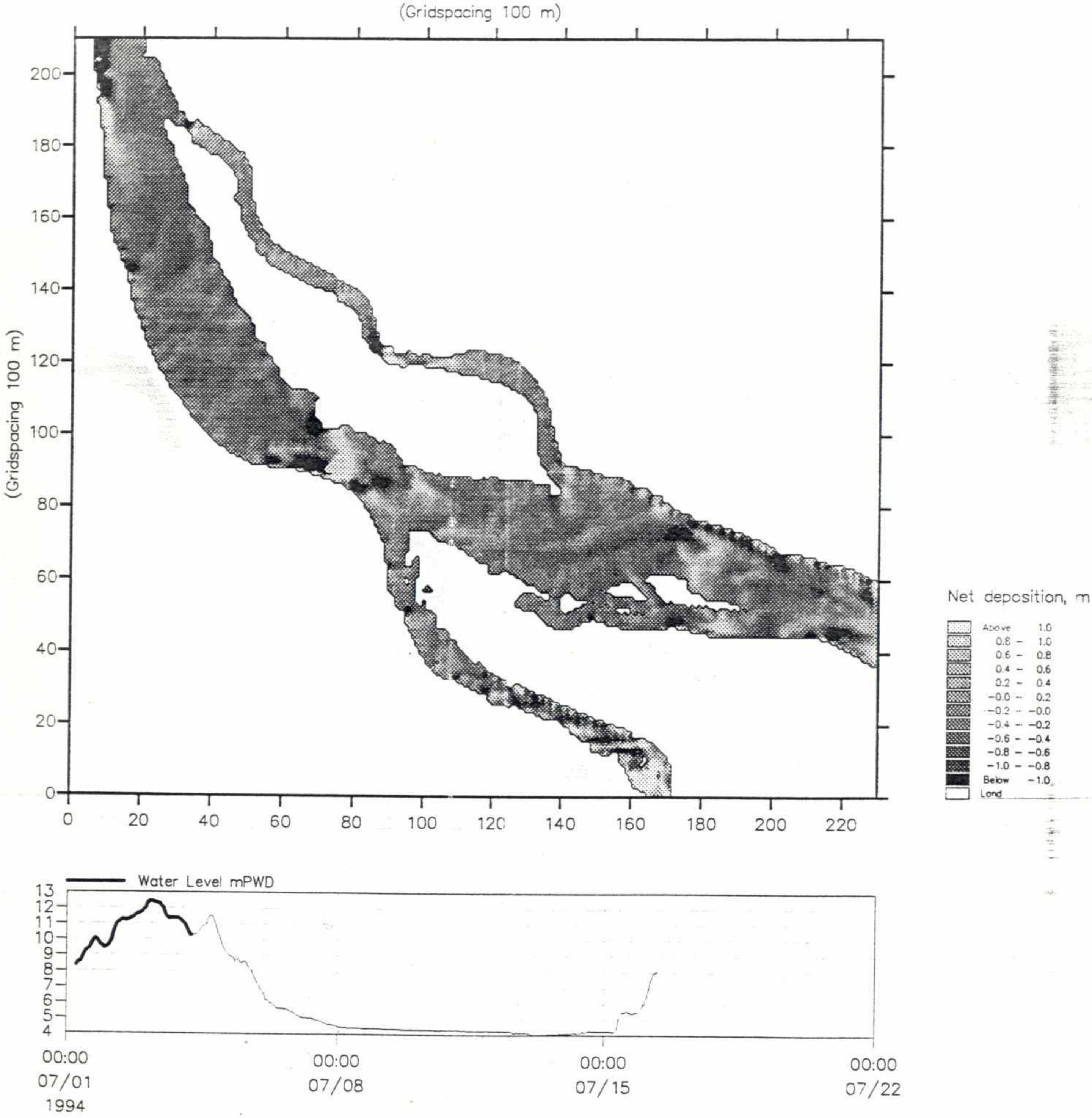

Figure 6.30: Calculated bed level change (example)

6.11 Optimization of sediment measurements (study topic 9.3)

6.11.1 Introduction

The River Survey Project (FAP 24) started operation in Bangladesh in 1992. One of its main objectives is to collect all-season quality data on hydrology and morphology in the main rivers of Bangladesh. Among others, the morphological data collection includes measurements of suspended sediment load and near bed sediment load. For the purpose of measuring suspended load, several instruments have been mobilized: (1) the Delft Bottle, (2) the point-integrated pumping method, (3) the depth-integrated bottle, (4) the depth-integrated collapsible bag, and (5) optical turbidity recorder. In addition, (6) ADCP back-scatter signals are used to indicate the sediment concentration qualitatively. Figure 6.31 shows the different samplers. The shaded Brinkley sampler is included here, because it is used by Bangladesh Water Development Board. The near-bed sediment samplers include the Helley-Smith sampler and the Delft Bottle.

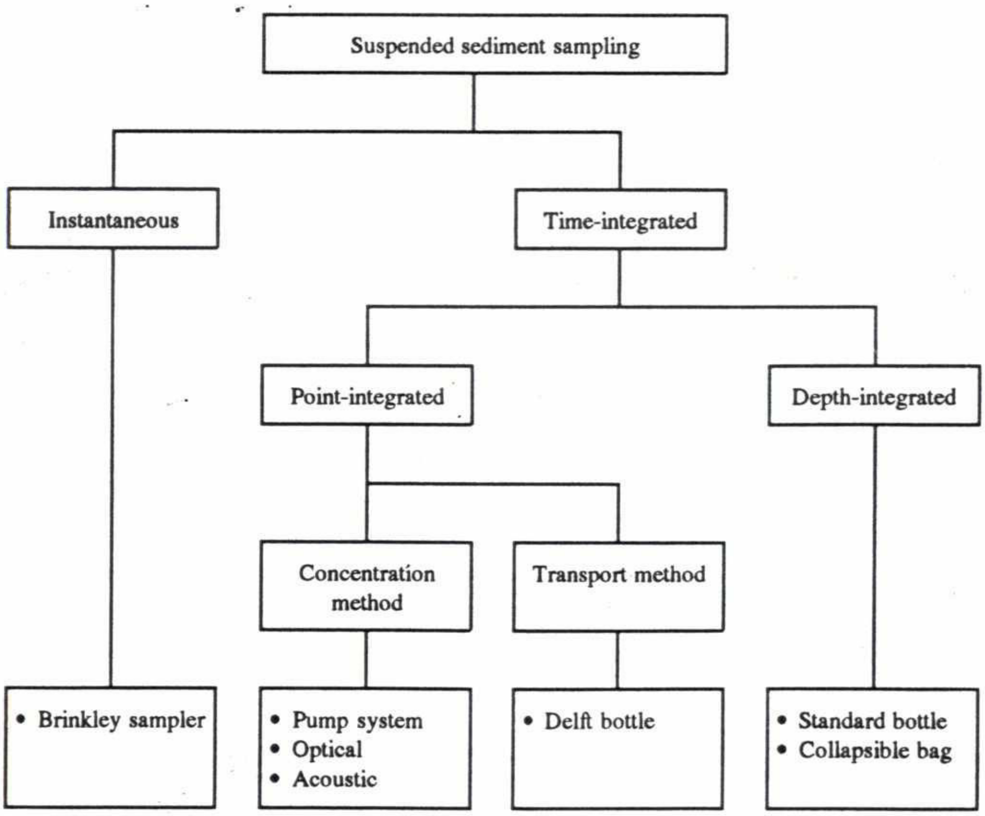

Figure 6.31: Categories of suspended sediment samplers

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Basically, the study topic contains the following sub-topics:

1) Selection of equipment and method
2) Optimal vertical and horizontal sampling distribution
3) Importance of fine sediments (wash load)

Several inter-comparison and test gauging exercises were made in the past, and the results are reported in several project reports (RSP, 1993a; RSP, 1993b; RSP, 1993c). The issues 1 and 3 are addressed in different working papers. Some preliminary analyses addressing issue no. 2 were reported in Study Report 3 (RSP, 1994). The present section is primarily dealing with issue no. 1.

6.11.2 Comparison and evaluation

In Table 6.7, different factors are compared and evaluated for the different samplers available with FAP 24. The influence of measuring facilities on the selection of a sampler is not shown (but is nevertheless an important criteria). The River Survey Project survey vessel DHA offers the required measuring facilities such as the vessel itself, winches (with power), booms, and fish and sounding weights. Similar facilities exist, although with a limited operational status, on the BWDB catamaran.

Among the different samplers discussed, the pump system is a useful system, which, if operated under isokinetic conditions, can represent all particle sizes. However, the present set-up of the pump in FAP 24 with umbilical chord is very expensive. Introduction of simple hose may reduce the price. But a flexible and un-stressed hose cannot be used at high flow velocities and larger water depths. Therefore, an effective system for all flow and sediment sediment ranges and for all depths may remain very expensive.

The Delft Bottle is a sturdy and reliable sampler. However, its use as a suspended sediment sampler is limited, because it does not represent particles finer than about 100 μm. One option is to adapt the sampler to Bangladeshi conditions. This can possibly be achieved by enlarging the sedimentation chamber of the bottle. Enlarging can be made by lengthening the sampler in the rear direction. Finer particles can settle better at reduced flow velocities and with an increase of the time-lag between the entry and the exit of the particles. In addition, the general practice of elutriation, which is followed in the field to separate sand from silt, can be eliminated.

A standard depth-integrated bottle has a depth limitation, inhibiting its use in large water depths. A larger size bottle can be used instead, but this requires a design adaption.

The Brinkley sampler, which is used by BWDB, should be applied only when repeated samples are taken.

Optical and acoustic sensors have a great potential use for the future, simply because they eliminate both the field and the laboratory processing, which are common sources of error. However, these technologies are still developing, and are, at their present stage, not yet suitable for regular and routine estimation of sediment load for the following reasons:

- o The techniques are extremely sensitive to sediment sizes of suspended load. Since the sediment sizes in the rivers of Bangladesh range from clay to coarse sand, and vary considerably in space and time, the instruments need frequent calibration to give representative results.

- o However, the optical method can be applied for routine monitoring of suspended sediment concentration near the surface with frequent calibrations. The acoustic (ADCP) method can similarly be applied for a qualitative indication of sediment scatter over the water column.

At this stage, the collapsible bag depth-integrated sampler appears to be an attractive solution for routine measurements by FAP 24. Hereby, some quality assurance steps have to be followed strictly: (1) a uniform transit rate, (2) isokinetic sampling and (3) minimization of the unsampled near-bed zone. The future use of the sampler, and its possible adoption by BWDB, depends on how the measuring facilities can be arranged on the vessels. It is difficult to ensure a uniform transit rate by a manually driven winch at larger water depths and at higher flow velocities. Therefore, a power winch is a necessity.

For sampling of near-bed sediments, the performance of the Delft bottle is better than the Helley-Smith sampler.

6.12.3 Conclusions

For routine surveys, the collapsible bag is possibly applicable for all hydraulic conditions, whereas the depth-integrated bottle can be used in shallow channels and during low river stages.

For special studies, any of the samplers can be used, depending on the specific purpose. However, a pump system accompanied by a depth sensor and a flow sensor is an ideal technique.

1 Instrument	Brinkley sampler	Depth-integrated bottle	Collapsible bag	Acoustic (ADCP)
2 Representa-tivity	Instantaneous sediment suspension	All particles under isokinetic conditions	All particles under isokinetic conditions	Primarily sand
3 Error	72 %	10-100 %	19 %	Only indicative at the present state of development
4 Reliability	Vulnerable to leakage	Sturdy and reliable, but has a depth limitation	Teflon bag leakage/tear	Vulnerable to electronic and software failure
5 Operation and maintenance	Easy and nearly maintenance free	Easy and nearly maintenance free	Moderately easy and relatively little maintenance	Operation very easy, maintenance of sensor required
6 Environ-mental sensitivity	Nil	Nil	Nil	Vulnerable to heat and humidity, high complexity
7 Dependency on crew expertise	Nil	Ensuring uniform transit rate according to ambient velocity	Ensuring uniform transit rate according to ambient velocity	Hardware and software use
8 Field processing	Nil	Splitting	Splitting	Nil
9 Laboratory processing	Concentration determination	Concentration and grain size determination	Concentration and grain size determination	Computer based, difficult to calibrate
10 Costs	500 ECU	2,000 ECU	2,000 ECU	46,000 ECU
11 Least required facilities	Catamaran	Catamaran, power winch	Catamaran, power winch	Medium vessel, electronic base
12 Remarks, routine gauging	Can be used only if a sufficient number of samples is taken at each point	Depth-limitation is a hindrance to its use	Can be used effectively under Bangladesh conditions	Has a great potential for future use, but is, at this stage, not suited for routine operations
13 Remarks, detailed studies	Cannot be used for accurate suspended sediment sampling	Vertical concentration profile is not available	Vertical concentration profile is not available	May be used for special research purposes

Notes:
- The Brinkley sampler has been included because it is used by BWDB
- Errors are primarily taken from Van Rijn and Scaafsma (1986). Errors for the pump system, Delft bottle, collapsible bag, and Brinkley samplers are determined by FAP 24
- Errors are relative standard deviations in percent: (std/mean)x100
- Prices are FAP 24 purchase costs. The collapsible bag sampler can be manufactured in Bangladesh at a lower cost

Table 6.7: Comparison of sediment samplers (continued on next page)

1 Instrument	Optical (MEX 3)	Delft bottle	Pump system
2 Representa-tivity	Primarily silt	Represents generally particles > 0.1 mm	All particle sizes under isokinetic conditions
3 Error	50 % for silt	10 %	14 %
4 Reliability	Vulnerable to electronic and software failure	Sturdy and reliable	Vulnerable to pump and hose breakdown and speed modulation
5 Operation and maintenance	Operation very easy, maintenance of sensor required	Moderately easy and nearly maintenance free	Moderately easy and comprehendible. Requires pump maintenance
6 Environ-mental sensitivity	Rather reliable	Nil	Pump house may clog under high sediment concentrations
7 Dependency on crew expertise	Software use	Adjusting nozzle size, rear openings, emptying and measuring volumes	Adjusting pump speed to ambient flow
8 Field processing	Nil	Measuring volumes	Splitting
9 Laboratory processing	Computer-based. Calibration required to obtain concentration	Transport and grain size determination	Concentration and grain size distribution
10 Costs	7,000 ECU	9,000 ECU	35,000 ECU
11 Least required facilities	Medium vessel, electronic base	Large vessel	Large vessel
12 Remarks, routine gauging	Potentially useful in the future	Not useful for sampling of suspended sediments under Bangladeshi conditions, neither for routine or special purposes, but can serve as a supplement to other methods	A useful system, not so essential for routine operation
13 Remarks, detailed studies	May be used for monitoring of surface water turbidity		A useful system, all size fractions can be sampled in detail

Notes:

- Errors are primarily taken from Van Rijn and Scaafsma (1986). Errors for pump system, Delft bottle, collapsible bag, and Brinkley samplers are determined by FAP 24
- Errors are relative standard deviations in percent: (std/mean)x100
- Prices are FAP 24 purchase costs. The pump system costs include umbilical chord and winch

Table 6.7 (continued): Comparison of sediment samplers

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7 Training

This chapter describes the training activities in the reporting period, and gives an outline of the training activities in the last part of the River Survey Project.

7.1 General

Apart from the inherent in-house training, the training activities have so far been modest only, in accordance with the contractual obligations and the agreed resource allocation.

A proposal on external training activities in Phase 2 of the River Survey Project was included as a part of the Final Report, Phase 1. A *'Note on training and institutional strengthening'* was submitted in April, 1994, and a *'Proposal for training programme'* was submitted in November, 1994.

So far, a consensus on such a programme has not been reached, and it has therefore not yet been implemented.

7.2 In-house training

The in-house training addresses almost all activities of the River Survey Project, as listed in Table 7.1. The in-house training may be divided into two main categories:

- Surveys, where the training is mainly executed as on-the-job training
- Studies, where the competence generation mainly takes place by personal professional responsibility for execution of one or several of the activities

Both categories imply a highly advanced level of training, since many of the survey activities of the project are carried out by state-of-the-art technology, while many of the study activities aim at producing new knowledge about river processes in general and in Bangladesh in particular.

A third in-house training component is

- Miscellaneous dedicated training activities, such as internal lectures, computer hardware and software courses, etc.

In the third year of the project, almost all routine activities are undertaken by Bangladeshi staff. The expatriate staffing has been reduced, and the expatriate staff is now mainly engaged with internal management, external liaison, trouble-shooting, and maintenance. On this basis, it is evaluated that the in-house training has been fully satisfactory.

Surveys
• Staff gauge and AWLR installation and operation
• Vessel operation, positioning, horizontal and vertical control
• Routine transect surveys
• Bathymetric surveys
• Sediment laboratory analyses
• Data processing and data reporting
Studies
• Hydrology
• Sediment transport
• Planforms and channel dimensions
• Offtakes and bifurcations
• Sand bars and bedforms
• Measuring techniques

Table 7.1: In-house training subjects

It is noted that the in-house training produces personal, rather than institutional competence, since it takes place in a framework of a temporary project organisation.

The dedicated in-house training activities in June, 1994 through May, 1995 can be summarized as follows:

- o Course on River Dynamics (June 1994)
- o Course on Autocad and Fortran 77 (June 1994)
- o Course on presentation techniques; a series of try-out presentations was conducted
- o Course on the use of the PSD24 database
- o Mr. Minhaj Uddin Ahmed was granted a Netherlands' fellowship at the IHE-DELFT and left the project for one year

7.3 External training

Below is given a chronology of external training activities from June, 1994 through May, 1995:

- o A lecture was given on sediment transport measurements and data elaboration in the Ganges - Brahmaputra River System by FAP 24 at the internal workshop of BWDB/Surface Water Hydrology at Bhagyakul on 5 July 1994

- o Mr. Joynal Abedin Mollah, Executive Engineer, BWDB joined the River Survey Project as a trainee on July 23, 1994
- o Mr. Anwar Haider completed his field training programme
- o Ms. Taslima Akhter joined the project as M.Sc. student (part-time) (March, 1995)
- o A lecture was presented by Dr. Phil Ashworth (UoL) at BUET

7.4 Planned activities in the remaining part of the project

In-house training
The on-the-job training will continue in the remaining project period.

External training
A provision has been made for a training of 4 BWDB staff members in field survey techniques. The 4 persons are anticipated to participate in 2 shifts, 2 at a time, onboard the DHA and the DHB vessel, respectively.

Further, a tentative provision has been made for participation of 2 BWDB staff members for training in data processing.

Apart from this, the extent of external training will be subject to a clarification of the scope between the involved parties, and will further depend on the resource availability.

8 Reporting

8.1 General

The reporting activities of the River Survey Project are reflected in the 'list of RSP reports' that is included as Section 8.2 below. The following categories of reports and notes are produced:

A General Project Reports (inception, interim, and final reports)
B Quarterly Progress Report
C Survey Reports
D Study Reports
E Study Notes
F Working papers
G Various
H Workshop contributions (6-8 November 1993)
I Lecture notes

8.2 List of RSP reports

(This list is updated regularly and is published in the Quarterly Progress Reports):

A General project reports

1. Inception Report, 22 August 1992
2. Revised Inception Report, 20 October 1992
3. 1° Interim Report, Vol. I: Main Report, February 1993
4. 1° Interim Report, Vol. II: Annexures on survey work, February 1993
5. 1° Interim Report, Vol. III: Annexures on studies, etc., February 1993
6. Draft Notes on Planning, June 1993
7. Final Report Phase 1
8. 1° Interim Report, Phase 2, February 1995
9. 2° Interim Report, Phase 2, September 1995

B Progress reports

1. 1° Quarterly Progress Report, September - November 1992
2. 2° Quarterly Progress Report, December 1992 - February 1993
3. 3° Quarterly Progress Report, March - May 1993
4. 4° Quarterly Progress Report, June - August 1993
5. 5° Quarterly Progress Report, September - November 1993
6. 6° Quarterly Progress Report, December 1993 - February 1994
7. 7° Quarterly Progress Report, March - May 1994
8. 8° Quarterly Progress Report, June - August 1994
9. 9° Quarterly Progress Report, September - November 1994
10. 10° Quarterly Progress Report, December 1994 - February 1995
11. 11° Quarterly Progress Report, March 1995 - May 1995

12. 12° Quarterly Progress Report, June 1995 - August 1995

C Survey reports

1. Additional survey, September 1992, 31 October 1992
2. Report on Land Survey: Water-level gauging, June 1993
3. Test Gauging Report: Survey procedures and data presentation, October 1993
4. Selection of survey techniques, November 1993
5. Dry season 1992/93, December 1993
6. AWLR Stations: Site selection, installation and O&M (not yet submitted)
7. Transfer of bench-mark levels across Jamuna River at Bahadurabad, December 1993
8. Flood season 1993, July 1994
9. Bathymetric pilot surveys on Jamuna River at Bahadurabad, July 1994
10. River Data Book, June 1993 to May 1995 (in preparation)
11. Bathymetric surveys, June 1993 to May 1995 (in preparation)

D Study reports

1. Selection of Study Topics for Phase 2, September 1993
2. Hydrological Study Phase 1, June 1993
3. Morphological Studies Phase 1
4. Study programme, February 1995

E Survey notes

1. Proposal for additional survey at Bahadurabad, July 1992
2. Anwesha survey, technical guidelines, September 1992
3. Proposal, additional field tests December 1992, 28 November 1992
4. Programme outline for test gauging, August 1993
5. Survey procedures for the routine gaugings in the dry season 1993/94, January 1994
6. Survey procedures, routine gaugings, monsoon season 1994, June 1994
7. Discharge survey on Jamuna River, February 1995
8. Survey procedures, routine gaugings, monsoon season 1995, May 1995
9. Determination of physical properties of sediments, June 1995
10. Jamuna sampler, note on conceptual design, June 1995
11. Overland flow measurements, June 1995

F Working papers

1. Technical Recommendation and Verification of the Acoustic Sensor type of AWLR, October 20, 1993
2. Qualitative Impact Assessment of FAP Implementation, January 1994
3. Bed load measurements for Phase 2 (1° draft, March 1994) (in preparation)
4. Tidal and backwater effects at Bhairab Bazar

5. Water level slopes
6. Development of hydraulic conditions and bed levels at Gorai mouth over the last 30 years, May 1995
7. Optimization of hydraulic measurements: Turbulent flow structure and an optimum averaging time (draft, August 1995)

G Various

1. Reporting Format (regularly updated)
2. Morphological Processes in The Bangladesh River System, a Compilation of Papers. October 25, 1993
3. Towards an Improved Understanding of the Rivers in Bangladesh (RSP brochure)
4. Procurement report, vehicles
5. Travel report (M. B. Butts), hydrology, March 1994
6. Note on training and institutional strengthening, April 1994
7. River bathymetry assessment by radar remote sensing, September 1994
8. Note on discharge and sediment distribution at bifurcations and off-takes, November 1994
9. Proposal for training programme, November 1994
10. Travel report (M. B. Butts), hydrology, February 1994
11. Remote sensing for morphological assessment and radar remote sensing pilot project, February 1995
12. Interim Report, study topics 6.1, 6.2, and 7.4, University of Leeds, March 1995
13. Flow and sediment transport processes, revised progress report, University of Nottingham, February 1995
14. 2D morphological modelling of Gorai off-take, June 1995

H Workshop contributions 6-8 November 1993

1. Klaassen, G. J: *On prediction methods for alluvial rivers with particular reference to planform changes*
2. Olesen, K. W.: *2-D mathematical modelling of bifurcations*
3. Mosselman, E., and G. J. Wensink: *River Bathymetry observation with radar remote sensing*
4. Iversen, C.: *Survey techniques selected by FAP 24*
5. Kuehl, S. A. and M. A. Allison: *Subaqueous delta of the Ganges-Brahmaputra river system and the holocene sediment budget: Implications for flood plain subsidence and sedimentation*
6. Executive summary - Selection of study topics for phase 2

I Lecture notes

1. On Sediment Transport and Hydraulic Roughness
2. River Dynamics. Lecturer: G. J. Klaassen
3. River Hydraulics. Lecturers: S. Mahmood & P. van Groen
4. Advanced River Processes, by G. J. Klaassen

9 Work programme

The present Chapter gives an outline of the activities in the fourth and final year of the River Survey Project. The work plans are tentative; they have been initially discussed with the PA/RSPMU, but have not yet been thoroughly reviewed nor approved.

9.1 General

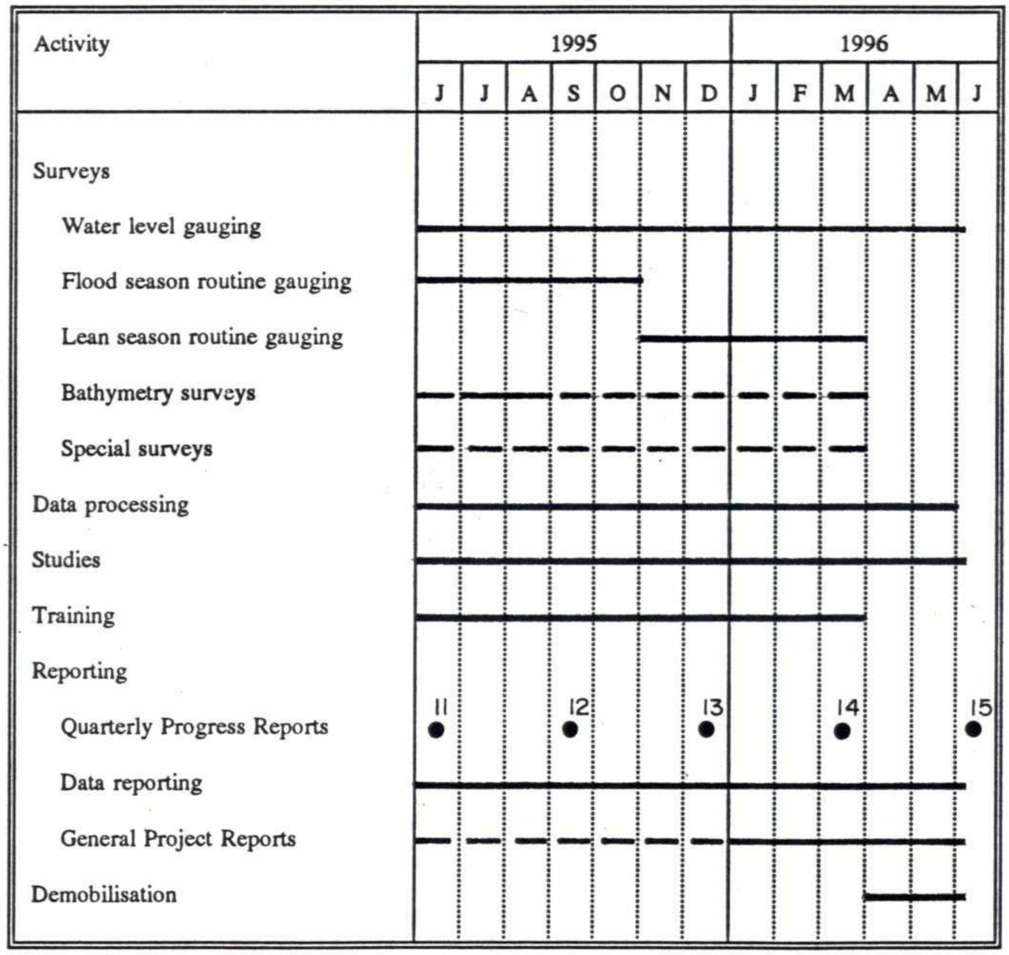

Figure 9.1: Main activities June 1995 - May 1996

9.2 Surveys

The survey work programme reflects the original scope of the River Survey Project, with adjustments as induced by experience gained and by external developments in the course of the project, and as discussed and agreed with the PA/RSPMU.

The target volume of routine gaugings (by end of the fourth project year) is as follows:

- o 62 flood season routine transect gaugings
- o Around 40 lean season routine transect gaugings

Additional capacity has been reserved for purposes such as additional flow measurements at Bahadurabad, overland flow, and analysis of physical properties of sediments.

A time schedule for the 1995 flood season programme is shown in Figure 9.2. The time schedule for the 1995/96 lean season is under preparation.

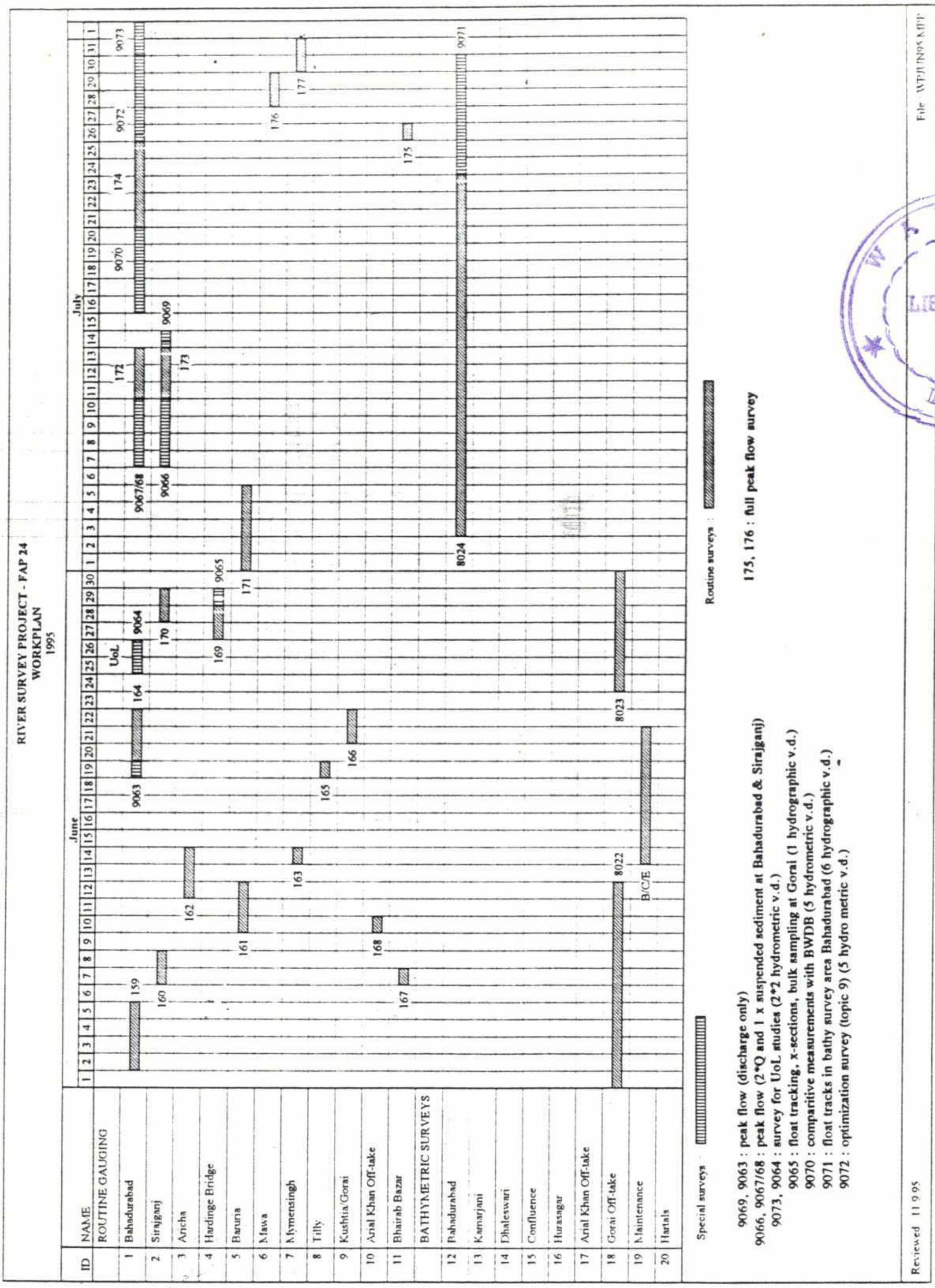

Figure 9.2.a: Work programme, surveys, flood season 1995 (continued)

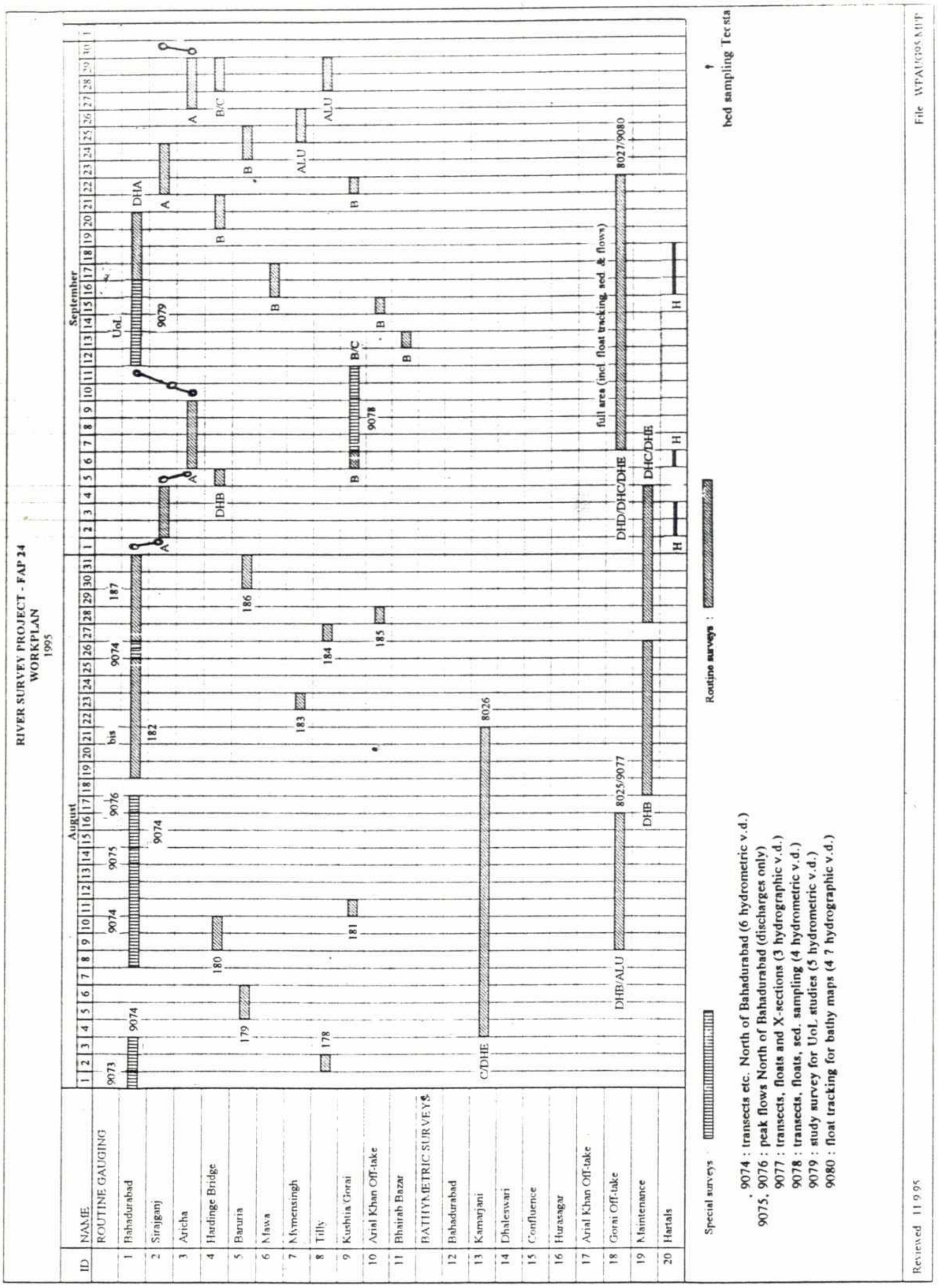

Figure 9.2.b: Work programme, surveys, flood season 1995 (continued)

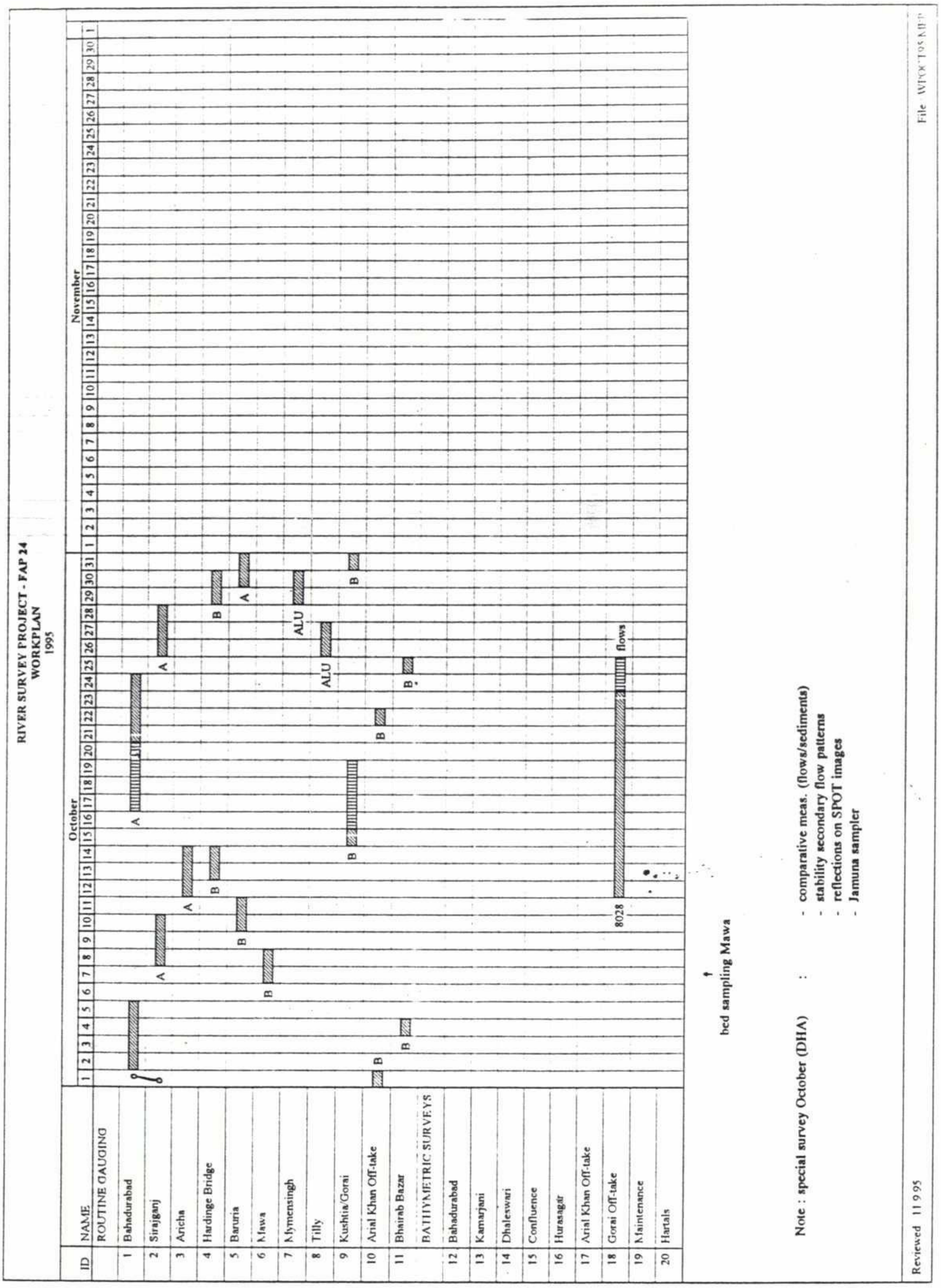

Figure 9.2.c: Work programme, surveys, flood season 1995 (continued)

9.3 Studies

Subject		Topic	1995 J	J	A	S	O	N	D	1996 J	F	M	A	M
1 Hydrology	1.1	Improved discharges and rating curves												
	1.2	Improved historic discharge time series												
	1.3	Water balances and overland flow												
	1.4	Water level profiles and slopes												
	1.5	Phase 2 updating												
2 Sediment transport and river aggradation and degradation	2.1	Rating curves and balances												
	2.2	Sediment transport predictors												
	2.3	Integration of existing knowledge												
	2.4	Long-term development of distributaries												
	2.5	Flood plain subsidence												
	2.6	Phase 2 updating												
	2.7	High sediment concentrations												
	2.8	Fine sediments												
3 Planform characteristics and channel dimensions	3.1	Planform classification												
	3.2	Channel dimensions (regime equations)												
	3.3	Bank erosion rates												
	3.5	Channel cut-offs												
	3.8	Local slopes and their importance for planform changes												
	3.9	Prediction of medium-term planform changes												
	3.10	Long-term changes of river locations												
4 Off-takes and bifurcations	4.1	Discharges and sediment distribution												
	4.3	Influence of bars												
5 Confluences	5	Confluences												
6 Sand bars	6.1	Dimensions and dynamics of bars												
	6.2	Time dependence of bars												
7 Bed forms	7.1	Occurrence, dimensions, and dynamics												
	7.2	Time dependency of bed forms												
	7.3	3-dimensionality of bed forms												
	7.4	Roughness and bed forms												
9 Measuring techniques	9.1	Selection of measurement sites												
	9.2	Optimization of hydraulic measurements												
	9.3	Optimization of sediment measurements												
	9.4	Bed load transport by dune tracking												
	9.5	Bathymetry and radar imagery												
	9.6	Sustainable survey techniques												

Figure 9.3: Planned study activities June 1995 – May 1996

9.4 Reporting

The final reporting of the River Survey Project will be made in a close dialogue with the PA/RSPMU. In brief, the final reporting comprises a hierarchy of reports that will present the data collection, the results of the study programme, and a comprehensive synthesis.

It is tentatively proposed that the Final Report will contain a main volume, and 5 annexes on the following subjects:

1 Surveys
2 Sustainable survey techniques
3 Hydrology
4 Sediment transport
5 River morphology

The final reporting will take place within the established framework of RSP reports, as outlined in Figure 9.4 below.

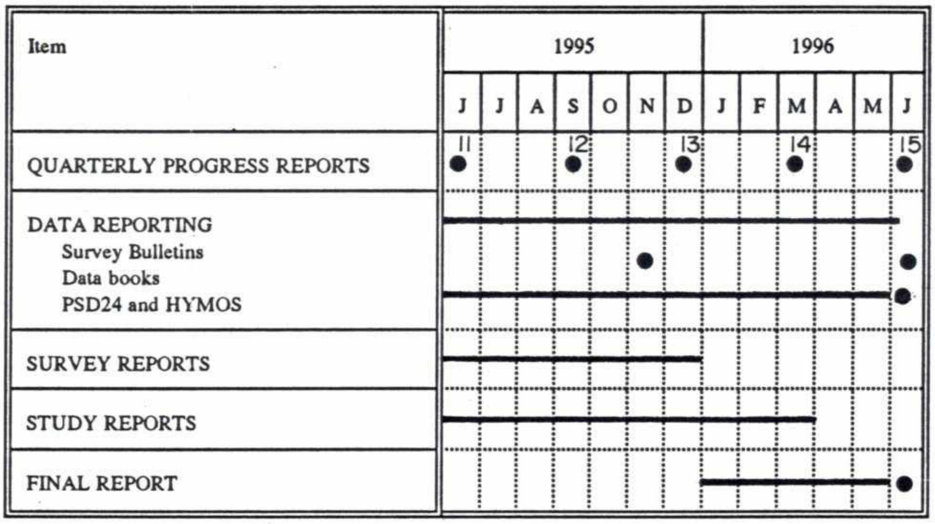

Figure 9.4: Work programme, reporting, June 1995 - May 1996

9.5 Demobilisation

The scheduled completion date of the River Survey Project is June 7, 1996. The demobilisation comprises

- o final reporting
- o re-export of equipment: Vessels, field instruments, computers, office equipment, cars
- o final demobilisation of facilities

A preliminary outline of the final reporting was presented to PA for initial comments in August, 1995.

Regarding equipment and facilities, the Consultant is, in principle, obliged to repatriate all capital equipment that has been brought into Bangladesh for the purpose of the project. Alternatively, import duties can be paid, whereafter the equipment can be sold to BWDB or to other agencies or project organisations in Bangladesh.

Unless a project extension materializes, the planning of the demobilisation will take place in late 1995/early 1996 in a close dialogue with PA/RSPMU.

10 References

BRISTOW, C. S. (1987): Brahmaputra River: Channel migration and deposition. The society of Paleontologists and Mineralogists, pp. 63-74

CARTER, R.W. AND ANDERSON, I.E. (1963): Accuracy of current meter measurements.
Jr. Hydr. Div., Proc. ASCE, HY 4, part 1, 105-115

CHANG, H. H. (1979): Fluvial processes in river engineering. John Wiley & Sons, USA

COLEMAN, J.M. (1969): Brahmaputra River: Channel processes and sedimentation. Sedimentary Geol., pp. 129-239

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1992): River Survey Project, FAP
24, Revised Inception Report

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1993A): River Survey Project, FAP
24, 1° Interim Report

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1993B): River Survey Project, FAP
24. Survey Report 3, Test gauging - survey procedures and data presentation

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1993C): River Survey Project, FAP
24, Study Report 1, Selection of study topics for Phase 2

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1993D): River Survey Project, FAP
24, Study Report 2, Hydrological study, Phase 1

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1994A): River Survey Project, FAP
24, Study Report 3, Morphological studies Phase 1, Available data and characteristics

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1994B): River Survey Project, FAP
24, Survey Report 4, Selection of survey techniques

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1994C): River Survey Project, FAP
24. Final Report Phase 1

DELFT HYDRAULICS AND DANISH HYDRAULIC INSTITUTE (1995): River Survey Project, FAP
24. Phase 2, 1° Interim Report

HASKONING AND DELFT HYDRAULICS (1991): Meghna river bank protection, short term
study, FAP 9B, Annex A: Hydrology

HOSSAIN, M. M. (1992): Dominant Discharge of the Ganges and Jamuna, Journal of the IEB, Vol. 20, No. 3

INGLIS, C. (1968): Discussion on 'Systematic evaluation of river regimes', Journal of
Waterways and Harbour Division, ASCE, Vol. 94. No. WW 1

ISO (INTERNATIONAL STANDARD ORGANIZATION) (1983): Measurement of liquid flow in open
channels. ISO standard handbook 16. ISO 1070-1973 (E), pp. 114-119

KLAASSEN, G. J. AND MASSELINK, G. (1992): Planform changes of a braided river with
fine sand as bed and bank material, 5th International Symposium on River Sedimentation, Karlsruhe, Germany

KLAASSEN, G.J. AND K. VERMEER (1988): Channel characteristics of the braiding Jamuna River, Bangladesh. International conference on river regime, Wallingford, UK

LEOPOLD, L.B., WOLMAN, M.G., MILLER, P.J. (1964): Fluvial processes in geomorphology. W.H. Freeman and Company, San Francisco, California, 522 pp.

W. A. R. P. O. LIBRARY. DHAKA

NEDECO (1967): Surveys of inland water and ports, hydrology and morphology. Vol. III, Part B, Hydrological and morphological phenomena. East Pakistan Inland Water Transport Authority

NEDECO (1983): Feasibility study of Ganges-Kobadak rehabilitation and improvement project. Final report, Vol.II, Technical Annexes A-D

PETERS. J. J. seventh mission repor of the FAP 24 Project Advisor, Annexure IV comments on \FAP 24 flow and sediment gauging Dhaka, Bangladesh, 1994.

RENDEL PALMER & TRITTON/NEDECO/BCL (1987): Jamuna Bridge appraisal study, Phase

1, Final Report, Appendix C - Hydrology, morphology and river engineering

RENDEL PALMER & TRITTON (1990): Jamuna Bridge Project, Phase II Study, River training works, Design Report Vol. II

RICHARDS, KEITH (1982): Rivers, forms and processes in alluvial channels. Methuen & Co., New York

SAUER, V.B. AND MEYER, R.W. (1992): Determination of errors in individual discharge

measurements. USGS open file report no. 92-144

SIR WILLIAM HALCROW & PARTNERS LTD. (1993): River training studies of the Brahmaputra River (FAP 1), Draft Final Report, Technical annexes, Annex 2, Morphology

VAN RIJN, L.C. (1986): Manual sediment transport measurements, Delft Hydraulics Laboratory, April 1986

VOLKER, A. (1981): Lecture notes on reclamation and polders. International Institute for Hydraulic and Environmental Engineering

WILLIAM, G. P. (1978): Bankfull discharge of rivers, Water Resources Res. 14(6), pp.

1141-1154

WORLD METEOROLOGICAL ORGANIZATION (WMO) (1980): Manual on stream gauging (vol.

1), field work, WMO No. 519