RIVER SURVEY PROJECT

FAP24

Government of the People's Republic of Bangladesh

Water Resources Planning Organization

European Commission

Delft Hydraulics

Danish Hydraulic Institute

Hydroland
Approtech
Osiris

Special Report No.15

Overland flow and floodplain sedimentation

October 1996

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Acronyms and abbreviations

ADCP	:	acoustic Doppler current profiler
BM	:	bench mark
BWDB	:	Bangladesh Water Development Board
DGPS	:	differential (high-accuracy) GPS
DHA	:	name of a survey vessel of RSP
DHI	:	Danish Hydraulic Institute
EDM	:	electronic distance meter
FAP	:	Flood Action Plan
FAP24	:	(FAP project no. 24) = the River Survey Project
FPCO	:	Flood Plan Coordination Organization
GoB	:	Government of Bangladesh
GPS	:	Global Positioning System (satellite-based)
MPO	:	Master Plan Organization
PWD	:	datum of Public Works Department
TBM	:	temporary bench mark
UNDP	:	United Nations' Development Programme
VIMS	:	Virginia Institute of Marine Science

1 Introduction

The River Survey Project (FAP 24) was initiated on June 9, 1992. The project is being executed by the Flood Plan Co-ordination Organisation (FPCO) under the Ministry of Irrigation, Water Development and Flood Protection (which was changed recently to the Ministry of Water Resources), and is funded by the Commission of the European Communities. The consultants for the project are from the DELFT-DHI joint venture in association with Osiris, Hydroland, and Approtech. Project supervision is undertaken by a Project Management Unit with participation by FPCO, a Project Advisor, and a Resident Project Advisor.

The objective of the project is to establish the availability of detailed and accurate field data as a part of the basis for the FAP projects, as well as adding to the basis for any other planning, impact evaluation, and design activities within national water resources and river engineering activities.

The project consists of three categories of activities:

- a survey component, comprising a comprehensive field survey programme of river hydrology, sediment transport, and morphology,
- a study component, comprising investigations of processes and effects within river hydrology, sediment transport, and morphology
- a training component.

The study programme of the project has been developed in a close dialogue with the Client and the Project Advisor, as outlined in the Study Programme (February 1995). Please refer to this programme for details about objectives and the scope of the entire programme.

The present study report combines the results of studies into two categories, overland flow and floodplain sedimentation. These studies concentrate on the overland flow and the sedimentation processes in a selected area of the Jamuna River floodplain.

Overland flow occurs when river water starts to flow over the floodplain of the river during peak flows in the monsoon season. Three types of overland flow can be distinguished: flow over chars in the Jamuna River, spill flow (by-pass), and overbank flow (Figure 1.1). Flow over chars is flow over shallow flooded bars and chars in the main river. Spill flow is flow that leaves the river via spill over banks that may or may not return to the main river further downstream. Spill flow occurs on the Jamuna, Old Brahmaputra, and Chatal Rivers, and it flows back to the Jamuna River via the Jhenai River (Figure 1.2). Overbank flow originates on the Jamuna River and flows directly over the banks of the channels of the Jamuna River. The flow enters the floodplain if the stage is higher than the bankfull stage. In addition, rainfall, and sometimes groundwater flow, contribute to the inundation of the floodplain. Turbid overland flow originating from the river carries sediment which may settle in the floodplain. This sedimentation is called floodplain sedimentation.

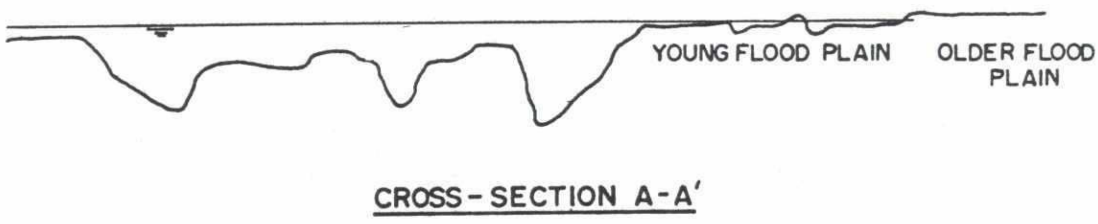
The general objective of the overland flow and floodplain sedimentation measurements was to assess the importance of this type of flow, as well as spill flow over the river banks, sediment transport, and sedimentation processes in the floodplain. These measurements will improve the understanding of:

- water and sediment balances along river stretches,

- overland flow patterns in view of impact assessment of man–made changes on the development of rivers and floodplains, and
- processes of floodplain sedimentation.

A comprehensive study of overland flow and floodplain sedimentation requires a large-scale research effort that is beyond the lifespan and financial resources of the River Survey Project. Therefore a regional pilot study was undertaken to monitor floodplain sedimentation during the 1995 wet season. The floodplain along the left bank of the Jamuna River was selected for overland flow and floodplain sedimentation sampling because this floodplain is one of the most extensive floodplains in Bangladesh. The overland flow and sediment flux were measured mainly at distributary and man-made outtakes (i.e., culverts). This study combines study topics 2.5 (Floodplain sedimentation and subsidence) and 1.3 (Water balance and overland flow) from the Study Programme (RSP, February 1995). In addition, VIMS has undertaken a sediment coring program in Bangladesh and partly in the study area. The mineralogical and physical properties of a number of sediment samples from the study area were analyzed and the results are reported in Special Report 14 (RSP, 1996). The main results of this analysis are summarized in this report.

In this study the overland flow and floodplain sedimentation are schematised in Chapter 2 using general characteristics of the floodplain of the Jamuna River. For these measurements a site was selected on the left bank floodplain of the Jamuna River downstream from Bahadurabad. Chapter 3 explains why this site was selected and describes the set-up of the measurements. The overland flow measurements during the peak flows of the 1995 monsoon are analysed in Chapter 4, and the analysis of the floodplain sedimentation measurements is presented in Chapter 5. The results are discussed in Chapter 6. The conclusions and recommendations from this study are summarised in Chapter 7. This study was performed in co-operation with Mr. A.M. Ibrahim, who was involved in the floodplain sedimentation measurements for this study. Mr. S. Kuhl and Mr. S. Goodbred of Virginia Institute of Marine Science, VIMS, performed vibrocoring in the study area and some of their results are included in this report. This study report has been prepared by Mr. K.C. Dey (RSP), Mr. A.M. Ibrahim (Consultant) and Mr. M. van der Wal (RSP). Geology Department at the University of Dhaka performed the mineralogical analysis and Mohammed Mamun helped with the laboratory analysis of sediment samples. Pieter van Groen (RSP) provided the overall guidance to the study.



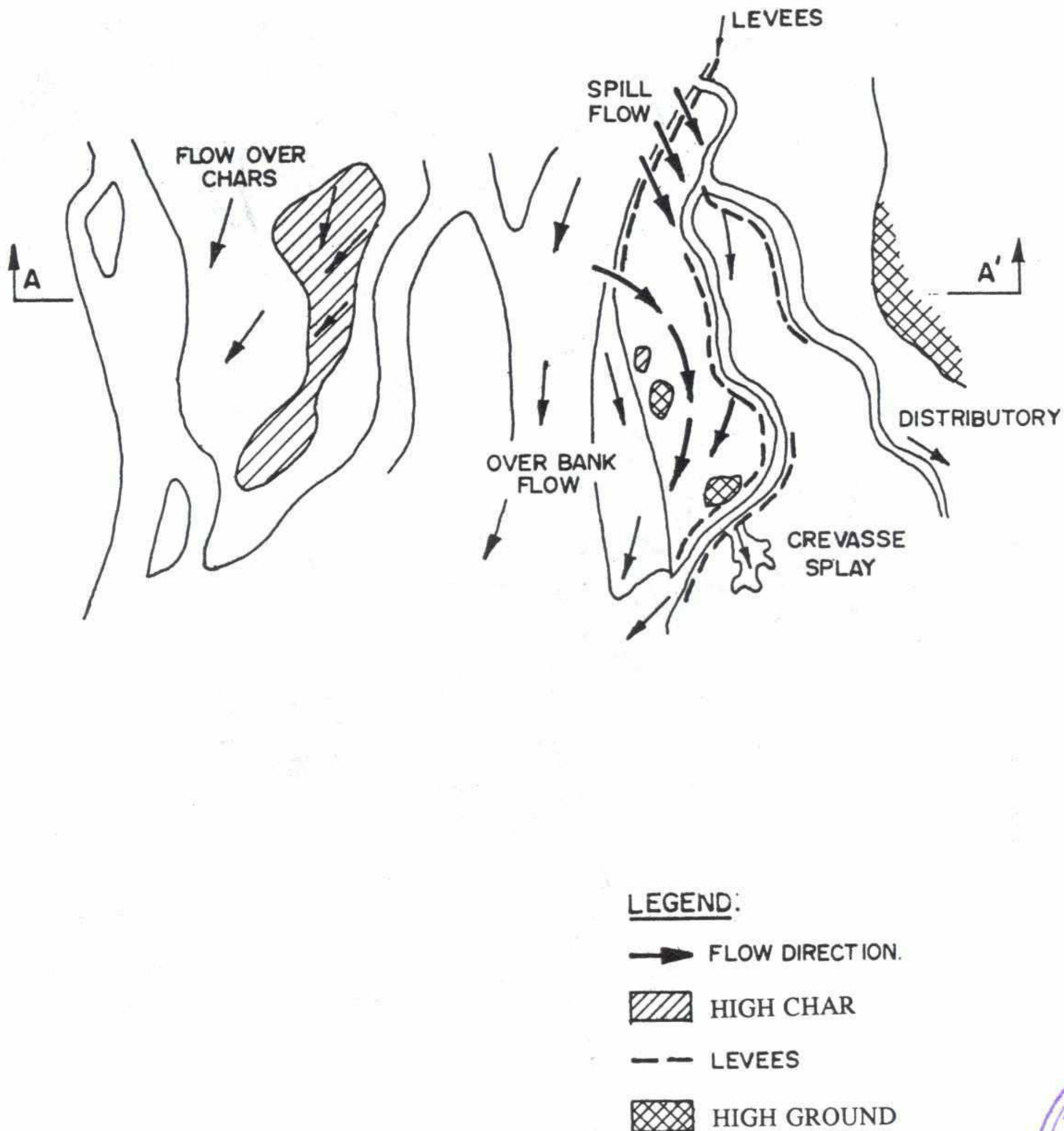


Figure 1.1: Schematised plan form and cross-section of a braided river

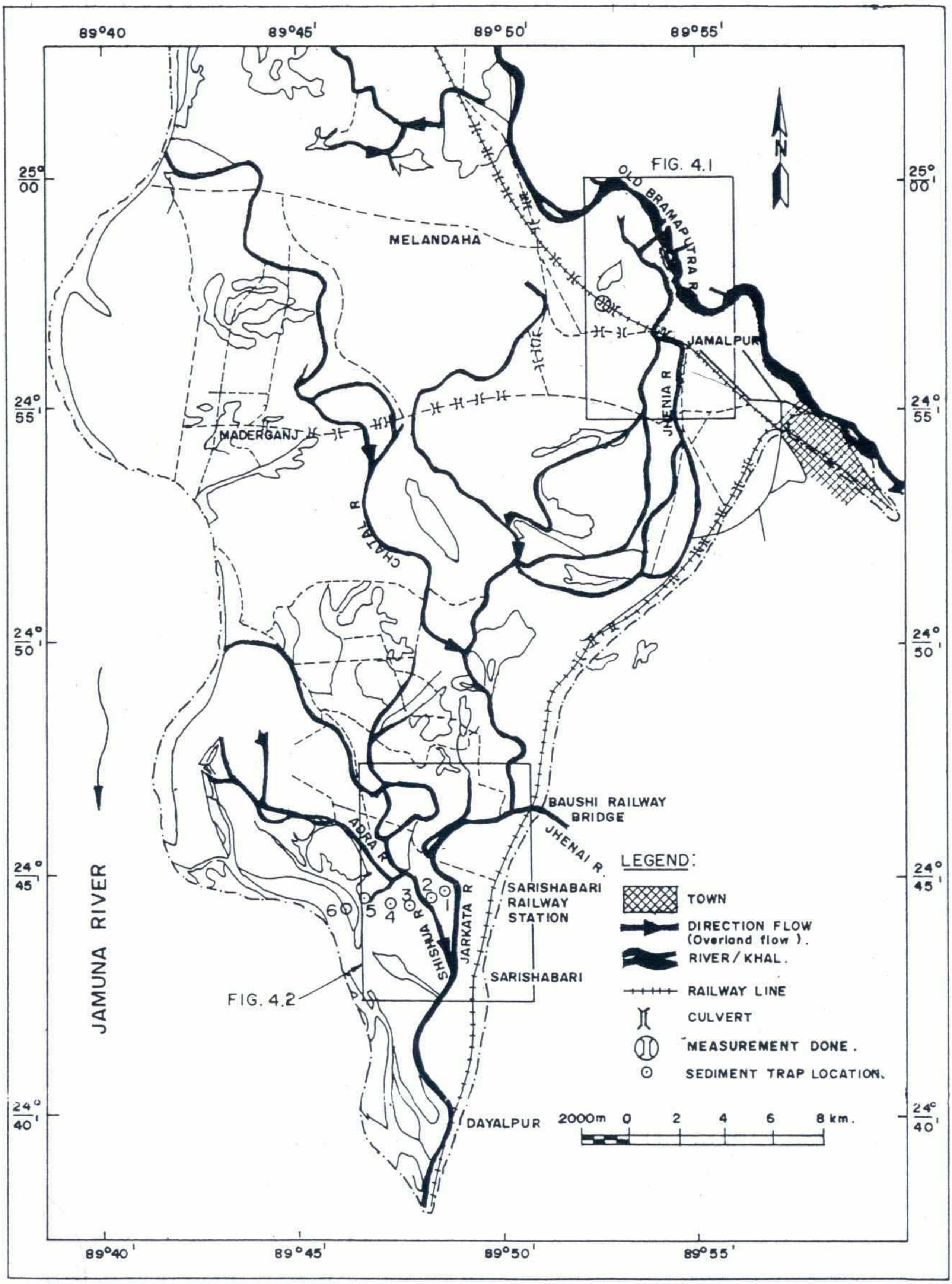


Figure 1.2: Map of the floodplain west of the line Jamalpur - Sharishabari

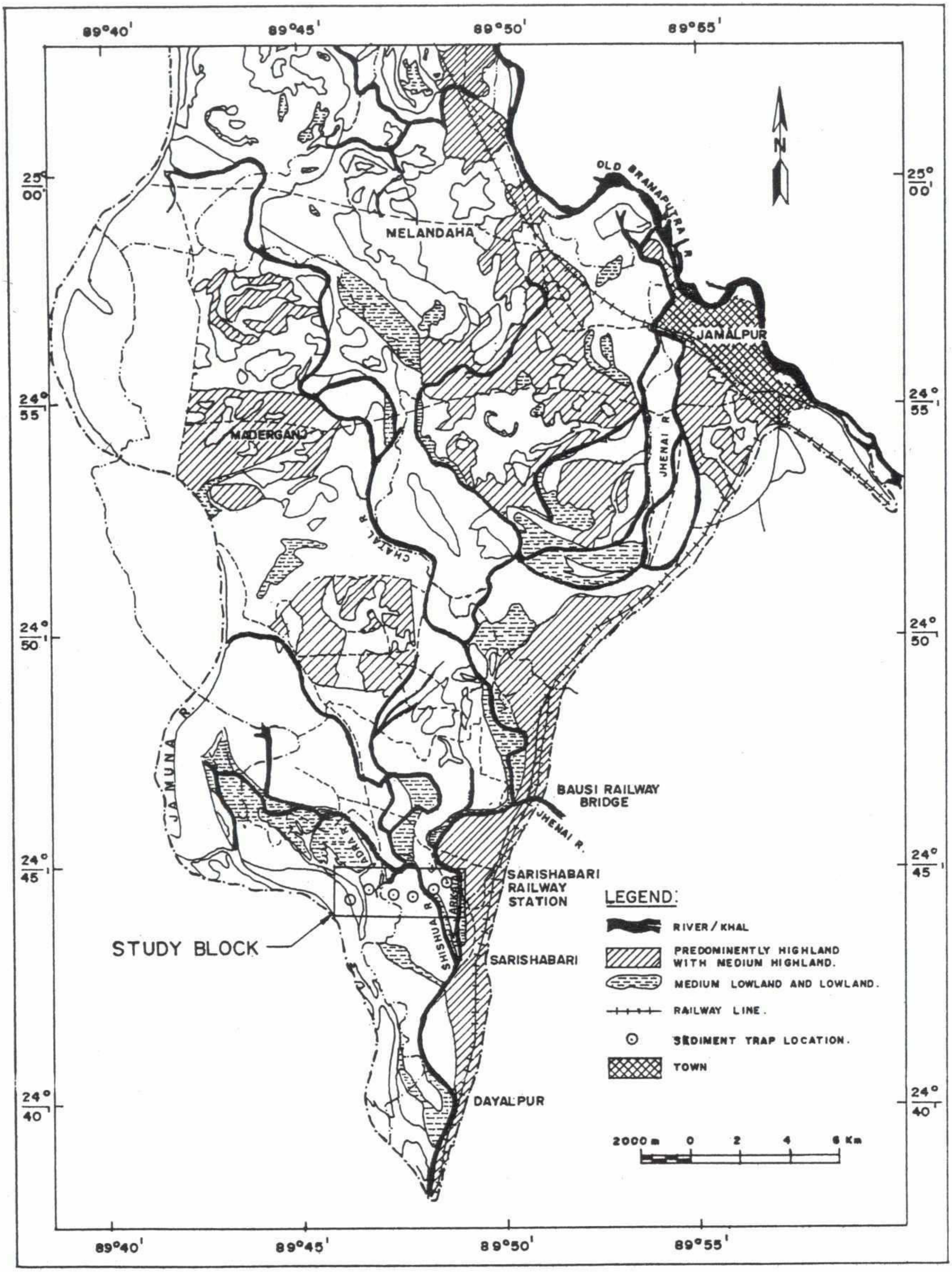


Figure 1.3: Map of the floodplain area with the study block (according to FAP 3)

2 Jamuna floodplain characteristics

In its natural state the floodplain being studied is the relatively smooth area that borders the Jamuna River and overflows during high water periods. This flooding starts as the discharge exceeds the bankfull discharge of 44,000 to 48,000 m^3/s. [For an explanation of the bankfull discharge see Special Report 6 (RSP, 1996)]. During the last few decades, embankments have been erected in several places in the floodplain to reduce the frequency of flooding. A typical floodplain is formed by small meandering rivers with point bars, meander scrolls, and depressions and rises on the convex side of bends that are formed as the river channel migrates. (For a general introduction to this topic see Leopold, Wolman, and Miller, 1964). Natural levees or crests above the floodplain surface are found adjacent to the channel and often contain sandy material deposited as the bed material load flows over the top of the channel banks. In some places during extreme flooding, sandy crevasse splays are formed. The washload of the flood water is often deposited in local depressions such as the meander-scroll depressions of the floodplain.
The Jamuna floodplain has three sub-units: the active floodplain, the young floodplain, and the older floodplain (FAP 19, 1995). These sub-units differ from each other in the relative maturity of their relief and soils. The boundaries between them are sometimes sharp, as is the case between the Young and Older Jamuna floodplains near Sharishabari.

The active Jamuna floodplain has stratified sands and silts on an irregular relief of linear ridges and inter-ridge depressions. The sediments are usually more sandy on the ridges and more silty in the depressions, but larger, more uniform areas of sand or silt sometimes occur after major floods. Active means that the floodplain is formed and eroded in a dynamic channel shifting process which limits the lifetime of a floodplain area to a maximum of about 30 years.

The young Jamuna floodplain occupies a broad band adjoining the active floodplain. As revealed in topographic and soil maps, young floodplain land has remained stable for 50 years or more; i.e., it has not been affected by bank erosion or burial by thick layers of sediments. The relief and soils, however, are still relatively young. An irregular pattern of ridges and inter-ridge depressions occurs within a broad ridge-and-basin landscape. The young Jamuna floodplain is flooded only during peak flows and fresh sediments are deposited at these times. The topsoil of this floodplain is near-neutral in reaction, probably because it receives sufficient new alluvium to counteract the acidification that occurs in older floodplain soils.

The older Jamuna floodplain generally has a smooth ridge-and-basin landscape with more mature soils and higher organic matter contents than are found on the younger floodplains. Near its eastern edge it overlaps the Old Brahmaputra floodplain; thus soils characterised by this type of floodplain are often found buried below Jamuna soils and sediments.

During the first three years of the project the monsoon floods did not reach extreme water levels and therefore significant overland flow did not occur in those monsoons. In anticipation of the 1995 flood the Project Advisor outlined an alternative approach to overland flow measurements. Taking into account the probability of a low flood in the 1995 monsoon he proposed in the report of his tenth mission (Peters, 1995) to concentrate the overland flow study on flow over the different types of chars that flood almost every year. They include:

- flow over middle chars where the flow may or may not pass from one major channel to the other,

- flow over attached chars where the flow does not occur in minor channels and does not escape the major river bed towards off-take channels, and
- flow over attached chars where flow does not occur in minor channels and escapes the major river bed towards off-take channels.

The topic of flow over middle chars is addressed in a study of the flow and sedimentation patterns of a char/bar in the left channel of the Jamuna River north of Bahadurabad (study topic 6, Special Report 9: Bars and bedforms, RSP, 1996). However, in the extreme 1995 flood the overland flow measurements were concentrated on the spill flow from the Chatal and the Jhenai Rivers (which is an offtake of the Old Brahmaputra River) and overbank flow on their chars. Therefore, it was concluded that it was not necessary to concentrate those measurements on the different kind of chars, but instead to concentrate mainly on the young Jamuna floodplain and to a lesser degree on the active Jamuna floodplain.

3 Site selection and set-up of the measurements

In March 1994, the FAP 19 Geographic Information System project started a floodplain sedimentation study of the floodplain along the left bank of the Jamuna River (ISPAN, 1995), but due to the low flood in 1994 no overland flow, and hence no sedimentation, occurred. In discussions with FAP 19 and FPCO it was decided that the River Survey Project should continue the sedimentation sampling begun by FAP 19. The set up of the overland flow measurements was discussed with the Project Adviser during his eleventh mission and some main points of this discussion are described in the report of that mission (Peters, 1995).

After several field surveys, FAP 19 Geographic Information System project (ISPAN, 1995) selected a study area west of Sharishabari Thana in Jamalpur District. In choosing the study area FAP 19 considered the following variables:

- the expected flood regime and the expected sedimentation pattern in the area,
- the natural setting, especially the physiography and the relief of the area,
- the variation in soil types in the area,
- the relatively few disturbances to natural conditions by roads, embankments and other structures,
- the availability of sufficient data, especially detailed maps,
- the close proximity to the Jamuna River and the accessibility of the study area during floods and at other times.

The study area is 5 km by 2 km (Figure 1.3). It is mainly within the Active and Young Jamuna floodplains and partially within the Older Jamuna floodplain.

Within the study area 6 sample plots measuring approximately 10 m by 10 m were selected to represent the major flood and sedimentation regimes identified. Sediment sampling was restricted to the centre of each plot to minimise disturbance by humans and animals. The plots were protected by strong bamboo fences that were partially covered with bamboo matting to keep out floating debris and vegetation. Landowners were financially compensated for keeping the plot fallow and undisturbed during the study period. A local person ensured that it was not disturbed and collected floodwater samples and daily inundation depth information.

FAP 19 selected many more sample plots and used a different numbering system than the one used in this study (Table 3.1).

Numbering FAP 19	FAP 24 numbering used in this study	Flood depth classification MPO	type of floodplain
15	1	F2	young floodplain
16	2	F1/F2	young floodplain
17	3	F1	young floodplain
18	4	F1	young floodplain
19	5	F1	active floodplain
20	6	F1/F2	active floodplain

Table 3.1: Numbering of the sample plots and their flood depth classification

A flood depth classification was developed using the country's reconnaissance soil surveys and agroecological zones. The classification was slightly modified by the Master Plan Organisation (1987). Different classes of land were assigned to the expected depth of flooding of farm land because the depth influences which crops farmers grow on their land (Table 3.2). The flood depths in this table are the depth ranges in average floods.

Class		Flood depth (m)
F0	medium high land-1	0.00 - 0.30
F1	medium high land-2	0.31 - 0.90
F2	medium low land	0.91 - 1.80
F3, F4	low land and bottom land	> 1.8

Table 3.2: MPO flood-depth classification

The area west of a line drawn between Jamalpur and Sharishabari includes areas with flood-depth classes of medium low land, low land, as well as some areas with high land and medium high land (Figure 1.2).

After selection of the Sharishabari study area, the overland flow measurement sites were located. These sites were used to determine the pattern of the overland flow upstream from the sedimentation sample plots. The study block was extended in an upstream direction so that the flow and sediment transport patterns could be studied.

4 Overland flow measurements

4.1 Introduction

The pattern of the overland flow in the floodplain west of the aforementioned Jamalpur-Sharishabari line is complicated; it is schematised as follows (Figures 4.1 and 4.2):

- The spill flow leaves the Jamuna River, flows into the Old Brahmaputra River, and just upstream from Jamalpur it passes the culverts in the railway line. It then enters the Jhenai and Jharkata Rivers where it spills over the floodplain. At this point part of the spill passes through sample plots 1, 2, and 3. Approximately 7 kilometres downstream from these sample plots the Jharkata River again joins the left channel of the Jamuna River.

- Downstream from Bahadurabad the spill leaves the Jamuna River and flows over the floodplain. The spill then enters the Chatal River which discharges partly into the Shishua River (just upstream from the floodplain area where sample plots 3 and 4 are located) and partly into the Jhenai River.

- Further downstream the flood water flows over the left bank of the left channel of the Jamuna River. This overbank flow follows the southeastern course of the Adra River and it passes the area of sample plots 5 and 6. The overbank flow again joins the Jamuna River a few kilometres downstream from these sample plots.

The amount of spill flow that passed through the Jhenai River was determined by measuring the discharge passing through the culverts in the railway line from Jamalpur to Melandaha. In addition, the discharges were measured during several surveys in about 16 locations on rivers and khals. These locations were west of Sharishabari, upstream from the sample plots, on the Adra, Shishua, Jharkata, and Jhenai Rivers.

The overland flow surveys were done in three periods during the 1995 monsoon. Measurements were started near Jamalpur, north of Sharishabari, from July 12th through the 15th. Discharge measurements were then taken in the Sharishabari area from July 20th through the 24th, and again from August 19th through the 22nd.

The field data were processed and analysed in order to compute the discharge and the sediment transport in this young and active Jamuna floodplain near Sharishabari. Water level data that were measured at neighbouring gauge stations are discussed in Section 4.3. The measured flow velocities and the cross-sections measured at the selected locations are presented in Section 4.4. These results are used to calculate the discharges in Section 4.5.

In addition, the suspended sediment transport in these rivers and khals was estimated (see Section 4.6. The results of these measurements in the transect west of Sharishabari are discussed in Section 4.7. Using all the flow measurements for this area, a rough water balance was made of overland flow during the second peak flow (see Section 4.8).

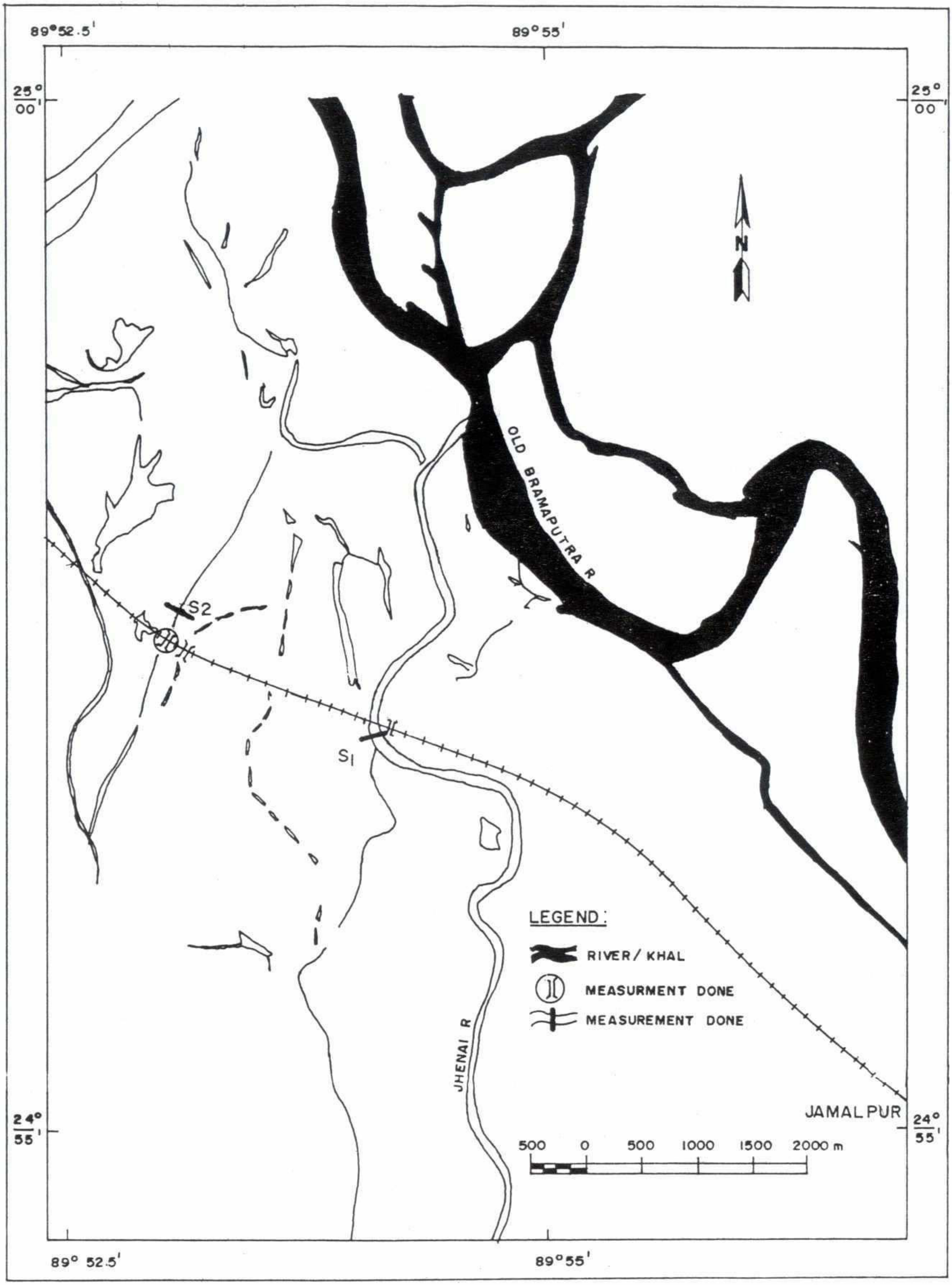


Figure 4.1: Survey locations near the Jamalpur - Bahadurabad Railway line

4.2 Set-up of the measurements

In the overland flow surveys a simple survey technique was applied using the following methods and instruments. The measurements were made from a country boat and the position of the country boat was determined using a hand-held GPS. The discharge and sediment transport was measured in several places on the floodplain rivers. The distance to the bank was measured by rope and tape in a transect in a floodplain river. The local water depth was measured using a lead line. In the July surveys the surface flow velocity was estimated by measuring the time that a surface float took to pass a certain distance. In the August surveys the flow velocity was measured using a Valeport current meter. Samples of the suspended sediment transport were taken near the water surface in 1 litre bottles and analysed in the sediment laboratory at the River Survey Project.

The overland flow measurements were taken in two places near Jamalpur and at about 16 study locations near Sharishabari (Figures 4.1 and 4.2). The first measurement near Jamalpur was taken on the Jhenai River about 300 m downstream from the Jhenai railway bridge. The second measurement near Jamalpur was taken on Sadhupur Khal about 100 m upstream from the railway culvert. Sadhupur Khal is situated approximately 3.5 km east of Melandaha. The flow and sediment transport measurements taken near Sharishabari were taken at eight locations in the floodplain rivers.

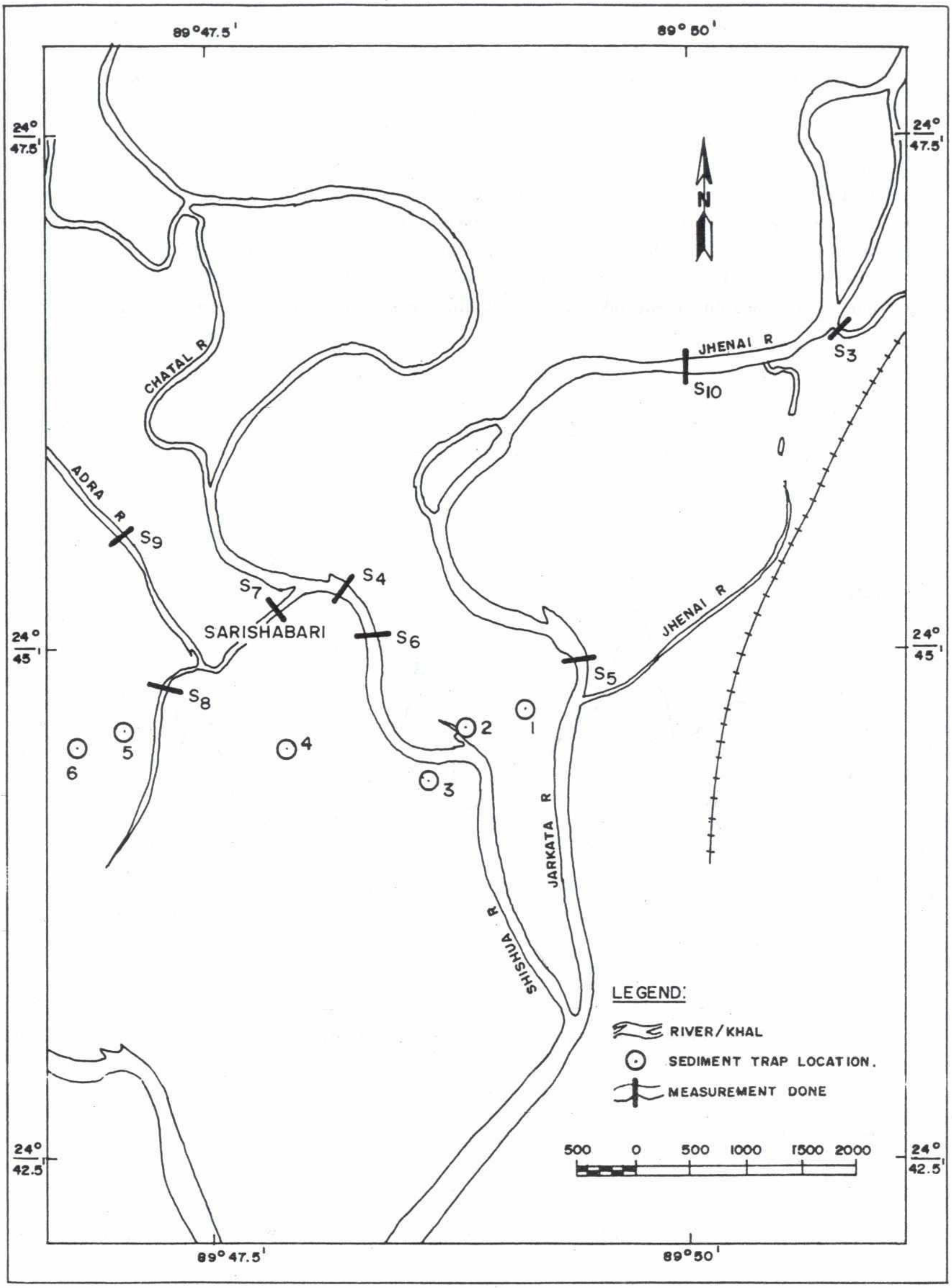


Figure 4.2: Survey locations near Sharishabari

4.3 Water-levels

There were four distinct peak flow periods during the 1995 monsoon as shown in the hydrograph in Figure 4.3. This hydrograph shows the water levels at Bahadurabad from June 1st to November 1st 1995. Water-level data were collected daily from July 10th through August 22nd (except for August 9th) in four gauge stations. The gauge locations include Bahadurabad Ghat on the left bank of the Jamuna River, Sirajganj on the right bank of the Jamuna River, and Jamalpur and Mymensingh along the Old Brahmaputra River (Figure 4.4). The first and second overland-flow measurements were done between the second and the third peak flow. During this period the water level was falling at a maximum rate of 0.2 m per day at all the gauging sites except the one on the Old Brahmaputra River at Mymensingh. At Mymensingh the water-level only rose during the first day of the survey. The third overland-flow measurement was taken during the third peak flow from August 19th through the 22nd.

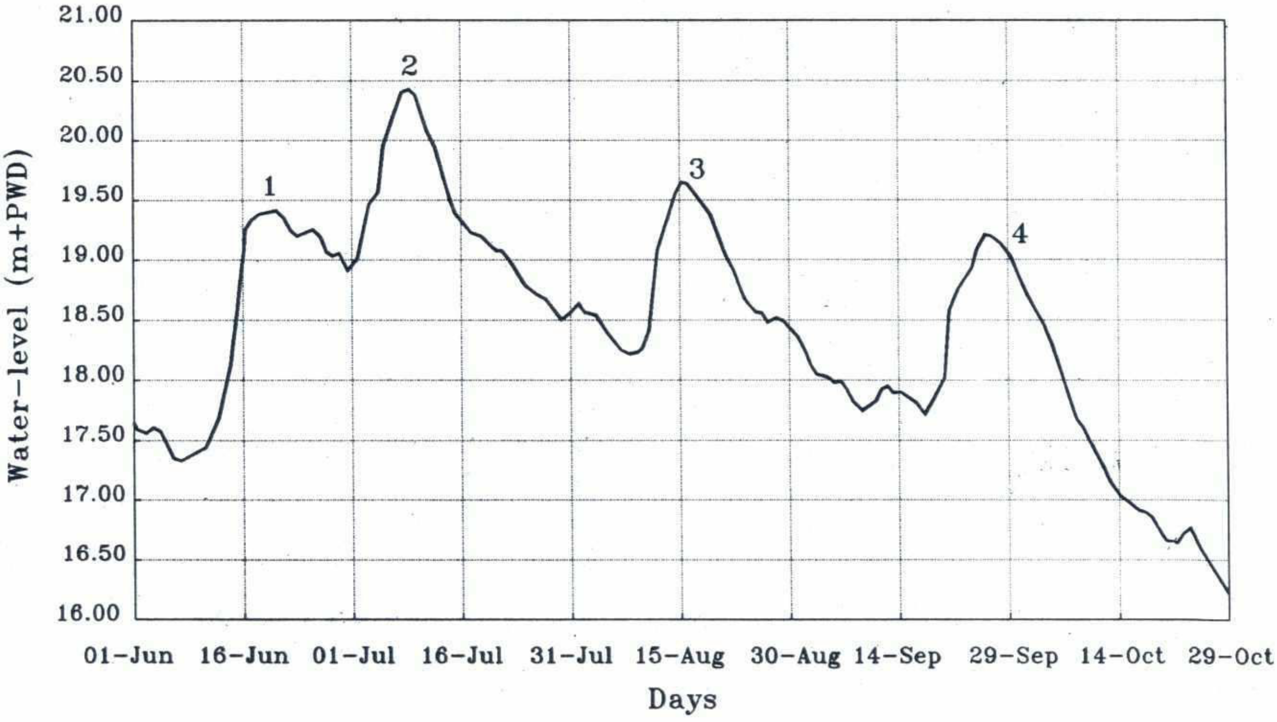


Figure 4.3: 1995 Water-level hydrograph at Bahadurabad during the measurement period showing the peaks 1 to 4.

4.4 Cross–sections and velocity profiles

During each survey cross-sections were measured on the smaller rivers and khals of the floodplain. However, only a few cross-sections were measured at the same places during different surveys (refer to Figures 4.1, 4.2, and 4.5 for the locations of the cross-sections S1 through S20). Three verticals were selected in each cross-section to measure flow velocities and to take a suspended sediment sample. The verticals were placed at intervals of one-fourth the total river width. At each vertical the flow velocity measurements were taken at four levels: the water surface, 0.2 h, 0.6 h, and 0.8 h (where h = water depth in meters). In areas where the water depth was less than 0.5 m the flow velocity was only measured at half the water depth. Each of the flow velocities presented is the average of 3 or 4 float tracking or Valeport current meter measurements. The depth averaged flow velocity in a vertical was calculated according to the method recommended by the World Meteorological Organization (1981).

Most velocity profiles seem to follow a characteristic logarithmic profile or power profile indicating fairly uniform flow with fully developed boundary layers. Vertical P-3 in cross-section S2 does not follow this pattern which might indicate an accelerating flow from a narrowing channel that passes through a culvert. (For an example refer to Figure 4.6 and the complete set of figures in Annexure 1). The verticals P-1 and P-3 in cross-section S5 also deviate from this characteristic profile; this is possibly due to measurement error or an unstable flow pattern.

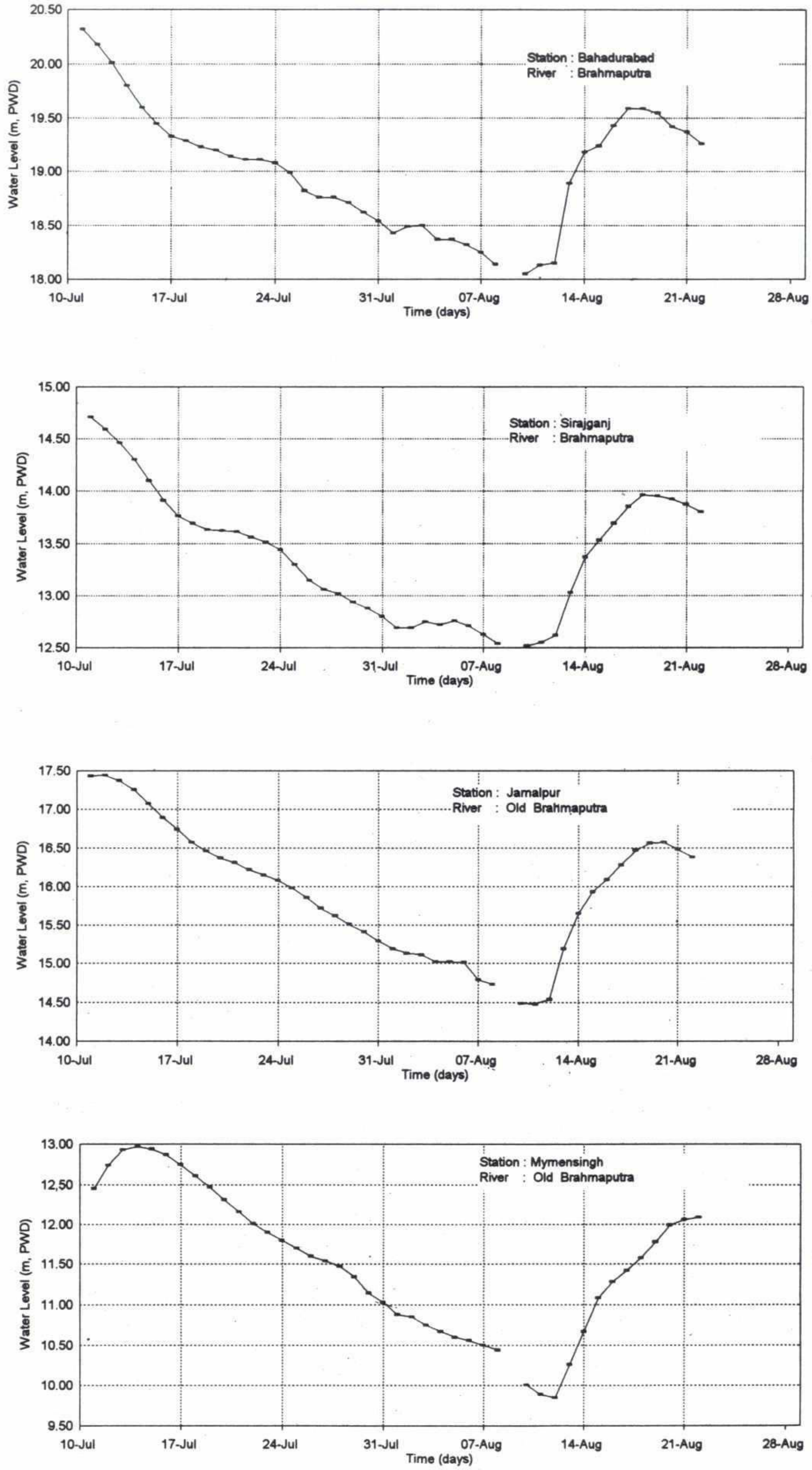


Figure 4.4: Hydrograph during July 11th through August 22nd in four stations

4.5 Discharges

In the first survey that was conducted from July 12th through the 15th the discharges were measured in 4 cross-sections, S1 to S4. In the second survey conducted from July 20th through 24th the discharges were measured in 6 cross-sections, S5 to S10. In the last survey conducted from August 20th through 22nd the discharges were measured in 10 cross-sections, S11 to S20. The discharges passing a cross-section were calculated by the mid-section method. The results of these calculations are presented in Table 4.1.

Date	Site No.	River	Location	Discharge m^3/s	Suspended sediment transport kg/s
12.07.95	S1	Jhenai River	Downstream of Jhenai Railway Bridge	270	50
13.07.95	S2	Sadhupur Khal	Sadhupur	160	19
14.07.95	S3	Jhenai River	Upstream Bousi Railway Bridge	230	31
15.07.95	S4	Shishua River	Char Shishua	470	60
20.07.95	S5	Jharkata River	Bhurarbari	630	105
21.07.95	S6	Shishua River	Char Shishua	370	75
22.07.95	S7	Shishua River	Char Shishua	80	16
22.07.95	S8	Kumuriabari Canal	Kumuriabari	65	20
23.07.95	S9	Adra River	Adra	160	47
24.07.95	S10	Jhenai River	Char Barbari	475	88
20.08.95	S14	Kumuria River	Kumuriabari	105	25
21.08.95	S11	Jharkata River	Char Baghmara	535	110
21.08.95	S12	Shishua River	Char Shishua	400	80
21.08.95	S13	Shishua River	Char Shishua	45	5
21.08.95	S15	Adra River	Rakkelgacha	150	30
21.08.95	S16	Sataria River	Sataria	290	50
22.08.95	S17	Jhenai River	Char Bir Bar-bari	420	65
22.08.95	S18	Jhenai River	Bousi Railway Bridge	120	15
22.08.95	S19	Jharkata River	Char Vatiani	260	60
22.08.95	S20	Jhenai River	Char Haripur	160	20

Table 4.1 : Discharges and suspended sediment transport measured in the rivers and khals.

A complete water balance for the area shown in Figure 4.7 requires rating curves for the floodplain rivers crossing the area because the measurements were performed on different days. A discussion of this is found in Section 4.8. The following calculations were performed.

During the second peak of the flood the spill flow through the Old Brahmaputra River was Q(S1) + Q(S2) which is approximately 430 m^3/s. The outflow passing the floodplain rivers during the receding flow was Q(S5) + Q(S6) which is approximately 1000 m^3/s. This outflow does not include the flow over the adjacent floodplain.

In the Jharkata River the discharge increases from S10 to S5 155 m^3/s; this probably indicates drainage of the floodplain.

The total discharge through S7 (a small branch of the Shishua River) and S8 (Kumuriabari Canal) is 145 m^3/s. This is slightly less than the discharge from S9 in the Adra River where Q(S9) = Q(S7) + Q(S8). This might indicate that on approximately July 23rd overland flow in this area had already almost disappeared.

Two discharge measurements were taken on the Shishua River. One (S4) was taken at Char Shishua during the floods on July 15, 1995. The other (S6) was taken 500 m down-stream from S4 when the water level was falling on July 21st. To estimate the water level drop (Δh) between the two measurement dates the following assumptions were made:

$$Q_1 = Q_2 \text{ and}$$
$$C_1(i_1)^{1/2} = C_2(i_2)^{1/2}$$

in which Q = discharge (m^3/s), C = Chèzy coefficient ($m^{0.5}/s$) and i = water level slope (-). The measured data are given in Table 4.2.

Date	Site No.	Area m^2	Width m	Mean depth m	Discharge m^3/s
15.07.95	S4	450	120	3.75	470
21.07.95	S6	350	110	3.18	370

Table 4.2 : Measured data at two sites

The Chezy formula and the continuity equations were solved first, and then the water level drop was estimated to be 0.80 m. This calculation assumes that the width of the river remains constant. This calculated water level drop was the same as the measured water level drop in Jamalpur during the study period (17.10 - 16.30 = 0.80 m). This confirms that the results of this calculation are accurate.

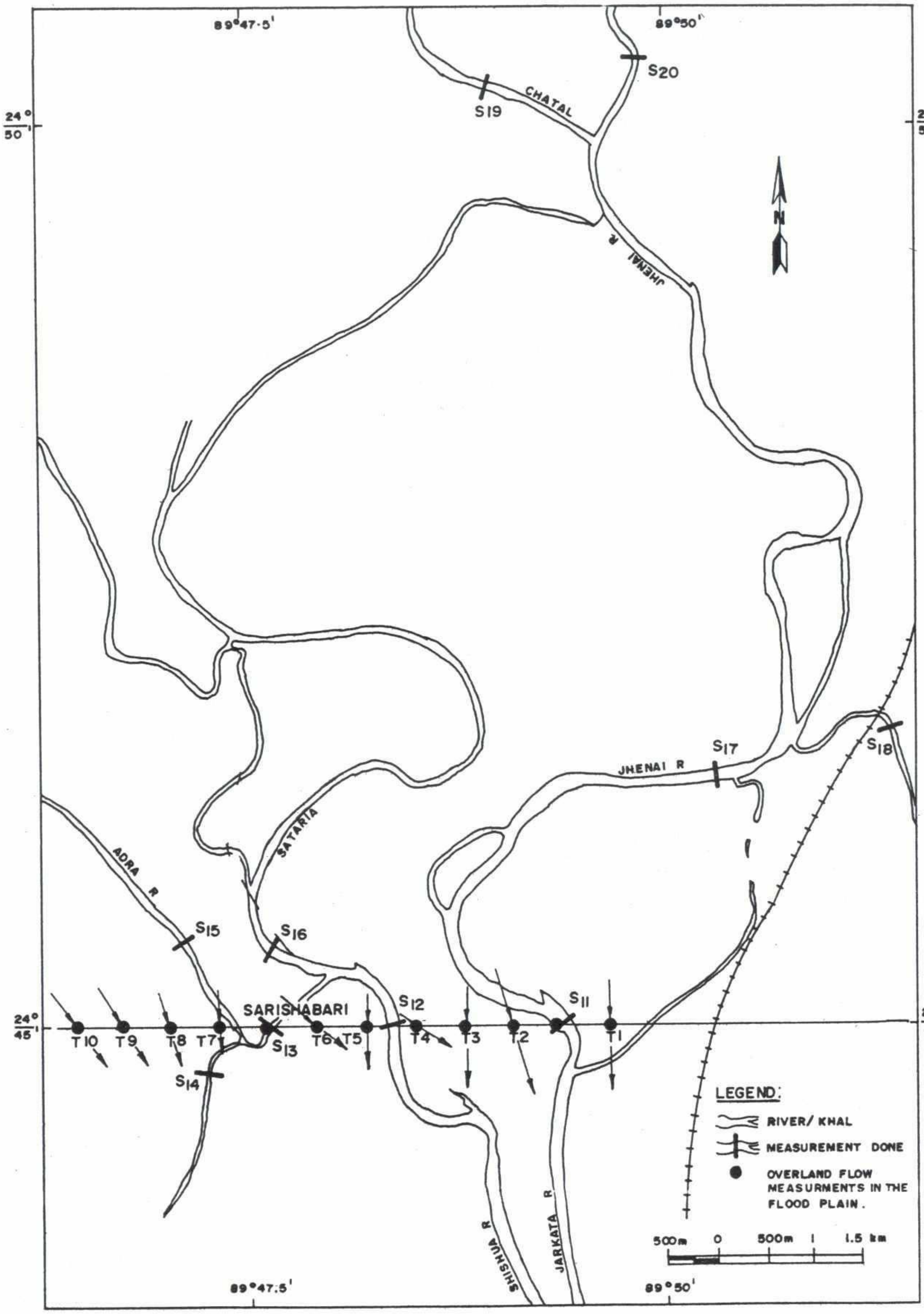


Figure 4.5: Sharishabari area

4.6 Sediment transport

The suspended sediment samples which were taken just below the water level in each measuring vertical were brought to the laboratory for sediment concentration determination. Assuming a homogeneous sediment distribution, the sediment transport was computed for each measuring site (Table 4.1).

In all three surveys the fine sediment concentration only varied between 100 and 250 mg/l. A small concentration of coarse sediments (from 0.5 to 50 mg/l) was found in all the measurements with the exception of the Adra River. Here higher concentrations of fine sediments (150 to 350 mg/l) and of coarse sediments (0 to 15 mg/l) were found.

The suspended sediment transport was computed for the measuring sites in the floodplain rivers. The data are insufficient to establish sediment transport rating curves for these sites; therefore a sediment balance for a selected floodplain area can not be created.

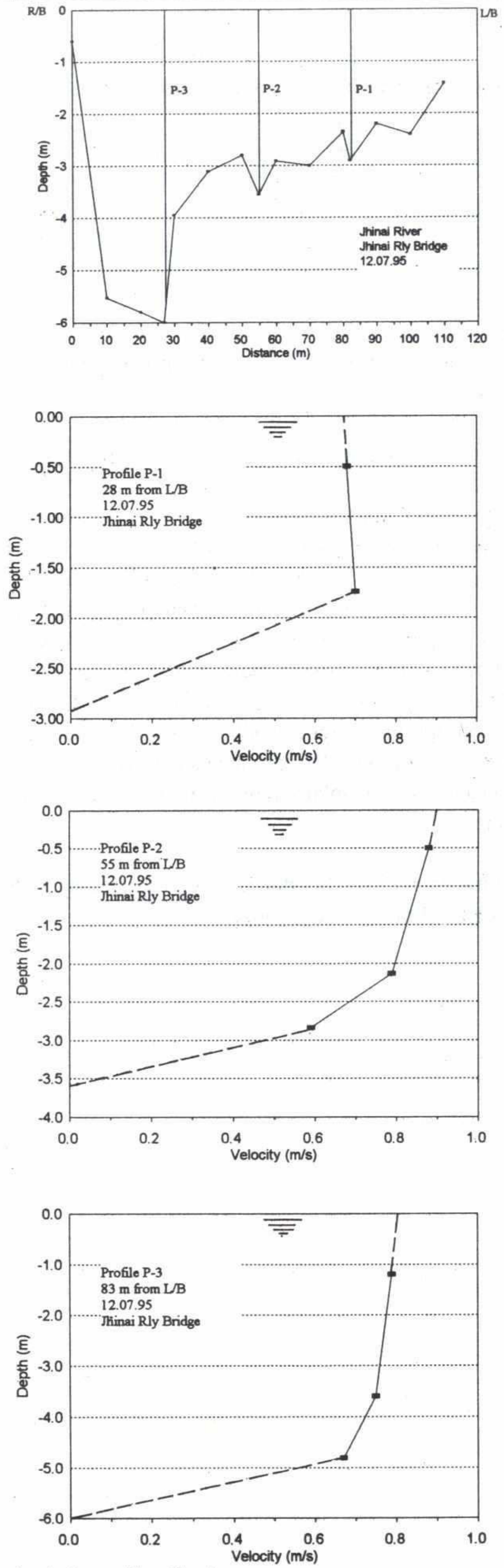


Figure 4.6: Cross-section and velocity profiles, Site 1

4.7 Transect measurements, discharges, and sediment transport

In a transect west of Sharishabari at 24°45′ latitude the discharge and the sediment transport were measured at regular intervals. This east-west transect is approximately 6 km long and crosses rivers in four locations. The transect crosses the Jharkata and Shishua Rivers once each and the Adra River in two different places (Figure 4.5). The following data were collected in verticals at 500 m intervals along this transect over the floodplain and at the river crossings:

- water depths at the verticals,
- flow velocities at the verticals and the flow direction at the water surface,
- samples of suspended sediments at the water surface.

The near bed sediment transport was not measured, but it is probably less important.

The measured water depths exhibit the variation in the elevation of the floodplain and reveal that there are levees along the Jharkata and the Shishua Rivers (Figure 4.8-1). These levees are approximately 1 m high and less than 500 m wide. The cross-section profiles where the transects cross rivers are shown with the sampling verticals in Figures A1.11 and A1.12 of Annexure 1. The flow velocity profiles along the transect are plotted as shown in Figure 4.8. The flow directions in Figure 4.5 show that flow over the floodplain is from north to south, but in the western part of the transect the flow direction is from north-west to south-east. The discharges passing the transect in the floodplain were computed per interval by multiplying average depth, average flow velocity, and the width of an interval (Table 4.3 and Figure 4.8). The Jharkata River conveys most of the discharge. The discharge is rather constant along the Young Jamuna floodplain transect; however, it increases considerably on the low Active Jamuna Floodplain.

The suspended sediment transport in the floodplain was calculated by multiplying the water discharge with the average suspended sediment concentration.

Date	Reach	Discharge m^3/s	Suspended sediment transport kg/s
20.08.95	T10 - T9	215	35
20.08.95	T9 - T8	225	35
20.08.95	T8 - T7	120	20
20-21.08.95	T7 - S13	40	5
21.08.95	S13	45	10
20-21.08.95	S13 - T6	80	10
19-20.08.95	T6 - T5	95	10
19.08.95	T5 - S12 - T4	490	90
19.08.95	T4 - T3	95	10
19.08.95	T3 - T2	340	55
19,21.08.95	T2 - S11	320	70
21.08.95	S11	535	105
19,21.08.95	S11 - T1	25	5
Total		2625	460

Table 4.3 : Discharges and suspended sediment transport passing the transect in the floodplain at a line 24°45′ (latitude) from west to east.

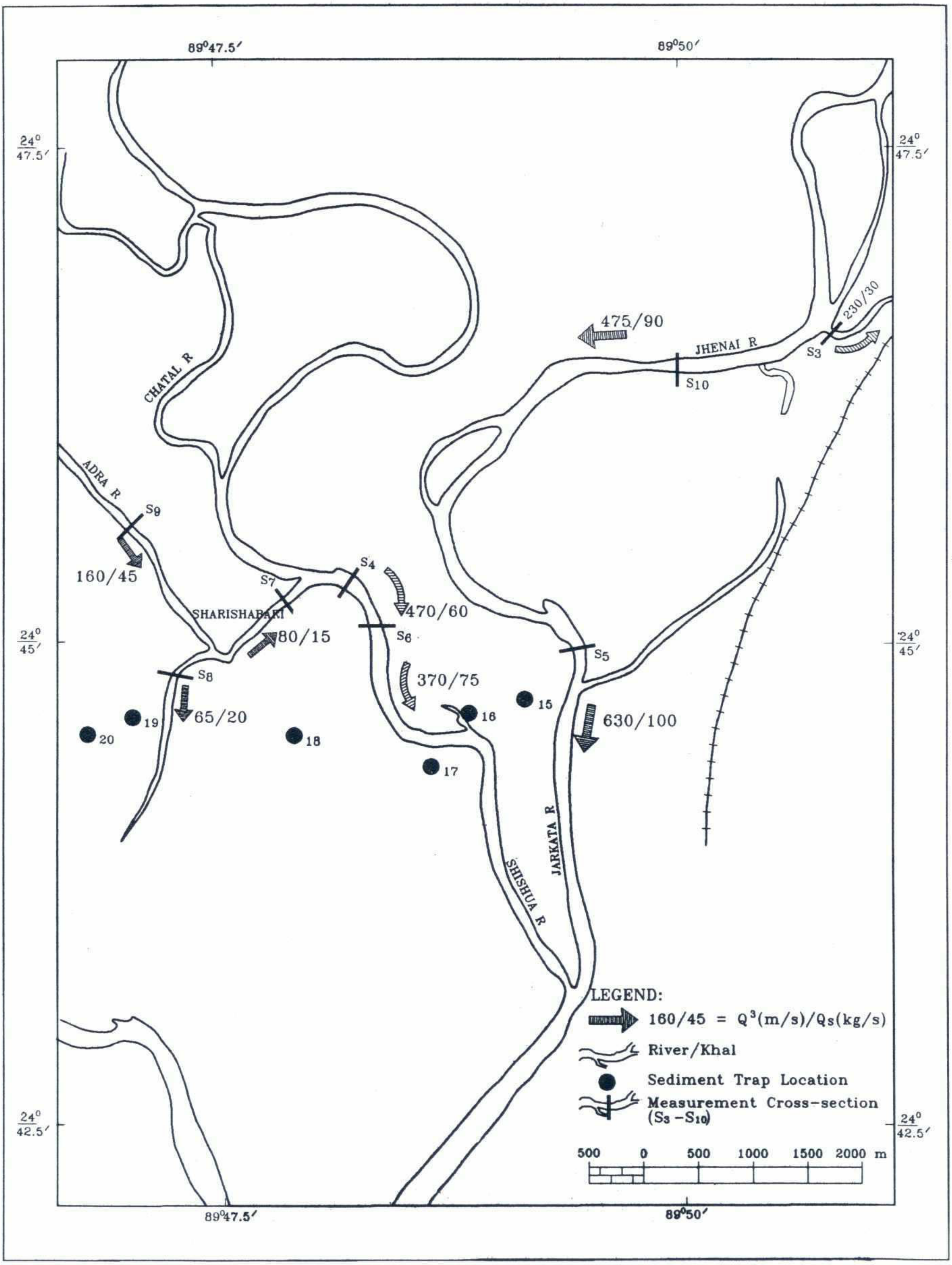


Figure 4.7: Discharge (m^3/s) and sediment transport (kg/s) in the floodplain rivers near Sharishabari

4.8 Water balance

The discharges measured on the rivers and khals (Table 4.1) and the transect discharges were analysed to determine the overall water balance during the extreme second peak flow. The water balance was determined for the area west of the line between Jamalpur and Sharishabari (Figure 4.9). To begin, rating curves were estimated because river discharges were measured on different dates which had different water levels. Maximum water levels in the second peak flow were extrapolated from these rating curves. The measurements suggest that the cross-section averaged flow velocity varies little when the water level changes. Constant flow velocities were assumed for these extrapolations.

- The maximum discharge in the Jamuna River near Bahadurabad was measured by RSP during the second peak flow as 80,100 m^3/s. According to the rating curve the maximum discharge during this second peak flow is estimated at 85,000 to 90,000 m^3/s with a return period of about 30 years.

- In Mymensingh on the Old Brahmaputra River the maximum discharge was 1,500 m^3/s during the second peak flow.

The three inflow estimates to the area are listed below:

- The maximum spill flow in the Old Brahmaputra River is feeded through the offtake from the Jamuna River and through the Jinjiram River which discharges just downstream of this offtake in the Old Brahmaputra River. That part of this spill flow which passes the culverts in the railway line Jamalpur to Bahadurabad Ghat, and feeds the Jhenai and the Jharkata Rivers, is estimated at 500 m^3/s. Consequently this maximum spill flow should be 500 + 1500 = 2000 m^3/s.

- The maximum spill flow on the Chatal River is estimated at 800 m^3/s, and the maximum spill flow on the surrounding floodplain is 1500 m^3/s.

- The maximum overbank flow on the Adra and Sataria Rivers is estimated at 500 m^3/s, and the maximum overbank flow of the adjacent active floodplain is 1000 m^3/s.

The two outflow estimates from the area are listed below:

- The maximum discharge passing the Bousi Railway Bridge on the Jhenai River is estimated at 250 m^3/s.

- The maximum discharge passing the transect is estimated at 4100 m^3/s.

The estimated values for the incoming floodplain flow close the water balance of the area sketched in Figure 4.10. These results show the importance of the Chatal River compared with the spill flow in the Jhenai River. The total overbank flow is probably higher than calculated because the east-west transect does not continue through the Jamuna channel.

A first estimate of the rating curve, which shows inundation depth as function of discharge passing the transect, was prepared using these results (Figure 4.10). It was estimated that inundation starts after total discharge of the Jharkata and Shishua Rivers exceed 600 m^3/s.

Between Sharishabari and Sirajganj the overland flow again joins the Jamuna River. The peak water level of the overland flow travels slower than the peak water level of the Jamuna River. Therefore most of the overland flow joins the Jamuna River when the water level of this river starts to recede. The discharge of the Jamuna River increased a maximum of 5% (4100/85000 * 100) in the second peak flow of the 1995 monsoon.

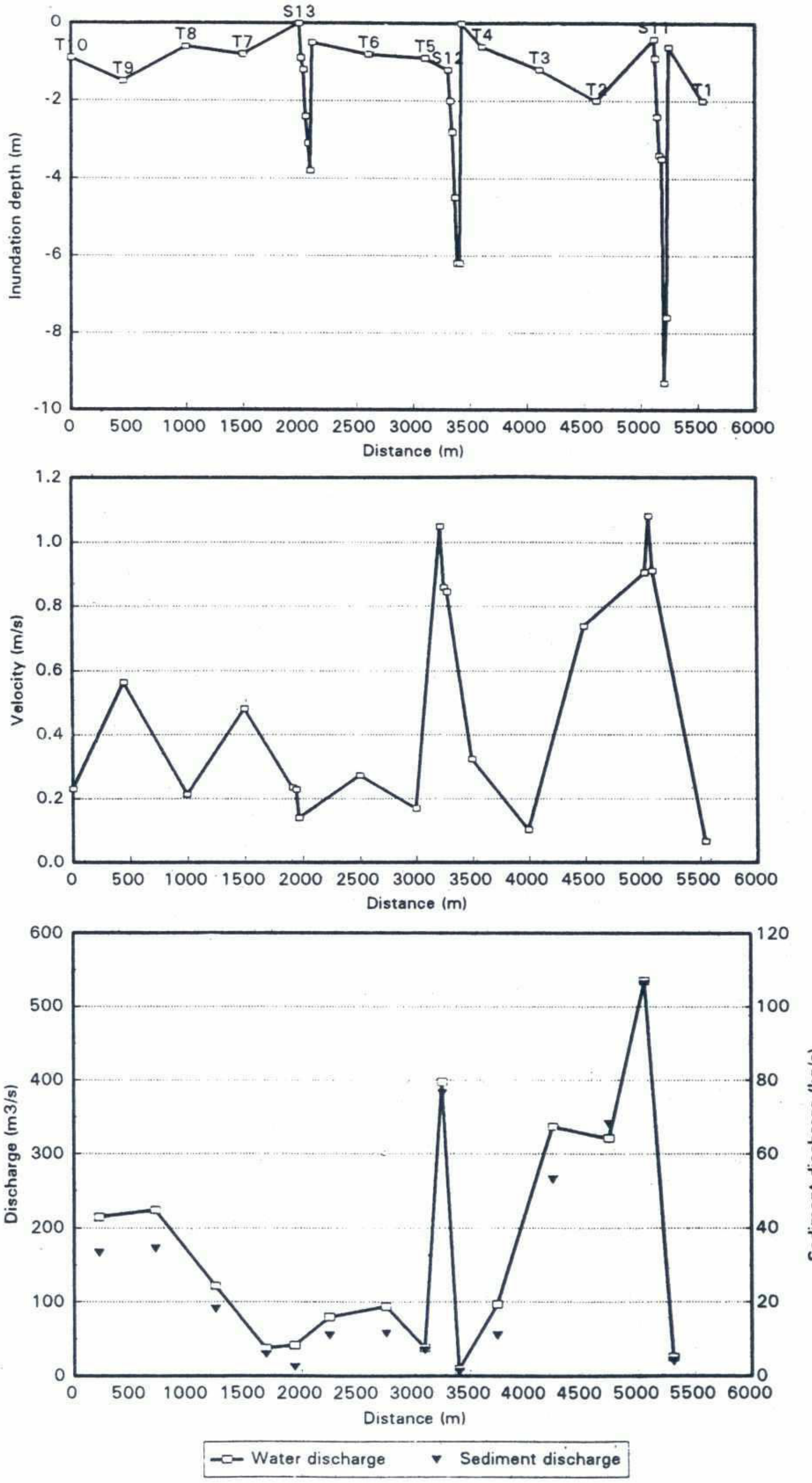


Figure 4.8: Overland flow measurements, Sharishabari, August 1995

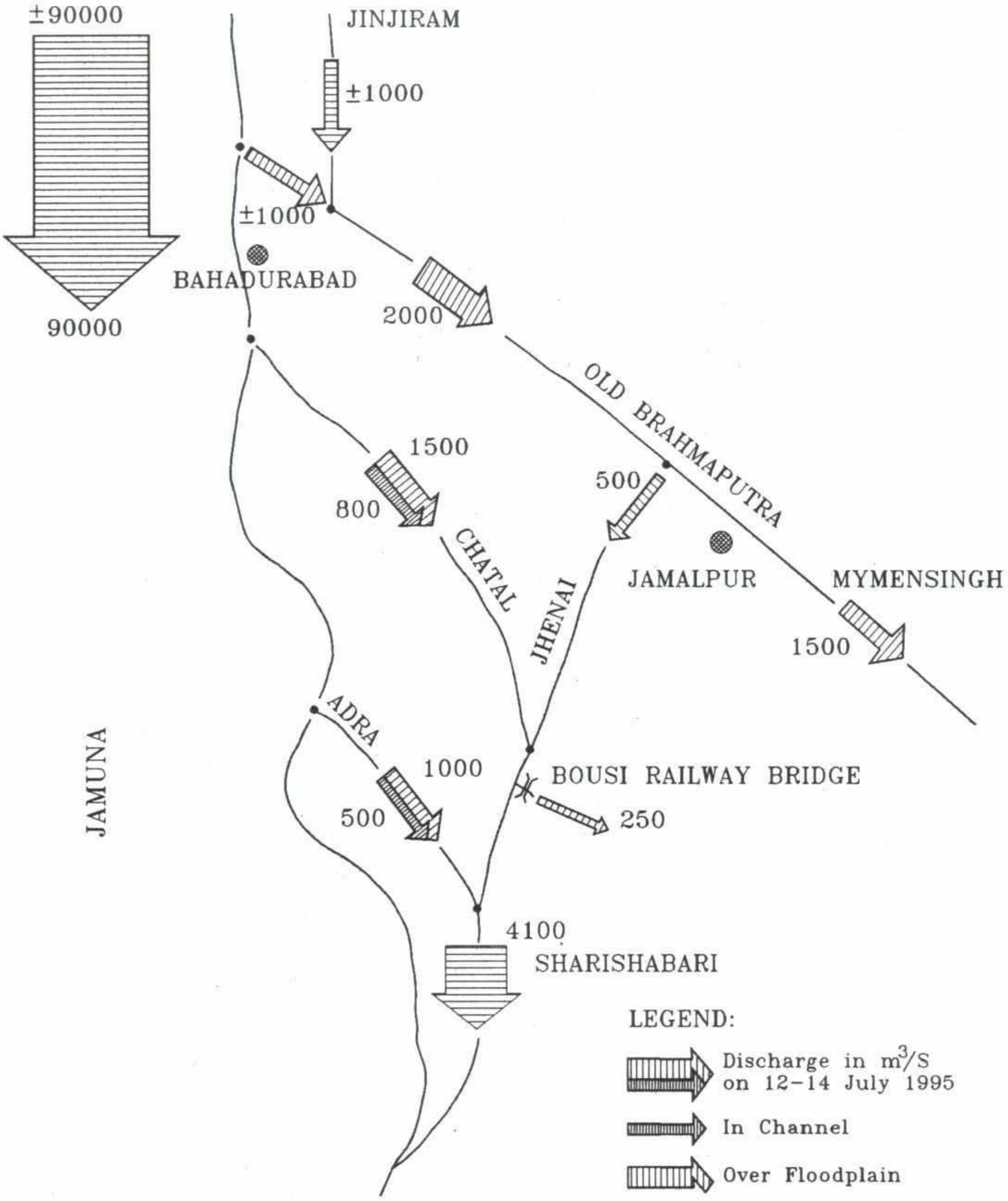


Figure 4.9: Waterbalance 12-14 July 1995

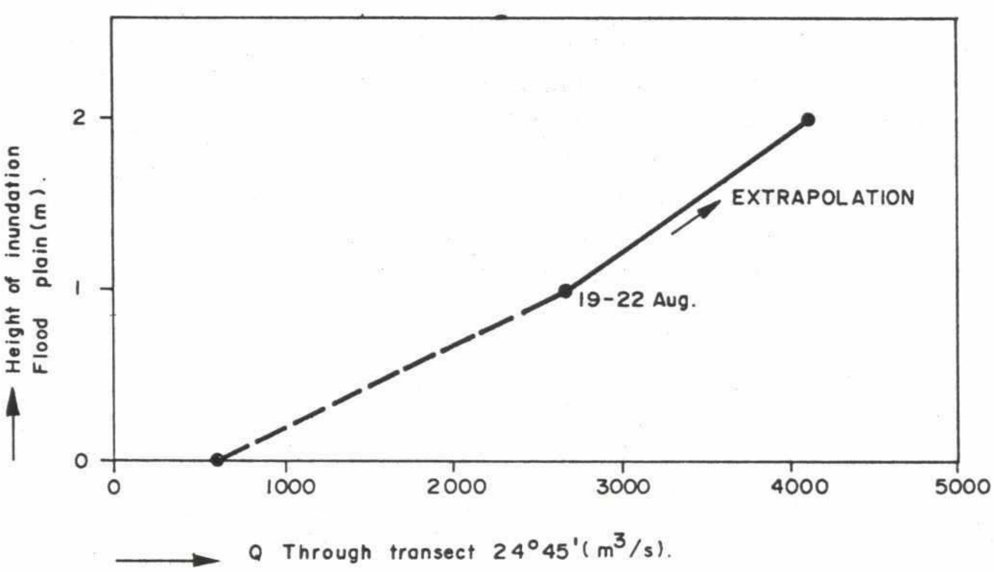


Figure 4.10: Rating curve overland flow through transect

5 Floodplain sedimentation

5.1 Introduction

To study the floodplain sedimentation six sampling plots were selected on the left bank of the Jamuna River. The sampling area is partly in Sharishabari Thana of Jamalpur District and partly in Kazipur Thana of Sirajganj District (Figure 5.1). Two sampling plots in this area are located in the Active Jamuna Floodplain; the remaining sites are in the Young Jamuna Floodplain. Inundation of these areas is not limited by flood protection embankments. All the sampling sites are on an approximately east-west line west of Sharishabari town. The sample plots are equipped with several devices to measure floodplain sedimentation as sketched in Figure 5.2. Special characteristics of each sample plot are described in Annexure 3. Three of each of the following different types of devices were placed at each sample plot to measure sedimentation (Plate 5.1):

- **Permeable mats:** On a permeable jute mat measuring 2 x 2 m, three 0.50 x 0.50 m permeable cloths were secured with iron nails (Figure 5.2). The deposition of sediment on these three cloths was measured.

- **Sediment traps**: Three sediment traps were buried in the ground so that the tops of the funnels were level with the ground surface. (See Figure 5.3 for a sketch of a sediment trap). The traps were initially filled with clean tubewell water and covered with funnel covers. These covers were removed when inundation started. The sediment from the flood water was deposited in the traps. When the flood water receded the traps were covered until the next peak flow.

- **Brick dust layer**: A thin layer of red brick dust was spread over the soil surface in three sub plots measuring 0.50 x 0.50 m. This was done so that the thickness of the sediment layer over the topsoil could be measured.

Three of each type of devices were selected because in general the average of three similar measurements is more accurate than a single measurement. In each sampling plot these devices were placed just before the first peak flow between June 8th and 11th in 1995. They were left in the field for the entire monsoon season. The sediments deposited on the cloths, on top of the dust layers, and caught in the traps were collected after the flood water receded from the fields. The sediments from Sample Plots 3, 4, and 5 in the higher part of the floodplain were collected when the water level started to rise for an unexpected fourth peak flow on September 25th and 26th. The sediment samples were collected from Sample Plots 1, 2, and 6 in the lower part of the floodplain on October 22nd and 23rd so that deposition during this last peak flow of the monsoon could be measured. In this way sedimentation during the entire monsoon was measured and no information on the sedimentation per peak flow was obtained. If these types of measurements are repeated in future then collection of sediments after each peak flow should be considered only for those sample plots where the floodwater will be drained completely after peak flow. It is difficult to collect sediment from an inundated sample plot without damaging any sample.

The results are described in the Sections 5.2 through 5.7. Section 5.2 presents results on the inundation of the sample plots during the monsoon by describing the depth of inundation as a function of time. In Section 5.3 the measured sediment concentration in the inundated floodplain is compared with the sediment concentrations in the smaller rivers of that floodplain and also with the sediment concentration in the Jamuna River. Section 5.4 shows sedimentation rate estimates determined from the sediments in the traps, the dust layers, and on the cloths. Section 5.5 describes sedimentation patterns as a function of distance from rivers. Section 5.6 presents the mineralogical and physical properties of selected sediment samples which reveal some information on the sedimentation patterns and the source of the sediments.

Plate 5.1: Sample Plot 6 on October 23, 1995 just before collection of sediments from the traps and the cloths

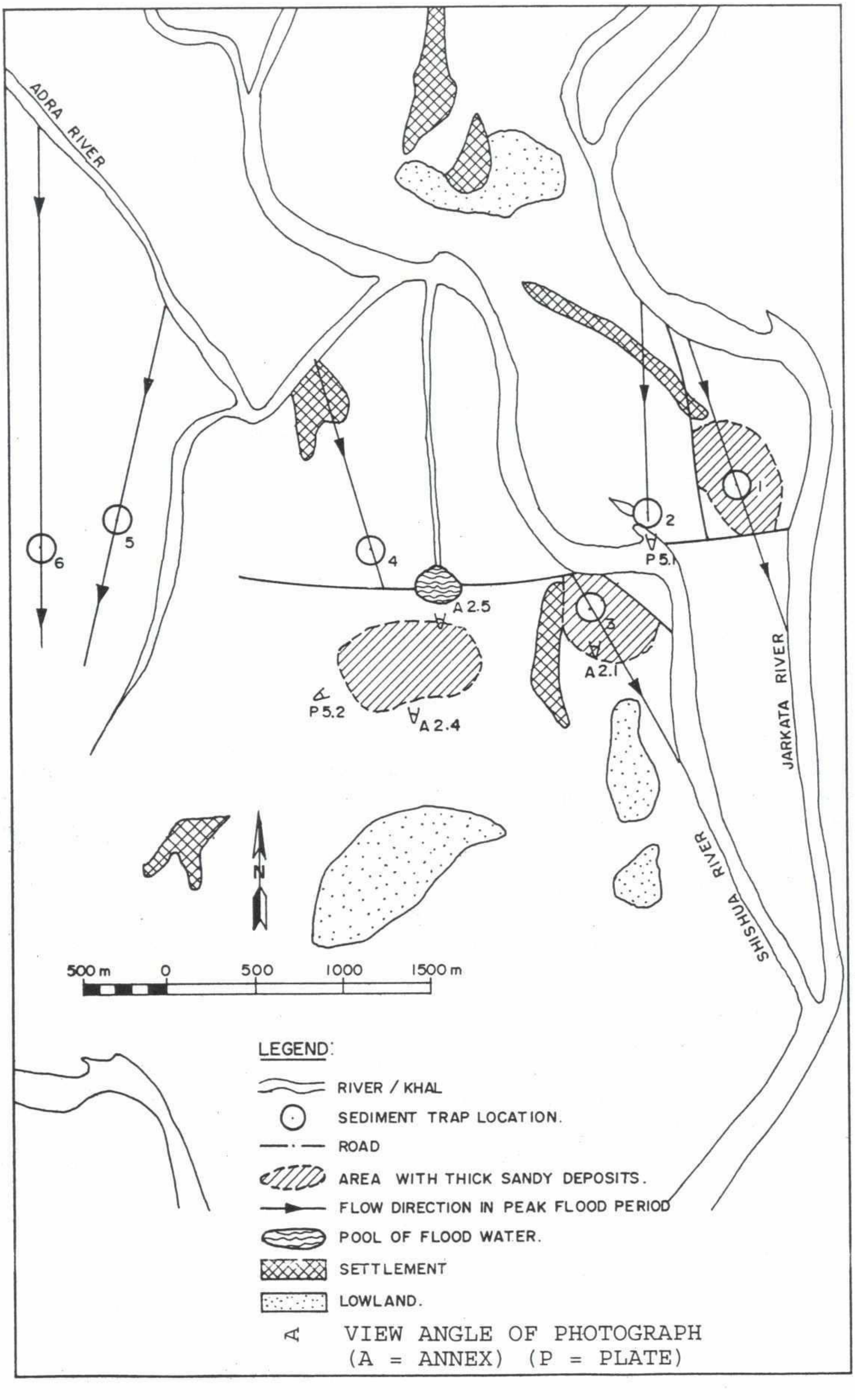


Figure 5.1: Map of sample plots areas

5.2 Inundation of sampling sites

The inundation of the floodplain west of Sharishabari started on June 17th and continued with some interruptions through October (Table 5.2 shows the inundation periods in the different peak flows). There was a severe flood in July. At this time the water level in the inundated floodplain was close to the maximum level reached in the 1988 flood. Standing crops and households were damaged. People living in low-lying areas had to move themselves and their livestock to safer places. Table 5.2 presents the period of inundation and the maximum inundation depth in the sample plots. The surface flow velocity of the flood water was measured on August 18th during the third flood peak; refer to Annexure 2 for the results. In the graphs of the daily inundation depth in which the different peak flows can be recognised easily (Figures 5.4 and 5.6).

Flood peak	Bahadurabad Ghat	Sharishabari	Jamalpur	Sirajganj
2nd	10 July	10 - 11 July	11 July	10 - 11 July
3rd	17 - 18 August	18 - 19 August	19 - 20 August	18 August
4th	28 September	29 - 31 September	-	29 September

Table 5.1: Dates when the maximum water level in the peak flow was reached in different places.

In the Sharishabari floodplain the peak water levels were delayed compared with those measured in Bahadurabad Ghat in Table 5.1. This occurred because Bahadurabad Ghat is upstream from the Sharishabari floodplain. The delay depended on the inundation depth. There was a shorter delay in the highest 2nd peak flow and a longer delay in the other peak flows. This is because during the lowest flood peak there is a tendency for flow resistance in the floodplain to influence the flood flow. The peak water level in Jamalpur is attained 12 to 24 hours later than in Sharishabari even though Sharishabari is downstream of Jamalpur. This indicates that flow through the culverts in the railway line from Jamalpur to Bahadurabad Ghat contributes little to flood flow west of Sharishabari.

In the Jamuna River the maximum water level in the 2nd peak flow was reached in Sirajganj at the same time as in Sharishabari. A few kilometres downstream of Sharishabari the spill flow returns to the Jamuna River, about 15 km upstream of Sirajganj. In the 3rd and 4th peak flow the maximum water level in the spill flow in Sharishabari was reached 0.5 day after the maximum water level in Sirajganj was reached. The maximum level in the flood wave of the spill flow discharges in the Jamuna River when the water level in that river starts to drop already. The flood wave propagates quicker in the main river than in the flood plain.

Sample plot	June		July		August		September		October	
	Max depth (m)	No. of days inundated	Max depth (m)	No. of days inundated	Max depth (m)	No. of days inundated	Max depth (m)	No. of days inundated	Max depth (m)	No. of days inundated
1	1.40	14	2.85	31	2.05	29	1.25	13	1.30	12
2	0.75	14	2.20	29	1.50	17	0.80	6	0.85	5
3	0.20	9	1.90	22	0.90	11	--	--	--	--
4	0.25	4	2.00	27	1.05	27	--	--	--	--
5	0.15	3	1.80	22	0.70	15	--	--	--	--
6	0.90	14	2.00	27	1.30	14	0.70	7	0.30	2

• devices already removed

Table 5.2: Period of inundation of the sample plots and the maximum inundation

Plate 5.1: Sample Plot 2 inundated during the 1995 flood.

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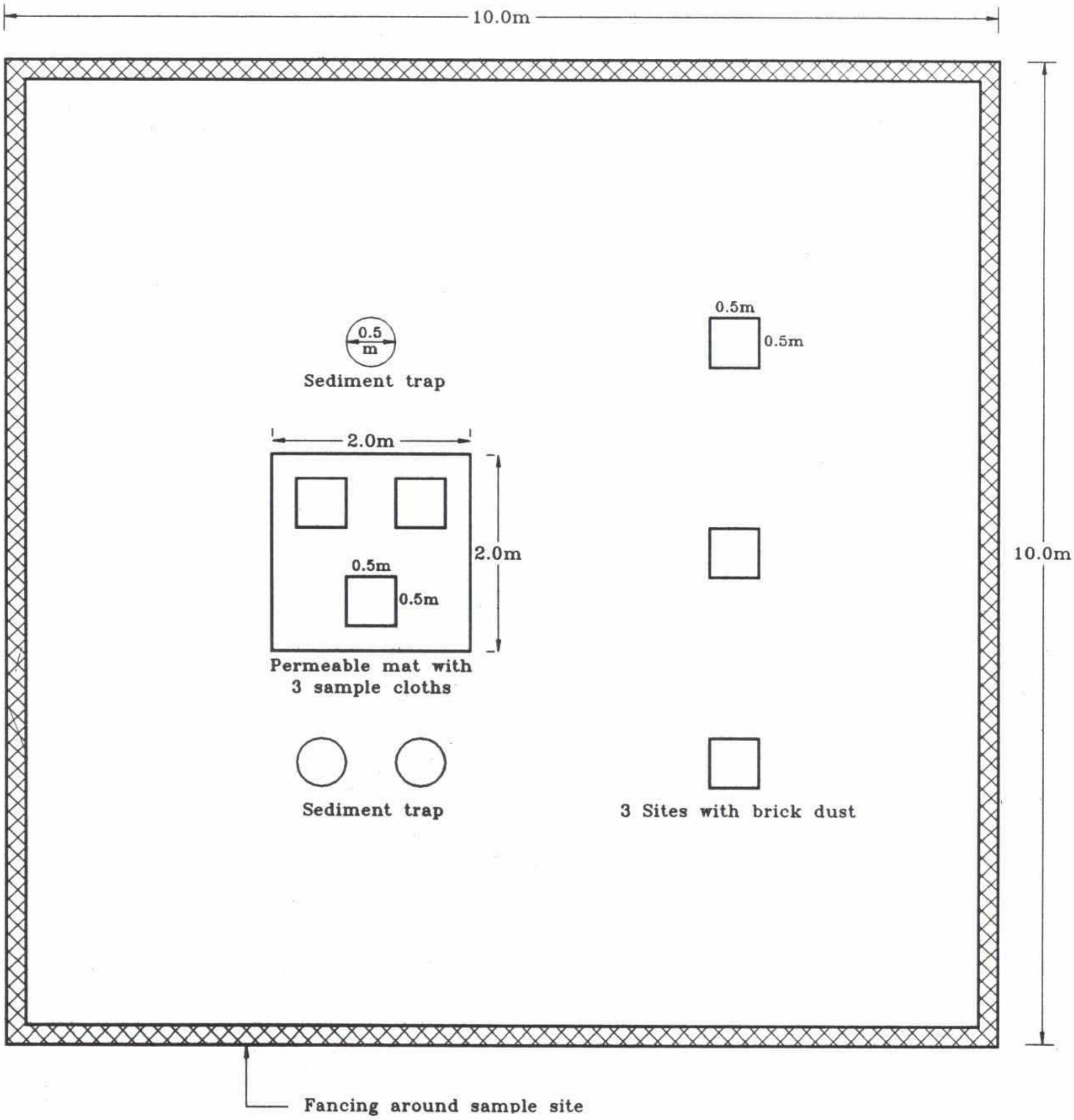

Figure 5.2: Typical layout of a sample plot

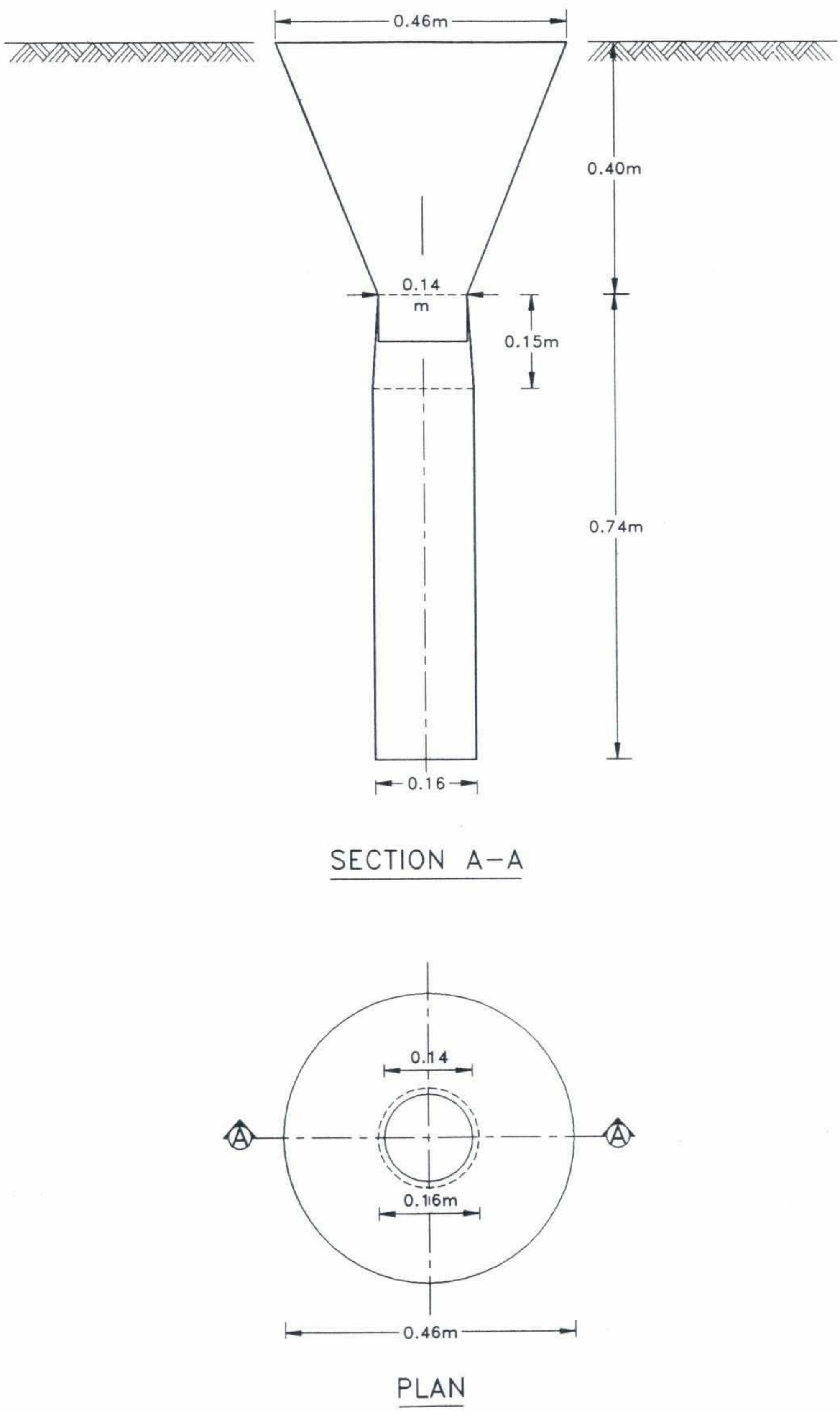

Figure 5.3: Sketch of a sediment trap used for the study (after ISPAN, 1995).

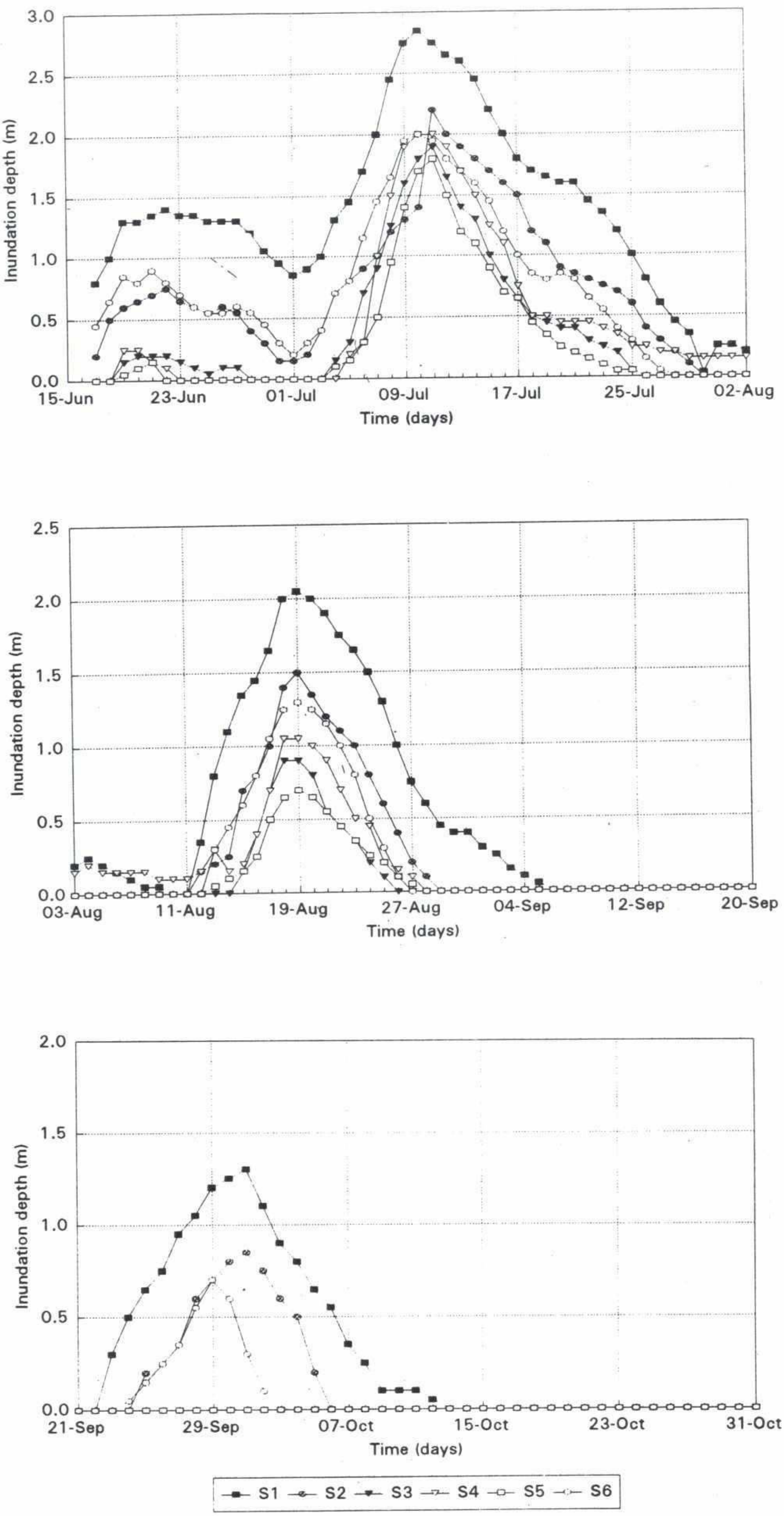

Figure 5.4: Inundation depth, measured near the sediment traps in the Sharishabari area

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5.3 Sediment concentration in flood water

During the monsoon samples of the flood water were collected weekly from the water surface of the inundated plots. From these samples the sediment concentration of the wash load (consisting of fine sediments such as silt) and the concentration of suspended course sediments (such as sand) were determined in the sediment laboratory of the project. In all of the samples the wash load percentages were high (usually more than 90%), and in general the percentages of coarse suspended material was less than 10%. This was due to the fact that all of the samples were collected from the water surface where the concentration of coarse material was relatively low. These results, therefore, should not be considered representative of coarse sediment transport in the flood water.

The maximum concentrations of suspended sediments occurred during the second peak flow period in July. Sample Plot 3, however, was an exception since the maximum suspended sediment concentration was measured in the third peak flow period in August.

Relatively high concentrations of sediment were found in the Plot 3 samples. This is probably because a migrating bend of the Shishua River caused considerable bank erosion not far upstream from this plot. The overland flow passing this plot can be compared with a (crevasse)-splay flow. If the measurements of this plot are ignored then the wash load concentration is almost proportional to the inundation depth (although the data are scattered). If the inundation depth is small in the rising and the receding limbs of the flood hydrograph, then some samples show a relatively high sediment concentration. However, the visual observation records mention relatively clear flood water. These samples probably include some floodplain soil sediments and the near-bed sediment transport.

Spill flow suspended sediment concentrations decrease on the way from the Jamuna River to the sample plots (Table 5.3). The silt and clay concentrations decrease from 500 - 600 mg/l in the Jamuna River near Bahadurabad to 100 - 200 mg/l in the smaller rivers of the floodplain. Very low concentrations (10 - 20 mg/l) were measured in the floodwater passing through the sample plots. This means an important part of the silt (and clay) particles settles in the spill flow. All of the concentrations were measured after the second peak flow from July 18th through the 22nd.

Overbank flow sediment concentrations decrease much less than do the spill flow concentrations. They decrease from 500 - 600 mg/l in the Jamuna River to 200 - 300 mg/l in the Adra River and to 100 - 400 mg/l in the floodwater passing through the sample plots. This is because the distance travelled by the overbank flow from the Jamuna River is much less than the distance travelled by the spill flow through the smaller floodplain rivers. In general, the concentration of silt decreases as a function of the time and/or the distance to the source, which is in this case the Jamuna River. The silt particles need time to settle and to deposit because the fall velocity of these particles is very small compared with the fall velocity of sand particles.

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These tendencies are presented in a map of the area in Figure 5.7.

Survey period	Flow	Wash load or silt concentration (mg/l)	Suspended material or coarse sediment concentration (mg/l)
18 - 20 July	Jamuna River, Bahadurabad Ghat	500 to 600	100 to 300
12 - 24 July	Overbank flow in Adra River	200 to 300	0 to 10
12 - 24 July	Spill flow in the smaller rivers	100 to 200	0 to 30
18 - 22 July	Overbank flow passing plots 5 and 6	100 to 400	1 to 10
18 - 22 July	Flow passing sample plots 2 and 4, mainly silt	10 to 20	0 to 2
18 - 22 July	Flow passing sample plots 1 and 3, mainly sandy	140	0 to 2

Table 5.3 Comparison of the sediment concentrations in the Jamuna River, the spill flow and the overbank flow.

Plate 5.2 Sandy depositions south of sample Plot 4.

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5.4 Sediment samples and sedimentation rates

The thickness of deposited sediment in the traps and on the brick dust was measured in the field. This was done at the end of the monsoon when sample plot sediment deposits were collected. The thickness of collected sediments was calculated assuming a density 2650 kg/m^3 and a rather low porosity of 0.4 (Table 5.4). In general, the porosity of non-consolidated sediments varies between 0.4 and 0.6. The D_{50} and the percentage of coarse and fine fractions (which are included in Table 5.4) were determined through a grain size analysis of the sediment samples. In most cases these results are mean values of three samples. The sedimentation rate in tons per hectares was calculated from the weight of the sample. Annexure 2 is a description of field observations of floodplain sedimentation for each plot.

In plots 1 and 3 near the Shishua and Jharkata Rivers the deposited sediment had a thickness of 0.2 to 0.3 m. Two samples were taken from the upper and lower sediment layers of these sites. In Plot 1 the sediment in both the upper and the lower layer was dominated by sand (45 to 55%), and the D_{50} was approximately 0.06 mm. In Plot 3, however, the sand was more coarse in the upper layer than the lower layer (D_{50} = 0.095 mm versus D_{50} = 0.04 mm). The coarse sand was probably deposited by a (crevasse)-splay flow which transported eroded sand from a migrating bend of the Shishua River. Plot 3 had a 0.08 to 0.10 m thick lower layer that contained much silt and clay (50 to 75%) from the first peak flow(s).

The bank erosion and the (crevasse)-splay phenomena that occurred upstream from Plot 3 probably developed in the first peak flow(s) after inundation by the overland flow. On August 18th, the measured flow velocity at this plot was 0.34 m/s, in other plots it varied from 0.34 to 0.61 m/s. These relatively high velocities can erode the soil if the inundation depth is low. The weeds and water hyacinth attached to the bamboo fencing might have enhanced sedimentation of this plot. Local people disliked thick sandy deposits which buried old fertile topsoil and changed the micro-relief of the area. During the following lean season the farmers removed the thick sandy deposits in Plot 1 and prepared the field for growing irrigated rice on the old top soil (Plate 5.2). In Plot 3 the farmers did not remove the deposited sand and started to grow cheena, a draught resistant crop (Plate 5.3).

In the other sample plots overland flow deposited a 1 to 4 mm thin layer of silt and clay. These layers contained less than 2% sand. These plots were further from the floodplain rivers than Plots 1 and 3. These sediments had more nutrients and were thus more fertile than the adjacent top soils (ISPAN, 1994 and 1995).

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Plate 5.4: Sample site no 1, Thick sandy sediment deposits have been removed from the field and stacked in the adjacent field (24 January 1996)

Sample plot no.	Type sampler	Catch area of sampler (m^2)	Weight sediment sample (kg)	Sedimentation thickness (m)	Sedimentation rate (ton/ha)	D_{50} (mm)	Percentage silt and clay (%)	Percentage sand (%)
1	Trap,U	0.1660	68.45	0.26	4120.0	0.063	43	57
	Trap,L					0.063	50	50
1	Cloth,U	0.0100	3.73	0.23	3730.0	0.064	44	56
	Cloth,L					0.058	54	46
2	Trap	0.1660	0.42	0.0016	25.3	0.0055	99.92	0.08
2	Cloth	0.2601	0.61	0.0015	23.4	0.007	99.95	0.05
3	Trap,U	0.1660	56.10	0.21	3380.0	0.094	15	85
	Trap,L					0.041	76	24
3	Cloth,U	0.0100	3.60	0.22	3600.0	0.096	14	86
	Cloth, L					0.042	77	23
4	Trap	0.1660	0.61	0.0023	36.7	0.010	99.15	0.85
4	Cloth	0.2550	1.38	0.0034	54.1	0.013	98.9	1.1
5	Trap	0.1660	0.24	0.0009	14.4	0.010	99.1	0.9
5	Cloth	0.2550	0.41	0.0010	16.1	0.016	99.5	0.5
6	Trap	0.1660	1.02	0.0038	61.4	0.010	99.0	1.0
6	Cloth	0.2601	0.60	0.0014	23.1	0.010	99.25	0.75

U = upper layer and L = lower layer

Table 5.4 Results of sediment samples with area for traps and cloths

A comparison of the sedimentation thickness and rates by different methods (cloths or brick-dust layers and traps) shows that the measurements differ by less than 10% with the exception of Plots 4 and 6.

The measured sedimentation was compared with information provided by local farmers. The farmers provided information on thickness of deposited sediment of the sampling plots for an average flood and for the extreme 1988 flood (ISPAN, 1995). Table 5.5 shows that sedimentation in Plots 1 and 3 is only 0.01 to 0.05 m for a normal year. This is much smaller than observed in the 1995 flood. However, the high sedimentation in Plot 2 during the 1988 flood was much more than measured during the 1995 flood. Extreme sedimentation rates (0.2 to 0.3 m) were probably caused by a phenomenon such as a (crevasse)-splay flow on the left bank of the Shishua and Jharkata Rivers. The bends in these rivers are active and they migrate downstream. This can be seen from a comparison of the planform in SPOT images in March 1989 and March 1994 (Figure 5.6). The eroded material may flow through a crevasse in the levees or spill over the levees. If it spills over the levees it will splay over the lower elevated floodplain that is behind and downstream from the levees. In this lower elevated floodplain the flow velocity decreases and therefore the capacity to transport sandy material also decreases. These sandy materials will form depositions quickly. These results indicate that a (crevasse)-splay phenomenon in the Sharishabari floodplain only occurs occasionally during extreme floods.

Sample plot No.	Physiographic unit	Flooding 1995		Sediment deposition rate		
		Maximum depth (m)	Period of inundation (days)	Normal monsoon (m/year) *	1988 monsoon (m/year) *	1995 monsoon (m/year) +
1	Young Jamuna Floodplain	2.85	99	0.05	0.10 - 0.12	0.23 - 0.26
2	Young Jamuna Floodplain	2.20	71	0.01	0.15 - 0.20	0.0015
3	Young Jamuna Floodplain	1.90	42	0.01 - 0.03	0.05 - 0.06	0.21 - 0.22
4	Young Jamuna Floodplain	2.00	58	0.01 - 0.02	0.08 - 0.10	0.002 - 0.003
5	Active Jamuna Floodplain	1.80	40	0.01	--	0.001
6	Active Jamuna Floodplain	2.00	64	0.03 - 0.04	--	0.001 - 0.004

* Farmers estimate ISPAN, 1995
\+ RSP, FAP 24 survey result

Table 5.5: Sediment deposition rate in sample plots in different floods

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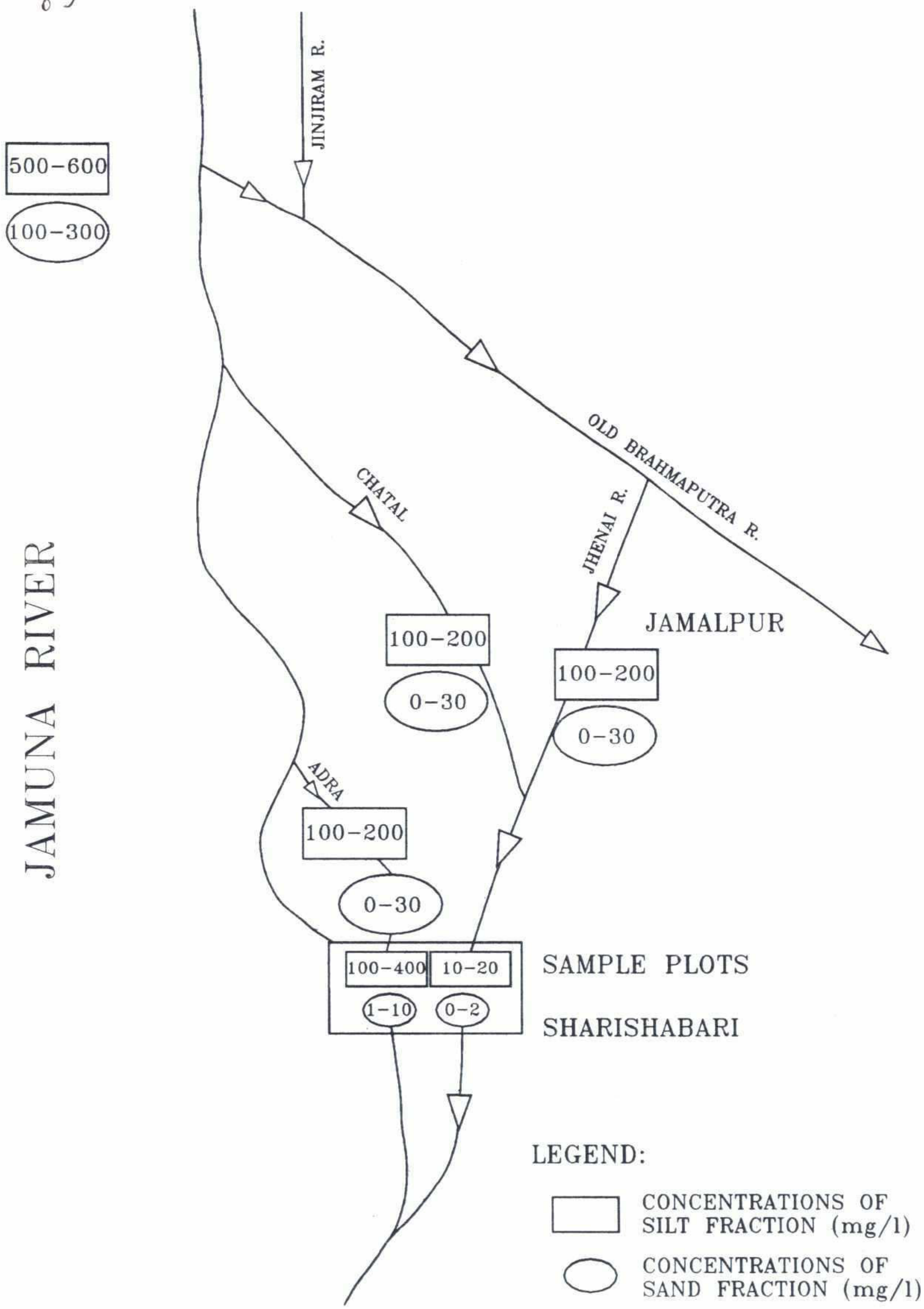

Figure 5.5: The concentrations (mg/l) of silt and sand fractions in the floodplain west of Jamalpur - Sharishabari during the measured peak flows.

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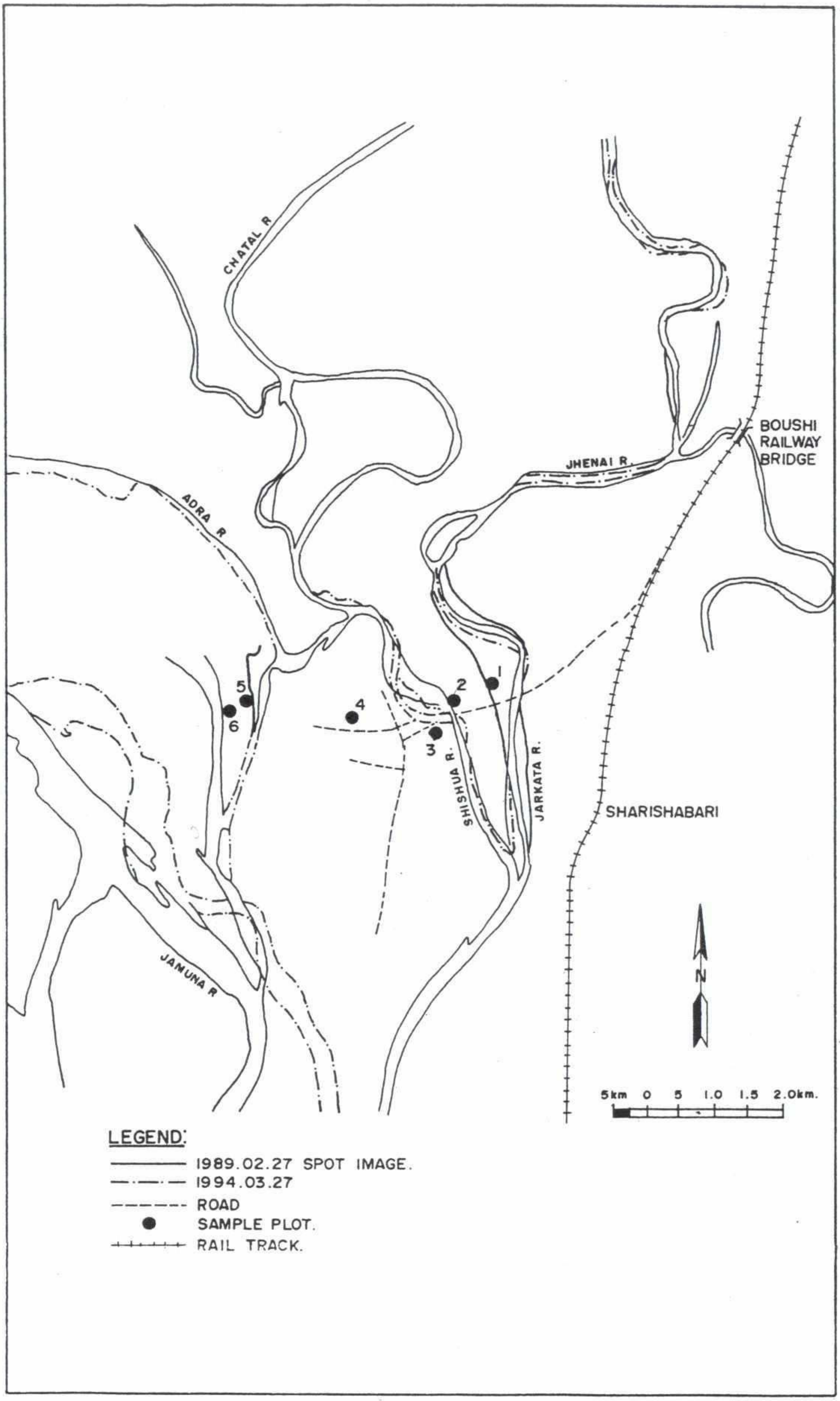

Figure 5.6: Comparison of the plan form of the floodplain rivers in 1989 and in 1994 traps area Sharishabari

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5.5 Sedimentation pattern

The sediment deposition on the floodplain decreases as a rule exponentially with distance along a flow line to the river source. This is evident in the flood layer thickness and the grain size variation as a function of the distance to the river see for example the case studies on floodplain sedimentation in the Mississippi River in the USA (Kesel et al., 1974) and in the Meuse and Rhine rivers in The Netherlands (Asselman et al., 1995) see Figure 5.7. As the flood spreads out onto the floodplain, decreasing overbank flow velocity reduces its sediment transport competence. Working in combination with convection and diffusion processes, this causes an exponential decrease in the size of the particles deposited farther from the channel. This process forms a coarser-grained natural levee near the channel, grading with distance into a finer-grained floodplain. Downstream of a levee the elevation of the floodplain lowers gradually. Levee gradients range from 0.0002 to 0.0005, the profiles of the natural levees on the vegetated bars and on the banks of the Jamuna River are both concave and convex in cross-section. These levees stand up to 3 m above the floodplain and are up to 1 km wide (Bristow, 1987). He studied the build up of a levee on a cut bank of a Jamuna channel in and after the 1984 and 1985 floods. As the overbank flow started to flow over the floodplain adjacent to the eroded bank several layers of sheet-splay deposits developed with the highest thickness near the bank, see Figure 5.8. In this example the thickness of the deposits decreases away from the river channel from 0.32 m in A, 0.20 m in B and 0.10 m in C. Most of the sheet-splays deposits coarsen up vertically, but some fine up. The thickness of each sheet-splay deposit decreases as the levee grows upwards. In a later stage overbank sand lobes deposit on top of the levee. Sand lobes are semi-elliptical in plan view with a radius of about 10 m. They have a convex up cross-section parallel to the bank and thin away laterally from the river channel. Overbank sand-lobes are readily distinguished from sheet-splays by their limited lateral extend, regular spacing and lack of observable sedimentary structures (Bristow, 1987). In a later stage these sand lobes can induce a crevasse flow through the levee and a splaying flow just downstream of the levee. A crevasse flow implies some channelisation of the flow as it breaches through the levee during the rising stage of the flood. This phenomena forms the typical crevasse-splay deposits during extreme floods (Coleman, 1969).

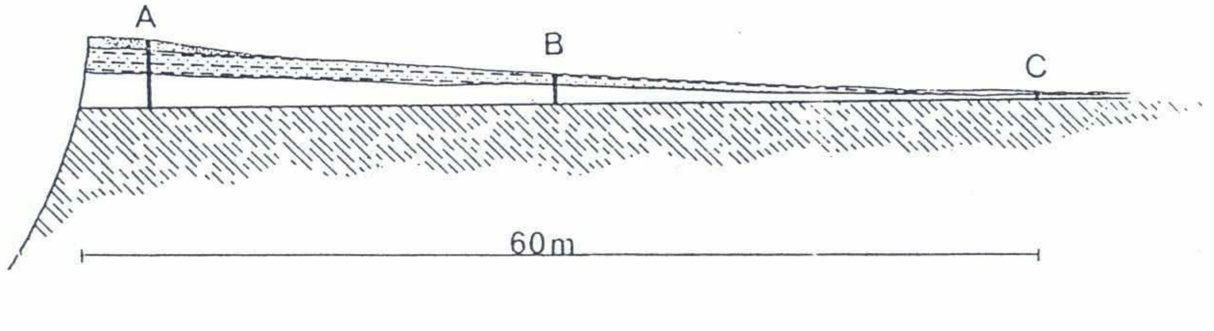

Figure 5.8: Example of sheet-splay deposits with on top an overbank-lobe deposit, after the 1985 flood measured near Sariakandi (Bristow 1987)

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This simple sedimentation pattern is complicated, however, by along-stream variation in the crest level of levees, variation in overbank and spill flow rates and sediment concentrations. The former can result in point-source introductions onto the floodplain that generate crevasse splay deposits and an irregular crest level of the levees, which may change the path that future overland flows take (FAP 19, 1995).

The sedimentation rate as a function of distance to the nearest upstream khal or floodplain river is presented in Figure 5.7. The measured sedimentation rate is defined as the layer thickness per year (Table 5.5). The distance from the khal or floodplain river is measured along flow lines of the overland flow. The flow directions were measured at the sample plots on a particular day. It is assumed that these flow directions did not change during the monsoon. As described earlier, sandy sedimentation in Plots 1 and 3 (which are both near a river) was probably caused by a crevasse splay. The silty sedimentation in the Plots 2, 4, 5, and 6 (which are all further from the floodplain rivers) was caused by "ordinary" overland flow.

The sedimentation rates in the sample plots are compared in Figure 5.7 with the relationship described by Kesel et al. (1974) who analysed floodplain sedimentation near the Mississippi River. The sedimentation rates in the present study are not highly accurate because it includes different sedimentation processes. Despite this inaccuracy, the Sharishabari data still confirms the relation in a qualitative way. The grain size relationship according to Kesel et al. fits fairly well for the deposition of silty sediments (Figure 5.9). In the Sharishabari floodplain the sandy deposits extend probably over a larger distance from the river than in the Mississippi River case study.

Some key data on floodplain sedimentation in a few different floods are compared in Table 5.6. This tables shows that the inundation period, suspended sediment concentration in the river and the inundation depth to less extend are main parameters for the floodplain sedimentation. The data on the Rhine and the Meuse River were presented by Asselman and Middelkoop (1995).

River	Year of flood	inundation period	inundation depth	suspended sed concentration in river	deposition rate levee	deposition rate flood plain
		days	m	mg/l	m	mm
Rhine	1993	2 - 7	0.3 to 2	>150	-	0.2 to 1
Meuse	1993	3	0.6	400	0.0025	0.2 to 1
Mississippi	1973	60	4	-	0.1 to 0.8	5 to 9
Jamuna	1995	40 - 99	2 to 2.8	500 to 600	0.2 to 0.3	1 to 4

Table 5.6 Comparison of different floods in different rivers.

The FAP 19 (ISPAN) floodplain sedimentation study calculated the average annual sediment deposition rate by doing a caesium (^{137}Cs) analysis. The formula (5.1) is a simplified form of the original formula (FAP 19, ISPAN, 1995):

¢D

$$\delta h_{annual} = 0.237 \cdot F_F \cdot F_{87} \cdot X_{dis}^{-1.36} \qquad (5.1)$$

in which
F_{87} = a constant for the 1987 flood, 1 (-)
F_f = flood depth parameter (-)
δh = annual sedimentation rate (mm/year)
where
F_f = 0.5 for F0 inundation depth (MPO classifications are discussed in Table 3.1)
F_f = 1 for F1 and higher (all considered sample plots are in this category)
A minimum δh for the Active and Young Jamuna River floodplain = 3 mm/year.
A minimum δh for the Older Jamuna and Old Brahmaputra Rivers floodplain 1 mm/year.

According to Formula (1) this sedimentation rate is the average deposition of consolidated silty sediments. The sedimentation rates measured during the 1995 flood in Plots 2, 4, 5, and 6 fit rather well with this curve. Some differences should be expected, however, because the 1995 flood had an estimated return period of 15 to 40 years. Therefore, the measured sedimentation rate for an average flood should be higher than the sedimentation rate found from Formula (1). The measured unconsolidated deposition in these plots was also compared with a curve of consolidated sediments from the ^{137}Cs analysis. Consequently, the measured sedimentation rate should be higher than the sedimentation rate calculated using Formula (1). If one takes into account that a part of the initial sedimentation in Plot 5 was eroded again then the higher sedimentation rate is confirmed by the data in Figure 5.10. In other words, the Plot 5 sedimentation rate underestimates the collected sediment samples.

The Virginia Institute of marine Science did some vibro-coring near sample plots 1 and 2 in February 1996. In plot 1 caesium 137 was found up to a depth of 0.75 to 0.80 m. This means an average sedimentation rate of 0.017 m per year over the last 45 years. In plot 2 caesium 137 was found throughout the 1.43 m long core. This indicates that the sedimentation rate was more than 0.033 m per year. These rates are more than the siltation rate of 0.001 to 0.004 m per year found in the sample plots during the 1995 flood. A possible explanation is that these plots are located close to meandering and shifting Shishua and Jharkata rivers. It seems likely that during the last 45 years at least a few times thick sandy depositions had occurred in these plots. These depositions had increased the average sedimentation rate.

The main results can be summarized as follows. The sedimentation rate in the Sharishabari floodplain can be assessed using the FAP 19 formula for the deposition of silt. This formula estimates the sedimentation rate fairly well; however, distance should be measured along flow lines when using this formula.

The results of the small number of samples that were tested show that the Kesel et al. curve of grain diameter is fairly accurate for the silty depositions on the floodplain west of Sharishabari.

Plate 5.4: Sample site no 1, seen from the south,Thick sandy sediment deposits were removed from the field. Formers prepare the field for growing irrigated rice crop on the old top soil. Also seen in the picture sediment samples by the VIMS team doing vibro-coring. (24 January 1996)

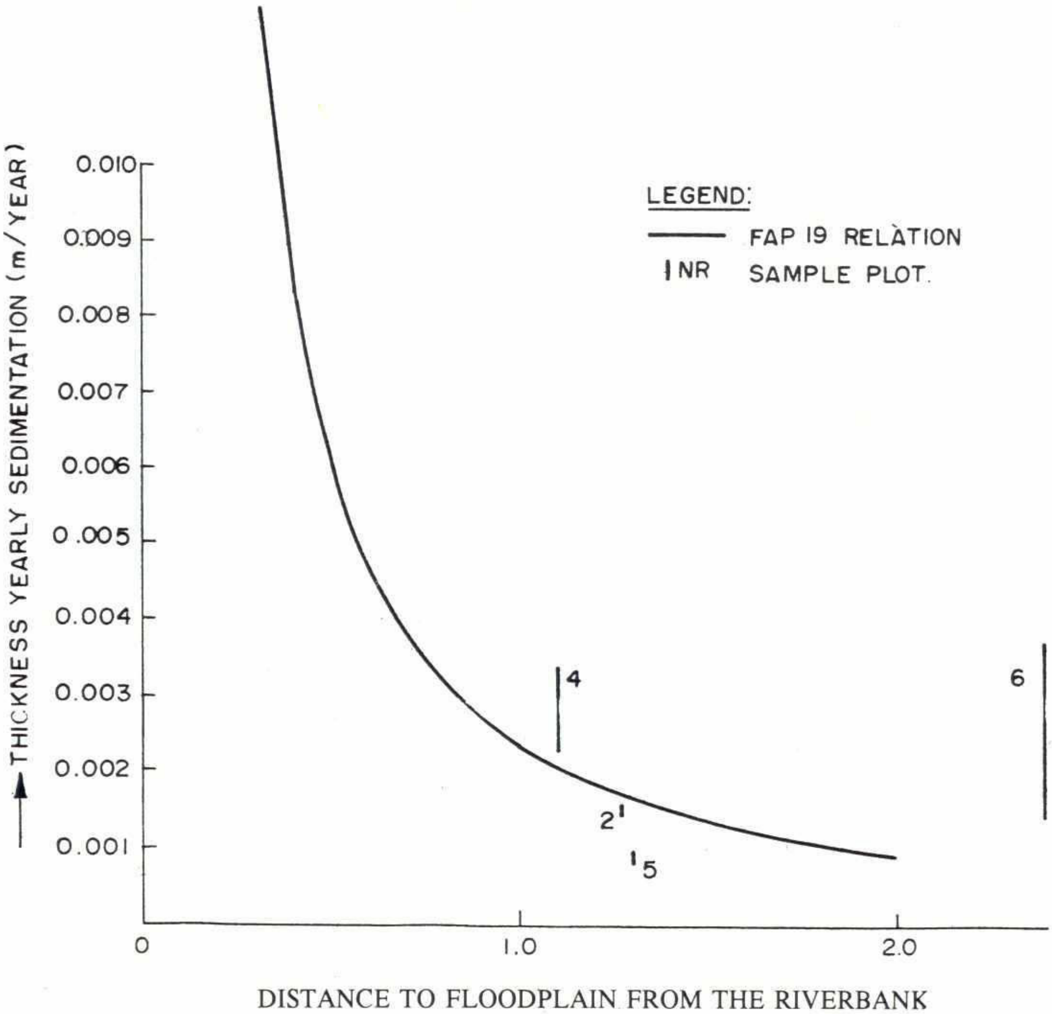

Figure 5.10: Yearly sedimentation rate as function of the distance along a flow line to a flood plain

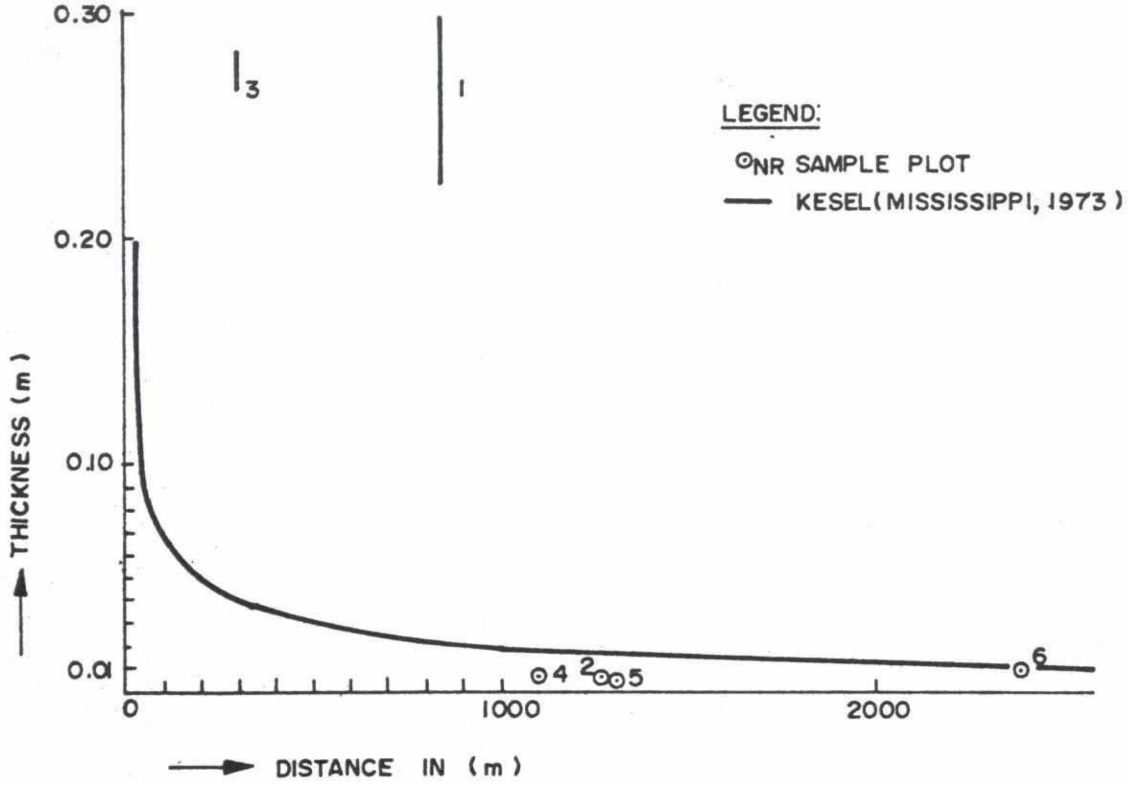

Figure 5.7: Thickness of the deposits as function of the distance to the floodplain river

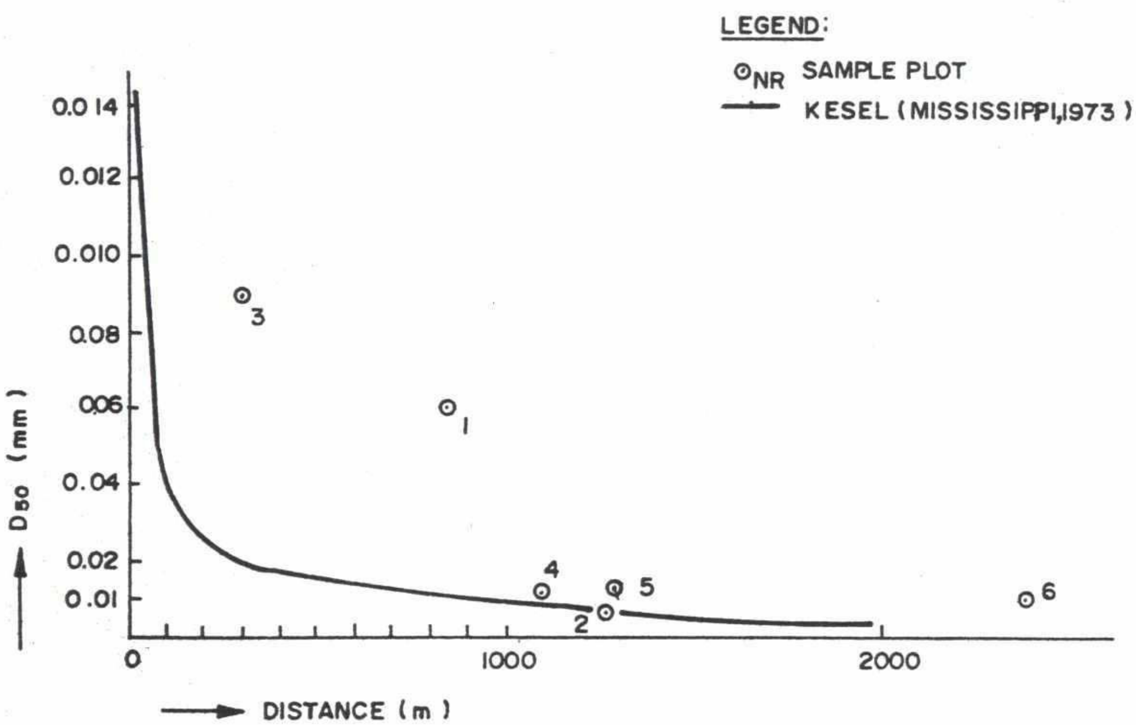

Figure 5.9: D50 as function of the distance to the floodplain river

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5.6 Mineralogical and physical properties of the sediments

From twenty-four samples which were taken from the sediment deposited on the cloths and in the traps the mineralogical composition and grain size distribution were determined. These results were compared with the composition and grain size distribution of sediment samples taken from the Jamuna River near Bahadurabad from May 29th to June 1st 1995. They were compared because it is hypothesised that most of the floodplain sediments originate from the sediments transported by the Jamuna River. The Jamuna samples were taken in the beginning of the monsoon during the rising stage. It is possible that at higher stages the composition of the sediment transport changes slightly. Here the results of the analysis of mineralogical and physical properties of sediment samples are presented briefly and detailed information on this analysis can be found in Special Report 14 "Mineralogical and physical properties of river sediments".

The floodplain grain size distribution showed that on average the sample consisted of 98% silt and 2% fine sand (percentages determined by weight). This silt percentage in the floodplain (98%) was higher than the percentage silt in the suspended sediments of the Jamuna River (70%) and also higher than the average percentage silt in the bed samples of the Jamuna River (1 to 15 %); however, the silt percentage in individual bed samples varied between 0 and 100%.

The average sediment diameter was D_{50} = 0.015 mm for all plots except 1 and 3 which had coarser sand that was deposited from the river banks. The average sediment diameter for all plots on the Jamuna was D_{50} = 0.042 mm.

The percentage of mica in sand and silt fraction was almost the same for the floodplain and Jamuna River samples (Table 5.7).

The concentration of heavy minerals was typically between 1 and 7% in sand and between 10 and 40% in silt. These concentrations are the same in the floodplain and Jamuna River samples (Table 5.7).

The concentration of rock fragments was usually between 2 and 15% of the sand fraction of the floodplain samples. In two samples, however, there was 80% concentration of rock fragments. In the Jamuna River samples the rock fragment percentage was the same as in the floodplain. However, in the silt fraction of the floodplain samples the percentage of rock fragments varied between 3 and 30%. This was higher than the 4 to 13% range found in the river samples (Table 5.7). The rock fragment percentage varies greatly; it seems that some accumulation of the rock fragments occurs in the silt fraction of the floodplain samples.

For both the floodplain and Jamuna River samples the quartz fraction is on average 36 to 44% of the sand fraction. Also, quartz and feldspar are on average 51 to 56% of the silt fraction (Table 5.7).

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	Jamuna River Bahadurabad			Floodplain Sharishabari
	Bed material sample %	Near-bed sample %	Suspended sed. transport sample %	%
Sand fraction				
Quartz	14 - 52	32 - 42	20 - 49	10 - 63
Feldspar	2 - 15	5 - 16	4 - 8	2 - 13
Rock fragments	5 - 37	10 - 21	11 - 17	2 - 84
Mica	6 - 70	15 - 40	23 - 59	2 - 47
Heavy minerals A.	1 - 10	4 - 6	1 - 5	1 - 7
N.O.	1 - 8	2 - 6	1 - 4	1 - 6
B.O.	1 - 7	-	1	-
Carbonates	-	-	-	-
Others	-	-	-	-
Silt fraction				
Quartz	38 - 68	40 - 63	46 - 65	31 - 65
Rock fragments	4 - 13	4 - 11	4 - 7	5 - 28
Mica	4 - 40	4 - 20	6 - 27	4 - 29
Heavy	12 - 42	21 - 39	18 - 28	15 - 37
Minerals	1 - 10	1 - 14	1 - 2	0 - 2
Clay fraction				
Illite	64 - 77	78	72	65 - 74
Kaolinite	23 - 35	22	28	26 - 35
Montmorillonite	-	-	-	-

A. = Amphibole
N.O. = Non opaque
B.O. = Black opaque

Table 5.7 The mineralogical composition of different fractions of the samples from the floodplain and the Jamuna River

The shape factor of the particles from the floodplain is rather constant; they vary from 0.70 to 0.72. These values are lower than in the Jamuna River where shape values of 0.72 to 0.76 were found. This means that the particles on the floodplain tend to be a bit more flaky and irregular in shape than those found in the Jamuna River. Shape factor standard deviations of 0.02 to 0.04 were found. This indicates that the difference in the average value falls within the scatter of the data. In other words, this difference is probably not significant.

The geometric standard deviation of the samples in the Jamuna River and the Sharishabari floodplain varies as indicated in Table 5.8. In general the geometric standard deviation increases with the percentage silt.

location of samples	Geometric standard deviation
river bed Jamuna River	1.3 to 3.0
near bed sediment transport in Jamuna River	1.5 to 1.8
suspended sediment transport in Jamuna River	2.2 to 3.3
plots 1 and 3	1.6 to 2.2
plots 2, 4, 5 and 6	2.4 to 3.0

Table 5.8 Geometric standard deviation of samples in the Jamuna River and in the floodplain

This shows that, in general, sandy sediments are more uniform, and silty sediments in suspended transport have a wider gradation. In the floodplain, Plots 1 and 3 have a geometric standard deviation from 1.6 to 2.2. Some silty floodplain samples have a wider gradation of 2.4 to 3.0 which is similar to the suspended sediments of the Jamuna River.

The results that there are similar concentrations of mica, heavy minerals, quartz, insignificant differences in shape factor and only a slight difference in the percentages of rock fragments, confirm the hypothesis that the suspended sediment transport in the Jamuna River delivers most of the floodplain sediments.

Approximately 40 to 50% silt was found in the Plot 1 samples. Only 15% silt was found in the upper layer of sediment in Plot 3. The D_{50} of those coarser sediments was between 0.060 and 0.100 mm which is smaller than the D_{50} in the Jamuna River bed. It is possible that the fine fractions in the floodplain river bed sediments were gradually washed out. Therefore, the sediments in the bed and in the levees of those floodplain rivers have a coarser grain size distribution than the other sample plots.
Mica has a low density, thus the concentration of mica in Plots 1 and 3 was lower than in the other plots (Table 5.9).

Fraction of sample	Mica concentration in weight percentages	
	Sample plots 1 and 3	Other sample plots
- sand fraction	15 to 33	10 to 47
- silt fraction	5 to 11	4 to 30

Table 5.9 Mica concentration in floodplain samples.

6 Discussion

Some selected issues related to overland flow and the floodplain sedimentation presented in the previous chapters are discussed in more detail in the present chapter.

Floodplain sedimentation and subsidence

Existing data suggest that a significant percentage of the sediment discharge of the rivers in Bangladesh is being trapped on the delta plain by subsidence and net aggradation. During the annual monsoonal floods, turbid river water inundates floodplain areas proximal to the channel, displacing a significant fraction of the population. Milliman and Syvitski (1992) suggest that 40 to 80% of the total sediment load accumulates as silt and clay deposits in the floodplain and lower (tidal) delta plain, supplemented by sandy crevasse deposits adjacent to the river channels (Coleman, 1969). This estimate was based on 1 to 2 cm y^{-1} subsidence (tectonic and sediment compaction) rates averaged from observations of buried forests and river terraces (Yount, 1990). Regional subsidence patterns are surmised to be controlled primarily by underlying tectonic features (fault traces) that also direct the long-term (10s to 100s of years) lateral migration of river channels in the Ganges-Brahmaputra delta (Eysink, 1983). The westward migration and recent (< 200 y BP) avulsion of the Jamuna course and eastward migration of the Lower Meghna are evidence that subsidence may be of considerable influence. The continued lowering of beel areas, such as the Sylhet depression and Gopalganj peat basin, suggests spatial inequities in sedimentation exist such that subsidence is not always balanced by input of sediment.

Previous studies of the Bengal Shelf (Kuehl and Allison, in prep.; Kuehl et al., 1989; Segall and Kuehl, 1992) and the associated submarine canyon (e.g., Swatch of No Ground) suggest that questions of sedimentation and subsidence in the floodplain should be approached by direct measurement of sedimentation rates on short and long time scales. These studies should utilise radiotracers coupled with investigations of seismic stratigraphy. Mass budget calculations resulting from these shelf studies have delineated the percentage of river discharge reaching offshore areas. These figures support the aforementioned hypothesis that more than 50% of the total sediment budget is trapped landward of the Bangladesh shoreline. Subsidence rates can be extrapolated from long-term sedimentation data, as well as by independent means. A more extensive review of the literature on floodplain sedimentation can be found in "Sedimentation in the Brahmaputra-Jamuna Floodplain" (FAP 19, 1995).

While the existing data indicate that a significant proportion of the sediment load of Bangladesh rivers is sequestered in the delta plain by subsidence, quantitative information about regional patterns, mechanisms, and an overall budget does not exist. This information is vital for gauging the effects of proposed flood control embankments on floodplain agriculture, land subsidence and groundwater recharge, river migration and avulsion, and marine invasion.

Local rainfall

The influence of local rainfall on the overland flow was approximated from daily rainfall data. These data were collected at the hydrometric station in Jamalpur. The average annual rainfall was about 1800 mm in Sharishabari and 2200 mm in Jamalpur. In Jamalpur the average rainfall in June, July, and August was approximately 400 mm per month, and in September it was 300 mm. In this area the evapotranspiration was estimated at approximately 150 mm/month (FAP 3, 1993). If the groundwater recharge is excluded then an average discharge of about 60 m^3/s leaves the catchment area west of the line Jamalpur - Sharishabari. This is rather small, however, when compared with the measured discharges in the floodplain rivers. Almost all of the water in the floodplain originates from the Jamuna River.

One can imagine that the water level in the overland flow rises slightly quicker if the depressions in the floodplain were already filled with rain water. This means that the hydraulic resistance in the overland flow reduces due to local rainfall. Another effect of rainfall is that the sedimentation due to overland flow in these depressions is less compared with dry depressions, which will be filled completely with turbid river water, as pointed out by Narinesingh (1995).
In special situations the rainfall can erode fresh depositions to level differences in elevations of the depositions. This phenomenon was observed near some of the sample plots in the study area in the period between the complete drainage of the flood water and the collection of the sediment sample. The present study does not consider these possible effects of rainfall. Therefore it is recommended to study these effects on the Jamuna floodplain sedimentation more in detail.

Comparison of sedimentation in different devices.

A comparison of the sedimentation thickness and rates of the samples taken from cloths or brick-dust layers and traps shows that the measurements differ by less than 10% with the exception of Plots 4 and 6. In Plot 6 the flow velocity in the overland flow was measured 0.57 m/s on August 18th and this velocity is probably sufficient to erode the sediment that was deposited; therefore, sediment samples from the cloths and brick dust layers had somewhat less sediment than the samples from the traps. Another effect contributing to the explanation for this finding is that the cloths did not have covers during the periods without overland flow. In those periods rainfall may have eroded topsoil from the adjacent elevated sites where sediments were deposited earlier. The surface wash could then be deposited on the cloths while the traps were covered. Consideration should be given to covering the cloths in the same way that the traps were covered.

The scatter in the measured sedimentation rate

In the study area the floodplain sedimentation rate was not uniform. Even within the plots, the sedimentation layer thickness was uneven. The bamboo fences with matting that were placed around the sample plots could have disturbed sedimentation. The results show that the three similar devices in a sample plot were necessary to eliminate scatter in the results of any individual device. Asselman and Middelkoop (1995) measured floodplain sedimentation in a small floodplains (area less than 0.5 square kilometre) along the Rhine and Meuse Rivers. They used artificial grass mats of 50 x 50 cm.

These traps were placed in a semi-regular grid consisting of several transects and a few clusters. The spacing between the transects was about 100 m. The sample spacing in the transects was about 50 m. Within a cluster the spacing between the traps varied between 1 and 10 m. To determine the total amount of sediment deposited on the floodplain they used kriging as a spatial interpolation method. Kriging is a form of weighted local averaging. It is recommended to consider such an approach for future floodplain sedimentation measurements in Bangladesh.

7 Conclusions and recommendations

This study of overland flow and floodplain sedimentation west of Sharishabari on the Jamuna floodplain during the 1995 monsoon has resulted in the following conclusions and recommendations.

Conclusions:

- The measured inundation depths ranged from 1.8 to 3.0 m in the second peak flow, 0.7 m to 2 m in the third peak flow, and 0.7 to 1.25 m in the fourth peak flow. The monsoon had a total of 4 distinct peak flows. In the floodplain west of Sharishabari the peak levels were reached 0.5 to 1.5 days after the peak levels of the Jamuna River near Bahadurabad.

- The flow velocities observed in the floodplain ranged from 0.2 to 0.6 m/s. During peak flows in the adjacent floodplain rivers the velocities were approximately 1 m/s, and in the Jamuna River they were between 2 and 3 m/s.

- The maximum flow through the culverts in the railway between Jamalpur and Melandaha was approximately 500 m^3/s during the second peak flow of the 1995 monsoon.

- The water balance of the area west of Sharishabari shows that in the second flood peak of the 1995 monsoon, when the water level was at its high point, the maximum discharge flowing downstream the Jamuna River as overland flow was only about 4100 m^3/s. This is small compared to the maximum discharge of the Jamuna River (about 85,000 m^3/s). The maximum overland flow can roughly be divided into two parts: 2600 m^3/s spill flow through Old Brahmaputra River and Chatal River, and 1500 m^3/s overbank flow through the Adra and Sataria Rivers. The maximum discharge measured in Mymensingh on the Old Brahmaputra River was only 1500 m^3/s compared with 4800 m^3/s in the extreme 1988 flood. This might indicate a continued deterioration of the Old Brahmaputra River.

- The suspended sediment concentration was measured after the second peak flow. This concentration decreases proportionally with distance to the Jamuna River. The concentration wash load or silt decreases from 500 to 600 mg/l in the Jamuna River to 10 to 20 mg/l in the overland flow passing through the sample plots. Similarly, the concentration of sand reduces from 100 to 300 mg/l in the Jamuna River to 0 to 2 mg/l in the overland flow passing through the sample plots. These measurements indicate that more than 90% of the sediments in the spill flow will deposit. In the overbank flow, however, this percentage will be much lower for silt and clay.

- Along the smaller floodplain rivers the levees have a maximum height of 1 m above the adjacent floodplain. In the floodplain west of Sharishabari, especially downstream from the active migrating meander bends in the Shishua and Jharkata Rivers, crevasse splay flows occasionally occur during extreme floods. A phenomenon similar to a crevasse splay occurs if a breach develops in the levee of a road; sediments from a local scour hole are eroded and the coarse fraction is splayed over the floodplain.

- The sedimentation rate in the Sharishabari floodplain can be fairly estimated by the FAP 19 formula. However, the distance parameter in this formula must be measured along flow lines. The FAP 19 formula is more valid for consolidated sedimentation than for the fresh, unconsolidated sedimentation that was measured in this RSP study. In addition, the FAP 19 formula gives an average sedimentation rate over a longer period, and the 1995 monsoon had a higher than average sedimentation rate.

- The results of the small number of samples that were tested show that the Mississippi curve of grain diameter is fairly accurate for the silty depositions on the floodplain.

- A comparison of the sedimentation thickness and rates for the samples taken from cloths and traps shows that the measurements differ by less than 10%. Therefore it is concluded that traps and cloth devices measure sedimentation equally well.

- Mineralogical and physical properties of selected sediment samples from the floodplain and the Jamuna River show that these properties are almost similar. This indicates that the majority of the floodplain sediment originates in the Jamuna River.

Recommendations:

- Consideration should be given to covering the cloths in the same way that the traps were covered and also to collecting samples after each peak flow.

- The effect of the rainfall on floodplain sedimentation was not studied in detail. It is recommended to carry out such a study in future.

- In future studies it should be considered to place only one type of sedimentation devices in a dense regular grid to make a fair estimate of the total sedimentation volume in the floodplain. In the floodplain rivers the sediment transport should be measured at different stages to prepare a sediment rating curves. With these measurements a sediment balance can be made for the considered floodplain area.

- The study was conducted in only one area of the Jamuna floodplain. Similar studies should be conducted in other major floodplains. These studies will contribute to the knowledge of overland flow and floodplain sedimentation processes in Bangladesh.

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Plate 5.5 Sample site no 3, Sediment samples were collected by vibro coring (VIMS team). 24 January 1996

ANNEXURE 1

OVERLAND FLOW SURVEYS

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Contents

List of Figures

1 Introduction

A short description of the measurements of each site is presented in chronological order. Descriptions of measurements in the first survey (Section 2) are followed by descriptions of measurements in the second and third surveys (Sections 3 and 4 respectively).

2 First overland flow survey

In the first overland flow survey, cross-sections S1 through S4 were surveyed from July 12th through the 15th. At this time the water levels had just started to recede in the second peak flow. A description of each cross-section survey follows.

12/07/95 (Site S1)

It was difficult to reach the measuring site under the railway bridge because the water level was near the top of the pillar. In order to pass under the bridge so that the measuring site could be reached, the bamboo shed on the boat was dismantled. The transect position was fixed using a rope connected to bamboo pegs on each bank. The water depth was measured in 10 m intervals using a lead line. The width of the transect was 110 m. Velocity measurements were taken using the float tracking method. They were taken in three verticals that were located at 1/4, 1/2, and 3/4 of the total width of the river. At each measuring point in a vertical either 3 or 4 readings were taken. Suspended sediment samples were collected at each vertical just below the water surface. The minimum and maximum depth averaged flow velocities were 0.70 m/s and 0.74 m/s respectively. The maximum water depth was 6 m. The direction of flow was observed to be from north to south.

13/07/95 (Site S2)

Almost the entire area on the way to Melandaha was inundated by floods. Sadhupur Khal crosses under a railway line through a culvert near Sadhupur village. Because the area was flooded, it was difficult to identify the bank line of the khal. Local people were asked about the location of the bank line. The transect was located on Sadhupur Khal which is a minor distributary of the Old Brahmaputra River. The width of the khal was 110 m. The flow velocities were measured by float tracking, and suspended sediment samples were taken. These measurements and samples were taken along the three verticals of this transect, see Figure A1-1. The minimum and maximum depth averaged flow velocities were 0.30 m/s and 0.46 m/s respectively. The maximum depth was 7 m. The direction of flow was observed to be from north to south.

14/07/95 (Site S3)

The transect S3 was located approximately 500 m west of the Bousi Baily Bridge on the Jhenai River in Kamrabad Union, Sharishabari Thana. The width of the transect was 65 m. The flow velocity profiles and sediment samples were taken in three verticals, see Figure A1-2. The minimum and maximum depth averaged flow velocities were 0.80 m/s and 0.96 m/s respectively. The maximum depth was 7 m. The direction of flow was observed to be from west to east.

yl

15/07/95 (Site S4)

The transect S4 was located approximately 2 km north-west of Jhalapara ferry ghat on the Shishua River in Sharishabari Thana (near sediment Plot 24, following the FAP 19 numbering system). The width of the transect was 120 m. The flow velocity profiles and suspended sediment samples were taken near the water surface in three verticals, see Figure A1-3. The minimum and maximum depth averaged flow velocities were 0.93 m/s and 1.2 m/s respectively. The maximum depth was 6.6 m. The direction of flow was observed to be from north to south.

3 Second overland flow survey

In the second overland flow survey, cross-sections S5 through S10 were surveyed from July 20th through the 24th. This time was during the receding limb of the second peak flow. A description of each cross-section survey follows.

20.07.95 (Site S5)

Transect S5 was located 500 m north east of Jhalopara ferry ghat on the Jharkata River. This location is approximately 750 m upstream from sediment Plot 1 near Bhurarbari. The water depth was measured in 10 m intervals using a lead line. The width of the transect was 140 m. Velocity measurements were taken using the float tracking method. They were taken in three verticals that were located at 1/4, 1/2, and 3/4 of the total width of the river. At each measuring point in a vertical 3 readings were taken. Suspended sediment samples were collected at each vertical just below the water surface. The minimum and maximum depth averaged flow velocities were 0.76 m/s and 1.31 m/s respectively, see Figure A1-4. The maximum water depth was 10.4 m. The direction of flow was observed to be from north to south.

21.07.95 (Site S6)

Transect S6 was located 500 m downstream from Site 4 on the Shishua River, a branch of the Jamuna River. This location is 1500 m upstream from the sediment trap number 16. The flow velocity profiles and suspended sediment samples were taken in three verticals, see Figure A1-5. The minimum and maximum depth averaged flow velocities were 0.77 m/s and 1.18 m/s respectively. The maximum depth was 7.4 m. The direction of flow was observed to be from north to south.

22.07.95 (S7 and S8)

Transect S7 was located on the Shishua River. The width of the transect was 110 m. Velocity profiles and sediment samples were taken in three verticals on the transect, see Figure A1-6. The minimum and maximum depth averaged flow velocities were 0.32 m/s and 0.5 m/s respectively. The maximum depth was 3 m. The flow direction was observed to be from south-west to north-east.

S8 was located on Kumuriabari canal, a branch of the Jamuna River, in Kazipur Thana, Sirajganj. This location is approximately 750 m upstream from Sample Plot 5. Kumuriabari canal was 70 m wide. Flow velocity profiles and sediment samples were taken, see Figure A1-7. The minimum and maximum depth averaged flow velocities were 0.55 m/s and 1.04 m/s respectively. The maximum depth was 2.4 m. The flow direction was north to south.

23.07.95 (Site S9)

Transect S9 was located on the Adra River in Adra village. The width of the transect was 90 m. Velocity profiles and sediment samples were taken in three verticals, see Figure A1-8. The minimum and maximum depth averaged flow velocities were 0.68 m/s and 0.89 m/s respectively. The maximum depth was 3 m. The flow direction was north to south.

24.07.95 (Site S10)

S10 was located in the middle of Char Barbari and Bir Barbari on the Jhenai River. The width of the transect was 135 m. The flow velocity profiles and sediment samples were taken in three verticals, see Figure A1-9. The minimum and maximum depth averaged flow velocities were 1.05 m/s and 1.10 m/s respectively. The maximum depth was 5.4 m. The flow direction was east to west.

During the second overland flow, there was no flow observed passing the railway culverts in the track between Jamalpur and Melandaha. This site was flooded. Navigation was possible on all the measuring transects except for the one on Sadhupur Khal.

4 Third overland flow survey

In the third overland flow survey, cross-sections S11 through S20 were surveyed from August 20th through the 22nd. At this time the water levels had just started to recede in the second peak flow. A description of each cross-section survey follows.

19-20.08.95 (Transects T1-T10 and S14)

The water depths and flow velocities were measured along an east to west transect at 24°45′ latitude. In order to measure discharge, three verticals on the river and one on the flood plain were located. Three flow velocity readings were taken at each point on the verticals. Sediment samples were taken from the water surface at each vertical. Sites S11 through S20 were river crossings and sites T1 through T10 were on the flood plain. Measurements were first taken on the flood plain and then they were taken on the rivers, see Figure A1-10. The first measurements were taken at Bhurarbari (T1) which is 300 m from the left bank of the Jharkata River. The water depth was 2 m and the flow velocity was 0.067 m/s. The transect bearing was 90° and the flow direction bearing was 180° (both bearings were relative to the north). After these measurements were taken the surveyors proceeded to S11 at the crossing of the Jharkata River.

Measurements were then taken 500 m west of the right bank of the Jharkata River on Dasherbari Char (T2). The water depth was 2 m and the flow velocity was 0.74 m/s. The flow direction was 160° relative to the north.

T3 was located 500 m west of T2 on Dasherbari Char. The water depth was 1.2 m and the flow velocity was 0.103 m/s. The flow direction was 180°.

T4 was located 500 m west of T3 on Darerbari Char. The water depth was 0.60 m and the flow velocity was 0.32 m/s. The flow direction was 121°.

T5 was located 500 m west of T4 on Sharishabari Char. The water depth was 0.90 m and the flow velocity was 0.17 m/s. The flow direction was 180°.

T6 was located 500 m west of T5 on Sharishabari Char. The water depth was 0.80 m and the flow velocity was 0.27 m/s. The flow direction was 120°.

The surveyors then crossed the Shishua River at S13.

T7 was located 500 m west S13 at Kumuriabari. This location is 100 m west of the right bank of the Adra River. The water depth was 0.80 m and the flow velocity was 0.48 m/s. The flow direction was 180°

T8 was located 550 m west of T7 at Kumuriabari. The water depth was 0.60 m and the flow velocity was 0.21 m/s. The flow direction was 164°.

T9 was located 450 m west of T8 at Kumuriabari. The water depth was 1.5 m and the flow velocity was 0.56 m/s. The flow direction was 147°.

T10 was located 500 m west of T9 at Salgram. The water depth was 0.90 m and the flow velocity was 0.23 m/s. The flow direction was 142°.

The surveyors proceeded along the transect to Kumuriabari channel (S14) which is in Kazipur Thana. The width of the cross section was 75 m. Depths were measured in 20 m intervals using a lead line. Three verticals were selected in the cross section; at each vertical the flow velocity was measured using a Valeport current meter. Suspended sediment samples were also collected just below the water surface. The maximum water depth was 2.8 m. The minimum and maximum surface flow velocities were 0.72 m/s and 1.10 m/s respectively.

21.08.95 (S11-S13, S15-S16)

On August 21st, measurements were taken on Baghmara Char which is on the Jharkata River (S11). The width of the transect was 130 m. The maximum water depth was 9.3 m. The minimum and maximum surface flow velocities were 0.91 m/s and 1.08 m/s respectively. The flow direction was 166°.

S12 was located on Shishua Char which is on the Shishua River. The transect bearing was 90° and the flow direction bearing was 190°_(both bearings were relative to the north). The width of the transect was 120 m. The maximum water depth was 6.3 m. The minimum and maximum surface flow velocities were 0.85 m/s and 1.05 m/s respectively.

S13 was also located on Shishua Char on the Shishua River. The transect bearing was 90° and the flow direction bearing was 45°. The width of the transect was 115 m. The maximum water depth was 3.8 m. The minimum and maximum surface flow velocities were 0.14 m/s and 0.24 m/s respectively.

S15 was located at Rakkalgacha on the Adra River. The transect bearing was 70° and the flow direction bearing was 180°. The width of the transect was 80 m. The maximum water depth was 4 m. The minimum and maximum surface flow velocities were 0.53 m/s and 0.76 m/s respectively, see Figure A1-11.

S16 was located at Sataria on the Sataria River. The transect bearing was 90° and the flow direction bearing was 170°. The width of the transect was 100 m. The maximum water depth was 8.5 m. The minimum and maximum surface flow velocities were 0.57 m/s and 0.77 m/s respectively.

22.08.95 (S17–S20)

On August 22nd, measurements were taken on Bir Bar-bari Char which is on the Jhenai River (S17). The width of the transect was 120 m. The transect bearing was 160° and the flow direction bearing was 260°. The maximum water depth was 6.5 m. The minimum and maximum surface flow velocities were 0.63 m/s and 0.88 m/s respectively, see Figure A1-12.

S18 was located at the Bousi Railway Bridge on the Jhenai River. The transect bearing was 60° and the flow direction was 140°. The width of the transect was 40 m. The maximum water depth was 8.8 m. The minimum and maximum surface flow velocities were 0.35 m/s and 0.49 m/s respectively.

S19 was located on Vatiani Char which is on the Jharkata River. The transect bearing was 40° and the flow direction was 140°. The width of the transect was 120 m. The maximum water depth was 4.8 m. The minimum and maximum surface flow velocities were 0.50 m/s and 0.71 m/s respectively.

S20 was located on Haripur Char which is on the Jhenai River. The transect bearing was 100° and the flow direction was 180°. The width of the transect was 80 m. The maximum water depth was 10.1 m. The minimum and maximum surface flow velocities were 0.26 m/s and 0.44 m/s respectively.

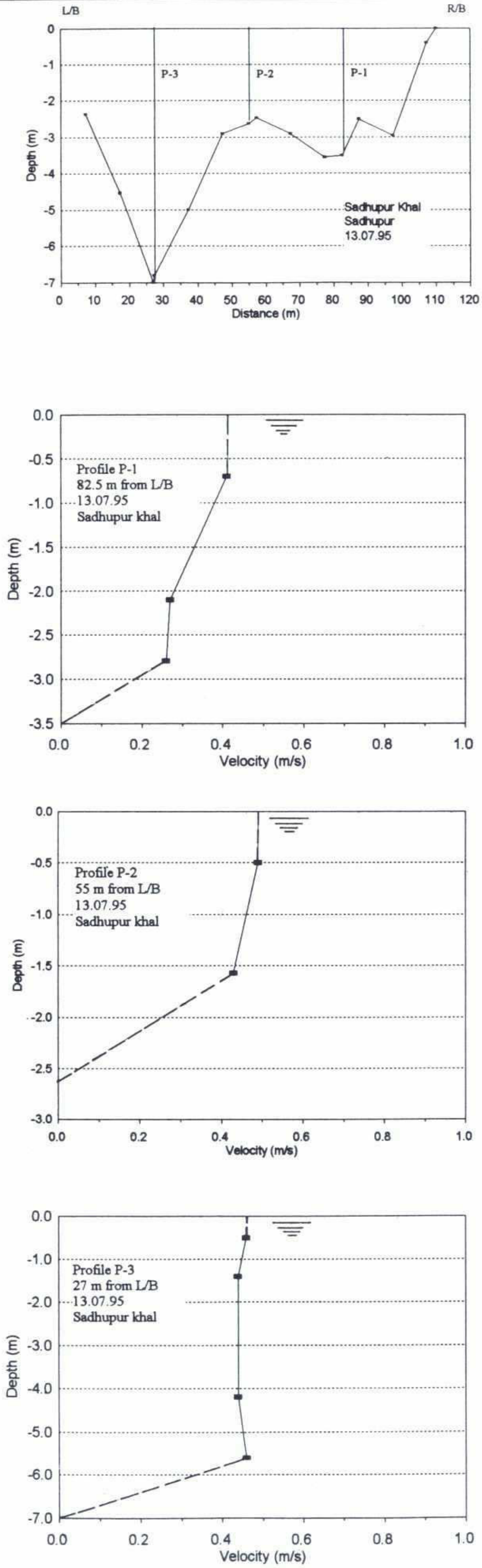

Figure A1-1: Cross-section and velocity profiles, Site 2

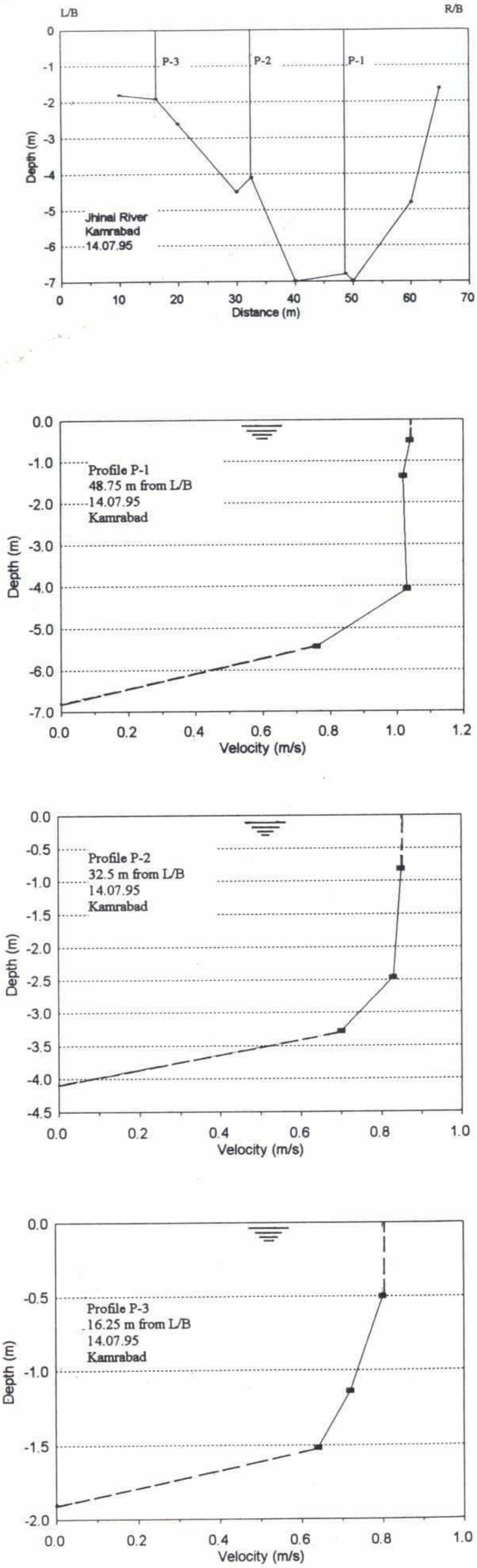

Figure A1-2: Cross-section and velocity profiles, Site 3

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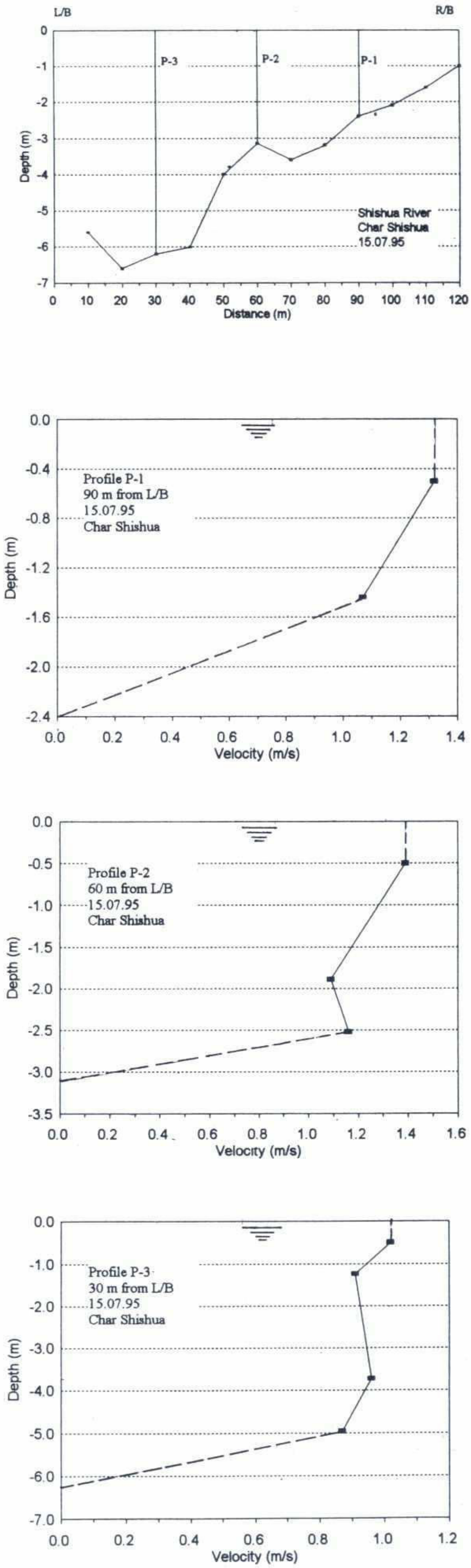

Figure A1-3: Cross-section and velocity profiles, Site 4

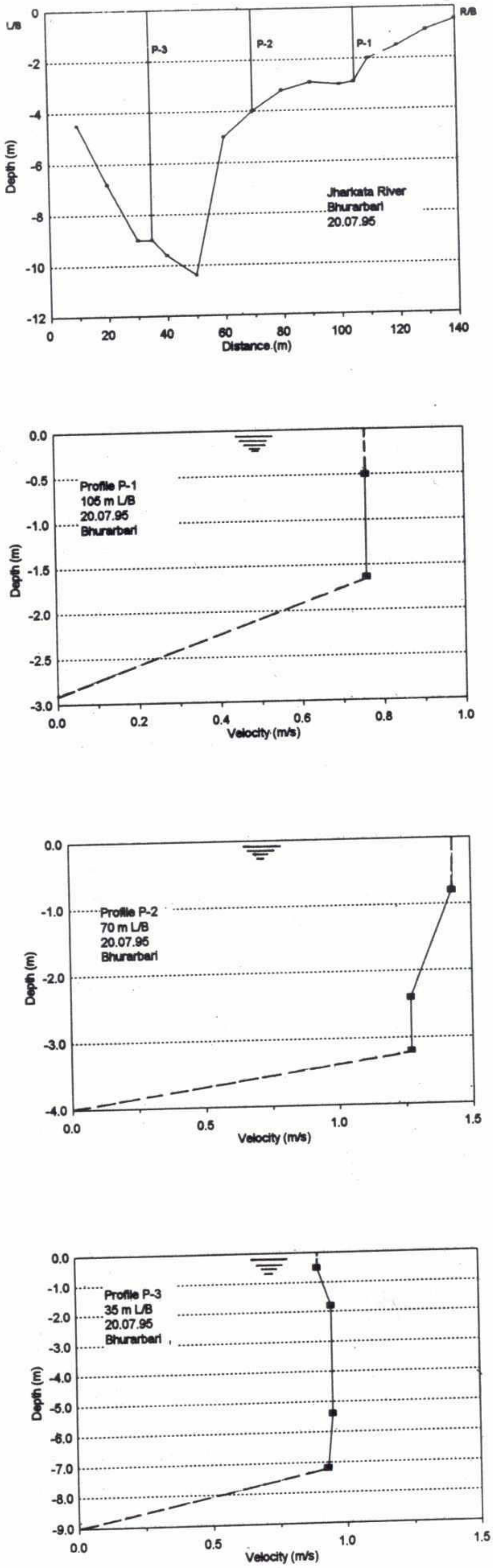

Figure A1-4: Cross-section and velocity profiles, Site 5

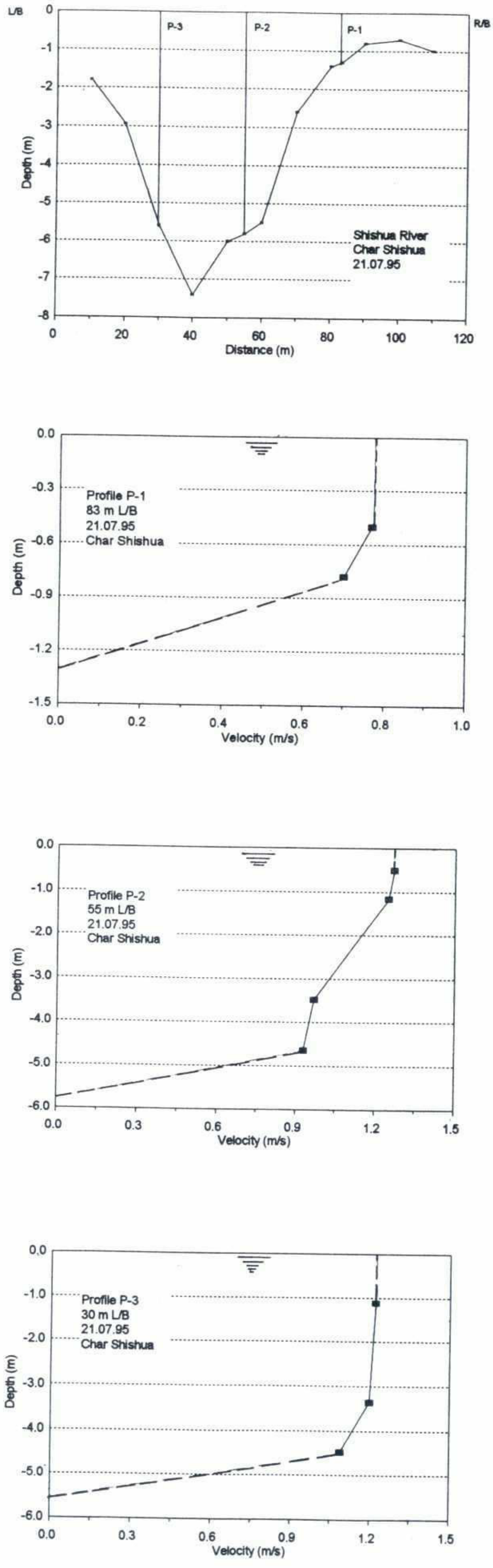

Figure A1-5: Cross-section and velocity profiles, Site 6

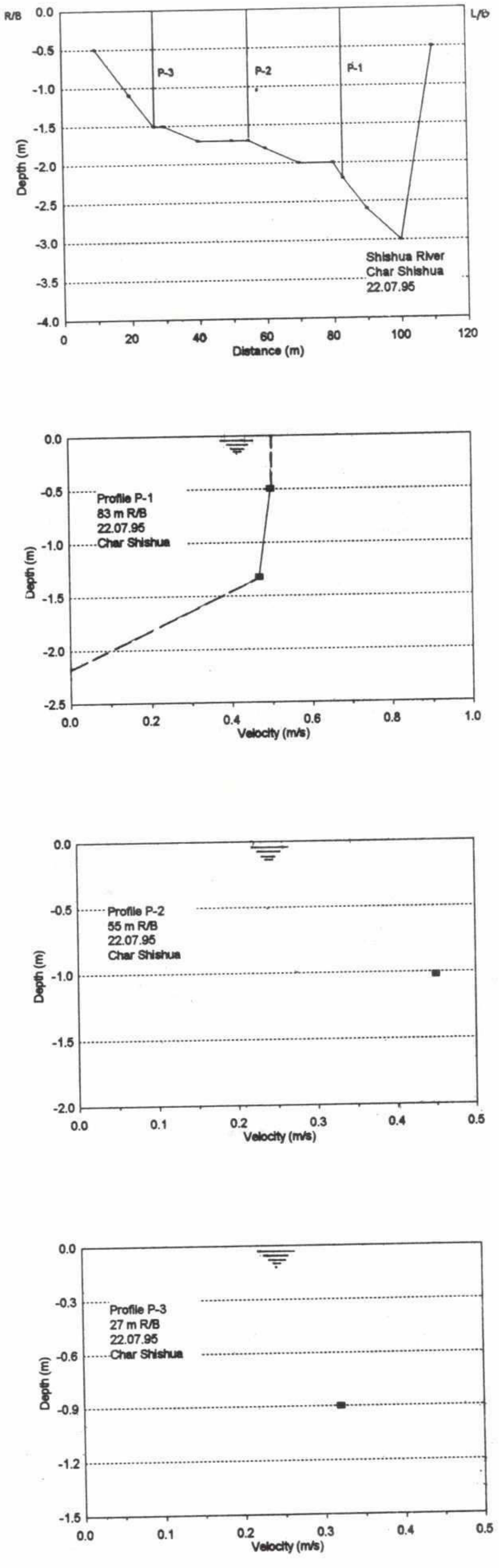

Figure A1-6: Cross-section and velocity profiles, Site 7

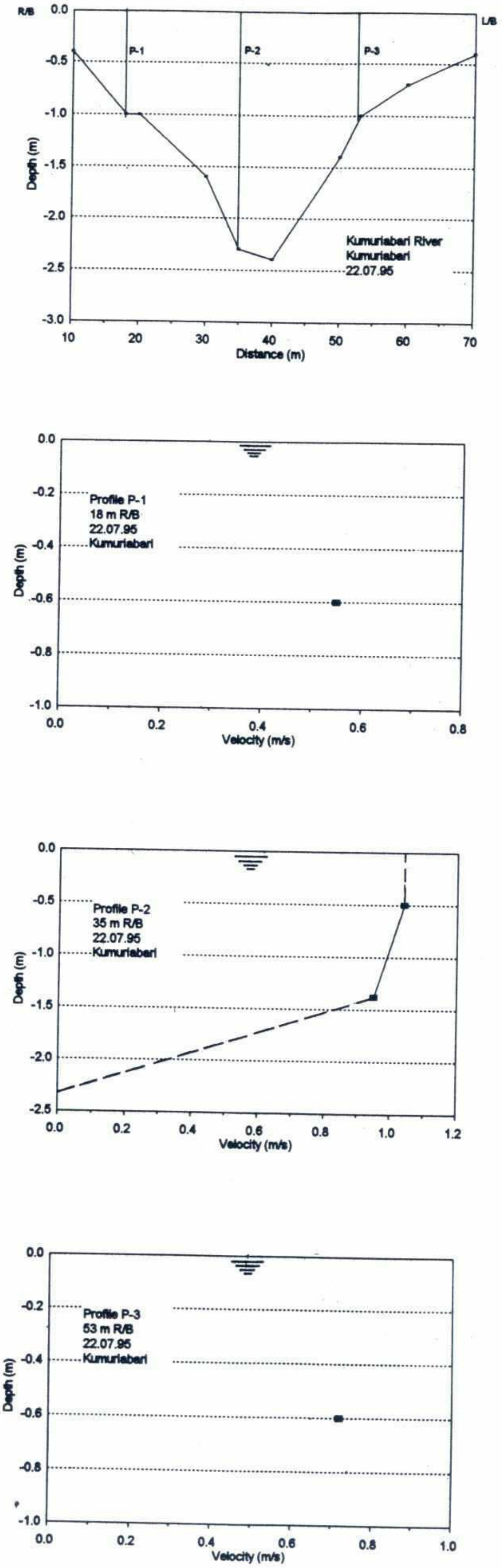

Figure A1-7: Cross-section and velocity profiles, Site 8

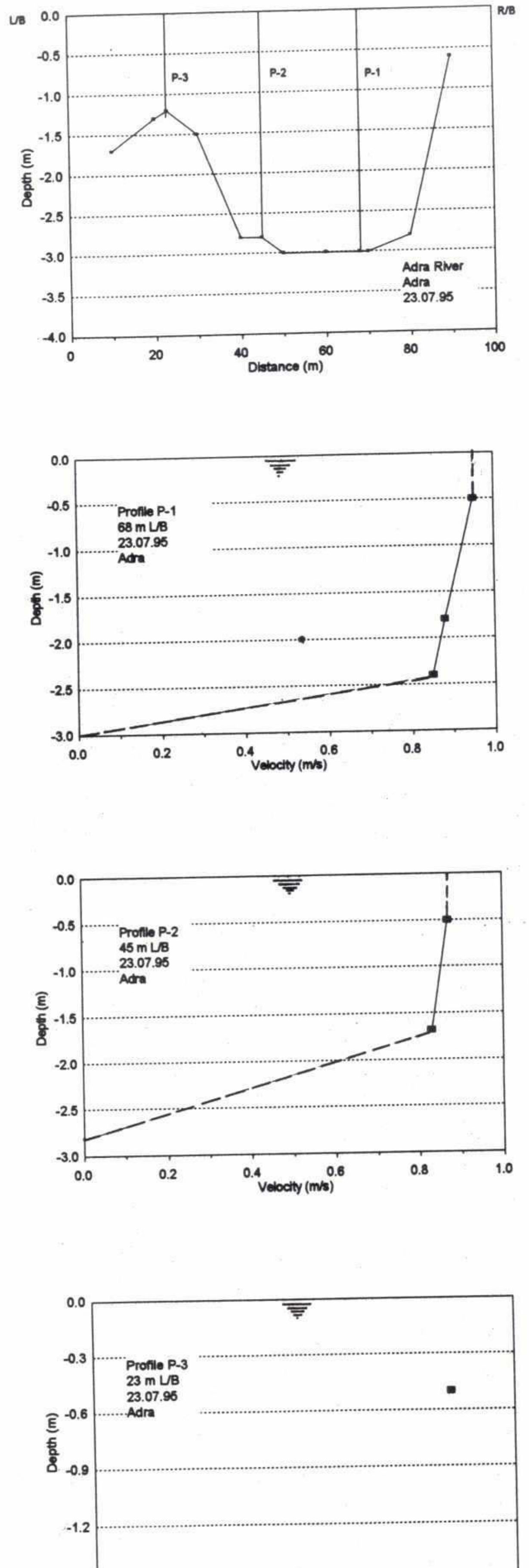

Figure A1-8: Cross-section and velocity profiles, Site 9

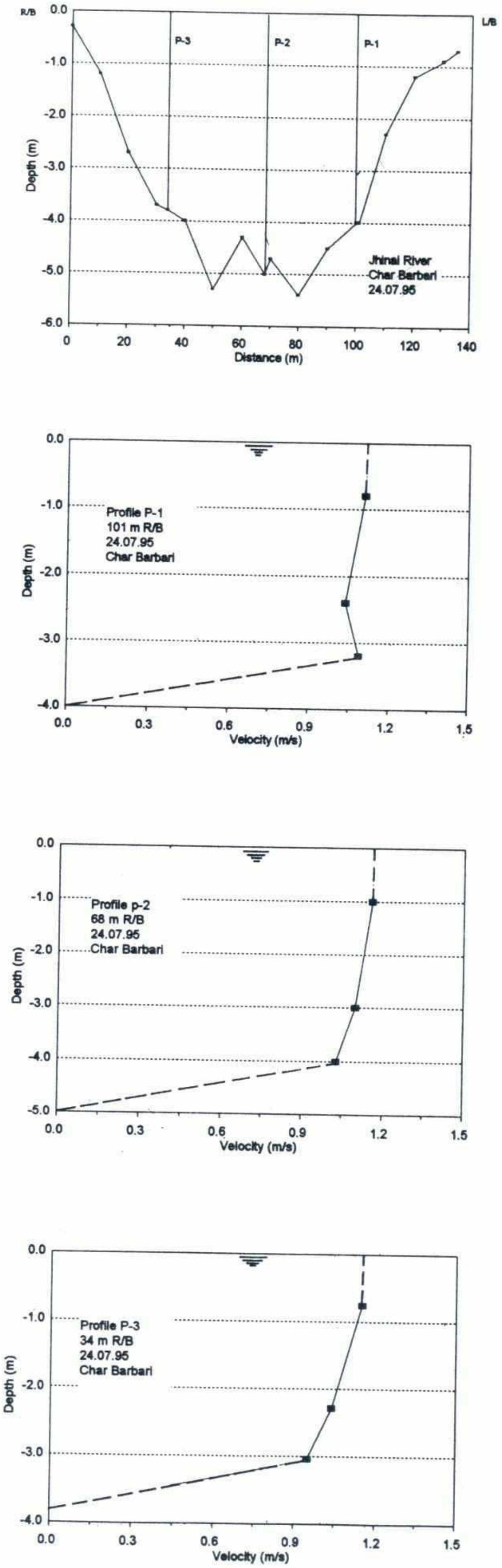

Figure A1-9: Cross-section and velocity profiles, Site 10

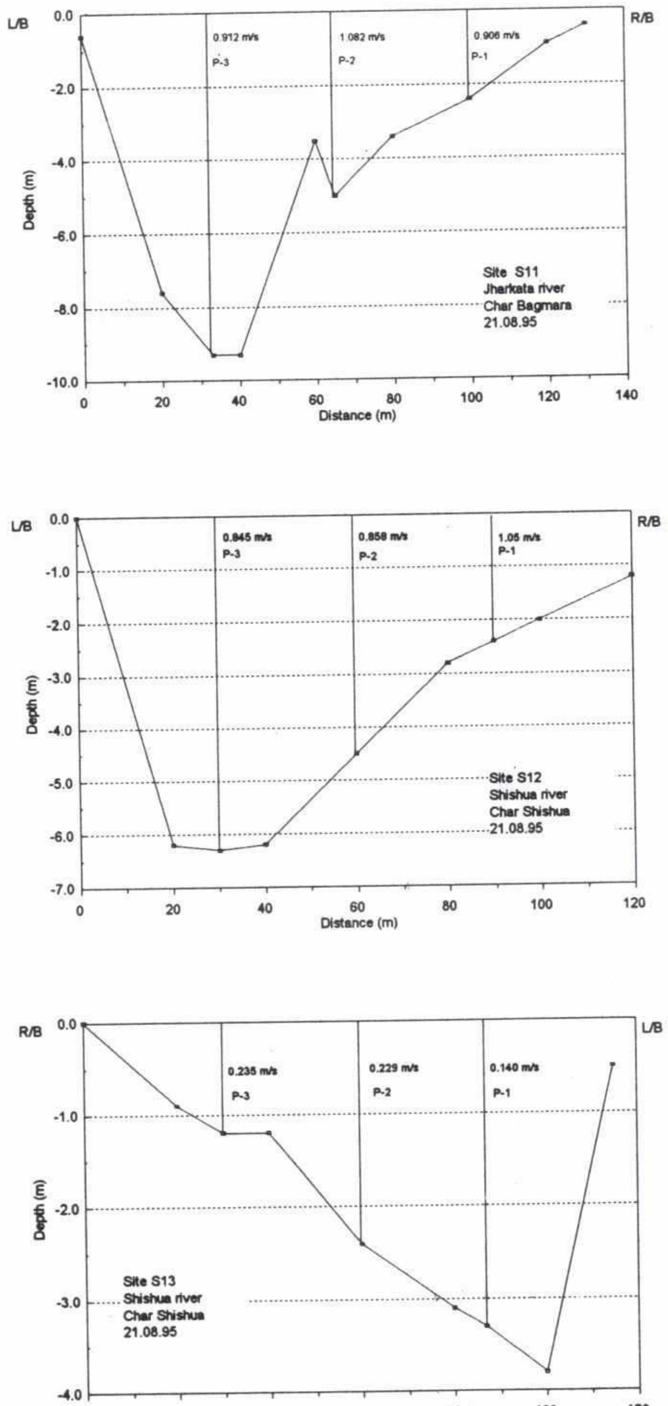

Figure A1-10: Cross-section profiles, S11 to S13

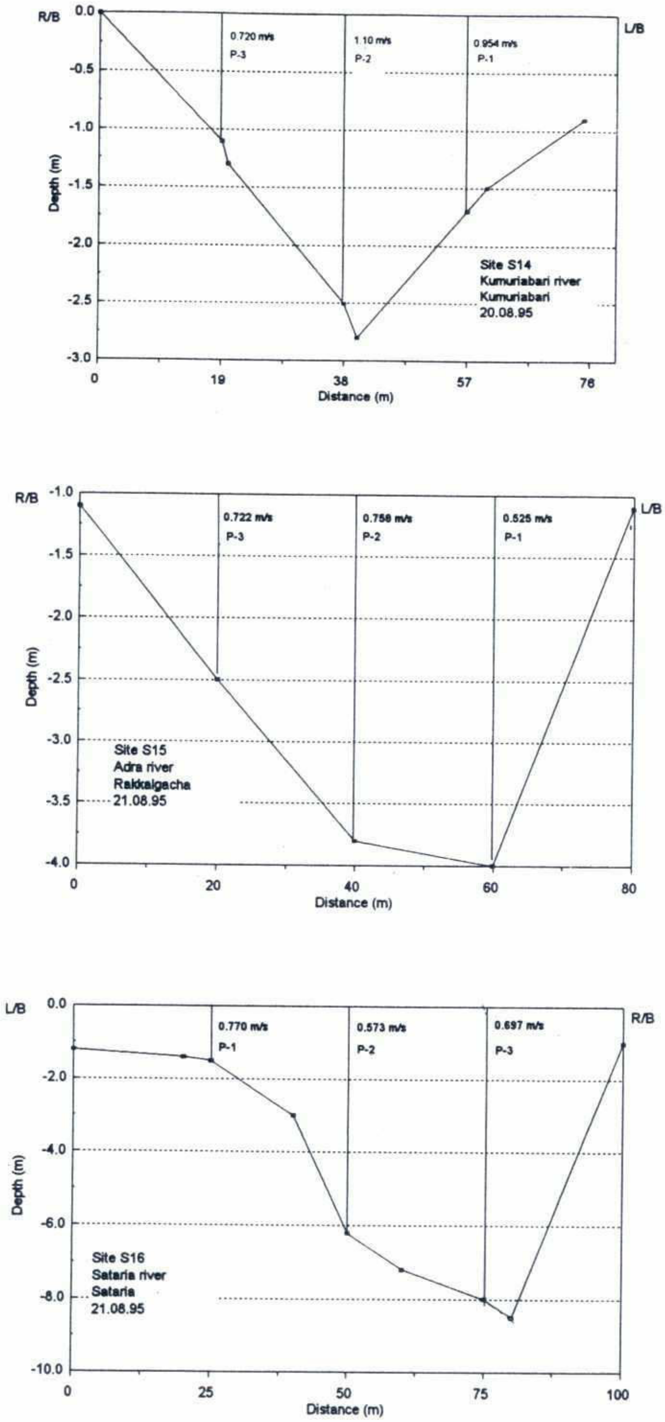

Figure A1-11: Cross-section profiles, S14 to S16

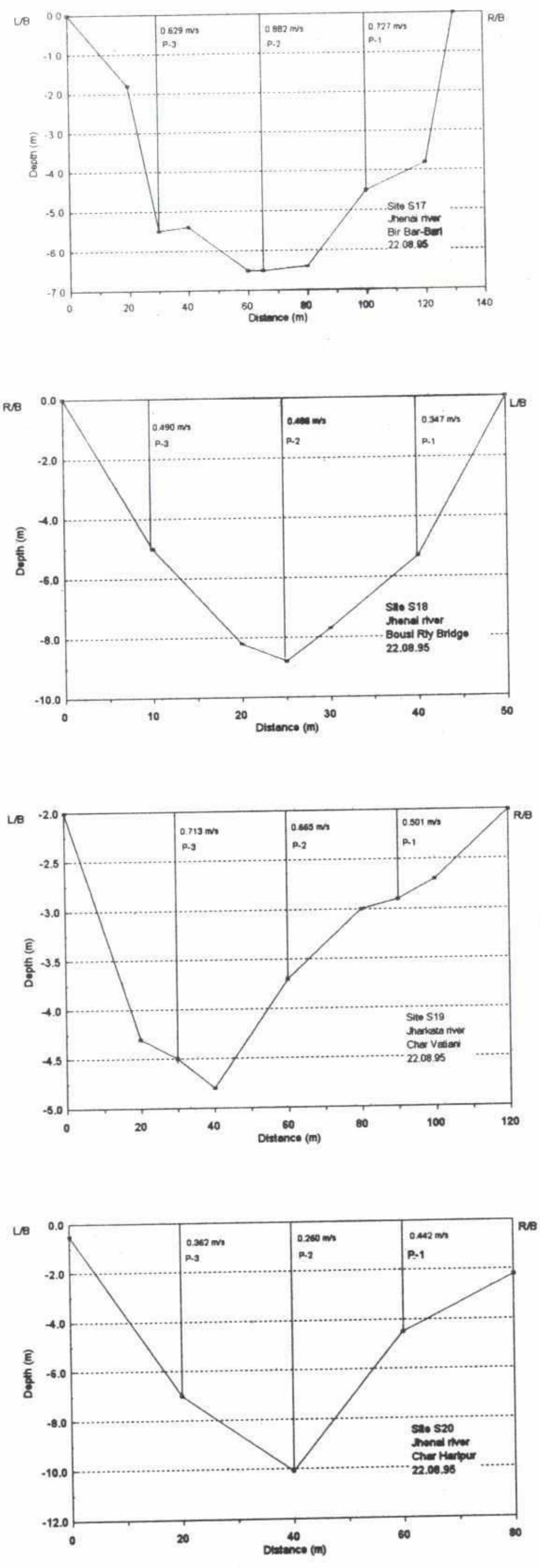

Figure A1-12: Cross-section profiles, S17 to S20

ANNEXURE 2

FLOODPLAIN SEDIMENTATION MEASUREMENTS NEAR SHARISHABARI

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Contents

List of Figures

Detailed descriptions of the six sample plots on the floodplain west of Sharishabari follow.

Sample Plot 1

Sample Plot 1 was near the right bank of the Jharkata River. This plot was on the lower slope of nearly level ridges. The topsoils had a loamy texture, and the subsoils had a clay loam texture. The area was generally used for agricultural crops; mustard was the main crop followed by boro. Surface irrigation water was used to grow these crops.

This area is normally flooded up to 1.80 to 2.10 m during the monsoon from June to October. Crops cannot be grown during the monsoon season because they would be damaged by the flood. Even though the site was bounded by two roads the land in this area was free from drainage congestion. The plot had a wide open front towards the north-east.

This area flooded on the June 17, 1995, and remained under water through July and August except for on August 10th and 11th. The maximum flood depth (2.85 m) was observed on July 10th. This was more than a meter above normal flood depth. The area remained was mostly not flooded in September. However from September 23rd to October 12th the area was flooded again. The sediment concentration as function of the inundation depth is shown in Figure A2-1.

A thick layer of sediment was deposited in this sample plot. The thickness of sediment on the cloths and mats was uneven, ranging between 0.23 and 0.26 m. Most of the sediments probably travelled a short distance from the adjacent eroded bank of the Jharkata River. More sediment was deposited inside the sample plot than on the adjacent fields. On the adjacent fields the sediment thickness ranged from 0.10 to 0.20 m. The bamboo fence around the sample plot decreased the flood water flow velocity resulting in more sediment deposition inside the plot. The sediments were coarse in texture. Part of the deposited sediments were again transported by the flood water. On August 18th, during the peak flood, the flow velocity was approximately 0.61 m/s. The flood water flowed from north-west to south-east.

Sample Plot 2

Sample Plot 2 was on the left bank of the Shishua River. The plot was on the middle slope of gently undulating ridges. The topsoils and subsoils had a silt loam texture. The area was generally cultivated with mustard and boro crops. River water was used for irrigating these crops.

This area is normally flooded by river water up to a depth of 1.00 m during the monsoon season. This plot has a wide open front towards the north, and the surface drainage system is good.

This area flooded on June 17th, and the flood receded on July 30th. The land remained dry until August 11th. The area was again flooded between August 12th and 28th. The flood water receded, and then the area flooded again between September 24th and October 5th. The maximum inundation depth (2.20 m) was observed on July 10th. This was more than a meter above the normal flood depth. The sediment concentration is shown in Figure A2-2 as function of the inundation depth.

A thin layer of fine textured sediment was deposited in the sample plot. The thickness of the sediment was approximately 0.0005 m. The three traps had a similar sediment thickness ranging from 0.21 to

0.22 m. The thickness of the sediment deposited on the cloths, however, ranged between 0.10 to 0.18 cm. A small amount of sediment in one of the cloths indicated that raindrops caused partial erosion of the deposited sediment. This occurred after the flood water totally receded from the floodplain. On August 18th, the direction of the flood water was from north to south, and the surface flow velocity was 0.05 m/s.

Plate A2.1 Sample Plot 3 was completely covered with sediments on September 25, 1995. The Shishua River can be seen in the background of this photograph.

Sample Plot 3

Sample Plot 3 was on the right bank of the Shishua River. The plot was on the upper slope of gently undulating ridges. The topsoils had a silt loam texture, and the subsoils had a sandy loam texture. The area is cultivated annually with jute, and in the kharif season aman crops are transplanted. Wheat is grown in the rabi season.

This area is normally flooded 0.60 to 0.90 m by river water during the monsoon from June to August. As soon as the river water spills over the river bank the land becomes flooded. The plot had a wide open area along the bank of the river.

This area was first flooded between June 19th and 27th. It flooded again between July 5th and 25th. The area remained dry until August 14th, and was flooded for a third time between August 15th and

26th. The maximum flood height (190 cm) was recorded on July 11th. The sediment concentration is shown in Figure A2-3 as function of the inundation depth.

This sample plot received large quantities of sediment mainly from upstream bank erosion along the right bank of the Shishua River (Plate A2-1). The Shishua River changed its course during the monsoon; after the monsoon it flowed much closer to the sample plot. The thickness of the deposited sediment ranged from 0.26 to 0.28 m. Two distinct layers of sediment were identified in the field (Plate A2-2). The upper layer had a thickness ranging from 0 to 0.18 m; it was made up of eroded materials that were mostly loamy sand. The lower layer had a thickness ranging from 0.18 to 0.26/0.28 m; it was finer in texture because these sediments were probably transported over a longer distance. The flow velocity (0.34 m/s) was measured on August 18th during the third peak flow. The flood water flowed from north-west to south-east.

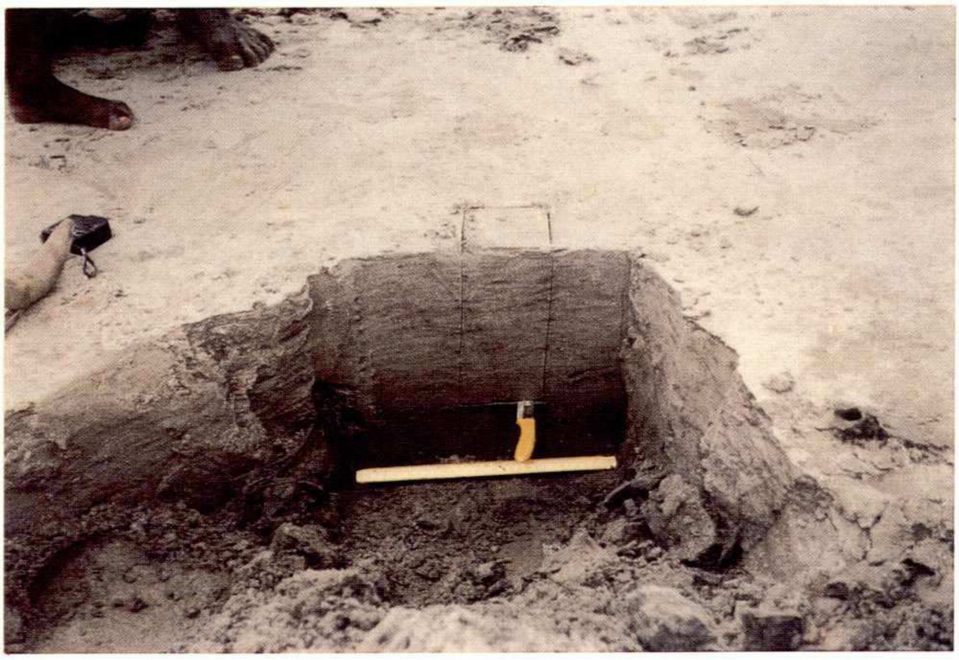

Plate A2-2: Sample Plot 3: Two distinct layers of sediment can be distinguished on the cloth. A knife divides the layers and a scale lays on the base of the deposited sand. Date: September 25, 1995

Sample Plot 4

Sample Plot 4 was on a gently undulating basin. The topsoils had a silt loam texture, and the subsoils had a clay loam texture. The area is cultivated annually with transplanted aman followed by mustard and boro crops. Shallow tubewells are used to irrigate the boro crops.

The area is normally flooded between 0.90 and 1.30 m during the monsoon from June to September. The flood water reaches the site through a channel that is connected to the Shishua River. In a later stage of the monsoon the flood water normally comes from overflowing the banks of the Adra River. The plot was located 50 m north of a road.

The flooding started on June 19th and continued until June 22nd. The area was again flooded between July 5th and August 27th. The maximum flood depth (200 cm) was observed on July 10th and 11th.

The sediment deposited at this site had a fine texture. Slightly more sediment was deposited on the cloths than in the sediment traps. The cloths received surface wash from a higher site as well as from flood water sediment. The sediment thickness was between 0.004 and 0.006 m (Plate A2-3). The flow velocity was 0.07 m/s on August 18, 1995. The flood water flowed from north-west to south-east.

Although the sampling site had a small amount of sediment, a large amount of sandy sediment was deposited in the neighbouring area south of the road (Plate A3-4). These sandy materials were scoured from the damaged part of the road by the strong flood water flow. The flood water flowed through a channel that connects the Shishua River and the damaged part of the road. The road now has a big pool of flood water that causes problems for pedestrians.

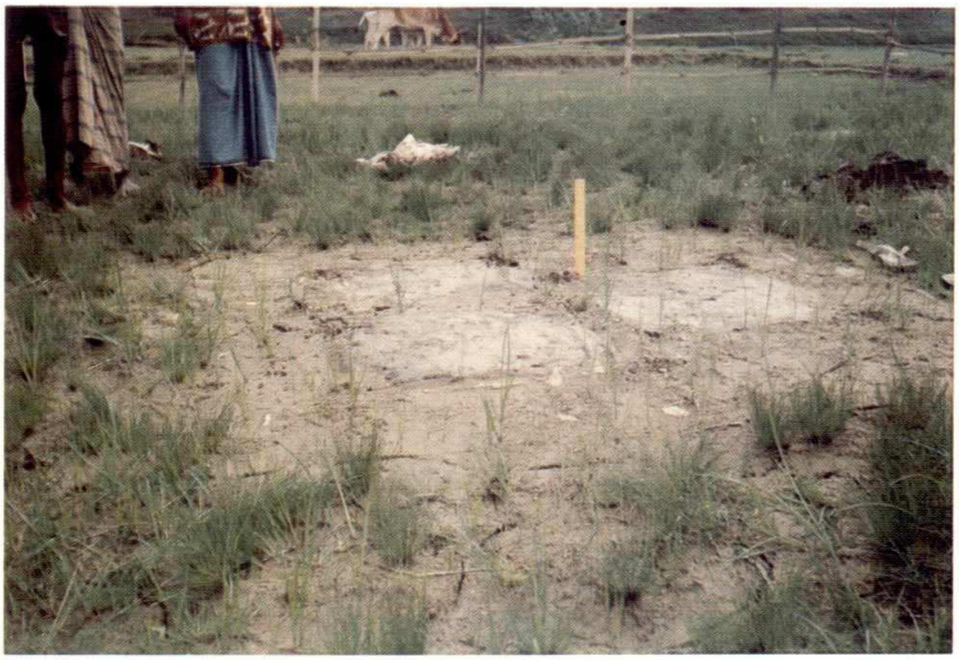

Plate A2-3: A thin layer of sediment was deposited on the cloth in sample Plot 4.
Date: September 26, 1995

Plate A2-4: A thick layer of sediment was deposited on agricultural land, South of sample plot 4
Date: September 26, 1995

Plate A2-5: Flood water erosion created a big pool in the road. The pool is connected to the river system by a small canal, south of Plot 4
Date: September 26, 1995

Sample Plot 5

Sample Plot 5 was on a very young char comprised of land that was accreted approximately 15 to 20 years ago. Before the char formed the area was part of the main channel of the Jamuna River. This plot was on the upper slope of gently undulating ridges. The soils of the area were not yet developed. The topsoils and subsoils were stratified and had a silt loam texture.

This area is normally flooded up to 0.60 to 0.90 m during the monsoon from June to August. The flood water generally comes from the Adra River, a distributary of the main channel of the Jamuna River. On the eastern side of this area there is a channel of the Adra River. The channel is active in the monsoon season and dry during the dry season. Plot 5 was located well within a big field that was open on all sides.

The site first flooded on June 19th but only remained inundated until June 21st. The area was again flooded from July 4th to July 25th. The area remained dry until August 12th. The last flood occurred from August 13th through the 27th. The maximum flood depth (1.80 m) was recorded on July 11th. The sediment concentration in the flood water is shown in Figure A2-4 as function of the inundation depth.

This plot had less sediment than the other sample plots because the area was inundated for the shortest time period. Similar to Plot 4, the cloths had more sediment than the sediment traps. This might indicate that there was a redistribution of surface soils from higher to lower sites during the monsoon season. The sediment traps in this plot captured only suspended sediments from flood waters, not eroded materials from the higher sites. Water flowed from north-east to south-west, and the flow velocity was 0.37 m/s on August 18, 1995.

Sample Plot 6

Sample Plot 6 was on the middle slope of gently undulating ridges. The soils of the area are not yet developed. The soils of the area were formed approximately 15 to 20 years ago. Similar to Plot 5, this land was accreted from the main channel of the Jamuna River. The topsoil texture was silt loam, and the subsoil texture was silty clay.

This area is normally flooded up to 1.00 to 1.20 m from June to October. The flood water generally comes from the Adra River. On the eastern side of this area is a dying channel of the Adra River which connects to the Jamuna River to the south. It acts only as a drainage channel that efficiently drains water in both the monsoon and dry season. The plot had a wide open area to the north-east. However, man-made mounds meant for homesteads bordered the western side of the area.

The site first flooded on June 17th and remained inundated until July 27th. The area was again flooded from August 13th to the 26th. The area remained dry until September 24th. The last flood occurred from September 24th to October 2nd. The maximum flood depth (2.00 m) was recorded on July 10th. The sediment concentration in the flood water is shown in Figure A2-5 as a function of the inundation depth.

There was more sediment in the traps (60 - 63 tons/ha) than on the cloths (16 - 30 tons/ha) (Plate A2-6). There was a strong flow velocity (0.57 m/s) during the peak flood season on August 18, 1995.

Thus, the sediment that was deposited on the cloths earlier may have been flushed away by strong flowing water. The flood water flowed from north to south without any physical resistance (e.g. roads, embankments etc.).

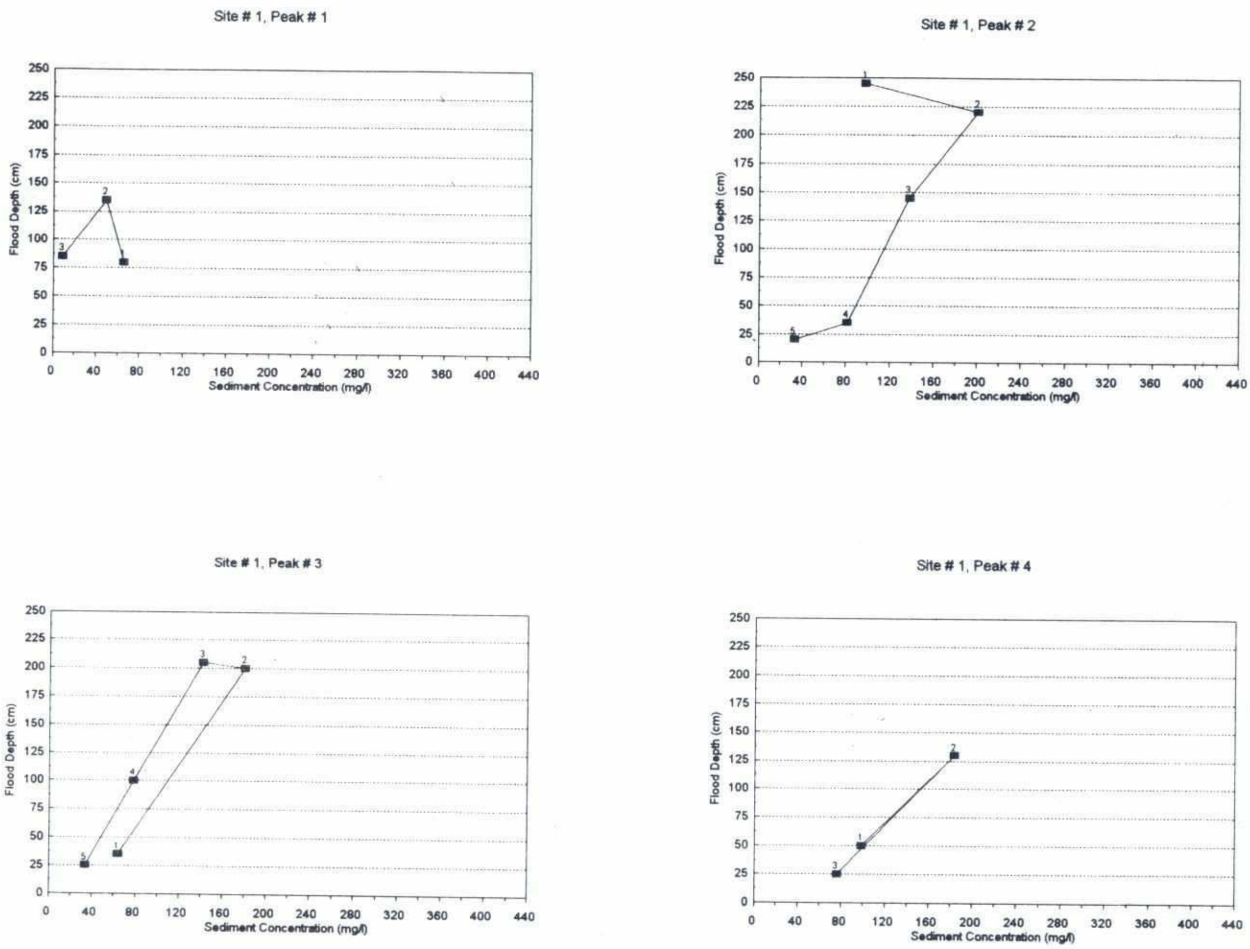

Figure A2-1: Sediment Concentration in different flood depth at Sample Plot 1

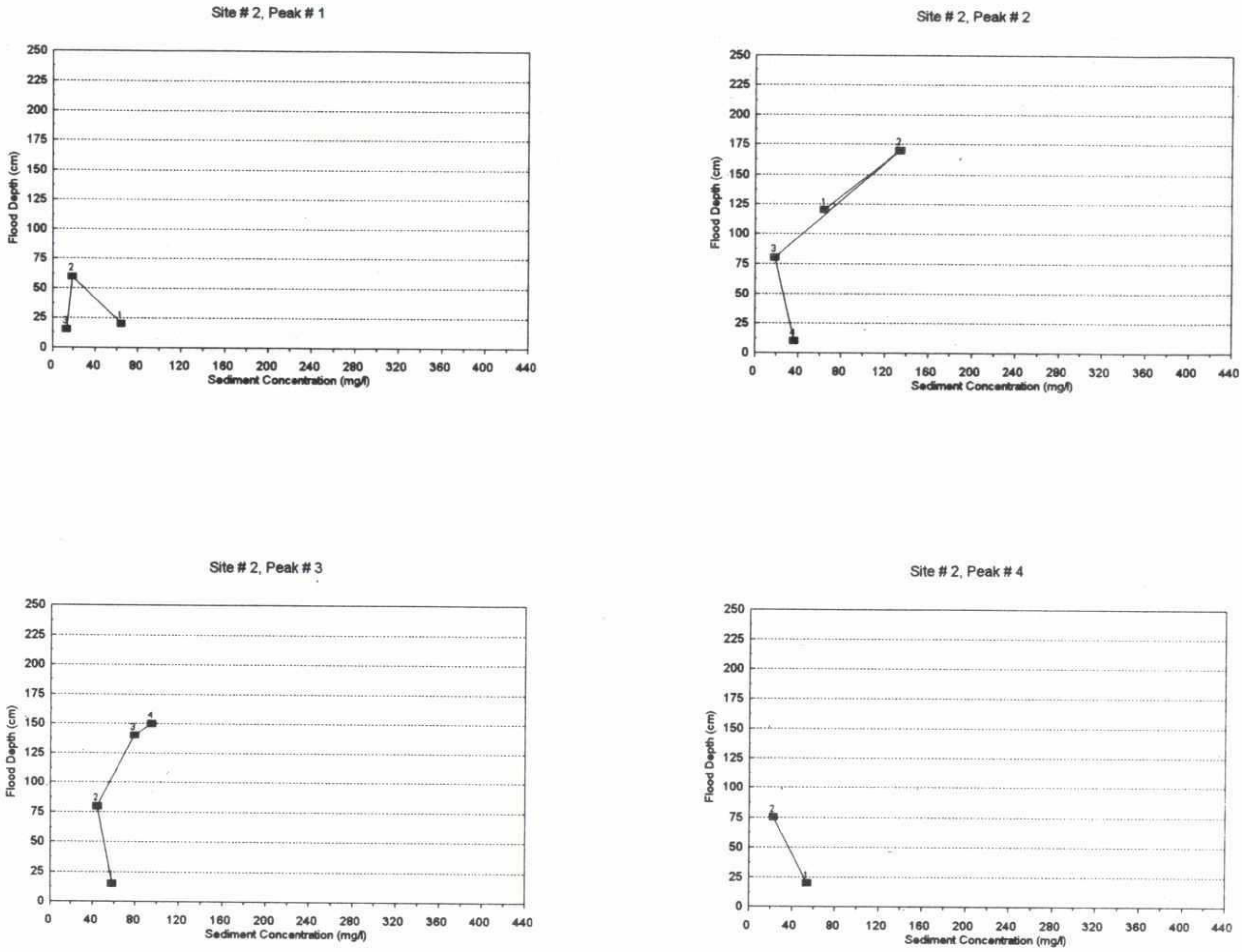

Figure A2-2: Sediment Concentration in different flood depth at Sample Plot 2

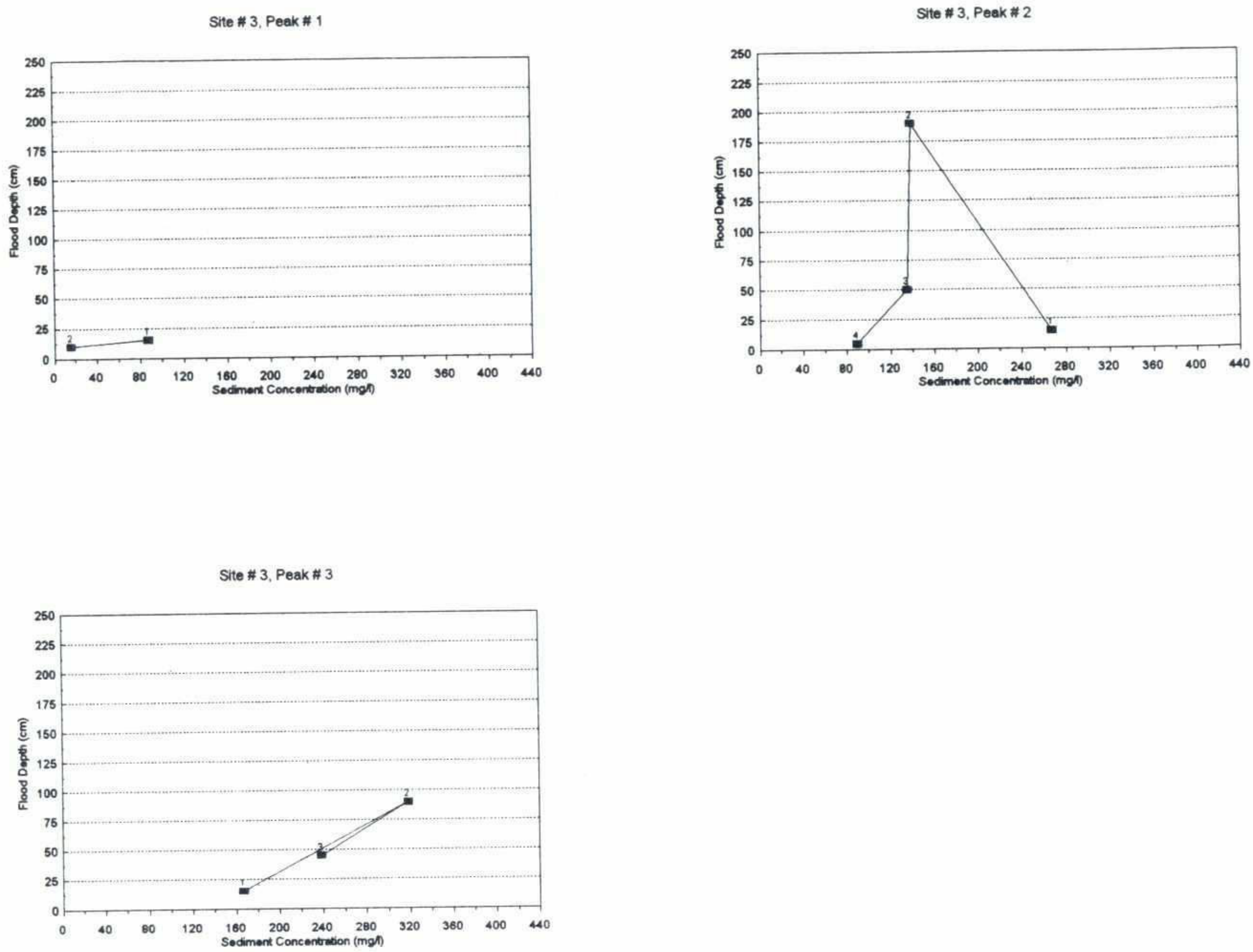

Figure A2-3: Sediment Concentration in different flood depth at Sample Plot 3

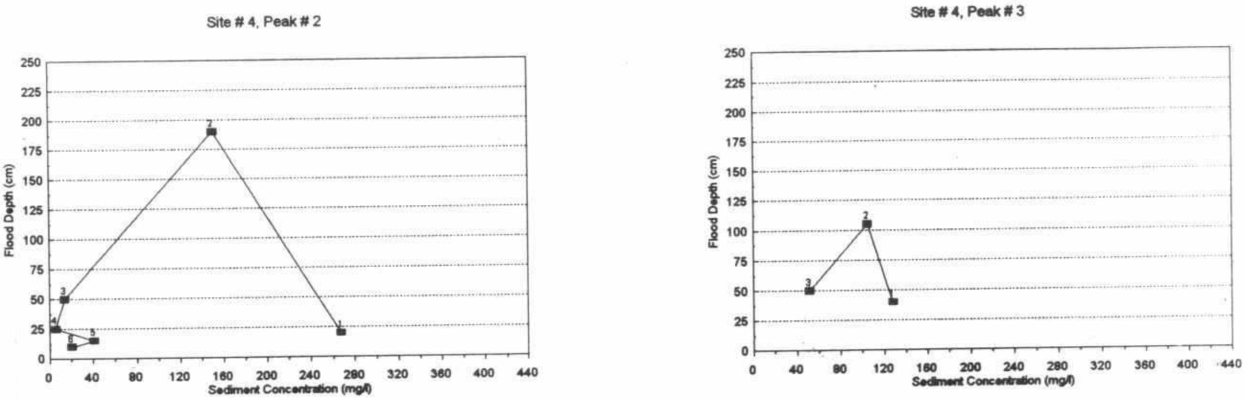

Fig. 5.4 : Sediment Concentration in different flood depth at Site 4

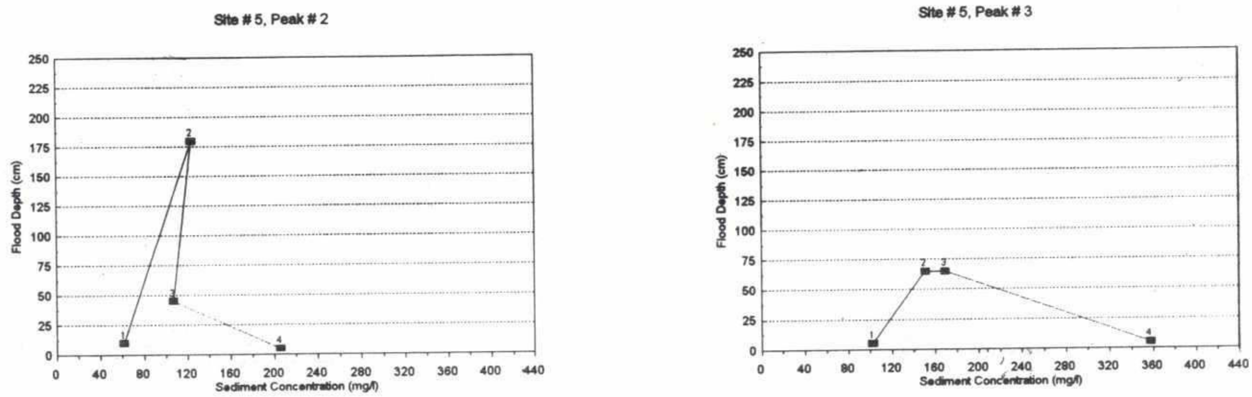

Figure A2-4: Sediment Concentration in different flood depth at Sample Plot 5

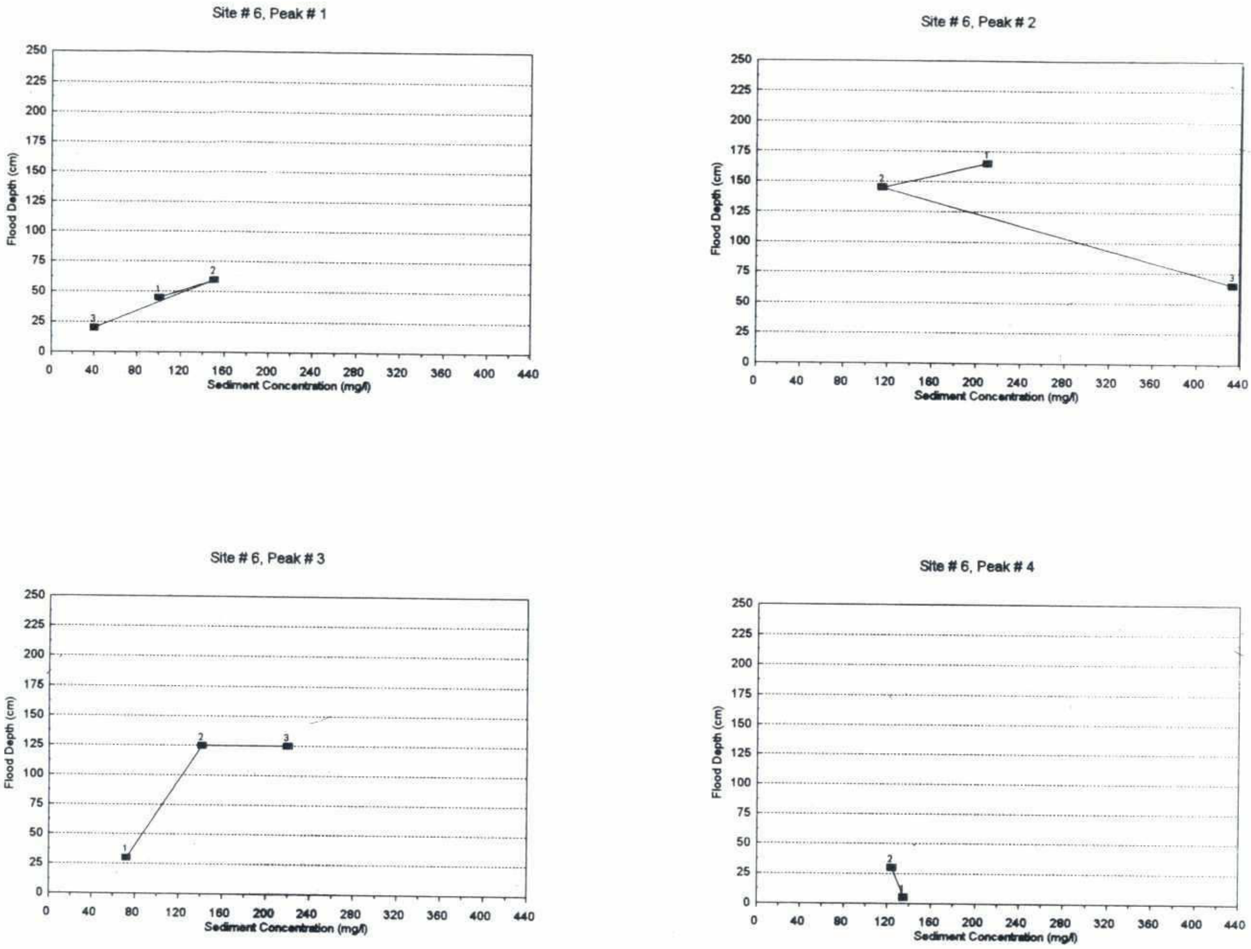

Figure A2-5: Sediment Concentration in different flood depth at Sample Plot 6