

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

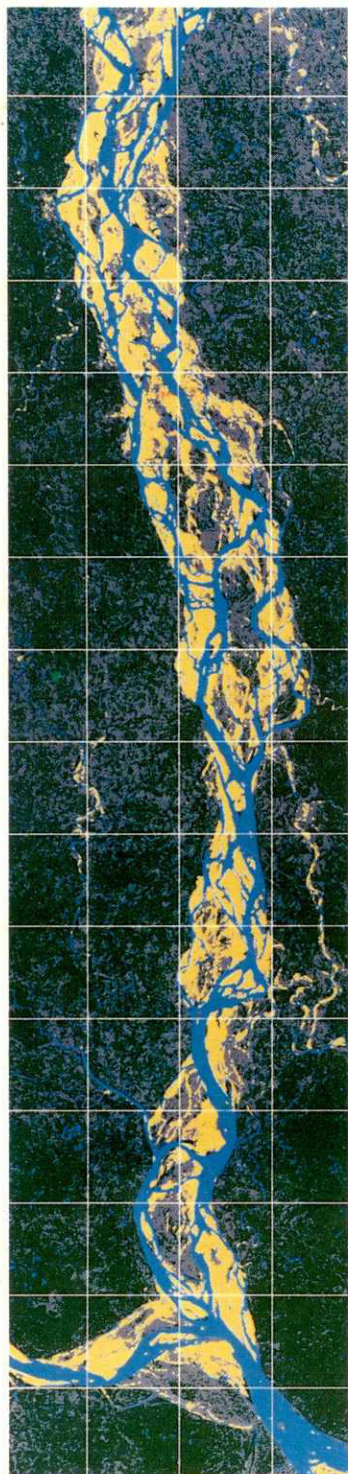
FEDERAL REPUBLIC OF GERMANY

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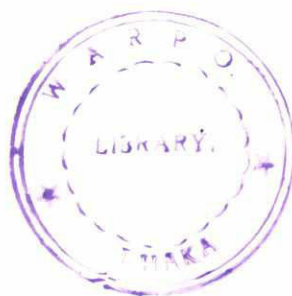
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**BANK PROTECTION AND
RIVER TRAINING (AFPM)
PILOT PROJECT
FAP 21/22**

**TEST
AND
IMPLEMENTATION
PHASE
FAP 21**



**REPORT ON
MONITORING AND ADAPTATION
AT
BAHADURABAD TEST SITE**

MONSOON 1999

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)

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HFN
2704

**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**

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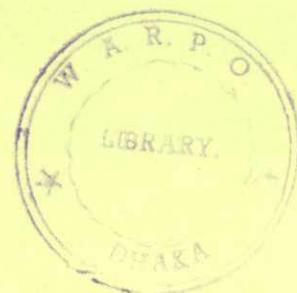
MARCH 2001

**BANK PROTECTION AND RIVER TRAINING/AFPM PILOT PROJECT
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).

2.4 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.





NOTES

Levels refer to 40.00m PWD


1. Measurements in meter

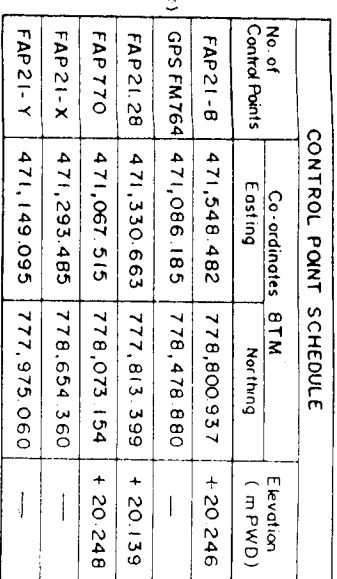
2. F.L. Finished level

3. F.L. Excavation level

4. Reference Drawings

DETAILED LAYOUT
OF
TEST STRUCTURE
(1996/97)

REV	21	4/97	ANOMOL	AS BUILT DRAWING	 APPROVED
DATE			NAME	DESCRIPTION	
GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH MINISTRY OF WATER RESOURCES WATER RESOURCES PLANNING ORGANISATION (WARPO)					
BANK PROTECTION PILOT PROJECT FAP-21					
JALAKATA TEST WORKS CONSULTANTS, PRIVATE LIMITED CONSULTING ENGINEER (FAP-21) BISHEN SINGH & CO. PVT. LTD., DORTMUND-GERMANY COMPACTION INVESTIGATOR FOR BANKING, CLAYING AND REPAIR WORKS AND MATERIALS RESEARCH LABS DORTMUND-GERMANY, FIELD INVESTIGATOR					
By: JALAKATA TEST WORKS CONSULTANTS, PRIVATE LIMITED BANGALADESH ENGINEERING & TECHNOLOGICAL UNIVERSITY, DAKA TEST REPORT NUMBER: 17/96					
TEST SITE 11 - BAHADURABAD					
DETAILED LAYOUT OF TEST STRUCTURE (1996/97)					
DRAWN	NAME	DATE	SCALE	1 : 1000	REVISION
ANOMAR		09-10-96			1
CHECKED	J.K.	03-11-96			
APPROVED					




*) not existent anymore

£471,400

£47,200


E 471000



LEGEND

Embarkment
 Road (Pucca, Kachra, Foot path)
 High River, Bank
 House Pucca, Kachra, A Tinsed
 Trowse Station, B shed
 Mosque
 Home shed

NOTES
 1. The topography shown on this drawing is based on J.T.W.C. survey of 1911, as combined with topographical map of Survey of Bangladesh.
 2. Levels refer to 10.000 m P.M.D.
 3. Bank line and bathymetric surveys on 09/10/2000
Reference Drawing
 R A 302 Structure layout of "Est Structure"



BANK PROTECTION PILOT PROJECT FAP-21

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF B
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION

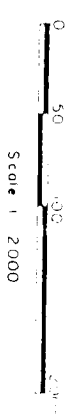
BANK PROTECTION PILOT PROJECT FAP-21

TEST SITE II - BAHADURABAD

GENERAL LAYOUT OF TEST STRUCTURE (1996/97)

DRAWING PHOTOREDUCTION BY 50%

SCALE		1:2,000
FIG. 2.1	REVISION	
	1	
DATE	NAME	
03-11-96	ANWAR	
03-11-96	CHECKED	
	APPROVED	
E470600		



- | | |
|-------------|------------------------------------|
| R - A - 302 | Detorted (Group of Test Structures |
| R - A - 304 | Geofabric Filter Materials |
| | General Arrangement: |

<p> #1 MIXED CC - BLOCKS 30cm + BOULDERS GRADE E IN ENVELOPE OF DOUBLE LAYER CHAIN LINK FENCE </p>	<p> #2 MIXED CC - BLOCKS 35 cm + BOULDERS GRADE F IN ENVELOPE OF DOUBLE LAYER CHAIN LINK FENCE </p>
--	---

DESIGNATION OF DESIGN SECTIONS AND MATERIALS

DRAWING PHOTOREDUCTION BY 50%


1	1.6.97	APPROVED	AS BUILT DRAWING
REV	DATE	NAME	DESCRIPTION

Quinn
APPROVED

GOVERNMENT OF THE PEOPLES REPUBLIC OF BANGLADESH
 MINISTRY OF WATER RESOURCES
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BANK PROTECTION PILOT PROJECT FAP-21

JALIANA TEST WORKS CONSULTANTS JOINT VENTURE
 CONSULTING ENGINEERS PVT LTD
 10/1, RAJABAZAR, DAKSHIN KALKAJI, DISTRICT CHITTAGONG
 RAJABAZAR, DISTRICT CHITTAGONG
 RAJABAZAR, DISTRICT CHITTAGONG



IN WITNESS WHEREOF,
 SIGNATURE OF ENGINEER, A
 RAJABAZAR, DISTRICT CHITTAGONG
 RAJABAZAR, DISTRICT CHITTAGONG

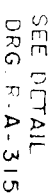
TEST SITE II - BAHADURABAD

**DESIGNATION OF DESIGN SECTIONS
AND MATERIALS**

NAME	DATE	SCALE
DRAWN	13-10-96	1:2000
CHECKED	16-10-96	
APPROVED		

FIG. 2.3

REVISION
1



[Handwritten musical notation]

[Handwritten musical notation]

1. Levels refer to ± 0.00 m FWD
2. Measurements are shown in meter
3. C/L : Finished level
4. Elevation level
5. Erection level
6. Trafficable filter materials and fabric mattresses will be supplied by the Employer
7. accordance with Specifications, Sub sections 2.20 and 2.30
8. Reference Drawings
R. A. - 302 Detailed layout of "as" structures
R. A. - 303 Unsettlement of Design Sections and Materials

	0	50	100
0			
50			
100			

	0	50	100
0			
50			
100			

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 (proper seam) to "win sheets".

(supplied by)

PRAYER SEAM
(without scale)

DRAWING PHOTOREDUCED BY 50%

GEOTEXTILE FILTER MATS
GENERAL ARRANGEMENT

SCALE: 1 : 2000

REVISION

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 MONITORING DURING THE MONSOON PERIOD 1999

3.2.1 Preliminary Remarks

Monitoring of the Revetment Test Structure started 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. 23 to 26 have been published.

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 1999 are shown in Table 3.1.

The results of the main survey from June to December 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 Electronic Distance Measurement (EDM) equipment and levelling instrument. During the period from June to December 1999 the following works were performed:

17 to 18/06	bankline from Harindhara to Ghutail bazar
27 to 28/06	survey of boundaries of roads and homesteads upstream from the test structure
29/06	survey of boundaries of roads and homesteads downstream from the test structure
05 to 06/07	bankline from the test structure to 3.0 km downstream from Ghutail bazar
21/07	bankline from the railway ghat to 2.0 km upstream from Harindhara school
27/07	survey at boundaries of embankment upstream from the railway ghat by single GPS
02/08	bankline from the railway ghat to 300 m upstream from Harindhara school
19/08	bankline from the test structure to Belgacha
21/08	waterline in front of the test structure
23 to 24/08	bankline from the test structure to 1.0 km downstream from Ghutail bazar
29/08	6 Nos cross-sections taken at Ghutail bazar along with bathymetry
06/09	bankline from the test structure to 2.5 km downstream from Ghutail bazar
11/09	bankline from the railway ghat to Harindhara
19/09	bankline along Belgacha
12/10	char downstream from the test structure in front of Belgacha
13/10	bankline from Section H to 2.5 km downstream from Ghutail bazar
14/10	char in front of the Ghat
15/10	bankline from 4 km upstream from the Ghat to Section C
04/11	bankline from Belgacha to 2.5 km downstream from the char in front of Ghutail
19 to 20/11	cross-sections at Ghutail
21 to 26/11	set out of third test structure at Ghutail
27/11	bankline at Ghutail
12/12	set out of third test structure at Ghutail
13 to 20/12	levelling for third test structure at 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 1999	July 1999	August 1999	September 1999	October 1999	November 1999
01		main survey				
02		main survey				
03		main survey				
04		main survey				
05		main survey				
06		main survey				
07						
08						
09						
10					main survey	
11					main survey	
12					main survey	
13					main survey	
14						
15						
16	main survey					
17	main survey					
18	main & site survey		main survey			
19			main survey			
20			main survey			
21			main survey			
22			main survey			
23			main survey	main survey		
24				main survey		
25				main survey		
26				main survey		
27				main survey		main survey
28	site survey			main survey	main survey	main survey
29				main survey	main survey	main survey
30						
31						

Table 3.1: Bathymetric survey at Bahadurabad Test Site from June to December 1999

3.2.5 Observations

The usual seasonal rise of the water level was delayed and started on April 11 only. Peaks during the second quarter of the year were recorded at 16.51 m+PWD on May 08 and at 18.21 m+PWD on June 05. The highest water level of the monsoon 1999 was measured at 19.50 m+PWD on August 29. After the last peak on October 26 at 17.33 m+PWD, the water level continuously dropped till end of December, when 14.03 m+PWD were recorded.

The following observations have been recorded from the period June to December 1999:

03/06	slow bank erosion along Section B
04/06	wind from west to east with a speed of 8-9 m/s at 4:00 a.m.
05/06	slow bank erosion along Harindhara and from Railway ghat to the structure
19/06	back flow at Section H
15 to 26/06	slow bank erosion just downstream from test structure
23 to 28/06	slow bank erosion along Belgacha area
24/06	cc-blocks falling down at Section H
24 to 28/06	blocks over the falling apron of curved portion (Section H) falling down. Strong back flow and eddies observed at this location.
01/07	rainfall of 117 mm recorded from 8:00 hrs. on 01/07 to 08 hrs on 02/07.
02/07	severe bank erosion at Belgacha at 16:50 hrs. 3 m erosion along the bank over a length of 150 m within 1 hour
03/07	4 m bank erosion occurred since 17:30 hrs. on 02/07 at Belgacha
07/07	approximately 2 m of bank erosion at Harindhara erosion progress at Belgacha almost stopped
08/07	erosion along Harindhara continued slow back flow occurred in front of test structure big eddies at Section G and H-1
11 to 13/07	erosion process at Harindhara continued strong current along the bank observed as well as eddies
19/07	rainfall of 93 mm recorded from 8:00 hrs. on 19/07 to 8:00 hrs. on 20/07
20/07	rainfall of 128 mm recorded from 8:00 hrs. on 20/07 to 8:00 hrs. on 21/07
01/08	approximately 1.5 m of bank erosion at Harindhara
02 to 05/08	bank erosion less than 1 m but eddies still observed at Harindhara
06 to 08/08	no erosion along Harindhara
09 to 13/08	approximately total 12 m of bank erosion over 100 m length along Harindhara
14/08	bank erosion at Ghutail bazar
15 to 13/08	slow bank erosion continued along Ghutail and Belgacha
24/08	approximately 2.5 m of bank erosion at Harindhara
25 to 26/08	approximately 5 to 20 m of bank erosion along various points at Harindhara for the last two days
27 to 31/08	approximately average 1 m of bank erosion per day at Harindhara
01 to 05/09	slow bank erosion continued along Ghutail and Belgacha
04/09	about 10 m erosion downstream from Harindhara during last 24 hours
09/09	severe bank erosion and eddies along railway ghat

M

11/09	bank erosion and eddies along railway ghat
08-10	in front of Belgacha a char visible
09/10	slow bank erosion downstream from Ghutail bazar
13/10	slow bank erosion in Harindhara area
27/10	slow bank erosion downstream from Ghutail bazar
29/10	slow bank erosion downstream from Ghutail bazar
30/10	slow bank erosion downstream from Ghutail bazar

4 MORPHOLOGICAL DEVELOPMENT AT BAHADURABAD IN 1999

During the dry season 1998/99 no significant morphological changes in the test site area had been observed. In May 1999 the flow velocities in front of the test structure increased and maximum values of 1.7 m/s were recorded. At the same time an erosion process started, which continued during the following month. The deepest part of the riverbed in June was found just downstream from Section H where 12 m erosion and flow velocities of more than 1.9 m/s were measured.

In July, the channel which aimed during the first five months of the year at an angle of about 40° at Section B and C of the test structure, shifted further downstream and the parallel channel in front of the falling aprons started to silt up to a level of about 16 m+PWD. Deposition of about 19 m were recorded in a time period less than one month. This sudden change from scouring to a deposition process happened in the same way as last year and can be studied in the cross-sections of Annex D.

During the last quarter of the year a strip of land gradually surfaced in front of the test structure due to the continuously falling water level. The local population started immediately to cultivate the new land. The flow velocity along the new bankline was about 0.3 to 0.4 m/s.

Another severe bank erosion started in July in the area of Harindhara upstream from Bahadurabad ghat. A new channel from north-west at an angle of about 40° caused bank erosion. A deep scour hole developed about 2 km upstream from the Revetment Test Structure and moved downstream in south-west direction. Mid September its location was only about 700 m away from the test structure and its depth was below PWD.

Small erosion continued also in October at Harindhara, whereas the scour hole in front of the railway ghat started to silt up. In November/December the morphological changes declined more and more. Only deposition and minor erosion of less than 2 m in the area from north of Harindhara to downstream from Ghutail were observed.

5 STRUCTURE OBSERVATIONS - DAMAGES

During the flood season 1999 no significant damages of the test structure have been observed.

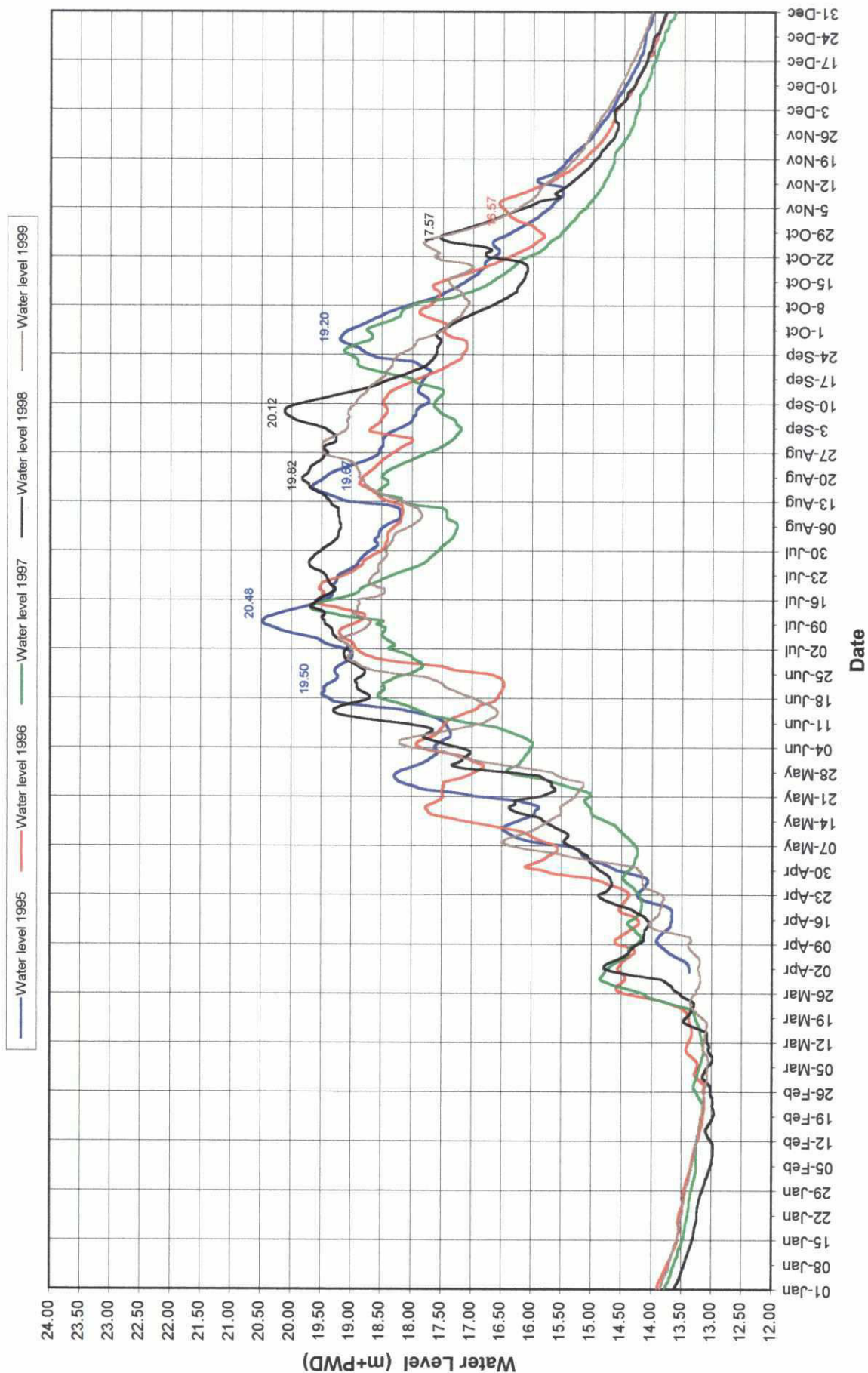
6 ADAPTATION AND REPAIR WORKS

No adaptation works of the test structure have been carried out after the monsoon season 1999. Only necessary repair of the revetment in Section E-2 by filling up the rain cuts was done.

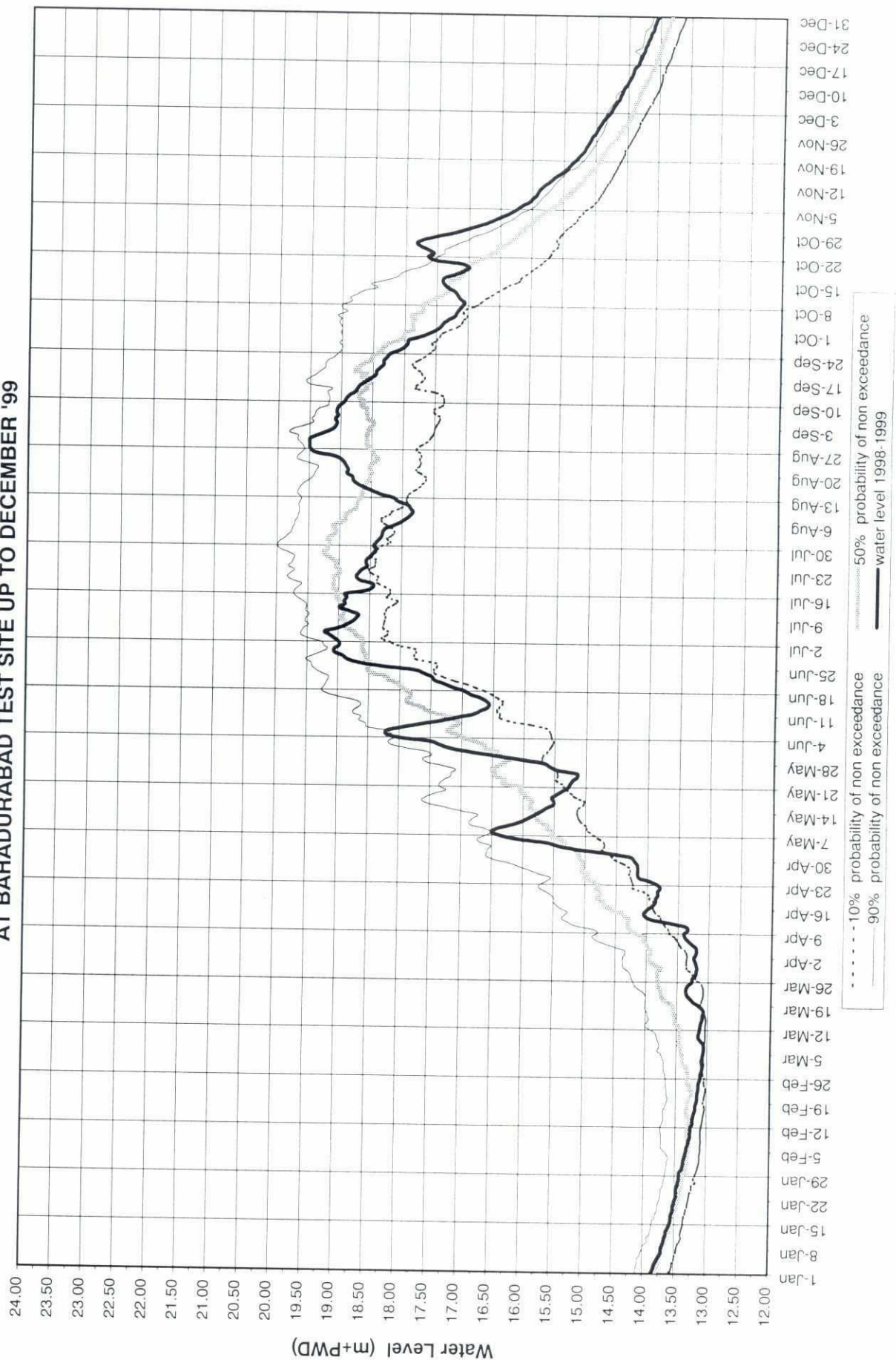
ANNEX A

Water Level

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

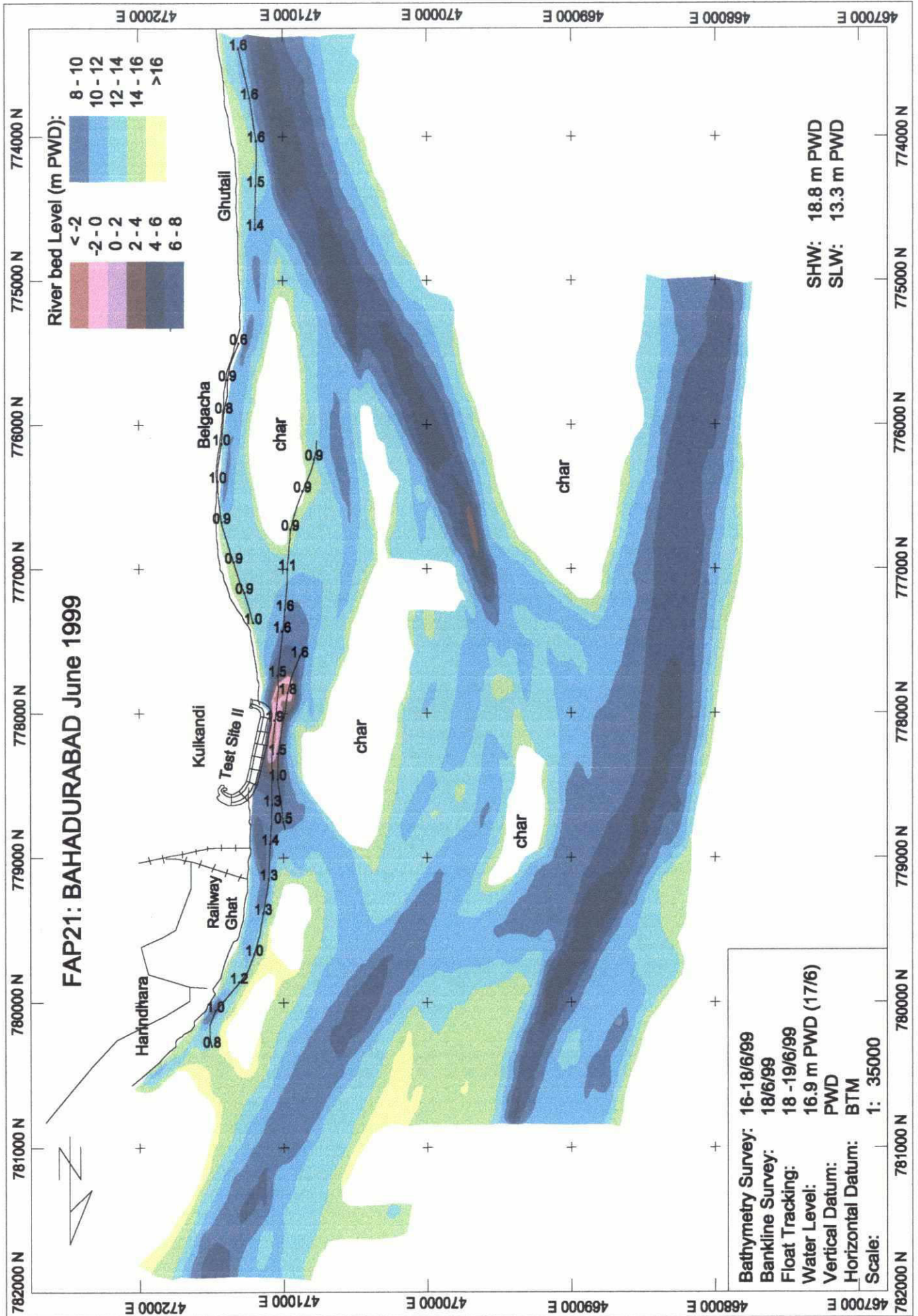


BANK PROTECTION TEST STRUCTURES - FAP 21 **BWDB WATER LEVEL FREQUENCY CURVES VERSUS ACTUAL FAP 21 WATER LEVEL** **AT BAHADURABAD TEST SITE UP TO DECEMBER '99**



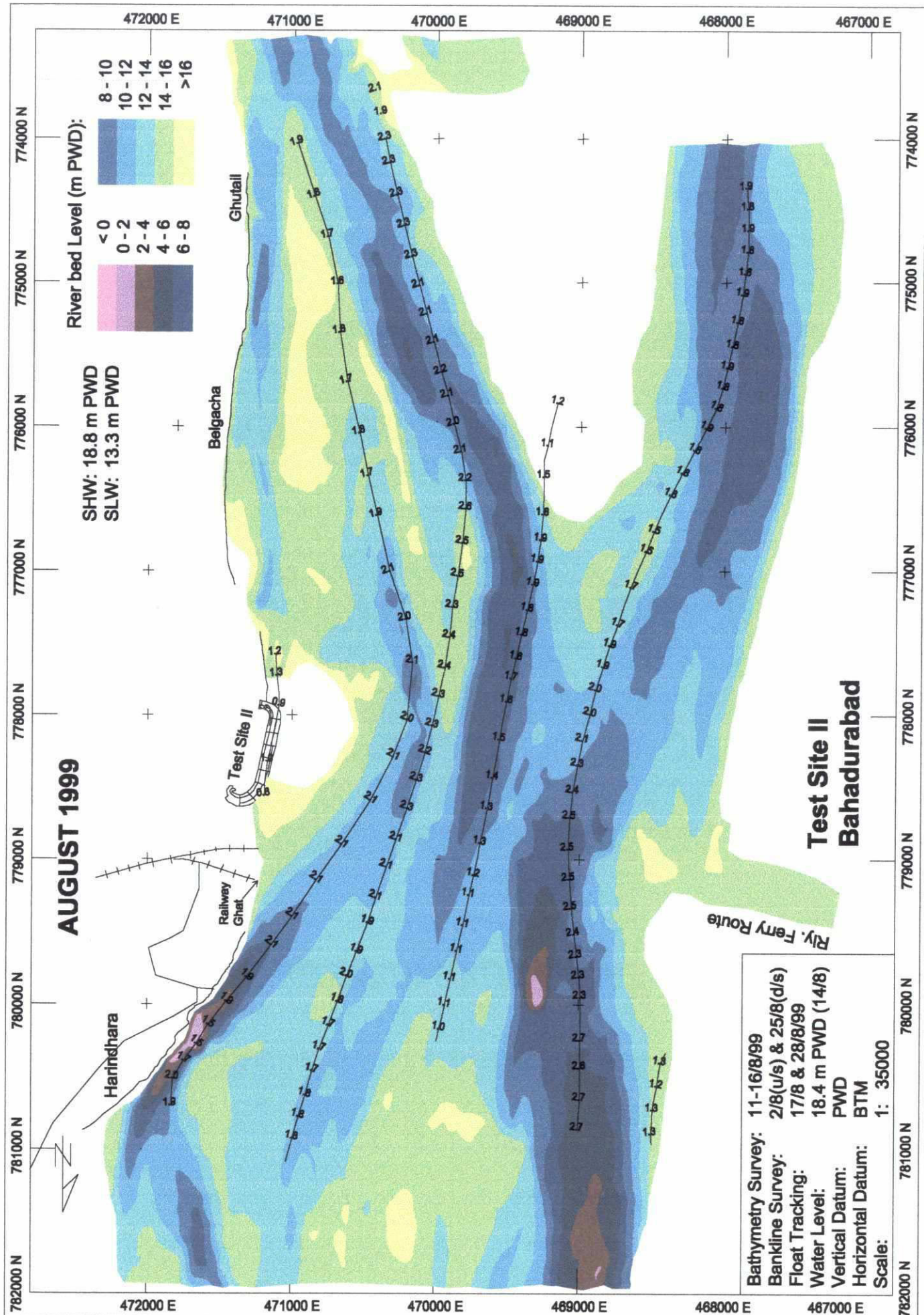
ANNEX B

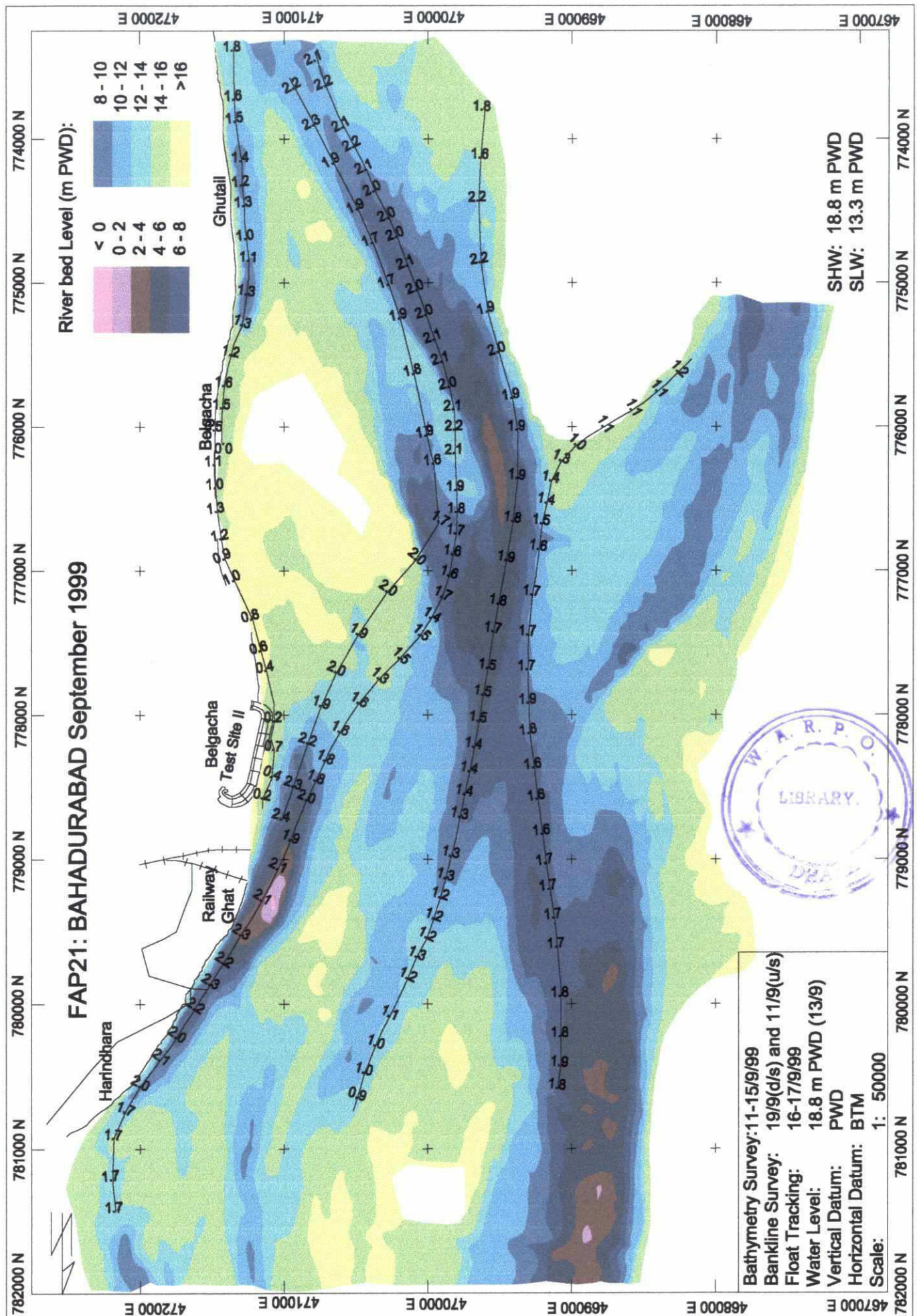
**Bathymetric Survey and
Flow Lines**

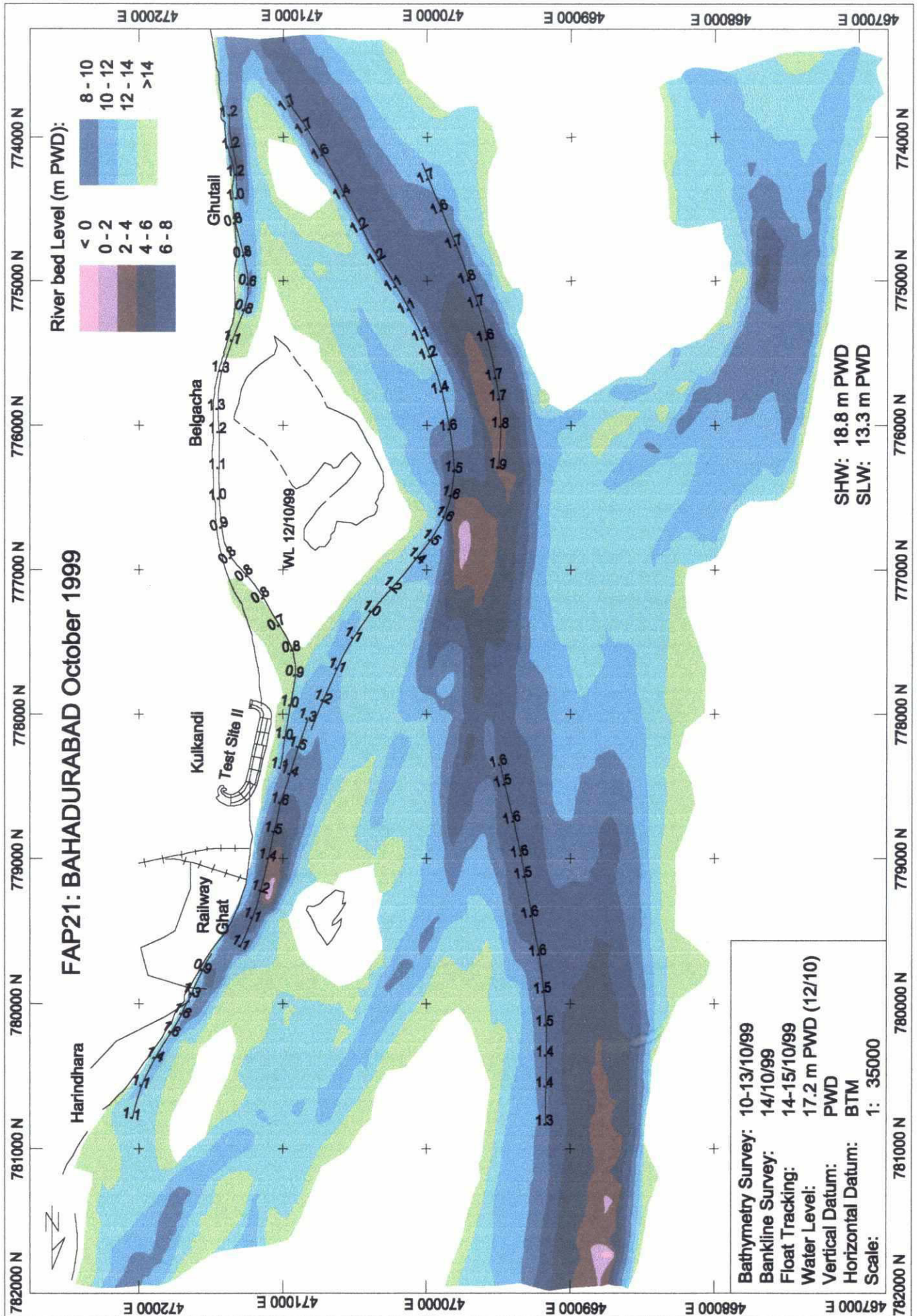


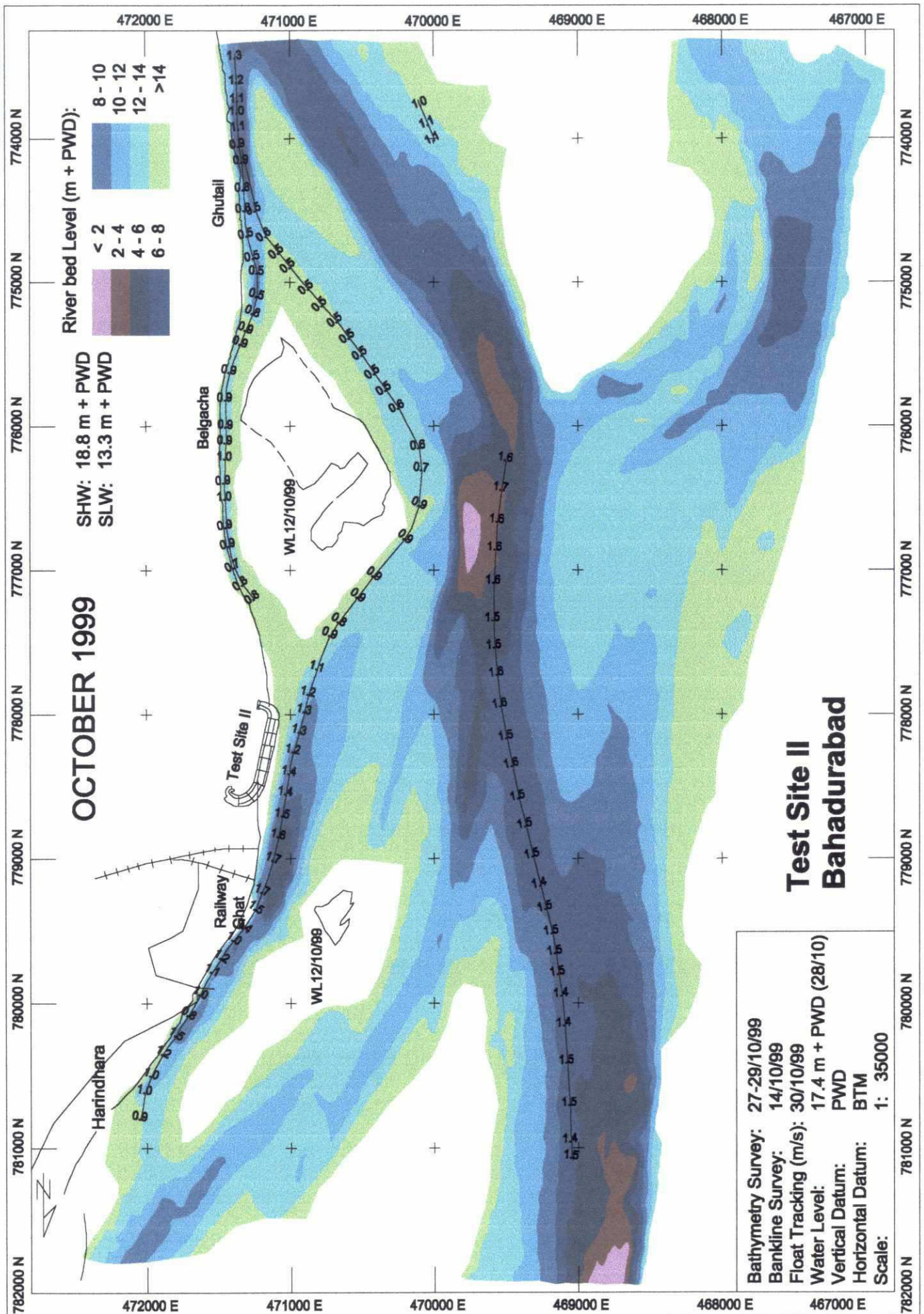


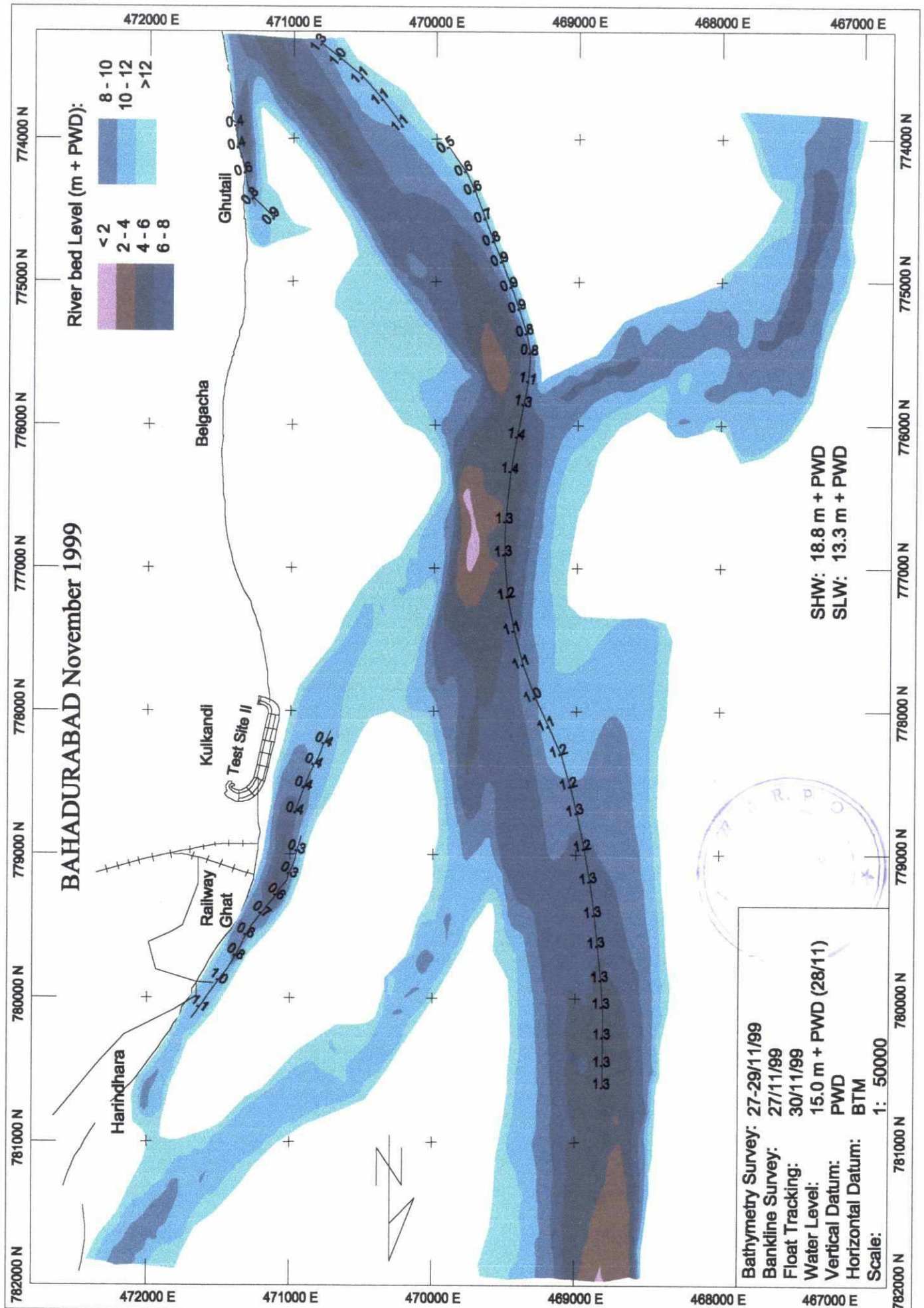
28

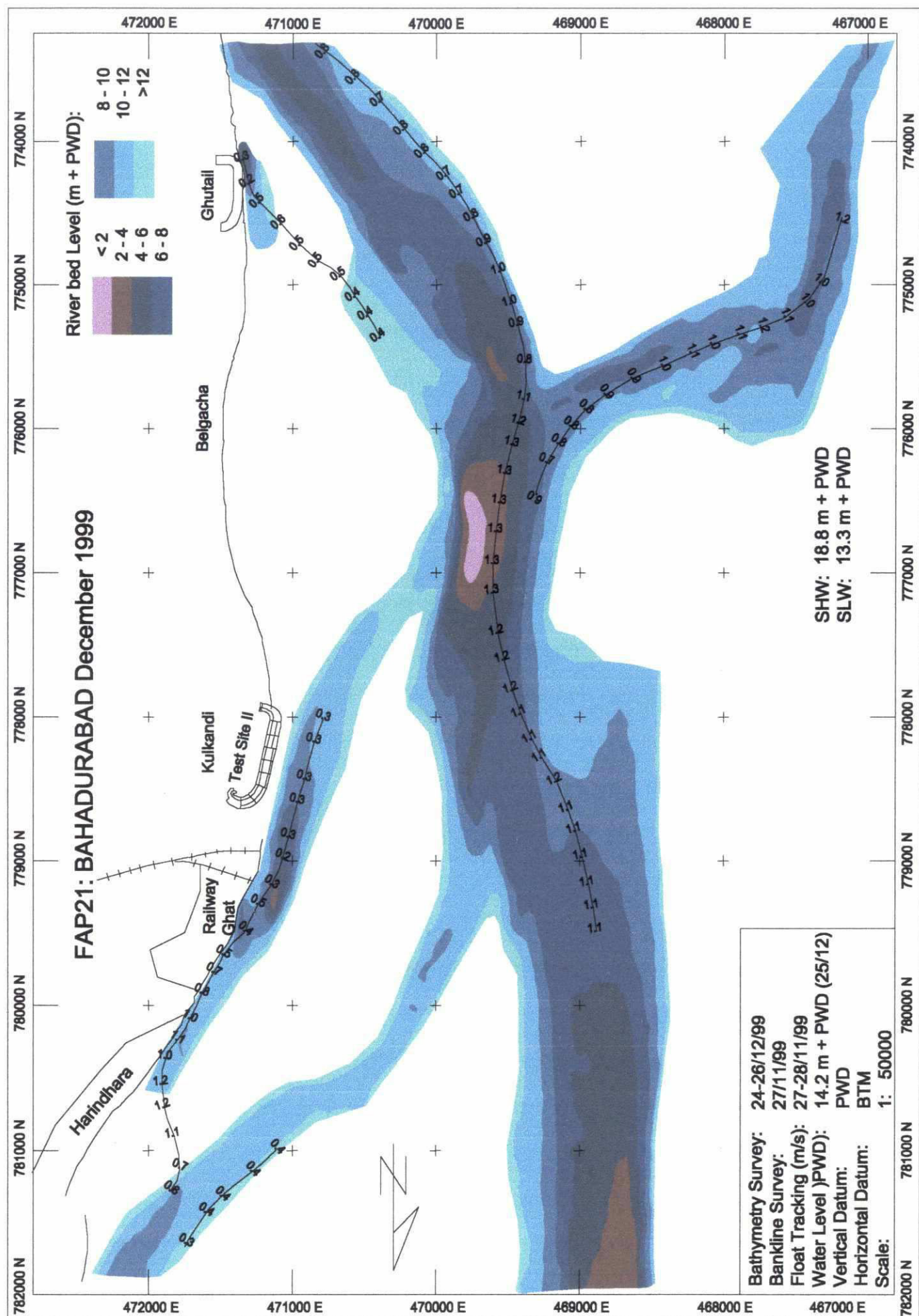






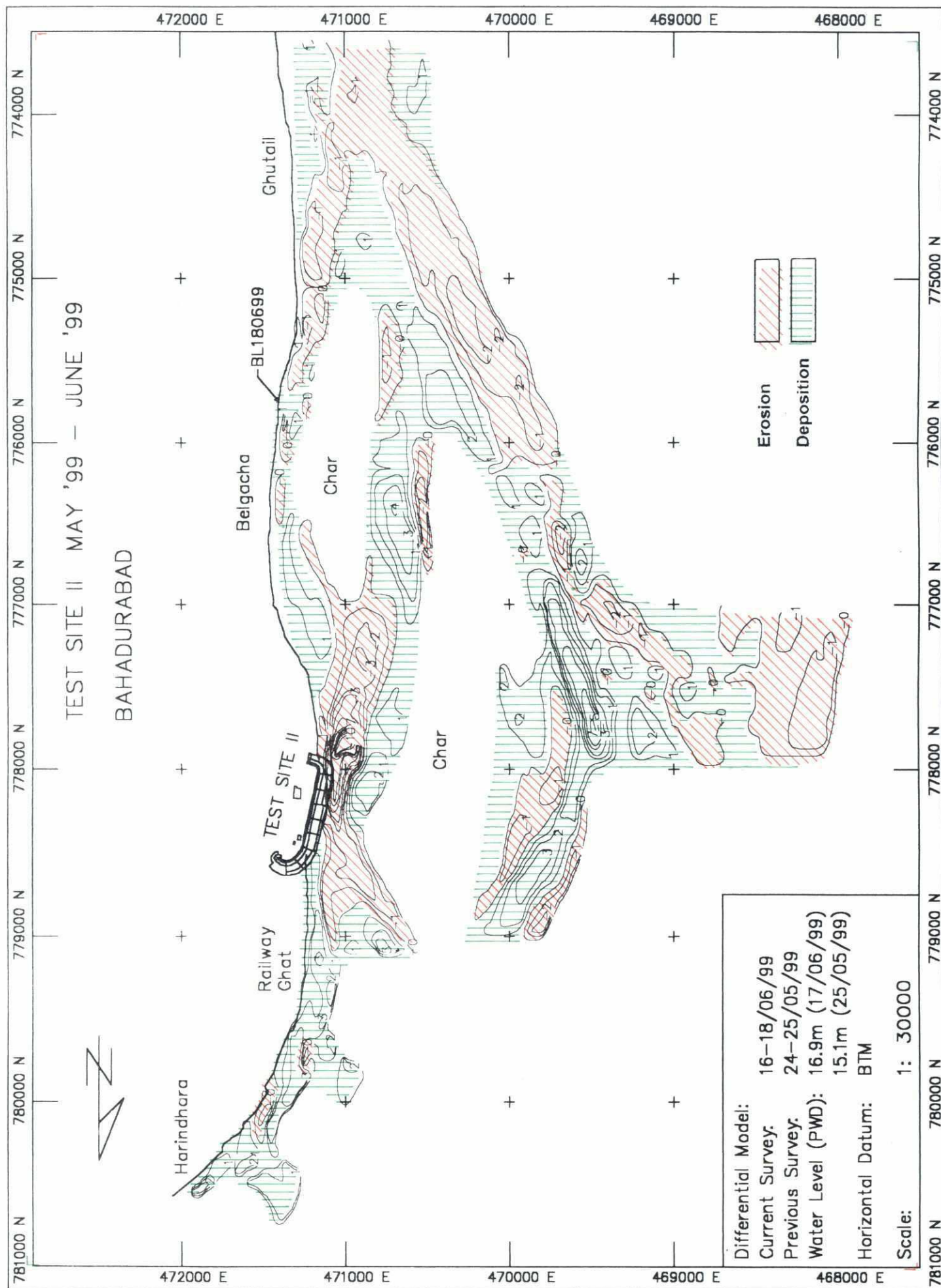


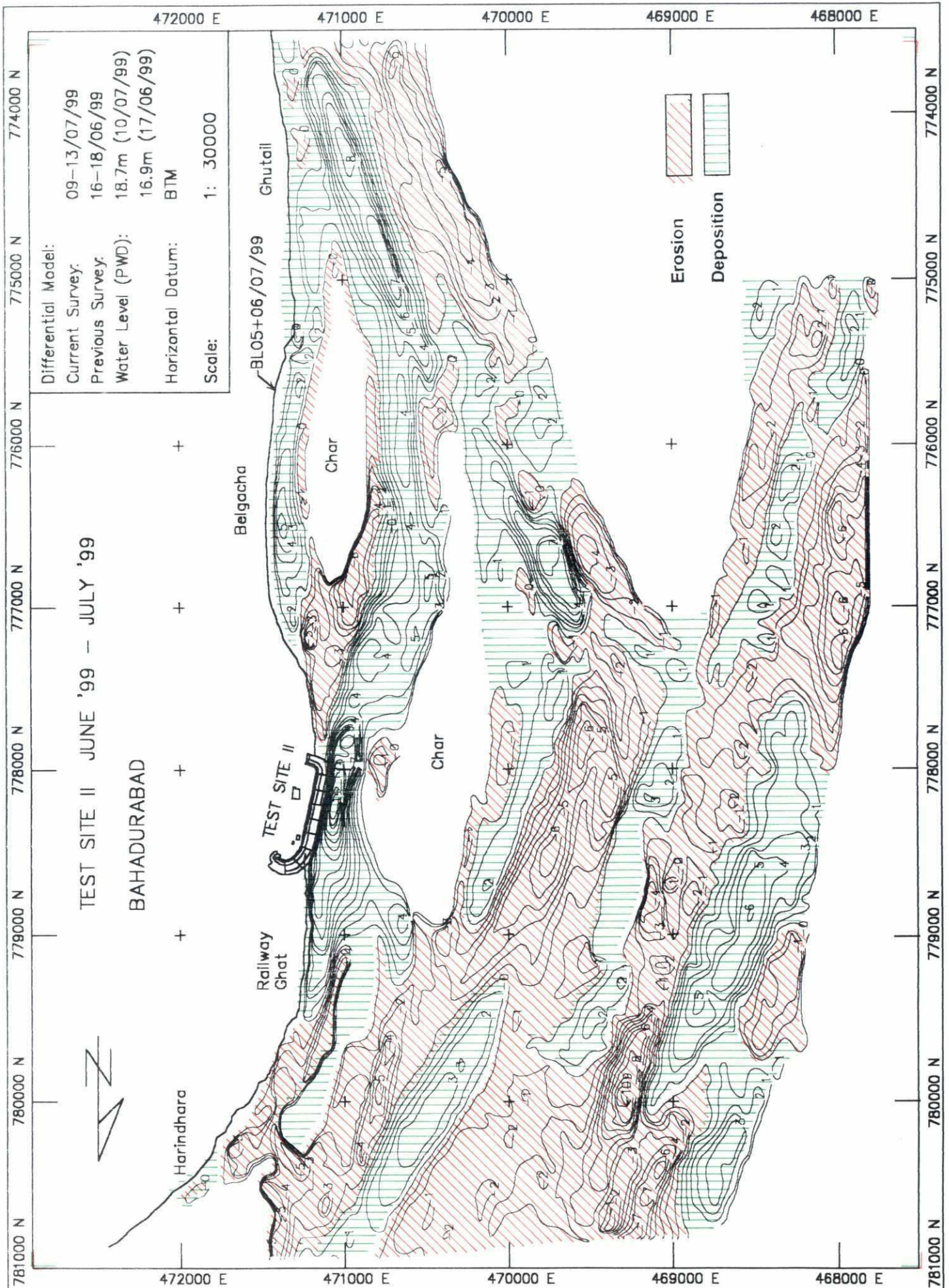


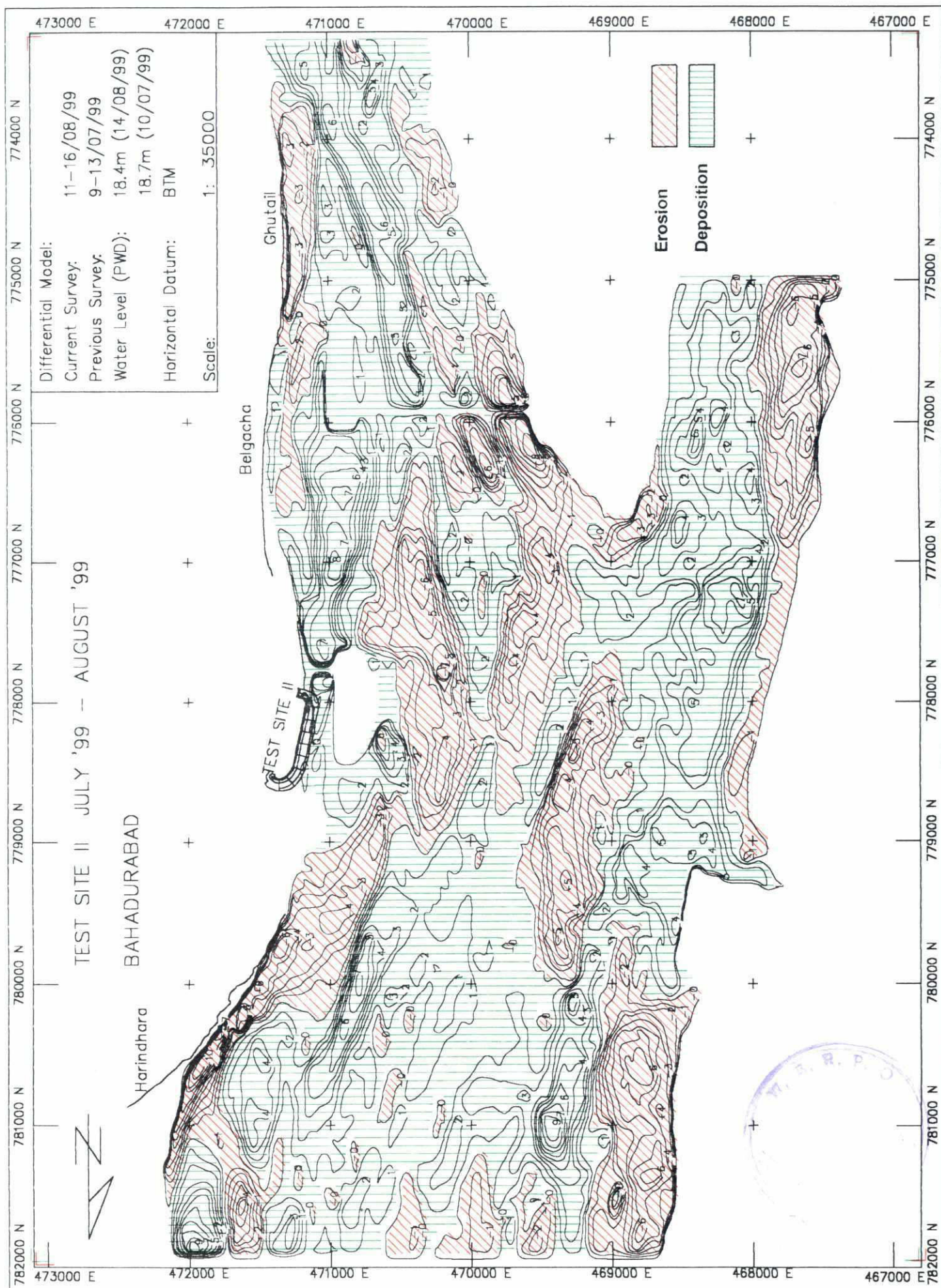


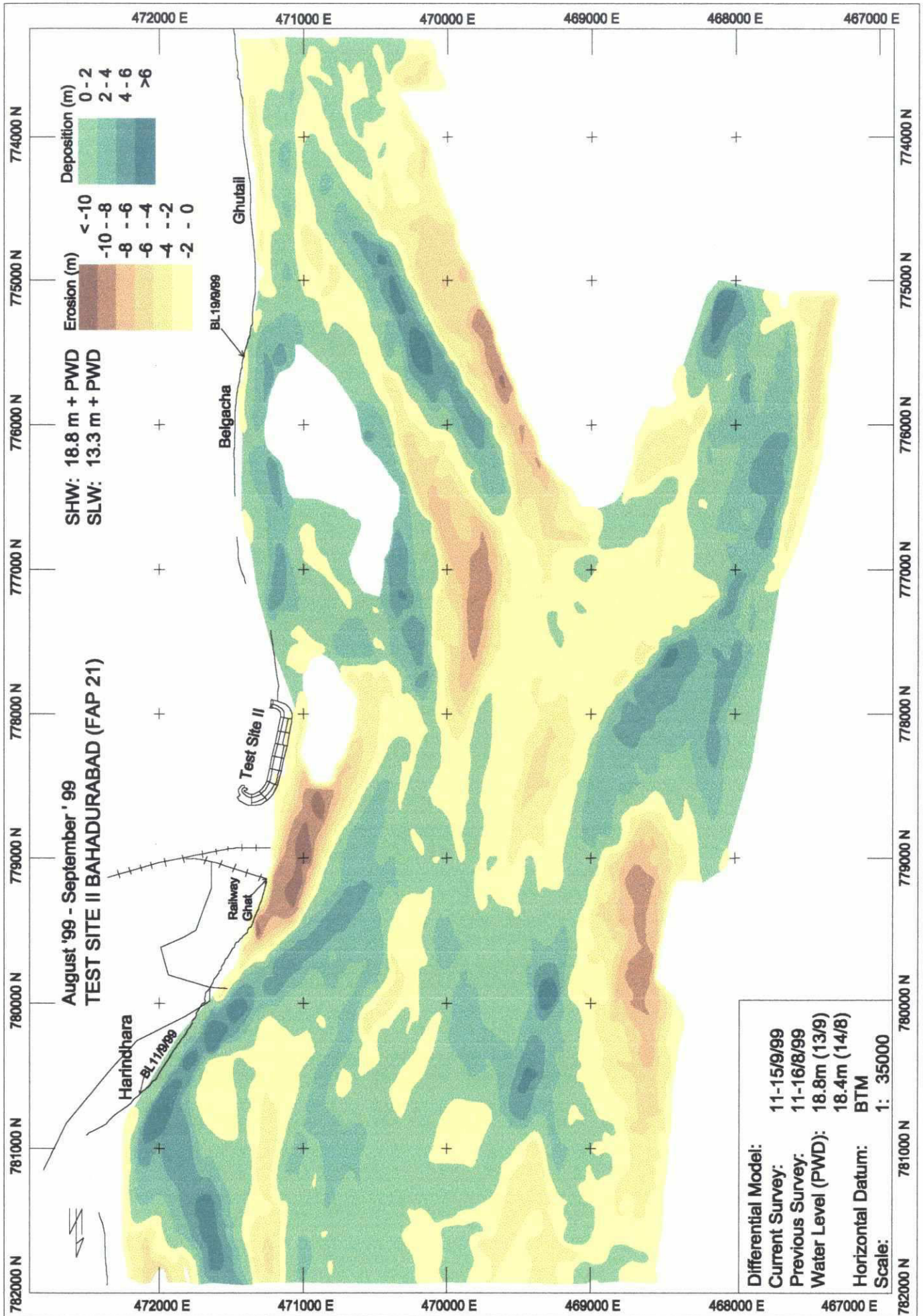
ANNEX C

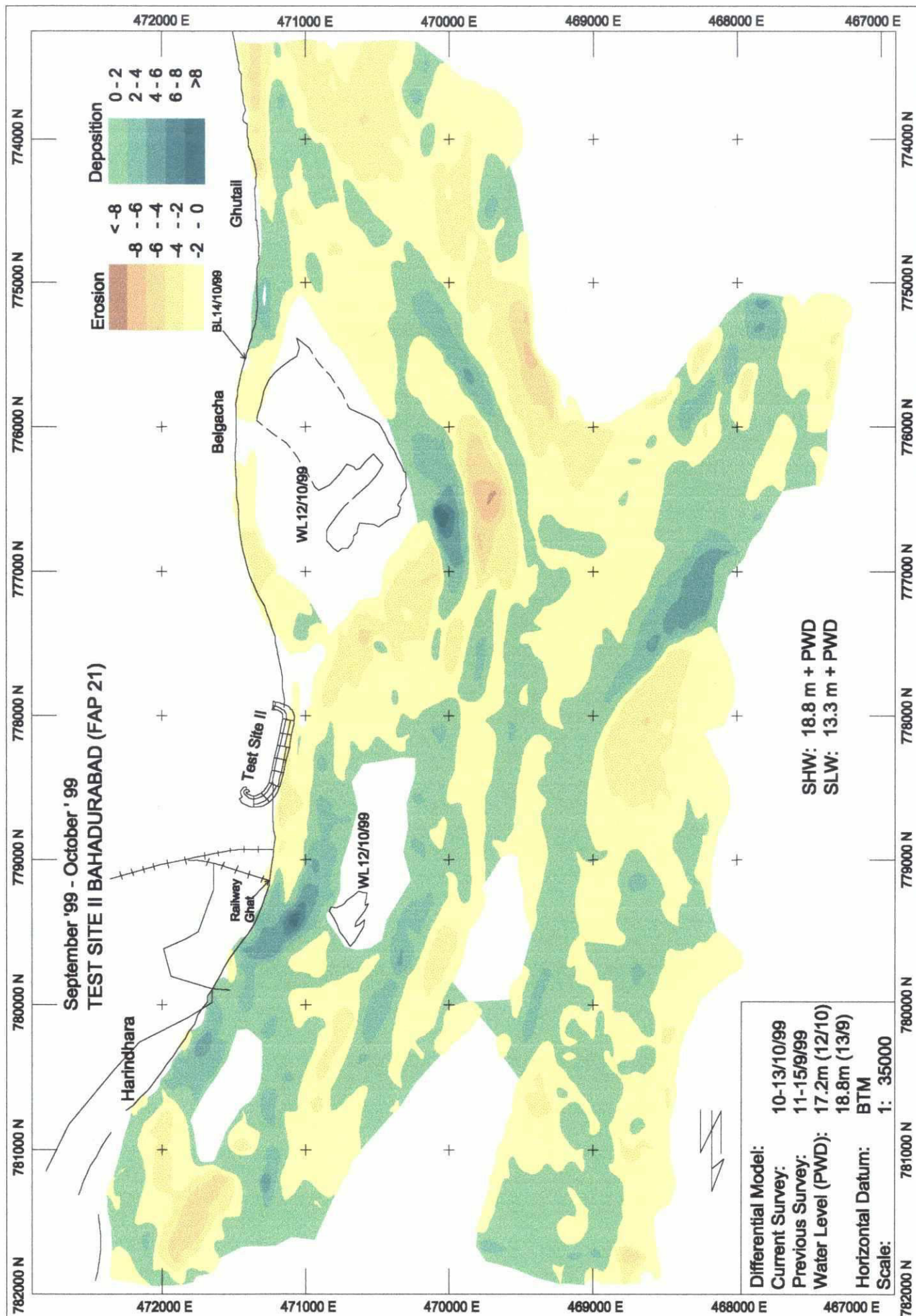
Differential Models

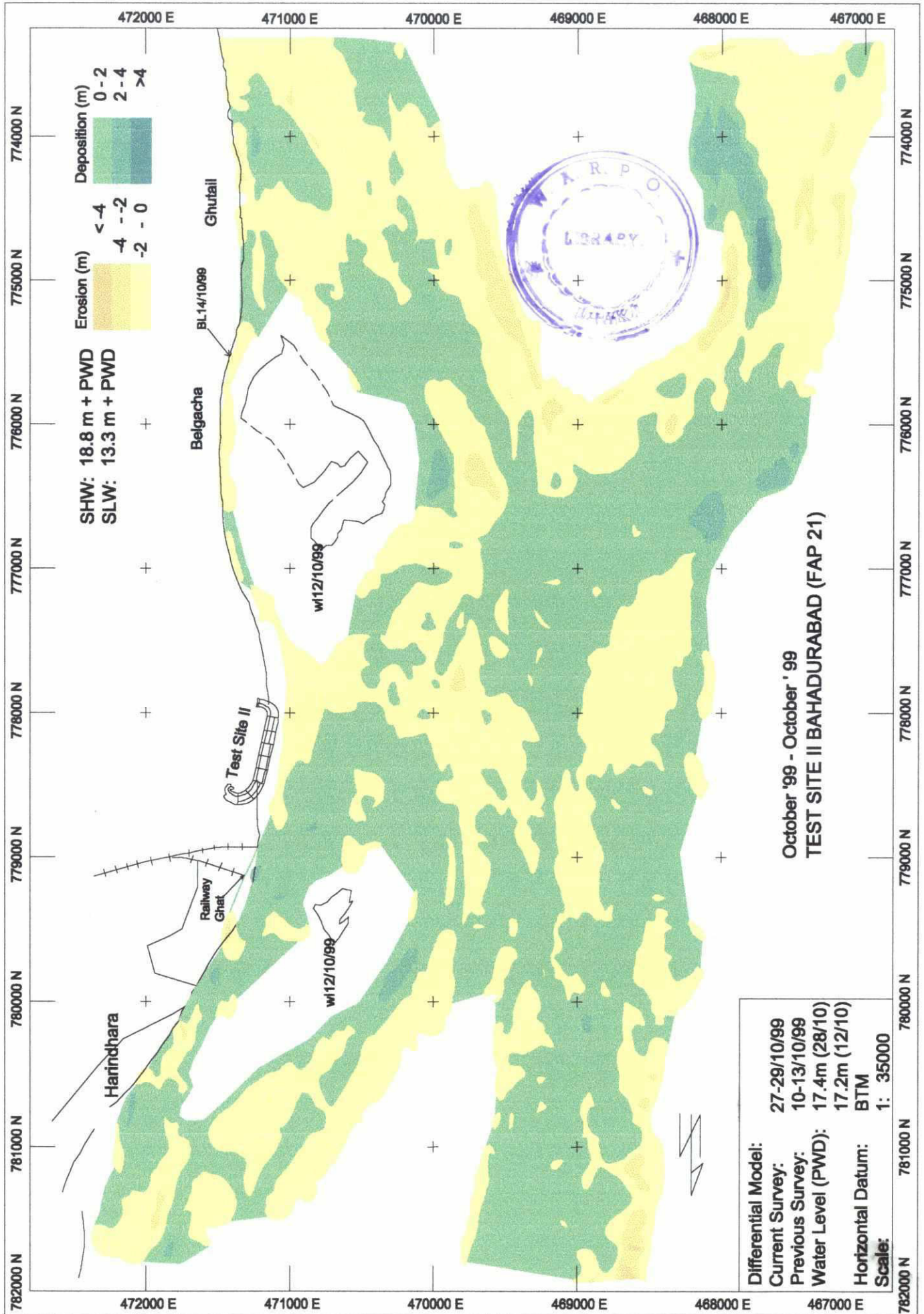


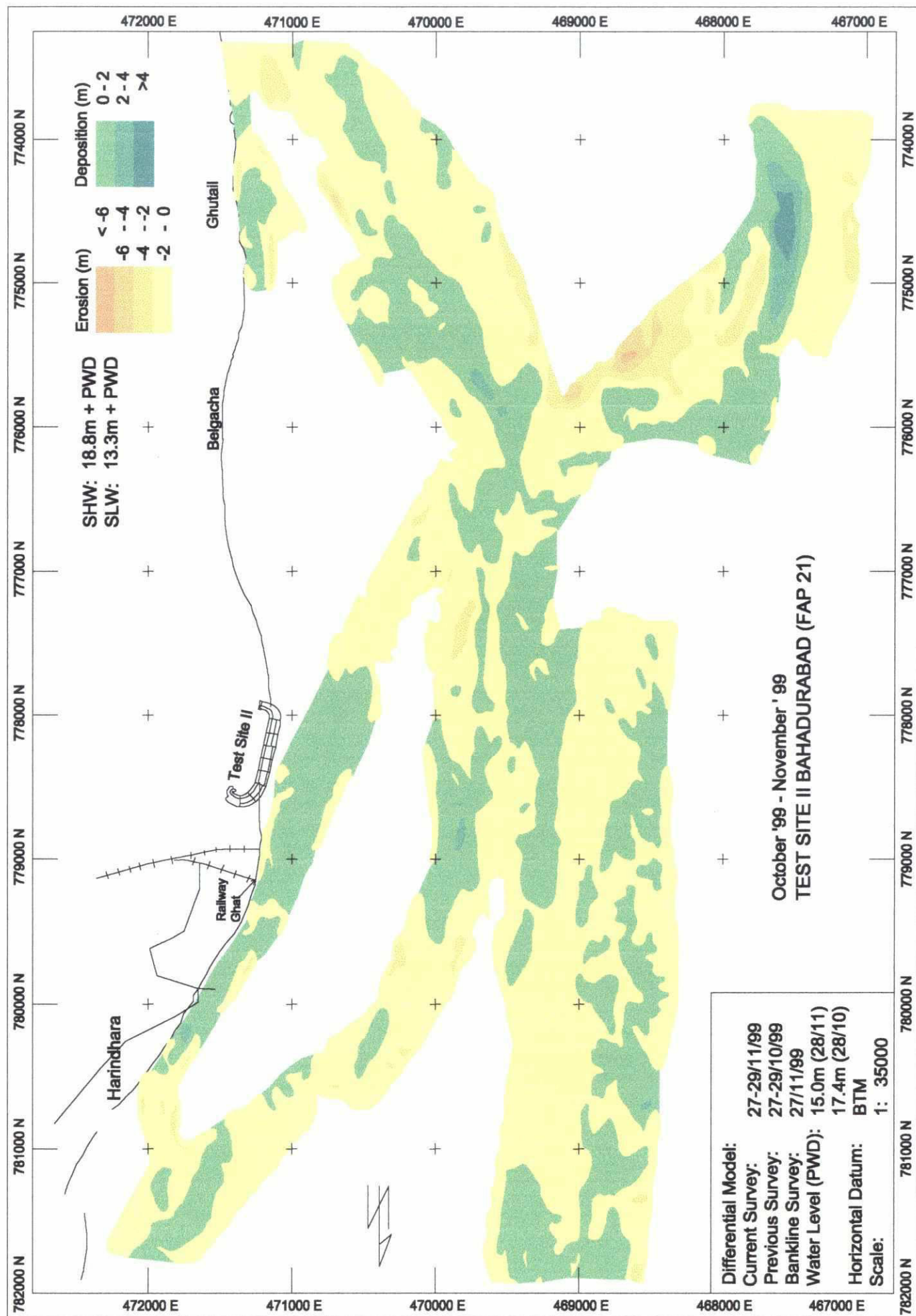


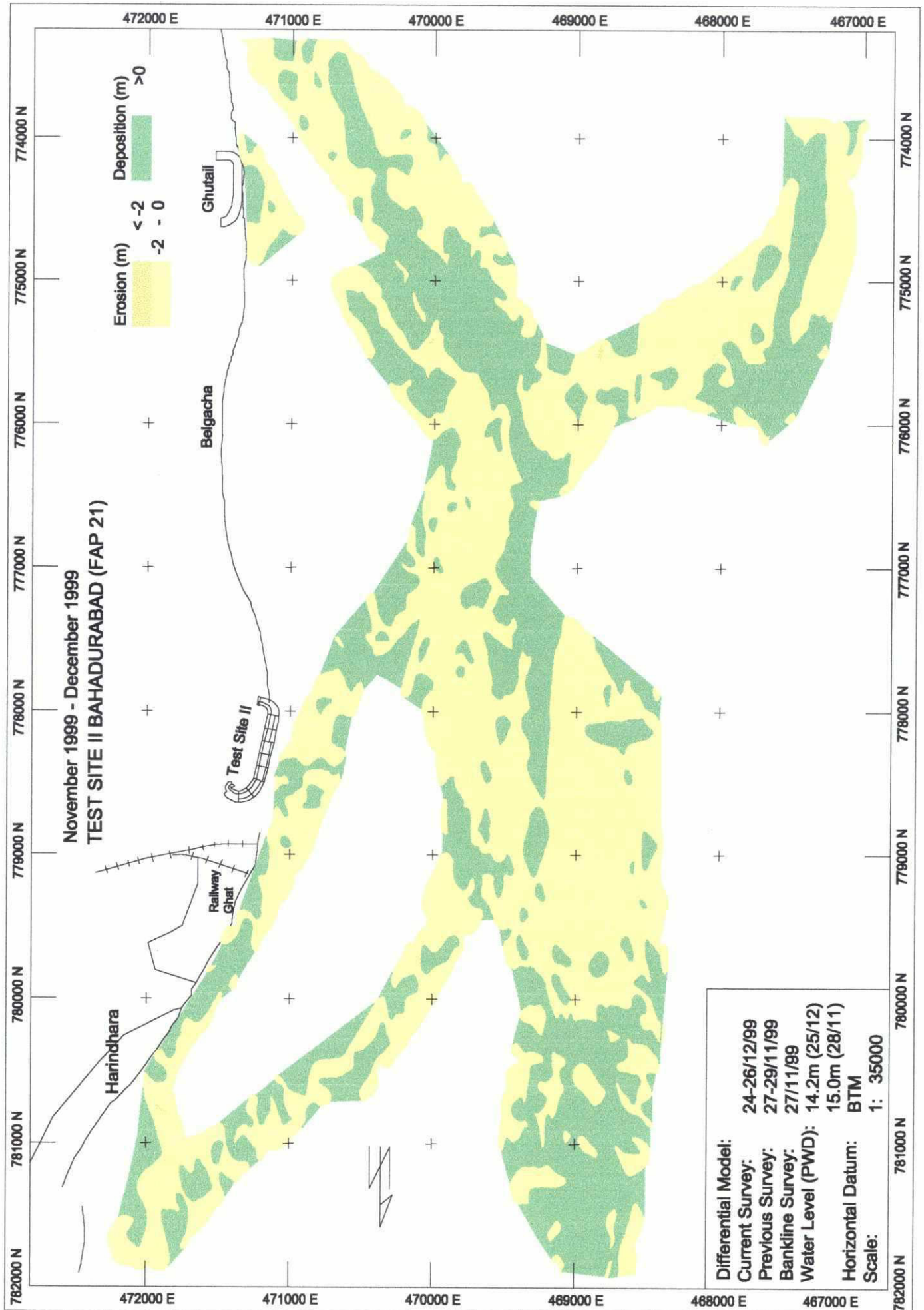








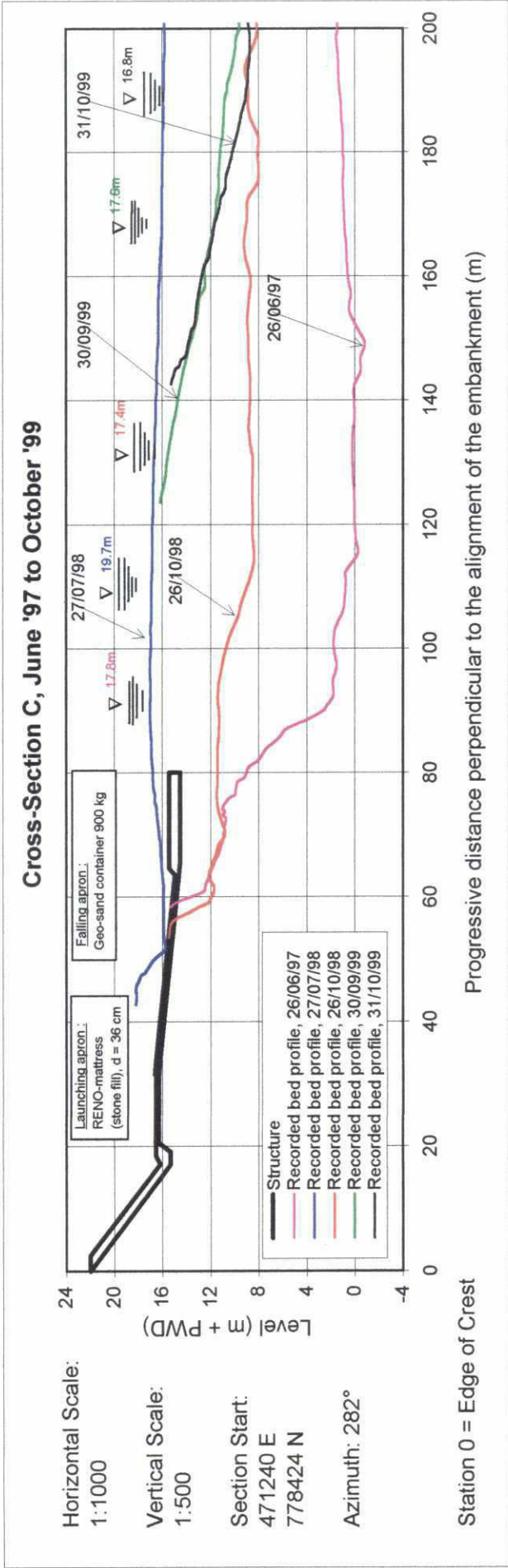
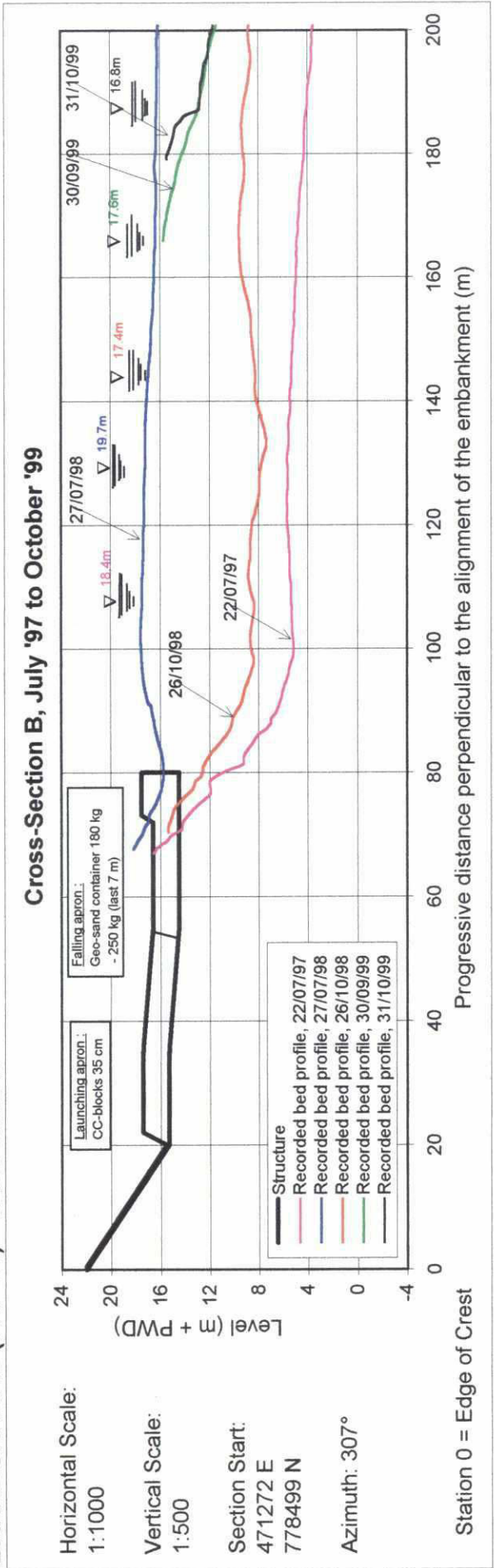




ANNEX D

Cross-Sections

BAHADURABAD (FAP 21) - TEST SITE II



BAHADURABAD (FAP 21) - TEST SITE II

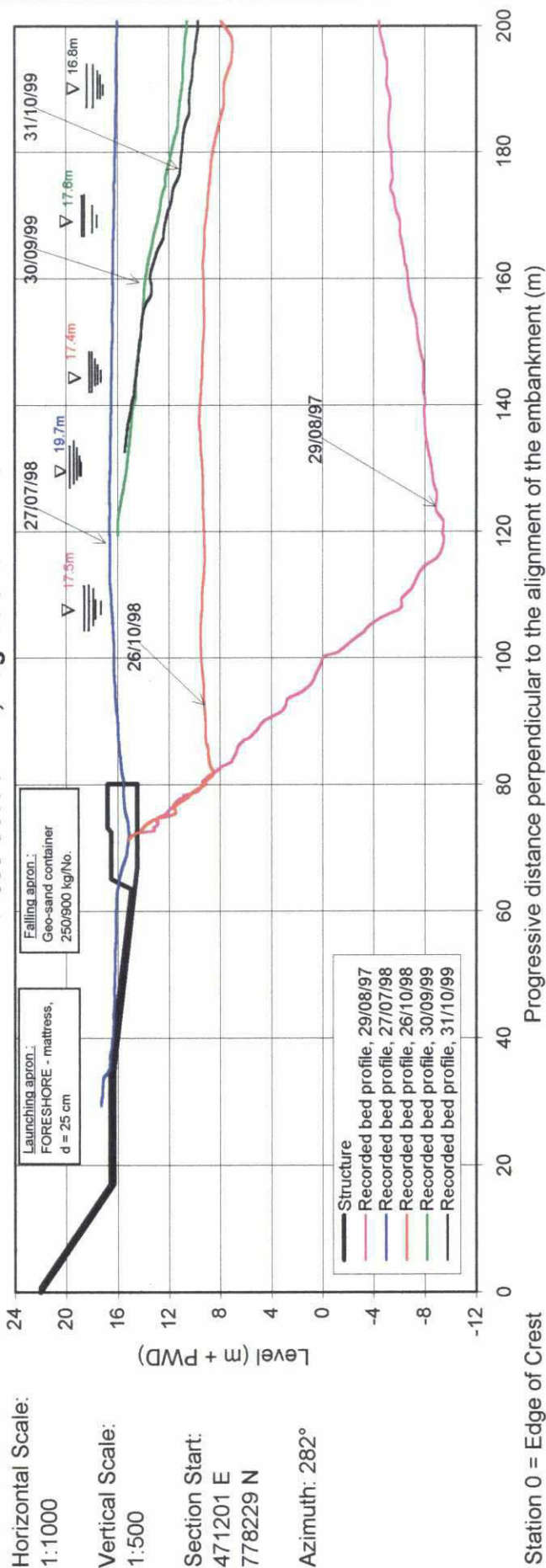
Cross-Section E-2, August '97 to October '99

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471201 E
778229 N

Azimuth: 282°



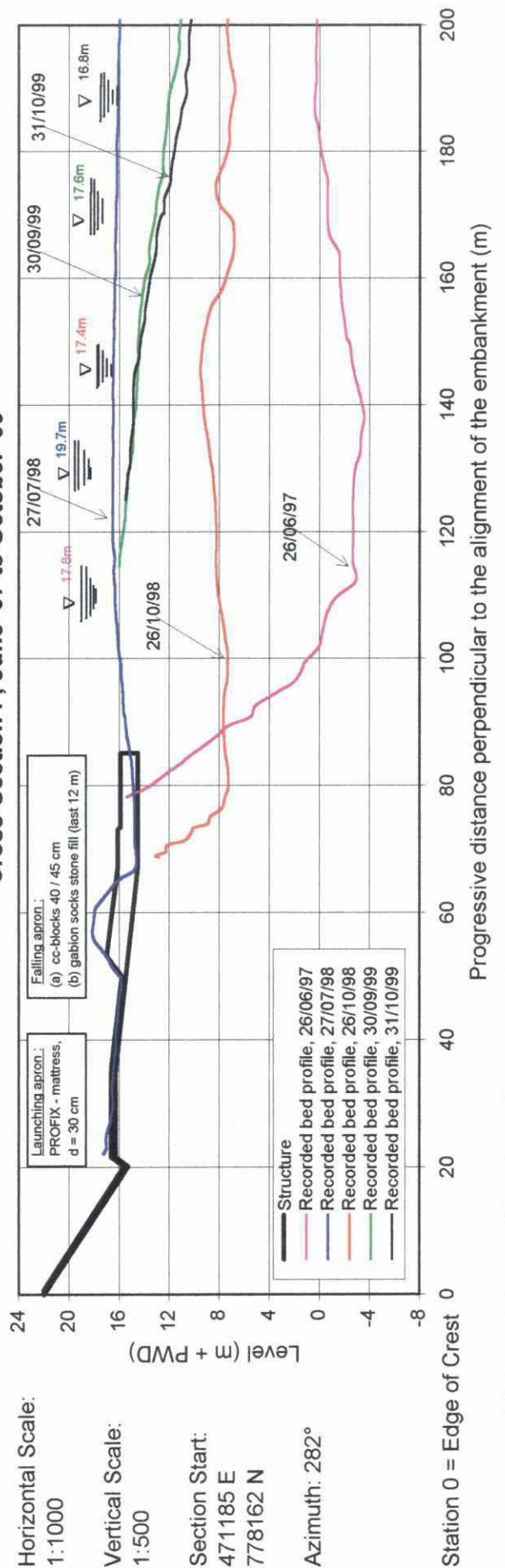
Cross-Section F, June '97 to October '99

Horizontal Scale:
1:1000

Vertical Scale:
1:500

Section Start:
471185 E
778162 N

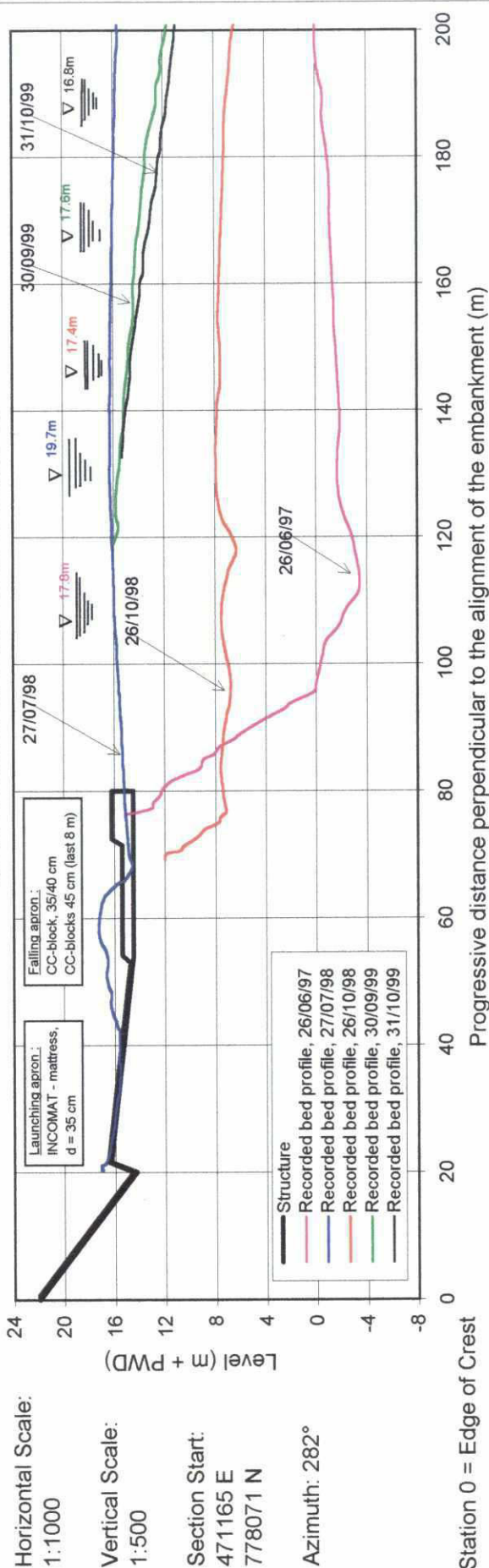
Azimuth: 282°



82

BAHADURABAD (FAP 21) - TEST SITE II

Cross-Section G, June '97 to October '99



Cross-Section H-1, August '97 to October '99

