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Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Flood Plan Coordination Organization

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

IMPROVED FLOOD WARNING

CONCEPT PAPER
September 1994

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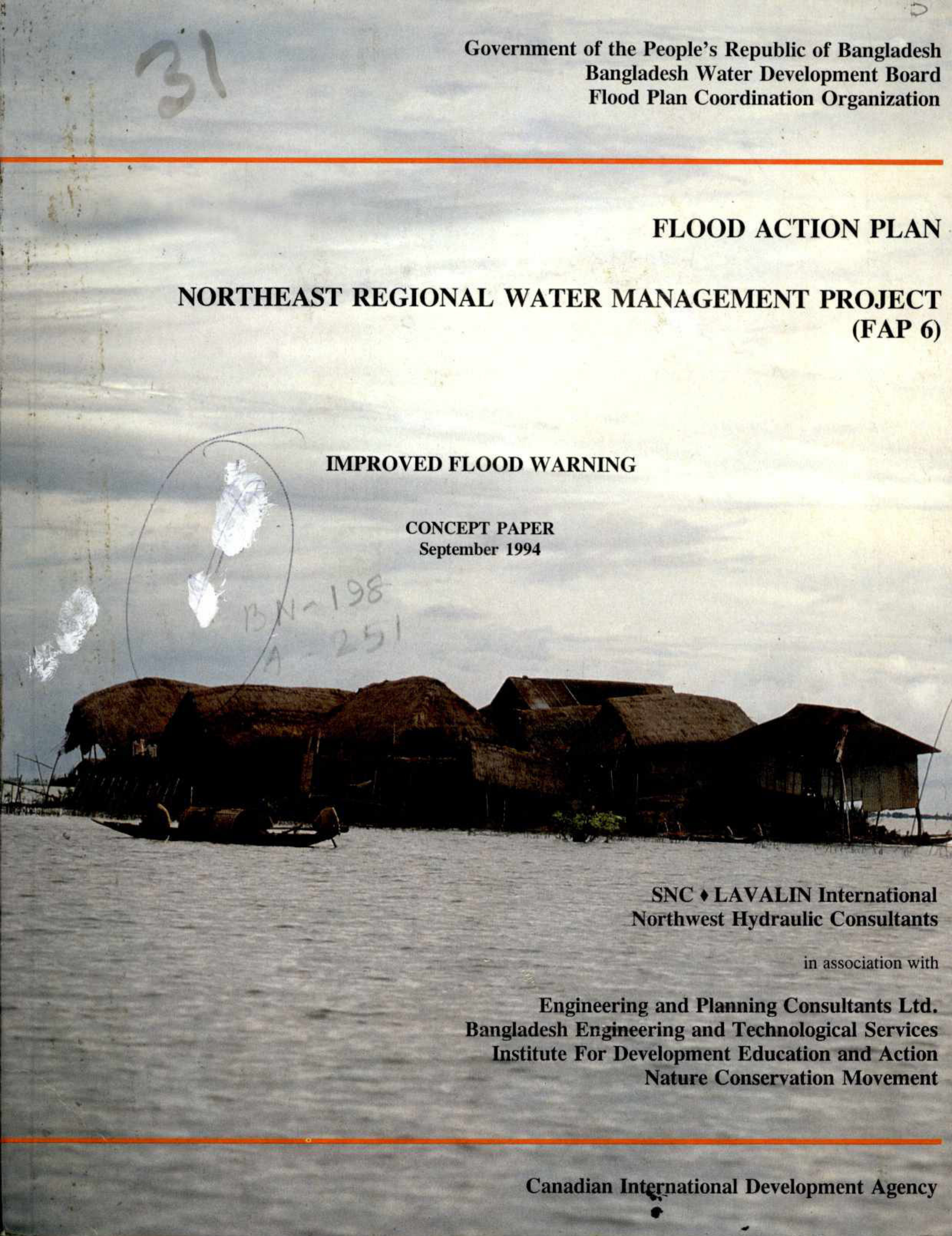

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Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services
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Nature Conservation Movement

Canadian International Development Agency

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
BMD	Bangladesh Meteorological Department
BSF	Border Security Force (of India)
BWDB	Bangladesh Water Development Board
CEA	Canadian Executing Agency (consultant)
CIDA	Canadian International Development Agency
FAP	Flood Action Plan
FFWA	Flash Flood Warning Agency (proposed)
FFWC	Flood Forecasting and Warning Centre (of BWDB)
FPCO	Flood Plan Coordination Organization
GOB	Government of Bangladesh
GOI	Government of India
NCO	Non-Commissioned Officer
NERP	Northeast Regional Water Management Project
O & M	Operation and Maintenance
PWD	Public Works Datum
SPARRSO	Space Research and Remote Sensing Organization (of Bangladesh)
UNDP	United Nation Development Programme

CURRENCY CONVERSION RATE
US$ 1 = Tk. 38

EXECUTIVE SUMMARY

The purpose of the project is to provide timely, readily understood, warnings to villagers in flash flood-prone areas of the Northeast Region of flash floods imminent in their locality and posing danger to them, and to promote their appropriate response to the warnings.

Storms over the adjacent Indian states of Meghalaya and Tripura are often severe, and are not restricted to the monsoon season. These storms generate severe flash floods in two areas of the Northeast Region, one between the border with Meghalaya and the Kangsha and Surma Rivers, the other between the border with Tripura and the Kushiyara River. Such floods impact riverside villages so endangering the lives of the villagers and their livestock, their homes, food stocks, belongings and crops. It is difficult to quantify these impacts on a regional scale but, on the basis of the small sample of flash flood-affected villages investigated so far, it has been estimated that some 250,000 people are exposed to flash flood dangers, and that over a period of 100 years perhaps as many as 30,000 human lives are lost.

The project proposed seeks to mitigate these impacts by giving villagers sufficient time in which to adequately prepare to evacuate their village, and to evacuate in safety to nearby safe ground. It is envisaged that these two basic actions will be initiated by two distinctly different light and sound signals, which can be readily understood and discriminated by all villagers. Details of the technology required to generate these warning signals, and of the actions villagers should take in response to the signals, have been worked out on a "first pass" basis to establish technical requirements of the system and estimate costs. Modifications may well be desirable or necessary in the light of constructive comments received and of experience gained from a pilot project.

Field investigations made to identify the needs for the flash flood warning system proposed, and the requirements of the system, have also revealed certain preparatory actions which need to be taken by government if benefits from the warning system are to be realized. These actions concern the structural integrity of various structures in the field which provide either protection from floods or access to safe ground, the availability of safe grounds of adequate capacity to which villagers can evacuate safely, and the availability of logical plans of action for villagers to follow in preparing and executing their evacuation to safe ground. These are not matters which any flood warning system can address but they will diminish its effectiveness if not simultaneously addressed by other appropriate measures. The need to implement the flash flood warning systems in a broader context of flood preparedness is, therefore, strongly emphasised.

The institutional arrangements for the project are briefly considered. It is recommended that a Flash Flood Warning Agency (FFWA) be set up as a full directorate within the BWDB to establish, operate and maintain the proposed flash flood warning systems, and to coordinate all other activities required to ensure their success.

The project would be implemented by the Bangladesh Water Development Board at an estimated cost, exclusive of preparatory structural works, of

1) US$ 258,028 (say US$ 260,000) for a pilot scheme on the Juri River.
2) US$ 2,399,256 (say US$ 2,400,000) for schemes on *eight* other rivers.

NERP DOCUMENTS

The Northeast Regional Water Management Plan is comprised of various documents prepared by the NERP study team including specialist studies, the outcome of a series of public seminars held in the region, and pre-feasibility studies of the various initiatives. A complete set of the Northeast Regional Water Management Plan Documents consists of the following:

Northeast Regional Water Management Plan

Main Report
Appendix: Initial Environmental Evaluation

Specialist Studies

Participatory Development and the Role of NGOs
Population Characteristics and the State of Human Development
Fisheries Specialist Study
Wetland Resources Specialist Study
Agriculture in the Northeast Region
Ground Water Resources of the Northeast Region
Surface Water Resources of the Northeast Region
Regional Water Resources Development Status
River Sedimentation and Morphology
Study on Urbanization in the Northeast Region
Local Initiatives and People's Participation in the Management of Water Resources
Water Transport Study

Public Participation Documentation

Proceedings of the Moulvibazar Seminar
Proceedings of the Sylhet Seminar
Proceedings of the Sunamganj Seminar
Proceedings of the Sherpur Seminar
Proceedings of the Kishorganj Seminar
Proceedings of the Narsingdi Seminar
Proceedings of the Habiganj Seminar
Proceedings of the Netrokona Seminar
Proceedings of the Sylhet Fisheries Seminar

Pre-feasibility Studies

Jadukata/Rakti River Improvement Project
Baulai Dredging
Mrigi River Drainage Improvement Project
Kushiyara Dredging
Fisheries Management Programme
Fisheries Engineering Measures
Environmental Management, Research, and Education Project (EMREP)
Habiganj-Khowai Area Development
Development of Rural Settlements
Pond Aquaculture
Applied Research for Improved Farming Systems
Manu River Improvement Project
Narayanganj-Narsingdi Project
Narsingdi District Development Project
Upper Kangsha River Basin Development
Upper Surma-Kushiyara Project
Surma Right Bank Project
Surma-Kushiyara-Baulai Basin Project
Kushiyara-Bijna Inter-Basin Development Project
Dharmapasha-Rui Beel Project
Updakhali River Project
Sarigoyain-Piyain Basin Development
Improved Flood Warning

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FOREWORD

This report presents an innovative concept for providing timely, readily understood, warnings to villagers in flash flood-prone areas of the Northeast Region of flash floods imminent in their locality and posing danger to them, and for promoting their appropriate response to the warnings.

The Draft Report was issued in January 1994, and this was commented on extensively by both CIDA and FPCO. The present Final Report addresses these comments to the extent possible prior to the Government of Bangladesh taking certain decisions particularly with regard to:

1) setting up appropriate institutional arrangements for implementation of the proposal

2) deciding whether to attempt augmenting the proposal by providing either a second weather radar to be located in the Northeast Region, or a network of telemetric rain gauges and river water level recorders/detectors to be located on Indian territory in the states of Meghalaya and Tripura.

The proposal can be implemented without the addition of weather radar or telemetric equipment. These advanced technologies would enhance the reliability of the flash flood warnings, but at great additional cost.

1. INTRODUCTION

1.1 Flash Floods in the Northeast Region

In some years, and often several times in such years, intense heavy rainfalls over the Indian states of Meghalaya and Tripura generate dangerous flash floods in the rivers entering the Northeast Region from these states. These flash floods are not restricted in their occurrence to the pre-monsoon season or to the monsoon season; they occur in both these seasons, and they may also occur in the dry season whenever nor-westers visit the area as in February 1993 and March 1994.

The flash floods travel down these rivers for some 20 to 30 km, wreaking havoc in riverside villages, before their energy is dissipated by the merging of their flows with those present in the larger rivers of the Region. Flash flood-caused damages are therefore incurred in two separate areas of the Northeast Region (Figure 1):

1) **Meghalaya Border Area**

   This area extends from the border with Meghalaya southwards to the Kangsha and Surma Rivers, and from the Malijhee River in the west to the Lubha River in the east.

2) **Tripura Border Area**

   This area extends from the border with Tripura northwestwards to the Kushiyara River, and from the Sutang River in the southwest to the Sonai-Bardal River in the northeast.

Flash floods generally are characterised by the rapidity with which the river water level rises to a peak level exceeding that of the river bank (Figure 2). The peak level typically occurs during nighttime, and is almost never reflected in BWDB water level records which are collected exclusively in daytime.

The time in which such a rise occurs is typically less than a day, often less than an hour, and the rise may occur instantaneously as a hydraulic bore. Such bores are certainly a feature of flash floods in arid zones like the Middle East where the river channels are normally dry ahead of the flash flood. The occurrence of bores in the Northeast Region is more questionable, but there is mounting evidence that they do occur there on occasion.

The rapid rise in water level not only inundates riverside villages but does so with fast-moving water. Flow velocities of 3 to 6 m/s typically occur when a flash flood peaks, and anyone or anything exposed to water travelling at such speeds will experience a strong drag force for as long as the flow persists, and a strong impact if the flood rise occurs as a bore. It is these impacts and drag forces which result in people losing their lives, in dwellings collapsing, and in livestock and belongings being swept away.

It has been estimated from field investigations in nine villages in the border areas of the Northeast Region, which were devastated by flash floods in 1988 and 1993, that the average losses were as follows:

- 0.5% of the villagers lost their lives;

- 40% of their dwellings were destroyed, and the dwelling contents lost; the latter included food and fuel stocks, cooking utensils and clothing, as well as furnishings;

- 38% of their livestock was lost including 13% of their buffaloes, 23% of their cows, 42% of their goats, and 72% of their chickens.

Such disasters appear to occur with an average frequency of about once in five years in the nine villages investigated. Altogether there are an estimated 250 villages beside the flash flood-prone rivers of the Northeast Region[1], each with an average population of around 1,000 (Table D1). On this basis it is tentatively estimated that, on a regional scale, some 250,000 people are exposed at some time to flash floods, and that over a period of 100 years some 30,000 lives may be lost. The scale of disaster will, however, diminish downstream from the Indo-Bangladesh border near which all of the villages investigated are located.

The scale of these losses and damages in the Northeast Region is clearly unacceptable, and it is acknowledged that something ought to be done to reduce them substantially. This report takes that acknowledgement as its starting point, and addresses the question: What, exactly, can best be done to effectively reduce these losses and damages to a more acceptable low level?

1.2 Means to Reduce Flash Flood Impacts

Elsewhere in the world several means are used to reduce the impacts of flash floods on riverside communities:

1) Flood control reservoirs

2) Flood diversion channels

3) Flood protection embankments

4) Riverside community re-settlement

5) Flood warning systems

All of these means have been considered for use in the Northeast Region prior to concluding that a flood warning system, coupled with certain structural measures in some cases, represents the best means of mitigating flash flood impacts in the Region.

Flood control reservoirs store flood water upstream of the area to be protected from floods, and release it subsequently as a steady low flow which does not result in river water levels rising

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1 It was stated in the Draft Final Report that there were estimated to be 2,580 riverside villages exposed to flash floods in the Northeast Region; this figure (2,580) actually refers to all villages in flash flood affected thanas, and it is now estimated that only about one tenth of these are actually riverside villages; numbers of persons affected and lives lost have, therefore, been reduced accordingly for this Final Report. The derivation of the mortality rate quoted here is given in Annex D, Section D11.

above the river banks in the protected area. In relation to the flash flood-prone areas of the Northeast Region there are, however, very few dam sites available where sufficient storage could be provided, and all of these sites are within Indian territory. Given the present difficulties of India-Bangladesh forming water resource arrangements it seems most unlikely that any of these sites could be developed on a cooperative basis in the foreseeable future. Furthermore, even if such development became possible, it is unlikely that the reservoirs would serve their purpose for very long; flash floods are notorious for their ability to transport river bed sediments of all sizes in huge quantities virtually all of which would be trapped in the reservoirs. Thus it is concluded that flood control reservoirs are not an appropriate means of reducing flash flood impacts in the Northeast Region.

Flood diversion channels enable flash flood water to be conveyed away from riverside communities along routes through relatively uninhabited territory and leading to a suitable disposal area. Only one such route, Manu River to Hakaluki Haor, has so far been identified in the flash flood-prone areas of the Northeast Region, and further work is needed to confirm its social and environmental acceptability. Elsewhere in the Region there do not appear to be any channel routes which could be developed without causing major social disturbance. Thus it is concluded that, with the one exception noted, flood diversion channels are also not an appropriate means of flash flood impact mitigation in the Northeast Region.

Flood protection embankments enable flash floods to be confined to the river channel in which they occur so that their fast-moving water does not enter the riverside villages. Such embankments are, of course, a well-known feature of the Northeast Region, but they have mostly been constructed for the purpose of protecting standing crops; any protection they afford to riverside villages is incidental. If the embankments fail during a flash flood these incidentally protected villages commonly suffer a worse disaster than would have occurred in the absence of the embankment. In field investigations of nine villages devastated during the flash floods of 1988 and 1993 it was found that in five of the villages the immediate cause of disaster had been the bursting of the local embankment during passage of a flash flood which eroded its riverside face until the remaining section was too thin to withstand the water pressure. It is therefore concluded that, pending great improvements in the design and construction of embankments in Bangladesh, embankments do not comprise an appropriate means by which to mitigate flash flood impacts on villages in the Northeast Region.

The re-settlement of riverside communities on higher safer ground can mitigate, even largely eliminate, flash flood impacts. Throughout most of the flash flood-prone areas of the Northeast Region, however, land which is high enough to classify as flood-free is either too far away for the villagers to access the fields they must cultivate to survive, and/or it is already fully occupied by some other community, or it is under (economically important) tea culture. There are estimated to be 250 riverside communities exposed to flash floods in the Northeast, each with around 1,000 inhabitants; thus, some 250,000 people might need to be re-settled and suitable land sufficient to accommodate this number of people is simply not available. Even if the land was available the front-end cost of resettlement to an acceptable standard would be very high and, as the case of the Kaptai oustees has shown[2], ongoing social problems are likely to persist for many years afterwards. The conclusion has to be, therefore, that resettlement is not an appropriate means for mitigating flash flood impacts in the Northeast Region.

Flood warning systems enable people in riverside communities to safely evacuate temporarily to safe ground, and to take with them the essentials required for a temporary stay on the safe ground. Essential to the success of these systems is the achievement of a satisfactory matching of the lead-time which the system can give, and the minimum time villagers need in which to evacuate. When such a satisfactory match is achieved no lives need be lost, the hardship of the evacuation period is greatly reduced, and many personal belongings and much livestock may be saved. These systems cannot, however, protect dwellings, anything left behind in the village, or crops, from the action of the flood. Such systems are relatively cheap to install and maintain, their installation involves no serious social disturbance, and if carefully planned in the context of a broader program of flood preparedness, which may include independent structural measures, they can be quite effective in mitigating flash flood losses and damages. Such structural measures may include 1) the provision/strengthening of flood protection embankments, 2) the provision of artificial islands with or without village re-location upon them, or 3) the provision of concrete shelters similar to those erected along the coast of Bangladesh, and which proved so successful during the May 1994 cyclone.

1.3 Improved Flood Warning Initiative

Based on the foregoing arguments NERP concluded that the only practical means of reducing flash flood impacts in the Northeast Region is a flood warning system. Since FAP 10: Flood Forecasting and Early Warning, is engaged in the development of a nation-wide flood warning system activated by flood forecasts it was logical, first, to see if this system could provide flash flood warnings for the Northeast Region. On reviewing FAP 10's mandate and progress it was concluded, however, that its system cannot, and will not, meet this need for the following reasons:

1) The radar component of the flood forecasting system, which was to have detected flash flood-causing rainfalls over Meghalaya and Tripura, has been abandoned for both technical and other reasons[3], and the forecasts will now be activated by telemetric water level recorders located in Bangladesh *downstream of the flash flood-prone river reaches;* thus, by the time the 4-hour computerised forecasting process is even initiated, the flash floods will already have passed through these reaches and done their damage;

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2 When the Kaptai Dam was raised on the Karnaphuli River, upstream of Chittagong, some 30 years or so ago, thousands of people were forced to leave the reservoir area. Up to the present time there has been long-standing problems in the area.

3 The reasons are discussed in Chapter 4

2) On production of the forecasts, which will now relate only to the network of the larger rivers, the early warning will be communicated only to disaster relief agencies and to the media; thus, whether a warning is given on a timely basis and in terms intelligible to rural people, or not, it will never reach these people since, for the greater part, they have no access to the media in any form.

In view of these findings NERP concluded that an entirely separate, and different, system is needed to produce warnings of flash floods in the border areas of the Northeast Region, and to communicate the warnings instantly, and in comprehensible form, to rural people scattered throughout these areas.

A basically appropriate concept for such a system was put forward by NERP in its Northeast Regional Water Management Plan of September 1993 as the Improved Flood Warning Initiative (see Annex A). The initiative envisaged:

- detection, at the Indo-Bangladesh border, of rising river water levels reaching, successively, *three* danger levels selected to correspond to "moderately", "very" and "extremely" dangerous conditions for villagers;

- activation, in response to these detections, of recognisably different audio and visual warning signals produced at warning stations located every 5 km along the flood's path;

- appropriate protective/evasive actions by villagers in response to each level of danger signal.

Details of the appropriate technology remained to be worked out at the time the Initiative was put forward, but it was anticipated that it would feature:

- simple electrode water level detectors; three of these, each one set at a different level in the river channel at the border, would be used to detect the occurrence there of "moderately", "very" and "extremely" dangerous river water levels;

- simple flashing/coloured light beacons and variable-pitch sirens to warn people that a flash flood had been detected; differing signal patterns would indicate which dangerous river water level had been detected;

- simple radio or cable signalling equipment, activated by the water level detectors, to activate the beacons and sirens according to which dangerous water level had been detected.

It was also anticipated that:

- all of this equipment would be energised by heavy-duty batteries recharged by photovoltaic cells; grid power is generally not available in the border areas and would, in any case, require potentially expensive AC/DC conversion and voltage transformation;

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- the beacons and sirens would be mounted, for maximum visibility, audibility and security, on guyed masts of, say, 20 m height; each mast would be located within or near one of the villages to receive the flood warning and, preferably, on flood-free ground.

It was envisaged that both beacons and sirens would be needed at each installation to ensure that people would be alerted regardless of what they were doing at the time of warning, or where they might be within the warning range of the installation, and that the differing light and sound signals would be intelligible to all villagers regardless of their state of literacy.

Details of appropriate actions to be taken by villagers on receiving warnings of each danger level also remained to be considered at the time the Initiative was put forward, but it was anticipated that plans of action for villagers to follow in response to the danger signals would have to be drawn up in consultation with them, and that they would require some instruction as to the meaning of each danger signal and on the rationale for each action to be taken in response according to a plan of action.

1.4 Studies Subsequent to the Initiative

At the time the Initiative was prepared attention focused on how to detect the occurrence of dangerous water levels at the border, and on how to communicate warnings instantly and effectively to villagers. The real need for such a system was taken for granted, and all its details remained to be worked out. Within the three months which elapsed after the Initiative was put forward, efforts were made to confirm the need for a flash flood warning system, and to establish its engineering viability at pre-feasibility level. These efforts included:

1) field investigation, based on a questionnaire, to elicit from villagers information on their need and desire for a flash flood warning system, their ability to understand the warnings given by it, their willingness to respond to the warnings, and what their response should be.

2) a desk study to assess the heights, velocities and profile forms of flash flood rises likely to be experienced in the border areas of the Northeast Region; this study was further supported by field investigation of villagers' observations of flood rises which occurred during disastrous flash flood events in the past.

3) a desk study to determine the electrical circuitry required for the warning system, to identify suitable, locally available components and their cost, and to select a suitable site for a pilot project to prove and demonstrate the system.

The field investigation (1) indicated that most villagers both need and desire a flash flood warning system, that they will understand warnings given in the form suggested in the Initiative, and that they are mostly willing to respond to the warnings. Their ideas as to what their response to the warnings should be were, however, less clear.

Desk study (2), and the associated further field investigation, strongly suggested that the flash floods arrive in some villages as hydraulic bores, but this could not be firmly established.

Desk study (3) led to a viable design of electrical circuitry required for the warning system, to knowledge that all components are available locally (in Bangladesh), and to a realistic cost estimate for the system.

The Draft Final Report (January 1994) on this concept was largely based on the outcome of these studies. The only significant change made to the original Initiative concept concerned the number of danger levels and their definition. The number of danger levels was reduced to two, the first corresponding to "possibility of a flash flood - prepare to evacuate", and the second to "confirmation of flash flood approaching - evacuate". This change was determined by practicalities of the situation, but represents a desirable simplification of the original concept.

1.5 Studies Subsequent to the Draft Final Report

In response to the Draft Final Report both CIDA and FPCO expressed interest in the Improved Flood Warning system, and agreed in principle to support a pilot project on the Juri River.

CIDA and FPCO raised numerous issues in commenting on the Draft Final Report; their comments, together with specific NERP responses, are given in Annex B. These comments have also been addressed in preparing the Final Report which contains new material on activation of the warning system, flash flood shelters, the institutional arrangements needed for implementation, and draft Terms of Reference for the pilot project. The draft Terms of Reference are given in Annex C, together with a negotiating brief for use by FPCO should it consider that "real time" data could, and would, be provided by India to Bangladesh.

1.6 Final Report Layout

The need for a warning system is assessed in Chapter 2 based on information provided by villagers as to what actually happened during the flash flood disasters of 1988 along the Meghalaya border, and of 1993 along the Tripura border. A description of the physical nature of flash flood rises is given in Chapter 3 together with conclusions reached on the basis of theoretical calculations and villagers' observations. Chapter 4 deals with the problems associated with effectively activating the flood warning system. Chapter 5 presents the technology of an appropriate flash flood warning system together with cost estimates. Chapter 6 considers associated flood preparedness actions which need to be taken by government, and what villagers need to do on receiving a flood warning. The institutional arrangements required not only to install, operate and maintain the flash flood warning system, but also to coordinate the other associated essential activities are considered in Chapter 7. Chapter 8 goes on to propose a pilot project on the Juri River which seems most appropriate as a system proving ground. Chapter 9 contains a list of related reference material. Details of the field investigations are given in Annex D, an outline of the electrical system in Annex E, and related drawings in Annex F.

2. NEED FOR A FLASH FLOOD WARNING SYSTEM

2.1 Field Investigations

Since it had been taken for granted, in preparing the Improved Flood Warning Initiative, that a need existed for flash flood warnings to villages in the Meghalaya and Tripura border areas, it was felt imperative to confirm this need before developing the concept any further. It also needed to be confirmed that villagers in these areas could, and would, respond to the warnings. To gain further insight on these highly significant issues, field investigations were carried out in a small but representative sample of villages in the flash flood-prone areas. The objectives of the field investigations were to identify:

1) A representative sample of flash flood-prone rivers.

2) The one village on each of these rivers which had been worst affected by flash flooding in recent memory.

3) The worst flash flood to have affected each of these villages.

4) The effects of this worst flood in terms of lives lost and property damage.

5) The causes of these losses and damages.

6) Villager's desires and needs for flash flood warnings.

7) Villager's ability to understand flash flood warnings in the format proposed in the Initiative.

8) Villager's willingness to respond to flash flood warnings.

9) The basic elements of appropriate plans of action to be followed by villagers in response to the warnings.

To achieve these objectives a questionnaire was designed, and the answers to its 29 questions obtained by interviews in the worst affected villages. The interviews were conducted by a Bangladeshi engineer, and the interviewees were village people, mainly farmers. An account of the interviews is given in Annex D.

2.2 Identification of Flash Flood-Prone Rivers

Flash floods are generated from intense rainfall on the southern slopes of the Shillong Plateau in Meghalaya, and in the structural valleys of Tripura. In both these areas the river channel networks are *dendritic* so that floods generated in the various tributaries of each river basin all converge on a single point in the network, the basin outfall. It happens that the basin outfalls are all on, or very close to, the Indo-Bangladesh border. From the basin outfall the large flood which has formed as a result of the combination of the tributary floods passes into Bangladesh through a single reach of river channel; this reach is usually quite short, and may be called the

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nodal reach. Downstream of the nodal reaches the river channel networks become *deltaic* so that floods leaving the nodal reaches are divided between the various distributaries of the delta; as a result of this division the floods in the distributaries are smaller than those passing through the nodal reaches. This process is illustrated in Figure 3.

It is to be expected, therefore, that the worst flash floods will be experienced in the nodal reaches connecting the dendritic and deltaic portions of the river channel networks, and which have the largest (dendritic) catchment areas. Map studies led to identification of the following nodal reaches along which flash flooding could be expected to be most severe:

River	**Reach**
Meghalaya Border Area:	
Bhogai	IBB to Kangsha River
Someswari	IBB to Kangsha River
Jadukata	IBB to Surma River
Dhalai (N)	IBB to Piyain River
Shari	IBB to Sari-Gowain River
Tripura Border Area:	
Juri	IBB to Dhaka-Sylhet Railway
Manu	IBB to Dhaka-Sylhet Railway
Dhalai (S)	IBB to Dhaka-Sylhet Railway
Karangi	IBB to Dhaka-Sylhet Railway

* IBB = Indo-Bangladesh Border

As so defined, some of these reaches include only a part of the nodal reach which in most cases extends a relatively short distance upstream into India, and in some cases the reaches extend downstream into the head reaches of some of the main distributaries.

The location of the selected river reaches is shown in Figure 4, together with the villages where interviews were conducted, and the floods which passed through some of these villages are illustrated in Figures 2(b), 5 and 6 for 1988 (data are not yet available for 1993).

2.3 Villages Worst Affected by Flash Floods

The interviewer went to each of the selected river reaches and on the basis of local enquiries he established which village along each reach had been worst affected by flash floods according to criteria given to him as set out in Annex D. The villages he selected were:

River	**Village**
Meghalaya Border Area:	
Bhogai	Nakuagaon

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Jadukata	Maharam
Dhalai (N)	Chilabhanga
Shari	Kamrangi

Tripura Border Area:

Juri	Jahangirai
Manu	Rainsaf
Dhalai (S)	Hiramati-Saisiri
Karangi	Himagao

In each of these villages the interviewer selected a group of three or four mature men for interview.

2.4 Worst Floods of Memory

In four of the five villages in the Meghalaya border area the interviewees identified the flood of 1988 as the one which had had the worst effect on their village; the exception was Dhalai (N)/Chilabhanga for which that of 1973 was the worst. In all of the four villages in the Tripura border area the flood of 1993 was identified as the worst flood. The rest of the interview focused on what had happened during these worst floods.

2.5 Effects of Worst Flood of Memory

A total of 53 lives were lost in the nine villages; 49 of these fatalities occurred in the Meghalaya border area in the 1988 flood, and 4 occurred in the Tripura border area in the 1993 flood.

In the Meghalaya border area 45 of the 49 lives lost were lost as a result of boats, used to flee the flood, having capsized; the other 4 lives were lost as a result of adults being overwhelmed by the flash flood and swept away.

In the Tripura border area only four lives were lost, all as a result of people being overwhelmed by the flash flood and swept away; three of these fatalities were children.

Property losses were substantial in both border areas, but they were significantly greater in the Meghalaya border area in the 1988 flood than in the Tripura border area in the 1993 flood. Estimated property losses are summarized in Table 2.1.

Crop losses or damages claimed in both border areas were very high, virtually 100 % for rice and vegetables, and 50% for orchard crops.

2.6 Causes of Losses and Damages

The causes of the losses and damages were explored in some depth during the interviews. The disasters which befell the nine villages resulted from two basic causes:

Table 2.1

Property Losses in Sample Border Villages (%)

Property Type	Meghalaya Border Area	Tripura Border Area	Both Border Areas
Belongings:			
Dwellings	56	24	40
Boats	45	0	23
Personal	60	26	43
Stocks:			
Drinking Water	76	45	61
Food	83	28	56
Fuel	77	44	61
Fodder	90	83	87
Livestock:			
Buffaloes	26	0	13
Cows	41	5	23
Goats	57	26	42
Chickens	86	58	72

1) *Occurrence of a flash flood rise which overtopped the river bank and passed through the village.*

2) *Bursting of the local flood protection embankment during passage of a flash flood rise.*

The villages can be grouped according to these two basic causes as follows:

Group 1 (Cause 1):

Jadukata/Maharam
Dhalai (N)/Chilabhanga
Shari/Kamrangi
Juri/Jahangirai

Group 2 (Cause 2):

Bhogai/Nakuagaon
Someswari/Bhabanipur
Manu/Rainsaf
Dhalai (S)/Hiramati
Karangi/Himagao

Secondary causes of disaster can all be related to human behaviour, and include the following:

3) *Failure to notice that a flood was rising in the river.* This was the case in only one village, Karangi/Himagao, where the entire flood event occurred after dark; spill from the Khowai River around the upstream end of its incomplete right embankment was a major factor in the generation of this flood.

4) *Failure to react in any way on noticing that a flood was rising in the river.* This was the case in three villages, besides Karangi/Himagao. In two villages 1 to 2 hours passed before disaster struck but no precautionary actions were taken. In Jadukata/Maharam, perhaps the most dangerously exposed village in the Meghalaya border area and one with an apparently long history of previous flood disasters, 8 precious hours elapsed between noticing the river rising and disaster striking, but no precautionary action was taken in that time!

5) *Reluctance to leave home.* This reluctance seems to reflect beliefs that events would not be as severe as they turned out to be, that there was still time to better secure their property, and that their homes might be robbed if left unattended.

The precautionary actions taken in the other five villages were limited to constructing *macha* (bamboo platforms) inside their dwellings to put valuables on, and moving cattle to safer ground. When disaster struck, there was no time left in which to do anything else but flee. Panic characterized flight in most cases, and almost certainly was reflected in the overloading of country boats in cases where these were used to flee.

2.7 Desire of Villagers for a Flood Warning System

In all nine villages the interviewees thought that if some external agency raised the alarm when a flash flood approached their village the villagers would take notice of it and initiate protective measures. In only eight villages, however, did they think this would provide the villagers with sufficient time to complete all necessary precautionary actions. In the five villages where lives had been lost they were sure that those lives would have been saved if an alarm had been given. In three villages they thought that their properties could also have been saved, but in six they thought that property loss could only be minimised. No one expected that crops could be saved by having an alarm which, of course, is the case.

When asked whether they thought the villagers would welcome some external agency providing them with clear and timely warnings of imminent flash floods, interviewees in eight villages said they would; in Dhalai(N)/Chilabhanga, however, they clearly stated that the money for the warning system would be better spent on dredging their river ! In seven of the eight remaining villages it was thought that flood warnings would help the villagers to reduce their losses and damages.

2.8 Villagers Needs of a Flood Warning System

In the eight villages which wanted a flood warning system the interviewees were asked to comment on the technology proposed in the Initiative.

The interviewees were first asked to identify levels in their village which they thought corresponded to critical water levels. In two of the villages they identified critical water levels on the local BWDB river gauge. In the other six villages they identified them in terms of the local flood protection embankment; in these villages the interviewees considered that:

1) there could be no danger until the water level reached the top of the embankment !

2) they perceived no danger until the water level was 0.3 to 0.6m above the top of the embankment !

They indicated that the villagers would want warnings several hours in advance that these critical water levels would be exceeded, and that they would carry out a planned sequence of appropriate protective measures in response to such warnings.

It was then explained to the interviewees how, under the Initiative, it had been proposed to communicate such warnings to the villagers. They were all of the opinion that both adults and children (except, obviously, the very young ones) would understand the sounds of the siren and the flashing of the beacons. They also thought that adults, at least, could discriminate between warnings corresponding to *two* different danger conditions.

2.9 Villagers Needs to Respond to Flood Warnings

It was explained to the interviewees that the warnings would be of little or no use to the villagers if they chose to take no notice of them, or failed to take the right actions when the warnings came. They were asked what they thought the villagers should do in response to the first and second warnings. They were of the opinion that:

1) on the first warning the villagers should remove women, children and the elderly, cattle and valuables to safe ground, but the men should remain in the village until the second warning came; this was the opinion in seven of the eight villages, but in Jadukata/Maharam they thought the men should also leave on the first warning.

2) on the second warning the men should leave the village and go to safe ground.

2.10 Conclusions

A number of valuable conclusions are reached from the results of these field investigations:

1) The maintenance of credibility in the flood warning system is a matter of paramount importance. Its credibility will be at risk if:

    a) the first warning is not given early enough for the villagers to take all reasonable protective actions before the second warning comes.

    b) dangerous conditions do not materialise following the second warning.

    What, exactly, should activate the first and second flood warnings is considered further in Chapter 4.

2) The flood warning system technology proposed in the Initiative appears basically appropriate, and not to be in need of any substantial modification; the number of warnings should, however, be limited to two. This technology is elaborated further in Chapter 5.

3) It is evident that the flood warning system cannot predict when, or if, flood protection embankments will burst. It is, therefore, essential in five of the nine villages investigated, or in any other village where bursting of the embankment is likely to be the immediate cause of disaster, that:

   a) the villagers be made to understand that the embankment may fail at any time during passage of the flood rise for reasons which may have no connection with it being overtopped.

   b) steps are taken by the BWDB to reinforce all sections of flood protection embankment the failure of which would result in disaster for the villagers.

   These important matters are considered further in Chapter 6.

4) The villagers must all know exactly what they should, and should not, do in response to the first and second flood warnings. It is evident from the answers obtained during the field investigation that:

   a) there is a need to assist villagers in establishing appropriate plans of action for them to follow on receiving the first and second warnings.

   b) there is a need to impress on the villagers the need for following these plans of action.

   These needs are also addressed in Chapter 6.

5) Appropriate institutional arrangements will have to be made to install and manage the technology described in Chapters 4 and 5, and to organize the activities described in Chapter 6. These arrangements are discussed in Chapter 7.

2.11 Recommendation

In view of these conclusions, particularly (3) and (4), and of the negative response of Dhalai (N)/Chilabhanga which may be repeated in other villages not covered by this investigation, it is strongly recommended that the flood warning system be implemented initially only on a pilot project basis. This recommendation follows from the fact that the success of any flood warning system depends on the warned population responding appropriately; if this population cannot, or will not, respond appropriately the warning system will be of little or no use to them.

Trial layouts of flood warning systems for the nine rivers covered by these field investigation are described in Chapter 8 where a conclusion is reached as to which of these would best serve as a pilot project.

3. FLASH FLOOD DANGERS

3.1 Introduction

Flash floods frequently occur in the border areas of the Northeast Region, but not all of them cause disasters for riverside communities such as occurred in the Meghalaya border area in 1988, and in the Tripura border area in 1993. Clearly, there was something different about the flash floods involved in those disasters, and it is a matter for concern to know how they differed from others which have passed harmlessly through the riverside communities. To say that these flash floods were simply larger, in the sense that their peak river flows and water levels were larger, than usual is to state the obvious. Less obvious, however, is the fact that it is other characteristics, albeit flow dependent, of flash floods which really pose danger and do damage. A clear view of all the characteristics of flash floods is therefore essential to understanding how they cause disasters and, hence, how their impacts can be effectively mitigated.

3.2 Flash Flood Profiles

It is well-known that river flows and water levels rise and fall in response to rainfall, one complete rise and fall comprising a *flood*. If, during the passage of a flood down a river channel, the river water levels are observed at a number of sections along the channel, and these levels are then graphed as a function of distance along the channel, the water surface *profile* of the flood is revealed. On this profile the flood is seen to have the form of a wave, and for this reason floods are described by hydraulic engineers as *flood waves*.

When floods are recognized as waves, the principles of wave theory can be applied to describe flood movements along river channels. The simplest case which can be so described is that of a flood wave moving along a prismatic channel of rectangular section, and this case is adequate for the present purposes of:

1) gaining a clear view of the damage-causing characteristics of flash floods

2) assessing the hydraulic circumstances which may have prevailed during the disasters of 1988 and 1993.

Considering a flood as a wave (Figure 7a(i)) it is seen that the *flood rise* extends upstream from the *wave-front* (Section 1) to the *wave-crest* (Section 2), and that the flood fall, or *recession*, extends upstream beyond the wave-crest. At both the wave-front and the wave-crest the water surface is parallel to the channel bed, but the water discharges and depths differ. The water discharge Q_1 and depth y_1 at the wave-front are always less than the discharge Q_2 and depth y_2 at the wave-crest, and so the water surface of the flood rise is inclined downstream at a steeper angle than the channel bed. The profile of this inclined water surface may vary from one flood to another, depending on the flow conditions prevailing during the flood at a particular site.

In general, flood waves move down river channels which are already carrying a flow of water; this preceding flow is called the *antecedent flow*, and it has a significant influence on the movement and profile of the following flood wave. A special case arises when the antecedent flow is zero, i.e. when the channel ahead of the flood wave is dry.

3.2.1 General Case

In general, flood waves move down river channels at a velocity, known as the *wave velocity* V_w which exceeds both the water velocities V_1 at Section 1 and V_2 at Section 2. To analyse the flood wave movement it is then necessary to apply the "technique of the moving observer". According to this technique an observer moving downstream with the same velocity as the wave will see the wave to be stationary with water apparently flowing upstream through it. As shown in Figure 7a(ii), the technique is applied by subtracting V_w from all velocities shown in Figure 7a(i). When this is done, the apparent upstream discharge, known as the *overrun discharge* Q_o, is:

$$Q_o = By_1(V_1-V_w) = By_2(V_2-V_w) \qquad (1)$$

in which B is the width of the river channel's rectangular section. By analogy with the flow of a single discharge in an open channel, a critical depth of flow, known as the *overrun critical depth* y_{∞}, can then be computed as:

$$y_{\infty} = (Q^2_o/B^2g)^{1/3} \qquad (2)$$

in which g is the gravitational acceleration. The overrun critical depth determines the shape of the flood wave profile.

For $y_1 > 0$ (the general case) the flood rise profile is determined by the *overrun critical depth* (y_{∞}), and the inclined surface will have one of three possible profiles depending on the magnitude of y_1 relative to y_{∞}. According to this comparison, the three profiles are:

Monoclinal Rise

A *monoclinal rise* occurs when $y_1 > y_{\infty}$. In this case the flood rise profile has the appearance of a flat ogee curve which is asymptotic to the slopes of the water surfaces prevailing at the wave-front and at the wave-crest. An observer standing on the channel bank will see the water level rise smoothly and gradually from y_1 to y_2 (Figure 7b(i)).

Undular Bore

An *undular bore* occurs when $y_1 = y_{\infty}$. In this case the flood rise profile has a wavy appearance, the waves being distributed along the inclined water surface and decreasing in amplitude towards the wave-crest; the waves actually die out at the wave-crest. An observer on the channel bank will see a train of smooth waves pass by as the water level rises from y_1 to y_2, the first wave being the largest. If y_{∞} slightly exceeds y_1 the observer will see the waves starting to break at their crest (Figure 7b(ii)).

Breaking Bore

A *breaking bore* occurs when $y_1 < y_{\infty}$. In this case the flood rise profile is theoretically vertical between y_1 and y_{∞} but has a logarithmic shape between y_{∞} and y_2. In reality, an observer on the channel bank will see a *near* vertical rise in water level from y_1 to y_{∞} in the form of a cascading wall of water; when this has passed he will see the water level rising smoothly, but ever more slowly, from y_{∞} to y_2 (Figure 7b(iii)).

Figure 8 presents some photographs of bores. The bores shown in Figure 8 b, c and d are tidal bores, but the physical structure of flood wave bores is exactly the same.

The height of any flood rise, regardless of which of these three profiles it has, is a convenient measure of the scale of the rise; called the *rise height*, it is given by:

$$h_r = y_2 - y_1 \tag{3}$$

For flood rises consisting of bores, the height of the bore is also of interest. The *bore height* is given by:

$$h_b = y_\infty - y_1 \tag{4}$$

If two observers, each standing at a different section, note the time when either the wave-front or the wave-crest passes them, and the time difference is T, they can compute the *wave velocity* as:

$$V_w = L/T \tag{5}$$

wherein L is the distance between the two sections. If this wave velocity is compared to the *water velocities* under the wave-front (V_1), and under the wave-crest (V_2), it will be found that, in general, V_w is greater than either V_1 or V_2. This is true because the wave must move more rapidly than the water if it is to make up the volume of the wave configuration at any time. From theoretical analysis of the flood rise movement it is found that, in general:

$$V_w = (V_2 y_2 - V_1 y_1)/(y_2 - y_1) \tag{6}$$

From this equation it can be understood that:

1) The smaller the rise height (y_2-y_1) the faster the wave travels

2) If the channel is dry ahead of the wave-front ($y_1 = 0$), as may be the case in the dry and pre-monsoon seasons, then:

$$V_w = V_2 \tag{7}$$

This is the minimum value that V_w can attain, and it can only be attained when $y_1 = 0$.

3.2.2 Special Case

For $y_1 = 0$ (the special case) $V_1 = 0$ and $V_w = V_2$. The flood rise profile is then determined by the *critical depth* at Section 2, as usually defined for open channel flow, i.e

$$y_c = (Q_2^2/B^2 g)^{1/3} \tag{8}$$

Since there is no antecedent flow in this case, the flood rise profile must have the form of a breaking bore, and the shape and height of the bore will depend on whether the approaching flood peak discharge is sub-critical ($y_2 > y_c$), or super-critical ($y_2 \leq y_c$):

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Partial Breaking Bore

A *partial breaking bore* occurs when $y_2 > y_c$. In this case the flood rise profile is theoretically vertical between $y_1 = 0$ and $y = y_c$, but has a logarithmic shape between y_c and y_2. In reality, an observer on the channel bank will see a near vertical rise in water level from $y_1 = 0$ to y_c in the form of a cascading wall of water; when this has passed he will see the water level rising smoothly, but ever more slowly, from y_c to y_2 (Figure 7c(i)).

Full Breaking Bore

A *full breaking bore* occurs when $y_2 \leq y_c$. In this case the wave-front and wave-crest coincide, and the profile of the inclined surface is theoretically vertical between the wave-front and the wave-crest. In reality, an observer on the channel bank will see a near vertical rise from $y_1 = 0$ to y_2 as a cascading wall of water; when this has passed he will see the water level immediately start to fall again (Figure 7c(ii)).

For a full bore ($y_1 = 0$), the bore height is the same as the rise height, i.e:

$$h_b = y_2 \tag{9}$$

3.2.3 Compound Bores

The differences in height and velocity of bores in channels with and without antecedent flow give rise to a sixth type of flood rise, namely:

Compound Bore

A *compound bore* occurs when $y_1 = 0$ over only a part of the river bed, the remaining part carrying a small antecedent flow. In this situation a full bore will tend to form over the dry part of the river bed, and a partial bore over the part carrying the antecedent flow. Since a partial bore travels faster than a full bore, the partial bore will surge ahead of the full bore, and since a full bore is higher than a partial bore a lateral flow of water must occur from behind the full bore into the rear of the partial bore. The results of these tendencies are that the wave-front is not straight across the channel but strongly curved, and that a partial bore forms along the whole wave-front. An observer on the channel bank will see a partial bore "fingering" its way downstream with the "point of the finger" always following the course occupied by the antecedent flow. Along the curved wave-front he will see a near vertical rise, from y_1 to y_c, as a cascading wall of water where the bore is moving over the antecedent flow, and that this cascade tends to die out away from the antecedent flow (i.e. over the higher parts of the dry portion of the channel bed) (Figure 7d).

3.3 Flash Flood Dynamics

At the wave-crest in a horizontal channel, where the water depth is y_2 and its velocity is V_2, the specific energy, or energy per unit weight, of the water is:

$$E_2 = y_2 + V_2^2/2g \tag{10}$$

g being gravitational acceleration. Similarly, at the wave-front, where the water depth is y_1 and its velocity is V_1, the specific energy is:

$$E_1 = y_1 + V_1^2/2g \tag{11}$$

Since $y_2 > y_1$ and $V_2 > V_1$, it is evident that there is an apparent loss of specific energy between Section 2 and Section 1, i.e.:

$$\Delta E = E_2 - E_1 = (y_2 - y_1) + (V_2^2 - V_1^2)/2g \tag{12}$$

In fact, since energy cannot be created or destroyed, this loss represents a conversion of pressure energy (y) and kinetic energy ($V^2/2g$) to another form. Thus, a part (y_2-y_1) of the pressure energy y_2, at the wave-crest and a part $(V_2^2 - V_1^2)/2g$ of the kinetic energy $V_2^2/2g$ at the wave-crest , are used to generate turbulence within the flow between the wave-front and the wave-crest. If sediment is present in the water, this turbulent energy is used to carry sediment particles; otherwise, if sediment particles are not available in the channel, the turbulent energy is converted into heat which is released through the boundaries of the flow. Clearly, the larger ΔE is, the more turbulence is generated, and the more sediment is carried.

Equation (12) can be expressed in the alternate form:

$$\Delta E = (y_2-y_1)^3/4y_1y_2 \tag{13}$$

From Equation (13) it can be understood that the energy available for the generation of turbulence increases very sharply with the rise height (y_2-y_1). Thus, for example, if y_1 = lm the energy used to generate turbulence in a 4m high rise exceeds that used in a 2m high rise by a factor of 3.2/0.67 = 4.8. Clearly then, the rise height has a very potent influence on the generation of turbulence and, hence, on the conveyance of sediment particles during a flood rise.

What has been said in the two preceding paragraphs applies equally to all flood rise profiles. The three profiles differ, however, in the rate at which energy is converted. Remembering that energy per unit of time is power, the power of a flood rise can be expressed as:

$$P = \Delta E/t \tag{14}$$

where t is the time of passage of the flood rise past any section of the channel. If a flood rise profile of height (y_2-y_1) occurs as a monoclinal rise, t will be large, say a day or 86400 seconds; in this case the power of the flood rise is ΔE/86400. If the same flood rise occurs as a full bore, however, t will be very small, say 100 seconds, and in this case the power will be ΔE/100. Comparing these powers it is evident that, in this particular case, the full bore is 864 times more powerful than the monoclinal rise. This means that in a monoclinal rise the energy conversion occurs over a considerable length of the channel, typically several kilometres, whereas as in a full bore it occurs over a very short reach, typically only several decimetres in length. During passage of a monoclinal rise, therefore, the turbulence will not be very evident although it can usually be seen as boils on the water surface; the sediment carried in the flow then generally consists of sand and particles of smaller size. During passage of a full bore, however, the turbulence is very evident in the cascading wall of water, and the sediment carried will include cobbles, stones and even boulders, depending on what sediment sizes are available in the channel.

3.4 Flash Flood Dangers

Generally in Bangladesh, and certainly in the flash flood-prone border areas of the Northeast Region, rural people are often to be found *in* or *on* the rivers. They get directly into the river flow for such purposes as:

1) wading across the river (mainly men)
2) recovering river sand, gravel, etc (mainly men)
3) fishing (mainly men, but also children)
4) ablutions (people of both sexes and all ages)
5) swimming (especially children)
6) drawing water for the home and laundry (mainly women)

They are also often on the river in boats, with "design" capacities ranging from about 5 to around 50 people, for such purposes as:

7) visiting local markets (mainly men)
8) transporting recovered river sand, gravel, etc. (mainly men)
9) fishing (mainly men, but also children)
10) travelling farther afield (whole families)

The incidence of people's exposure to flash flood rises is therefore unusually high, and if even a fairly large flood rise occurs rapidly and catches them before they have time to get out of the river, they can find themselves in considerable difficulties leading in some cases to disaster. A disaster is particularly likely if the flood rise occurs as a bore.

3.4.1 Danger to an Exposed Person

Danger to a person caught in a flash flood rise derives from changes in his weight, and in the pressure, momentum and turbulence of the flow around him. These changes occur relatively slowly if the flood rise has the form of a monoclinal rise, but relatively very rapidly if it has the form of a bore.

To illustrate these changes consider a man, weighing 713N (about 70 kg force), fishing in an antecedent river flow when a flash flood arrives. If the antecedent flow depth is 0.5 m he will be up to his knees in water just before the flood arrives, and if the peak flood flow depth is 1.5 m he will be up to his shoulders in water at the time of peak flow (assuming he is still able to stand). The forces acting on his body can then be calculated to be approximately as follows:

1) If the flood rise occurs gradually as a monoclinal rise the vertical force holding him to the river bed, which would be 713N if the river was dry, decreases, due to his increasing buoyancy, to 517N (73% of 713N) when he is standing in the antecedent flow, and to 124N (17% of 713N) when he is standing in the peak flow; thus he will still be firm on his feet when standing in the antecedent flow, but he will, at best, be very unsteady on his feet by the time the peak flow arrives. At the same time the horizontal drag force exerted on him by the flow will increase, due to the increasing pressure and momentum of the flow, from 10N when he is standing in the antecedent flow to 1180N when the peak flow arrives. Acting together with his reduced weight, this 100-fold increase in horizontal force will sweep him off his feet and he will be obliged to swim; if he cannot swim he will probably drown. If he can swim then he should be able, since turbulence is not excessive, to reach the river bank and escape from the flood flow.

2) If the flood rise occurs rapidly as a hydraulic bore the change in the vertical forces is the same as for a monoclinal rise, but when the bore strikes him the horizontal force, assuming the bore height is 0.48 times the rise height, will be 10176N (about 1 tonne force). There is no way, no matter how strong he may be, that he will be able to resist this horizontal force; he will be dashed to the river bed instantly. For a bore of the height postulated in this example he might be able, after the bore has passed over him, to swim or get back on his feet, but if the bore was much larger he would not succeed; once he was down the stones flying in the excessively turbulent flow would strike him, possibly fatally, or so as to bury him until he drowned.

These calculations provide an explanation of how people are "swept away", often without trace, by flash floods. In the field investigations it was reported that eight people, of whom only three were children, had been lost in this way.

Similar calculations can be made for other objects caught in a flash flood, and the relative magnitudes of the forces will be found comparable. Livestock, which tend to be top heavy and to have more rigid legs, are likely to be more easily killed than man; this is reflected in the loss data given in Chapter 2. Rural housing in Bangladesh is typically of semi-pucca, sheet metal or kutcha construction, and is very likely to collapse when a flash flood overtops the river banks even if it occurs as a monoclinal rise; if it occurs as a bore such housing is likely to collapse in an "explosive" way. Anyone trapped in such housing when it collapses has virtually no chance of survival; they will drown before they can be freed.

3.4.2 Danger to an Exposed Boat

Danger to a boat caught in a flash flood rise derives from *heeling* of the boat i.e rotation of the boat about its longitudinal axis, leading to *swamping* or *capsizing*.

When a boat is floating in water the height of its hull, i.e. the vertical distance from the keel to the gunwhale, is divided by the water-line; the part below the water-line is called the *draft,* and the part above is called the *freeboard*. Except for ferry-type country boats, all boats in the Northeast Region have a freeboard of a few inches when empty, four inches (0.1 m) being fairly typical, and a beam width of about 1.5 m; this means that, when they heel under the influence of waves passing beneath the hull, the maximum angle through which the boat can heel without water slopping over the gunwhale is about 8°. Such boats are, however, habitually loaded until the freeboard is reduced to about one inch; the maximum angle through which the boat can heel without water slopping over the gunwhale is then only about 2°. The water which slops over the gunwhale accumulates inside the hull causing the freeboard to decrease even more; when the freeboard is reduced to zero, the boat is swamped with water and sinks.

The phenomenon of capsize, in which the boat actually turns over and empties its contents into the river, is rather more complex. It depends on changes in the relative positions of the centre of gravity of the boat G, and its centre of buoyancy B which is the centre of gravity of the water displaced by the boat; the weight of the boat acts through G, and the hydrostatic pressure force supporting the boat acts through B. If the weight of the boat is symmetrically distributed about its centre-line, G and B both lie on the centre-line. When the boat heels B moves off the centre-line, and a vertical through B then intersects the tilted centre-line at M, the *metacentre*. As long as M lies above G the hydrostatic force opposes the force causing the boat to heel, and the boat remains stable in the water. If M falls below G, however, the hydrostatic force supports the force causing the boat to heel, and the boat immediately turns right over. The more a boat is loaded, and the more asymmetrically it is loaded, the greater is the tendency for G to move off centre-line towards B; as it so moves, M drops rapidly, and when it passes below G the boat capsizes. In flash flood events people may opt, or have no alternative but, to flee from the flood in boats. For reasons of over-confidence in the boat's stability, determination to escape from the flood as soon as possible, etc, people crowd onto to any available boat; as a result the boat leaves in an over-loaded condition and, very likely also, in asymmetrically loaded condition. In this critical condition it only takes one person, maybe even only a child, to move from one side of the boat to the other, and so cause the boat to capsize; a wave passing beneath the boat will have exactly the same effect, and these critical movements can occur simultaneously. This, apparently, is what happened at Someswari/Bhabanipur during the 1988 flood when 40 people lost their lives when the boat they were escaping in capsized.

3.5 Occurrence of Bores in the Northeast Region

As a consequence of the high-grade turbulence, and the movement of heavy sediment particles, bores, particularly full bores, characteristically make a lot of noise. This noise consists of both a rushing sound made by turbulent eddies impacting each other, and a grinding noise made by heavy sediment particles (cobbles, stones and boulders) impacting one another. In the field investigation of the impact of the 1988 and 1993 floods in the Meghalaya and Tripura border areas, respondents in three out of nine villages remarked, un-prompted, that the flood in their village was accompanied by "tremendous noise" which they found frightening; in one of these villages, where there is a steel bridge pier in the river channel, they remarked that the flood "banged on the bridge". These remarks comprise some evidence for the occurrence of bores in the border areas of the Northeast Region.

In view of these remarks about "tremendous noise" further enquiries were made in five of the villages previously investigated. In these enquiries other villagers were shown several photographs of different types of hydraulic bore (Figure 8), and asked if they had seen such "waves" in their river during the disastrous events of 1988 and 1993. On the basis of these photographs they confirmed that bores had occurred in the steeper Meghalaya border area rivers, and they were able to identify which type had occurred. In the less steep Tripura border area rivers bores had not, apparently, occurred except as a result of embankment failure. Details of their responses are given in Table 3.1, and comprise further evidence for the occurrence of bores in the border areas of the Northeast Region.

Table 3.1
Villagers Observations of Bores

River	Village	Bore Type Identified	Bore Height (m)	Dates Seen:
Bhogai	Nakuagoan	Breaking	0.3	1988
Someswari	Bhabanipur	Undular	?	Often
Jadukata	Maharam	Undular	2.3	Every year
Shari	Kamrangi	Undular	1.4	1988
Juri	Jahangirai	-	-	Never

Eye-witness accounts can, of course, sometimes be exaggerated, even imaginative, especially if the eye-witness senses that an affirmative response is desired. Therefore, the above accounts need to be treated with some caution, and more objective evidence from hydrological records or hydraulic studies adduced if possible.

Unfortunately, water level records kept for the Northeast Region all consist of spot observations of water levels on staff gauges. Usually such observations are made only once a day, but in some cases they are made every 3 hours. Even the latter frequency of observation is, however, inadequate to detect the passage of a bore which typically occurs over a period of a minute, or so, at a particular river section. Experience in the Middle East, where the occurrence of bores is the rule rather the exception, shows that automatic water level recorders are definitely needed if bores are to be detected. On their trace bores appear as vertical lines even if the chart movement is as high as 9.6 inches/day, but even with this high chart speed detail of the bore profile is not obtainable. At present no automatic water level recorders are operating in the Northeast Region, so no hydrological evidence can yet be adduced for the occurrence of bores there.

Hydraulic studies can, however, shed some light on this matter, but tractable solutions involve assumptions which are only approximated in natural river channels and so might be misleading to some extent. Such studies have been made in relation to a representative river channel, i.e a channel having a similar section shape, bed slope and roughness to those prevailing in the flash flood-prone rivers of the Northeast Region (Figure 9). The results of this study suggest that, in these rivers:

1) full breaking bores probably occur in the dry season and early pre-monsoon season when, and where, antecedent flows are non-existent, i.e the channel bed is completely dry ahead of the flood wave; in this connection it may be noted that flash floods do occur in the dry season, as they did in February 1993 and in March 1994 when quite large flash floods occurred in the Northeast Region.

2) compound bores probably occur in the early pre-monsoon season when, and where, antecedent flows are relatively small and occupy only a small part of the channel bed width.

3) partial bores probably occur in the early pre-monsoon season when, and where, antecedent flows are relatively small but large enough to fill the channel bed width completely; if $y_1 = y_\infty$ undular bores may occur in these circumstances

4) monoclinal rises probably occur in the monsoon season when, and where, antecedent flows are relatively large and completely fill the channel bed width.

An important sub-category of flash floods involving bores are those released into riverside communities when flood protection embankments burst. Rainsaf on the Manu River, which is protected by such an embankment, was badly affected in 1993 when a flash flood in the river caused the embankment to burst. The failure mode involved erosion at the foot of the riverside face of the embankment followed by collapse into the river of a succession of vertical slabs of embankment material; eventually the remaining section of the embankment was so thin that it burst under the pressure of water in the river (Figure 10a and b). The sudden release of water into the village, where the ground was wet from rain but otherwise dry, must, at least initially, have resulted in a strong bore entering the village; the form such bores take is shown in Figure 10c which shows a computer simulation of the three-dimensional flood profile at an embankment breach (Chaudry, 1993).

4. WARNING SYSTEM ACTIVATION

4.1 Warning Activation

On the basis of the field investigations it is apparent that the flash flood warning system should provide *two*, not more, flood warnings in connection with any particular event:

1) The first warning should be given early enough for villagers to take all appropriate preparatory actions before evacuating their village on the second warning.

2) The second warning should be given early enough for the villagers to reach safe ground before the flood rise reaches their village.

It is to be noted that the *three* flood warnings envisaged in the original Initiative (see page 5) are not needed, and would complicate the system unnecessarily; two warnings will be quite sufficient.

These warnings must, clearly, be activated by detectable hydrological phenomena in the field.

4.2 First Warning Activator

It is apparent from the field investigations that the villagers will have various tasks to perform between the first and second warnings, all of which are very important to them and should be so regarded by the flood warning agency also.

4.2.1 Preparatory Time Required Before Evacuation

Exhaustive studies of what these tasks comprise remain to be made, but on the basis of the field investigations carried out so far they include the following *as a minimum*:

Task 1:

All family members at home when the first warning comes need to be given directions as to what to do next by the head of the household, and children not at home need to be located and brought home.

Task 2:

Valuables and cooking utensils need to be packed ready for transport to safe ground, together with sufficient drinking water, food, and fuel to last the family for several days, possibly as much as a week.

Task 3:

Other household items and food stocks, which it is impractical for the family to take to safe ground on an emergency basis, need to be stored on pre-constructed *macha* within the house so that, if water enters the house, they are not swept away or damaged by the water.

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Task 4:

Livestock, especially chickens which are particularly vulnerable in floods and which may provide the family with a meal during the evacuation period, need to be rounded up and either taken to the safe ground or restrained in a safe place in the village such as on a rooftop.

Task 5:

Boats need to be securely tied to pre-constructed mooring posts, or otherwise anchored; the use of boats to flee in a flood situation, especially one occurring at night, should, however, be strongly discouraged.

These are the sort of actions which ought be taken under prescribed plans of action, the details of which remain to be worked out in all specific cases. Here the concern is with how much time these tasks may take. Time and motion studies of practice executions of each plan of action should be made in order to more accurately assess the times required for each task, but for the purposes of this report the following times appear realistic:

Task	Time Required for Performance (minutes)
1	20
2	30
3	10
4	30
5	10

Total	100

In no circumstances should allowance be made for these tasks to be performed in parallel even though this may occur in practice; always, to ensure a freedom from panic, these tasks should be performed sequentially by one or other senior member of the household while the other senior member keeps an eye on children and livestock so as to prevent them from wandering off.

It is to be noted that these times do not include for such matters as constructing *macha* within the house, constructing boat mooring posts, or deciding where safe ground is and the safest route to it, while the flood is approaching; these are all matters which should be attended to on a permanent basis previously.

4.2.2 Flood Travel Times

Accepting, for the present purposes, that the villagers will need an absolute minimum of 100 minutes to execute these essential preparatory tasks, it is apparent that it is the detection of rainfall occuring in the hills which must activate the first warning. This follows from consideration of the travel times of flash floods from the Indo-Bangladesh border to the villages investigated.

It is often not appreciated how fast flash floods travel, and there may be a need to do some research on this aspect in Bangladesh. Elsewhere, velocities up to 6m/s (21.6 km/hour) have been observed. Thus, times of travel from the Indo-Bangladesh border, the farthest upstream point at which they can be detected in the river channel, are likely to be substantially less than the 100 minutes required by most villagers in the flash flood-prone border areas to prepare to evacuate. Table 4.1 lists the river distances from the border to the villages investigated, and gives the travel times corresponding to possible flood wave velocities.

Table 4.1

Times of Flood Travel from Indo-Bangladesh Border to Investigated Villages

River	Village	Distance Downstream IBB	Travel Times from IBB to Village at Velocity Indicated			
			3m/s	4m/s	5m/s	6m/s
		Km	Minutes			
MEGHALAYA BORDER AREA						
Bhogai	Nakuagaon	2.1	12	9	7	6
Someswari	Bhabanipur	6.8	38	28	23	19
Jadukata	Maharam	5.9	33	25	20	16
Dhalai (N)	Chilabhanga	1.8	10	8	6	5
Shari	Kamrangi	6.1	34	25	20	17
TRIPURA BORDER AREA						
Juri	Jahangirai	13.5	75	56	45	38
Manu	Rainsaf	10.7	60	45	36	30
Dhalai (S)	Hiramati	16.6	92	69	55	46
Karangi	Himagao	22.1	122	92	74	61

Comparing the times in Table 4.1 with the minimum 100 minutes notice needed by villagers it is evident that the first warning cannot be given early enough on the basis of detecting the flood in the river channel at the Indo-Bangladesh border, and that it must therefore be given on the basis of rain falling on the Indian side of the border.

4.2.3 Detection of Rainfall Over Indian Catchments

How to effectively activate the first warning on the basis of rain falling on the Indian side of the border is a critical issue. Technically, the first warning would preferably be activated by using one of the following technologies to detect flood-producing rainfalls over the Indian catchment areas:

- weather radar
- telemetric rain gauges
- weather satellite

These technologies are all expensive, and numerous practicalities effectively oppose, for the near future, their application in the presently proposed flood warning system. Whenever these practicalities are resolved either telemetric rain gauges or, preferably, weather radar could appropriately be added on to the system.

4.2.4 Weather Radar

Weather radar offers the best possibility to obtain the needed rainfall information without need of India's agreement, although India might protest radar intrusion of its air-space.

Perception of the feasibility of using weather radar to activate the first warning seems to derive from the existence at Dhaka of the BMD's (10-cm wavelength) weather radar; this was funded by UNDP in the early 1980s, apparently in the belief that it would meet the needs both of the BMD for storm-tracking and of a future, but then non-existent, FFWC for flood forecasting and warning. In the years elapsing between supply of this radar and establishment of the FFWC, the BMD had exclusive use of it, and no doubt put it to good use in providing accurate weather status reports to civil aviation using Dhaka international airport, cyclone warnings, etc.

Since the FFWC was established attempts have been made to utilize this radar for flood forecasting also, but these have been frustrated by its location at Dhaka, by inability to calibrate it so as to obtain the quantitative rainfall estimates needed for flood forecasting, and by conflict of interest in its use by BMD and by FFWC. To meet its need FFWC requires the radar to cover the northeastern catchment areas, and this means that either the radar would have to be re-located in the northeast, or its range increased substantially. BMD have successfully resisted re-location on the grounds that this would frustrate its use in weather reporting for civil aviation, etc. Increasing the radar's range involves operating it at higher power with either the risk of over-loading it, or the necessity of drastically modifying its electrical components, and the conclusion seems to be that the required increase in range cannot be achieved either way. These factors, coupled with the inability over three years to calibrate the radar and the anticipation that another five years research is needed to achieve calibration, led to the present situation in which the BMD retains primary use of the radar at Dhaka, and the FFWC awaits donor-funding for a second radar to be located in the Northeast Region for its exclusive use in flood forecasting. So far such funding, if it has been sought, is not yet forthcoming. UNDP indicated that it would not fund a second radar, presumably because of the unresolved calibration problem. In view of this situation the prospect of using either the Dhaka radar, or a new radar for FFWC in the Northeast Region, to support the present proposal seems extremely remote, especially as only a storm-tracking capability is needed to activate the first warning.

4.2.5 Telemetric Rain Gauges

Telemetric rain gauges offer the second best possibility to obtain the needed rainfall information but these would have to be located within Indian territory, and so India's cooperative involvement would be essential. Given the present state of Indo-Bangladesh relations on other water related issues affecting both countries, it seems unlikely that India's cooperation could be obtained. Even if agreement on cooperation could be achieved at the federal level in India, the probability that operations under the agreement (pertaining to installation, maintenance and security of the gauges) might be frustrated by actions of low-level officials of the several Indian state governments involved, and of the Indian BSF, is considered high. It is noteworthy that, apparently, the FFWC has not attempted to establish any telemetric rain gauges on Indian territory.

A Negotiating Brief has been prepared for FPCO's use should they wish to pursue negotiations with India. This brief, given in Annex C2, indicates the nature and quantity of telemetric equipment required for the nine river catchments, appropriate locations for the equipment, and the access requirements for Bangladesh personnel.

4.2.6 Weather Satellite

Weather satellites also appear to offer the possibility to obtain the needed information without need of India's agreement, and with less likelihood of protest by India. It is thought that the satellite imagery could readily be obtained through SPARRSO. In this case, however, the problem is purely technical and relates to the minimum cell size for which rainfall estimates can be made on the basis of cloud properties measurable by satellites; this is 2.5° x 2.5°. This cell size is large enough to encompass the whole of the Meghna River basin, and so no detail would be available of the spatial distribution of rainfall within the basin. Thus it is concluded in relation to flood warning that a weather satellite could not "see" rainfall over individual catchments, and would either activate all warning systems in the Region simultaneously, or activate none of them. Furthermore, the minimum time step for which rainfall estimates can be prepared is one month which is far too long in relation to any flood forecasting requirement.

4.2.7 Conclusion

Among these technologies radar, located on a hill near Moulvi Bazar, would be the most suitable for activating the first warning. However, in light of the above considerations it is concluded that, unless funding for a second radar is available to be definitely located in the Northeast Region and to provide, probably among other outputs, activation of the first warning signal, there appears to be no possibility to detect flood-producing rainfalls by radar for the purposes of this proposal. It follows that, *for the foreseeable future,* the first warning must be activated by an observer who has been trained to observe rain falling on the relevant river basin in India.

4.2.8 Manual Observation

Accepting that rainfall over the upper river basin will have to be detected by an observer it is pertinent to examine what will be involved in achieving successful detection in this way.

The observer should be posted on a hilltop which is close to the Indo-Bangladesh border and high enough to provide a deep and wide view over the river basin upstream of the border, but not so high as to be above cloud base level. It is noteworthy in this connection that the villagers of Dhalai (N)/Chilabhanga remarked during the field investigations that they always knew when a flood was coming because they could see it raining in the hills to the north. The observer should look and listen for:

1) cloud cover developing over the river basin, particularly high cumulus, cumulonimbus and nimbostratus.

2) rain falling from the cloud base *and reaching the ground* (vergis rain is quite common in these areas).

3) lightning; this is invariably associated with the formation of cumulonimbus clouds, the most usual source of the intense rainfall producing flash floods.

4) thunder; this is invariably associated with lightning, but can only be heard when the source of the lightning is relatively close by.

The Northeast Region is well-known for spectacular sky-wide lightning displays so it is important for observers to observe carefully just where the lightning is occurring. They must know in which direction from their observation post their river basin lies, and focus their attention on what is happening in that direction. It is quite possible, for example, for an observer on the Tripura border to observe all four of the phenomena listed above occurring over the Shillong Plateau while nothing is happening over Tripura, and vice versa. Observers will therefore need training and experience development if they are to activate first warnings when, and only when, appropriate.

4.3 Second Warning Activator

On completion of all of the foregoing five tasks, each whole family should move, together with those of their belongings which they will need, their emergency supplies of drinking water, food and fuel, to pre-identified safe ground. They should move, however, when, and only when, a second warning confirms that a *dangerous* flood is *definitely* coming. Not all flash floods are dangerous, so if they go to the considerable trouble of moving to safe ground and a dangerous flash flood does not then materialize they will be discouraged from ever taking notice of the flood warnings again. Thus, rather than move when ready they should wait until the second warning is given, or the first warning signal is cancelled.

The second, and final, warning should definitely be based on the occurrence of a high flood water level in the river channel at the border. If such an occurrence is to mean that a *dangerous* flood is *definitely* coming to the village, the second warning activation mechanism must be very carefully set so that the second warning is not given on the basis of a non-dangerous flood water level. The setting needs to be carefully researched using the Northeast Regional hydrodynamic model to evaluate the downstream water levels in the villages corresponding to each possible setting of the mechanism.

How to effectively activate the second warning on the basis of a flood water level at the border is also a critical issue. Suitable technologies which could be used include:

- telemetric water level recorders
- telemetric water level detectors

4.3.1 Telemetric Water Level Recorders

Telemetric water level recorders continually monitor a water level of interest, and transmit the value every minute (usually) to a flood forecasting centre. They are expensive, sophisticated instruments which will need to be imported to Bangladesh. Those installed recently by the FFWC at the heads of the main river reaches in the Northeast Region for flood forecasting purposes have performed very poorly, no data being transmitted in the first year of operation; whether this poor performance is due to acquisition of poor quality instrumentation, it is not known.

Basically, this type of sophisticated equipment is not needed for the flash flood warning system proposed. If introduced successfully it will produce masses of digitized data only one item of which (the critical water level) will be of use to the warning system. The introduction of this type of equipment will not circumvent the need to determine the value of the critical water level, and responsibility for deciding when the critical water level is exceeded will still reside with a human observer.

4.3.2 Telemetric Water Level Detectors

Telemetric water level detectors respond only to a critical water level, and transmit a single unambiguous signal when it is exceeded. They are relatively inexpensive, unsophisticated and robust instruments which can be manufactured in Bangladesh. They can be readily set to respond to any critical water level desired, and preclude the need to have a human observer decide when that level is exceeded. They can be expected to be simple to install, and trouble-free in operation.

4.3.3 Conclusion

In light of the above considerations it is strongly recommended that the second warning signal be activated by a telemetric water level detector, and not by a telemetric water level recorder.

5. WARNING SYSTEM DESIGN

5.1 Warning System Components

It was concluded from the field investigations that the basic technology proposed in the Improved Flood Warning Initiative was appropriate. The main components of each river's flood warning system are therefore envisaged to be:

1) A flood-generating rainfall detector station consisting of an observer-manned observation post located on a hill very close to the Indo-Bangladesh border.

2) A critical river water level detector station consisting of a telemetric water level detector installed in a stilling well located in the river channel very close to the Indo-Bangladesh border.

3) A number, typically about five for each river, of flood warning stations located about every 5 km along the river, each consisting of a beacon and a siren mounted on a 20 m high mast.

4) Radio or cable communication links between the detector and warning stations, and with the control located at the manned observation post.

The structural layout of the systems is shown in Figure 11.

The external circuitry needed to connect and power these main components, so that the warnings can be activated as described in Section 4.1, is quite complex. Annex E outlines the entire electrical system including suitable equipment and relevant external circuitry, and its cost, and the external circuitry is shown in Figures 12 to 16.

5.1.1 Rainfall Detector

When the observer is satisfied that heavy rainfall is occurring over his river basin he should, by simply pushing a button on the control panel in his observation post, activate the flood warning system to give the first warning signal. His observation post must, therefore, be connected by radio or land line both to the river water level detector station and to the flood warning stations down-river. The control panel must be located at the observation post, since the observer must also monitor the flood warning system operation. Figure 11a shows the observation post building arrangement.

5.1.2 River Water Level Detector

The detection of the critical high river water level will be made automatically by an electrode detector similar in manufacture to a hydrogeologist's M-Scope. The detector will be connected by radio or cable to the nearby observation post building, and from there by radio or cable to the flood warning stations down-river which it will cause to emit the second warning signal.

The electrode detector will need to be housed in a properly designed stilling well of the type used by hydrologists to house automatic river water level recorders. Such a housing is necessary to protect the detector from the force of the flood water, and from interference by the public. The type of stilling well adopted will depend on topographic and foundation conditions at each detector site. Figure 11b shows one possible type of stilling well, to which costs given later relate.

The level at which the detector is set in the stilling well will require careful consideration for each installation. If it is set too low it will activate the second warning for floods which are too small to pose any danger to the villagers, and if it is set too high it may fail to activate the second warning for floods which do pose danger to them. Modelling studies should be used to simulate flood water levels throughout the flash flood-prone reach of each river, and the results compared to critical levels in each village. Even so, the appropriateness of the detector setting should be frequently reviewed in the light of experience gained, and its level adjusted accordingly. The objective is to activate the second flood warning in all cases of floods posing danger to the villagers, but only in those cases.

5.1.3 Beacons and Sirens

There is no question that both beacons and sirens will be needed to communicate the warnings to villagers. Beacons are needed for those who, at the time the warning is given, are out of hearing range of the siren, or deaf. Sirens are needed for those who, at the time the warning is given, are sleeping or have their attention focused on something other than the warning station beacon, as will normally be the case. It is considered that each beacon should be visible, and each siren audible, for a distance of at least 5km from the site of the warning station, and the power rating of the beacons and sirens should be chosen accordingly.

For each beacon to be visible, and each siren audible, over the required range of 5km, and to maintain freedom from interference by the public, the warning equipment should be mounted on a mast at least 20m high and set on the highest ground available in the vicinity of the villages to be warned. A structurally suitable warning station arrangement is shown in Figure 11c.

For the first warning the beacon should continuously flash yellow, and the siren should *yelp* continuously first for half an hour, and then for five minutes every half hour until either the second flood warning is communicated, or the flood warning is aborted (as when a first warning is given on the basis of rainfall seen in the hills, but the rainfall fails to generate a dangerous flood).

For the second warning the beacon should continuously flash red, and the siren should *wail* steadily first for half an hour, and then for five minutes every half hour until the flood has passed right through the river channel covered by the flood warning system.

Because of the irritation caused by sirens, which might lead to villagers opposing continuance of the system after it has been installed, it is strongly recommended to limit continuous yelping and wailing of the sirens to the first half hour (perhaps less) after the warnings are initiated. As a reminder to villagers that the warning is still in force, the siren should yelp or wail again for five minutes only every half hour until either the first warning is superseded by the second, or either warning is cancelled.

5.1.4 Radio Communication

It is thought that radio communication between the detector and warning stations would be preferable to cable communication. An overhead cable would have to be strung on poles over considerable distances, and would tend to be vulnerable to adverse weather conditions, floods, and vandals. An underground cable, although the most reliable means of communication, would also be the most costly.

The radio must have a range of at least 30 km so that its signal will, with sufficient power, reach the farthest warning station in the system. The radio must be capable of communicating four distinct signals, one to activate the beacons and sirens to emit their first warning signal, one to activate them to emit their second warning signal, one to switch the beacons and sirens off when the flood emergency is over, and one to alert the observer at the observation post of any fault which has developed at the water level detector station, or at any of the warning stations.

5.1.5 Underground Cable Communication

The use of underground cable communication is possible, and quite widely practised by other Bangladesh organizations. It is more costly than radio because the saving on radios does not completely offset the cost of the cable, and because of the excavation required which, in a rural setting, needs to be quite deep.

5.1.6 Power Sources

It is expected that the power source for the flood warning system will have to be heavy duty batteries recharged by solar photovoltaic panels since power from the grid, although it would be preferred, is generally not available at sites where the system would be installed.

Studies of the electrical aspects of the flood warning system show that each observation post will require two heavy duty batteries and two solar panels, and each warning station will require four of each. The solar panels at the observation post would be mounted on the roof of the detector station building, and those at the warning stations would be mounted on the mast.

5.2 Costs

Costs have been estimated for two variants of the system: the radio communication variant which will probably be preferred, if not mandated, at most sites, and the cable communication variant to see just how much more expensive it is likely to be. The basis for comparison of the two variants is the same, i.e. a flash flood warning system for a single river consisting of two detector stations (rainfall and river water level) and five warning stations.

Details of the costs of electrical equipment are given in Annex E, particularly Tables E3 to E5. Overall costs, including associated civil works, are summarised in Table 5.1. From this table it can be seen that the cable communication variant is 16.2% more expensive than the radio communication variant. The difference in cost is as follows:

	Taka
Radio Communication Variant	7,542,360
Cable Communication Variant	8,766,512

Difference	**1,224,152**

Careful consideration should be given as to whether, or not, it would be wise to invest an additional Taka 1,224,152 in the interest of having the more reliable, more trouble-free, cable communication variant.

Table 5.1
COST COMPARISON FOR ONE WARNING SYSTEM WITH RADIO OR CABLE COMMUNICATION

Item	Radio Communication (Tk)	Cable Communication (Tk)
Electrical Equipment	1,757,360	2,676,512
Freight	20,000	30,000
Installation	300,000	100,000
Cable laying (25 km)	-	100,000
Commissioning	60,000	20,000
Masts (5 No.)	2,030,000	2,030,000
First Month O & M	50,000	35,000
Detector Station Building (1 No.)	675,000	1,125,000
Detector Stilling Well (1 No.)	300,000	300,000
Jeeps (1 No)	2,350,000	2,350,000
Total	**7,542,360**	**8,766,512**

NOTES:
1) Freight is for Dhaka to site only
2) Installation includes tools and labour
3) Maintenance is for first month of operation only
4) Detector station building and stilling well costs are lump sums which may vary from site to site.
5) Jeep is based on Nissan Patrol showroom price 1994 (including duty, VAT and LC), and is considered essential to satisfactory system O & M. Only 1 jeep is needed per flood warning system, but if more than one system is implemented the supervisor will also need a jeep.
6) Land acquisition costs are not included as they may vary from site to site.
7) Living accommodation for 3 duty technicians not included (They may, or may not, be able to live in a nearby village, depending on the particular site).

Attention is drawn to the Notes under Table 5.1 which clarify the assumptions made for costing purposes. Some of these require further consideration and may result in higher costs if changed; for this reason a further 5% should be included for further engineering studies, and 25% for cost contingencies, as follows:

Item	Radio Variant (Taka)	Cable Variant (Taka)
Radio Basic Cost (Table 5.1)	7,542,360	8,766,512
Further Engineering (5%)	377,118	438,326
Contingencies (25%)	1,885,590	2,191,628
	-------------	-------------
	9,805,068	**11,396,466**
Equivalent in US Dollars	US $ 258,028	US $ 299,907

The conversion to US dollars is made assuming Taka 38=US$ 1. The dollar costs are reasonably consistent with those given for the Improved Flood Warning Initiative in the Regional Plan (US $250,000 - see Annex A).

Uncertainties surround the evaluation of some items in Table 5.1, and these can only be evaluated adequately during feasibility level studies made for specific sites. In particular:

1) No provision is made for land acquisition in the present costing since the cost may vary considerably from site to site, or the land may be obtainable free of charge in some cases. For example, if a station is located on government land it could, presumably, be obtained free of charge, and village beneficiaries of the warning system may be persuaded to donate land free of charge in their own interest. The patches of land required for the observation post, stilling well, and warning stations are, in any case, very small, and probably will not amount to more than about 900 m^2 per river system in total. (Five warning stations per river system will each require a 10m x 10m patch of land, and the observation post and stilling well will each require a 10m x 20m patch.)

2) There will be a need for a second jeep for the Warning Systems Supervisor if more than one system is installed. No provision has been made for this second jeep in the present costing, but at Taka 2,350,000 per jeep (see Table 5.1) this is a significant future cost item. It should be noted that the need for the first jeep arises from the necessities for the Observer/Technicians to travel from their observation post to the stilling well and warning stations to carry out routine maintenance and fault rectification, and from their accommodation to the observation post. It is presently envisaged that the three Observer/Technicians required per system will not reside at the observation post, but that all three may reside in rented accommodation in a nearby village. The living room provided at the observation post (see Figure 11) is primarily intended to serve as a kitchen/dining room for the duty Observer/Technician, not as a bedroom; if rented accomodation is not available nearby (as will be the case for Juri/Jahangirai - the pilot project site) a 3-man bedroom will have to be incorporated in the observation post.

3) The provision in the present cost estimate for first month operation and maintenance is made in recognition of the fact that, when commissioning has been completed, there will be a need for the installation engineer and technicians to further debug the system. and to provide training to the duty Observer/Technicians regarding operation and routine maintenance of the system. Operation and maintenance costs in this first month will therefore be higher than in following months.

4) Routine operation and maintenance costs are not included in the costing. These will depend on the organization provided for the purpose. Assuming this will be a government organization routine O&M costs are expected to be Taka 15,000 per month based on current government pay scales.

5) The cost for a river water level detector station stilling well is likely to vary rather widely from site to site depending on the nature of the river bank (hard rock or loose soil, steep or mild slope, heavy or light bed load, etc.). At some sites a much longer walkway, or much more substantial structural support, may be needed; at others an entirely different design may be preferable.

6. ASSOCIATED FLOOD PREPAREDNESS ACTIVITIES

6.1 Flash Flood Warning Agency

The field investigations have revealed several activities in flood preparedness which need to be taken in support of the flash flood warning system if it is to be effective in preventing future disasters, and its credibility so maintained. These actions concern the structural integrity of various structures in the field which provide either protection from floods or access to safe ground, the availability of safe grounds of adequate capacity, and the availability of appropriate and logical plans of action for villagers to follow in preparing for, and executing, their evacuation to safe ground.

These are not matters which the proposed flash flood warning system can address, but neglect of them will diminish its effectiveness and could lead to a total loss of credibility in the system. It is therefore strongly recommended that a Flash Flood Warning Agency (FFWA) be set up, not only to install, operate and maintain the flash flood warning (engineering) system, but also to coordinate all the other activities required to ensure its success. To achieve the required degree of coordination it is thought essential that the FFWA be set up within the BWDB.

6.2 Flood Protection Embankment Strengthening

In five of the nine villages investigated it was found that the immediate cause of disaster in the 1988 and 1993 flash floods had been bursting of the local flood protection embankment (Figure 10). While a flash flood warning system can notify villagers that conditions favourable to embankment failure are about to occur, it cannot notify them that it will occur on any specific occasion. Thus, an embankment may erode significantly without failing on numerous occasions on which villagers are warned, before the occasion on which it fails. Villagers will then develop a false sense of security during the earlier events, and completely fail to respond to the warning of the flood which finally causes the embankment to fail. To minimise the chances of disaster under such circumstances it is considered essential that:

1) All flood protection embankments beside the flash flood-prone rivers of the Northeast Region be thoroughly inspected with a view to identifying all stretches requiring strengthening

2) The required strengthening is devised in consultation with a recognised expert on soil mechanics with experience in embankment design and construction.

3) The strengthening is implemented before the flash flood warning systems begin operation.

The need for an appropriate method of strengthening flood protection embankments (item 2 above) cannot be over-emphasized in view of the present unsatisfactory nature of flood protection embankment construction, inappropriate tendencies in current design, and the need to recognise the highly erosive nature of hydraulic bores.

Present design of embankments is limited to setting the crest level, crest width and side slopes. The uniform section is then constructed, partly by female labourers, and without adequate supervision, using soil excavated from nearby agricultural fields. There is no mechanical compaction of the soil, and such human compaction as it receives is quite inadequate and spatially haphazard. It is hardly surprising, therefore, that the embankments are so easily eroded to the extent shown in the photograph of Figure 10 where half the section has gone. Without mechanical compaction these embankments are also highly prone to failure by piping. This unsatisfactory construction derives from the following policies:

1) for financial (foreign currency) reasons the importation of construction machinery, such as bulldozers and sheepsfoot rollers, is severely restricted;

2) for social stability reasons landless and poor people are employed as they largely depend on this employment for their survival.

One approach to achieving better compaction would be to implement well supervised systematic manual tamping of the fill material as it is placed in 6" layers, using hand tampers. This would avoid importing heavy construction machinery, create a cottage industry making hand tampers, and double the employment opportunities for labour working on embankment construction.

Present tendencies in design are to retire embankments farther from the river, and to reduce side slopes. While it is true that retirement lessens the confinement effect and so exposes the embankment to lower high water levels and lower flow velocities at its toe, it is equally true that it results in less agricultural land being protected from flooding; it can also result in riverside villages being unprotected by the embankments. (The undesirability of the latter is well evidenced at the Manu River Irrigation Project where the retired project embankment is frequently cut by angry residents of such villages; the cutting is extremely detrimental to the project's viability - see NERP Report: Manu River Improvement Project). Again, while it is true that reducing the side slopes lengthens the seepage path through the embankment so discouraging piping and slip circle failure of the embankment, it is equally true that it substantially increases the requirements for land on which to build the embankment, and for agricultural soil with which to build it. It would appear then that there is a need for "core and shell" construction of embankments; this would reduce the volume of agricultural soil required to that required for the core, enable agriculturally useless soils such as river bed sands and gravels to be used for the shells, and so enable side slopes to be kept reasonably steep in the interest of minimising land requirements.

The existence of hydraulic bores during flash floods has not, it is believed, so far been recognised as a factor needing to be taken into account in embankment design. One bore will erode an embankment to the same extent as many monoclinal rises, and this needs to be recognised in design by providing an erosion-resistant facing on the river side of the embankment. Turf, held in place by geo-jute netting until well-rooted, and large size river cobbles bedded in river gravel, may provide facings with adequate erosion-resistance. In this connection it should be noted that much of the erosion of embankments seen in the field is widely attributed by local people to a mysterious "wave action", and it is widely assumed by design engineers that the waves involved are wind-generated waves. The latter seems rather unlikely in view of the results of NERP PMP observations on wind-generated waves at Shanir Haor where it has been found that such waves rarely attain an amplitude of 0.3 m even on the haor side of the embankments where the large fetch encourages the generation of larger wind-generated waves than on the river side. In the case of embankments beside flash flood-prone rivers it would seem more likely that the waves described by local people as occurring on the river side of the embankments are associated with undular or breaking bores in the river.

Precisely how these suggestions for better embankment construction and strengthening could best be implemented is a matter for expert soil mechanical advice to the BWDB.

6.3 Safe Grounds

While in all of the nine villages investigated the villagers have some sort of safe ground to which they can evacuate while their village is flooded these safe grounds are, in fact, characteristically unsafe in most cases, and of inadequate capacity in all cases. Furthermore, the route by which the safe ground is reached from the village is also often unsafe. The following examples illustrate these points:

1) At Someswari/Bhabanipur during the 1988 flood the 900 people of the village all flocked to the local school building as the nearest safe ground. This building cannot possibly accommodate this number of people even when both the floor and the roof are used. The building did not collapse under the weight of the people who were able to gain access to it, but the possibility of collapse is always present when a building is loaded with too many people. Because of the inadequate capacity of this building an attempt was made to move some of the people from it to high ground farther west using a country boat since water had surrounded the school. Forty people were crowded into the boat, and after travelling some distance it capsized in deep water with the loss of all aboard. Clearly, a much larger area of safe ground is needed near to the village so that in future neither the school building nor country boats need be used (Figure D2).

2) At Juri/Jahangirai during the 1993 flood the 4500 people of the village all escaped to the nearby railway embankment. Since the embankment is very long it probably had adequate capacity to accommodate everybody if they spread along it, but for reasons of keeping an eye on their homes, going no further than necessary, etc., they remained packed together on a relatively short section of the embankment. This would not matter greatly except for the fact that when trains pass (they pass at 0600, 0900, 1200, 1530 and 0200 hours) the people are forced to move off the crest of the embankment onto its slopes where space is severely limited by the high water level. Thus, at times of train passage instant over-crowding can occur leading to some people being pushed into the water. It is not known for sure how the three children who were lost in this flood event actually came to lose their lives, but it is quite possible that they were accidentally pushed into the water near the railway bridge and swept away by the strong current there (Figure D6).

3) At Dhalai (S)/Hiramati no lives were lost during the 1993 flood, but they might well have been. When the embankment burst everyone fled in panic along the Adampur road heading for safe ground beyond Madhabpur Market, but they had extreme difficulty crossing the site of a broken bridge around which the flood water was particularly deep. The villagers wish they had had some boats that afternoon so that they could have crossed the bridge site in safety but they had none. Clearly, if the embankment had burst at night the situation of the villagers would have been much worse than it was, and

lives would almost certainly have been lost due to both the embankment bursting and to the escape route being so obstructed (Figure D8).

These examples demonstrate the point that if villagers do not have safe ground of adequate capacity to escape to, or they cannot reach it safely, they will be unable to benefit from any flood warning. To achieve this benefit, therefore, steps must be taken to ensure that truly safe ground, and a truly safe route to it, exist for all villagers covered by a flash flood warning system.

In some cases, such as that of Dhalai (S)/Hiramati, it may be sufficient to repair the bridge so ensuring that the escape route to safe ground is secure. In other cases, such as Someswari/Bhabanipur, safe ground needs to be created in some form close to the village; suitable forms of artificially-created safe ground include:

1) artificial islands

2) cyclone-type shelters.

6.3.1 Artificial Islands

Artificial islands could be formed using river bed materials as fill, but the fill should be surrounded by a revetment of boulders, or a mortared masonry retaining wall, to withstand the erosive action of the flood waters. If, having constructed such an island, the villagers could be persuaded to re-locate their village on it, then their problem with flash floods would be solved permanently, and there might then be no need for flash flood warnings. It may be noted that this artificial island concept closely parallels that suggested in NERP's pre-feasibility study: "Flood and Erosion Affected Villages Development Project (FEVDEP)".

The construction of artificial islands, especially with new villages on them, will be very costly, and will take much time to achieve. It may not be necessary in all villages in the flash flood-prone areas, and the needs for safe ground therefore need to be evaluated individually for each village. Even where an artificial island and village re-location are decided upon a flash flood warning system may be useful until construction is completed. As pointed out in the FEVDEP report there are thousands of villages in line for implementation of artificial islands and re-location of villages upon them so, with thinly spread resources, it is likely to be some time before the villages in the flash flood-prone areas get such a project.

6.3.2 Cyclone-Type Shelters

The cyclone (hurricane) of April 1991 caused the deaths of an estimated 138,000 people along the shores of the Bay of Bengal; most of these deaths occurred as a result of the cyclone-associated tidal wave, or bore, which penetrated several kilometres inland. In response to this disaster "cyclone shelters" were conceived and designed, and many were constructed by the Danish contractor, Kampsax, in time for the May 1994 cyclone; in this event the death toll was only 201, and about half of the dead were Thai fishermen who had been fishing off the Bangladesh coast and had not received or taken notice of the cyclone warning issued in time by the Bangladesh authorities. The dramatic reduction in the death toll attests to the success of the shelters in protecting from the tidal wave people who had been warned, and who had chosen to take notice of the warning by going into the shelters.

The situation in the border areas of the Northeast Region during a dangerous-scale flash flood event is basically the same as that in the coastal areas along the Bay of Bengal during a cyclone. Although the causes are different the main agent of death is an hydraulic bore, and the protective measures required are the same in both cases, namely;

1) timely warning of the population

2) timely evacuation of the population

3) safe ground for the population to evacuate to.

With regard to (3) the safe ground provided in the coastal areas consists of a cyclone shelter in the form a four-storey building without walls on the ground floor so that the tidal wave can pass through the ground floor while people shelter on the higher walled floors. The shelters are supported on robust deep piles which are carried up to the first floor level; thus only these piles are exposed to the force of the tidal wave when it passes the shelter. An impression of these cyclone shelters is given in Figure 17, and it is strongly recommended that consideration be given to adopting similar structures in villages along flash flood-prone rivers in the Meghalaya and Tripura border areas of the Northeast Region.

Such shelters have one substantial advantage over natural safe grounds and artificial islands in that they can be constructed within the flood-exposed village, and so the evacuation time can be reduced considerably to be commensurate with lead times provided by the second warning signal of the flash flood warning system.

6.4 Plans of Action for Villagers

As indicated in Chapter 4 villagers coming under a flash flood warning system have numerous tasks they should carry out:

1) in anticipation of a flash flood

2) on receiving the first flash flood warning

3) on receiving the second flash flood warning.

Detailed study of what these tasks should be remains to be studied in consultation with specific village communities between which they may differ. In such study a clear distinction needs to be made between tasks they would like to carry out before evacuating their village, and those they must carry out. Time between the first and second warnings, and between the second warning and the arrival of the flood, will always be severely limited and it must be put to the best possible use.

The field investigations shed some light on what tasks the villagers are interested in carrying out, and what concerns they have about leaving their homes unattended. It is evident that they need to be made to think more deeply about these tasks, especially regarding their relative importance and when, according to the three categories given above, they should carry them out. For this, it is thought necessary for the FFWA to provide expertise to help them think through these matters logically, and draw up Plans of Action to be followed during flood warning events. The d9

resulting, agreed, plans of action should be written down, and posted in every home in Bangla; for the illiterate, their plan of action should be gone over several times until they have committed it to memory. All should understand the reasoning behind it.

6.4.1 Anticipatory Actions

A guiding principle should be that: Nothing which can be done ahead of the first warning should be left undone by the time the first warning is given. Many worthwhile tasks can be undertaken during slack periods in the farming schedule and, since these require time and effort to accomplish, they should be performed on a permanent basis. Such tasks are seen from the field investigations to include:

1) Constructing *macha* in the home so that they are already available for use when, in a flood event, they are needed to put valuables, rice stocks, etc. on. Clearly, it is impractical to take everything in the home to the safe ground, and anything that it is not needed during the evacuation period should be left in the home. Stored on a macha, there is a good chance that these items will stay above the highest water level, and so not be spoilt. With a little thought to their design these macha could be a useful permanent feature of the home.

2) Constructing bamboo cages so that they are available for use when, in a flood event, they are needed to restrain chickens in a safe place, and erecting guyed bamboo pole masts up which the chicken-filled cages can be hauled using a rope and pulley system. Chickens restrained at the head of such masts may have a better chance of surviving a flood than those restrained on the roof of a house which may collapse into the flood water.

3) Installing boat mooring posts to which boats can be tied during a flood event. Too often boats are simply dragged up onto the river bank, and when a flood comes they float away and are lost. Boats are not a cheap item to replace and if, by providing a post and a short length of rope, they can be preserved for future use, the little money required for the post and rope will have been well spent.

4) Constructing platforms on which to stack hay, and so keep it out of the flood water. Often hay stacks are made on lower ground in the village so that when a flood comes they simply float away, and ultimately disintegrate. Considering how important livestock are to rural people, the preservation of its fodder is seen to be very important.

5) Constructing bamboo cages to put chickens in for transport to safe ground, or for keeping them safe on rooftops The field investigations indicated that the loss of chickens during flash flood events is very high at 72%, and this loss seems to be quite unnecessary. Since chickens are a main source of protein for rural people more effort ought to be made to preserve them.

6) Acquiring and fixing locks on the home, so that the chances of homes being robbed during an evacuation are reduced. Fear of being robbed is, apparently, a prime reason for villagers being reluctant to leave their village until the last possible minute. This reluctance needs to be overcome if evacuations are to occur on a timely basis, and without panic and confusion.

Other anticipatory actions will no doubt come to light on further investigation, and every effort should be made to identify them, and how they can be carried out.

6.4.2 Actions Following First Warning

The guiding principle on receiving the first warning should be that: Every member of the household should report home as quickly as possible, ready to undertake his or her allotted tasks prior to the second warning being given. Time is of the essence at this stage, and everyone should realise that a task not done may result in a loss of some kind. From the field investigations it is apparent that the following are among the more important first warning tasks for each household:

1) Everyone of the household should be accounted for as quickly as possible. If anyone, particularly children, is missing one, and only one, adult should search for them; the remaining adults should proceed with the following tasks:

2) Valuables, some cooking utensils, fuel, food and drinking water sufficient for a week should be assembled and packed ready for the journey to safe ground. No attempt should be made to take items which will not be needed during the evacuation; these should all be placed on the already-made *macha*.

3) Rounding up livestock, caging chickens, and taking them to the safe ground. Some members only of the household should be involved in taking the livestock to safe ground, and once they are there they should remain there until the emergency is over. The other household members can stay at home, getting on with task (2) and keeping an eye open for would-be robbers until the second warning comes, or the alarm is cancelled.

6.4.3 Actions Following Second Warning

The guiding principle on receiving the second warning should be: Lock up, and leave immediately for the safe ground. Tasks which have not been completed should be left undone. No-one should linger after the second warning is given; to do so could cost them their life. Further studies should explore the possibility of villagers leaving together, so as to minimise opportunities for robbery.

All who go to the safe ground should follow the prescribed safe route, and proceed along it in an orderly fashion. Throughout this stage the avoidance of confusion and panic is essential; everyone must remain calm and act responsibly with consideration for others.

7. REFERENCE

7.1 Flood Forecasting in Bangladesh

FAP 10, 1993: Expansion of Flood Forecasting and Warning Services: Draft Terms of Reference; Flood Plan Coordination Organization, Dhaka

UNDP, 1992: Hydrological Survey and Investigation: Improvement of Flood Forecasting and Warning System, Report of the Technical Evaluation Mission; United Nations Development Programme, Dhaka.

7.2 Flood Wave Hydraulics

Chaudhry, M.H., 1993: Open-Channel Flow; Prentice Hall, New Jersey

Chow, V.T., 1973: Open-Channel Hydraulics; McGraw Hill, Singapore.

Chadwick, A. and Morfett, J., 1993: Hydraulics in Civil and Environmental Engineering, E&F Spon (Chapman & Hall), London.

7.3 Weather Radar

Bruce, J.P. and Clark, R.H., 1966: Introduction to Hydrometeorology, Pergamon Press, Oxford. See pages 77-80.

Maidment, D.R., 1993: Handbook of Hydrology; McGraw Hill Inc., New York. See pages 3.20 - 3.26.

ANNEX A

IMPROVED FLOOD WARNING INITIATIVE
(September, 1993)

ANNEX A
IMPROVED FLOOD WARNING INITIATIVE

THRUST: INSTITUTIONAL STRENGTHENING AND DEVELOPMENT

Initiative: **Improved Flood Warning**

Location *Regional areas adjacent to Meghalaya and Tripura*

Area 5000 km^2 north of the Kangsha-Surma Rivers alignment; 4000 km^2 south of the Kushiyara River

Population Impacted 2.3 million north of the Kangsha-Surma Rivers alignment; 2.9 million south of the Kushiyara River

Objectives To provide timely, readily understood, warnings to villagers in flash flood-prone areas of flash floods imminent in their locality and posing danger to them, and to promote their appropriate response to the warnings.

Description Storms over Meghalaya and Tripura are often severe, are increasing in severity, and are not restricted to the monsoon season. These storms produce severe flash floods in two areas, one between the border with Meghalaya and the Kangsha and Surma Rivers, the other between the border with Tripura and the Kushiyara River. Such floods impact riverside villages so endangering the lives of the villagers and their livestock, their homes, food stocks, belongings, and crops.

The water management strategy supports ongoing development of FAP 10's forecasting effort but recognises that it is unlikely to be able to produce timely warnings of flash floods and disseminate them to village people; hence this initiative.

The initiative proposed involves: 1) detection, at the Indo-Bangladesh border, of rising river water levels reaching, successively, three danger levels selected to correspond to "moderate", "very", and "extremely" dangerous conditions for villagers; 2) activation, in response to these detections, of recognizably different audio and visual warning signals every 5 km along the flood's path; 3) appropriate protective/evasive actions by villagers in response to each level of danger signal. Details of appropriate technology remain to be worked out but it is expected to feature simple electrode detectors, radio signalling, small sirens and flashing lamps, all battery-powered with recharge by photo-voltaic cells because of the lack of mains electricity and mounting of these components on guyed masts to maximise audibility, visibility, and security of equipment. Details of actions to be taken by villagers also remain to be worked out in consultation with them.

Institution BWDB, and local administrations

Cost US $250,000 for Pilot Project on one dangerous river; US $6 million for extension to 20 other rivers

ANNEX B

COMMENTS ON DRAFT FINAL REPORT

ANNEX B1
CIDA COMMENTS ON DRAFT FINAL REPORT

General Comments

Project Characteristics

1. The concept paper proposes a warning system that would help reduce the damage caused by flash floods originating in the Meghalaya and Tripura Hills, both located on Indian territory, the first to the North and the second to the South of the Northeast Region. The flash floods endanger the lives of the villagers and of their livestock and damage their homes, food stocks, belongings and crops. Although difficult to quantify, the flash floods are estimated to cause annually on average serious damage to 25,000 households and the loss of 3,000 human lives.

NERP Response:

The number of households damaged and lives lost were over-estimated in the Draft Report. The correct best estimates are now 33,000 households (250,000 people/7.5 persons per household) and 300 lives lost per year. See NERP Response to CIDA Comment 12 below.

2. Nine rivers have been identified along which the flash flooding is expected to be the most severe and which would, therefore, be prime candidates for the installation of the proposed system. Five rivers originate in the Meghalaya Hills: Bhogai, Someswari, Jadukata, Dhalai (N), and Shari. Four originate in the Tripura Hills: Juri, Manu, Dhalai (S), and Karangi.

3. The objective of the proposed warning system is to give people sufficient time to adequately prepare the evacuation of the village and to move to nearby high ground. This would save human lives, livestock and the villager's most valued belongings.

4. The flood warning would be provided by beacons and sirens installed on towers (four or five per system) of at least 20 m height and designed to reach people within a 5 km radius. A first warning, emitted when intensive rain falls on the river's catchment, would initiate the evacuation process. A second warning, emitted when the river's water level reaches a critical stage, would be the signal for the immediate evacuation of the last persons remaining in the village.

5. The cost of installing the system on the nine rivers is estimated at US$ 2.7 millions. The paper recommends to test the proposed concept on a pilot system installed for US$ 260,000 on the Juri River. This river is thought to offer the most favourable conditions for the test to be successful.

9 4

Review of Concept Paper

6. The concept paper presents an excellent account of flash flood hydraulics and of the social factors to be considered in the design and operation of the warning system, the latter based on structured interviews conducted in a flood-affected village near each of the nine target rivers.

7. The paper rightly stresses the need to implement the proposed system within "a broader context of flood preparedness", which includes elements such as the people's awareness of possible mitigating measures, the availability of nearby high ground of sufficient capacity, and a safe route to it.

8. The paper, in particular, also stresses the need for adequately constructed and maintained flood protection embankments and points to the warning system's inability to predict embankment failure. "In five out of the nine villages investigated it was found that the immediate cause of disaster in the 1988 and 1993 flash floods had been bursting of the local flood protection embankments."

9. The development of an effective flash flood warning system is seriously hampered by the target rivers's upper catchment being located in India. This prevents the use of rain and stream gauges where they are needed to make such systems functional. Given this constraint, the proposed concept provides: 1) an observer who estimates visually, from Bangladesh soil, the intensity of the rain falling over the Indian portion of the catchment, and 2) a stream gauge installed just below the international border. The first alarm would be issued when the observer judges that the rain will produce a damaging flash flood, the second one when the stream gauge measures a water level predetermined as being critical for the villages downstream.

10. The proposed system has two evident fundamental weaknesses: 1) the huge responsibility borne by the rainfall observer; and 2) the short time span between the moment the stream gauge measures the critical water level and the moment the flood wave reaches the villages (due to the high velocity of the flood wave and the short distance separating concerned villages from the international border). These factors can be expected to result in the observer playing it safe and the critical level at the stream gauge being set relatively low. An overly conservative operation of the system would quickly impair its credibility with the people and lead to the loss of its effectiveness.

NERP Response:

These weaknesses are well appreciated by the author. (1) is unavoidable pending the availability of a second radar located in the Northeast Region, or India's cooperation over telemetric rain gauging on its territory. (2) is unavoidable owing to the topography prevailing. This emphasises the needs to recruit observers with a high sense of responsibility, a relevant technical background, and to provide them with adequate training.

It is anticipated that no observer can infallibly predict a dangerous flash flood. For this reason NERP has changed the first warning response by villagers to "prepare to evacuate", not "evacuate", so that inconvenience to villagers will be minimized in the event that the observer plays it safe. Villagers will need to be fully appraised of what the observer can and cannot do *for them in this matter.*

The critical level at the stream gauge will, undoubtedly, have to be fine-turned in the light of experience. It is anticipated that it will initially be set based on NER Hydrodynamic Model studies but it is unlikely that such studies will get the level exactly right first time. Again, villagers will need to be full appraised of this problem, and of the FFWA's need of their forbearance until it can get it right.

Above all, villagers should not be given high hopes that the system will work perfectly from the beginning; rather, they should be encouraged to work with the FFWA in modifying the system progressively, in the light of experience, until it does meet their requirements.

11. It is recalled that FAP 10 "Flood Forecasting and Early Warning" has the objective to strengthen and integrate the country's existing flood forecasting and warning system. One of the required tasks is the "installation of a data management system (a central computer system including software) to forecast the behaviour of both the main rivers and the eastern flashy rivers with sufficient lead time". The concept paper mentions that FAP 10 is not producing a satisfactory solution for the flashy rivers and has, in particular, abandoned the original idea of using weather radar to estimate rainfall intensity over Meghalaya and Tripura. The paper does not give the reasons for this situation, although they are essential background information for the design and the assessment of the proposed warning system.

NERP Response:

The reasons are given in Section 4.2.4 of the Final Report. Basically, FAP 10 appears not to be pursuing the problem of flash flood forecasting for the foreseeable future.

12. The concept paper's treatment of institutional matters is limited to suggesting the creation of a Flash Flood Agency within BWDB, mainly to ensure the flood warning system's complementarity to the structural aspects of flood protection and preparedness (soundness of embankments, safe grounds of adequate capacity, safe access to these grounds, etc.). The report does not address the question of the system's sustainability. Would their recurring costs be assumed by the beneficiaries, by the local authorities, or by the GOB? Also, what is the institutional setup and cost recovery mechanism proposed by FAP 10? An important aspect in this regard is the realistic quantification of the warning systems's benefits. It is not clear, for example, how the concept paper arrives at an estimate, for current flash flood conditions, or "2,500,000 households.. seriously impacted and some 300,000 human lives lost" over a period of 100 years.

NERP Response:

The sustainability of the system will be reviewed by the GOB. The possibility of the beneficiaries supporting the recurring costs needs to be explored. Many of the rural people are poor, and will not likely have the ability to pay even if they are willing.

It is agreed that further work is needed, during feasibility study of the system, on the *quantification of its benefits. The figure of 2580 villages given in the Draft Report was misleading as it included all villages in the thanas of the two border areas. It is now estimated that only about 10% of these are actually located beside flash flood-prone rivers. The "correct" calculation of the estimate is now given in Annex D, Section D11, of the Final Report.*

Conclusions and Recommendations

13. The idea to test the social and technical feasibility of the proposed flood warning system at the pilot level is no doubt sound. It is important, however, that prior to the test the questions of appropriate institutional arrangements and of the sustainability of such systems be addressed and the result taken into account in designing and carrying out the test. Also, the test should be undertaken in the "broader context of flood preparedness" mentioned by the concept paper. This would mean the design and implementation of a pilot project for flood preparedness that has as one of its components the proposed warning system. Such a pilot project would be expected to put into practice many of the measures identified and promoted by FAP 23 (Flood Proofing Pilot Project).

NERP Response:

It is agreed that appropriate institutional arrangements, sustainability, embankment strengthening, etc., should be addressed before the system is tested. Some further suggestions have been added to the Final Report as to how these questions might be addressed - see Annex F.

14. The flood preparedness pilot project would, in turn, advantageously be part of a sub-regional water management project. Thus the development of flood preparedness along two of the flashy rivers originating in the Meghalaya Hills—the Bhogai and Someswari—should be integrated in NERP's Upper Kangsha River Basin Development Project. Of the rivers flowing into Bangladesh from Tripura, the Juri, the Manu and the Dhalai should be the subject of flood preparedness work in the framework of the Manu River Improvement Project, and the Karangi as part of the Habiganj-Khowai Area Development Project.

NERP Response:

It is agreed that the flood warning systems could be part of sub-regional water management projects.

15. The technical feasibility and social acceptability of the proposed flood warning concept is seen to depend, above all, on the capacity of a human being to look at rainfall from a distance and to decide when the point is reached where the resulting flood waters might threaten the downstream villages. It must be recognized that flood forecasting on a headwaters stream is very difficult under the best of circumstances. Successful forecasting requires the thorough knowledge of the catchment's rainfall-runoff relationship (variable in the course of the year and with soil-moisture and plant-growth conditions) and the capability of performing real-time analysis of current precipitation data. Information on the water level's rise is of limited usefulness because of the extremely short lag times.

NERP Response:

It is agreed that the technical feasibility and social acceptability of the proposed flood warning concept does depend on the capacity of a human being (in the absence of radar) to evaluate rainfall at a distance. However, this is a flood warning system, not a flood forecasting system. It only has to discriminate between flood producing and non-flood producing situations, and in the case of flood producing situations between dangerous and non-dangerous ones; it does not have to make predictions in the form "Expected maximum water level will be 4.98 m PWD". This is true even if, at a later stage, radar replaces the human observer. Given that the FFWC's flood forecast production time for the main river system is 4 hours the irrelevance of flood forecasting to solution of the flash flood warning problem is quite apparent.

Also, while it is agreed that the short lag times are a problem, it is apparent that:

1) *there is not way of lengthening them significantly, especially in the Meghalaya border area; even if India would operate telemetric water level recorders/detectors at the heads of the nodal reaches little time would be gained since these heads are located, typically, within 5 km of the Indo-Bangladesh border; to locate them farther upstream would risk non-detection of floods in some main tributaries.*

2) *locating safe grounds (of whatever form) as close to the village as possible will enable safe route travel times to be commensurate with the short lag times;for example, cyclone-type shelters built in the villages would greatly reduce the need for long lag times.*

16. If the proposed visual rainfall observation is the only way possible to predict the flood conditions caused by the storms over Indian territory, the effectiveness of the method should be assessed before the pilot project is initiated. This would amount to devising and carrying out a program to determine: 1) the reliability of the observers's flood predictions (both during the day and the night), and 2) whether the degree of reliability is adequate to operate a system in which the people exposed to the floods have confidence.

NERP Response:

It is agreed that the effectiveness on observers be assessed before the pilot project is initiated. Pending acquisition of a radar/telemetry system there is nothing to be done to improve the effectiveness of the method. Thus the system will depend entirely on the calibre of observer personnel. The test should be designed to assess the effectiveness of several groups of observers, the groups consisting of, for example:

1) *recently retired NCOs of the Bangladesh armed forces technical branches*

2) *observers typical of those hired by the BWDB for its river gauging operations*

3) *local persons with local knowledge of weather patterns.*

17. The far better way would, of course, be to use data from rain gauges in the upper catchment and, if possible, weather radar. This would require close cooperation with India. Subject to the approval of the GOB, CIDA recommends that the CEA prepare a

technical brief that could serve as a basis for the GOB to initiate negotiations with India.

NERP Response:

It is agreed that it would be better, technically, to use radar, especially as this would not require India's cooperation. A technical brief for the GOB to use in negotiating with India over a telemetric network on its territory is given in Annex C.

Detailed Comments

1. Introduction

Page 1, para 1: The reasons for FAP 10 to abandon the weather radar for predicting flash floods should be given. They represent important background information for the proposed system.

NERP Response:

The reasons are outlined in Section 4.2.5 of the Final Report.

3. Flash Flood Dangers

Page 16, bottom para.: The last two lines of this paragraph are repeated on the following page.

NERP Response:

The repetition has been eliminated for the Final Report.

Page 17, para.1: The part "as they will be seen by an observer" of the first sentence is not necessary.

NERP Response:

Agreed; these words have been eliminated for the Final Report.

Page 20, para.2 from bottom: What is the probability for a bore to occur? It would be interesting to take a representative catchment and figure out the necessary rainfall intensity and duration.

NERP Response:

The probability for a bore is high for steep river channels such as those emanating from the Shillong Plateau. If, in addition, the antecedent flow in such channels is small or zero the probability tends to certainty ($P = 1$). The probability diminishes rapidly as river channel slope decrease and antecedent flow increases. The author does not, however, have any statistics on the probability of bores either in Bangladesh or elsewhere; the subject is one which hydrologists/ hydraulic engineers have tended to *neglect worldwide so far. Note, however, that rainfall intensity, provided it is sufficient to generate runoff, has virtually not influence on whether or not a bore will develop; such development depends mainly, if not exclusively, on the two hydraulic factors cited above, i.e. bores are a hydraulic phenomenon, rather than a hydrologic one.*

4. Warning System Technology

Page 30, para. 1&2: The light signals defined here do not correspond to those described in Annex C (p.C-2)

NERP Response:

The light signals given in Annex C, page C-2, are the correct ones. These are intended to minimize the irritation caused by the siren and the corresponding statement in Section 5.1.3 of the Final Report has been amended accordingly.

Page 32, Table 4.2: Note 4) should in part read "stilling well", not "stilling basin"

NERP Response:

Agreed; it has been corrected for the Final Report.

ANNEXES

Figure 7: In illustration c) Special Case, titles of figures should numbered i) and ii), instead of e) and f), to be coherent with text.

NERP Response:

Agreed; the correction has been made for the Final Report.

Figure 25: The latitudes of the two coordinates locating the area shown don't make sense.

NERP Response:

Agreed; the coordinates have been corrected for the Final Report.

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ANNEX B2
FPCO COMMENTS ON DRAFT FINAL REPORT

Reviewed by A. Hannan, POE, FPCO
April 24, 1994

General:

The important characteristics of flash floods of NE region have been discussed and the various means to face the flash floods to reduce the damages have been considered in the concept paper. After discussing the various means of reducing the flash flood damages it has been concluded that flood warning is the only practical means for mitigating flash flood impacts in the North East Region. This method will reduce the damages to a large extent with minimum cost provided the method works correctly in time and people respond to it properly.

Considering the lead time needed for forecasting and warning and the practicability of having such lead time for villages located at various distances from border it is apparent that flood warning method may be more effective in the village relatively far away from border. This effectiveness also will depend on how people will respond to such a system and how they will remain faithful to respond to such warnings if over years warnings and happenings have not been more or less same.

The resettlement of riverside communities on higher safe grounds and on artificial islands created near the village will be a more acceptable and possibly more effective even though costly means of facing flash flood specially in villages not sufficiently away from border and also in villages where flash flood suddenly raises the water level by meters.

NERP Response:

The point made in the last paragraph is well taken. Higher grounds will not, however, easily be found nearby many villages, and artificial islands, if they are to be raised high enough, will be costly to construct and will involve costly village structure re-location costs also. A third alternative, cyclone-type shelters, is introduced in this Final Report in view of the great success achieved with these shelters in coastal areas during the May 1993 cyclone; essentially similar structures could be used in the flash flood-prone villages of the Northeast Region, and could serve as school/community buildings when not in use as flash flood shelters.

It is to be noted, nevertheless, that only artificial islands with villages re-located on them would preclude the need for flash flood warnings.

Review by: Patricia Lane, POE, FPCO
March 1994

General Comments:

The objective of this project is to mitigate the impacts of flash floods in riverine villages in the Meghalaya and Tripura border areas of the northeast by providing villagers with a flood warning system. The system is expected to function so as to: (1) give villagers sufficient time to prepare for evacuation and, (2) allow for safe evacuation to nearby higher and flood-free grounds. Technically, the proposed system consists of a flood detector station and a water level detector located near the Indo-Bangladesh border which will be connected via radio or cable communication to a series of flood warning stations (typically 5 per flash-flood prone river) located about every 5 km along the river. The flood detector stations are to be situated near the border with India on high enough grounds so as to provide extensive views over the river basins. These stations will be operated by an observer trained to identify meteorological conditions conducing to heavy rainfall in the areas upstream and consequently, to dangerous flash floods.

This study stands out from the majority of pre-feasibility reports on at least two grounds: First, it is one of the most sensible projects proposed for the Northeast region, perhaps in conjunction with the Integrated Farming Systems project, in the sense that they both attempt to mitigate the adverse effects of floods by working with nature, rather than against it. Second, the questionnaire appears to have been carefully thought through and the report is very well written indicating a depth of understanding of the problems. Chapter 3 contains clear descriptions of the dynamics of flash floods. Based on these descriptions, flash floods with partial or full breaking bores would appear to be more dangerous than floods with monoclinal rises. The question then is at what stage could the observer located in the flood detection station discriminate between conditions likely to lead to these different flood front types? Would this distinction not be necessary?

NERP Response

The author of this report considers it unlikely that any observer could discriminate between rainfall conditions likely to lead to the different flood front types, and that the distinction is not necessary. As explained in Section 3.5 the occurrence of bores in a particular river is mainly dependent on the river's channel steepness and on the magnitude of the antecedent flow. In the Rift Valley of Jordan, for example, rainfall of almost any runoff generating intensity will result in bore-fronted floods due to the extreme steepness, and usual initial dryness, of the river channels descending into the Valley; it may be noted here that the southern slopes of the Shillong Plateau in Meghalaya have a strong structural resemblance to the sides of the Jordan Rift Valley, and so it its thought that bores are likely to occur in the Meghalaya Border Area.

The report also correctly states that, for the warning system to be of any use, several structural improvements are fundamental. First, the structural integrity of existing embankments needs to be strengthened. Second, access to safe ground in the vicinity of villages has to be made available, and these safe grounds have to be large enough to hold everyone in the villages.

The discussion of the influence of the type of flash-flood front on the erosive power of the flood on embankments is informative. The authors suggest that embankment design and construction methods have to be reviewed and substantially improved. Although not the subject of the current study, they identify and briefly discuss the negative social and economic consequences of using very expensive, imported heavy construction material for this purpose and suggest, instead that better compaction of embankments can be achieved through well supervised, systematic manual tamping of the fill material.

Specific Comments:

List of acronyms: PWD: surely not Pakistan Water Department.

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NERP Response:

For the Final Report the general list of acronyms used for the Draft Report has been replaced by one giving only those acronyms relevant to this report. For the purpose of this report PWD stands, in all cases, for Public Works Datum. It is important to specify the datum when quoting water levels, etc., as the GTS (Greater Triangulation System) datum is also used in Bangladesh; the PWD is 0.457 m. lower than the GTS datum, and so there is considerable scope for error if the datum used is not specified.

Notes in Figure 2 are very hard to follow. Note 4: Does the Meghna River not suffer flash floods. If not, then it should be stated.

NERP Response:

The Notes in Figure 2 anticipate queries which might arise from reviewing hydrologists. $Q_{1.1}$ *refers to a discharge in the river which occurs on average once every 1.1 years; such a discharge corresponds fairly closely to that discharge (the bankful discharge) which just fills the river channel without spilling onto the floodplain.*

With regard to Note 4: No, the Meghna River does not suffer flash floods as defined in Section 1.1, second paragraph.

p.3, para 3 from bottom: What is the Kaptai ousters case?

NERP Response:

Footnote 1 on Page 2 of the Final Report provides a brief explanation of the Kaptai ousters cases.

p.6 Why was the Juri River chosen for the pilot project?

NERP Response:

The explanation is given in Section 4.4 of the Draft Report, and this has been elaborated in Annex G of the Final Report.

Chapter 2:

Figure 3 is very informative

p.8 The report states that the 8 rivers studied were chosen because they are likely to be those in which flash flooding is expected to be most severe, but does not specify why this is so.

NERP Response:

Flash flooding is expected to be most severe in these rivers because they are the ones with the largest catchment areas. Flood intensity is proportional to catchment area for storms covering the whole catchment area so the rivers with the largest catchment areas can be expected to carry the largest flood peak flows. It may be noted that there are many smaller rivers (with smaller catchments) in between the selected rivers; these are also prone to flash floods, but these smaller *floods are less likely to wreak havoc in the villages they pass through.*

p.9 Interviewees appear to have been only men (see questionnaire as well). Could the answers have been any different had they interviewed women either exclusively or in addition to men?

NERP Response:

Most flood peaks occur at night when women are in the home. Thus it is apparent that women are less likely to have seen the physical phenomena of concern. It is possible that women may be able to give more detail on the physiological impact of the floods - the terror, panic, deprivation and hardship, etc.; this aspect may merit pursuit by female sociological interviewers at a later stage.

With regard to the statistics generated by the interviews conducted there is not reason to think that these would differ significantly (in the statistical sense) if women were interviewed.

Chapter 3:

Is Figure 6 referred to?

NERP Response:

Figure 6 was referred to in the Draft Report at the end of Section 2.2. The reference stands in the Final Report.

p.16: It is not clear where formula (2) comes from or how it was derived. It is important that this be clarified.

NERP Response:

Formula (2) is very well known to hydraulic engineers. Reference may be made to textbooks on open channel hydraulics such as Ven Te Chow (1973), Chaundhry (1993), Chadwick and Morfett (1993) - see References in the Final Report.

The description of the flash flood profiles is excellent.

As (with) almost all other pre-feasibility studies, this one also lacks a proper reference list. How is the reader/reviewer supposed to locate Chaudry, 1993? If this is judged not necessary, then why bother putting it in?

NERP Response:

For this Final Report, References are given in Section 7.

As stated above, the description of flood rise types and associated dangers and sources of these dangers is excellent.

Chapter 4:

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The report should state that because the warning system relies on human observers, it will be subject to human failure. Thus, the proposed FFA (Flash Flood Agency) should take measures to minimize this possibility. Also, if the conditions leading to fast rises in water levels occur at night, how are the observers expected to detect them?

NERP Response:

The point is well taken that the use of human observers raises the probability of human failure occurring with this system, and this is stressed in the Final Report, Sections 4.2.8 and Annex F.

Many evening flood rises result from afternoon rainfall, and their detection should not present too much difficulty. Late night/early morning flood rises can be anticipated from the state of the sky at sundown, from the observation of thunder and lightning during the night, and of rainfall caught in a rain gauge at the observation post. Suitable, trained observers should be able to anticipate a flood with reasonable reliability once they have gained some experience. Continuing correlation of their observations with corresponding floods in the river will be important in developing their experience.

p.30 (4.2.4 radio communication) Why should the observer at the detection station be warned of faults developing at warning station? What can he (or she) do?

NERP Response:

The detection of faults before they result in a disaster is an important feature of any disaster avoidance system such as the flood warning system proposed.

Built-in fault detection enables quick fixing of the fault and, therefore, disaster avoidance; hence the provisions made for fault detection in the flood warning system.

Fault warnings will be given to the observer on duty at the observation post because he will be the only person available to receive them. Since one observer cannot be on duty 24 hours a day it is clear that there will have to be three observers; at any time one of these will be on duty, and the other two will be resting but on-call for emergencies. Thus it is envisaged that the duty observer, on receiving the fault signal, will notify the two on-call observers that a fault has developed and they will go out in the jeep and fix it using spare parts, materials and tools kept at the observation post.

References to this was made in Section 4.3 of the Draft Report, and it is now covered in Section 5.2 of the Final Report.

COMPARISON OF FAP 6 REPORT WITH FPCO EIA GUIDELINES

TITLE: IMPROVED FLOOD WARNING
NO.: 22
REVIEWED BY: Patricia Lane, POE, FPCO
DATE REVIEWED: March, 1994

		1 Excellent	2 Satisfactory	3 Fair	4 Poor	5 Not Applicable	6 Missing	7 Foot-notes
1	Project Description	X	—	—	—	—	—	—
2	Environmental Description	X	—	—	—	—	—	—
3	Scoping	—	X	—	—	—	—	—
4	Bounding	—	X	—	—	—	—	—
5	Field Investigation	—	X	—	—	—	—	—
6	Impact Assessment and Methodology	—	—	X	—	—	—	—
7	Identification of Project Impacts	—	—	X	—	—	—	—
8	Identification of Cumulative Impacts	—	—	—	—	X	—	—
9	Environmental Management Planning	—	—	—	—	X	—	—
10	Mitigation and Enhancement	—	—	—	—	X	—	—
11	Compensation Plan	—	—	X	—	—	—	1
12	Environmental Monitoring	—	—	X	—	—	—	—
13	Disaster Management Plan	—	—	X	—	—	—	—
14	Institutional Support	—	—	—	X	—	—	2
15	Reporting/Accountability Framework	—	—	—	X	—	—	—
16	Peoples' Participation	—	X	—	—	—	—	3

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General Comments:

Overall this is an excellent report on an apparently very sensible project. Because the authors considered this a concept paper and not a pre-feasibility study, an Initial Environmental Evaluation was not undertaken. Consideration has been given, however, to environmental impacts in an informal way, and these appear to be relatively benign. Likewise, no formal Environmental Management Plan has been designed because the entire project is an elaboration of one EMP component - the Disaster Management Plan. It would appear necessary, however, to pay more attention to disaster management planning by incorporating some redundancy into the system, both in terms of personnel and equipment.

[1] The need for compensation for the displacement of people whose properties accommodate buildings and towers should be anticipated.

NERP Response:

Footnote (6) to Table 4.2 of the Draft Report, and to Table 5.1 of the Final Report, anticipate variable site-specific land acquisition costs. Note (1) of Section 4.3 of the Draft Report, and of Section 5.2 of the Final Report, indicates the difficulties attaching to evaluation of these costs which, it is considered, is a feasibility report-level task.

[2] The authors are to be commended for including a separate annex on institutional strengthening and development. They propose the creation of a Flash Flood Agency within the framework of BWDB. No details are given, however, of how this agency will operate or be funded, what its manpower will be, etc.

NERP Response:

The minimum manpower requirements are hinted at in Note (2) of Section 4.3 of the Draft Report, and in the modified Note (2) of the Final Report. They are further elaborated in Chapter 6 of the Final Report. How the Flash Flood Agency will be set up, funded and staffed is considered to be a matter for the GOB to determine; the consultant can only indicate certain criteria, minimum requirements, etc., at this stage.

[3] This is the study with probably the most thorough account of peoples' perceptions of their problems. Most other reports simply state that peoples' perception of their problems were obtained through personal interviews, etc. without much more detail.

NERP Response:

Noted

ANNEX C

DRAFT TERMS OF REFERENCE

AND

NEGOTIATING BRIEF FOR FPCO

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ANNEX C1
DRAFT TERMS OF REFERENCE FOR PILOT PROJECT

IMPROVED FLOOD WARNING:

SPECIFIC ELEMENTS OF PROFESSIONAL SERVICES REQUIRED TO PROCEED WITH THE IMPROVED FLOOD WARNING PILOT PROJECT INITIATIVE

Background

The Pilot Project on Improved Flood Warning originates from the Concept Paper prepared by NERP entitled *Improved Flood Warning*. The purpose of the Improved Flood Warning project is to provide timely, readily understood, warnings to villagers in flash flood-prone areas of the Northeast Region of flash floods imminent in their locality and posing danger to them, and to promote their appropriate response to the warnings.

CIDA, together with FPCO and BWDB, have decided to proceed with the evaluation component of the Improved Flood Warning pilot project.

Purpose

The Consultant shall supply professional services relating to the hiring and training of suitably pre-qualified candidate observers/technologists to observe floods, and the subsequent assessing of the reliability of observers to predict floods.

Output

The output produced by the Consultant shall conform to the Guidelines issued by FPCO, and the stipulations of the present Terms of Reference, and the findings of relevant FAP studies and activities. The required output is an Evaluation Report on the reliability and effectiveness of the rainfall observers to predict floods. The report shall include an assessment of the local people's possible response to the proposed scheme. Reference shall be made to the Flood Management Model and the work of FAP 10.

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Activities

The Consultant shall produce the required outputs by carrying out the following activities:

1) Prepare a detailed methodology for evaluation of the system and develop criteria for assessing its success.

2) Select suitably pre-qualified candidate observer/technologists for training in rainfall observation.

3) Establish an observation post on suitably elevated ground and carry out visual observations of storms producing rainfall on the Juri River catchment.

4) Establish a staff gauge on the Juri River close to the international border and monitor water levels in the Juri River through the pre-monsoon and early monsoon season to July 1995.

5) Inform the local community about the rainfall observations through project community organizers. The need for the initiative should be reviewed, and the basic operation of the proposed warning system explained to the local community.

6) Assess the reliability and effectiveness of the rainfall observers.

7) Prepare the Evaluation Report including the criteria for success, and the conditions constraining success. Reference to the Flood Management Model shall be made.

Organization and Management

The CEA in-country team will be responsible for management, training of rainfall observers, and the preparation of the Evaluation Report. They will liaise with other projects in Bangladesh involved in flood warning systems, specifically FAP 10. NGOs will assist the CEA in the community organization aspects of the work.

Schedule

The pilot project is scheduled to begin in January 1995 and end in August 1995 (See attached Activity Schedule).

f2

ANNEX C2
NEGOTIATING BRIEF FOR FPCO ON TELEMETRIC EQUIPMENT IN INDIA

Specific Elements of Negotiations Required for the Establishment & Operation/Maintenance of Telemetric Rain Gauges and River Water Level Gauges on Indian Territory in Support of Flash Flood Warning Systems in Bangladesh.

Background to Negotiations

FPCO has received a proposal for the establishment and operation of flash flood warning systems on nine rivers entering Bangladesh from India. The systems have the potential to be highly effective in warning rural populations in Bangladesh of flash floods occurring in these rivers, and so enabling timely evacuation of these populations to safe grounds. A key element in the systems is, however, the establishment and operation/maintenance of telemetric rain gauges, and of telemetric river water level recorders/detectors, in the catchment areas of these rivers which are located entirely within Indian territory. The establishment and operation/maintenance of this telemetric equipment requires the cooperation of the Government of India, and of all its organizations which may become involved with this equipment in one way or another.

Accordingly, the FPCO wishes, on behalf of the Government of Bangladesh, to negotiate with the relevant Indian authorities an agreement whereby either:

(a) Bangladesh could, with India's approval/cooperation, establish and operate/maintain the required telemetric equipment on the relevant catchment areas in India,

or:

(b) relevant Indian authorities would establish and operate/maintain the required telemetric equipment on Bangladesh's behalf.

In either case it is envisaged that the Government of Bangladesh would bear the costs of providing the required telemetric equipment, and of its operation/maintenance. It is also envisaged that the Government of India would guarantee security of the equipment, and of those involved in its establishment, operation and maintenance, from all interference from unauthorised Government of India personnel and from the public.

Purpose of Negotiations

The general purpose of the proposed negotiations is for Bangladesh to obtain India's approval/cooperation with respect to either Alternative (a) or Alternative (b). It is thought Alternative (a) would be preferable to both governments because technical control/responsibility would reside with Bangladesh, so minimising India's input to the agreement. It may be noted that the data obtained by this telemetric equipment would likely be of little or no use to India.

One purpose of the negotiations specific to Alternative (a) will be to obtain India's approval/cooperation for Bangladesh personnel to freely cross the international border locally, and to freely access the sites where the equipment is installed, for the purposes of establishing the equipment, servicing it at regular intervals, and speedily rectifying faults whenever they occur.

Similarly, one purpose of the negotiations specific to Alternative (b) will be to arrange payments for India's services in establishing, operating and maintaining the equipment on Bangladesh's behalf.

It is envisaged that three objectives of a first negotiation meeting will be:

(1) to secure India's approval/cooperation with respect to either Alternative (a) or Alternative (b)

(2) to identify for Bangladesh all Indian organizations which must be involved in the establishment, operation and maintenance of the equipment, and in the on-going security of the equipment and the personnel involved in its establishment, operation and maintenance

(3) to identify for India all Bangladesh organizations which are to be involved in the establishment, operation and maintenance of the equipment.

With regard to Objective (2) it is envisaged that these organizations will include branches of the Indian federal government, and of the state governments of Meghalaya and Tripura. The Indian BSF (Border Security Force), and the police forces of the states of Meghalaya and Tripura, must be included in connection with security of the equipment and of Bangladesh personnel involved with it.

Depending on the outcome of the first meeting, later meetings will work out the detailed arrangements necessary for establishment, operation and maintenance of the equipment, and for security of the equipment and personnel involved with it. Joint field visits by Indian and Bangladesh government officials and engineers will be necessary to establish the precise nature of these arrangements.

The negotiations would initially relate to the nine common rivers identified in this Brief. It should be borne in mind, however, that if flash flood warning systems on these rivers are successful Bangladesh would want to negotiate similar arrangements with India relating to such other rivers as the Nitai, Jhalukhali, Umium, Piyain, and Lubba in Meghalaya, and the Sonai-Baidal in Tripura; the door to future negotiations regarding these rivers should, therefore, always be kept open.

Nature and Quantity of the Equipment

Telemetric rain gauges and telemetric water level recorders/detectors are scientific instruments which measure, respectively, rainfalls and river water levels, and communicate the measured values of these quantities by radio to a flood forecasting/warning centre located at some distance from the instruments. The transmitted data are used in preparing timely flood forecasts and warnings only, and no other kind of information can be transmitted. It is presently envisaged that such instruments established on Indian territory would communicate data to a centre in the Northeast Region, probably Sylhet.

Each instrument will need to be established on a small patch of land, probably no more than 10m x 10m in size, surrounded by a security fence. In the case of telemetric rain gauges the land patch should be on open level ground with no trees or buildings within a radius of approximately 100 m. In the case of telemetric water level recorders/detectors the land patch must be on the river bank and extend from the top to the bottom of the bank; these instruments have to be housed in steel or concrete stilling wells to protect them from the force of the river flow and from public interference. Within the patch of land a radio aerial will need to be erected, probably on a mast of some kind. Depending on the local security situation a guard may need to be hired to fully ensure security of the instrument.

It is presently envisaged that, for the nine rivers along which flash flood warning systems will be established in Bangladesh, the quantities of these instruments needed to be installed on Indian territory are as follows:

General Location	Instrument Type	Number
State of Meghalaya	Rain Gauges	7
	WL Recorders	6
State of Tripura	Rain Gauges	6
	WL Recorders	4
Totals	Rain Gauges	11
	WL Recorders	10

Approximate Required Locations of Equipment (See Figures C1 and C2)

Precise locations for the equipment will have to be decided by engineers on the ground but, for negotiating purposes, the following locations may be envisaged:

Meghalaya State:

1) **Bhogai River Catchment** (Area in India: 428 Km^2)

   a) Telemetric Rain Gauges

   One telemetric rain gauge is required to be installed north of Rimrangpara, centrally between the two main tributaries of the Bhogai River, but in front of the Tura Range (of hills).

   b) Telemetric Water Level Recorders/Detectors

   One telemetric water level recorder/detector is required to be installed on the Bhogai River just east of Rimrangpara but below the confluence of the river's two main tributaries.

2) **Someswari River Catchment** (Area in India: 2479 km^2)

   a) Telemetric Rain Gauges

   Two telemetric rain gauges are required to be installed, one north of the Tura Range near Nengkhra Agalgiri, the other south of the Tura Range near Rewak Songmong.

b) Telemetric Water Level Recorders/Detectors

One telemetric water level recorder/detector is required to be installed on the Someswari River in, or near, the gorge some 10 km upstream of Rewak Songmong.

3) **Jadukata River Catchment** (Area in India: 2,479 km^2)

a) Telemetric Rain Gauges

Two telemetric rain gauges are required to be installed, one in the western tributary catchment area 12 km due south of Mawmarin, the other in the eastern tributary catchment area 12 km due south of Kulailongsugun.

b) Telemetric Water Level Recorders/Detectors

Two telemetric water level recorders/detectors are required to be installed, one on the western tributary of the Jadukata River 12 km south of Mawmarin but below the confluence of the two main tributaries near this point, the other on the eastern tributary of the Jadukata River 12 km due south of Kulailongsugun.

4) **Dhalai (N) River Catchment** (Area in India: 348 km^2)

a) Telemetric Rain Gauges

One telemetric rain gauge is required to be installed at Cherrapunji.

b) Telemetric Water Level Recorders/Detectors

One telemetric water level recorder/detector is required to be installed on the Dhalai (N) River 5 km east of Cherrapunji just below the confluence of the rivers two main tributaries.

5) **Shari River Catchment** (Area in India: 867 km^2)

a) Telemetric Rain Gauges

One telemetric rain gauge is acquired to be installed at Tarangblang

b) Telemetric Water Level Recorders/Detectors

One telemetric water level recorder/detector is required to be installed on the Shari River 4 km northeast of Tarangblang just below the confluence of the river's two main tributaries.

Tripura State:

1) **Juri River Catchment** (Area in India: 734 km^2)

   a) Telemetric Rain Gauges

   One telemetric rain gauge is required to be installed near Rajnagar.

   b) Telemetric Water Level Recorders/Detectors

   One telemetric water level recorder/detector is required to be installed on the Juri River 5 km northwest of Rajnagar just below its confluence with its western tributary.

2) **Manu River Catchment** (Area in India: 2254 km^2)

   a) Telemetric Rain Gauges

   Two telemetric rain gauges are required to be installed, one in the western tributary catchment about 7 km southwest of Khopaiyapara, the other in the eastern tributary catchment 12 km southeast of Mainoraipara.

   b) Telemetric Water Level Recorders/Detectors

   One telemetric water level recorder/detector is required to be installed 5 km north of Dudhpur just below the confluence of the river's two main tributaries.

3) **Dhalai (S) River Catchment** (Area in India: 782 km^2)

   a) Telemetric Rain Gauges

   One telemetric rain gauge is required to be installed at Salema.

   b) Telemetric Water Level Recorders/Detectors

   One telemetric water level recorder/detector is required to be installed on the Dhalai River near Salema.

4) **Khowai River Catchment*** (Area in India: 1368 km^2)

   a) Telemetric Rain Gauges

   Two telemetric rain gauges are required to be installed, one in the western tributary catchment at Charanmanibari, the other in the eastern tributary catchment at Methraipara.

b) Telemetric Water Level Recorders/Detectors

One telemetric water level recorder/detector is required to be installed on the Khowai River 5 km north of Charanmanibari just below the confluence of the rivers two main tributaries.

*Note to FPCO: Equipment in this catchment area is for the benefit of the Karangi River community; presently the Karangi River is a distributary of the Khowai River from which its floods mainly emanate.

Establishment Works

Establishment of telemetric equipment at sites in India will involve minor construction work as follows:

For Telemetric Rain Gauges

A security fence around each 10m x 10m patch of land will be needed; it is envisaged this would consist of chicken wire mounted on concrete or steel posts, and topped with strands of barbed wire.

A centrally-placed concrete plinth will be needed on each patch of land as a foundation for the telemetric rain gauge.

A second concrete plinth may be needed as a foundation for a radio mast; the need for this will depend on the specification of the telemetric rain gauges purchased by Bangladesh.

For Telemetric Water Level Recorders/Detectors

Regardless of whether this equipment consists of a recorder, or simply of a critical water level detector, a stilling well will be needed on each 10m x 10m patch of land. The form of stilling well required at a particular site will depend on site conditions; however, for negotiating purposes, it can be assumed that the form adopted will be similar to that shown in Figure 16 of the NERP Final Report: Improved Flood Warning.

In negotiation it should be determined whether these works are better constructed by a Bangladesh team sent into India for the purpose, or by local Indian contractors under Bangladesh supervision.

Operation & Maintenance Works

There is a requirement for frequent visits to all telemetric equipment sites for purposes of:

1) routine servicing of the equipment as recommended by the equipment manufacturer

2) fault rectification on an emergency basis

It is, therefore, absolutely necessary that staff responsible for operating and maintaining this equipment have free access to the sites at all times.

Access Requirements for Bangladesh Personnel under Alternative (a)

It will be necessary under Alternative (a) for Bangladesh personnel to gain free access to all the above-mentioned sites in Meghalaya and Tripura and such access must, for reasons of time-saving in emergencies and overall cost minimization, be by the shortest and most direct routes available. These routes are tentatively envisaged to be as follows:

To Meghalaya:

1) **Bhogai River Catchment**

Bangladesh personnel would travel from Mymensingh to Nalitabari, cross the border between Nakuagoan (in Bangladesh) and Thibapara (in India), and then proceed north towards Tura but turn off to Rimrangpara. The route beyond Rimrangpara is unknown, and may lie across open country.

2) **Someswari River Catchment**

Bangladesh personnel would travel from Mymensingh to Netrakona, cross the border between Durgapur (in Bangladesh) and Rewak Songmong (in India), and then proceed north towards Nangkhra Agalgiri turning off the road to the three sites where convenient. The routes beyond the Rewak Songmong to Nengkhra Agalgiri road are unknown, and may lie across open country.

3) **Jadukata River Catchment**

Bangladesh personnel would travel from Sunamganj almost certainly by country boat to the Indian border at the Jadukata River gorge. From there they would hire Indian vehicles to take them by roads westwards towards Mawmarin and/or eastwards towards Rangthong.

4) **Dhalai (N) River Catchment**

Bangladesh personnel would travel from Sylhet to Cherrapunji by road, crossing the border near Chilabhanga.

5) **Shari River Catchment**

Bangladesh personnel would travel from Sylhet towards Jarain (in India) by road, crossing the border between Jaintiapur (in Bangladesh) and Palengshakap (in India), and turning off to Tarangblang where convenient. The route beyond the turnoff is unknown, and may lie across open country.

To Tripura:

1) **Juri River Catchment**

Bangladesh personnel would travel from Sylhet via Fenchuganj to Kamarkandi, crossing the border between Bara Dhamai (in Bangladesh) and Baghadohar (in India), but turning off within India before Baghadohar and proceeding south to Rajnagar. The routes beyond Rajnagar are unknown, and may lie across open country.

2) **Manu River Catchment**

Bangladesh personnel would travel from Sylhet via Moulvi Bazar and Kamalganj, crossing the border between Adampur (in Bangladesh) and Dudhpur (in India) near Takirambari. From Dudhpur they would follow Indian roads to Mainaraipara and Khopaiyapara. Routes between the Indian road system and the sites are unknown, and may lie across open country.

3) **Dhalai (S) River Catchment**

Bangladesh personnel would travel from Sylhet via Moulvi Bazar and Kamalganj, crossing the border between Adampur (in Bangladesh) and Kamalpur (in India), and then proceeding south to Salema. Routes beyond Salema are unknown, and may lie across open country.

4) **Khowai River Catchment**

Bangladesh personnel would travel from Sylhet via Moulvi Bazar and Shaistaganj, crossing the border between Ballah (in Bangladesh) and Khowai (in India), and proceeding south to Charanmanibari and Methraipara.

It is to be noted that these routes have been selected from 1:500,000 scale mapping, and their suitability needs verifying on the ground. It also needs to be recognized that these routes may be impossible in the monsoon season in which case access would have to be by motor boat straight up the river concerned. The availability of suitable immigration/emigration facilities at the border crossings also needs to be verified in consultation with the Indian authorities. Thus, the routes suggested here are subject to variation during the negotiations.

Figure C1

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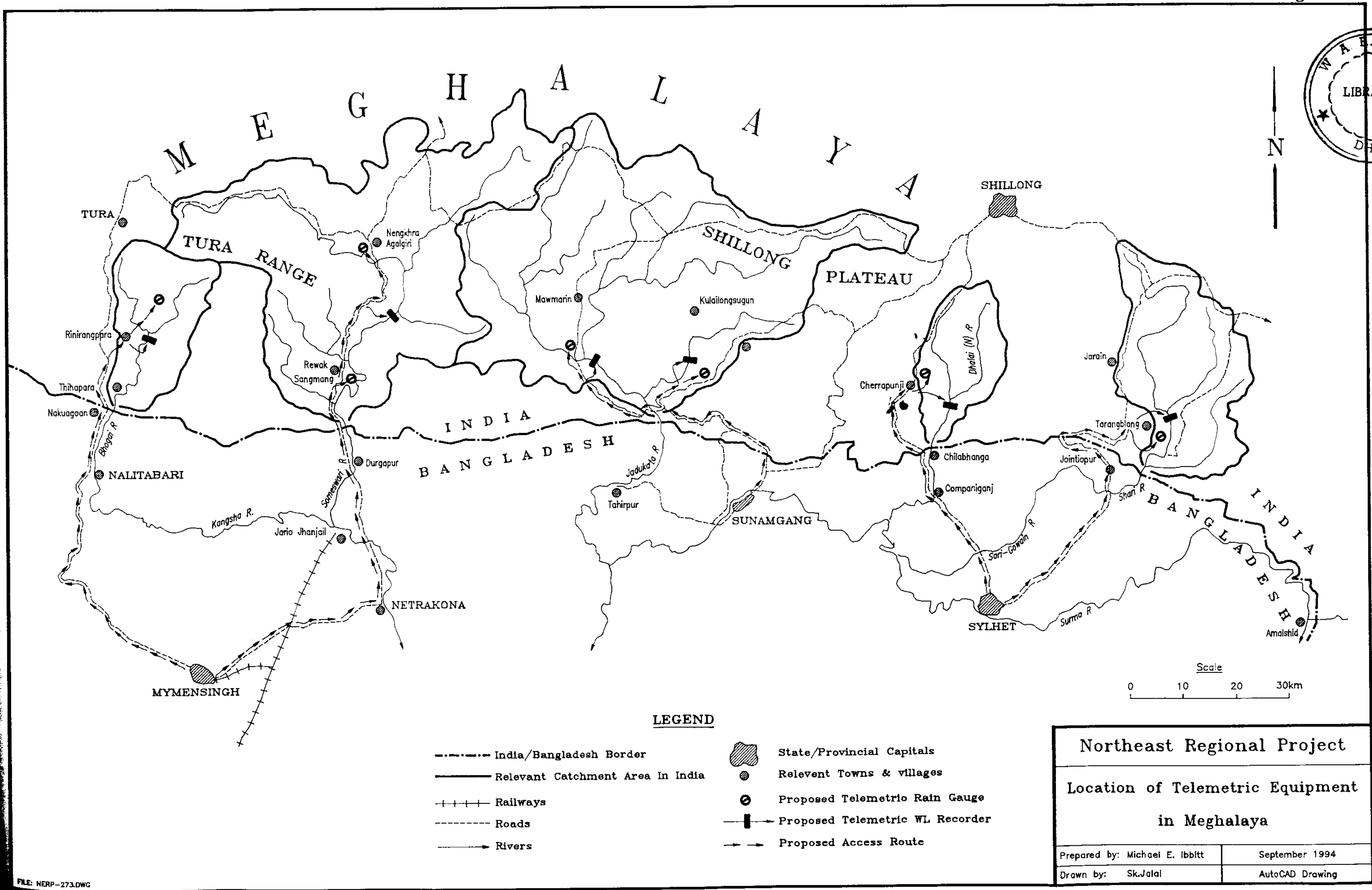
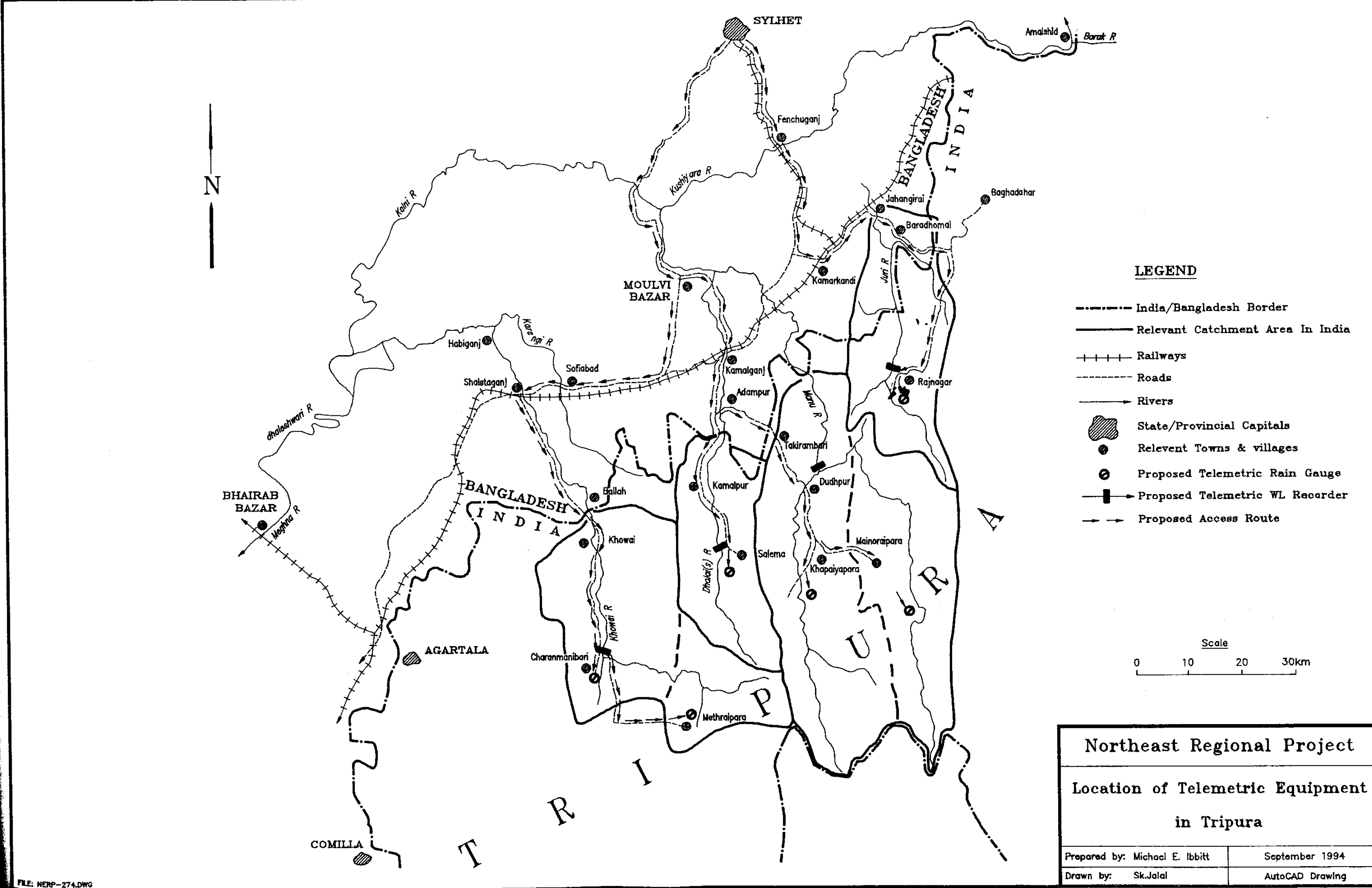


Figure C2



Northeast Regional Project

Location of Telemetric Equipment in Tripura

Prepared by: Michael E. Ibbitt	September 1994
Drawn by: Sk.Jalal	AutoCAD Drawing

ANNEX D

DETAILED ACCOUNT OF FIELD INVESTIGATIONS

ANNEX D
DETAILED ACCOUNT OF FIELD INVESTIGATIONS

D1 Identification of Flash Flood-Prone Rivers

Rivers suitable for investigation were selected according to the following criteria:

- The river had to comprise a nodal reach connecting the dendritic (convergent) river channel network in India to the deltaic (divergent) river channel network in Bangladesh; it is in such reaches that flash floods attain their maximum force, and do the most damage.
- The rivers had to represent the full range of flash flood generation experienced along the borders with Meghalaya and Tripura.

In line with these criteria the Bangladeshi interviewer was instructed to locate, on the basis of local enquiries, the worst affected villages on the rivers listed in Table D1.

D2 Identification of Villages Worst Affected by Flash Floods

Villages suitable for investigation on each of the selected rivers were selected according to the following criteria:

- The village had to be located right beside the selected river, not inside any adjacent haor; this criterion was to ensure as far as possible that the phenomena discussed with the villagers would relate to flooding by flash floods in the river, not by backwater from some downstream location.
- The village had to have been badly affected by flash flooding within recent memory; this criterion was to ensure that the phenomena discussed with the villagers would be sharply etched in their memory, and serious enough to be of interest to this study.
- The village had not to be so large that the interviewees could not possibly know in detail what had transpired in all parts of the village during the worst flood of memory.

Armed with these criteria the Bangladeshi interviewer made cautious enquiries in several villages along the river until he was satisfied that he knew which village best fitted these criteria. The villages he selected are listed in Table D1, together with an estimate of the number of dwellings in each village. Figures D1 through D9 illustrate the situation at each village.

D3 Identification of Suitable Interviewees

Persons suitable for interview were selected according to the following criteria:

- The interviewees had to be men of the village who were present in the village when it was struck by the worst flood of memory; this criterion was to ensure that all statements of fact gathered during the interview came from eyewitnesses.

- The interviewees had to be men of mature years; this criterion was to ensure as far as possible that understanding of the facts of the flood situation, and any statements of opinion gathered during the interview, would be balanced and based on common sense.

- The interviewees had to be, or to have been, engaged in some occupation which would keep them abreast of grass roots issues in the village; this criterion was to eliminate temporarily assigned "specialists" such as border guards, government officers, etc.

In line with these criteria the Bangladeshi interviewer made cautious enquiries in each selected village until he was satisfied that he had a group of 3 or 4 reasonably honest and knowledgeable men. The interviewees he selected are listed in Table D1, together with their occupations and age.

The interviewees of each village were then interviewed as a group, not individually, so that they could jog each other's memories, and qualify each other's statements.

D4 Identification of the Worst Flood of Memory

At the start of the interview the interviewer, on instruction, made the following statement, followed by Questions 1 and 2:

Statement:

As you are no doubt aware flooding is a problem which affects many people in the Northeast Region, and we need to better understand its effects on people's lives, property, and livelihood. To gain this better understanding we are conducting an investigation in a small number of villages which we have been told are often badly affected by flooding, and your village is one of those selected for investigation of the effects of flooding.

Question 1:

Would you agree that this village has been seriously affected by flooding in the past ?

Answer 1:

Every group of village interviewees confirmed that their village had been seriously affected by flooding in the past.

Question 2:

Please cast your minds back over the last 10 years or so, and try to remember the floods which had a really bad effect on this village. In which years and months did they occur ?

Answer 2:

The answers given to Question 2 are recorded in Table D2. In every village the interviewees identified from 2 to 6 floods which had had serious effects on their village. Understandably, they were a little uncertain as to the exact month in which these floods occurred, and even of the exact year of long ago floods, but there is no reasonable doubt that floods having serious effects have occurred in each of these villages, on average, about once in 3.69 years.

Having established the list of floods the interviewer, again on instruction, made the following statement followed by Questions 3 and 4:

Statement:

Studies have shown that there are two basic types of flooding in the Northeast Region:

a) Flash Flooding: This results from the sudden onrush of water through rivers coming from the hills in nearby Meghalaya/Tripura.

b) Backwater Flooding: This results from the backing up of water in downstream rivers like the Kangsha/Surma/Kushiyara.

It is important that you (the interviewees) understand this difference because our present investigation concerns only flash flooding. If you have difficulty understanding this difference I will try to explain it more clearly.

Question 3:

Which of the flooding events we have just listed (see Table D2) would you say were due to flash floods from the Meghalaya/Tripura Hills ?

Answer 3:

Every group of interviewees confirmed that the floods they had entered in their list were all flash floods, not backwater floods.

Question 4:

Which of these flash floods would you say caused the worst effects in this village ?

Answer 4:

With the exception of Dhalai(N)/Chilabhanga which identified the 1973 flood as its worst, all of the villages in the Meghalaya Border Area identified the 1988 flood as their worst flash flood. In contrast, all of the villages in the Tripura Border Area identified the 1993 flood as their worst.

2a

D5 Identification of the Effects of the Worst Flood

Having established which was the worst flood, the interviewer made the following statement followed by Questions 5 through 8:

Statement:

I think you all agree now that it was the flash flood of (year, month) which caused the worst effects in this village. I want you now to focus your attention on that flood only and tell me what its effects were.

Question 5:

Were any lives lost because of this flood ?

a) How many lives were lost ?

b) Were the people who lost their lives children, adults, or elderly people ?

c) How many were children, adults, or elderly people ?

d) Were they swept away by the river water and drowned ?

e) Were they trapped in some building and drowned ?

f) Were they killed when a building collapsed on them ?

Answer 5:

The answers given to Question 5 are recorded in Table D3. A total of 53 lives were lost in the nine villages, and of these 45 were lost as a result of boats, used to escape from the flood, capsizing. Among the 53 lives lost, 50 were (able-bodied) adults, and only 3 were children. Deaths due to being swept away by the flood were equal at 4 in both border areas.

Question 6:

About how many households/dwellings are there in this village ?

Answer 6:

The answers given to Question 6 are recorded in Table D1. The villages ranged in size from 150 households (Manu/Rainsaf) to 4500 households (Juri/Jahangirai), with an average of 1072 households.

Question 7:

How many dwellings collapsed during the flood ?

Question 8:

How many households lost:

a) Boats
b) Personal belongings
c) Drinking water stocks
d) Food stocks
e) Fuel stocks
f) Fodder stocks
g) Buffaloes
h) Cows
i) Goats
j) Chickens
k) Rice crops
l) Vegetables crops
m) Orchard crops

Answers 7 and 8:

The answers to Questions 7 and 8 are recorded in Table D4 for the Meghalaya Border Area villages, and in Table D5 for the Tripura Border Area villages. The data are, obviously, only approximate and may exhibit a tendency to exaggeration; the areal averages given in the tables help to dampen these effects. Comparing the areal averages for the two border areas suggests that, overall, loses were consistently higher in the Meghalaya Border Area than in that of Tripura. Except in the case of crops in the field, there is little consistency among the villages in damages to particular items.

D6 Identification of Causes Losses/Damages in Worst Flood

Having established a reasonably clear picture of the effects of the worst flood in terms of lives lost and properties damaged, the interviewer made the following statement:

Statement:

We now have a clear picture of the effects of the worst flood to strike this village. Now I would like you to tell me a bit more about why these losses and damages occurred.

The interviewer then went on to ask Questions 9 through 19 which elicited the sequence of physical events and human responses in each village's worst flood situation. Tables D6 through D14 record the answers to these questions for each village individually; below the answers to each question are summarised on a collective basis, and with reference to Tables D15 and D16.

Question 9:

About what time of day/night were you aware that there was a flash flood rising in the river ?

Answer 9:

The times recorded in Table D15 indicate that, while flood rises can occur at any hour of day or night, they are more likely to be noticed in the afternoon (5 cases) than in the morning (2 cases), or after dark (one noticed, and one not).

Question 10:

What action did you take, based on your awareness ?

a) Did you, or anybody, raise the alarm ?
b) Did you keep an eye on the river for a while ?
c) Did you begin to take protective measures ?
d) What measures did you take ?

Answer 10:

As indicated in Table D16, in four villages, two in the Tripura Border Area and two in the more vulnerable Meghalaya Border Area, no action was taken in anticipation of the flood coming. In the other five villages some actions (moving cattle, and raising belongings in the home) were taken, but nobody left home. In all cases nobody raised any alarm on the basis of their first awareness that a flood was coming; in only one case (Dhalai (N)/Chilabhanga) was a watch set on the river.

Question 11:

About what time of day/night did you realise that this flood was going to cause serious problems in the village ?

Answer 11:

The times recorded in Table D15 indicate that the floods struck mainly at night; in only two cases did the flood strike in daylight. In four cases it struck while most people would have been asleep (11pm to 5am inclusive).

Also given in Table D15 are the times which elapsed between first awareness of a flood rising in the river and the flood striking; they range from zero to eight hours. Comparing these times with the precautionary activities undertaken within them, it is apparent that much more such activities could have been undertaken in the time available in at least five of the nine cases.

In Table D16 an indication is given of what it was that finally made the villagers realise they were in danger. In three cases, it was the noise the river was making, but such noise was not reported in the other six cases. In five cases it was the collapse of a local flood protection embankment, followed by water rapidly entering the village; in the other four cases no flood protection embankment was involved, and it was water entering the village when the natural river bank was overtopped which alerted the villagers to the danger they were in.

Question 12:

What actions did you then take, based on the realisation that this flood was going to cause serious problems in the village ?

Answer 12:

The answers to Question 12 are given in Tables D6 through D14. Basically, in all nine villages the people fled for their lives; in two cases, where boats were used to flee, accidents occurred involving high losses of life. In only two villages was an alarm raised, and in only two was there time to move belongings and cattle to safe places.

Question 13:

In what order did you take these actions ?

Question 14:

Did you have time to take all necessary actions ?

Question 15:

What actions did you not have time to take ?

Answer 13 through 15:

Questions 13 through 15 were basically irrelevant in the context of Answer 12; the answers given are in Tables D6 through D14. They generally indicate that there was no time to do anything but flee in panic. There is no evidence of any plans of action, to be followed in the event of a flood, either existing or being followed.

Question 16:

If you had to live through that experience (of the worst flood) again, what would you have done differently ?

Answer 16:

The answers to Question 16 are given in Tables D6 through D14. They indicate a generally fatalistic attitude on the part of the villagers, coupled with an inability to see what else they could have done on that occasion, or could do in a similar future situation. Two village groups only said that if they had had more time they would have tried to save their belongings and cattle.

Question 17:

Would you say that the village community as a whole responded appropriately as the flood was rising ?

Answer 17:

The answers to Question 17 are given in Tables D6 through D14. They indicate mixed feelings ranging from "We lost our senses" to "We think we acted appropriately". A lack of time in which to respond was generally cited, and attributed to a failure to recognise the danger posed by the flood.

Question 18:

Would you say people generally were too slow to realise that this (worst) flood posed danger to them ?

Answer 18:

The answers to Question 18 are given in Tables D6 through D14. They indicate that the villagers were quite oblivious of the rising danger in four cases, in two because the flood occurred while they were asleep, and in two because of unexpected bursting of the local flood protection embankment. In three villages it was thought that people were too slow to realise the danger, but in two others they did not think this was the case.

Question 19:

Would you say people generally took important actions first, or did they panic and take actions haphazardly ?

Answer 19:

The answers given in Tables D6 through D14 indicate clearly that in all nine villages the people panicked and took actions haphazardly, if at all.

D7 Identification of Villagers Desire for a Flood Warning

Having established that a lack of time in which to react to the danger had been a problem for all the villagers during their worst flood, the interviewer tried to explore whether they thought they would benefit from a flood warning.

Question 20:

Do you think that, if some external agency had raised the alarm in the village, people would have :

a) taken notice of the alarm and initiated protective measures ?

b) had time to complete all necessary protective measures ?

c) suffered no loss of lives ?

d) suffered no losses of, or damages to, properties ?

e) suffered no losses of, or damages to, crops ?

Answer 20:

The answers to Question 20 are given in Tables D17 through D25. All nine villages responded positively to (a), and eight responded positively to (b); only Dhalai (N)/ Chilabhanga was doubtful whether a warning would have given them the time needed. Since no lives were lost in four of the villages (c) was not applicable in those villages; the other five villages thought that the lives they lost would have been saved. In response to (d) three villages thought that a warning would have saved their property, but the other six villages were more realistic in saying that property damage could only be minimised. In response to (e) all the villages realised that nothing could be done to save crops.

Question 21:

Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?

Answer 21:

The answers to Question 21 are given in Tables D17 through D25. Eight villages said that they would welcome timely warnings. The exception was Dhalai (N)/Chilbhanga where it was clearly stated that the money for the warning system would be better spent dredging their river; in view of this negative response the interview in this village was terminated at this point.

Question 22:

How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses of life and property damages which flash floods cause in this village ?

Answer 22:

Again, the answers to Question 22 are given in Tables D17 through D25. This question was not asked in Dhalai (N)/Chilabhanga in view of its negative response to Question 21. In seven of the remaining eight villages it was strongly felt that a flash flood warning system would be of help to the villagers, but Karangi/Himagao expressed doubt.

D8 Identification of Villagers Needs of a Flood Warning System

In the eight villages which were in favour of a flood warning the interviewer explored whether the suggested form of the warning would be appropriate for the villagers, and how they thought they would react to it. The interviewer began this section of the interview with the following statement followed by Questions 23 through 25.

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Statement

It seems clear now that you think the village people would definitely, or might, benefit from some external agency providing warnings of flash floods approaching this village. To do this the agency would have to set up some kind of flash flood warning system so it is important to establish the essential features of that system. It is equally important that the villagers understand the meaning of the warning, and that they have a clear plan of action of follow when the warning comes. It is already clear to us that the warnings must indicate the level of danger posed by the flood, and that they must be given early enough for people to have the time needed to take appropriate measures. The main problems faced by the designers of such a flood warning system are :

a) What levels of danger need to be communicated to the village people.

b) What form the warnings should take in order that the village people will be in no doubt as to their meaning.

Clearly, the villagers must not be alarmed needlessly or they may soon start to ignore the warnings; not every flood that occurs poses a danger to the villagers so there has to be some means of discriminating between small floods which present no danger and to which villagers need not respond, moderate floods which may become dangerous and to which villagers should respond with sensible precautionary actions, and large floods which definitely pose serious danger and to which villagers should respond by taking all appropriate actions. To design a suitable flood warning system we need to know the answers to the following questions:

Question 23:

What water levels in the river passing through this village would you consider:

a) present no danger to people and their property ?

b) present a serious danger to people and their property ?

c) present a disaster to people and their property ?

The interviewer was instructed to identify these levels in terms of the top of the natural river bank, local embankment, or village mound, or other easily recognisable levels such as window levels on houses, etc. He was to walk around the village with the group of interviewees and identify these levels on the ground.

Answer 23:

The answers to Question 23 are given in Tables D26 through D34. In six of the eight villages the levels were related to the local flood protection embankment, and in the other two to the local BWDB river water level gauge. It is noteworthy that where levels were related to the embankment, the villagers considered that there could be no danger until the water level reached the top of the embankment, and that they perceived no serious danger until it was 0.3 to 0.6m above the top of the embankment !

Having established two recognised critical water levels separating the conditions of no danger, danger, and disaster, the interviewer asked Question 24.

Question 24:

Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions ?

Answer 24:

In all eight villages there was no doubt at all that the villagers would want such warnings (see Tables D26 through D34).

Question 25:

Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?

Answer 25:

Again, in all eight villages there was no doubt that the villagers would carry out such a plan.

D9 Confirmation of Suitability of Proposed Flood Warning Format

Having established that the villagers would want and respond to such warnings, the interviewer sought confirmation of whether the proposed means of communicating the warnings would be understood by village people. He began with the following statement followed by Questions 26 and 27.

Statement:

We are aware that most village people do not have access to TV, radio or newspapers and that, even if they do, the flood warnings communicated through these media may not be readily understood by village people because of the technical language used in the warning. Communicating the warning in a way which will be clearly understood by everyone in the village, and which will reach everyone no matter what they are doing or where in the village or its paddy fields they happen to be when the warning is given, is vitally important to the success of the flood warning system. We think that the best way is by means of sirens and lights mounted on a tower in, or near, the village. The sound of the siren, and the colour of the light, when a warning is given would be different for the various degrees of danger posed by the flood; for example, the first level of danger might be indicated by a series of short hoots on the siren and by a flashing red light, and the second more serious level of danger by a series of long hoots on the siren and by continuous exposure of the red light.

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Question 26:

Do you think that such audio and visual means of communicating the warning would be readily understood by:

a) Adults

b) Children

Answer 26:

In all eight villages the answer to Question 26 was positive with respect to both adults and children (see Tables D26 to D34).

Question 27:

Do you think adults, at least, would be able to discriminate between the first level danger signal and the second ?

Answer 27:

Again in all eight villages the answer to Question 27 was positive (see Tables D26 to D34).

D10 Identification of Villagers Needs to Respond to Flood Warnings

Having established that the villagers would be able to understand warnings given in this form, the interviewer explored what sort of response they would make to the warnings. He began by making the following statement, followed by Questions 28 and 29.

Statement:

A vital ingredient in getting the benefit of any flood warning is for the villagers to take appropriate protective actions on receiving the warning. Clearly, if people ignore the warning, or do not take the right actions, the warning will have served little or no useful purpose. It cannot be emphasised too strongly that the external agency can only provide the warning; it cannot make people act upon it. Thus, the responsibilities for drawing up a prudent, sensibly sequenced plan of actions to be followed on reciept of a warning, and for acting upon it, lie primarily with the villagers. The external agency can, and will if required, assist the villagers with drawing up such plans of action, but it is only the villagers who know and understand their own detailed circumstances around which the plan of action must be built if it is to be effective; possibly, every household should have its own plan to suit its specific needs. It is important that we understand the villager's needs for assistance in drawing up suitable plans of action.

Question 8:

Which actions do you think ought to be taken by the villagers on the first warning, and which actions do you think could wait for the second warning to come ?

Answer 28:

In seven of the eight villages it was basically said that on the first warning they would remove women, children, the elderly, cattle and valuables to safe ground, but the men would remain in the village until the second warning came; only then would they leave the village. In one village, Jadukata/Maharam, it was said that no one should wait for the second warning - a reflection, perhaps, of the speed with which their village was engulfed in 1988 (see Tables D26 to D34).

Question 29:

Do you think it wise to wait for the second warning before starting the second group of actions ?

Answer 29:

Basically, the response to this question was the same as for Question 27. In seven of the eight villages the men only should wait for the second warning, and then simply leave for the safe ground; in Jadukata/Maharam they did not think even the men should wait for the second warning (see Tables D26 to D34).

D11 Tentative Estimate of Present Regional Mortality Rate

It is possible, on the basis of the information gathered during the field investigation, to tentatively estimate the numbers of people in the Northeast Region who are presently:

a) exposed to flash flood dangers
b) lose their lives as a result of flash floods.

These estimates are of considerable interest in assessing the benefits of the proposed flash flood warning system, but definitely need verification by detailed sociological investigation during feasibility studies of individual flash flood warning systems. It is emphasised that these are "order of magnitude" calculations only.

The number of villages in flash flood-affected thanas of the Northeast Region is 2580, but it is estimated that only about 10% of these are actually located beside flash flood-prone rivers, i.e. only about 258 villages are really exposed to flash flood dangers. From Table D1 the average village population of the nine villages investigated is 1072. The number of people exposed to flash flood dangers throughout the Region is then 258 x 1072 = 276,576, or say 275,000.

The total population of the nine villages investigated is, from Table D1, 9650; of these, 53 or 0.549%, lost their lives in either the 1988 flash floods in the Meghalaya Border Area or in the 1993 flash floods in the Tripura Border Area. Applying this percentage, say 0.5%, to the flash flood-exposed population of the Northeast Region, gives the mortalities during a single flash flood event as 0.5% x 275,000 = 1375. From Table D2 the average frequency of the worst flash floods of memory is one every 4.66 years, or 21 per century. The average mortality rate is then 1350 x 21 = 28,350, or say 30,000 lives lost per century.

Table D1
Selected Villages and Interviewees

River	Village (Population)	Interviewees	Occupation	Age
Meghalaya Border Area				
Bhogai	Nakuagaon (~ 1000)	Abdul Basit Minhazuddin Dewan Mohammad Jalaluddin Abdul Halim	Farmer Farmer Rickshaw Shopkeeper	55 75 35 32
Someswari	Bhabanipur (~ 900)	Maktul Hossain Makhtaruddin Sarkar Nurul Islam Naresh Chandra Sheel	Labourer Shopkeeper Teacher Barber	55 52 48 67
Jadukata	Maharam (~ 1000)	Abdur Rashid Abdul Aleem Shahjahan	Farmer Farmer Farmer	50 30 30
Dhalai (N)	Chilabhanga (~ 300)	Abdul Aleem Mohammad Tofazzal Hossain Abdul Huq	Farmer Farmer Farmer	70 60 70
Shari	Kamrangi (~ 600)	Durjadhan Pradhan Shahid Ali Khalilur Rahman	Farmer Shopkeeper Farmer	60 25 30
Tripura Border Area				
Juri	Jahangirai (~ 4500)	Abdur Rashid Mohammad Ali Mohammad Wasihudin Qamaruzzaman	Gauge Reader Farmer Farmer Businessman	45 55 68 30
Manu	Rainsaf (~ 150)	Mohammad Aftab Ali Birendra Chandra Dey Pramatesh Chandra Dey	Farmer Farmer Farmer	55 54 35
Dhalai (S)	Hiramati/ Saisiri (~ 750)	Ranumia Arzat Ali Anumia	Farmer Farmer Farmer	72 52 35
Karangi	Himagao (~ 450)	Abu Miah Abdul Jalil Abdul Malek	Farmer Farmer Farmer	45 22 50

Total Population of Nine Villages : 9650
Average Village Population : 1072

2D3

Table D2
Damaging Flash Floods of Memory

River	Village	Dates of Damaging Flash Floods		Rated Worst	Probability of Flood	Return Period (Years)
		Year	Month			
MEGHALAYA BORDER AREA						
Bhogai	Nakuagaon	1988 1989 1993	September/October September June/July	1988	3/5	1.67
Someswari	Bhabanipur	1962 1974 1988 1992	September/October " " "	1988	4/31	7.75
Jadukata	Maharam	1974 1988	June/July June	1988	2/19	9.50
Dhalai (N)	Chilabhanga	1973 1988 1991 1993	June/July " May/June "	1973	4/20	5.00
Shari	Kamrangi	1972 or 1973 1988 1993	May/June " "	1988	3/21	7.00
TRIPURA BORDER AREA						
Juri	Jahangirai	1976 or 1977 1984 1991 1993	March/April May April/May June	1993	4/17	4.25
Manu	Rainsaf	1981 1990 1991 1993	June/July " " May/June	1993	4/12	3.00
Dhalai (S)	Hiramati and Saisiri	1980 1991 1993	June/July " 18 July	1993	3/13	4.33
Karangi	Himagao	1988 1989 1990 1991 1992 1993	May/June June/July ? August/September May/June July/August	1993	6/6	1.00

Probability = Number of damaging floods/(1993-year of earliest flood)
Return Period = 1/Probability
Average Return Periods: Meghalaya Border Area, 6.18 years
Tripura Border Area, 3.14 years
Northeast Region, 4.66 years

Table D3
Lives Lost in Worst Flash Flood and Cause

River	Village	Worst Flood	Lives Lost		Cause
			No.	Category	
MEGHALAYA BORDER AREA					
Bhogai	Nakuagaon	1988	4	Adults	Swept Away
Someswari	Bhabanipur	1988	40	Adults	Launch Capsize
Jadukata	Maharam	1988	0*	-	-
Dhalai (N)	Chilabhanga	1973	0	-	-
Shari	Kamrangi	1988	5	Adults	Boat Capsize
TRIPURA BORDER AREA					
Juri	Jahangirai	1993	3	Children	Swept Away
Manu	Rainsaf	1993	1	Adult	"
Dhalai (S)	Hiramati	1993	0	-	-
Karangi	Himagao	1993	0	-	-

* Lives reported lost in nearby villages

Table D4

Property Losses in Worst Flash Flood Affecting the Meghalaya Border Area (%)

Property Type	River/Village					Areal Average
	Bhogai/ Nakuagaon	Someswari/ Bhabanipur	Jadukata/ Maharam	Dhalai (N)/ Chilabhanga	Shari/ Kamrangi	
Belongings:						
Dwellings	95	70	65	25	25	56
Boats	0*	50	60	25	90	45
Personal	80	90	90	30	10	60
Stocks:						
Water	100	90	100	90	0*	76
Food	85	90	100	50	90	83
Fuel	90	90	90	25	90	77
Fodder	100	90	90	80	90	90
Livestock:						
Buffaloes	0*	0*	100	0*	30	26
Cows	25	0	100	50	30	41
Goats	80	25	100	50	30	57
Chickens	100	50	100	90	90	86
Crops:						
Rice	75	100	100	100	100	95
Vegetables	75	100	100	100	100	95
Orchard	80	80	35	35	60	67

Note: * None owned, therefore none lost

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Table D5
Property Losses in Worst Flash Flood Affecting the Tripura Border Area (%)

Property Type	River/Village				Areal Average
	Juri/ Jahangirai	Manu/ Rainsaf	Dhalai (S)/ Himmati	Karangi/ Himagao	
Belongings:					
Dwellings	9	33	30	25	24
Boats	0	0*	0*	0*	0
Personal	5	50	0	50	26
Stocks:					
Water	90	90	0*	0*	45
Food	5	65	0	40	28
Fuel	25	80	20	50	44
Fodder	100	90	80	60	83
Livestock:					
Buffaloes	0*	0*	0*	0*	0
Cows	0	20	0	0	5
Goats	25	50	5	25	26
Chickens	25	100	30	75	58
Crops:					
Rice	100	100	100	100	100
Vegetables	100	100	100	100	100
Orchard	10	50	50	25	34

Note: * None owned, therefore none lost

Table D6
Events at Bhogai/Nakuagaon during the Flash Flood of 1988

Question 9	About what time of day/night were you aware that there was a flash flood rising in the river ?
Answer 9	About 8 am we noticed a rise in water level.
Question 10	What action did you take based on your awareness (that a flash flood was rising in the river)?
Answer 10	We did not take any particular action.
Question 11	About what time of day/night did you realise that this flood was going to cause serious problems in the village ?
Answer 11	Around 10am the embankment collapsed, and the village was instantly flooded.
Question 12	What actions did you then take based on that realisation ?
Answer 12	Some of us swam to nearby hills, others climbed on tall trees or the roofs of their huts.
Question 13	In what order did you do these actions ?
Answer 13	The only thing in our minds was how to save our lives. We did not have time to take actions in an orderly fashion.
Question 14	Did you have time to take all necessary actions ?
Answer 14	No, none at all.
Question 15	What actions did you not have time to take ?
Answer 15	We lost most of our belongings. If we had had more time we could have saved those.
Question 16	If you had to live through this experience again, what would you do differently ?
Answer 16	If a flood like that (of 1988) strikes again we will run towards the Indian road embankment; it is easier to reach. Since the flood in 1988 we have taken shelter on the hills. Few have come back to their homes near the river. Now the Forestry Department is trying to evict us from the hills.
Question 17	Would you say that the village community as a whole responded appropriately as the flood was rising ?
Answer 17	No, we should have been more cautious when the flood water was rising in the river.
Question 18	Would you say people generally were too slow to realise that this flood posed danger to them ?
Answer 18	Yes, we were too slow
Question 19	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ?
Answer 19	People took actions haphazardly, but who can blame them ? It was a matter of life and death.

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Table D7
Events at Someswari/Bhabanipur during the Flash Flood of 1988

Question 9 Answer 9	About what time of day/night were you aware that there was a flash flood rising in the river ? Around 5pm we noticed a rise in river water level.
Question 10 Answer 10	What action did you take based on your awareness (that a flash flood was rising in the river)? We moved our cows to relatively safer places. We constructed raised platforms inside our huts, and put our belongings on those.
Question 11 Answer 11	About what time of day/night did you realise that this flood was going to cause serious problems in the village ? Around 11pm the water began to rise rapidly.
Question 12 Answer 12	What actions did you then take based on that realisation ? We could hear a deafening sound. People in the village raised the alarm. Fortunately, a motorised country boat was available and we began transporting women and children to high ground. On one of these trips the boat capsized (with the loss of 40 lives).
Question 13 Answer 13	In what order did you do these actions ? We did not act in an orderly fashion. First of all, it was a dark night and a strong gale was blowing. We were frightened by the horrendous sound of the river. Everyone acted on his own. We did not even have time to see if our neighbours were alright.
Question 14 Answer 14	Did you have time to take all necessary actions ? No, there was little time.
Question 15 Answer 15	What actions did you not have time to take ? We escaped with our lives, but most of our belongings were destroyed. If we had had more time we could have saved our belongings.
Question 16 Answer 16	If you had to live through this experience again, what would you do differently ? Our village is frequently flooded. Flood is an event we must live with. If a disastrous flood like the one in 1988 strikes again, we would probably do whatever we did then.
Question 17 Answer 17	Would you say that the village community as a whole responded appropriately as the flood was rising ? We did whatever we could do. Of course, if we had had prior notice we would have been more cautious.
Question 18 Answer 18	Would you say people generally were too slow to realise that this flood posed danger to them ? People did not realise that this flood would be so devastating.
Question 19 Answer 19	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ? People panicked, and acted haphazardly.

Table D8
Events at Jadukata/Maharam during the Flash Flood of 1988

Question 9 **Answer 9**	About what time of day/night were you aware that there was a flash flood rising in the river ? The river swelled a bit in the afternoon, around 5pm.
Question 10 **Answer 10**	What action did you take based on your awareness (that a flash flood was rising in the river)? We did not take any action.
Question 11 **Answer 11**	About what time of day/night did you realise that this flood was going to cause serious problems in the village ? Around 1:30 am we heard a tremendous noise.
Question 12 **Answer 12**	What actions did you then take based on that realisation ? It took only minutes to flood our village after the noise. We escaped to nearby hills as fast as we could.
Question 13 **Answer 13**	In what order did you do these actions ? Only one thing was in our mind. How to escape to the hills with our families.
Question 14 **Answer 14**	Did you have time to take all necessary actions ? Not at all. Most of our properties were lost.
Question 15 **Answer 15**	What actions did you not have time to take ? We could not save our cattle, boats or belongings.
Question 16 **Answer 16**	If you had to live through this experience again, what would you do differently This river is so flashy that there is little we can do. We do not want to go through that experience again. That is why many villagers have permanently left the village.
Question 17 **Answer 17**	Would you say that the village community as a whole responded appropriately as the flood was rising ? Perhaps we should have moved our cattle and belongings to the hills. But we do not know if a flood will cause disaster or not. That is why people do not want to live on low ground.
Question 18 **Answer 18**	Would you say people generally were too slow to realise that this flood posed danger to them ? The flood came late at night, and we were not aware that the river water level was rising to a dangerous level.
Question 19 **Answer 19**	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ? There was no time for taking actions in an orderly fashion. We did not even have time to see if our neighbours were alive or not.

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Table D9
Events at Dhalai(N)/Chilabhanga during the Flash Flood of 1973

Question 9 **Answer 9**	About what time of day/night were you aware that there was a flash flood rising in the river ? About 2pm the river water level began to rise.
Question 10 **Answer 10**	What action did you take based on your awareness (that a flash flood was rising in the river)? We took some protective measures such as constructing raised platforms inside our huts, and putting our belongings on it. We expected a flood as we could see the rain falling in the Indian hills. As night fell, we kept watching the river.
Question 11 **Answer 11**	About what time of day/night did you realise that this flood was going to cause serious problems in the village ? Around 8pm river water began to enter the village. A strong gale was blowing. We realised that a dangerous flood was about to strike our village.
Question 12 **Answer 12**	What actions did you then take based on that realisation ? It did not take much time to flood the village. We were very frightened. Some of us climbed on the raised platforms we had constructed inside our huts. Some of us took shelter in the Government buildings. We also tried to save our cattle and boats.
Question 13 **Answer 13**	In what order did you do these actions ? There was no order in our actions. Every family tried to fend for itself in whatever way seemed appropriate.
Question 14 **Answer 14**	Did you have time to take all necessary actions ? No, we lost cattle, utensils and other belongings.
Question 15 **Answer 15**	What actions did you not have time to take ? We did not have time to drive our cattle to safe places. We also lost some boats.
Question 16 **Answer 16**	If you had to live through this experience again, what would you do differently ? We probably would act in the same manner.
Question 17 **Answer 17**	Would you say that the village community as a whole responded appropriately as the flood was rising ? Under the circumstances we think we acted appropriately.
Question 18 **Answer 18**	Would you say people generally were too slow to realise that this flood posed danger to them ? No, we expected a flood
Question 19 **Answer 19**	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ? We had to act very fast, so it was a bit haphazard.

Table D10
Events at Shari/Kamrangi during the Flash Flood of 1988

Question 9 **Answer 9**	About what time of day/night were you aware that there was a flash flood rising in the river ? The water began to rise around midnight
Question 10 **Answer 10**	What action did you take based on your awareness (that a flash flood was rising in the river)? We packed our belongings, and woke up those who were sleeping.
Question 11 **Answer 11**	About what time of day/night did you realise that this flood was going to cause serious problems in the village ? Flood water entered the village rather quickly, within in an hour of the rise in river water level (we had noticed earlier).
Question 12 **Answer 12**	What actions did you then take based on that realisation ? We grabbed whatever belongings we could, and ran for safe ground.
Question 13 **Answer 13**	In what order did you do these actions ? There was no particular order. Everyone acted differently.
Question 14 **Answer 14**	Did you have time to take all necessary actions ? No, there was very little time.
Question 15 **Answer 15**	What actions did you not have time to take ? We did not have time to move our cattle to high places.
Question 16 **Answer 16**	If you had to live through this experience again, what would you do differently ? We would have moved our cattle to safe places.
Question 17 **Answer 17**	Would you say that the village community as a whole responded appropriately as the flood was rising ? When the flood came we lost our senses. Everyone ran for his life.
Question 18 **Answer 18**	Would you say people generally were too slow to realise that this flood posed danger to them ? It was night, and we really could not guess the disaster the flood was bringing. Things happened very fast.
Question 19 **Answer 19**	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ? Panic set in, and people acted haphazardly.

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Table D11
Events at Juri/Jahangirai during the Flash Flood of 1993

Question 9	About what time of day/night were you aware that there was a flash flood rising in the river ?
Answer 9	Around 4am the water began to rise.
Question 10	What action did you take based on your awareness (that a flash flood was rising in the river)?
Answer 10	We did not take any actions.
Question 11	About what time of day/night did you realise that this flood was going to cause serious problems in the village ?
Answer 11	By 5am the water swelled and entered huts.
Question 12	What actions did you then take based on that realisation ?
Answer 12	People raised a hue and cry, started packing up whatever it was possible to bring along, and took shelter on the railroad embankment and on the highway. Cows were driven to high ground. After making sure that everybody was safe, and whatever could be saved, saved, people started building little huts with bamboo stalks and polythene paper to protect themselves from the rain. Some moved to other villages, together with their cattle.
Question 13	In what order did you do these actions ?
Answer 13	(See Answer 12).
Question 14	Did you have time to take all necessary actions ?
Answer 14	Yes, we had enough time.
Question 15	What actions did you not have time to take ?
Answer 15	If we had had more time, we could have saved more items.
Question 16	If you had to live through this experience again, what would you do differently ?
Answer 16	Nothing (i.e we would have done nothing differently).
Question 17	Would you say that the village community as a whole responded appropriately as the flood was rising ?
Answer 17	Everybody acted as he thought best. There was no coordinated effort.
Question 18	Would you say people generally were too slow to realise that this flood posed danger to them ?
Answer 18	No
Question 19	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ?
Answer 19	Villagers panicked, and acted haphazardly.

Table D12
Events at Manu/Rainsaf during the Flash Flood of 1993

Question 9 **Answer 9**	About what time of day/night were you aware that there was a flash flood rising in the river ? Around 4pm we noticed a rise in river water level.
Question 10 **Answer 10**	What action did you take based on your awareness (that a flash flood was rising in the river)? We drove the cows to high ground. Some constructed platforms inside their huts, and put their belongings on there.
Question 11 **Answer 11**	About what time of day/night did you realise that this flood was going to cause serious problems in the village ? Around 7pm the river swelled very much, and the embankment started to give way.
Question 12 **Answer 12**	What actions did you then take based on that realisation ? When the embankment breached, water entered the village. We started to run for safety. Some climbed on roofs, others headed for the railway embankment.
Question 13 **Answer 13**	In what order did you do these actions ? There was no order.
Question 14 **Answer 14**	Did you have time to take all necessary actions ? No, we could not save our properties.
Question 15 **Answer 15**	What actions did you not have time to take ? We could not remove food stocks, or even valuables from our houses. Some of us lost cattle.
Question 16 **Answer 16**	If you had to live through this experience again, what would you do differently ? Floods come here every year, and we have to suffer. Sometimes we suffer a lot, and sometimes little. We have to live with it.
Question 17 **Answer 17**	Would you say that the village community as a whole responded appropriately as the flood was rising ? If we had known it would cause such devastation we would have taken our cattle and valuables to safe places, but we had no idea that the flood would be so ferocious.
Question 18 **Answer 18**	Would you say people generally were too slow to realise that this flood posed danger to them ? One cannot really predict what this river will like an hour later. When we realise that the river water level is getting too high, it is usually too late (to do anything).
Question 19 **Answer 19**	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ? The villagers panicked.

Table D13
Events at Dhalai(S)/Hiramati-Saisiri during the Flash Flood of 1993

Question 9	About what time of day/night were you aware that there was a flash flood rising in the river ?
Answer 9	Around 3pm the river water began to rise.
Question 10	What action did you take based on your awareness (that a flash flood was rising in the river)?
Answer 10	Some constructed raised platforms inside their huts, and put their belongings on it. Others packed their belongings.
Question 11	About what time of day/night did you realise that this flood was going to cause serious problems in the village ?
Answer 11	About 4pm water broke through the embankment inundating the village almost instantly.
Question 12	What actions did you then take based on that realisation ?
Answer 12	There was little to do except flee from the village with their belongings. People had to swim or wade to high ground.
Question 13	In what order did you do these actions ?
Answer 13	People simply ran for their lives.
Question 14	Did you have time to take all necessary actions ?
Answer 14	No.
Question 15	What actions did you not have time to take ?
Answer 15	We had to suffer much while escaping from the village. Fortunately, the cows were able to swim to high ground, otherwise they would have been lost. If we had had time we would have left our village before the water entered it.
Question 16	If you had to live through this experience again, what would you do differently ?
Answer 16	Reaching high ground from our village is most difficult. Swimming in flood water is terrifying. We would try to get some boats if we have to live through it again.
Question 17	Would you say that the village community as a whole responded appropriately as the flood was rising ?
Answer 17	Well, we did what we could. What else could we do ?
Question 18	Would you say people generally were too slow to realise that this flood posed danger to them ?
Answer 18	As we told you the flood came because of a breach in the embankment. We had no idea it would break.
Question 19	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ?
Answer 19	Panic seized us. It was total mayhem.

Table D14
Events at Karangi/Himagao during the Flash Flood of 1993

Question 9	About what time of day/night were you aware that there was a flash flood rising in the river ?
Answer 9	Around 11pm we heard a tremendous sound made by the river. It was the first indication of a flood. Then we could hear the river banging on the railway bridge.
Question 10	What action did you take based on your awareness (that a flash flood was rising in the river)?
Answer 10	People raised a cry. The embankment broke, and water entered the village. People fled from the village.
Question 11	About what time of day/night did you realise that this flood was going to cause serious problems in the village ?
Answer 11	Things happened very fast. The noise alarmed us. Before we could realise the ferocity of this years flood, water was already entering our village.
Question 12	What actions did you then take based on that realisation ?
Answer 12	We simply fled to higher ground with whatever things we could take with us.
Question 13	In what order did you do these actions ?
Answer 13	There was no order at all. Everybody acted on his reflex.
Question 14	Did you have time to take all necessary actions ?
Answer 14	No
Question 15	What actions did you not have time to take ?
Answer 15	If we had had time we could have saved our property. We lost goats and food grain.
Question 16	If you had to live through this experience again, what would you do differently ?
Answer 16	We probably would not act differently. Floods come every year; sometimes they are mild, sometimes devastating. We have to live with it.
Question 17	Would you say that the village community as a whole responded appropriately as the flood was rising ?
Answer 17	The flood came at night. By the time we realised there was a flood, there was little we could do.
Question 18	Would you say people generally were too slow to realise that this flood posed danger to them ?
Answer 18	We had no idea we would be hit by such a severe flood.
Question 19	Would you say people generally took the important actions first, or did they panic and take actions haphazardly ?
Answer 19	Panic seized us, and we acted haphazardly.

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Table D15

Times of First Awareness of Flash Flood and of Recognition of Danger

River	Village	Times		Time Difference (hrs)
		First Awareness	Recognition of Danger	
MEGHALAYA BORDER AREA				
Bhogai	Nakuagaon	8am	10am	2
Someswari	Bhabanipur	5pm	11pm	6
Jadukata	Maharam	5pm	1am	8
Dhalai (N)	Chilabhanga	2pm	8pm	6
Shari	Kamrangi	Midnight	1am	1
TRIPURA BORDER AREA				
Juri	Jahangirai	4am	5am	1
Manu	Rainsaf	4pm	7pm	3
Dhalai (S)	Hiramati	3pm	4pm	1
Karangi	Himagao	11pm	11pm	0

Table B16

Precautionary Actions Taken and Indicators of Danger Observed

River	Village	Precautionary Actions Taken	Indicators of Danger Observed	Note
MEGHALAYA BORDER AREA				
Bhogai	Nakuagaon	None	Embankment collapse water entering village	
Someswari	Bhabanipur	Some Did not leave home	"Deafening sound" Embankment collapse Water entering the village	
Jadukata	Maharam	None	"Tremendous noise" Water entering the village	(1)
Dhalai (N)	Chilabhanga	Some Watch on river	Rainfall seen in the hills Water entering the village	(1)
Shari	Kamrangi	Some	Water entering the village	(1)
TRIPURA BORDER AREA				
Juri	Jahangirai	None	Water entering the village	(1)
Manu	Rainsaf	Some Did not leave home	Embankment collapse Water entering the village	
Dhalai (S)	Himmati	Some Did not leave home	Embankment collapse Water entering the village	
Karangi	Himagao	None	"Tremendous noise" River "banging" on bridge Embankment collapse Water entering the village	(2)

Table D17

Desire of Bhogai/Nakuagaon Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Yes d) Losses would have been minimised e) No, it is not possible to save crops
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Yes, we would welcome such an agency.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	We feel strongly that it would.

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Table D18
Desire of Someswari/Bhanipur Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Yes d) Yes e) No, crops cannot be saved from flash flood
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Villagers would welcome timely warnings
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	Villagers strongly feel that it would

Table D19

Desire of Jadukata/Maharam Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Not applicable (No lives were lost in the worst flood). d) Damages and losses (to property) could be minimised. e) No, crops cannot be saved.
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Yes, we would welcome such agency.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	We feel strongly that a warning system would greatly help us.

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Table D20

Desire of Dhalai (N)/Chilabhanga Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Maybe c) Not applicable (No lives were lost in the worst flood). d) There will always be some loss. e) Crops cannot be saved in case of flood.
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	No, we do not need early warnings. Whenever it rains heavily in the mountains across the border we have a flood situation here. We can see the rainfall clearly from our village. We do not think an early warning system would help us much. **Note:** 1) This is the only village where people did not welcome an early warning system. 2) The villagers suggested that instead of spending money on an early warning system, we should dredge the river. Only that would bring relief to this village.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	(Question not asked in view of answer to Question 21).

Table D21
Desire of Shari/Kamrangi Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Yes d) Some loss of property in unavoidable e) No, crops cannot be saved.
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Yes, we would welcome an early warning system.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	We feel strongly that such warnings would help us.

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Table D22
Desire of Juri/Jahangirai Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Yes d) Yes e) No, crops cannot be saved on short notice.
Question 20	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Villagers would welcome timely warnings.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	Villagers strongly feel that a warning system would be helpful.

Table D23

Desire of Manu/Rainsaf Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Yes d) Some loss is unavoidable. e) Crops cannot be saved.
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Yes, we would welcome such an agency.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	We feel strongly that it would.

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Table D24
Desire of Dhalai (S)/ Hirmati-Saisiri Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Not applicable (No lives were lost in worst flood). d) Yes e) No, it is not possible to save crops on short notice.
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Yes, we would welcome such an effort.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	We strongly believe it would help us.

Table D25
Desire of Karangi/Himagao Villagers for a Flash Flood Warning System

Question 20	Do you think that if some external agency had raised the alarm (during the worst flood) that people would have: a) taken notice of the alarm and initiated protective measures? b) had time to complete all necessary measures? c) suffered no losses of lives? d) suffered no losses of, or damages to, properties? e) suffered no losses of, or damages to, crops?
Answer 20	a) Yes b) Yes c) Not applicable (No lives were lost in worst flood) d) Some losses are unavoidable. e) Crops cannot be saved in short time.
Question 21	Would you say that the people of this village would welcome an external agency providing them with clear and timely warnings of imminent flash floods ?
Answer 21	Yes, we would welcome such agency.
Question 22	How strongly do you feel that a flash flood warning would enable the people of this village to avoid or reduce the losses and damages which flash floods cause in this village ?
Answer 22	Maybe

Table D26
Flash Flood Warning System Requirements of Bhogai/Nakuagaon Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water levels less than the top of the embankment are not dangerous. b) Water levels close to the top of the embankment pose a threat. c) Water levels higher than the top of the embankment would cause serious damage.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes, we would be able to distinguish.
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We would remove women, children and elderly people to the hills. We would also move valuables and cattle. Second Level Warning: We (the men) would leave home immediately.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	We do not think everybody has to move out in case of a first warning - only women, children and old people should go. The rest of us can wait until the second level warning is given.

Table D27
Flash Flood Warning System Requirements of Someswari/Bhabanipur Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water levels up to embankment top level pose no problem. b) Water level 0.3m above the embankment top poses a threat. c) Water level more than 0.3m above the embankment top poses a serious threat.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes, they would like to be warned in advance
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes.
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We would make sure everybody is aware of the danger, move cattle to a safer place, transport old/sick people, women children and valuables to a safe place. Second Level Warning: We (the men) would leave home immediately
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	Able-bodied adults can wait until the second level warning before leaving home.

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Table D28
Flash Flood Warning System Requirements of Jadukata/Maharam Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water levels less than the natural river bank pose no threat; this is about 9m PWD (on the BWDB river gauge at nearby Lorerghar). b) Water levels of about 10m PWD pose a threat. c) Water levels of more than 10m PWD would cause serious danger.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes, we would like to be warned.
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We should move our cattle and belongings to the hills at the first warning. It would be best to evacuate all people to the hills also (at this time). Second Level Warning: One should not wait for the second warning.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	One should not wait for the second warning.

Table D29
Flash Flood Warning System Requirements of Dhalai (N)/Chilabhanga Villagers

Note: Questions 23 to 29 were not asked of this village in view of the antipathy expressed towards a flood warning system.

Table D30
Flash Flood Warning System Requirements of Shari/Kamrangi Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water levels up to the top of the embankment pose no danger. b) Water levels 0.3m or less on the top of the embankment pose some danger. c) Water levels 0.6m or more above the embankment top cause serious damage.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes, villagers would like to be warned.
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We will stay at home but keep vigil. We will drive our cattle to high ground and tie our boats securely. Second Level Warning: We will leave our houses and take shelter on high places.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 28	One should not wait for the second warning.

Table D31
Flash Flood Warning System Requirements of Juri/Jahangirai Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water levels up to 9.5m PWD (on the BWDB Juri river gauge) pose no threat. b) Water levels above 10m PWD (embankment level) pose a threat. c) Water levels above 11m PWD would cause complete disaster.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes, they would like to be warned in advance.
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We would wake up family members, make sure everyone knows about the danger, pack up removable possessions, take cattle to high ground, harness boats securely, and be ready to move out of the house on short notice if things got worse. Second Level Warning: We would leave the house immediately and take shelter on high ground.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	No, it is better to be on safer place as soon as possible.

Table D32

Flash Flood Warning System Requirements of Manu/Rainsaf Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water level lower than the natural bank poses no threat. b) Water level close to the top of the embankment poses a threat. c) Water level higher than the top of the embankment is dangerous.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We would drive cattle to safe ground, construct platforms (inside the house ?), evacuate old/sick people and children, and pack up belongings. Second Level Warning: We would leave the village immediately.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	Yes, one should wait for the second warning.

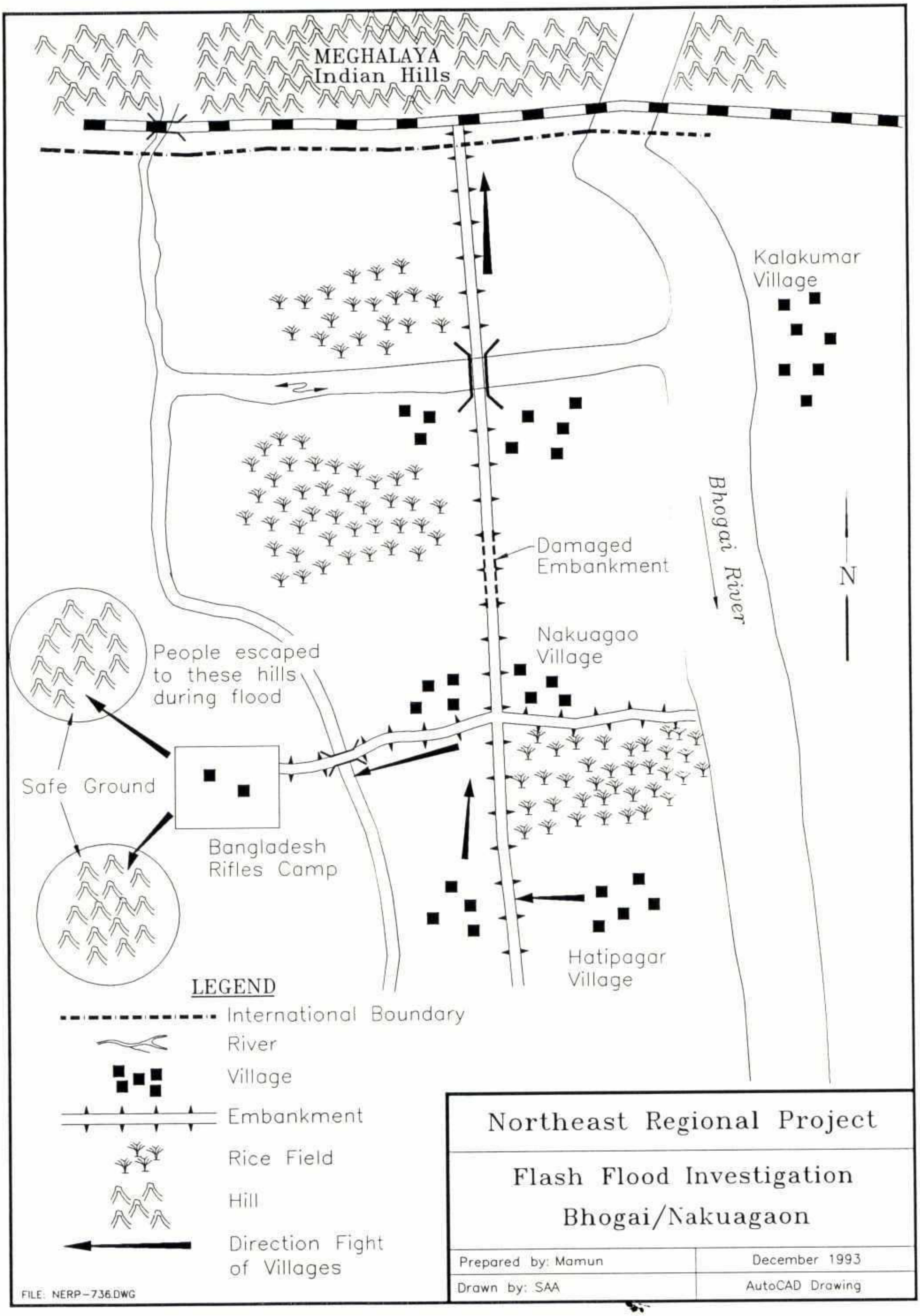
Table D33
Flash Flood Warning System Requirements of Dhalai(S)/Hiramati-Saisiri Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water level 1m (or more) below embankment poses no danger. b) Water level close to top of the embankment is dangerous. c) If water level rises further disaster will strike.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes, we want to be warned.
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We would first see if the embankment needs to be raised or strengthened at any point. We would mend the embankment if necessary. Next, we would pack up our removable belongings, and drive our cattle to high ground. Second Level Warning: We would leave our houses and take shelter on the hills in the tea estates.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	If there are sick or old people or children in our homes we can send them to the hills before the second warning. Able-bodied adults do not need to leave their houses before the second warning.

Table D34
Flash Flood Warning System Requirements of Karangi/Himagao Villagers

Question 23	What water levels in the river passing this village would you consider to present to the people and their property: a) no danger b) serious danger c) a disaster
Answer 23	a) Water levels less than the crest of the embankment are safe. b) Water levels close to the top of embankment are threatening. c) Water levels higher than the embankment crest pose a serious danger.
Question 24	Do you think the villagers would want to be warned several hours in advance that the river water level will pass the critical levels separating these three conditions?
Answer 24	Yes
Question 25	Do you think the villagers would respond to such warnings by carrying out a planned sequence of appropriate protective measures ?
Answer 25	Yes
Question 26	Do you think that such audio/visual means of communicating the warning would be readily understood by : a) Adults ? b) Children ?
Answer 26	a) Yes b) Yes
Question 27	Do you think adults, at least, would be able to discriminate between the first level of danger signal and the second ?
Answer 27	Yes
Question 28	Which actions do you think ought to be taken on the first warning, and which actions do you think could wait until the second warning comes ?
Answer 28	First Level Warning: We would put our belongings on raised platforms (inside our huts ?) Second Level Warning: We would leave home.
Question 29	Do you think it wise to wait for the second warning before starting the second group of actions ?
Answer 29	We will not leave home until the second level warning is issued.

Figure D1



MEGHALAYA
Indian Hills
Kalakumar Village
Bhogai River
N
Damaged Embankment
Nakuagao Village
People escaped to these hills during flood
Safe Ground
Bangladesh Rifles Camp
Hatipagar Village
LEGEND
International Boundary
River
Village
Embankment
Rice Field
Hill
Direction Fight of Villages
Northeast Regional Project
Flash Flood Investigation
Bhogai/Nakuagaon
Prepared by: Mamun
December 1993
Drawn by: SAA
AutoCAD Drawing
FILE: NERP-736.DWG

Figure D2

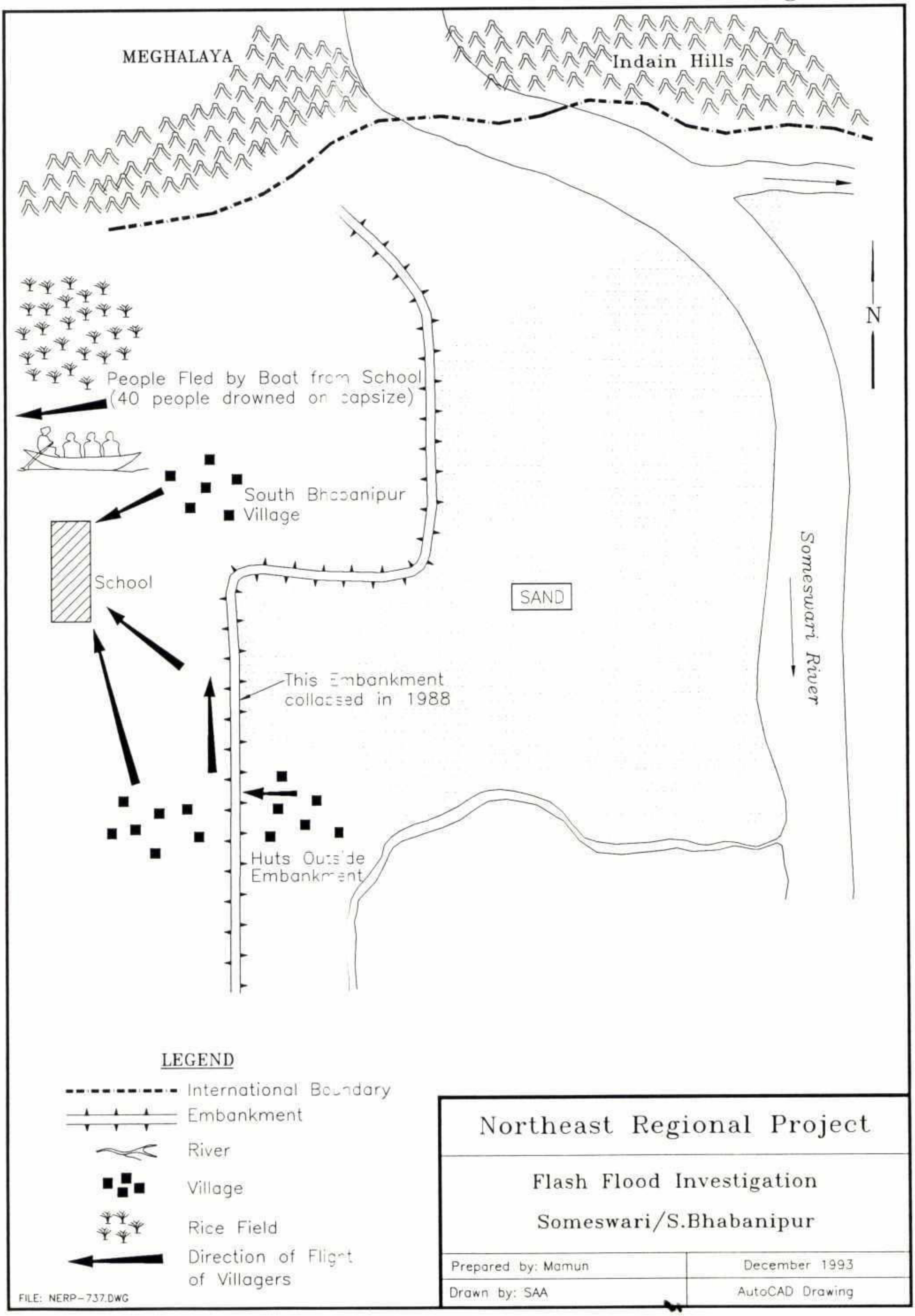

MEGHALAYA
Indain Hills
People Fled by Boat from School
(40 people drowned on capsize)
South Bhabanipur
Village
School
SAND
This Embankment
collapsed in 1988
Huts Outside
Embankment
Someswari River
N
LEGEND
International Boundary
Embankment
River
Village
Rice Field
Direction of Flight
of Villagers
FILE: NERP-737.DWG
Northeast Regional Project
Flash Flood Investigation
Someswari/S.Bhabanipur
Prepared by: Mamun
December 1993
Drawn by: SAA
AutoCAD Drawing

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Figure D3

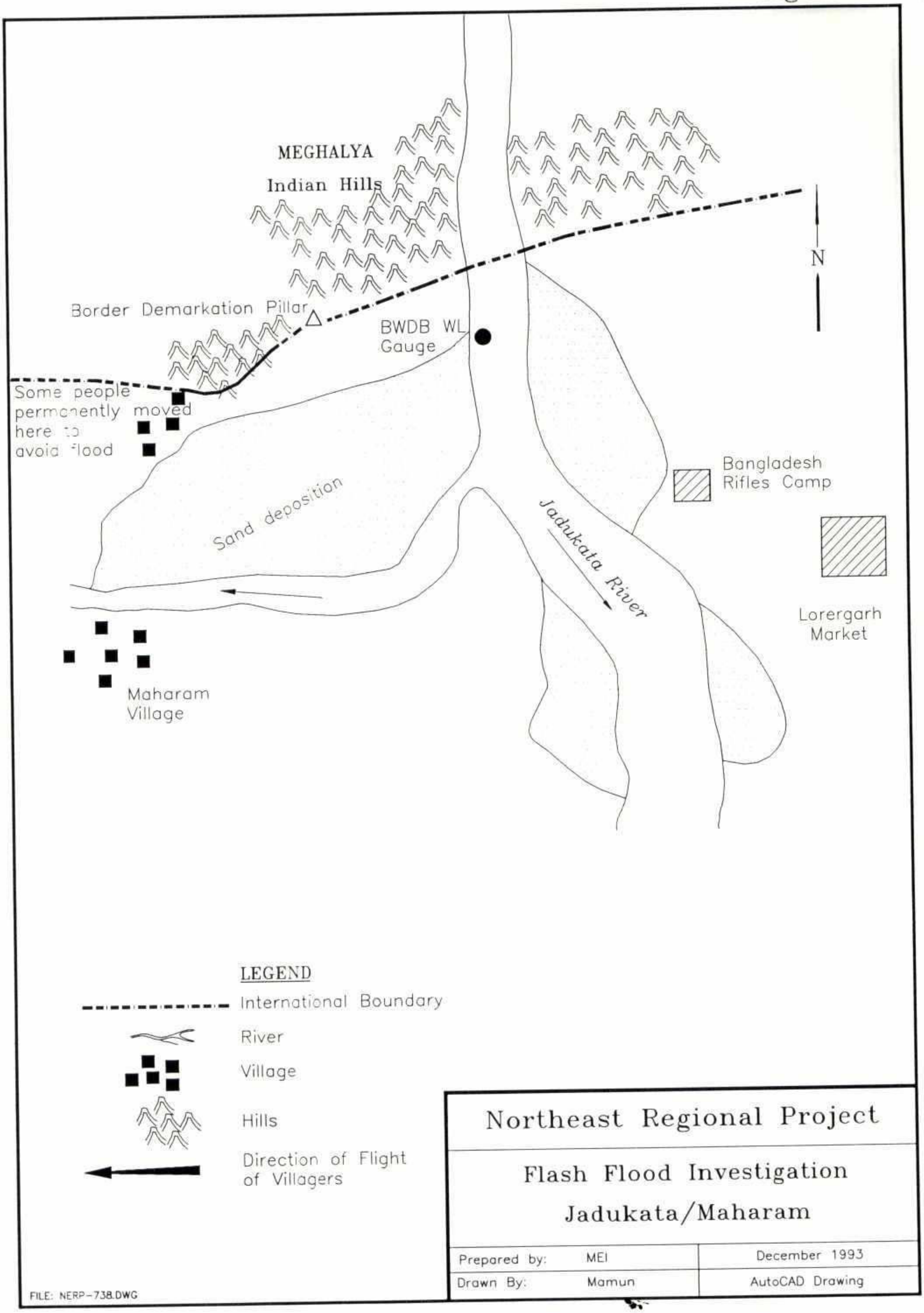
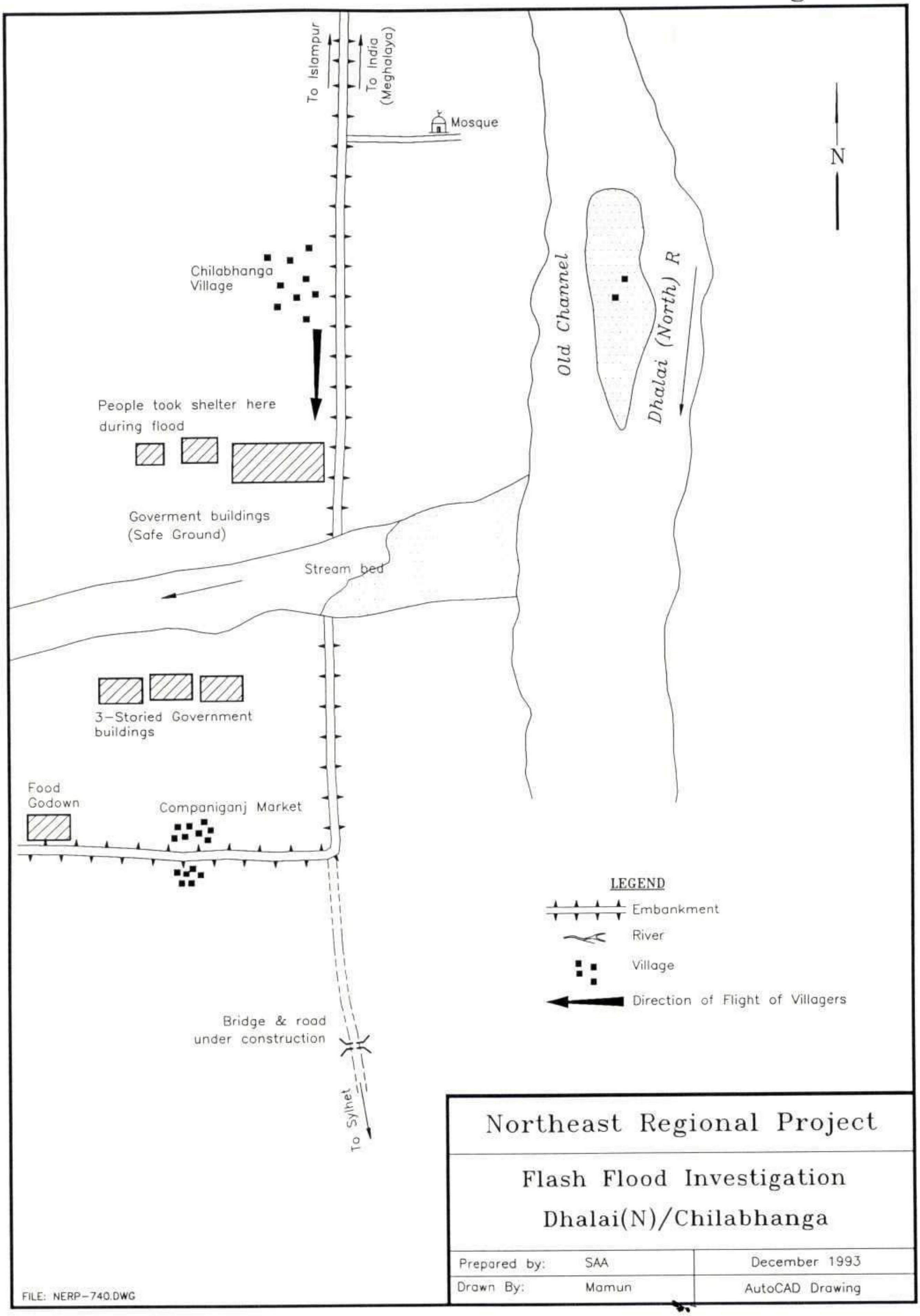
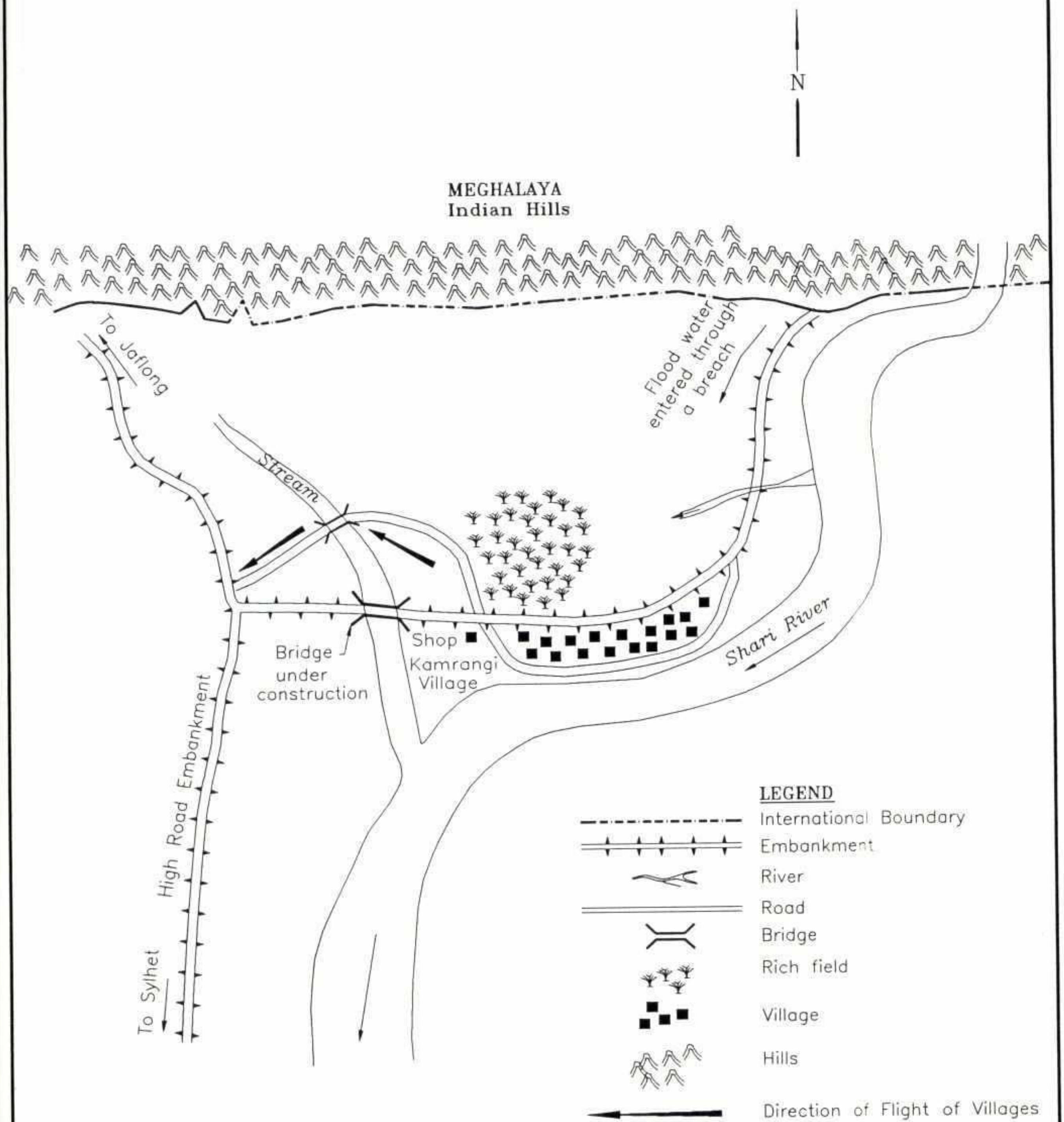


Figure D4



To Islampur
To India (Meghalaya)
Mosque
N
Chilabhanga Village
Old Channel
Dhalai (North) R
People took shelter here during flood
Goverment buildings (Safe Ground)
Stream bed
3-Storied Government buildings
Food Godown
Companiganj Market
LEGEND
Embankment
River
Village
Direction of Flight of Villagers
Bridge & road under construction
To Sylhet
Northeast Regional Project
Flash Flood Investigation
Dhalai(N)/Chilabhanga
Prepared by: SAA
December 1993
Drawn By: Mamun
AutoCAD Drawing
FILE: NERP-740.DWG

Figure D5



Northeast Regional Project

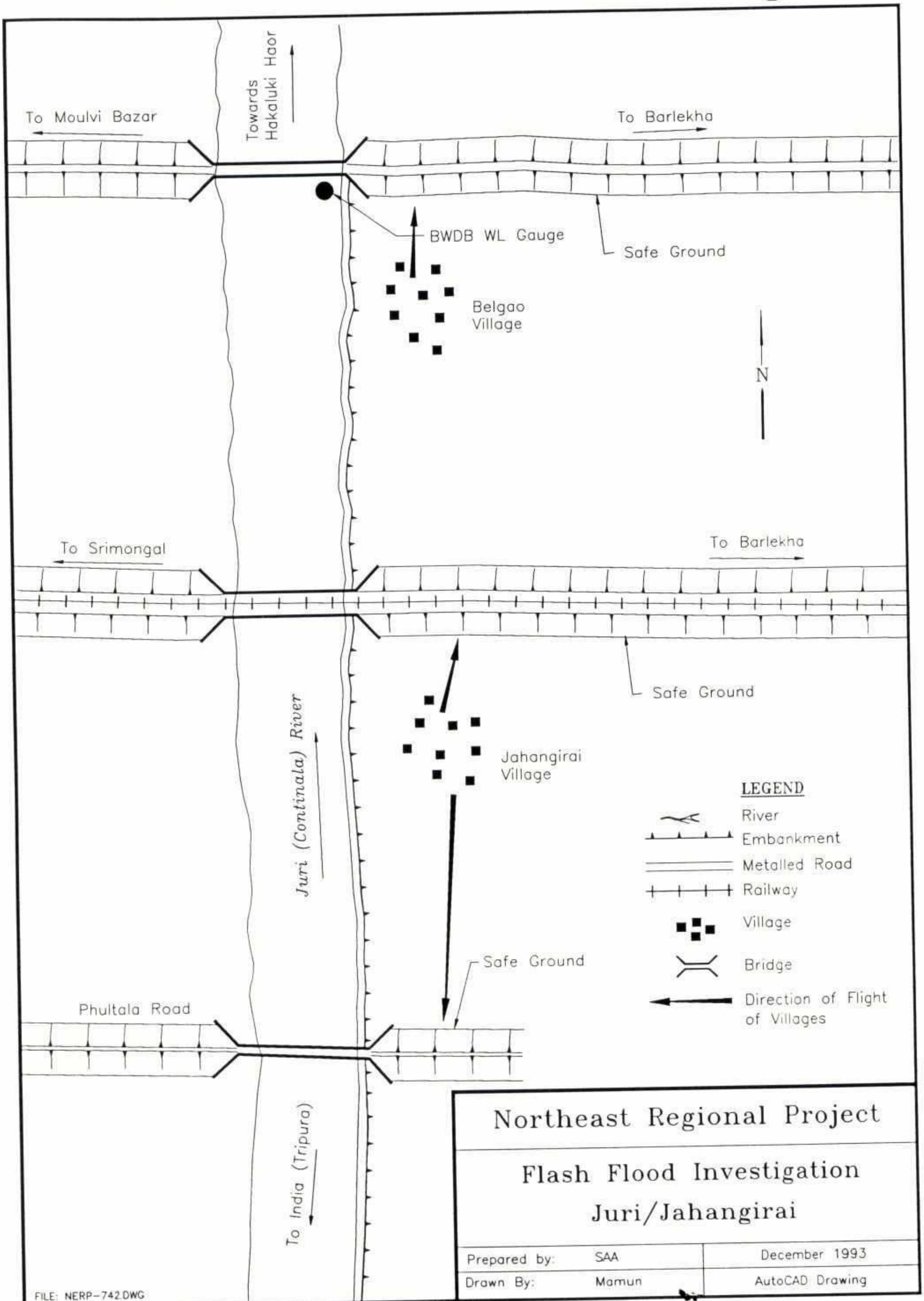
Flash Flood Investigation

Shari/North Kamrangi

Prepared by:	SSA	December 1993
Drawn By:	Mamun	AutoCAD Drawing

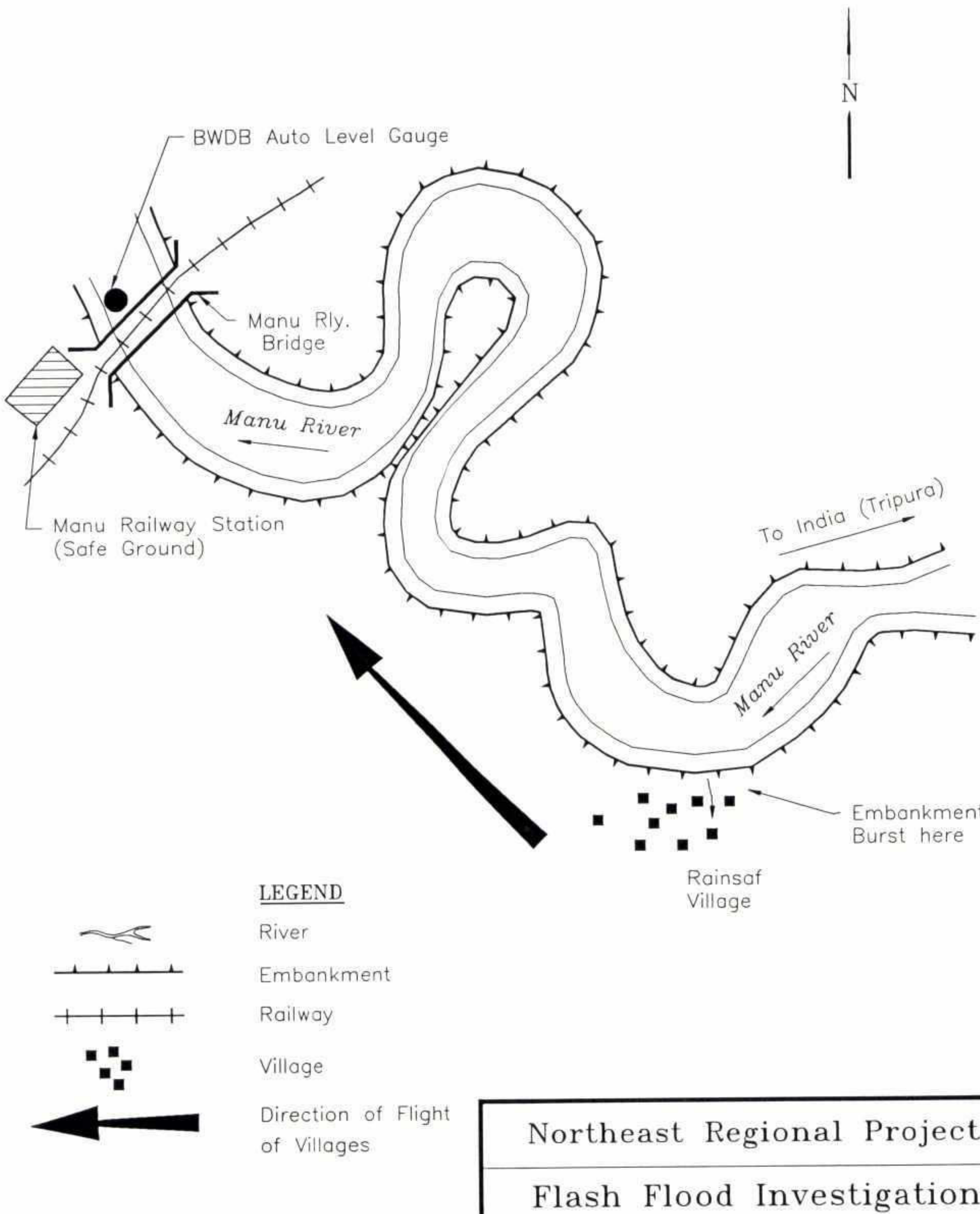
FILE: NERP-741.DWG

Figure D6



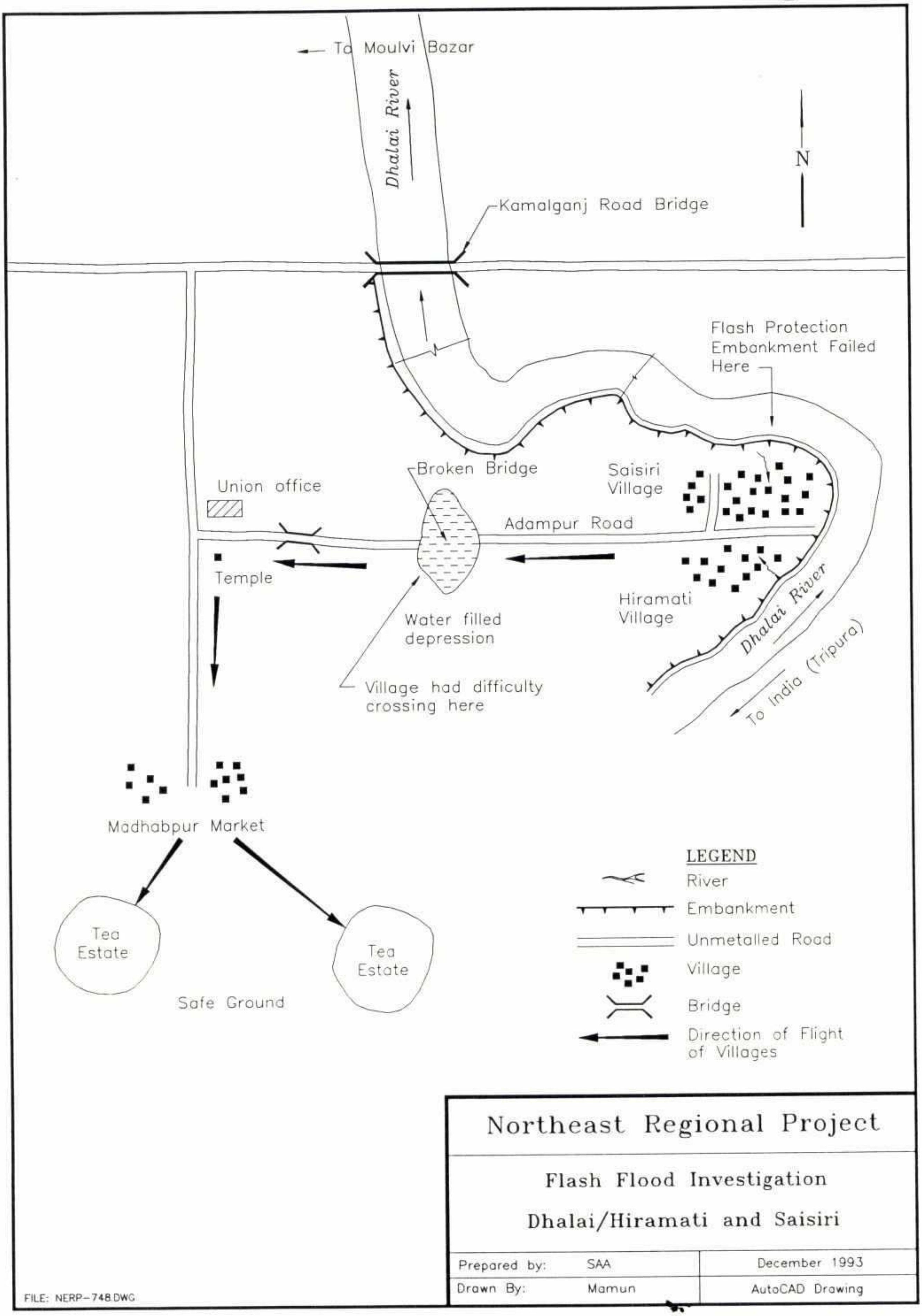
To Moulvi Bazar
Towards Hakaluki Haor
To Barlekha
BWDB WL Gauge
Safe Ground
Belgao Village
N
To Srimongal
To Barlekha
Safe Ground
Juri (Continala) River
Jahangirai Village
LEGEND
River
Embankment
Metalled Road
Railway
Village
Bridge
Direction of Flight of Villages
Safe Ground
Phultala Road
To India (Tripura)
Northeast Regional Project
Flash Flood Investigation
Juri/Jahangirai
Prepared by: SAA
December 1993
Drawn By: Mamun
AutoCAD Drawing
FILE: NERP-742.DWG

Figure D7



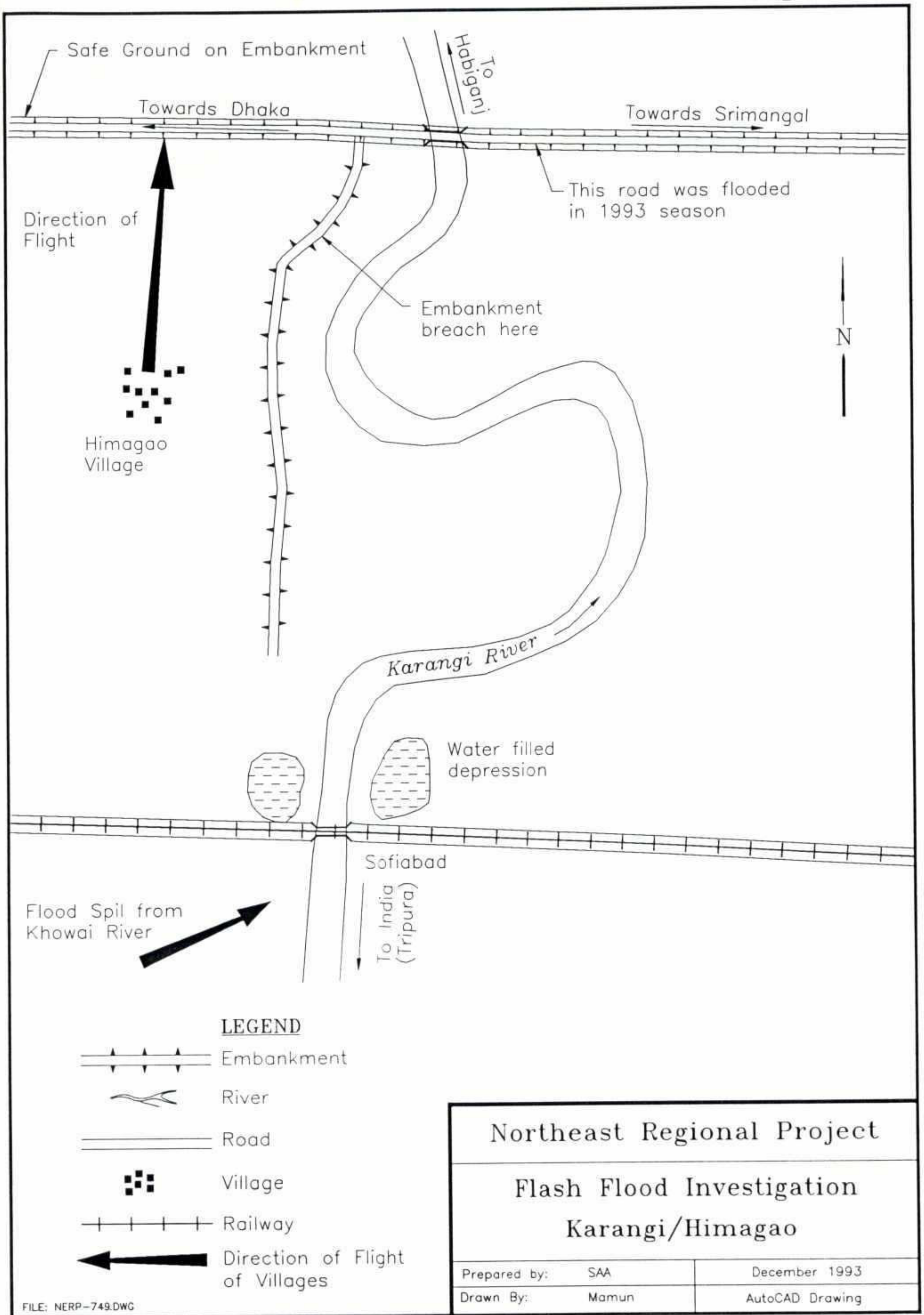
Northeast Regional Project			
Flash Flood Investigation Manu/Rainsaf			
Prepared by:	SAA	December 1993	
Drawn By:	Mamun	AutoCAD Drawing	

FILE: NERP-747.DWG



Northeast Regional Project	
Flash Flood Investigation Dhalai/Hiramati and Saisiri	
Prepared by: SAA	December 1993
Drawn By: Mamun	AutoCAD Drawing

Figure D9



Northeast Regional Project			
Flash Flood Investigation Karangi/Himagao			
Prepared by:	SAA	December 1993	
Drawn By:	Mamun	AutoCAD Drawing	

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ANNEX E

OUTLINE OF ELECTRICAL SYSTEM

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ANNEX E
OUTLINE OF ELECTRICAL SYSTEM

E1 Introduction

The flood warning system is basically an electrical engineering system, an outline of which is given in this annex.

E1.1 System Components and Staffing

It is envisaged that a flood warning system for a single flash flood-prone river will consist of:

1) Two detector stations located at or near the Indo-Bangladesh border, one a rainfall detector station or "observation post", the other a river water level recorder/detector station.

2) Several (typically five) identical warning stations located at 5 km intervals along the river.

Ideally, the two detector stations will be located close to each other for ease of operations but, in general, they may be several kilometers apart as in the case of the Juri River; the observation post needs to be on top of a fairly high hill, but the river water level station has to be in the river channel. The structural layout of the system is shown in Figure 11.

The observation post will be manned continuously by three technicians each working an 8 hour shift. The technician on duty will be responsible for:

1) Observing the weather over the river catchment area.

2) Monitoring satisfactory operation of the warning system.

3) Rectifying any fault at the detector or warning stations.

If a fault develops at any of the stations the technician on duty will notify the two off-duty technicians to go to the station and rectify the fault. The three technicians will be required to reside at the observation post, and they must have a jeep at their disposal at all times for maintenance and fault rectification at any of the stations in their system.

One supervisor (electrical technologist) will be required to monitor the satisfactory operation of all flood warning systems in the Northeast Region, to organize major repairs at both detector and warning stations, implement system modifications, obtain spare parts, provide technical training to duty technicians etc. He also must have a jeep at his disposal at all times for work purposes.

E2 Warning and Signal Requirements

The system will give two warnings during each flash flood event to people living in riverside communities along the river as far as its confluence with one of the Region's major rivers:

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First Warning

The first warning will be based on the duty technician's observation of weather conditions likely to cause a flash flood. The purpose of this warning is give the people time to round up their family members and livestock, and *prepare* to move them to safe ground.

Second Warning

The second warning will be based on automatic detection of a dangerous river water level at the border. The purpose of this warning is to confirm to the people that a dangerous flood is definitely coming, and to advise them to *leave* their village for safe ground.

The warnings will be communicated to the people by both audio and visual signals emanating from the warning stations as follows:

First Warning

A siren will *yelp*, first for half an hour, and then for five minutes every half hour thereafter until either the second warning signal is given or the all clear is indicated by cessation of the yelping.

Throughout the duration of the first warning a beacon will also flash *yellow* continuously.

Second Warning

A siren will *wail*, first for half an hour, and then for five minutes every half hour thereafter until the all clear is indicated by cessation of the wailing.

Throughout the duration of the second warning a beacon will also flash *red* continuously.

At each warning station the siren and beacon will be mounted on top of a 20 m high guyed mast to ensure optimum audibility and visibility.

The electrical system of the flood warning system described below is designed to achieve these warning signal requirements.

E3 System Alternatives and Modifications

The external circuitry is designed for solar powered radio communication between the detector and warning stations, but is easily adaptable for main's power and underground cable communication.

The electrical system is based on components known to be available through local (Dhaka) suppliers, and can be installed by local electrical engineers and technicians. Variations in the components will necessitate minor changes in the external circuitry, but these can easily be made on site by the installing electrical engineer.

The following notes relate primarily to a solar powered radio communication system because at most locations where this flood warning system may be installed, main's power will not be available, and because radio communication will be less expensive than cable communication. Later sections of these notes outline modifications needed to the solar powered radio communication system if mains power or cable communication are preferred for reasons of availability or reliability.

E3.1 Circuit Diagrams

External circuit diagrams are shown in five drawings, Figures 12 to 16, the first of which provides a legend of symbols used in the other drawings. Table E1 presents a list of component labels used both in the drawings and in the text. The drawings relate to two variants of the system:

1) Solar powered radio communication system

2) Solar powered cable communication system

The first of these variants (1) offers comparative ease of installation, and is the least costly one. The second variant offers marginally greater reliability but at about 5% extra cost.

Table E2 presents a list of electrical equipment considered suitable for use in the flood warning system.

E4 Solar Powered Radio Communication System

A solar powered radio communication system is proposed. The external circuitry for this variant is shown in Figures 13, 14, and 15.

E4.1 Key Components

The key components of this variant are as follows:

1) Water Level Detector

2) Radio Transmitter/Receiver

3) Sirens

4) Beacons

The water level detector is located at the detector station, and the sirens and beacons at the warning stations. Radios are located both at the detector station (RDI) and at each warning station (RD2).

E4.1.1 Water Level Detector (M-Scope)

Detection of the dangerous water level, which will trigger the more important second warning signal, will be made by a water level detector located in a suitable stilling well constructed at the river bank close to the detector station.

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In the design an electronic type water level indicator, similar to an hydrogeologist's M-Scope, is proposed. Float-actuated water level indicators are definitely *not* suitable for this flood warning system.

Such M-Scopes are supplied complete with a reel, and several metres of coaxial cable which must not be shortened or lengthened during installation; such action will affect the resistance of the instrument, and so put reliable operation at risk. The M-Scope must be connected directly to the radio communication system located in the detector station building.

E4.1.2 Radio Transmitter & Receiver

For the flood warning system radio communication between the detector and warning stations is preferred to overhead line communication which may be affected by adverse weather conditions, floods, etc. In the present design Anritsu Corporation Type SS120A radios are proposed, but the external circuit is arranged so that any other simple radio with a morse code button could be used.

With the present circuit arrangement the radio is capable of transmitting three distinct signals which are used to denote rainfall, dangerous flood level, and termination of the flood warning.

Nowadays many companies are producing radios with a built-in alarm system having sensors for smoke, fire, light, temperature, etc. Such radios can also be used with this design, but with a minor change in the external circuit which can be made on site by the installing electrical engineer according to the type of radio supplied.

E4.1.3 Sirens

In this design the Apollo Company electronic dual sound system siren is proposed. This siren has a directional character so one siren cannot cover a 360 degree sector. For this reason two sirens are proposed to cover opposite 180 degree sectors. Even with this arrangement, however, some silent pockets, or audio shadows, may be found within the desired 360 degree sector so, during installation, practical checking is important. If any audio shadow is found a third siren should be used, and the three sirens arranged at 120 degrees to each other.

Some authorities, including Bangladesh Railways, prefer repeater signals to increase people's recognition of both visual and audio signals. Such repeater signals must, however, be separately powered, and should be connected to the warning stations by wire, not by radio.

Sirens of other companies, provided they have the same rating, can also be used with this design, but the use of a mechanical siren will require use of an inverter of adequate capacity. A siren of larger capacity can also be used, but will require an additional solar panel and battery.

E4.1.4 Beacons

In this design only one flashing beacon is provided at each warning station. Many commercially available beacons flash only; they cannot also give a steady light. If both flashing and steady light are required two beacons will probably be needed at each warning station, and this will require a minor change in the system circuitry.

Flash Technology Corporation of USA, TOA Engineering of Japan, and perhaps some other companies, are producing beacons for air traffic control and navigational uses, and such are considered appropriate for use in the flood warning system.

These beacons are available in three colours: red, yellow and green. These colours are considered appropriate for use in the flood warning system as follows:

Yellow : First Warning Signal (Rain)
Red : Second Warning Signal (Flood)

When a beacon is flashing, current relay CR3 will vibrate and this vibration may damage the relay; to prevent this, a capacitor should be connected across the relay coil.

E4.2 System Operation

E4.2.1 First Warning Signal Transmission

The first warning signal will be triggered manually by the duty technician at the detector station pushing a push-button switch when he observes heavy rainfall over the river catchment likely to cause a flash flood. Push button switch P3 (Figure 15) activates the rainfall signal. Through this switch, relay RFL completes the circuit and picks up. Next, through the front contact (12,22) of relay RFL, signal relay SLR2 completes the circuit and picks up. The front contact of SLR2 is connected to the switch of the transmitter of radio RD1, so the result of the duty technician pushing P3 is to actuate radio RD1 to transmit the signal. The maximum time length of this signal is three seconds because time relay TM6 disconnects the circuit through back contact (18,28) after three seconds. Time relay TM6 gets power through the front contact (11,21) of relay RFL. At the receiving end this signal will be interpreted as the rainfall alarm or first warning signal. In practice, the time of three seconds can be adjusted by moving the nob of TM6, but any adjustment in TM6 will require a change in TM1 (Figure 13) to maintain signal synchronization between the two radios.

E4.2.2 First Warning Signal Reception

Figure 13 shows the warning station circuit (receiving end). Polarized relay PR1 picks up only when the signal is received. In this design PR1 is connected to the receiver of radio RD2 through an amplifier. Generally, radio receivers are equipped with only transistor output; very few models have microprocessor output or relay output. This amplifier is not necessary for receivers having relay output, in which case polarized relay PR1 should be connected directly to the output of radio receiver RD2. High sensitivity and low power consumption are advantages of polarized relays. Instead of a polarized relay any other common relay can be used providing the amplifier output is sufficient.

Through the front contact (11,21) of relay PR1 , RPR completes the circuit and picks up. Through the front contact (12,22) of RPR, time relay TM1 gets power and picks up after three seconds (Figure 13). Any signal of more than three seconds, but less than two minutes, will energize relay RALR through contact (11,21) of time relay TM1. Rain alarm relay RALR is a sticking relay which, once it picks up, does not release automatically even after withdrawal of the supply voltage. It has another release coil which drops only when power is applied to the release coil, so relay RALR stays in pick up position until the next signal. This will activate the siren to yelp through RALR contact (13,23) (Figure 15). This is the first warning or rainfall alarm signal.

E4.2.3 Second Warning Signal Transmission

The second and final warning is based on the occurrence of a dangerous flood water level in the river channel at the border. The rising water level touches the electrodes ET1 and ET2 (Figure 15). As the resistance of water is less than that of air, the resistance between ET1 and ET2 decreases when water contacts the electrodes. Decreased resistance increases current flow through terminal (3,4) of the water level indicator LI. The output of the water level indicator is connected to an amplifier. The amplified information passes through the collector C of transistor T4 to negative terminal N12, so the polarized relay PR2 picks up and the light emitting diode LD4 lights up. Through the front contact (11,21) of relay PR2, coil of RR2 picks up, and the circuit is completed. Through the front contact (12,22) of RR2, signal relay SLR2 completes the circuit and picks up. The front contact (11,21) is connected with the switch of the transmitter of radio RD1, so the radio sends the second warning signal. The time length of this signal is controlled by the back contact of relay TM7. The timing of TM2 and TM7 (Sheet No.1) should be the same to ensure receiving of the second warning signal at the warning station.

E4.2.4 Second Warning Signal Reception

If the receiving signal length is more than two minutes, relay DALR will pick up through the front contact (11,21) of time relay TM2 (Figure 13). Front contact (11,21) will cut off the previous rainfall alarm, and through the front contact of DALR (12,22) the siren will get power and wail steadily. Contact (14,24) of DALR is connected to the beacon, so the beacon will also given the second warning signal at the same time.

E4.2.5 Termination Signal Transmission

Decrease of the water level to below the electrodes ET1 and ET2 is followed by the dropping of relay PR2 (Figure 14). Consequently, time relay TM7 also drops. But TM7 will delay approximately half a second as diode D4 is connected across the coil of TM7. The delay in the dropping of TM7 is caused by the barrier capacitance of diode D4. Half a second delay is sufficient to activate the transmitter of radio RD1 through the front contact (11,21) of TM7, and the back contact (18,28) of RR2. At the warning station this signal will be interpreted as a clearance signal.

It is also possible to activate the clearance signal manually by pushing push-button P3 at the detector station, but the pushing time should be less than 3 seconds otherwise the rainfall signal will be activated instead.

E4.2.6 Termination Signal Reception

At the warning station relay RPR picks up for a moment (Figure 13). Through the front contacts (14,24) and (11,21) of relay RPR respectively, relays DALR and RALR drop. The dropping coils are shown in the drawing as DALQ and RALQ; these are sticking relays which have a special release coil for dropping. An extra arrangement is provided to stop the siren and beacon also from the warning station with the help of push-button P2 (Figure 13).

E4.2.7 Audio Warning Signal

High water level in the river or rainfall may continue for several days. If the siren wails for several days continuously the battery will discharge and the siren will stop because, on cloudy days, the solar panel may not get sufficient light to recharge the battery. Also, continuous siren wailing cannot be tolerated by the people and they may learn to ignore the signal. For both these reasons the circuit is arranged so that the siren will wail first for half an hour (Figure 13), then it will stop for half an hour, and then it will wail for five minutes only every half hour until the termination signal is received. This arrangement will also increase longevity of the equipment. If people are confused by this timing of the siren wails, TM3, TM4, and TM5 may be disconnected. Instead of these three relays a single electronic time-switch can be used with this circuit. Details of appropriate times-switches are given in the attached brochure list.

E4.2.8 Visual Warning Signal

The beacon is not, however, connected to this timing arrangement. In strong sunlight the beacon may not be visible even over a short distance. To save valuable power the beacon can be connected to a photo resistor which will actuate under strong sunlight and automatically stop the beacon.

E4.3 Other System Components

E4.3.1 Relays

DALR and RALR are sticking relays. To keep these relays in pick up position, continuous power is not necessary, and the circuit is arranged so that these relays will get power for a moment only. To achieve this, the opposite contact of the relay is used. This arrangement will increase longevity of the relay and save valuable power.

In this design Ericsson Company relays are proposed. Relays of other companies having the same characteristics can be used, but respective contact numbers will change in the drawing.

E4.3.2 Panel Buzzer

Relays CR3 and CR5 are used to check the filament of the beacon, and relays CR1 and CR2 are used to check the voice coil of the siren (Figure 14). Voltage relays VR1 and VR2 check the battery voltage at the warning station (Figure 14). In fault condition these relays will drop. Through the back contact (18,28) of these relays, panel buzzer PB1 completes the circuit and starts the fault alarm. At the same time light emitting diode LD will indicate, on the panel board, where the fault is (Figure 14).

Absence of an attending person at the warning station panel will delay quick repair of a fault at the warning station, so the circuit is designed so that the duty officer at the detector station can be informed about the fault automatically.

Any fault in the equipment of the warning station will actuate relay FTR (Figure 14) and through FTR contact (11,21), relay SLR1 picks up. Signal relay SLR1 actuates radio RD2 and sends the fault signal to the detector station; consequently, the duty officer will be informed about the fault immediately.

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E4.3.3 Counters & Hour-Meters

An hour-meter is connected to check the operating times of both the siren and the beacon. Hour-meter HR1 will be sealed and, except for the supervisor, nobody will be able to change the hour-meter reading. The readings of all warning station hour-meters should be the same; any difference will indicate an equipment fault.

Counters are connected to signal relays SLR1 and SLR2. Counter C1, C2 will check the number of signals (Figures 14 & 15). For better supervision two more counters can be connected across the relay PR.

E4.3.4 Power Supply

The power supply arrangements are shown in Figures 13 and 15. It is thought that commercial power will not be available at most sites, so solar power with heavy duty battery is the only solution.

Arco Solar Company solar panels are proposed in this design. Four solar panels, each of 45 watts, will be needed at every warning station, but only two solar panels are needed at the detector station.

Four batteries, each of 100 amp-hour capacity, will be required for each warning station, and two batteries of the same capacity for the detector station.

When the lead acid batteries are fully charged the system will run for seven cloudy days with the alarm signal on. On sunny days the system can run for an indefinite period. However, it is suggested to check battery condition twice a month.

With larger capacity sirens and beacons, power supply from solar panels may not be sufficient. To meet the additional power demand it would not be wise to increase the number of solar panels. In that case, one small generator (maximum capacity 2kw) should be used.

E4.3.5 Switches, Voltmeters, and Ammeters

Voltmeter V1 is used for checking the panel voltage through selector switch SL1. Control panels CP1 and CP2 are to protect the batteries from over-charging and under-charging.

Through the selector switch SL2, 12 volt or 24 volt DC power can be selected, switch SL2 also provides the facility to choose 12 volt DC power from either battery LB1 or LB2.

A DC ammeter is connected to both power lines.

E4.3.6 Lightning Arrestors and Earthing Arrangements

To save the equipment from lightning and overvoltage, lightning arrestors LR1, LR2, LR3 and LR4 are used on the connecting cables of the siren and beacon.

For equipment safety, solar panels and other equipment must be earthed. All earth connections should be interlinked with a common wire.

Fuses 10 and 11 are 7 amp fuses, fuses 9 and 12 are one amp, and fuses 1 to 8 are 3 amp.

E4.4 Costs

Tables E3 and E4 present, respectively, costs of the electrical equipment required at a detector station and at a warning station. In summary, these are as follows:

	Taka
Detector Station	191,085
Warning Station	312,855

The total cost of electrical equipment for a complete flood warning system for *one* flash flood-prone river is then estimated to be:

	Taka
Detector Station	191,085
Five Warning Stations	1,566,275
Total	**1,757,360**

Additional to the cost of electrical equipment are costs for freight, installation, commissioning, first month operation and maintenance, masts, detector station building, and detector stilling well. These are estimated in Table 4.2, leading to a total capital cost for one complete flood warning system of Taka 7,542,360.

Routine operation and maintenance costs (beyond the first month) are expected to amount to Taka 35,000 per month.

E5 Solar Powered Cable Transmission Alternative System

Radio communication is not always free from weather disturbance, thunder, noise, etc; even satellite communication is not completely free from such disturbance. Recently, improved design and digital technology have lessened the risk of false alarms due to noise, disturbance, etc., but such technology can be very costly, and may not be appropriate for Bangladesh.

Among the many alternate methods, signal transmission by underground cable is feasible in Bangladesh where many private and public sector organizations are successfully using underground cable for communications. The initial cost of cable laying is slightly more than for other conventional system, but in the long run it becomes cheaper due to its greater reliability.

E5.1 Technical Aspects

An alternate proposal based on cable transmission is shown on Figure 16. Five-core armoured cable is used in this design. FR1, FR2 are filament checking relays. In case of filament failure relay FR will drop and, consequently, relay FRF will drop. Through the back contact (18,28) of relay FRF, panel buzzer and light emitting diode will complete the circuit. TJ1 and TJ2 are telephone jacks necessary for maintenance purposes.

S12 is the switch for the rainfall alarm. One generator of 5.5 KVA capacity is used in this design. Generator G will start automatically with the signal. TR1, TR2, TR3, TR4 are step-down transformers to match with siren and beacon. It may happen that at the farthest warning station the voltage drops too much, in which case one step-up transformer should be used. Dotted lines with switches 13 and 14 are drawn to show the extra arrangements needed for commercial power use at any one of the warning stations. If commercial power is available the warning station generator G should be removed, and points "a" and "b" should be strapped. In this drawing the strap is shown as a dotted line. In this case, a telephone jack should be used with a special filter circuit; otherwise a shock hazard may exist.

The circuit at the receiving end is very simple, so at the receiving side a big panel board is not necessary. A small signal box, which can be mounted at the bottom of the signal mast, will be sufficient.

Rectifier bridges RC1, RC2 are used with a DC operated siren. For an AC operated siren these bridges are not necessary. Flasher FL is to maintain the siren interval. An electronic time-switch can be used as a flasher.

E5.2 Costs

Table E5 presents costs of the electrical equipment required for a flood warning system, based on cable communication, for *one* flash flood-prone river, leading to a total electrical equipment cost of Taka 2,676,512.

Additional to this cost are costs for freight, installation, commissioning, first month operation and maintenance, masts, detector station building, detector stilling well, and cable-laying. These are estimated in Table 4.2, leading to a total capital cost for one complete flood warning system of Taka 8,766,512.

Routine operation and maintenance costs (beyond the first month) are expected to amount to Taka 15,000 per month.

Table E1

LABELS USED FOR ELECTRICAL COMPONENTS

Label	**Component Description**
A1,...,A5	Ammeter
AM1, AM2	Amplifier
B24	Positive Terminal of 24V DC
BC1, BC2	Beacon
C1,...,C3	Counters
CP1,...,CP5	Control Panels (battery charging)
CR	Current Relays: CR1 (voice coil check) CR2 (steady voice coil check) CR3 (filament check) CR4 (transmitter fault) CR5 (steady filament check) CR6 (beacon) CR7 (siren)
D1,...,D10	Diode
DALQ	Danger Alarm Relay Dropping Coil
DALR	Danger Alarm Relay
DALRI	Danger Alarm Relay, Cable Communication
E1,...,E13	Earthing sets
EM	Emergency Switch (Spare)
ET1, ET2	Water Level Detector Electrodes: 3,4 input terminal 5,6 output terminal
F1,...,F28	Fuse
FALRI	Rainfall Alarm Relay, Cable Communication
FL	Flasher
FRI, FR2	Filament Failure Relays
FRF	Repeater of Filament Failure Relay
FRL	Fault Receiving Relay (sticking relay)
FTR	Fault Transmitting Relay
G	Generator
HRI, HR2	Hour Meters
LB1,...,LB5	Battery (Lead acid)
LD1,...,LD9	Light Emitting Diodes: LD1 (voice coil fault) LD2 (filament fault) LD3 (battery under-voltage at warning station) LD4 (high water level in river) LD5 (radio fault at detector station) LD6 (battery under-voltage at detector station)

LD7 (radio fault at warning station)
LD8 (Fault in Siren or Beacon)
LD9 (Battery Undervoltage)

LI	Water Level Detector
LR1,...,LR4	Lightning Arrestor
N24	Negative Terminal of 24V DC
P1,...,P5	Push-Button Switches:
	P1 (clearance signal at warning station)
	P2 (rainfall signal at warning station)
	P3 (rainfall and clearance signal at detector station
	P4 (Spare)
	P5 (fault clearance signal at detector station)
PB1,...,PB3	Panel Buzzers:
	PB1 (receiving end)
	PB2 (transmitting end)
	PB3 (detector end)
PR1,..,PR3	Polarized Relays:
	PR1 (transmitting end)
	PR2 (receiving end)
	PR3 (fault receiving at detector end)
R1...R6	Resistor
RALQ	Rain Alarm Relay Dropping Coil
RALR	Rain Alarm Relay
RC1, RC2	Rectifier Bridges
RD1	Radio at Detector Station (input terminal 1,2)
RD2	Radio at Warning Station
RFL	Rainfall Relay
RPR, RR2	Repeaters:
	RPR (of PR1)
	RR2 (of PR2)
S1,...,S12	Switches
SL1,...,SL3	Selector Switches
	SL1 (solar panels)
	SL2 (battery)
	SL3 (Solar Panels)
SLR1, SLR2	Signal Relays
SP1,...,SP7	Solar Panel
SR1,...,SR3	Siren
T1,..,T4	P-N-P Transistor
TJ1, TJ2	Telephone Jacks
TM1,..,TM7	Time Relays:
	TM1 (for RPR)
	TM2 (for RPR)

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TM3 (for flashing)
TM4 (for TM3)
TM5 (for RALR and DALR)
TM6 (for RFL)
TM7 (for RR2)

TR1,...,TR4 Step-Down Transformers 220V AC to 12V AC

V1,...,V7 Voltmeters:
V1 (digital for solar panel, warning side)
V2 (analogue 24V DC, warning side)
V3 (analogue 12V DC, warning side)
V4 (digital for solar panel, detector side)
V5 (analogue, 24V DC, detector side)
V6 (analogue, 12 V DC, detector side)
V7 (digital, 12 V DC)

VR1,...,VR4 Volt Checking Relays:
VR1 (24V, receiving end)
VR2 (12V, receiving end)
VR3 (24V, transmitting end)
VR4 (12V, detector side)

Table E2

LIST OF SUITABLE ELECTRICAL EQUIPMENT FOR FLOOD WARNING SYSTEM

BATTERY

Manufacturer	:	Industrial Batteries Ltd. (IBL)
Model/Type	:	6 BC 160 P/3
Specification	:	12V, 100A hour
Local Supplier	:	Rahim Afroz Ltd., Motijheel CA, Dhaka
Unit Cost	:	Taka 7000/-

BATTERY CHARGER

Manufacturer	:	Bosch, Germany
Model/Type	:	Batmax 6
Specification	:	12V, 7A
Local Supplier	:	Nowabpur (Electrical) Market, Dhaka
Unit Cost	:	Taka 4500/-

BEACON

Manufacturer	:	TOA Engineering Corporation, Japan
Model/Type	:	Rotary
Specification	:	12V, 55W, Red & Green
Local Supplier	:	Radio Electric, Stadium 24, Dhaka
Unit Cost	:	Taka 3550/-

CABLE

Manufacturer	:	Ericsson, Sweden
Model/Type	:	Armoured, Type: EKKR
Specification	:	5 Core x 1.5 mm^2 + 1.5 mm^2
Local Supplier	:	Kanta International Ltd, 7/4 Aurangzeb Road, Mohammadpur, Dhaka
Unit Cost	:	Taka 89.31/m

CONTROL PANEL

Manufacturer : Rahim Afroz Ltd., Bangladesh

Model/Type : Battery Charging

Specification : 12V, 5A

Local Supplier : Rahim Afrox Ltd, Motijheel CA, Dhaka

Unit Cost : Taka 5000/-

COUNTER

Manufacturer : Dong-A Electric Device Co. Ltd, Korea

Model/Type : 72 mm Series

Specification : 12V DC, Four Digit

Local Supplier : Melody House, Baitul Mukarrom, Dhaka

Unit Cost : Taka 950/-

EMERGENCY SWITCH

Manufacturer : Maxim, New Zealand

Model/Type : BO1

Specification : 10A

Local Supplier : Nawabpur (Electrical) Market, Dhaka

Unit Cost : Taka 450/-

GENERATOR

Manufacturer : Honda, Japan

Model/Type : EP 6500S (autostart)

Specification : 50 Hz/60 H, 5.5 KVA

Local Supplier : 35/A, Indira Road, Farmgate, Dhaka

Unit Cost : Taka 120,000/-

LIGHT EMITTING DIODE

Manufacturer : Hanyang Electronics Co. Ltd, Korea

Model/Type : Red Lamp

Specification : 24V DC, Display Board System

Local Supplier : Melody House, Baitul Mukarrom, Dhaka

Unit Cost : Taka 20/-

MAST

Manufacturer : Wibe Company, Sweden

Model/Type : Guyed

Specification : Height, 20 m

Local Supplier : Advantec, Road 16, House 4, Dhanmondi RA, Dhaka

Unit Cost : Taka 406,000/-

PANEL BUZZER

Manufacturer : Korea Auto Company Ltd., Korea

Model/Type : HRB-P 80 D4

Specification : DC 24V, 65 mA

Local Supplier : KH Electric Stores, 124/A Nawabpur Road, Dhaka

Unit Cost : Taka 425/-

PROGRAMMED SWITCH

Manufacturer : Kraus & Namer, New Zealand

Model/Type : OCA 20

Specification : 8 pin, 25A

Local Supplier : Abdullah Electric Co., Bulbul Market, Nawabpur, Dhaka

Unit Cost : Taka 850/-

PROGRAMMED SWITCH

Manufacturer : Kraus & Namer, New Zealand

Model/Type : OCA 20

Specification : 10 pin, 32A

Local Supplier : Abdullah Electric Co., Bulbul Market, Nawabpur, Dhaka

Unit Cost : Taka 1800/-

POLARIZED RELAY

Manufacturer : Ericsson, Sweden

Model/Type : JRK 1047

Specification : Biased, Power Consumption - 70 mA

Local Supplier : Kanta International Ltd., 7/4 Aurangzeb Road, Mohammadpur, Dhaka

Unit Cost : Taka 5000/-

PUSH-BUTTON SWITCH

Manufacturer : Han Kuk Relay Co. Ltd, Korea

Model/Type : Double Contact

Specification : 10A, 500V

Local Supplier : KH Electric Stores, 124/A, Nawabpur Road, Dhaka

Unit Cost : Taka 110/-

PUSH-BUTTON SWITCH

Manufacturer : Korea Auto Control Company, Korea

Model/Type : Single Contact

Specification : 10A, 500V

Local Supplier : KH Electric Stores, 124/A, Nawabpur Road, Dhaka

Unit Cost : Taka 105/-

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RADIO

Manufacturer : Anritsu Corporation, Japan

Model/Type : SSB Type SS120A

Specification : 12VDC, 20W, 3 to 10 MH_2, 11 Channels

Local Supplier : Advantech, Road 16, House 4, Dhanmondi RA, Dhaka

Unit Cost : Taka 30000/-

SELECTOR SWITCH

Manufacturer : Kraus & Namer, New Zealand

Model/Type : Voltmeter Type

Specification : 10A, 500V

Local Supplier : Abdullah Electric Co., Bulbul Market, Nawabpur, Dhaka

Unit Cost : Taka 800/-

SELECTOR SWITCH

Manufacturer : Kraus & Namer, New Zealand

Model/Type : Ammeter Type

Specification : 10A, 500V

Local Supplier : Abdullah Electric Co., Bulbul Market, Nawabpur, Dhaka

Unit Cost : Taka 800/-

SIGNAL RELAY

Manufacturer : Ericsson, Sweden

Model/Type : JRF 310 JRF 150

Specification : 0.05 to 3.3W, 10A, Neutral, Silver Contact

Local Supplier : Kanta International Ltd., 7/4 Aurangzeb Road, Mohammadpur, Dhaka

Unit Cost : Taka 5000/-

SIREN

Manufacturer : Apollo Company, Japan

Model/Type : CS-588 Electronic Dual Siren

Specification : 12V DC, 50W

Local Supplier : Radio Electric, Stadium 24, Dhaka

Unit Cost : Taka 2850/-

SOLAR PANEL

Manufacturer : Arco Solar Inc., USA

Model/Type : M65, Solar Electric Modules

Specification : 43W, 17V at no load

Local Supplier : Rahim Afroz, Motijheel CA, Dhaka

Unit Cost : Taka 20,000/-

STICKING RELAY

Manufacturer : Ericson, Sweden

Model/Type : JRF 320 JRF 520

Specification : Magnetic Stick, Silver Contact

Local Supplier : Kanta International Ltd., 7/4 Aurangzeb Road, Mohammadpur, Dhaka

Unit Cost : Taka 5000/-

TELEPHONE JACK

Manufacturer : Dolee Corporation, Korea

Model/Type : Two Pin Contact

Specification :

Local Supplier : Melody House, Baitul Mukarrom, Dhaka

Unit Cost : Taka 200/- each pair

TIME RELAY

Manufacturer : Ericsson, Sweden

Model/Type : JRF 320 with Timeswitch

Specification : From 0 Sec to 30 Min.

Local Supplier : Kanta International Ltd., 7/4 Aurangzeb Road, Mohammadpur, Dhaka

Unit Cost : Taka 500/-

TIME SWITCH

Manufacturer : Diehl Flasch Company, Germany

Model/Type : Electronic, Group 328

Specification : Daily & Weekly Program, One Channel

Local Supplier : Abdullah Electric Co., Bulbul Market, Nawabpur, Dhaka

Unit Cost : Taka 4500/-

TRANSFORMERS

Manufacturer : Nam Yang Electric Co. Ltd, Korea

Model/Type : Step Down

Specification : 220 V AC - 12 V AC, 50 VA

Local Supplier : Spare Parts Shops, Stadium (Electrical) Market, Dhaka

Unit Cost : Taka 1100/-

TRANSISTOR

Manufacturer : (Unknown) Taiwan

Model/Type : AC 128, p-n-p Type

Specification : Signal Amplification

Local Supplier : Stadium (Electrical) Market, Dhaka

Unit Cost : Taka 100/-

WATER LEVEL DETECTOR (M-SCOPE)

Manufacturer	:	Micro Electronics Ltd.
Model/Type	:	Electronic Type (Not Floating Ball)
Specification	:	Input 12V DC, Output 3.3V, 2.9V at electode
Local Supplier	:	Micro Electronics, Purana Paltan, Dhaka
Unit Cost	:	Taka 1500/- (with coaxial cable)

Table E3

COST OF ELECTRICAL EQUIPMENT FOR ONE DETECTOR STATION

Item	Quantity	Unit Price (Taka)	Total Price (Taka)
Selector switch	2	800	1600
Push button switch	2	110	220
Panel buzzer	1	425	425
Emergency switch	1	450	450
Relay	9	5000	45000
Solar panel	2	20000	40000
Lead acid battery	2	7000	14000
Control panel	2	5000	10000
Water level indicator	1	1500	1500
Transistor AC128	2	100	200
Light emitting diode	3	20	60
Diode	4	80	320
Resistor	3	20	60
Cabinet	1	15000	15000
Fuse set	8	300	2400
Connecting wire	200 m	30	6000
Voltmeter (digital)	1	5000	5000
Voltmeter (analogue)	2	700	1400
Connecting terminals	1 set	500	500
Ammeter	2	700	1400
Wire chute	15 m	100	1500
Fixing net	1 m^2	5000	5000
Busbars	2	300	600
Radio	1	30000	30000
Lightning arrestor	1	400	400
Switch double contact	6	850	5100
Earthing	1 set	2000	2000
Counter	1	950	950
Total			**191085**

Table E4

COST OF ELECTRICAL EQUIPMENT FOR ONE WARNING STATION WITH RADIO COMMUNICATION

Item	Quantity	Unit Price (Taka)	Total Price (Taka)
Siren	3	2850	8550
Selector switch	2	800	1600
Beacon	1	3550	3550
Push button switch	3	110	330
Panel buzzer	1	425	425
Emergency switch	1	450	450
Relay	16	5000	80000
Solar panel	4	20000	80000
Lead acid battery	4	7000	28000
Control panel	2	10000	20000
Switch	6	850	5100
Transistor AC 128	4	100	400
Light emitting diode	3	20	60
Diode	4	80	320
Resistor	6	20	120
Cabinet	1	15000	15000
Fuse set	12	300	3600
Connecting wire	200 m	30	6000
Power cable	40 m	210	8400
Voltmeter (digital)	1	5000	5000
Voltmeter (analogue)	2	700	1400
Connecting terminals	1 set	500	500
Ammeter	2	700	1400
Wire channel	15 m	100	1500
Fixing net	1 m^2	5000	5000
Busbars	2	300	600
Radio SS120A	1	30000	30000
Lightning arrestor	2 set	400	800
Earthing	1 set	2000	2000
Counter	1	950	950
Hourmeter	1	2200	2200
Total			313255

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Table E5
COST OF ELECTRICAL EQUIPMENT FOR ONE WARNING SYSTEM WITH CABLE COMMUNICATION

Item	Quantity	Unit Price (Taka)	Total Price (Taka)
Panel buzzer	1	425	425
Emergency switch	1	450	450
Siren	15	2850	42750
Beacon	5	3550	17750
Telephone jack	6 set	200	1200
Relay	16	5000	80000
Flashing unit	5	1300	6500
Rectifier bridge	10	900	9000
Solar panel	1	20000	20000
Lead acid battery	1	7000	7000
Control panel	1	5000	5000
Switch	2	850	850
Light emitting diode	3	20	60
Diode	2	80	160
Cabinet	1	15000	15000
Fuse set	24	300	7200
Connecting wire	400 m	30	12000
Power cable	200 m	210	42000
Voltmeter (digital)	1	5000	5000
Connecting terminal	3 set	500	1500
Ammeter	1	700	1400
Wire chute	15 m	100	1500
Fixing net	1 m^2	5000	5000
Busbar	1	300	300
Lightning arrestor	10 set	400	4000
Earthing	6 set	2000	12000
Signal cable 5X1.5 mm^2 + 1.5 mm^2	25000 m	89	2232767
Hour meter	1	2200	2200
Generator (5.5 KVA)	1	120000	120000
Water level indicator	1	1500	1500
Transformer (step down)	20	1100	22000
Total			**2676512**

ANNEX F

INSTITUTIONAL ARRANGEMENTS

ANNEX F: INSTITUTIONAL ARRANGEMENTS

F.1 Introduction

In Section 6.1 it was suggested that a Flash Flood Warning Agency (FFWA) be set up, within the BWDB, to install, operate and maintain the flash flood warning (engineering) systems described in Chapters 4 and 5, and to coordinate the other engineering and community organizing activities described in Sections 6.2, 6.3 and 6.4 and which are also required to ensure success of the systems.

F.2 Empowerment

In the interests of effective and efficient operation of the systems, and of effective coordination of the other supporting activities, it is essential that the FFWA be fully empowered to act on all matters within its purview.

To attain this objective the FFWA should be set up as a full directorate of the BWDB.

The FFWA should be empowered to:

a) carry out itself all further studies needed to identify/confirm needs and requirements for flash flood warning systems, needs of villagers for flood protection embankment works, safe grounds and routes to safe grounds, and for plans of action, including all related public participation and community organization activities.

b) carry out itself all administration and engineering pertaining to the installation, operation and maintenance of the flash flood warning (engineering) systems, including such matters as procurement of staff, materials and equipment, and the tendering and supervision of all related engineering and construction contracts.

c) require on a priority basis action by BWDB O&M Circles regarding the construction, repair and/or strengthening of embankments intended to protect warned communities, of safe routes to safe grounds, and of safe grounds of whatever form the FFWA shall decide is appropriate.

It is suggested that the FFWA would *not* be set up either as a sub-directorate of either BWDB Hydrology Directorates (I and II), or as an adjunct to the FFWC. The reason for this position is partly because the objectives of the FFWA and FFWC will not, as may too easily be assumed, be related and convergent for many years to come. For the foreseeable future:

a) the FFWA will be producing warnings for the rural public of flash floods in the border areas based on direct observations of rainfalls and river water levels, not on computer-produced forecasts.

b) the FFWC will be computer-producing forecasts of major floods in the main river systems downstream of the flash flood-prone border areas, and giving warning only to government officials, relief agencies and the media.

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Thus, there will be no overlap of either the objectives or the activities of the FFWA and the FFWC, and both organisations could function independently.

F.3 Staffing

The nature of the work to be done by the FFWA is such that, in the context of nine or more warning systems, many and diverse staff will be required. It is envisaged, however, that in the interests of efficiency and economy there should be relatively few permanent staff, and that any other staff required should be attached to the FFWA only for as long as they are needed to accomplish specific tasks.

In line with this view, roles in the FFWA are foreseen as follows:

Permanent Professional Staff:

Director (Overall Responsibility and Authority)
Deputy Director I (Civil Works Organization)
Deputy Director II (Electrical Works Organization)
Deputy Director III (Community Organization)
Deputy Director IV (Personnel and Financial Management)

Temporary Professional Staff:

Meteorologist
Hydrologist
Hydraulic Modeller
Geotechnical Engineer
Structural Engineer
Construction Engineer
Sociologist

Permanent Technical Staff:

Warning Systems Supervisor
Community Organizer
Warning System Observer/Technicians (3 per system)

Temporary Technical Staff:

Civil Works Foreman/Supervisor (1 per system)
Electrical Works Foreman/Supervisor (1 per system)
Community Field Workers (1 per system)

Except where otherwise indicated above, the number of people in each role will normally be one. Role functions, and required qualifications of incumbents, are expected to be as described below.

F.3.1 Permanent Professional Staff

Director

The incumbent will be responsible for successful operation of the FFWA, and should be given the necessary authority. He will report directly to a Member, BWDB.

The incumbent should be a qualified civil engineer with previous experience equivalent to that of a Superintending Engineer in the BWDB's O & M Circles.

Deputy Director I

The incumbent will be responsible to the Director for organizing the execution of all civil engineering works relating to components of the warning systems, construction, repair and strengthening of flood embankments intended to protect warned communities, of safe routes to safe ground, and of safe grounds of whatever form (artificial islands, cyclone-type shelters, etc.)

The incumbent should be a qualified civil engineer with previous experience equivalent to that of an Executive Engineer in the BWDB's O&M Circles.

Deputy Director II

The incumbent will be responsible to the Director for organizing the execution of all electrical engineering works relating to components of the warning systems, including installation, testing, operation and maintenance.

The incumbent should be a qualified electrical (communications) engineer with experience equivalent to that of an Executive Engineer in the BWDB's O&M Circles.

Deputy Director III

The incumbent will be responsible to the Director for organizing communities which will receive warnings to establish public review bodies, draw up plans of action, and identify requirements perceived by the public for embankment reinforcement, safe route improvement, safe ground establishment, etc.

The incumbent should be a qualified community organizer with previous experience organizing communities to respond to, and cooperate in achieving the success of, government initiatives to benefit the public. This position may have to be filled from outside the BWDB.

Deputy Director IV

The incumbent will be responsible to the Director for budget management, the mechanics of staff hiring/contracting, payroll administration, disbursements to contractors, etc.

The incumbent should be a qualified accountant with auxiliary experience in personnel management.

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F.3.2 Temporary Professional Staff

Meteorologist

The incumbent will be responsible to Deputy Director II for training warning system Observer/Technicians in the visual detection of flood-generating rainfalls over the various catchment areas in India; this is a short-term assignment.

The incumbent should be a qualified meteorologist with experience in training weather station observers for the BMD; he would probably be seconded from the BMD for a few months only.

In the far future, if a radar is substituted for visual rainfall detection, there may be a permanent role for a radar meteorologist within the FFWA.

In this case, the incumbent should be a qualified radar meteorologist; such expertise is unlikely to be readily found in Bangladesh, and the need for early postgraduate level training of a BMD meteorologist in this specialty should be borne in mind as soon as the possibility of obtaining a radar for the Northeast Region arises.

Hydrologist

The incumbent will be responsible to Deputy Director II for the installation of water level recorders/detectors at water level detector stations, and for training warning system Observer/Technicians in their operation and maintenance.

The incumbent should be a qualified hydrologist/hydrometrist with experience in operating and maintaining water level recorders/detectors, and in training observers in this work; he would probably be seconded from a BWDB Hydrology Directorate for a few months only.

Hydraulic Modeller

The incumbent will be responsible to Deputy Director II for model studies leading to initial setting of the critical water level detectors.

The incumbent should be a qualified hydraulic engineer with experience in using the Northeast Regional Hydrodynamic Model; he would probably be seconded for a few months only from the FFWC, and would preferably be ex-NERP (Modelling Group).

Geotechnical Engineer

The incumbent will be responsible to Deputy Director I for the design of significant earthworks including embankments, artificial islands, and cyclone-type shelter pier foundations.

The incumbent should be a qualified geotechnical engineer with experience in design and construction of significant earthworks and foundations; he would probably be seconded from the BWDB Design Circle on an intermittent basis with each individual assignment lasting a few weeks.

Structural Engineer

The incumbent will be responsible to Deputy Director I for the design of significant structures including bridges along safe routes to safe grounds, and cyclone-type shelters.

The incumbent should be a qualified structural engineer with experience in the design and construction of small to medium size steel or reinforced concrete bridges, and of medium to large steel or reinforced concrete frame buildings (cyclone-type shelters); he would probably be seconded from the Public Works Department (PWD) on an intermittent basis with each individual assignment lasting a few weeks.

Construction Engineer

The incumbent will be responsible to Deputy Director I for all construction supervision of civil works, whether carried out by direct labour or contractor, including embankments, safe route bridges and roads, artificial islands, and cyclone-type shelters, such supervision being to ensure that such works conform to the designs and specifications of the Geotechnical and Structural Engineers.

The incumbent should be a qualified civil engineer with at least 10 years site experience in construction; he would probably be seconded from the BWDB O&M Circles (equivalent to a Sub-Divisional Engineer), or from the Public Works Department.

Sociologist

The incumbent will be responsible to Deputy Director II for planning the community organization programme, including the preparation of suitably structured questionnaires and the analysis of public responses to them.

The incumbent should be a qualified sociologist with several years experience in establishing the public's requirements, seeking public approval and cooperation, and community organization, in relation to public works projects; he would probably be seconded from an NGO specializing in social issues and community organization but must have an established reputation for being able to focus on project-relevant social issues.

F.3.3 Permanent Technical Staff

Warning System Supervisor

The incumbent will be responsible to Deputy Director II for all field aspects of the installation, operation and maintenance of the flash flood warning systems electrical works.

The incumbent should be a qualified electric (communications) technologist with several years experience in communications technology, he would probably be seconded from another branch of government which is heavily involved in telecommunications.

Community Organizer

The incumbent will be responsible to Deputy Director III for all field aspects of community organization including public meetings, public review body formation and operation, and information gathering through surveys based on appropriately structured questionnaires, etc.

The incumbent should be an experienced community organizer with an established reputation for being able to focus on *project-relevant* social issues; he would probably be seconded from the same NGO as the Sociologist.

Warning System Observers/Technicians

The incumbents will be responsible to the Warning Systems Supervisor for day-to-day observation of rainfall conditions, monitoring of system performance, and for fault rectification on an emergency basis. The incumbents should be secondary high school graduates with passes in physics and mathematics and with previous training, experience and proven aptitude in the operation and maintenance of telecommunications equipment.

F.3.4 Temporary Technical Staff

Civil Works Foreman/Supervisor

The incumbents will be responsible to the Construction Engineer for day-to-day organization and supervision of civil works forming parts of the warning systems (observation posts, stilling wells, plinths, erection of fences and mats), and associated with the construction/repair/strengthening of embankments, safe routes structures, artificial islands and/or cyclone-type shelters.

The incumbents should be secondary high school graduates with passes in physics and mathematics and at least 5 years experience in civil works construction. They would probably be seconded from the BWDB's O & M Circles.

Electrical Works Foreman/Supervisor

The incumbents will be responsible to the Warning Systems Supervisor for supervision of installation and testing of all electrical components of the warning systems.

The incumbents should be secondary high school graduates with passes in physics and mathematics, and at least 5 years experience in electrical (tele-communications) work. They would probably be seconded from a branch of government which is heavily involved in tele-communications.

Community Field Workers

The incumbent will be responsible to the Community Organizer for carrying out surveys based on structured questionnaires, and such other *project-relevant* tasks as the Community Organizer may depute to them.

The incumbents should be secondary high school graduates with passes in social sciences such as geography and history, and would preferably have prior experience in field social survey work.

F.4 Funding/Sustainability

The capital cost of the engineering works involved in establishing the flash flood warning systems is expected to be provided for under a bilateral aid programme, or a soft loan from one of the international banks.

The routine on-going costs of operation and maintenance of the systems are expected to be provided for by the GOB.

In the cases of both bank loans for capital works and on-going operation and maintenance costs, it is not envisaged that the beneficiaries of the system *could* contribute to loan repayments or to the on-going costs except, perhaps, on a nominal basis. It has to be realised that many of the beneficiaries of the flood warnings are poor rural people who are unable to pay even a nominal amount, even if in principle they are willing to. There are points both for and against nominal contributions from the beneficiaries. Certainly nominal contributions would serve as an introduction to the principle of eventual sustainability, and engender public interest and pride in the systems

Clearly, this issue requires much careful thought and debate before a relevant decision is brought down by the GOB.

ANNEX G

PILOT PROJECT

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ANNEX G: PILOT PROJECT

G.1 Pilot Project Site Selection

Following the recommendation made in Chapter 2, Section 2.11, some consideration has been given to identifying the best site for a pilot project. To aid in this identification tentative layouts have been prepared for flash flood warning systems on each of the nine rivers covered by the field investigations; these are shown in Figures 18 to 26.

Clearly, the site selected for the pilot project should the one which gives the flash flood warning system the best chance to be effective; if the system proves to be ineffective at the most favourable site there is little chance of it proving effective elsewhere in the Region.

Appropriate criteria for selecting the best site appear to be the following:

1) The site should enable the best match possible between the lead-time which the system can give the villagers, and the minimum time they need to prepare for and execute their evacuation to safe ground.

2) The site should be one where no flood protection embankment is present to complicate evaluation of the system by breaching during system operation.

3) The site should enable the largest possible number of villagers to benefit from the warnings given by the pilot project; if the pilot project is successful there will then be a large body of rural people available to persuade rural people on the other rivers of the value of the system; if it is not successful there will be a large number of observations from rural people as to why it is not successful, and these will improve the chances of its being successfully modified.

4) The site should be one where the villagers have expressed a positive interest in the system (not Dhalai (N)/Chilabhanga).

The minimum time required by villagers to prepare for their evacuation is 100 minutes. Referring to Table 4.1 the best chance for the system to match this time will occur in the Tripura border area rivers for which the lead-times are considerably longer than for the Meghalaya border area rivers, and comparable to the 100 minutes required; this reflects the facts that: 1) river bed slopes, and hence, travel velocities, are lower for the Tripura rivers than for the Meghalaya rivers, and 2) the worst affected Tripura villages tend to be further downstream from the Indo-Bangladesh border than the worst affected Meghalaya border area villages. On this basis the rivers offering the best time match are the Karangi, Dhalai (S) and Juri Rivers.

These three rivers are all embanked but the Juri River embankment apparently did not burst during the 1993 flood; in contrast, the embankments on the Dhalai (S) and Karangi did burst. According to the second criterion given above, the Juri River therefore appears to be the most suitable of the Tripura border area rivers for the pilot project.

It happens that Juri/Jahangirai, with a population of about 4500, is by far the largest of the villages investigated, so a pilot project on the Juri River would benefit the most people. This village is also one of those which expressed a positive interest in having a flood warning system.

Inspection of Figure D6 shows that the villagers of Jahangirai have a relatively short distance to travel (< 1 km) to reach the safety of the railway embankment which is, apparently, the only safe ground available to them. It is estimated that they would require only about 15 minutes to reach this safe ground. Their total time requirement is therefore 100 minutes to prepare to evacuate plus 15 minutes to evacuate, or 115 minutes. The first flood warning, now to be based on rainfall detection, would give them at least 1 hour and probably several hours in which to prepare to evacuate and the second flood warning, based on river water level detection, would give them another 75 minutes (see Table 4.1) to evacuate; the total time available to them (135+ minutes) therefore exceeds their total requirement (115 minutes) by at least 20 minutes. Thus, they could overrun their preparation time by 20 minutes, and still reach the embankment before the flood arrives in the village.

The Indo-Bangladesh border is first encountered about 2.5 km upstream of Jahangirai but the Juri River forms the border for about 11 km upstream of that point (Figure 23); thus, the water level detector can be located 13.5 km upstream of Jahangirai on the left bank of the river. This point has not been visited to assess its suitability for stilling well installation, and this is a matter to be addressed as soon as a decision is made to implement the pilot project on this river.

Some 10 km west of the stilling well site there is a high point on an anticlinal ridge which should serve well for the rainfall observation post. With an elevation of 336 m there should be a good view over the Indian portion of the Juri river basin even under cloudy conditions since, in the tropics generally, the cloud base is typically at around 700 m during storms. It should be noted, however, that 10 km of cable will be needed to link the stilling well to the observation post, and no provision for such a long length of cable has been made in the costing given in the report; this matter will, therefore, require special consideration during feasibility study of the Juri Pilot Project. The accessibility by jeep of both the stilling well site and the observation post also needs further investigation at this stage.

Suitable hillocks, or other prominent grounds, are available for location of the warning stations of which it is thought only four will be required (Figure 23). The saving on one warning station may finance the extra cable link required between the stilling well and the observation post.

G.2 Prior Evaluation of First Warning Activation by Observer/Technicians

As discussed in Chapter 4, Section 4.2, while weather radar would be the best means of observing rainfall over the Indian catchments, and telemetric rain gauge network the second best means, neither of these technologies is likely to be implementable in the foreseeable future because:

1) funding on the scale required for a weather radar may be extremely difficult to obtain.

2) negotiating the installation, operation and maintenance of a telemetric gauge network in India may be difficult.

Thus it has been concluded that, for the foreseeable future, activation of the first flash flood warning signal will have to depend on human observations of rainfalls on the Indian catchment areas. Such observations will, in turn, depend for their success on the calibre of the observers deployed. The selection and training of the Observer/Technicians are, therefore, matters of extreme importance over which the FFWA should exert very considerable care and attention. It cannot be emphasised too strongly that poor calibre Observer/Technicians with inadequate training comprise a recipe for system failure.

Since it is critically important that Observer/Technicians be effective in observing rainfall over the Indian catchment areas, assessing its flood-generating potential, and activating the first warning signal, it is essential that they be well trained and tested before:

1) a decision is taken to proceed with a pilot project

2) they are accepted as permanent staff of the FFWA.

With regard to (1) CIDA is insisting (See Annex B, CIDA General Comment No. 16) that the effectiveness of the Observer/Technicians in visually assessing rainfalls over the Indian catchments be assessed before the pilot project is initiated, and this matter must be addressed as indicated in the attached Draft Terms of Reference (see Annex C1). It is considered unlikely that a significant proportion of candidate Observer/Technicians, however well selected, would pass an effectiveness test without prior appropriate training, and such training must be provided before the test.

It is considered that the training and evaluation of the effectiveness, of candidate Observer/Technicians should be carried out at the Juri River Pilot Project site. If human observations of flood-generating rainfalls on the Indian portion of the Juri catchment prove to be ineffective there is little chance of such observations proving effective elsewhere in the Region; this follows from the fact that the site for the Juri observation post is the most nearly ideal site for such observations in the Region (it is high enough to command a good view over the catchment area, but low enough to remain below cloud base level under most storm conditions.)

G.2.1 Selection of Candidates

Observer/Technicians will be required to reside permanently at a relatively isolated observation post in the countryside. This fact suggests that candidates should be prepared to live apart from their families and be physically robust.

The nature of the work Observer/Technicians must perform is also an extremely important factor to be considered in the selection of candidates. There will be 3 Observer/Technicians in residence at each observation post; at any time of day or night one will be "on duty", and the other two will be "on call". An 8-hour work shift schedule will prevail such that, during any shift:

a) One Observer/Technician will be on duty

b) One Observer/Technician will be asleep

c) One Observer/Technician will be awake and attending to the food supply, preparation of meals, and other housekeeping activities.

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The Observer/Technician on duty must focus his attention on:

i) the state of weather conditions prevailing in the area, particularly over the relevant Indian catchment area

ii) the state of the flash flood warning system as indicated by the status of system fault indicating lights on the system control panel in the observation post.

His duties with regard to (i) will include:

- listening to weather forecasts broadcast by the BMD, particularly any special broadcasts which may be arranged in support of the Observer/Technicians activity

- observing the local weather conditions and assessing whether flood-generating rainfall is occurring over the relevant Indian catchment area and, if so, activating the first warning signal.

His duties with regard to (ii) will include:

- frequently (say every 5 minutes) checking the control panel to see if any of the fault indicating lights is on and, if so, identifying the nature and location of the fault and alerting the awake on-call Observer/Technician to address the problem

- entering details of the fault, and of rectifying actions taken and their outcome, in the System Logbook, and notifying the Warning Systems Supervisor accordingly.

Given the nature of his duties the Observer/Technician *on duty* must be *in command* of the system, and the Observer/technicians *on call* must take their instructions from him and act accordingly.

The Observer/Technician off duty but on call and awake must, in the event of a fault occurring in the system, break off from his "household" activities and attend to fixing the fault as quickly as possible. The nature and location of the fault having been identified to him by the duty Observer/Technician, he must:

- take whatever tools, spare parts, or other materials are needed to fix the fault, from the observation post store

- wake the other off-duty Observer/Technician to assist him as necessary

- proceed by jeep to the fault location, and fix the fault; in the event that he is unable to fix the fault he must notify the Warning Systems Supervisor who will then decide what further action should be taken.

Given the nature of their work it is apparent that candidate Observer/Technicians must:

1) be accustomed to exerting the necessary levels of authority and self-discipline

2) have an appropriate educational background in physics and mathematics, and be fully literate

3) be trainable in the techniques of weather observation and electro-mechanical fault fixing

G.2.2 Candidate Training/Practice

It is envisaged that the training will be carried out in two stages:

Stage 1

In Stage 1, of approximately one week duration, the candidates will be given an explanation of the flash flood warning system as proposed, and of their critically important role in its successful operation. This should be followed by:

a) a description of the living and working conditions in the field (camp during the Evaluation, observation post accommodation when a system is in place)

b) a short course on *relevant* meteorological observation techniques including understanding BMD forecast broadcasts, observing the state of the local weather (cloud types and cover amount), assessing the flood-generating potential of rainfall (shower density, thunder and lightning)

Stage 2

In Stage 2, of approximately 3 months duration, the candidates will be taken to the proposed pilot project observation post (in the Juri catchment) to experience the living and working conditions in the field, receive continual on-site training/practice in observing runoff-generating rainfalls, and have their individual effectiveness assessed during each practice session. The practice sessions will have to be held when storms are passing over the site. It is extremely important that this stage is scheduled for the pre-monsoon season when the incidence and variety of storms is sufficient to support adequate training/practice; in the dry season the number of storms is too few, and in the monsoon season every storm will produce a flood - as a consequence performance statistics compiled in these seasons will inevitably tend to indicate success rates of 0% or 100%!

Prior to State 2 the following tasks must have been completed:

1) Robust installation of three standard BWDB type staff gauges, one at the proposed site of the pilot project's river water level detector station near the Indo-Bangladesh border, one on the upstream side of the Dhaka-Karimganj railway bridge at Jahangirai, and one on the upstream side of Jahangirai where the backwater effect caused by the railway bridge constriction is negligibly small; BWDB - standard observers will need to be appointed to read these gauges over a period of several months for the purpose of:

    a) calibrating a hydrodynamic model of this reach of the Juri River (see 2 below)

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b) providing the training instructor with information on occurrences of the critical water level during Stage 2 of the training.

2) A hydrodynamic model study, using the NER HD Model, to determine:

a) the dangerous river water level at Jahangirai

b) the corresponding critical water level at the Indo-Bangladesh border.

G.2.3 Effectiveness Testing

Assessing the effectiveness of the method of observation of flood-generating rainfall, and of individual candidates in applying it, will involve:

1) establishing criteria for assessing the success of individual candidates, and of the candidate group as a whole

2) enumerating the successes of individual candidates, and compiling performance statistics on each individual, and on the group

3) assessing, based on the group performance statistics, the effectiveness of the manual observation technique

4) identifying, based on the individual performance statistics, the best candidates for subsequent induction into the FFWA as Observer/Technicians.

Since the objective of manual observation is to identify rainfalls over Indian catchments which result in dangerous high river water levels, the criterion for success must be based on a comparison between candidates' responses to rainfalls observed over the test catchment area in India and exceedances of the critical water level in its river.

Basically, candidates will have to make up their minds, based on their personal observation of the weather conditions prevailing during each practice session, whether or not "to press the button" to activate the first warning signal and, if so, when to do it. In each practice session, of which there ought to be at least ten (weather permitting), they should be asked to secretly record the time at which they decided to press the button on a sheet of paper bearing their name; if they decide the weather conditions are not bad enough to justify pressing the button they will turn in a blank report sheet.

On the day following each session, by which time it will be known to the instructor whether or not the critical water level in the river was exceeded or not and, if so, when it was exceeded, the instructor will make the comparison between the candidates' reports and the occurrence of the critical water level. He should make this comparison in front of the candidate class.

The scoring system set out in Table G.1, Part (A), is based on the tentative calculation made in Section 4.2 that the first warning signal needs to be given 100 minutes before the second one. An effective Observer/Technician will, therefore, be one who presses the button exactly 100 minutes before the critical water level in the river is exceeded and the second warning signal is automatically activated by it. To the extent that candidates press the button earlier or later than

100 minutes before the critical water level is exceeded they will be less effective, and they will be scored lower as indicated in the table. Perfection will not, of course, be achieved so the maximum score of 10 should be given to any candidate pressing the button within +/-20 minutes of the optimum time.

The scoring system set out in Table G.1, Part (B), is based on the obvious fact that if the critical water level is *not* exceeded the candidate should *not* press the button.

At the end of Stage 2 each candidate's total score T will be computed, again in front of the class, as the sum of his scores for the individual practice sessions. If, in Stage 2, there were N_1 practice sessions (i.e. storms) in which the critical water level was exceeded, and N_2 in which it was not exceeded, then the maximum possible total score would be $(10N_1 + 10N_2)$. The effectiveness of each candidate can then be expressed as:

$$EC(\%) = 100T/(10\ N_1 + 10N_2)$$

Table G.1

Evaluation Test Scoring System

Test Condition/Candidate Action			Score
A)	Critical Water Level Exceeded:		
	Time elapsed between candidate pressing the button and critical water level occurring (minutes): -		
	>200	(far too early; observer "trigger happy"	0
	180-200		2
	160-180		4
	140-160		6
	120-140		8
	100-120	(about right; well-judged by observer)	10
	80-100	(about right; well-judged by observer)	10
	60-80		8
	40-60		6
	20-40		4
	0-20		2
	<0	(far too late; observer "asleep")	0
B)	Critical Water Level Not Exceeded:		
	Candidate pressed the button (wrong response)		0
	Candidate did not press the button (right response)		10

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If a candidate's effectiveness (EC) is less than, say 65%, he should probably be rejected for induction into the FFWA on the grounds that:

a) he has failed to absorb the training

b) he lacks relevant aptitude.

Assuming a sufficient number of candidates score 65% or more then:

i) the three with the highest scores will be accepted for deployment on the pilot project

ii) the rest of those who scored 65% or more will be retained, possibly for further training, for later deployment on other river systems if the pilot project is successful

iii) those who scored less than 65% will be advised that they have not reached the required standard and cannot be employed by FFWA.

If a sufficient number of candidates do not score 65% or more then the effectiveness of the manual method of detecting flood-generating rainfalls is in question. At the end of Stage 2 also, therefore, the effectiveness of the whole group of candidates must be computed (this need not be done in front of the class). If there were n candidates in the class then:

a) the class score would be $\overset{n}{\Sigma}$ T

b) the maximum possible class score would be $n(10N_1 + 10N_2)$

and the effectiveness of the class (i.e. the method) would be:

$$EM\ (\%) = 100 \overset{n}{\Sigma}\ T/n\ (10N_1 + 10N_2)$$

If the candidate class effectiveness (EM) is found to be less than, say 50%, then it will have to be subjectively assessed whether this result is due to:

i) weakness in the candidate selection process

ii) ineffective training/inadequate practice

ii) weakness of the manual method.

Clearly, if weakness of the manual method is to be positively identified as the reason for a poor class effectiveness, the FFWA must take great care in selecting and training the candidate's. It is considered essential, therefore, that those carrying out the selection and training of the candidates are themselves monitored for their effectiveness, possibly by an independent appropriate qualified consultant.

It is to be noted also that, if meaningful values of EC and EM are to be obtained, the values of n, N_1 and N_2 must be as large as it is practical for them to be. In particular:

a) the number of candidates in the class (n) should not be less than 20 (more than 30 will probably be impractically large)

b) the number of storm events available for candidates to score on, $(N^1 + N_2)$, should not be less than about 10 (more than 10 storms are unlikely to occur in the test pre-monsoon season, so Stage 2 should *not* be shorter than the 3 months proposed above).

If the independent monitor is satisfied that the FFWA took all reasonable care in the selection and training of the candidates, and the values of n and $(N_1 + N_2)$ were equal to or greater than the minimum values indicated above, then it could be appropriately concluded that the manual method will not be adequate.

If it is concluded that the manual method is inadequate then, it would seem, further implementation of the Improved Flood Warning proposal should be postponed pending either acquisition of a second radar for the FFWA, or establishment of an effectively operating network of telemetric equipment on the Indian catchment areas.

G.3 Interim Institutional Arrangements

The prior evaluation of first warning activation by Observer\Technicians, and the subsequent implementation and test operation of the Pilot Project, are both activities which, if not pursued with sufficient motivation and vigour, could lead to abandonment of further activity on implementing the flash flood warning systems. If failure of either of these activities is to be avoided it is imperative that they are organized and executed by highly motivated and vigourous senior staff who are appropriately empowered and funded. It is strongly recommended, therefore, that the FFWA be set up, albeit in embryonic form, as soon as a decision is made to proceed with the prior evaluation of first warning activation by Observer\Technicians, and that the senior staff appointed be charged with "working themselves into permanent positions" on the basis of their achieving successful outcomes from these first two major activities of the FFWA.

Accepting that the FFWA will be established as recommended above, it is recommended to appoint on a provisional basis the Director and Deputy Directors I and IV (see Section F.3) for the purpose of organizing and executing the prior evaluation of the first warning activation by Observer/Technicians. For this propose they will need, apart from electrical support, drivers, etc., to locate and arrange for the secondment of the following temporary professional staff:

1) The Hydrologist who will set up the staff gauges along the Juri River, carry out river section surveys, and organize such staff gauge observations and flow gauging as the Hydraulic Modeller may require

2) the Hydraulic Modeller who will set up the hydro-dynamic model study to determine the dangerous water level in Jahangirai, and the corresponding critical water level at the Indo-Bangladesh border

3) The meteorologist who will plan and later give the necessary course of instruction to candidate Observer/Technicians on observing flood-generating rainfalls over the Pilot Project catchment area in India, and who will subsequently prepare the Evaluation Report for CIDA and FPCO consideration.

Assuming that the Evaluation Report is accepted favourably by CIDA and FPCO, the Director will then be authorized to appoint Deputy Directors II and III, and then to proceed with the Pilot Project. For this purpose they will need to locate and arrange for the secondment of:

1) The Construction Engineer who will supervise the construction of the detector and warning station civil works components of the Pilot Project

2) The Sociologist who will set up the necessary social surveys and community organization programme for the Pilot Project.

Also for the purpose of the Pilot Project they will need to appoint on a provisional basis the following permanent staff:

3) The Warning Systems Supervisor who will supervise the installation and testing of detector and warning station electrical works components of the Pilot Project, and who will eventually contribute to the System Operation Report on the Pilot Project

4) The three Observer/Technicians who passed top of the class during the prior evaluation of first warning activation by Observer/Technicians

5) The Community Organizer who will carry out the necessary social surveys and community organization, including drawing up Plans of Action for the Pilot Project beneficiaries.

Assuming that the Pilot Project is successful and that the System Operation Report (on it) is accepted favourably by CIDA and BWDB, then the FFWA may be confirmed as a permanent organization. The Director will then be authorised to:

1) locate and arrange the secondment of all the remaining temporary professional staff needed for the investigation, design and construction of embankments, cyclone-type shelters, etc., i.e the Geotechnical and Structural Engineers

2) appoint (after suitable selection and training) the additional Observer/ Technicians required to man the eight other flash flood warning systems.

G.4 Terms of Reference and Schedule for Pilot Project

Draft terms of Reference for the Pilot Project, including the prior evaluation of first warning activation by Observer/Technicians, are presented in Annex C.

Here it will suffice to make two important points to those who will be responsible for organizing and executing the prior evaluation and pilot project:

1) The sites shown in Figure 23 for the detector and warning stations must be adhered to within a distance of, say, +/- 0.5 km; any greater deviations in station locations will risk disturbing anticipated lead times and warning signal overlaps. It is emphasised that the sites have not yet been thoroughly investigated on the ground, and this needs to be done as soon as the next work

phase begins; in particular, the best locations for the 3 staff gauges and the observation post need to be confirmed before the evaluation test, and those for the observation post building, stilling well and warning station masts need to be confirmed before work starts on the pilot projects. Access routes to all these sites also need to be identified, and improved as necessary for a jeep.

2) The evaluation test and pilot project is scheduled to start in January 1995. It is essential, however, to recognise that all the activities are seasonally-dependent, and that if start up is delayed it will have to be delayed by one whole calendar year; it will prove impossible to carry out the activities at other times of the year.

LIBRARY

ANNEX H

DRAWINGS

Figure 1

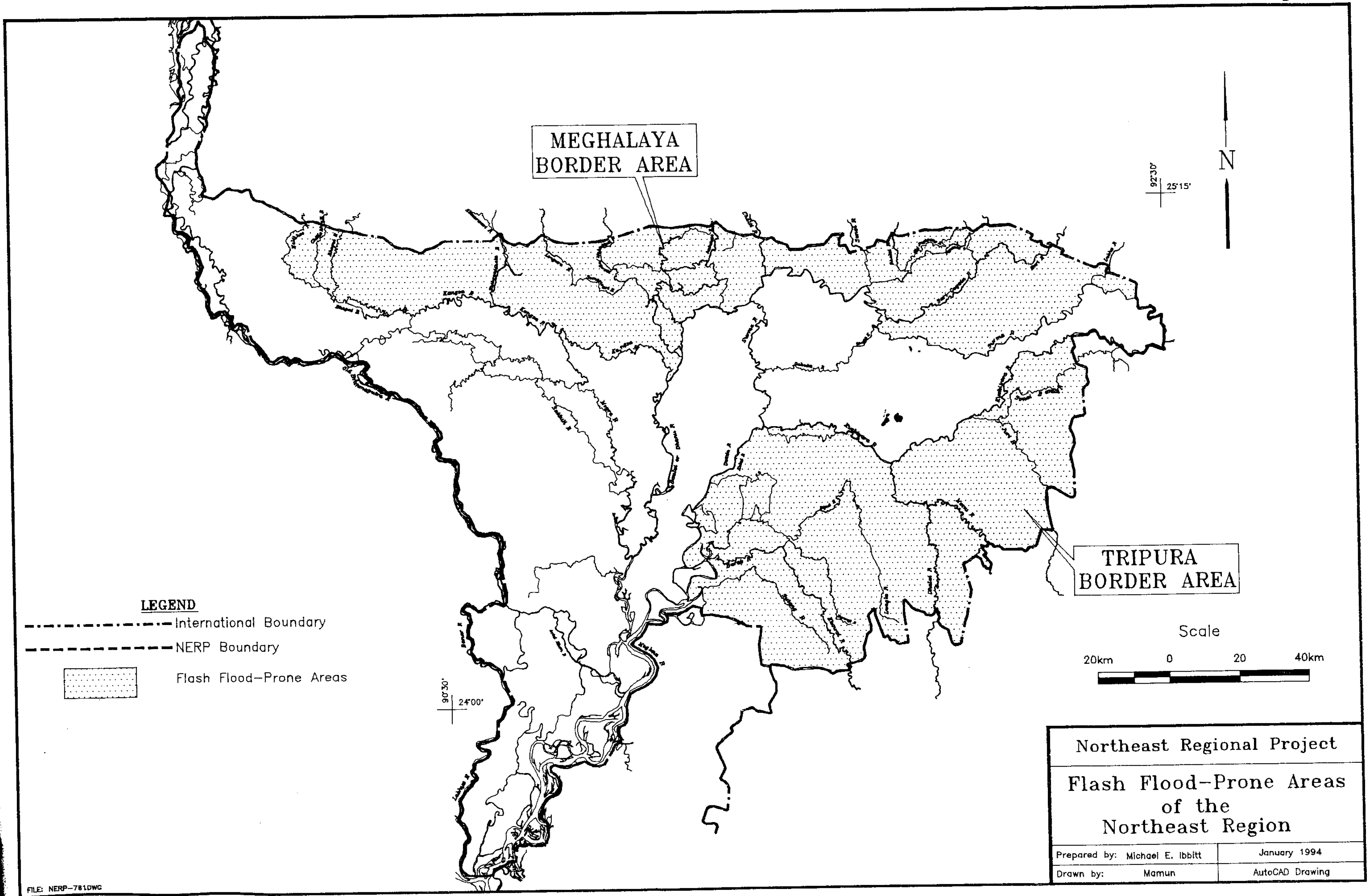
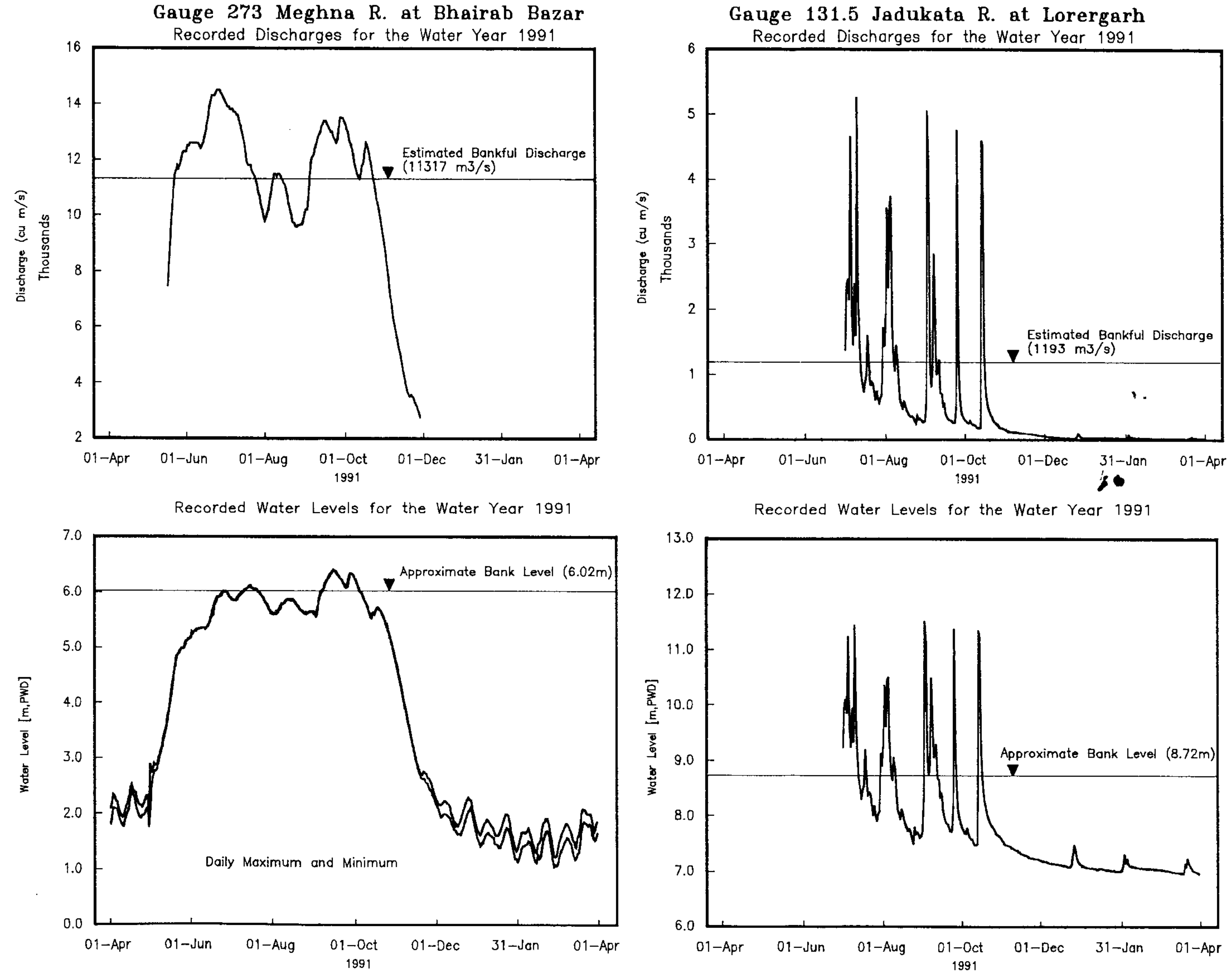

MEGHALAYA BORDER AREA
TRIPURA BORDER AREA
N
92°30'
25°15'
90°30'
24°00'
Scale
20km 0 20 40km
LEGEND
International Boundary
NERP Boundary
Flash Flood–Prone Areas
Northeast Regional Project
Flash Flood–Prone Areas of the Northeast Region
Prepared by: Michael E. Ibbitt
January 1994
Drawn by: Mamun
AutoCAD Drawing
FILE: NERP-781DWG

Figure 2



(a)

Example of a Seasonal Flood Regime

(b)

Example of a Flash Flood Regime

NOTES:

1. Bankfull discharges estimated from flood discharge frequency curve as $Q_{1.1}$
2. Bankfull water levels estimated visually to correspond with $Q_{1.1}$
3. Time discrepancies between bankfull discharges and water levels are attributed to variable river bed erosion and deposition
4. Note the greater tendency for flash floods to overtop the river bank by several metres; in contrast the Meghna River overtops its bank by only about 0.5 metre

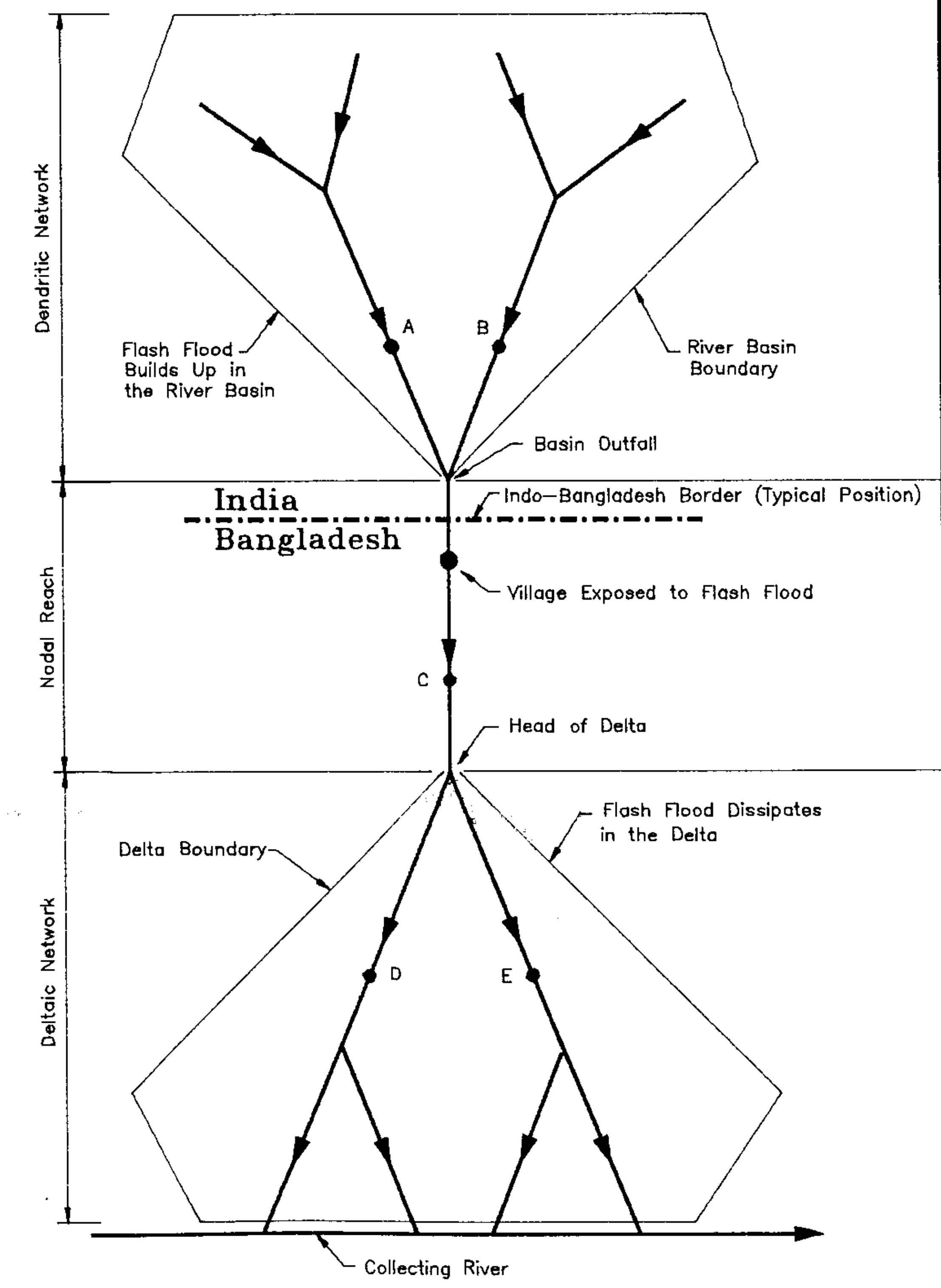
FILE: NERP-782.DWG

Northeast Regional Project

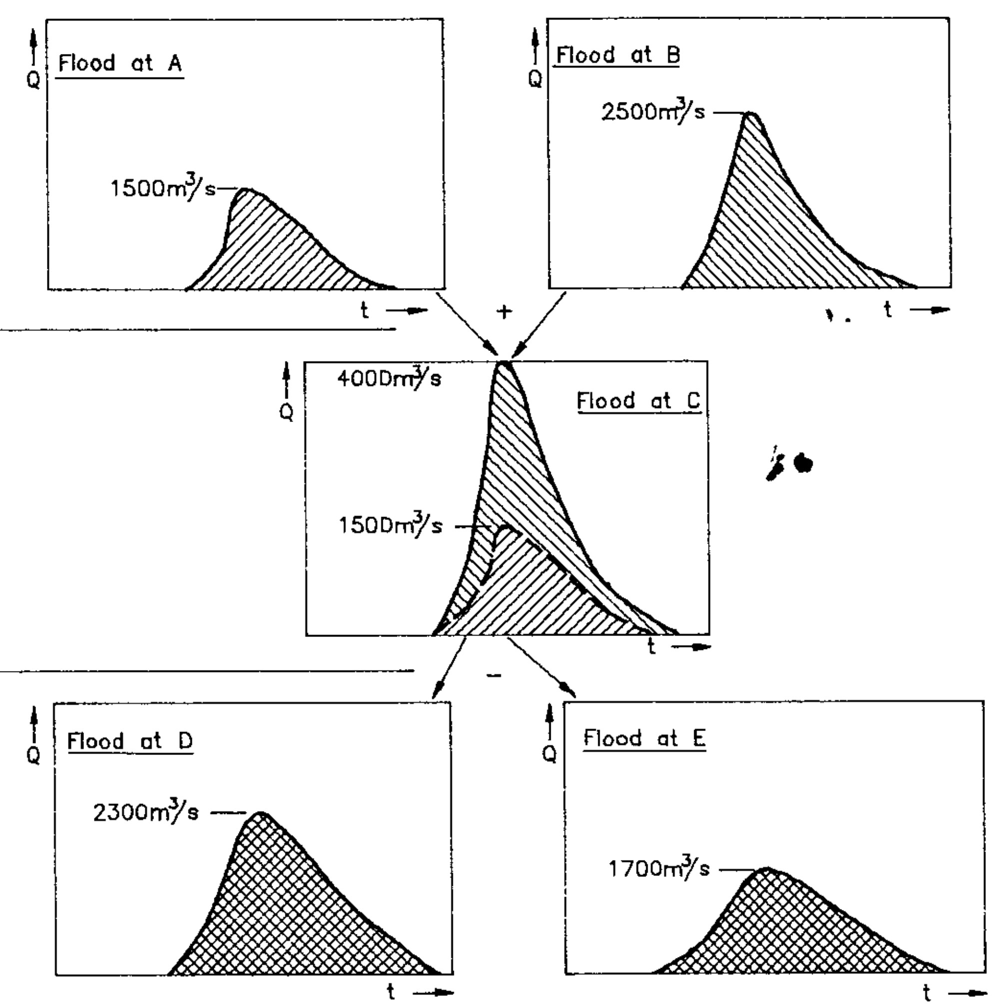
Comparison of Seasonal and Flash Flood Waves

Prepared by:	RKA	January 1994
Drawn by:	Mamun	AutoCAD Drawing

Figure 3



GENERALISED PLAN OF RIVER CHANNEL NETWORK



HYDROGRAPHS AT SELECTED POINTS IN THE RIVER CHANNEL NETWORK

EXPLANATION

1) Rainfall over India generates floods in the tributaries at A and B in the dendritic River channel network

2) Floods at A and B converge at the basin outfall and become superimposed to form a large flood in the nodal reach at C

3) At the head of the delta the large flood at C is divided between the distributaries to form smaller floods at D and E

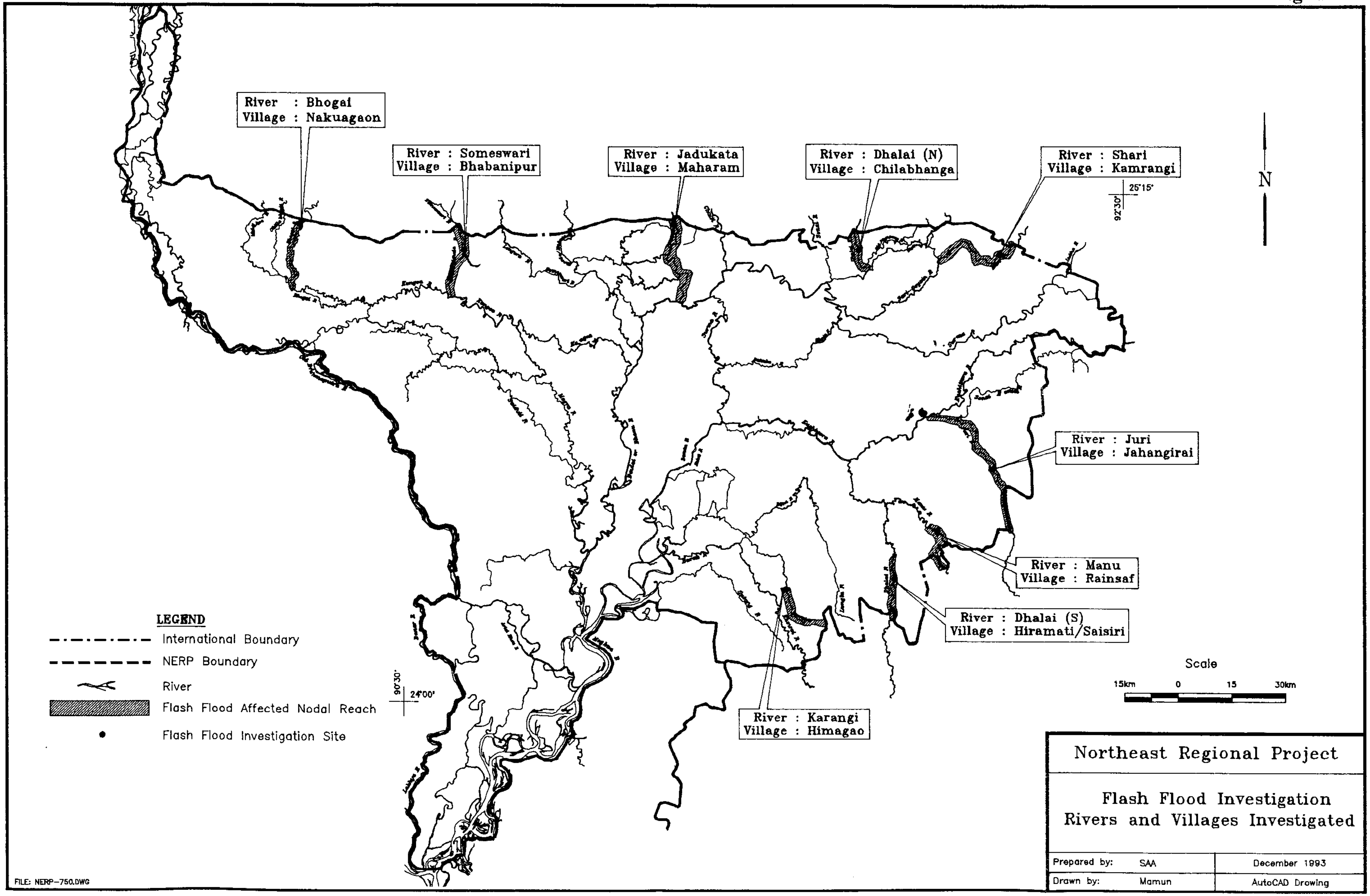
F.A.R.P.O. LIBRARY. DHAKA

Northeast Regional Project

Influence of River Channel Network on Flash Floods

Prepared by:	Michael E. Ibbitt	February 1994
Drawn by:	Mamun	AutoCAD Drawing

FILE: NERP-800.DWG



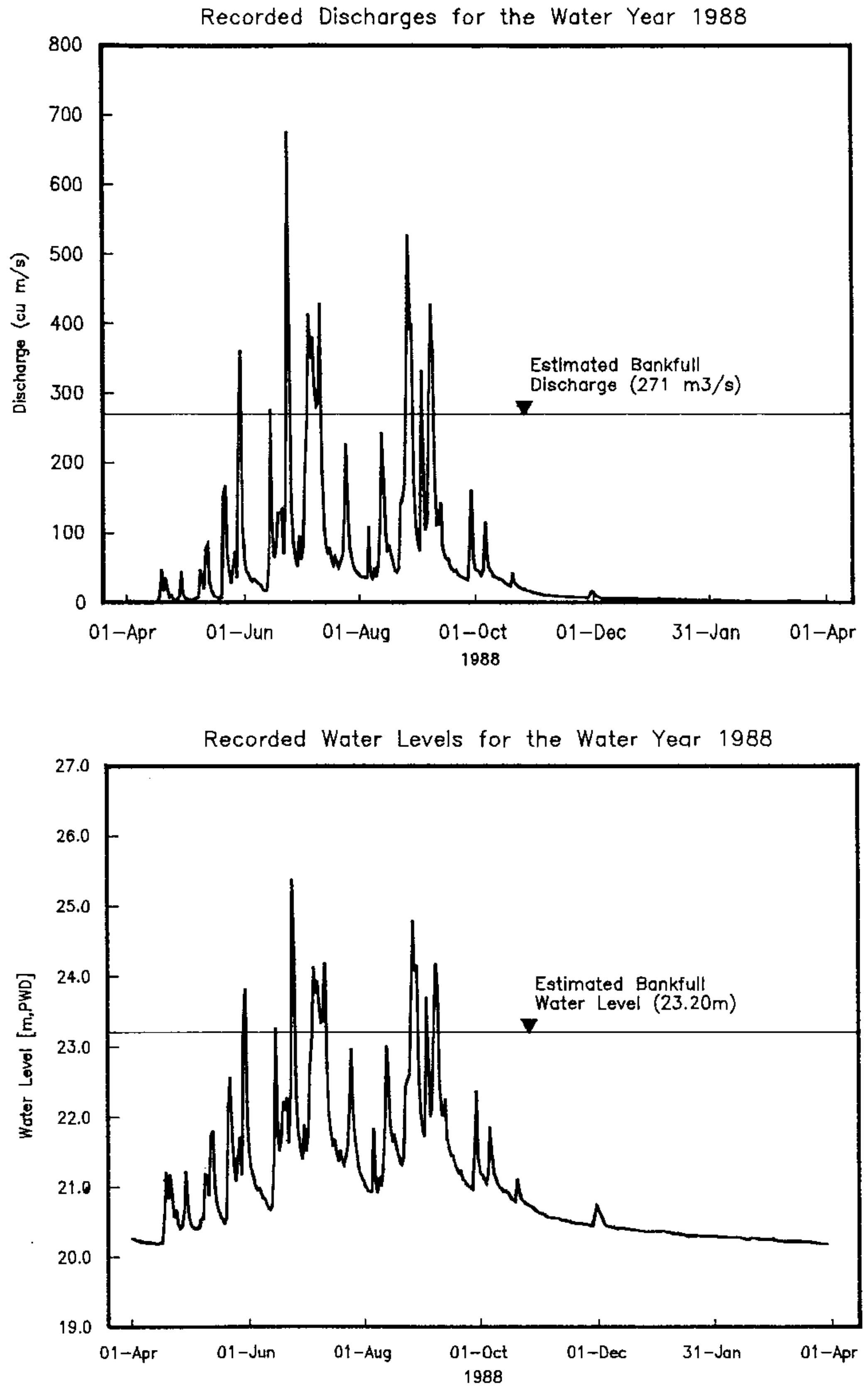
Northeast Regional Project

Flash Flood Investigation
Rivers and Villages Investigated

Prepared by:	SAA	December 1993	
Drawn by:	Mamun	AutoCAD Drawing	

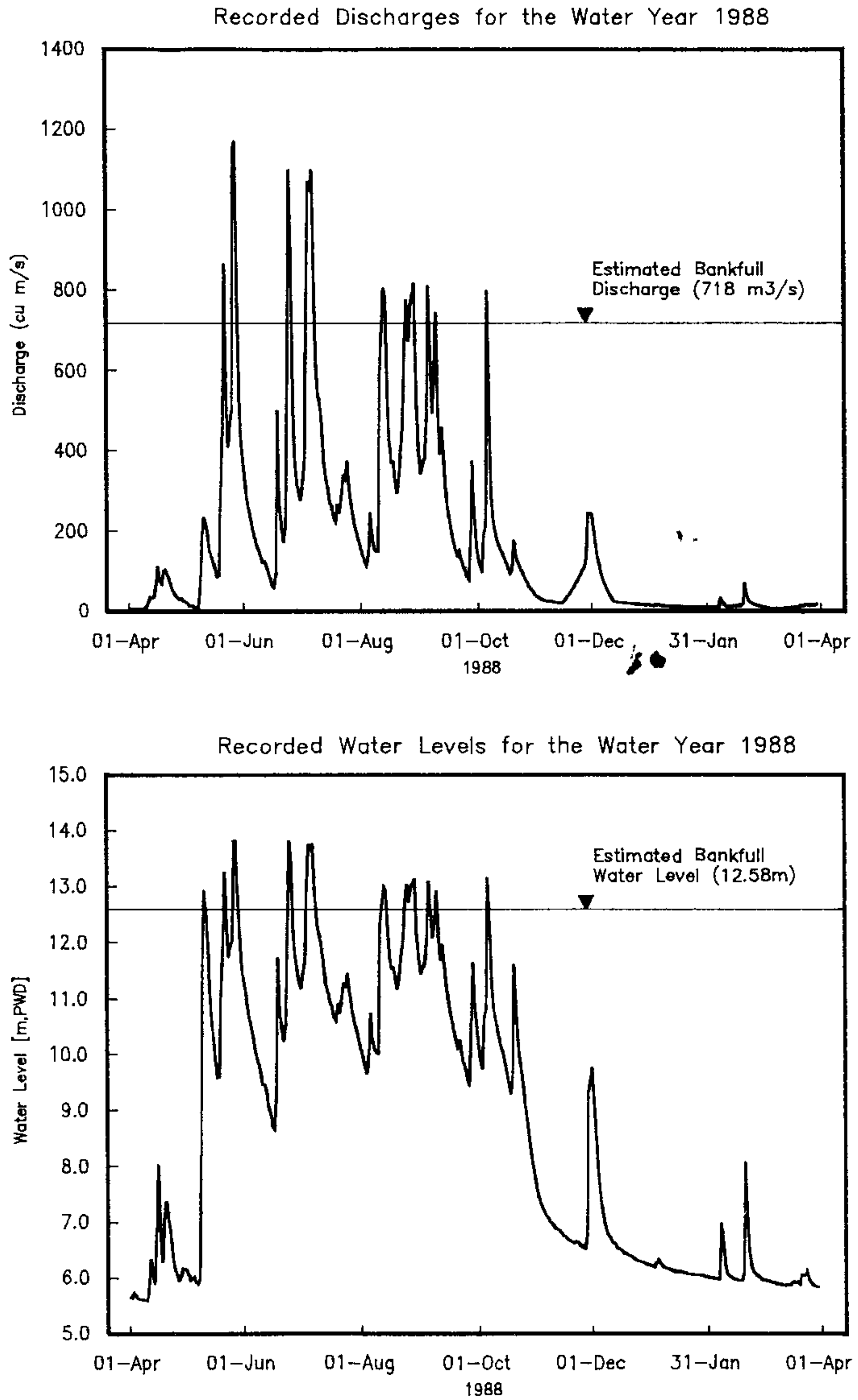
Figure 5

Gauge 34 Bhugai-Kangsha R. at Nakuagaon



(a)

Gauge 251 Sari-Gowain R. at Sarighat



(b)

Notes:

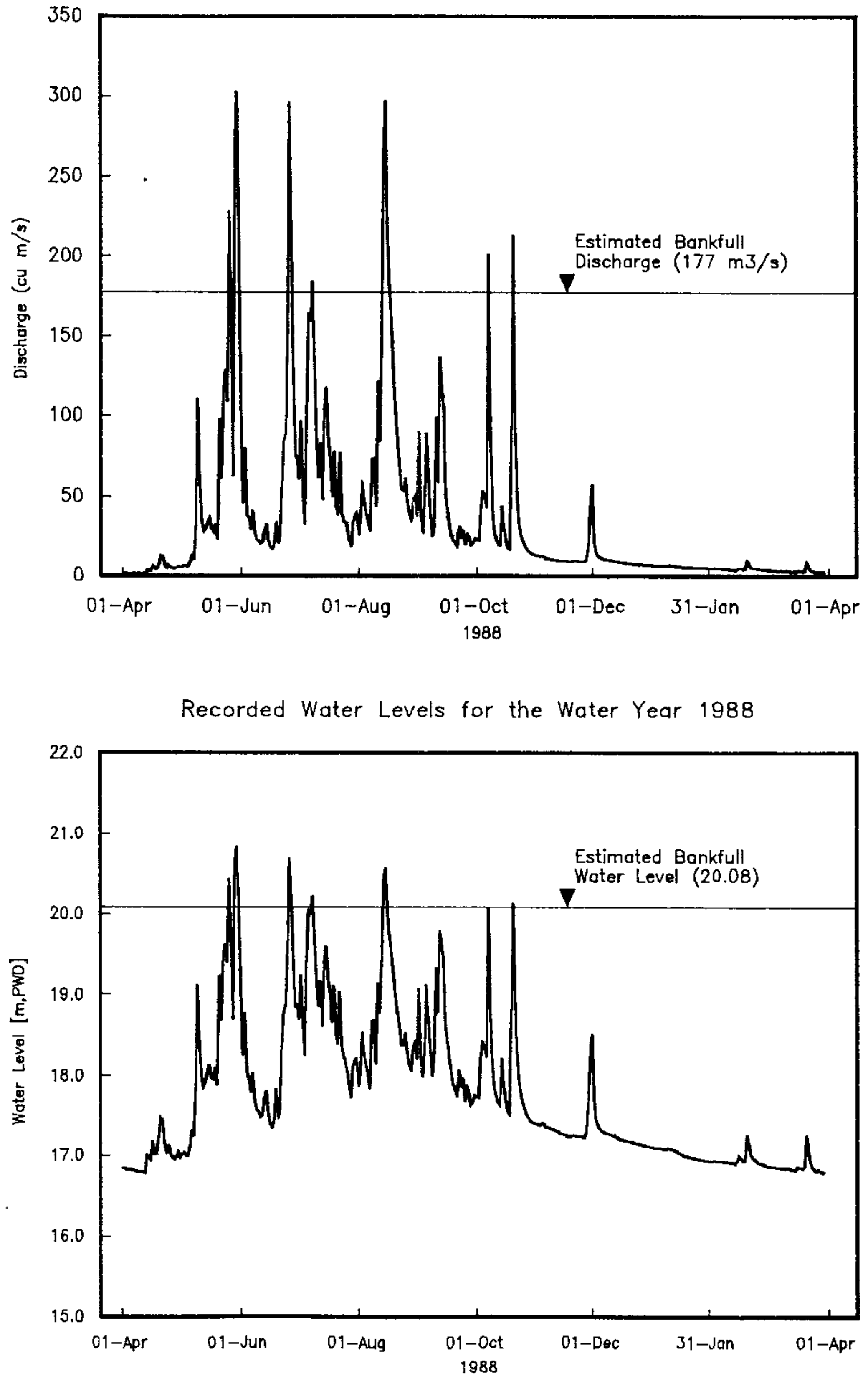
1. Bankfull discharges estimated from flood discharge frequency curves as $Q_{1.1}$
2. Bankfull water levels estimated visually to correspond with $Q_{1.1}$

Northeast Regional Project		
Meghalaya Border Area Flash Floods of 1988		
Prepared by:	RKA	January 1994
Drawn by:	Mamun	AutoCAD Drawing

FILE: NERP-801DWG

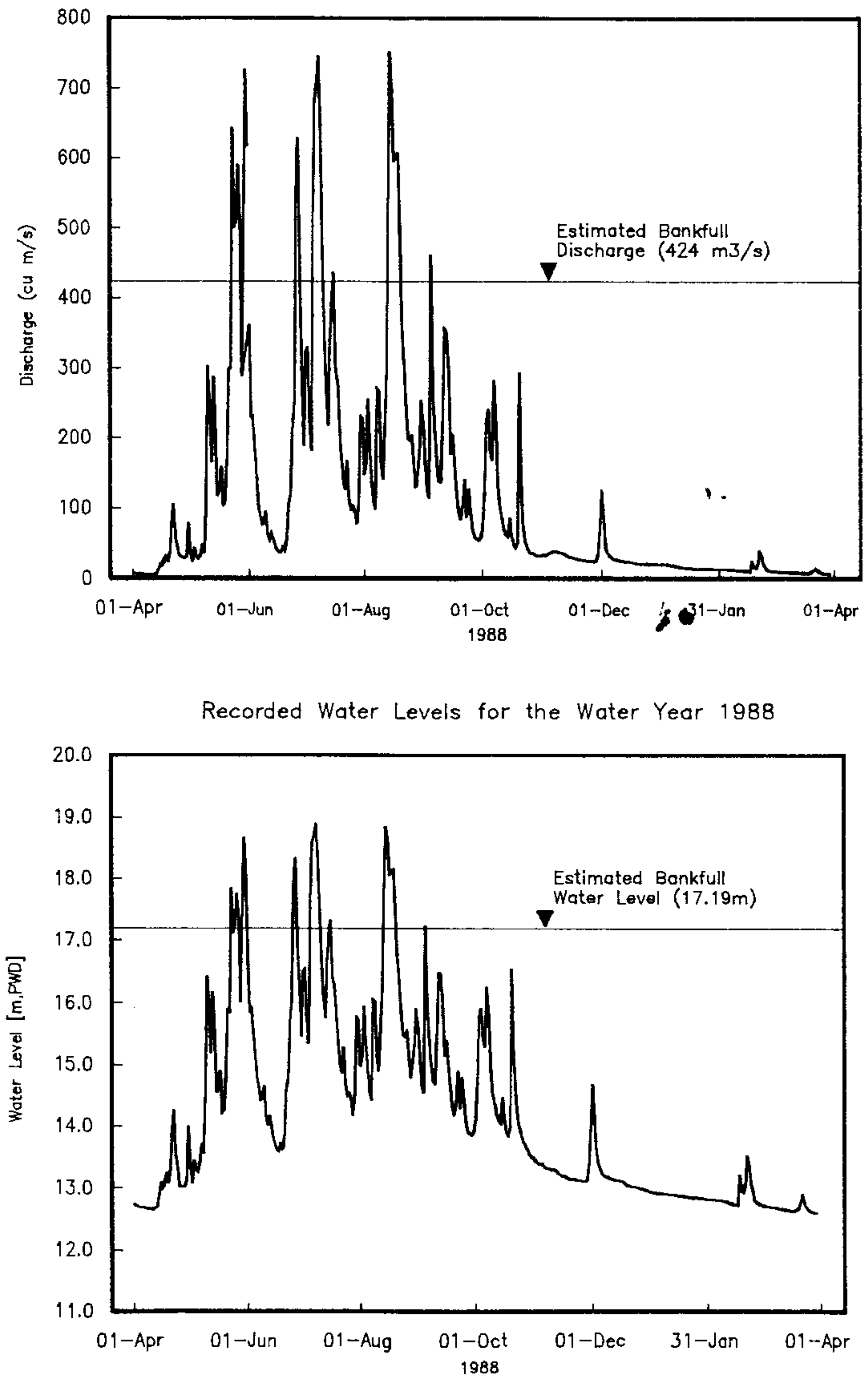
Figure 6

Gauge 67 Dhalai R. at Kamalganj



(a)

Gauge 201 Manu R. at Manu Rly. Bridge



(b)

Notes:
1. Bankfull discharges estimated from flood discharge frequency curves as $Q_{1.1}$
2. Bankfull water levels estimated visually to correspond with $Q_{1.1}$

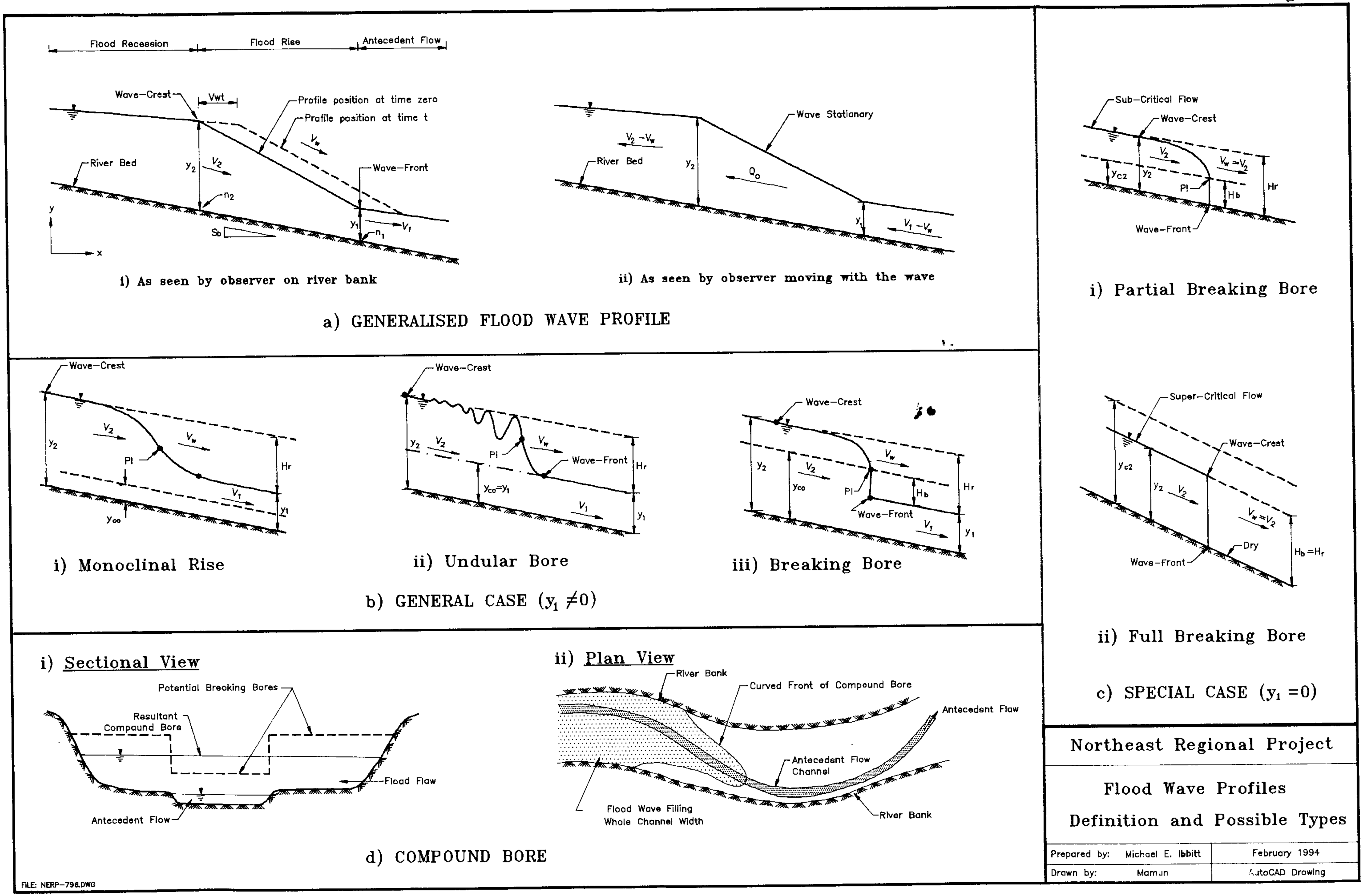
Northeast Regional Project

Tripura Border Area
Flash Floods of 1988

Prepared by:	RKA	January 1994
Drawn by:	Mamun	AutaCAD Drawing

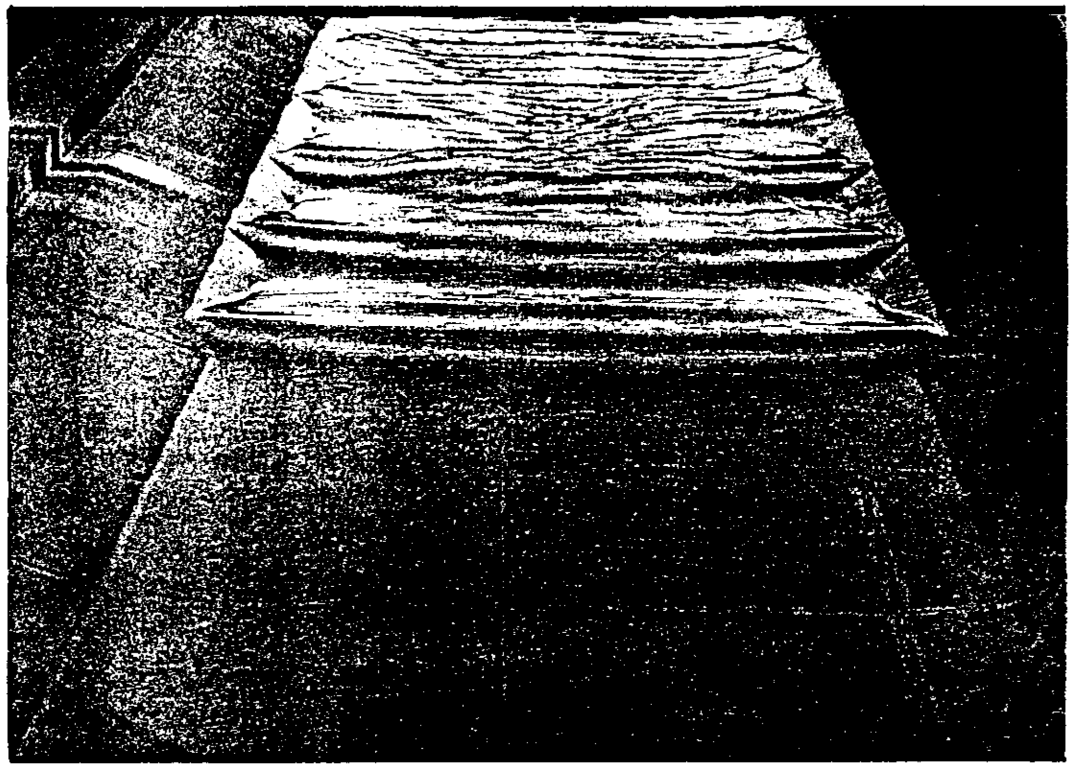
FILE: NERP-602.DWG

Figure 7



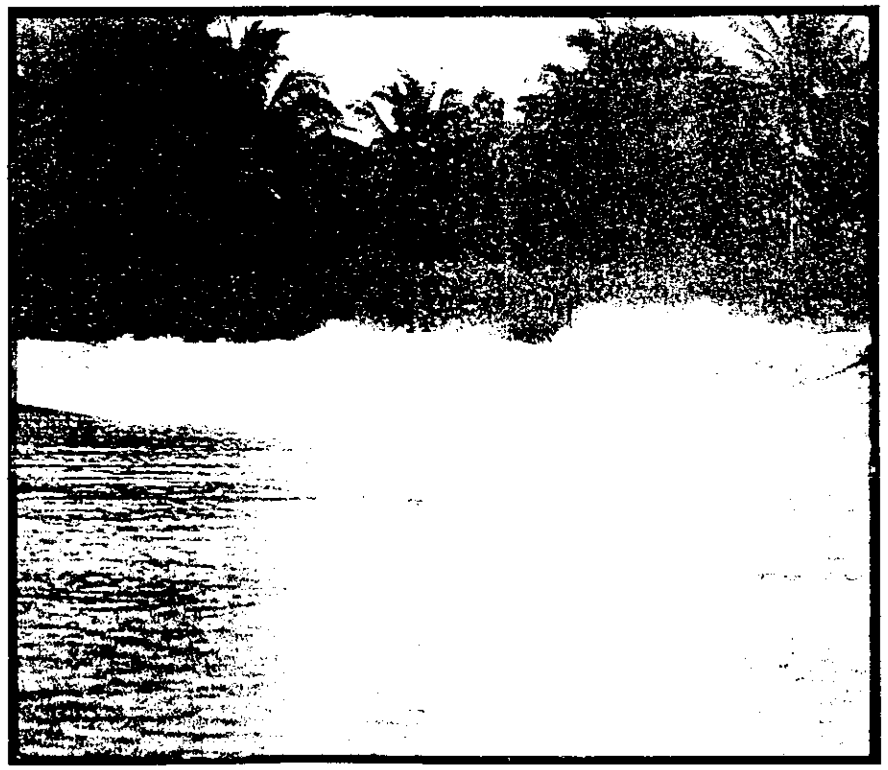
Flood Recession
Flood Rise
Antecedent Flow
Wave-Crest
Vwt
Profile position at time zero
Profile position at time t
River Bed
Wave-Front
y
x
i) As seen by observer on river bank
Wave Stationary
River Bed
ii) As seen by observer moving with the wave
a) GENERALISED FLOOD WAVE PROFILE
Wave-Crest
PI
Hr
i) Monoclinal Rise
Wave-Crest
Wave-Front
ii) Undular Bore
Wave-Crest
Wave-Front
iii) Breaking Bore
b) GENERAL CASE ($y_1 \neq 0$)
Sub-Critical Flow
Wave-Crest
Wave-Front
i) Partial Breaking Bore
Super-Critical Flow
Wave-Crest
Dry
Wave-Front
ii) Full Breaking Bore
c) SPECIAL CASE ($y_1 = 0$)
i) Sectional View
Potential Breaking Bores
Resultant Compound Bore
Flood Flow
Antecedent Flow
ii) Plan View
River Bank
Curved Front of Compound Bore
Antecedent Flow
Antecedent Flow Channel
Flood Wave Filling Whole Channel Width
River Bank
d) COMPOUND BORE
Northeast Regional Project
Flood Wave Profiles
Definition and Possible Types
Prepared by: Michael E. Ibbitt
February 1994
Drawn by: Mamun
AutoCAD Drawing
FILE: NERP-796.DWG

Figure 8



a) Undular Bore in a Laboratory Channel

c) Breaking Bore in a Chinese River



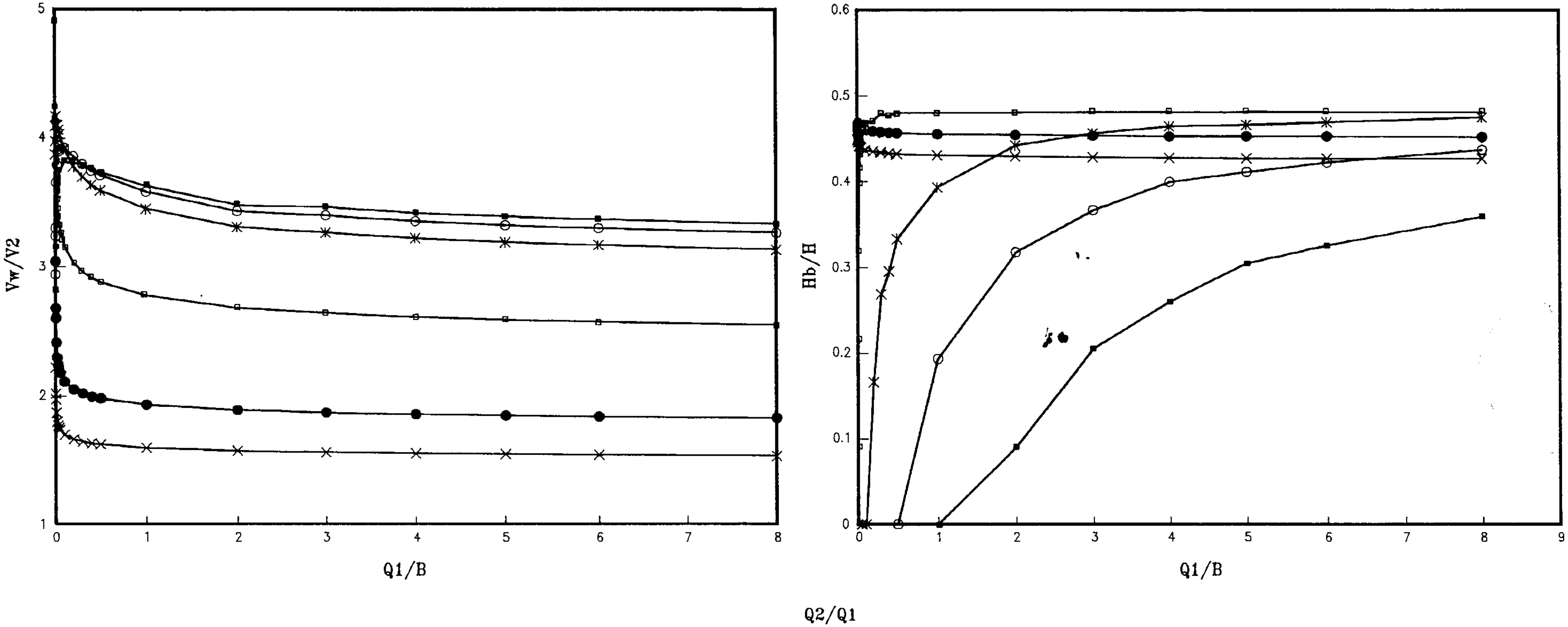
b) Breaking Bore in a Malaysian River

d) Breaking Undular Bore in a Malaysian River

Northeast Regional Project	
Photographs of Hydraulic Bores	
Prepared by: Michael E. Ibbitt	February 1994
Drawn by: Mamun	AutoCAD Drawing

FILE: NERP-797.DWG

Figure 9



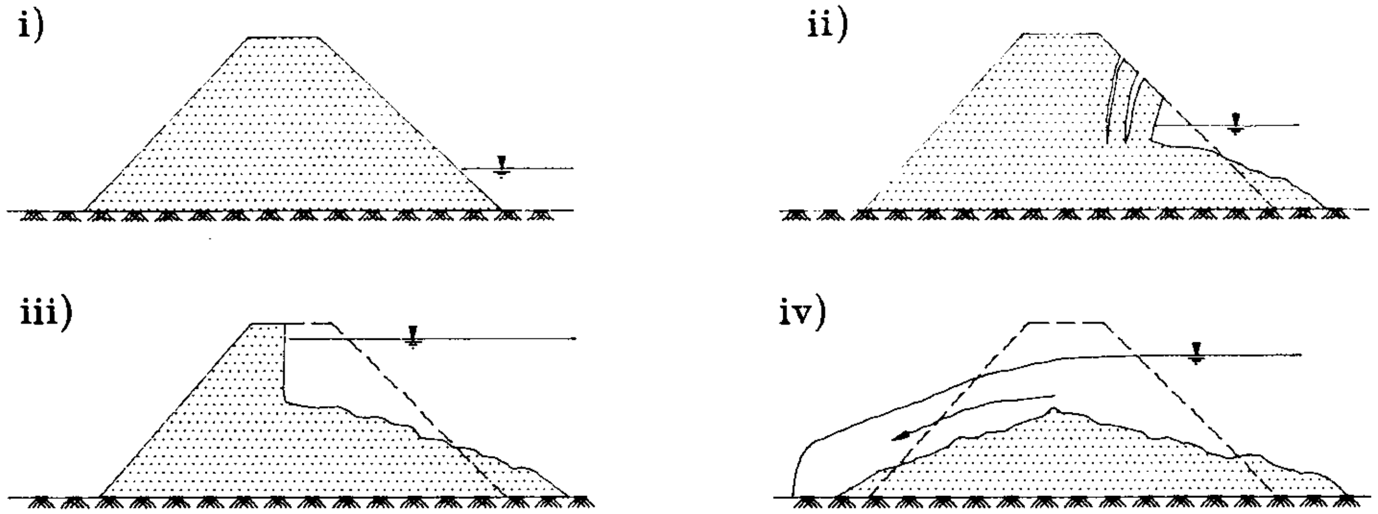
LEGEND

Q1= Antecedent Flow
Q2= Flood Peak Flow
B = Channel Width
Vw= Wave Velocity
V2= Water Velocity at Flood Peak
Hb= Bore Height
H = Flood Rise Height

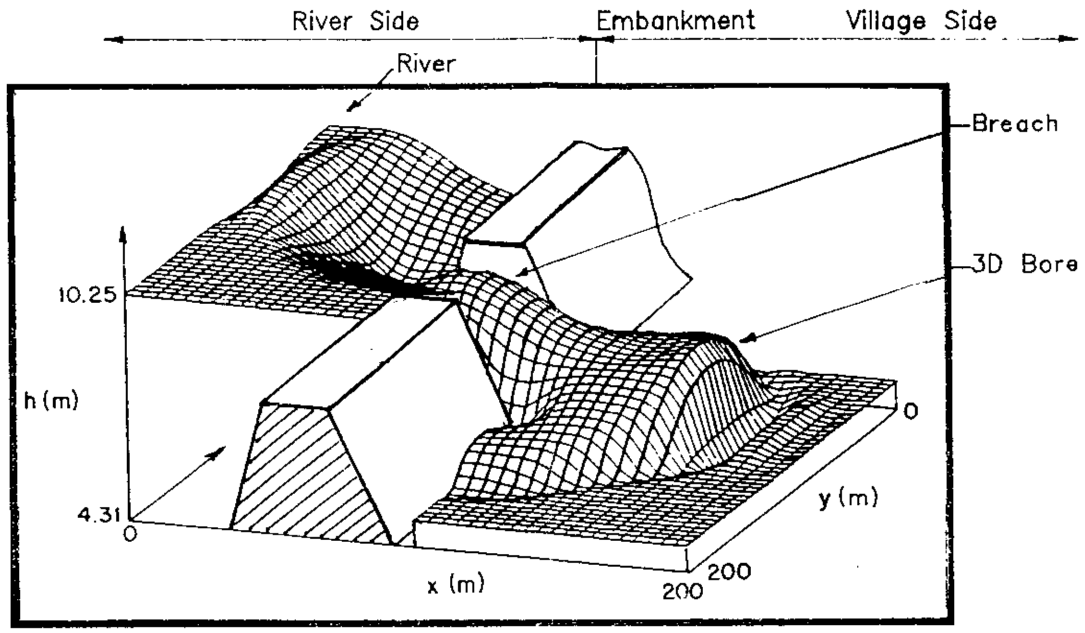
FILE: NERP-813.DWG

Northeast Regional Project	
Characteristic Curves for Bores in Flash Flood-Prone Rivers of the NE Region	
Prepared by: RKA	February 1994
Drawn by: Mamun	AutoCAD Drawing

Figure 10



a) Embankment Failure Development in Flash Flood (See Notes)



c) Simulation of Bore Released on Embankment Failure

b) A Failing Embankment At Abdullahpur (North of Manu River Project)

LEGEND

a) Embankment Failure Development

(i) Before a flash flood arrives the embankment in intact

(ii) As the flash flood rises longitudinal cracks develop on the river side face of the embankment and slabs of embankment material fall into the river

(iii) Eventually the section remaining intact becomes critically thin, and bursts open under the water pressure when the flood is at maximum stage

(iv) A three-dimensional hydraulic bore is then relased into the village

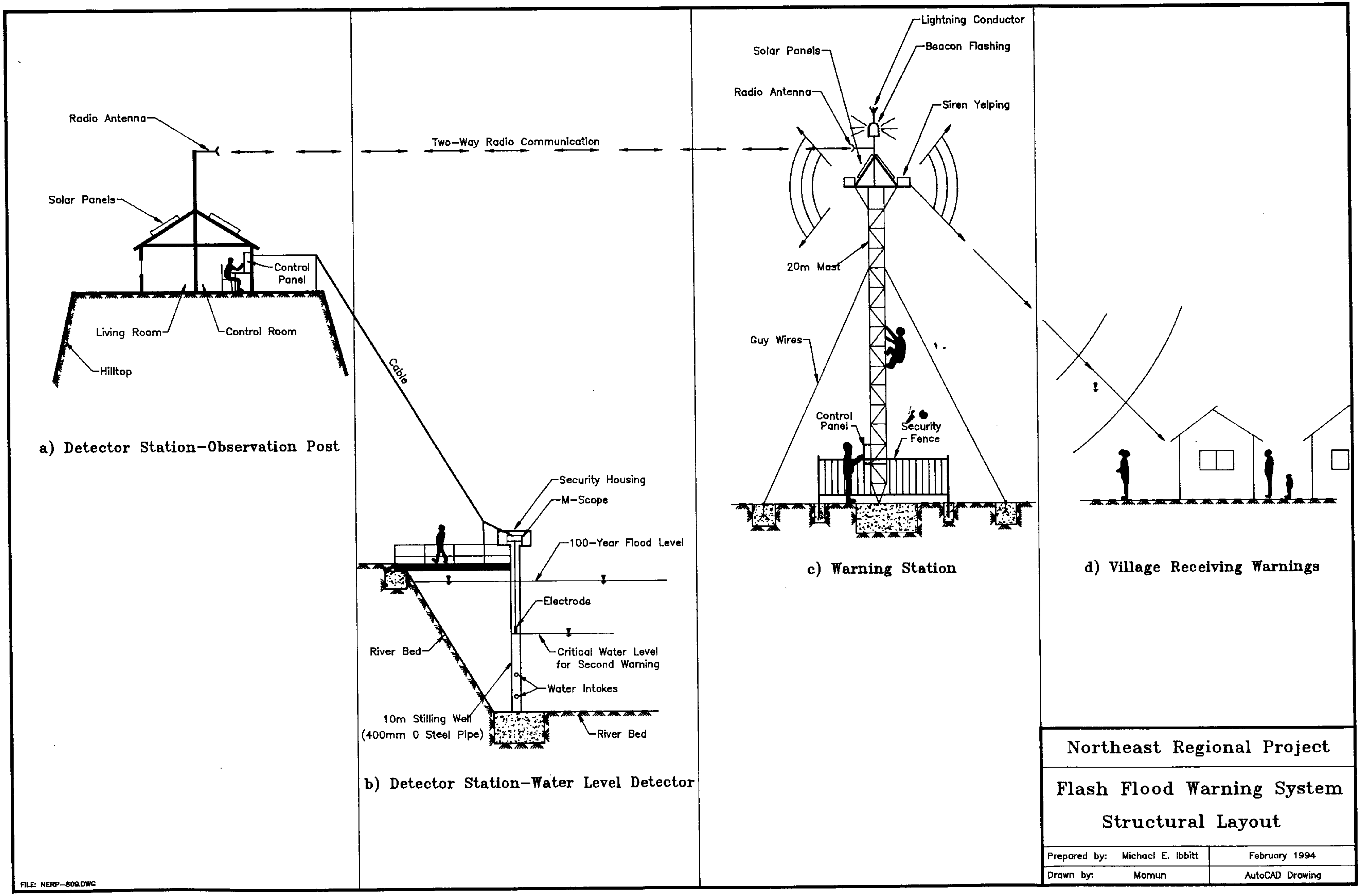
b) This photograph vividly illustrates a critically thin remaining embankment section

c) Bores released through embankment breaches can nowadays be simulated by computer solution of the governing Navier-Stokes equations

Northeast Regional Project	
Embankment Failure during Flash Flood	
Prepared by: Michael E. Ibbitt	February 1994
Drawn by: Manun	AutoCAD Drawing

FILE: NERP-807.DWG

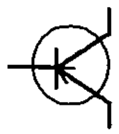
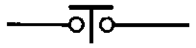
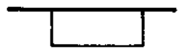
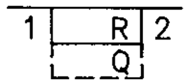
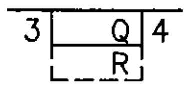
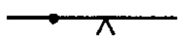
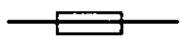
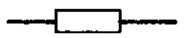
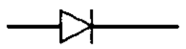
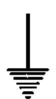
Figure 11

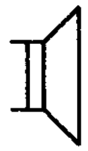
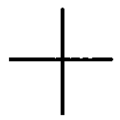
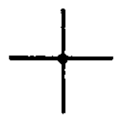


Radio Antenna
Solar Panels
Control Panel
Living Room
Control Room
Hilltop
a) Detector Station–Observation Post
Two–Way Radio Communication
Cable
Security Housing
M–Scope
100–Year Flood Level
Electrode
River Bed
Critical Water Level for Second Warning
Water Intakes
10m Stilling Well (400mm 0 Steel Pipe)
River Bed
b) Detector Station–Water Level Detector
Lightning Conductor
Solar Panels
Beacon Flashing
Radio Antenna
Siren Yelping
20m Mast
Guy Wires
Control Panel
Security Fence
c) Warning Station
d) Village Receiving Warnings
Northeast Regional Project
Flash Flood Warning System
Structural Layout
Prepared by: Michael E. Ibbitt
February 1994
Drawn by: Momun
AutoCAD Drawing
FILE: NERP–809.DWG

208

Figure 12

	T	P-N-P TRANSISTOR
	S	SWITCH
	P	PUSH BUTTON SWITCH
		RELAY COIL
		PICK UP COIL OF STICKING RELAY
		DROPPING COIL OF A STICKING RELAY
		FRONT CONTACT OF A RELAY
		BACK CONTACT OF A RELAY
	F	FUSE
	R	RESISTOR
	LD	LIGHT EMITTING DIODE
	D	DIODE
B24		POSITIVE TERMINAL OF 24V DC
N24		NEGATIVE TERMINAL OF 24V DC
		EARTHING

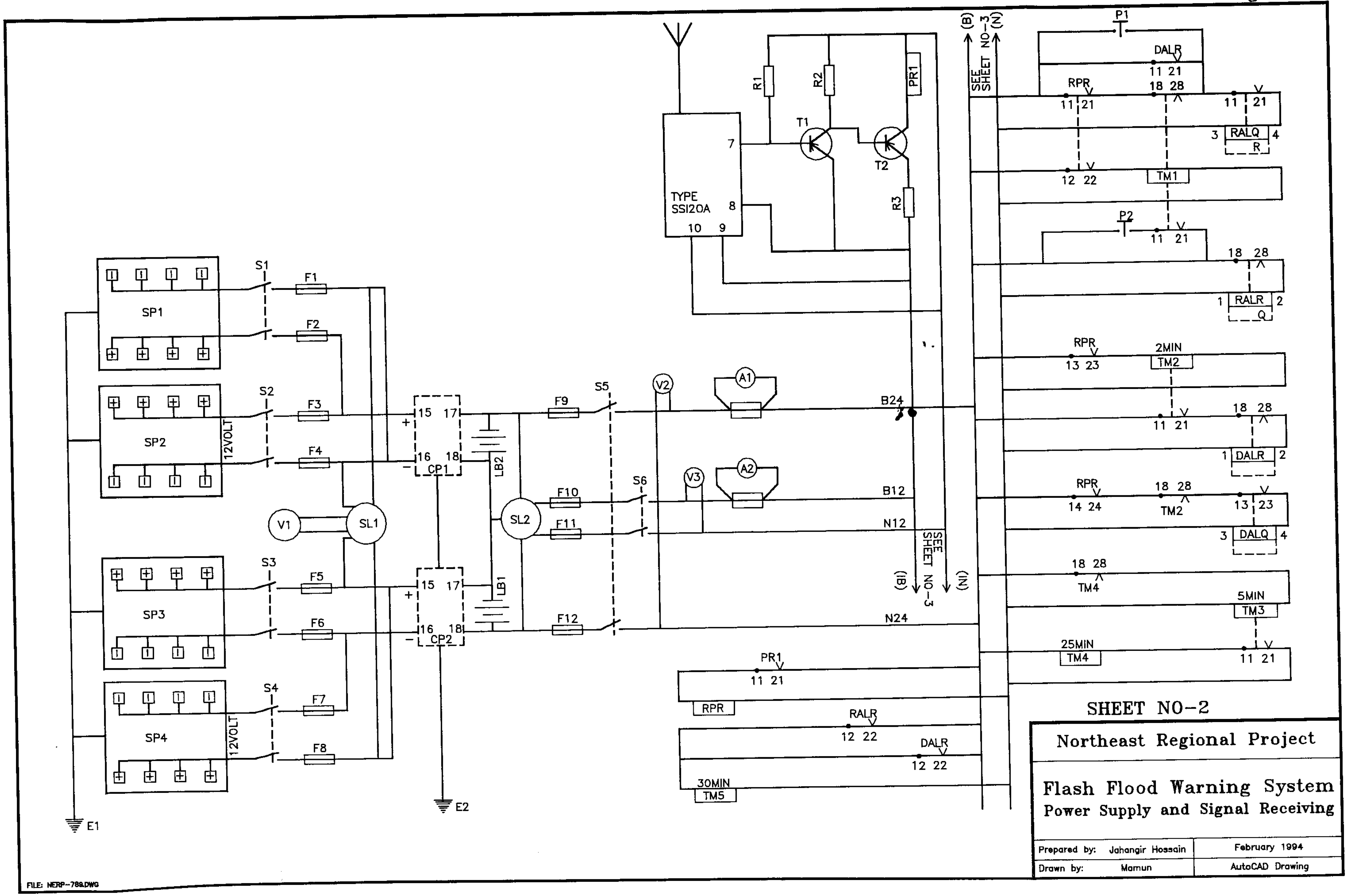
		PANEL BUZZER
		SIREN
		BEACON
		NOT CONNECTED
		CONNECTED
BX220		PHASE OF 220 VOLT AC
NX220		NEUTRAL OF 220 VOLT AC

SHEET NO-1

Northeast Regional Project	
Flash Flood Warning System **Symbols Used in Electrical Drawings**	
Prepared by: Jahangir Hossain	February 1994
Drawn by: Mamun	·.oCAD Drawing

FILE: NERP-790.DWG

Figure 13



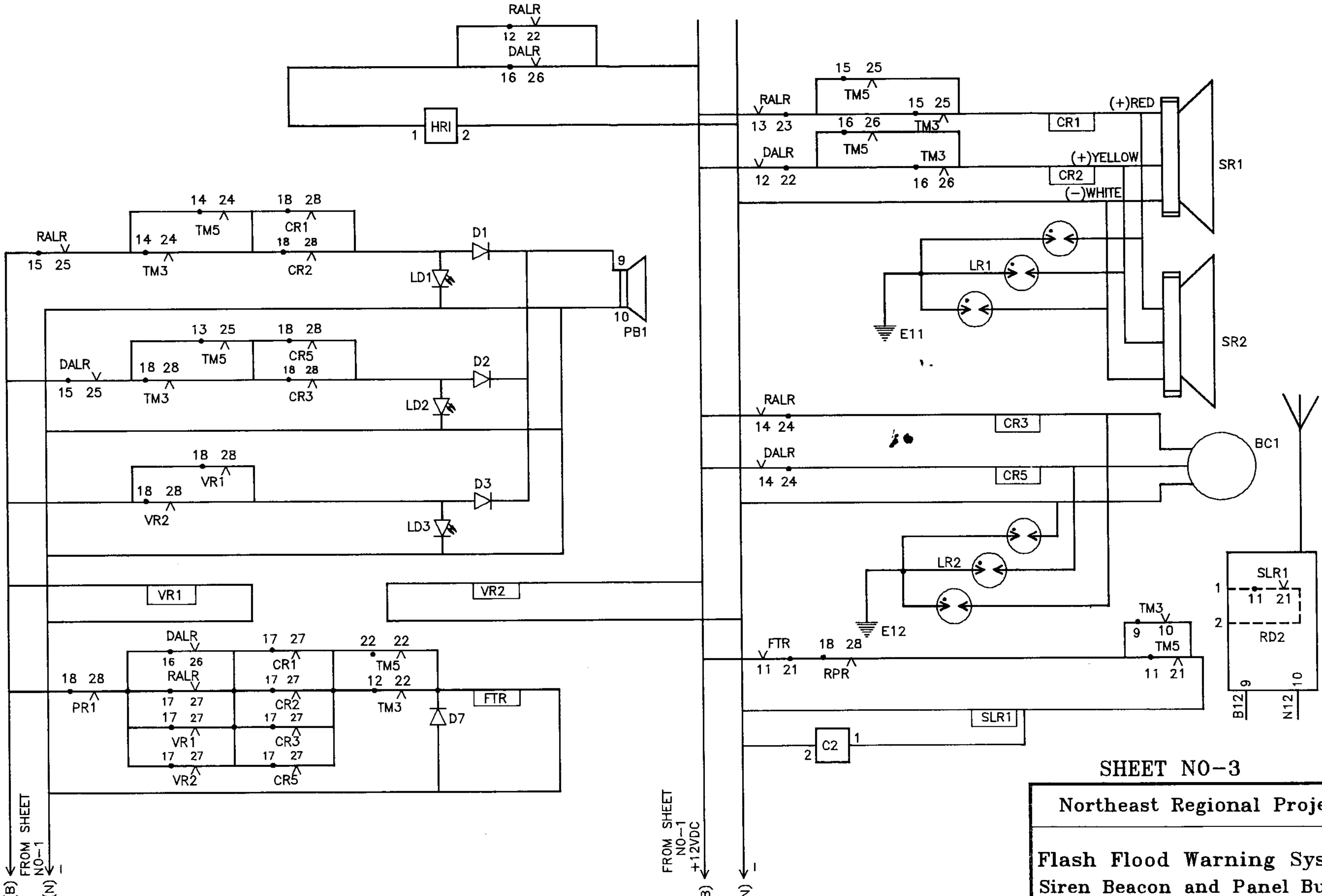
SHEET NO-2

Northeast Regional Project

Flash Flood Warning System
Power Supply and Signal Receiving

Prepared by: Jahangir Hossain	February 1994
Drawn by: Mamun	AutoCAD Drawing

Figure 14

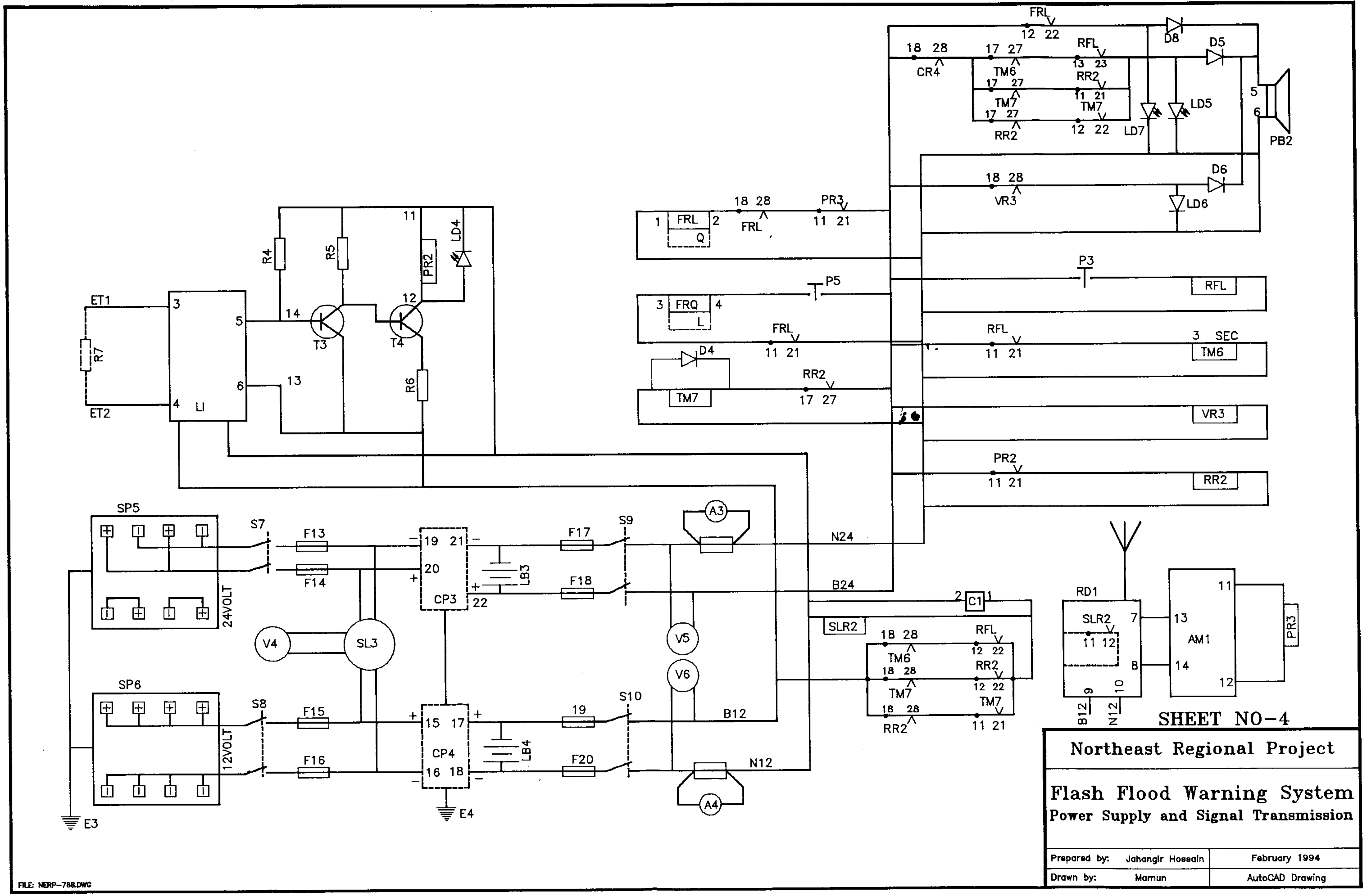


SHEET NO-3

Northeast Regional Project	
Flash Flood Warning System **Siren Beacon and Panel Buzzer**	
Prepared by: Jahangir Hossain	February 1994
Drawn by: Mamun	AutoCAD Drawing

FILE: NERP-784.DWG

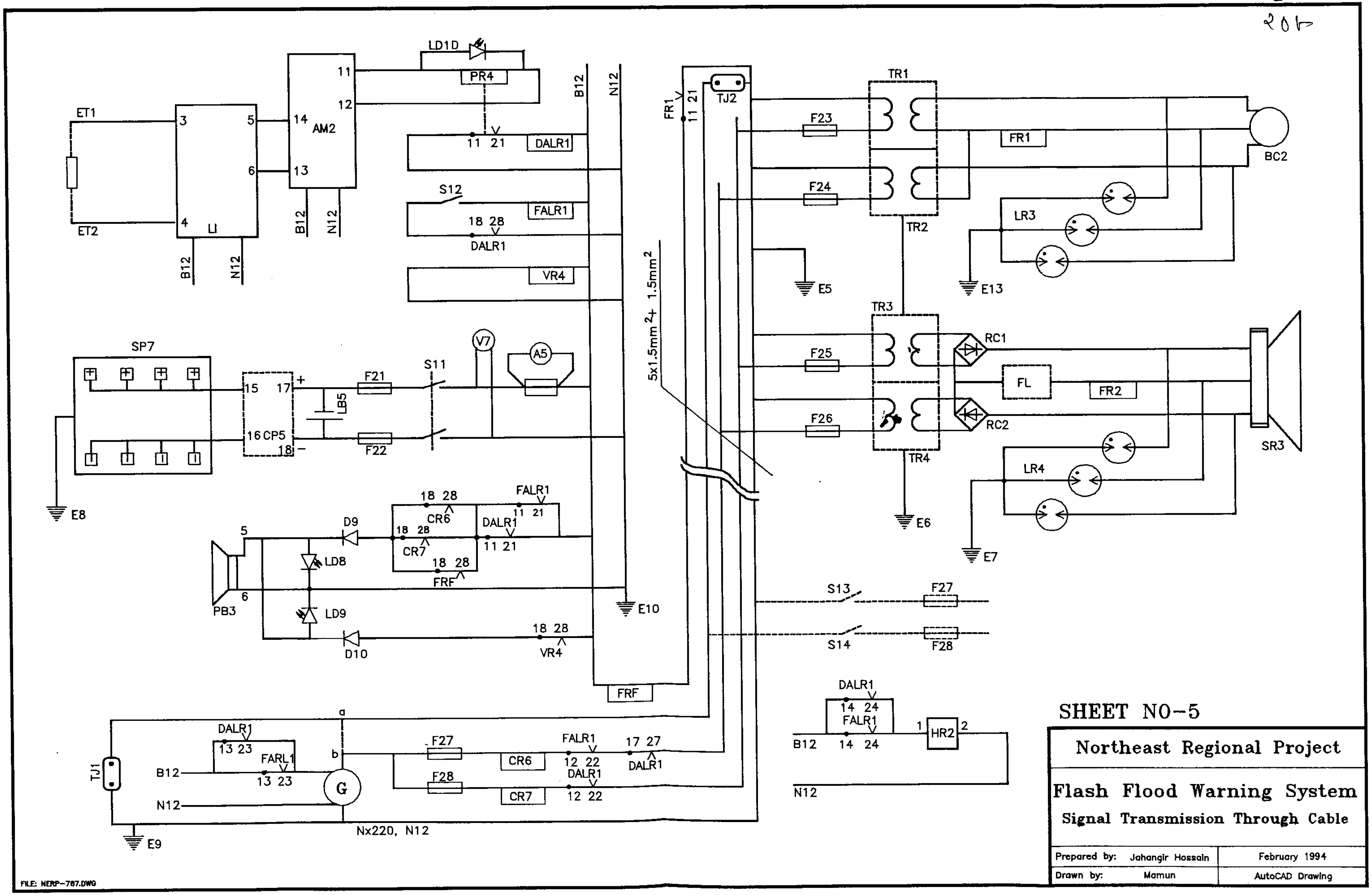
Figure 15



FRL
12 22
18 28
CR4
17 27
TM6
TM7
RR2
RFL
13 23
11 21
12 22
D8
D5
LD5
LD7
PB2
D6
LD6
VR3
PR3
FRL
Q
FRQ
L
P5
P3
RFL
3 SEC
TM6
D4
TM7
VR3
PR2
RR2
ET1
ET2
R7
LI
R4
R5
R6
T3
T4
LD4
PR2
SP5
SP6
24VOLT
12VOLT
S7
S8
S9
S10
F13
F14
F15
F16
F17
F18
19
F20
CP3
CP4
LB3
LB4
V4
SL3
V5
V6
A3
A4
N24
B24
B12
N12
C1
SLR2
RD1
AM1
PR3
E3
E4
SHEET NO-4
Northeast Regional Project
Flash Flood Warning System
Power Supply and Signal Transmission
Prepared by: Jahangir Hossain
February 1994
Drawn by: Mamun
AutoCAD Drawing
FILE: NERP-788.DWG

Figure 16

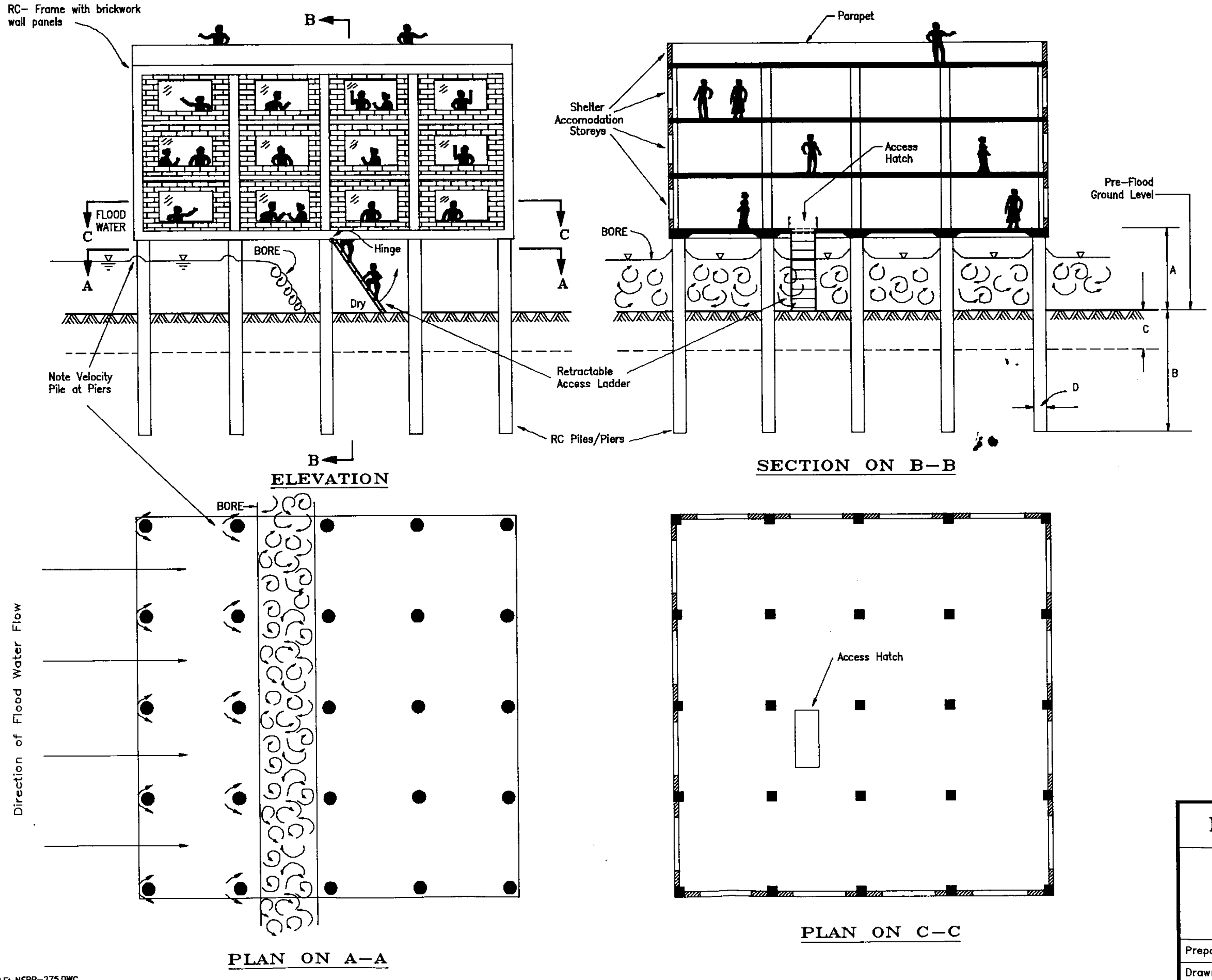
206



SHEET NO-5

Northeast Regional Project	
Flash Flood Warning System **Signal Transmission Through Cable**	
Prepared by: Jahangir Hossain	February 1994
Drawn by: Mamun	AutoCAD Drawing

Figure 17

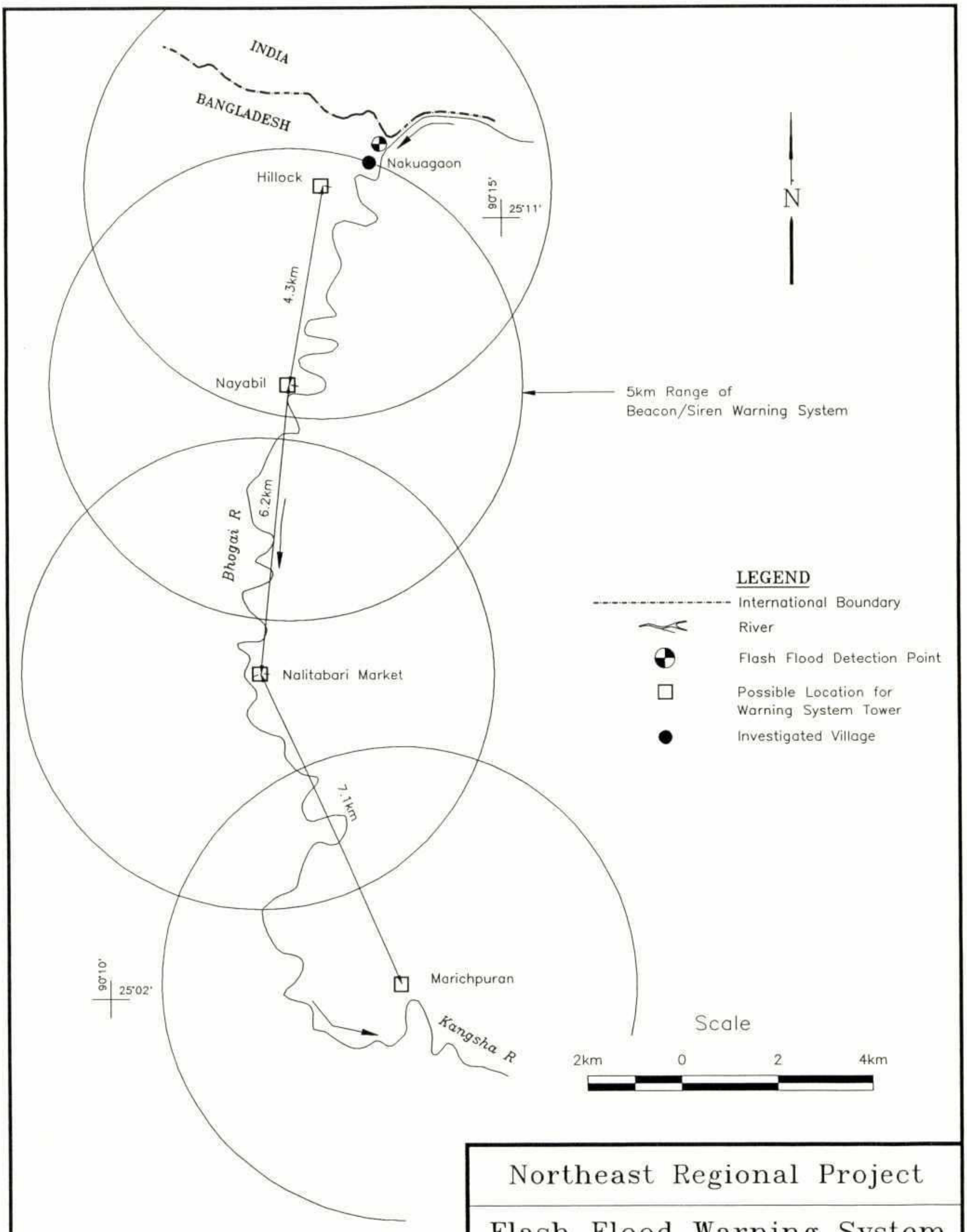


NOTES

1. This drawing is based on a photo of an existing cyclone shelter on the Bangladesh coast
2. Note how any tidal/flash flood induced bore can move through the ground storey unimpeded except for the piers. People shelter on the upper stroeys witch can be used for other community activities when there is no flood.
3. Dimension A,B,C and D are critically important and must be based on expert hydraulic and geotechnical advice. C is the depth of scour witch may occur during a flood.

Northeast Regional Project	
CYCLONE TYPE SHELTER	
Prepared by: Michael E. Ibbitt	September 1994
Drawn by: Sk.Jalal	AutoCAD Drawing

Figure 18



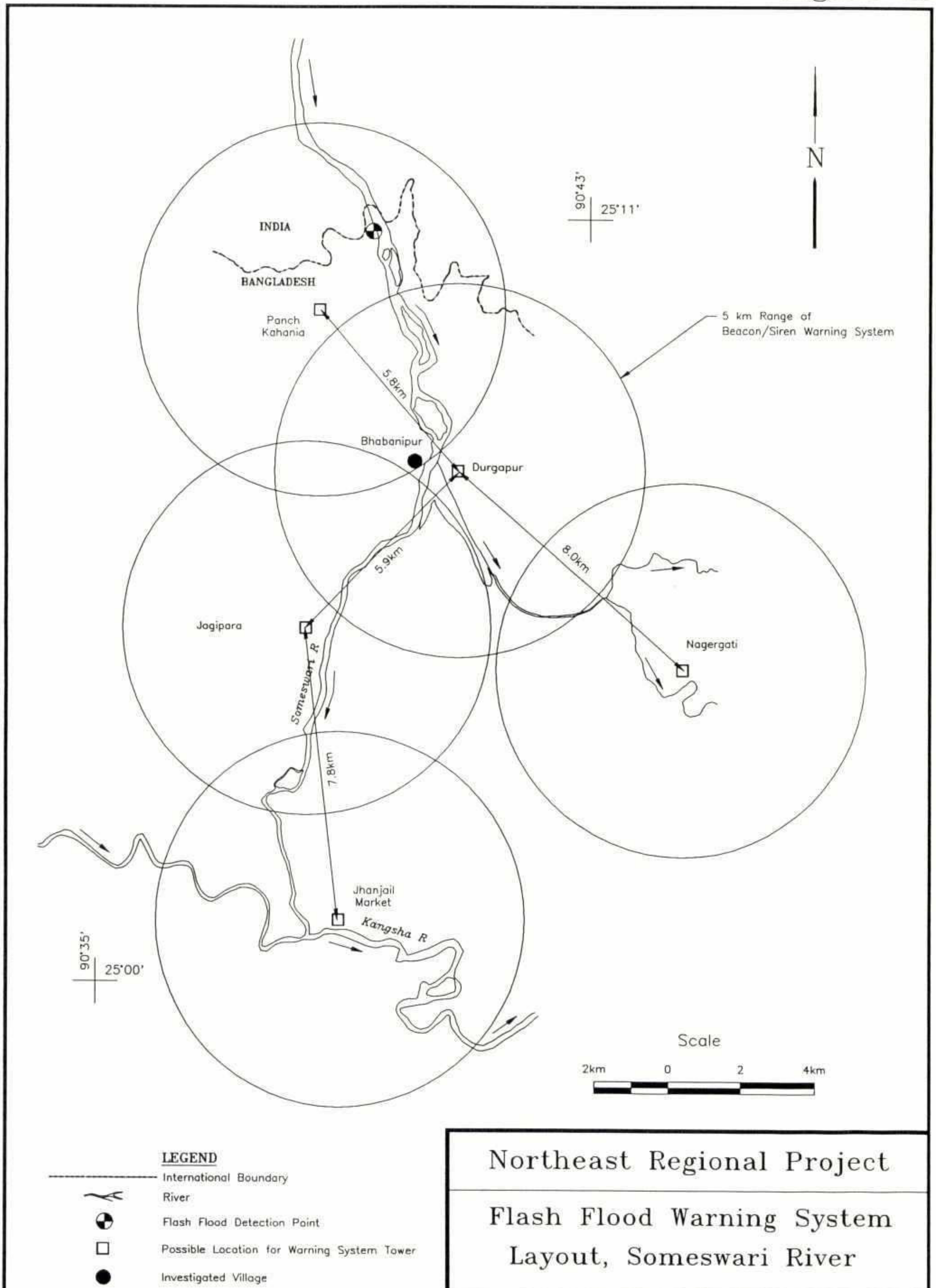
Northeast Regional Project

Flash Flood Warning System
Layout, Bhogai River

Prepared by: SAA	January 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: NERP-755.DWG

Figure 19



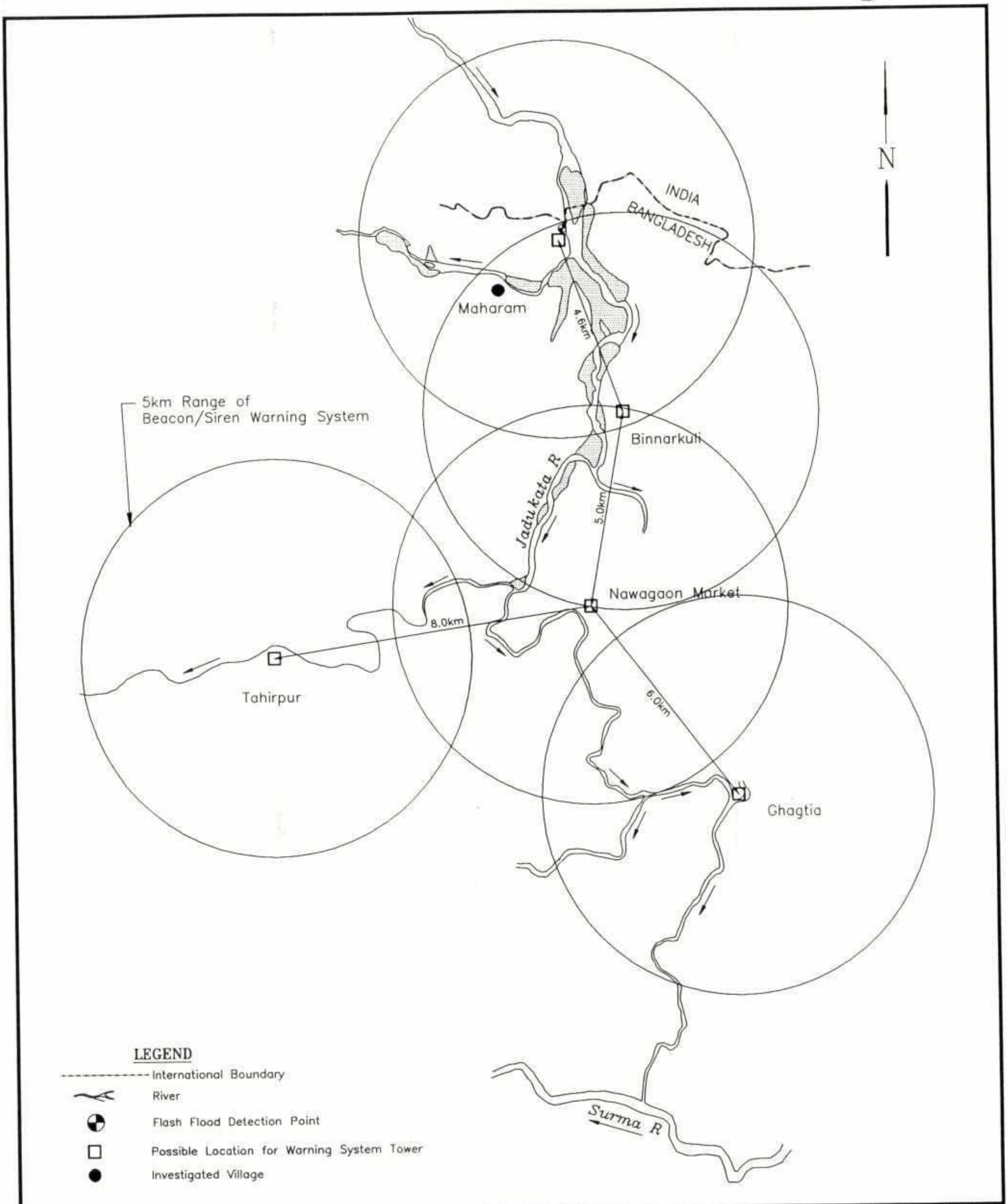
Northeast Regional Project

Flash Flood Warning System Layout, Someswari River

Prepared by:	SAA	December 1993
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-753.DWG

Figure 20

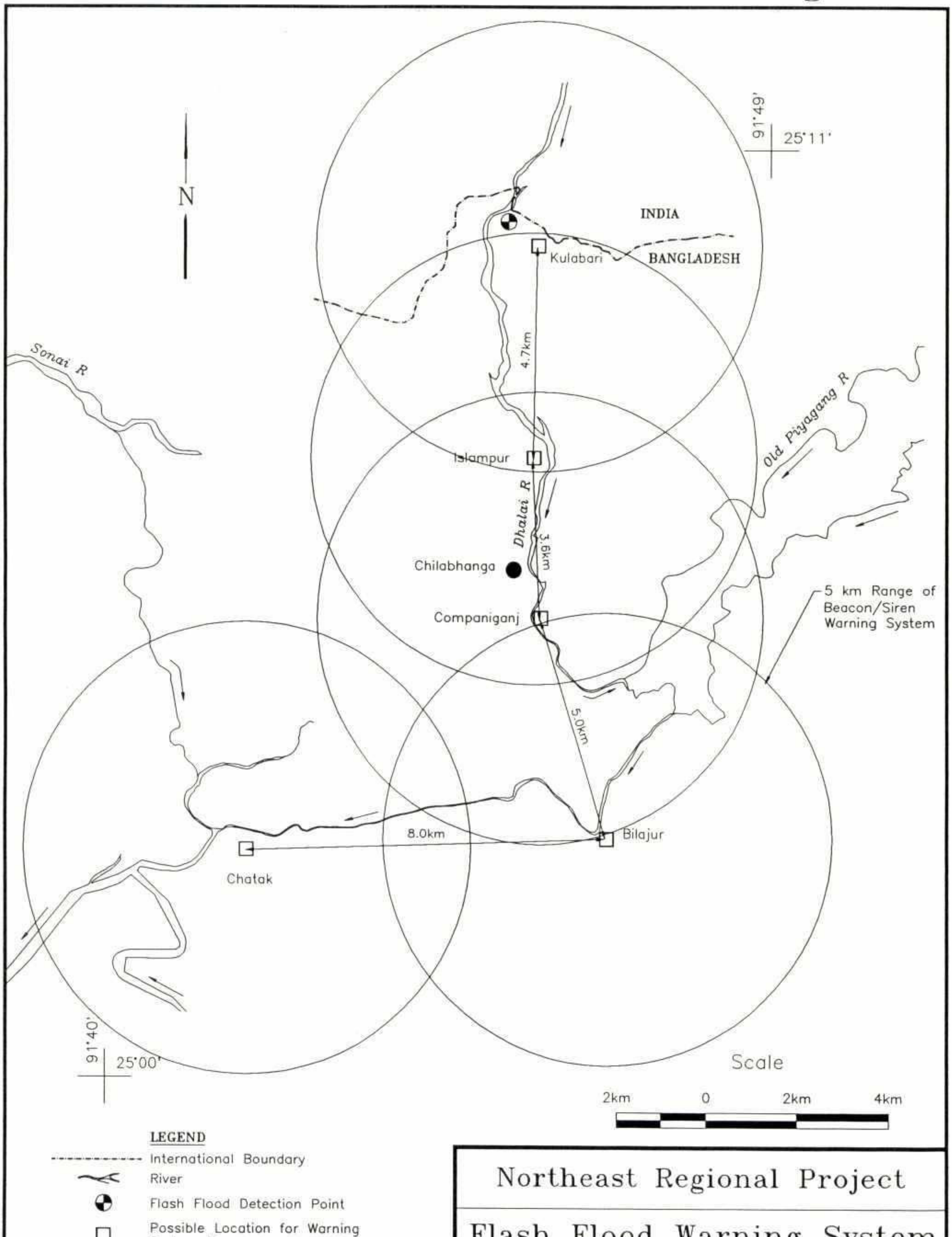


Northeast Regional Project

Flash Flood Warning System Layout, Jadukata River

Prepared by:	SAA	January 1994
Drawn By:	Mamun	AutoCAD Drawing

Figure 21



Northeast Regional Project

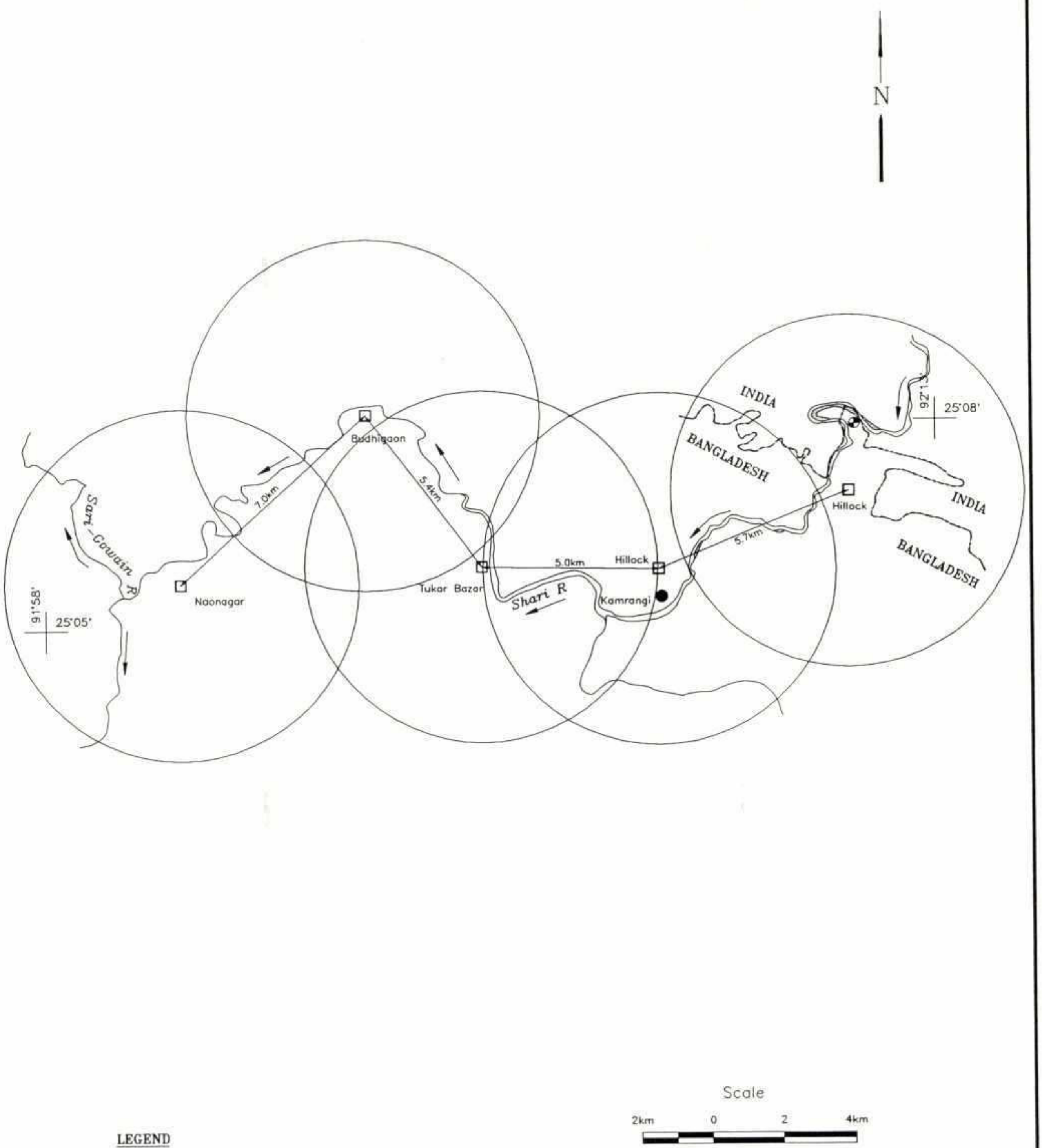
Flash Flood Warning System Layout, Dhalai River (N)

Prepared by:	SAA	January 1994
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-753.DWG

228

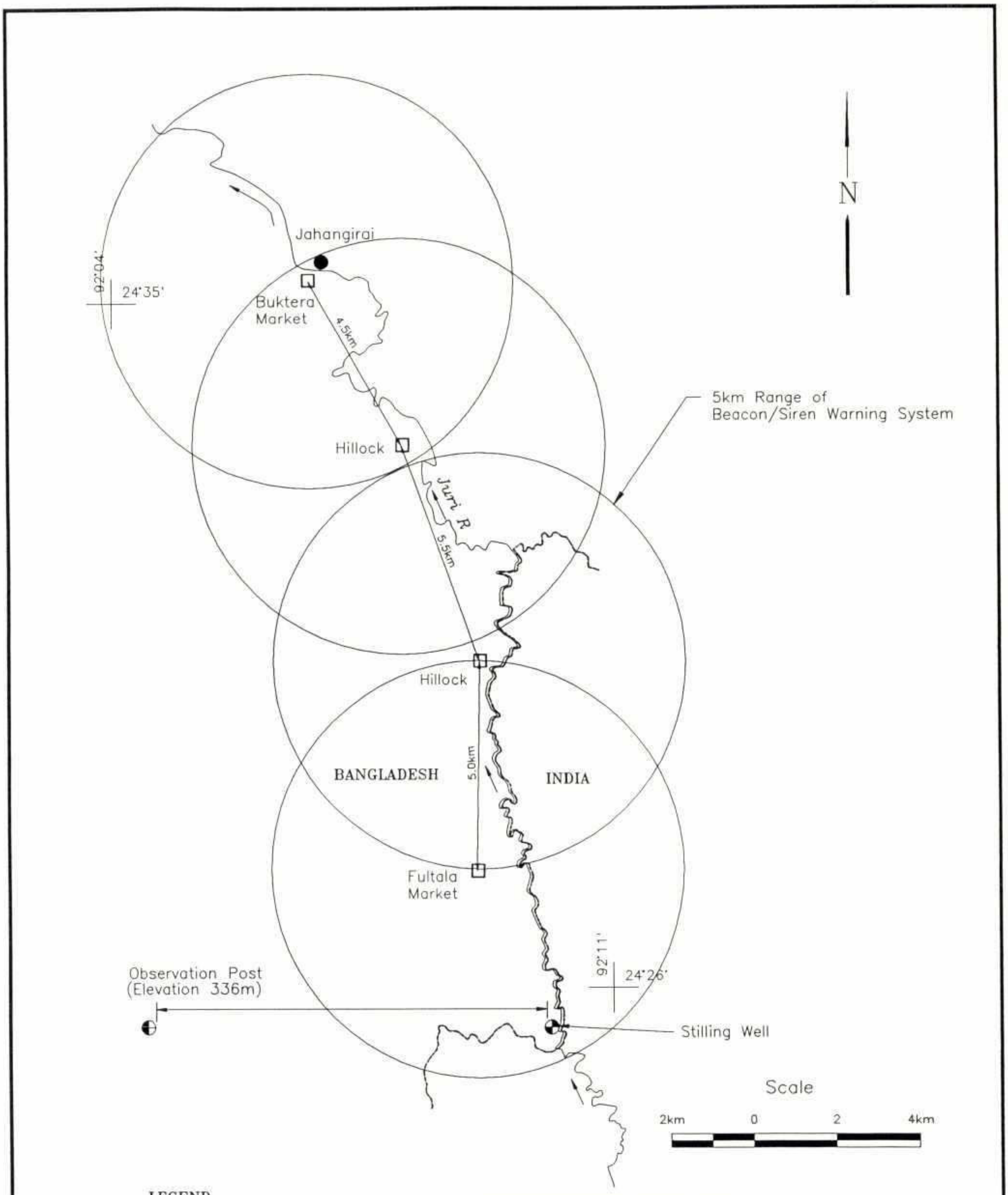
Figure 22



Northeast Regional Project	
Flash Flood Warning System Layout, Shari River	
Prepared by: SAA	January 1994
Drawn By: Mamun	AutoCAD Drawing

FILE: NERP-757.DWG

Figure 23



LEGEND

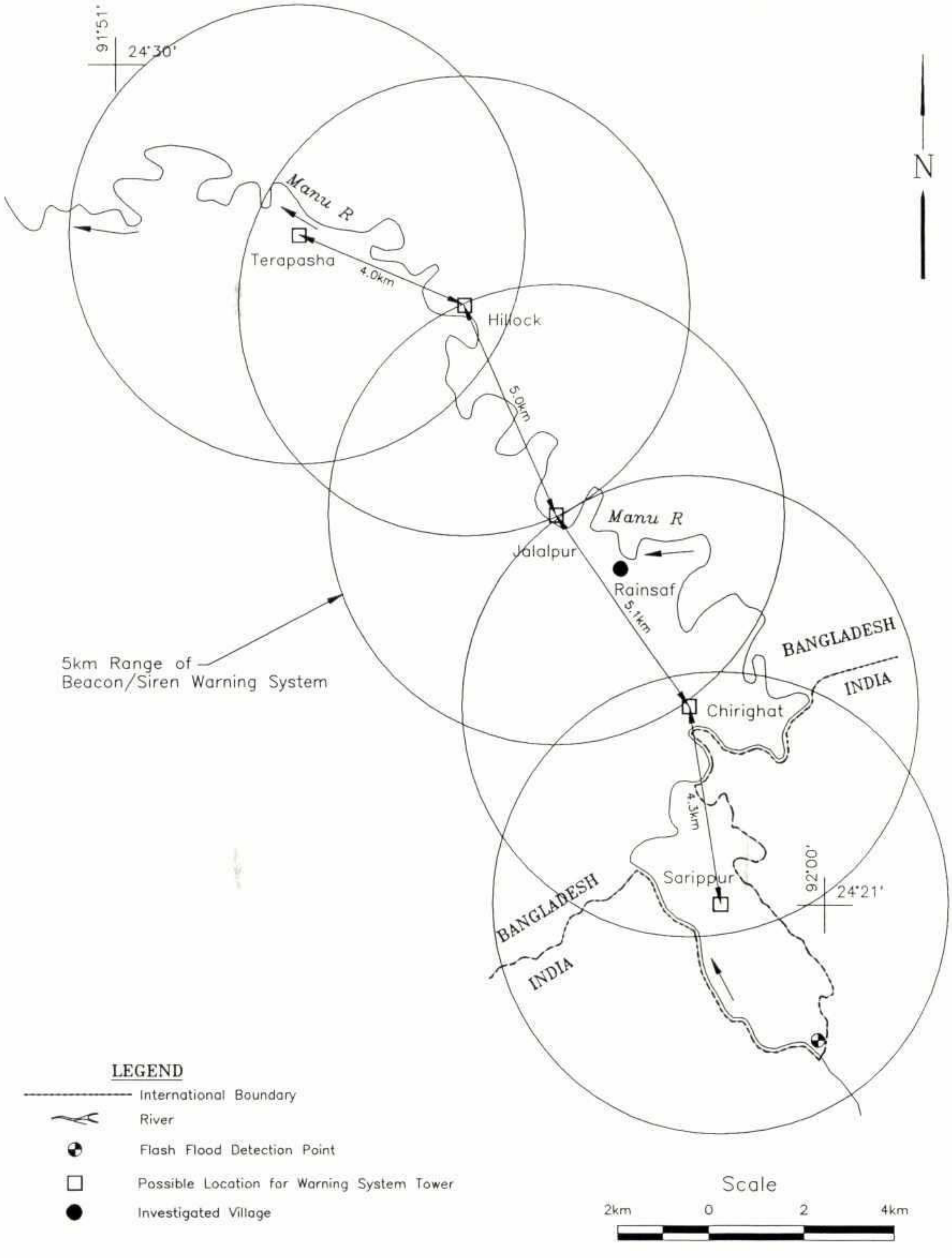
- International Boundary
- River
- Detector Station (Stilling Well)
- Detector Station (Observation Post)
- Possible Location for Warning System Tower
- Investigated Village

FILE: NERP–758.DWG

Northeast Regional Project

Flash Flood Warning System Layout, Juri River

Prepared by:	SAA	January 1994
Drawn By:	Mamun	AutoCAD Drawing



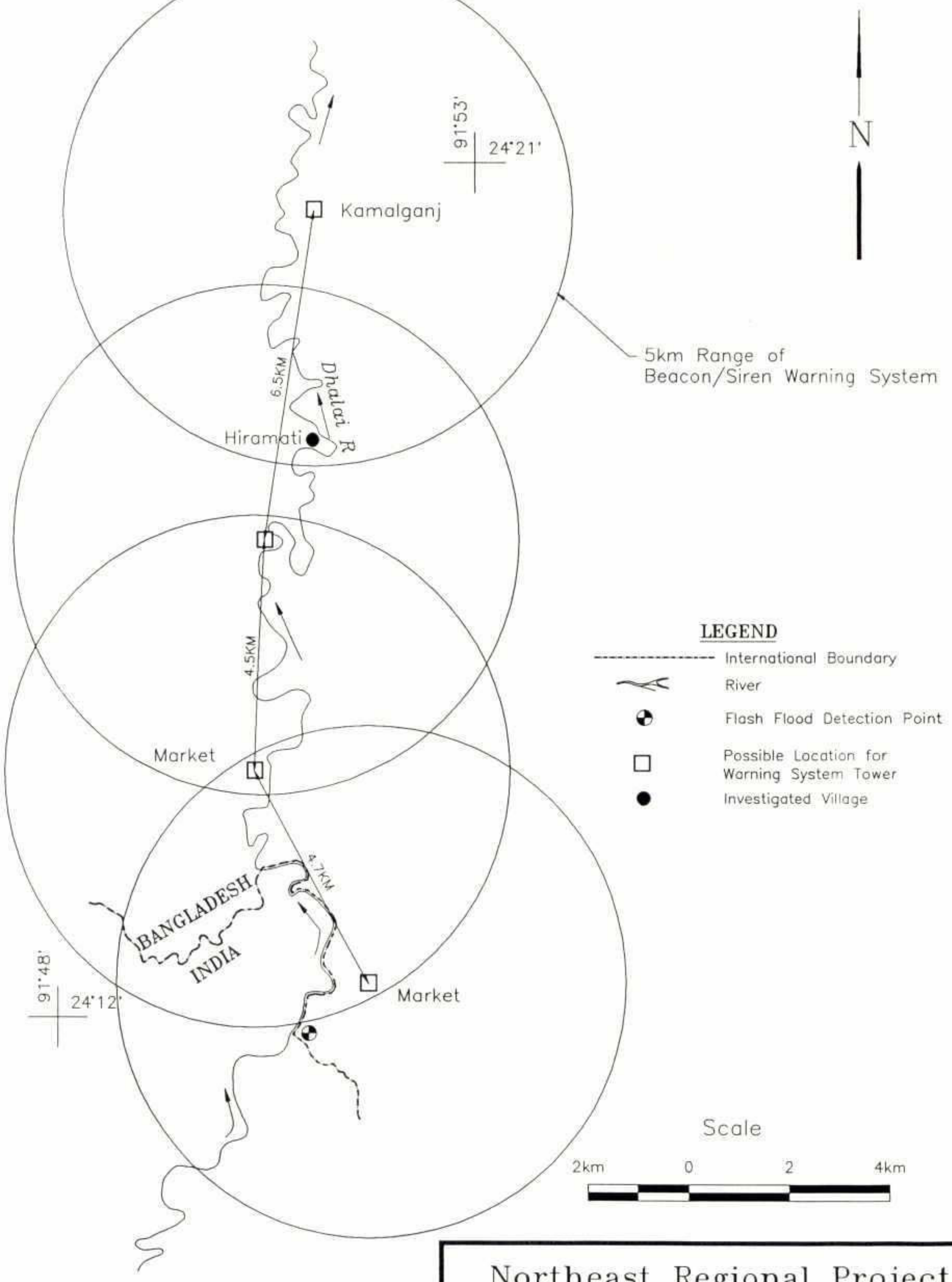
Northeast Regional Project

Flash Flood Warning System Layout, Manu River

Prepared by:	SAA	January 1994
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-761.DWG

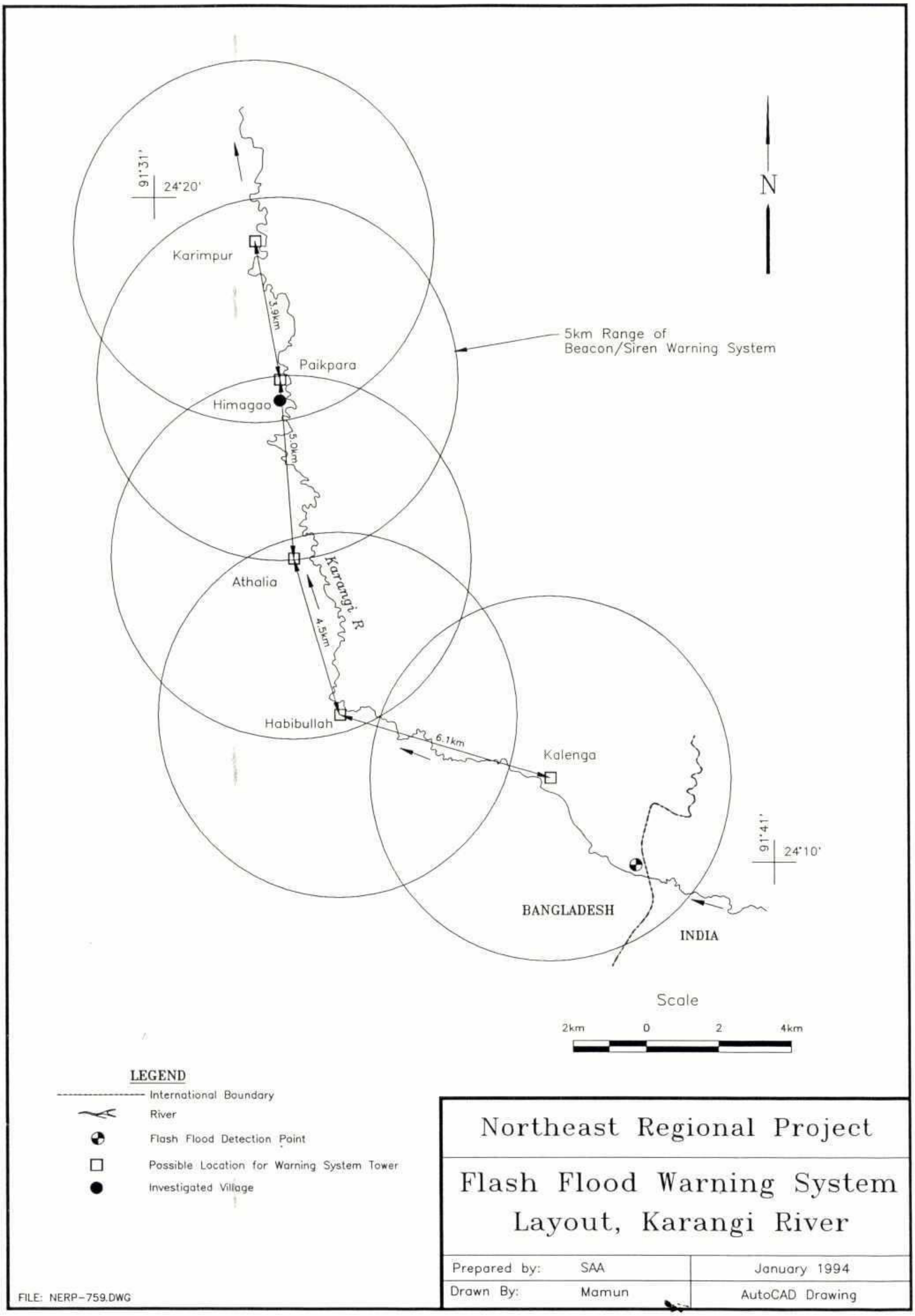
Figure 25



Northeast Regional Project			
Flash Flood Warning System Layout, Dhalai River (S)			
Prepared by:	SAA	January 1994	
Drawn By:	Mamun	AutoCAD Drawing	

FILE: NERP-760.DWG

Figure 26


N
91°31'
24°20'
Karimpur
3.9km
5km Range of Beacon/Siren Warning System
Paikpara
Himagao
5.0km
Athalia
Karangi R.
4.5km
Habibullah
6.1km
Kalenga
91°41'
24°10'
BANGLADESH
INDIA
Scale
2km 0 2 4km
LEGEND
International Boundary
River
Flash Flood Detection Point
Possible Location for Warning System Tower
Investigated Village
Northeast Regional Project
Flash Flood Warning System Layout, Karangi River
Prepared by: SAA
January 1994
Drawn By: Mamun
AutoCAD Drawing
FILE: NERP-759.DWG