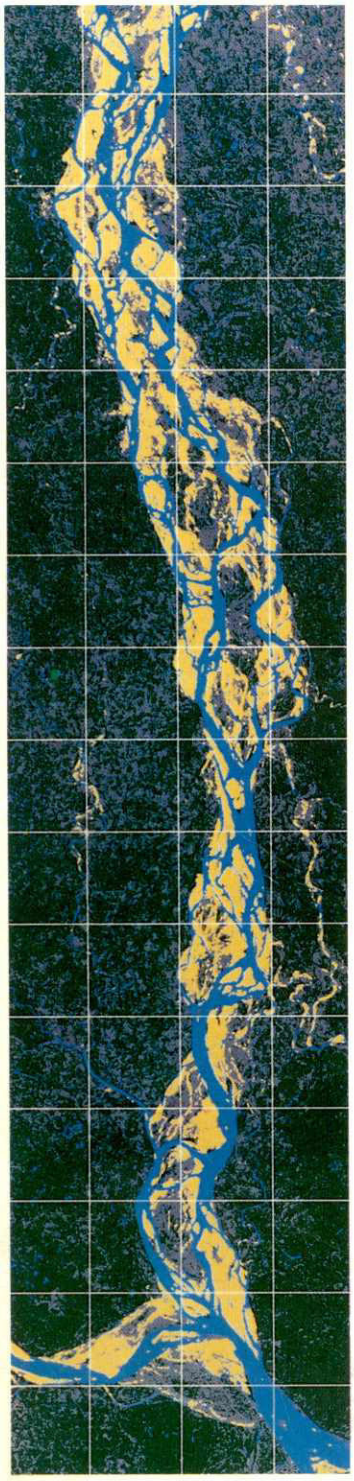
GOVERNMENT OF PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANIZATION

FEDERAL REPUBLIC OF GERMANY

KREDITANSTALT FÜR WIEDERAUFBAU (KfW)

FRENCH REPUBLIC

CAISSE FRANCAISE DE DEVELOPPEMENT (CFD)



BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

TEST AND IMPLEMENTATION PHASE FAP 21

REPORT ON MONITORING AND ADAPTATION AT BAHADURABAD TEST SITE

MONSOON 2000

MARCH 2001

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP 21/22

RHEIN-RUHR ING.-GES.MBH, DORTMUND/GERMANY

COMPAGNIE NATIONALE DU RHONE, LYON/FRANCE
PROF.DR. LACKNER & PARTNERS, BREMEN/GERMANY
DELFT HYDRAULICS, DELFT/NETHERLANDS

In association with:

BANGLADESH ENGINEERING & TECHNOLOGICAL SERVICES LTD. (BETS)
DESH UPODESH LIMITED (DUL)

BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

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FAP 21/22

REPORT ON MONITORING AND ADAPTATION AT BAHADURABAD TEST SITE

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1 INTRODUCTION

1.1 BACKGROUND

The Bank Protection Pilot Project is component 21 of the Flood Action Plan (FAP). It is jointly financed by Germany and France and was awarded by the Flood Plan Coordination Organization (FPCO) represented by the Kreditanstalt für Wiederaufbau (KfW) to the joint venture Rhein-Ruhr Ingenieur-Gesellschaft mbH as lead partner, Compagnie Nationale du Rhône, Prof. Dr. Lackner & Partners and Delft Hydraulics in association with Bangladesh Engineering and Technological Services Ltd. (BETS) and Desh Upodesh Ltd. (DUL).

As per Terms of Reference the Consultancy Services are to be performed in two phases, a Planning Study Phase (Phase I) followed by a Test and Implementation Phase (Phase II).

After submission of the Draft Final Planning Study Report in January 1993 a joint mission of KfW and CFD has carried out the project appraisal to proceed into Phase II of the Project. The Mission agreed to the overall concept of Phase II proposed by the Consultant the essence of which is the construction of a combination of permeable and impermeable groynes and of various types of revetments at two different test sites in two successive seasons.

The Test and Implementation Phase started on June 01, 1993 after the "Letter to Proceed" had been issued by FPCO on May 15, 1993.

The final design of the Revetment Test Structure at Bahadurabad Test Site began in September 1994 and was finalised in April 1995 based on the preliminary design and construction methods of the Planning Study, supplemented by additional studies and investigations viz. morphological studies, geotechnical investigations, physical model tests in Bangladesh and France as well as topographic and hydrographic survey. After suspension of the construction works in January 1996 and necessary modification of layout and design of the test structure, the actual execution of works started in November 1996. The structure was complete in all respects on June 12, 1997.

1.2 OBJECTIVES OF THE PROJECT

The objectives of the Project are to find improved solutions for bank protection works against erosion by designing, specifying and constructing different types of groynes and revetments using different materials and protective layers and investigating at the same time the suitability of local materials and construction methods. After construction of the test structures their behaviour is to be monitored for a period of at least three years. The final objective is to develop and optimise design criteria, cost-effective construction and maintenance methods, which shall serve as future standards, most appropriate for the prevailing conditions at the Jamuna and other rivers of Bangladesh. Hence, the test structures were to be designed in such a way and with such a level of safety that certain damages of the structures are allowed, are even required, because a test work which does not suffer any damage in the course of the monitoring and adaptation period may be oversized and therefore not be suitable to identify the limits and to develop new standards.

To achieve the above objectives, regular monitoring of the test structures is a must after their completion as well as preventive maintenance and adaptation of the structures taking into account the results and observations of each monitoring period. For the development of suitable adaptation measures, however, further studies and investigations are possibly required.

2 THE STRUCTURE

2.1 INTRODUCTION

The construction of the Revetment Test Structure was originally planned about 4 km south of Bahadurabad Ghat based on the investigations during the Study Phase. Since, however, no substantial erosion occurred at the pre-selected test site, this area was abandoned and a more suitable one was selected in September/October 1995 at Kulkandi-village just downstream from Bahadurabad Ghat. The decision on the final location of the test structure was taken on October 11, 1995. However, end November it emerged that the Subcontractor could not mobilise the main construction equipment for dredging and under water works in time. Therefore, the design of the structure was modified in such a way that all components of the structure, even the falling and launching aprons could be built entirely in the dry during the lean season 1995/96. Since, however, even then the rate of progress of all works was too slow to comply with the contractual Time of Completion, it was finally decided on January 31, 1996 to defer the final completion of the test structure until the next dry season.

Based on the experience in 1995 and January 1996, and after identification of the main constraints preventing the completion of Works as per original schedule, a proposal for the final implementation of the revetment test structure during the dry season 1996/97 was submitted in April 1996 taking into account the morphological analysis of the test area until then.

To verify that the location of the selected test site was still suitable for the revetment test structure, a further morphological analysis had been carried out in September 1996 on the basis of satellite images and survey data. This update on the morphological developments indicated that continued attack in 1997 had a high probability.

The most important prediction in March 1996 was that the eastern approach channel would excavate its bed until it would meet the western approach channel, thereby creating a confluence scour hole in front of the bank at Kulkandi around Northing 779000 and 778000. Indeed a large scour hole developed at Northing 778800 in the second half of July, while a scour hole 1200 m further downstream disappeared completely by locally more than 10 m sedimentation. The situation became more complicated in August, when a deep channel shifted towards the bank over the full length of the planned structure with severe erosion of the riverbank resulting in a complete loss of the unprotected structure of 1995/96. Hence, another location of the Revetment Test Structure had to be determined and the design of the structure to be adapted accordingly. A proposal was presented in October 1996, which was discussed with the Client and the donors during a review mission of the latter in November with the final decision in favour of the location as shown in Fig. 2.1.

2.2 DESCRIPTION OF THE REVETMENT TEST STRUCTURE

The final design of the Revetment Test Structure is based on the modified design of November 1995, which allowed all construction works in sheltered conditions without any under water works. The deepest excavation level for the construction of the launching and falling aprons was fixed at 14.50 m+PWD, which is above the Standard Low Water (SLW) level of 13.30 m+PWD.

The total length of the structure is 662.5 m split up into 10 sections, each consisting of a sloped revetment, a launching apron and a falling apron. For the construction of the individual sections different material had been used for the cover layer and filter layer of the revetment as well as for the

launching and falling aprons. As to the detailed layout of the structure and details of the used materials see Fig. 2.2 to 2.4. The as-built drawings of the individual sections were presented in Annex A of the "Report on Monitoring and Adaptation" of March 1999.

2.3 DAMAGES

2.3.1 Damages during the Monsoon 1997

During the monsoon the falling aprons and partly the launching aprons started to function as expected. No significant damages were observed on the entire structure apart from rain-cuts beneath the geotextile filter in Section E-2.

2.3.2 Damages during the Monsoon 1998

During the flood season 1998 no significant damages of the test structure had been observed. However, again rain-cuts beneath the filter layer caused some deformations/settlements of the cover layer in Section E-2 (see Subsection 2.3-1 and Section 2.4).

2.3.3 Damages during the Monsoon 1999

No damages to the test structure had been observed during the monsoon season 1999.

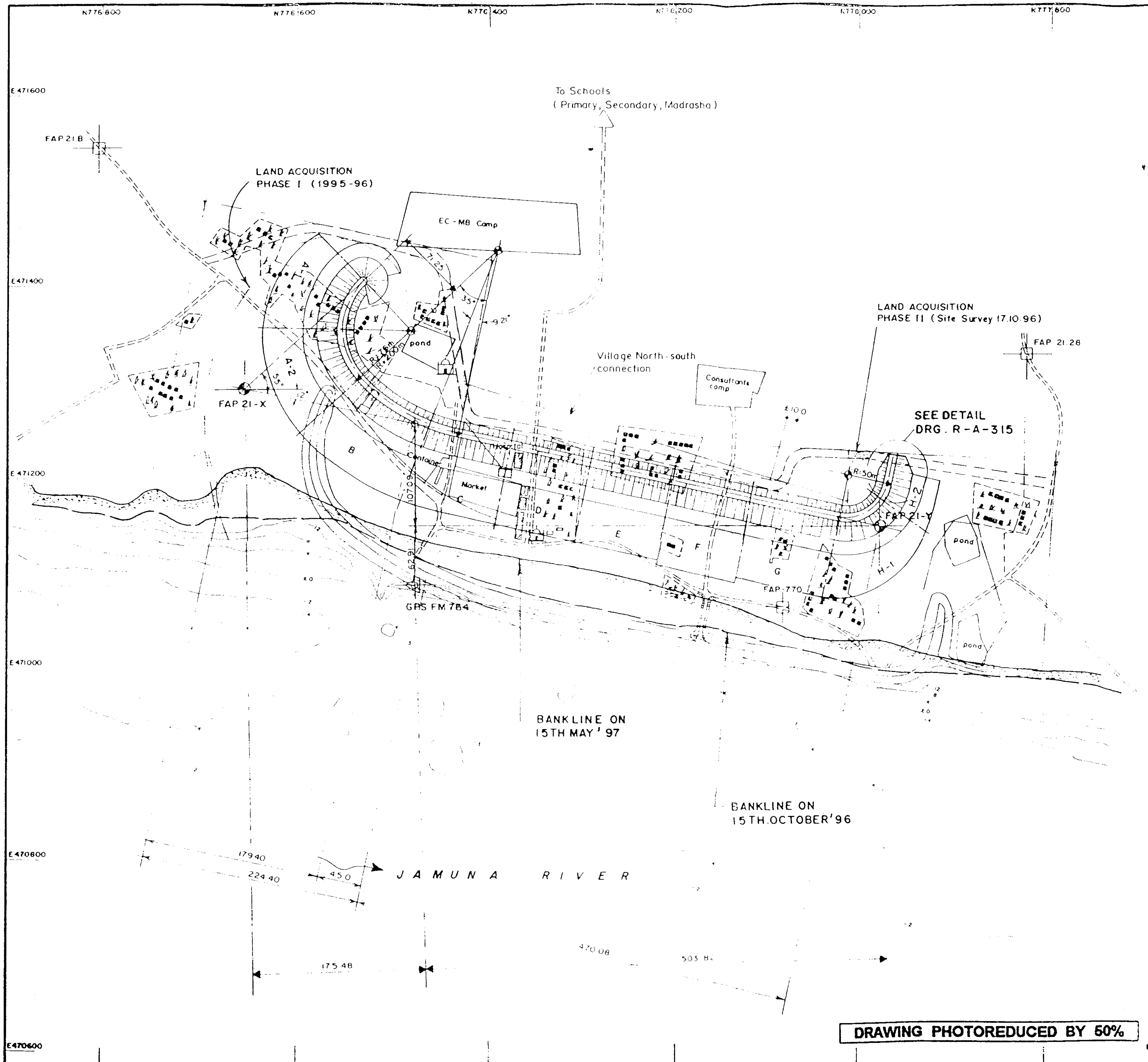
2.4 ADAPTATION AND REPAIR WORKS

Based on the results of all observations and investigations during and after the flood 1997 repair works were only necessary in Section E-2 and adaptation works in Section H.

To stabilise the slope of the revetment above the berm in Section E-2 the cover layer and filter layer had to be removed. The rain-cuts were filled up and the composite geotextile filter, which had been placed with the wrong side up during the construction phase, was replaced now with the right dark/coarse side down. On that a 5 cm thick filter layer of khoa was placed and finally the cc-slabs.

In Section H a supplemental falling apron of cc-blocks with a width of about 7.5 m was placed on the remaining part of the original falling apron following the bankline as existing in March 1998. The bottom of the slope was filled up by boulders grade E/F and the existing slope protected by a fill of cc-blocks of 30 and 40 cm.

During the dry season 1998/99 no adaptation and repair works were executed. Also after the monsoon season 1999 no adaptation works were required. Only filling up of the rain cuts, which developed already in 1998 in Section E-2 was done.



CONTROL POINT SCHEDULE

No. of Control Points	Co-ordinates BTM Easting	Northing	Elevation (m PWD)
FAP21-8	471,548.482	778,800.937	+ 20.246
*) GPS FM764	471,086.185	778,478.880	—
FAP21.28	471,330.663	777,813.399	+ 20.139
FAP770	471,067.515	778,073.154	+ 20.248
FAP21-X	471,293.485	778,654.360	—
FAP21-Y	471,149.095	777,975.060	—

*) not existent anymore

SCALE 1 : 2000

LEGEND

- Embankment
- Road Pucca, Kacha, Footpath
- High River Bank
- House Pucca, Kacha & Finished
- Traverse Station & Pillar
- Home stead
- Mosque

NOTES

1. The topography shown on this drawing is based on J.T.W.C.'s survey of Oct. '96 combined with topographical maps of Survey of Bangladesh.
2. Levels refer to ±0.00 m PWD.
3. Bankline and bathymetric survey as of
4. Reference Drawing
   R-A-302 Detailed Layout of Test Structure

REV	DATE	NAME	DESCRIPTION	APPROVED
1	01.6.97	Anowar	AS BUILT DRAWING	

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT FAP-21

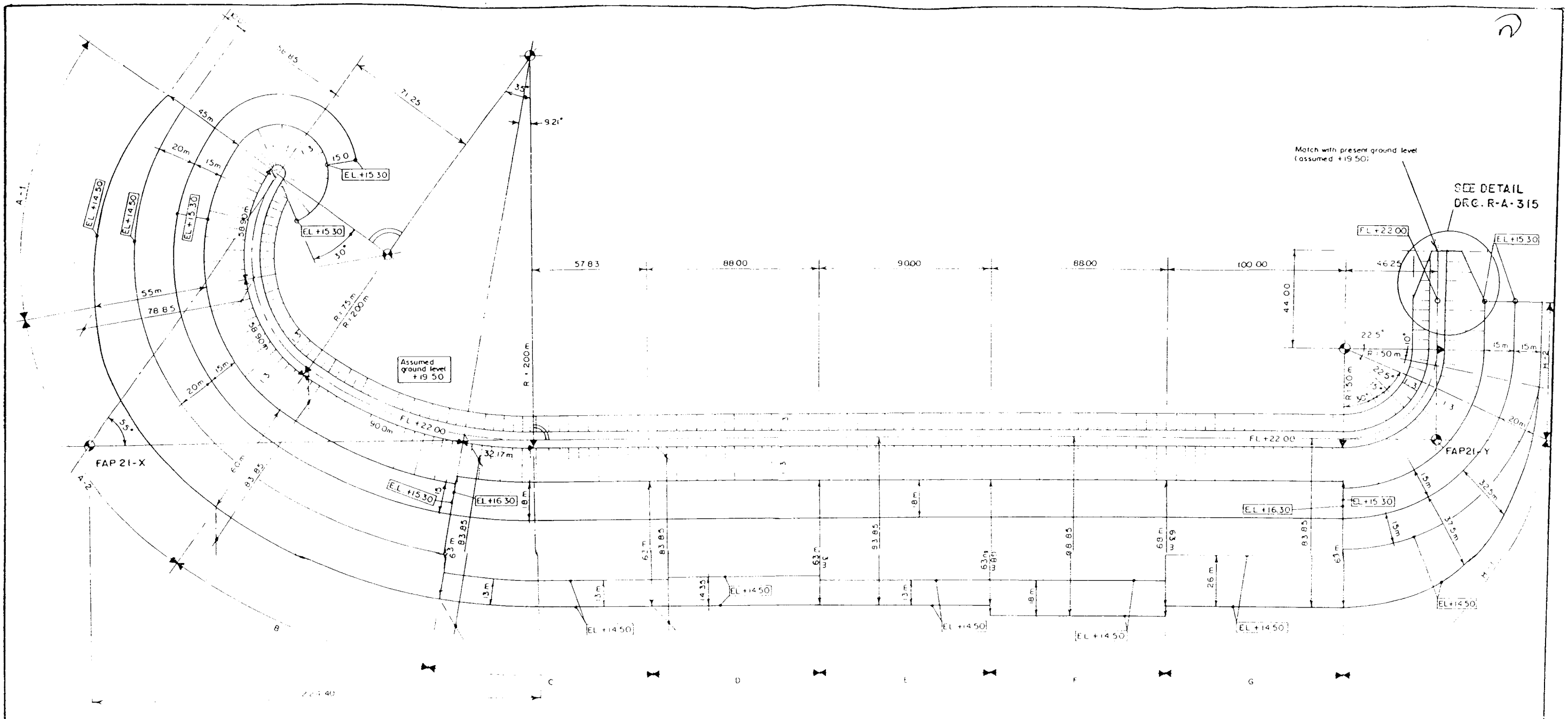
JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

GENERAL LAYOUT OF TEST STRUCTURE (1996/97)

DRAWING PHOTOREDUCED BY 50%

	NAME	DATE	SCALE 1 : 2,000	
DRAWN	ANOWAR	03-11-96		
CHECKED		03-11-96	FIG. 2.1	REVISION 1
APPROVED				



CONTROL POINT SCHEDULE			
No. of Control Points	Co-ordinates BTM		Elevation (m PWD)
	Easting	Northing	
FAP 21-X	471,293.485	778,654.360	----
FAP 21-Y	471,149.095	777,975.060	----

NOTES

1. Levels refer to +0.00m PWD
2. Measurements in meter
3. F.L. : Finished level
4. E.L. : Excavation level
5. Reference Drawings

R-A-301 General Layout of Test Structure (1996/97)
R-A-305 Test Structure A General Plan and Cross Sections
R-A-313 Test Structure H Cross-Sections H-1, H-2 Cross-Sections, Details

DRAWING PHOTOREDUCED BY 50%

REV	DATE	NAME	DESCRIPTION	APPROVED
1	21.4.97	Anowar	AS BUILT DRAWING	

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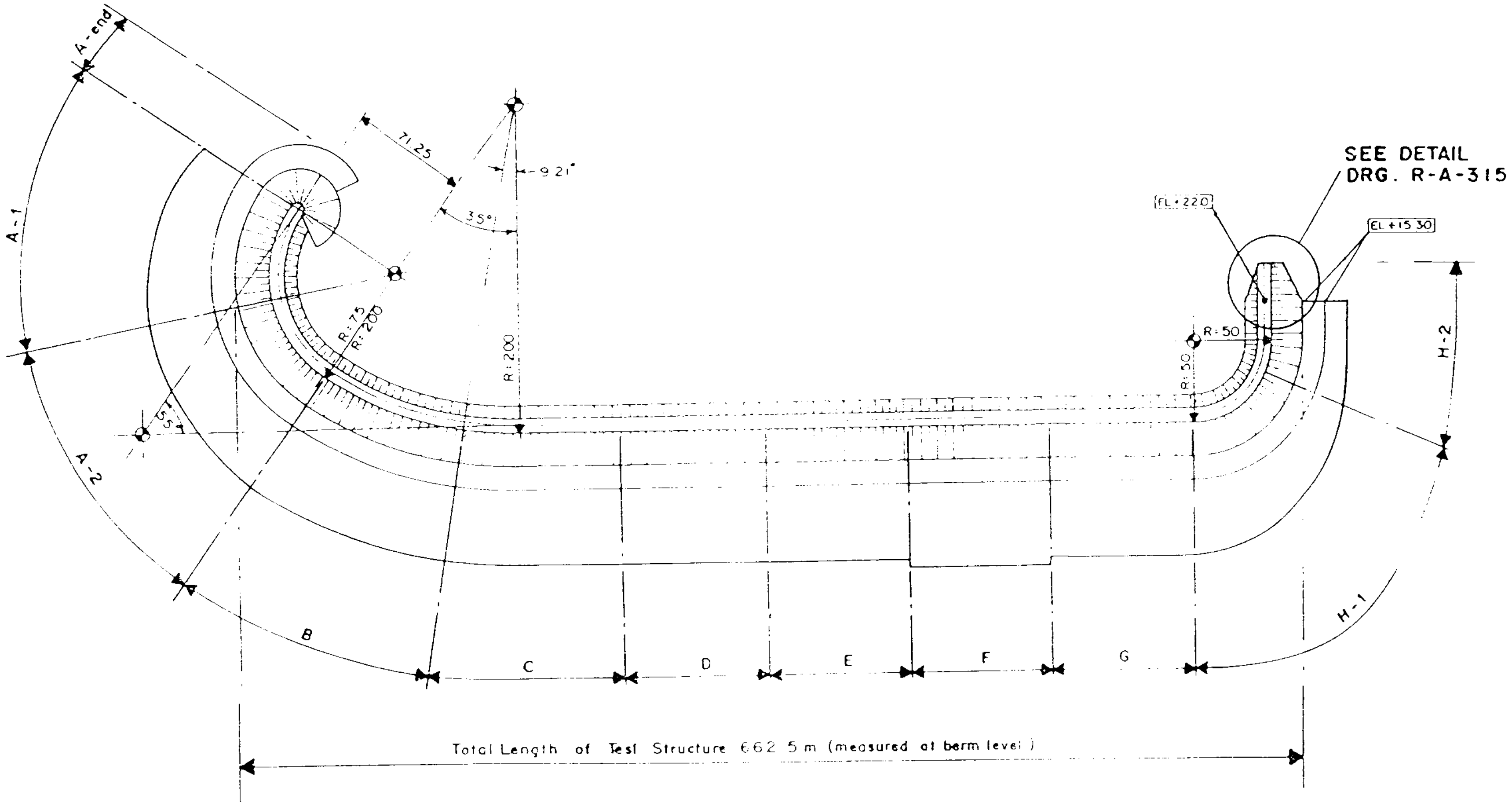
JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP 21/22

TEST SITE II - BAHADURABAD

DETAILED LAYOUT OF TEST STRUCTURE (1996/97)

	NAME	DATE	SCALE : 1 : 1000
DRAWN	ANOWAR	09-10-96	
CHECKED		03-11-96	FIG. 2.2
APPROVED			REVISION 1



Scale 1 : 2000

NOTES
1 Levels refer to 0.00m PWD
2 Measurements are shown in meter
3 F.L. : Finished level
E.L. : Excavation level
4 Reference Drawings
R-A-302 Detailed Layout of Test Structures
R-A-304 Geotextile Filter Materials General Arrangement

Test Structure		A-end	A-1	A-2	B	C	D	E	F	G	H-1	H-2	H-2 (end)
Land sided slope		Brick mattress d : 15cm	In all sections Durba grass sods laid on Geo jute soil saver							Detail Top of Embankment Drg.No R-A-314			Village Road
River side	Approximate length along toe of upper slope (at berm level)	~87.40	~74.70	~74.70	~99.10	~93.20	88.0	90.0	88.0	100.0	~82.75	~97.60	~20.0 / ~30.0
River side	Revetment above berm level (+15.3m to +22.0m PWD)	Brick mattress d : 15cm	Brick mattress d : 15 cm	Wiremesh mattress d : 23/36 cm with stone fill Grade B (D_{50} : 15 cm)	Wiremesh mattress d : 23 cm with stone fill Grade B (D_{50} : 15 cm) on intermediate rubble layer (d : 25cm)	CC-blocks D_n : 30 cm hand-laid in single, diagonal lines	CC-blocks D_n : 30cm hand-laid in single, parallel lines	Interlocking CC-slabs (ship-lap type)	Wiremesh mattress d : 36 cm with brick fill	Interlocking CC slabs (tongue groove type) on intermediate layer	Rip-rap Grade C (D_{50} : 20cm) Top 20cm with stone pitching (d : 50cm)	Rip-rap Grade C (D_{50} : 20cm) Top 20cm with stone pitching (d : 40cm)	As H-2 / Rip rap E+F 80cm on 20cm
River side	Launching Apron at and below berm level (+14.5m to +15.3m PWD)		Dumped CC blocks D_n : 30 cm	Dumped CC-blocks D_n : 35cm	Dumped CC-blocks Edge us D_n : 50 cm Center D_n : 35 cm Edge ds D_n : 40 cm	Articulated Reno-mattress d = 23/36 cm, stone fill grade B, C,D (D_{50} = 25 cm) with inter-connecting steel wire ropes and anchor piles at berm level	Articulated CC-block mattress with inter-connecting steel wire ropes and anchor pipes at berm level	FORESHORE mattress (collapsible block mattress with cement grout fill)	PROFIX-mattress (tubular fabric mattress with sand and sand-bitumen fill)	INCOMAT sandflex mattress (collapsible block mattress with sand fill)	Rip rap Grade F (D_n : 25-35-45cm)	CC blocks D_n : 30 cm D_n : 35 cm (mixed)	
River side	Transition between launching apron and falling apron		CC-blocks D_n : 30cm	CC-blocks D_n : 30 cm	CC-blacks D_n : 35 cm				Rip-rap Grade F CC-blocks, D_n : 30cm *1	CC blocks D_n : 35cm *2			
River side	Falling Apron (level +14.5m PWD)	Dumped CC-blocks D_n : 30cm	Dumped CC-blocks D_n : 35cm D_n : 40cm (mixed)	Rip-rap, Grade E (D_{50} : 30cm)	Geo-sand-container Type C (180kg/No)	Geo-sand-container Type E (900kg/No)	CC-blocks D_n : 40 cm	CC-blocks D_n=40 cm / Geo-sand container D	CC-blocks D_n : 40/45 cm (mixed)	CC blocks D_n : 35/40 cm (mixed)			
River side	Exposed edge of falling apron			Rip-rap, Grade F (D_n : 25/35/45 cm)	Geo-sand-container Type D (250kg/No)		CC-blocks D_n : 45 cm	CC-blocks D_n=45 cm / Geo-sand container E	Gabion sacks with stone fill Grade B (D_{50} : 15cm) (1300kg/No)	CC blocks D_n : 40cm	Selected boulders D_n : 35-45cm		

us : upstream
ds : downstream

*1 MIXED CC-BLOCKS 30cm + BOULDERS GRADE E IN EVELOPE OF DOUBLE LAYER CHAIN LINK FENCE

*2 MIXED CC-BLOCKS 35 cm + BOULDERS GRADE F IN EVELOPE OF DOUBLE LAYER CHAIN LINK FENCE

i.e. FEATURES INTERCHANGED C, D CORRECTION AND ADDITION E TO H-2

REV	DATE	NAME	DESCRIPTION	APPROVED
1	1.6.97	Anowar	AS BUILT DRAWING	

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WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

DESIGNATION OF DESIGN SECTIONS AND MATERIALS

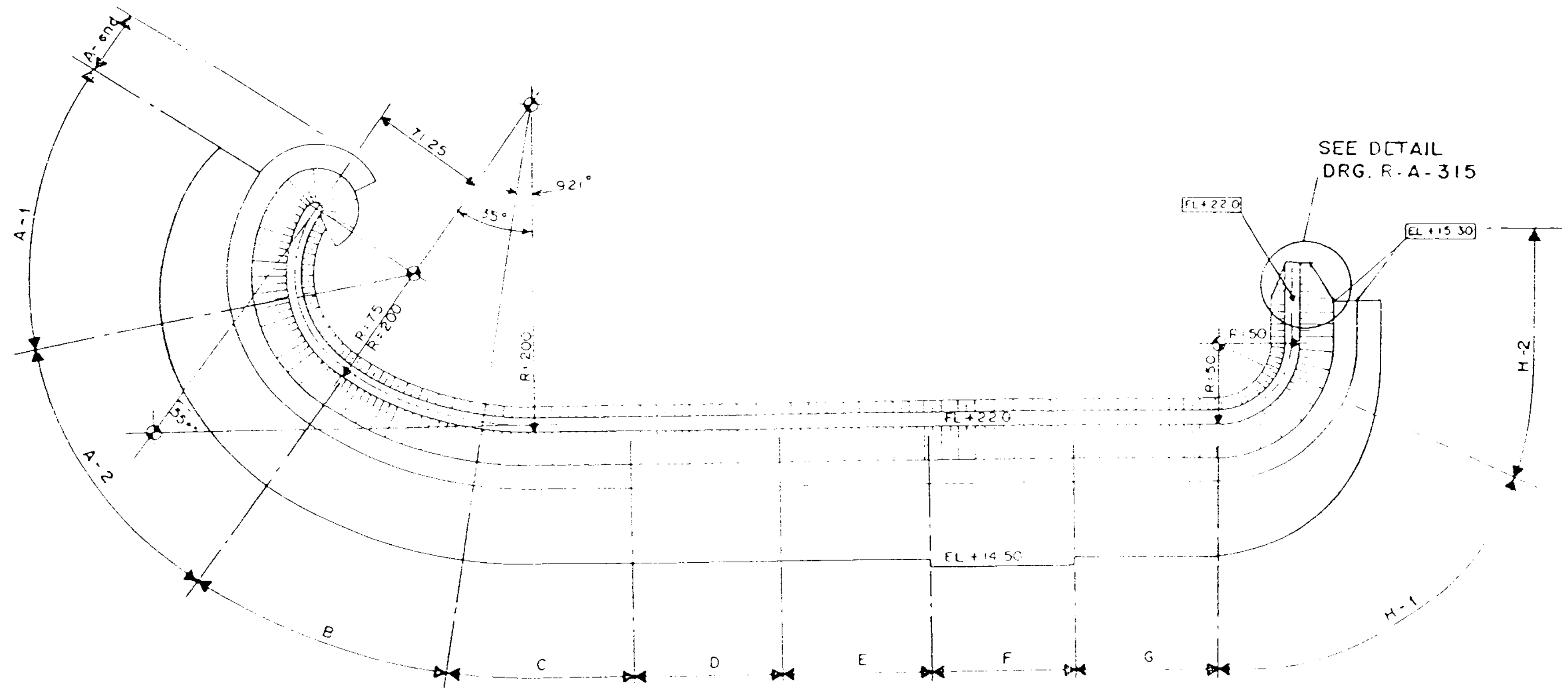
	NAME	DATE
DRAWN	ANOWAR	15-10-96
CHECKED		18-10-96
APPROVED		

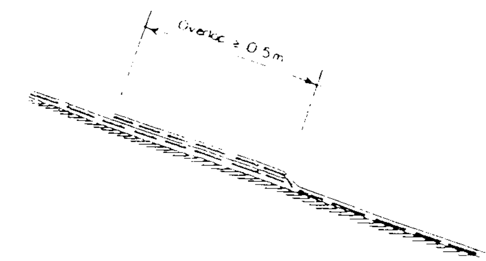
SCALE 1 : 2000

FIG. 2.3

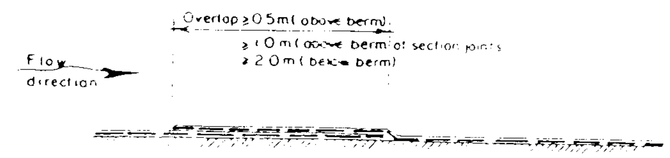
REVISION 1

DRAWING PHOTOREDUCED BY 50%





POSITION OF OVERLAPS DOWN-THE-SLOPE



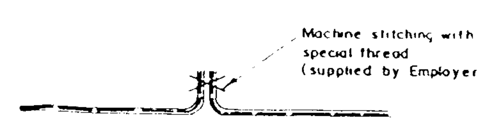
POSITION OF OVERLAPS IN DIRECTION OF FLOW

NOTES

1. Levels refer to ±0.00 = PWD
2. Measurements are shown in meter
3. FL = Finished level
   EL = Excavation level
4. Geotextile filter materials and fabric mattresses will be supplied by the Employer in accordance with Specifications, Sub sections 220 and 230
5. Reference Drawings
   R-A-302 Detailed Layout of Test [illegible]
   R-A-303 Designation of Design [illegible] and Materials

Test Structure		A-end	A-1	A-2	B	C		D	E		F	G	H-1	H-2	H-2 (end)	
Land-sided slope		GF-1	In all sections Geo-jute Soil Saver								Detail on Top of Embankment Drg No R-A-314				Village Road	
River Side: Approximate length along toe of upper slope (at berm level)		~87.40	~74.70	~74.70	~99.10	~93.20		88.0	90.0		88.0	[illegible]	~82.75	~97.60	+20.0-0	~30.0
River Side: Geotextile filter mats above berm level	Spec Type	GF-1/-5	GF-1	GF-5	GF-2	Filter III on filter II	Khoa on filter II	GF-2	GF-1	GF-5	GF-1	GF-1	GF-4	GF-4/-2	As	GF-2
	Brand Name	BIDIM b7 HaTe O2214	BIDIM b 7	HaTe O 2214	BIDIM S 550			BIDIM S 550	DATEX AD1300	Hate 39014	BIDIM S 3[illegible]	DATEX AD 1300	BIDIM S 700	HaTe E650/K251	H-2	HateE650
River Side: Geotextile filter mats at and below berm level	Spec Type	GF-1/-5	GF-2	GF-2	GF-4	GF-2		GF-4	FORESHORE-mattres (collapsible fabric black mattress with cement grout fill)		PROFIX-mattress (tubular fabric mattress with sand and sand-bitumen fill)	GF-1 (sub layer to INCOMAT sand flex mattress)	GF-1	GF-1	—	—
	Brand Name	BIDIM b7 HaTe O2214	BIDIM S 550	BIDIM S 550	HaTe K 251	DATEX AD 1600		BIDIM S 700				BIDIM b 7	BIDIM S 390	BIDIM S 390	—	—

NOTE In Section A and H-1 all geotextile filter mats are to be placed as single sheets in all other sections two sheets each are to be joined by stitching (prayer seam) to "twin sheets"



PRAYER SEAM
(without scale)

0 50 100
SCALE 1:2000

Le FEATURES INTERCHANGED C.D

REV	DATE	NAME	DESCRIPTION	APPROVED
1	1.6.97	Anowar	AS BUILT DRAWING	

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WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE

TEST SITE II-BAHADURABAD

GEOTEXTILE FILTER MATS
GENERAL ARRANGEMENT

	NAME	DATE
DRAWN	ANOWAR	17-10-96
CHECKED		19-10-96
APPROVED		

SCALE 1:2000

FIG. 2.4

REVISION 1

DRAWING PHOTOREDUCED BY 50%

3 MONITORING OF THE TEST STRUCTURE

3.1 GENERAL

Since the final objective of this pilot project is to develop and optimise design criteria, cost-effective construction and maintenance methods, which will serve as future standards appropriate for the prevailing conditions at the Jamuna and other rivers of Bangladesh, regular monitoring of the structures after their completion till end of the project is one of the focal points of this pilot project.

Monitoring of the works undertaken at the test sites shall help to

- detect damages at an early stage;
- understand failing mechanisms, and
- plan suitable adaptation/repair works.

However, monitoring does not only refer to detecting damages of the structure but to observe their behaviour under load and to relate the loads to the structure's response. This requires on the one hand to monitor the loads (especially flow velocities, wave action etc.) and on the other hand to adapt the design rules. After adapting the design rules and the design, the works are to be adapted accordingly. Hence, the requirements of monitoring are to take care of the structures features as well as on the loads and natural effects, which may influence the structures. Records are therefore to be taken of

- the natural conditions acting at the structures (water level rise and fall, waves, currents, wind, precipitation etc.);
- the morphological changes of the river in the area of the test structures;
- the movements of structures and important structural parts;
- the deterioration of materials used;
- the variations of the surrounding river bed and bankline, and
- any damage by human and/or animal action.

Thereby it is of utmost importance for drawing right conclusions to record the above information with respect to

- exact location (referred to fixed points established in the hinterland);
- exact time of occurrence/survey;
- method of recording and equipment used;
- staff involved, and
- special observations etc.

All observations and data are entered in a Logbook developed for this particular purpose, which at the same time serve as a checklist for completeness of monitoring. Besides the results of regular hydrographic surveys, the Logbook is a basis for evaluation and selection of necessary measures to be taken. The Logbook and associated records enable to keep a continuous record of events showing the development of failure mechanisms and interrelation with acting forces.

Apart from daily routine observations, regular and periodic inspection programmes are carried out for each and every subject. However, time intervals have to be shortened in case deterioration is expected to increase not in line with the expectations and linear but at an accelerated pace. Additional inspections are required after extraordinary loading conditions, accidents etc.

The monitoring activities are subdivided into two main categories:

- survey of the properties and the behaviour of the structures, and
- reference measurements of physical phenomena that produce the loads on the structure.

The survey carried out under the monitoring programme is as follows:

- Logbook of activities and daily observations;
- Priority/alert information to FAP 21, Dhaka;
- Bathymetric surveys and recording;
- Water level recordings;
- Wind and wave recordings;
- Current measurements;
- Flow direction measurements;
- Topographic measurements;
- Bankline surveys;
- Changes/movements in the area of revetment, launching apron and falling apron of the individual sections;
- Meteorological measurements;
- Visual wave observations;
- Site processing quality control of data;
- Data transfer to FAP 21, Dhaka, and
- Detailed damage surveys during/after the flood period.

Final quality control of site data, final processing, presentation and evaluation is done in the office in Dhaka. The tasks are the following:

- Quality control of field monitoring;
- Final processing/presentation of survey results;
- Determination/confirmation of priority/alert situation;
- Initiation of emergency measures;
- Statistical evaluation of wind/wave records;
- Evaluation of water level recordings;
- Evaluation of current measurements;
- Comparison of results with applied design criteria, and
- Comprehensive annual report on results of field monitoring.

The organisation of the monitoring activities and adaptation of works is similar to and comparable with that one of Test Site I, which has been explained in more detail in the "Report on Monitoring and Adaptation at Kamarjani Test Site" of September 1996.

3.2 MONITORNG DURING THE MONSOON PERIOD 1999

3.2.1 Preliminary Remarks

Monitoring of the Revetment Test Structure stated already during the construction phase in January 1997 following the programme described in Section 3.1. Summaries of all activities have been reported in monthly monitoring reports. The progress of the whole project including the main results and observations of monitoring is reported in quarterly progress reports. In 1998 progress reports No. 27 to 30 have been published.

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3.2.2 Bathymetry

Bathymetry surveys were mainly done to record riverbed changes in front of the test structure and to detect their influence on the stability of the structure, in particular to find out the behaviour/functioning of the falling aprons and launching aprons, since this is decisive for the overall stability of the test structure. The activities during the months of June to December 2000 are shown in Table 3.1.

The results of the main survey from June to October are presented in Annex B and some differential models in Annex C.

In addition to the main survey and the site survey bathymetric surveys were carried out at each section of the structure. The results of these measurements are given as cross-sections in Annex D.

3.2.3 Topographic Measurements

The topographic measurements were done by using **E**lectronic **D**istance **M**easurement (EDM) equipment and levelling instrument. During the period from June to December 2000 the following works were performed:

04/05	bankline and waterline from Test Site II to Ghutail
25/05	bankline and waterline from Harindhara to Belgacha
27/05	char in front of Belgacha
28/05	bankline from Belgacha to Ghutail
18 to 19/06	bankline from Harindhara to 1.5 km d/s from Ghutail
27 to 28/07	bankline from Harindhara to 1.5 km d/s from Ghutail
25 to 29/08	bankline from Harindhara to 1.5 km d/s from Ghutail
27 to 29/09	bankline from Harindhara to 1.5 km d/s from Ghutail

3.2.4 Measurement of Flow Velocity and Direction

Float track measurements were continued as well as measurements with the Valeport currentmeter. Results are presented in the monthly reports on monitoring of the test structures. For details see also Annex B.

Date	Survey Area						
	June 2000	July 2000	August 2000	September 2000	October 2000	November 2000	December 2000
01							
02							
03							
04							
05							
06							
07							
08							
09							
10							
11							
12							
13							
14							
15							
16							
17							
18	main survey						
19	main survey						
20	main survey						
21							
22							
23							
24							
25							
26		main survey	main survey		main survey		
27		main survey	main survey	main survey	main survey		
28		main survey	main survey	main survey	main survey		
29		main survey	main survey	main survey			
30		main survey	main survey	main survey			
31		main survey	main survey				

Table 3.1: Bathymetric survey at Bahadurabad Test Site from June to December 2000

3.2.5 Observations

The lowest water level during the dry season 1999/2000 of 13.25 m+PWD was recorded on March 11 and 12, 2000. The usual seasonal rise of the water level started thereafter and at the end of March 13.72 m+PWD were measured. A sharp rise of more than 1 m within a few days was observed in April and May and the same happened again during the period June 12 to 17, when a rise of 1.65 m was recorded.

The highest water level of the year was recorded at 19.85 m+PWD on August 06 after a sharp rise of 1.27 m within six days only, followed by a period with small fluctuations only. From mid August to mid September the total changes were 0.35 m only and the average level was at 19.00 m+PWD. After the last peak at 19.41 m+PWD on September 19 the water level continuously dropped and at the end of year 13.79 m+PWD were recorded.

The following observations have been recorded from the period June to December 2000:

01/06	severe bank erosion d/s from Ghutail structure
06/06	low flow velocity along Ghutail structure and slow bank erosion from 400 m d/s from the structure
08 to 09/06	medium erosion along Harindhara and slow erosion from 100 m to 2.5 km d/s from the Ghutail structure
12/06	severe bank erosion 500 m d/s from Ghutail structure
14 to 23/06	severe bank erosion 500 m d/s from Ghutail structure. Medium bank erosion along Belgacha and slow erosion along Harindhara
26 to 30/06	Bankline under water
28/06	at Harindhara eddies
02 to 05/07	erosion and eddies along Harindhara and very low velocity along Ghutail structure
06/07	little erosion along Harindhara
21 to 31/07	no bank erosion at all
01/08	strong wind and wave prevailing
02 to 03/08	little erosion along Harindhara and d/s from Ghutail structure
04/08	flood protection embankment at Harindhara broken. Heavy erosion at Harindhara and 4.0 km d/s of Ghutail
08 to 19/08	slow bank erosion along Harindhara and Belgacha
20/08	heavy bank erosion along Harindhara
21/08	eddies along Harindhara
23 to 31/08	slow bank erosion along Harindhara as well as Belgacha
12 to 14/08	severe bank erosion along Harindhara
15 to 20/09	slow bank erosion along Harindhara and sometime also at Belgacha

4 MORPHOLOGICAL DEVELOPMENT AT BAHADURABAD IN 2000

No erosion in front of the structure was observed during the dry season 1999/2000, but the width of the strip of land, which had started to develop in the last quarter of 1999, slightly increased simultaneously with the falling water level. Only upstream from the test structure in the area of Harindhara small erosion was observed. The flow velocities were between 0.6 and 1.0 m/s in that area, whereas in the main channel 1.0 to 1.1 m/s were measures.

Also during the monsoon period no significant morphological changes were observed in the test site area. In front of the test structure a sedimentation process was recorded and flow velocities along the structure were between 1.2 and 1.6 m/s only. However, severe erosion continued upstream from the railway ghat in the area of Harindhara, where a deep scour hole developed in September. This erosion process continued till end of the year whereas a large char developed downstream from the Revetment Test Structure in the area of Belgacha and partly in front of the third test structure at Ghutail bazar.

5 STRUCTURE OBSERVATIONS - DAMAGES

During the flood season 2000 no significant damages of the test structure have been observed.

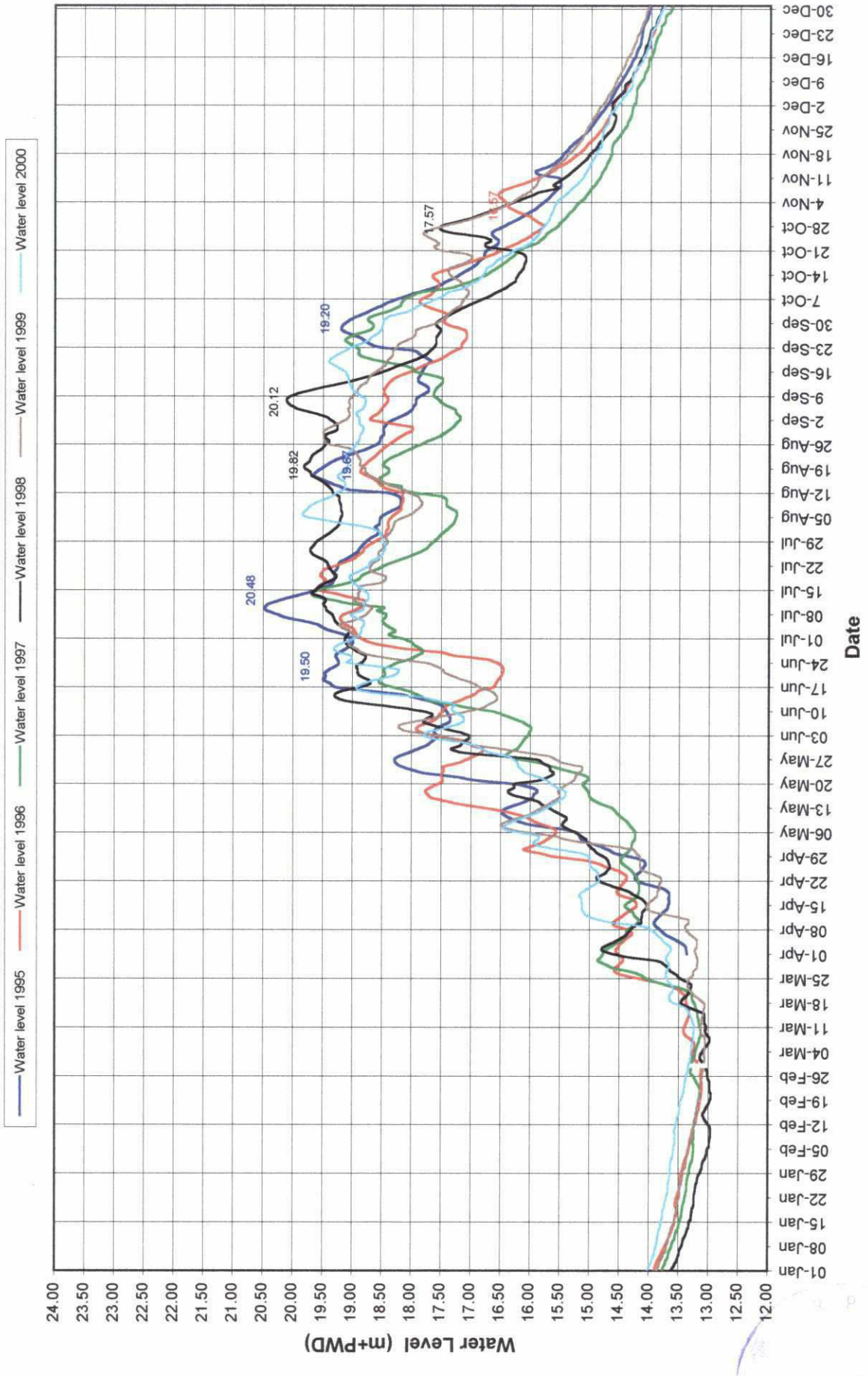
6 ADAPTATION AND REPAIR WORKS

No adaptation works of the test structure have been carried out after the monsoon season 2000.

ANNEX A

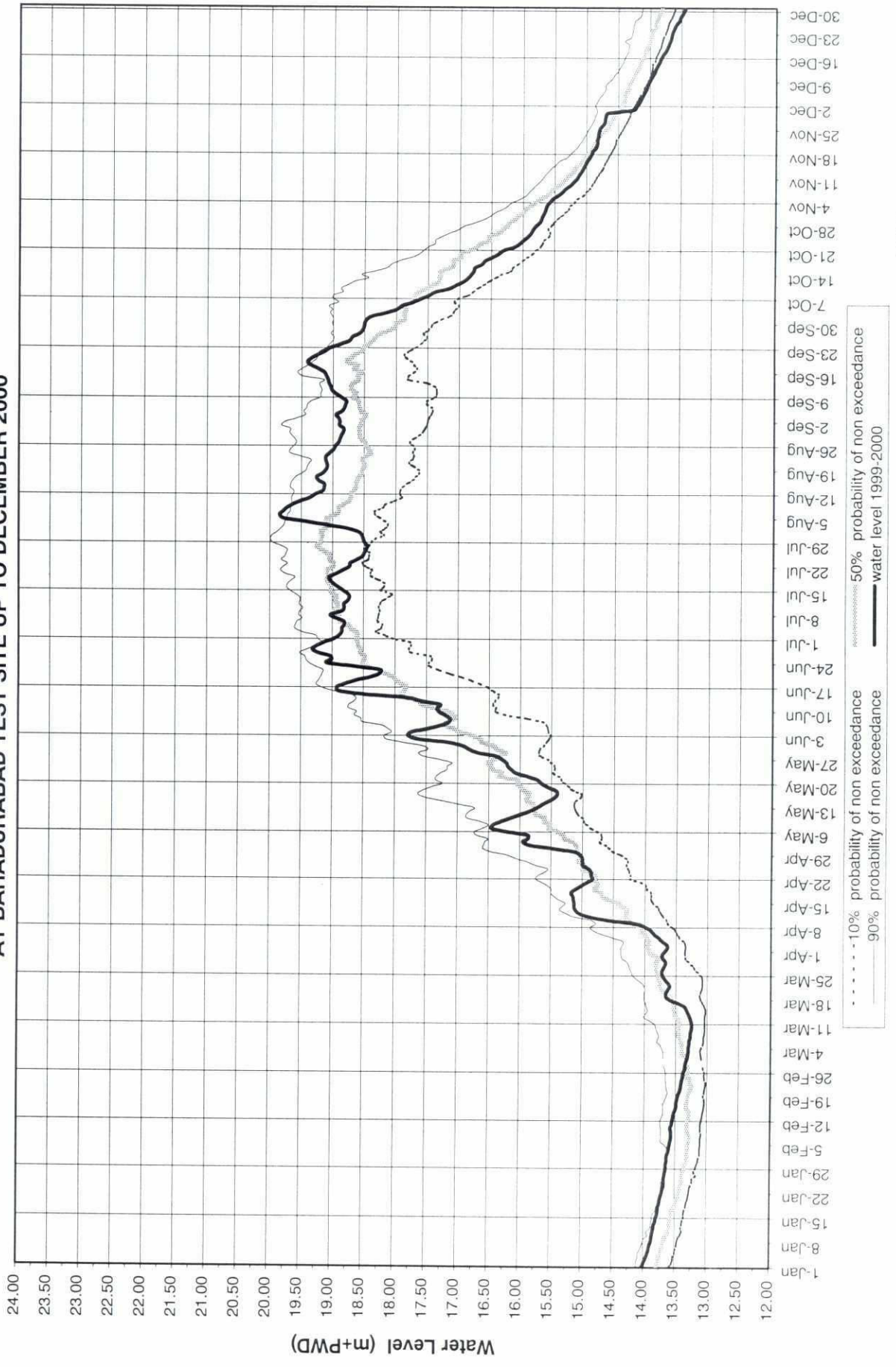
Water Level

BANK PROTECTION TEST STRUCTURES - FAP 21
WATER LEVEL AT BAHADURABAD TEST SITE
(January to December)



BANK PROTECTION TEST STRUCTURES - FAP 21

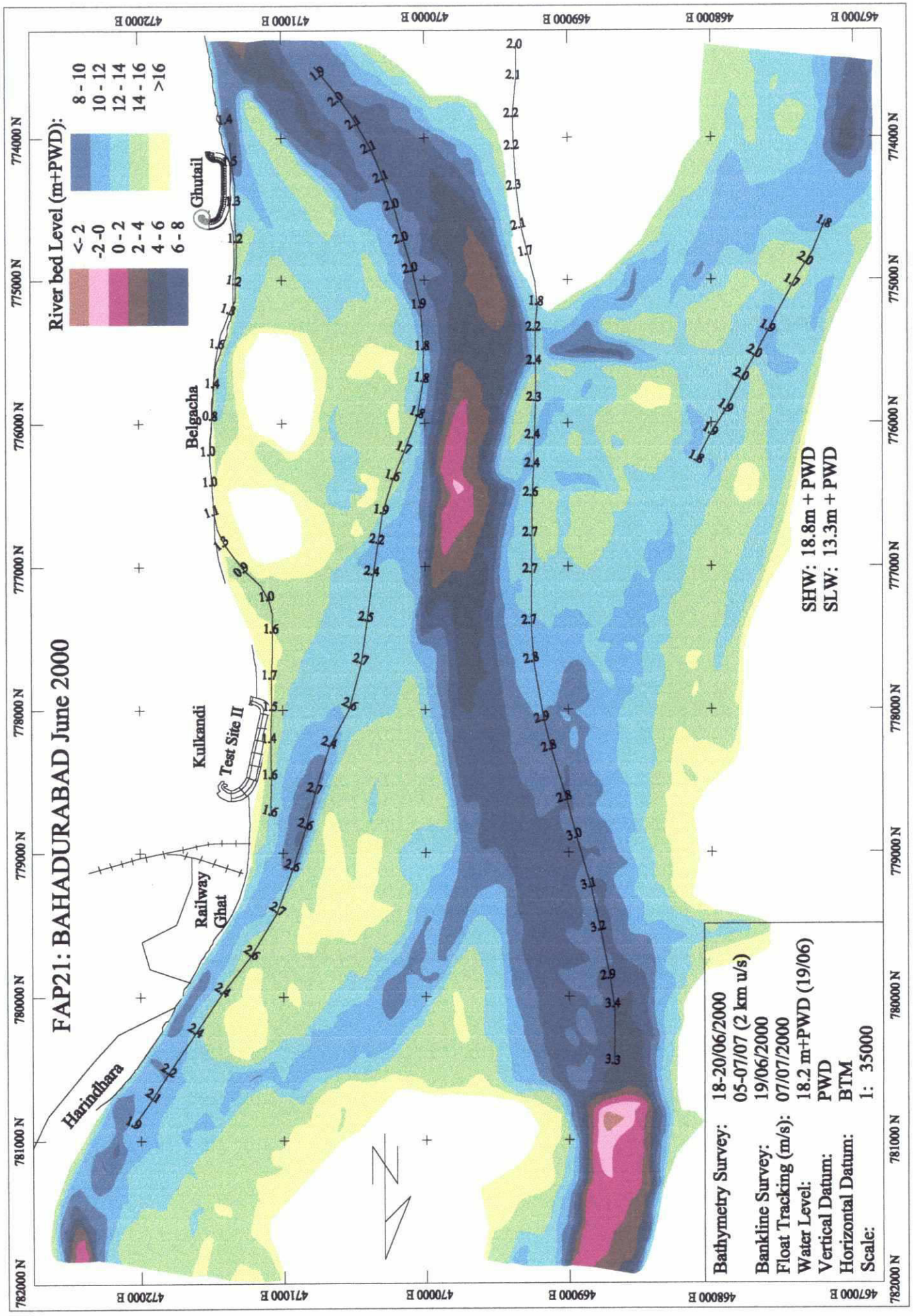
BWDB WATER LEVEL FREQUENCY CURVES VERSES ACTUAL FAP 21 WATER LEVEL AT BAHADURABAD TEST SITE UP TO DECEMBER 2000

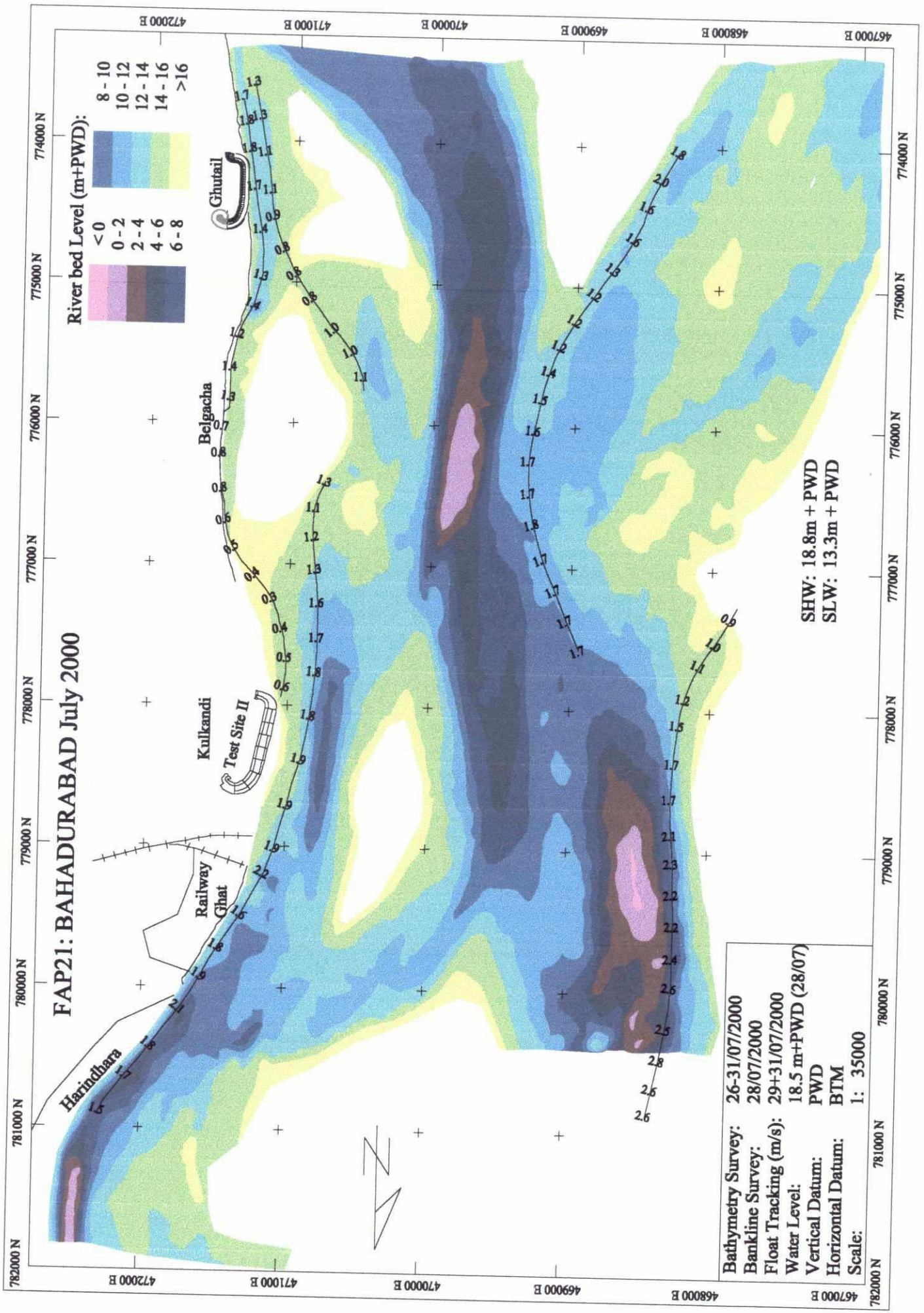


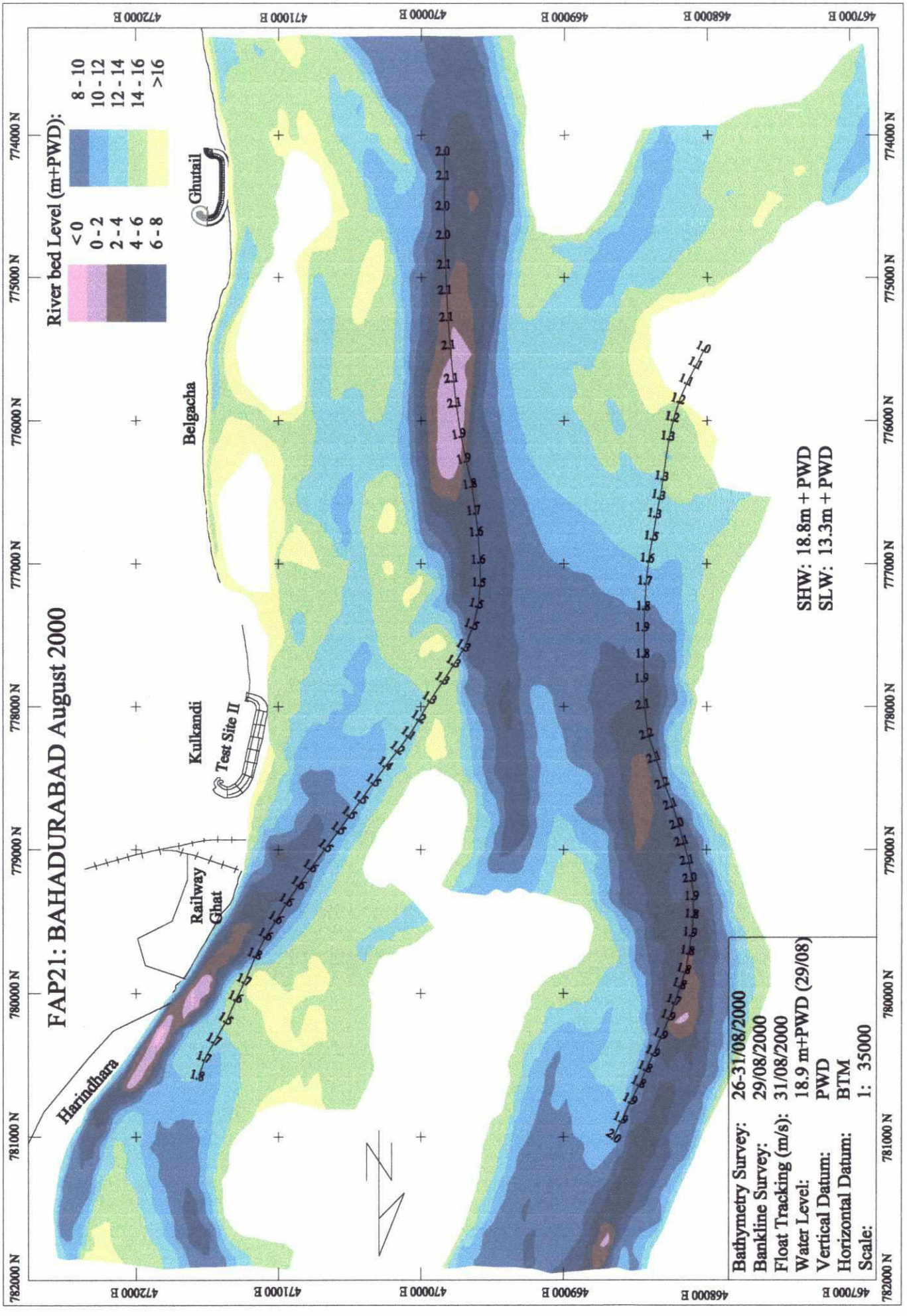
BWDB Data: Period of Record 1962 - 1994

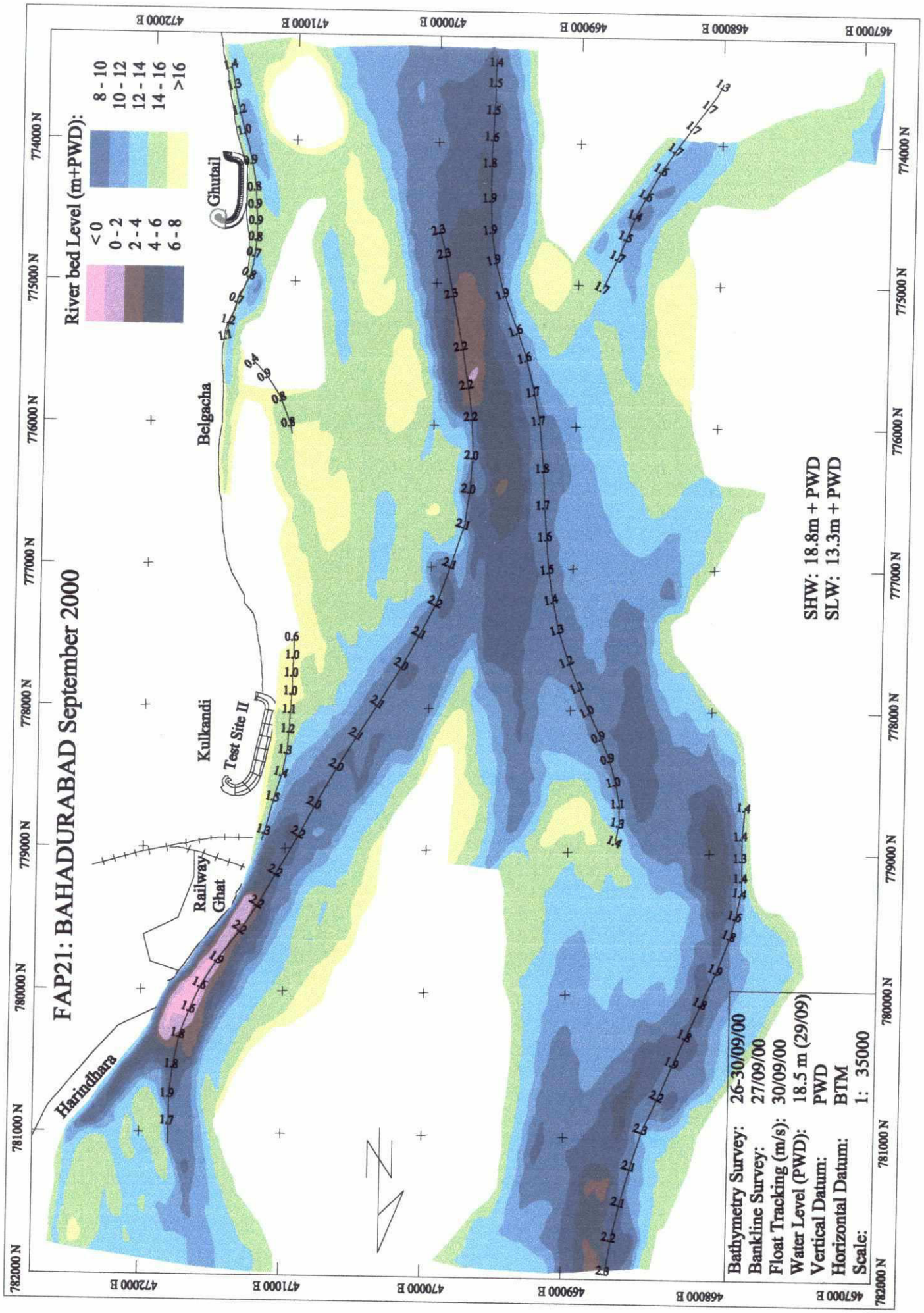
ANNEX B

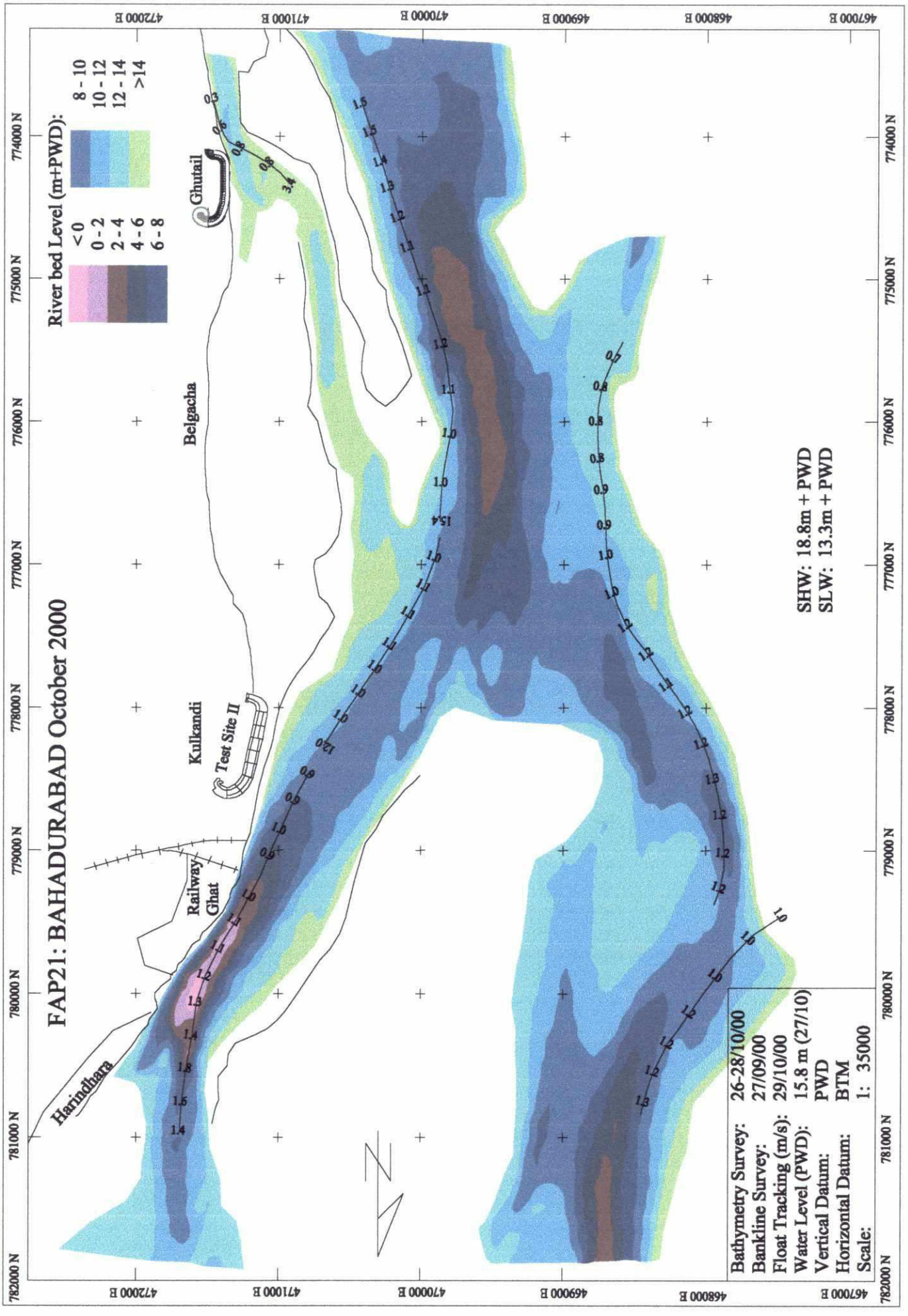
Bathymetric Survey and Flow Lines


FAP21: BAHADURABAD June 2000
River bed Level (m+PWD):
<-2
-2-0
0-2
2-4
4-6
6-8
8 - 10
10 - 12
12 - 14
14 - 16
>16
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
SHW: 18.8m + PWD
SLW: 13.3m + PWD
Bathymetry Survey: 18-20/06/2000 05-07/07 (2 km u/s)
Bankline Survey: 19/06/2000
Float Tracking (m/s): 07/07/2000
Water Level: 18.2 m+PWD (19/06)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
N
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E
774000 N
775000 N
776000 N
777000 N
778000 N
779000 N
780000 N
781000 N
782000 N


FAP21: BAHADURABAD July 2000
River bed Level (m+PWD):
<0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
>16
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
SHW: 18.8m + PWD
SLW: 13.3m + PWD
Bathymetry Survey: 26-31/07/2000
Bankline Survey: 28/07/2000
Float Tracking (m/s): 29+31/07/2000
Water Level: 18.5 m+PWD (28/07)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
N
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E
774000 N
775000 N
776000 N
777000 N
778000 N
779000 N
780000 N
781000 N
782000 N

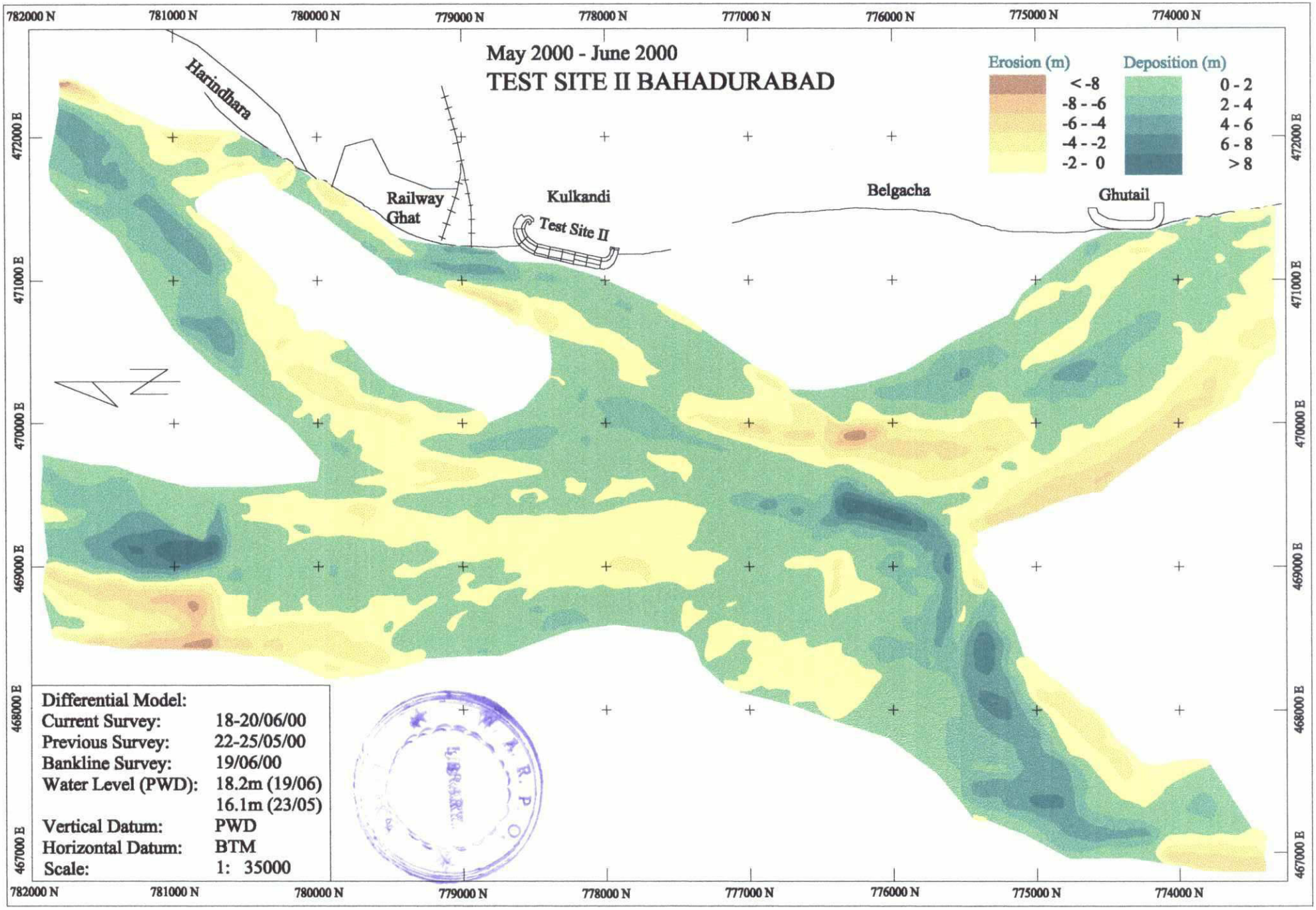

FAP21: BAHADURABAD August 2000
River bed Level (m+PWD):
< 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
>16
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
SHW: 18.8m + PWD
SLW: 13.3m + PWD
Bathymetry Survey: 26-31/08/2000
Bankline Survey: 29/08/2000
Float Tracking (m/s): 31/08/2000
Water Level: 18.9 m+PWD (29/08)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
N
467000 E
468000 E
469000 E
470000 E
471000 E
472000 E
782000 N
781000 N
780000 N
779000 N
778000 N
777000 N
776000 N
775000 N
774000 N

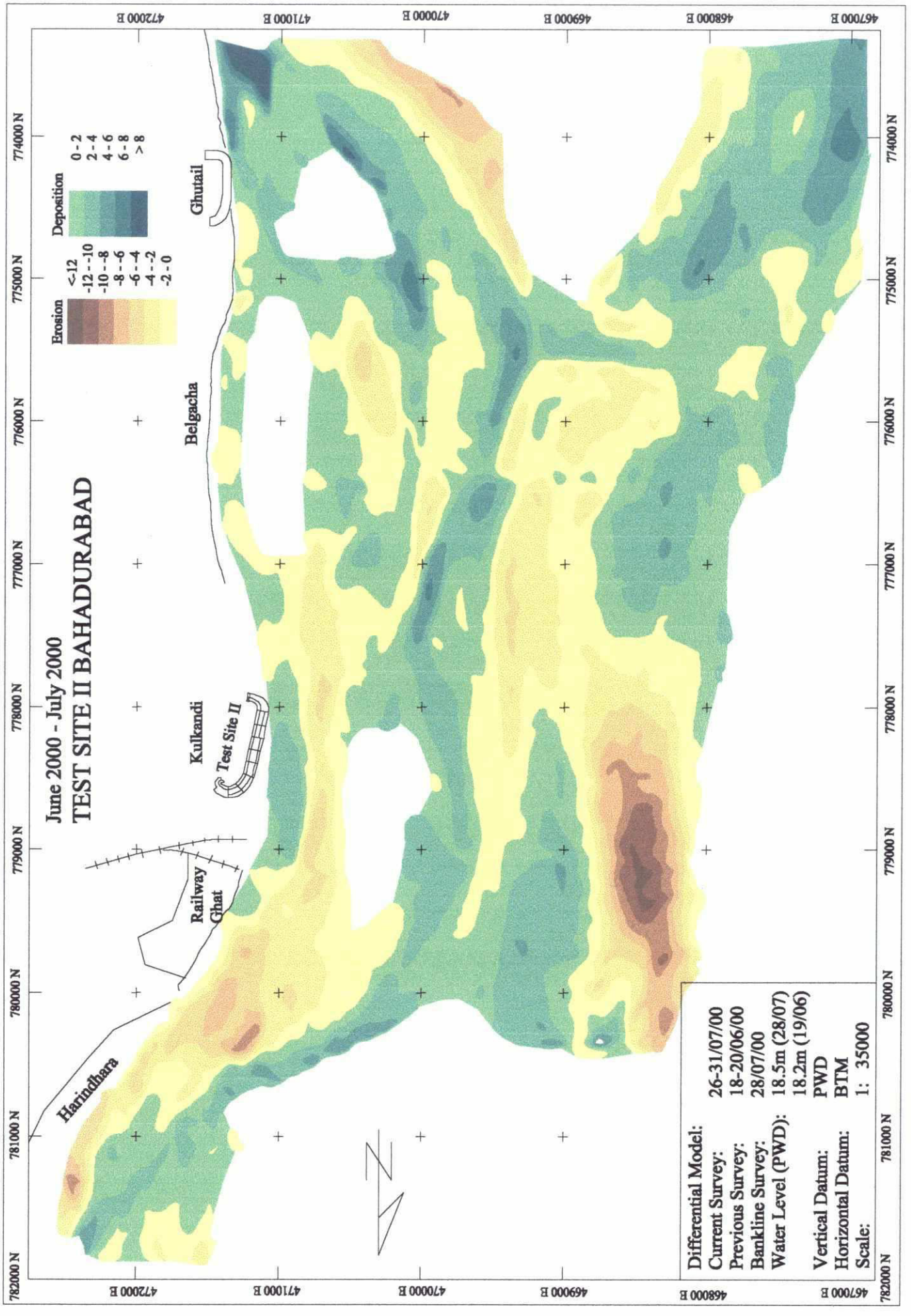

FAP21: BAHADURABAD September 2000
River bed Level (m+PWD):
<0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
>16
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
SHW: 18.8m + PWD
SLW: 13.3m + PWD
Bathymetry Survey: 26-30/09/00
Bankline Survey: 27/09/00
Float Tracking (m/s): 30/09/00
Water Level (PWD): 18.5 m (29/09)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E
774000 N
775000 N
776000 N
777000 N
778000 N
779000 N
780000 N
781000 N
782000 N

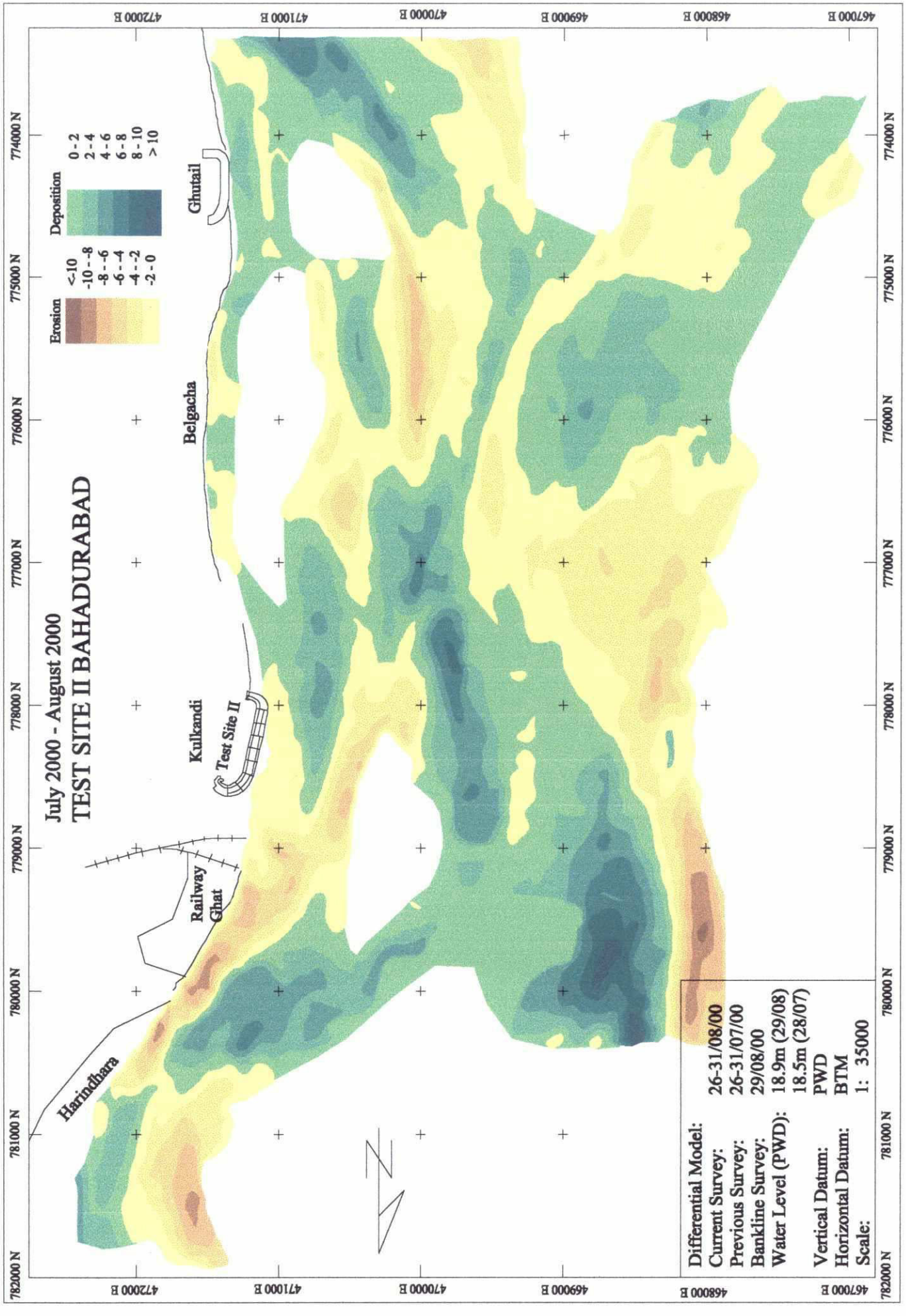

FAP21: BAHADURABAD October 2000
River bed Level (m+PWD):
<0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
>14
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
SHW: 18.8m + PWD
SLW: 13.3m + PWD
Bathymetry Survey: 26-28/10/00
Bankline Survey: 27/09/00
Float Tracking (m/s): 29/10/00
Water Level (PWD): 15.8 m (27/10)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
N
467000 E
468000 E
469000 E
470000 E
471000 E
472000 E
774000 N
775000 N
776000 N
777000 N
778000 N
779000 N
780000 N
781000 N
782000 N

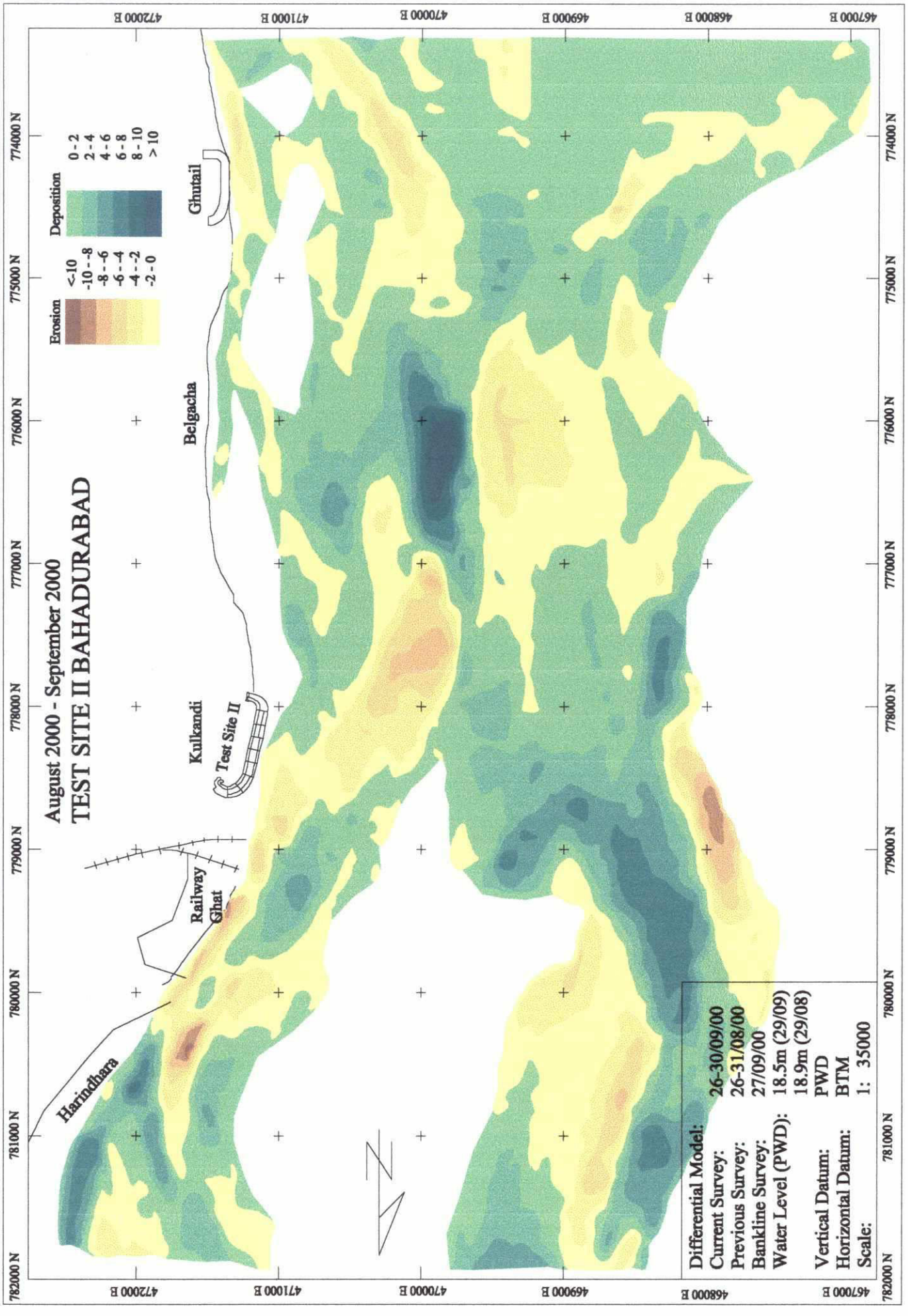
ANNEX C

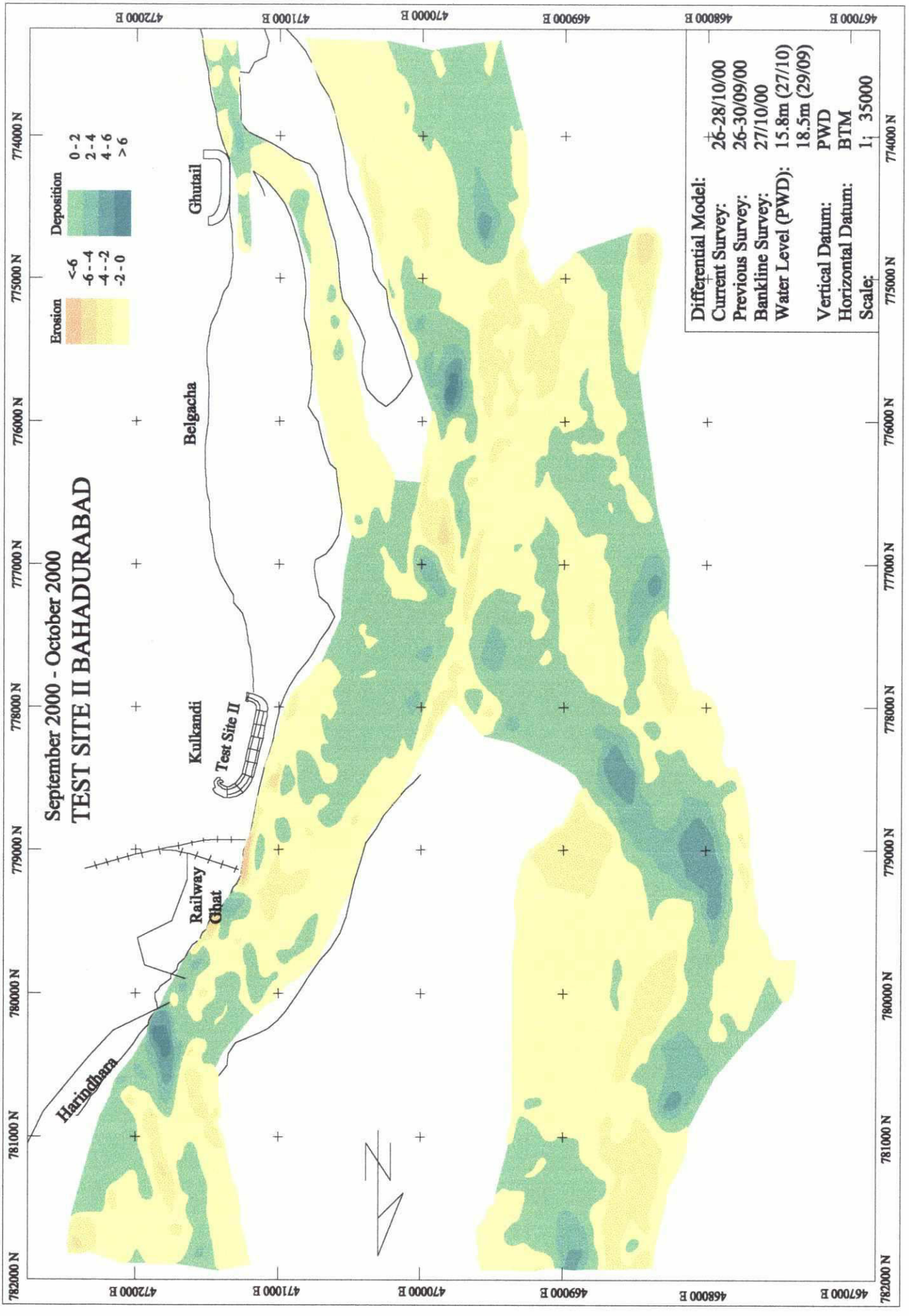
Differential Models


May 2000 - June 2000
TEST SITE II BAHADURABAD
Erosion (m)
< -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
Deposition (m)
0 - 2
2 - 4
4 - 6
6 - 8
> 8
Harindhara
Railway Ghat
Kulkandi
Test Site II
Belgacha
Ghutail
N
782000 N
781000 N
780000 N
779000 N
778000 N
777000 N
776000 N
775000 N
774000 N
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E
Differential Model:
Current Survey: 18-20/06/00
Previous Survey: 22-25/05/00
Bankline Survey: 19/06/00
Water Level (PWD): 18.2m (19/06)
16.1m (23/05)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000


June 2000 - July 2000
TEST SITE II BAHADURABAD
Erosion
<-12
-12 - -10
-10 - -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
6 - 8
> 8
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
Differential Model:
Current Survey: 26-31/07/00
Previous Survey: 18-20/06/00
Bankline Survey: 28/07/00
Water Level (PWD): 18.5m (28/07)
18.2m (19/06)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
782000 N
781000 N
780000 N
779000 N
778000 N
777000 N
776000 N
775000 N
774000 N
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E


July 2000 - August 2000
TEST SITE II BAHADURABAD
Erosion
<-10
-10 - -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
> 10
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
Differential Model: 26-31/08/00
Current Survey: 26-31/07/00
Previous Survey: 29/08/00
Bankline Survey: 18.9m (29/08)
Water Level (PWD): 18.5m (28/07)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
782000 N
781000 N
780000 N
779000 N
778000 N
777000 N
776000 N
775000 N
774000 E
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E


August 2000 - September 2000
TEST SITE II BAHADURABAD
Erosion
<-10
-10 - -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
> 10
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
Differential Model:
Current Survey: 26-30/09/00
Previous Survey: 26-31/08/00
Bankline Survey: 27/09/00
Water Level (PWD): 18.5m (29/09)
18.9m (29/08)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E
782000 N
781000 N
780000 N
779000 N
778000 N
777000 N
776000 N
775000 N
774000 N


September 2000 - October 2000
TEST SITE II BAHADURABAD
Erosion
<-6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
>6
Differential Model:
Current Survey: 26-28/10/00
Previous Survey: 26-30/09/00
Bankline Survey: 27/10/00
Water Level (PWD): 15.8m (27/10)
18.5m (29/09)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 35000
Ghutail
Belgacha
Kulkandi
Test Site II
Railway Ghat
Harindhara
N
472000 E
471000 E
470000 E
469000 E
468000 E
467000 E
774000 N
775000 N
776000 N
777000 N
778000 N
779000 N
780000 N
781000 N
782000 N

ANNEX D

Cross-Sections

BAHADURABAD (FAP 21) - TEST SITE II

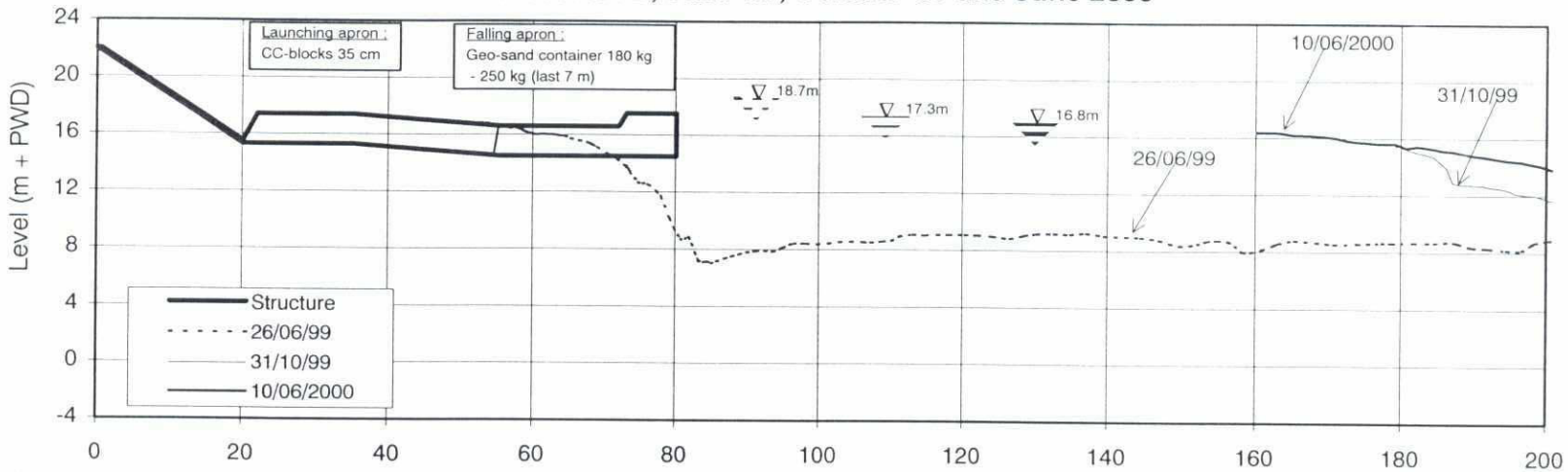
Cross-Section B, June '99, October '99 and June 2000

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471272 E
778499 N

Azimuth: 307°



Station 0 = Edge of Crest

Progressive distance perpendicular to the alignment of the embankment (m)

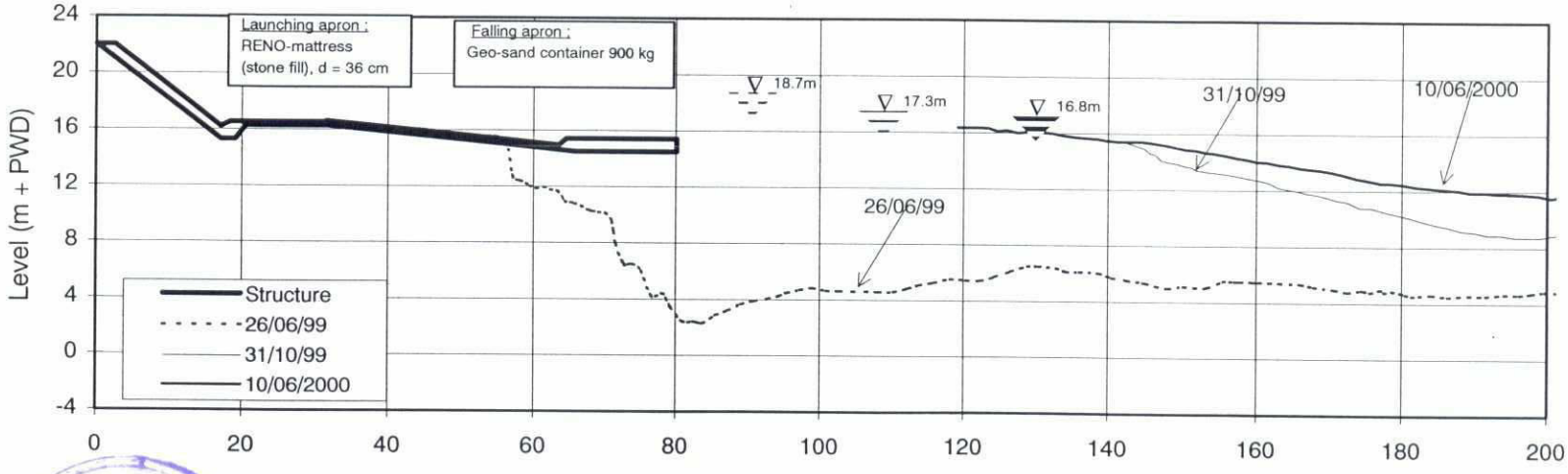
Cross-Section C, June '99, October '99 and June 2000

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471240 E
778424 N

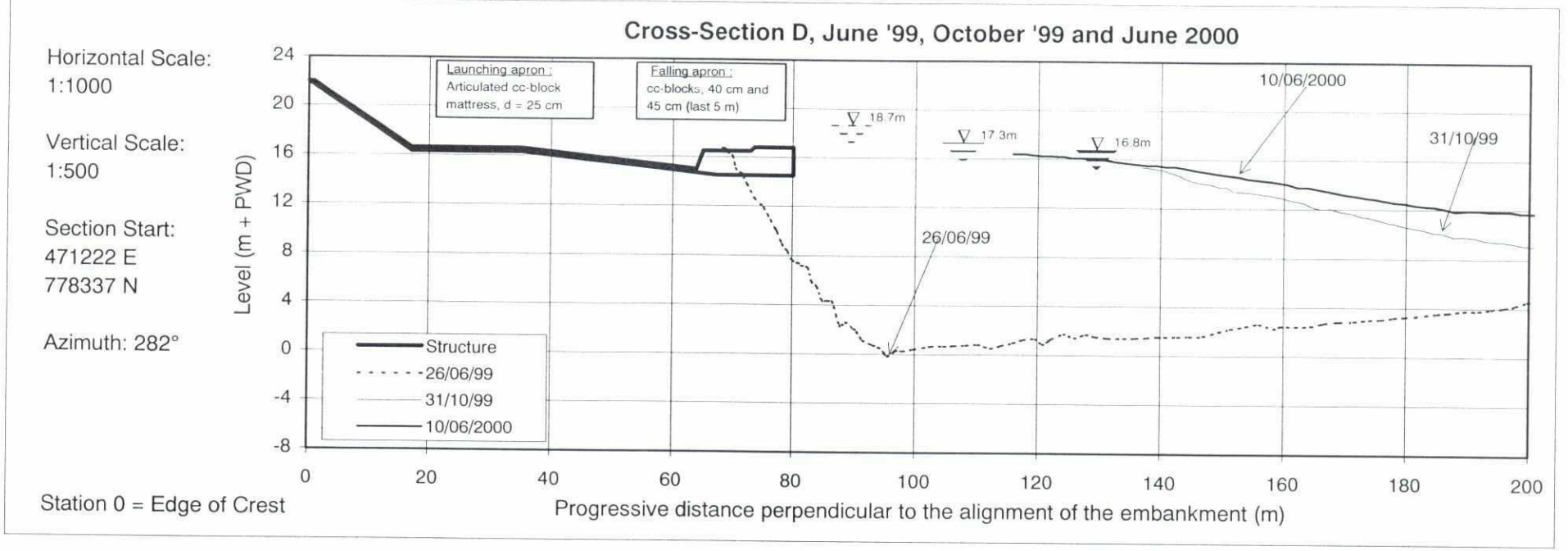
Azimuth: 282°

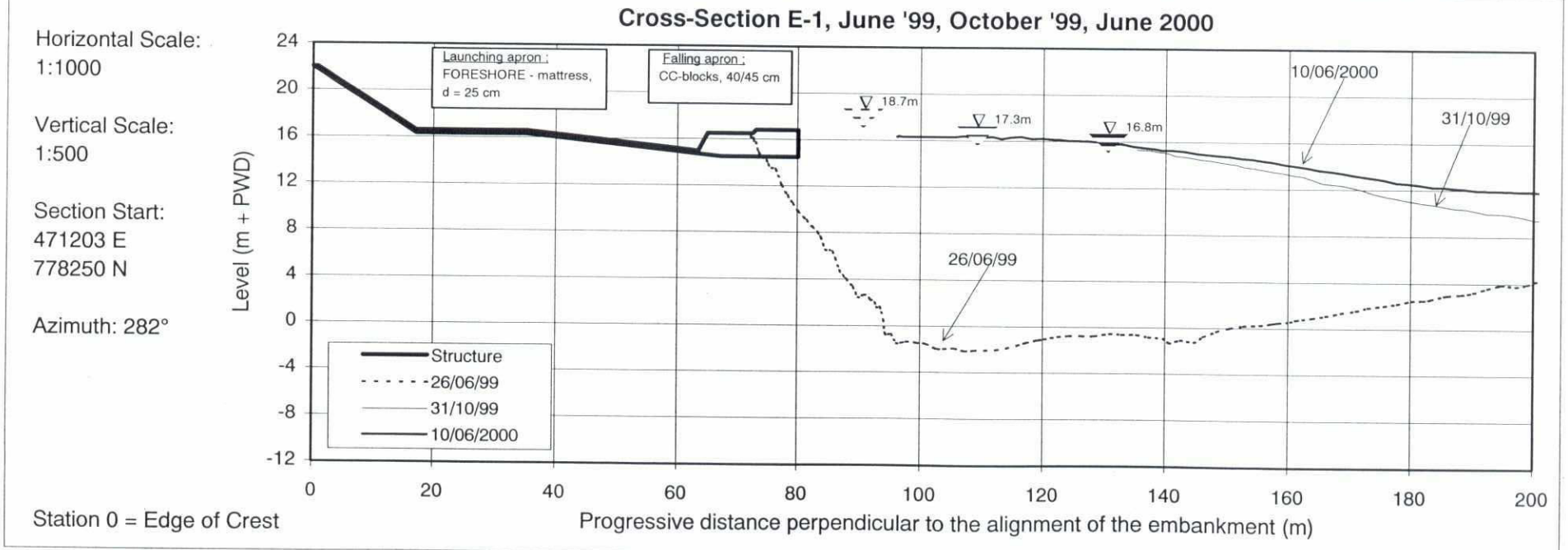


Station 0 = Edge of Crest

Progressive distance perpendicular to the alignment of the embankment (m)

BAHADURABAD (FAP 21) - TEST SITE II





BAHADURABAD (FAP 21) - TEST SITE II

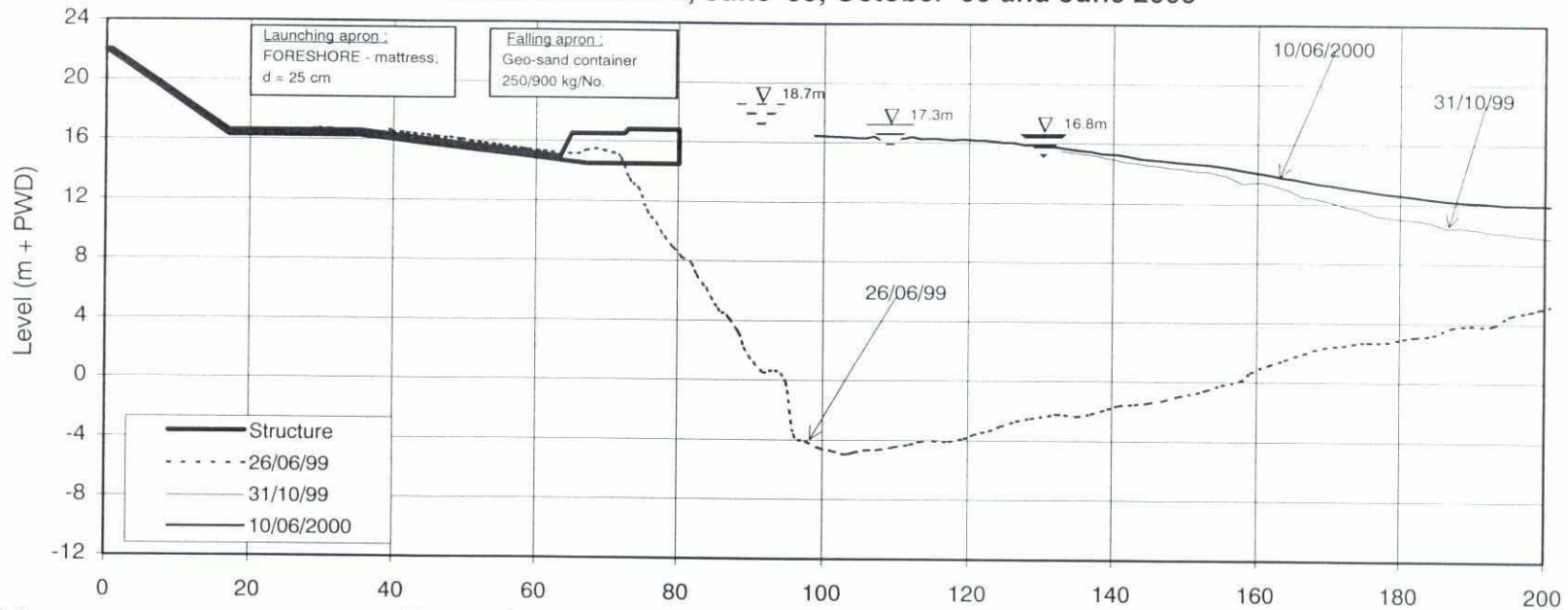
Cross-Section E-2, June '99, October '99 and June 2000

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471201 E
778229 N

Azimuth: 282°



Station 0 = Edge of Crest

Progressive distance perpendicular to the alignment of the embankment (m)

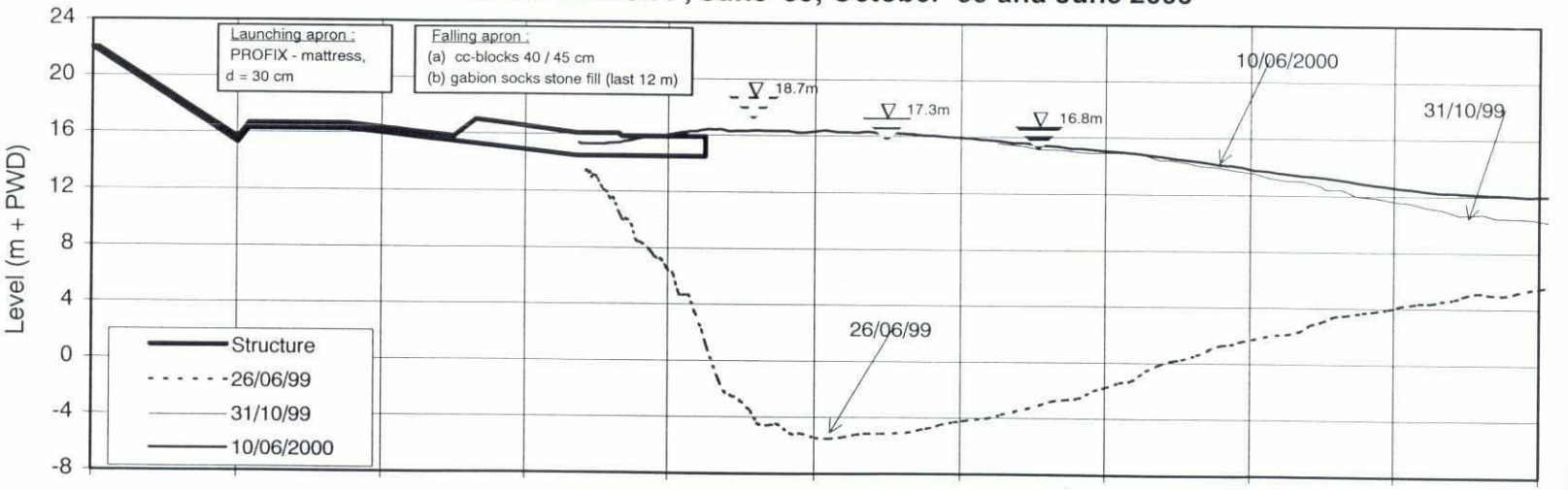
Cross-Section F, June '99, October '99 and June 2000

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471185 E
778162 N

Azimuth: 282°



Station 0 = Edge of Crest

Progressive distance perpendicular to the alignment of the embankment (m)

BAHADURABAD (FAP 21) - TEST SITE II

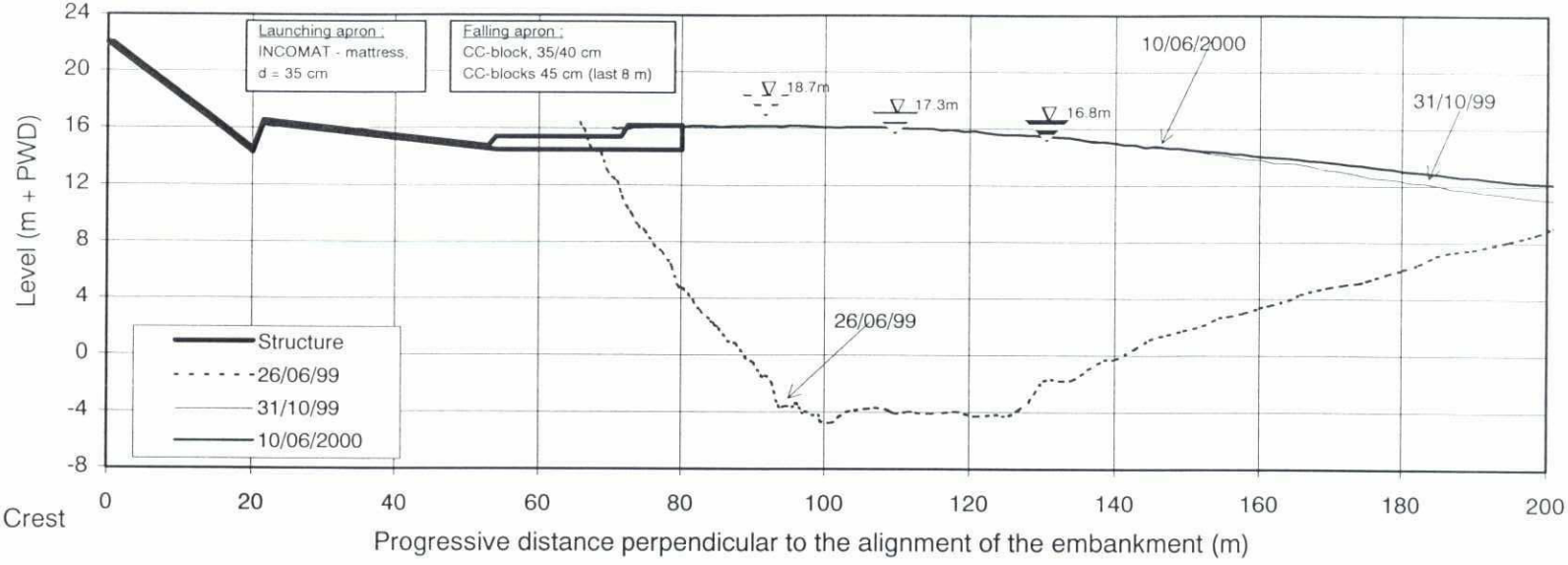
Cross-Section G, June '99, October '99 and June 2000

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471165 E
778071 N

Azimuth: 282°



Station 0 = Edge of Crest

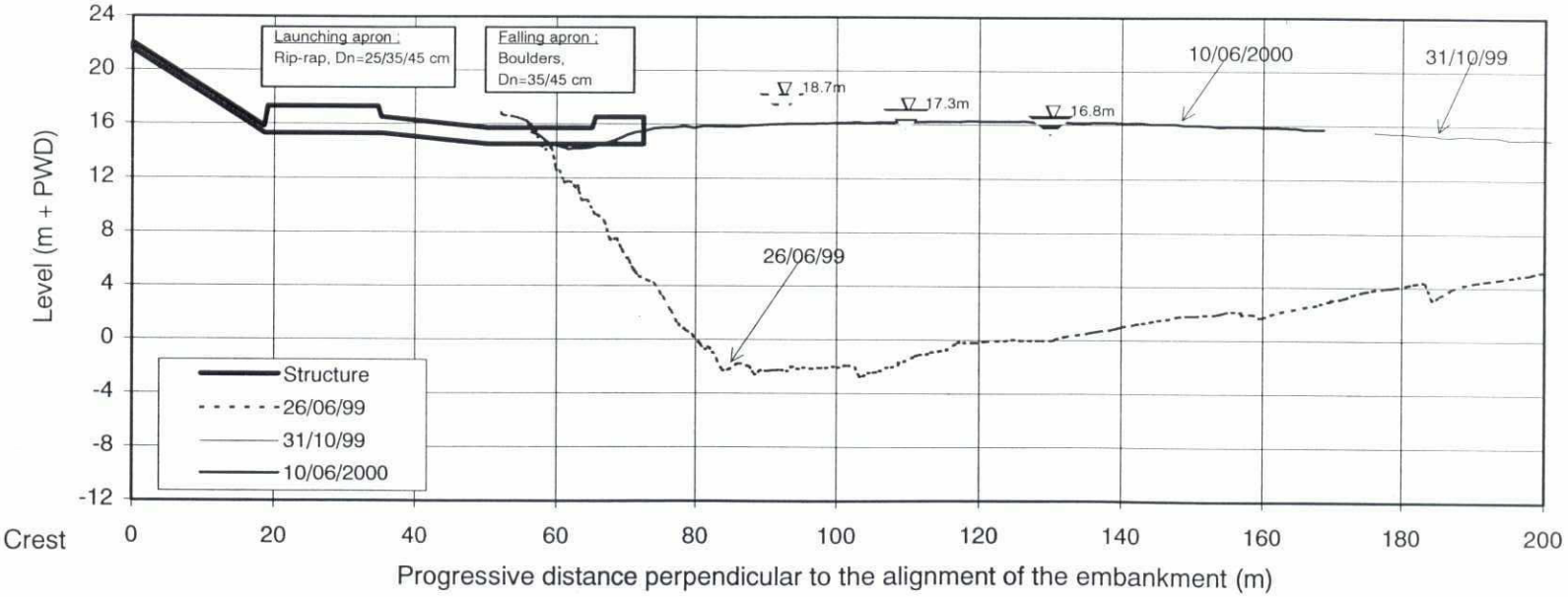
Cross-Section H-1, June '99, October '99, June 2000

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471158 E
777994 N

Azimuth: 242°



Station 0 = Edge of Crest