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BGD/86/037

Regional Plan Report
Volume 4

Annex V Hydrogeology
Annex VI Hydrology and Water Modelling

August, 1993

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ANNEX V

HYDROGEOLOGY

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ANNEX V - HYDROGEOLOGY

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FOREWORD/ADDENDUM

The work contained in this annex was carried out in the early months of 1991. with a few small exceptions the work remains valid. However, the qualifications need to be stated.

(i) There have been profound changes in policy towards groundwater irrigation, whereby the supply of deep tubewells (until recently an effective public monopoly through BADC) is to be opened to the private sector, principally through the actions of the National Minor Irrirgation Project (NMIDP). The associated changes are likely to radically transform the nature of groundwater irrigation. The main technical changes will be reduced discharge capacities and reduced capital costs. Accompanying these changes is a preference to use the more accurate terms "force mode" and "suction mode" instead of DTW and STW. The original Annex (although correctly anticipating the impact of lower capacities, through its consideration of 1 cusec DTWs) is principally concerned with resource issues. Importantly, in terms of the areas of land that might realistically be brought under irrigation by the force mode wells, there is little difference between the different capacities of well. Thus its findings on resoruce availability, although couched in the language of DTWs and STWs, apply equally to the new well types.

(ii) Recent Investigations carried out initially by the Deep Tubewell II Project, but mainly under the Gumti Phase II Feasibility Study (1992/3) have identified natural gas discharges as a major constraint on the feasibility of suction mode tubewells in parts of this area (see Annex of the Gumti Phase II Sub-Project Feasibility Study June 1993).

(iii) It is recognised that there are a significant number of DTWs operating from a slightly deeper aquifer horizon in Noakhali and Laksmipur districts, where it had previously been believed the aquifers were too saline, as indeed in the intermediate depth range of 50 to 100 metres they are. Even though these wells are relatively expensive, it changes the nature of the development options in the area (to either surface water or groundwater). The sustainability of abstractions from these deeper aquifers requires urgent investigation.

(iv) Minor irrigation statististics from the AST survey of March 1991 (now regarded to be the best available) provide a new basis for evaluating current resource use and generally point to a higher irrigation coverage than was previously recognised.

(v) Further investigations indicate the appropriate salinty criterion for irrigation water in Bangladesh is 2,000 uS/cm limit used earlir) and even this is probably conservative for the local agro-climatic conditions.

ANNEX V - HYDROGEOLOGY

CHAPTER V.1

LANDFORM AND GEOLOGY

V.1.1 Landforms

The geomorphic evolution of the study area has been investigated by a number of workers (Morgan and McIntyre, 1959; Brammer, 1971; Bakr, 1976; Umitsu, 1985, 1989). The following brief discussion on relief and topography, drainage and its evolution and above all the geomorphic evolution of the area is presented based on the above work.

V.1.1.1 Relief and Topography

The south-east study area encompasses a triangular-shaped tract bounded by the Meghna river in the west, the Indian territory on the east and the Meghna estuary at its south. The dominant topographical feature is represented by a vast expanse of deltaic plain with the Lalmai hills elongated north-south prominently in the landscape as an outlier, remnant of older sediments. The terrain slopes westward from the foot of the Tripura Hills up to the main channel of the Meghna river. The average elevation of the base of the Tripura hills is about 10 metres, and that of the western margin at the bank of the river Meghna is around 2 metres (Figure V.1.1a). Across the Bangladesh-Indian border, the Tripura Hills forming a series of north-south trending hill ranges rise in elevation from 65 metres to 130 metres. Further east they rise to 600 metres.

V.1.1.2 Landform Units

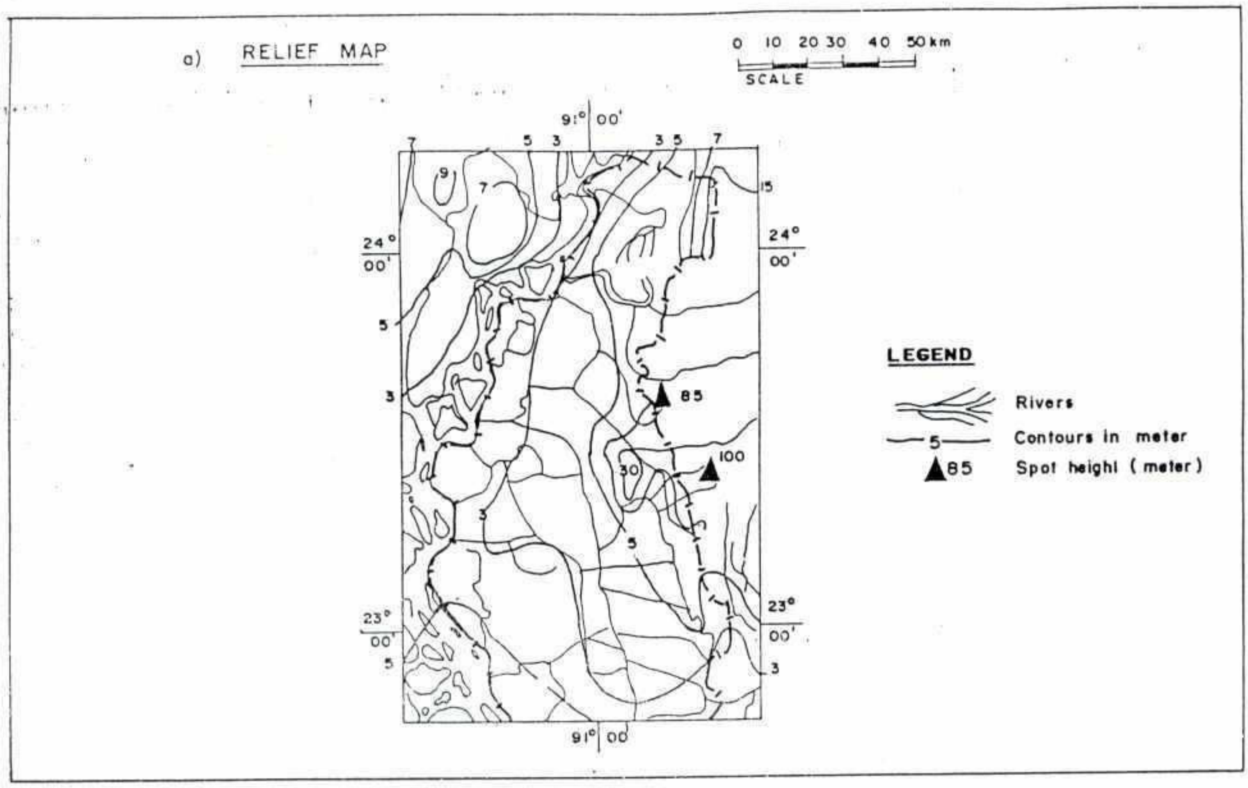
Bakr (1976) divided the area into three landform units (Figure V.1.1b):

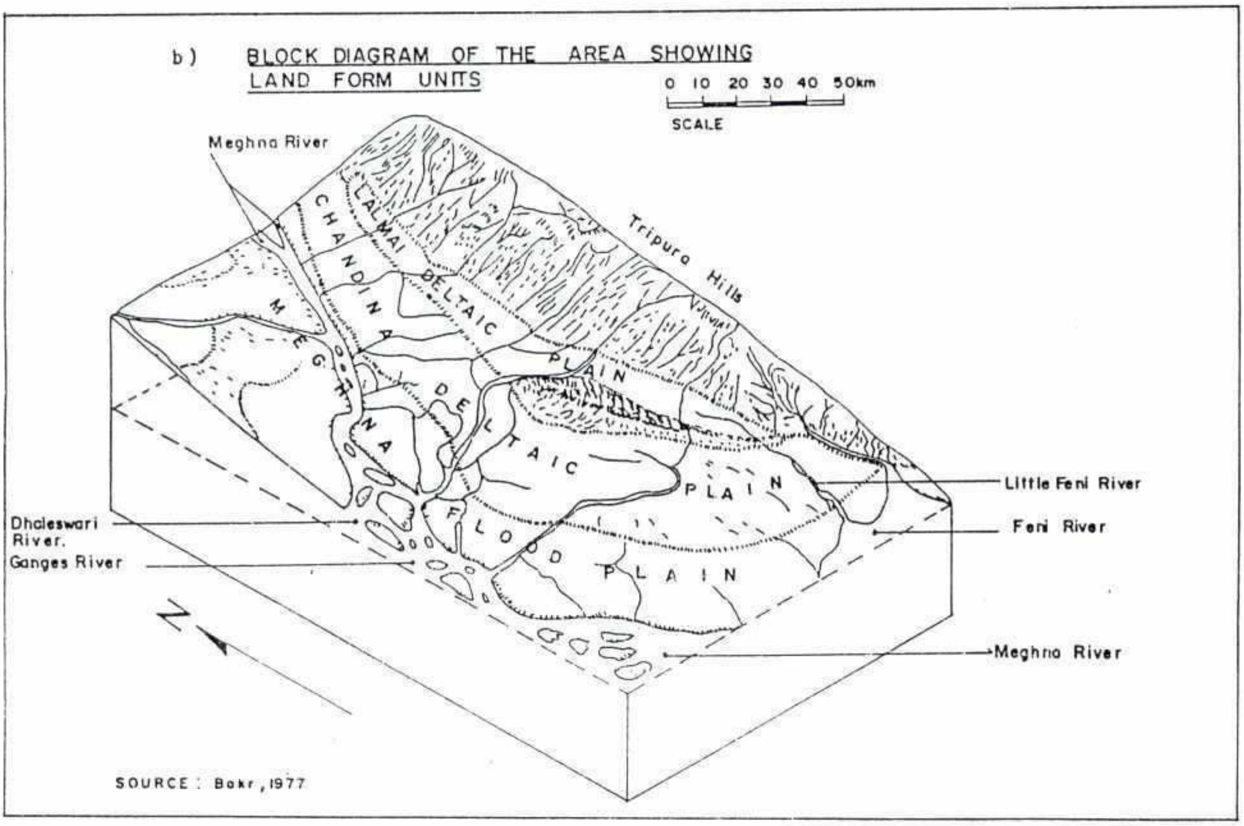
a) Lalmai Deltaic Plain: skirting the Tripura Hills and sloping to the west;
b) Chandina Deltaic Plain: generally level land, occurring at a slightly higher elevation than the adjacent flood plain; and
c) Meghna Flood Plain: flood plain of the Meghna river and its tributaries.

The Lalmai Deltaic Plain stretches from Shahji Bazar in the north to Dattasar in the south, bulging at Dighalgaon. Skirting the western boundary of the Tripura Hills the plain gradually slopes westward. It is named after the Lalmai Hills because, east of the Meghna, it is one of the few areas where the Madhupur Clay of the Pleistocene age are exposed and its relationship with older and younger formations can be studied. The sediments capping the Lalmai Hills comprise unconsolidated, flat lying reddish brown and yellowish brown clay and sandy clay. The shape of the plain is arcuate with convexity westward. As it is slightly uplifted with respect to the adjacent plains it is also referred to as Lalmai uplifted Deltaic Plain or Lalmai Deltaic Terrace. The typical drainage pattern developed in the unit is dendritic, sometimes tightly dendritic.

Figure V.1.1

Relief and Land Form Units in the Study Area





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The Chandina Deltaic Plain lies between slightly uplifted Lalmai Deltaic Plain on the east and comparatively low lying Meghna Flood Plain on the west. The unit is referred to as the as the Tipperah surface by Morgan and McIntyre (1959), Older Alluvial surface by Umitsu (1985) and Old Meghna Estuarine Surface by Brammer (1971). The unit is made up of silt, silty loam, silty clay and greyish clay and has been named as the Chandina Formation. The sediments resemble those of the Recent Meghna Flood Plain, but are more compact, decomposed and oxidized. Remnants of numerous meander scars, meander scrolls, old levels, ox-bow lakes can be detected in aerial photos and Landsat imageries. A similar surface with few drainage systems was identified by Umitsu (1985) in the region south of Calcutta City, West Bengal (Figure V.1.2). This surface is tentatively called here as the Calcutta surface. The drainage developed in this unit is rectangular partly due to man-made irrigation network. The unit is uplifted to the southeast a few metres higher than the adjacent floodplain of the Meghna river.

The third landform unit in the study area is the Meghna floodplain. It is least elevated and comprises the eastern bank of the river Meghna. The Meghna floodplain has been built up by the present day sediments carried by the Meghna river which is generally meandering in character but in places braided resulting a vast plain criss-crossed by numerous small streams, merging and branching, and building out channel bars, meander bars and levees. The sediments are mainly composed of sands, silts and clays.

Based on the above landform characteristics and rocktypes, the southeast region is divided into a number of morphostratigraphic units, clearly identifiable in Landsat images, as presented in Table V.1.1 and Figure V.1.3

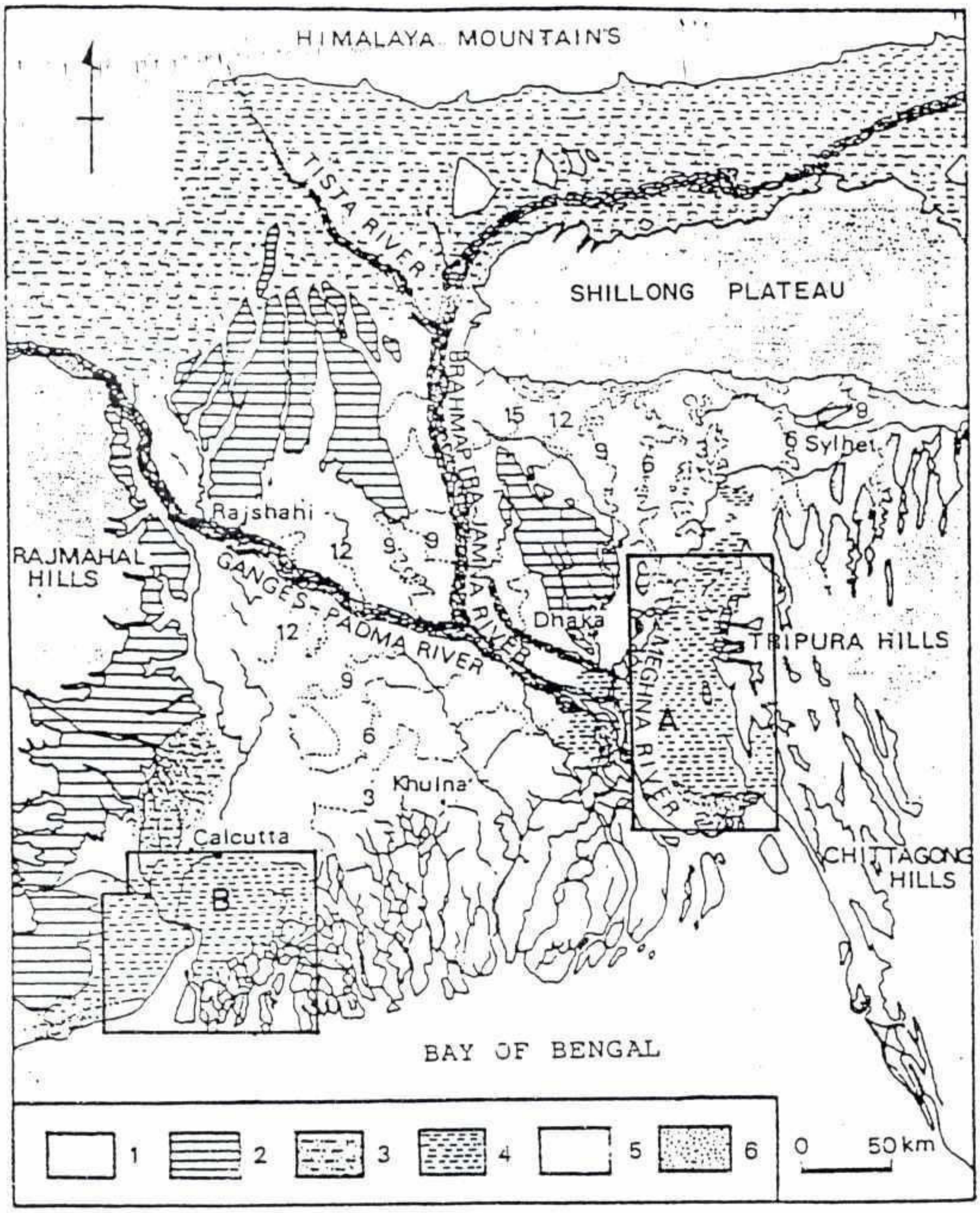
V.1.1.3 Drainage

The area, as described by Bakr (1977), is drained by:

a) the Titas river in the northern part;
b) the Gumti river in the central part;
c) the Dakatia river in the south-central part;
d) the Little Feni river in the south-eastern part; and
e) the Meghna

bounding the area on the west and into which a), b), and c) empty, while the Meghna and the Little Feni fall into the Bay of Bengal. The major drainage pattern characteristics of the landform units described in Section V.1.1.2 (artificial, rectangular pattern of the Chandina Deltaic surface; braiding and meandering pattern of the Meghna floodplain and the dendritic stream pattern of the Lalmai deltaic plain) has been dealt with by Morgan and McIntyre (1959) and is shown in Figure V.1.4. Careful analyses of the courses of the above river

Map Showing the Land Forms of the Bengal Basin and Locations of Older Alluvial Surfaces - Tippera Surface (Block A) and Calcutta Surface (Block B)



1. Mountains and hills 2. Pleistocene terraces 3. Alluvial fans 4. Older alluvial surface (Tippera surface) 5. Younger alluvial surface 6. Youngest alluvial surface. (contour intervals are three meters)

SOURCE : UMITSU, 1985.

WATER RESOURCES DEVELOPMENT PROGRAMME
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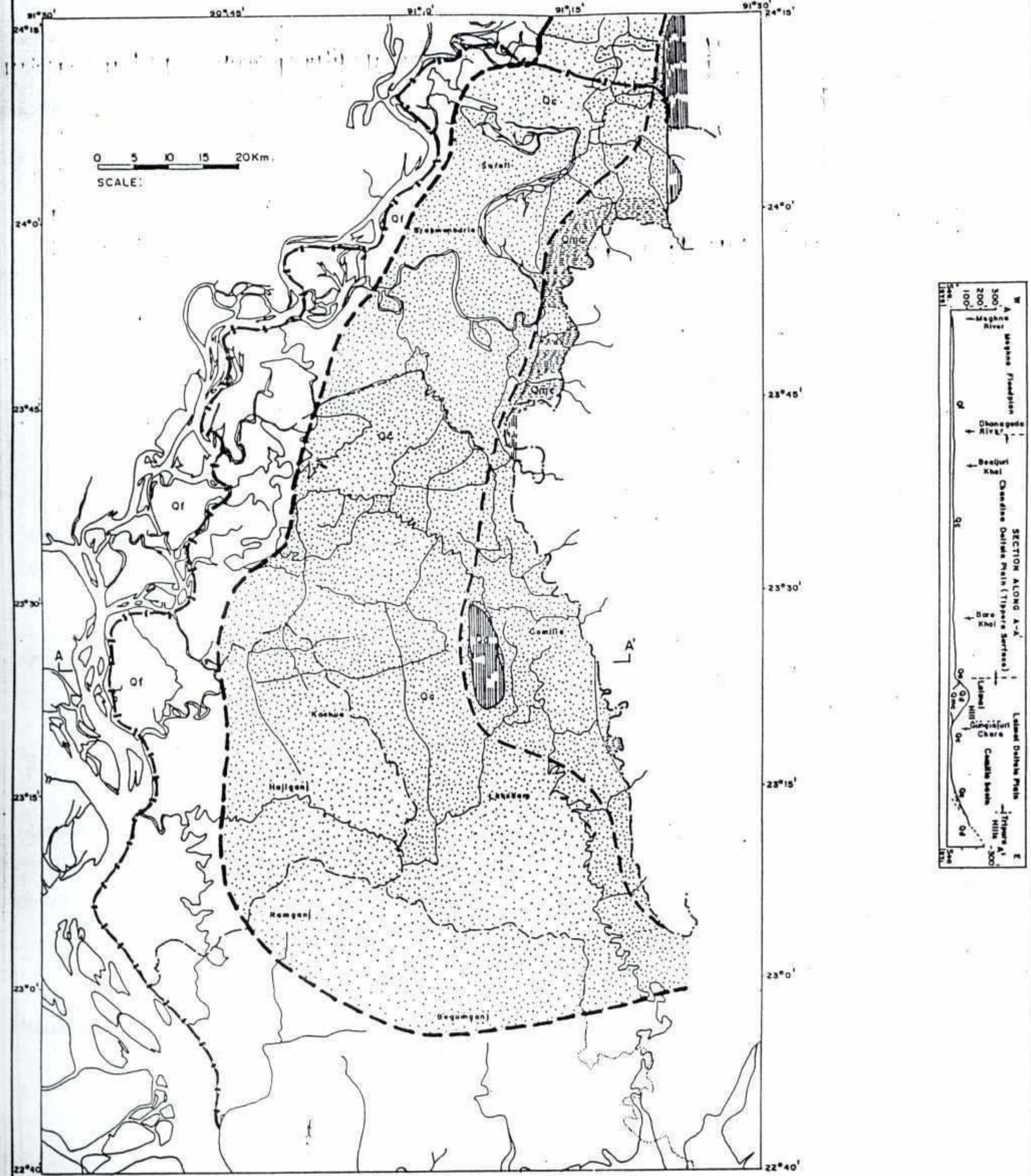
Figure V.1.3

Morpho-Stratigraphic Units in the Study Area



EXPLANATION

INTERNATIONAL BOUNDARY

STUDY AREA BOUNDARY

DISTRICT BOUNDARY

PROBABLE LIMIT OF THE CHANDINA DELTAIC PLAIN

PROBABLE LIMIT OF THE LALMAI DELTAIC PLAIN

AGE	GEOMORPHIC UNIT	GEOLOGIC UNIT	SYMBOL FOR GEOLOGIC UNIT
LATE	MEGHNA FLOOD PLAIN	MEGHNA FLOOD PLAIN DEPOSIT	Qf
EARLY	CHANDINA DELTAIC PLAIN	CHANDINA FORMATION	Qc
	LALMAI DELTAIC PLAIN	MADHUPUR CLAY	Qmc
		DUPI TILA FORMATION	Qd

SOURCE: Bakr, 1977

WATER RESOURCES DEVELOPMENT PROGRAMME
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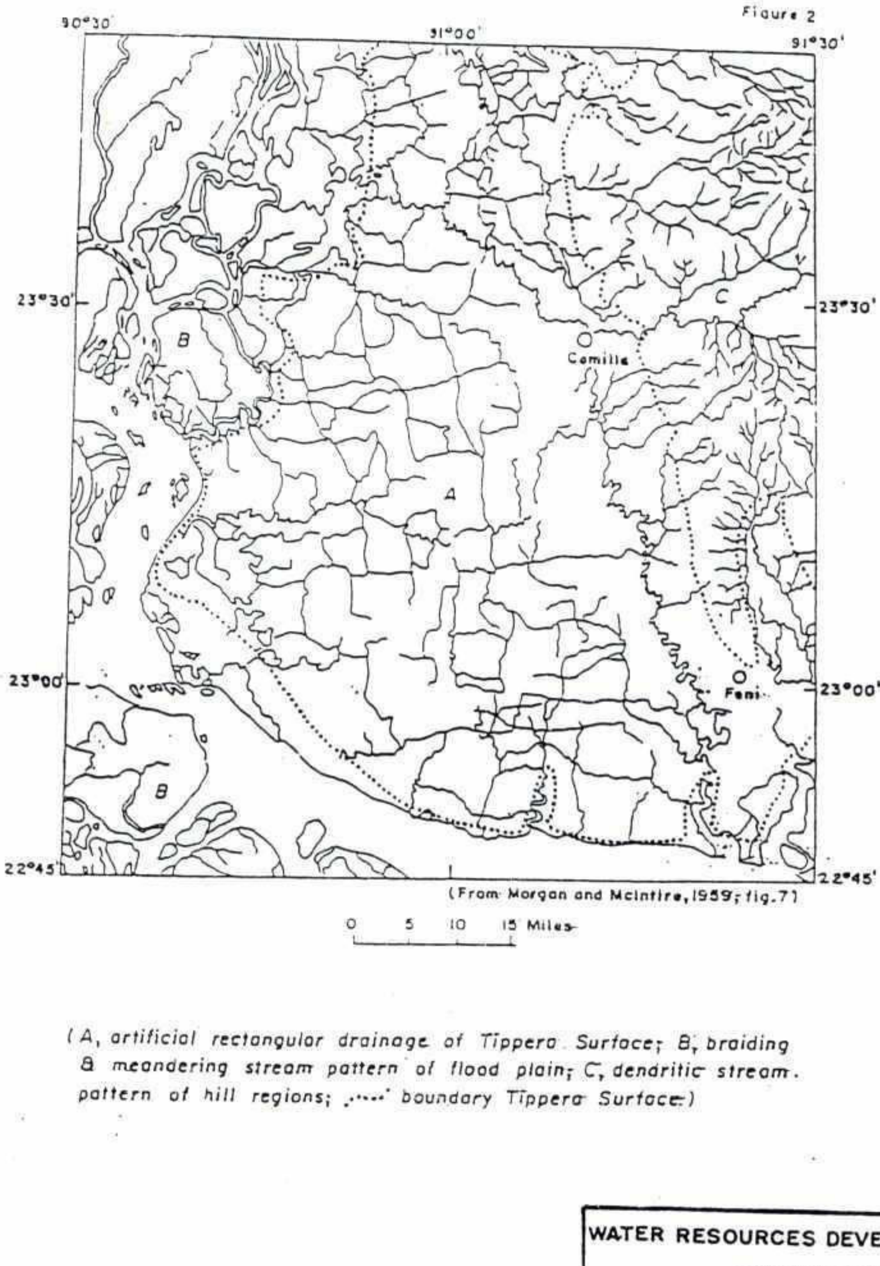
Figure V.1.4

Map Showing the Major Drainage Patterns in the Brahmanbaria-Noakhali Area



(A, artificial rectangular drainage of Tippera Surface; B, braiding & meandering stream pattern of flood plain; C, dendritic stream pattern of hill regions; ...... boundary Tippera Surface)

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TABLE V.1.1

Geomorphic Evolution of the Study Area

A): Morphostratigraphic Units

Age		Geomorphic Units	Geologic Units
Recent (12 000 - Present	Late	Meghna Flood Plains	
	Early	Chandina Deltaic Plain (Tipperah Surface/Older Alluvial Plain)	Meghna Flood Plain Deposit Chandina Formation
……Unconformity……			
Pleistocene (.93-.73 MYr.)		Lalmai Deltaic Plain (Lalmai Terrace)	Madhupur Clay
……Unconformity……			
Plio-Pleistocene > .93 MYr.		-	Dupi Tila Formation

B) Sequence of drainage

Artificial drainage

4.	Rectangular drainage	...	Artificial - developed by man for agricultural purpose

Natural drainage

3.	Present-day drainage	...	the present day Meghna river system meandering and braded; present day Gumti River

2.	Disappearing drainage	...	the present Titas River, Bijni Nadi, Ghungur Nadi, Majora Nadi, Buri Nadi, Dakatia and Little Feni rivers-partially degenerated rivers characterized by tight meanders, oxbow lakes, and neck cut offs; rivers in old age (maturity)
1.	Nearly extinct or extinct drainage	...	Older courses of the Titas and of Gumti also the older loops and trends of channels

C. Broad aspects of Geomorphic Evolution

	Stage	**Aspects**	**Remarks**
3.	Present day drainage regime	The modern Meghna, Titas, Gumti and Dakatia river	
Uplift and development of the Chandina Deltaic Plain (Tipperah surface/Older Alluvial Plain)			
2.	Older drainage regime	Deposition of the Chandina formation in the deltaic flood plain of the older Brahmaputra - Meghna rivers, and older Titas and Gumti rivers	
Uplift and development of the Lalmai deltaic Plain (Lalmai terrace) (correlatable with the fourth Himalayan upheaval)			
1.	The Oldest drainage regime	Deposition of the Madhupur Clay in the then delta, hugging the Tripura Hills	

Source: **Bakr, M.A., 1977**

ii) general uplift of the central part of the area particularly development of the Chandina Deltaic Plain; and

Map Showing Sequence of Drainage in the Titas River and the Gumti River System

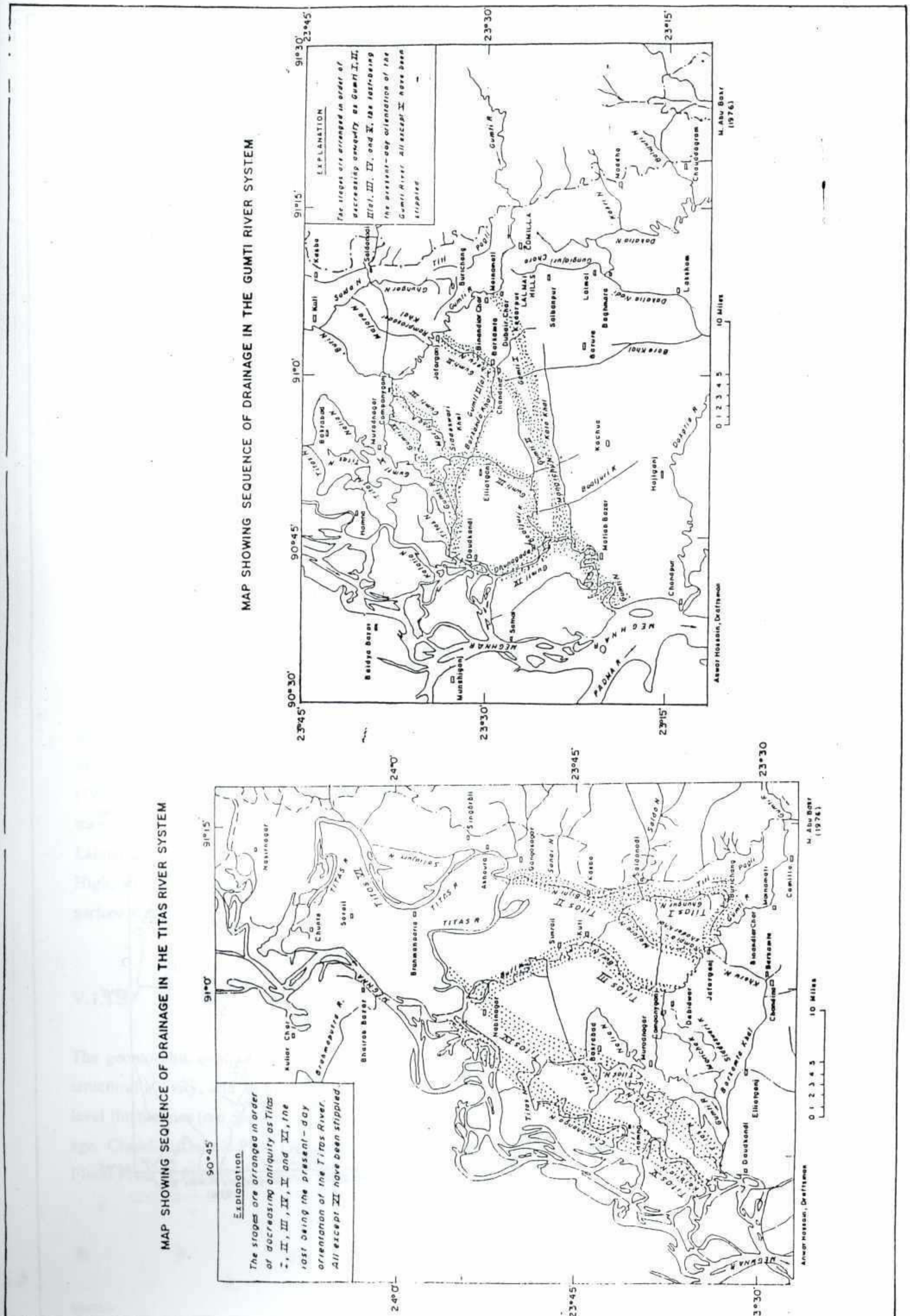
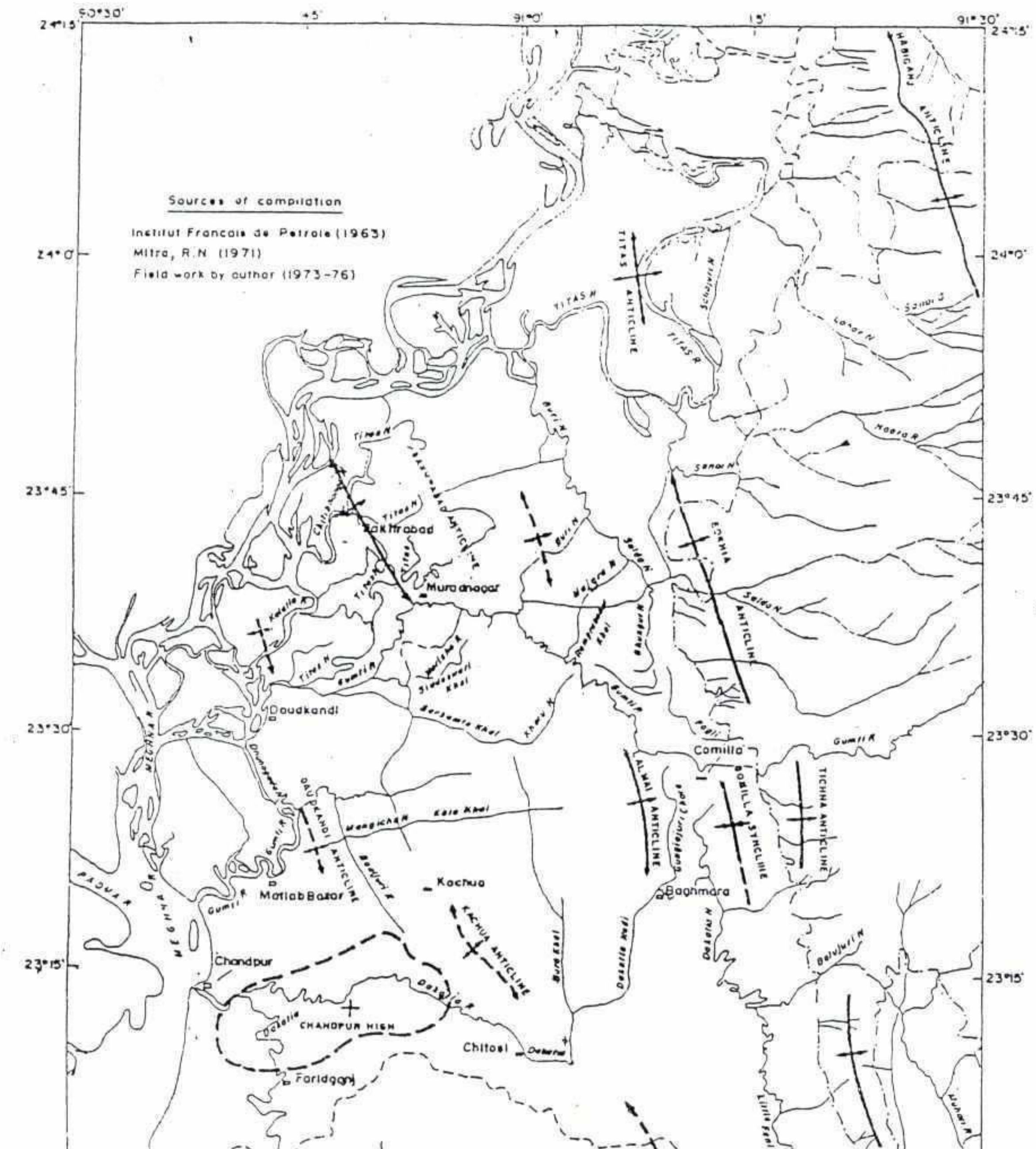


Figure V.1.6

Map of Brahmanbaria-Noakhali Area Showing the Trend of Floods (Anticline and 'High')



iii) abandonment of the old course of the Brahmaputra in favour of the present Jamuma course, thus cutting off a vast water source.

Bakr (1977) elaborated the sequence of the stages of the Titas and Gumti river systems (Table V.1.2). The possible orientation of the stages is shown in Figure V.1.5. It is apparent that the Titas Stage I is correlatable with the Gumti Stage IV (Table V.1.2). The development of successive stages of these river systems has been due to:

i) general slope of the region from east to west;

ii) uplift of the land in the east forming the Chandina deltaic plain;

iii) general NW-SE trend of a number of subsurface folded structures - Bakhrabad, Lalmai, Daudkandi, etc.; and their possible reactivation causing minor uplift during the Quaternary period; and

iv) diversion of the Brahmaputra flow during the years following Rennell's mapping.

V.1.1.4 Drainage and Structure

Morgan and McIntyre (1959) and Bakr (1977) demonstrated that the evolution of the drainage in the region has been largely controlled by the sub-surface structures. The gradual slope of the entire land from east to west and upliftment along pre-existing folds have affected the stream courses and building up of the deltaic plains with the result that the pattern of the drainage is the outcome of the adjustment between these two factors. Late Tertiary and Pleistocene folding activity resulted in the formation of gentle folds and broad highs, striking north and northwest. During Pleistocene and sub-recent time the sediments have been affected by movements. The upliftment of the Chandina deltaic plain at this also affected the orientation of the rivers in the area. Bakr (1976) observed that the broad bends of the meandering streams are mostly pointed toward northwest. This may be related to the orientation of the anticlines. The Gumti river through its long history, adjusted with the Lalmai and Bakhrabad anticlines, the Dakatia river with Begumganj and Kachua anticlines and the Chandina High, and the Little Feni river with the Comilla Syncline. This relationship between the rivers and the sub-surface structures is shown in Figure V.1.6.

V.1.1.5 Geomorphic Evolution

The geomorphic evolution of the study area has been dealt by Bakr (1976), based on drainage pattern and structural activity, and Umitsu (1987), based on landform characteristics, sedimentary environments and sea level fluctuations (see Section V.1.2). Three Quaternary geomorphic units -Lalmai Deltaic Plain of Pleistocene age, Chandina Deltaic Plain (Tipperah Surface or older alluvial surface) of Early Recent age and to Meghna Flood Plain of Recent Age -have been identified in the area.

TABLE V.1.2

Sequences of Stages of the Titas and Gumti River Systems, Comilla District (see Figure V.1.5)

A. Titas River System

Stages		Remarks
Titas VI	Present day course of the degenerated Titas river from Chunta to Nabinagar in the shape of letters M (a giant loop stuck to the Meghna river)	
Uplift of the Chandina Deltaic Plain: diversion of the Brahmaputra from the east to its present site in the west.		
Titas V	Course outlined by the present day Titas river extending through Titas Nadi (west of Nabinagar) - Chitibhanga Nadi - Kalatia Nadi.	
Titas VI	Course outlined by the present-day Titas Nadi - several interlaced branches of the Titas Nadi between Muradnagar and Homna and extending up to Daudkandi.	
Titas III	Course outlined by the present-day Titas River - Buri Nadi.	
Titas II	Course outlined by the upper part of the Titas river - Bijni Nadi - Majora Nadi -Ramprarshader Khal (the Titas fell into the Gumti)	
Beginning of uplift leading to the development of the Chandina Deltaic Plain; beginning of the westward diversion of the Brahmaputra.		
Titas I	Course outlined by the upper part of the Titas river - Bijni Nadi - Ghungur Nadi	This course joined the Gumti river in in Rennelt's Map 1778 AD

TABLE V.1.2 (Contd)

B. Gumti River System

Stages		Remarks
Gumti V	Present-day course that discharges into the Meghna at Daudkandi	
Gumti IV	Course outlined by the present-day Gumti river-Dhonagoda Nadi Gumti Nadi, past Matlab Bazar, and meeting the Meghna north of Chandpur	This course is shown in Rennell's map 1778 AD
Gumti III	Course outlined by the Gumti river upto Companiganj and then following Maricha Khal and Siddeswari Khal	
Gumti IIA	Course outlined by the Gumti river upto Jaffarganj and then following Keru Nadi-Barakamta Khal upto the Meghna river	
Gumti II	Course outlined by the Gumti river upto Jaffarganj and then following Kheru Nadi, with bifurcation around Barakamta, the major discharge flowing southwest towards Gumti Nadi, past Matlab Bazar, swinging between the upper part of the Boaljuri khal and Mangichu Nadi	
Gumti I	Course outlined by the Gumti river after coming out of the Tripura Hills and then swinging around the northern head of the Lalmai Hills via deserted loops in the present day Binanadiar char - Dubair char and through Kedarpur - Kheru Nadi - Mahespur - Kala Khal - Mangichu Nadi	Gumti Nadi, passed Matlab Bazar

Source: **Bakr, M.A., 1977**

Figure V.1.7

Comparative Drainage Changes in the Brahmanbaria-Noakhali Area (1778 A.D. to the Present)

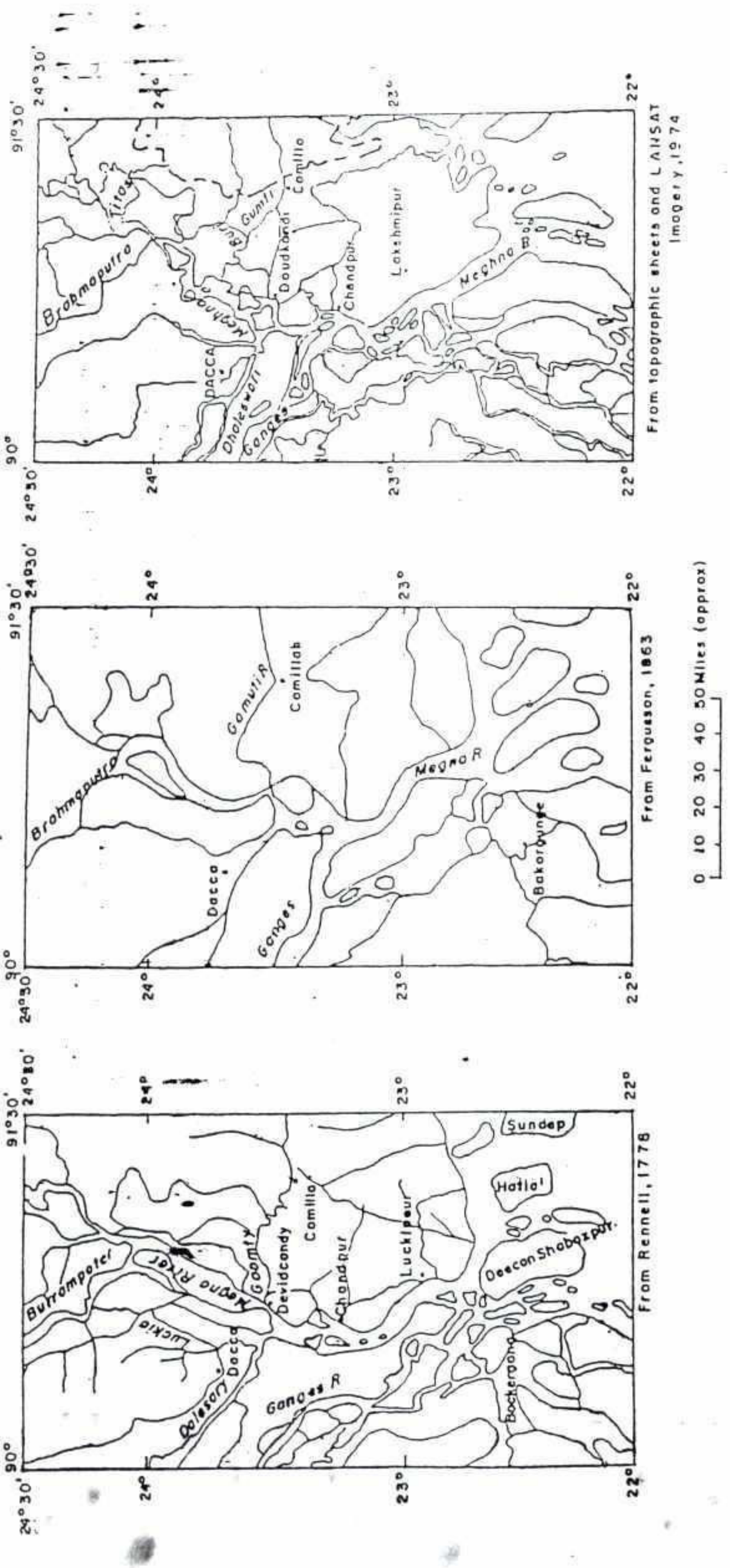


Figure V.1.9

Structural Elements in the Study Area and the Area Surrounding

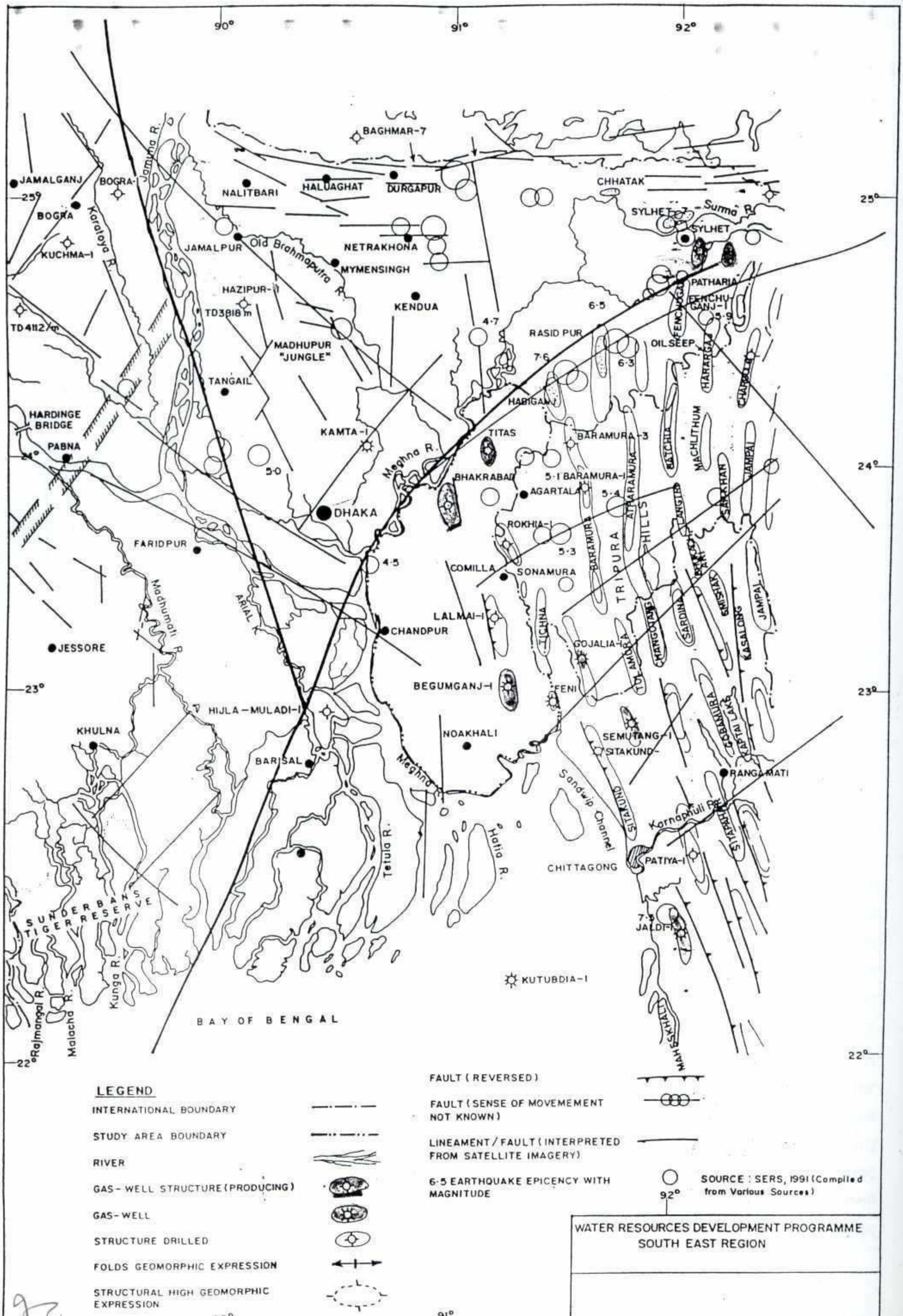


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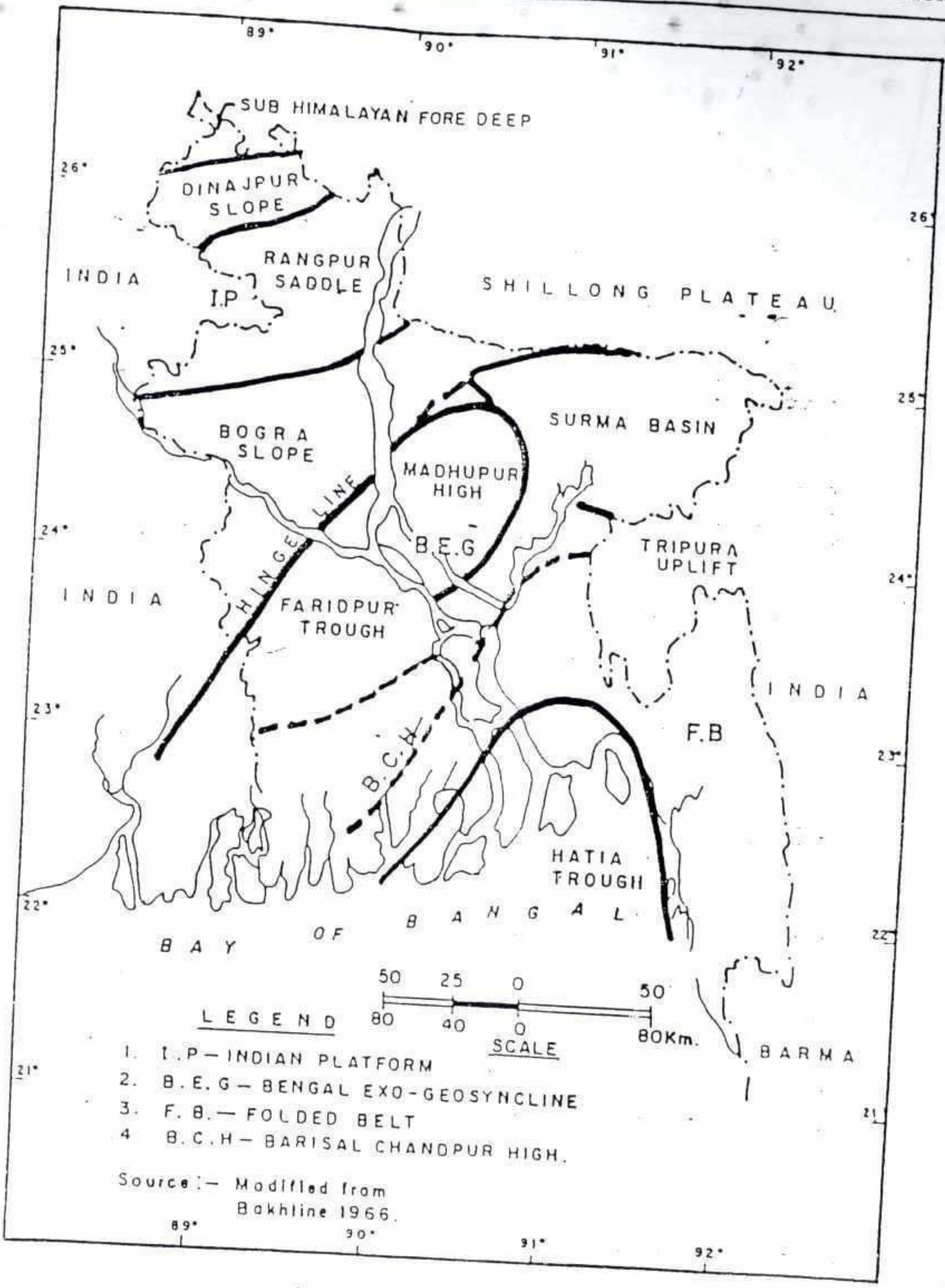
Figure V.1.8

Schematic Map Showing the Location of the Tripura Folded Belt and its Adjoining Western Extension and Surrounding Tecnotic Elements



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Madhupur Clay of Pleistocene age (0.93 Ma - 0.73 Ma) forms the Lalmai Deltaic Plain that extends as piedmont surface from the Tripura hills slopes with elevations ranging from 5 m - 30 m above MSL. The Madhupur Clay, unconsolidated reddish brown clay and red sandy clay, unconformably overlies the folded Dupitilla sandstone of Plio - Pleistocene age (> 0.93 Ma old). Terraced and gently rolling landform, subsequent and dendritic drainage pattern and arcuate disposition indicate that the surface has been uplifted. After the deposition of the Madhupur Clay, tectonic activity set in with the concomitant upheaval of the Himalayas because of which the Lalmai Hills were raised (Hasan, 1990). As a result they were eroded and highly dissected and fragmentary terrace was generated. After the building of the terrace, the drainage system changed and the Chandina deltaic flood plain deposits - clay, silty clay, silt and sand - were laid down (Ca 10,000 yrs. - 6.000 yrs.) lead to the formation of the Chandina Deltaic Plain. Comparative drainage changes in the Brahmanbaria - Noakhali area (Figure V.1.7) from 1778 A.D. to the present indicate that the Chandina Deltaic Plain had also suffered from tectonic activity (epeirogenic or vertical) and at least a significant part of it have been uplifted. The upliftment might have taken place in the years following Rennell's survey (1764 - 1778 A.D.) in the area. This could mean that the widespread earthquake activity of 1762, 1869 and 1897 (see section 1.2) had definite impact on the development of this geomorphic feature. As a result of uplift, this deltaic plain became a terrace surface, called by Morgan and McIntyre as the Tipperah surface (1959). The river system again changed giving rise to the existing Meghna flood plain.

These terraces are as consequence of epeirogenic movement. The elevation of the Lalmai terrace may be related to the final (fourth) Himalayan orogeny, which caused uplift of the Pleistocene deposits in the Himalayas. The elevation of the Chandina Deltaic Plain is possibly related to Recent minor activation of the pre-existing folds in the area (Figure V.1.6). Table V.1.1 illustrates the broad aspects of the Quaternary geomorphic evolution of the area.

V.1.2 Geologic Setting

V.1.2.1 Structure and Tectonics

The study area lies in the folded belt of Bengal Foredeep within the Bengal Basin and constitutes the western extension of the Tripura-Chittagong folded belt, a continuation of the Indo-Burman ranges (Figure V.1.8). The important tectonic element that bounds the area in the west is the prominent Meghna Fault Zone, an active basement controlled fault. Geophysical (BOGMC, 1975, G.S.B., 1991) and geomorphological (Bakr, 1977) investigations reveal the presence of a number of structural elements (Figures V.1.6 and V.1.9). The 20-km long north-south trending Lalmai anticline is the only structure that appears in the landscape as a hill range exposing the Quaternary sediments. The Lalmai structure is delineated on the west by Comilla syncline and Tichna anticline; Daudkandi and Kachua anticlines on the west; Begumganj and Feni structures on south and Bakhrabad, Titas and Bokhla structures on the north. The Habiganj, Titas, Bakhrabad, Begumganj and Feni structures are gas bearing. A prominent geomorphic high, called the Chandpur High, corresponds well to Barisal - Chandpur gravity high. All these folds, except the Lalmai, are at the sub-surface and may represent the quieter expression of the diastrophic activity.

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The fold belt is characterised by the gentle and box-like north-south trending folds, occasionally disrupted and complicated by faults on the flanks, as in the Lalmai and Bakhrabad. Though the folding episode had continued in Quaternary, initiation of folding appears to have taken place earlier. Recently acquired seismic and drilling data in the Tripura fold-belt (Roy, 1986) and also in the study area (Figures V.1.10 and V.1.11) suggest existence of mild shale diapirism in the region. Intensity of folding is found more in Tripura - Mizoram (Roy, 1986) and became gentle and subdued in Bangladesh . Structures get higher and higher to the east and older beds of early Miocene age are exposed in the core of the anticlines while Mio-Pliocene and Quaternary beds are exposed in the west. Compressive forces acting along east-west direction associated with the upliftment of the Indo-Burman ranges have been responsible for the development of folds in the area.

In the light of the currently accepted plate tectonics theory, the area is situated in the eastern margin of the Indian plate and has been formed by the collision of the Indian and Burmese Plate. According to Curray and Moore (1974, 1981) and Curray (1990), the present relative plate motion between the Indian and Eurasian plates is apparently in north-east and south-west direction that is causing underthrusting of the Indian plate under the Burmese plate in the east and has been responsible for the development of east-west compression in the region. The Burmese plate, being overridden by the Indian plate, has served as the main pushing force for the compression of the Tertiary sediments to produce folds. The tectonic forces thus generated from the east became progressively weak towards the west giving rise to the relatively broad, box-shaped folds in the area. Detailed structural analyses of the folded belt in Bangladesh (Hoque, 1982; Hossain, 1985) and study on similar structures of Tripura hills (Mitra, 1966) indicate that the folder belt of Chittagong - Tripura area, including the study area, has developed both by the horizontal east-west compression and by differential vertical crustal movement with additional complication of shale diapivism.

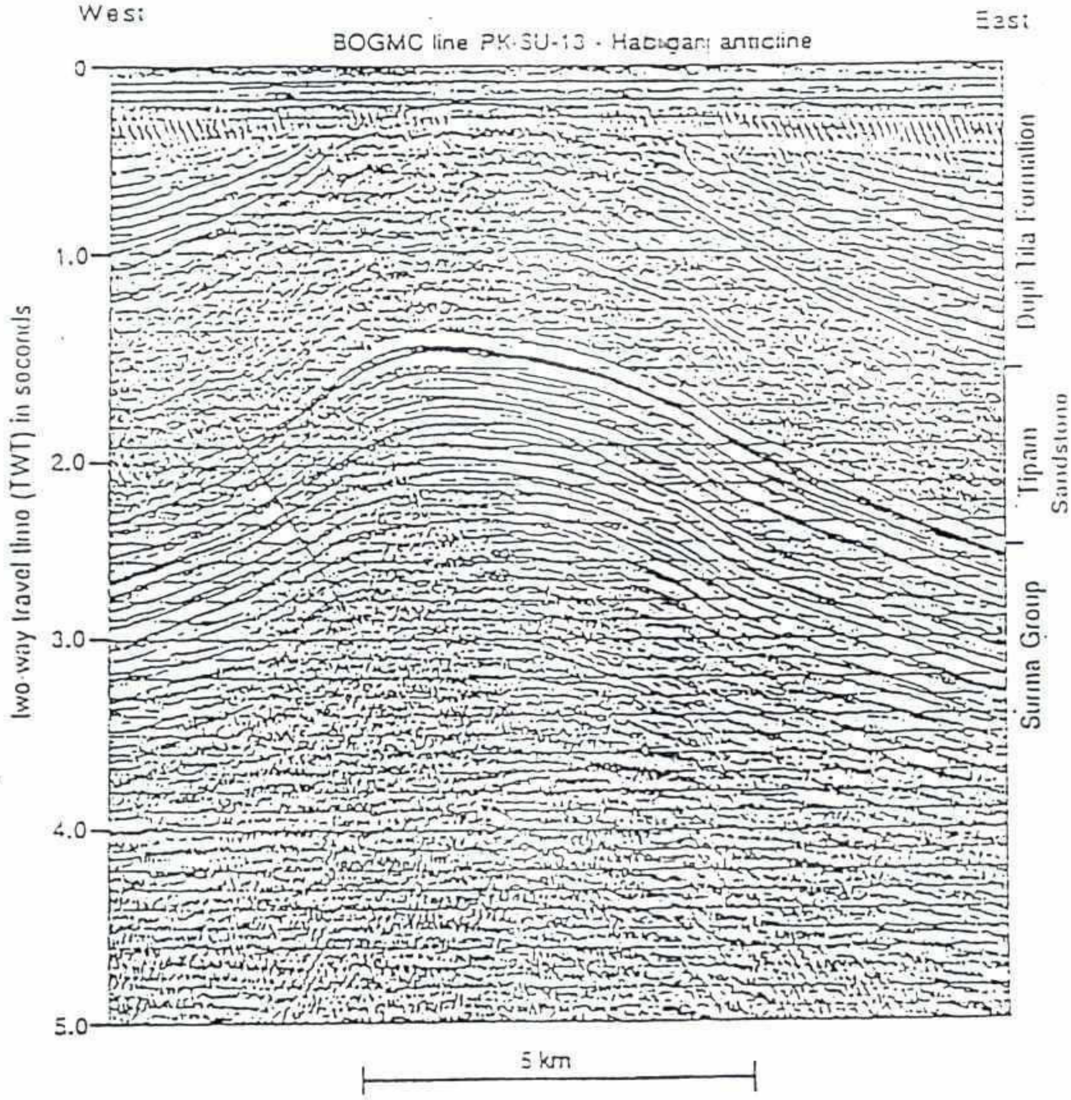
V.1.2.2 Seismicity

Bangladesh covering the major portion of the Bengal Basin is situated in the northeastern part of the Indian subcontinent. The Bengal Basin was brought into existence at the Tertiary time as a result of inter-plate movements involving the Indian, Tibetian and Burmese plates which also produced the Himalayas and the Indo-Burman ranges, including the Tripura folded belt and its western extension, to the north and east of the Basin respectively. The study area forming an integral part of the frontal folded belt lies at the juncture of three plates and is one of the most tectonically and seismically active areas in the world (Khondker, 1990 and Hoque et al, 1990).

Sesmotectonic studies have been undertaken by various workers in the Burmese arc comprising the Indo-Burman ranges and their western extension and in the northern India (a complete list of references is provided in Hoque, 1990). Table V.1.3 provides a list of large earthquake events ($M \geq 7.0$) that occurred in and around the area. Using data from various sources a seismicity map of Bangladesh and its adjoining areas has been prepared by Mominuddin (1991) (Figure V.1.12). The seismotectonic map of Bangladesh presented in Figure V.1.13 shows that the most of the epicentral distribution are concentrated along a number of faults/lineament system.

Figure V.1.10

BOGMC Line in PK-SU-13 - Habiganj Anticline



SORCE : BOGMC, 1991

Figure V.1.11

Portion of BOGMC Seismic Line BG-01 (Unmigrated)
Across the Begumganj Anticline

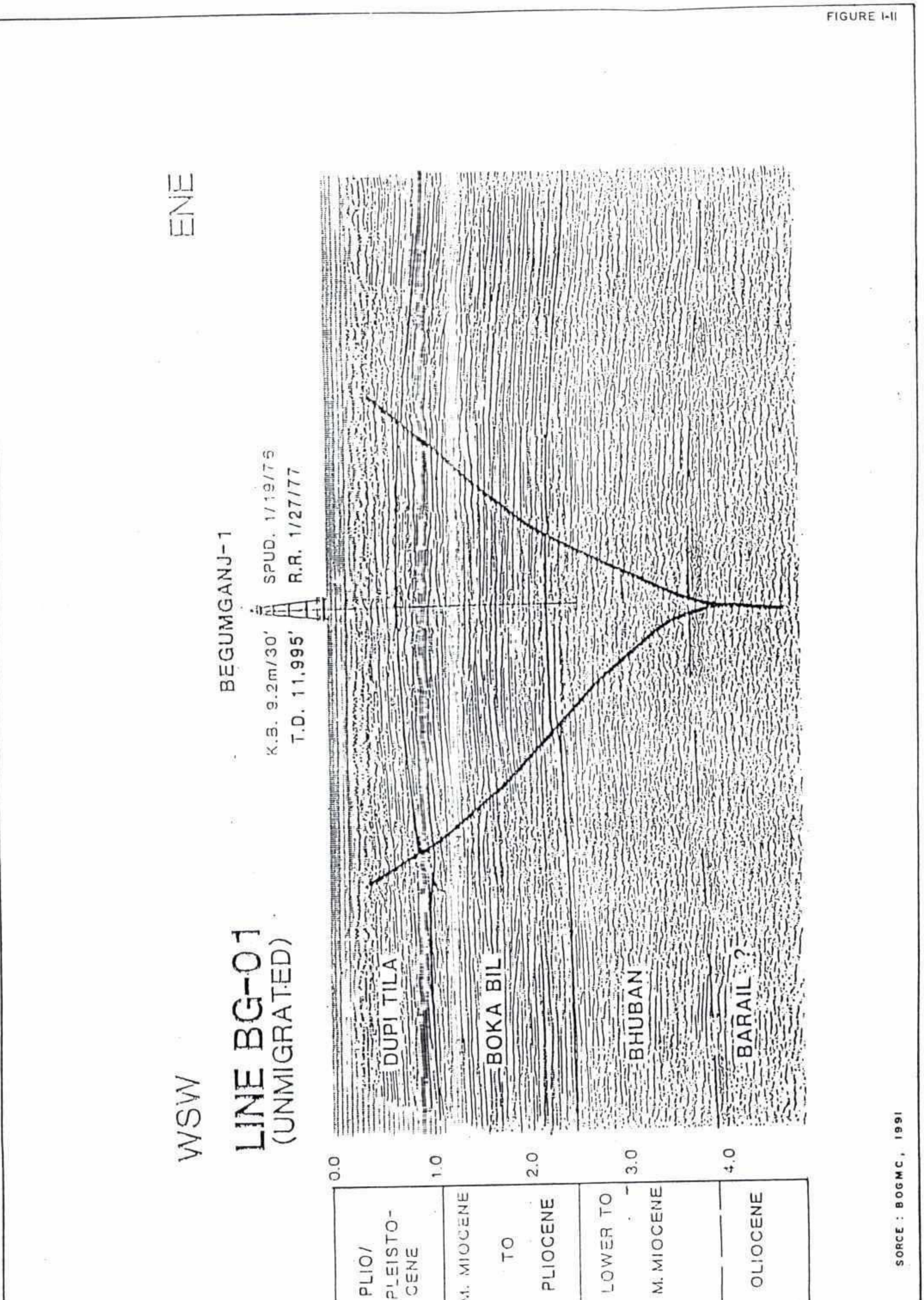
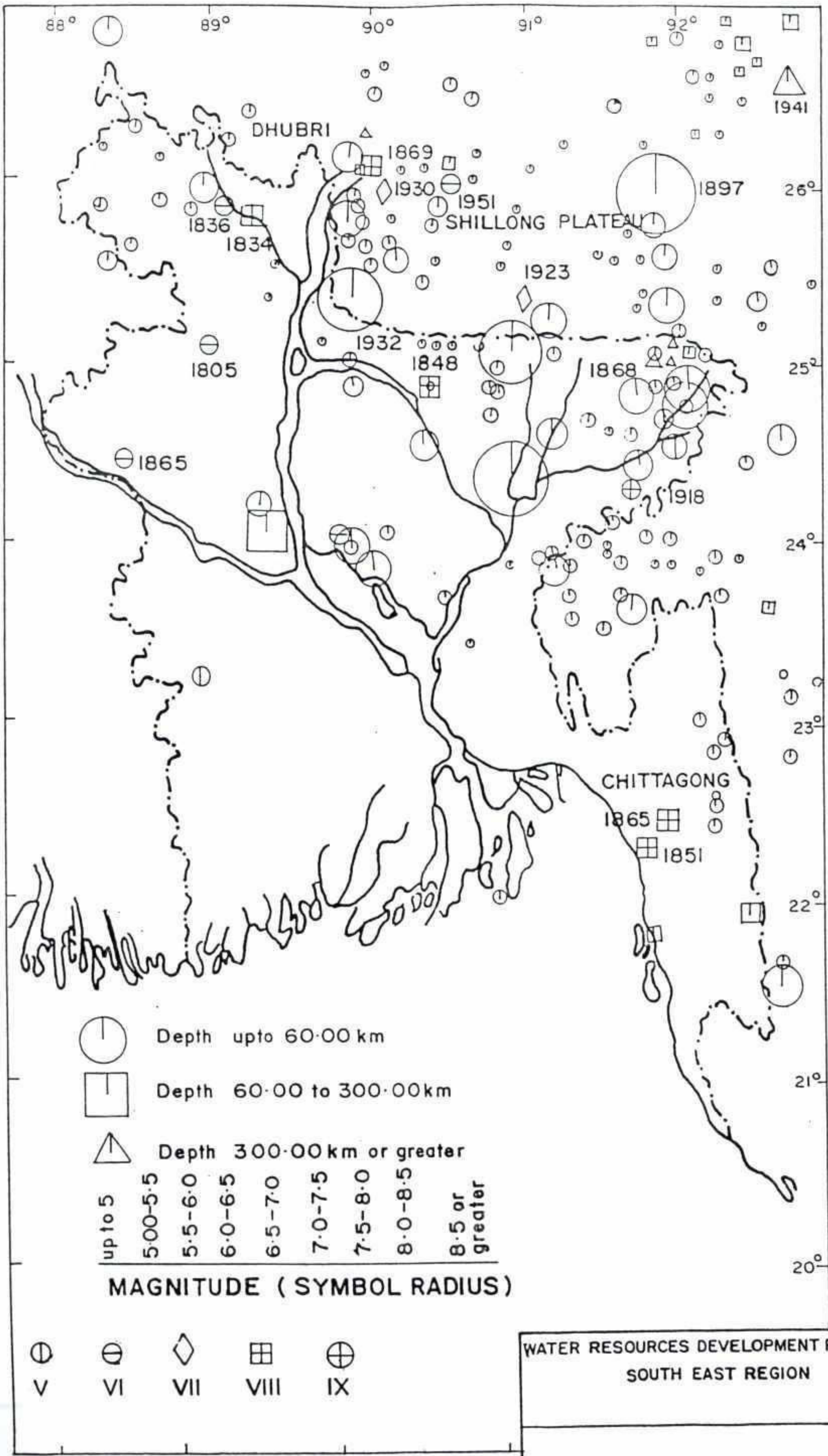


Figure V.1.12

Seismicity Map of Bangladesh and Its Adjoining Areas

FIGURE 1-12

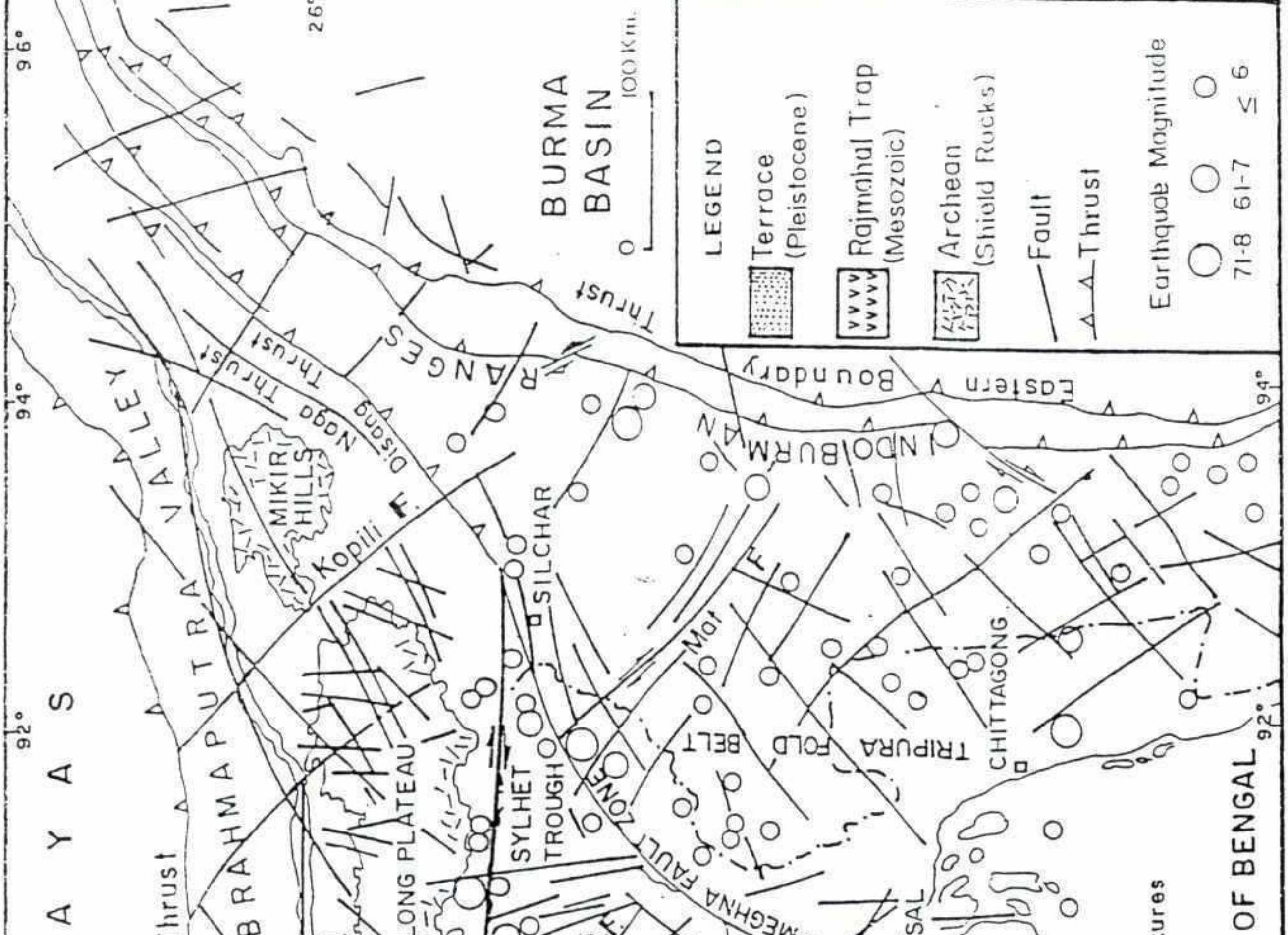


WATER RESOURCES DEVELOPMENT PROGRAMME
SOUTH EAST REGION

Source: Kamaluddin, Momin (1991)

Figure V.1.13

Seismotectonic Map of Bangladesh



Tectonic map of the Bengal Basin and adjoining areas. Only prominent geologic and tectonic features are shown. Data sources are cited in text

SOURCE: HOQUE, M & KHANDKER, R.A, 1990

TABLE V.1.3

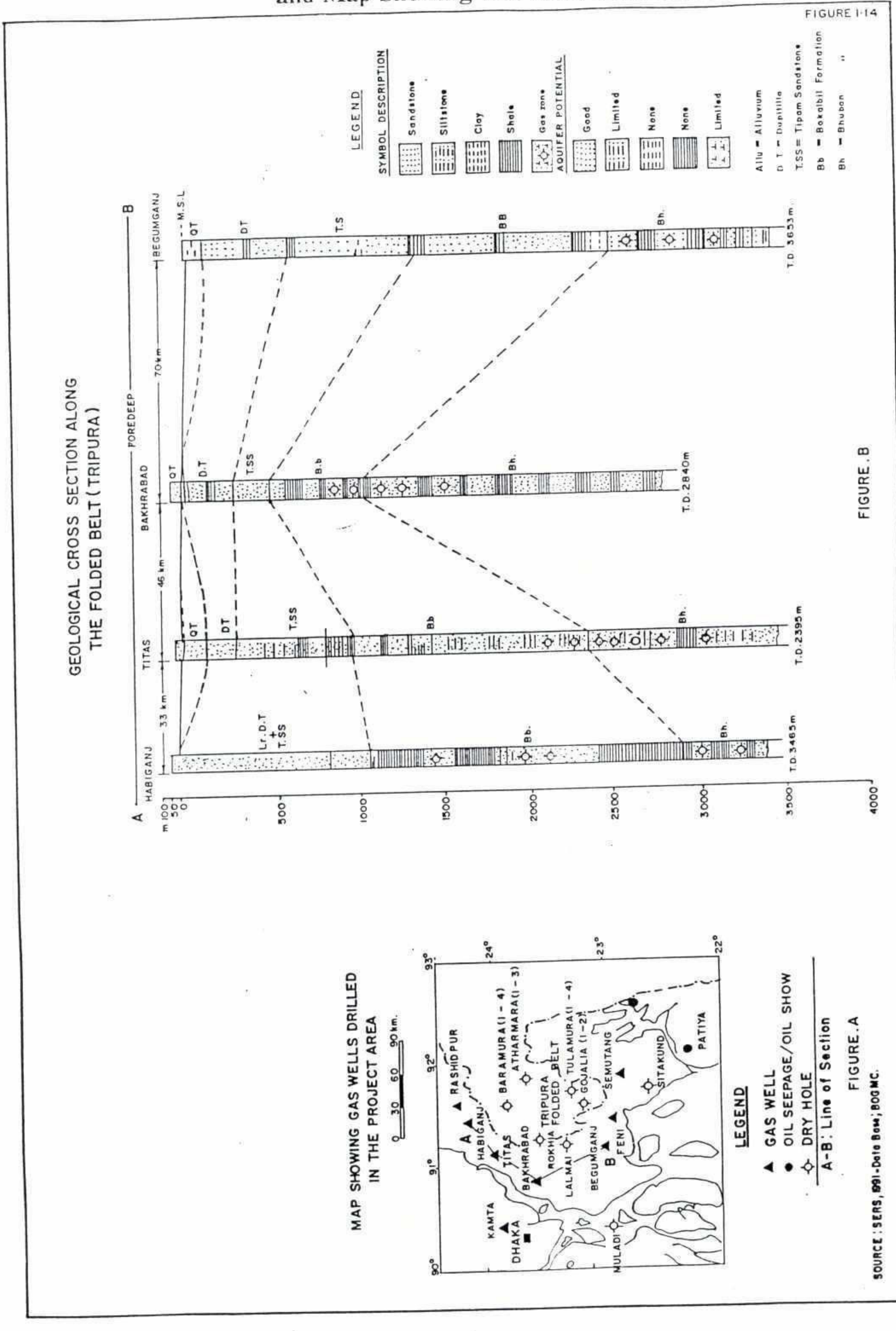
Historical Earthquake Felt in the Victinity of Bangladesh

Date			Name	Epicentral Lat.	Long.	Location	Mag.	Felt Area Sq. Miles
1762	April	2	Arakan Earthquake	22°	92°	Chittagong	7.5	-
1867	January	10	Cachar Earthquake	24.3°	92.2°	Cachar dist. Assam	7	250 000
1885	July	14	Bengal Earthquake	23°.59'20"	90°.6'30"	Manikganj	7	30 000
1897	June	12	Great Assam Earthquake	26°	21°	Shillong Plateau	8.7	1 750 000
1905	April	4	Kangra Earthquake	33°	76°	Kangra Valley	8.4	1 625 000
1906	September	29	Calcutta Earthquake	-	-	Bagirathi River	Intensity VI	50 000
1918	July	8	Srimangal Earthquake	24.5°	91.0°	Srimangal	7.6	800 000
1930	July	2	Dhubri Earthquake	25.8°	90.2°	Dhubri Garo Hills	7.1	350 000
1934	January	15	Bihar-Nepal Earthquake	26.5°	86.5°	Bihar	8.4	260 000
1950	August	15	Assam Earthquake	28.5°	96.7°	Mishmi Mountain	8.7	1 130 000
1975	July	8	Assam Earthquake	-	-		6.7	-
1988	August	6	Manipur-Burma Earthquake	25°	95°	Humain Burma	7.3	-
1988	August	21	Bihar-Nepal Earthquake	26.775°	86.609°	India-Nepal Border	6.4	-

Source: Hossain, K.M. 1986.

Figure V.1.14

Geological Cross Section Along the Folded Belt (Tripura) and Map Showing Gas Wells Drilled in the Project Area



Some of the important conclusions that might be drawn by studying Figures V.1.12 and V.1.13 are as follows:

1) The study area is tectonically very active and the tectonic activity might have brought about geomorphological changes in the area with successive intervals. The geomorphological processes are the terrace building (Lalmai and the existing flood plain - Meghna flood plain) building in an ascending antiquity during the Quaternary period.
2) Seismicity map of Bangladesh shows that maximum earthquake concentration occurs east of the Jamuna-Padma-Meghna trends.
3) The Jamuna fault, the Madhupur fault, the Old Brahmaputra fault, the Banar fault and the Meghna fault are the major faults bounding the geomorphic terraces and that the Quaternary deltaic plains in the study area bounded on the west by the Meghna fault zone.
4) The most important lineament is the 180 km long NW-SW trending Meghna fault zone passing through the river Meghna in the NE and the Ganges tidal flat in the SW merging with the Dauki fault, north of Silchar. A number of NE-SW lineaments parallel the Meghna fault zone on both sides. A number of epicentral plots falls on or close to this lineament.
5) The distribution of epicentres is distinctly linear along prominent tectonic elements like the Dauki fault system, the Meghna fault zone, the Madhupur fault and others.
6) Seismo-tectonic study shows that courses of the major rivers are controlled by pronounced active faults.

V.1.3 Stratigraphy and depositional history

The area is covered by a sequence of fining upward deltaic and flood plain deposits of the Quaternary age. Surface section of the exposed Lalmai Hills, shallow drill hole data for groundwater by the BADC, exploratory drill hole data of the GWC of the BWDB provide stratigraphic information of the water bearing aquifers while deep seismic section and drill hole data of the gas bearing structures in the Brahmanbaria-Noakhali folded belt and the adjoining Tripura hills form the basis of the subsurface stratigraphic information presented in Table V.1.4. Figure V.1.14 shows the NE-SW stratigraphic cross-section aligned roughly along the folded belt.

In the context of the present study concerning the hydrogeology of the water bearing sediments the focus of the presentation is on the Mio-Pliocene and Quaternary stratigraphy of the area and pre-Miocene stratigraphy are briefly dealt with.

I) Pre-Oligocene Stratigraphy

Pre-Oligocene, Cretaceous - Eocene, rocks crop out on the northern and eastern margins of the Surma basin, they have not been penetrated by boreholes in the subsurface of the folded belt in Tripura and Bangladesh. Regionally, these rocks reflect mainly transgressive sedimentation on a passive margin (Hoque, 1982, Salt, 1986). Cretaceous - Eocene rocks in the Naga Hills - Indo-Burman ranges comprise the Disang group and has been divided by Ranga Rao (1986) into lower and upper units. The Upper Cretaceous Lower Disang unit (> 2300 m thick) comprises slates, phyllites, and graywacke and is unconformably overlain by the Upper Disang unit (1 250-3 000 m thick) comprising grey shale and sandstone. These rocks (>5000 m thick) are geosynclinal facies equivalents of the shelf Jainta series of rocks and are expected to overlie the Early Cretaceous Oceanic basaltic basement complex in the Tripura folded belt (G.S.B., 1991) (See Table V.1.4).

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TABLE V.1.4

Stratigraphic Succession in the Folded belt and its Western Extension (Study Area)

	Cachar-Tripura Fold Belt *			Western Extension of Fold Belt **		
Approx Age	Group	Formation	Lithology and Thickness (m)	Group	Formation	Lithology and Thickness (m)
					Alluvium	Sands, Silts and Clay
					Madhubpur Clay	Sands Clay
Quaternary	Dupitila		Mainly sandstone (3 3000)	Dupitilla		Mainly Sandstone (620)
---Unconformity---				---Unconformity---		
	Tipam	Tipam	Mainly sandstones with clays in lower part (900)	Tipam	Tipam	Mainly Sandstone (620)
		Bakabil	Essentially Shale with sandstones in upper and lower part (1 500)		Bakabil	Essentially shale with sandstone (1 200)
	Surma (>2 500 m)			Surma (>2 200 m)		Upper part renaceous lower part argillaceous
Mio-Pliocene		Bhuban	Upper part arenaceous, lower part argillaceous (1 200)		Bhuban	(1 000 +)
---Unconformity---				---Unconformity---		
Oligocene	Barali	Renji	Mainly sandstone (700)	Barail ***		
		Jenam	Mainly thick shales (975)		Jenam	Siltstone, finegrained sandstone and
carbonaceous						shale (> 800 - 1 000 m)
		Laosong	Sandstone and **shales** (1700)			
Late cretaceous to Ecene	Disang	-	Flysch, mainly shales with sands (3 000)		-	-
Early Cretaceous Basement			Oceanic Basalt		-	-

Note: * **Roy, T.K., 1986**
** **Based on drilling data,** BOGMC
*** **Speculative, based on information on Surma Basin**

ANNEX-V

II) Oligocene - Early Miocene (40-20 Ma)

Lithological observations (Evans, 1964) indicate that environment of deposition since Eocene had been quite different in the North East India. Since plate collision in Eocene and subsequent uplift due to collision orogeny, the frontal foreland basin that formed in front of the rising axial Indo-Burman ranges, and the remnant ocean basin in further southwest,[1] were being filled up by the fluviodeltaic and shallow-marine sediments with continuous delta progradation towards south and south west. Large part of the Oligocene and possibly a part of earliest Miocene, known as Barail in the fold belt, have three units - a lower marine shale and sand, middle deltaic and shallow-marine shales and uppermost coal shale succession deposited in coastal swamps, lagoons and mixed environment. While deltaic sedimentation was in progress in the Naga Hills area during Oligocene time, depositional environment in the Tripura - Brahmanbaria - Noakhali area was probably deeper marine and lithology consists mainly of shale as suggested by seismic data (Roy, 1986). Over 3500 m of Oligocene - early Miocene sediments that overlie the pre-Oligocene sediments are not encountered by drilling in the area.

Mio-Pliocene (20-2r3 Ma)

The early Miocene - mid Miocene sequence of the frontal fold belt near the convergence and collision boundary, known as the Surma Group, deposited in a shallow transgressive and regressive sea where thick sequence of clastic was formed. Lower part of the sequence named as the Bhuban formation consists of alternation of thick sandstone and gray shale, channel fill sand and conglomerates, argillaceous sequence, in turn, is succeeded by thick arenaceous unit. Final phase of deposition of this group is marked by a thick, mainly argillaceous formation, known as the Bokabil. At the last phase of Surma sedimentation, large scale regression of the sea commenced and the delta building process that ceased at the end of Oligocene resumed with continuous west and southwestward progradation. The sedimentation that was continuing under transgressive regressive seas in the foreland basin in front of the rising Indo-Burman ranges, was changed over to fluvial environment resulting in the deposition of the Tipam group of sediments, largely composed of multistoried sandstones. Depositional environment of an alluvial valley encroached over vast tidal deltaic plains west and southwest into Tripura - Comilla region and finally graded into the deltaic environment of Bay of Bengal.

The Surma group in the study area has been divided into the Bhuban and Bokabil formations. The thickness encountered in drill holes ranges from 2 300 m in Bakhrabad to over 3 000 m in Titas structures where none of the drill holes reached the base. The contact with the underlying Barail formation is an apparent transgressive onlap, placed approximately on the Oligocene-Miocene boundary, whereas the contact with the overlying Tipam sandstone is clearly diachronous from Middle Miocene in Assam to Early Pliocene in Tripura.

---

[1] The Cretaceous - Holocene Bengal Basin, underlying the deltaic portions of Bangladesh and adjacent India, and the Bay of Bengal forms a 'remnant ocean' (Mitchell and Reading, 1986) at the junction of the Indian plate and Burma plate let. Basin development began in the late Cretaceous - about 127 Ma ago - when the Indian plate was rifted away from Antarctica along an inferred Northeast-Southwest trending ridge system. After a plate re-organization at about 90 ma, the northward, leading to its collision with Asia, initiated during the Eocene between about 55 and 40 Ma. Major uplifts in the Himalayas and the Indo-Burman ranges began in Mid-Miocene and the plate movement is still continued.

The lithological characters of the Surma group, as revealed by drillers are not much different from the monotonous sandstone - shale sequential nature of the rocks in the exposed Chittagong folded belt. The intercalcitions of sandstones, shale and claystones are frequent; thus intimate mixing of these lithologies are quite evident. The sand shale ratio of the group is approx. 1:1.5.

The Tipam sandstone and Dupitilla formation comprise the Pliocene and Pleistocene deposits of the Surma basin and folded Tripura hills. The units can easily be identified on seismic records (Figures V.1.10 & 11). The Tipam sandstone is a massive, coarse grained unit with seismic homogenity which is easily contrasted with the banded reflectors of the underlying Surma and overlying Dupitilla sandstone. The Dupitilla and, to a lesser extent the Tipam each thin over anticlinal crests, indicating that they were contemporous with folding. The Tipam - Dupitilla contact is conformable in synclines but is commonly in angular unconformity near anticlines.

Lithologically both the Tipam and the Dupitilla formations are arenaceous with subordinate shale but the Dupitilla sandstones are fine grained, less indurated and more shaly. The Tripura folded belt and its adjoining western extension in Bangladesh experience fluvial sedimentation resulting in thick and extensive sheets of fining upward coarse sand - medium sand - fine sand - clay sequences. The Tipam sandstone is regarded as bed-load dominated (braided) river deposit and the fine-grained Dupitilla formation as mixed load (meandering) river deposits. The fluvial regime graded in the offshore into the environment of the Ganges - Brahmaputra - Meghna delta system.

The maximum penetration of the Tipam - Dupitilla section in Begumganj well is about 1 400 m but in Titas - Bakhrabad wells it varies from 250 - 500 m.

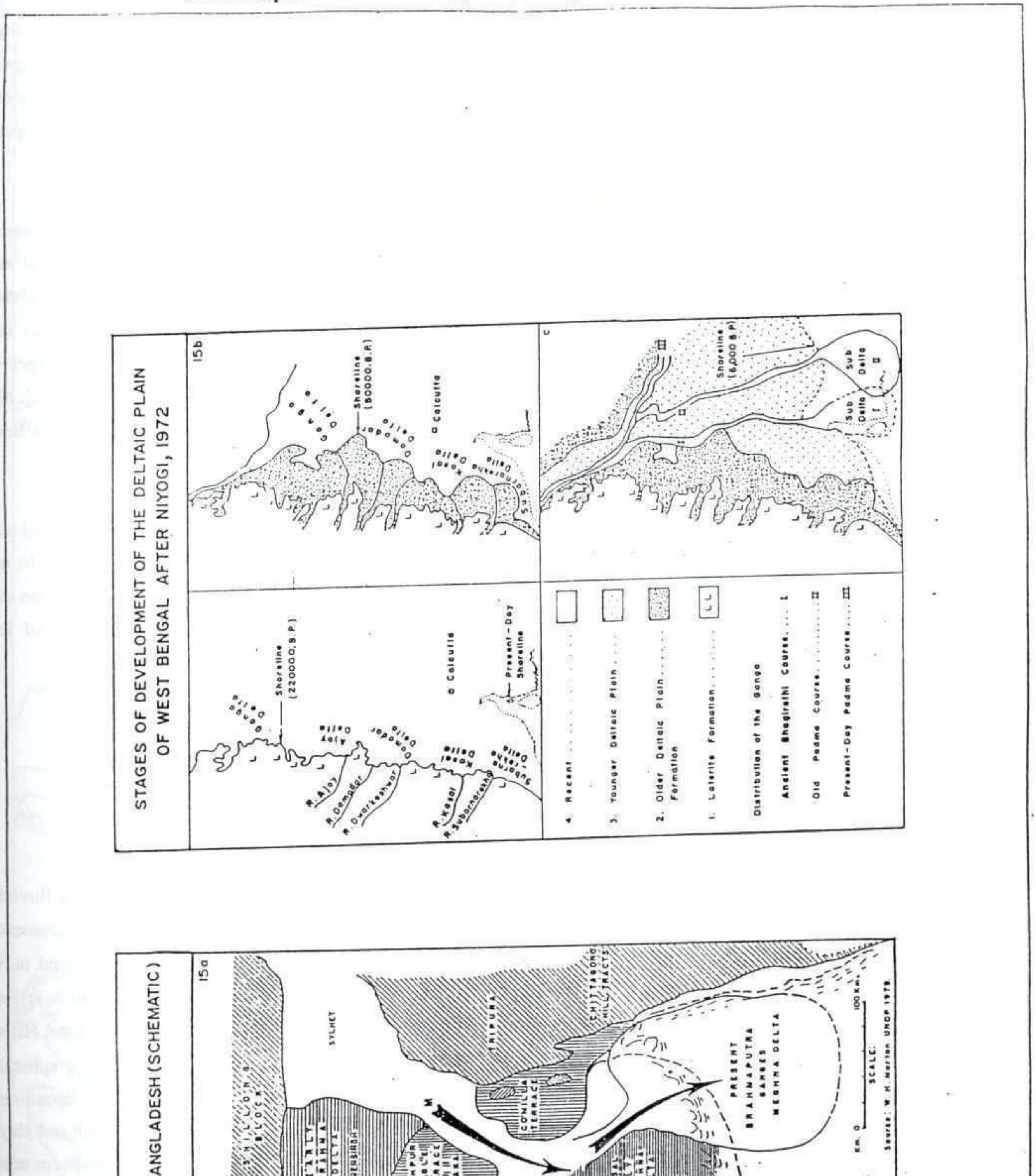
Quaternary

The youngest of the geological periods, the Quaternary, including both Pleistocene and Holocene epoch, lasts over 2 Ma and is characterized by recurring occurrences of glacial and interglacial phenomena resulting in fluctuations of sea level on a global scale to the magnitude of 100 - 150 m. The sea level dropped during glacial time and during interglacials sea level rose. Recent study (Bakr, 1977), Coleman, 1968, Morgan and McIntyre, 1959, Niyogi, 1972 and Umitsu, 1985 and 1989) of the vast alluvial plains in Bangladesh and West Bengal has demonstrated that these plains were built as deltas of different river systems during the Quaternary in response to sea level oscillations. During each fall of sea level, as a result of lowering of base level, large incised valleys were formed along ancient rivers and during each high stand of the sea, rivers draining the adjacent high land have given rise to individual deltas. These deltas coalesced to give rise to long belts of alluvial plains. The sedimentation pattern during such a set up is expected to be coarse substrata during valley cuts and fine topstrata during valley fills period i.e. a series of fining upward sequences corresponding to each glacial-interglacial event.

Figure V.1.15a illustrates Niyogi's (1975) reconstruction of the palaeogeographic development of the deltaic West Bengal based on geomorphic and geological data analyses in the context of usual glacioeustratic oscillatiions. Four belts of landsurfaces; lateritic upland (Worgram Plain), older deltaic plain younger deltaic plain (Kalna plain) and Recent deltaic plain (Baghirathi meander belt), represent the exposed top portions of four series of sediments deposited in an offlap sequence during the four high stands of the sea level of the

Figure V.1.15

Development of the Quaternary Deltaic Arcs in the Bengal Basin



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Quaternary. Delta building by the existing set of rivers continued through the Quaternary period thereby pushing the shoreline steadily eastward. Due to continuous uplift of the region in the west, each younger formation was deposited further seaward than the proceeding one thereby leaving a portion of the later uncovered. At each junction, the older formation goes below the younger formation and takes the proper stratigraphic position.

Morton (1979), based on Landsat imagery studies, delineated the Quaternary deltaic arcs in Bangladesh (Figure V.1.15b). The Barind Tract, the Madhupur Jungle Tract and the Lalmai Tracts were regarded as remnants of Pleistocene sediments deposited over Bangladesh from the early Ganges - Brahmaputra - Meghna system. The 'early Ganges delta' and the 'early Brahmaputra delta' are two simultaneous deltaic arcs in Holocene time whereas the development of the early Meghna delta is a result of diversion of the Ganges - Brahmaputra systems to their present directions in order to build a third early Holocene deltaic arc. Much of the present day delta building activity is at the Meghna estuary whereas alongside the early Meghna delta lies the Sunderbans or the later Ganges delta.

The surface geology map of the area presented in Figure V.1.16 is based on the Geological Map published by the Geological Survey of Bangladesh (G.S.B., 1990) and a brief description of various units is obvious from Table V.1.5 that is found on the explanatory notes provided in the map. The sedimentological description of exposed lithostratigraphic units are described by Hassan (1986) and a brief presentation is provided in Table V.1.6. The lithostratigraphic units analysed include:

a) Dupitilla Formation
b) Madhupur Clay Formation
c) Chandina Deltaic Deposit
d) Meghna Flood Plain Deposit

The Dupitilla formation includes a sand member and silt member of Plio-Pleistocene age representing a fluvial meandering product. The Madhupur Clay subsidivisable into a lower sandy and an upper clay unit represents an episodic flood product of Pleistocener age. The Dupitilla sandstone and lower Madhupur Clay sand unit form the principal aquifer of the area. The Madhupur clay with high percentage of little and halloysite overlies unconformably the Dupitilla formation. After the deposition of this unit, tectonic activity raised the Lalmai Hills which have been eroded and dissected giving rise to fragmentatory terrace. Consequently, a topographical unconformity had been formed. As a consequence, the drainage system then changed resulting into deposition of the Chandina deltaic flood plain deposit or Chandina formation, a sequence of grey silt, clayey silt and clay with high percentage of illite and kaolinite, which has built up the Chandina Deltaic Plain. The landform unit was also uplifted giving rise to a terrace surface called the Tipperah surface. The formation of the Chandina deltaic plain is reminiscent of two Holocene substages which are the Atlantic and the sub-boreal. The Meghna Flood Plain is then ascribed to the sub-Atlantic age as a younger formation.

Figure V.1.16

Surface Geologic Map in the Study Area

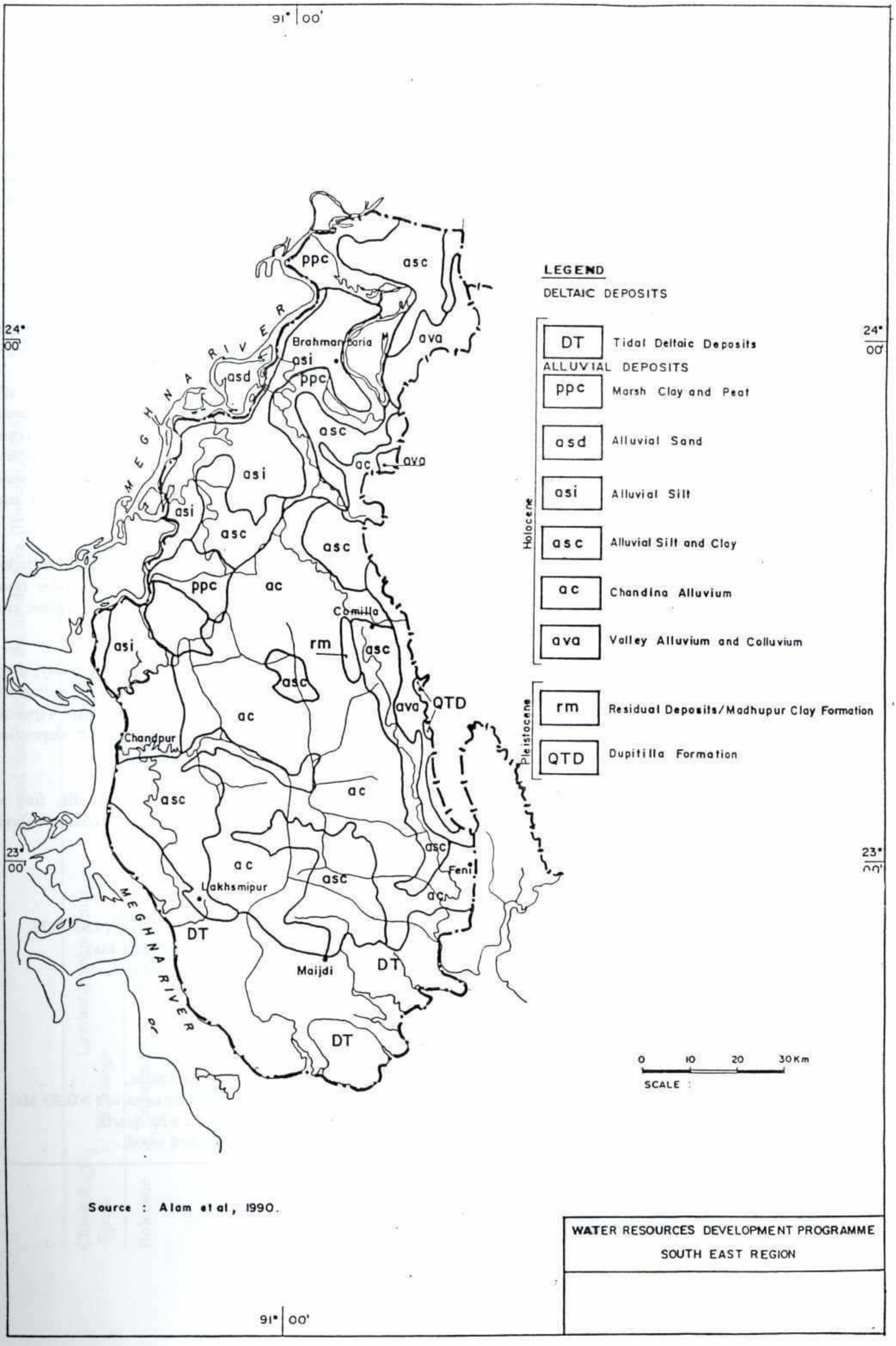

TABLE V.1.5

Brief Description of lithologic/morpholithologic units mapped in the Qvarternary Deltaic Plains of Brahmanbaria-Noakhali area. (GS.B. 1990: Geol. Map of Bangladesh)

Age	Code	Lithologic units	Description
dt	Tidal Deltaic Deposits		Light to greenish grey, silt to clayey-silt with lenses of fine sand along active and abandoned stream channels; contains some brackish water deposits.
	Alluvial	Deposits	-
	ppc	Marsh clay and Peat	-
	asd	Alluvial sand	Light to brownish grey coarse sand to fine silty sand; Meghna river sand is medium, quartz-rich.
	asi	Alluvial Silt	Light to medium grey, fine sandy to clayey silt; chiefly deposited in flood basis and inter stream areas. Unit includes small backswamp deposits and varying amounts of inter stratified sand deposits. Illite is the most abundant clay mineral. Most areas are flooded annually leaving thin veneer of sand (radio-carbon dated 500-6000 yrs B.P.)
	asc	Alluvial silt and Clay	Medium to dark grey silt to clay, colour is darker with increase in organic content; includes flood basin silt, backswamp silty clay and organic rich clay.
	ac	Chandina Alluvium	Yellowish brown, greyish brown silt to clay, more consolidated than active flood plain sediments. Upper 0.5 m is oxidized. Underlies Tipperah surface. Radiocarbon dates suqqust deposition ceased during the Middle Holocene.
	av	Valley Alluvium and Colluvium	Medium to dark grey silt, clayey silt, fine to medium sand and locally derived coarse debris; includes small alluvial deposits.
		------------Unconformity------------	
Pleistocene	rm	Madhupur Clay/Clay Residuum	Light yellowish grey orange, light (0.93-0.73 to brick red micaceous silty clay; Ma) dominant clay kaolinite and illite C.
		------------Unconformity------------	
Plio-Pleistocene	Qtdd	Dupitila Formation	Yellow to light brown sandstone, siltstone and conglomerate; massive (>0.93 Ma) to thin bedded sandstone with quartz, shale pebbles and silicified wood.

TABLE V.1.6

Exposed Succession in the Study Area (Hossain, 1988)

Chronology Epoch	Sub-stage	Litestratigraphic Units	Lithology	Depositional Environment	Geomorphological Processes
Holocene	Subatlantic	Meghna flood plain deposit	Greenish gray sandy silt, olive gray silt and light olive gray clayey silt P^{H} varies from 4.51 - 6.14	Flood (3)	Existing flood plain-building
	Atlantic to Subboreal	Chandina Deltaic flood plain deposit	Greenish gray, light olive gray to light gray clayey silt, peat development in low lands and swamps P^{H} varies from 6.92 - 7.77	Flood (2)	Terrace surface-building (Tippera surface)
..........Erosion..........			..........Unconformity..........		
PLEISTOCENE		MADHUPUR ALAY (Unit A)		EPISODIC	
		Clay sub-unit (A_2)	Reddish yellow clayey silt and sand-tilt-clay containing ferruginous nodules, concretions and micas. Occasional lignite pebbles, silicified woods and lateritic blocks available P^{H} varies from 5.15 - 5.58	Flood (1)	Terrace-buildings (Lalmai and Madhupur)
		Sand sub-unit (A_1)	Mottled silty sand and clayey sand in places, variously coloured loose and containing micas. Occasional iron oxides (centrally hollow) and also silicified woods. Calcareous silicified woods. Calcareous modules at the base in places, gravels sparsely present.	Channel	
..........Erosion..........			..........Unconformity..........		
PLIOCENE		DUPI TILA FORMATION:			
		Siltstone Member (Unit B)	Yellowish brown siltstone alternated with brownish yellow silty sand or sandy silt Ferruginous bands common	Topstratum (Level)	River cycle
		Sand Member (Unit C)	Light brown to strong brown sand, cross-bedded, laminated and loose; micas present.	Substratum	

CHAPTER V.2

HYDROGEOLOGICAL BACKGROUND

V.2.1 Aquifers and Aquifer Facies

A two-fold division of the Neogene - Quaternary sediments into an upper and a lower sequence is made for the country (MPO, 1987 and Jones, 1985) on the basis of their differing hydrogeological characteristics and as can be seen in Table V.2.1, the same division is applicable for the study area. The aquifer potential in the study area is related to the stratigraphic column as shown in Table V.2.2 and Figure V.1.14. The upper geological unit is a heterogenous fining upward sequence of sands, silts and clays, all essentially in hydraulic continuity, over a thickness extending upto 150 m or so. The upper sequence has a tripartite subdivision while the lower sequence is provisionally subdivided into five independent aquifers separated by impervious clays.

A. Upper Sequence

The current description of the upper aquifer sequence is based on borelog data analyses of over 850 lithology procured from the MPO and the groundwater reservoir has been divided into:

- an upper silty clay layer
- a middle composite aquifer of fine to very fine sands averaging over 20 m thickness; and
- the main aquifer of medium to fine or medium to coarse sands with interlayers of clays and silts extending to a depth of over 150 m.

a) Upper Silty Clay and Clay layer

The upper silty clay and clay layer is generally characterized by high porosity and low permeability (Table V.2.1) The layer increases in thickness from less than 20 m in north to over 60 m in the south (Figures V.2.1 and V.2.2).

Statistical analyses of the clay facies help in dividing the upper silty clay cover into:

- Maximum clay thickness
- Mean clay thickness

Figures V.2.1a and V.2.2a illustrate the isopach maps of maximum and mean clay thickness and percentages of sands and silts within maximum and mean clay. Small clay thickness (0-20 m) and high sand content (60 - over 80%) can be seen in the north-west and west central part of the area adjacent to the Meghna River. The sand and silt content and layers of fine sand within the clay provide ground water to shallow wells such as hand tubewells.

The physical and hydraulic properties of the clay layers are hydrogeologically important as they regulate vertical recharge to the underlying aquifers in addition to acting as a semi-confined to confined layer to the more permeable zones below.

Figure V.2.1

Upper Silty Clay Thickness and Lithology (Maximum)

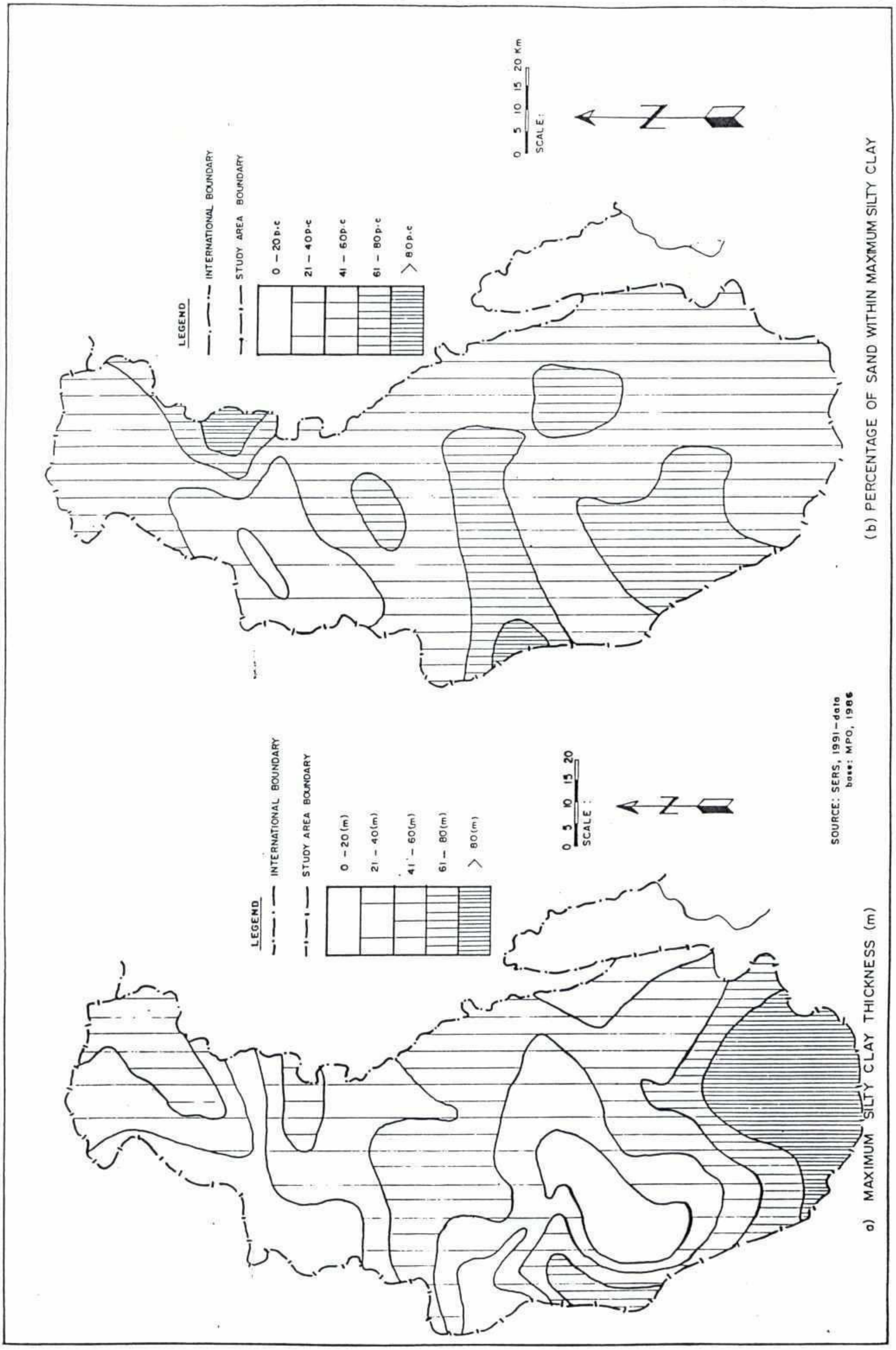

Figure V.2.2

Upper Silty Clay Thickness and Lithology (Mean)

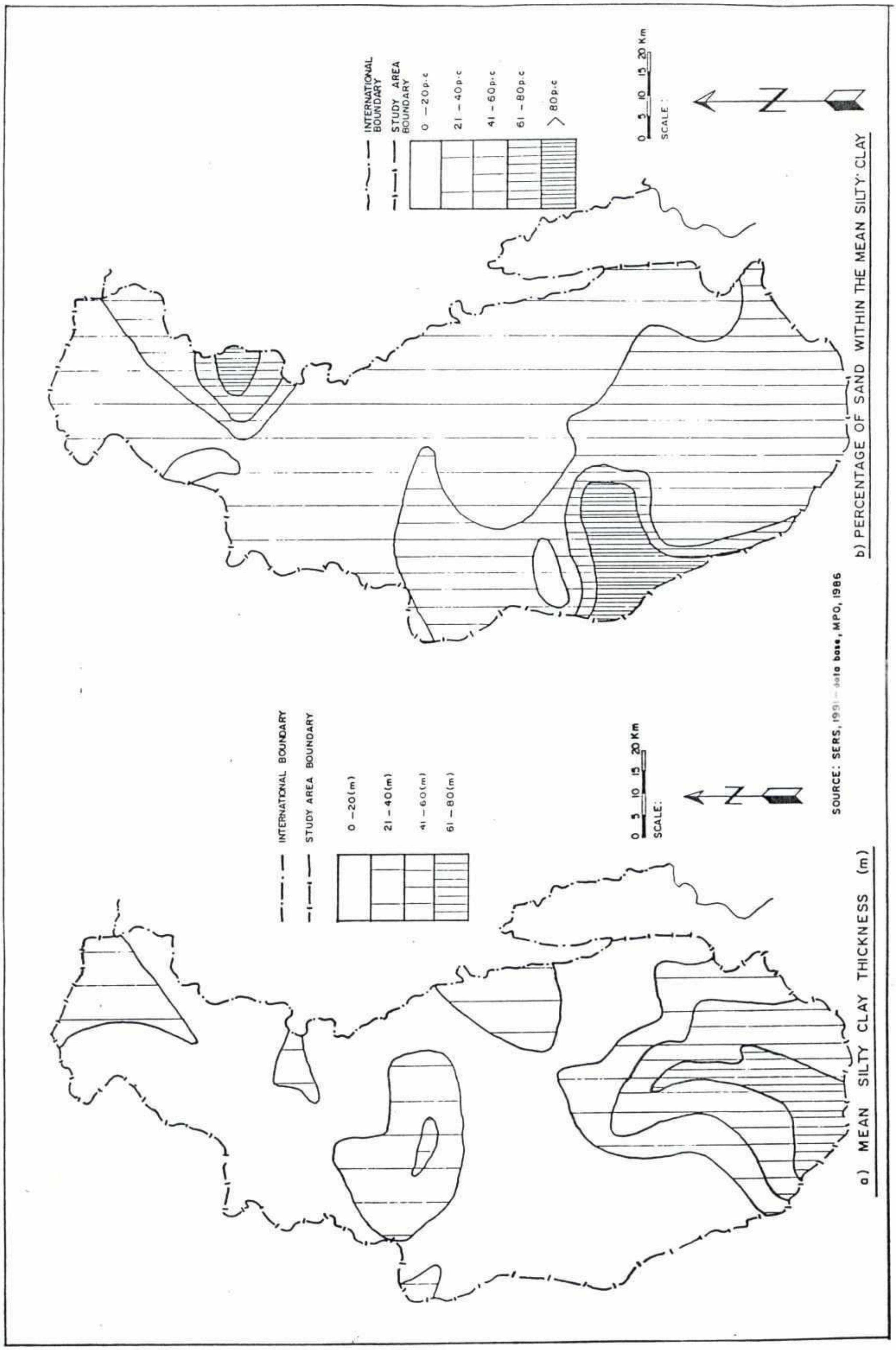

TABLE V.2.1

Hydrogeological Classification of the Neogene-Quaternary Sediments in Bangladesh

Sequence		Sub-units	Thickness (m)	Recharge Area	Remarks
Upper Aquifer Sequence (Quarternary)	a)	Silty Clay	0 to over 90 m		Hydrogeological characteristics and water resources well defined based on over 850 well logs-in the study area.
		Composite Aquifer	3 to 60 m		
		Main Aquifer	30 to over 60 m		
Lower Aquifer Sequence (Mio-Pliocene)	b)	Clay Aquitard	20 to 80 m		Hypothetical based on 36 well logs and 20 geo-electric logs; hydrogeological interpretation speculative. Aquifer Nr 4, 5 and 6 are salty, in the eastern part. Tripura Hills form the recharge area.
		Aquifer Nr 2	60 to 120 m		
		Clay Aquitard	0 to 170 m		
		Aquifer Nr 3	140 to 180 m		
		Clay Aquitard	110 to 140 m		
		Aquifer Nr 4	100 to 170 m		
		Aquifer Nr 5	80 to 160 m		
		Clay Aquitard	30 to 60 m		
		Aquifer Nr 6	110 to 190 m		

Notes: **a)** Upper Aquifer, MPO, 1987
b) Lower Aquifer, Jones, 1985

TABLE V.2.2

Aquifer Types and Characteristics in the SE Groundwater Region in the Study Area

Aquifer Unit Area (km^2)	District	Relief/ Physiographic Unit	Lithology	AQUIFER CHARACTERISTICS GEOMETRY			WATER QUALITY CHEMISTRY			Development Potential
				Thickness of Aquifer (m)	Depth to top of main Aquifer (m)	Type	T.D.S in in mg/l	Iron Content in mg/l	Chloride Content	
1	2	3	4	5a	5b	6	7a	7b	7c	8
Unit SE-1 Eastern Piedmont	Comilla Noakhali	Piedmont plains of the Tripura Hills, lying along the border belt of Comilla and Noakhali.	Predominantly medius sand with subordinate fine sand at the bottom. Sorting in the sand is poor. Sandy materials are covered with a clay bed of more than 20 m thick.	Not precisely known, around 50 m.	Range: 10-60 Arrange: 50	Extensive unconfined with local semiconfined to confined and multiple.	Less than 500	1-10	10-50	Aquifer chara-cteristics make the area suitable for ground-water development.

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TABLE V.2.2 (Contd)

1	2	3	4	5a	5b	6	7a	7b	7c	8
Unit SE-2 Old Meghna Floodplain	Comilla Noakhali	Floodplains formed by the Meghna and its tributaries & distributaries. Typically flat, shallowly to intermittently flooded.	Predominantly medium sand with subordinate fine sand at the bottom. About 20 m clay covers the aquifer materials.	Known thickness of the main aquifer is around 10 m.	Range: 30-60 Arrange: 50	Mainly unconfined.	Variable 300-700, locally over 1,000.	Variable locally over 10.	10-50 locally over 2000	The area is highly suitable for ground water development as the aquifer characteristics are good. Development potential is constrained in vast areas by saline ground water occurences.
Unit SE-3 Lower Meghna Floodplain	Comilla Noakhali	Floodplain formed by the present day Meghna. Deeply flooded.	25 to 40 m upper clay covers a layer of fine to medium sand. This is followed by occurrence of a second clay layer beneath which the main aquifer of medium to coarse sand lies.	The aquifer at the top (Composite one) is about 60 m thick. Thickness of the main aquifer in not known.	1st aquifer: Range: 50-70m Average: 60m	Semiconfined to confined, multiple.	500-700	Variable: 0-10.	10-50 locally over 100	Development potentiality is moderately good.

TABLE V.2.2 (Contd)

1	2	3	4	5a	5b	6	7a	7b	7c	8
Unit SE-4 Coastal plains and offshore Islands of Noakhali.	Noakhali	Coastal plains and offshore Islands formed at the Meghna estuary.	A 50-100m or more clay materials cover of sandy sequence with a heterogenous mixture of clay and silt. In some of the coastal islands, fine to medium sand found at the top which is followed by thick layer of silt and clay. Sandy materials are predominantly fine with sub-ordinate medium and coarse materials at greater depths.	A shallow aquifer of about 20-30m thickness exists. Thick-ness of the main aquifer in not known.	Shallow aquifer exists at around 50-100m depth. Main aquifer is deep seated.	Semiconfined to confined.	700-1000; locally over 5,000.	0-10	200-1000	Development potential is limited because of greater depth to tap of the aquifer and salinity problems.

Source: UNDP, 1982; MPO, 1986 and Present study (SER, 1991).

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b) **Main and Composite Aquifer**

These aquifers, which range in thickness from less than 20 m to over 60m, have good to excellent water transmission properties in the north central part of the study area. Their development potential is constraint by the occurrences of saline groundwater (see Section V.3).

The top of the aquifer unit, referred to as composite aquifer (UNDTCD/BWDB GWC, 1982) is composed of very fine to fine sand, sometimes medium sand and constitutes the uppermost water bearing zone. It varies in thickness from less than 20 m in the east to over 60 m in the west and north-west (Figure V.2.3). Almost all the 7537 STWs in the study area tap their groundwater from this aquifer.

Below the uppermost water bearing zone, lies a series of medium to fine or medium to coarse sands with interlayers of clay. This zone, sometimes separated by a clay layer from the composte aquifer, is known as the main aquifer because it is the principal water bearing horizon for the high capacity irrigation wells all over the country. The maximum depth to the top of the main aquifer ranges from less than 40 m to 60-80 m in the area except in the south-west, west and north central where it is over 80 m (Figure V.2.4). While the full extent of the main aquifer is nowhere penetrated by any of the BADC DTWs, the thickness of the exploited aquifer ranges from 20 m to 60 m over much of the area except in the southern part (Figure V.2.5).

Figure V.2.6 illustrates a typical cross-section of the upper part of the groundwater reservoir in Kashba, Brahmanpara, Debidwar, Muradnagar and Daudkandi thanas indicating lithologic inhomogeneity and lack in consistency in the tripartite aquifer facies variation mentioned above.

B. Lower Sequence

Figure V.2.7 reproduced from Jones (1985, Figure 7) with minor modification, is a NW-SE to E sub-surface geologic cross-section that shows the occurrences of deep fresh water bearing aquifers overlying salty water aquifer. This conjecture is based on electrical and gamma ray correlation and interpretation of oil and gas test well logs. It has been suggested that the lower aquifer sequence is only recharged on its eastern unconfined outcrop in the Tripura hills and that each of the aquifer units from 2 to 6 is isolated by impervious clay layer. A number of conceptual and practical problems, however, exclude the planned use of the potential deep aquifer resource.

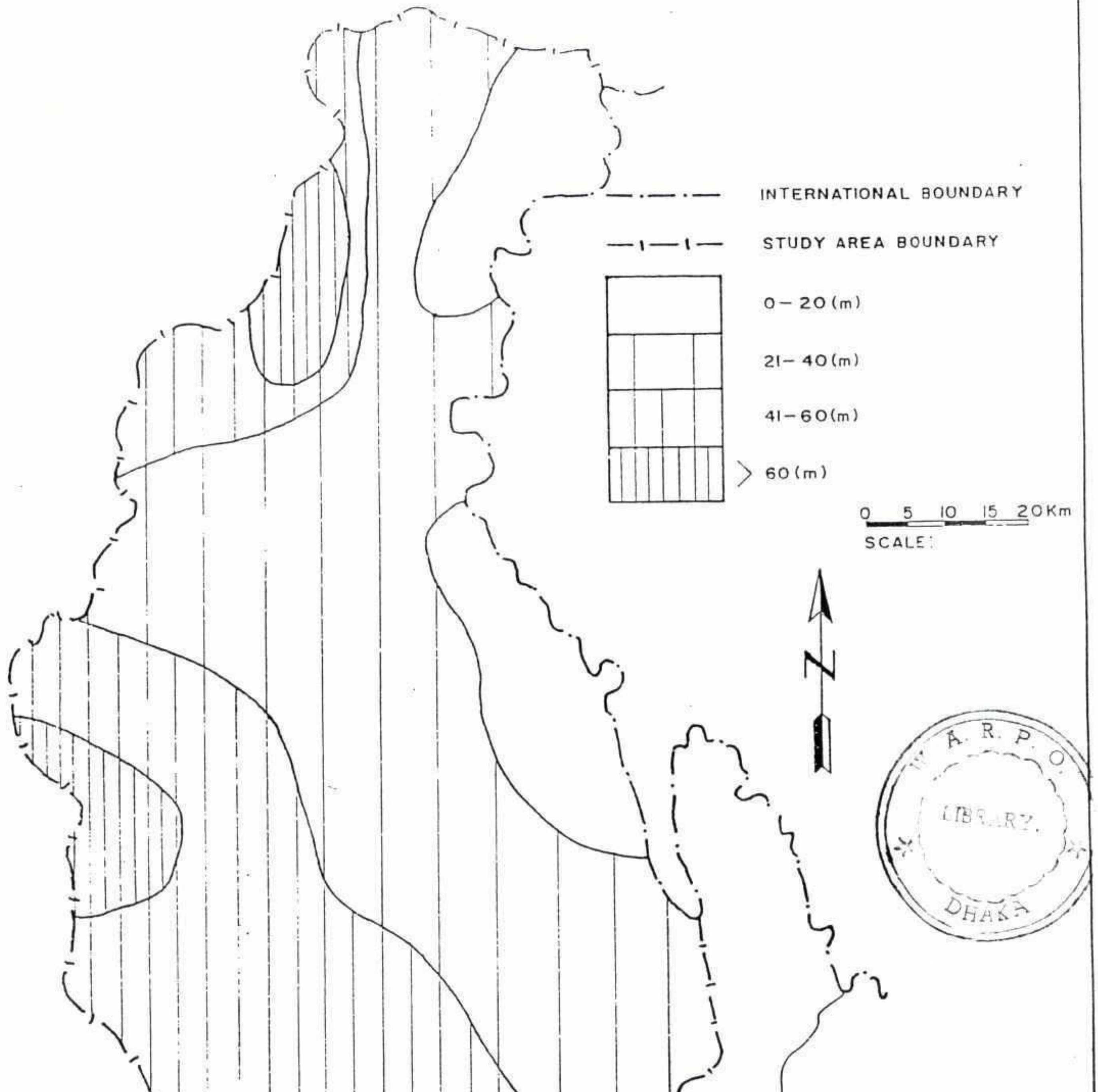
The south-east study area covers the northwestern portion of the SE Groundwater region as defined by MPO (1987). The physical properties of the various aquifer units are summarized in Table V.2.1 while Table V.2.6 shows the data base for preparation of various aquifer facies maps.

V.2.2 Aquifer Characteristics

Transmissivity and storage co-efficients are two principal properties that determine how effective an aquifer system is as a groundwater reservoir. Characterization of these properties, as presented here, is based on limited pumping test data performed for the UNDP (UNDTCD/GWS, 1981) and IDA/DTWII (1991) studies. Results of these analyses are shown in Tables V.2.3 to V.2.5 while Figure V.2.8 illustrates the locations of pump tested wells along with the transmissivity distribution of the main aquifer.

Figure V.2.3

Composite Aquifer Thickness



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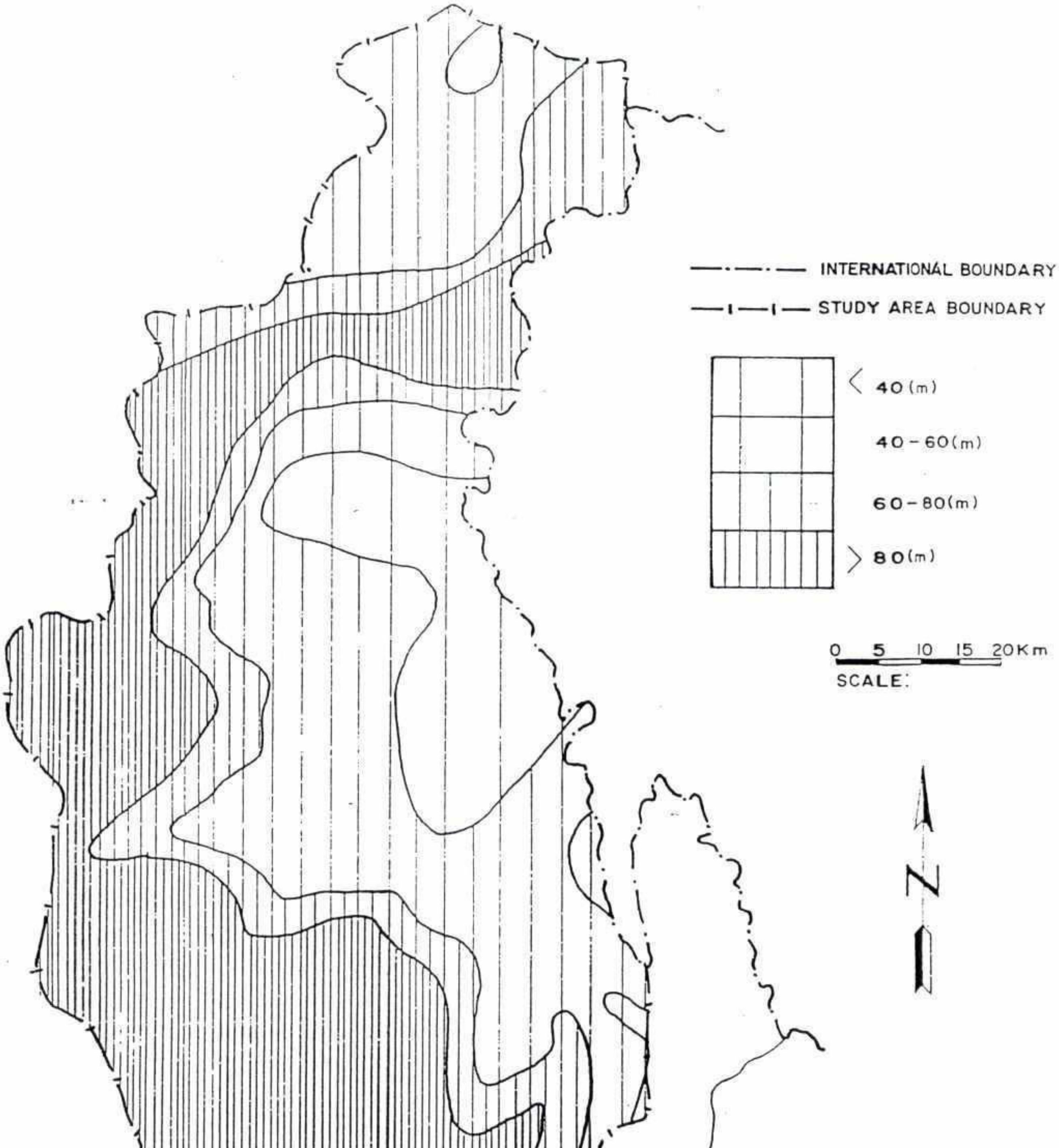
SOURCE: SERS, 1991– data base: MPO, 1986

Figure V.2.4

Maximum Depth to the Top of the Main Aquifer



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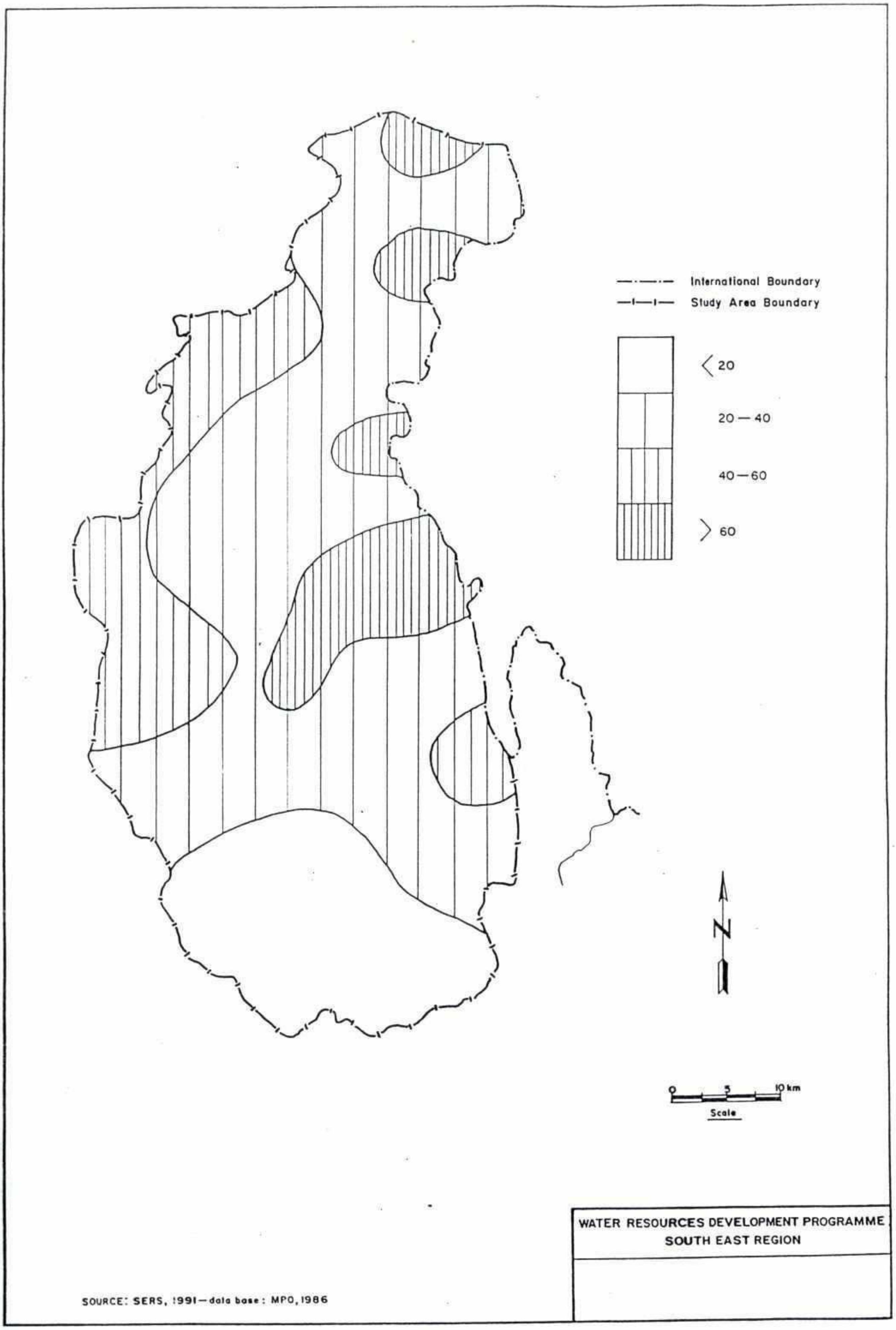
SOURCE: SERS, 1991 - data base: MPO, 1986

Figure V.2.5

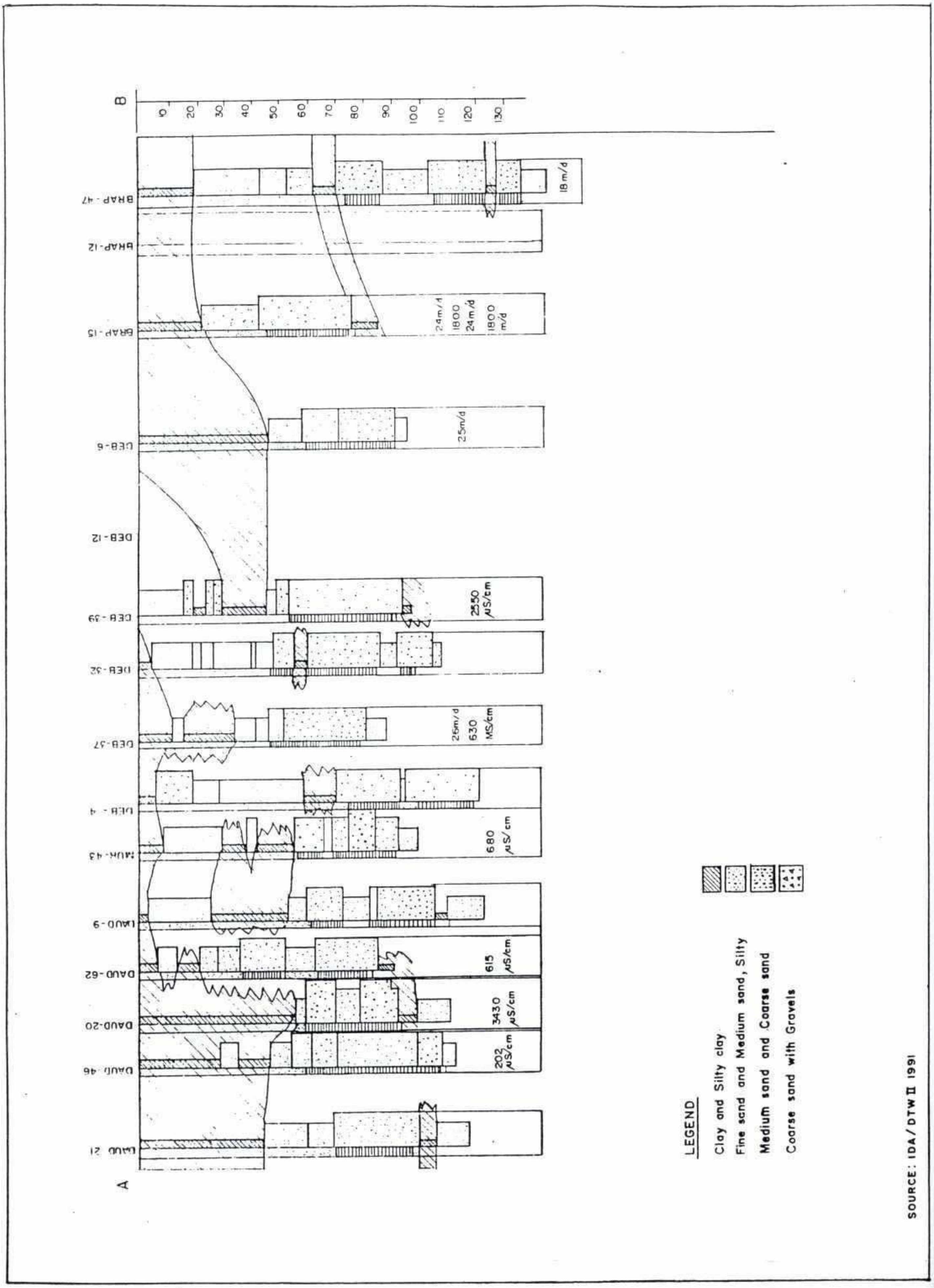
Exploited Main Aquifer Thickness, m.



SOURCE: SERS, 1991 — data base: MPO, 1986

Figure V.2.6

E-W Geological Cross Section of Upper Aquifer Sequence



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Geologic Cross Section From Kamta to Chittagong Folded Belt Showing Fresh Water and Salt Water Aquifers

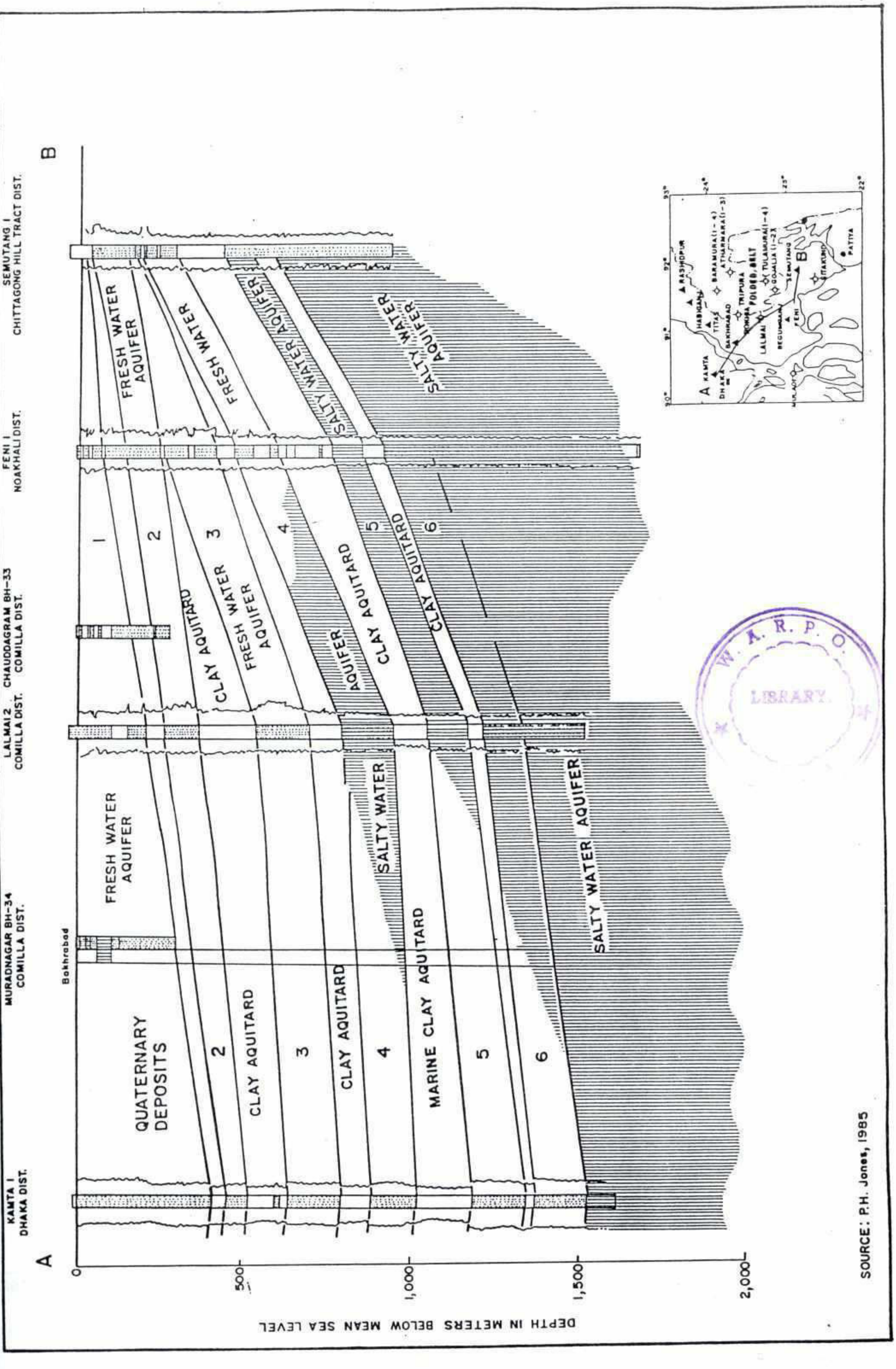

Figure V.2.8

Pumping Test Borehole Locations and Transmissivity Values

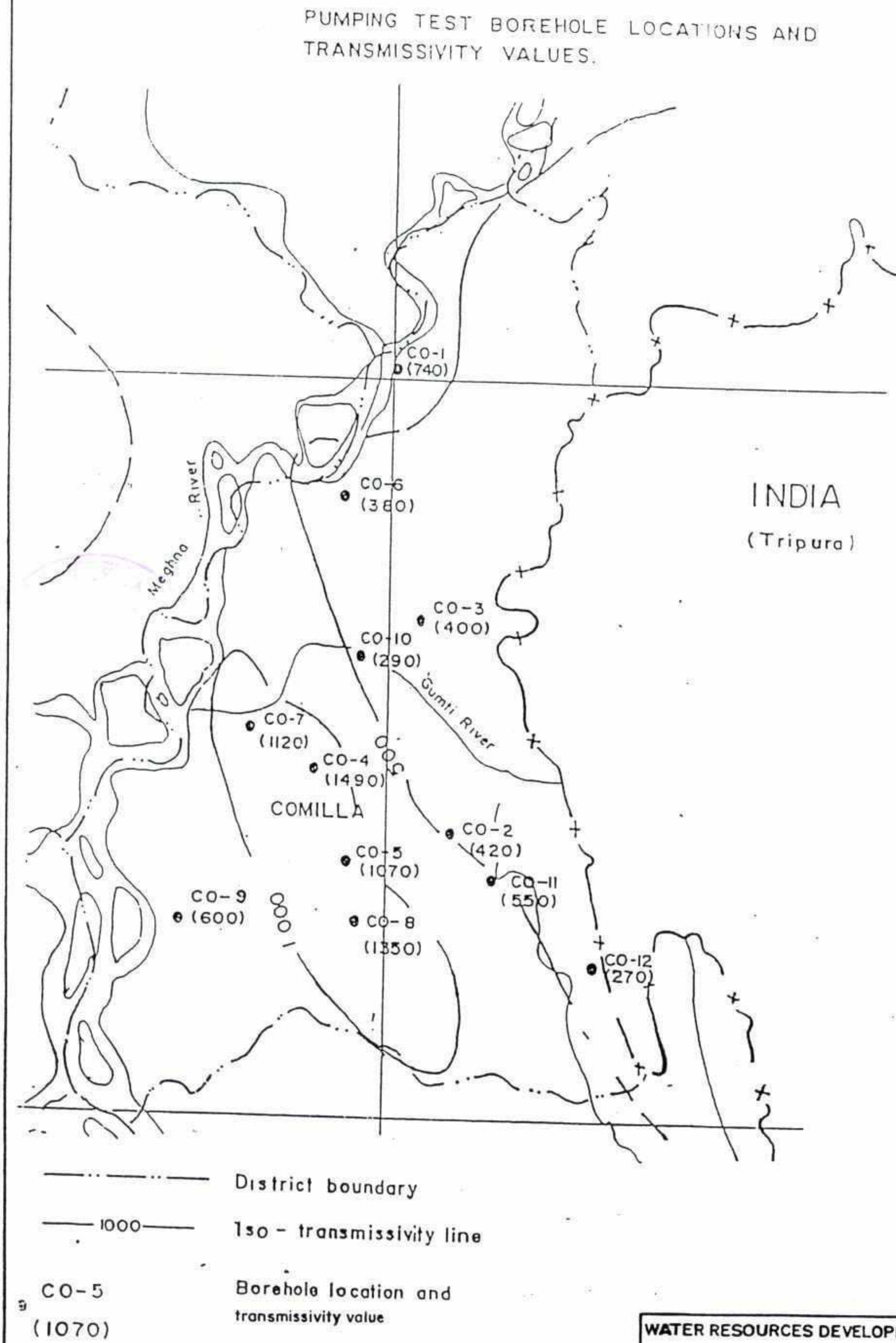

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TABLE V.2.3

Transmissivity and Storage Co-efficient Values
from pump test data for the Comilla Region

Well Description Nr	Thana	1) Transmissivity (m²/day)	2) Storage Co-efficient	Specific Yield
C0-1	Brahmanbaria	700	3.2×10^{-3}	0.014
C0-2	Comilla	628	2.2×10^{-3}	0.06
C0-3	Burichang	570	1.3×10^{-3}	0.04
C0-4	Chandina (N)	1 790	9.5×10^{-4}	0.007
C0-5	Chandina (S)	1 242	4.1×10^{-4}	0.03
C0-6	Nabinagar	462	9.1×10^{-4}	0.006
C0-7	Daudkandi	1 200	3.3×10^{-4}	0.007
C0-8	Hajiganj	1 625	3.9×10^{-4}	0.004
C0-9	Chandpur	795	1.4×10^{-3}	0.07
C0-10	Debidwar	333 ✓	1.6×10^{-3}	0.07
C0-11	Laksham	656	6.0×10^{-4}	0.03
C0-12	Chauddagram	328 ✓	2.2×10^{-3}	0.10

Date Source: UNDTCD/GWS, 1981

Note: 1) Average calculated values obtained from Walton, Hantush, Theis and De Glee methods.

2) Average of several values.

TABLE V.2.4

Hydraulic Properties of the Upper Clay and Main Aquifer Materials in the Study Area

South East Regional study Area

Thana Code	Thana Name	Upper Clay Thickness (m) MPO (#)	Upper Clay Thickness (m) IDA/DTW ($)	Upper Clay Permeability (m/d) MPO	Aquifer Transmissivity (m2/d) MPO	Aquifer Transmissivity (m2/d) IDA/DTW	Thana Average Specific Yield 0-5 m MPO	0-5 m IDA/DTW	5-10 m MPO	5-10 m IDA	10-15 m MPO	10-15 m IDA
302	Madhabpur	15		0.04	850		0.027		0.033		0.038	
362	Nasirnagar	20		0.10	800		0.034		0.031		0.021	
437	Sarail	10	8	0.10	1000	891	0.033	0.028	0.039	0.042	0.061	0.055
87	Brahmanbaria	24	14	0.10	600	1023	0.023	0.024	0.042	0.038	0.057	0.044
14	Ashuganj	15		0.10	650		0.020		0.020		0.035	
42	Bancharampur	9	3	0.10	1000	777	0.043	0.055	0.038	0.070	0.049	0.080
345	Nabinagar	21	8	0.10	750	1000	0.022	0.028	0.023	0.042	0.027	0.055
249	Kasba	20	11	0.10	1000	845	0.036	0.025	0.039	0.042	0.027	0.050
6	Akhaura	5		0.10	1000		0.068		0.068		0.068	
204	Homna	18		0.10	900		0.037		0.037		0.029	
343	Muradnagar	15	8	0.10	1000	835	0.020	0.029	0.029	0.047	0.034	0.056
88	Brahmanpara	15	17	0.10	800	766	0.060	0.025	0.055	0.034	0.021	0.040
125	Dakatia	25	11	0.05	800	962	0.022	0.029	0.031	0.038	0.370	0.045
130	Debidwar	15	8	0.10	900	706	0.028	0.034	0.035	0.046	0.045	0.052
90	Burichang	20		0.05	1000		0.028	0.025	0.031	0.040	0.028	0.045
94	Chandina	10		0.10	1000		0.021		0.027	0.035		
53	Barura	21		0.05	750		0.028		0.039	0.046		
271	Kotwali	15		0.10	1000		0.039		0.035	0.026		
287	Laksham	21		0.10	700		0.023		0.035	0.039		
111	Chouddagram	33		0.10	700		0.020		0.020	0.038		
356	Nangolkot	12		0.10	750		0.027		0.048	0.058		
312	Matlab	22		0.10	550		0.037		0.031	0.025		
225	Kachua	25		0.05	600		0.028		0.033		0.028	
96	Chandpur	15		0.10	800		0.026		0.039		0.052	

TABLE V.2.4 (Contd)

South East Regional study Area

Thana Code	Thana Name	Upper Clay Thickness (m) MPO (#)	(m) IDA/DTW ($)	Upper Clay Permeability (m/d) MPO	Aquifer Transmissivity (m2/d) MPO	IDA/DTW	Average Specific Yield 0-5 m MPO	0-5 m IDA/DTW	5-10 m MPO	5-10 m IDA	10-15 m MPO	10-15 m IDA
195	Hajiganj	18		0.05	600		0.020		0.028		0.056	
447	Shahrasti	12		0.10	600		0.024		0.031		0.059	
155	Faridganj	20		0.10	600		0.024		0.022		0.029	
194	Haimchar	15		0.10	700		0.025		0.043		0.057	
411	Ramganj	24		0.05	550		0.023		0.024		0.026	
405	Raipur	25		0.10	700		0.029		0.021		0.026	
288	Lakshmipur	18		0.05	550		0.020		0.027		0.020	
413	Ramgati	30		0.05	500		0.020		0.020		0.048	
102	Chatkhil	42		0.05	650		0.020		0.020		0.020	
58	Begumganj	60		0.05	600		0.020		0.020		0.040	
445	Senbag	30		0.05	750		0.020		0.020		0.040	
459	Sudharam	25		0.05	500		0.020		0.020		0.038	
116	Companiganj	25		0.05	500		0.063		0.051		0.020	
120	Daganbhuiyan	21		0.10	650		0.020		0.020		0.045	
465	Sonagazi	18		0.05	800		0.020		0.034		0.038	
161	Feni	15		0.10	600		0.023		0.029		0.047	
104	Chhagalnaiya	25		0.05	500		0.020		0.022		0.046	
166	Fulgazi	15		0.05	550		0.023		0.041		0.023	
388	Parsuram	15		0.05	800		0.021		0.027		0.053	

Transmissivity refers to mean screen section transmissivity for DTW

 # MPO, 1986 & 1991
$ IDA/DTW II, 1991

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TABLE V.2.5

Unionwise Permeability Values of the Main Aquifer for selected thanas in the study area
(Data Source: IDA/DTWII, 1991)

District	Thana	Union	Thana Average (m/day)	Union Average] (m/day)
Brahmanbaria	Sarail	Chunda	25	21
		Noagaon		36
		Shahjadpur		25
		Shabajpur		23
		Sarail		28
		Paniswa		19
	Brahmanbaria	Badhanti	31	40
		Chandura		27
		Hopur		32
		Singarbil		18
		Paltan		24
		Bashudeb		33
		Machhihola		34
		Brahmanbaria		40
	Nabinagar	Sreerampur	35	33
		Shyamgaon		33
		Rasilabad		30
		Bitghar		47
		Kallolla		32
	Kasba	Monlanda	25	31
		Mirgram		27
		Bodair		18
Comilla	Brahmanpara	Madhabpur	25	22
		Chandla		24
		Baramanpara		21
		Shahedabad		24
		Brahmanpara		24
		Shaplador		35

TABLE V.2.5 (Contd)

District	Thana	Union	Thana Average (m/day)	Union Average (m/day)
	Muradnagar	Akabpur	27	31
		Bangora		28
		Purbadhoir		32
		Sreekail		20
		Chapitala		23
		Nabipur		23
		Dhamghar		33
	Debidwar	Barashalghar	22	20
		Gunaighar (N)		22
		Gunaighar (S)		23
		Rajmehar (N)		19
		Rajmehar (S)		24
		Dhamti		23
	Daudkandi	Jogalipur	31	28
		Balarampur		32
		Nazidpur		35
		Gouripur		28
		Sundulpur		30
		Mohammadpur		32
		Maruka		24
		Pachgosla		30
		Daudkandi		36

Note: Permeability, K, calculated using, $K = \frac{\text{Logan T}}{\text{Screen Length}}$

TABLE V.2.6

Surface silty Clay and Aquifer Facies
Data for the study Area
(Data Sources : MPO, 1987)

District	Thanas	Nr of bore-logs analysed for computation	Mean Silty Clay Thickness		Sand	Maximum Silty Clay Thickness		Sand	Depth to main Aquifer		Tl M
			F	(m)	P.C	F	(m)	P.C	F	(m)	
Comilla	Brahmanpara	10	30	(9)	31	90	(27)	52	100	(30)	2(
	Kasba	38	80	(24)	36	180	(55)	39	180	(55)	18
	Akhaura	1	0		100	0		100	Unknown	Unknown	
	Brahmanbaria	42	70	(21)	41	180	(55)	58	160	(48)	2(
	Chandpur	15	20	(6)	31	250	(76)	64	260	(79)	11
	Chouddyagram	75	120	(36)	37	140	(42)	43	160	(49)	14
	Haziganj	4	40	(12)	40	80	(24)	60	160	(49)	13
	Matlab	2	20	(6)	60	20	(6)	60	Unknown	Unknown	
	Laksham	81	50	(15)	33	110	(33)	59	140	(42)	16
	Kotwali	162	50	(15)	27	150	(46)	4	100	(30)	36
	Nangolkot	5	20	(6)	28	140	(42)	73	160	(48)	14
	Muradnagar	9	60	(18)	33	80	(24)	43	100	(30)	17
	Barura	56	10	(3)	20	140	(42)	66	140	(42)	20
	Burichang	57	70	(21)	34	120	(36)	50	150	(45)	18
	Daudkandi	19	120	(36)	40	180	(55)	49	210	(64)	16
	Kachua	29	20	(6)	33	170	(51)	65	200	(61)	15
	Nasirnagar	5	70	(21)	25	100	(30)	41	120	(36)	13
	Shahrasti	28	20	(6)	32	30	(9)	44	150	(45)	22
	Sarail	28	40	(12)	36	80	(24)	55	170	(51)	19

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TABLE V.2.6 (Contd)

District	Thanas	Nr of bore-logs analysed for computation	Mean Silty Clay Thickness F	(m)	Sand P.C	Maximum Silty Clay Thickness F	(m)	Sand P.C	Depth to main Aquifer F	(m)	Thickness of M. Aquifer F	(m)
Comilla	Chandina	59	150	(45)	44	190	(58)	51	170	(51)	190	(58)
	Faridganj	Interpolative	30	(9)	20	30	(9)	20	Unknown		Unknown	
	Homna	Interpolative	30	(9)	25	30	(9)	25	Unknown		Unknown	
	Bancharampur	Interpolative	30	(9)	20	30	(9)	20	Unknown		Unknown	
	Nabinagar	1	50	(15)	20	50	(15)	20	290	(88)	110	(33)
	Haimchar	Interpolative	10	(3)	20	10	(3)	20	Unknown		Unknown	
	Debidwar	62	50	(15)	35	170	(51)	71	150	(45)	180	(54)

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The transmissivity of the main aquifer ranges from 300 to as high as 1790 m^2/day (Tables V.2.3 and V.2.4). As can be seen in Figure V.2.8, high values of transmissivity occur within the central part of the area, in a strip extending from the present Meghna river valley at Daudkandi on the north-west to the south-west part of the Comilla district. This trend seems to extend to south-east in the Noakhali district. The northeastern region of the area exhibits the lowest transmissivity values where it is approximately 298 m^2/day.

Values of storage co-efficients, computed from records of pump test data (Table V.2.3), range from 9.5×10^{-4} to 4.1×10^{-3}. Comparison of transmissivity versus storage co-efficient values indicates that the lowest values of storage co-efficients have been found in almost the same area where the transmissivity is the highest.

The permeability of the upper clay, as determined by MPO (1990) (Table V.2.4), ranges from 0.04 to 0.10 m/d while the permeability of the main aquifer determined by the IDA/DTWII (1991) (Table V.2.5) for selected thanas in the Comilla and Brahmanbaria district ranges from 22 to 35 m/day.

The average specific yield of the upper clay materials within the depth range of 0 - 15 m varies from 2% to about 8% (Table V.2.4).

V.2.3 Groundwater Occurrence

Groundwater in the area occurs in all hydrogeological units, all of which are in hydraulic continuity. A high degree of continuity exists in the groundwater reservoir system which probably functions as a semi-confining storage system. It is likely that the clay aquitard separating the upper aquifer from the lower would be either confining or semi-confining layer.

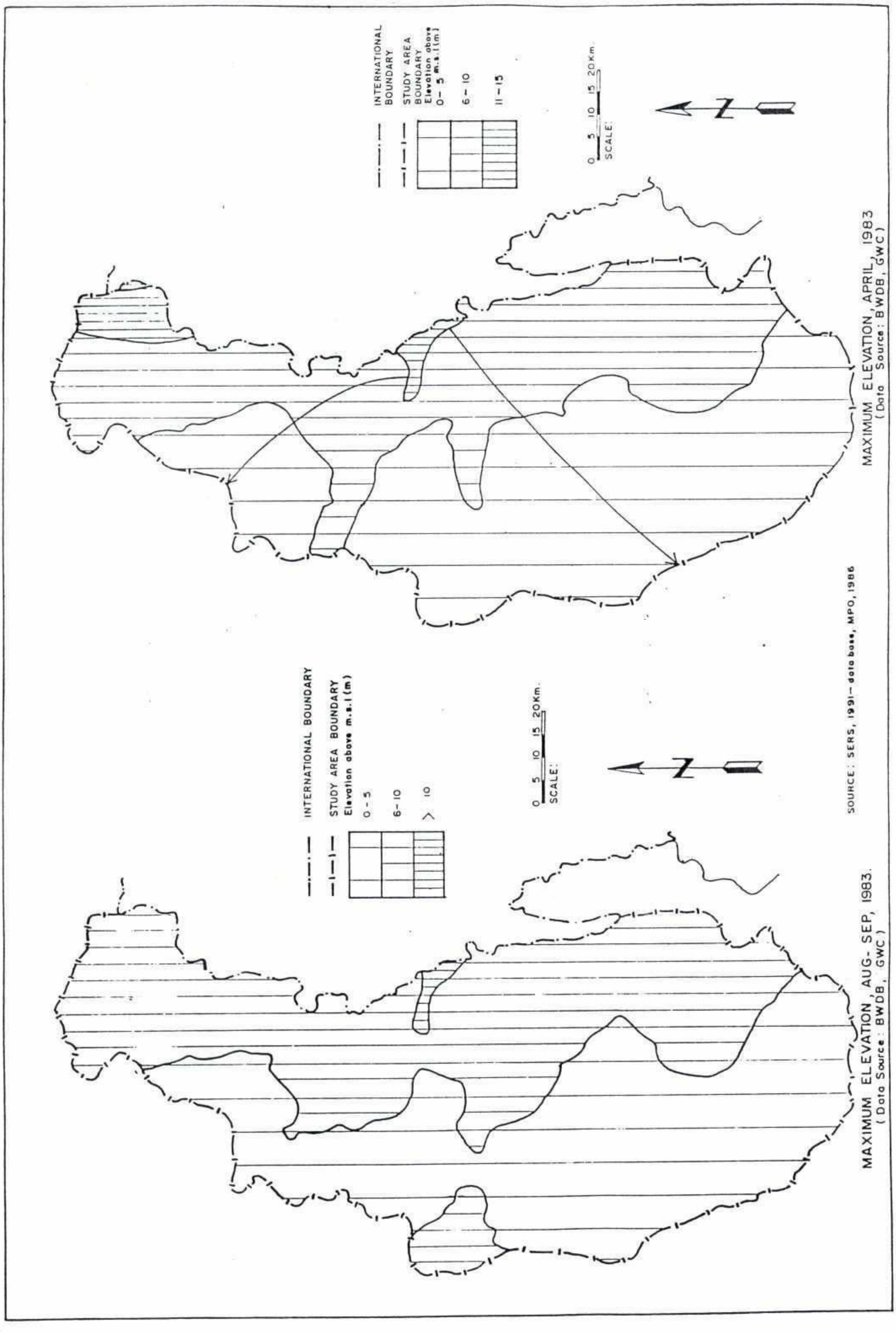
Groundwater occurs in the area at shallow depth, except in the eastern piedmont area of the Tripura hills, and ground water levels are at or near ground levels during the period August-September and lowest in April-May. The lowest ground water levels range from less than 3 m below the surface in the west to more than 6.5 m in the east (MPO, 1987). Studies (UNDTCD/UNDP, 1982); MPO, 1987 and Gumti Phase II, 1990) show that the water table, and piezometric surface where present, rise in response to recharge during May and generally reach their highest level in late July. Groundwater levels are semi-constant between July and October indicating equilibrium with surface water levels and fully recharged aquifers. Groundwater levels fall from October in response to the rapid drainage of surface water and changes in base levels. The rate of decline is highest in October-November but with the onset of irrigation after January (resulting in the abstraction of groundwater) large changes occur locally.

From studies carried out elsewhere in Bangladesh, groundwater movement is found to be mainly vertical, upward in response to capillarity in the dry season and downward in response to vertical infiltration in the wet season. Lateral transfer of groundwater is a much smaller component of flow because of the low hydraulic gradient.

The regional groundwater flow in the main aquifer is generally towards the main river and the Bay of Bengal. The main direction of groundwater flow, as can be seen in Figures V.2.9 and V.2.10 is generally westward - south-west to the Meghna estuary, west and north-west to the Meghna River. The Gumti Phase II study (1990), using dry season water levels for April 1987 (Figure V.2.10) shows a widespread depression in the water table in Burichang and Kashba thanas illustrating a relationship between surface and groundwater and implying flow away from the rivers towards the centre of the depression.

Figure V.2.9

Potentiometric Surface in the Study Area



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V.2.4 Summary of Hydrogeological Findings

In nearly all of the project area the aquifer system is composed of a main aquifer of variable thickness overlain by a semi-confining layer also of variable thickness. The aquifer is composed of fine to medium/coarse sand with the finer materials predominating in the upper section. The thickness of the aquifer is not generally defined from the borelogs but is in the range of 20 m to over 60 m according to the MPO (1987). The water transmitting properties of the aquifer may be classed as moderate to good for most of the area with aquifer transmitivities generally ranging from 500 to 1000 m^2/day. The permeability of the aquifer materials is also high.

The semi-confining layer, with permeabilities ranging from 0.05 to 0.10 m/day, is composed mainly of silty and clayey materials and ranges in thickness from less than 3 m to over 60 m. Thick surface clays predominantly occur in the southern part of the area.

Water levels both in the aquifer and the semi-confining layers are under natural recharge and discharge conditions, strongly controlled by the elevation of the ground surface. The lateral movement of ground water on a regional scale is nearly always of minor significance if compared with vertical and localized lateral movement.

CHAPTER V.3

HYDROCHEMISTRY

V.3.1 Groundwater Quality

The first comprehensive report on the groundwater quality of the study area is made available in the BWDB water supply paper 428 (1981) where water quality data from sampling stations and 13 boreholes in the greater Comilla district were analysed with a view to evaluating groundwater for agriculture and domestic use. Of the sampling stations (Figure V.3.1), five are shallow wells ranging in depth from 23 m to 45 m and two are deep wells with depth range from 107 m to 229 m. Among the 13 boreholes where water samples have been collected, twelve are from 86 m depth. The Survey and Investigation Division of the BADC started sampling and analyses of irrigation water in 1980.

Table V.3.1 presents the chemical analyses of the ground water samples collected during the dry season of 1976-1979 by the groundwater circle of the BWDB while Table V.3.2 shows the results of partial chemical analyses of irrigation water sampled by the BADC in 1980. The data presented in tables serve to provide a general indication of the hydrochemical conditions in the study area. The groundwater quality in the greater Comilla district (Table V.3.1) according to the report, is generally suitable for domestic, agricultural and industrial purposes excepting few sampling stations and borehole sites in Daudkandi, Hajiganj and Chandpur thanas. The total dissolved solid content and consequently salinity expressed in electrical conductivity in water samples collected during 1976-1979 period for stations 85, 87 and 88 including borehole sample Nr 2Q are associated with high chloride levels indicationing localized concentration of saline groundwater. The presence of elevated occurrence of salinity is also indicated in Table V.3.2 for BADC irrigation water samples in Debidwar, Brahmanbaria and Hajiganj thanas.

The chemical analyses presented in Table V.3.3 show groundwater tapped from both composite and main aquifer has pH values ranging 7 to 10 indicating a strong trend in alkalinity. In eight of 35 analysed samples, iron concentration in the area ranged from 0.5 to 14.4 mg/l and is far above the Bangladesh standards. Generally, the shallow aquifer contains higher iron concentrations than the main aquifer. Extreme variation of these values even within the same well (station Nr 85Q and 87Q), however, leads to questions as to whether or not there were either sampling or analytical errors. The general high iron content is associated with the ferrugineous aquifer materials of the Quaternary sediments into which the water is tapped and iron is presumably mobilized in the groundwater due to low pH in-situ hydro-chemical conditions. Although in theory iron can have an adverse effect uper soil structure, as well as the nuisance caused by the precipitation of a sludge many tubewells producing water of high iron contents have been operating for 10 or more years in Bangladesh without significant detriment to agriculture.

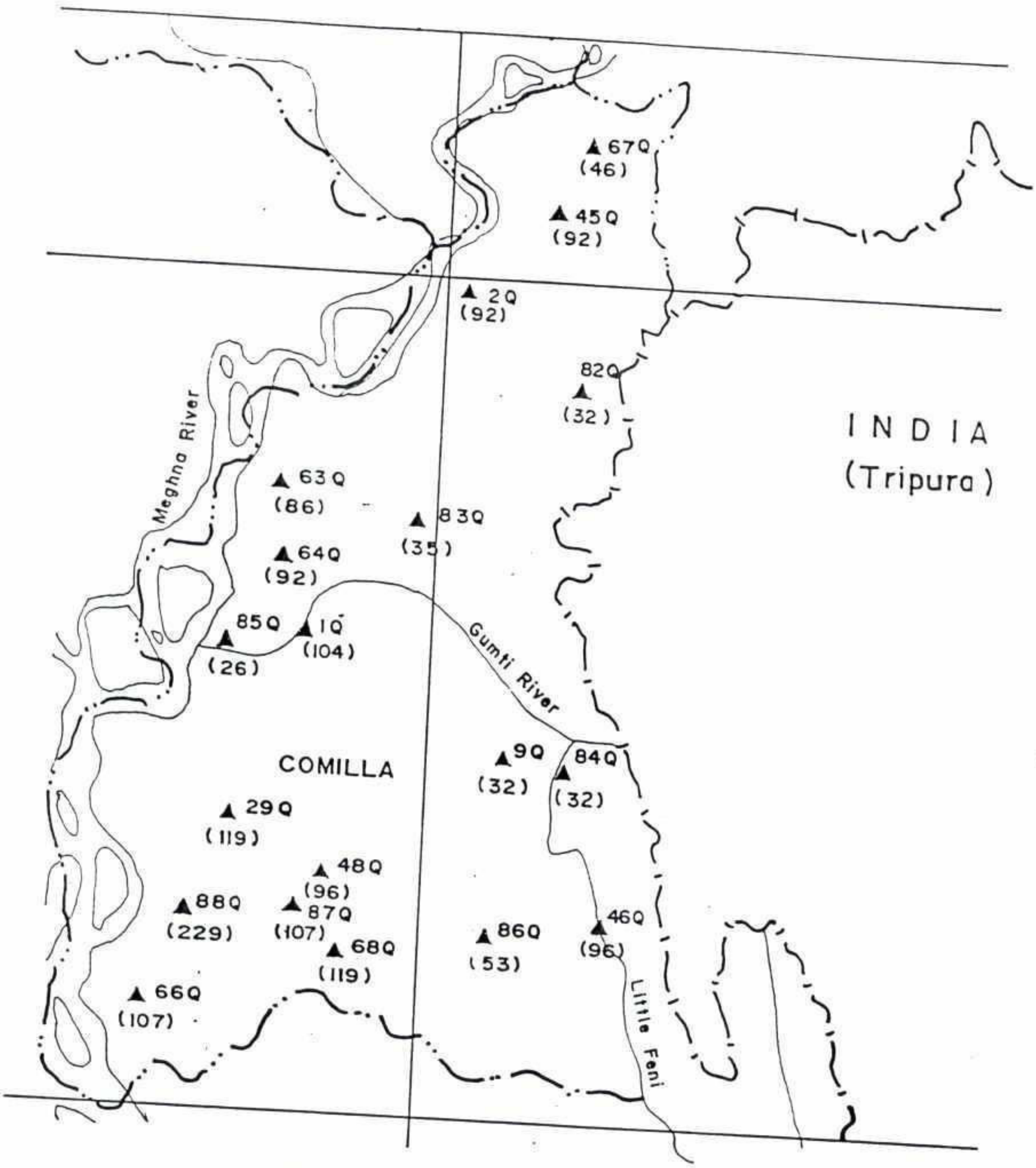
V.3.2 Occurrence of Saline Groundwater

V.3.2.1 Previous Surveys

The occurrence of saline groundwater has been indicated in few of the BADC irrigation wells and the BWDB groundwater quality stations (Tables V.3.1 and V.3.2) but it was not until 1985 when IDA/BADC DTW project (1987) in its progress report published the results of water quality surveys, the problem of saline groundwater occurrences in the former Comilla district drew the attention of policy makers. The NWP (1986) marked this anomalous groundwater salinity problem in the Comilla region as a constraint to estimating groundwater resource potential and to further irrigation development of groundwater.

Figure V.3.1

Water Quality Sampling Points - Greater Comilla District



LEGEND

▲87Q SAMPLING POINT SHOWN ON TABLE 3·1

(92) DEPTH OF THE SAMPLED WELL OR TEST HOLE IN METRE

Source: UNDTCD/GWS, 1981

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TABLE V.3.1

Results of Groundwater's Chemical Analysis within Comilla District
(Years 1976-1979)
Source : BWDB (1981)

Location of water sampling station	Date of Collection	Depth of the well	P-H Value	TDS (mg/l)	Est.EC (TDS x 1.43) /μs/cm	SiO2 (mg/l)	Ca^{2+} (mg/l)	Fe^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	Cl (mg/l)	SO_4^{2-} (mg/l)	CO_3^{2-} (mg/l)	HCO_3 (mg/l)	NO_3 (mg/l)	SAR (Sodium Adsorption Ratio)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Station No. 82Q	28.3.77	32	9.0	110.0	157	37.0	11.5	6.5	7.6	30.7	4.5	T	4.0	64.0	T	1.72
Vill. Akhaura	20.1.78	62	7.0	102.0	146	32.8	14.0	0.7	3.1	45.8	?	Nil	Nil	?	Nil	2.88
P.S. Akhaura																
Station No. 83Q	27.2.77	45	-	108.0	154	30.5	9.0	7.4	4.6	40.2	4.0	T	22.0	44.0	T	2.72
Vill. Muradnagar	30.1.78	45	7.0	280.8	400	31.8	9.5	3.4	18.3	73.2	22.5	Nil	Nil	212.0	11.0	3.20
P.S. Muradnagar	18.4.79	45	10.0	298.4	426	31.3	23.5	0.5	20.1	58.9	86.0	Nil	6.0	106.0	2.0	2.15
Station No. 84Q	19.3.76	32	7.9	174.0	246	41.0	13.0	1.0	8.0	27.0	5.0	N.T.	Nil	144.0	2.0	1.45
Comilla Town	12.1.77	32	9.0	147.0	210	19.5	11.0	0.3	7.6	23.2	7.0	Nil	2.0	78.0	0.5	1.32
	28.1.78	32	8.0	115.2	164	35.5	15.0	1.3	7.6	45.8	8.0	Nil	Nil	120.0	Nil	2.40
Station No. 85Q	6.3.76	32	8.1	437.0	624	32.0	54.0	0.1	31.0	48.0	52.0	T	Nil	334.0	N.T	1.29
Daudkandi Town	22.1.77	32	8.5	375.0	536	30.6	61.0	4.8	14.0	1.8	12.0	Nil	4.0	171.0	10.0	0.05
	26.2.78	25	9.5	650.0	929	21.0	55.0	0.2	34.8	157.3	188.3	T	37.8	320.0	12.0	4.09
	31.3.79	33	7.5	296.0	566	32.0	70.0	14.4	22.9	106.3	105.3	Nil	Nil	364.0	Nil	2.81
Station No. 86Q	21.3.76	22	7.8	194.0	277	26.0	12.0	0.9	19.0	22.0	7.0	N.T	Nil	176.0	N.T.	0.92
Laksham Town	18.2.77	22	-	157.0	225	20.0	20.0	2.1	14.0	15.3	8.5	Nil	Nil	115.0	1.5	0.64
	27.1.78	22	7.0	180.4	257	19.0	12.5	Nil	19.8	39.5	10.0	Nil	Nil	187.0	1.0	1.62
Station No. 87Q	11.2.77	106	9.0	175.0	250	29.5	23.5	0.4	12.8	14.4	Nil	17.0	8.0	104.0	3.0	0.59
Hajiganj Town	28.1.78	106	7.0	173.6	247	24.3	23.0	6.1	15.3	37.9	17.0	Nil	Nil	169.0	Nil	1.51
	15.4.79	106	10.0	519.2	742	32.3	7.5	0.2	10.4	211.7	127.5	Nil	28.0	196.0	12.0	11.74
Station No. 88Q	11.1.77	228	9.5	252.0	360	46.0	35.5	3.2	17.7	92.9	135.0	Nil	3.0	82.0	0.5	3.18
Vill. Shalogher	29.1.78	228	8.0	428.0	612	32.2	44.0	3.9	17.4	89.7	130.0	Nil	Nil	11.0	T	2.90
P.S. Chandpur	14.4.79	228	9.5	553.2	790	22.0	61.5	3.9	41.5	92.4	76.0	Nil	18.0	430.0	12.0	2.23
Hole No. 45Q	14.3.77	92	8.35	297.0	426	30.0	26.4	0.7	29.2	18.7	34.0	2.5	6.0	109.8	-	0.60
Vill. Kalikacha																
P.S. Sarail																
Hole No. 46Q	28.4.77	92	8.45	641.0	917	53.0	22.4	0.3	39.4	120.6	17.4	2.5	12.0	134.0	-	3.55
Vill. Daulatganj																

TABLE V.3.1 (Contd)

Location of water sampling station	Date of Collection	Depth of the well	P-H Value	TDS (mg/l)	Est.EC (TDS x 1.43) /µs/cm	SiO2 (mg/l)	Ca^{2+} (mg/l)	Fe^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	Cl^{-} (mg/l)	SO_4^{2-} (mg/l)	CO_3^{2-} (mg/l)	HCO_3 (mg/l)	NO_3 (mg/l)	SAR (Sodium Adsorption Ratio)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Hole No. 48Q Kachua Bazar	9.4.77	92	8.65	402.0	575	41.0	24.0	0.2	47.1	37.0	28.4	5.0	24.0	145.4	-	1.01
Hole No.65Q Muradnagar Town	24.10.77	107	-	457.2	535	28.5	23.0	Nil	48.2	114.8	47.5	Nil	Nil	415.0	-	3.12
Hole No. 1Q Vill. Couripur P.S. Couripur	12.1.79	104	8.0	227.2	396	25.3	25.5	4.5	11.3	80.1	67.5	Nil	Nil	180.0	10.0	3.32
Hole No. 2Q Vill.& P.S. Sadekpur	11.2.78	93	7.5	632.4	903	30.0	12.5	5.0	6.7	207.6	217.0	25.1	Nil	157.0	T	11.78
Hole No. 9Q Vill. Saktola P.S. Kotwali	28.3.79	32	9.0	150.8	216	31.8	12.5	9.5	10.7	47.3	11.0	Nil	Nil	134.0	T	2.37
Hole No. 29Q Matlab Town	16.5.78 2.5.78	52 119	9.0 10.0	80.4 312.4	114 446	5.4 21.5	10.0 62.5	9.0 2.5	0.6 18.6	21.2 33.8	16.0 15.5	5.0 T	- -	- -	2.0 3.5	2.76 0.96
Hole No. 63Q Bancharampur	6.11.77	86	9.0	287.2	410	26.2	48.5	8.0	17.1	37.6	23.0	Nil	32.0	176.0	2.5	1.18
Hole No. 64Q Homna	16.11.77	92	8.5	162.8	232	20.8	23.0	2.7	8.2	32.5	13.0	Nil	Nil	135.0	Nil	1.48
Hole No. 66Q Vill. Mahamaya P.S. Chandpur	12.5.79	107	10.0	775.6	1110	34.0	37.0	7.8	51.2	153.2	347.0	Nil	?	100.0	0.2	3.83
Hole No. 67Q Vill. Kunda P.S. Nasirnagar	5.6.79	46	10.0	403.6	576	35.5	26.0	2.1	40.0	105.4	98.0	Nil	46.0	155.0	10.0	3.03
Hole No. 86Q Vill Nawara,P.S.Hajiganj	9.4.79	119	10.0	311.6	446	37.3	24.0	3.8	10.7	94.4	79.0	Nil	10.0	146.0	Nil	4.03

TABLE V.3.2

Results of Groundwater Chemical Analysis of Irrigation Water Samples Collected in 1980 (Survey and Investigation Division, BADC)

District	Thana	No.	Union	JL	Plot	Type	Depth (m)	Total Hardness (mg/l)	TDS (mg/l)	Est.EC (1.43xTDS (/μs/cm)	Chemical Constitments (expressed in (mg/l) Chloride	Bicarbo-nate	Iron	Sulphate
Comilla	Barura	37	Shilmuri (N)	327	268	DTW	72	121	224	320	10.0	168	5.4	0
Comilla	Brahmanpara	37	Rajapur	65	1698	DTW	104	44	188	269	12.0	93	1.3	0
Comilla	Burichang	45	Burichang (E)	77	635	DTW	95	50	205	293	6.5	162	1.6	0
Comilla	Chandina	47	Chandina (E)	231	471	DTW	66	194	394	563	25.5	328	4.5	0
Comilla	Chauddagram	12	Golpaha	71	246	DTW	80	46	159	227	5.0	76	0.5	0
Comilla	Daudkandi	1	Gouripur	255	661	DTW	104	110	317	453	61.0	163	6.5	0
Comilla	Debidwar	36	Debidwar	197	99	DTW	122	259	702	1004*	278.0	87	0.7	0
Comilla	Homna		Bhasania	102	1436	DTW	21	128	380	543	30.0	248	2.1	0
Comilla	Laksham	98	Bornaliuna	76	374	DTW	104	67	175	250	8.5	125	0.5	0
Comilla	Muradnagar		Muradnagar	15	1465	DTW	24	305	451	645	51.0	252	20.8	0
Brahmanbaria	Brahmanbaria	BB-11	Municipality					131	215	307	23.0	146	7.4	0
Brahmanbaria	Kasba	BK-4	Kasba					16	229	327	18.0	164	1.1	0
Brahmanbaria	Nabinagar	BNP-9	Sadekpur (E)					154	357	511	28.0	217	6.1	0
Brahmanbaria	Nasirnagar	BS-1	Chapartola					69	154	220	7.0	92	6.8	0
Brahmanbaria	Sarail	BS-25	Sarail					177	825	1180*	354.0	86	12.1	0
Chandpur	Chandpur	5	Ashikati	35	523	DTW	116	198	345	493	44.0	139	0.1	0
Chandpur	Faridganj	5	Balithoba (W)	79	1443	DTW	27	204	373	533	26.0	195	1.2	0
Chandpur	Hajiganj	11	Mehera (S)	371	303	DTW	73	153	678	970*	266.0	114	4.6	0
Chandpur	Hajiganj	16	Hatila	221	147	DTW	110	198	1050	1502*	448.0	151	11.5	0
Chandpur	Kasba	26	Ashakpur	332	37	DTW	116	130	312	446	92.0	116	5.0	0

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TABLE V.3.3

Water Quality of Selected Water Quality Stations, Borehole Locations and Irrigation Wells in the Study Area

District	Thana	Location	Aquifer	Depth (m)	Year of Sampling	TDS (mg/1)	Est.EC in µs/cm (TDSx1.43)	pH	Fe (mg/1)	SAR (Sodium adsorption ratio)	Remarks
Comilla	Daudkandi	St.No. 85Q	Shallow (Composite)	32	19.3.76	437	624	8.1	0.05	1.29	Shows tendency towards salinisation; pH indicates trends towards alkalinisation. Iron content variable within the same well over time.
		do	do	32	12.1.77	375	536	8.5	4.85	0.05	
		do	do	25	26.2.78	650	929	9.5	0.20	4.09	
		do	do	33	31.3.79	396	566	7.5	14.40	2.81	
Chandpur	Hajiganj	St.No. 87Q Hajiganj Town	Main	106	11.2.77	175	250	9.0	0.40	0.59	Ground water shows tendency towards increased salinisation over time; high alkalinity and high iron content. Increased SAR doubtfull.
			do	106	28.1.78	174	248	7.0	6.10	1.51	
			do	106	15.4.79	519	742	10.0	0.20	11.74	
Chandpur	Chandpur	St.No. 88Q	do	228	11.1.77	252	360	9.5	3.24	3.80	High iron content; tendency towards salinisation; high alkalinity.
			do	228	29.1.78	428	612	8.0	3.90	2.90	
		Hole no. 2Q Sadeqpur	do	228	14.4.79	553	790	9.5	0.65	2.20	--
			do	93	11.2.78	632	903	7.5	5.00	11.78	High iron content, shows tendency towards salinisation
Comilla	Debidwar	BADC DTW-36	do	122	1980	702	1004	-	0.70	-	High Salinity.
Brahman-baria	Sarail	BADC BS-25	do	-	1980	825	1180	-	12.10	-	Very high iron contents, increased salinisation.
Chandpur	Hajiganj	BADC DTW-11	Shallow	73	1980	678	970	4.6	-	-	Increased salinisation.
Chandpur	Hajiganj	BADC DTW-16	Main	110	1980	1050	1502	11.5	-	-	Increased salinisation.

Source: UNDTCD/GWS, 1981

The general quality survey of groundwater studied and documented during the IDA DTW Phase I, and reported in the Phase I completion report in 1985 revealed a deterioration of groundwater quality with electrolytic conductivity (Ec) exceeding 1000 μs/cm over large parts of the southern portion of greater Comilla district and small, relatively isolated patches of poor quality water in the northern sector (Figure V.3.2). Actual sample sites and EC variations are shown in the accompanying map where distribution of sample sites reflects actual distribution of deep and shallow tubewells. The Figure V.3.2 showing isolated patches with EC values above 750 μs/cm and reaching over 1500 μs/cm compares with a background value of 100 and 300 μs/cm. Some of the higher salinity values seem to be surrounded by fresh water.

Apart from measuring the electrolytic conductivity (EC) of water samples by portable water analysis kits, more comprehensive tests were undertaken at selected sites covering pH, alkalinity, chloride, calcium, hardness (total hardness), iron nitrate, phosphate and sulphate. Field EC values and results of the above analyses are presented in Appendix I.

The IDA DTW project during its Phase II study excluded, on the grounds of water quality, most of the thanas in the greater Comilla district from the project but continued ground water quality survey in four thanas - Daudkandi, Muradnagar, Debidwar and Brahmanpara - in the northern sector where water quality was found generally acceptable. During 1990, poor quality groundwater with EC exceeding 6000 μs/cm was encountered at a number of DTWs in three of the four thanas, viz, Muradnagar, Debidwar and Daudkandi, with the result that IDA DTW project authority had to suspend tubewells drilling in 12 unions of the above thanas pending investigations of groundwater quality (Table V.3.4).

TABLE V.3.4

List of the Thanas where further sinking of Deep Tubewells are proscribed by the BADC for Saline Groundwater problem

District	Thana	Union
Comilla	Muradnagar	Jatrapur
		Muradnagar
		Dhamghar
		Darora (E)
		Sree Kail
		Chapitora
	Debidwar	Gunaghar (South)
	Daudkandi	Maruka
		Mohammadpur
		Sundulpur (East)
		Balarampur (North)
		Jagathpur (North)

Source: IDA DTW II Project, BADC, December, 1990

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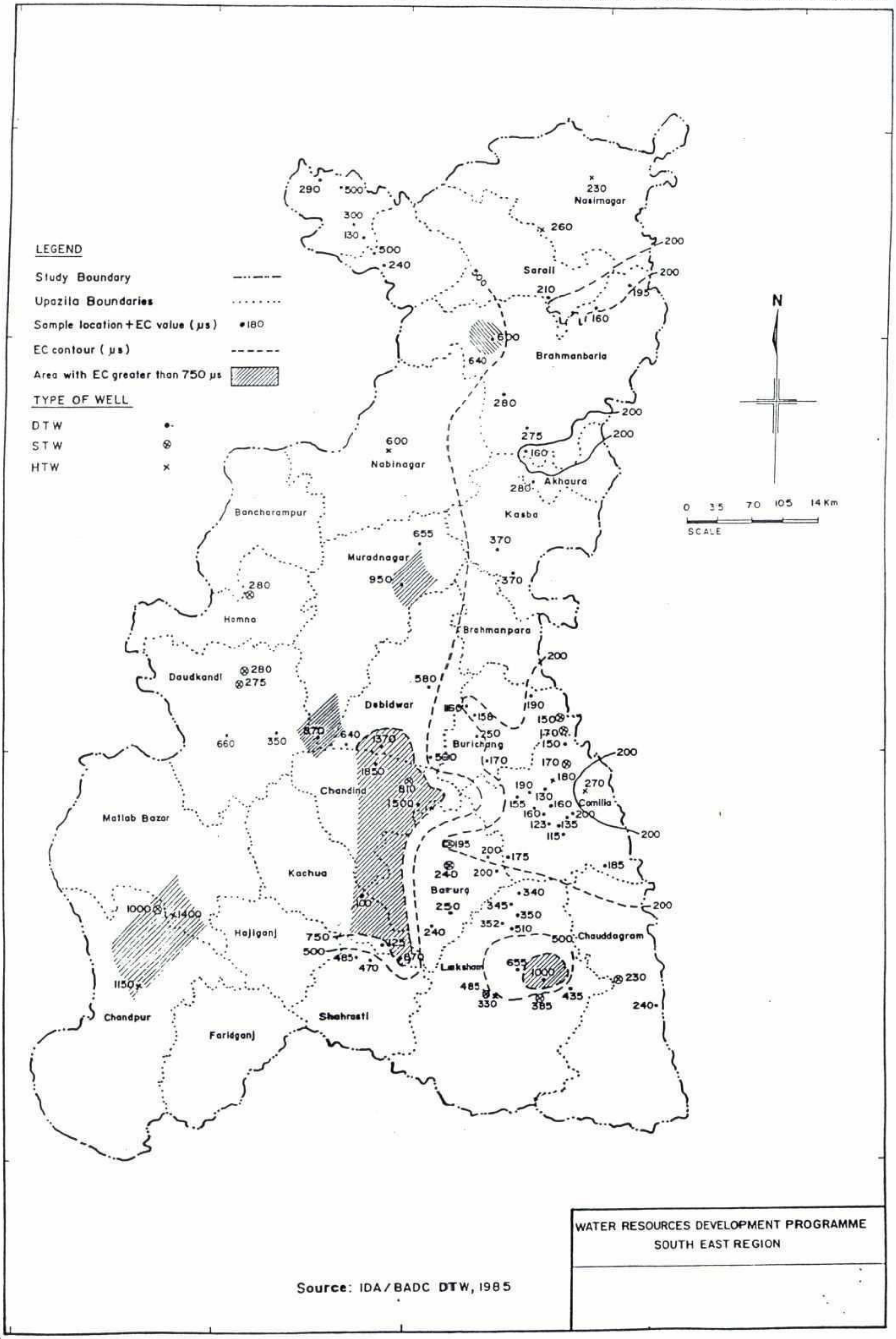
Figure V.3.2

EC Variations in the Greater Comilla District



Source: IDA/BADC DTW, 1985

V.3.2.2 Present Survey

Salinity surveys conducted by the IDA DTW project in 1985 and 1990-91 have indicated the occurrence of brackish groundwater which is not associated with saline intrusion as has been indicated in NWP (1987). The primary objectives of the present study on the saline groundwater problem are:

a) to identify the extent of occurrence of brackish water by analysis of the existing data and by collection of additional data from the field;

b) to sample wells surveyed in 1985 to see if significant changes have occurred;

c) to collect any other data of relevance to groundwater salinity;

d) to suggest modes of occurrence of the extensive salinised groundwater tract in the study area and

e) to make recommendations for further studies to be undertaken.

A seven day field survey was undertaken during the second week of May, 1991 to sample tubewells in selected thanas of the project area, viz. Chandina, Muradnagar, Chandpur, Matlab, Hajiganj and Laksham. EC variations and total dissolved solids (TDS) of groundwater samples from DTWs and HTWs at 25 sampling sites, of which seven sites were resurveyed, were measured with the help of a portable EC-meter. The water samples from the sampling tubewells were collected for complete chemical analyses.

The results of the salinity measurements expressed in μs/cm and total dissolved solid contents of the visited sites are presented in Table V.3.5 while Table V.3.6 shows the results of re-visited sites. Figure V.3.3 presents the EC variations collected during the survey along with the survey results conducted by the IDA DTW II project field survey personnel.

The iso-electrolytic conductivity contour map prepared from these EC variations (Figure V.3.4) presents a number of zonings as shown below:

Zone	EC variations (μs/cm)
Zone I	< 500
Zone II	500 - 750
Zone III	750 - 1000
Zone IV	1000 - 2000
Zone V	> 2000

Some of the major findings of 1990-91 IDA DTW II and 1991 SER field surveys are presented below:

a) The extent of salinized groundwater occurrence in the Comilla region is far more extensive than what was revealed during 1984/85 IDA/BADC DTW Phase I survey (compare Figures V.3.2 and V.3.4).

Figure V.3.3

EC Variations in the Greater Comilla District (1990 and 1991 Positions)

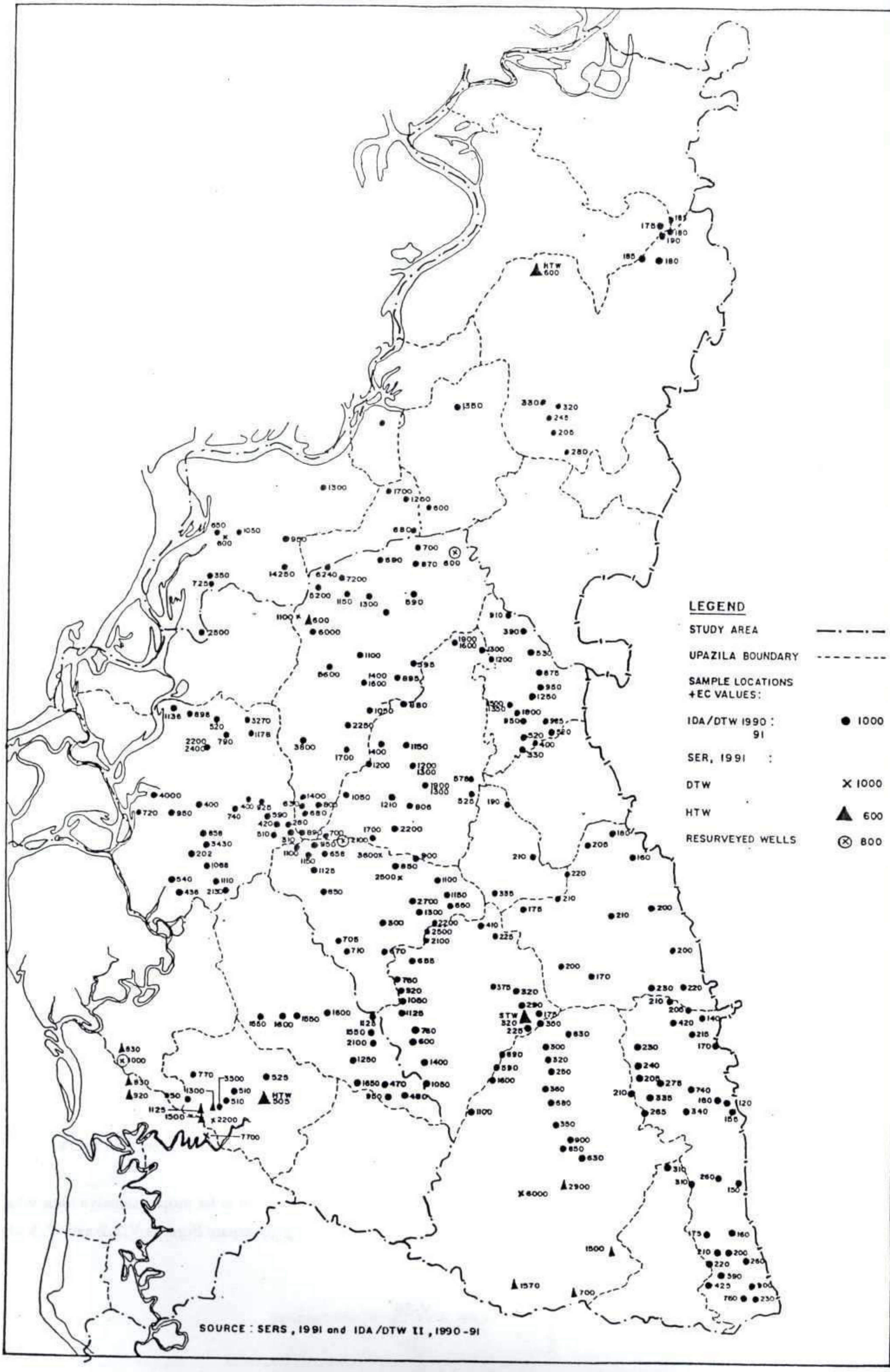


TABLE V.3.5

Variation of Groundwater Sample Surveyed during 1991 SER Field Survey

Sl Nr	Type of Tubewell	Well Nr	Water Sample Nr	Thana	Mouza	Union	JL Nr	Plot Nr	Date	Time	Temp.	EC		TDS		Remarks
													In	Out	In	Out
1	DTW	57	1	Chandina	East Sree Ram	Purba Chandina	239	471	13.5.91	2 p.m	30 C°	530	710	380	500	Resurvey
2	DTW	-	2	Chandina	Harong	Pashim Chandina	233	1934	13.5.91	3 p.m	30 C°	2500	2650	1800	2200	New Survey
3	DTW	91	3	Chandian	Keronkhal	4 Har Barera Union	47	1177	13.5.91	5 p.m	29 C°	2100	2500	1400	1700	Resurvey
4	DTW	39	4	Debidwar	Sultanpur	Dhamti	266	1009	13.5.91	6 p.m	29 C°	1700	2000	1200	1400	Resurvey
5	DTW	-	5	Chandina	Belashar	-	234	64	13.5.91	7 p.m	28 C°	3600	4100	2500	2900	New Survey
6	DTW	-	6	Muradnagar	Bakhrabad Gas Field	-	-	-	14.5.91	12 noon	30 C°	1100	1300	700	900	New Survey
7	HTW	-	7	Muradnagar	Bakhrabad Gas Field	-	-	-	14.5.91	12.15	30 C°	590	610	410	425	New Survey
8	HTW	-	8	Muradnagar	Bakhrabad Gas Field	-	-	-	14.5.91	12.30 p.m	29 C°	570	600	400	425	New Survey
9	DTW	-	10	Muradnagar	Bangora	Bangora	92	1463	15.5.91	4.30 p.m	29 C°	600	675	400	475	Resurvey
10	HTW	-	11	Chandpur	Roldia (S)	-	14	120	15.5.91	12.30 p.m	30 C°	830	950	590	660	New Survey
11	DTW	7	12	Chandpur	Raldia (S)	-	14	120	15.5.91	1.00 p.m	30 C°	920	1050	655	740	Resurvey
12	DTW	12	13	Chandina	Monihar	Rampura	61	260	15.5.91	3.30 p.m	29 C°	7700	8100	5400	5700	New Survey
13	DTW	-	14	Hajiganj	Ucagaga	Hajiganj	198	87/88	15.5.91	4.30 p.m	29 C°	2200	2375	1500	1650	Not yet commissioned
14	HTW	-	14A	Hajiganj	Ucahaga	Hajiganj	198	87/88	15.5.91	4.35 p.m	29 C°	3000	3125	2100	2200	New Survey
15	HTW	-	15	Hajiganj	Bakali bazar (S)	Rajargram	-	-	15.5.91	5 p.m	29 C°	1125	1230	800	825	New Survey
16	HTW	-	16	Hajiganj	Bakali-bazar (E)	Rajargram	-	-	15.5.91	5.10 p.m	29 C°	1300	1375	900	960	New Survey
17	HTW	-	17	Hajiganj	Bakali-bazar (Cent.)	Rajagram	-	-	15.4.91	5.20 p.m	29 C°	2500	2600	1700	1820	New Survey

Contd...

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TABLE V.3.5 (Contd)

Sl Nr	Type of Tubewell	Well Nr	Water Sample Nr	Thana	Mouza	Union	JL Nr	Plot Nr	Date	Time	Temp.	EC		TDS		Remarks
													In	Out	In	Out
18	HTW	-	18	Hajiganj	Sadar	BARD Office Complex	-	-	15.5.91	5.30 p.m	28 C°	575	600	400	420	New Survey
19	HTW	-	19	Matlab	Mubarakddi (Bazar)	-	162	-	15.5.91	7 p.m	28 C°	830	930	590	650	New Survey
20	HTW	-	20	Matlab	Mubarakddi (Bazar)	-	162	-	15.5.91	7.10 p.m	28 C°	1000	1100	700	770	New Survey
21	HTW	-	26	Chandpur	Baghadi	Baghadi	111	-	15.5.91	8 p.m	28 C°	1600	1800	1100	1200	Resurvey
22	HTW	-	21	Laksham	Thengarpar	Uttara	278	154	16.5.91	2 p.m	30 C°	1400	1625	970	1150	New Survey
23	HTW	-	22	Laksham	Thengarpar	Uttara	278	154	16.5.91	2.30 p.m	30 C°	2900	3300	2000	2300	New Survey
24	HTW	-	23	Laksham	Bhugui	Nather Petur	470	103	16.5.91	4.20 p.m	29 C°	1500	1800	1070	1300	New Survey
25	HTW	-	24	Laksham	Batachu (Bazar)	Nather Petur	459	2457	16.5.91	6 p.m	28 C°	1570	1800	1100	1250	New Survey
26	DTW	-	25	Chauddagram	South Sreepur	Gunabari	-	-	-	-	-	750	850	530	600	Test boring sample at 190-200 depth.

TABLE V.3.6
EC Variation in Resurveyed Wells, SER Study Area

District	Thana	Union	Type of Well	Well No.	Mauza	JL No.	Plot No.	Previous[1] Result (μs/cm)	Resurveyed[2] Result (μs/cm)	Remarks
Comilla	Debidwar	Dhamti	DTW	39	Sultanpur	266	1009	2550 (4.5.90)	1800 (13.5.91)	Salinity decreases
	Chandpur	Chandina (East)	DTW	57	East Sreemantpur	239	471	1300 (18.2.85)	650 (13,5,91)	Salinity decreases
	Chandina	Uttar Barera	DTW	91	Kerankhel	47	1172	1850 (29.12.84)	2100 (13.5.91)	Salinity increases
	Chandina	Chandina West	DTW	126	-	233	1934	-	2500 (13.5.91)	
	Chandina	Dhamti	DTW	39	Sultanpur	260	1009	2550 (4.5.90)	1770 (13.5.91)	Salinity decreases
	Chandina	Barera	DTW	-	Belar Char	234	64	1000 (25.12.90)	3600 (13.5.91)	Salinity increases
	Murad-nagar	Bangora	DTW	-	-	-	-	655 (12.2.85)	600 (14.5.91)	No change in salinity
Chandpur	Chandpur	Baghadi	HTW	-	Baghadi	14	-	1150 (4.3.85)	1600 (15.5.91)	Salinity increases
	Matlab	-	STW	-	Mobarakdi	162	-	1000 (4.3.85)	1000 * (15.5.91)	

Source: 1) IDA DTW Project II, 1986
2) SER Survey, 1991 [* The EC value for Matlab was increased from water sample collected from a HTW in the neighbourhood of the STW which was lifted].

ANNEX-V

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b) Low EC variations ranging from 100 to less than 500 (Zone I) indicating low chloride concentrations and hence fresh groundwater occur along an arcuate zone flanking the Tripura foothills from Nasirnagar thanas in the north to Chouddagram thana in the south. Two slightly salinised pockets in Chouddagram thana, one in north central and the other in extreme south, can be noticed.

c) An elongated north-south stretching belt (Zone II, wide in the north and narrow in the south), occupies the area immediately west of Zone I. The zone has an EC variation ranging from 500-750 μs/cm and contains a few isolated patches, of saline groundwater.

d) The rest of the area, west of Zone II, comprises a generally higher saline groundwater zone, with EC variations ranging from 750 to over 6 000 μs/cm. Areas of highly salinised groundwater (EC value over 2 000 and upto 10 000 μs/cm) are found particularly in Muradnagar, Bancharampur, Chandina, Debidwar, Chandpur and Laksham thanas in a background EC values of 1000 and 2000 μs/cm.

e) The areas marked with note of interrogation in parts of Matlab, Hajiganj, Machua, Nabinagar and Sarail thanas represent lack of data control and zonation numbers indicated may change considerably after the availability of more data.

f) It is misleading to interpret that the extent of the occurrence of saline groundwater has considerably increased in 1991 (see Figure V.3.4) in comparison 1984-85 survey map (Figure V.3.2) because of the increased with the abstraction of groundwater by increased number of DTWs and STWs (Tables V.3.7A and V.3.7B). The reason for such extensive occurrence is just because that more sites of irrigation tubewells were surveyed in 1990-91 than those of 1984-85.

TABLE V.3.7A

District-wise Distribution of STWs and DTWs in operation, SER Study Area

District	STWs 1984/1985 [1]	STWs 1989/1990 [1]	STWs 1990/1991 [2]		DTWs 1984/1985 [3]	DTWs 1989/1990 [3]	DTWs 1990/1991 [2]	
Brahmanbaria	1 151	2 718	2 847	(106)	393	420	450	(101)
Chandpur	64	210	213	(23)	50	138	187	(30)
Comilla	3 506	4 371	4 024	(419)	1 003	1 514	1 394	(286)
Feni	483	284	162	(19)	79	113	74	(24)
Lakshmipur	4	18	22	(1)	0	2	24	(2)
Begumganj	187	318	149	(50)	13	38	31	(14)
Habiganj	75	64	126	(16)	37	53	35	(22)
	5 470	7 983 (46%)	7 537 (138%)	(634)	1 575	2 278 (145%)	2 175 (138%)	(479)

1) **MPO, 1986**
2) **AST (CIDA), June 1991**
3) **BADC, 1990**

Note: **Figures in parenthesis, with %, indicate P.C. increase from 1984/85, and without %, indicate Nr of wells not operating.**

TABLE V.3.7B

Thana Distribution of STW's and DTW's (Operating)

	Thanas	1) STW 1984-85	1) 89-90	2) 1990/91	DTW 3) 84/95	3) 89/90	2) 1990/91
1.	Akhaura	24	159	156 (6)	10	13	23 (1)
2.	Bancharampur	21	475	411 (6)	-	-	13 (2)
3.	Brahmanbaria	498	697	956 (38)	158	169	187 (20
4.	Kasba	342	413	401 (17)	107	103	92 (30
5.	Nabinagar	27	210	123 (11)	19	19	34 (13
6.	Nasirnagar	76	413	516 (12)	22	24	11 (13
7.	Sarail	163	351	284 (14)	77	92	92 (22
8.	Chandpur	8	5	22 (0)	9	11	16 (0)
9.	Faridganj	5	0	9 (0)	-	-	-
10.	Haimchar	1	0	0 (0)	-	-	-
11.	Hajiganj	8	3	14 (4)	2	2	12 (0)
12.	Kachua	15	17	8 (2)	15	73	88 (21
13.	Matlab	18	182	158 (17)	-	2	6 (0)
14.	Shahrasti	9	3	2 (0)	24	50	65 (9)
15.	Barua	509	682	651 (66)	69	109	86 (36
16.	Brahmanpara	162	276	318 (19)	17	51	69 (7)
17.	Burichang	448	540	406 (59)	118	150	126 (20
18.	Chandina	165	217	256 (14)	81	142	134 (26
19.	Chauddagram	392	265	218 (35)	161	219	193 (5
20.	Daudkandi	101	218	196 (9)	34	76	84 (6
21.	Debidwar	345	352	393 (21)	61	85	82 (1
22.	Homna	43	378	407 (21)	-	-	1
23.	Comilla	717	646	410 (68)	273	361	300 (27
24.	Laksham	572	480	496 (85)	162	221	178 (60
25.	Muradnagar	28	152	106 (15)	10	48	62 (12)
26.	Nangalkot	24	165	167 (7)	17	52	69 (22)
27.	Chagalnaiya	64	15	-	-	-	-
28.	Daganbhuiya	7	19	24 (0)	24	16	13 (2)
29.	Feni	263	114	135 (19)	63	81	54 (22
30.	Fulgazi	104	-	-	-	-	-
31.	Parsuram	21	134	-	1	10	-
32.	Sonagazi	24	2	3	3	6	7
33.	Lakshmipur	2	17	18 (0)	-	2	14 (1)
34.	Raipur	0	1	-	-	-	-
35.	Ramganj	2	6	4 (1)	0	0	0 (1)
36.	Ramgati	0	0	0	0	0	0
37.	Begumganj	146	197	52 (42)	1	1	1 (1)
38.	Chatkhil	0	2	0 (0)	0	0	0 (3)
39.	Companyganj	1	1	0 (0)	0	0	0
40.	Shudharam	3	0	0 (0)	0	0	0
41.	Senbag	37	118	97 (8)	12	37	30 (10)
	Madhabpur (65) Habiganj	75	64	120 (16)	37	53	35 (22)

1) **MPO, 1986**
2) **AST (CIDA), June 1991**
3) **BADC, 1990**

Note: Figures in parenthesis indicate no. of wells not operating.

g) A fresh saline groundwater belt seems to extend from Barura thana through Kachua and then through the northern part of Matlab thana between the salinized zones of Chandpur - South Matlab and Daudkandi through a palaeo channel (Figure V.3.4). This assumption awaits verification pending further studies.

h) The fresh groundwater zone I (with EC less than 500 μs/cm) parallels the arcuate Lalmai deltaic plain and the fresh water seems to be recharged from outcropping Dupitilla and Tipam sandstone of the Tripura hills in the east. The extensive saline groundwater belt corresponds to the Chandina Deltaic Plain where the groundwater is tapped from the upper 100 - 125m semi-confined aquifer that underlies the Holocene estuarine deltaic sediments of the Chandina formation.

i) EC measurements during the present survey from seven resurveyed wells in Muradnagar, Chandina and Chandpur thanas could not establish whether groundwater quality is continuing to deteriorate or improve by reference to 1985 observations (Table V.3.6) as salinity of groundwater tends to decrease or remains the same.

V.3.3 Chemical Analyses

Most natural waters contain few dissolved inorganic constituents in cations and anions in chemical equilibrium with one another. Ordinarily, the most abundant cation constituents are two alkalies (Ca and Mg) and (Na and K). In the geochemical classification of Piper (1942), alkaline cations (Na and K) are called primary constituents and the alkali earths cations (Ca and Mg) secondary constituents; the strong acid anions (SO_4, Cl and NO_3) as saline constituents and weak acids comprise CO_3 and HCO_3. Mutual balancing of these anions determines the chemical character of water. It ascribes primary salinity to a water to the extent that alkalies of water are balanced by strong acids and secondary alkalinity to the extent that alkaline earths (Ca & Mg) are balanced by weak acids. Further, it ascribes primary alkalinity to the extent that alkalies exceed strong acids and are balanced by weak acids and secondary salinity to the extent that alkaline earths exceeded weak acids and are balanced by strong acids.

To study origin, chemical character and quality of groundwater in the area 25 water samples were collected and sent to the Bangladesh Rice Research Institute (BRRI) for complete chemical analyses covering the determination of salinity (specific conduct), pH, SiO_2, Ca, Mg, Na, B, Bi-Carbonate (HCO_3), Chloride (Cl), Sulphate (SO_4), Nitriaite (NO3), Total Hardness (TH) and Total Dissolved Solids (TDS). In absence of the availability of these results at the time of the writing up of this report, presentation made here on the chemical analyses and their interpretation is based on secondary source of data.

Table V.3.8 presents the results of complete chemical analyses of seven well samples collected and analysed by the DTW II project of BADC (1991) from Daudkandi and Muradnagar thanas. The results are compared with the chemical analyses of groundwater samples collected from the area south of Calcutta as both the Chandina Deltaic plain, wherein lies the aquifer system of the project area, and the Calcutta have the similar geomorphic, sedimenttological and therefore geohydrological histories (Umitsu, 1985, 1989). The chemical composition of the groundwater of the region is compared with estuarine river water samples (Hiooghly river - samples collected during dry and wet season), normal sea-water, sea-water from areas around the St. Martin's Island and also the Miocene Pliocene formational water of the folded belt adjoining the Tripura Hills (Tables V.3.9 and V.3.10). Weight ratios of ions of various water sources - river, sea, groundwater collected both from the study area and from the Calcutta surface, formational water collected from Miocene gas bearing reservoir rocks - are also computed to interpret the origin of the water (Tables V.3.9 and V.3.10). Brief comments are also made on the suitability of groundwater tapped in the upper aquifer system in Muradnagar and Daudkandi thanas.

Figure V.3.4

ISO - Electrolytic Conductivity Contour Map of the Greater Comilla District

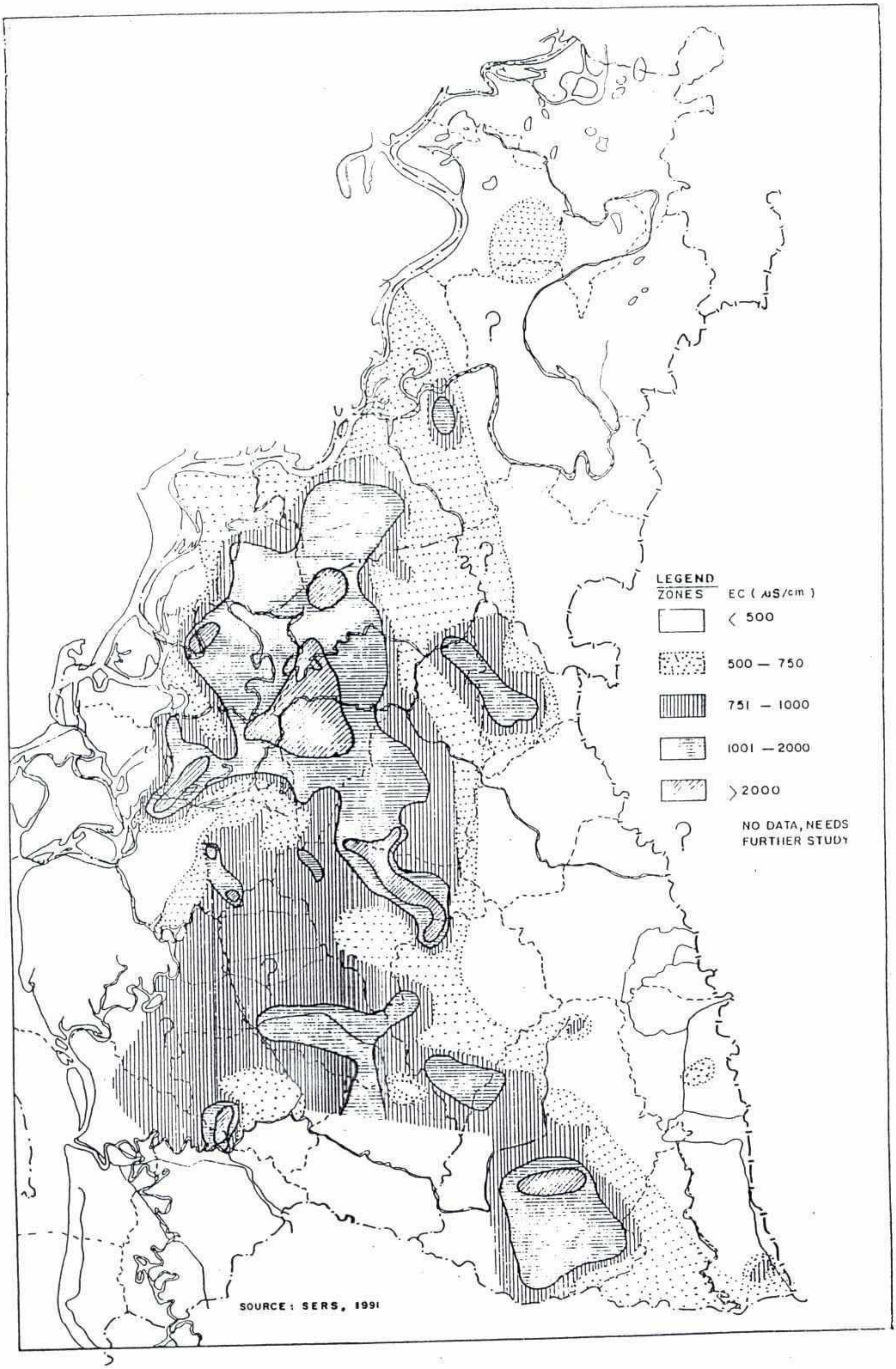

TABLE V.3.8

Comparison of Chemical Constituents of Saline Group Water Samples Extracted from Upper Shallow aquifer (90-150m) between the Calcutta Surface and Chandina Deltaic Plain (Tipperah Surface)

	Calcutta Surface (West Bengal) *			Chandina Deltaci Plain (Tipperah Surface) **						
Chemical Properties	Calcutta City	Area South of Calcutta	Area North of Calcutta	Daudkandi Upazila well no			Muradnagar Upizilas well no			
				Daud-59	Daud-38	Daud-20	Mur-4	Mur-50	Mur-42	Mur-9
EC (/μs/cm)	1596	1298	599	1100	872	3430	5600	1000	6240	3280
TDS (mg/1)				770	610	2195	3584	700	4368	2240
pH				7.72	7.88	-	8.1	8.27	6.94	7.12
Ca (Meq/1)	5.48	4.00	3.95	2.70	3.20	3.80	5.15	1.44	8.75	4.17
Mg (Meq/1)	4.35	2.38	1.90	3.08	2.67	7.90	10.41	3.75	17.5	-
Na (Meq/1)	6.52	6.20	1.30	4.78	3.48	38.0	39.56	6.74	40.2	25.50
K (Meq/1)	0.16	0.12	0.03	0.08	0.08	0.26	0.32	0.26	0.89	0.53
CO_3 - (Meq/1)	-	-	-	0.03	0.03	-	1.32	1.30	6	-
HCo_3- (Meq/1)	7.90	6.66	6.37	2.60	2.70	2.92	4.23	6.10	3.4	8.00
Cl- (Meq/1)	9.05	6.88	0.42	7.91	5.71	36.0	43.00	2.00	48.9	24.80
S04- (Meq/1)	0.15	4.70	0.15	0.00	0.00	-	-	0.22	5.12	0.15
B (Meq/1)	-	0.11	0.11	-	-	-	-	0.22	0.3	0.50
F (Meq/1)	-			-	-	-	-	-	-	-
Cl/HCO_3 Wt. ratio	0.70	0.56	0.03	1.77	1.23	7.16	5.9	0.19	8.36	4.23
Ca/Mg Wt. ratio	2.15	3.00	3.57	1.45	1.97	0.79	0.81	0.63	0.82	-
Na/Cl Wt. ratio	0.88	2.09	0.98	0.39	0.39	0.68	0.60	2.18	0.53	0.66
Ca/Na Wt. ratio	0.90	1.63	3.62	0.49	0.80	0.08	0.11	0.18	0.19	0.14
Na/Mg Wt. ratio	3.22	1.04	1.32	2.93	2.46	9.09	7.18	3.39	4.34	-

* **G.S.I. Proc. Seminar, 1972**

** **DTW2 Project BADC, 1991.**

TABLE V.3.9

Comparison of Chemical Constituents of Various Water
(only selected Ions)

Sl Nr	Chemical Constituents	River Water * (Hooghly) (Sample date 2.5.69) EC=6400 μs/cm	River Water * (Hooghly) (Sample date 27.7.69)	Sea Waters #	Water of $ St.Martion's island (Bay of Bengal)	Formation $ water of Miocene sediments (Folded Area)	Saline @ Ground water Comilla (Mur-A2)
1	Cl^- (mg/l)	1 934	13	19 400	23 581	7 583	17 355
2	SO_4^{2-} (mg/l)	278	9.5	2 700	2 486	198	246
3	CO_3^{2-} (mg/l)	-	-	-	-	70	18
4	HCO_3^- (mg/l)	300	152	1 400	207	1 424	207
5	Na+ (mg/l)	1 096	20	10 800	14 253	5 421	925
6	K+ (mg/l)	51	1.8	400	-	-	38
7	Ca^{2-} (mg/l)	94	28	400	392	66	175.35
8	Mg^{2-} (mg/l)	149	12	1 300	982	43	212.8
9	Cl/HCO_3 (Wt. ratio)	6.45	0.08	13.85	114.0	36.60	8.38
10	Na/Cl (Wt. ratio)	0.56	1.53	0.556	0.60	0.71	0.53
11	Ca/Mg (Wt. ratio)	0.63	2.33	0.31	0.39	1.53	0.82
12	Ca/Na (Wt. ratio)	0.08	2.15	0.04	0.02	0.012	0.19
13	Na/Mg (Wt. ratio)	7.35	1.66	8.3	14.50	126.0?	4.34
14	Mg/Cl (Wt. ratio)	0.07	0.92	0.06	0.04	0.006	0.12
15	SO_4/Cl (Wt. ratio)	0.14	0.73	0.14	0.11	0.02	0.14
16	ΣM, mg/l	3 902	236	36 400	41 895	14 805	3 557

Note:

* **Handa, B.K., 1972: G.S.I. Proc. Seminer**
\# **Hunt, J.M. 1979**
$ **BOGMC, 1985**
@ **SER, 1991.**

TABLE V.3.10

Chemical Constituents of Formation Water of Miocene Sediments from Gas Bearing Structures in Folded belt of Bangladesh.

Well	Sample depth (m)	Formations		Na+K	Ca^{2+}	Mg^{2+}	Fe^{2}	$NH4^{-}$	Cl^{-}	$So4^{-2}$	$Co3^{-2}$	HCO_3^{-1}		I^{-} mineroli-sation	Br^{-1} Cl/HC03	Total Ca/Mg	Na/cl	Wt. ratio Ca/Na	of various irons Na/Mg
Begumganj-1	2996-3012	Bhuban	4675.6	26.32	5.82	3.36	-	5449.49	901	45	1906	-	-	13 010	2.85	4.5	0.85	0.005	803
do	3033-3036	do	5710.0	57.0	13.5	1.72	-	7850.00	68.6	204	1261.5	7.3	211.37	15 390	6.22	4.22	0.72	0.009	423
Begumganj-2	2807-2815	do	6524	47.37	2.4	-		92176	69.15	-	1520.8	-	-	17 370	6.06	19.8	0.71	0.007	2718
do	3140-3148	do	5263	69.02	22.5	0.76		7401	118.3	72	1257	-	-	13 580	5.88	3.06	0.71	0.013	233
Sitakund-1	575-600 m	do	5088	80	85	-	-	7269	82.3	420	702			13 720	10.35	0.94	0.70	0.015	60
Kamta-1	2923-2949	do	4891	27.64	16.8	-	-	6294	321	-	1906			13 460	3.30	1.64	0.77	0.006	291
Muladi-1	4447-4458	do	4420	131.3	40	0.55	2.95	4910	1385	60	2135	14.39	104	13 250	2.3	3.30	0.90	0.029	110

Note: **All chemical constituent values expressed in mg/1.**

Some of the findings based on the chemical composition of above sources of water are presented below.

a) Groundwater of the area and also of the Calcutta surface can be divided into two broad zones - groundwater from upper zone of saturation or unconfined to semi-confined aquifer and groundwater belonging to lower zone of saturation or confined to semi-confined aquifer. The upper group of aquifer occurring down to about 140 m is highly mineralised. It is not known whether the water bearing lower aquifer in the study area is fresh or mineralized but the lower group of aquifers occurring between 150 to 350 m below the Calcutta surface is essentially fresh. However, water samples collected for analyses in the study area might belong to several water bearing zones and the water would be mixed water from more than one aquifer.

b) The water quality in the study area is quite variable, characteristic conductivity value found to be over 1 000 $\mu s/cm$, though in the area adjoining the Tripura Hills in the Lalmai deltaic plain and the eastern portion of the Chandina deltaic plain the value is less than 750.

c) Groundwater in the Calcutta surface is alkaline earth bicarbonate type an that of Chandina surface is a mixed type sodium chloride and alkaline earth bicarbonate types (Tables V.3.11 and V.3.12).

TABLE V.3.11

Quality Classification of Groundwater, SER Study Area

Thana	DTW No.	Total Hardness (ppm)	Non-carbonate Hardness (NCH) in ppm	Na%	SAR	RC (mg/l)	Remark
Daudkandi	Daud-59	289	157.5	46	2.8	-	Hard groundwater, low saline hazard.
do	Daud-38	293	157	3775	2.04	-	do
do	Daud-20	585	439	76.6	10.27	-	do
Muradnagar	Mur-4	778	500	72	14.2	-	Hard groundwater and moderate sodium hazard.
do	Mur-50	260	-	57	4.1	2.21	Hard ground water with residual sodium carbonate problem.
do	Mur-42	1313	1112	61	11.05	-	Very hard groundwater with moderate sodium problem.
do	Mur-9	208	-	86	17.6	3.83	Moderate to moderately high sodium hazard with sodium carbonate problem.

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TABLE V.3.12

Hydro-geochemical Characteristic of a part of Lower Gangetic Plains (Calcutta Surface), West Bengal, India.

Sl No.	Location	Region	Geohydrological Characteristics	Average Water Quality	Water Type.
	Lower Gangetic Plain (Calcutta Surface)	Calcutta	Intercalated beds of clay, sand & silt; peat beds and Kankar common; groundwater occurs under unconfined to confined state.	Chlorinity av. 300 ppm, Fe av. 0.5 ppm TDS normally 100 ppm (Ec ≡ 1430/μs/cm) Ferrugenous water with high Mn., extremely hard water.	Alkaline earth bi-carbonate type
1.	do	24-Parganas, area north of Calcutta.	do	TDS below 300 ppm, Cl below 50 ppm	do
2.	do	Area south of Calcutta	Intercalated beds clay, silt and sand.	TDS av. 1000 ppm, Chlorinity.av. 2200 ppm, (av. 2.5 mg/l)	Mixed Type.
3.	do	Coastal Tract, 24-Parganas & Midnapore.	Pockets of fresh ground water.	TDS highly variable.	do.

Source: G.S.I. Proc. Seminar, 1972

d) Concentration of Na and Cl ions is dominant in samples Mur-42 and Mur-9 indicating primary salinity (Table V.3.8).

e) Cl/HCO3 weight ratio provides indication of probable contamination of fresh groundwater with sea water. In samples Daud-59 and Daud-38, this ratio exceed 1 but less than 2 indicating slight contamination but in samples Daud-20, Mur-4 Mur-42 and Mur-9, the value exceeds 4 indicating strong contamination with sea water (Table V.3.8). Cl/HCO_3 ratio for groundwater in the Calcutta surface is less than 1 (Table V.3.8) indicating slight or low contamination.

f) Sea water with average salinity has a Na/Cl weight ratio of 0.556 or less, fresh water 0.8-1.1 and freshwater contaminated with sea water 0.50-0.78 (Handa, 1972). The Na/Cl weight ratio of groundwater collected from Daudkandi and Muradnagar (Table V.3.8) indicates brackish nature of the water with very little fresh water contamination with the exception of sample collected from Mur-20 (Na/Cl is 2.18). Na/Cl weight ratio values for the Miocene formation water indicates that the water is brackish but is flushed by fresh water (Na/Cl ratio varying from 0.7 to 0.9).

g) In Mur-4 and Mur-42 wells (Table V.3.8) the Ca-ions (in terms of meq/l) exceed or equal the total of HCO_3 + SO_4 ions (in terms of meq/l) indicating the presence of $CaCl_2$. Since C_aICl_2 is highly hygroscopic, the presence of this constituent in the area is related to the process of base exchange, by virtue of which the sodium ions present in groundwater are exchanged for Ca-ions present in the clay complex present in the path of circulation of sub-terranean water.

h) A study of the occurrence of residual sodium carbonate (RSC or RC) viz, HCO_3 - Ca+Mg in terms of meq/l for seven wells in Daudkandi and Muradnagar (Table V.3.11) indicate that Mur-9 and Mur-50 water samples have RSC value exceeding 2 meq/l indicating that in some of the study area Mg and Ca ions present in the groundwater are being exchanges for Na ions present in the clay complex, with the consequent depletion of alkaline earth ions in groundwater with the result that the value of RSC tends to increase.

i) Total hardness contents (Table V.3.11) range (except well no. Mur-9) from 260 to 1313 indicating that groundwater is moderate hard to very hard.

j) The sodium absorption ratio (SAR), a valuable criterion for determining the suitability of water for irrigation purposes, is directly related to the absorption of Na by soil. It is given by concentration of Na, Ca, and Mg in meq/l as follows:

$$SAR = \frac{Na}{\left(\sqrt{\frac{Ca + Mg}{2}}\right)}$$

The SAR value for water samples analysed (Table V.3.11) range from 2.04 to 17.6 indicating low to high sodium hazards (SAR > 10.00 is regarded as low sodium hazard).

V.3.3.1 Effect of Saline Groundwater

High salt concentration in groundwater used for irrigation has adverse effect on both soil and consequently on crop. Two such cases reported below:

a) Salinity problems in Laksham - The DTWs and STWs in southern portion of Laksham thana face salinity problem. Extensive area including no. 23 Natherpetua and Uttarda unions is affected by salinity problem. One DTW at Uttarda union (JL 278, Plot 154) has a command area of 72 acres. The EC measured from water samples collected from the DTW during the field survey undertaken by project personnel in May 16, 1991 was found to be over 6000 µs/cm whereas the water samples collected from HTWs showed EC variations ranging from 1400 - 2900 µs/cm. The boro paddy grown with water the DTW and HTWs was totally damaged. Similar crop damages were reported in other unions visited in the southern Laksham

b) Yusufnagar, Muradnagar thana: Table V.3.13 demonstrates how DTW yielding saline groundwater destroys both the soil and crop. The DTW water has an EC of 5600 μs cm indicating extreme salinity which makes the water unsuitable for irrigation. The chemical analysis presented in Table A shows that the water is quite alkaline (pH 8.1) and has high concentration of Na and Mg relative to Ca and K which is likely to create ionic imbalance in the soil with adverse effects on plant nutrition. The high pH of the water coupled with high HCO_3 and CO_3 concentration will probably create micro nutrient deficiencies in the soil. Soil analysis shows that the soil of the DTW command area has already been salinised to some extent. Continuous use of the saline DTW water for irrigation is likely to hasten the process of salinization and alkalization resulting in a bleak future for crop production.

V.3.4 Origin of the Saline Groundwater

The saline groundwater in the study region occurs in two forms:

- one occurs at a depth between 20m to about 150m in the coastal area of the greater Noakhali district;

- the other occurs either as isolated patches or as extensive area between 15m to about 100m in the greater Comilla district.

The occurrence of saline groundwater in the first region is determined from log analysis and empirically from Ghyben-Herzberg relationship and the source of saline water is the saline water intrusion from the sea while for the second area, the saline groundwater occurrences are not related to sea water intrusion.

The source of the poor quality brackish ground-water in Muradnagar, Daudkandi, Debidwar, Chandpur, Hijiganj and Laksham thanas is not adequately known. One probable explanation is that the saline water could be drawn up from deep seated gas bearing Miocene sediments in the Comilla region under the control of geological structures, most possibly the crests of anticlinal structures or faults that either cross the anticlines or parallel the folds (Figure V.3.5). The other explanation could be that the occurrence of saline groundwater is related to the entrapment of seawater during regression and transgression phase of the land formation during the Late Quaternary or to the entrapment of connate saline water in the Holocene sediments (thick clay blanket over the salinized aquifer and lack of possibility of upconing of saline groundwater from the subsurface because of groundwater mining in the area provide support to the idea).

Source of the saline groundwater in the region cannot be ascertained without:

a) a detailed and systematic survey of all the operating tubewells - HTWs, STWs and DTWs.

b) a systematic chemical analyses of groundwater from selected sites (HTWs, STWs and DTWs in order to study the variation in the chemical quality of water with depth).

c) isotopic analyses of the salinized groundwater for age dating (14_C for age dating and S^2H, $S18_0$ and $S13_C$ for environmental isotopic studies).

d) chemically analyses of Miocene gas bearing formational water from the gas fields (Bakhrabad, Titas, Feni and Begumganj).

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Figure V.3.5

Saline Ground Water Occurrences and Subsurface Structures

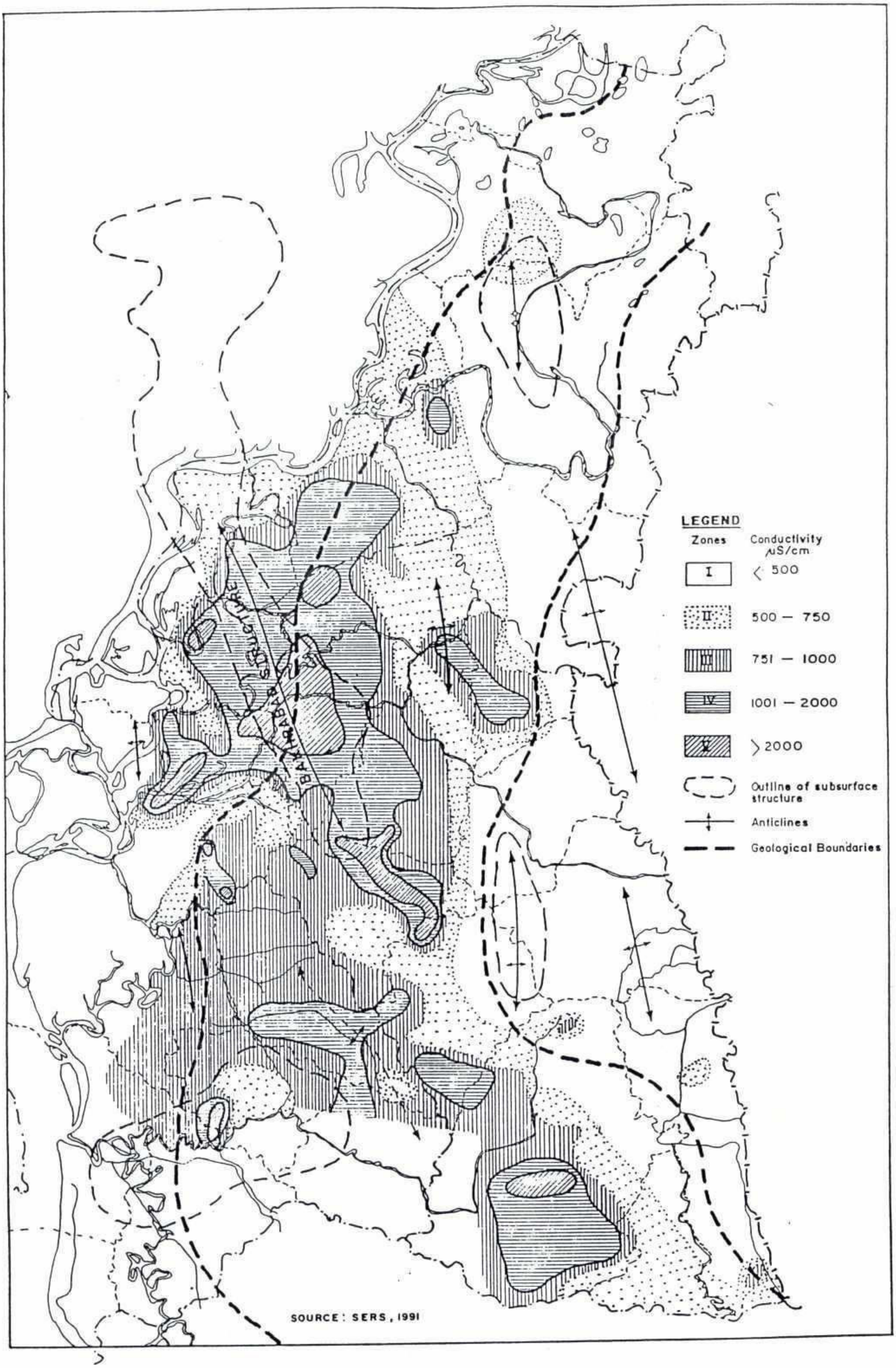

TABLE V.3.13

Effect of Saline Groundwater on Soil and Crop
(Case Study: Yusufnagar, Muradnagar)

TABLE A. Chemical analysis of water samples collected from DTW at Yusufnagar, Muradnagar (sample tested on 20/4/89 from DTW-40, Mur-4)

pH	EC ($\mu s/cm$)	Na	K	Ca	Mg	Fe (PPM)	Mn (PPM)	Zn (PPM)	Cl	CO3	HCO3
8.1	5600	39.56	0.32	5.15	10.41	4.0	0.29	0.1	42.98	1.32	4.23

TABLE B. Analysis of Soil Samples collected from Yusufnagar, Muradnagar

Spot	Location	pH	EC ($\mu s/cm$)	CEC (meg/1009)	Exchangeable Cations (meg/1009)			
					Ca	Na	K	Mg
1	Yusufnagar DTW Project Near Pump at slightly elevated land (not water logged)	6.31	998	18.56	8.0	2.08	0.19	4.6
2	Yusufnagar Near pump Low land (water logged)	5.59	3210	19.99	6.4	2.78	0.18	5.2
	Yusufnagar Dryland, tillage completed for jute (not serviced by DTW)	5.40	208	22.85	7.0	0.52	0.32	3.6

Data source: IDA/BADC DTW II, 1991

CHAPTER V.4

ASSESSMENT OF GROUNDWATER RESOURCE DEVELOPMENT POTENTIAL

V.4.1 Previous Work

The first comprehensive national/regional assessment of groundwater resources in Bangladesh was undertaken within the first phase of the National Water Plan. During the second phase a re-assessment of resource potential took place using additional data which had been collected from special study areas and the feedback from the significant groundwater development which had since taken place. The optimum development of groundwater was derived by the Master Plan Organisation (MPO) with the use of a variety of simulation models. These models have a number of build-in constraints, which are given below:

- **Recharge.**

  Potential recharge, defined as the maximum possible rate of recharge to an infinite sub-surface reservoir was taken as the upper limit of resource potential. The recharge was related only to natural sources such as rainfall and flooding and did not take into account of the recharge from surface water irrigation return flow.

  The potential recharge is sensitive to a number of key parameters. These include the deep percolation characteristics of the sub-soil, the rainfall during the pre-monsoon and monsoon season, and the extent and depth of flooding. The extent of flooding is closely associated with the flood phase distribution.

  Within the analysis procedures of the MPO different recharge types are defined, viz. usable recharge and available recharge. Usable recharge was taken as 75 per cent of the estimated mean potential recharge. Available recharge is an areal modification of the usable recharge values to account for development constraints such as groundwater salinity, topography. etc.

- **Pump and well technology.**

  The main constraint for suction mode technology such as used by shallow tubewells (STW) and deepset shallow tubewells (DSSTW) is the maximum allowable or operational depth to pumping level. The depth was set at 7.0 m for STW and 9.0 m for DSSTW, assuming a 2.0 m deep pit. It should be borne in mind that this is an average setting value and should probably be seen in the context of F2 or F3 land. Deeper settings (pits) are known to exist in various parts of the Atrai basin. Deeper pits are common in other countries such as Pakistan and India. Assuming a setting of 4.0 m below ground level makes a considerable impact on the available resource. The deeper pits should perhaps be viewed in the context of the higher lands.

  For DTW no suction lift constraint exists but limits were based on the general setting of the pump intake at 20 m below ground surface. This is common for many existing wells, there is, however, generally no reason to exclude greater depth settings for the pump intake.

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- Hydraulic constraints of the aquifer system.

Low aquifer transmissivity will cause excessive drawdown in the tubewell if high abstraction rates are used. The use of low capacity pumps may be possible under these conditions, although economic viability may become a constraint.

A high hydraulic resistance of the clay layers which overly the aquifer in most of the country can constrain the vertical downward leakage (recharge) to the aquifer to the extent that it is less than the rate of potential recharge (see above). In the majority of the country this forms no serious constraint for force mode units.

The hydraulic resistance, if high, can cause important hydraulic head differences between the water table and the piezometric level in the aquifer, which adds to the depth to the pumping level in the wells.

The MPO assessment of resource potential assumed an aquifer system comprising two aquifer units, a main aquifer and a composite aquifer, which are assumed to be in free hydraulic contact, overlain by a clay/silt aquitard. In many parts of the south east region (see Chapter V.2) the main aquifer is separated from the composite aquifer by extensive layers of clay. It should be borne in mind that STW abstract water mainly from the composite shallow aquifer, while deep tubewells have their screen set in the lower main aquifer. The occurrence of mid-aquifer clay layers will cause an increase in the depth to pumping level for DTW and thus limit the resource potential to levels below those derived by the MPO.

The thickness of the upper clays may form a constraint on the normal methods of construction of STW and DSSTW.

- Groundwater salinity.

In major parts along the southern coast of Bangladesh brackish/saline water of marine origin renders the groundwater unsuitable for irrigation and water supply. In addition extensive areas are found in the central and western parts of the study area where groundwater salinity exceeds 1000 μS/cm. and is in the range of 2000-8000 μS/cm in localised areas (see Chapter V.3). For EC values in excess of 2000 μS/cm groundwater becomes unsuitable for irrigation of rice. Yield decreases may result with slightly lower salt concentrations whilst seriously impairing cultivation if higher.

- **Additional constraints imposed by the MPO.**

The MPO has introduced additional planning constraints, which reduce the resource potential, yielding the available recharge as defined above. These include:

- adverse soil conditions, such as saline soils and peat soils;
- difficult terrain such as deep flooded and hilly areas;
- surface water irrigation projects.

Some of these constraints should be reconsidered since some are inappropriate or unnecessary in a regionally continuous aquifer, particularly those related to terrain and to surface water irrigation projects. Terrain irregularities are not always grouped in one large contiguous area and groundwater development may well be possible in close proximity of such classified lands. Likewise in existing irrigated areas there is probably scope for using groundwater to irrigate areas which are out of command of the surface water system or difficult to command. Surface water irrigation in effect enhances the resource availability and conjunctive use of surface water and groundwater should be considered as a viable development option.

Deep flooded areas although not suitable for tubewell irrigation, especially by fixed force mode units, do contribute to recharge which could be used in (and pumped from) immediately adjacent areas.

Other factors considered include:

- higher priority groundwater users (e.g. potable supplies), and
- financial and economic viability of tubewells and groundwater development, i.e. it may be inadvisable to proceed beyond the potential of suction mode units where the incremental benefits of force mode technology are small.

For the south east region the groundwater resource availability without planning constraints as estimated by the MPO (June 1987) is shown in Table V.4.1. Table V.4.2 gives the resource potential with the imposed planning constraints. The reserves for potable water supply represent only 5 per cent of total potential, although in Planning Area 10 all available fresh groundwater is reserved for potable use.

TABLE V.4.1

MPO 1987 Estimate of Available Groundwater without Planning Constraints

Planning Area	Annual Recharge (Mm^3) Potential	Usable	Available Groundwater (Mm^3) Conserved Baseflow	Stored Recharge	Total Available
29	1 924	1 443	188	1 086	1 274
31	1 671	1 253	273	739	1 012
32	1 013	760	195	392	587
33	1 439	1 079	168	761	929
34	460	345	75	178	253
35	884	663	168	366	534
36	518	389	n.d.	n.d.	n.d.
Total	**7 909**	**5 932**	**1 067**	**3 522**	**4 589**

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TABLE V.4.2

MPO 1987 Estimate of Available Groundwater with Planning Constraints

Planning Area	Maximum Available Resource (Mm^3)	Pot/Ind. Reserves	Potential (Mm^3)
29	544	15	529
31	530	21	509
32	51	16	35
33	501	23	478
34	193	11	182
35	10	10	0
36	41	6	35
Total	1 870	**102**	1 768

The resource potential was re-assessed during the second phase of the National Water Plan (NWP II). The potential recharge and resource potential without planning constraints were re-evaluated on an thana basis. In the assessment account was given of the effect of local relief differences (flood phases) on the available modes of pumping. The results are summarised in Table V.4.3. In all cases the potential for one cusec DTW is greater than that of two cusec DTW because of the reduced specific drawdown values. The table presents information related to each thana and does not consider any constraints, not even the salinity constraint. The much increased resource utilisation potential of force mode units needs to be noted, the smaller capacity 30 l/s (DTW1) units showing the maximum potential.

In the assessment undertaken by NWP II of groundwater resource potentials (not yet published) no account is taken of the beneficial effects of surface water Low Lift Pumps (LLP) on recharge and consequent groundwater development potential. In Section V.4.2 a re-evaluation of groundwater resource potential is given which takes account of surface water irrigation.

Table V.4.4 gives a comparison between estimated net groundwater use in 1989/90 and the unconstrained resource potential as prepared by the MPO. For a significant number of thanas the present groundwater use exceeds the limits on STW and sometimes even DSSTW resource potential, this despite the fact that large numbers of STW are in operation in the study area. There are several factors to be considered in this context, but primarily the main questions relate to the actual abstraction characteristics of the groundwater abstraction units, depending on:

- rainfall characteristics;
- crops grown;
- working efficiency of the units;
- availability of fuel/power, and
- deep percolation characteristics of the soils.

TABLE V.4.3

MPO Estimates of Resource Potential (1991) without (mm/unit gross area)

Thana Code	Thana Name	District	Area km²	MPO GW Potential (MCM)				Potential (mm/unit gross area)			
				STW	DSSTW	DTW1	DTW2	STW	DSSTW	DTW1	DTW2
302	Madhabpur	Haibiganj	279	14	30	141	96	49	106	504	344
362	Nasirnagar	Brahmanbaria	313	17	41	122	95	54	131	390	304
437	Sarail	Brahmanbaria	212	14	31	143	98	66	146	675	462
87	Brahmanbaria	Brahmanbaria	416	0	21	189	77	0	50	454	185
14	Ashuganj	Brahmanbaria	119	1	6	35	17	8	50	294	143
42	Ban:harampur	Brahmanbaria	207	20	37	93	93	97	179	449	449
345	Nabinagar	Brahmanbaria	352	6	22	108	68	17	63	307	193
249	Kasba	Brahmanbaria	207	21	38	105	86	101	184	507	415
6	Akhaura	Brahmanbaria	93	7	23	70	66	75	247	753	710
204	Homna	Comilla	178	14	27	91	75	79	152	511	421
343	Muradnagar	Comilla	341	22	37	144	105	65	109	422	308
88	Brahmanpara	Comilla	119	17	32	77	66	143	269	647	555
125	Daudkandi	Comilla	375	16	32	137	89	43	85	365	237
130	Debidwar	Comilla	235	20	35	135	91	85	149	574	387
90	Buri:hang	Comilla	181	12	22	79	61	66	122	436	337
94	Chandina	Comilla	202	8	19	82	57	40	94	406	282
53	Barura	Comilla	240	14	28	120	75	58	117	500	313
271	Kotwali	Comilla	277	24	46	135	111	87	166	487	401
287	Laksham	Comilla	427	22	42	190	113	52	98	445	265
111	Chouddagram	Comilla	271	7	18	88	54	26	66	325	199
356	Nangolkot	Comilla	235	12	27	106	97	51	115	451	413
312	Matlab	Chandpur	409	0	32	147	92	0	78	359	225
225	Kachua	Chandpur	238	8	21	89	53	34	88	374	223
96	Chandpur	Chandpur	287	16	34	164	102	56	118	571	355
195	Hajiganj	Chandpur	157	5	11	56	27	32	70	357	172
447	Shahrasti	Chandpur	186	5	16	89	38	27	86	478	204
155	Faridganj	Chandpur	235	4	15	76	40	17	64	323	170
194	Haimchar	Chandpur	186	3	17	107	55	16	91	575	296
411	Ramganj	Lakshmipur	170	7	14	52	38	41	82	306	224
405	Raipur	Lakshmipur	202	0	12	59	39	0	59	292	193
288	Lakshmipur	Lakshmipur	515	7	29	191	82	14	56	371	159
413	Ramgati	Lakshmipur	650	0	28	163	96	0	43	251	148
102	Chatkhil	Noakhali	134	3	8	35	21	22	60	261	157
58	Begumganj	Noakhali	409	15	28	93	57	37	68	227	139
445	Senbagh	Noakhali	160	7	13	50	30	44	81	313	188
459	Sudharam	Noakhali	828	4	38	207	108	5	46	250	130
116	Companiganj	Noakhali	189	3	25	123	68	16	132	651	360
120	Daganbhuiyan	Feni	132	4	9	43	23	30	68	326	174
465	Sonagazi	Feni	259	11	22	139	81	42	85	537	313
161	Feni	Feni	221	5	16	95	44	23	72	430	199
104	Chhagalnaiya	Feni	157	2	8	41	20	13	51	261	127
166	Fulgazi	Feni	108	0	5	53	22	0	46	491	204
388	Parsuram	Feni	72	4	6	39	22	56	83	542	306

STW Maximum total potential at which STW stop operating on F2 land
DSSTW Maximum total potential at which DSSTW stop operating on F2 land
DTW1 Maximum total potential for 1 cusec DTW on all land
DTW2 Maximum total potential for 2 cusec DTW on all land

TABLE V.4.4

Comparison of Actual (1989) Groundwater Resource Utilisation Versus MPO Estimate of Resource Potential

Thana Code	Thana Name	District	Area km²	NCA km²	Ratio %	Existing minor irrigation (Nr.)					GW (MCM)	MPO GW Potential (MCM)			
						DTW	STW	LLP	eq DT	eq 2cu		STW	DSSTW	DTW 1	DTW2
302	Madhabpur	Haibiganj	279	247	89	65	193	39	113	144	11.5	14	30	141	96
362	Nasirnagar	Brahmanbaria	313	256	82	24	413	425	127	467	12.9	17	41	122	95
437	Sarail	Brahmanbaria	212	177	83	92	351	444	180	535	18.2	14	31	143	98
87	Brahmanbaria	Brahmanbaria	416	357	86	169	697	575	343	803	34.7	0	21	189	77
14	Ashuganj	Brahmanbaria	119	97	82	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1	6	35	17
42	Bancharampur	Brahmanbaria	207	175	85	0	475	293	119	353	12.0	20	37	93	93
345	Nabinagar	Brahmanbaria	352	282	80	19	210	671	72	608	7.2	6	22	108	68
249	Kasba	Brahmanbaria	207	178	86	98	413	157	201	327	20.4	21	38	105	86
6	Akhaura	Brahmanbaria	93	81	87	13	159	159	53	180	5.3	7	23	70	66
204	Homna	Comilla	178	137	77	0	378	214	95	266	9.6	14	27	91	75
343	Muradnagar	Comilla	341	289	85	28	152	474	66	445	6.7	22	37	144	105
88	Brahmanpara	Comilla	119	106	89	1	276	126	70	171	7.1	17	32	77	66
125	Daudkandi	Comilla	375	315	84	49	218	823	104	762	10.5	16	32	137	89
130	Debidwar	Comilla	235	194	83	51	352	143	139	253	14.1	20	35	135	91
90	Burichang	Comilla	181	137	76	125	540	80	260	324	26.3	12	22	79	61
94	Chandina	Comilla	202	167	83	113	217	96	169	244	16.9	8	19	82	57
53	Barura	Comilla	240	196	82	68	682	31	239	263	24.1	14	28	120	75
271	Kotwali	Comilla	277	219	79	282	646	135	444	552	44.9	24	46	135	111
287	Laksham	Comilla	427	353	83	168	480	400	288	608	29.1	22	42	190	113
111	Chouddagram	Comilla	271	224	83	163	265	101	229	310	23.2	7	18	88	54
356	Nangolkot	Comilla	235	182	77	28	165	60	69	117	7.0	12	27	106	97
312	Matlab	Chandpur	409	274	67	0	182	340	46	318	4.6	0	32	147	92
225	Kachua	Chandpur	238	191	80	49	17	228	53	236	5.4	8	21	89	53
96	Chandpur	Chandpur	287	145	51	10	5	275	11	231	1.1	16	34	164	102
195	Hajiganj	Chandpur	157	110	70	1	3	329	2	265	0.2	5	11	56	27
447	Shahrasti	Chandpur	186	141	76	38	3	182	39	184	3.9	5	16	89	38
155	Faridganj	Chandpur	235	182	77	0	0	745	0	596	0.0	4	15	76	40
194	Haimchar	Chandpur	186	85	46	0	0	77	0	62	0.0	3	17	107	55
411	Ramganj	Lakshmipur	170	135	79	0	6	206	2	166	0.2	7	14	52	38
405	Raipur	Lakshmipur	202	125	62	0	1	70	0	56	0.0	0	12	59	39
288	Lakshmipur	Lakshmipur	515	379	74	2	17	470	6	382	0.6	7	29	191	82
413	Ramgati	Lakshmipur	650	366	56	0	0	20	0	16	0.0	0	28	163	96
102	Chatkhil	Noakhali	134	100	75	0	2	349	1	280	0.1	3	8	38	21
58	Begumganj	Noakhali	409	309	76	0	197	887	49	759	5.0	15	28	93	57
445	Senbagh	Noakhali	160	124	78	13	118	164	43	174	4.3	7	13	50	30
459	Sudharam	Noakhali	828	816	99	0	0	100	0	80	0.0	4	38	207	108
116	Companiganj	Noakhali	189	190	101	0	1	26	0	21	0.0	3	25	123	68
120	Daganbhuiyan	Feni	132	103	78	13	19	120	18	114	1.8	4	9	43	23
465	Sonagazi	Feni	259	139	54	5	2	75	6	66	0.6	11	22	139	81
161	Feni	Feni	221	165	75	59	116	382	88	394	8.9	5	16	95	44
104	Chhagalnaiya	Feni	157	120	76	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2	8	41	20
166	Fulgazi	Feni	108	80	74	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0	5	53	22
388	Parsuram	Feni	72	60	83	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4	6	39	22

40 acres per 2 cusecs (16 ha per two cusecs) 4 STW are regarded as equivalent to DTW
625 mm net irrigation demand for tubewells 1 LLP are regarded as equivalent to 0.8 DTW

In the comparison it was assumed that four STW were equivalent to a single two cusec DTW and that each two cusec unit irrigates 16 ha. The 16 ha is in reasonable agreement with the command areas given by the MPO during the first phase of the National Water Plan. Recent AST CIDA information indicates higher per unit coverages, however the 16 ha per two cusec unit was retained for the current analysis.

The cause of the difference between present groundwater use and MPO's estimate of STW and DSSTW potential could be the over-estimation of existing abstraction volumes as defined above, or alternatively it could be due to the fact that the beneficial effect of LLP irrigation was not taken into consideration. In many instances the magnitude of the differences are such that rational adjustment of the first factor could not account for the mismatch. Yet another cause could be the rather conservative estimates of a number of key parameters that dictate the results of the various groundwater models. The parameters related to the groundwater models are associated with the:

- thickness of the upper clays, which, judging from lithologic evidence in the IDA DTW project area, is sometimes overestimated by the MPO,

- depth dependent specific yield values, which are likely to be underestimated; higher values had to be used in the detailed calibration of the MPO special study area in Debidwar; in general the values following from lithologic interpretation of IDA DTW logs are also higher than those used by the MPO,

- transmissivity values, which, in certain cases, are lower than those obtained from the IDA DTW project, although in general there is good agreement.

The groundwater resource evaluation for the original Gumti Phase 2 study relied totally on the MPO work done during the first phase of the National Water Plan, values of groundwater potential differed little from those presented by the MPO and are in effect marginally modified copies of the latter.

V.4.2 Groundwater Development Potential in the Study Area

V.4.2.1 Approach

The groundwater resource potential was re-evaluated using similar modelling techniques to those developed by the MPO and with use of a newly developed model.

The initial assessment of the resource potential without planning constraints has been based on the values derived by the MPO but taking account of existing surface water irrigation from LLP. The impact of flood protection on the potential recharge and thus the upper limit of the resource availability was also assessed.

A single cell thana model (SCMTM) was developed to analyse groundwater resource potential in more detail in a selected number of thanas.

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V.4.2.2 Effect of Flood Protection on Potential Recharge

The implication of flood protection on potential recharge was evaluated with the MPO recharge model. In this model only recharge from natural sources is considered and thus the beneficial effects of surface water irrigation are not taken into consideration.

In the recharge model, a synthesised flood hygrograph was used for different sub-regions. Each hygrograph was kept constant for each of the 17 years which cover the simulation period. Rainfall was allowed to vary and was based on rainfall records for the historical period from 1972 to 1988. Real flood hygrographs are as yet not available and will require a considerable amount of time to be incorporated in the data base of the model. The synthesised flood hygrographs were compared with a few actual situations and found to be representative.

The case of full flood protection was compared with the natural case, whereby with full flood protection a complete removal of flooding is imposed on all flood phases. The synthesised flood hygrographs for the natural case is shown in Figure V.4.1.

The comparison between the mean values of potential recharge and the coefficients which define the linear relationship between annual rainfall and potential recharge are shown in Table V.4.5. It also shows the minima and maxima for both rainfall and recharge.

The reduction in potential recharge can be very large, especially during dry monsoons, and is strongly related to the proportion of total land which is normally flooded (particularly F2 to F4 land).

Potential recharge was checked against maximum resource potential derived by the MPO for 1 cusec DTW development. It was found that it has an effect on the resource potential in only nine out of the 36 thanas for which potential recharge could be calculated.

The reduction in potential recharge, although dramatic, should, however, not be directly related to a reduction in groundwater resource potential, since other factors such as land availability and well technology often control the limits on resource development, as will be shown in Section V.4.2.3.

Three thanas, Faridganj, Kasba and Nabinagar, were selected to study the effect of partial flood protection on potential recharge. Firstly it was assumed that only F2 land was protected from flooding, secondly, both F2 and F3 land were protected. Partial flood protection was simulated by simply lowering the maximum flood levels as is shown in Figure V.4.1. The implication of partial flood protection is shown in Table V.4.6. Again the effect is strongly controlled by the relative extent of the different flood phase.

Figure V.4.1

Synthesised Flood Hydrographs

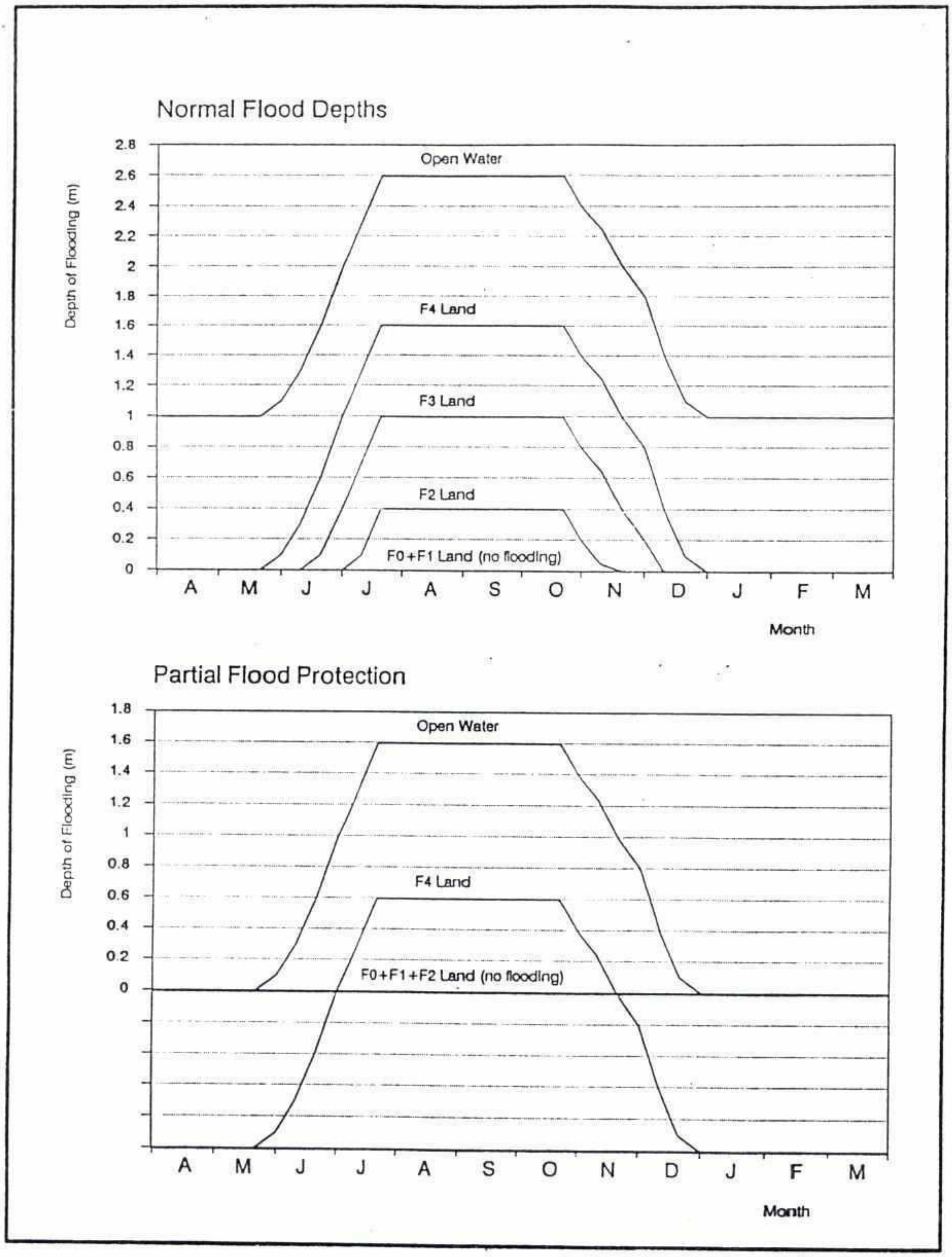

TABLE V.4.5

Effect of Full Flood Protection on Potential Recharge and MPO full Development Potential with 1 cusec DTW

Thana Code	Thana Name	District	Area km2	FFP A	B	NFP A	B	Rainfall (mm/year) MIN	MEAN	MAX	Potential Recharge Flood Protection (mm/yr) MIN	MEAN	MAX	Potential Recharge No Flood Protection MIN	MEAN	MAX	Percentage Reduction MIN	MEAN	MAX	Usable Recharge FFP (Mm3) MEAN	NFP (Mm3) MEAN	MPO max GW Potential (Mm3) NFP	(Mm3) FFP
302	Madhabpur	Habiganj	279	−248.0	0.37	29.0	0.32	1745	2310	3121	398	607	907	587	768	1028	32	21	12	127	161	141	127
437	Sarail	Brahmanbaria	212	−361.0	0.51	1556.0	0.22	1577	2174	2723	443	748	1028	1903	2034	2155	77	63	52	119	323	143	119
87	Brahmanbaria	Brahmanbaria	416	−326.5	0.44	1158.0	0.23	1511	2129	2957	338	610	975	1506	1648	1838	78	63	47	190	514	189	189
345	Nabinagar	Brahmanbaria	352	−401.0	0.49	1207.0	0.25	1435	2065	3165	302	611	1150	1566	1723	1998	81	65	42	161	455	108	108
249	Kasba	Brahmanbaria	207	−428.5	0.48	530.0	0.31	1368	2024	2584	228	543	812	954	1157	1331	76	53	39	84	180	105	84
6	Akhaura	Brahmanbaria	93	−266.0	0.35	716.0	0.20	1381	2022	2872	217	442	739	992	1120	1290	78	61	43	31	78	70	31
204	Homna	Comilla	178	−371.0	0.53	2488.0	0.14	1584	2307	3269	469	852	1362	2710	2811	2946	83	70	51	114	375	91	91
343	Muradnagar	Comilla	341	−218.0	0.38	1357.0	0.17	1439	2239	3844	329	633	1243	1602	1738	201	79	64	38	162	444	141	114
88	Brahmanpara	Comilla	119	−515.0	0.59	1183.0	0.26	1103	2119	3010	283	723	1231	1518	1712	1966	82	58	37	65	155	77	65
125	Daudkandi	Comilla	375	−118.5	0.38	2112.0	0.15	1754	2601	3478	548	870	1203	2375	2502	2634	77	65	54	245	704	137	137
130	Debidwar	Comilla	235	−310.5	0.42	678.0	0.24	1385	2210	3201	271	618	1034	1010	1208	1446	73	49	29	109	213	135	109
90	Burichang	Comilla	181	78.5	0.21	478.0	0.16	1399	2269	2889	372	555	685	707	841	940	47	34	27	75	114	79	75
94	Chandina	Comilla	202	−352.0	0.49	1290.0	0.19	1401	2193	2986	334	723	1111	1556	1707	1857	79	58	40	109	259	82	82
53	Barura	Comilla	240	226.5	0.44	552.0	0.26	1423	2120	3099	400	706	1137	922	1103	1358	57	36	16	127	199	120	120
271	Kotwali	Comilla	277	13.5	0.25	255.0	0.18	1517	2183	3037	393	584	773	528	666	802	26	12	4	121	138	135	121
287	Laksham	Comilla	427	−157.0	0.34	600.0	0.21	1777	2512	3249	417	697	918	973	1128	1282	51	38	26	223	361	190	190
111	Chouddagram	Comilla	271	132.0	0.19	375.0	0.15	1826	2583	3525	479	623	802	649	762	904	26	18	11	127	155	88	88
356	Nangolkot	Comilla	313	−276.0	0.43	1769.0	0.14	1723	2300	3247	465	713	1120	2010	2091	2224	77	66	50	167	491	122	122
312	Matlab	Chandpur	409	−378.5	0.51	1367.0	0.22	1693	2275	3273	485	782	1292	1739	1868	2087	72	58	38	240	573	147	147
225	Kachua	Chandpur	238	−441.0	0.51	1260.0	0.18	1365	2133	3128	255	647	1154	1506	1644	1823	83	61	37	115	293	89	89
96	Chandpur	Chandpur	287	271.0	0.27	1221.0	0.16	1578	2197	3496	697	864	1215	1473	1573	1780	53	45	32	186	338	164	164
195	Hajiganj	Chandpur	157	−224.5	0.37	879.0	0.17	1186	1991	3221	214	512	967	1081	1217	1427	80	58	32	60	143	56	56
447	Shahrasti	Chandpur	186	−412.0	0.57	627.0	0.35	1421	2130	3195	398	802	1109	1124	1373	1715	65	42	19	112	191	89	89
155	Faridganj	Chandpur	235	−375.0	0.45	(76.5)	0.42	1531	2109	3218	314	574	1073	567	809	1275	45	29	16	101	143	76	76
194	Haimchar	Lakshmipur	186	248.0	0.34	1329.0	0.20	1548	2343	3795	774	1045	1538	1639	1798	2088	53	42	26	146	251	107	107
405	Raipur	Lakshmipur	202	−279.0	0.43	263.0	0.35	1416	2280	3241	330	701	1115	759	1061	1397	57	34	20	106	161	59	59
288	Lakshmipur	Lakshmipur	515	67.7	0.30	541.0	0.20	1646	2582	4077	562	842	1291	870	1057	1356	35	20	5	325	408	191	191
413	Ramgati	Lakshmipur	650	−393.0	0.63	677.0	0.44	2248	3298	4014	1023	1685	2136	1666	2128	2443	39	21	13	821	1037	163	163
102	Chatkhil	Noakhali	134	−220.0	0.43	298.0	0.36	1773	2560	3289	542	881	1194	936	1220	1482	42	28	19	89	123	35	35
58	Begumganj	Noakhali	409	−113.5	0.41	743.0	0.19	1918	2882	2707	673	1068	1406	1107	1291	1447	39	17	3	328	396	93	93
445	Senbag	Noakhali	160	−67.0	0.31	464.0	0.17	1877	2921	3700	515	839	1080	783	961	1093	34	13	1	101	115	50	50
116	Companiganj	Noakhali	189	−14.5	0.41	1389.0	0.18	1991	3099	3915	802	1256	1591	1747	1947	2094	54	35	24	178	276	123	123
465	Sonagazi	Feni	259	79.0	0.34	953.0	0.21	2092	3037	3808	790	1112	1374	1392	1591	1753	43	30	22	216	309	139	139
161	Feni	Feni	221	145.0	0.17	347.0	0.13	2003	3009	3817	486	657	791	607	738	843	20	11	6	109	122	95	95
166	Fulgazi	Feni	108	−80.0	0.27	(53.0)	0.27	1985	2796	3594	456	675	890	483	702	917	6	4	3	55	57	53	53
388	Parsuram	Feni	72	−114.0	0.25	(70.0)	0.25	1795	2520	3530	335	516	769	379	560	813	12	8	5	28	30	39	28

Potential recharge computed as A + B*Rainfall

Usable recharge computed as 0.75 X Potential Recharge

MPO data based on DTW 1 mode

TABLE V.4.6

Effect of Full Flood Protection on Potential Recharge

Thana Code	Thana Name	District	Area km2	Flood Phase F0	F1	F2	F3	F4	Rainfall (mm/year)			Potential Recharge NFP (mm/yr)			Potential Recharge PFP1 (mm/yr)			Potential Recharge PFP2 (mm/yr)			Potential Recharge FFP (mm/yr)		
				%	%	%	%	%	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX
345	Madhabpur	Habiganj	352	0	22	39	9	30	1435	2065	3165	1566	1723	1998	765	1024	1475	523	806	1301	302	611	1150
249	Sarail	Brahmanbaria	207	18	27	29	9	18	1368	2024	2584	954	1157	1331	420	709	955	284	592	855	228	543	812
155	Brahmanbaria	Brahmanbaria	235	21	43	11	2	23	1531	2109	3218	567	809	1275	356	610	1098	322	582	1081	314	574	1073

BFP No Flood Protection

PFP1 Flood protection on F2 lnd

PFP2 Flood protection on F2 and F3 land

FFP Full flood protection

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V.4.2.3 Assessment of Development Potential without Constraints

The groundwater development potential without constraints was re-evaluated for all thanas in the study area in two ways. Firstly the potential was re-evaluated for thanas for which an improved definition of the aquifer system is available. These include eight thanas covered by the IDA DTW Project. Secondly the potential was evaluated for all thanas with the incorporation of the beneficial effect of surface water irrigation. The extent of surface irrigation was based on the existing number of LLP in each thana.

Table V.4.7 shows the unconstrained development limits for different pumping modes, derived by the MPO and derived from the new analysis. The effect of surface water irrigation on the development potential of STW and DSSTW is significant. It is less pronounced, in relative terms, for DTW.

Table V.4.8 gives a comparison between estimated net groundwater use in 1989/90 and the unconstrained resource potential based on the case which takes account of LLP irrigation. The table can be directly compared with Table V.4.4 and indicates a more realistic comparison.

V.4.3 Groundwater Resource Development Constraints

The optimum irrigation development from groundwater is constrained in a major part of the study area by the occurrence of brackish groundwater.

The land constraints have not much bearing on the groundwater resource availability but may restrict the area that can be commanded from groundwater.

The environmental impact of intensive groundwater development can at this stage only be addressed in a qualitative manner. Intensive field monitoring combined with simulation modelling would be required to quantify the possible effects. A discussion on the environmental impacts is given in Section V.4.5.

Unacceptable levels of groundwater salinity occur in the southern part of the project area, while in the central and western parts isolated occurrences of brackish water with EC values in excess of 2000 μS/cm have been observed. An analysis of the extent and the origin of the saline/brackish groundwater is given in Chapter V.3.

In the southern part of the region the presence of saline groundwater would be expected. However, the extent of the salinity in the central and western parts of the region is of considerable concern and could have important implications on the method and scope of groundwater development over half of the study area. Not only is the extent of the salinity affected area and the salinity variation with depth in need of better delineation, but also the probable cause. New data collected during the study indicates that the problem is more extensive than initially thought. Both surveys undertaken in 1984 and during the 1990/91 dry season have concentrated on sampling of DTW. Some STW were also sampled and have given a clear indication that salinity problems are much less severe in the upper part of the aquifer system from which STW and DSSTW withdraw water.

TABLE V.4.7

Comparison of Resource Potential Estimates (without any constraints)

Thana Code	Name of Thana	District	Area km2	Gross area irr. by SW %	Groundwater Potential (MCM)												Flood phases (% of gross area)				
					MPO Estimate (GW only)				SERS Estimate (GW only)				SERS Estimate (with existing SW)				F0	F1	F2	F3	F0..F3
					STW F2+F3	DSSTW F2+F3	DTW1	DTW2	STW F2+F3	DSSTW F2+F3	DTW1	DTW2	STW F2+F3	DSSTW F2+F3	DTW1	DTW2	%	%	%	%	km²
302	Madhabpur	Habiganj	279	2	13.7	39.6	140.5	96.0	13.7	39.6	140.5	96.0	13.7	39.6	140.5	96.0	17	53	18	1	247
362	Nasirnagar	Brahmanbaria	313	17	17.0	41.0	122.0	95.0	17.0	41.0	122.0	95.0	26.7	51.2	133.0	105.0	0	1	47	16	197
437	Sarail	Brahmanbaria	212	27	14.2	31.0	143.0	98.0	14.2	31.0	143.0	98.0	25.5	42.6	154.0	109.0	0	16	25	28	145
87	**Brahmanbaria**	**Brahmanbaria**	416	18	0.0	21.0	189.0	77.0	20.5	43.4	249.0	171.0	35.0	57.8	264.0	185.0	10	15	22	17	265
14	Ashuganj	Brahmanbaria	119	n.d	1.4	6.2	35.0	17.0	1.4	6.2	35.0	5.0	1.0	6.2	35.0	17.0	0	35	36	10	96
42	Bancharampur	Brahmanbaria	207	18	20.3	37.0	93.0	93.0	14.5	38.5	93.0	93.0	21.9	45.9	93.0	93.0	0	17	28	11	116
345	Nabinagar	Brahmanbaria	352	24	5.7	22.0	108.0	68.0	22.5	50.9	235.0	166.0	39.0	67.6	252.0	182.0	0	22	39	9	245
249	Kasba	Brahmanbaria	207	10	21.2	38.0	105.0	86.0	12.6	27.2	123.0	82.0	16.6	31.2	127.0	86.0	18	27	29	9	171
6	Akhaura	Brahmanbaria	93	22	6.7	23.0	70.0	66.0	6.7	23.0	70.0	66.0	11.1	27.2	70.0	70.0	18	12	23	21	69
204	**Homna**	**Comilla**	178	15	14.5	27.0	91.0	75.0	14.5	27.0	91.0	75.0	19.4	32.1	97.0	80.0	0	0	4	43	85
343	**Muradnagar**	**Comilla**	341	18	22.3	37.0	144.0	105.0	26.4	51.3	227.0	150.0	38.4	63.4	240.0	163.0	3	17	25	37	283
88	Brahmanpara	Comilla	119	14	16.9	32.0	77.0	66.0	7.4	14.1	61.0	39.0	10.6	17.3	64.0	42.0	1	17	63	5	102
125	Daudkandi	Comilla	375	28	15.9	54.1	137.0	89.0	22.1	40.1	182.0	131.0	42.1	60.2	203.0	152.0	0	0	5	57	231
130	Debidwar	Comilla	235	8	23.4	38.2	135.0	91.0	17.2	38.2	135.0	91.0	20.0	38.2	135.0	91.0	2	41	30	10	194
90	Burichang	Comilla	181	6	15.8	26.3	79.0	61.0	15.8	26.3	79.0	61.0	17.7	28.2	81.0	63.0	7	47	26	1	147
94	Chandina	Comilla	202	6	8.4	19.0	82.0	57.0	8.4	19.0	82.0	57.0	10.8	21.4	85.0	59.0	3	29	10	41	167
53	Barura	Comilla	240	2	13.6	28.0	120.0	75.0	13.6	28.0	120.0	75.0	14.5	28.9	120.0	76.0	3	32	47	0	195
271	Kotwali	Comilla	277	6	32.4	53.5	135.0	111.0	32.4	53.5	135.0	111.0	35.6	56.7	138.0	114.0	19	43	19	0	225
287	Laksham	Comilla	427	12	21.8	42.0	190.0	113.0	21.8	42.0	190.0	113.0	31.5	52.1	200.0	123.0	4	27	42	8	348
111	Chouddagram	Comilla	271	5	10.9	22.6	88.0	54.0	10.9	22.6	88.0	54.0	13.4	25.0	91.0	57.0	16	52	13	1	221
356	Nangolkot	Comilla	235	3	17.2	33.9	106.0	97.0	17.2	33.9	157.0	97.0	18.5	35.2	158.0	98.0	7	55	16	2	190
312	Matlab	Chandpur	409	11	0.0	32.0	147.0	92.0	0.0	32.0	147.0	92.0	12.9	40.5	157.0	101.0	0	2	53	12	274
225	Kachua	Chandpur	238	12	7.6	21.0	89.0	53.0	7.6	21.0	89.0	53.0	12.4	25.6	94.0	58.0	2	17	47	15	191
96	**Chandpur**	**Chandpur**	287	12	16.2	34.0	164.0	102.0	16.2	34.0	164.0	102.0	22.8	40.6	171.0	108.0	2	20	30	1	150
195	Hajiganj	Chandpur	157	27	4.9	11.0	56.0	27.0	4.9	11.0	56.0	27.0	12.7	18.7	64.0	35.0	4	0	58	8	110
447	Shahrasti	Chandpur	186	13	5.6	16.0	89.0	38.0	5.6	16.0	89.0	38.0	10.2	20.8	94.0	43.0	6	12	43	14	140
155	Faridganj	Chandpur	235	41	7.7	18.9	76.0	55.0	3.3	17.0	107.0	55.0	5.0	18.8	109.0	57.0	5	15	26	0	86
194	**Haimchar**	**Lakshmipur**	186	5	3.3	17.0	107.0	55.0	3.3	17.0	107.0	55.0	5.0	18.8	109.0	57.0	5	15	26	0	86
411	Ramganj	Lakshmipur	170	16	7.0	14.0	52.0	28.0	7.0	14.0	52.0	28.0	11.8	19.0	57.0	33.0	13	20	33	13	134
405	Raipur	**Lakshmipur**	202	4	3.1	17.0	59.0	39.0	3.1	17.0	59.0	39.0	4.9	18.6	60.0	41.0	11	49	7	0	135
288	**Lakshmipur**	**Lakshmipur**	515	12	16.0	36.3	191.0	82.0	16.0	36.3	191.0	82.0	27.3	47.8	202.0	93.0	6	47	21	0	379
413	Ramgati	Lakshmipur	650	0	0.0	25.2	147.0	70.0	0.0	25.2	147.0	70.0	0.0	25.2	147.0	70.0	0	56	6	0	405
102	Chatkhil	Noakhali	134	33	4.4	9.5	35.0	21.0	4.4	9.5	35.0	21.0	11.5	16.8	41.0	28.0	4	32	31	8	99
58	**Begumganj**	**Noakhali**	409	28	14.9	28.0	93.0	57.0	14.9	28.0	93.0	57.0	32.2	45.8	110.0	74.0	2	10	62	1	309
445	Senbag	Noakhali	160	13	8.1	14.0	50.0	30.0	8.1	14.0	50.0	30.0	11.7	17.7	54.0	34.0	2	36	39	0	124
459	Sudharam	Noakhali	828	2	17.4	49.5	207.0	108.0	17.4	49.5	207.0	108.0	20.4	52.5	203.0	104.0	0	59	14	1	609
116	Companiganj	Noakhali	189	2	11.7	32.5	123.0	68.0	11.7	32.5	123.0	68.0	12.2	33.0	124.0	69.0	0	44	6	0	94
120	Daganbhuiya	Feni	132	12	5.1	10.5	43.0	23.0	5.1	10.5	43.0	23.0	8.1	13.5	46.0	26.0	1	42	33	3	103
465	Sonagazi	Feni	259	4	15.1	26.6	139.0	81.0	15.1	26.6	139.0	81.0	17.0	28.5	135.0	78.0	0	53	8	0	158
161	Feni	Feni	221	22	9.1	16.0	95.0	44.0	9.1	16.0	95.0	44.0	18.4	29.0	105.0	54.0	3	61	7	3	164
104	Chagalnaiya	Feni	157	44	3.9	9.7	41.0	20.0	3.9	9.7	41.0	20.0	16.2	22.1	54.0	32.0	24	65	1	0	141
166	Fulgazi	Feni	108	31	2.1	7.6	53.0	22.0	2.1	7.6	53.0	22.0	8.2	13.8	57.0	28.0	27	63	2	0	99
388	Parsuram	Feni	72	31	4.6	7.4	39.0	22.0	4.6	7.4	39.0	22.0	8.8	11.7	30.0	30.0	40	52	1	1	67

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TABLE V.4.8

Comparison of Actual (1989/90) Groundwater Resource Utilisation Versus SERS Estimate of Resource Potential

Thana Code	Thana Name	District	Area Km²	NCA Km²	Ratio %	Existing minor irrigation (Nr)					GW (MCM)	SERS GW Potential (MCM)			
						DTW	STW	LLP	eq DT	eq 2cu		DSSTW	DTW+ DSSTW	DTW1	DTW2
302	Madhabpur	Haibiganj	279	247	89	65	193	39	113	144	11	30	40	141	96
362	Nasirnagar	Brahmanbaria	313	256	82	24	413	425	127	467	13	43	51	133	105
437	Sarail	Brahmanbaria	212	177	83	92	351	444	180	535	18	36	43	154	109
87	Brahmanbaria	Brahmanbaria	416	357	86	169	697	575	343	803	35	12	58	264	185
14	Ashuganj	Brahmanbaria	119	97	82	n.d	n.d	n.d	n.d	n.d	n.d	5	6	35	17
42	Bancharampur	Brahmanbaria	207	175	85	0	475	293	119	353	12	37	46	93	93
345	Nabinagar	Brahmanbaria	352	282	80	19	210	671	72	608	7	47	68	252	182
249	Kasba	Brahmanbaria	207	178	86	98	413	157	201	327	20	22	31	127	86
6	Akhaura	Brahmanbaria	93	81	87	13	159	159	53	180	5	18	27	70	70
204	Homna	Comilla	178	137	77	0	378	214	95	266	10	32	32	97	80
343	Muradnagar	Comilla	341	289	85	28	152	474	66	445	7	48	63	240	163
88	Brahmanpara	Comilla	119	106	89	1	276	126	70	171	7	15	17	64	42
125	Daudkandi	Comilla	375	315	84	49	218	823	104	762	10	60	60	203	152
130	Debidwar	Comilla	235	194	83	51	352	143	139	253	14	27	38	135	91
90	Burichang	Comilla	181	137	76	125	540	80	260	324	26	22	28	81	63
94	Chandina	Comilla	202	167	83	113	217	96	167	244	17	17	21	85	59
53	Barura	Comilla	240	196	82	68	682	31	239	263	24	23	29	120	76
271	Kotwali	Comilla	277	219	79	282	646	135	444	552	45	44	57	138	114
287	Laksham	Comilla	427	353	83	168	480	400	288	608	29	40	52	200	123
111	Chouddagram	Comilla	271	224	83	163	265	101	229	310	23	18	25	91	57
356	Nangolkot	Comilla	235	182	77	28	165	60	69	117	7	25	35	158	98
312	Matlab	Chandpur	409	274	67	0	182	340	46	318	5	29	41	157	101
225	Kachua	Chandpur	238	191	80	49	17	228	53	236	5	21	26	94	58
96	Chandpur	Chandpur	287	145	51	10	5	275	11	231	1	34	41	171	108
195	Hajiganj	Chandpur	157	110	70	1	3	329	2	265	0	15	19	64	35
447	Shahrasti	Chandpur	186	141	76	38	3	182	39	184	4	14	21	94	43
155	Faridganj	Chandpur	235	182	77	0	0	745	0	596	0	31	37	95	59
194	Haimchar	Chandpur	186	85	46	0	0	77	0	62	0	9	19	109	57
411	Ramganj	Lakshmipur	170	135	79	0	6	206	2	166	0	15	19	57	33
405	Raipur	Lakshmipur	202	125	62	0	1	70	0	56	0	11	19	60	41
288	Lakshmipur	Lakshmipur	515	379	74	2	17	470	6	382	1	36	48	202	93
413	Ramgati	Lakshmipur	650	366	56	0	0	20	0	16	0	16	25	147	70
102	Chatkhil	Noakhali	134	100	75	0	2	349	1	280	0	14	17	41	28
58	Begumganj	Noakhali	409	309	76	0	197	887	49	759	5	41	46	110	74
445	Senbagh	Noakhali	160	124	78	13	118	164	43	174	4	16	18	54	34
459	Sudharam	Noakhali	828	816	99	0	0	100	0	80	0	41	53	203	104
116	Companiganj	Noakhali	189	190	101	0	1	26	0	21	0	26	33	124	69
120	Daganbhuiyan	Feni	132	103	78	13	19	120	18	114	2	12	14	46	26
465	Sonagazi	Feni	259	139	54	5	2	75	6	66	1	24	29	133	78
161	Feni	Feni	221	165	75	59	116	382	88	394	9	23	29	105	54
104	Chhagalnaiya	Feni	157	120	76	0	15	500	4	404	0	19	22	54	32
166	Fulgazi	Feni	108	80	74	8	90	200	31	191	3	11	14	57	28
388	Parsuram	Feni	72	60	83	8	90	200	31	191	3	10	12	30	26

40 acres per 2 susecs (3.54 l/s/ha).
625 mm net irrigation demand

In the coastal zone groundwater salinity makes STW large exploitation not feasible. Occurrence of superficial bodies of fresh water should be reserved completely for rural water supply. The area thus constrained from all shallow groundwater irrigation development is shown in Figure V.4.2.

In the central and western parts of the study area DTW development is constrained by groundwater salinity. Areas with salinities in excess of 2000 μS/cm should be totally excluded from DTW development. Areas with salinities below 1000 and 2000 μS/cm may be included. Development potential for STW and DSSTW is much less constrained by salinity although this requires additional confirmation from field surveys during the next dry season.

In the short term the areas identified to have unacceptable groundwater salinity, i.e. in excess of 2000 μS/cm, should be excluded from DTW development. STW development should be allowed if water quality in the upper part of the aquifer is acceptable, particularly if the upper part is isolated from the main aquifer by layers of clay and silt. The electrolytic conductivity of DTW is shown in Figure V.4.3.

The development potential for STW and DSSTW is locally constrained by the occurrence of thick deposits of clays and silts which makes access to any screenable aquifer material difficult or even impossible. The potential areas for this mode are illustrated in Figure V.4.4.

The irrigable areas used in the assessment may be an overestimate but more precise data was not available at the time of derivation of the resource potentials. It should also be taken into consideration that the types of irrigated crop can have a marked effect on the extent of the area that can be irrigated from groundwater.

V.4.4 Development Potential with Constraints

V.4.4.1 Development Potential

Table V.4.9 shows the unconstrained groundwater development potential based on the re-evaluation conducted during the present study. Account is thereby given of the beneficial effect on development potential of existing LLP irrigation. The estimates of development potential also take account on potable reserves based on population forecast for year 2000 and a per capita consumption of 45 l/s. The constraint is only applied for a 150 day period, which roughly coincides with the dry season irrigation period.

In view of the present knowledge of the extent of the occurrence and potential of the main confined aquifer it would be prudent to exclude further groundwater development with force model units (DTW) in the thanas marked in Table V.4.9.

Figure V.4.2

Salinity Constraints in the Study Area

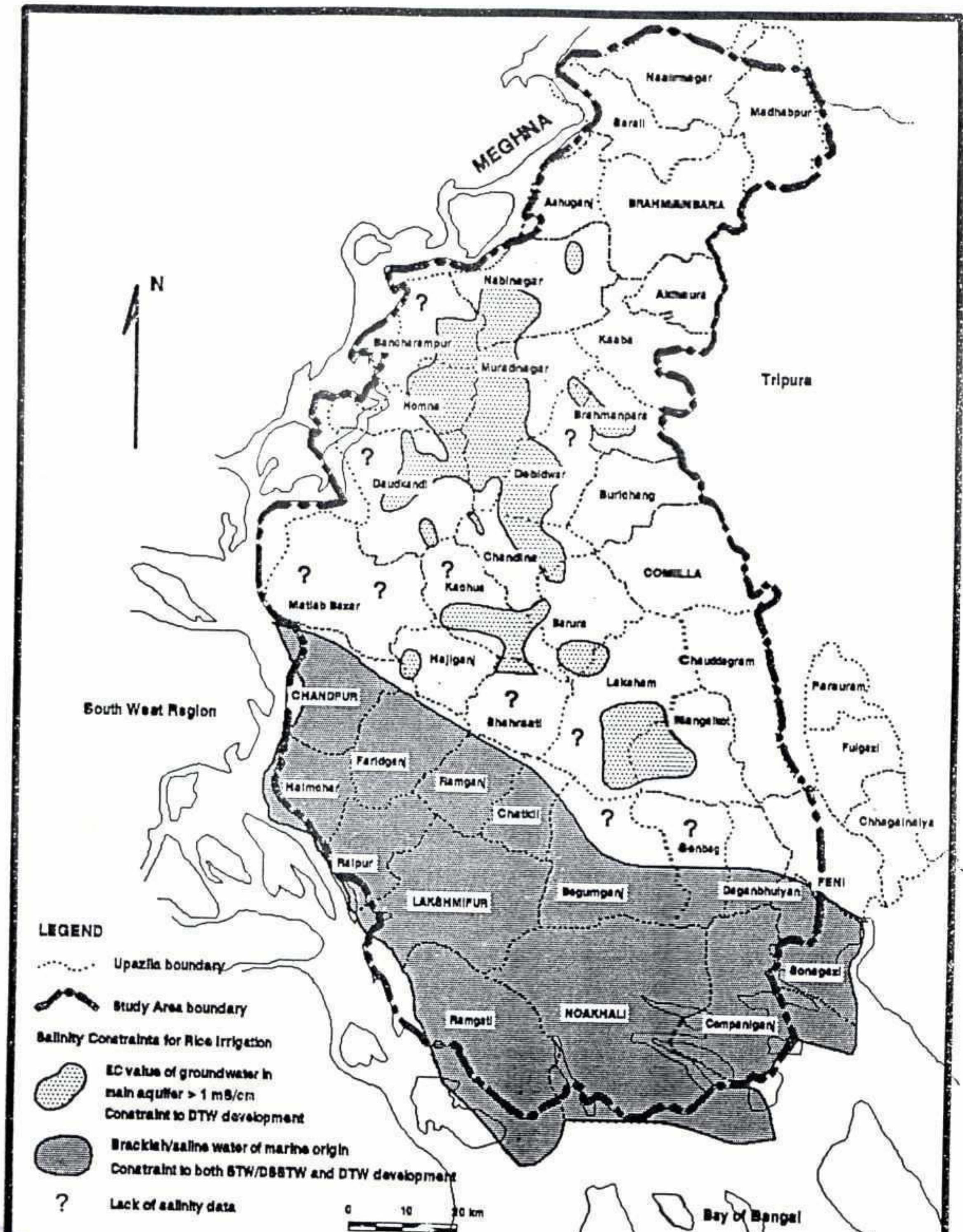

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Figure V.4.3

Electrolytic Conductivity of DTWs in the Study Area

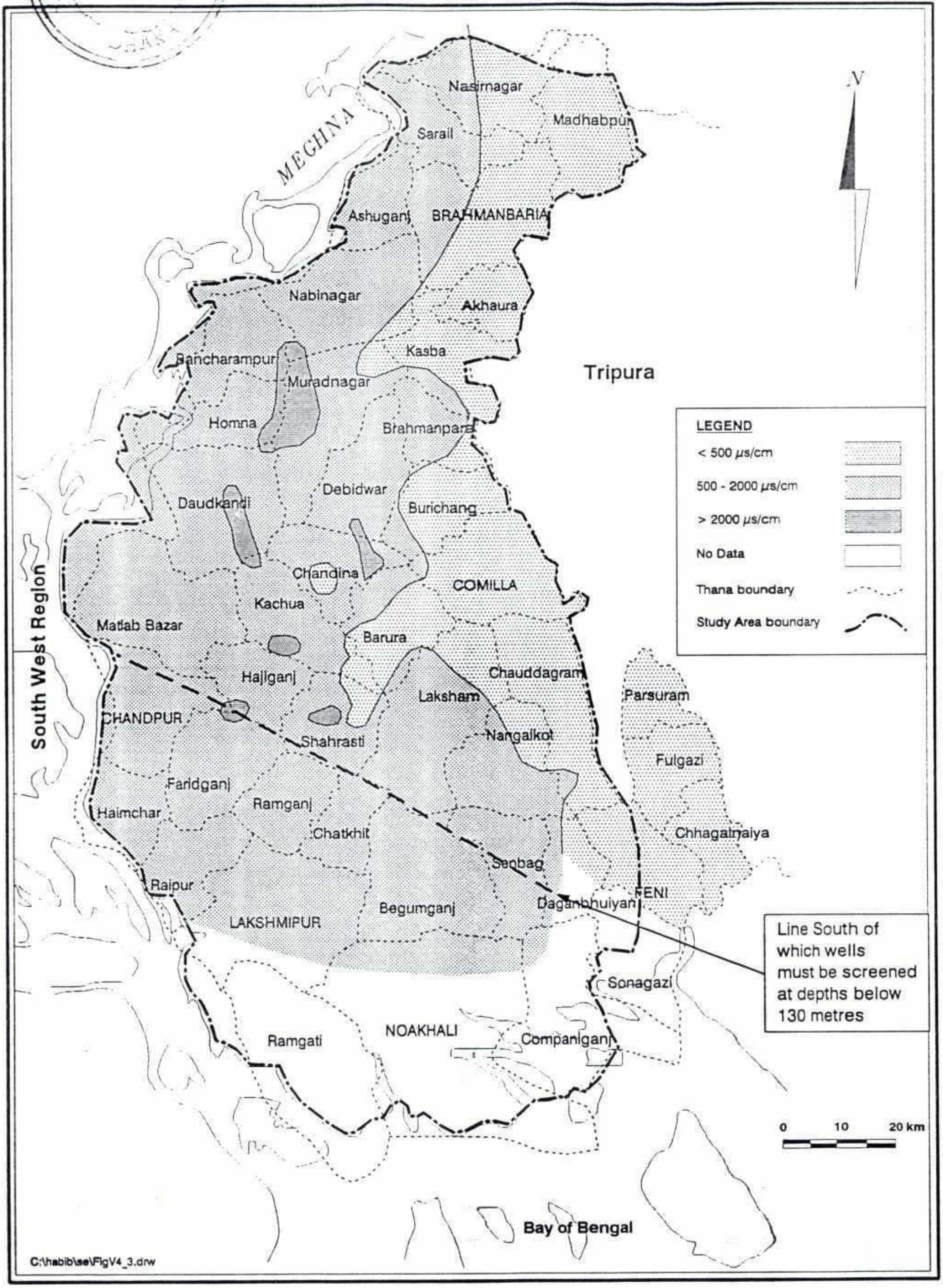

Figure V.4.4

Suction Mode Only - Constrained Development Levels

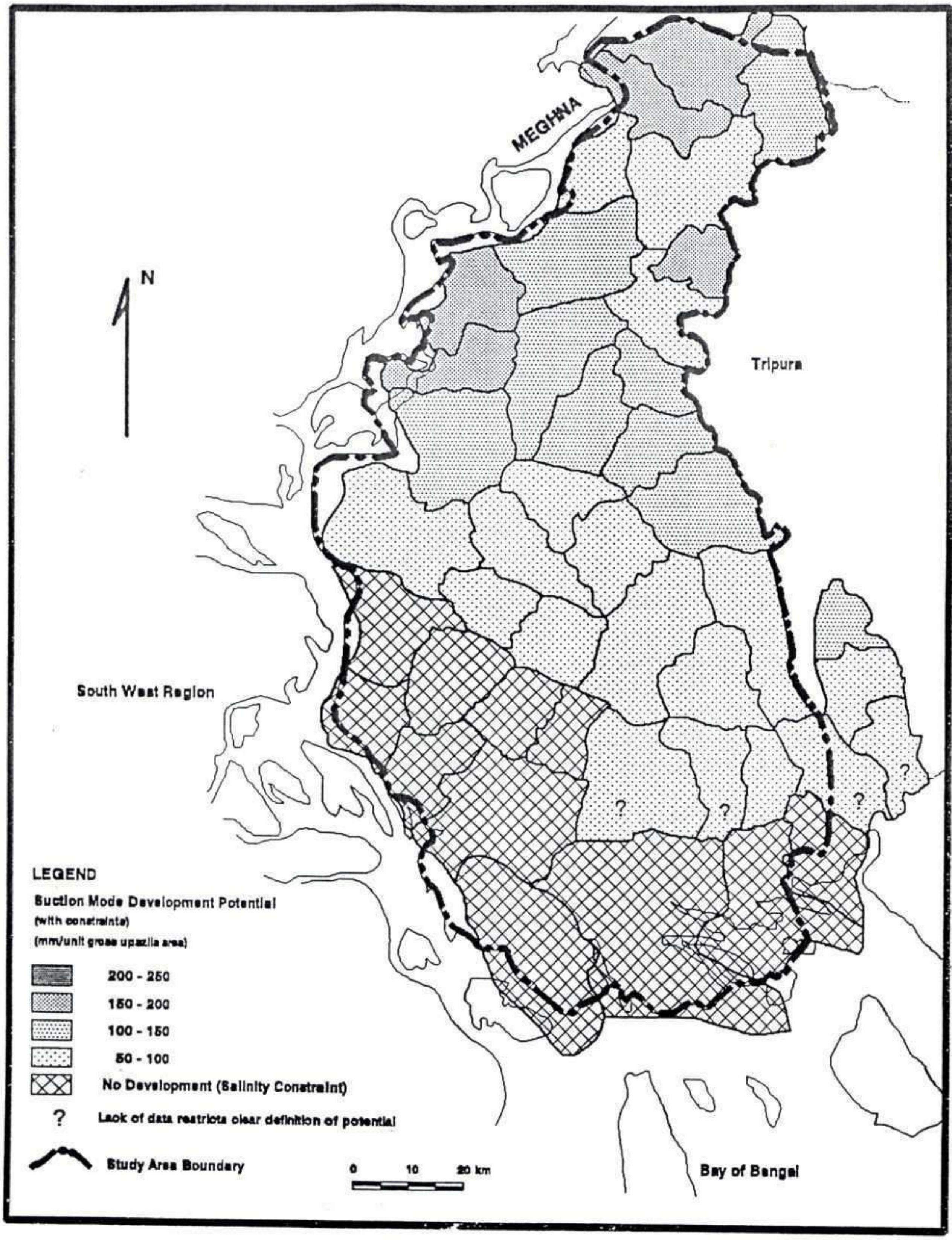

TABLE V.4.9

Groundwater Development Potential (estimates without any constraints)

	Name of Thana	District	Area km2	Gross area irr. by SW %	Population yr 2000 (*1000)	GW Reserve Mm³	SERS GW Potential (MCM) (with existing SW) DSSTW All land	FMTW	Flood Phases (% of gross area) F0 %	F1 %	F2 %	F3 %	F0...F3 km²	Net Area for GW F0+F1 ha	F2+F3 ha	Tubewell Potential (number of units) Mode 1 DSSTW	Mode 2 DTW	Groundwater Potential Percentage of Net Area for GW Irrigated Tubewells DSSW	FMTW
1	Madhabpur	Habiganj	279	2	200	1.4	29.6	140.5	17	53	18	1	247	17062	4602	1117	1338	21	100
2	Nasirnagar	Brahmanbaria	313	17	297	2.0	51.2	133.0	0	1	47	16	197	107	12320	1945	768	63	100
3	Sarail	Brahmanbaria	212	27	304	2.1	36.3	154.0	0	16	25	28	145	1745	5622	1354	455	74	100
4	Brahmanbaria	Brahmanbaria	416	18	708	4.8	43.5	264.0	10	15	22	17	265	6434	9965	1531	1013	38	100
5	Ashuganj	Brahmanbaria	119	n.d.	n.d.	0.0	4.5	35.0	0	35	36	10	96	3749	4912	178	346	8	65
6	Bancharampur	Brahmanbaria	207	18	334	2.3	36.6	93.0	0	17	28	11	116	2021	4723	1358	417	81	100
7	Nabinagar	Brahmanbaria	352	24	542	3.7	46.9	252.0	0	22	39	9	245	4235	9369	1710	840	51	100
8	Kasba	Brahmanbaria	207	10	285	1.9	22.3	127.0	18	27	29	9	171	7210	6077	806	821	25	100
9	Akhaura	Brahmanbaria	93	22	165	1.1	17.9	70.0	18	12	23	21	69	1708	2456	664	257	65	100
10	Homna	Comilla	178	15	304	2.1	32.1	97.0	0	0	4	43	85	0	4956	1188	306	97	100
11	Muradnagar	Comilla	341	18	571	3.9	47.9	240.0	3	17	25	37	283	4756	14566	1741	1194	36	100
12	**Brahmanpara**	**Comilla**	119	14	192	1.3	14.7	64.0	1	17	63	5	102	1504	5982	530	462	29	100
13	**Daudkandi**	**Comilla**	375	28	633	4.3	60.2	203.0	0	0	5	57	231	0	10331	2211	638	87	100
14	Debidwar	Comilla	235	8	420	2.8	26.7	135.0	2	41	30	10	194	8082	7470	944	961	25	100
15	Burichang	Comilla	181	6	293	2.0	21.8	81.0	7	47	26	1	147	8041	4123	784	751	26	100
16	**Chandina**	**Comilla**	202	6	327	2.2	17.4	85.0	3	29	10	41	167	5394	8394	601	818	18	96
17	**Barura**	**Comilla**	240	2	387	2.6	23.1	120.0	3	32	47	0	195	7175	9902	810	1055	19	100
18	Kotwali	Comilla	277	6	635	4.3	44.1	138.0	19	43	19	0	225	14178	4400	1574	1148	34	100
19	Laksham	Comilla	427	12	632	4.3	39.6	200.0	4	27	42	8	348	10171	16048	1397	1620	22	100
20	Chouddagram	Comilla	271	5	395	2.7	18.1	91.0	16	52	13	1	221	15325	3191	610	873	13	78
21	**Nangolkot**	**Comilla**	235	3	333	2.2	24.7	158.0	7	55	16	2	190	12743	3654	888	1013	22	100
22	Matlab	Chandpur	409	11	666	4.5	28.8	157.0	0	2	53	12	274	738	19456	961	1247	19	100
23	Kachua	Chandpur	238	12	367	2.5	20.5	94.0	2	17	47	15	191	3373	10943	713	884	20	100
24	Chandpur	Chandpur	287	12	514	3.5	33.8	171.0	2	20	30	1	150	4148	5891	1199	620	48	100
25	Hajiganj	Chandpur	157	27	322	2.2	15.1	64.0	4	0	58	8	110	342	5274	511	347	37	100
26	Shahrasti	Chandpur	186	13	239	1.6	14.4	94.0	6	12	43	14	140	2498	7711	506	631	20	100
27	Faridganj	Chandpur	235	41	476	3.2	30.7	95.0	21	43	11	2	182	5561	1145	1087	414	66	100
28	Haimchar	Lakshmipur	186	5	143	1.0	8.6	109.0	6	15	26	0	86	3002	3810	302	421	18	100
29	Ramganj	Lakshmipur	170	16	301	2.0	14.7	87.0	13	20	33	13	134	3844	5512	501	648	22	91
30	Raipur	Lakshmipur	202	4	284	1.9	11.1	60.0	11	49	7	0	135	10263	1117	363	574	13	82
31	Lakshmipur	Lakshmipur	515	12	723	4.9	35.8	202.0	6	47	21	0	379	20060	7831	1222	1723	18	100
32	Ramgati	Lakshmipur	650	0	402	2.7	15.8	147.0	0	56	6	0	405	32795	3662	517	1428	6	63
33	Chatkhil	Noakhali	134	33	276	1.9	13.7	41.0	4	32	31	8	99	2170	2362	468	280	42	100
34	Begumganj	Noakhali	409	28	890	6.0	40.8	110.0	2	10	62	1	309	2605	13753	1376	1010	34	100
35	Senbag	Noakhali	160	13	272	1.8	15.5	54.0	2	36	39	0	124	4430	4642	540	516	24	92
36	Sudharam	Noakhali	828	2	737	5.0	40.6	203.0	0	59	14	1	609	42697	10486	1408	1937	11	60
37	Companiganj	Noakhali	189	2	209	1.4	25.5	124.0	0	44	6	0	94	7161	962	952	502	47	100
38	Daganbhuiya	Feni	132	12	245	1.7	11.5	46.0	1	42	33	3	103	4234	3488	389	438	20	92
39	Sonagazi	Feni	259	4	274	1.8	23.7	133.0	0	53	8	0	158	11456	1687	864	812	27	100
40	Feni	Feni	221	22	417	2.8	22.8	105.0	3	61	7	3	164	8524	1353	790	610	32	100
41	Chagalnaiya	Feni	157	44	210	1.4	18.6	54.0	24	65	1	0	141	5727	66	679	358	47	100
42	Fulgazi	Feni	108	31	149	1.0	10.5	57.0	27	63	2	0	99	5454	130	375	345	27	100
43	Parsuram	Feni	72	31	77	0.5	10.0	30.0	40	52	1	1	67	3749	82	375	237	40	100
44																			

Net Area for GW = 90% of area of F0...F3 land minus area area irrigated by LLP

45 l/d per capita consumption

40 acres per DTW

10 acres per STW

625 mm net irrigation demand

90 ratio net/gross irrigable (%)

Mode 1 SMTW

Mode 2 0.5>1 cusec FMTW

SMTW: Suction Mode Tubewells

FMTW: Force Mode Tubewells

[Open box] Salinity Constraints

[Shaded box] DTW Potential to be defined by investigation of confined aquifer

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STW and DSSTW development is constrained by groundwater salinity in the southern part of the study area. In thanas such as Matlab Bazar, Kachua, Faridganj and Shahrasti STW/DSSTW development may be constrained by the occurrence of thick surface clay/silt deposits. This is, however, not fully confirmed from available data. Other thanas may have localised problems with surface clay/silt deposits. The constrained areas are shown in Figure V.4.4.

For DSSTW a maximum allowable depth to pumping level was set at 9.0 m, while for DTW (both types) this was set at 20.0 m below ground surface. The thanas that are marked in Figures V.4.2 and V.4.4 with question marks indicate a high degree of uncertainty with respect to the resource potential estimates. This refers particularly to STW/DSSTW development potentials.

In all figures the development potential is expressed in terms of the depth of water available for groundwater irrigation, for the gross area, i.e. irrigable areas of F0 to F3 land which are not served by LLP irrigation.

Figure V.4.5 shows the current (AST/CIDA 1991) extent of groundwater development, and Table V.4.10 shows the present total irrigation development including all forms of surface and groundwater.

V.4.4.2 Uneven Distribution of Development

One of the basic principle that underly the derivation of groundwater development potential is the assumption of an even distribution of irrigation development over a thana area. In reality this will, however, seldom occur; LLP areas area often to a large degree contiguous and associated with the low lands (F2 and F3 lands).

The availability of surface irrigation allows for additional recharge to the aquifer and thus maintains water levels at a level which allows for more intensive suction mode (STW) development within and adjacent to the LLP irrigated areas.

At distance from LLP irrigated areas it is in most cases likely that one has to resort to the use of force mode units (DTW) in order to reach a similar level of development.

Figure V.4.5

Present Groundwater Irrigation in the Study Area

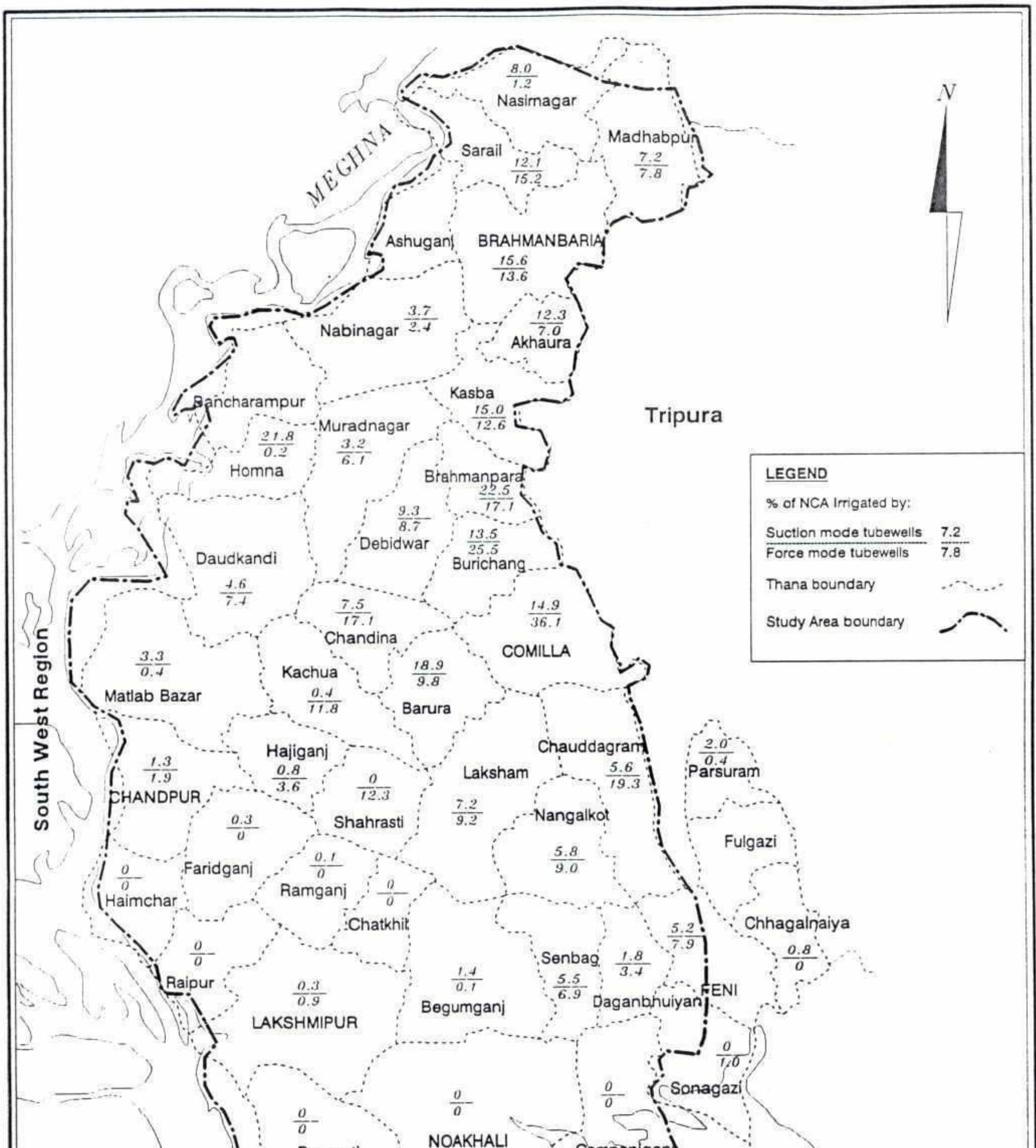

TABLE V.4.10

Minor Irrigation Inventory for 1991

Thana	STW nr	DSSTW nr	MTW nr	DTW nr	LLP < 1 cs nr	LLP 1 cs nr	LLP 2 cs nr	LLP 3 cs nr	STW ha	DSSTW ha	MTW ha	DTW ha	LLP < 1 cs ha	LLP 1 cs ha	LLP 2 cs ha	LLP 3 cs ha	Tradi-ional ha	Irrigated Area ha	Surface Water ha	Suction Mode GW ha	Ground-water ha	Total as a % of NCA
MADHABPUR	185	0	3	54	1	26	2	0	1 772	0	1	1 936	0	263	28	0	3 708	7 709	4 000	1 773	3 709	31%
NASIRNAGAR	316	0	0	11	2	89	294	16	2 052	0	0	308	6	931	4 949	465	2 168	10 880	8 520	2 052	2 359	42%
SARAIL	284	0	10	92	11	222	257	9	2 130	0	8	2 701	87	3 213	5 822	445	1 603	16 009	11 171	2 138	4 838	90%
ASHUGANJ																		4239	2602	894	1637	54%
BRAHMANBARIA	956	2	402	187	21	203	343	1	5 462	8	107	4 844	143	1 946	5 877	77	5 013	23 478	13 056	5 578	10 421	66%
AKHAURA	156	0	14	23	50	42	100	1	993	0	4	567	118	263	1 225	53	1 860	5 083	3 519	997	1 564	63%
KASBA	401	0	55	92	8	52	133	1	2 614	0	53	2 240	32	488	2 094	283	1 633	9 438	4 531	2 667	4 907	53%
NABINAGAR	128	0	41	34	64	131	446	3	1 010	0	24	693	352	1 445	8 297	107	1 100	13 027	11 300	1 034	1 727	46%
BANCHARAMPUR	411	0	442	13	1	45	208	0	1 937	0	79	230	1	324	2 929	0	1 735	7 236	4 990	2 016	2 246	41%
HOMNA	407	0	4 323	1	50	108	138	0	2 279	0	708	20	156	867	1 708	0	580	6 319	3 312	2 987	3 008	46%
DAUDKANDI	196	0	263	84	37	249	482	4	1 372	0	79	2 324	247	1 995	7 523	219	642	14 401	10 626	1 451	3 775	46%
MURADNAGAR	106	0	195	62	11	102	257	5	860	0	72	1 756	34	997	5 157	342	505	9 723	7 035	932	2 688	34%
DEBIDWAR	393	0	1	82	27	28	44	2	1 795	0	0	1 688	63	420	852	81	347	5 246	1 762	1 795	3 483	27%
BRAHMANPARA	318	0	1	68	22	9	46	2	2 389	0	0	1 808	79	93	585	57	137	5 148	951	2 389	4 197	49%
BURICHANG	406	7	3	126	3	0	56	0	1 807	38	0	3 499	20	0	1 147	0	250	6 761	1 417	1 815	5 344	49%
COMILLA	410	103	2	300	11	27	84	0	2 454	799	1	7 926	66	202	1 665	0	365	13 477	2 298	3 253	11 179	62%
CHAUDDAGRAM	218	0	28	193	13	21	78	0	1 236	0	10	4 336	60	156	1 157	0	1 319	8 275	2 692	1 246	5 583	37%
NANGALKOT	167	0	74	69	43	31	30	0	998	0	63	1 641	170	208	425	0	1 024	4 529	1 827	1 061	2 702	25%
LAKSAM	496	0	2	178	457	157	122	3	2 558	0	1	3 236	2 140	1 270	2 655	105	1 390	13 354	7 559	2 559	5 794	38%
BARURA	651	0	172	86	61	0	0	0	3 624	0	81	1 928	245	0	0	0	314	6 193	559	3 705	5 633	32%
CHANDINA	256	2	7	134	33	24	25	0	1 244	15	2	2 848	50	187	429	0	304	5 079	970	1 261	4 109	30%
KACHUA	8	0	103	88	140	92	51	12	45	0	25	2 254	376	458	556	170	561	4 445	2 120	71	2 325	23%
MATLAB	158	0	29	6	80	306	102	0	881	0	15	107	212	3 364	1 575	0	5 247	11 402	10 398	896	1 003	42%
CHANDPUR	22	0	4	16	35	65	160	1	182	0	4	276	241	510	1 987	121	458	3 779	3 317	186	462	26%
HAJIGANJ	14	0	2	12	37	128	151	2	82	0	1	312	149	1 064	3 715	22	352	5 697	5 303	83	395	52%
SHAHRASTI	2	0	11	65	84	87	68	1	4	0	2	1 727	314	731	1 444	47	242	4 512	2 779	6	1 733	32%
FARIDGANJ	9	0	0	0	2	83	621	1	61	0	0	0	6	611	10 338	53	926	11 995	11 934	61	61	66%
HAIMCHAR	0	0	0	0	0	18	63	0	0	0	0	0	0	117	677	0	42	836	836	0	0	10%
RAIPUR	0	0	0	0	56	54	388	0	0	0	0	0	123	229	5 005	0	32	5 389	5 389	0	0	43%
RAMGANJ	4	0	4	0	321	144	148	7	14	0	1	0	972	924	1 933	113	329	4 286	4 271	15	15	32%
LAKSMIPUR	18	0	3	14	211	171	413	0	101	0	0	342	773	1 519	6 490	0	1 064	10 289	9 846	102	444	27%
RAMGATI	0	0	0	0	0	7	0	0	0	0	0	0	0	49	0	0	2	51	51	0	0	0%
NOAKHALI	0	0	21	0	84	47	6	1	0	0	17	0	1 475	1 326	287	73	1 594	4 772	4 755	17	17	6%
BEGUMGANJ	52	0	19	1	549	192	55	1	397	0	49	28	2 199	1 418	762	51	4 219	9 122	8 648	446	474	30%
CHATKHIL	0	0	4	0	428	24	2	0	0	0	1	0	1 871	153	14	0	157	2 196	2 195	1	1	22%
SENBAG	97	0	4	30	144	29	4	0	685	0	1	849	525	130	36	0	416	2 642	1 107	686	1 535	21%
COMPANIGANJ	0	0	2	0	6	2	0	0	0	0	1	0	3	1	0	0	45	49	49	1	1	0%
SONAGAZI	3	0	16	7	48	30	79	0	1	0	6	138	80	240	1 728	0	112	2 305	2 161	7	144	17%
DAGANBHUIYA	24	0	2	13	79	24	69	0	183	0	0	355	138	169	1 257	0	112	2 212	1 675	183	538	21%
FENI	135	0	23	54	61	52	282	0	847	0	8	1 300	116	355	5 288	0	350	8 264	6 109	855	2 155	50%
Total	7 407	114	6 285	2 195	3 291	3 121	5 807	73	44 069	859	1 425	54 217	13 643	28 637	97 619	2 883	42 257	289 848	187 641	47 247	102 207	34%
									5.9	7.5	0.23	24.7	4.1	9.2	16.8	39.5						

Source: AST/CIDA (1991)

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Although the model simulations indicated that at maximum development levels, suction mode units are no longer operational, in practice there will always be areas were DSSTW or even STW are still operating. These areas would be located within or very near to contiguous areas of surface water irrigation, or near surface water bodies and rivers.

V.4.5 Environmental Impact of Groundwater Development

V.4.5.1 Introduction

The environmental impacts of groundwater development are discussed in a qualitative manner in the following sections. The importance of these impacts is at the present time difficult to quantify due to the lack of basic monitoring data. The potential impacts discussed relate purely to the dynamics of the groundwater system.

The environmental impacts of large scale groundwater development may include:

- reduced drainage to low lands;
- implications of flood protection on the groundwater balance of the high lands, with particular respect to the possible increased need for supplementary irrigation during the monsoon season;
- effects on river base flows, and
- effects on rural water supply.

V.4.5.2 Reduced Drainage to Low Lands

Localised drainage is strongly controlled by local relief. Elevation differences between F0 and F4 land can be in excess of 3 m.

Following the monsoon season a rapid decline in flood levels occurs with groundwater levels on the high land areas lagging behind. Localised differences in groundwater levels thus cause a lateral drainage from the high land to the low land areas. The quantification of this drainage is possible with simulation models provided that the controlling parameters are well defined.

It is conceivable that surface water in the low land areas, which is used for irrigation of local boro, originates to a significant extent from local drainage of high land areas.

With the development of groundwater a more rapid decline of water levels in the high land areas will occur which will reduce the drainage to the low lands. Conditions may even alter to the extent that the surface water bodies in the low land areas start to contribute to the aquifer, i.e. a reversal of the natural process.

The quantification of local drainage will require extensive monitoring of selected pilot areas for a number of years. Of particular interest would be the areas that are anticipated to experience a rapid growth in tubewell development in the near future and also areas that are already intensively developed.

Collection of field data should be guided by simulation modelling. The models, following calibration, would form useful tools to predict the implications of further increase in groundwater development.

V.4.5.3 Implications of Flood Protection

Extensive flood protection will cause the type of drainage described in Section V.4.5.2 to occur during the monsoon season. This may have an implication on the rice crops grown on the high land areas, particularly during dry years.

The consequence of this drainage may be the need for supplementary irrigation during the monsoon season, particularly for T. aman.

The model developed for the present study is capable of quantifying the need for supplementary irrigation. The preparation of the model runs will, however, require information on the irrigation requirements of monsoon crops and their sensitivity to drought conditions.

V.4.5.4 Effect of Groundwater Development on Rural Water Supply

The optimum development of groundwater resources requires in nearly all cases the use of village hand tubewells fitted with Tara pumps, which allow for a maximum lift of 15 m.

This 15 m is measured from village level, and was used by the MPO to identify possible constraints on optimum development of the groundwater resource. The results of the analysis are shown in Table V.4.11. Maximum development levels for one cusec force mode units generally exceed the MPO constraint, while for two cusec force mode development the constraint is of minor significance.

It is of great importance that the response of the water table in village areas is continuously monitored in thanas which experience a rapid increase in tubewell development. Contingency planning for replacement of village hand tubewells presently fitted with Nr 6 pumps needs to be considered.

V.4.5.5 Effect of Groundwater Development on Base Flow to Rivers

The implications of additional groundwater development on base flow to rivers is difficult to assess in quantitative terms without extensive modelling. The use of surface water (LLP) for irrigation along the river banks will in effect reduce the impact of further groundwater development at distance from the river. The actual river flow, during the dry season, would, however, be most strongly affected by increase in LLP development.

TABLE V.4.11

Effect of Village Handpump Constraint (15 m lift) on Groundwater Potential

Thana Code	Thana Name	District	Area km²	MPO GW Potential DTW1 Mm3	MPO GW Potential DTW2 Mm3	Constraint for HTW Mm3
302	Madhabpur	Haibiganj	279	141	96	113
362	Nasirnagar	Brahmanbaria	313	122	95	104
437	Sarail	Brahmanbaria	212	143	98	97
87	Brahmanbaria	Brahmanbaria	416	189	77	166
14	Ashuganj	Brahmanbaria	119	35	17	28
42	Bancharampur	Brahmanbaria	207	93	93	93
345	Nabinagar	Brahmanbaria	352	108	68	84
249	Kasba	Brahmanbaria	207	105	86	88
6	Akhaura	Brahmanbaria	93	70	66	69
204	Homna	Comilla	178	91	75	74
343	Muradnagar	Comilla	341	144	105	109
88	Brahmanpara	Comilla	119	77	66	71
125	Daudkandi	Comilla	375	137	89	110
130	Debidwar	Comilla	235	135	91	102
90	Burichang	Comilla	181	79	61	63
94	Chandina	Comilla	202	82	57	60
53	Barura	Comilla	240	120	75	98
271	Kotwali	Comilla	277	135	111	114
287	Laksham	Comilla	427	190	113	164
111	Chouddagram	Comilla	271	88	54	76
356	Nangolkot	Comilla	235	106	97	106
312	Matlab	Chandpur	409	147	92	139
225	Kachua	Chandpur	238	89	53	83
96	Chandpur	Chandpur	287	164	102	131
195	Hajiganj	Chandpur	157	56	27	48
447	Shahrasti	Chandpur	186	89	38	78
155	Faridganj	Chandpur	235	76	40	70
194	Haimchar	Chandpur	186	107	55	90
411	Ramganj	Lakshmipur	170	52	38	49
405	Raipur	Lakshmipur	202	59	39	52
288	Lakshmipur	Lakshmipur	515	191	82	176
413	Ramgati	Lakshmipur	650	163	96	145
102	Chatkhil	Noakhali	134	35	21	30
58	Begumganj	Noakhali	409	93	57	86
445	Senbagh	Noakhali	160	50	30	38
459	Sudharam	Noakhali	828	207	108	200
116	Companiganj	Noakhali	189	123	68	119
120	Daganbhuiyan	Feni	132	43	23	35
465	Sonagazi	Feni	259	139	81	97
161	Feni	Feni	221	95	44	84
104	Chhagalnaiya	Feni	157	41	20	41
166	Fulgazi	Feni	108	53	22	50
388	Parsuram	Feni	72	39	22	30

Exceedence of Potable Water Constraint

CHAPTER V.5

CONCLUSIONS AND RECOMMENDATIONS

V.5.1 Conclusions

General

- The assessment of groundwater development potential has been based on an thana basis for a variety of pumping modes. One of the basic assumptions in the assessment is that major controlling parameters are evenly distributed over the thana area. These include amongst others the distribution of flood phases and surface water irrigation, hydrogeological parameters and future irrigation development.

  In reality this even distribution does not exist and the derived development potential limits will therefore have to be carefully interpreted.

Effects of Surface Water Irrigation

- The present study of groundwater resource potential has shown that surface water (LLP) irrigation during the dry season enhances groundwater potential, particularly suction mode development.

- With additional surface water development in extensive contiguous areas, suction mode operation is likely to be maintained within and adjacent to the area irrigated from surface water, even if development levels as an thana average indicate that suction mode limits have been exceeded: (note suction mode irrigation may take place in areas which are out of command of surface water irrigation).

Groundwater Salinity

- The extent of the occurrence of brackish water in the main aquifer, which is used for DTW development, is greater than was initially thought. Surveys conducted during 1990/91 by study teams from the project and the IDA_DTW II project have indicated that the EC value of the groundwater in the main aquifer exceeds 2000 μS/cm in some areas of the central and western parts of the study area. This water is unavailable for rice irrigation and therefore these areas have been excluded from additional deep force mode development.

- Within the saline areas there exist localised areas within which water quality in the main aquifer is acceptable. The extent of these areas is not clearly defined and additional field surveys will be required. Further field work has been done by the Deep Tubewell II Project in the season of 1991/1992. This confirmed that salinity increases with depth in Muradnagar but did nor indicate any progressive deterioration of water with time, although it did identify saline water in areas where no wells existed previously. Two explanations of the origin of the saline groundwater are considered most

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likely, either by upward leakage from deep geo-pressurised horizons within the area of the Bakrabad anticline or hydraulic entrapment of early Holocene estuarine water. Further work is recommended (Mott Macdonald International Ltd.- Deep Tubewell Project Interim Report - Hydrogeology of the Comilla Region with Special Reference to Groundwater Salinity, February 1992).

Further fieldwork is to be undertaken by a Canadian University research project in the dry season of 1992/93.

- In the upper part of the aquifer which is exploited by suction mode units, water quality is generally acceptable in the areas known to have underlying brackish water. Suction mode development in these areas is generally feasible.

- In the southern part of the study area the occurrence of saline groundwater of marine origin, generally combined with poor aquifer conditions, excludes all development for irrigation. Whatever fresh groundwater (at shallow depth) is available, should be reserved for potable use.

Flood Protection

- Full flood protection has a major impact on potential recharge, particularly if extensive parts of a thana are covered by F2 and F3 land.

- For only a few thanas, however, does the reduction in potential recharge have an effect on the optimum groundwater development potential. This optimum development is in nearly all cases determined by either tubewell technology constraints, i.e. maximum allowable depth to pumping level, or by availability of irrigable land.

V.5.2 Recommendations

- Extensive field surveys will be required to obtain a better understanding of the origin and the extent of groundwater salinity in the study area. This will require a sampling programme for hand tubewells (HTW), STW and DTW for measurement of EC values. A selected number of samples could be taken to be analysed for isotopes to establish the age of the groundwater.

- The additional field survey will enhance the knowledge of the salinity problem. However, to obtain an understanding of the origin of the saline/brackish groundwater and to assess how tubewell development will affect the situation in the future, would require a volume of work which is beyond the scope of the present study.

The investigation of the salinity problems, which should be considered the subject of a separate study, would need to include the following components:

- Study of the geology and hydrogeology, based on existing data.

- Development of hypothesis regarding the origin of the saline/brackish groundwater. The likely hypotheses include the upcoming of deep groundwaters through faults, and the possibility of residual salinity in deposits laid down in a marine environment.

- Additional field studies, which would include water sampling and testing and drilling of boreholes to define the salinity stratification.

- Computer modelling on a regional scale to allow for the simulation of both mass and solute transport in the aquifer system. The model would form an important tool in the study of the origin of the saline/brackish groundwater, and could be used in its calibrated stage to assess the implications of groundwater development.

APPENDIX V.A

SINGLE CELL MODE THANA MODEL (SCMTM)

APPENDIX V.A

Single Cell Mode Thana Model (SCMTM)

V.A.1 Introduction

a single cell four layer model was developed for the simulation of groundwater resource potential on an Thana basis. The model is derived from the multi-cell model developed for the MPO in 1990.

The model simulates the response of the aquifer system to resource development for a 17 year simulation period, using third monthly time steps. The period of 17 years, which represents the rainfall conditions for the years from 1972/73 to 1988/89, was chosen to reflect the variability in rainfall and consequent potential recharge on the resource potential.

V.A.2 Model Approach

V.A.2.1 Model Geometry

The aquifer system can be simulated as either 2 or 4 layerd, whereby the geometry of the aquifer system for an upazila area is defined by the average ground surface elevation and the elevation on the base of the modelled layer. These layers include:

Layer 1 : Upper clays and silts, modelled as a semi-confining layer

Layer 2 : For the two layered situation this represents the combined aquifer whereby it is assumed that the upper finer textured composite aquifer is in complete hydraulic continuity with the medium to coarse textured main aquifer. For the four layered system this layer represents the composite aquifer.

Layer 3 : For the four layered system this represents the aquitard that separates the composite and main aquifers.

Layer 4 : For the four layered system this represents the main aquifer.

V.A.2.2 Hydrogeological Parameters

For layers 1 and 3 in which vertical flow is simulated the mean vertical hydraulic conductivity values are specified. Together with the saturated thickness they control the hydraulic resistance of these layers.

For the aquifer layers the mean section permeability is specified. Since the model is operated in a single cell mode no lateral transfer of groundwater is simulated. Transmissivity values are however required for the computation of drawdown in wells due to pumping. For the two-layered system two permeability values are used to enable realistic drawdown simulation for different well technologies (STW and DTW).

Specific yield values which exercise the main control over release of water from aquifer storage are specified for the upper 22 m of the aquifer system with values defined for each 1 m interval. The specific yield values were based on the MPO analysis of Thana wise depth storage relationships.

V.A.2.3 Rainfall

Third monthly rainfall totals have been used based on the available records for the period from 1972/73 to 1988/89. These data are available for each Thana.

V.A.2.4 Recharge

The recharge routine is used to compute potential recharge to the aquifer system both from natural sources such as rainfall, flooding and open water bodies, and form irrigation return flow. Potential recharge is equivalent to the potential rate of deep percolation through the base of the active rootzone of dry land crops or through the plough pan for wet land crops. It represents the maximum possible recharge to the aquifer system. In the computation of potential recharge it is assumed that the aquifer system is an infinite storage reservoir without capacity to reject recharge.

Actual recharge is computed int he model by taking into account the constraints of the aquifer system. Actual recharge is always less or equal then potential recharge and can indeed be very small during periods of the monsoon season when groundwater tables are at ground surface. During such period potential recharge is rejected from the system.

The recharge routine simulates potential recharge for their monthly time steps from an analysis of the water balance of the rootzone of different crops.

The methodology of the recharge mechanism is detailed in Annex V.A.1.

V.A.2.5 Crop Distribution over Land Type Areas

One of the uncertainties associated with the model simulation is the distribution of crops over different land types. During the MPO recharge studies the land type distribution within a thana was derived from the SODAPS data base.

Land type classification is according to the SODAPS definition based on the depth of normal flooding during the monsoon season. In addition the SODAPS data based specifies permeability ratings namely rapid, moderate and slow. In the recharge model permeability rating is either permeable or impermeable, a distinction mainly based on the capability of impermeable soils to be puddled. The guidelines for determining the permeability ratings used during the MPO recharge studies are as follows:

- Soils categorised in the SODAPS data base as slowly permeable were classified as impermeable, while those with rapid permeability were classified as permeable.

- For those soils described as moderately permeable, the crop suitability was used to classify them as either permeable or impermeable. soils with a suitability rating of less than 3 for sugarcane were classified as permeable while those with a suitability rating of less than 3 for boro as impermeable.

The land types are classified for modelling purposes into 10 categories as follows:

Code	Land Type
Hp	High Land Permeable
Hi	High Land Impermeable
MHP	Medium High Land Permeable
MHi	Medium High Land Impermeable
MLp	Medium Low Land Permeable
MLi	Medium Low Land Impermeable
L	Low Land
B	Bottom Land
OW	Open Water
HO	Homesteads

The crop suitability of the different land types has been adopted from the MPO studies and is defined as follows for irrigated and non irrigated crops:

Non-irrigated crops

Land Type	Crops
High Land Permeable	Perennial crops or B.Aus/T.aus/Jute followed by Wheat/Rabi
High Land Impermeable	B.Aus/T.Aman/Jute followed by Rabi
Med. High Land Permeable	B.Aus/T.Aus/Jute followed by Wheat/Rabi
Med. High Land Impermeable	B.aus/T.aman/Jute followed by Rabi
Med. Low Land Permeable	Mixed B. aust+B.Aman followed by Boro/Wheat/Rabi
Med. Low Land Impermeable	Mixed B.Aus+B.Aman followed by Boro/Rabi
Low Land	B.Aman followed by Boro/Rabi
Bottom Land	Boro

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Irrigated Crops

Land Type	Crops
High Land Permeable	T.Aus followed by wheat/Rabi
High Land Impermeable	T.Aman followed by Boro
Med. High Land Permeable	T.Aus followed by Wheat/Rabi
Med. High Land Impermeable	T.Aman followed by Boro
Med. Low Land Permeable	Boro
Med. Low Land Impermeable	Boro
Low Land	Boro
Bottom Land	Boro

Planting and harvesting periods are spread over a period of 40 days for rice crops and 30 days for dry land crops.

V.A.2.6 Flooding

flood depths are specified for each modelled time step for each land category (ie high land, medium high land etc). Time constraints have limited to specification of an idealised flooding sequence which has been kept constant for the 17 year simulation period.

If flood control is exercised within a thana area the impact on potential recharge and resource potential can simple be evaluated by specifying different flooding depths for the different land categories.

V.A.3 Assessment of Groundwater Resource Potential

The groundwater resource potential is expressed in terms of percentage of irrigable land that can be irrigated from groundwater during the dry season. the optimum rate of development is controlled by a number of constraints, which are:

- Recharge

  the groundwater resource is utilised as a replenishable resource and thus potential recharge (from both natural sources and from surface water irrigation returns) forms an upper limit on resource development potential.

- Pumping modes

  the suction limit (for STW and DSSTW) and the pump intake setting (for DTW) form constraints to development. In many cases this constraint is the dominant one if STW or DSSTW are selected as the pumping modes. For DTW there is in theory no limit on the pump intake setting although for most existing DTW a intake level of 20 m below ground surface is used.

The assessment of resource potential is one of repeated model simulation. The model would normally first be run under the worst conditions which implies the use of groundwater only for irrigation of high, medium high, medium low and low land without taking account of the beneficial effects of existing surface water irrigation. The cropping pattern would thereby be biased towards boro within the suitability constraints given in Table 2.5. If the resource is capable to sustain the full groundwater development one would have to consider the resulting mode of pumping to achieve the full development level. If full development can thus be achieved by DSSTW there will be no need for further simulation runs.

If the maximum development can only be sustained by DTW the beneficial effects of surface irrigation need to be taken into consideration. If this is done one assumes that bottom land is served by surface water, while the higher lands may be served by groundwater as well as surface water. In the model a ratio is specified of area irrigated from groundwater and total irrigated area. this ratio is specified on a time step basis. the impact of surface water irrigation on the groundwater resource potential can thus be analysed and it is conceivable that under these conditions a suction mode pumping technology is possible.

If potential recharge is shown to be a constraint to groundwater development then the area irrigated from groundwater will have to be reduced. The reduced area could then either not be irrigated or be irrigated from a surface water resource.

If the aquifer system consists of four layer it is assumed that STW and DSSTW abstract from the upper aquifer while DTW have their screen set in the lower aquifer. In this case the user would specify the proportion of total groundwater abstraction derived from the lower (main) aquifer. This set up of the model allows for a realistic simulation of conditions in areas where STW and DSSTW are still operation despite the fact that piezometric levels in the lower aquifer have drop below the suction limit of the STW/DSSTW.

V.A.4 Model Output

The output from the model is directed to a .PRN file which can be imported into a Lotus spreadsheet for additional manipulation and for preparation of graphical output. The output is described in detail in Appendix 1 and includes in summary the following for each modelled time step:

- Pumping levels for force mode and suction mode wells (generally 2 cusec DTW and 0.5 cusec STW/DSSTW).

- Piezometric levels in the two aquifer layers.

- Water table levels for 6 relief phases (H, Mh, ml, l, b AND ow).

- Gross abstraction from groundwater.
- Actual recharge (sum of natural recharge and irrigation return flow).
- Storage changes in the aquifer and in the upper clay/silt layer.
- Storage changes in the aquifer and in the upper clay/silt layer.
- Total gross application of irrigation water (sum of groundwater and surface water supply).
- Return flow from irrigation.
- Gross rainfall.

All flow components are presented in mm/d/unit gross area.

ANNEX V.A.1

Methodology of Recharge Simulation

V.A.1.1 Methodology

In then model a distinction is made between infiltration and deep percolation rates. The infiltration rate is defined as the rate of flow through the soil surface. The deep percolation is the rate of downward flow through the base of the active rootzone or through the ploughman.

The model assumes that all recharge is vertical. This includes the interaction between surface water (rivers, heels, etc.) which given the basic assumption of a very deep groundwater table is valid. The model does thus not simulate the lateral transfer between riverts and the aquifer.

A large number of parameters affect the potential recharge. They may be categorised in major groups as summarised below:

- Physical parameters
  - land type distribution;
  - soil characteristics within land type areas;
  - local relief characteristics.

- Hydrological parameters
  - rainfall (totals, distribution, frequency);
  - relationship between effective and gross rainfall;
  - surface water retention capacity for different land types;
  - surface runoff characteristics;
  - extent, duration and depth of deep flooding;
  - reference crop evapotranspiration.

- Parameters related to agricultural practices
  - crop coefficients;
  - cropping calender;
  - cropping patterns related to soil and land types;
  - rooting depth of crops, or depth to ploughman;
  - ratio of cultivable to gross area;
  - crop statistics.

Deep percolation is calculated from the water balance of the rootzone and is assumed only to take place if the moisture content int he rootzone is above the value at field capacity. This simply assumes the build up of perched conditions at the base of the rootzone and in this case the deep percolation is equal to the gravity drainage capacity of the plough pan or the subsoil. If flood levels build up, then the rate of deep percolation increases in proportion to the height of the standing water at the soil surface. Summarised the deep percolation (for potential recharge) follows from:

If soil moisture below field capacity	:	DP = 0
If soil moisture above field capacity but no deep flooding	:	$DP = K_v$
If deep flooding	:	$DP = (DF+1)*k_v$

where DP = deep percolation

K_v = vertical permeability of the subsoil or ploughman

DF = flood level relative to soil surface

V.A.1.2 Data Requirements

Introduction

The data requirements for the recharge model are summarised as follows:

(a) Land type distribution
(b) Soil distribution over land type areas
(c) Crop statistics
(d) Cropping calendar
(e) Reference crop evapotranspiration
(f) Crop coefficients
(g) Effective rooting depths
(h) Rainfall
(i) surface water retention and flooding
(j) Infiltration and deep percolation rates
(k) soil moisture characteristics
(l) Effective rainfall and surface runoff
(m) Initial soil moisture conditions

Most data were derived from the MPO data and only required some restructuring into appropriate data files. These structure of these data files is given in appendix 1.

Land Type Distribution

Land type classification is according to the SODAPS definition, which takes as the main criterion for classification the depth of flooding during the monsoon season. The land types are classified for the recharge model into 10 major categories as shown in Table V.A.2.1

The permeability rating, permeable or impermeable, is different from the one used in the SODAPS data base, SODAPs uses three.

TABLE V.A.2.1

Land Type Classification

Code	Land type	
1	High Land Permeable	HP
2	High Land Impermeable	HI
3	Medium High Land Permeable	MHP
4	Medium High Land Impermeable	MHI
5	Medium Low Land Permeable	MLP
6	Medium Low Land Impermeable	MLI
7	Low Land	L
8	Bottom Land	B
9	Open Water	OW
10	Homesteads	HO

permeability ratings namely rapid, moderate and slow. The guidelines for determining the permeability ratings used in the land type classification are as follows:

- Soils categorised in the SODAPS data base as slowly permeable were classified as impermeable, while those with rapid permeability were classified as permeable.

- For those soils described as moderately permeable, the crop suitability was used to classify them as either permeable or impermeable. soils with a suitability rating of less than 3 for sugarcane were classified as permeable while those with a suitability rating or less than 3 for boro as impermeable.

It should be noted that permeability ratings relate to sub-soil characteristics.

The land type distribution for the thanas within the project area are given in Table V.A.2.1.

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Soil Distribution over Land Type Areas

A veriety of soil types may exist for each and types. In the model only the three most dominant soil types within the land type area are taken into consideration. Soil types used in the model are shown in Table V.A.2.2. Their physical characteristics were based on Rijtema (1969).

TABLE V.A.2.2

Soil Types Used in the Recharge Model

Code	Type	Abbreviation
1	Fine Sandy Loam	FSL
2	Silt Loam	Sil
3	Loam	L
4	Silty Clay Loam	SiCL
5	Clay Loam	CL
6	Basin clay	BC
7	Silty Clay	BiC
8	Sandy Clay Loam	SCL

TABLE V.A.2.3

Land Type Distribution in Project Area

Thana Code Name	Area Km^2	Hp	Hi	MHp	MHi	MLp	MLi	L	B	OW	HO
6 AKHAURA	93.0	14.74	3.55	9.72	2.41	8.03	14.70	21.01	12.65	5.88	7.31
14 ASHUGANJ	119.0										
42 BANCHARAMPUR	207.0										
53 BARURA	240.0	11.10	0.00	24.36	9.10	30.05	16.94	0.13	0.00	8.32	0.00
58 BEGUMGANJ	409.0	21.51	0.00	9.72	0.24	32.46	29.97	1.10	0.00	5.00	0.00
87 BRAHMANBARIA	416.0	14.96	1.69	14.41	0.81	16.43	5.20	17.14	21.93	7.43	0.00
88 BRAHMANPARA	119.0	0.37	0.18	10.80	5.80	36.99	26.02	5.27	0.00	6.39	8.18
90 BURICHANG	181.0	2.84	2.00	14.50	34.43	4.76	21.45	1.36	0.00	9.98	8.68
94 CHANDINA	202.0	0.12	0.00	19.43	12.74	2.81	6.73	40.69	0.00	8.37	9.11
96 CHANDPUR	287.0	6.63	0.00	15.38	0.11	22.86	2.78	0.54	0.00	28.47	23.23
102 CHATKHIL	134.0	24.70	0.00	22.50	9.11	12.07	18.84	7.78	0.00	5.00	0.00
104 CHAGALNAIYA	157.0										
111 CHOUDDAGRAM	271.0	12.86	2.06	41.89	19.16	4.33	9.06	0.65	0.00	9.99	0.00
116 COMPANIGANJ	189.0	0.00	0.00	15.95	24.62	0.93	1.50	0.00	0.00	46.75	10.25
120 DAGANBHUIYA	132.0	17.16	0.00	39.52	2.15	13.07	19.60	2.70	0.00	5.81	0.00
125 DOUDKANDI	375.0	0.00	0.00	0.00	0.00	4.75	0.00	56.96	22.20	10.13	5.96
130 DEBIDWAR	235.0	0.00	0.00	28.27	14.56	18.07	11.50	10.02	0.00	8.60	8.98
155 FARIDGANJ	235.0	20.83	0.00	37.48	5.74	3.96	7.16	2.07	0.00	5.39	17.37
161 FENI	221.0	21.95	0.00	41.46	19.51	4.30	2.99	2.86	0.00	6.93	0.00
166 FULGAZI	235.0	20.83	0.00	37.48	5.74	3.96	7.16	2.07	0.00	5.39	17.37
194 HAIMCHAR	186.0	4.99	0.00	10.02	3.53	19.70	4.32	0.01	0.00	43.85	13.58
195 HAJIGANJ	157.0	25.04	0.00	1.40	0.00	26.18	31.33	7.97	0.00	8.08	0.00
204 HOMNA	178.0	0.00	0.00	0.00	0.00	4.17	0.00	43.43	28.78	19.55	4.07
225 KACHUA	238.0	0.03	0.00	0.99	0.00	44.14	7.10	11.96	0.00	20.26	15.52
249 KASBA	207.0	16.93	0.87	24.86	2.07	24.95	4.21	8.54	3.60	7.42	6.55
271 KOTWALI	277.0	12.27	3.33	11.41	34.94	0.75	18.48	0.00	0.00	6.25	12.57
287 LAKSHAM	427.0	10.04	0.00	28.44	2.99	29.07	12.59	8.24	0.00	8.63	0.00
288 LAKSHMIPUR	515.0	20.97	0.94	21.86	24.45	14.43	5.73	0.00	0.00	11.62	0.00
312 MATLAB	409.0	0.03	0.00	0.00	0.00	44.14	7.10	11.96	0.00	20.26	15.52
343 MURADNAGAR	341.0	0.00	0.00	14.69	5.73	16.86	8.48	37.20	1.69	7.29	8.06
345 NABINAGAR	352.0	6.27	0.00	21.44	0.22	37.39	1.82	8.72	10.48	13.66	0.00
356 NANGALKOT	235.0										

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TABLE V.A.2.3 (Contd.)

362 NASIRNAGAR	313.0	0.00	0.00	0.54	0.00	33.09	13.66	15.71	18.65	7.46	10.89
388 PARSURAM	72.0	38.95	0.61	39.93	12.08	0.00	0.00	0.00	0.00	1.32	7.11
405 RAIPUR	202.0	11.15	0.00	31.79	16.05	3.99	1.12	0.00	0.00	17.87	18.03
411 RAMGANJ	170.0										
413 RAMGATI	650.0	0.00	0.00	29.50	23.81	2.50	1.01	0.00	0.00	32.13	11.05
437 SARAIL	212.0	0.00	0.00	16.25	0.00	17.82	6.69	27.85	14.94	7.60	8.85
445 SENBAG	160.0	20.03	0.00	34.45	1.64	15.53	23.64	0.46	0.00	4.25	0.00
447 SHAHARASTI	186.0	24.62	0.00	9.10	3.63	15.90	27.11	13.94	0.00	5.70	0.00
459 SHUDHARAM	828.0	6.03	13.14	20.52	32.49	4.51	2.85	0.00	0.00	20.46	0.00
465 SONAGAZI	259.0	1.10	0.00	38.14	13.10	5.93	1.46	0.00	0.00	28.53	11.74

Crop Distribution over Land Type Areas

Crop statistics are available on a thana basis from the BBS data books. The Agronomy Section of MPO have computerised this data from 1974/75 for 16 major crops or crop groups. Fro the recharge model the number of crops was reduced to 10 major non-irrigated crops or crop groups plus forest and grass/wild vegetation plus four irrigated crops. The correlation between the crops is given in Table V.A.2.4.

The statistics data do not indicate the distribution of crops over the various land type areas. For the recharge calculations the link between crop type and land type is, however, of major significance. The correlation between crops and land types is based on Table V.A.2.5. In the model adjustments are made if necessary.

Cropping Calendar

Date of first planting, harvesting dates and length of growing season vary slightly throughout the country and planting and harvesting may stretch out over quite significant periods. For ease of calculation in the model it is assumed that planting and harvesting periods for rice and jute are 40 days, and for wheat and rabi 30 days. It is further important that the growing seasons of successive crops do not overlap, since this may cause the successive crops do not overlap, since this may cause the occurrence of cropped areas in excess of available cultivable areas. Starting dates are approximate and can be modified for each area considered.

TABLE V.A.2.4

Crop Types

Agronomy Section		Recharge Model Non-irrigated	
1	B.Aus	1	B.Aus
2	T.Aus	2	T.aus
3	B.Aman	4	B.Aman
4	Local T.Aman	3	T.Aman
5	HYV T.Aman	3	T.Aman
6	Local Boro	5	Boro
7	HYV Boro	5	Boro
8	Wheat	7	Wheat
9	Potato	7	Wheat
10	Jute	6	Jute
11	Sugarcane	9	Sugarcane
12	Pulses	8	Rabi
13	Oil Seeds	8	Rabi
14	Spices	8	Rabi
15	Other Crops	8	Rabi
16	Orchards	10	Orchards
		11	forest
		12	Grass/wild vegetation Irrigated
		13	Wheat/Rabi
		14	boro
		15	T.Aus
		16	T.Aman

TABLE V.A.2.5

Land Type Versus Crop Type

Land Type	Crops (non-irrigated)
High Land Permeable	Orchards/Forest/sugarcane B.aus/T.Aus/Jute, Wheat/Rabi
High Land Impermeable	B.Aus/T.Aman/Jute, Rabi
Med. High Land Permeable	B.Aus/T.Aus/Jute, Wheat/Rabi
Med. Low Land Permeable	B.Aus/T.aman/Jute, Rabi/Boro Mixed B. Aus + B.Aman, Wheat/Rabi/Boro
Med. Low Land Impermeable	Mixed B. Aus + B.Aman, Rabi/Boro
Low Land	B.Aman, Rabi/Boro Boro

Land Type	Crops (irrigated)
High Land Permeable	Wheat/Rabi, T.Aus
High Land Impermeable	Boro, T.Aman
Med. High Land Permeable	Wheat/Rabi, T.Aus
Med. High Land Impermeable	Boro, T.Aman
Med. Low Land Permeable	Boro
Med. Low Land Impermeable	Boro
Low Land	Boro
Bottom Land	Boro

T.Aman may shift to medium low and low land if this becomes flood protected.

Reference Crop Evapotranspiration

Reference crop evapotranspiration is available from a number of meterological stations throughout the country. Monthly data can be reworked into shorter periods with reasonable confidence using curve fitting and interpolation routines.

Crop Coefficients

Crop coefficients were based on values derived during the first phase of MPO and are shown in Table V.A.2.6. For broadcast rice the consideration is given to possible saturated soil conditions during the early stages of the crop. Under such conditions a coefficient of 1.1 is used in the recharge model.

TABLE V.A.2.6

Crop Coefficients

Values given are for third monthly periods from 1st March
Note : Values given should be in accordance with the cropping calendar

Non-Irrigated Crops

B.aus											
0.00	0.00	0.45	0.51	0.59	0.68	0.83	0.96	1.05	1.09	1.09	1.05
0.99	0.95	0.90	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T.aus											
0.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
0.99	0.95	0.90	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T.aman											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
1.09	1.05	0.99	0.95	0.90	0.85	0.00	0.00	0.00	0.00	0.00	0.00
B.aman											
0.00	0.00	0.45	0.51	0.59	0.68	0.83	0.96	1.05	1.09	1.10	1.10
1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.99	0.95	0.90
0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boro											
1.19	1.24	1.26	1.22	1.11	1.06	0.98	0.85	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.14
Jute											
0 .00	0.00	0.00	0.00	0.00	0.40	0.42	0.45	0.59	0.57	0.70	0.85
0.98	1.00	1.11	1.15	1.11	1.02	0.98	0.90	0.80	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rabi											
1.01	0.80	0.69	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.45	0.51	0.59	0.75	0.92	1.05	1.12	1.13	1.10

TABLE V.A.2.6 (CONTD.)

Sugar Cane											
0.97	1.00	1.04	1.06	1.08	1.10	1.12	1.13	1.14	1.14	1.15	1.15
1.15	1.15	1.14	1.13	1.12	1.09	1.06	1.02	0.98	0.93	0.88	0.84
0.81	0.79	0.77	0.75	0.74	0.74	0.74	0.76	0.79	0.83	0.87	0.92
Fruit Trees											
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Forest											
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Non-cultivable Waste											
0.20	0.20	0.20	0.20	0.20	0.30	0.40	0.40	0.40	0.50	0.60	0.60
0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.50	0.50	0.40	0.30
0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Irrigated Crops											
Wheat											
0.80	0.69	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.45	0.51	0.59	0.75	0.92	1.05	1.12	1.13	1.10	1.01
Boro											
1.11	1.14	1.19	1.24	1.26	1.22	1.11	1.06	0.98	0.85	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10
T.aus											
0.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.09	1.05
0.99	0.95	0.90	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T.aman											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
1.09	1.05	0.99	0.95	0.90	0.85	0.00	0.00	0.00	0.00	0.00	0.00

Effective Rooting Depth

The effective rooting depth is for most crops dependent on the subsoil conditions and may thus be greater or smaller than general values such as presented in FAO Publication 24. A tight clay at shallow depth would restrict root penetration to a major extent, while the existence of a plough pan will have a similar effect. The range of values that may be adopted in the model are shown in Table V.A.2.7. adjustments may be required depending on local conditions.

TABLE V.A.2.7

Rooting Depths

Crop	Rooting Depth (m)		
Rice	0.3	-	0.6
Jute	0.4	-	0.8
Wheat	0.6	-	1.0
Rabi	0.4	-	1.0
Sugarcane	1.0	-	2.0
Trees	2.0	-	3.0
Wild vegetation	0.5	-	1.0

Surface Water Retention and Flooding

The land is classified into different land types according to the depth of normal flooding during the height of the monsoon season. The relationship between land type and flood depth is given in Table V.A.2.8.

TABLE V.A.2.8

Land Type Versus Flood Depth

Land Type	Flood Depth
High Land	not flooded or less than 0.3 m
Medium High Land	0.3 to 0.9 m
Medium Low Land	0.9 to 1.8 m
Low Land	1.8 to 3.0 m
Bottom Land	greater than 3.0 m

The depth of flooding may very throughout the monsoon season, while its duration will depend on the land type and other factors. In the model flood depths and start and end of the deep flooding period have to be specified. A simple example is given in Figure 2.3.

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For land not subject to flooding, water can be held in surface storage between field bunds. This also applies for periods outside the flood season for land that is subject to flooding. In the model hypothetical "bund" heights for the different land types are adopted for "wet" (rice and jute) and "dry" (wheat, rabi etc) crops which do not necessarily reflect actual bund height in the field. Water can thus be held in surface storage up to a maximum level determined by the specified "bund" height.

Infiltration and Dep Percolation Rates

Data based on field experiments conducted by the Soils Survey Department give infiltration rates for dry and moist soil conditions. The range of values for seven soil types are given in Table V.A.2.9.

TABLE V.A.2.9

Infiltration Rates

	Infiltration Rates (m/d)*	
Soil Texture	Dry	Moist
Fine sandy loam	0.48 - 2.40	0.048 - 0.249
Silt Loam	0.48 - 2.40	0.048 - 0.192
Loam	0.48 - 2.40	0.396
Silty Clay Loam	0.48 - 2.40 +	0.048 - 0.120
Clay Loam	0.48 - 2.40 +	0.048
Silty Clay	1.80 +	0.048 - 0.072
Basin Clay	0.84 - 1.92+	0.028 - 0.072

* Increased rate due to soil cracks

\+ Values obtained from MPO soils Section

Values adopted in the recharge model are 0.025 m/d for silty clay and basin clay, and 0.05 m/d for the other soils.

Deep percolation rates are often an order of magnitude smaller than the infiltration rates. The likely range for eight soil types and for "wet" and "dry" conditions were based on simulation of potential recharge by the MPO and are given in Table V.A.2.10.

TABLE V.A.2.10

Deep Percolation Rates

Soil Texture	Minimum Deep Percolation Rates (mm/d) "Wet"	"Dry"
Fine sandy loam	5-15	25
Silt loam	3-9	10
Loam	5-15	15
Silty clay loam	3-9	15
Clay loam	2-6	5
Basin clay	1-3	5
Silty clay	1-3	5
Sandy clay loam	3-9	15

Soil Moisture Characteristics

Soil moisture characteristics are based on Rijtema (1970). The soil moisture contents at full saturation, field capacity and wilting point for the eight soil types are given in Table V.A.2.11. Field capacity is defined as the condition where moisture tension is 100 cm (pF=2.0) and approximates the moisture content that can be held in the soil against gravity forces. Wilting point is defined as the condition where moisture tension is 16,000 cm (pF=4.2) and represents the condition where plants loose their ability to extract moisture from the rootzone.

TABLE V.A.2.11

Soil Moisture Characteristics

Soil Texture	Moisture Content (%) Full Saturation	Field Capacity	Wilting Point
Fine sandy loam	50.4	42.3	8.7
Silt loam	50.9	46.1	9.2
Loam	50.3	42.0	9.8
Silty clay loam	47.5	37.2	18.5
Clay loam	44.5	41.1	25.5
Basin clay	54.0	51.9	32.1
Silty clay	50.7	46.3	25.7
Sandy clay loam	43.2	33.8	18.0

Effective Rainfall and Surface Runoff

Effective rainfall is calculated for "wet" and "dry" land areas for each land type according to the following equations :

If mean daily rainfall is less than 1 mm/d for the considered time period:

$$ER = 0$$

Otherwise :

$$ER = PR * (R - 1)$$

where ER - effective rainfall in mm/d

R - actual rainfall in mm/d

ER - factor depending on land type and land use ("wet" and "dry") (PR .= 1)

Values for PR were based initially on findings from previous modelling studies and the likely range is shown in Table V.A.2.12.

TABLE V.A.2.12

Effective Rainfall Factors

	PR		
Land Type		"Wet"	"Dry"
High Land	P	0.7 - 0.9	0.7 - 0.9
High Land	I	0.7 - 0.9	0.7 - 0.9
Med. High Land	P	0.7 - 0.9	0.7 - 0.9
Med. High Land	I	0.7 - 0.9	0.7 - 0.9
Med. Low Land	P	0.8 - 1.0	0.8 - 1.0
Med. Low Land	I	0.8 - 1.0	0.8 - 1.0
Low Land		0.8 - 1.0	0.8 - 1.0
Bottom Land		0.8 - 1.0	0.8 - 1.0

Surface runoff due to excess rainfall is calculated as the difference between actual and effective rainfall minus interception (1 mm/d).

ANNEX V.A.2

V.A.2.1. Structure of the Model

The structure of the model and an associated data preparation data checking programme and the functions of the programmes and associated subroutines are summarised as follows:

- Programme DATAPREP

  This programme reworks basic data into a binary master file, which is used as input file to the model. Two subroutines are associated with this programme. Subroutine LTCMOD is used to distribute crops over land type areas. subroutine INFMOD is used to convert infiltration, deep percolation and soil moisture characteristics from a soil type basis to as land type basis.

- Programme CHECK

  This programme is used to create a printer ready copy of the data generated by programme DATAPREP.

- Programme SCMTM

  This programme performs the numerical calculations required for the simulation of the groundwater system. 21 subroutines are linked with the programme which are briefly described in the following.

- Subroutine RECHMOD

  Recharge to groundwater and irrigation requirements are computed in this subroutine.

- Subroutine STORAGE

  In this subroutine the storage changes in the aquifer and the semi-confining layer are computed.

- Subroutine HDCORRM

  In this subroutine head corrections are computed for the aquifer and for the 6 land categories of the semi-confining layer.

- Subroutine INPUT

  Model input data are entered in this subroutine.

- Subroutine PRIMOD

  In this subroutine the actual crop coverage for the current time step is computed for each land type.

- Subroutine FLOOD

  Recharge due to deep flooding conditions is computed in this subroutine.

- Subroutine RBALMFOD

  In this subroutine the moisture balance of the rootzone of non-irrigated crops computed for conditions where the water table is positioned below the base of the rootzone.

- Subroutine CAPILM

  Capillary flux from the water table to the rootzone is computed in this subroutine.

- Subroutines WHEAT, BORO< AUS and AMAN

  In these subroutines the moisture balance and the irrigation requirements are computed for the four irrigated crops.

- Subroutines SUB1 to SUB6 and SUB8

  These subroutines are linked to the subroutines that compute the moisture balance for irrigated crops.

- Subroutine SUB7

  In this subroutine soil moisture and surface storage are redistributed.

V.A.2.2 File Specification

The file structure of the model may be summarised as follows:

- files which need to be specified for each thana

These files include :

(a) File re_GHijk.DAT

This file contains the data defining the aquifer geometry, its hydrogeological parameters and the soil type distribution over land type areas. The file also contains infiltration, deep percolation and soil moisture characteristics for the 8 soil types incorporated in the model.

(b) File re_LTijk.DAT

This file contains the data defining the land type distribution within each thana information regarding flood protection of certain land types, and the cropped areas for each cropping season of the simulation period.

(c) File re-RAijk.DAT

This file contains the third monthly rainfall totals for the simulation period.

(d) File re-FLijk. DAT

This file contains the depth of deep flooding for each third monthly period for each land type. The flooding characteristics represent the long term mean for the simulation period.

(e) File re_ICijk.DAT

This file contains initial values of aquifer piezometry and water table levels and data defining non-agricultural groundwater abstraction.

(f) file re_IPijk.DAT

This file contains data defining effective rainfall factors, bund heights, rooting depths and irrigation management parameters.

The file name convention is such that the region code and the thana number can be recognised from the file name. "re" refers to the region code (NE, NW, SE or SW) while ijk refers to the thana number (eg 054).

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- Files which need to be specified for the region

These files include :

(g) File re_RCE.DAT

This file contains the mean reference crop evapotranspiration values for third monthly periods and the crop coefficients for 12 non-irrigated crops and 4 irrigated crops.

(h) File re-PRI.DAT

This file contains the cropping calendar for the 12 non-irrigated and 4 irrigated crops in the form of proportion crop coverage relative to maximum crop coverage for each simulated tiem step.

(i) File FARAM.DAT

This file contains the model run control parameters.

The file names include the region code "re".

- Screen file

(j) File INPUT.SCR

This file contains the start-up template for a model simulation run.

- Output file

(File re_MOijk.DAT

This file contains the simulated model output for each third monthly time step.

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ANNEX VI

HYDROLOGY AND WATER MODELLING

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ANNEX VI - HYDROLOGY AND WATER MODELLING

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ANNEX VI - HYDROLOGY AND WATER MODELLING

CHAPTER VI.1

HYDROMETEOROLOGY

VI.1.1 General

The hydrometeorology of the study area has been described to some degree in several publications, the most note worthy of which are "The Agro-Climatic Survey of Bangladesh" (Manalo, Ref. 1), and "Net Irrigation Requirement of Rice and Evapotranspiration of Wheat and Potato for Different Locations in Bangladesh" (Karim and Akland, Ref 2). For completeness of the present study, some further analysis of climatic conditions of particular relevance to the project area has been carried out. In the case of rainfall, more extensive analysis has been carried out than in previous studies, utilising records up to the 1989-90 water year. The analysis of basic climatic data has been based on the readily available published data for stations in the project area, generally covering the period 1965-80. The monsoonal climate which affects the South East Region, and indeed the whole of Bangladesh, is part of a system which affects the whole of the Indian sub-continent. There are three main seasons:

i) the south-west monsoon:

lasting approximately from May to October, and producing the main rainy season; almost 90% of the annual rainfall total in the study area occurs during this period, when both temperatures and relative humidity are high;

ii) the north-east monsoon:

extending from November through to March, establishes the cool dry season of winter: only occasional rainfall occurs, associated with weak cyclonic disturbances;

iii) a short hot season:

this precedes the south-west monsoon and can extend from late March through till May; the highest maximum daily temperatures can occur at this time, and the season is associated with variable convective storm activity which can occasionally develop into severe cyclonic storms; during this season, flash flooding from the rivers draining the Tripura hills to the east of the region can be a problem.

The region is affected by severe tropical cyclones which develop in the Bay of Bengal. Cyclones most commonly occur in the periods before and after the main monsoon season in the months of May and October. In recent times, severe cyclones have affected the region in 1970, 1985 and 1991. Tropical cyclones are generally accompanied by very strong winds, high rainfall, and storm surge, which in coincidence with high tides can have disastrous consequences in coastal regions.

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VI.1.2 Climatic Norms

The locations of climatic stations in the South East Region are shown in Figure VI.1.1. The climate stations of relevance to the study are at Comilla, Chandpur, and Noakhali. Data at each station date from 1965, although there is some variability in the parameters recorded, and the completeness of records. The key parameters of temperature, relative humidity and wind speed are recorded at each of the climate stations. Neither hours of bright sunshine or radiation are recorded at any of the stations, however, and reference has been made to data for the stations at Dhaka and Chittagong. This is a limitation in the existing network, and it is recommended that efforts be made to upgrade each of the stations. Significant variations exist in rainfall across the region, and there will therefore be variability in insolation.

Climatic norms for Comilla, Chandpur and Noakhali are summarised in Figures VI.1.2 - VI.1.4, and in Tables VI.1.1 - VI.1.3. From these, the general characteristics in climate described in the introduction above are obvious, with very similar patterns being observed at each station. Wind speeds are lowest in the north-east monsoon period, but then pick up during the pre-monsoon hot season when Nor' westers and localised storm activity can occur. Wind speeds tend to level off during the south-west monsoon. In collecting climatic data for the present study it was noted that discrepancies exist in the units of wind speed measurement are several stations. It is recommended that original records at the existing climate stations are completely standardised. The mean monthly wind speeds are significantly higher than those recorded in some other parts of the country.

Mean daily temperatures in the region are fairly constant between the months of April and September, and show little variation across the region, being of the order of 28°C. From October, temperatures begin to decline, and mean daily temperatures reach a minimum of about 19-19.5°C in January. In April, maximum daily temperatures in the region can often exceed 35°C, while in January, minimum daily values can be below 10°C. Increased cloud cover during the south-west monsoon period prevents extremes of temperature when the sun s at its maximum declination. This is reflected clearly from the plots of sunshine hours. There is a dramatic fall in the hours of bright sunshine during the main monsoon period.

Relative humidity is high throughout the year. Maximum values occur in July, when the mean is of the order of 87.5% throughout the region. February generally produces the lowest values of 71% at Chandpur and Noakhali, and about 67% at Comilla.

Potential evapotranspiration has been calculated using the modified Penman Method, and these estimates are included in Tables VI.1.1 to VI.1.3. Pan evaporation measurements are made at a number of stations in Bangladesh, but must be treated with caution. There are few countries in which practical use can be made of pan measurements. A comparison of potential evapotranspiration estimates for Brahmanbaria is presented in Table VI.1.4. The pan estimates (taken from Manalo, Ref. 1) are clearly inappropriate. Differences between those estimates prepared under the present study and those of the Water Balance Study (Ref. 3) and Karim & Akland (Ref. 2) are partly attributable to differences in the length of available data base, but wind speed data quality is a problem. Differences in the dry season are of rather more significance than differences in the wet season when irrigation is not required. The reliability that can be attached to the potential evapotranspiration estimates is not particularly high. In view of the size of differences noted in Table VI.1.4, serious efforts should be made to rationalise the data base.

Figure VI 1.1
Hydrometric Stations in the South East Region

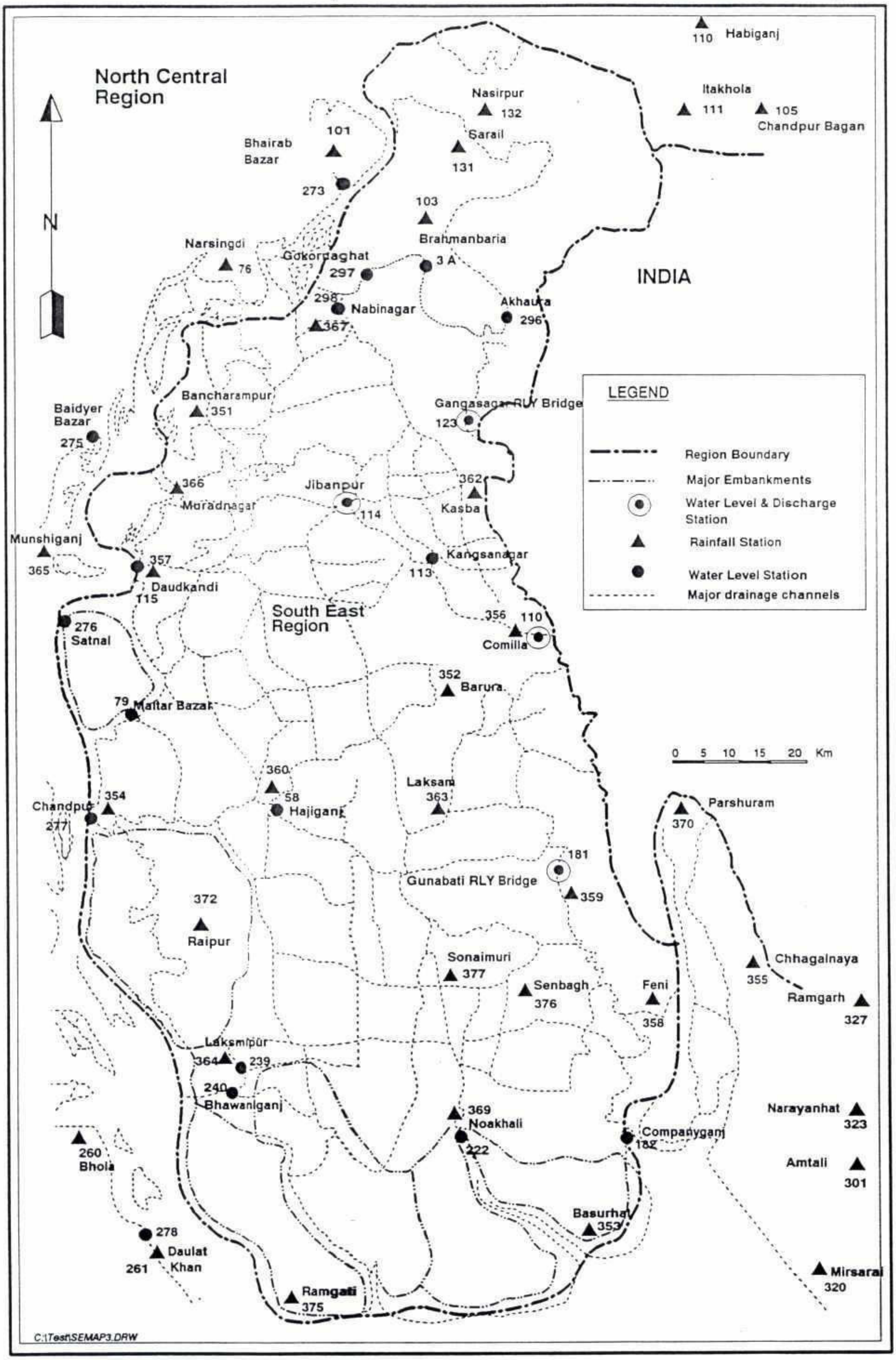

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Figure VI.1.2

Climatic Norms at Comilla

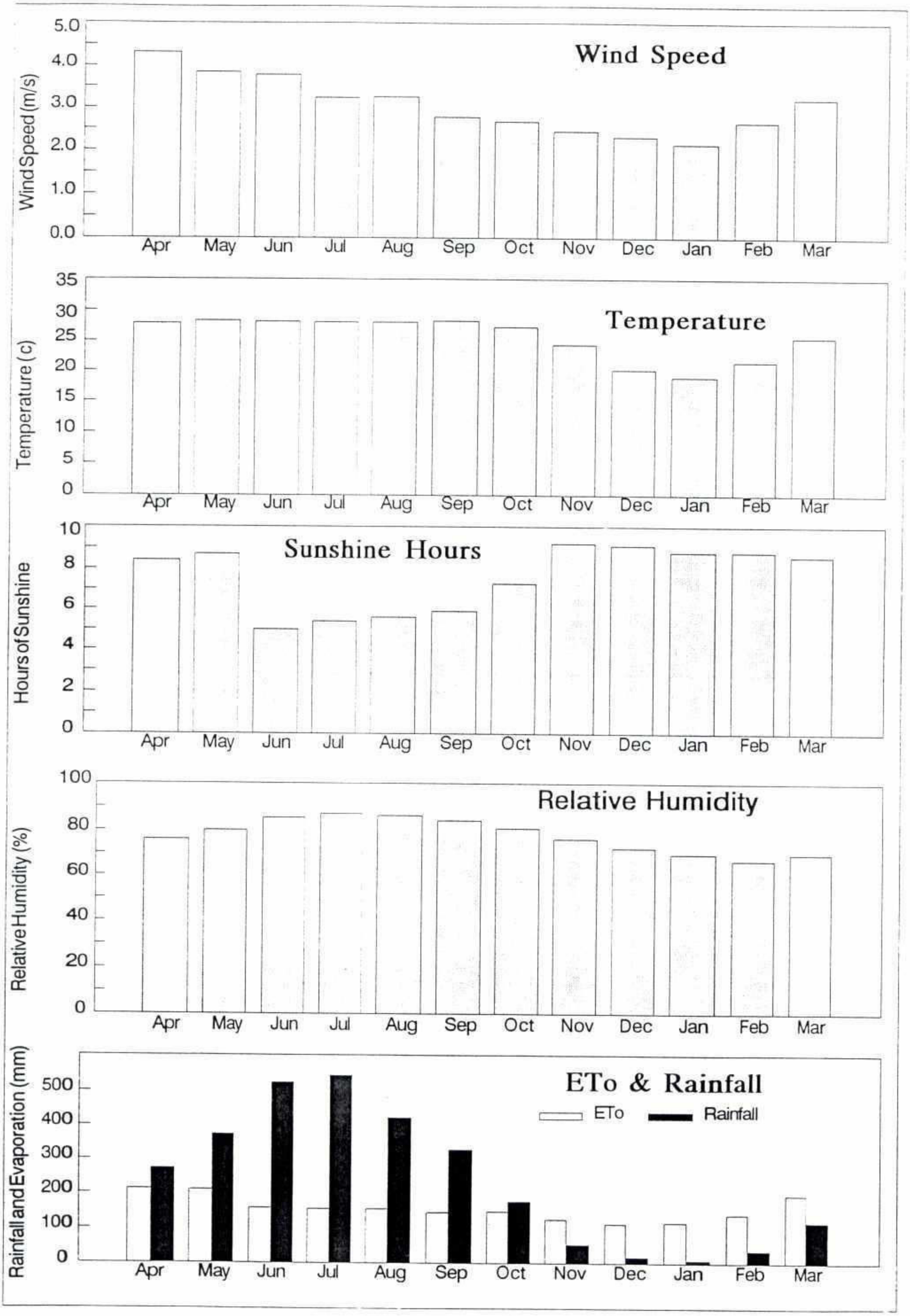

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Figure VI.1.3

Climatic Norms at Chandpur

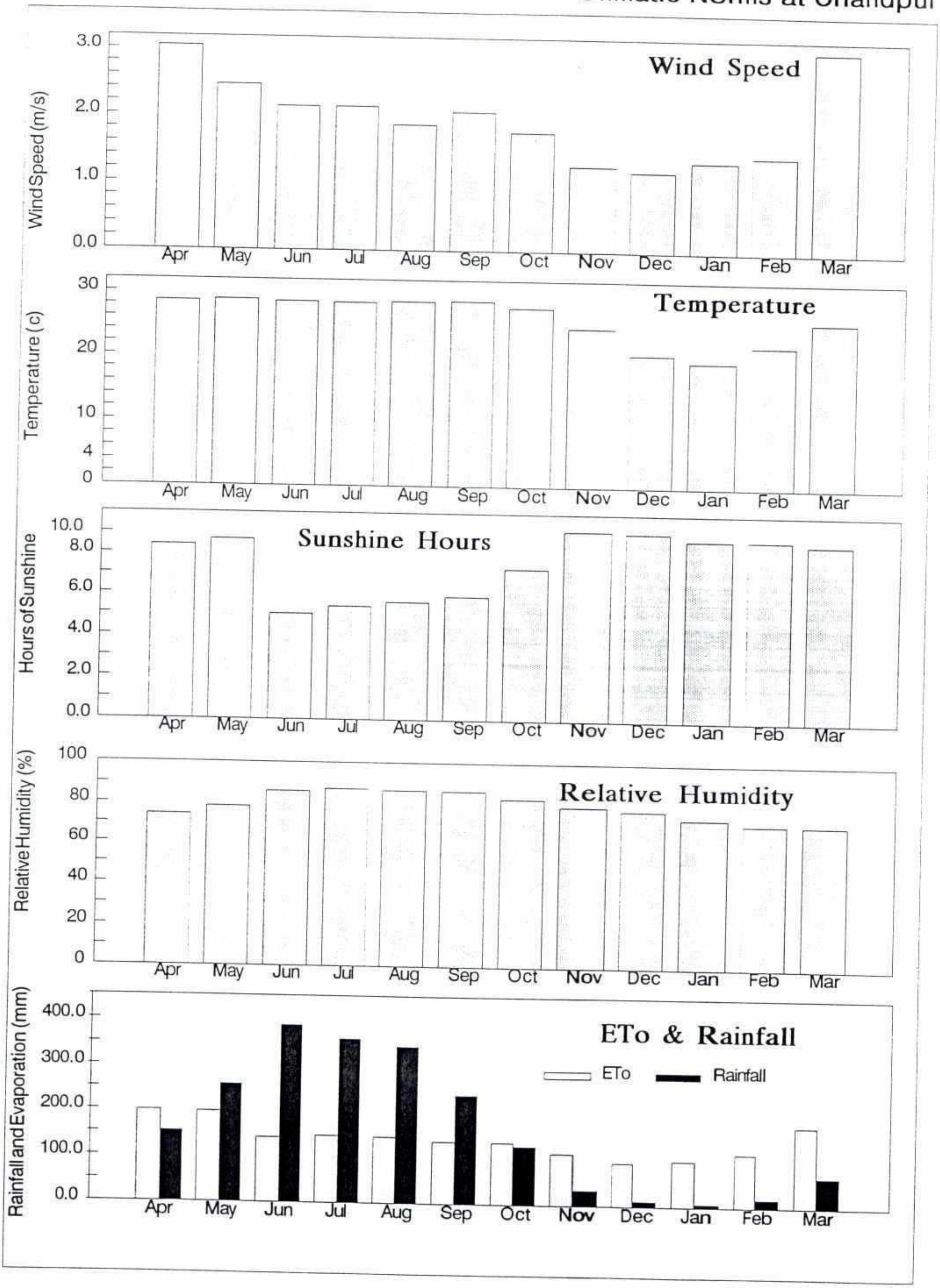

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Figure VI.1.4

Climatic Norms at Noakhali

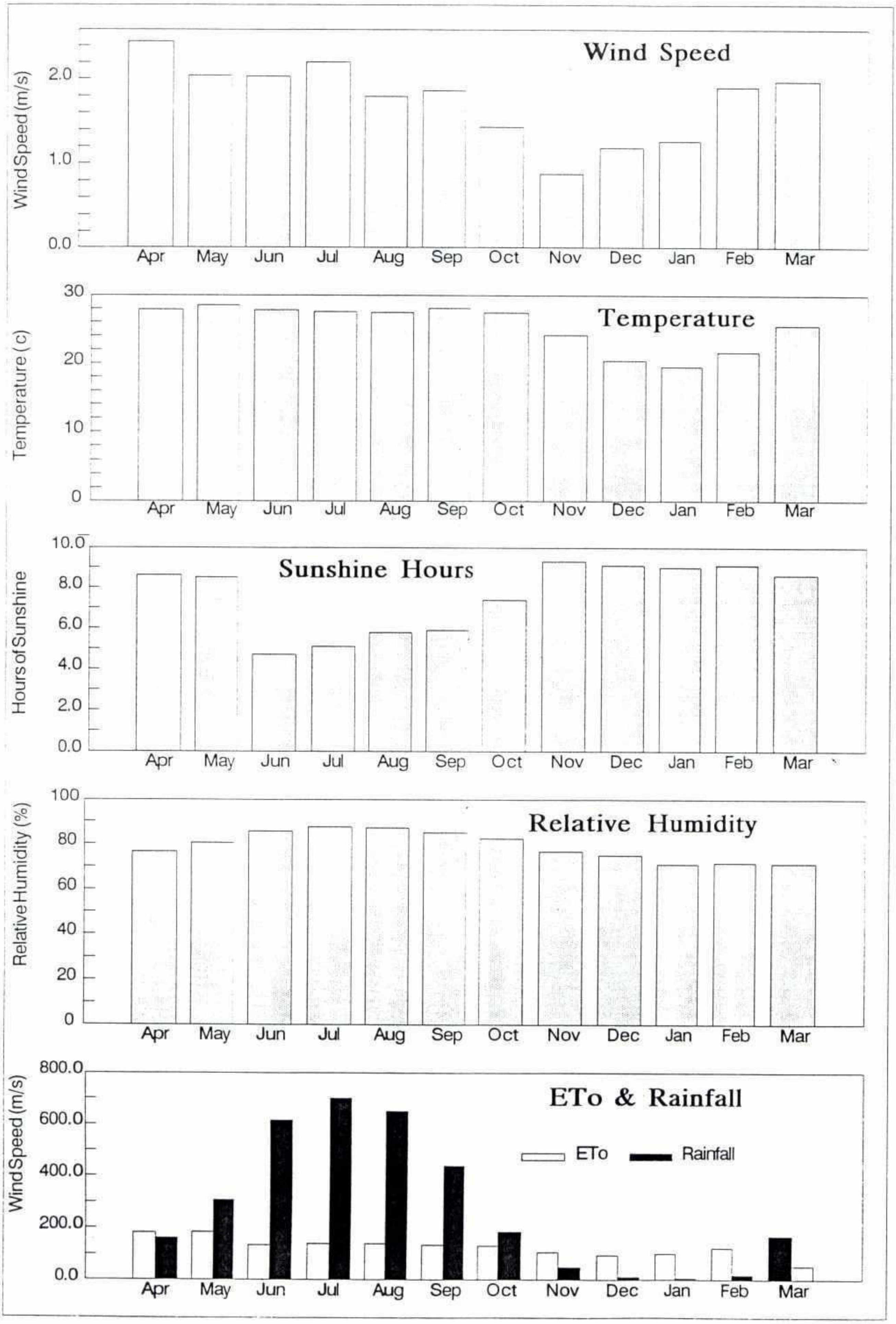

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TABLE VI.1.1

Climatic Norms at Comilla

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
Mean Temperature (c)	27.9	28.3	28.2	28.1	28.1	28.3	27.3	24.4	20.2	19.0	21.6	25.6	25.6
Relative Humidity	76.1	80.1	85.3	87.1	86.4	84.3	80.9	76.4	72.4	69.6	66.8	69.7	77.9
Windspeed (m/s)	4.3	3.8	3.8	3.2	3.3	2.8	2.7	2.4	2.3	2.2	2.7	2.2	3.0
Sunshine (hrs/d)	8.4	8.7	5.0	5.4	5.6	5.9	7.3	9.2	9.1	8.8	8.8	8.6	7.6
Peanman Eto (mm)	212	210	157	156	155	145	147	126	113	117	139	195	1872
Rainfall (mm)	192	325	416	455	368	261	174	59	38	10	29	60	2870

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TABLE VI.1.2

Climatic Norms at Chandpur

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
Mean Temperature (c)	28.5	28.8	28.5	28.4	28.6	28.7	27.7	24.5	20.4	19.3	21.9	25.7	25.9
Relative Humidity	74.1	78.3	86.2	87.4	86.7	86.5	82.9	79.2	77.6	73.8	71.0	70.7	79.5
Windspeed (m/s)	3.0	2.5	2.1	2.1	1.9	2.1	1.8	1.3	1.2	1.3	1.4	3.0	2.0
Sunshine (hrs/d)	8.4	8.7	5.0	5.4	5.6	5.9	7.3	8.8	9.1	8.8	8.8	8.6	7.5
Peanman Eto (mm)	195	196	140	145	143	134	134	97	94	100	115	174	1670
Rainfall (mm)	152.0	257.0	387.0	358.0	343.0	237.0	126.0	7.0	12.0	7.0	18.0	66.0	1970

TABLE VI.1.3

Climatic Norms at Noakhali

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
Mean Temperature (c)	27.9	28.5	27.8	27.6	27.4	28.1	27.4	24.1	20.4	19.5	21.6	25.5	25.5
Relative Humidity	76.6	80.4	85.6	87.5	87.2	85.0	82.3	76.7	74.9	71.0	71.5	71.3	79.2
Windspeed (m/s)	2.5	2.0	2.0	2.2	1.8	1.9	1.4	0.9	1.2	1.3	1.9	2.0	1.8
Sunshine (hrs/d)	8.6	8.5	4.7	5.1	5.8	5.9	7.4	9.3	9.1	9.0	9.1	8.6	7.6
Peanman Eto (mm)	183	183	135	140	140	134	131	108	96	103	123	169	1645
Rainfall (mm)	161.0	306.0	614.0	700.0	648.0	439.0	186.0	49.0	13.0	6.0	19.0	53.0	3194

TABLE VI.1.4

Comparison of Evaporation Values for Noakhali Area ·

Method	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
Pan Evaporation	124	119	95	69.0	60	63	90	81	83	85	115	138	1122
Karim & Akland Evaporation	102	102	69	62	56	63	71	57	53	53	76	102	866
Manalo (mean monthly)	129	133	89	90	78	84	86	71	65	65	82	121	1093
SERM *	108	101	93	74	85	80	86	88	73	67	73	104	1032

* Based on Brahmanbaria Pan Evaporation

Potential evapotranspiration at Comilla is significantly higher than at either Noakhali or Chandpur. The reason for this is the higher recorded wind speeds at Comilla, possibly related to its proximity to the hills.

In an average year, potential evapotranspiration exceeds rainfall between the months of October an March throughout the region. Rainfall in the early and late monsoon periods is highly variable however, and the average conditions do not give a representative indication of requirements for irrigation. It is clear from Figures VI.1.1 to VI.1.4 that there is a requirement for irrigation between the months of October and April, even under average rainfall conditions. Rainfall and effective rainfall for agriculture are considered in greater detail in sections VI.1.3 and VI.1.4.

The peak rainfall months in the region are June, July and August. During these three months, about 55-60% of the annual rainfall total can be expected.

VI.1.3 Regional Rainfall

VI.1.3.1 General

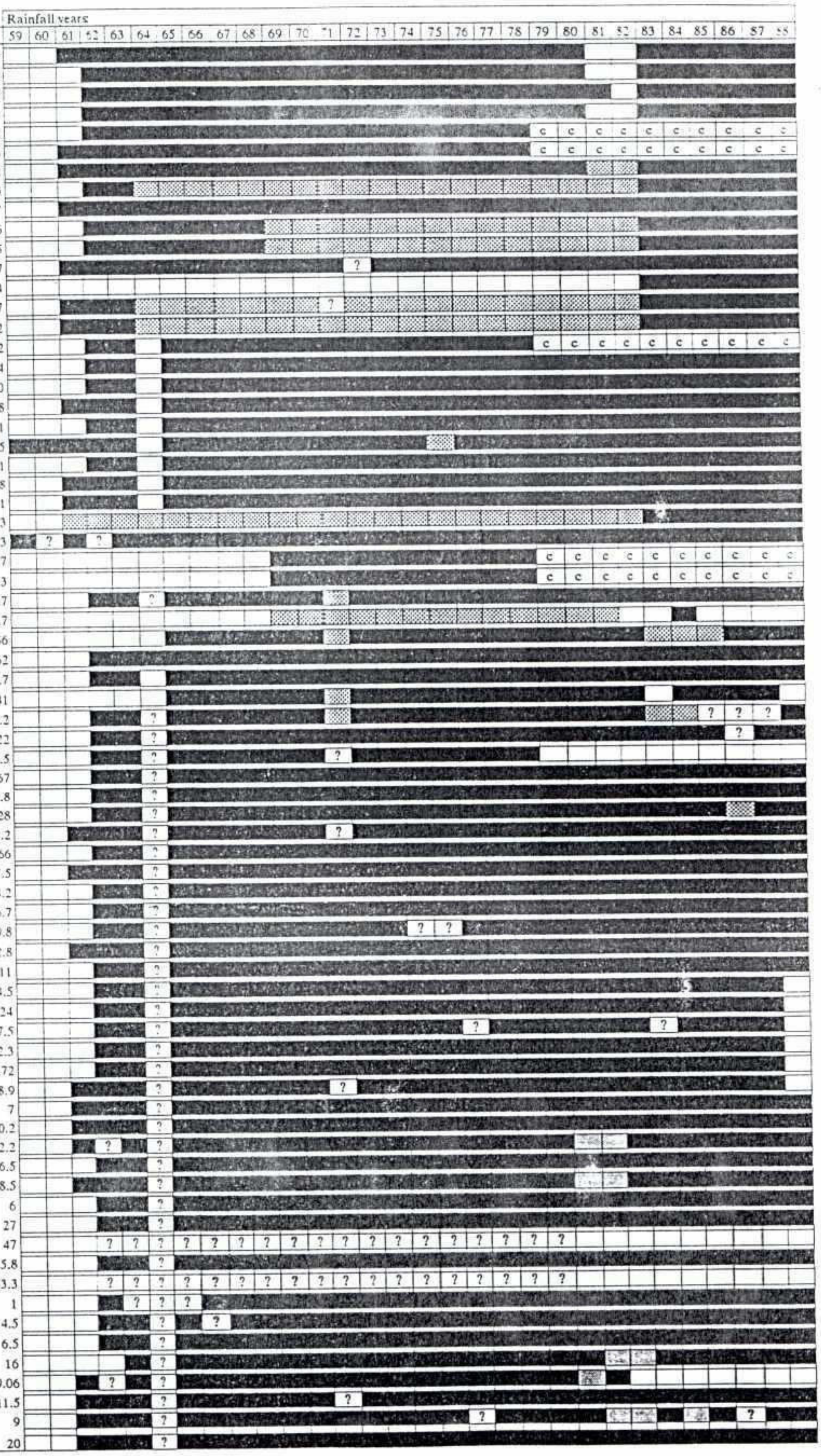
The locations of raingauges of relevance to the study have been indicated in Figure VI.1.1. The general availability of daily data for these stations is indicated in Table VI.1.5. In general terms the continuity of records is fairly good. A total of 40 daily gauges have been used on the study, and a data base created with a common record period of covering the 1962-1989 water years. These 40 stations were selected on the basis of their data availability and are highlighted in Table VI.1.5.

TABLE VI.1.5

Availability of Rainfall Data

Mean Daily Rainfall Data Availability for South East Region

Station	Latitude		Longitude	
R-017	24	9	90	25
R-031	24	5	90	10
R-031	23	49	90	18
R-037	24	11.7	90	29
R-069	23	55.3	90	35
R-070	24	7	90	36
R-076	23	57.3	90	42
R-101	24	2.7	90	59.3
R-103	23	58.7	97	7
R-105	24	7.92	91	29.06
R-110	24	22	91	25.5
R-111	24	8.14	91	22.97
R-126	24	18.2	91	44
R-131	24	4.3	91	7
R-132	24	11.8	91	12
R-251	22	56.5	90	33.2
R-252	22	32.7	90	20.4
R-254	22	47	90	10
R-255	22	25.1	90	33.8
R-257	22	29.9	90	43.1
R-258	22	42	90	22.5
R-260	22	41	90	39.1
R-261	22	37	90	46.8
R-263	22	58.4	90	14.1
R-264	22	39	90	11.3
R-266	22	22.3	90	21.3
R-268	22	11	90	48.7
R-270	22	7.6	90	39.3
R-301	22	44.5	91	45.7
R-304	22	44.2	92	22.7
R-308	23	15	92	1.86
R-311	22	39.64	91	50.62
R-315	22	29.8	92	13.7
R-318	22	55.93	92	1.41
R-319	22	50.5	91	48.2
R-320	22	46.71	91	49.22
R-321	22	47	91	43.5
R-323	22	55.07	91	53.67
R-324	22	38	91	47.8
R-327	23	1.29	91	48.28
R-330	22	28	92	4.2
R-334	22	36.86	91	42.66
R-351	23	44.5	90	47.5
R-352	23	21.43	91	4.2
R-353	22	52.3	91	16.7
R-354	23	14.3	90	49.8
R-355	23	2.5	91	32.8
R-356	23	27.5	91	11
R-357	23	31.7	90	44.5
R-358	23	1	91	24
R-359	23	5.8	91	17.5
R-360	23	15.2	90	52.3
R-361	22	29.14	91	25.72
R-362	23	45.4	91	8.9
R-363	23	14.3	91	7
R-364	22	56.2	90	50.2
R-365	23	33.1	90	32.2
R-366	23	42.6	90	56.5
R-367	23	53.5	90	58.5
R-369	22	50.3	91	6
R-370	23	12.8	91	27
R-371	23	32	90	47
R-372	23	2.5	90	45.8
R-373	23	43	90	53.3
R-375	22	34	91	1
R-376	22	59.2	91	14.5
R-377	23	1.9	91	6.5
R-402	23	31	90	16
R-408	23	38.57	90	29.06
R-410	23	12.57	90	11.5
R-412	23	38	90	9
R-413	23	15	90	20



Legend: c – station closed; ? – availability uncertain; ■ – full record; ▒ – Incomplete record

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VI.1.3.2 Data Reliability

A number of forms of analyses have been carried out to test the reliability of the data, including cross correlation and double mass.

Cross correlations for ten day and monthly rainfall totals between the months of April and October are presented in Figures VI.1.5 and VI.1.6. The correlation coefficients are generally higher for the monthly totals than for the ten day totals, as would be expected, and the indication is of general consistency. The exceptions, however, are stations R-357, R-365 and R-366, which correlate very poorly with each other and with their neighbouring stations. These stations are in close proximity to each other, and high correlations would have been expected. Correlation coefficients between station R-375 and its neighbours are also low, but not as significantly so as with stations R-357, R-365 and R-366. There is therefore reason to suspect data quality at each of these stations.

Double mass curve analysis has been carried out on each of the four stations identified through cross correlation analysis as having suspect data quality, and on a further two stations which were considered to be typical from the correlation analysis. The stations tested, and the groupings of check stations used are summarised in Table VI.1.6.

Station R-375, Ramgati, appears to have experienced some change in regime between 1966 and 1980 (Figure VI.1.7). The slope of the mass curve before and after this period is similar, but seems to have undergone progressive change in between. The mean annual rainfall total at this station is particularly high, and it could be important to the design of drainage facilities in the south of the region. The data are apparently unreliable and should not be used in any detailed analysis until the station history can be verified and reasons, if any, for the apparent unreliability defined.

Station R-357, Daudkandi, appears to have experienced some change after 1973, and again after 1984 (Figure VI.1.8). The mass curve is typical of what could be expected with changes in station location, and the station history must be verified. The data for this station should not form the basis of any detailed analysis. An inspection of the station history should be carried out.

The double mass curve for station R-365, Munshiganj, is shown in Figure VI.1.9. There are obvious discontinuities in the records in 1973 and in 1980. In the daily records for 1973, the daily total of 101.6 mm occurs on 12 occasions between April and September, which is clearly impossible. There are also frequent occurrences of daily values of 20.3, 25.4 and 50.8, in 1973 and other years. These must in fact be missing values, and have been set as such. In 1980, the daily records indicate only 44 mm annual rainfall for the station and clearly the entire record for this year should be considered to be missing. With the removal of these two anomalies, there still remain problems of changes in the shape of the mass curve, which may be due to changing exposure of the gauge. There is therefore considerable doubt about the overall reliability of the record, and confirmation of station history is required.

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Figure VI 1.5
Cross Correlations for 10 Day Rainfall Totals

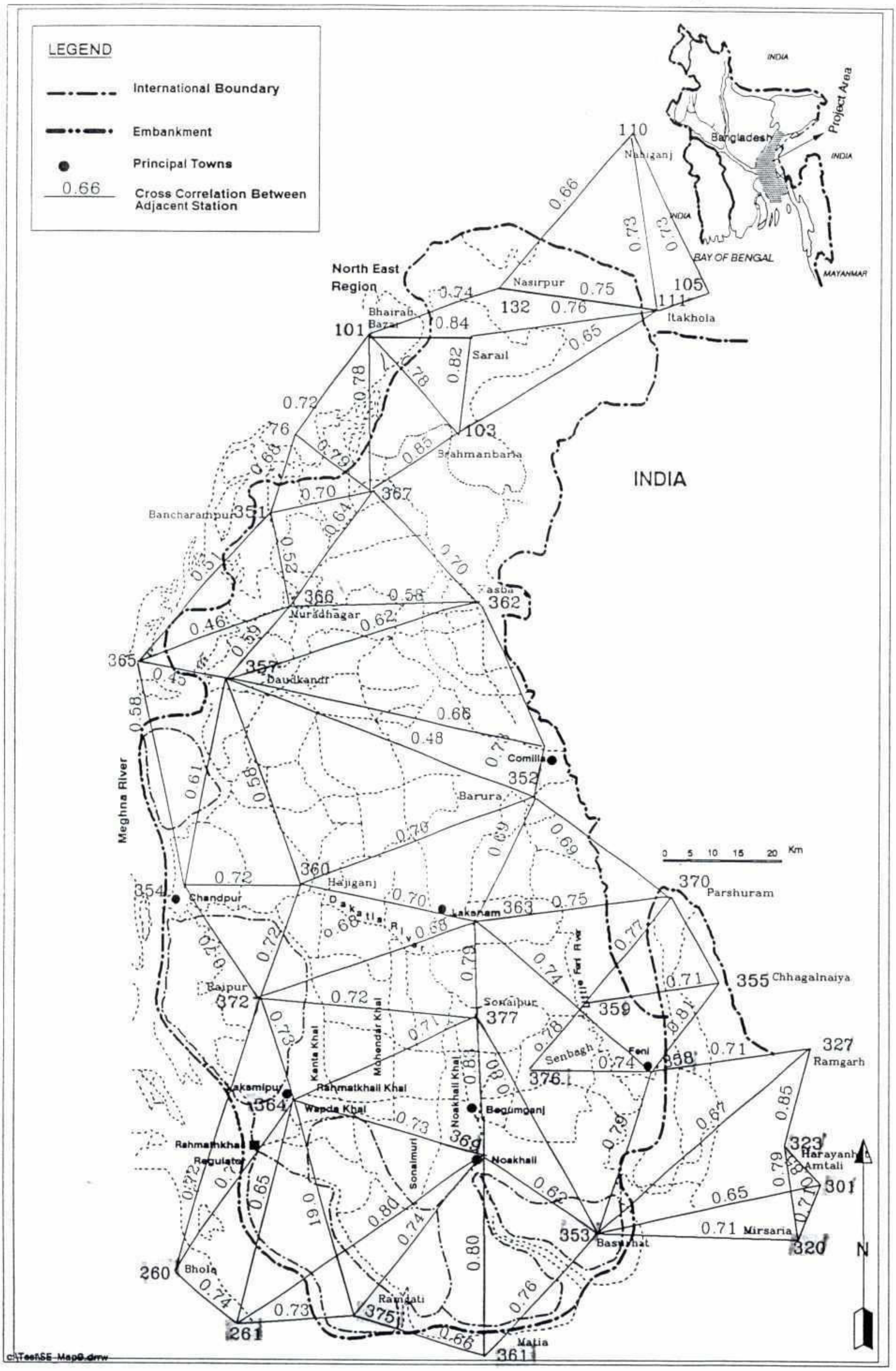

Figure VI 1.6
Cross Correlation for Monthly Rainfall Totals

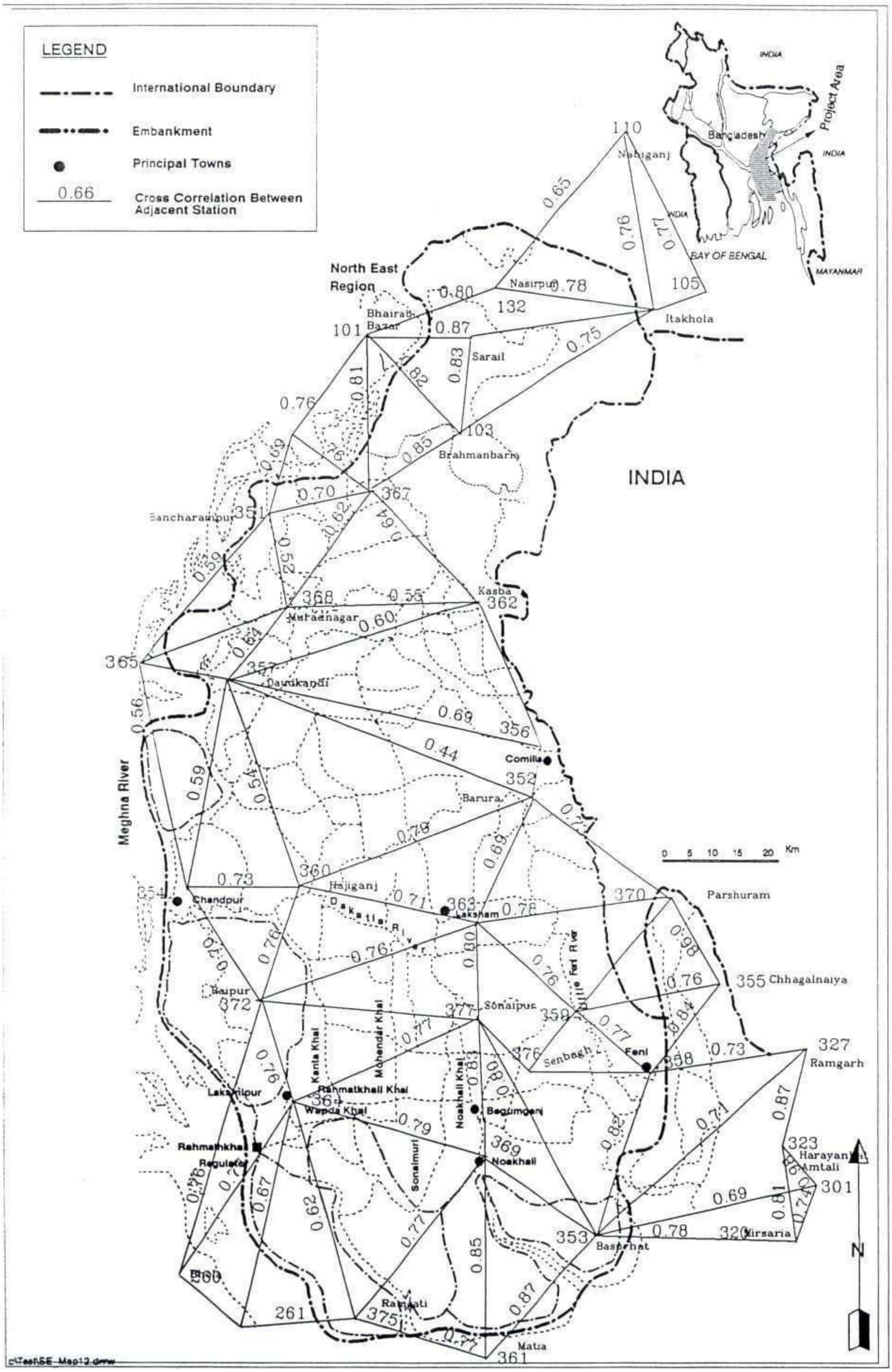

Figure VI.1.7

Double Mass Curve Analysis, Station R-375

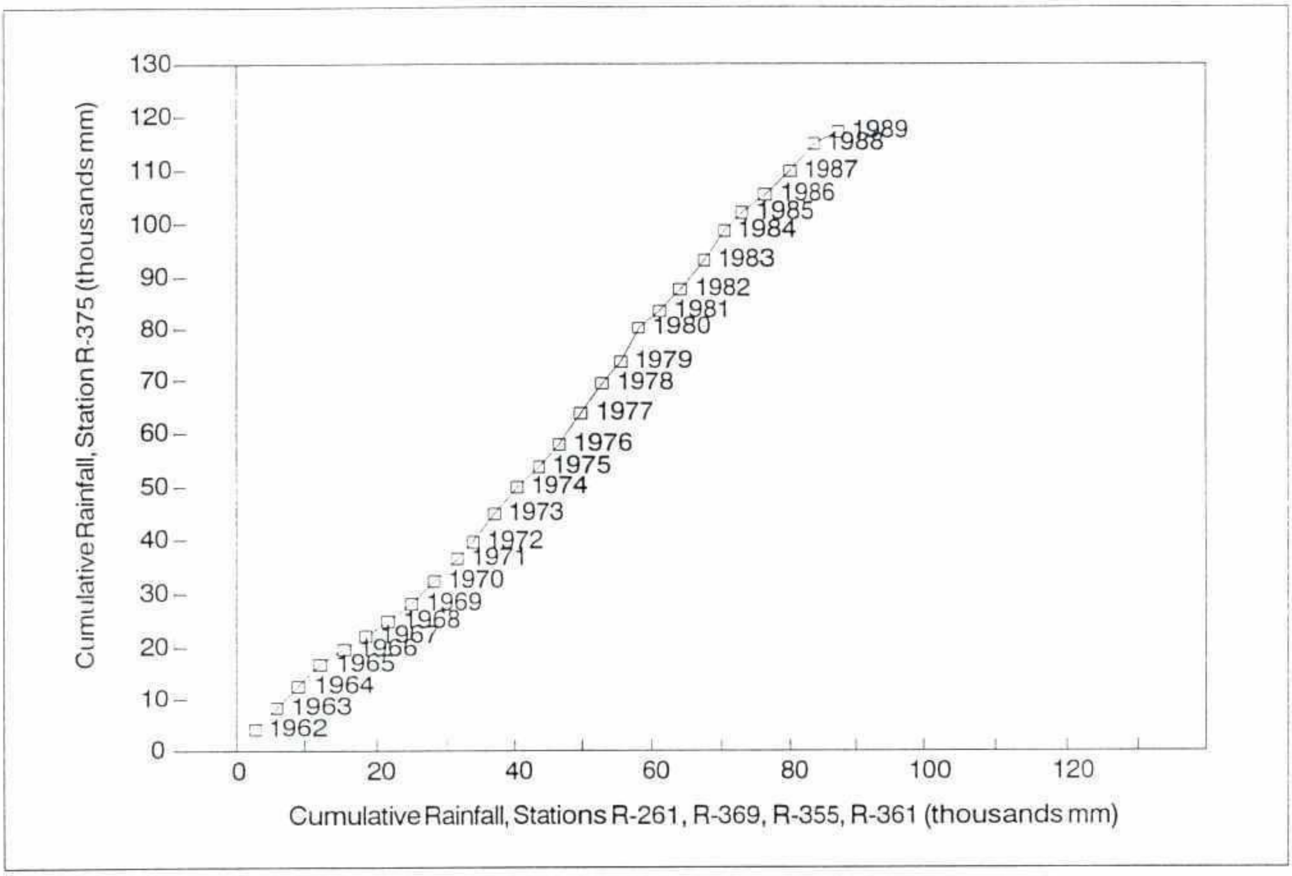

Figure VI.1.8

Double Mass Curve Analysis, Station R-357

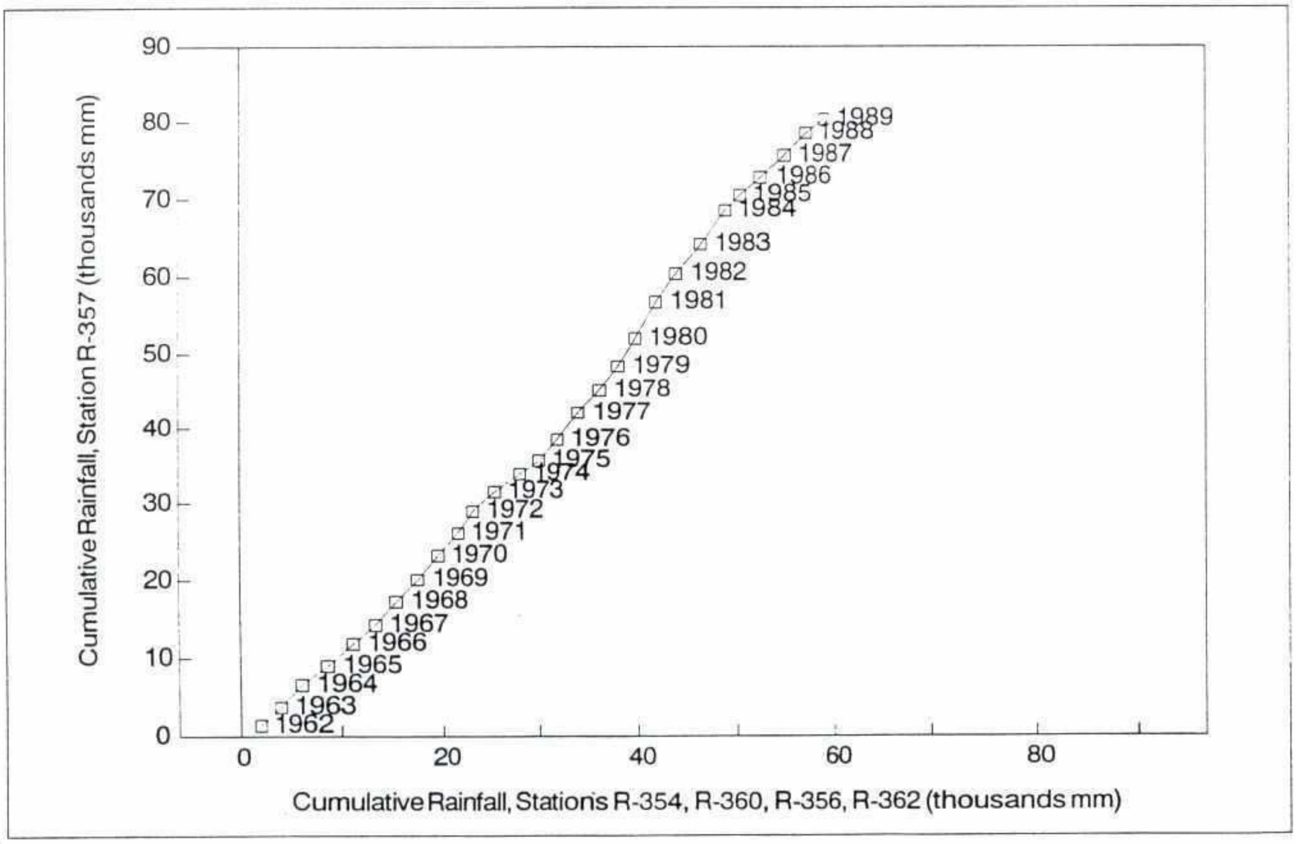

Figure VI.1.9

Double Mass Curve Analysis, Station R-365

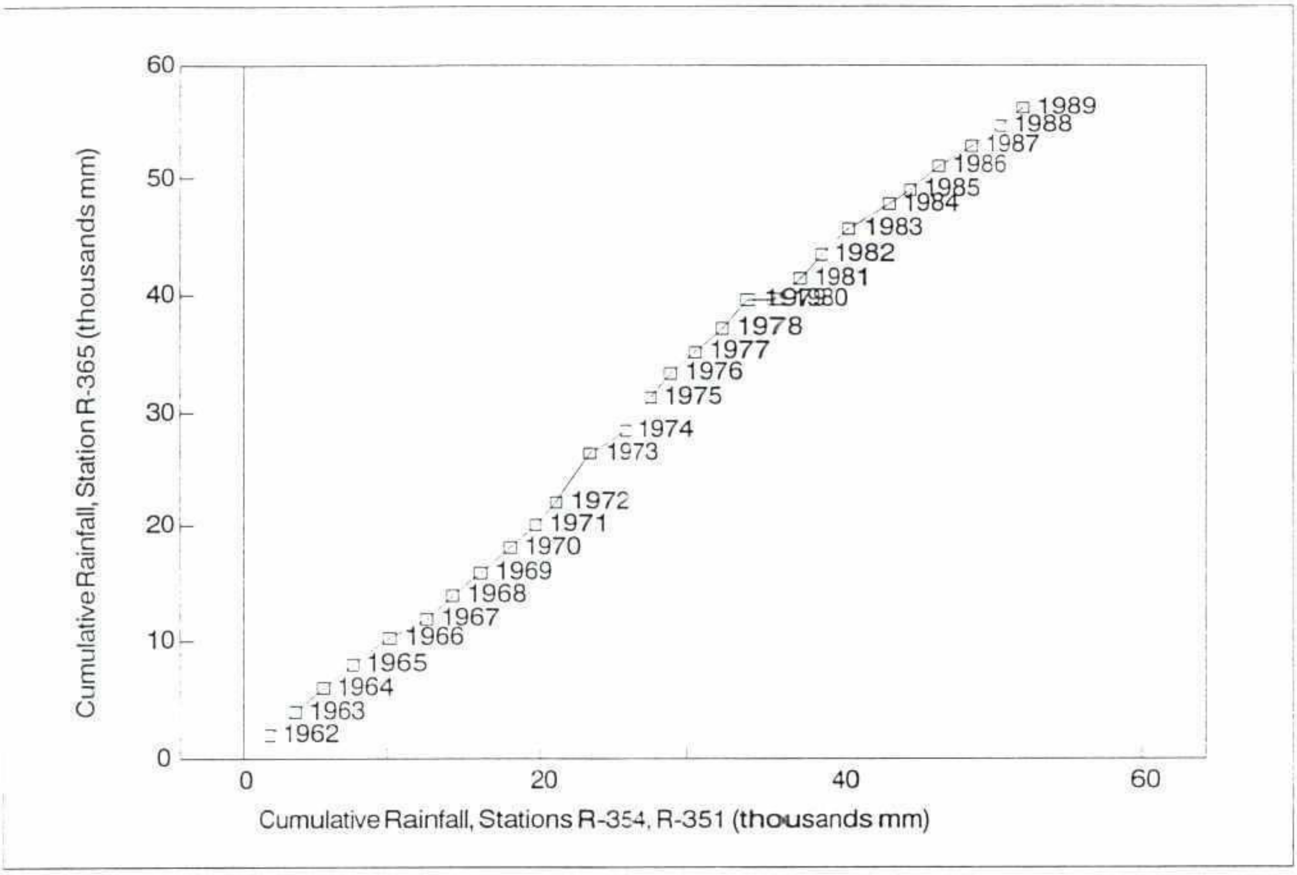

Figure VI.1.10

Double Mass Curve Analysis, Station R-366

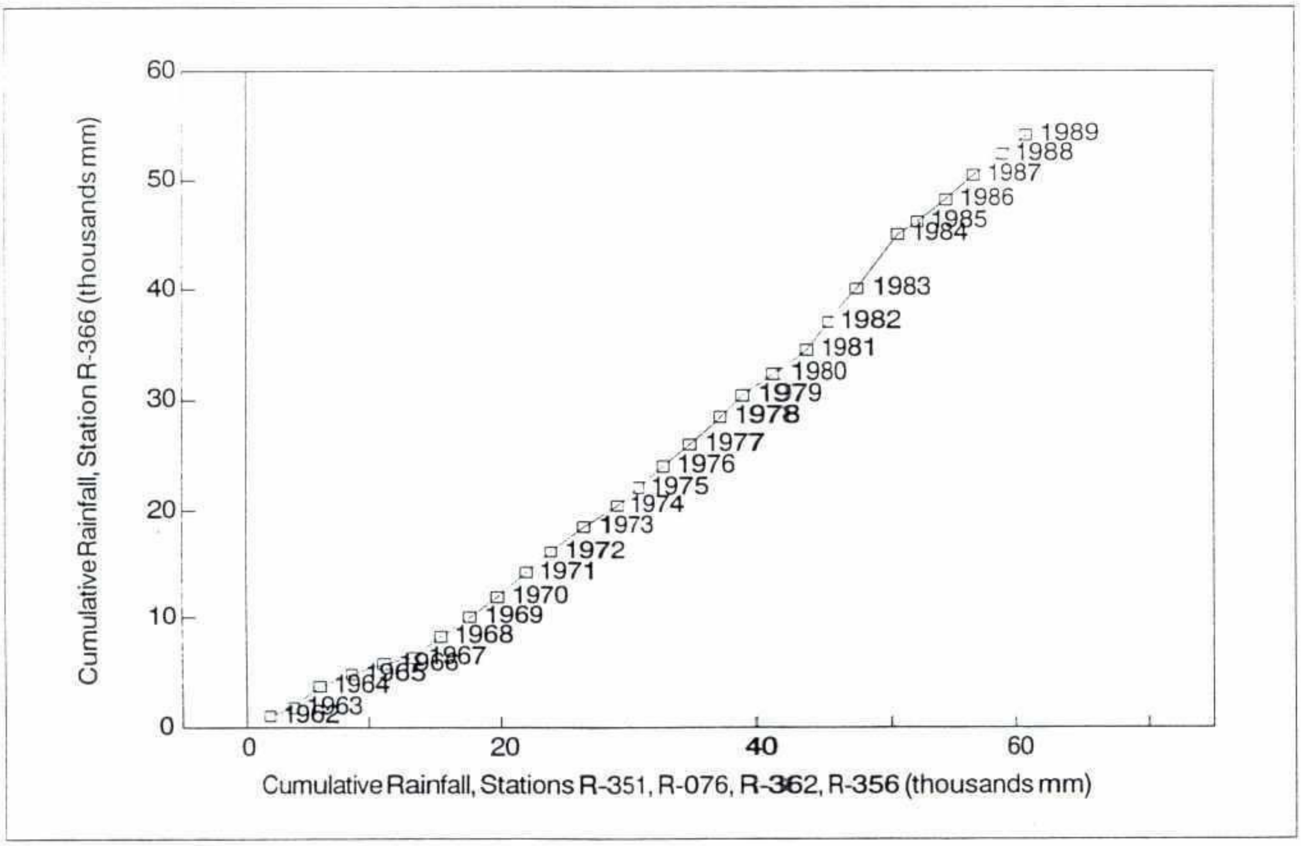

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TABLE VI.1.6

Raingauges Used in Double Mass Analysis

Test Station	Check Stations
R-375	R-261, R-369, R-353, R-361
R-357	R-354, R-360, R-356, R-362
R-365	R-354, R-351
R-366	R-351, R-076, R-362, R-356
R-131	R-103, R-101, R-132, R-111
R-376	R-377, R-359, R-369, R-358

The records for station R-366, Muradnagar, are clearly unreliable prior to 1968 (Figure VI.1.10). For the purposes of the present study, this period of record has been excluded from all analyses, but it is important that the station history be checked to ascertain the reasons for data unreliability. The other apparent problems in the data lie in 1983 and 1984, when there is a significant increase in the slope off the mass curve. In 1984, storms in June and August seem to have contributed significantly to the rainfall totals, and are an order of magnitude higher than the rainfalls recorded on the same days at station R-351, and R-357 which are nearby. Checking of the original station records for R-366 in 1983 and 1984 is therefore considered to be advisable. The data have not been excluded from analysis for regional planning purposes, but should only be used with caution until verification of the records can be carried out. Subsequent work carried out as part of the Gumti Phase II feasibility studies has also raised some doubts about the records at station R-076.

Figures VI.1.11 and VI.1.12 present mass curves for stations R-131 and R-376. These are more typical of expected plots for reliable data. The indications are that the rainfall data quality is, on the whole, good.

VI.1.3.3 Time Series Analysis

Time series analysis has been carried out on the annual rainfall data for stations R-131 and R-376. The records are too short and have too many gaps to permit detection of any long term trends, but the analysis does assist in giving an understanding of the inter-annual variations in rainfall data that exist. The missing values in the annual totals for each of these stations also restricts the usefulness of any statistical interpretation.

Figure VI.1.13 presents the deviations from the long term mean of annual rainfalls at stations R-131 and R-376. Direct comparison is difficult because of differences in the years of missing data at each station, and the influence of the very dry 1972 at station R-376, which was a missing year at R-131. The results of a series of statistical tests for randomness, trend and persistence, on the records of both stations are presented in Table VI.1.7. At station R-131 there is some evidence of weak persistence caused by the below average rainfall after 1974, which was the wettest year on record at the station. At station R-376 the general randomness tests are biased by the number of missing years of record. There is evidence of weak persistence, probably caused by the bias introduced by the influence of the very dry 1972 on the long term mean.

Figure VI.1.11

Double Mass Curve Analysis, Station R-131

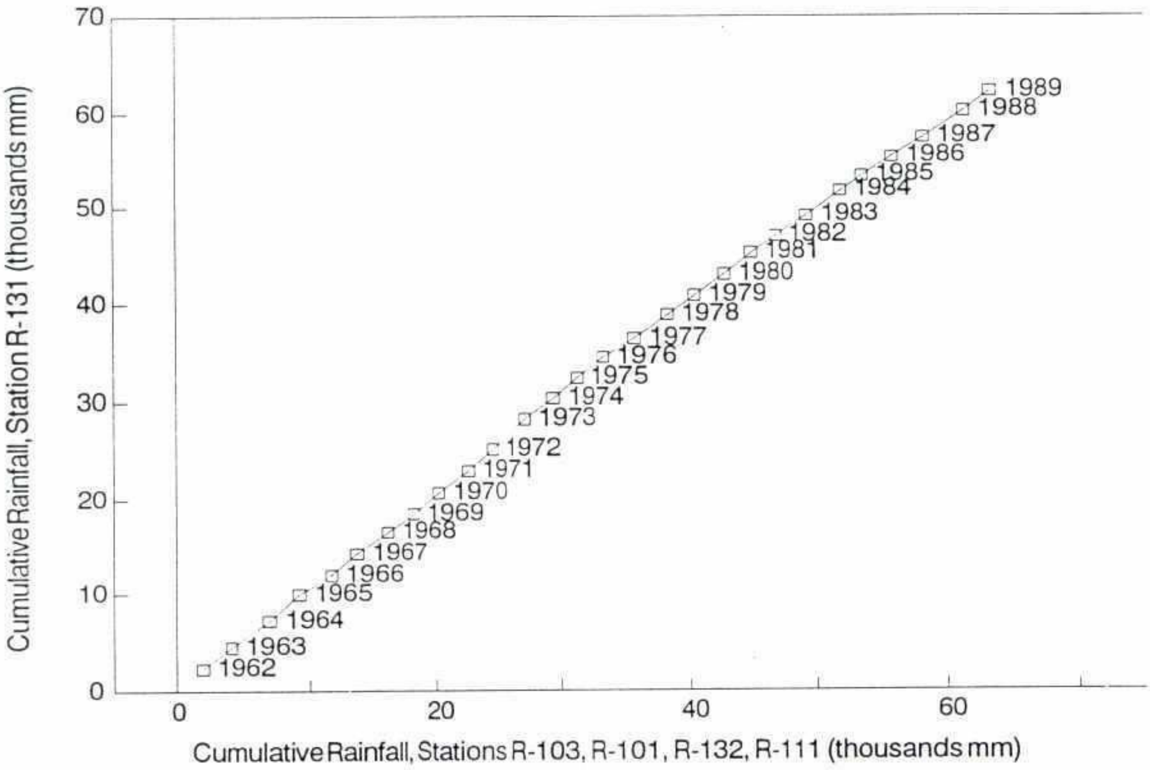

Figure VI.1.12

Double Mass Curve Analysis, Station R-376

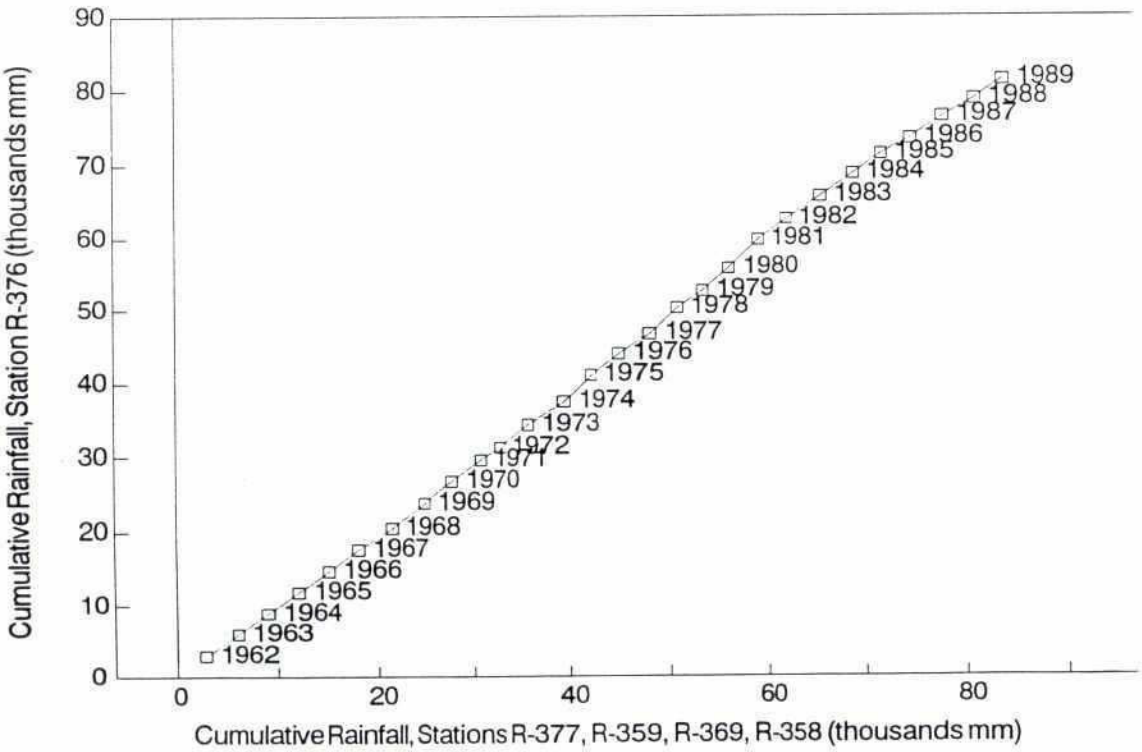

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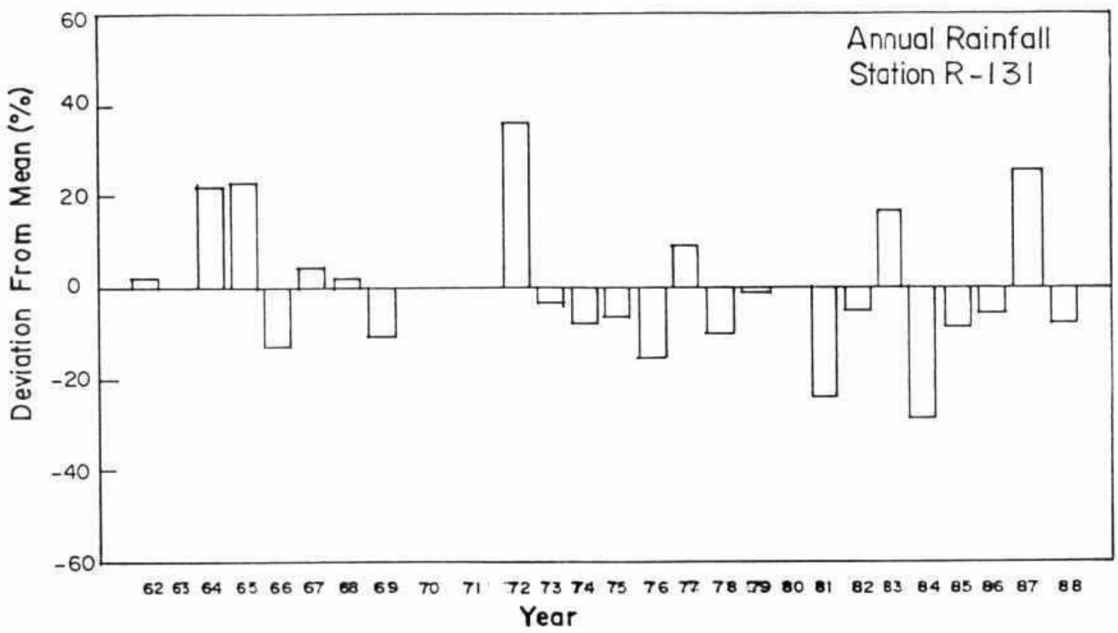
Figure VI.1.13

Annual Rainfall Deviations



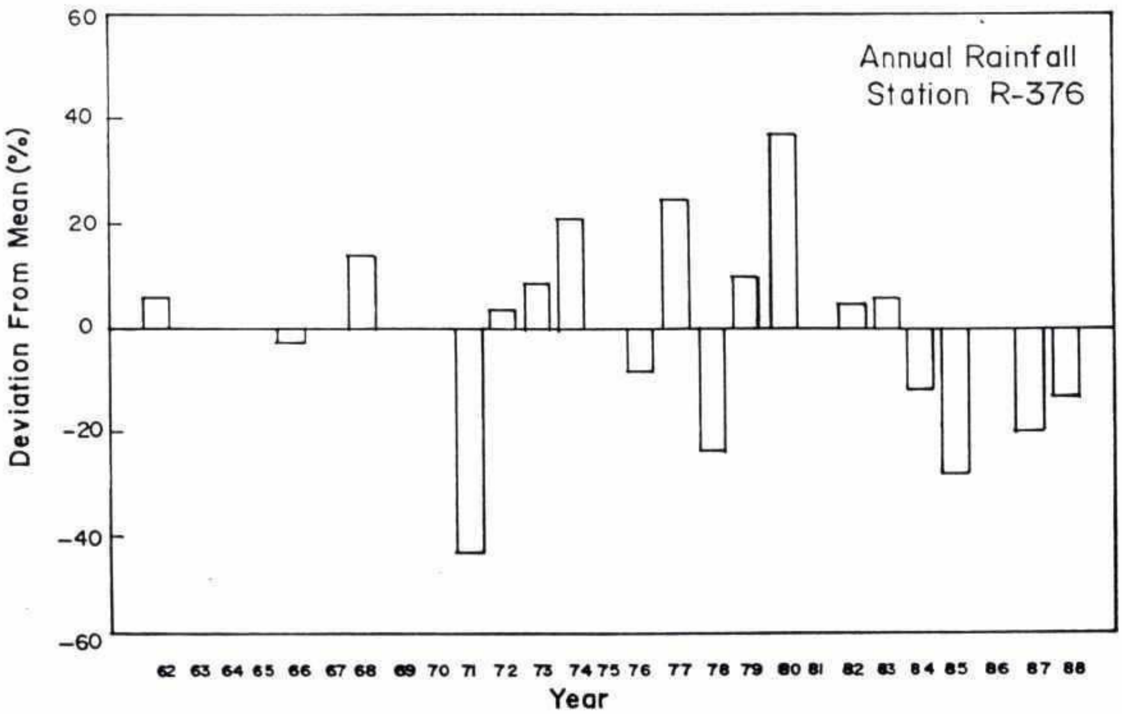


TABLE VI.1.7

Statistical Tests on Annual Rainfall

Statistical Test	R-131, Sarail		R-376, Senbag	
	Expected	Observed	Expected	Observed
Randomness				
Median Crosses	11 +/- 6	12	8 +/- 5	5
Turning Points	14 +/- 3	13	7 +/- 3	3
Persistence				
First Order Serial Correlation	-0.05+/-0.42	-0.12	-0.06+/-0.49	0.01
Spearman Rank	-0.05+/-0.43	-0.60	-0.09+/-0.56	0.56
Trend				
Rank Order	-0.05+/-0.41	-0.12	-0.06+/-0.47	-1.43
Mann-Whitney U Test	66 +/- 32	50	36 +/- 20	35
Wald-Wolfowitz Runs Test	12 +/- 5	12	9 +/- 4	10

It is difficult to draw any particular conclusions from the time series analysis, and much longer homogeneous records would be required for any meaningful evaluation of non-stationarity to be made.

VI.1.3.4 Annual Rainfall Distribution

Isohyetal maps of mean annual rainfall, and of annual rainfall equalled or exceeded in 80 per cent of years have been prepared and are presented in Figures VI.1.14 and VI.1.15. The maps have been prepared on the basis of the available data at 40 stations in the region for the 1962-89 period. Infilling of missing years of data at individual stations has not been carried out, but this is does not limit the usefulness of the maps as the general data availability is good. It should be noted that the isohyets do not represent a homogeneous pattern, and that in any particular year, the regional distribution of rainfall may be quite different to that shown.

The isohyets have been prepared by fitting a multi-quadratic surface to the irregularly spaced rainfall data points. Unlike mathematical surfaces based on low-order polynomials, orthogonal polynomials or double Fourier series which are generally fitted by least squares, multi-quadratic surfaces exactly fit the data points. In order to permit plotting, the surface has been output on a 5 km grid, and a further automatic routine interpolating between grid points, used to plot the contours.

The highest rainfalls occur in the south of the region, particularly around stations R-375, Ramgati. There has been some discussion about data quality at this station in the preceding section, but for the purposes of isohyetal mapping, this and the other stations at which problems were highlighted have been included. Mean annual rainfall at Noakhali is of the order of 3200 mm, and decreases northwards to about 2000 mm at Comilla. Moving north from Comilla, annual totals start to increase again towards the Sylhet depression, reaching about 2500 mm by Nasirpur.

Figure VI 1.14
Isohyets of Mean Annual Rainfall

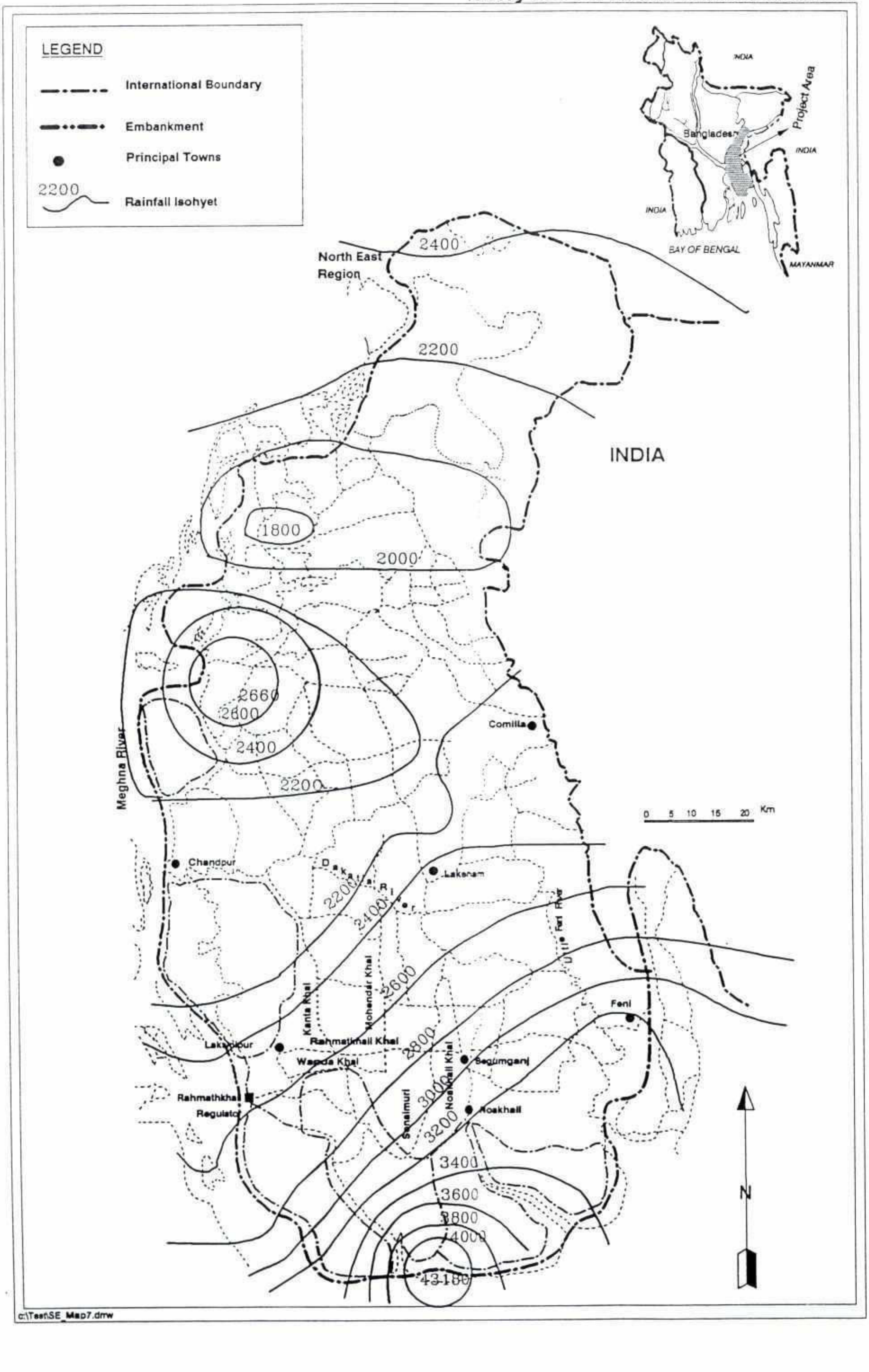
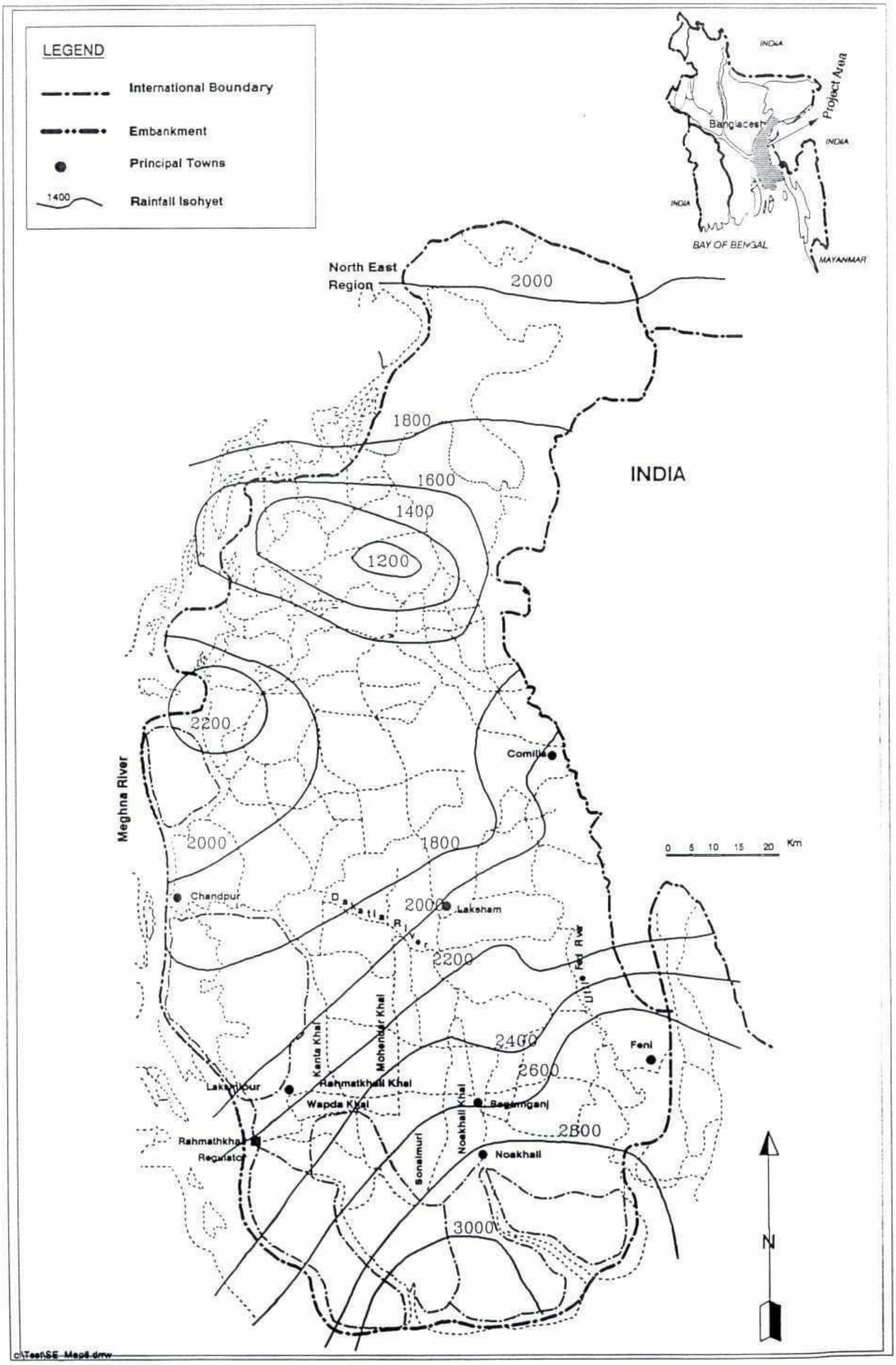


Figure VI 1.15
Isohyets of Annual Rainfall Exceeded in 80% of Years



The influence of station R-357, Daudkandi, on the isohyets should also be noted. This record is suspect, and results in a significant localised peak in the isohyetal pattern.

The pattern of annual rainfall distribution at 80 per cent exceedance probability is similar to that for the mean condition, and annual totals are generally about 500 mm lower.

VI.1.4 Decad Rainfalls at 80 Per Cent Exceedance

Decad rainfalls at 80 per cent exceedance probability have been evaluated for every station in the region, and are presented in Table VI.1.8. The purpose of this analysis is to provide the basis of irrigation water demand calculations throughout the year in different parts of the region. The methodology adopted has been to rank each series of decad totals, and to calculate the rank corresponding to 80 per cent exceedance probability using the Blom formula; the corresponding rainfall is then computed through linear interpolation between the ranks. It should be noted that the values presented in Table VI.1.8 do not represent a homogeneous series, and there is no dependence between decad values. It is also recommended that the values for the stations identified as being of suspect data quality be ignored. Station R-367 has a large number of missing records in its daily form, and the results from this station are therefore for a less complete record period and are not representative.

Table VI.1.8, taken in conjunction with Figure VI.1.15, gives a clear indication of the length of the irrigation season throughout the region. North of the Gumti, there is no effective rainfall between mid October and mid April. In the south of the region, it is often mid May before there is any significant rainfall at the 80 per cent exceedance level.

VI.1.5 Pentad Analysis

An analysis has been carried out of 5 day rainfalls in order to give an indication of the periods for which supplemental irrigation could be required. For the purposes of the present analysis, a wet pentad is defined as follows:

- the central 5 days of a fifteen day period in which the total rainfall exceeds 45 mm;
- the rainfall in at least one of the pentads other than the one containing the maximum rainfall in the 15 days must exceed 9 mm.

A typical output from the analysis is presented in Table VI.1.9. Appendix I contains the results for each of the daily raingauges in the study area. It is emphasised that the results are indicative only, taking no account of soil conditions, water table position, or crop requirements. They are therefore only a first level planning tool to help identify areas in which further more detailed forms of analysis are likely to be required. The analysis does give a good indication of the frequency with which supplemental irrigation will be required at any location.

TABLE VI.1.8

Decad Rainfalls at 80% Exceedance Probability (mm)

Station	Apr 1	Apr 2	Apr 3	May 1	May 2	May 3	Jun 1	Jun 2	Jun 3	Jul 1	Jul 2	Jul 3	Aug 1	Aug 2	Aug 3	Sep 1	Sep 2	Sep 3	Oct 1	Oct 2	Oct 3	Nov 1	Nov 2	Nov 3	Dec 1	Dec 2	Dec 3	Jan 1	Jan 2	Jan 3	Feb 1	Feb 2	Feb 3	Mar 1	Mar 2	Mar 3	80% Ann.	Ann. Mean
R-076	0	21	28	41	38	42	69	98	75	29	63	46	31	47	61	24	30	17	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2149	2642
R-101	0	5	6	40	32	17	63	94	34	36	69	42	32	44	47	20	36	17	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1913	2183
R-103	0	9	20	15	48	32	55	102	18	25	61	55	37	30	41	24	27	16	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1679	2139
R-105	0	29	18	37	46	45	62	125	54	35	45	54	49	52	54	55	45	31	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1953	2355
R-110	0	22	19	32	52	55	52	113	51	56	64	73	53	61	68	39	35	29	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2138	2548
R-111	0	29	13	25	35	35	52	77	24	39	64	45	41	48	56	41	41	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2058	2232
R-131	0	18	21	22	22	28	49	81	28	39	54	66	45	52	43	32	37	16	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1999	2221
R-132	0	34	27	27	37	17	47	79	51	39	62	65	44	53	74	46	44	24	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2080	2484
R-260	0	0	6	4	8	36	44	102	79	79	52	86	62	76	81	42	39	24	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2227	2460
R-261	0	0	0	0	0	20	66	83	85	91	85	71	118	112	91	104	29	19	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2263	2788
R-301	0	0	4	0	12	19	67	106	48	44	57	63	33	60	80	28	24	12	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2224	2900
R-311	0	0	2	7	23	33	71	56	46	64	47	95	59	62	67	34	23	16	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2110	2661
R-315	0	0	14	13	11	34	64	120	67	67	49	95	77	64	86	60	25	47	24	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2248	2635
R-320	0	0	0	14	17	38	68	71	66	105	100	114	71	85	132	58	53	36	40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2832	3437
R-323	0	0	8	8	16	39	77	76	39	67	41	70	61	58	97	41	32	34	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2342	2784
R-327	0	2	1	17	23	31	64	90	42	82	62	56	77	68	74	46	37	36	29	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2188	2858
R-351	0	9	6	10	15	15	17	48	31	19	33	37	29	27	29	30	23	14	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1300	1731
R-352	0	0	2	12	1	12	41	71	52	45	75	60	24	43	71	29	30	8	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1493	2044
R-353	0	0	4	6	32	25	96	73	72	95	97	106	112	86	151	39	37	45	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2868	3321
R-354	0	5	10	6	16	26	62	81	48	58	29	63	56	35	45	27	9	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1786	2008
R-355	0	3	0	16	43	26	66	79	50	73	55	75	44	50	111	58	41	37	16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2667	2867
R-356	0	10	14	17	16	27	58	64	61	35	41	77	46	53	63	41	30	15	20	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2000	2325
R-357	0	4	33	27	41	31	42	73	41	81	91	59	46	41	57	32	43	36	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2156	2870
R-358	0	1	2	9	27	22	81	112	74	70	111	102	53	67	97	54	40	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2874	3298
R-359	0	0	0	4	7	7	71	67	78	71	64	59	39	60	82	44	45	22	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2197	2689
R-360	0	7	7	10	2	11	36	74	45	55	52	58	46	37	51	35	34	12	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1752	2084
R-361	0	0	2	7	4	26	91	63	91	134	89	112	124	93	113	81	37	21	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2739	3161
R-362	0	6	7	29	30	32	47	42	24	23	57	31	16	24	32	17	27	14	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1712	1990
R-363	0	2	5	3	19	21	44	92	88	40	60	88	66	61	75	30	38	5	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2201	2574
R-364	0	2	7	1	11	18	95	69	63	86	70	88	70	60	89	54	33	35	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2106	2536
R-365	0	3	3	7	27	18	28	59	22	14	25	53	22	13	19	6	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1239	1717
R-366	0	2	25	0	50	26	20	58	59	28	38	50	32	18	58	41	43	9	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1772	2248
R-367	7	4	29	29	36	60	7	64	31	49	19	39	37	4	47	24	42	7	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1494	1857
R-369	0	0	2	12	16	51	86	110	114	94	105	101	111	106	131	70	62	29	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2864	3198
R-370	0	2	7	12	6	21	57	74	31	46	59	77	48	59	94	55	24	26	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2075	2441
R-372	0	6	15	10	5	17	41	51	78	72	62	68	67	72	57	52	43	18	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1805	2162
R-375	0	0	0	3	2	31	62	96	128	173	128	141	116	120	119	77	19	33	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2975	4185
R-376	0	1	2	0	27	15	33	87	78	138	115	67	55	76	133	46	34	13	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2417	2907
R-377	0	2	2	0	8	23	94	71	52	96	85	97	64	55	103	86	51	24	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2544	2758
R-402	0	10	21	20	14	29	33	37	39	53	59	46	45	27	36	37	26	13	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1521	1916

TABLE VI.1.9

Pentad Analysis at Station R-076, Narsingdi

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-*.*....**.........*..........*......************************************
1963	***...***......................***..**..**..******************************
1964	*..........**.................—..........*******************************
1965	*******..***...........................****...*****************************
1966	**.......**..........................*****************************...**
1967	**........**....*....**...................******************************...
1968	.....**...........................************************************..*
1969	**....***..**********************************
1970	*...**...*.........*..................**......*******************************
1971	**..................................***...****..******************************.
1972	....*.*..*****************************.*.*****
1973	***.......................................*.****.****************************..
1974	...**.........*..........—.........************************************
1975	**...****......*****......***..........************************************
1976	****..........................*....**..**
1977	....*......................**....*****..***********************************
1978	***..................*.....****..****..*************************************
1979	***...***..**...............*.......**...*********..*************************
1980	***.......................................*******************************
1981	*...***......****.****............***.***
1982	***......**........****...............********************************....**
1983	***.........***.......*...............**...**********************************
1984	.****...............................**....******************************...
1985	.*.*.................................**..***********************************
1986	.............*...........................******************************.***
1987	*.......*..............................*.*****************************..*...**
1988	***....*...............**..................**************************..******-
1989	————————————————————————————————

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

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VI.1.6 Drainage Design Rainfalls

Frequency analyses have been carried out on all daily rainfall stations in the project area, with the exception of the four stations identified as being unreliable. The objective has been to provided the basic data for drainage design purposes. EV1 (Gumbel) distributions have been fitted to the annual maximum series rainfalls of the following durations:

- 1 day;
- 2 day;
- 3 day;
- 4 day;
- 5 day;
- 7 day;
- 10 day.

The seasonality of rainfall extremes is also important and forms part of the drainage design process. This is to account for the different stages of crop growth that are likely at different times of the year, as well as the influence different drainage conditions in terms of main river levels and outfall controls. In accordance with practice in Bangladesh, rainfall extremes have been evaluated at each of the above durations for the following periods:

- pre-monsoon (April to June inclusive);
- mid-monsoon (July and August);
- post-monsoon(September and October).

A sample of results is presented in Table VI.1.10, and typical fitted distributions for each period at station R-131 (Sarail) shown in Figures VI.1.16 to VI.1.19. The results for all stations are included in Appendix II. Summary results for 1 day, 2 day and 3 day durations at return periods of 2, 5 and 10 years are presented in Table VI.1.11. These give a good indication of how conditions vary across the region. The rainfall extremes are high by world standards. The results of the analysis are consistent with the annual rainfall distribution, with greater extremes in areas of highest rainfall. Of particular note are the extremely high annual maxima at stations R-301, R-315, R-320 and R-327, which are in the Chittagong Hills to the south east of the study area.

VI.1.7 Storm Reduction Factors

An attempt has been made to investigate likely storm reduction factors in the region. Guidelines do exist in the BWDB design manual for aerial reduction factors. These are appropriate for project design, but for the analysis of regional events, it was considered appropriate to attempt an investigation of the order of storm reduction factors likely to be experienced. This proved to be less successful than had been hoped, partly as a result of missing records at some of the stations being used in analysis. The results may serve as a starting point for further analysis at some future date.

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Figure VI.1.16

Annual Maximum 5 Day Pre-Monsoon Rainfall
Station R-131

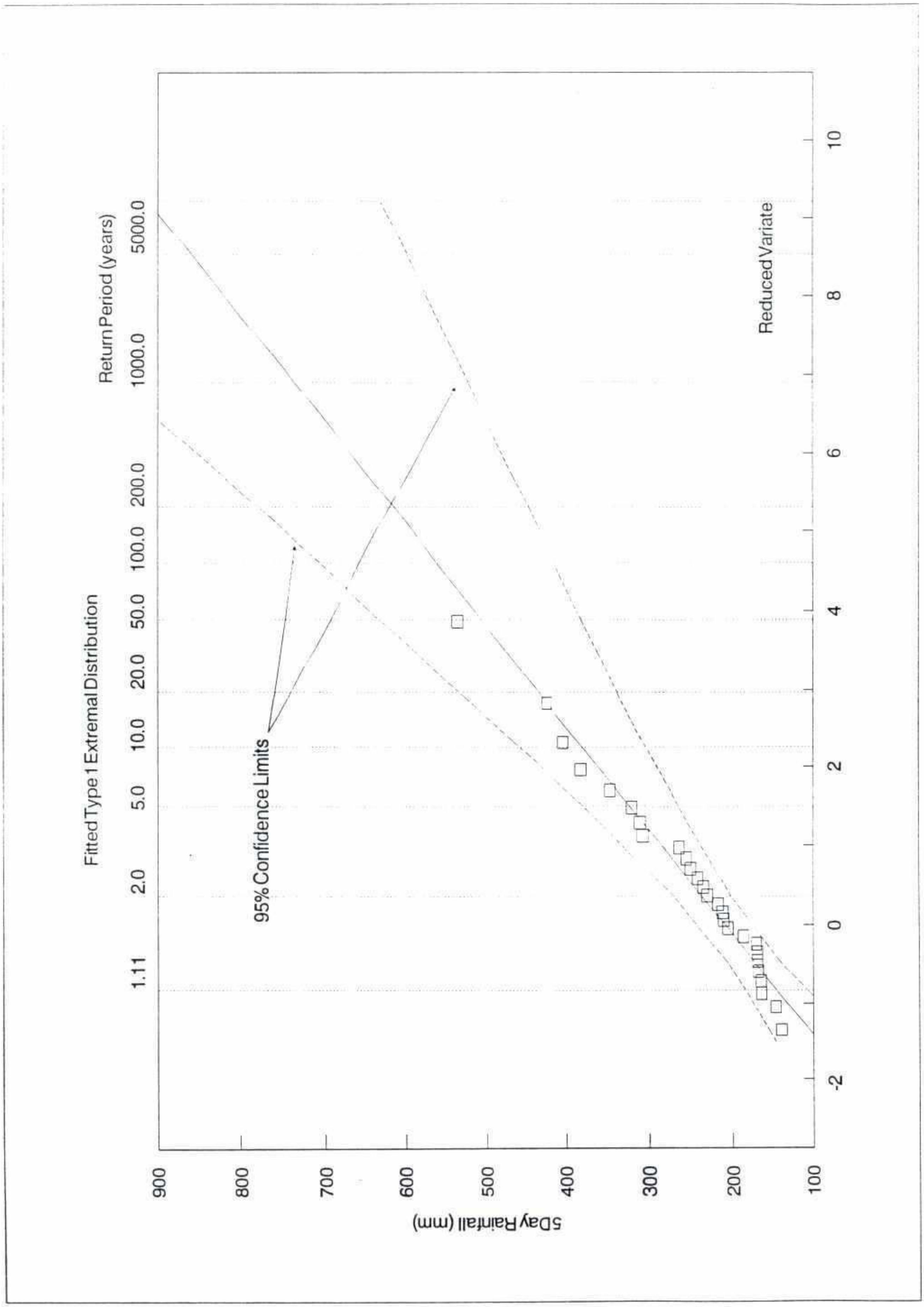

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Figure VI.1.17

Annual Maximum 5 Day Mid-Monsoon Rainfall
Station R-131

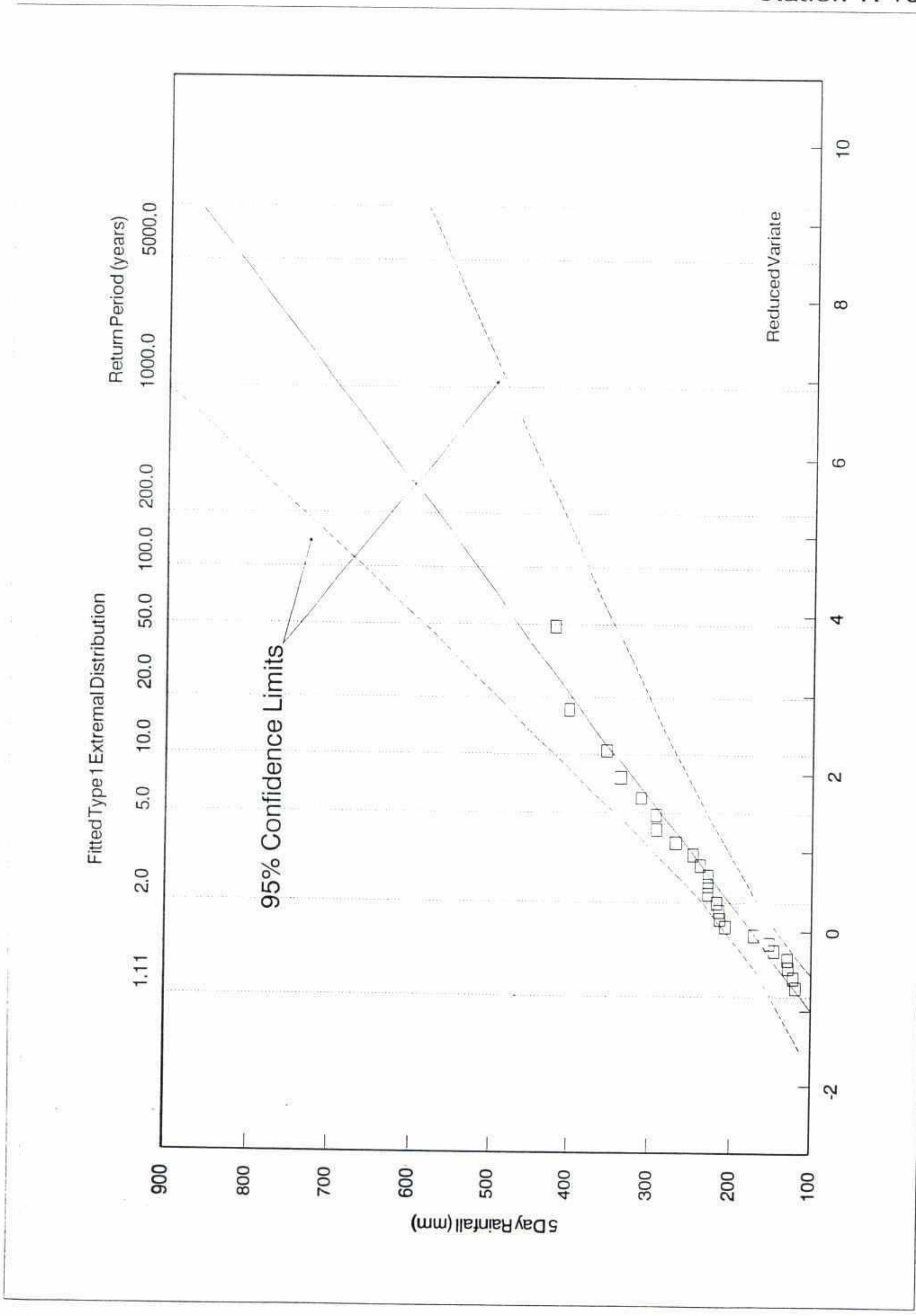
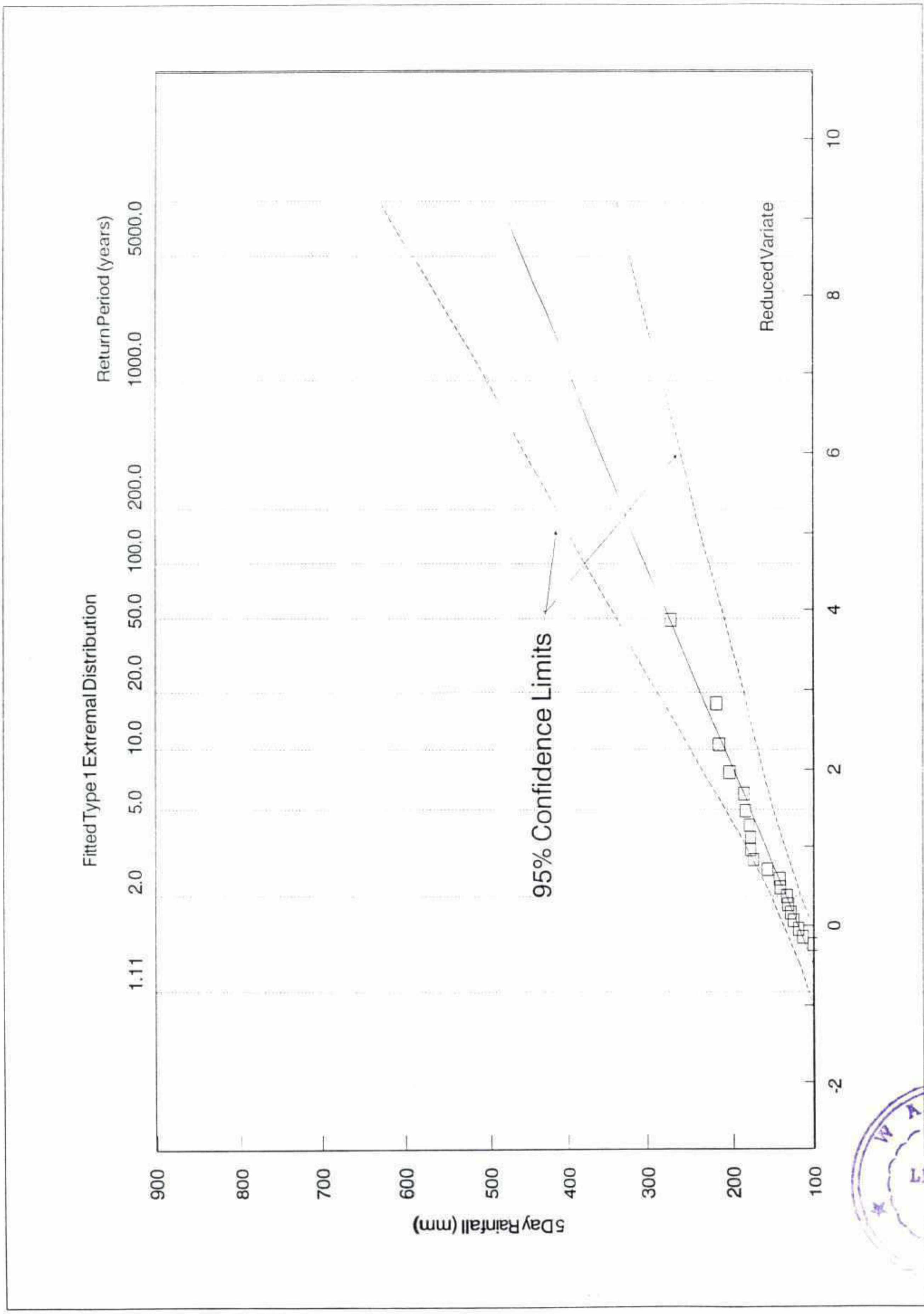


Figure VI.1.18

Annual Maximum 5 Day Post-Monsoon Rainfall
Station R-131



c:\rpr\a_iv-fig\Fig1_18.gem

Figure VI.1.19

Annual Maximum 5 Day Rainfall
Station R-131

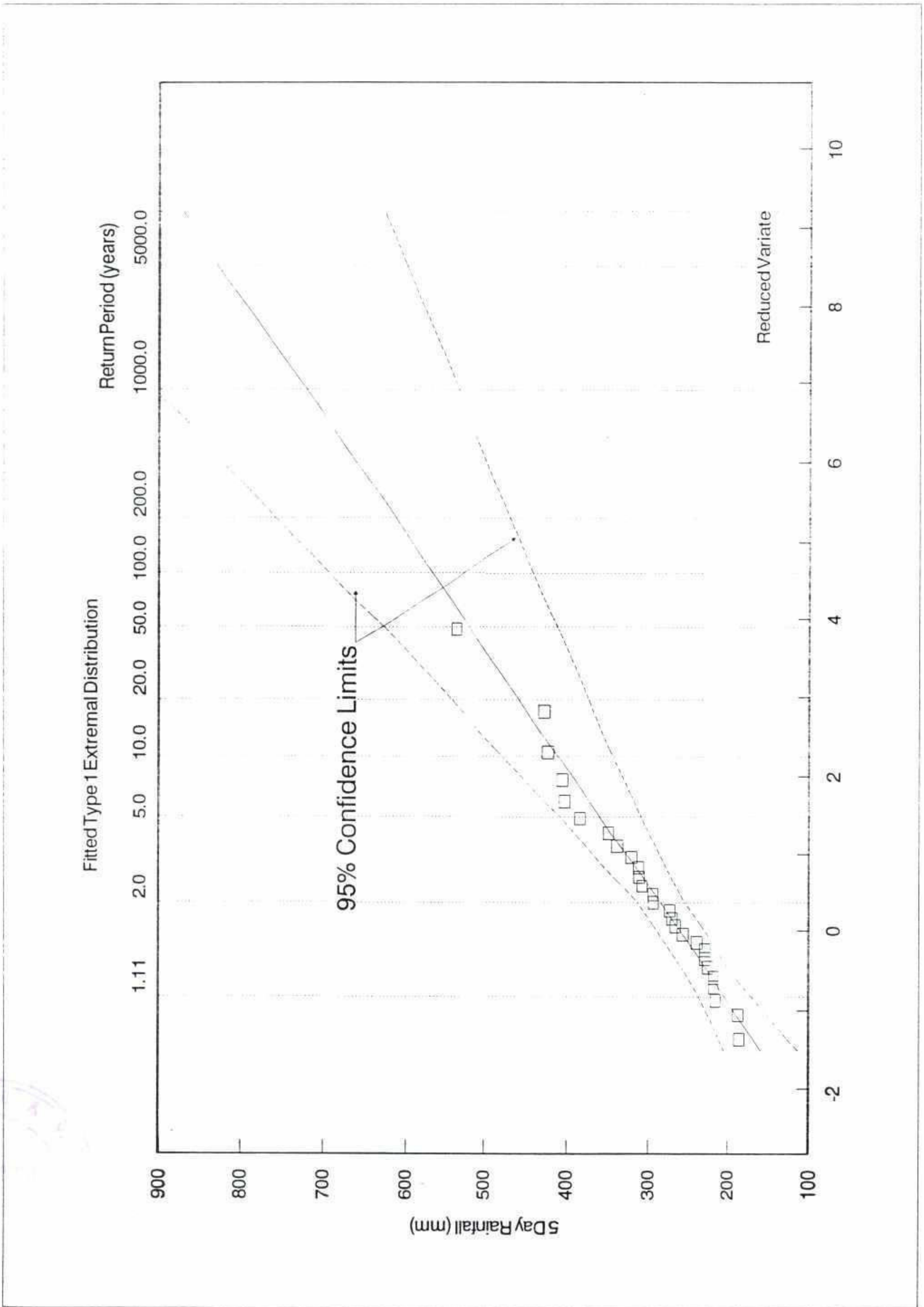


TABLE VI.1.10

Annual Maximum Rainfall Frequencies, Station R-321, Sarail

Annual maximum Pre-Monsoon Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	117	155	179	203	234
2	156	205	237	268	308
3	188	253	296	337	390
4	220	300	353	404	471
5	236	323	380	435	506
7	271	367	430	491	570
10	329	434	503	570	656

Annual Maximum Mid-Monsoon Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	107	163	201	237	283
2	145	212	257	299	355
3	172	250	302	352	417
4	188	269	323	375	441
5	202	287	343	397	467
7	232	324	385	444	520
10	261	353	415	474	550

Annual Maximum Post-Monsoon Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	77	102	119	136	157
2	100	137	161	185	215
3	113	152	177	201	233
4	123	168	198	226	263
5	134	179	209	237	274
7	146	192	223	252	289
10	172	227	263	297	342

TABLE VI.1.11

Annual Maximum Rainfalls (mm)

Duration	1 Day			3 Day			5 Day		
Return Period / Station No.	2	5	10	2	5	10	2	5	10
R-076	150	187	212	262	321	360	326	401	451
R-101	138	185	216	223	302	354	275	359	415
R-103	156	193	217	246	316	362	300	392	453
R-105	141	187	218	238	316	367	287	377	437
R-110	145	177	198	247	307	347	305	380	430
R-111	148	199	232	251	328	379	305	390	446
R-131	145	192	224	233	298	341	285	360	410
R-132	132	166	189	235	293	331	287	352	396
R-260	154	185	205	205	248	277	241	299	338
R-261	134	177	206	259	359	426	325	437	511
R-301	184	262	313	336	486	585	425	626	759
R-311	165	209	238	313	411	475	392	512	592
R-315	182	254	302	323	461	552	394	582	706
R-320	203	251	283	354	450	514	446	560	636
R-323	175	218	246	330	412	466	402	499	564
R-327	184	239	276	336	457	537	402	568	678
R-351	129	174	204	216	302	359	270	368	433
R-352	124	168	197	201	291	351	247	354	424
R-353	172	227	263	322	422	488	389	505	582
R-354	132	176	205	200	263	304	238	312	362
R-355	171	229	267	298	383	439	353	434	487
R-356	125	164	189	211	269	306	263	326	368
R-357	119	153	175	229	284	320	296	374	426
R-358	179	218	244	315	386	434	396	490	552
R-359	161	197	221	282	376	438	340	456	533
R-360	115	161	192	196	250	285	251	314	355
R-361	174	222	253	308	388	442	375	470	533
R-362	119	165	196	203	277	326	253	337	393
R-363	126	166	193	236	304	349	302	391	449
R-364	119	162	191	224	298	347	282	372	432
R-365	129	173	202	230	314	369	285	399	474
R-366	106	161	197	179	286	357	222	337	414
R-367	125	168	196	187	246	285	227	285	323
R-369	183	220	244	292	345	380	353	425	474
R-370	153	189	212	259	331	379	312	396	452
R-372	115	156	184	199	250	283	250	313	355
R-375	136	174	200	300	392	453	415	552	643
R-376	178	231	266	298	391	452	356	475	554
R-377	156	197	224	258	327	373	314	393	445
R-402	146	200	236	215	282	326	259	338	391

A Theissen polygon network was prepared (Figure VI.1.20), and storm reduction factors evaluated for annual maximum 1 day, 2 day, 3 day, 4 day, 5 day, 7 day and 10 day rainfalls at stations R-363, R-369 and R-377. The stations used in the analysis and the relative areas were:

Station R-363, Laksham

Level 1	R-352, R-360, R-377, R-359, 2121 km^2
Level 2	R-352, R-360, R-377, R-3359, R-110, R-354, R-372, R-376, R-370, 4090 km^2
Level 3	R-352, R-360, R-377, R-3359, R-110, R-354, R-372, R-376, R-370, R-364, R-369, R-358, R-355, 6409 km^2

Station R-369, Noakhali

Level 1	R-377, R-376, 1195 km^2
Level 2	R-377, R-376, R-358, R-353, R-375, R-364, 3988 km^2
Level 3	R-377, R-376, R-358, R-353, R-375, R-364, R-372, R-360, R-363, R-359, R-370, R-355, R-361, R-261, 8044 km^2

Station R-377, Sonaimuri

Level 1	R-376, 642 km^2
Level 2	R-376, R-359, 969 km^2
Level 3	R-376, R-359, R-369, R-363, 2023 km^2
Level 4	R-376, R-359, R-369, R-363, R-360, R-3372, R-364, R-375, R-353, R-358, R-355, R-370, R-352, 7475 km^2

The results of the analysis, which included a number of different storm durations between 1 and 10 days, are included in Appendix III. A summary of the results is presented in Figure VI.1.21, from which the general reduction of storm intensity with area is apparent. As might be expected, aerial reduction factors during the mid monsoon season are higher than in the pre-monsoon period, indicating the more widespread nature of rainfall occurrence in the mid-monsoon period. The results are in broad agreement with what would be expected. Considerably more work would be required before the results could be used as the basis of any design criteria for larger project areas. The analysis has been based on annual maximum values, and a missing value at any one of the chosen stations on the date or dates of annual maximum occurrence at the key station causes a null result, and is indicated by an asterisk. The sample size is therefore limited. In future analyses it will be necessary to use a greater selection of events, and to prepare isohyets for each event considered, such that a better assessment of storm distribution is obtained.

Figure VI.1.20

Theissen Polygon Network

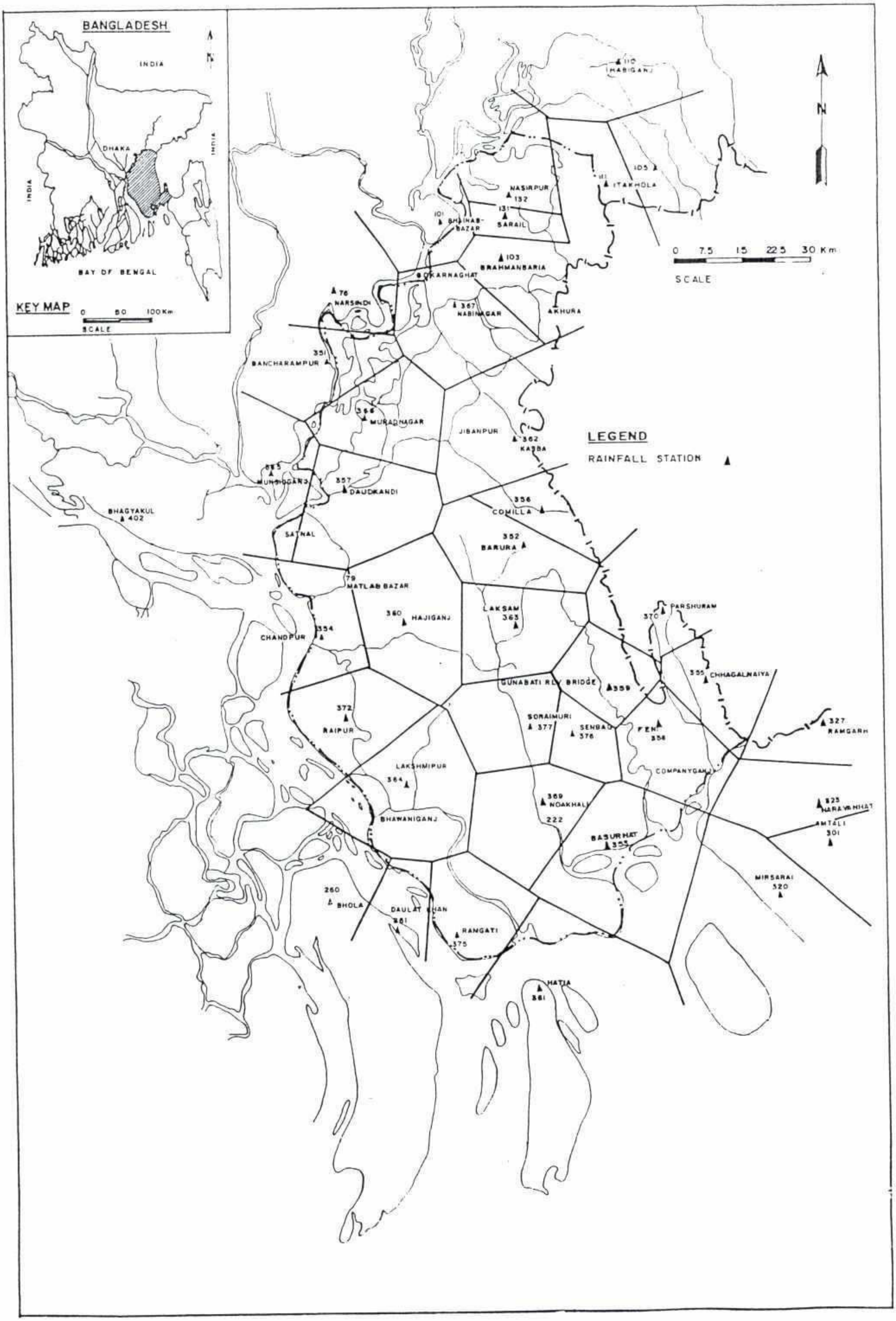
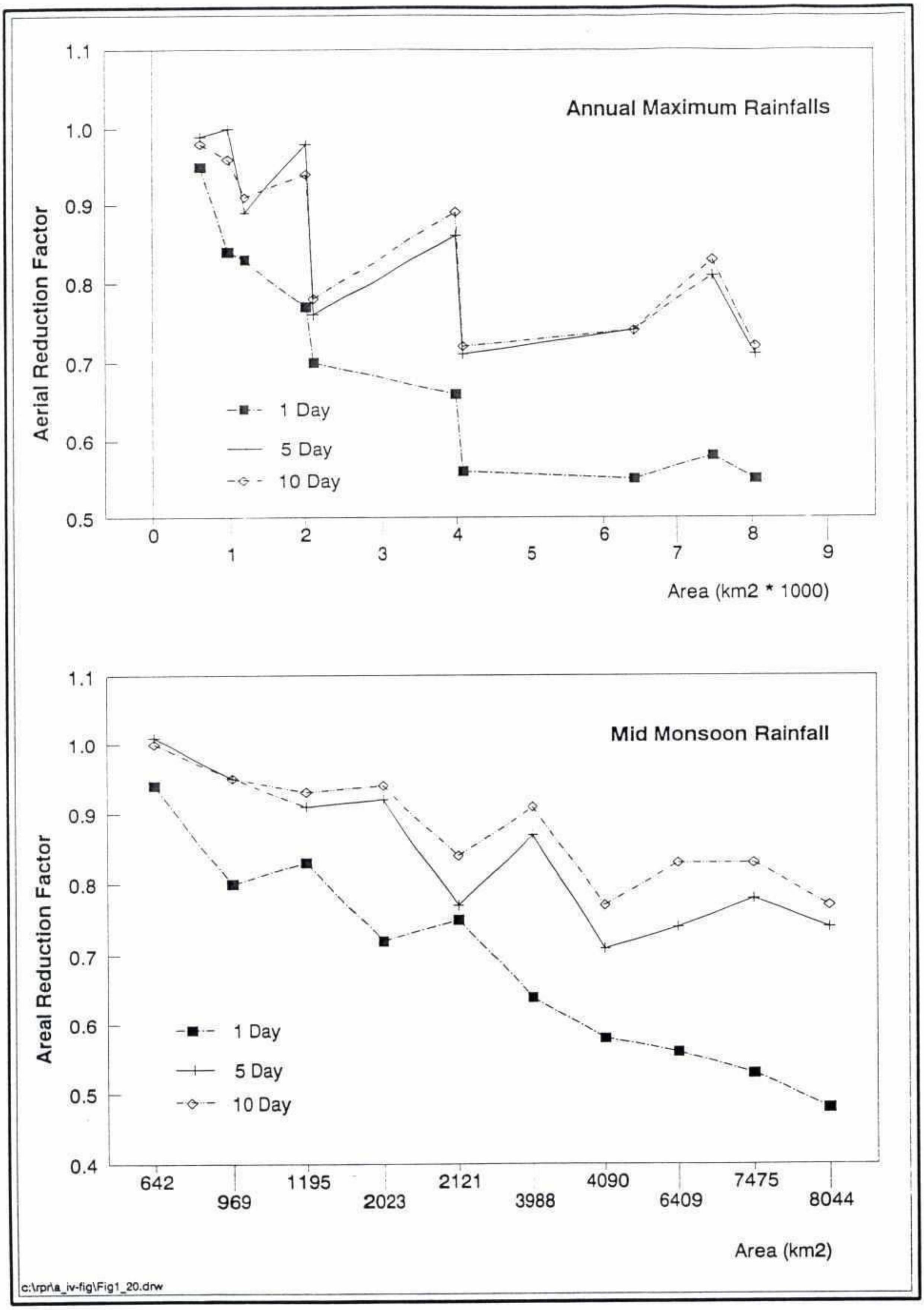


Figure VI.1.21

Aerial Reduction Factors



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CHAPTER VI.2

THE DRAINAGE SYSTEM

VI.2.1 Introduction

A general map of the drainage system in the project area is presented in Figure VI.2.1. The entire region is bounded to the west by the River Meghna, and it is this that dominates drainage of the greater part of the region. At Bhairab Bazar in the north west of the project area, the River Meghna has a catchment area of 64 500 km^2. The mean annual flow at Bhairab Bazar is of the order of 4 600 m^3/s, but seasonally the discharge varies between a mean monthly minimum of 260 m^3/s in February and a mean monthly maximum of 12 400 m^3/s in August. The Meghna is joined by the Padma about 100 km downstream of Bhairab Bazar. The Padma carries the combined discharges of the Ganges and Jamuna (Brahmaputra) Rivers, and has a total catchment area of some 1 639 300 km^2 (Source: J.R.C) at its confluence with the Meghna. Mean annual runoff in the Padma is of the order of 30,000 m^3/s, and varies between 75,000 m^3/s in August and 6000 m^3/s in February. The annual rainfall on the South East region, in volume terms, is less than 2% of the annual runoff in the lower Meghna, and contributes little to the runoff in the latter. The coincidence of seasonal rainfall with peak flood discharges in the Meghna does, however, exacerbate internal drainage problems. The basic parameters of the internal drainage problem of the region, are the same as those for the country as a whole.

The Meghna is the outfall water level control on drainage for almost the entire region. The seasonal range in Meghna water levels reduces in a southerly direction towards the Bay of Bengal. Seasonal water surface profiles between Bhairab Bazar and Daulat Khan are shown in Figure VI.2.2. The profiles shown are for 1981, but the chosen year is of no significance. At Bhairab Bazar, the seasonal range of water levels is of the order of three metres, and there is very little tidal influence in the dry season. At Chandpur the seasonal range in water levels is of the order of 1.5 - 2.0 m, with a tidal range in the monsoon season of the order of 0.6 m. At Daulat Khan towards the south of the region, and close to the outfall of Rahmatkali Khal, the tidal range is much larger, of the order of two metres, and the difference in seasonal water levels much lower, being of the order of 0.5 metres. This variability in the range of Meghna water levels across the region does result in different drainage problems in different parts of the region. These are discussed further in section VI.2.2.

General topography is indicated in Figure VI.2.3. Comparison with Figure VI.2.2 gives an indication of the areas most susceptible to flooding, particularly to the north of the Gumti River. Figure VI.2.3 is at a macro level and is included only to help illustrate the general problems. Micro relief is of regional importance and is discussed in some detail in section VI.3.3, where the approach to regional flood risk and susceptibility is discussed.

The internal drainage of the region may be considered under three general areas:

i) the area north of the railway line at Brahmanbaria
ii) the area between the Gumti River and the railway line at Brahmanbaria
iii) the area to the south of the Gumti River.

To the north of the railway at Brahmanbaria, there is an area of deep flooding, known as the Habiganj depression, lying in an old meander loop of the Meghna. Drainage through this area is by the Titas River.

Figure VI 2.1
The Drainage System

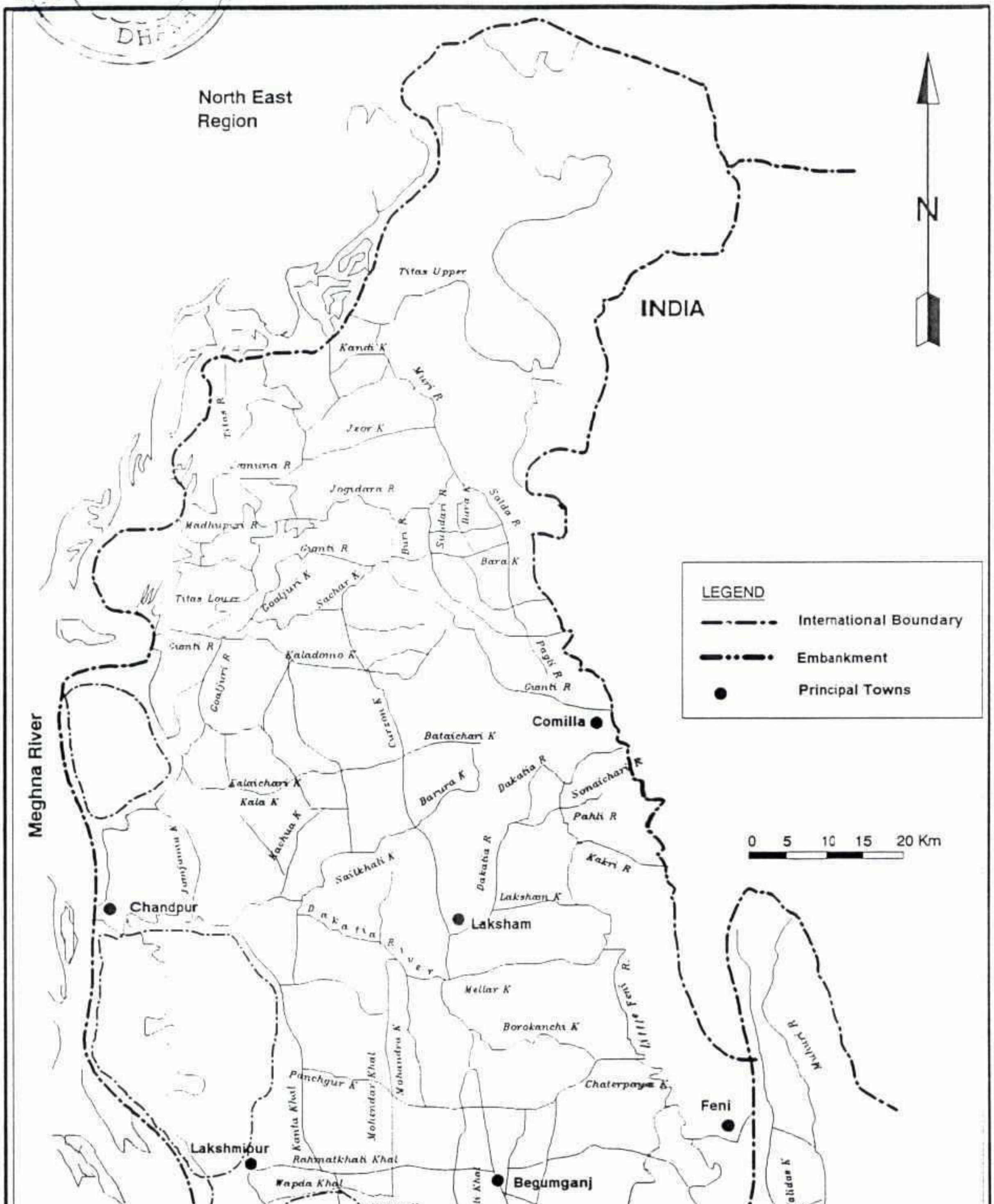


Figure VI.2.2

Meghna Water Surface Profiles

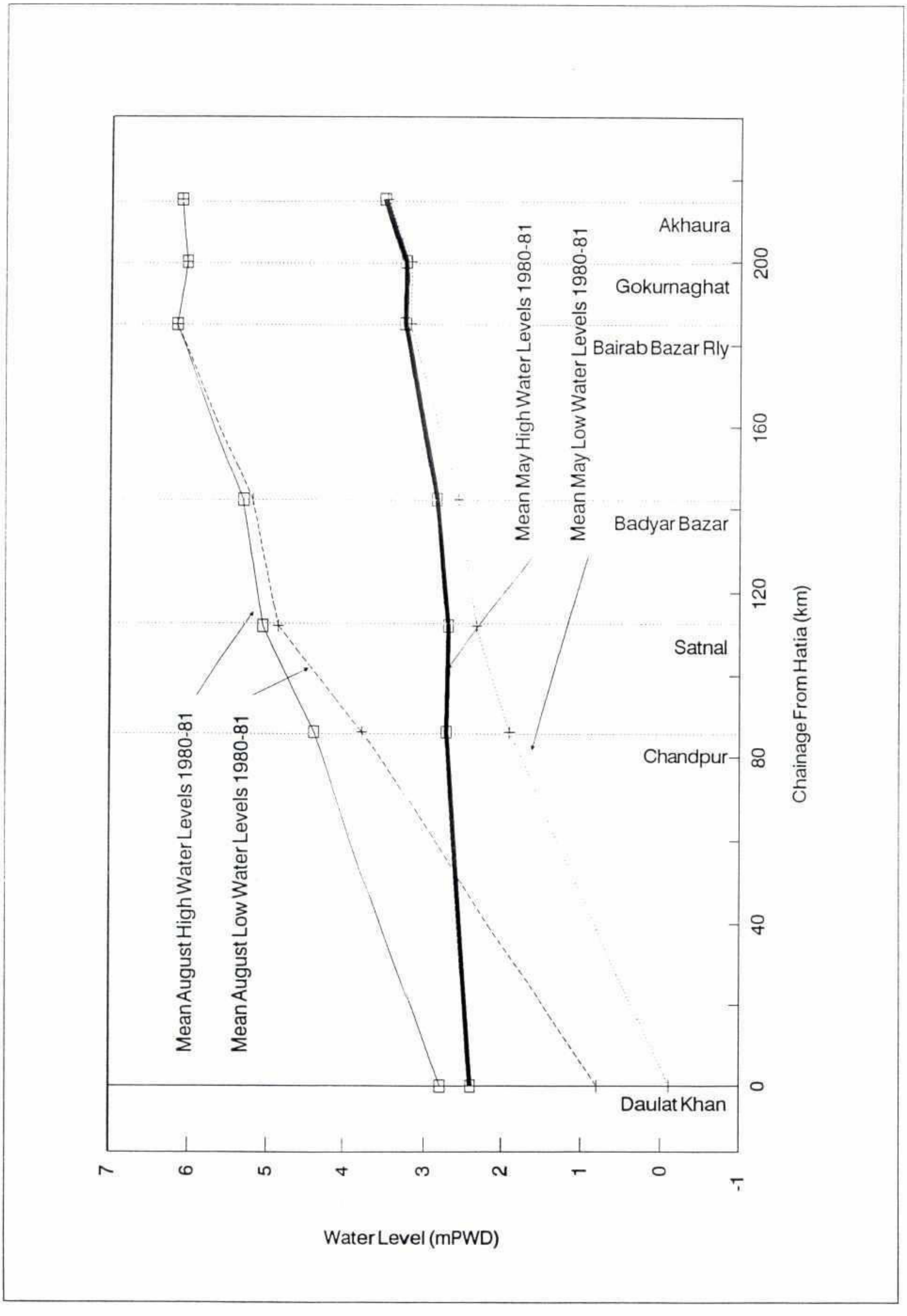
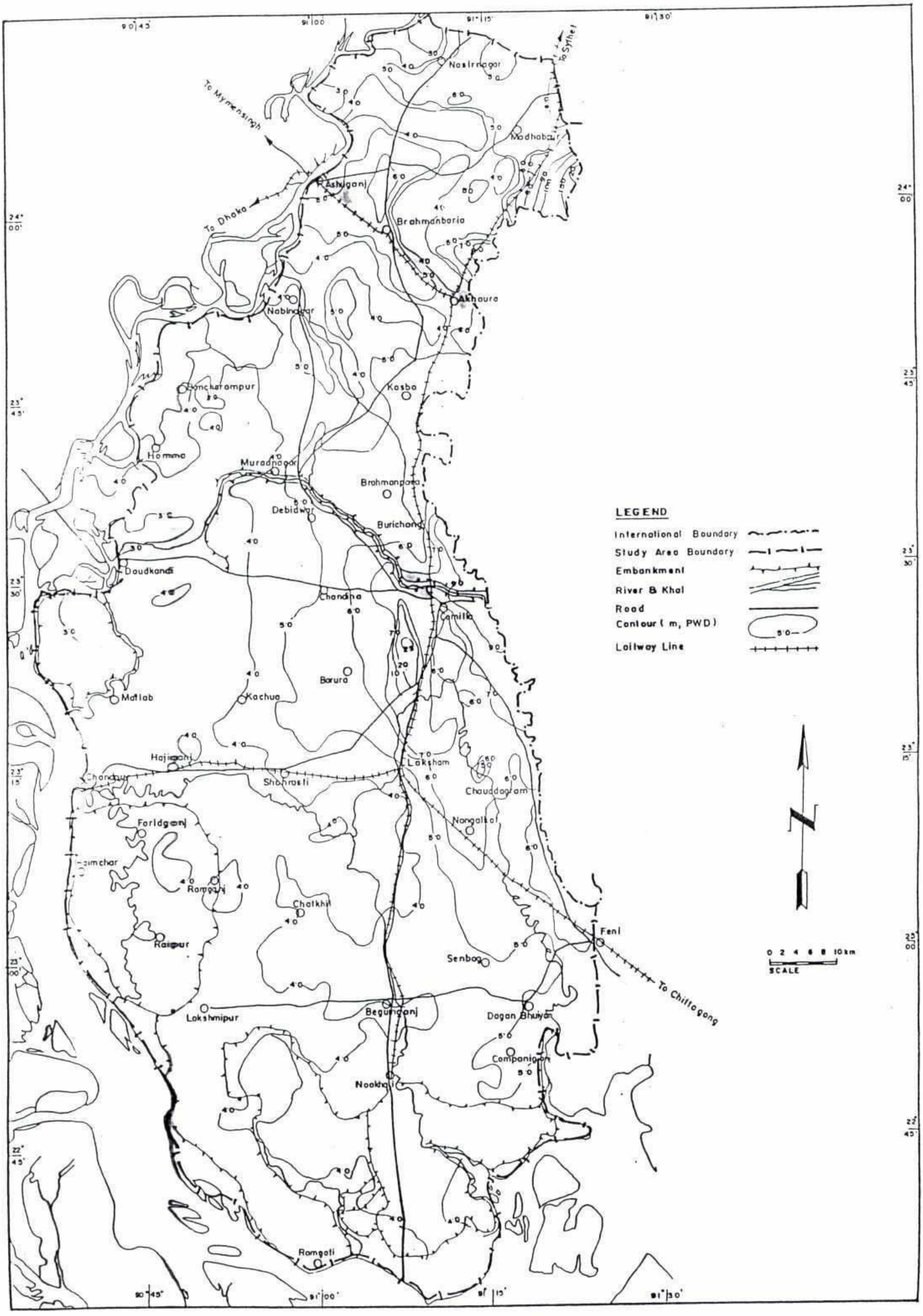


Figure VI.2.3

General Regional Topography



There are also areas of relatively deep flooding between the railway at Brahmanbaria and the Gumti River. The most deeply flooded areas are close to the Meghna. Drainage in this area is complex, with a series of interconnected channels and remnants of former main river courses. It is difficult to identify any singularly important main rivers, other than perhaps the Howra which flows into the Buri and Titas rivers, and the Salda River. Some of the channels in the area had formerly been fed by spills from the Gumti River, prior to completion of embankments and the construction of a regulator at the head of the Buri Nadi River. The area does receive inflows from a number of rivers draining the western slopes of the Tripura Hills. These catchments and their areas are given in Table VI.2.1 below. These are referred to as external catchments.

TABLE VI.2.1

External Catchments North of the Gumti

Catchment	Area (km^2)
Salda	447
Sonai	176
Howra	496
Total	1119

The area in Bangladesh between the railway and the Gumti is about 1400 km^2. Thus about 50% of the drainage through this area is generated in external catchments. During the pre-monsoon season, flash floods in these rivers can cause serious damage.

The Gumti River is the largest drainage feature in the South East Region. At Comilla it has a catchment area of 1950 km^2. The Gumti is embanked from upstream of Comilla, almost to its confluence with the Meghna. The annual maximum mean daily flood in the Meghna at Comilla is 500 m^3/s. During times of flood, water levels in the Gumti are significantly higher than the surrounding land. The hydrology and morphology of the Gumti has been the subject of recent investigation (Ref. 4). The Gumti River and its embankments form an effective barrier across the study area.

Immediately south of the Gumti River, the Daudkandi to Comilla road and Gumti Phase I project embankments isolate a significant area, from which drainage in mainly west to the lower Gumti and Meghna. The area south of the Daudkandi to Comilla road has three principal drainage features. These are the Dakatia River, the Rahmatkali Khal, and the Little Feni River. These rivers are in fact interconnected by a complex system of channels, but they do provide primary drainage routes. The Dakatia River does have its source with the Sonaichari River which drains a small catchment in the Tripura Hills. The Little Feni collects drainage from a number of catchments in the Tripura hills, but these are all significantly smaller than those north of the Gumti. The hill catchments draining into the area south of the Gumti River are listed in Table VI.2.2 below.

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TABLE VI.2.2

External Catchments South of the Gumti

Catchment	Area (km^2)
Sonaichari (Chowara)	64
Pagli South (Shuagazi)	56
Kakri	76
Kakri South	45
K2	68
Total	**309**

The catchment marked as K2 in fact contains diffuse drainage over a length of some 27 km of the Little Feni. These catchments, although small, do bring in significant sediment loads to the river system, and also cause flash floods. Unfortunately none are gauged.

Rahmatkali Khal forms the principal drainage route in the south of the region. Formerly, before completion of the coastal embankments and polders, it is believed that Noakhali Khal was more important. However, with land accretion in the south, the primary drainage route from the Noakhali area is now to the west.

The general drainage system is a complex network of interconnected channels, in which flow directions often reverse. Almost the entire system is inter-linked, and changes to one part of the system have an impact else where. The evaluation of project impacts on flood levels thus requires the use of sophisticated hydrodynamic modelling techniques.

VI.2.2 The Present Flood Problems

VI.2.2.1 Seasonal Flood Characteristics

Much of the land in the project area is regularly flooded. The flood problem cannot be considered in terms of depth of flooding alone, however. The timing, rate of rise, and duration of flooding are, in addition to the flood peak attained, very important factors influencing agricultural damage and cropping patterns, and indeed general disruption caused. Seasonality of flooding is therefore a key variable.

In terms of seasonality, the flood problems are:

pre-monsoon	April-June	rapid rise in water level before boro crops are harvested, and kharif I crops planted; loss of young crops and seedlings;
monsoon	July-August	the rate of rise of flood levels exceeding the rate of growth of rice; peak main river levels and prolonged flooding, partly through

		backing up from the main rivers, and reduced gradients for local rainfall; duration of flood inundation is important, and whether flood water is clear or sediment laden;
post-monsoon	Sept.-Oct.	drainage at too slow a rate to permit timely planting of certain crops;

In addition to the above flood periods, the general categories under which flooding in the region can be considered are:

- monsoon floods from the River Meghna and Lower Meghna;
- flash floods from those rivers rising in the Tripura Hills to the east of the region;
- localised flooding as a result of heavy and intense rainfall;
- floods resulting from storm surges in the Bay of Bengal.

VI.2.2.2 Sub-Regional Flood Characteristics

The above categories of flooding affect different parts of the region to different degrees, as has been introduced in section VI.2.1. Following from that introduction, it is apparent that for the purposes of flood assessment, and for the definition of design approaches, the study area might best be considered under five zones:

i) north of the railway at Brahmanbaria;
ii) between the railway and the Gumti River;
iii) the area between the Gumti and the Dakatia rivers;
iv) the Little Feni catchment;
v) the area south of the Dakatia river.

The area to the north of the railway is very deeply flooded, and the primary control is in fact the Meghna River. Closer to the Tripura Hills, flash flooding can be a problem in the pre-monsoon season, and of course throughout the area the rate of rise of Meghna water levels is of importance in determining potential damage to crops on low lying land. This area requires consideration with the North East Region, as it has no natural northern boundary, and any works that might be undertaken would influence, and be influenced by, other works outside the project area.

The area between the railway and the Gumti River is well defined, and although linked to the north by cross drainage beneath the railway, and also linked to the Gumti River with a regulator at Buri Nadi, the area has fixed physical boundaries. Problems of drainage within the area are very similar to those experienced to the north of Brahmanbaria, and the areas close to the Meghna are particularly susceptible to deep flooding. The flood problems of this area have been considered is some detail at feasibility level as part of the Gumti Phase II feasibility studies (Ref. 5). During the main monsoon season, the Meghna dominates flood extent in the area, and in the northern part of the area, there is very little west to east gradient, as indicated in Figure VI.2.2. From the elevation area characteristics published for MPO planning areas 29 and 31, and water level records, it is apparent that the Meghna is the primary source of prolonged monsoon flooding.

South of the Gumti to the Dakatia river, the flood problems are less directly associated with inundation from the Meghna, than with impediment to the drainage of local rainfall caused by high outfall water levels in the Meghna. It has been noted by some observers that flood waters are relatively clear in this area, indicating their main origin to be local rainfall rather than the Meghna. It is, however, the Meghna which ultimately does form the control on the potential drainage of the area. There are areas of deep flooding to the east of the Meghna Dhonagoda project area, but there is less susceptibility to flash flooding than in the areas to the north of the Gumti, or in the Little Feni catchment. A number of roads also form natural drainage barriers in the region. These include the road from Matlab Bazar to Chandpur and to Eliotganj, and the Chandpur to Comilla road. These roads apparently have adequate cross drainage provision, but they do impede floodplain flow. The Dakatia River forms the main arterial drainage for the area, discharging westwards to the Meghna at Chandpur. There is, however, a very complex interconnected network of channels.

The Little Feni River drains to the south from Comilla, collecting drainage laterally from the Tripura Hills, and from its own catchment area in Bangladesh. The hill catchments draining in to the Little Feni have a total area of 309 km^2. The catchment area of the Little Feni in Bangladesh is some 570 km^2. There are flash flooding problems from the Tripura Hill catchments, some of which (notably the Kakri) carry substantial sediment loads. Sediment deposition can result in further drainage problems. The Little Feni is regulated at its lower end by Kazirhat regulator. This prevents the ingress of saline tidal water during the dry season, and provides a reservoir for irrigation. During the monsoon the regulator is kept open, but problems can occur in the pre-monsoon season as estuarine silts deposited downstream of the regulator during the dry season require excavation before the tidal flaps can be operated. There are a number of drainage connections from the Little Feni system to the Dakatia system, and to the Noakhali area, although the primary drainage is southwards through the main channel.

In the area to the south of the Dakatia River, the drainage is provided primarily by the WAPDA Khal and the Rahmatkali Khal. This area is generally considered to suffer from congested drainage, and one of the most notable features is the Begumganj depression which is seasonally flooded. It is thought that there may have been some deterioration in drainage of the area following the completion of the coastal embankment and polder projects. At Noakhali for example, the maximum tidal range has declined from 2.6 m in the 1960's to about 0.35 m now, indicating the general loss of channel capacity, and the impact of accretion and land formation to the south.

The nature of the drainage system throughout the region is such that specific areas cannot be considered in isolation. Although division into zones is useful in the definition of primary flood mechanisms and design requirements, the holistic view of the system and its seasonal flood response must not be lost. It was for this purpose that the South-East Regional Model (SERM) was created. The model is discussed in Chapter VI.3.

VI.2.3 Data Availability

VI.2.3.1 General

The locations of water level and discharge measurement stations in the region are given in Figure VI.2.1. Data availability for these, and for the main river stations is summarised in Table VI.2.3. A considerable volume of additional field data was collected for the region as part of the SWSMP. No additional field data were collected as part of the regional study.

VI.2.3.2 Discharge Measurement

There are very few relevant discharge measurement stations in the region. Table VI.2.3 indicates a total of 10 stations in the region, but they are in fact of limited value to the regional study. The station at Bhairab Bazar (273) on the Meghna is a strategic station in the national hydrometric network, but other than assisting in defining boundary flow conditions in the Meghna, gives little insight to conditions within the region itself. Discharge stations in the north of the region include Ganga Sagar Railway Bridge (123), Shaistaganj (158.1), and Brahmanbaria Railway Bridge (3A). All of these stations are affected by backwater effects from the Meghna, and stable ratings do not exist. At Brahmanbaria Railway Bridge, flow measurement has now been abandoned, and some uncertainty exists over the quality of data for Ganga Sagar Railway Bridge and Shaistagonj.

The flow record at Comilla (110) is almost complete from 1965, and is free from any backwater influences from the main rivers. This is an important station, being representative of Tripura Hill catchments. The Gumti is also gauged at Jibanpur, as is the Buri Nada River (114). Flows to the Buri Nadi River are controlled, however, and the record is thus of limited value. The Little Feni River is gauged at Gunahati Railway Bridge, but in effect there is only one year of monsoon discharge data at this station. The record is thus of little value.

The stations at Kaliachari (84.1) and Parshuram (212) are in the Muhuri catchment. They are indicative of runoff conditions from Tripura Hill catchments, and are also of direct relevance to investigations of Muhuri Reservoir.

There is effectively very little discharge data for the study area, and the majority of inflows from the Tripura Hills are engaged. Most of the discharge data indicated in Table VI.2.3 are available in digital form, but little is of direct relevance for the purposes of the present investigations.

VI.2.3.3 Water Level Data

Water Level data in the study area is generally more widely available than streamflow, as indicated in Figure VI.2.1 and Table VI.2.3. For the South East Region, many of the data are tidal, however, and usual practice is to record daily maximum and minimum levels. Unfortunately, daily data are only available from 1983 in digital form. Resources were not available to the present project to encode all of the available daily water level records. Maximum 10 day water levels for the period April to October have been encoded, however, and combined with similar data extracted from the existing digital daily water level data base. These data are presented in Appendix IV. At tidal stations, the data base includes daily tidal range, and these data have been available for preliminary engineering evaluations of tidal drainage structures.

The water level data base is adequate to give an indication of historical flood problems over the region. There are notable gaps in the data coverage, however, particularly in the area to the south of the Gumti River. There are generally fewer problems associated with water level data than river flow data, although problems have been noted with gauge datums at a number of locations, notably Daulat Khan. Such problems stem from difficulties in transferring bench marks across large expanses of water, and of course from the usual problems of gauge settlement or gauge re-establishment following damage.

TABLE VI.2.3

Availability of Water Level and Discharge Data

Mean Daily Discharge Availability for South East Region

No.	Station Name		59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
3A	Brahmanbaria Rly Bridge	T																														
84.1	Kalichari																															
110	Comilla																															
114	Jibanpur (Gumti)														?																	
114	Jibanpur (Burinadi)										?	?		?	?	?										?	?						
123	Ganga Sagar Rly Bridge									?	?	?	?	?	?	?		?		?												
158.1	Shaistaganj														?																	
181	Gunabati Rly Bridge	T																					c	c	c	c	c	c	c	c	c	c
212	Parshuram														?																	
273	Bhairab Bazar	T													?						?	?	?	?								

Average Daily Water Level Availability for South East Region

No.	Station Name		59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
3	Brahmanbaria	T																														
3A	Brahmanbaria Rly Bridge	T																								c	c	c	c	c	c	c
58	Hajiganj	T																														
74	Matlab Bazar	T																														
79	Matlab Bazar	T																														
86	Dhoomghat	T																														
87	Charsonapur	T																														
110	Comilla																															
114	Jibanpur (Gumti)																															
114B	Jibanpur (Burinadi)																									c	c	c	c	c	c	c
115	Duadkandi	T																														
123	Ganga Sagar Rly. Bridge																															
157	Ballah																															
158	Chunarghat																															
158.1	Shaistaganj																															
181	Gunabati Rly Bridge (d)	T																														
181A	Gunabati Rly Bridge (u)	T																			c	c	c	c	c	c	c	c	c	c	c	c
182	Companiganj	T																														
213	Haripur	T																														
221	Noadona	T																			c	c	c	c	c	c	c	c	c	c	c	c
222	Noakhali	T																														
230.1	Bhairab Bazar Rly Bridge	T																														
239	Lakshmipur	T																														
240	Bhawaniganj	T																														
257	Malipur	T																														
272	Madna	T																														
272.1	Austagram	T																														
273	Bhairab Bazar	T																														
274	Narsingdi	T																														
275	Baidyer Bazar	T																														
275.5	Meghna Ferry Ghat	T																														
276	Satnal	T																														
277	Chandpur	T																														
280	Sutang Rly Bridge																															
295	Ajabpur	T																														
296	Akhaura	T																														
297	Gokorna Ghat	T																														
298	Habinagar	T																														

Main River Average Daily Water Level data Availability

No.	Station Name		59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
46.9L	Bahadurabad																															
90	Hardinge Bridge	(57)													?																	
91.9L	Baruria	T																														

Main River Mean Daily Discharge Data Availability

No.	Station Name		59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
46.9L	Bahadurabad	(57)																														
90	Hardinge Bridge (1933–	(57)													?																	
91.9L	Baruria	T													?																	

Legend: c – station closed ? – availability uncertain ■ – full record □ – incomplete record

VI.2.3.4 Sediment Data

Sediment deposition from rivers rising in the Tripura Hills is a problem in several areas. There are, however, very few sediment data available for the region. There is no routine sediment or water quality sampling at any location in the region. Some data have been collected by the Surface Water Modelling Centre, on the Gumti at Comilla and on the Buri Nadi at Jibanpur. Sediment data were also collected as part of the "Hydrological and Morphological Studies of the Gumti-Titas and Atrai Basins" (Ref. 4). Sampling points included the Gumti at Comilla and the Howra at Ganga Sagar. Data are available for one complete wet season, and their use on the present study is discussed in section VI.2.5.

VI.2.4 Analysis of Available Data

VI.2.4.1 General

The analysis of flood conditions within the project area has been largely based on computational hydraulic modelling, in view of the complexities of the system. The extent of more traditional forms of analysis in flood hydrology, has therefore been at a fairly general level, and is discussed in the following sections.

Analyses have been made of all primary streamflow and water level data relevant to the project area. The focus has been on water level data, which is most widely available and which for the flood alleviation aspects of the project, is perhaps of most relevance. Some analysis has also been carried out of the water levels and discharges on the main river systems in order to help put the recent floods into perspective, to assist in defining appropriate distributions for regional multi-station analysis, and to test the data for non-stationarity. Much of this analysis preceded FAP-25 (Ref. 6). Analysis of streamflows has effectively been restricted to the Gumti at Comilla, although use has been made of flow records at Pashuram and at Kaliachari in the assessment of water resources for Muhuri Reservoir. This is discussed in more detail in Chapter VI.5.

VI.2.4.2 Analysis of Main River Data

In view of the fact that the study area is bounded by the Meghna, and that flooding through much of the project area is controlled by the Meghna, either directly or indirectly, an analysis and understanding of the boundary conditions is important.

The manner in which the boundary conditions could change in the future under different scenarios of flood mitigation upstream of the study area is an output of the hydrodynamic modelling studies undertaken by FAP-25 (Ref. 6). It was considered important, however, to try and assess whether or not there were any underlying trends of increasing flood magnitude or frequency resulting from upper catchment activity, which should be incorporated in the analyses. In order to ascertain this, trend analysis has been carried out on the series of annual maximum water levels at Bahadurabad, Hardinge Bridge, and Baruria. The results of a number of statistical tests are presented in Table VI.2.4. These are on the basis of the common data period 1964-1988, the maximum record available at the time of the analysis. The deviations from the mean and the five year moving mean for each station are presented in graphical form in Figure VI.2.4.

Figure VI.2.4

Annual Maximum Water Levels in the Major Rivers

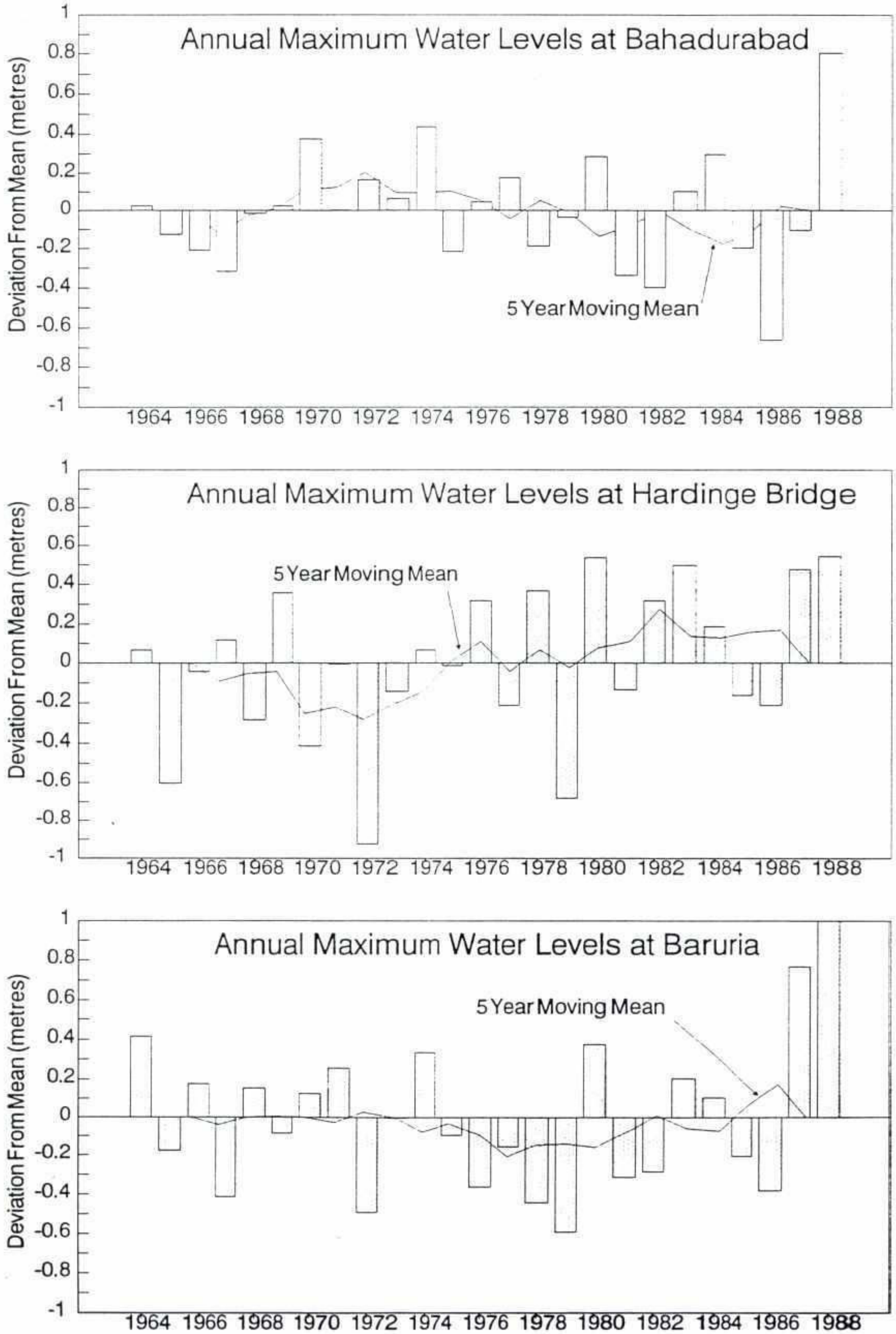

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TABLE VI.2.4

Statistical Tests on Annual Maximum Water Levels

Statistical Test	Bahadurabad		Hardinge Bridge		Baruria	
	Expected	Observed	Expected	Observed	Expected	Observed
Randomness						
Median Crosses	11 +/- 6	9	11 +/- 6	17	11 +/- 6	11
Turning Points	14 +/- 3	13	14 +/- 3	16	14 +/-3	14
Persistence						
First Order Serial Correlation	-0.04 +/- 0.41	0.06	-0.04 +/- 0.41	-0.18	-0.04 +/- 0.41	0.13
Spearman Rank	0-05 +/- 0.41	0.01	-0.05 +/- 0.41	-0.28	-0.05 +/- 0.41	0.17
Trend						
Mann-Whitney U Test	72 +/- 34	65	72 +/- 34	46	72 +/- 34	69
Wald-Wolfowitz Runs Test	13 +/- 5	11	13 +/- 5	10	13 +/- 5	15

The annual maxima series indicates that there is no detectable trend of increasing flood frequency at either Bahadurabad or Baruria, although at Baruria, 1987 and 1988 provided the two highest events on record. There is very weak evidence of a trend of increasing flood levels in the Ganges at Hardinge Bridge, however. The indication from Figure VI.2.5 is that peak water levels at Hardinge Bridge have been consistently higher since 1976. This could be due to morphological changes following construction of Farakka Barrage, and would be worthy of further investigation in view of the importance of the station. For the purposes of the South-East Regional Study, the evidence of the Baruria record is sufficient to indicate the absence of any trends of increasing flood levels at the present time. This is not to say that trend does not exist, only that it is not detectable with the present data set, which is in any case rather short for this form of analysis.

General Extreme Value distributions have been fitted to the series of annual maximum water levels at each of the main river stations. It is generally preferable to work with discharges in order to avoid stage induced influences when rivers go out of bank, but the analysis was intended to be preliminary and would in itself indicate whether or not considering a single population is appropriate. At Hardinge Bridge and Bahadurabad, statistically the best fits are produced by Type III distributions. At Bahadurabad, this is in part due to bias caused by the lowest event on record, and a Type I distribution in fact gives a better fit to higher levels. At Baruria the best fit is provided by a Type I distribution. Plots of the fitted distributions are presented in Figures VI.2.5 to VI.2.8. Good fits have been achieved in all cases. At Baruria, which is the station of most relevance to the present study, the 1988 flood was the highest on record, with a return period of about 50 years. The return period of the 1987 flood at Baruria was about 20 years. A fuller treatment of main river flood

Figure VI.2.5

Annual Maximum Water Level Frequencies at Hardinge Bridge

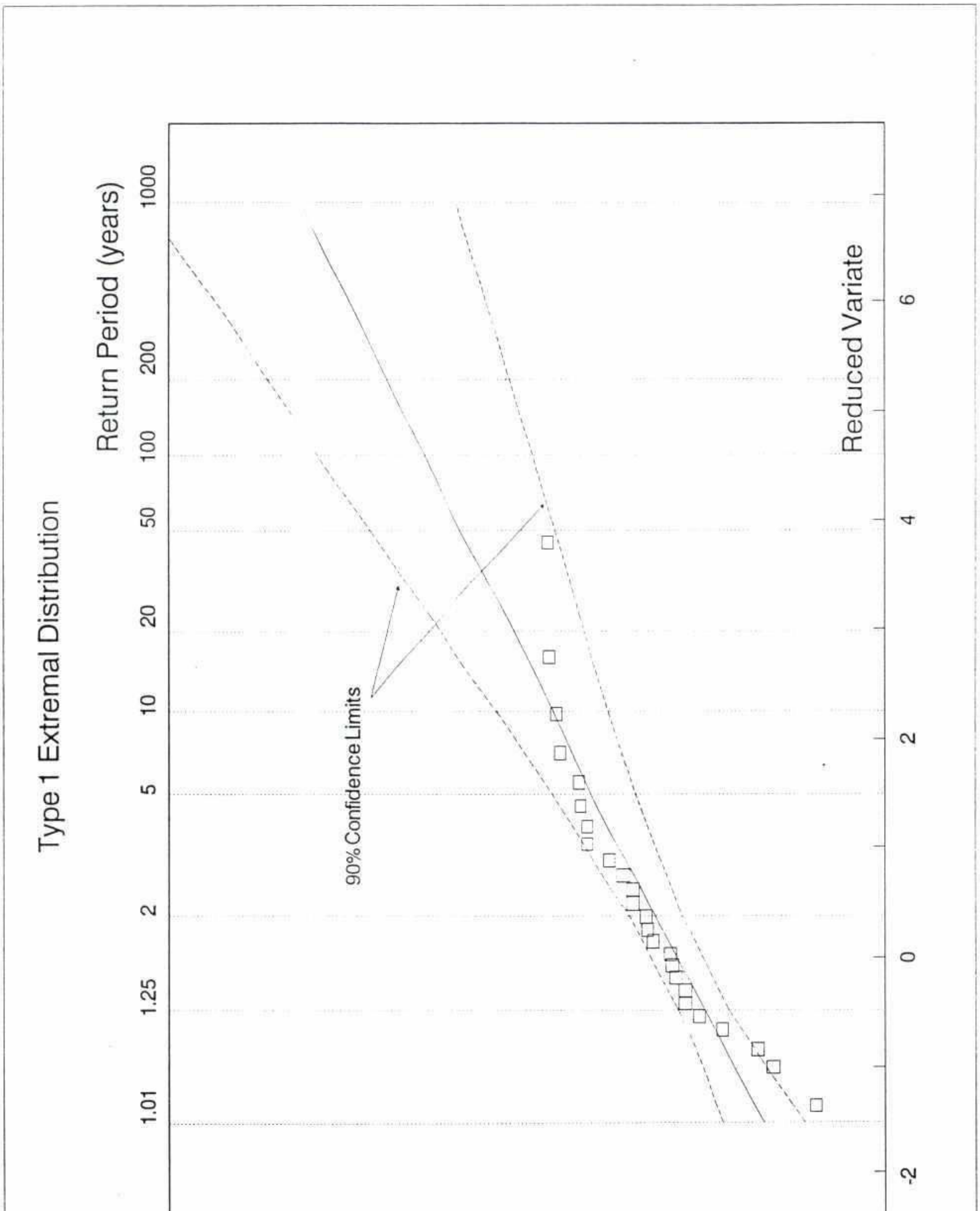

Figure VI.2.6

Annual Maximum Water Levels at Bahadurabad - EV3

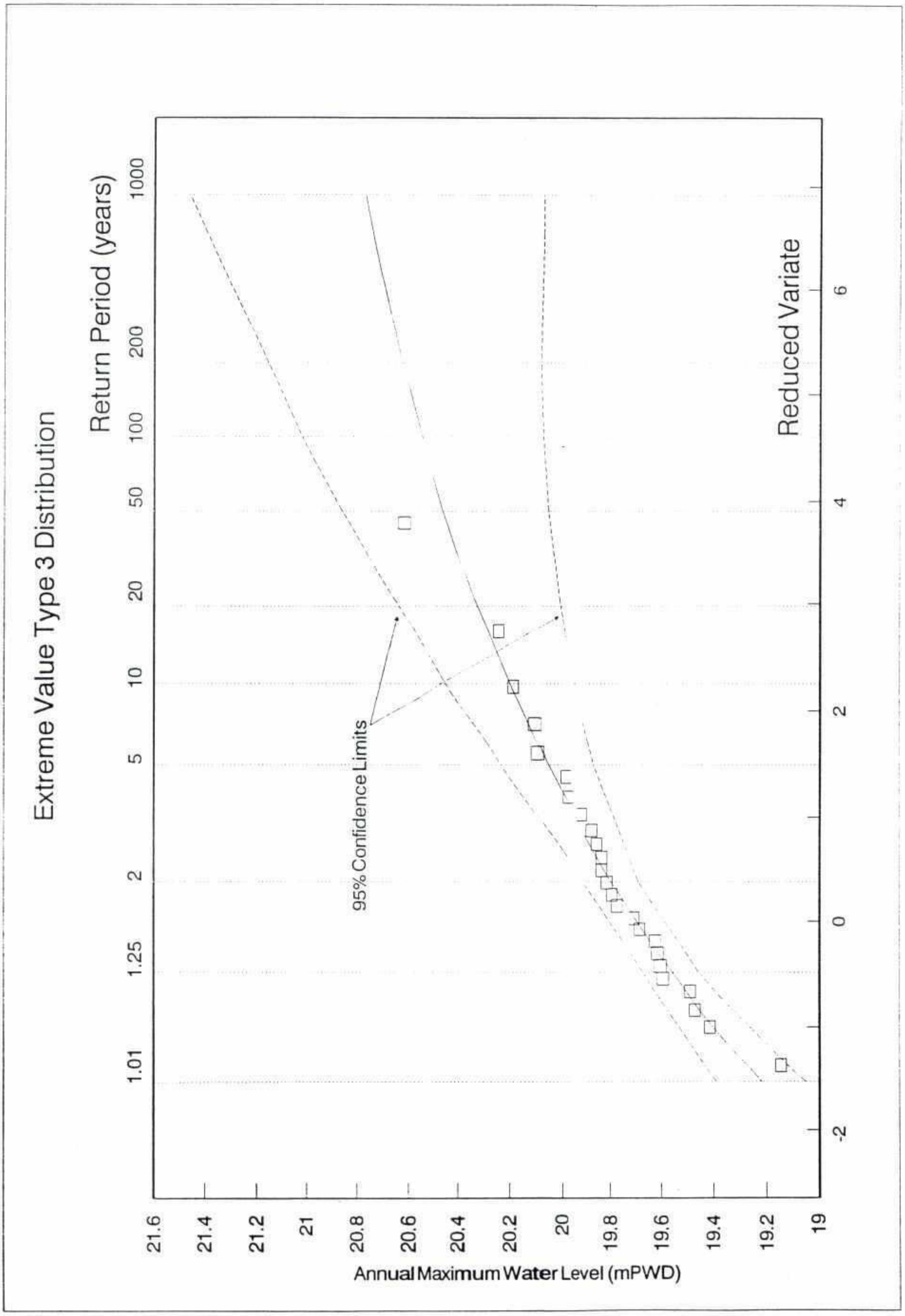

Figure VI.2.7

Annual Maximum Water Level Frequencies at Bahadurabad

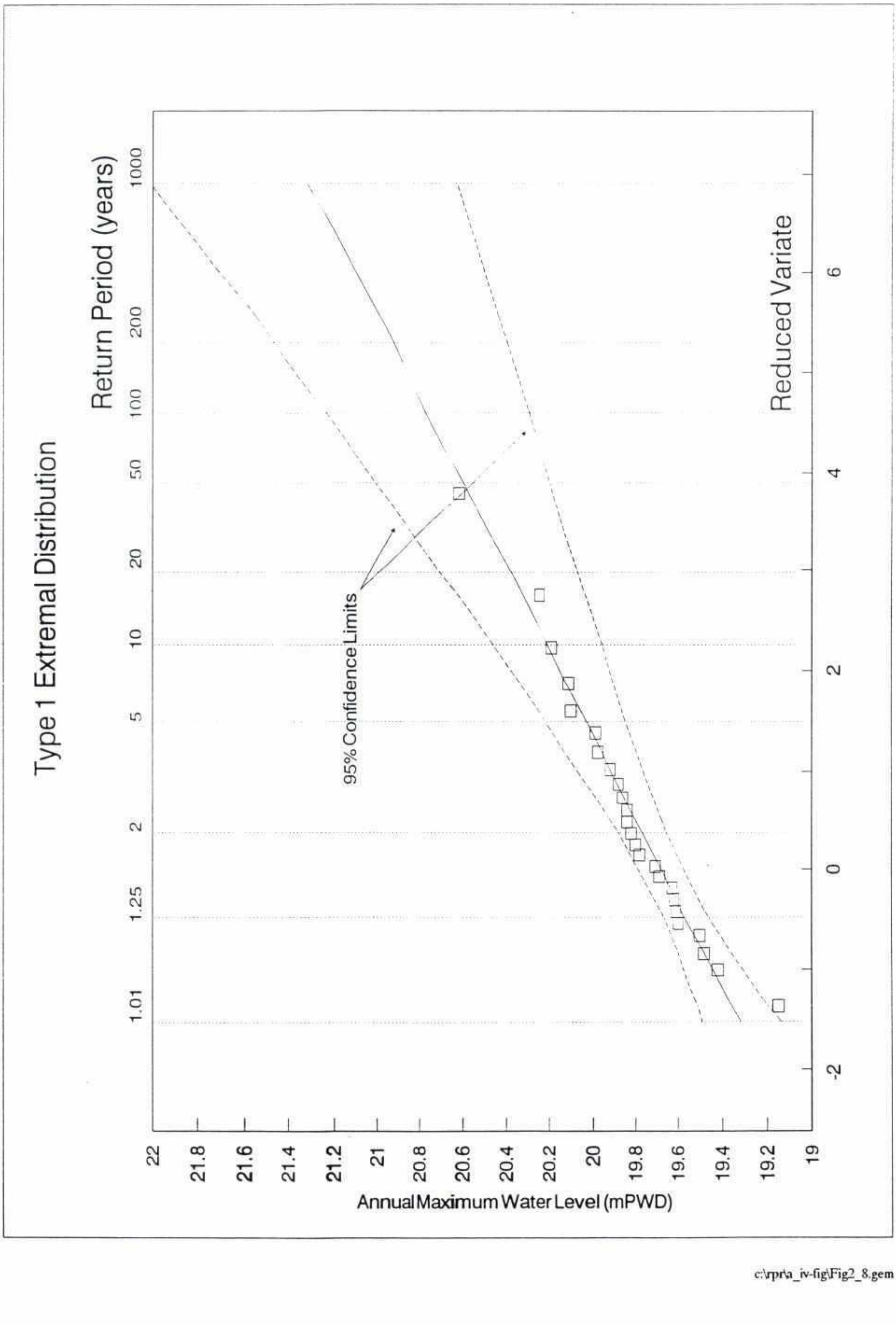

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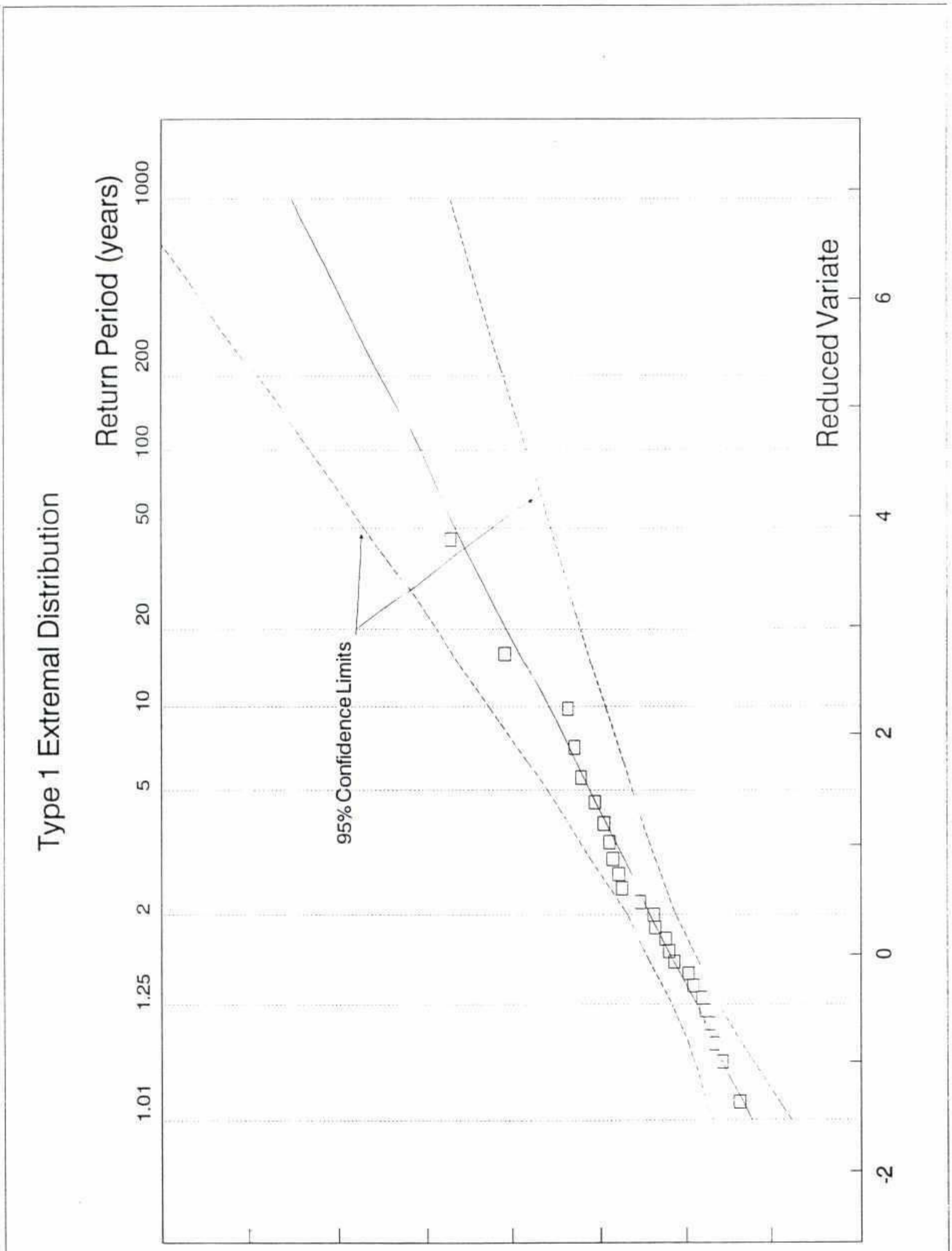
Figure VI.2.8

Annual Maximum Water Level Frequencies at Baruria



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characteristics has been provided under FAP-25. The analysis presented here was carried out in order to gain a preliminary understanding of the importance of different aspects of the flood problem, rather than as a possible basis for any design or evaluation work.

VI.2.4.3 Analysis of Water Levels in the South East Region

There has been discussion at various stages during the Flood Action Programme about the most appropriate choice of statistical distribution for frequency analysis of both water levels and discharges. The analysis for the South East Regional Study preceded much of this discussion, and it was considered that at a regional planning level it was not appropriate to go into great detail in assessing the most appropriate statistical distribution for each station or group of stations, although this could be a requirement where the data of particular stations are being used at full feasibility level, or in detailed design. Analysis showed that application of Extreme Value Type I distributions provided good fits to the main station data on the Meghna, and this distribution was therefore used throughout. The fitted distributions to the series of annual maximum daily water levels at Chandpur, Satnal and at Baidyer Bazar, are shown in Figures VI.2.9 to VI.2.11. The EV1 distribution apparently fits the data well, and for the purposes of regional analysis it has been considered appropriate to adopt this. Tabulated values of estimated water levels at these locations are presented in Table VI.2.5. It is of particular interest to note the range of variability in levels at different locations. At Chandpur, the 50 year flood level is only 0.61 m above the 2 year flood level, while at Baidyer Bazar, the 50 year flood level is 1.18 m above the 2 year flood level. The northern parts of the region are therefore expected to be more susceptible to the influences of major river flooding than the southern parts of the region.

TABLE VI.2.5

Annual Maximum Water Levels

Return Period (years)	Annual Max. Water Level (mPWD)		
	Chandpur	Satnal	Baidyer Bazar
1.01	4.42	5.64	4.85
1.25	4.61	4.94	5.21
2	4.78	5.18	5.49
5	4.96	5.47	5.83
10	5.1	5.7	6.12
20	5.22	5.88	6.32
50	5.39	6.13	6.67

Typical mean high and low water surface profiles for the Meghna between Daulat Khan and Bhairab Bazar have been shown in Figure VI.2.3, for the months of May and August. These give an indication of the range in

Figure VI.2.9

Annual Maximum Water Level Frequencies at Chandpur

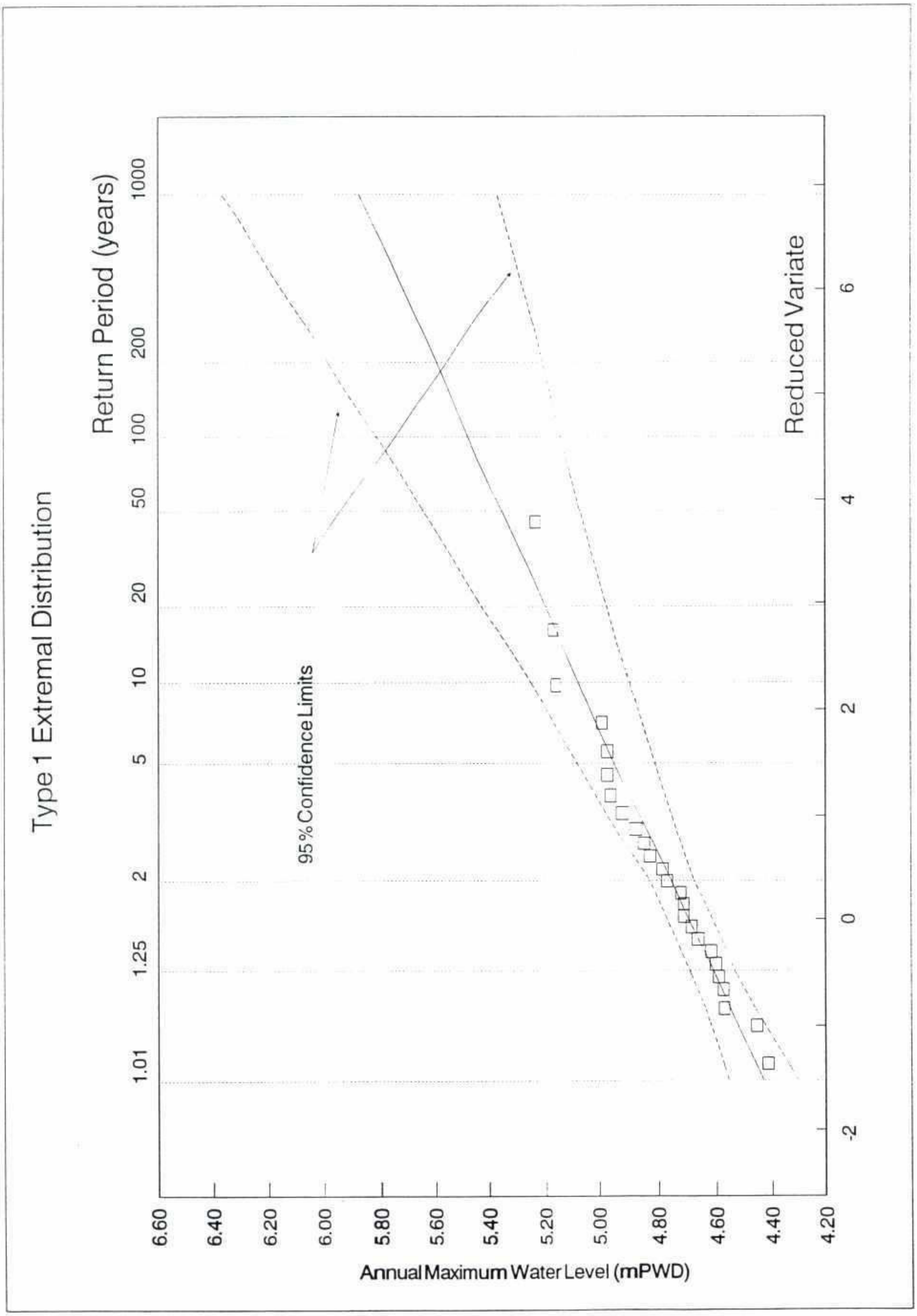

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Figure VI.2.10

Annual Maximum Water Level Frequencies at Satnal

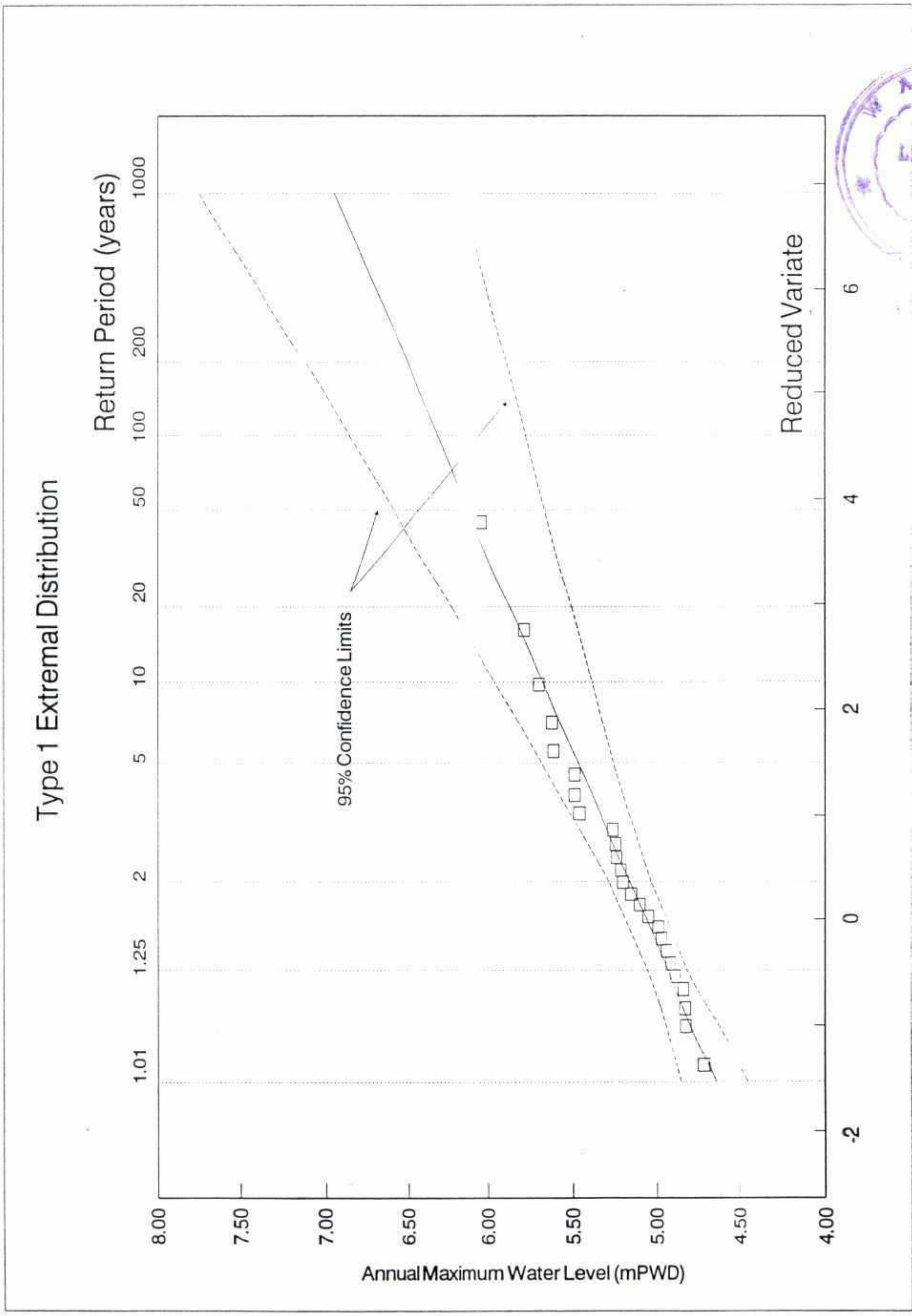

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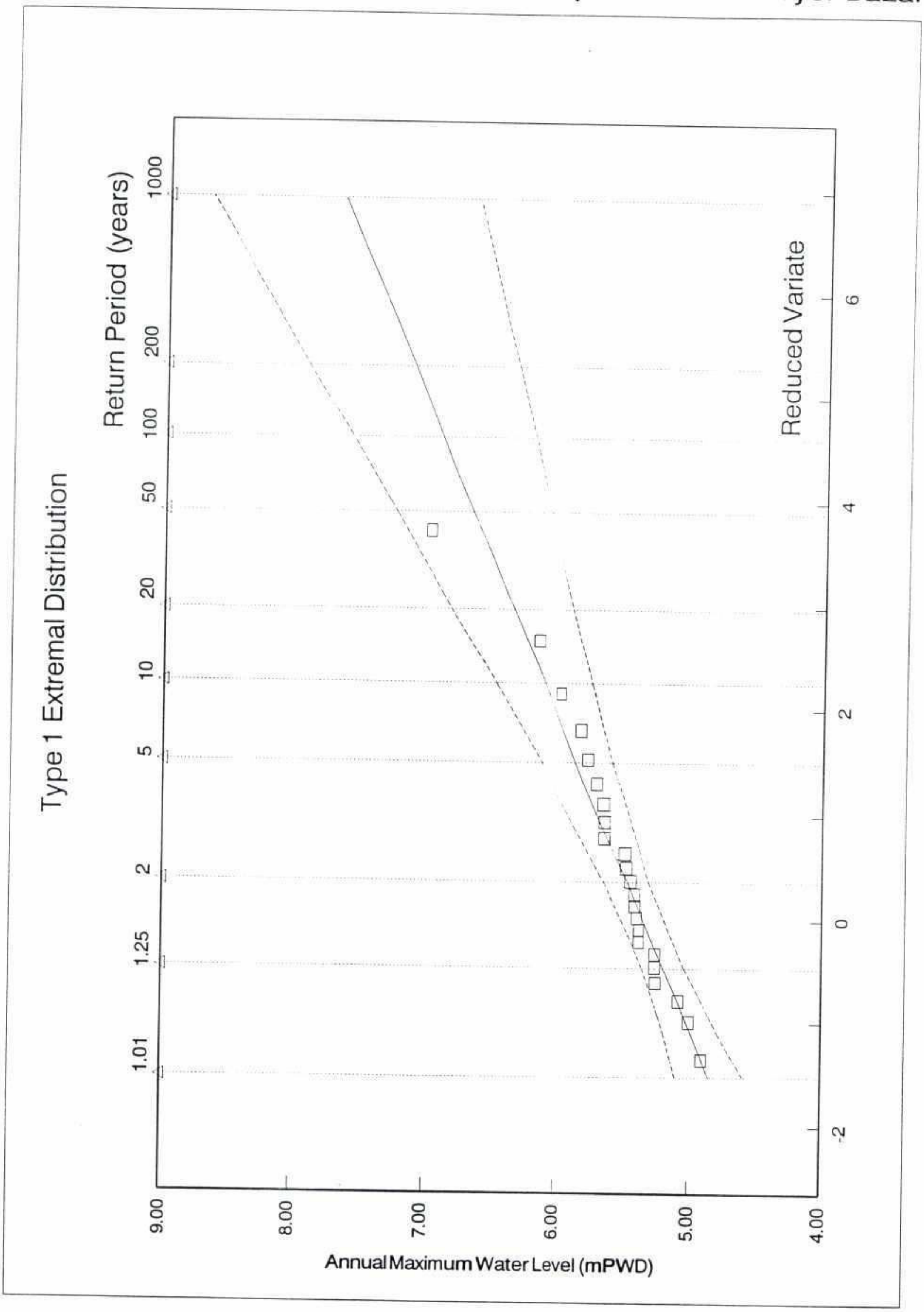
Figure VI.2.11

Annual Maximum Water Level Frequencies at Baidyer Bazar



water levels that can be expected in different parts of the region. It should be noted that the stations used upstream of Bhairab Bazar are not main river stations, and in real terms are at a similar chainage to Bhairab Bazar. It is thus to be expected that the seasonal variation in flooded areas in the north of the region will be much greater than in the areas south of the Gumti. Similarly, the impact of flood extremes could be greater in the northern areas, subject of course to the overall distribution of land levels relative to flood levels.

Regionally, frequency analysis has been carried out on all available records of 10 day water levels. For the period April to October, frequency distributions have been fitted to each 10 day period, resulting in a series of independent seasonal water level frequency estimates. The full results of the analysis are presented in Appendix V, and a sample table shown in Table VI.2.6. The analysis provides a preliminary basis for the evaluation of embankment design for both full polder and submersible embankments. In conjunction with local topographic data it will also give an indication of flood risk on different land types. The seasonal presentation of results permits flood levels to be related directly to cropping conditions.

It was also considered important to prepare flood level frequency duration tables, from which an indication of the duration of inundation to certain flood depths could be obtained. The results of the analysis could also be related to elevation area characteristics for different parts of the region in order to give preliminary indications of flood depth area frequency relationships. Flood level frequency duration tables have been prepared for each of the water level stations in the area. The full results of the analysis are presented Appendix VI. Table VI.2.7 presents the typical results output format. A summary of the results for selected flood durations and return periods is presented in Table VI.2.8, and serves to give an indication of variability across the Region.

With the exception of the main river station data, the analysis discussed above is not based on homogeneous record periods, but utilises all available data at each station. It will be noted from Table VI.2.3 that at some stations record periods are very short. Caution must therefore be exercised in the use of any the results. The purpose of the analysis was broad level planning and this must be borne in mind.

Frequency analysis based on historic water levels are of value in identifying appropriate design events, or preliminary outline design criteria. The statistical analysis of the historic record cannot however, be used as any form of predictor for flood levels that might be expected under future embanked river or polder conditions. The evaluation of such situations requires the use of hydrodynamic modelling techniques. These are discussed in Chapter VI.3.

VI.2.4.4 Analysis of Discharge Data

The analysis of discharge data has effectively been limited to that of the Gumti at Comilla, for reasons of data availability and quality. For the purposes of the regional study, the main objective of analysing the Gumti record has been to gain some understanding of the likely flood response of those rivers draining from the Tripura Hills into the project area. In terms of the developable water resources in these rivers, the findings of the National Water Plan have been that all dry season inflows from these rivers are fully utilised at present. There has in fact been a slight increase in dry season flow availability in the Gumti in recent years, but this is related to the phasing of development works upstream, and is unlikely to continue.

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TABLE VI.2.6

Seasonal Water Level Frequencies at Station T-3A

T-3A. Brahmanbaria Railway Bridge : Maximum 10 day levels, April - October.

Return Period (Yrs.)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.53	1.87	2.09	2.21	2.51	2.55	2.94	3.61	4.27	4.78	5.30	5.65	5.91	5.92	5.73	5.57	5.45	5.43	5.26	4.79	4.16	5.76
1.25	1.62	1.97	2.19	2.37	2.69	2.76	3.13	3.81	4.46	4.99	5.48	5.81	6.04	6.04	5.88	5.73	5.62	5.58	5.39	4.93	4.33	5.95
2	1.82	2.20	2.42	2.75	3.10	3.26	3.59	4.28	4.91	5.49	5.91	6.19	6.36	6.34	6.23	6.10	6.03	5.93	5.69	5.28	4.74	6.39
5	2.09	2.50	2.74	3.27	3.65	3.92	4.21	4.91	5.51	6.16	6.48	6.70	6.80	6.74	6.70	6.60	6.57	6.41	6.10	5.75	5.29	6.99
10	2.27	2.71	2.94	3.60	4.02	4.36	4.63	5.33	5.91	6.60	6.86	7.04	7.08	7.01	7.01	6.94	6.92	6.72	6.37	6.06	5.66	7.39
20	2.44	2.90	3.14	3.93	4.37	4.78	5.02	5.73	6.29	7.03	7.22	7.37	7.36	7.27	7.31	7.26	7.27	7.02	6.63	6.36	6.01	7.77
50	2.66	3.16	3.40	4.35	4.82	5.33	5.53	6.25	6.78	7.58	7.69	7.79	7.12	7.60	7.69	7.67	7.71	7.41	6.97	6.74	6.46	8.26

TABLE VI.2.7

Flood Level Frequency Duration at Station T-3A

T-3A, Brahmanbaria Railway Bridge ; Maximum 10 day levels, April - October

Duration Days	Return Period (Years)						
	1.11	1.25	2	5	10	20	50
20	5.88	6.02	6.36	6.82	7.12	7.41	7.79
30	5.80	5.92	6.19	6.56	6.81	7.04	7.35
40	5.68	5.78	6.01	6.32	6.53	6.72	6.98
50	5.58	5.69	5.93	6.27	6.49	6.70	6.98
60	5.49	5.60	5.87	6.22	6.45	6.68	6.97
80	5.28	5.39	5.65	6.01	6.24	6.47	6.76
100	4.92	5.03	5.29	5.64	5.87	6.09	6.37
120	3.98	4.15	4.53	5.05	5.40	5.73	6.15
150	2.54	2.74	3.20	3.82	4.23	4.62	5.13

TABLE VI.2.8

Summary of Flood Level Duration Frequencies

Duration Return Period	20 Days			40 Days			60 Days		
	2	5	10	2	5	10	2	5	10
Station									
W-110	10.34	11.01	11.45	9.84	10.49	10.91	9.42	9.95	10.29
W-113	7.69	8.25	8.62	7.27	7.80	8.16	6.80	7.38	7.76
W-114	6.81	7.05	7.21	6.45	6.75	6.95	6.27	6.55	6.73
W-123	5.84	6.24	6.50	5.57	5.84	6.02	5.47	5.75	5.94
W-157	21.59	22.42	22.97	20.95	21.49	21.48	20.65	21.16	21.50
W-158	15.48	16.07	16.45	14.63	15.18	15.54	14.36	14.78	15.05
T-3A	6.36	6.82	7.12	6.01	6.32	6.53	5.87	6.22	6.45
T-79	4.75	4.98	5.12	4.58	4.81	4.95	4.45	4.62	4.74
T-115	5.11	5.48	5.73	4.90	5.22	5.44	4.79	5.10	5.30
T-230	6.44	6.86	7.14	6.03	6.40	6.65	5.87	6.30	6.58
T-240	3.45	3.88	4.17	3.37	3.78	4.06	3.21	3.65	3.94
T-275	5.20	5.61	5.88	4.96	5.22	5.39	4.81	5.09	5.27
T-276	4.86	5.16	5.36	4.67	4.93	5.10	4.51	4.74	4.88
T-277	4.43	4.64	4.78	4.31	4.49	4.60	4.23	4.38	4.48
T-296	6.38	6.85	7.16	6.03	6.38	6.62	5.89	6.27	6.51
T-298	6.05	6.44	6.69	5.73	6.01	6.19	5.61	5.91	6.10

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The Gumti records at Comilla have been tested for trend and persistence. Both mean annual runoff and annual maximum flood discharges have been evaluated. The results of the statistical tests are presented in Table VI.2.9, and the data presented in Figure VI.2.12. There is no evidence of persistence or trend in either the mean annual runoffs or annual maximum flood discharges in the Gumti. The situation with regard to mean annual runoff may change with future developments upstream, but it is unlikely that there will be any significant change in the flood response of the catchment.

TABLE VI.2.9

Statistical Tests on Gumti Flows at Comilla

Statistical Test	Mean Annual Flow		Annual Maximum	
	Expected	Observed	Expected	Observed
Randomness				
Median Crosses	11 +/- 6	9	11 +/- 6	11
Turning Points	14 +/- 3	11	14 +/- 3	12
Persistence				
First Order Serial Correlation	-0.04+/-0.41	0.03	-0.04+/-0.41	0.20
Spearman Rank	-0.05+/-0.42	-0.08	-0.05+/-0.42	0.10
Trend				
Rank Order	-0.04+/-0.40	-0.06	-0.04+/-0.40	-0.06
Mann-Whitney U Test	72+/-34	67	72+/-34	70
Wald-Wolfowitz Runs Test	13+/-5	12	13+/-5	12

The Gumti is a flashy type of river, and its' response is likely to be typical of many of the other smaller rivers draining from the Tripura Hills. Figure VI.2.13 shows a typical annual hydrograph for the Gumti at Comilla. This is quite different to those of the main rivers, exhibiting direct rainfall response. Frequency analysis has been carried out on the annual maximum series of mean daily flows on the Gumti. The results are summarised in Table VI.2.10. The objective of the analysis has been to evaluate characteristics which might be transposed to the other cross boundary rivers on the basis of catchment area. Of interest therefore is the growth factor on the frequency distribution, as well as the specific mean annual flood discharge.

Other records which were thought to be of potential value in assessing flood frequency for cross boundary rivers were those at Shaistagonj (158.1), Parshuram (212), and Kaliachari (84.1). The records at Shaistagonj are thought to be unreliable. Figure VI.2.15 shows a plot of deviations from the mean of annual maximum floods at Shaistagonj. There are clearly inconsistencies at the station, which could not be resolved as part of the present study. The record at Shaistagonj has not been included in analyses.

Figure VI.2.12
Annual Runoff at Comilla

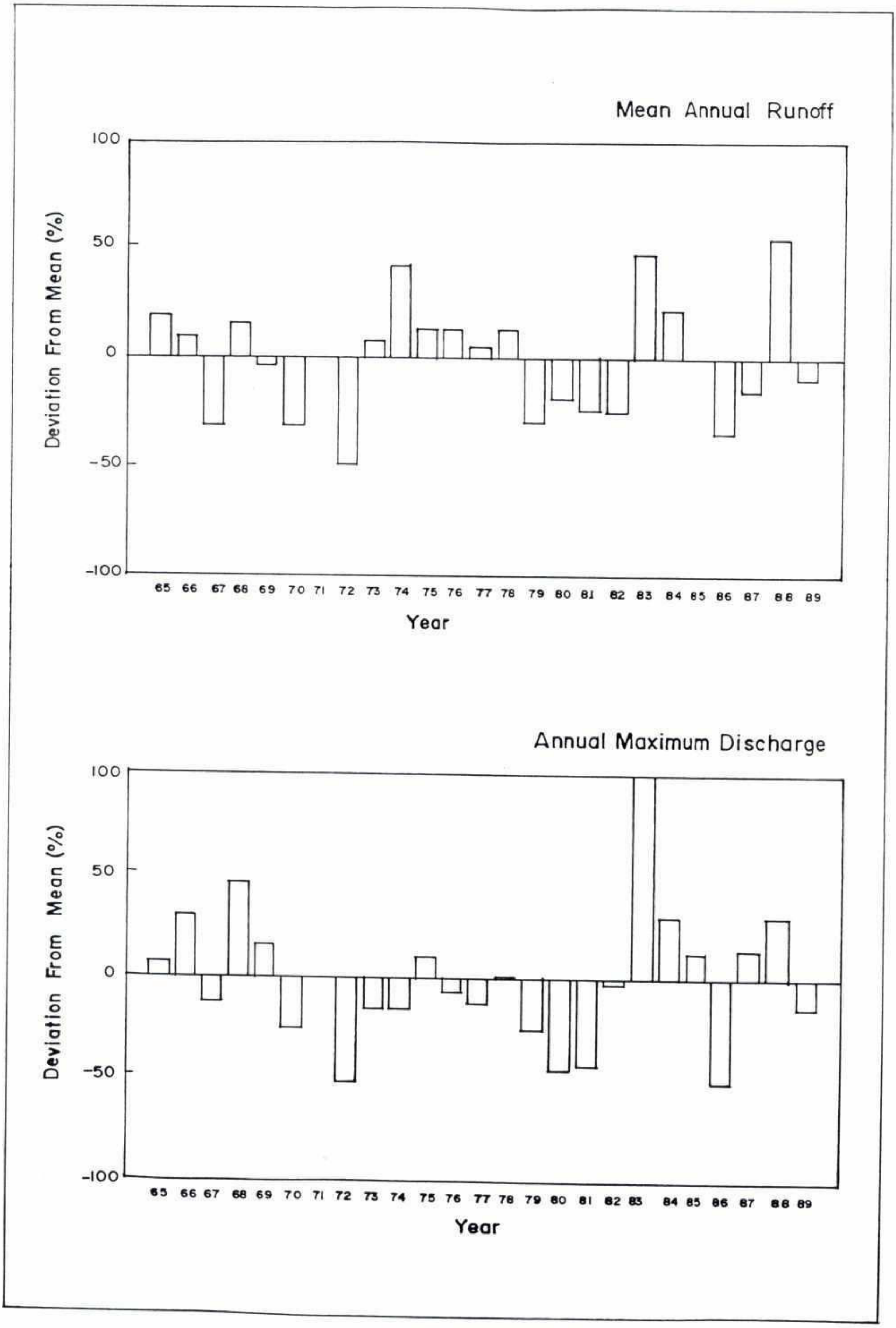


Figure VI.2.13
Annual Hydrograph for the Gumti at Comilla

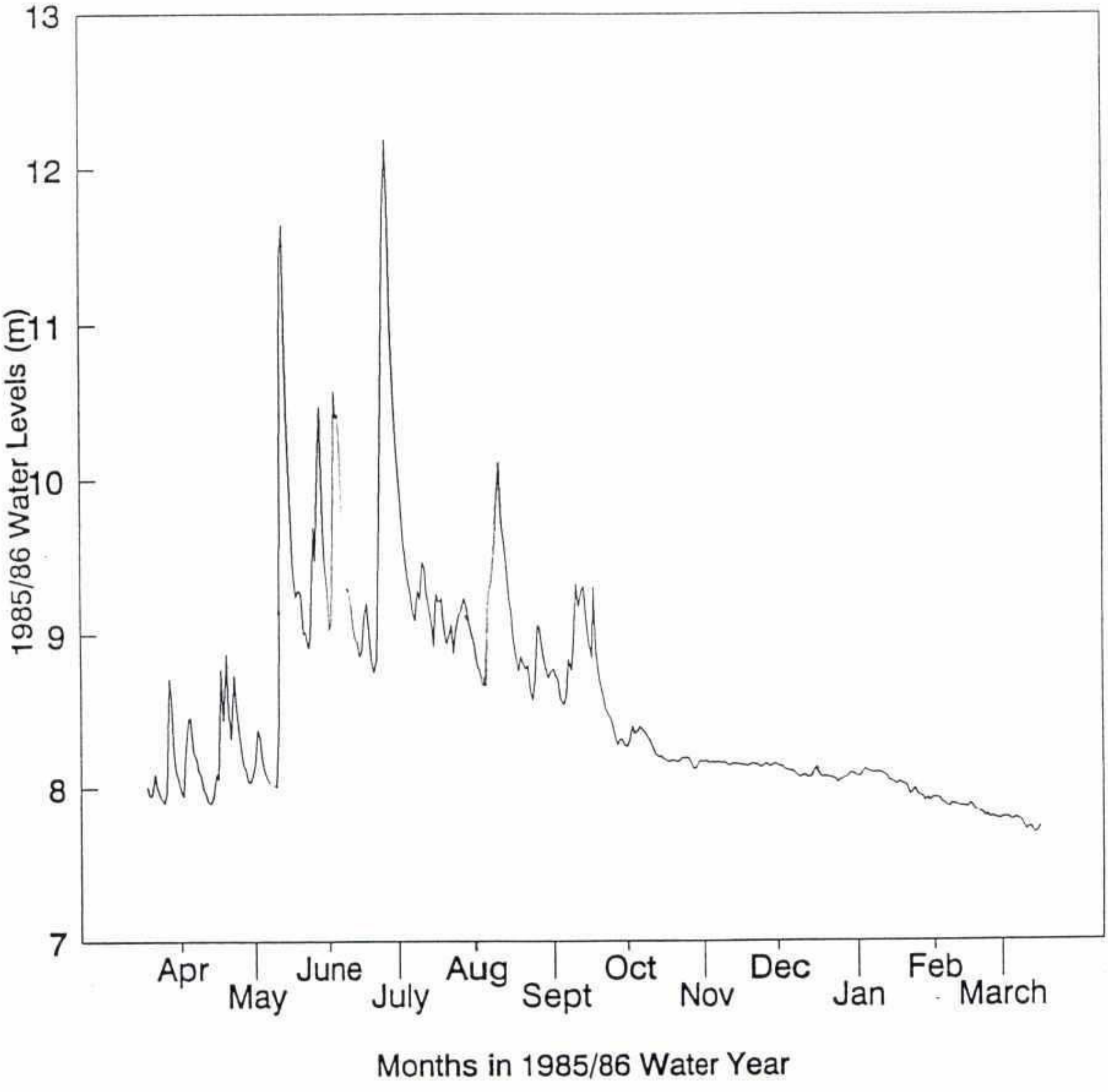


Figure VI.2.14

Annual Maximum Discharge at Shaistagonj

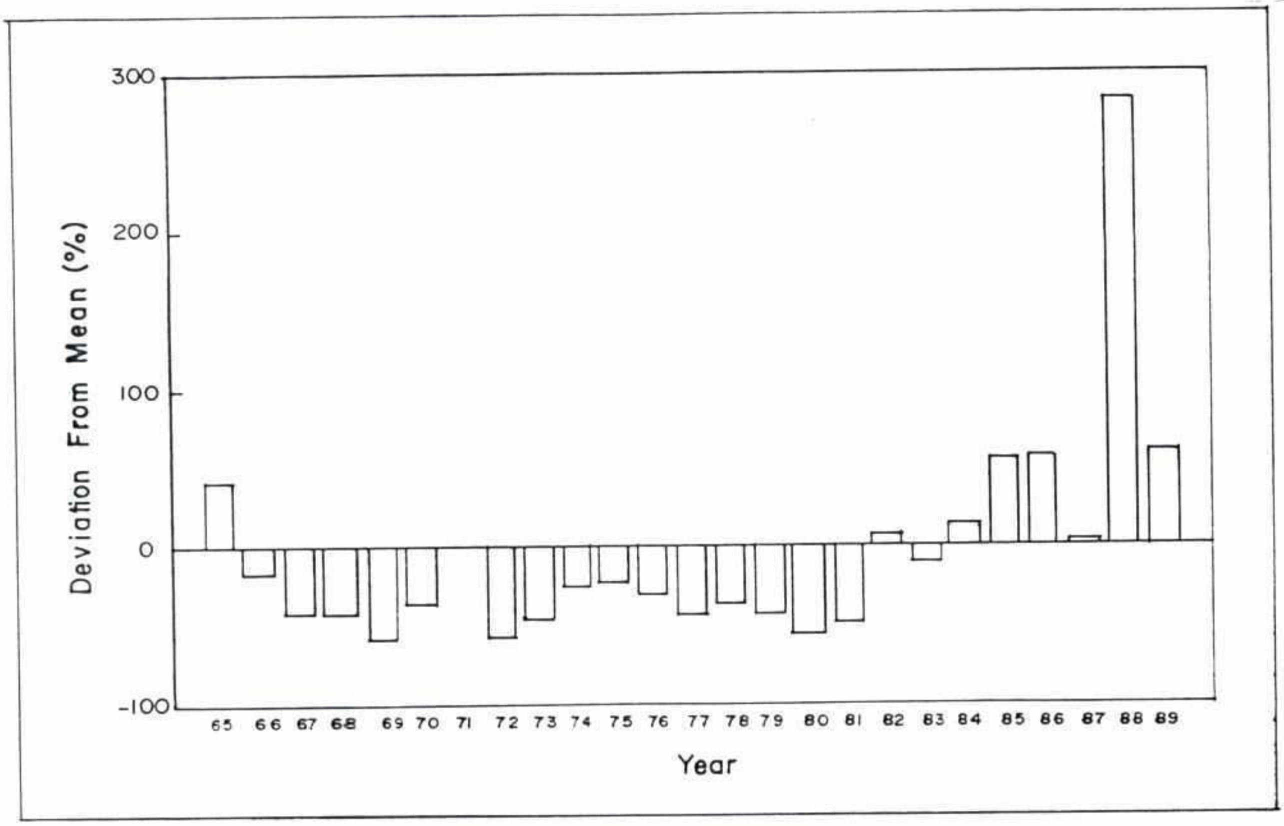


Figure VI.2.15

Annual Maximum Discharge at Parshuram

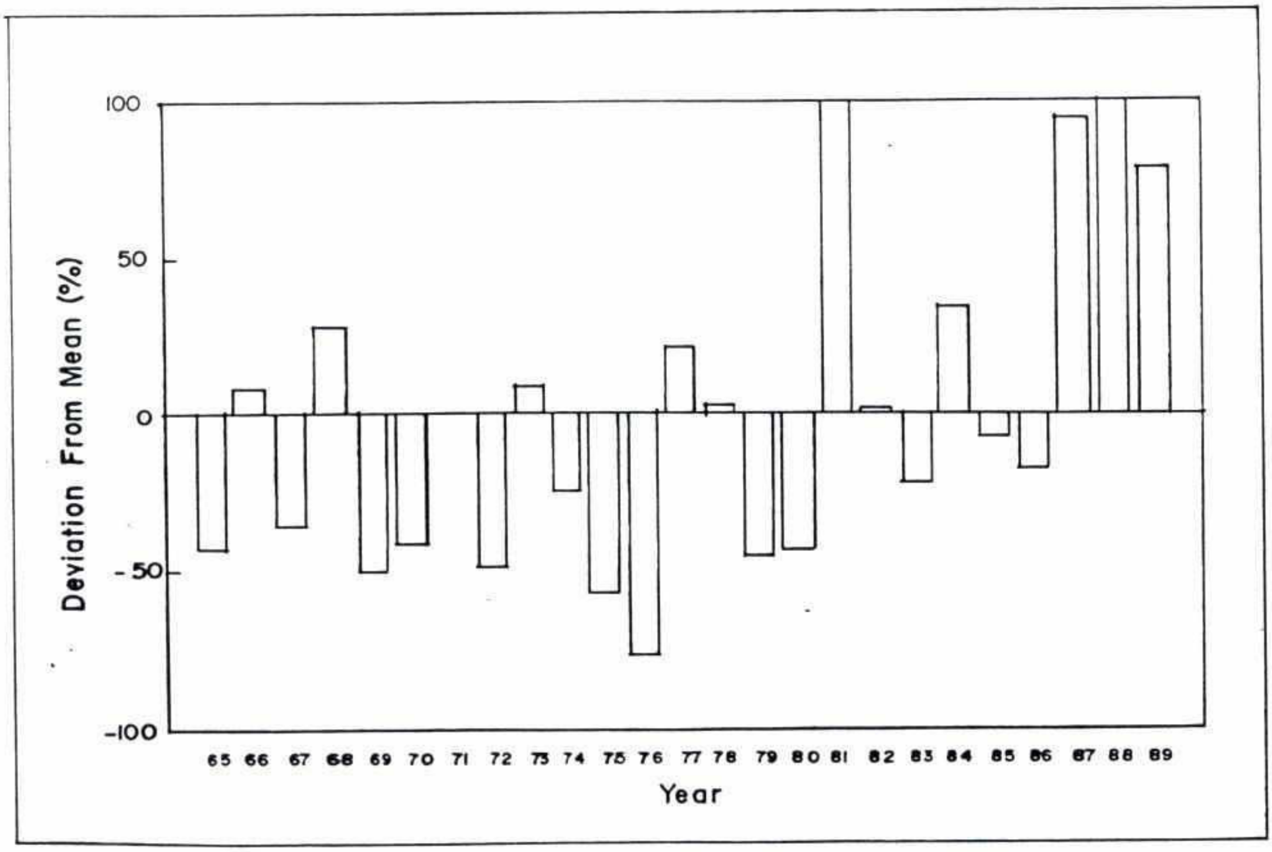


TABLE VI.2.10

Flood Frequencies, Gumti at Comilla

Return Period (years)	Estimated Maxima (m^3/s)	Q/Q_{mean}
2	468	0.94
5	630	1.27
10	738	1.48
20	842	1.69
50	975	1.96

At Parshuram there is also apparently a trend of increasing flood discharge (Figure VI.2.15), although the possible reasons for this are unknown. It has not been possible to investigate this. At Kaliachari there are problems with the streamflow record, and in August 1982, the equivalent runoff depth over a four day period from the catchment was over 1500 mm. The maximum rainfall recorded in the area at this time was 357 mm, and there are therefore problems with this record.

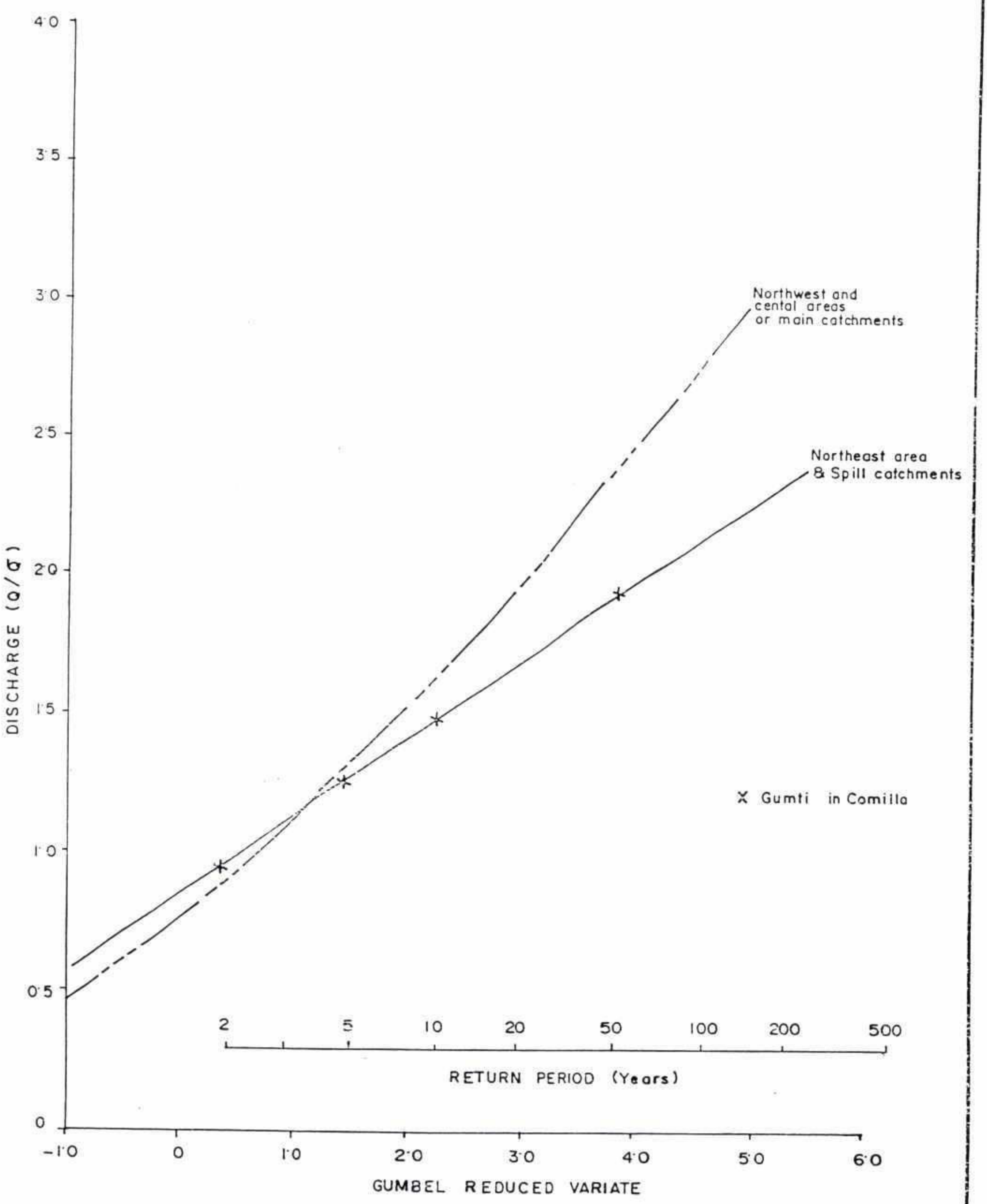
Regional flood frequency analysis was carried out as part of the Water Balance Studies (Ref. 3). General consistency was found in regional growth curves. The results from the Water Balance Studies are plotted with those for the Gumti in Figure VI.2.16. There is excellent agreement, and use of the growth factors on mean annual floods is considered to be an appropriate means of estimating cross boundary flood flows into the region. The difficulty remaining is in evaluating a mean annual flood for any particular catchment area, given that only the Gumti is gauged. The mean annual flood on the Gumti has a specific peak mean daily discharge of 0.26 $m^3/s/km^2$. On the Muhuri at Pashuram the mean annual flood has a specific peak mean daily discharge of 0.52 $m^3/s/km^2$. Rainfall over this area is significantly higher than at Comilla, and this combined with a smaller catchment area, results in a higher specific discharge. This analysis has not therefore resulted in any quick assessments for flood peaks from ungauged catchments. The data available are annual maximum mean daily flood discharges, and not instantaneous flood peaks. It is not considered appropriate to use the specific discharge approach for any of the smaller ungauged catchments. It is recommended that for investigations of specific areas, a synthetic unit hydrograph approach be adopted. An appropriate methodology for the hill catchments would be the USSCS method (Ref. 7). This could be used with rainfall estimates from Bangladesh, and catchment characteristics estimated from available mapping or imagery. Application of the USSCS method to catchments draining through the Sonaichari area south of Comilla is included in Appendix VII.

VI.2.5 Sediment Discharges

The availability of sediment discharge data for the region is quite limited, as discussed in section 2.3.4. Work on the Hydrological and Morphological Study of the Gumti, Titas and Atrai Basins (Ref. 4), has however, given some general figures on typical size fractions and annual sediment yields, and these are considered to be

Figure VI.2.16

Regional Growth Curves for Flood Frequency



Source : Water Balance Studies, Ref. 3

appropriate for outline planning purposes in the region. The annual sediment yield from the Gumti was estimated to be 770 tonnes/km^2/year, which compared well with a previous estimate for a catchment in north-east India of 700 tonnes/km^2/year (Ref. 8). Studies of reservoir sedimentation in India have indicated sediment yields of the order of 600 to 1400 tonnes/km^2/year for catchments in Southern India of less than 150 km^2. Similar measurements for mountain catchments in Northern India indicated annual yields of the order of 1200 to 2000 tonnes/km^2. For smaller catchments draining from the Tripura Hills, sediment yields could be in excess of those estimated for the Gumti. Annual sand extraction from the Kakri River is equivalent to a yield of 490 tonne/km^2.

The composition of Gumti sediment was 700 tonnes/km^2/year of silt, and 70 tonnes/km^2/year of sand. Morphological modelling runs carried out on the Gumti adopted a sand size of 0.2 mm, and a silt size of 0.03 mm.

CHAPTER VI.3

THE SOUTH EAST REGIONAL MODEL

VI.3.1 General

The Surface Water Simulation Modelling Programme (SWSMP) in Bangladesh commenced in 1986, following a report commissioned by the Master Plan Organisation (MPO), which recommended that mathematical models be applied to analyse the hydrological and hydraulic processes of the river systems. The objectives of the programme were:

> "to develop a fully operational model of the South East Region; and to develop a structured approach to modelling with a general model covering the whole country."

Training formed a very important part of the programme. The Surface Water Modelling Centre (SWMC) existed until 1992 as part of the MPO, but is now attached to the Rivers Research Institute (RRI). There is active support from the Bangladesh University of Engineering Technology (BUET), and from the Danish Hydraulics Institute who are consultants to the programme.

Application of the modelling approaches was shown to be successful, and a second phase, in which models are being developed for the entire country commenced in December 1989. These models form a particularly significant part of the evaluations required under the Flood Action Plan. The objectives of Phase II of the SWSMP were:

- to maintain existing and develop further regional surface water models in response to the countries need;
- to demonstrate the practical use of the models in planning and design, and in flood forecasting;
- to consolidate and extend the local capacity and capability in mathematical modelling;
- to ensure long-term sustainability of the established technology.

For the purposes of the South East Regional Study, both the General Model and the South East Regional Model (SERM), were of particular importance. The General Model can be used to evaluate the response of the main river systems to regional development programmes, and hence to the impact of such developments on main river levels forming regional boundaries. The regional model utilises these in the evaluation of internal conditions in the region.

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VI.3.2 The South East Regional Model

The south-east regional model covers the area bounded in the west be the Meghna River, in the east by the Indian border, in the north by the Bhairab to Comilla railway line, and in the south by the Bay of Bengal.

The model was initially set up using the NAM hydrological model to provide the local rainfall runoff response, and the System 11 hydrodynamic model developed by the Danish Hydraulic Institute. An extensive field programme was carried out as a part of the Phase I activities, including the establishment of 119 water level stage boards, 14 discharge stations and six raingauges, in addition to utilisation of existing BWDB stations.

The catchment delineation and associated raingauges used in the NAM model are shown in Figure VI.3.1. A total of 24 catchments have been defined. Calibration of the NAM model was primarily against observed groundwater levels in view of the lack of discharge observation stations and the degree of interconnection between catchments through the river system. Independent calibration of NAM was initially carried out on the period April 1986 to October 1987, and was generally very good. Some 26 BWDB observation wells were used in the calibration. Calibration was found to be sensitive to surface detention storage capacity, overland runoff coefficients and thresholds for this and groundwater recharge. A full description of NAM and of the preliminary calibration is given in the SWSMP Phase I report (Ref. 9). The NAM calibration has made the best possible use of available data in the region, but the lack of calibration on discharges could be a limitation for some applications. Sensitivity analysis will be required at feasibility and design stage studies in order to evaluate the possible impacts of inaccuracies in either model calibration or structure.

The System11 model was set up with 175 channel reaches and 100 nodes. Some 230 river cross sections were surveyed, and floodplain topography defined to some extent from the MPO 1 km grid of land levels (this was a data base developed for water resource investigations and is discussed in section VI.3.3). In view of the DOS operating system limitations, the model was set up in two parts, effectively divided by the Daudkandi to Comilla road (Figure VI.3.1). The road does form a natural divide, and water level stations were set up by the SWMC in order to provide control on the model. The System11 model included 12 discharge and 12 water level boundaries. In the southern part of the modelled area, the boundaries were set upstream of the existing regulator structures at Kazirhat and Rahmatkali. This proved necessary in view of the uncertain operation of the structures, and the necessity of very short time steps had they been incorporated in the model. The System11 network as used in Phase I is shown in Figure VI.3.2

The calibration results achieved with the System11 model were, on the whole, extremely good. Discrepancies in the simulation that were observed are most likely to have been related to inaccuracies in the physical definition of certain floodplain features or their measurement, rather than any problem with the model itself.

Under Phase II of the SWSMP, the models were transferred from System11 to Mike11. Mike11 comprises the same basic hydrodynamic model as System11, but includes better user interface and data management facilities. In the South East Region, the SWMC has carried out full verification of the model on transfer to the Mike11 system.

Figure VI 3.1
South East Region NAM Model Sub Catchments

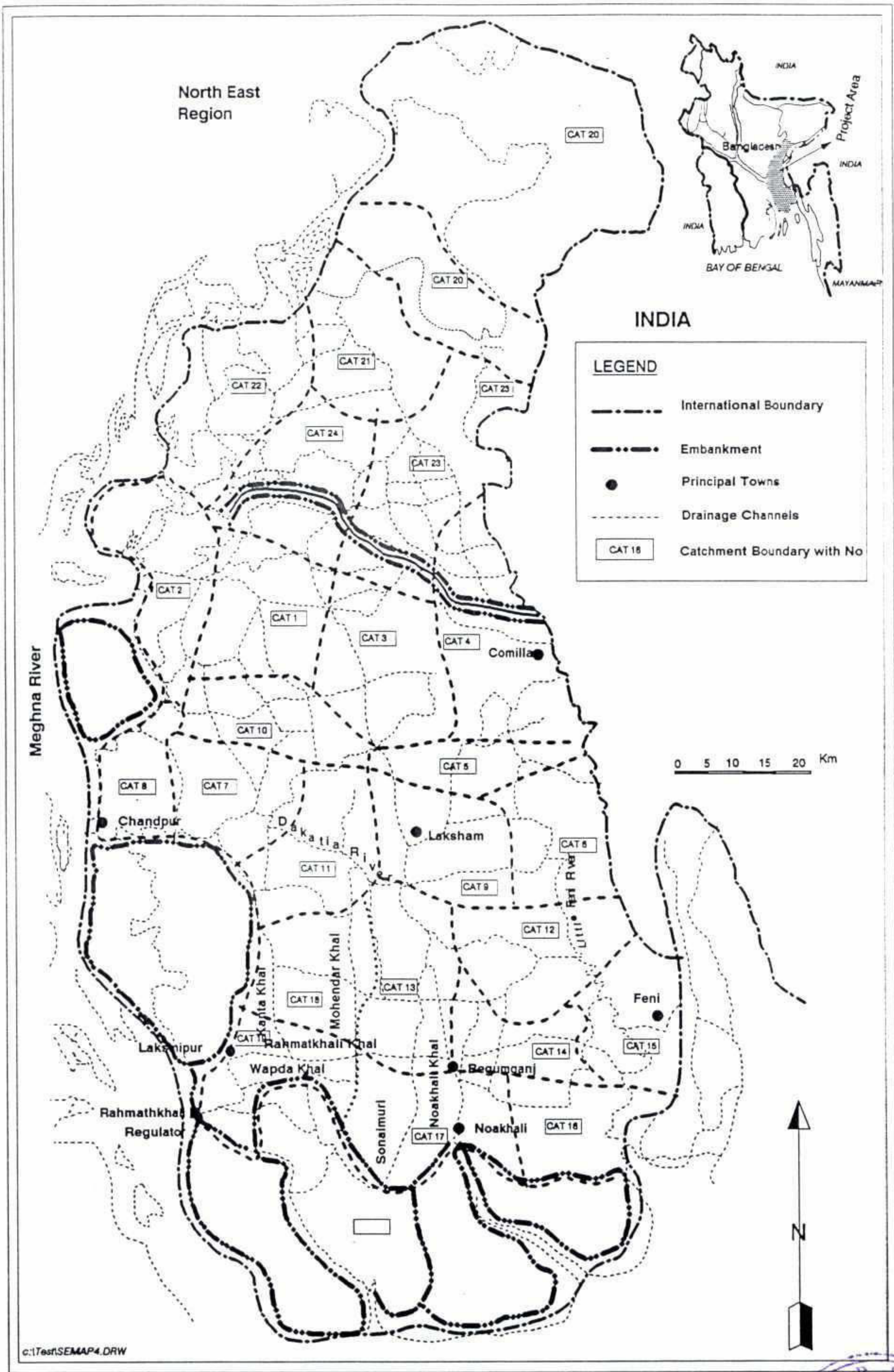
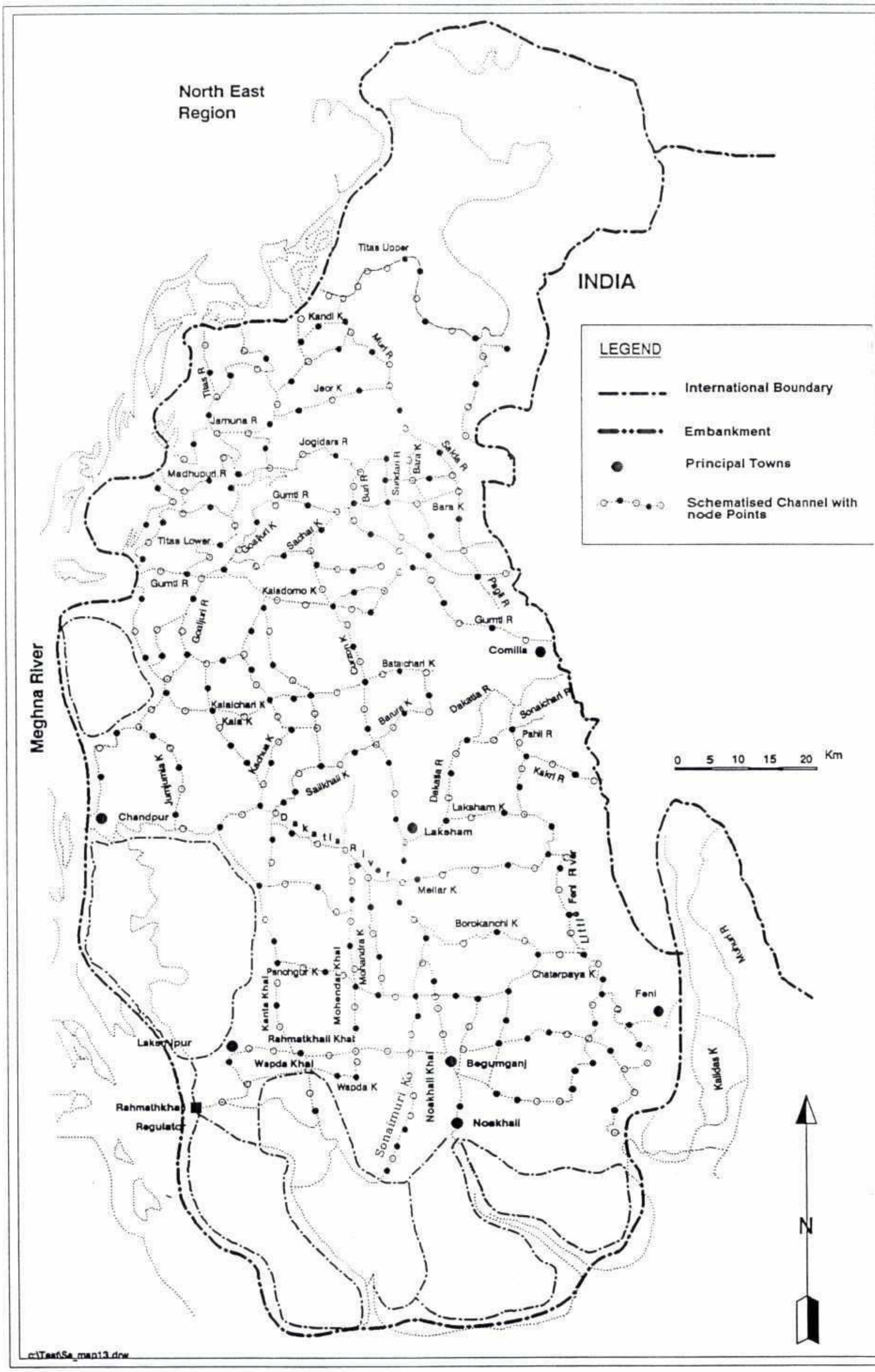


Figure VI 3.2
SERM - System 11 Model Network



Under the Mike11 system, further refinement of calibration and verification was carried out using data for the 1988/89 hydrometric year. It was found that verification of the NAM model for 1988/89 was not as good in certain parts of the region as had been achieved previously. Part of the reason for this is likely to be that during 1988, main river flood inundation would have contributed to groundwater recharge, and the feedback loop from flood inundation to recharge is not incorporated in the model. The SWMC have investigated the possible reasons for poorer verification, and as with all such models, it is under continual improvement. For the regional level planning studies, the poorer verification of the NAM model in 1988 was not considered to be of any particular significance. The hydrodynamic model response was still very good.

Models were transferred from the DOS operating system to a UNIX environment in 1992. This removes the memory limitations on the size of model that can be run, and permits the SERM to be run as a single model, rather than in two parts as was required at the time of the regional study. This facility has been utilised in subsequent feasibility level studies.

The division of the models was not a problem in application to the years so far modelled by the SWMC, as water level observations were available on the boundary between the northern and southern sub-models. It was, however, a limitation to the application of the models in years for which such data is not available. Discussion on the approach which has been adopted for the present study is given in section VI.3.7.

For the South East Regional Study, all modelling work was carried out in the offices of the SWMC, in co-operation with the SWMC team responsible for the region. This was an arrangement which worked extremely well. Models were verified when transferred to the project computer system in order to ensure that the base models were reproducing the results produced by the SWMC, but in all other respects, the models have been accepted as proven and well calibrated planning tools.

VI.3.3 Model Outputs

The outputs from Mike11 are time series of water levels and discharges for each reach and node in the network. These may viewed as hydrographs, or printed as water surface profiles. These outputs are useful in determining in a qualitative manner the effectiveness of different flood mitigation options, but for full project evaluation, further processing of the model outputs in relation to surrounding land levels has been required. Commonly, hydrodynamic models are used in application to individual river systems, for which the desired output is a design water surface profile. In the South East Region there is a complex interconnected channel network, and for evaluation of the existing flood conditions, or improved post project conditions, an assessment of flood depths and areas was required. The approach adopted has been to relate flood levels output from Mike11 to a simplified terrain model built up from elevation area characteristics on 1' grid squares. This has permitted assessments to be made of the aerial distribution of flood depths.

A land level data base was prepared by the MPO, based on a 1 km grid. This data base was prepared for use in broad level water resources planning, using lumped models. The approach adopted by the MPO in preparation of the data was to overlay a 1 km grid on 4" to 1 mile map sheets, and to note the level of the closest spot height to the grid intersection. The technique was thus an objective sampling approach, quite appropriate for planning and modelling studies covering the entire country. It's creation was in fact a significant achievement at the time. For regional planning and sub-regional planning, it was considered that the MPO land level data base may be too coarse, missing out on important micro-relief which is represented on existing mapping at a scale of 4" to 1 mile.

Figure VI.3.3
Land Level Data Base

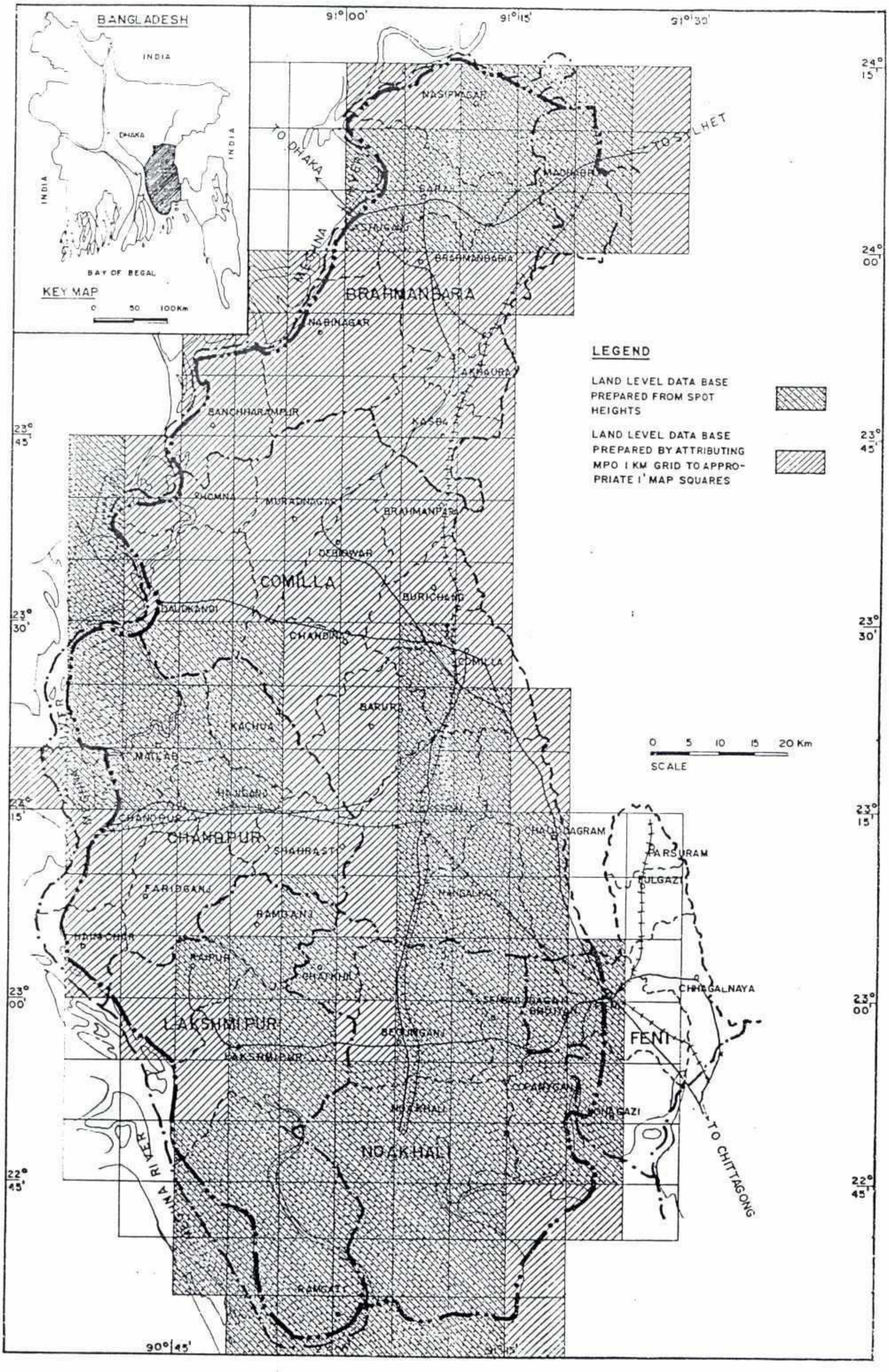


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Figure VI.3.4

Regional Planning Context Map

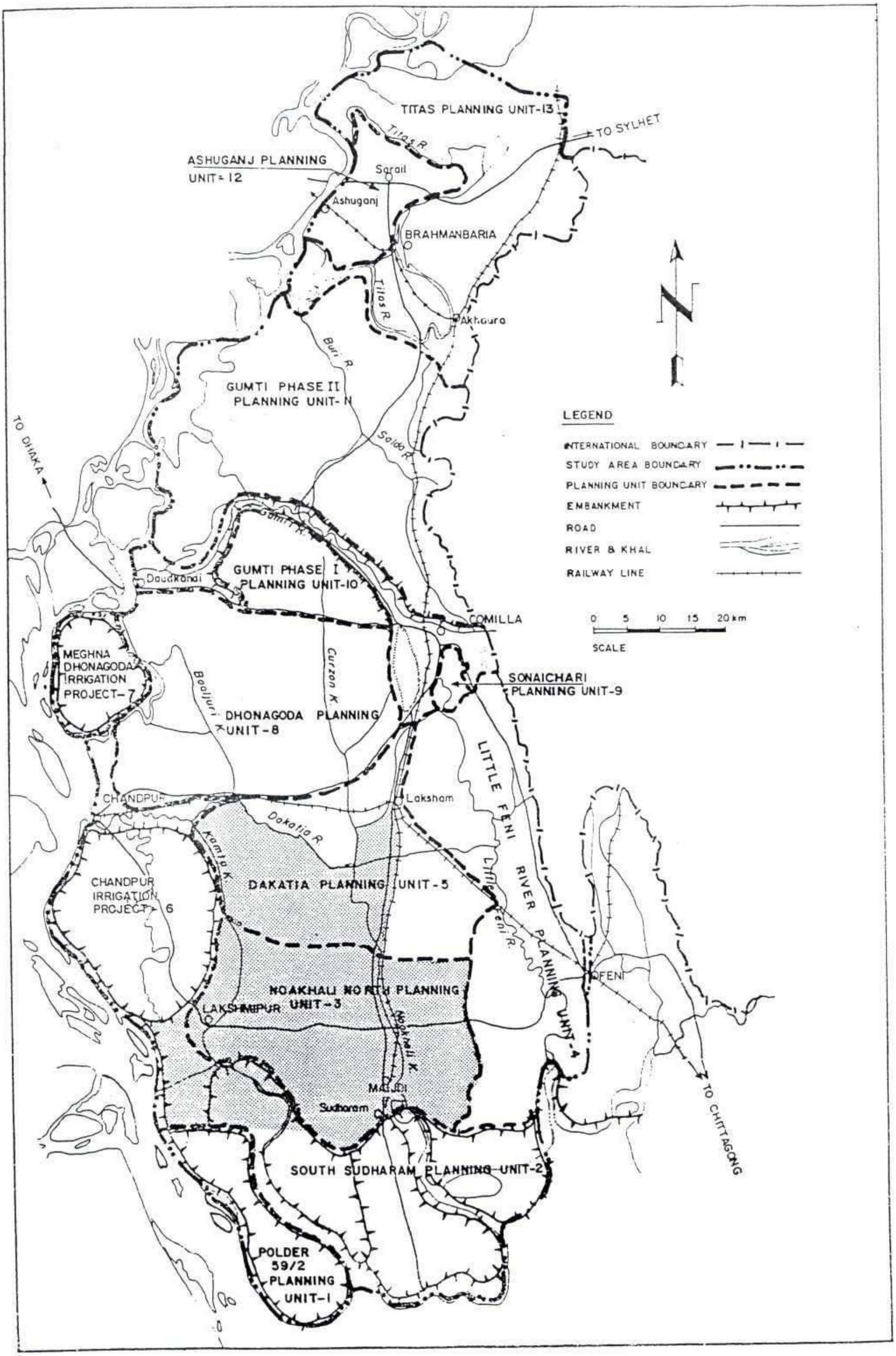
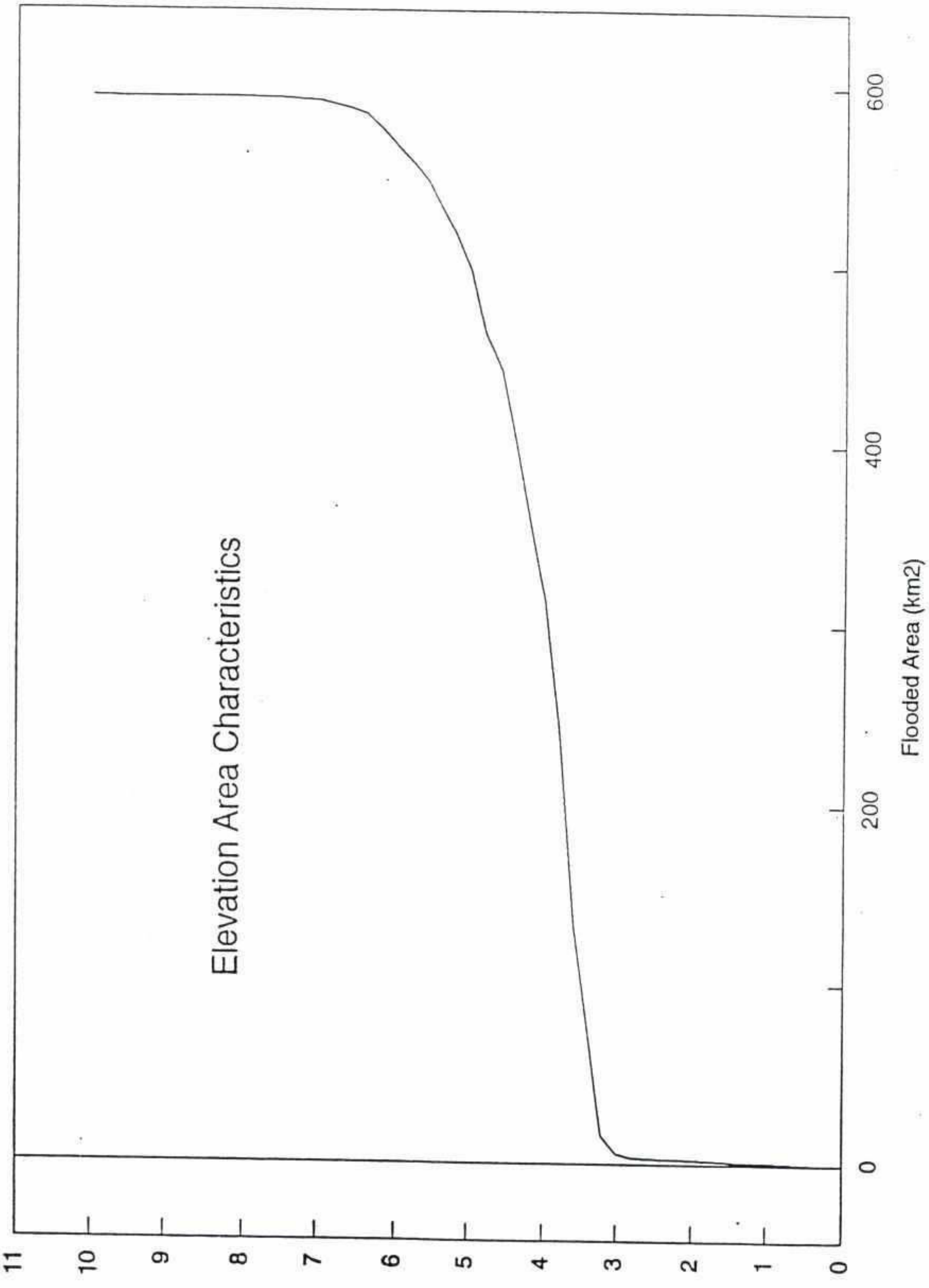


Figure VI.3.5

Elevation - Area Characteristics, Dakatia Planning Unit



Each 4" to 1 mile map sheet covers an area of 5' longitude by 5' latitude, divided into 25 1' squares. In each 1' map square there are on average 80 to 90 spot heights, thus giving an excellent indication of micro-relief, or at least the micro-relief at the time of survey. As far as has been possible, and given the time constraints on the regional study, this data was utilised to permit elevation area characteristics to be prepared on a 1' grid square basis. The extent of mapping for which this was achieved is presented in Figure VI.3.3. In areas where it has not been possible, the MPO 1 km grid of land levels have been attributed to appropriate 1' map squares. Much of the mapping for the study area is to Survey of Bangladesh datum. All levels have been converted to PWD which is compatible with that used by the SWMC. It is generally considered that the accuracy of the 4" to 1 mile mapping is accurate within each map sheet, but that small discrepancies may exist between sheets prepared from different bench marks. There was of course no solution to this, and upgraded 1:16,000 scale mapping for the region will not be available before 1994 or 1995.

Using the Mike11 model network and floodplain allocation diagrams, 1' grid squares were attributed to each model node, thereby permitting flood depth area characteristics to be evaluated from model results on a local basis. Each model node was therefore considered to be representative of flood levels over a selected area. For planning area analysis, aggregations of 1' squares lying within the planning unit were compiled, permitting the Mike11 output results to be aggregated into flood depth area characteristics by planning unit. In this manner the micro relief and detailed level of model output was retained in the approach to macro level planning.

The identified planning units are shown in Figure VI.3.4. With the exception of Gumti I and Gumti II, for which inadequate data were available from any source, the elevation area characteristics of each of the planning units are presented in Appendix VII . A typical planning unit elevation area curve is presented in Figure VI.3.5. Of particular note from each of the elevation area curves is that a very small change in water level can result in a very significant change in the area of possible inundation. There are obvious implications for model accuracy, and for the sensitivity and accuracy of the evaluations of model results. Errors in water levels within normal modelling tolerances can make a substantial difference in the simulated area of flooding. Also, relatively small changes in water level in unprotected areas, resulting from the construction of flood mitigation measures, could have far reaching impacts at certain threshold levels..

VI.3.4 Approach to Model Application

The approach to handling model outputs and relating them to existing topography in a spatial manner as discussed in section VI.3.3, is the first step towards evaluation of model results. It is essential, however, to consider the impacts of floods of varying return periods, and for conditions in Bangladesh, the definition of events at selected return periods is not straight forward. The seasonality of flooding is also of importance, although for preliminary plan formulation on a regional basis, this could not be addressed to the degree that might be expected of feasibility level studies.

Flooding in the project area is produced by a combination of boundary water level conditions in the Meghna River, and local rainfall. Antecedent conditions of soil moisture and surface water storage in rivers, khals and beels are important, and a flood event in Bangladesh, with the exception of local flash floods, must be considered as the entire monsoon period, being dominated by the hydrographs of the major rivers.

The event variables are major river flow, local rainfall and flash floods from the Tripura Hills. The manner in which these can combine to produce any particular return period of flooding at a particular location, is very difficult to approach analytically on a regional scale. While a flash flood, or response to pre-monsoon rainfall, may be considered as a discrete event in combination with some outfall water level, the seasonality of regional flood response requires that the entire duration of the Padma flood between June and September be considered. The definition of an event in the evaluation of existing regional flooding conditions is in fact the seasonal main river hydrograph and the associated seasonal rainfall pattern.

Considering a combined probability approach to evaluation of the interaction of major river floods and local or regional rainfall is complex because of seasonality in both parameters. An approach would be to divide the flood season into a series of discrete 10 or 15 day periods, and to evaluate rainfall and runoff probabilities in each of these independently. In the pre-monsoon period, it is possible that in much of the area rainfall will be the dominant influence on flooding, while in the main monsoon period, main rivers will be dominant influence over much of the area. These dependencies have to be reflected in approach, and for each time slice throughout the season the combined probability approach would require:

a) a normal probability distribution of main river or outfall water levels, and an annual maximum series of rainfalls;

b) a normal probability distribution of local rainfalls, and an annual maximum series of main river or outfall water levels;

c) modelled flood response under each of the above and combination of probability matrices.

The above would assume independence between major river flow and local rainfall, which in fact is not likely to be the case, and would be further complicated by the requirement to account for antecedent storage conditions throughout the system and their probability for each time slice.

A large number of computer runs would be required were the above approach followed (probably about 50 per 10 day period), and it may be found that there are few areas in which the interaction affects a significant area. Considering a single river system with outfall water level control, water level frequencies in the lower reaches would be dominated by outfall level, while in the upper reaches fluvial influences would be dominant. It is for the interaction zone between that combined probabilities are required. Prior to embarking on such analyses, system sensitivity must be established. Sensitivity analysis has been carried out and is discussed in Section VI.3.5.

It is important to recognise the distinction between the requirements and approach to a regional evaluation and those of an individual sub-area or particular project, such as a polder. The regional approach is intended to address the regional problems and to provide the basis for more detailed subsequent analysis. Given the analytical difficulties in trying to combine frequency distributions of seasonal variables, the ideal approach to the evaluation of existing flood frequency and extent is to carry out a continuous simulation for the entire period of available hydrometeorological record. The size of the study area, the nature of the computational framework, and resource constraints, did require that the approach be modified, however. Pre-definition of likely conditions causing flooding was required in order to achieve a manageable number of computer runs, and a manageable volume of output data.

VI.3.5 System Sensitivity

VI.3.5.1 General

A number of sensitivity runs have been carried out in order to determine the relative importance of rainfall and main river levels in producing floods in the southern part of the region. Extremes of rainfall and main river level were combined to give an indication of the requirement for combined probability analysis or for long term simulation runs in order to determine flood level frequencies.

The model runs were carried out with main river boundary conditions for 1988 and 1986, and rainfall and inflows for 1986 and 1987. In terms of main river levels, the highest annual maxima occurred in 1988, and the lowest in 1986. In terms of regional rainfall, 1986 was very dry, and 1987 had the wettest mid monsoon period in record. The combinations carried out were:

1.	1988 main river water levels		High
	a)	1986 rainfall and local runoff	Low
	b)	1987 rainfall and local runoff	High
2.	1986 main river water levels		Low
	a)	1986 rainfall and local runoff	Low
	b)	1987 rainfall and local runoff	High

The runs carried out therefore reflect extreme conditions.

The results of the model sensitivity are presented in terms of maximum water surface profiles in Figures VI.3.6 to VI.3.8 for the Dakatia River, the Little Feni River, and Rahmatkali Khal. These are fairly representative of the sub-regions of the project area.

VI.3.5.2 Dakatia River

It is clear that between chainages 40 and 100 on the Dakatia, the dominant influence on flooding is main river levels (Figure VI.3.6). Local rainfall adds about 0.2m to flood levels at chainage 50, and for design purposes, there would be little point in going to great lengths to try and refine water level estimates. The combination of extreme rainfall and extreme water levels results in only a small overestimate in flood levels, and as can be seen by comparison with the 1988 flood levels, this is unlikely to result in any over-design.

VI.3.5.3 Little Feni River

The Little Feni River is effectively unaffected by assumptions about main river boundary conditions, and local rainfall dominates the flood response throughout most of the system (Figure VI.3.7). The operation of Kazirhat regulator is dominant over the last 20 km, and obviously influences the flood response.

It is of interest to note that throughout most of the system, the difference in peak water levels between the rainfall extremes is only of the order of 0.3m in the centre of the basin.

Figure VI.3.6

System Sensitivity, Dakatia River

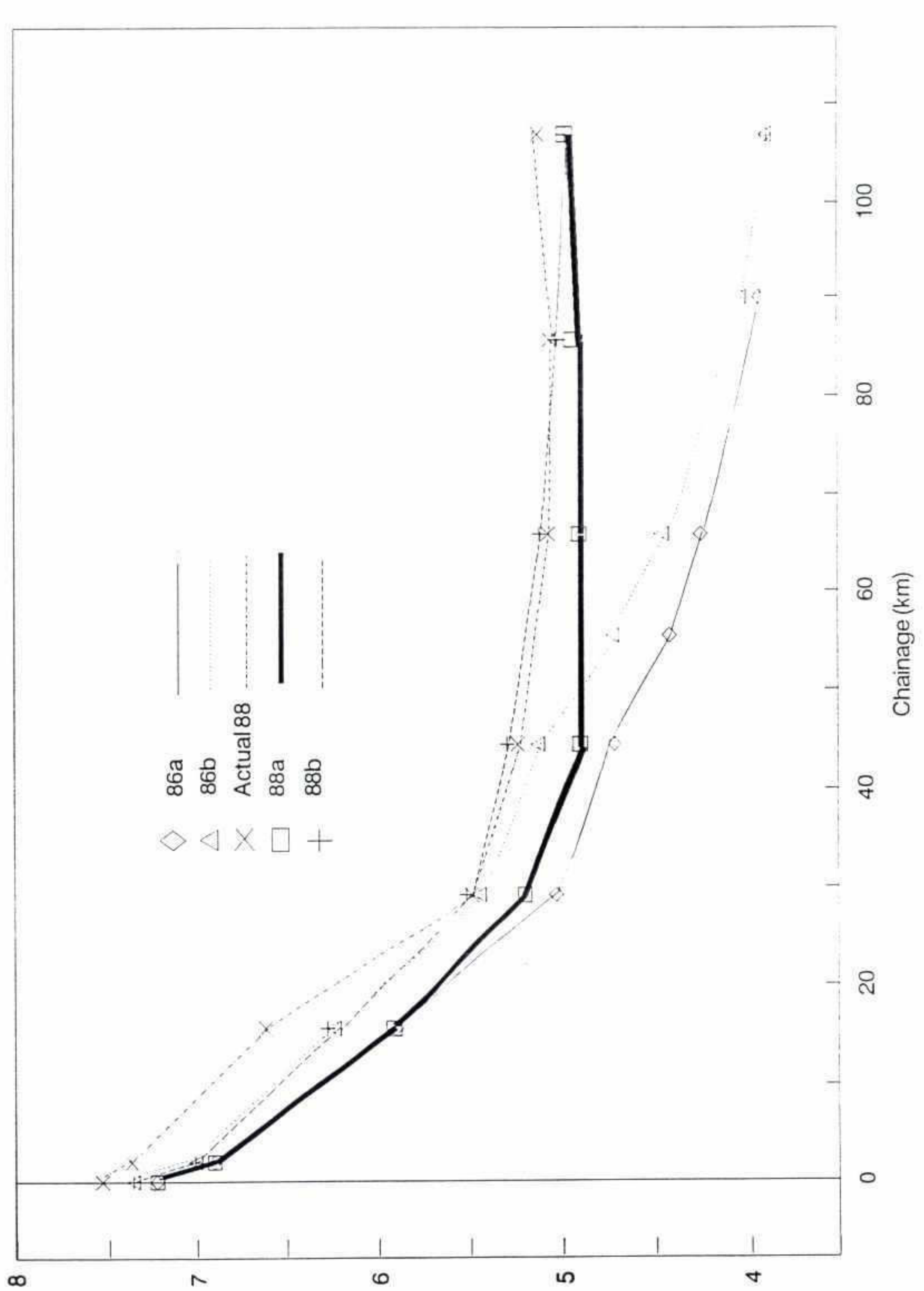


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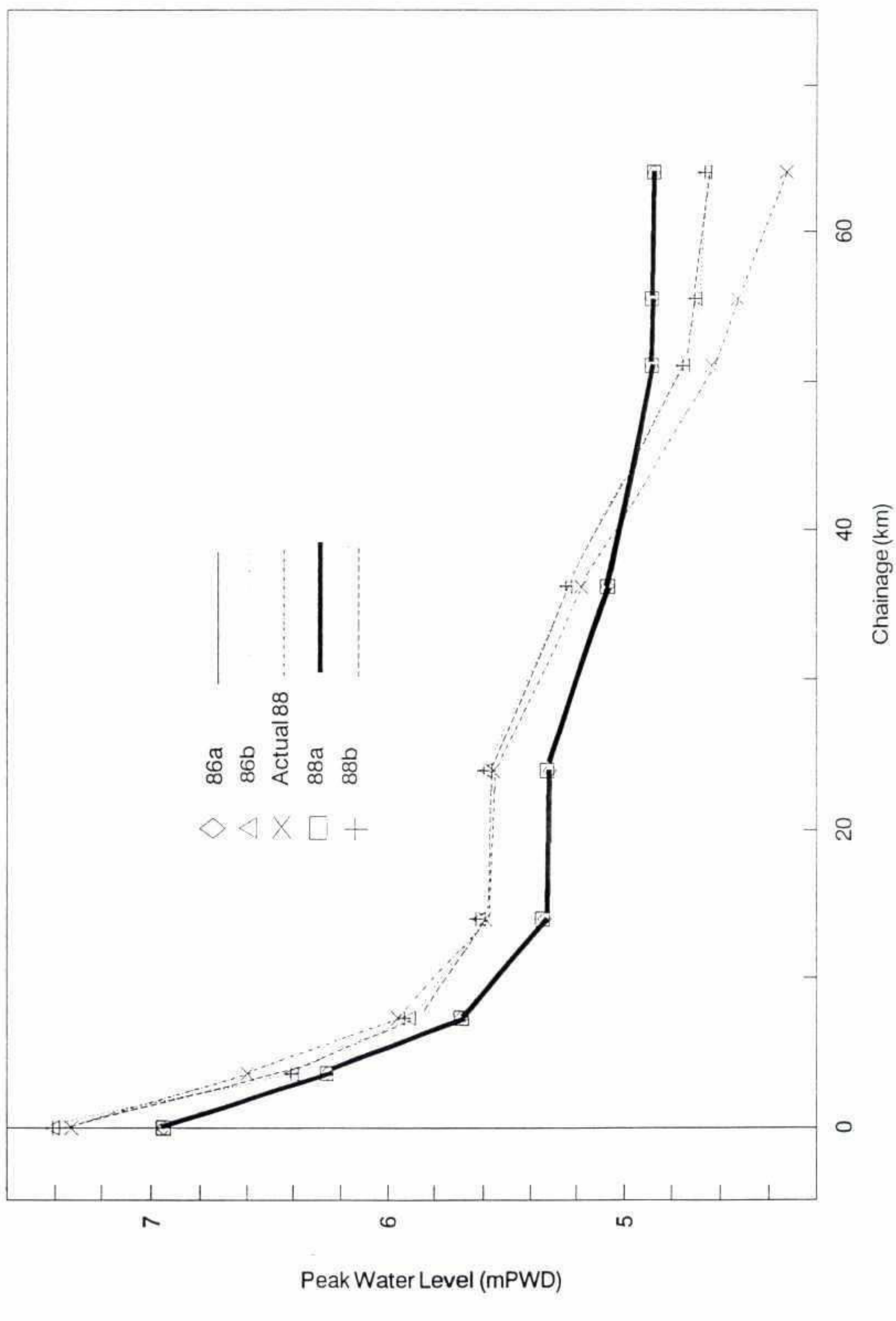
Figure VI.3.7

System Sensitivity, Feni River



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VI.3.5.4 Rahmatkali Khal

The Rahmatkali Khal and Begumganj depression areas show most sensitivity to the chosen combination of main river boundaries and local rainfall (Figure VI.3.8). This is probably the result of the combined influences of the Dakatia and the Little Feni river spills on the area. This said, however, the dominant influence is apparently local rainfall, and the maximum influence of Meghna levels is only 0.20m.

VI.3.5.5 Planning Unit Analysis

The above discussion has been based on water surface profiles. Project evaluation will, however, be at planning unit level, and an assessment of the sensitivity of flood depth area relationships by planning unit was considered to be appropriate.

In the Dhonagoda planning unit (Figure VI.3.9), the dominant influence is Meghna water levels, but rainfall is also important. A relatively small change in water level can result in a significant change in flooded area.

In the Dakatia planning unit (Figure VI.3.10), the influence of main river levels on flooding is less pronounced, and rainfall is apparently more dominant. Main river levels are thus apparently still important, but less so than rainfall. The shape of the flood depth area curves is again important, and small changes in flood depth occur over a very large area.

In the Noakhali-North planning unit (Figure VI.3.11), it is clear that rainfall is the dominant influence, and that the main river levels have much less of an influence than in the Dakatia area. The influence of the Meghna is, however, still apparent.

In the Little Feni planning unit (Figure VI.3.12), the Meghna has no influence on flood levels at all, and the predominant influence is apparently rainfall alone.

VI.3.6 Selection of Representative Events

From the preceding discussion, it is clear that there are significant differences in the root causes of flooding in different parts of the region. This was alluded to Chapter VI.2. A simple criteria for selection of critical years for analysis based on main river levels alone would not therefore be appropriate. The most appropriate approach would, in fact, be long term simulation.

Within the time frame of the regional plan, full simulation using all years of hydrological record was not possible, and the selection of particular years of record for analysis was the preferred approach, albeit that these may produce different return periods of flooding in different parts of the region. Accepting that for regional planning, and for the assessment of the present flooding problem, the main focus would (at least initially) be on the depth and duration of main monsoon flooding, identification of appropriate events was based on an appraisal of annual maximum peak river levels, and annual and seasonal rainfall. Table VI.3.1 summarises years of record approximating closest (by rank) to specified return periods for rainfalls and water levels at Chandpur and at Satnal.

Figure IV.3.8

System Sensitivity, Rahmatkhali Khal

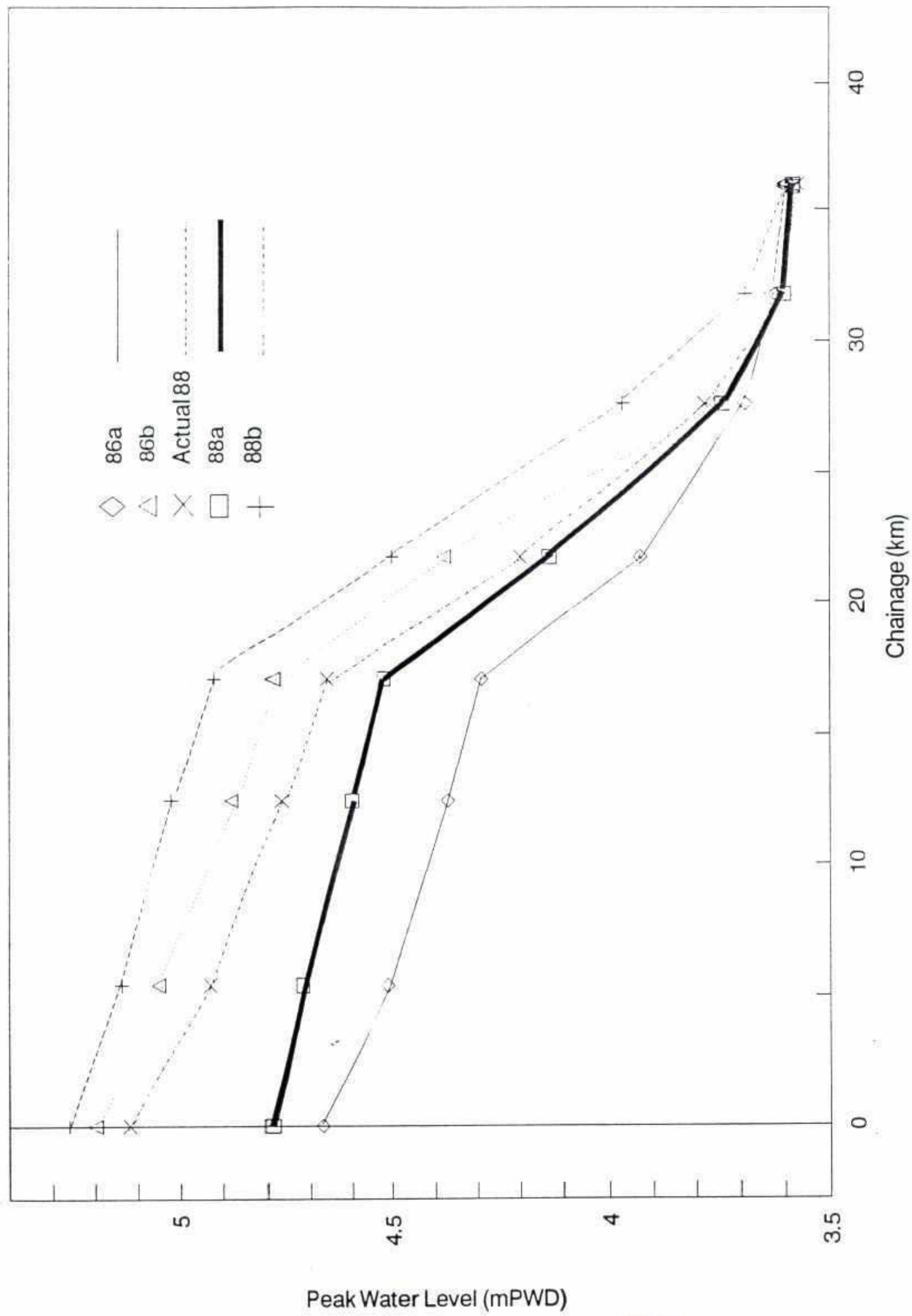

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Figure VI.3.9

System Sensitivity, Dhonagoda Planning Unit

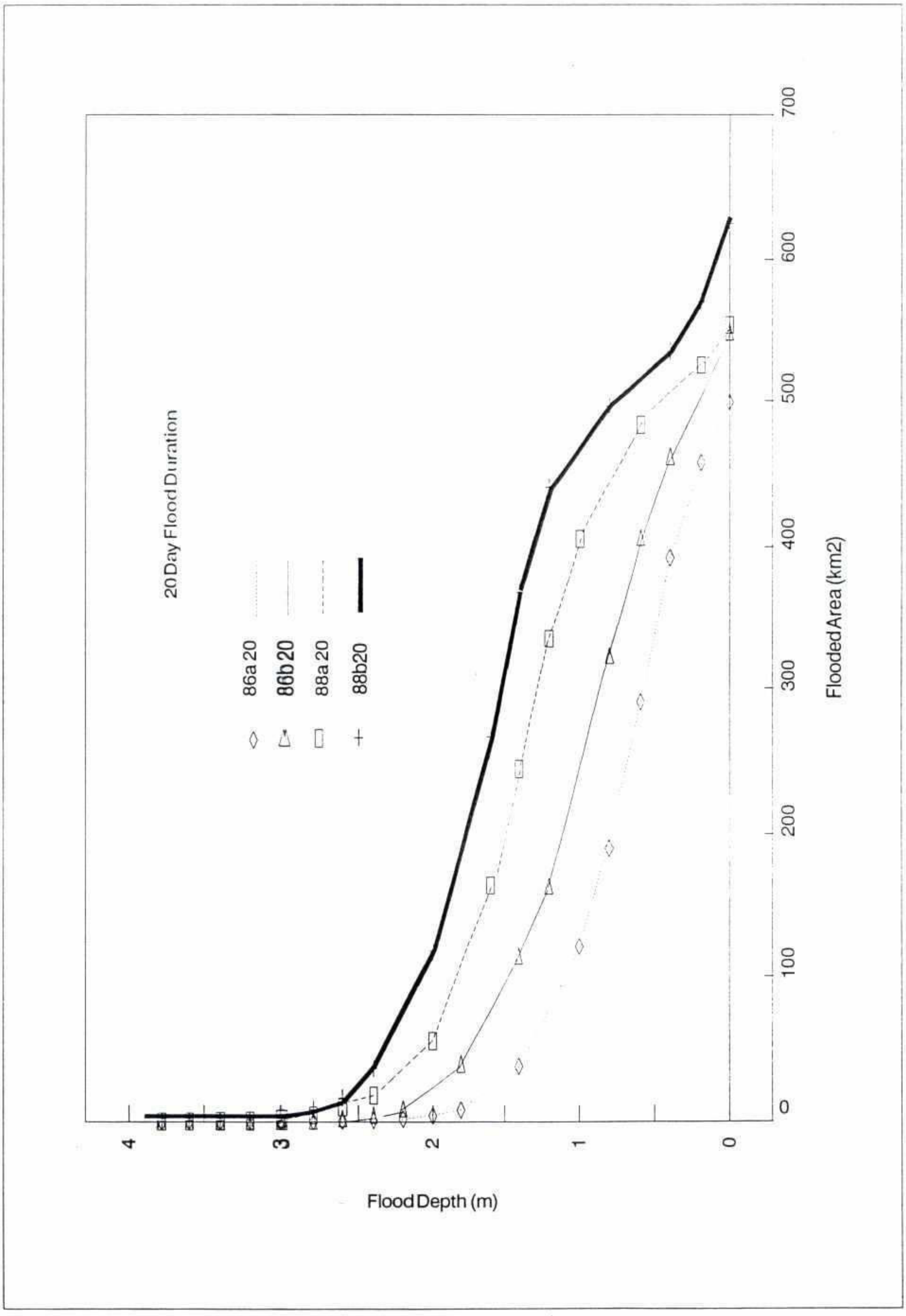

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Figure VI.3.10

System Sensitivity, Dakatia Planning Unit

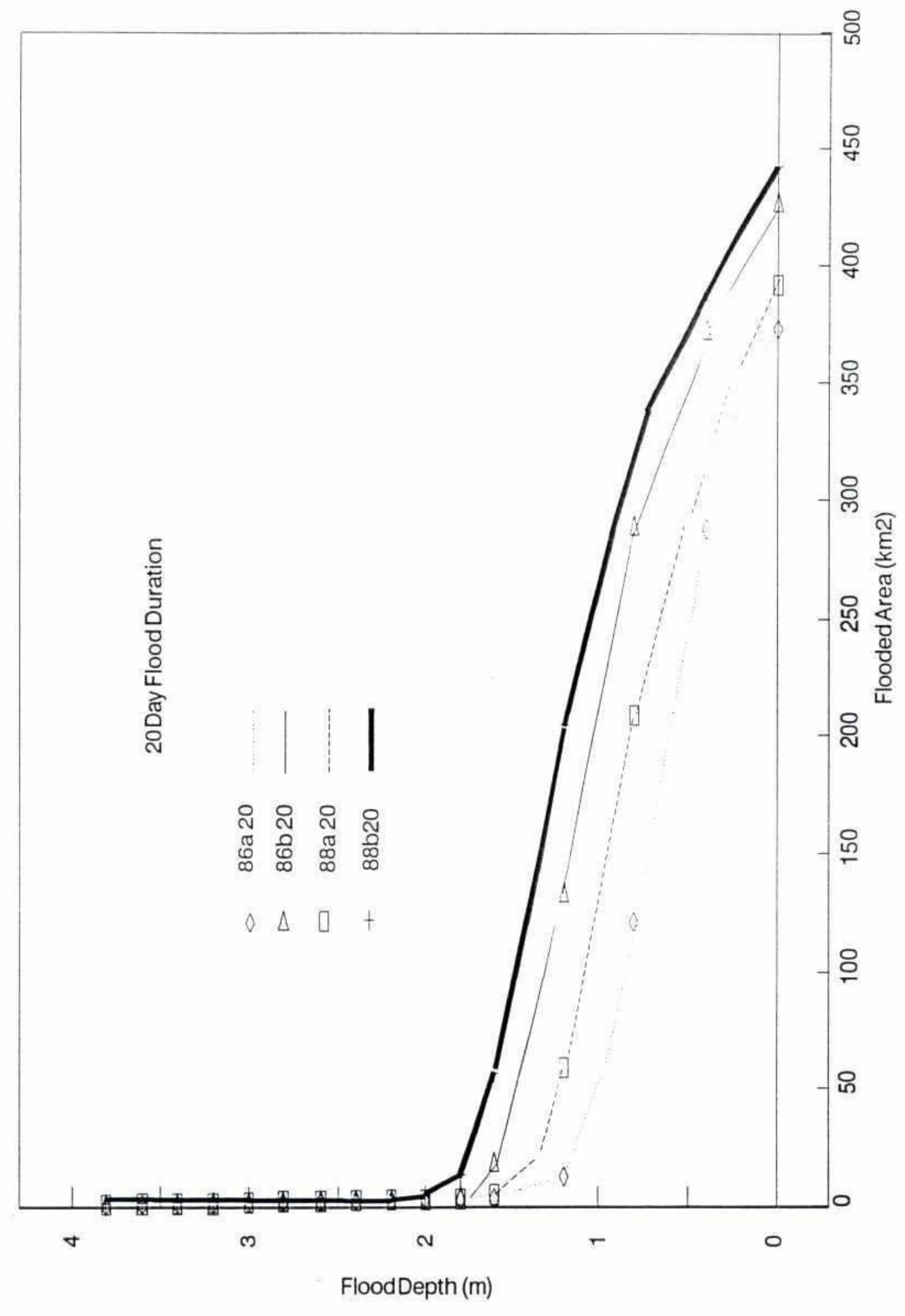

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Figure VI.3.11

System Sensitivity, Noakhali-North Planning Unit

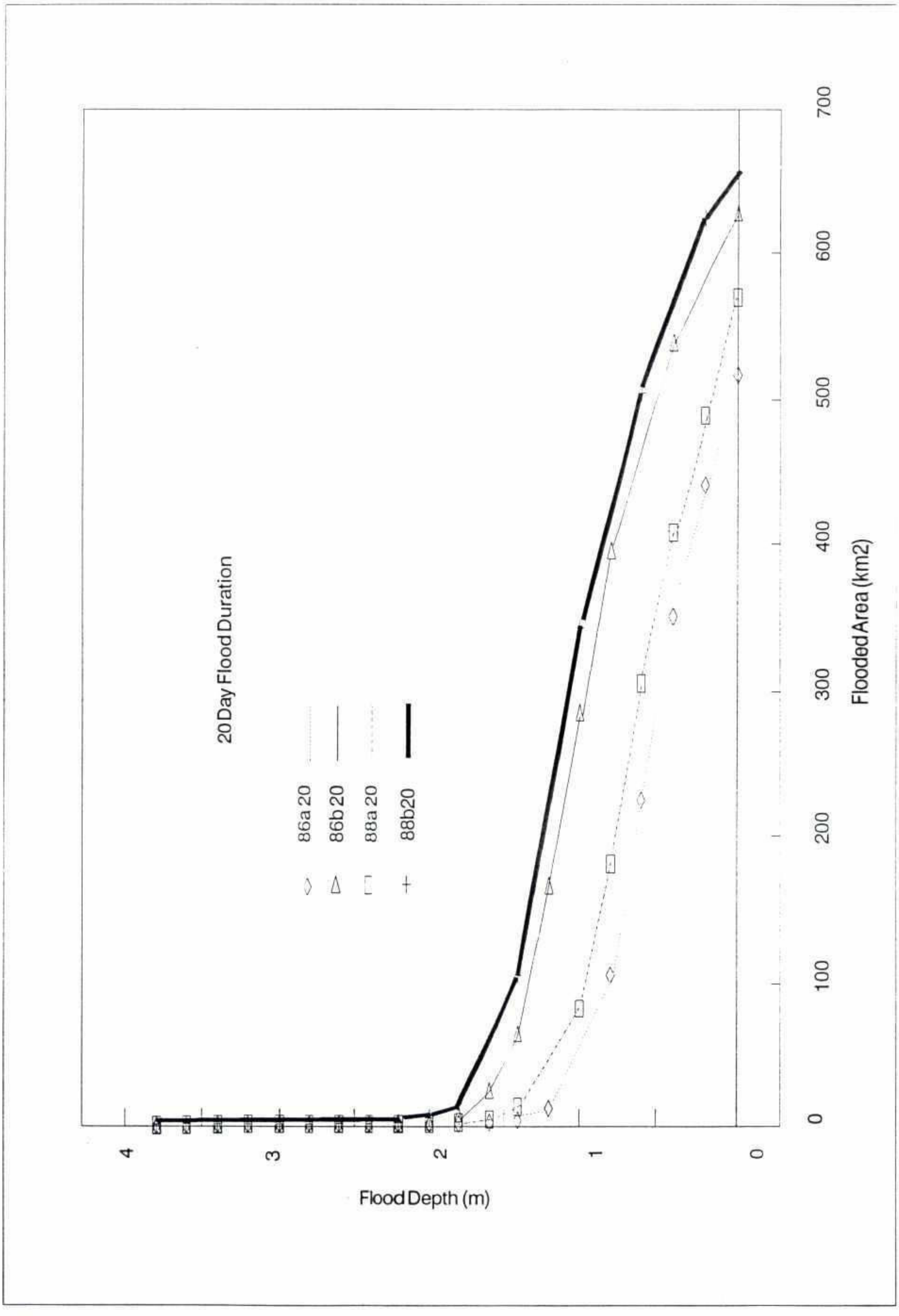

Figure IV.3.12

System Sensitivity, Little Feni Planning Unit

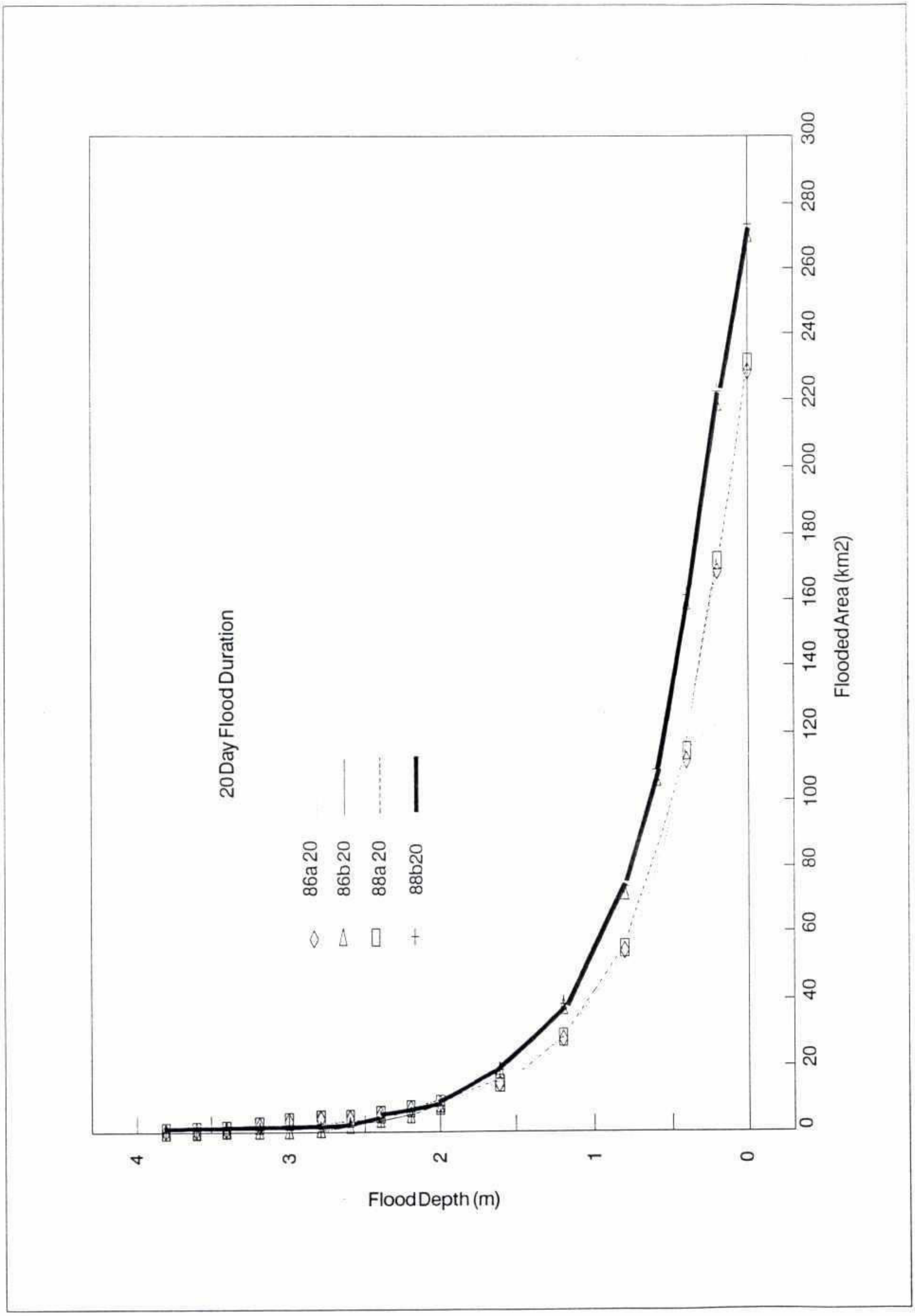

TABLE VI.3.1

Years of Record Approximating to Specified Return Periods

Return Period	Rainfall Mid Monsoon	Rainfall Annual	Water Level Chandpur	Water Level Satnal
50	1987	1974	1974	1988
20	1974	1983	1971 (1988)	1974
10	1969 (1983)	1987	1988	1971 (1984)
5	1976 (1983)	1988	1970 (1984)	1987
2	1982 (1988)	1986	1987	1977 (1983)

The years indicated in brackets above are alternative years which are sufficiently close to the ranked year to justify use of that year. It is apparent that a significant amount of overlap exists, in the top five ranked events, and that a suitable selection for analysis would be:

1974
1983
1984
1986
1987
1988

It is significant to note the number of events in the last ten years. The above six events include three of the worst on record, and should form a suitable basis for analysis and evaluation of flood phases.

VI.3.7 Adoption of Boundary Conditions

The boundaries for the SERM have been indicated in Figure VI.3.2. While some of these do relate to sites at which long term observations of water level or discharge are available, there are a number of locations at which special observation sites were established as part of the SWSMP. For these sites, data are only available from mid 1986.

As has been indicated in Chapter VI.2, it was the southern section of the model that was of most interest for the regional plan. In the northern area, the Gumti II project had already been studied in some detail, and the available water level data were adequate for preliminary planning in the rest of the unmodelled area.

In the southern model, most of the boundaries on the Meghna correspond with well established BWDB water level stations. Boundaries for which data are not available prior to 1986 include those on the Daudkandi to Comilla road; the cross boundary flows from the Sonaichari, Kakri and Pagli Rivers; the southern boundaries in the area of the coastal polders, and the boundaries downstream of the Kazirhat and Rahmatkali regulators..

Considering firstly the drainage routes across the Daudkandi to Comilla road, these were found to be reasonably well correlated with water levels at Daudkandi in the monsoon season, and the following relationships were derived:

Elliotganj = -1.81109 + 1.30857 * Daudkandi (r^2 = 0.84)

Gouripur = 0.39983 + 0.9159 * Elliotganj (r^2 = 0.92)

Haripur = 1.311832 + 0.76565 * Elliotganj (r^2 = 0.91)

The relationship between Elliotganj and Daudkandi is shown in Figure VI.3.13. It is apparent from Figure VI.3.13, that there is no justification for attempting anything other than linear regression at this stage.

The boundaries at the southern end of the model could not be related to any of the nearby long term water level stations. Correlation coefficients for between the Sonaimuri and Sankerbangsi boundaries and Noakhali were of the order of 0.4. The reasons for the southern boundaries being at apparent inland locations are:

- the lack of data on the drainage system
- the dynamic nature of the drainage system.

The SWMC has been investigating the possible extension of the model into the area. In evaluating model results, it was noted that the flows emanating from or to the southern boundaries were in fact low. Sensitivity trials were therefore carried out in which the southern boundaries were set to zero flow boundaries. Figure VI.3.14 shows the influence of this assumption on flood depth distributions in the Noakhali North area for 1987 conditions. The assumption has no significant impact on planning unit water levels.

The other important boundaries to be considered are those on the Little Feni River. The Sonaichari and Pagli rivers do not have a large catchment area in India, and interpretation of satellite imagery indicates Indian catchment areas of 64 and 56 km^2 respectively. Flash floods in each of these rivers do cause localised problems. However, for regional planning the influence of these outside of the Little Feni catchment is not significant. Sensitivity trials were carried out using the inflows for 1986 and 1987 with 1986 base conditions. The results are shown in the form of flood depth area curves for the Dakatia and Noakhali North planning units in Figures VI.3.15 and VI.3.16. There is minor influence in the Dakatia area, and almost none in the Noakhali area.

Neither Kazirhat or Rahmatkali regulators were included in the basic set up of the south-east regional model, and the SWMC have run the model with internally defined boundary conditions. This is acceptable for modelling present conditions at Rahmatkali Regulator, where reasonably long term records exist, but at Kazirhat regulator on the Little Feni River, the only suitable long term station is Companiganj, which is downstream of the regulator. The model has therefore been extended to include an idealised operable regulator at Kazirhat. The structure has been represented as a flapped culvert in the model, and an assessment made of the impact of various operating efficiencies. Of particular relevance in project evaluation, however, is the influence that the operation of Kazirhat regulator has on other parts of the region, and on Noakhali North in particular.

Figure VI.3.13

Correlation Between Elliotganj and Daudkandi Water Levels

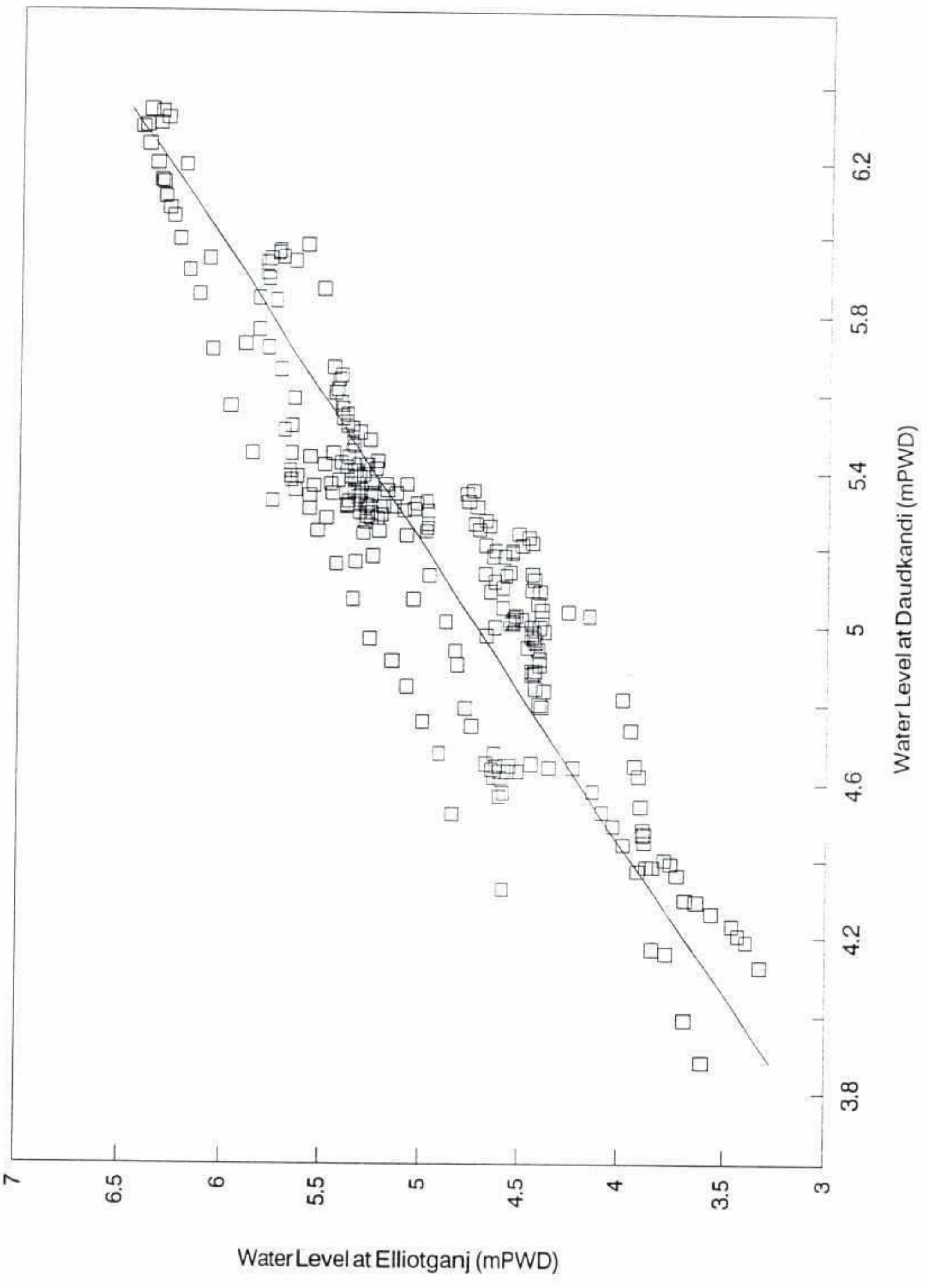

Figure VI.3.14

Sensitivity to Boundary Assumptions, Noakhali North

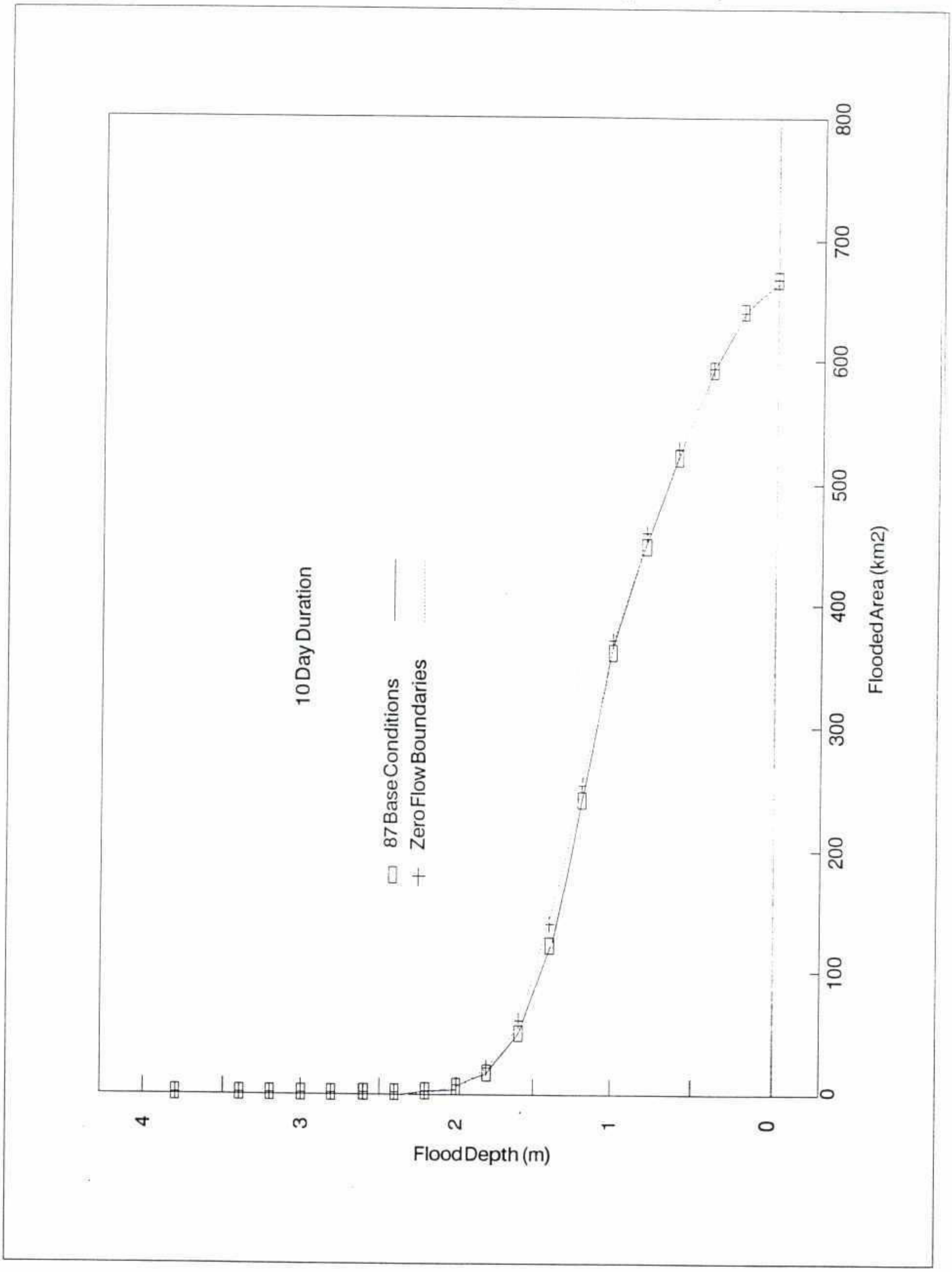

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Figure VI.3.15

Influence of Little Feni on Flooding, Dakatia Planning Unit

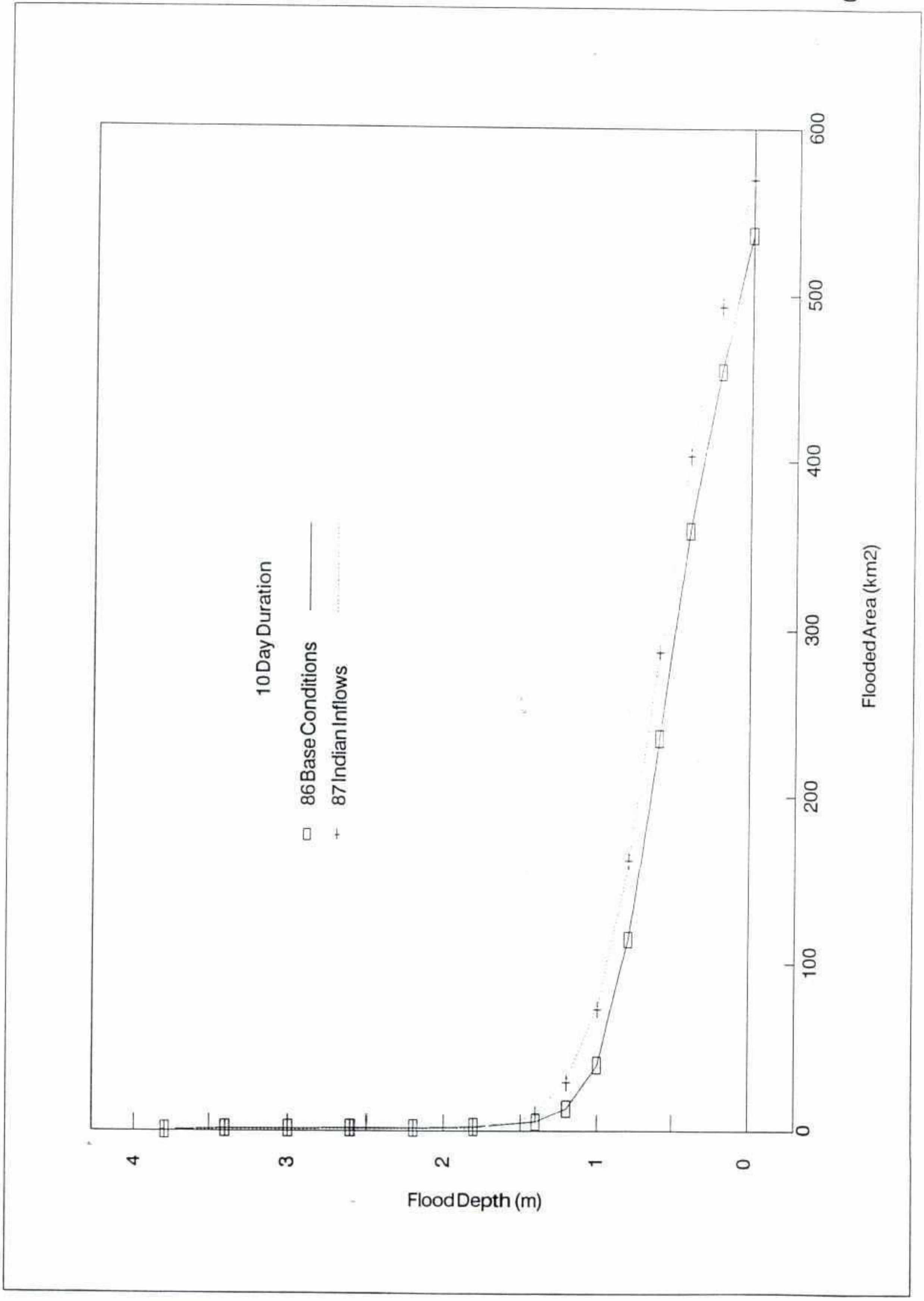

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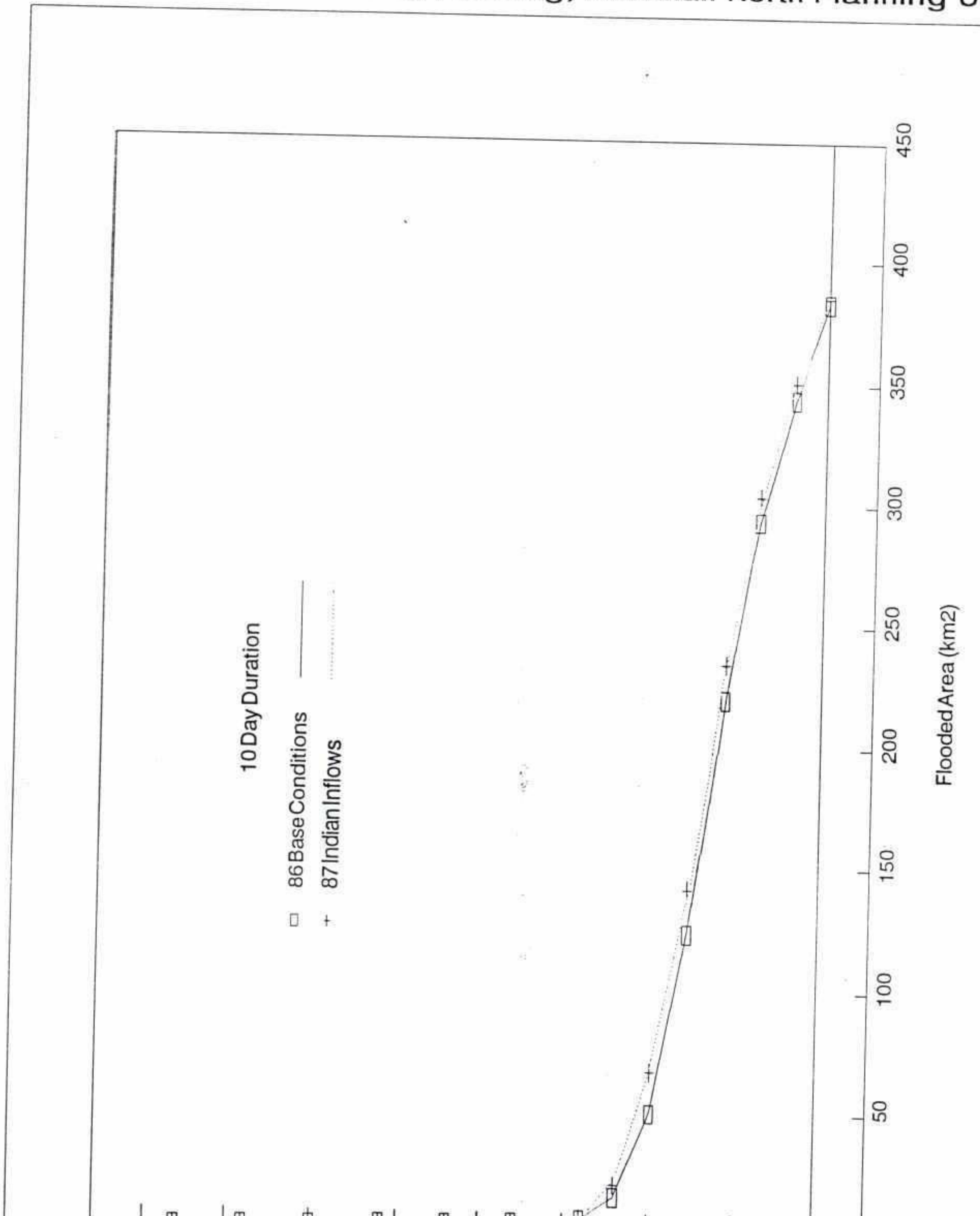
Figure VI.3.16

Influence of Little Feni on Flooding, Noakhali North Planning Unit



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A series of sensitivity trials were therefore carried out using 1987 conditions. Figures VI.3.17 and VI.3.18 indicate the effect of no regulator, and of a fully functional regulator on flood levels in the Noakhali North and Little Feni areas respectively. It is apparent that the regulator has little or no effect on flood levels in these areas. For comparative purposes outside of the Little Feni planning unit, the regulator is therefore not particularly important.

At Rahmatkali regulator, downstream boundary conditions were generated by interpolating between water level records at Daulat Khan and Chandpur. Subsequently, following some general model runs carried out by the SWMC, doubts were raised over about the accuracy of the datum of the gauge at Daulat Khan. Initially there had been suggestions that the Daulat Khan records were 0.70 m too low. The outcome of various investigations by the SWMC, BWDB and by the SERS has been that errors in gauge datum at Daulat Khan are unlikely to exceed 200 mm, and most likely to be in the range of 120 - 200 mm. A more detailed treatment of the definition of boundary conditions for Rahmatkali is given in the Noakhali Project Feasibility Report (Ref. 10).

Figure VI.3.17

Influence of Kazirhat Regulator, Noakhali North

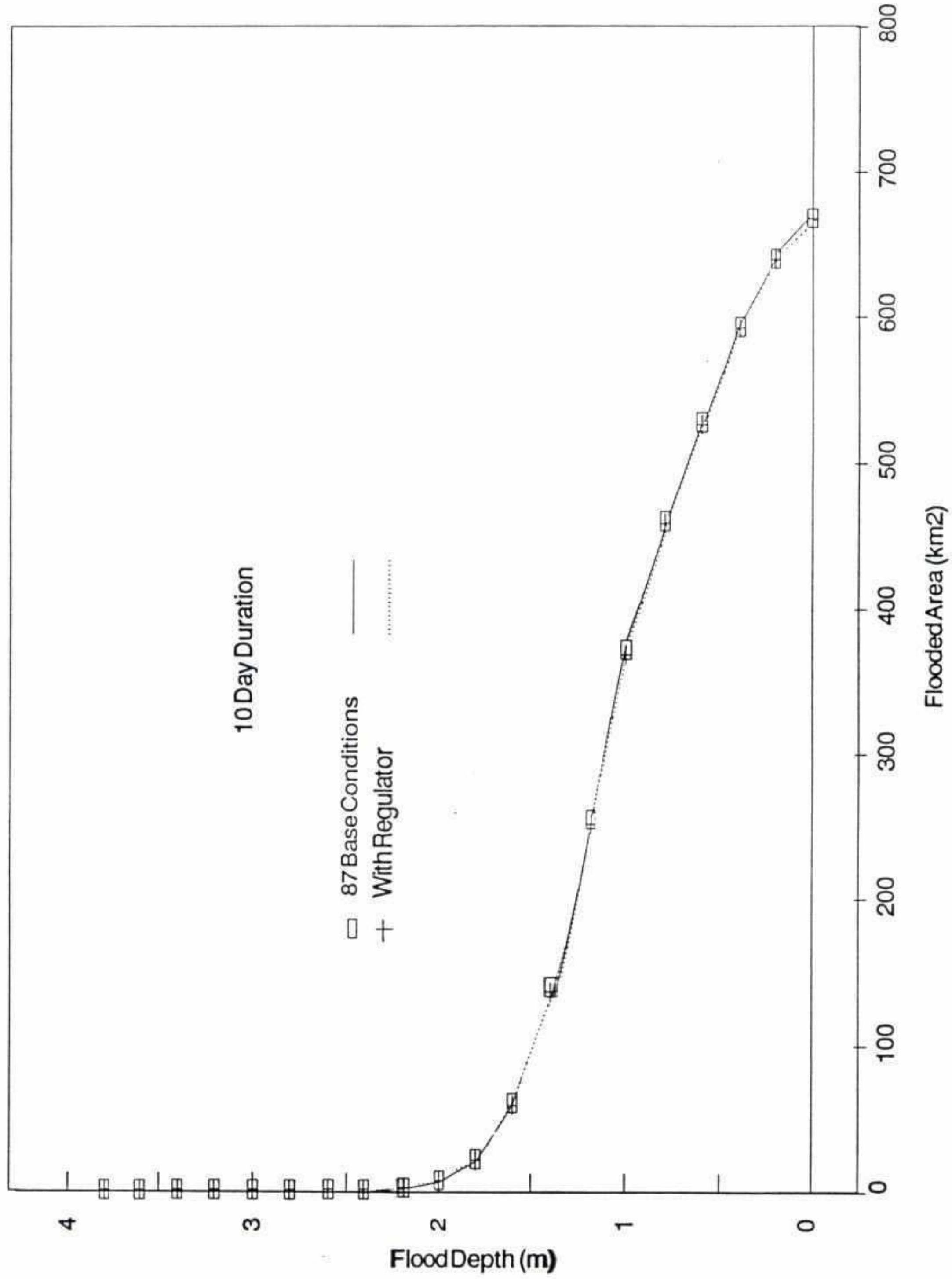
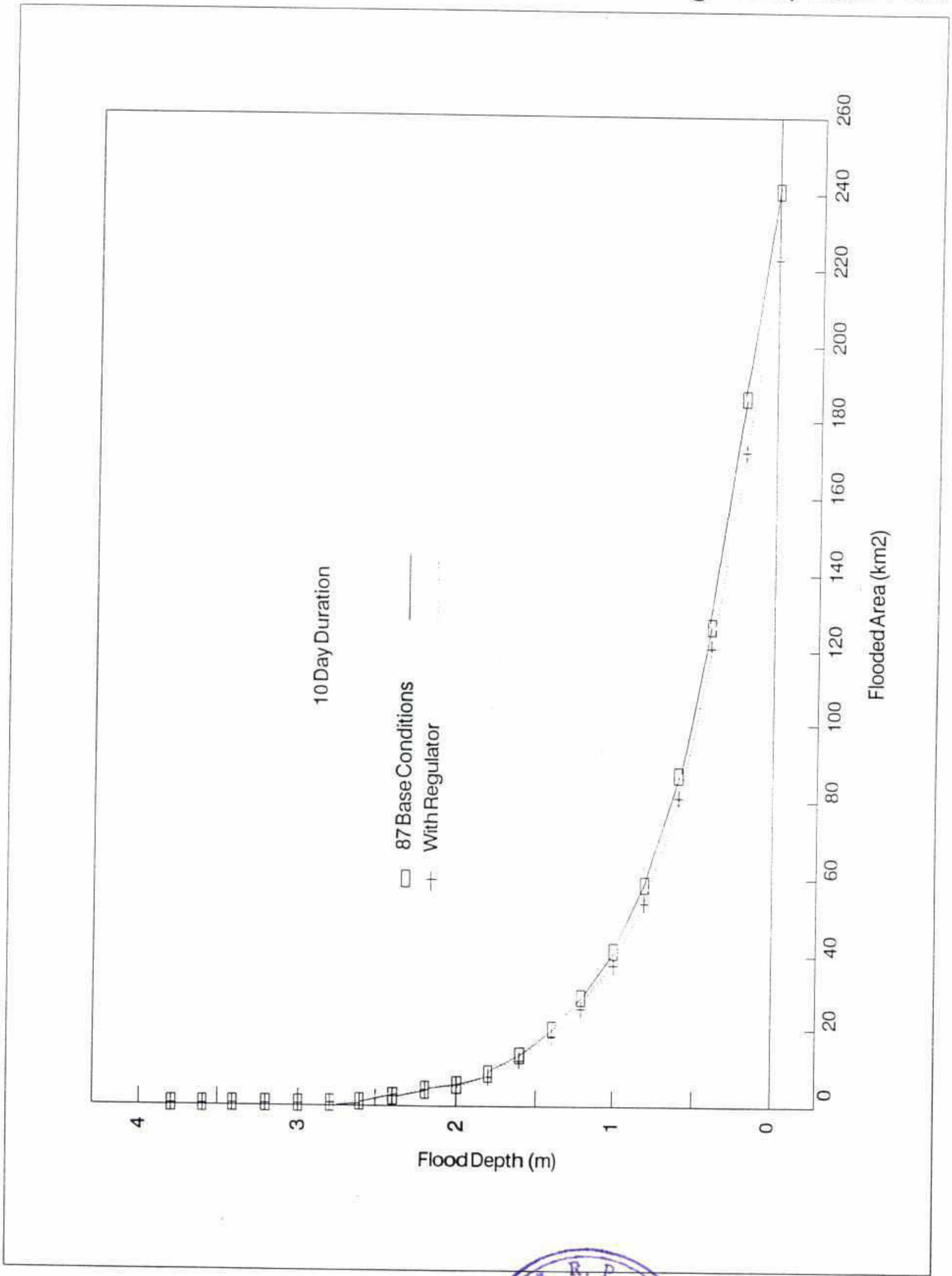


Figure VI.3.18

Influence of Kazirhat Regulator, Little Feni



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CHAPTER VI.4

MODELLING RESULTS

VI.4.1 General

For regional plan formulation, the SERM has been used to evaluate the effectiveness of various flood mitigation options. The objective has been to evaluate the technical effectiveness of the options, and to provide a basis on which the relative benefits of the options could be assessed. A number of potential flood mitigation options have been identified, and the objective of the modelling has been to evaluate flood depth area characteristics within the identified planning units for pre- and post-project situations. From this, economic benefits could be derived.

With regard to agricultural production, the benefits of flood mitigation derive through land enhancement benefits (i.e. bringing more land into production) and through damage avoidance. Land enhancement benefits may be assessed through determining pre- and post-project flood depth duration frequency characteristics, or flood phases. The determination of damage avoidance is, however, much more difficult, and generally requires that flood damage frequency curves be prepared.

A deterministic approach to damage avoidance evaluation would require a seasonal crop production model linked to the outputs of the hydrodynamic model, and would be difficult without running through a full historical simulation, as the timing of the flood relative to the stage of crop growth is of critical importance. The formulation of the damage functions would not be particularly difficult, but cropping patterns and cropped areas would have to be modelled and related to the hydrodynamic model outputs. A full deterministic approach to the evaluation of crop damages is therefore a complex process, and one which cannot be fully justified at the regional plan stage. The preliminary approach must be to determine historical flood damages associated with floods of known return periods, and then to determine whether the more exacting effort of a fully deterministic approach can be justified. The approach to flood damage assessment adopted for regional plan formulation was to try and attach return periods to years in which damage has been recorded. A more exacting approach was defined and incorporated in subsequent feasibility studies.

The identified flood mitigation options, their preliminary screening and evaluation are discussed in the following sections.

VI.4.2 Project Identification

Project identification and a description of the engineering components is given in Chapter 5 of Part 2 of the Main Report. Only a brief description is given here, focusing on those aspects which relate to the manner in which the options are represented in the hydrodynamic model.

In the representation of all projects, completion of Gumti Phase I is assumed, and has been represented in the northern model. This influences cross drainage through the Daudkandi to Comilla road. For base case conditions, the culverts on Gouripur Khal and Elliot Khal remain open, but the culvert for Curzon Khal is closed. For the southern model, appropriate boundary conditions have been set up to reflect these conditions.

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The options and their particular features are discussed below:

Option 3	Comprises closure of all drainage routes on the Daudkandi to Comilla road, and is thus relatively cheap to implement, although there would be negative impacts to the north of the road, and possibly on drainage from the Gumti I area.
Option 4	Construction of an embankment from Daudkandi to the Meghna-Dhonagoda project area. This excludes flows from the Meghna into the Dhonagoda River and thus from the Dhonagoda planning unit. A small regulator and a ship lock would be included in the embankment at the upstream end of the Dhonagoda river in order to permit navigation through what is a preferred wet season route to the main river, to continue. The morphological impacts of closure would require further consideration should the option prove effective, as would impacts on fisheries.
Option 34	A combination of options 3 and 4.
Option 34a	Extension of Option 34 to include a regulator on the outfall of the Dhonagoda River at Matlab Bazar, where back flow from the Meghna into the Dhonagoda planning unit is also possible. Also included would be the closure of the upstream end of the Jumjumia River, and provision of an embankment from there to the Chandpur to Comilla road, thus excluding the ingress of floodplain flow from the Meghna.
Option 5	Closure of the Jumjumia River with construction of an embankment from there to the Chandpur to Comilla road, and provision of a regulator on the Dakatia River, tying into the Chandpur embankment. Back flow from the Meghna to both the Dhonagoda and Dakatia planning units would thus be prevented.
Option 34a5	Combination of options 34a and 5, effectively isolating the entire area between Chandpur and the Gumti from the Meghna.
Option 6	Provision of flapped culverts on the Chandpur to Comilla road to exclude potential back flow from the Dakatia and Meghna into the Dhonagoda planning unit.
Option 346	The combination of options 34 and 6.
Option 7	Improvement of the Rahmatkali and WAPDA Khals to improve drainage in the Noakhali-North planning unit and Begumganj depression.
Option 7a	Combination of option 7 with an improved Rahmatkali Regulator.
Option 8	Construction of a new drainage line south from near Sonapur to outfall close to Polder 59/2.

VI.4.3 Preliminary Project Screening

A preliminary screening of options has been carried out on the 1988 and 1985 floods, using the Dhonagoda, Dakatia and Noakhali-North planning units.

Figures VI.4.1(i) and VI.4.1(ii) show the impacts of options 3 to 6 on 10 day flood level distributions in the Dhonagoda area for the 1988 flood. It is apparent that option A34a provides the best improvement in terms of flood mitigation. A regulator on the Dakatia river apparently provides no benefit in terms of flood mitigation. Similarly flapped culverts on the Chandpur to Comilla road provide no benefit.

Figures VI.4.2(i) and VI.4.2(ii) show the impacts of options 3 to 6 on 10 day flood level distributions in the Dhonagoda area for the 1985 flood, which was below average. The results confirm that option A34a is likely to provide the best improvements, and that neither culverts on the Chandpur to Comilla road or a regulator on the Dakatia river provide any benefits.

The Meghna is tidal at Chandpur, and generally the model runs have been carried out with average daily water levels. Further model runs were therefore carried out with tidal boundary conditions at Chandpur in order to assess whether regulator operation to exclude tidal back flow but permit drainage on a falling tide would achieve better results than being indicated with the mean daily boundary condition. The results are presented in Figures VI.4.3 and VI.4.4. It is apparent that there is indeed no flood mitigation benefit from a regulator on the Dakatia river. While the Meghna is the dominant influence in controlling water levels in the Dakatia River, the simulation results demonstrate that local runoff is such, that even with exclusion of high Meghna levels, the tidal range during the peak monsoon season is not adequate to permit drainage of local runoff, and this builds up at the same rate as the outfall level control. This point is perhaps most clearly demonstrated by the water surface profiles shown in Figure VI.4.5.

Options 3 to 6 have almost no impact on conditions to the south of the Dakatia River. Figures VI.4.6(i) and VI.4.6(ii) show flood depth area characteristics for the Dakatia planning unit under 1988 conditions. There will be minor secondary benefits in the Dakatia area, but the flood phase classification may be too coarse to reflect this.

Options 7 and 7a. are those most likely to benefit the area to the south of the Dakatia River. Preliminary evaluation of these options for 1985 are indicated in Figure VI.4.7. Option 7 does result in significant improvements to drainage in the Noakhali region, and also has secondary benefits in the Dakatia planning unit, as indicated in Figure VI.4.8.

Option 8 also results in improvements to drainage in both the Noakhali North and Dakatia planning Units, although these are not as significant as for option 7a, as indicated in Figures VI.4.7 and VI.4.8.

Figure VI.4.1(i)

Project Screening, Dhonagoda Planning Unit, 1988 Flood

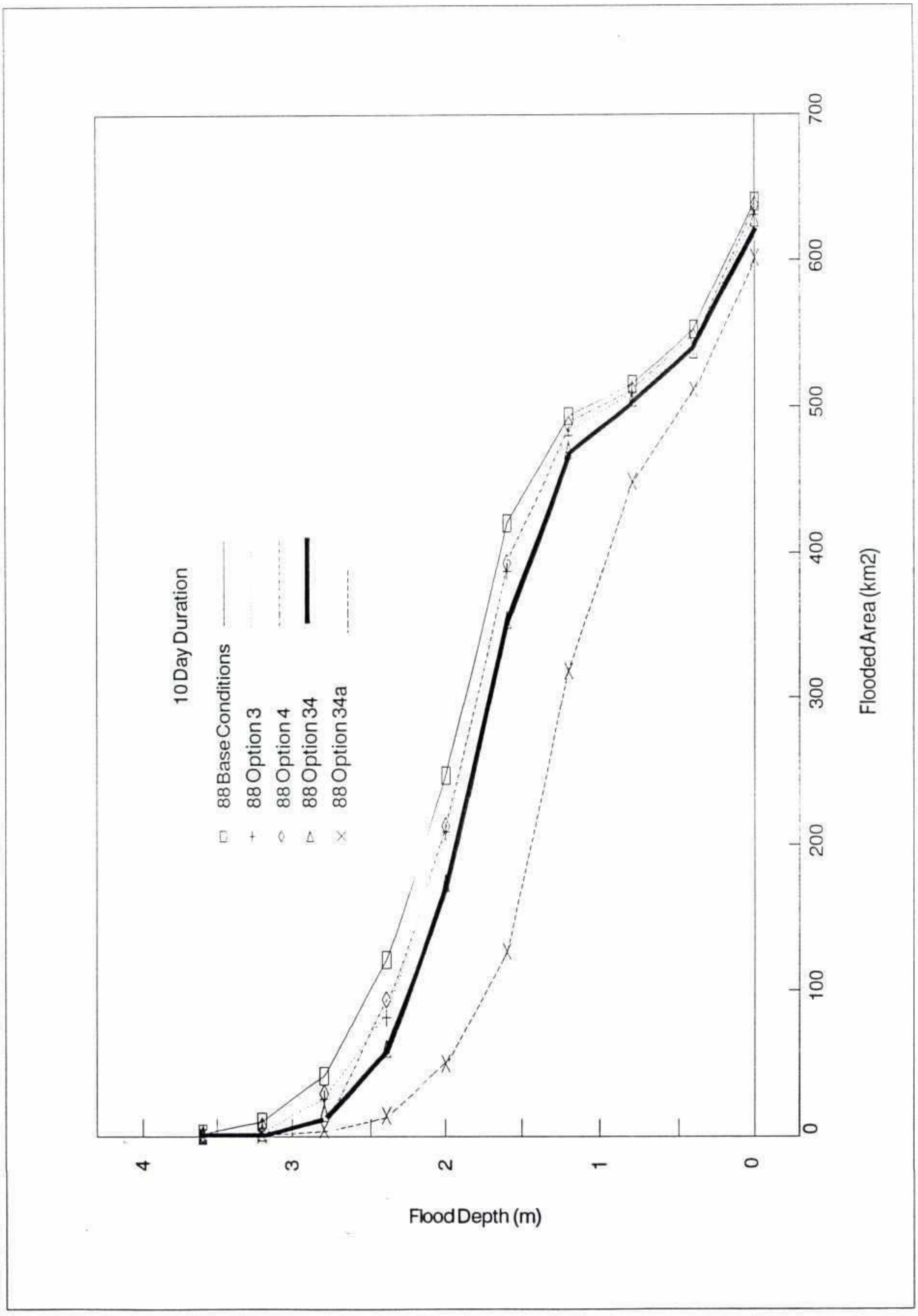

Figure VI.4.1(ii)

Project Screening, Dhonagoda Planning Unit, 1985 Flood

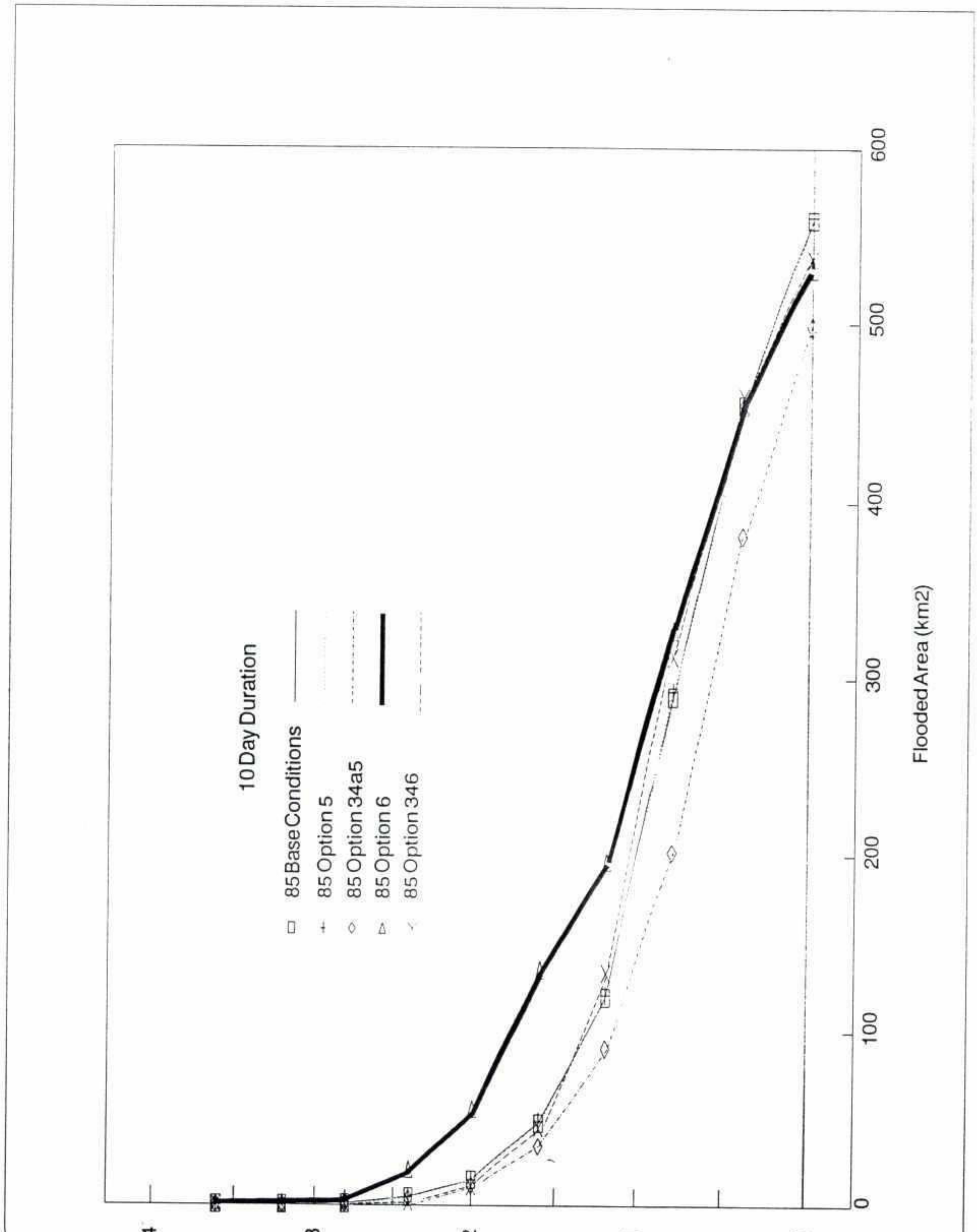

Figure VI.4.2(i)

Project Screening, Dhonagoda Planning Unit, 1985 Flood

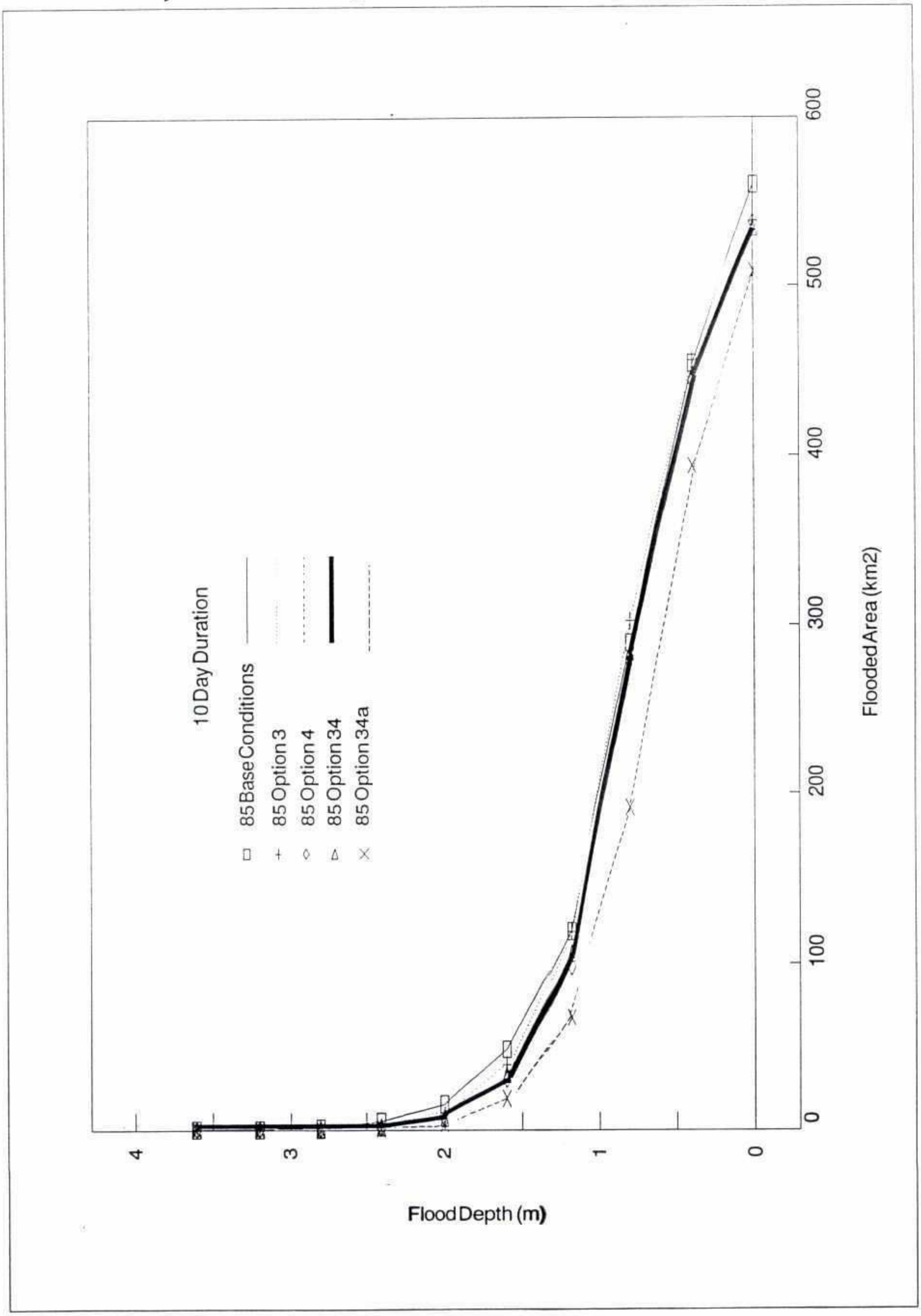

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Figure VI.4.2(ii)

Project Screening, Dhonagoda Planning Unit, 1988 Flood

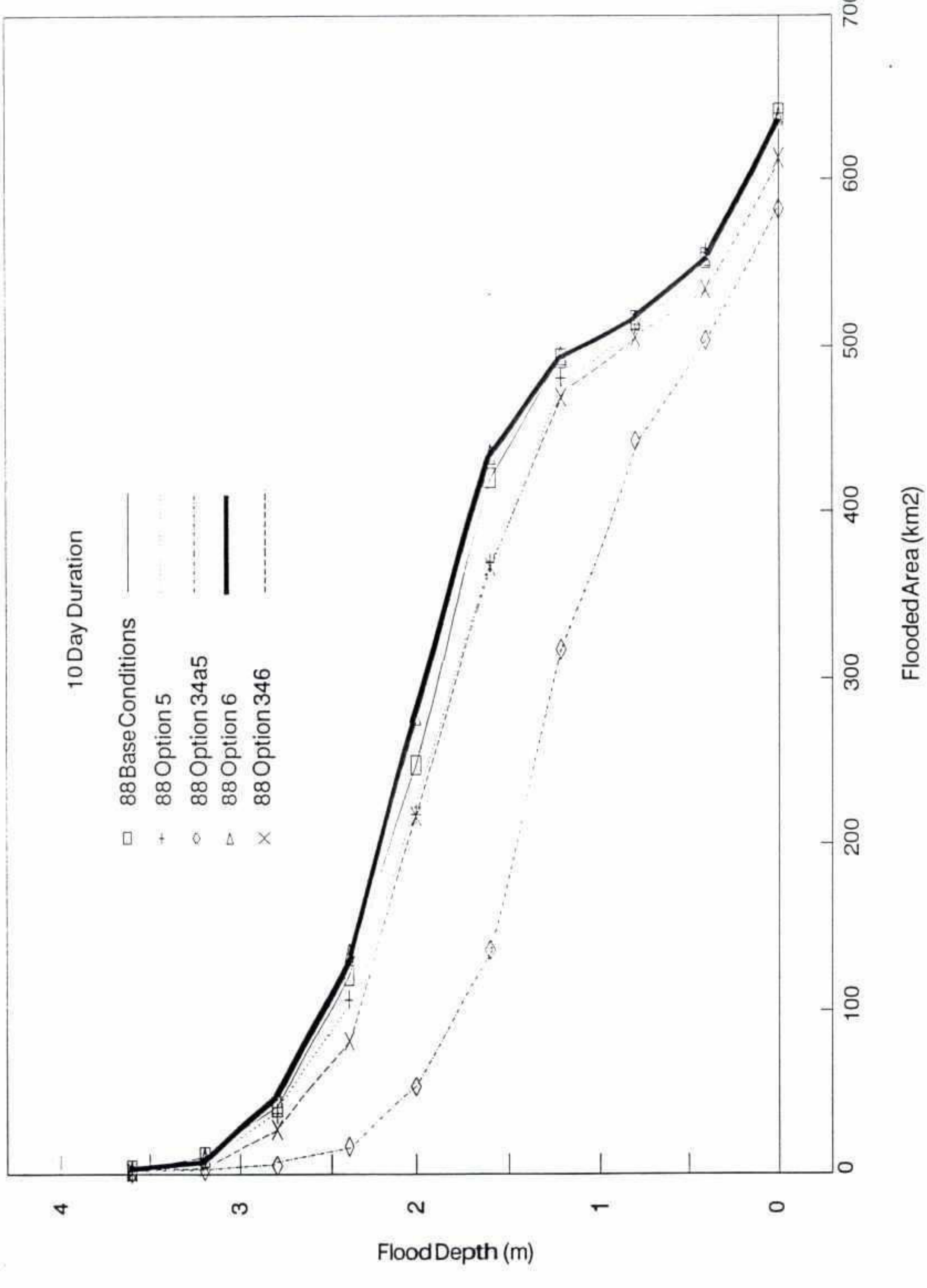

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Figure VI.4.3

Flood Depth Distribution, Dhonagoda Planning Unit, 1988 Flood

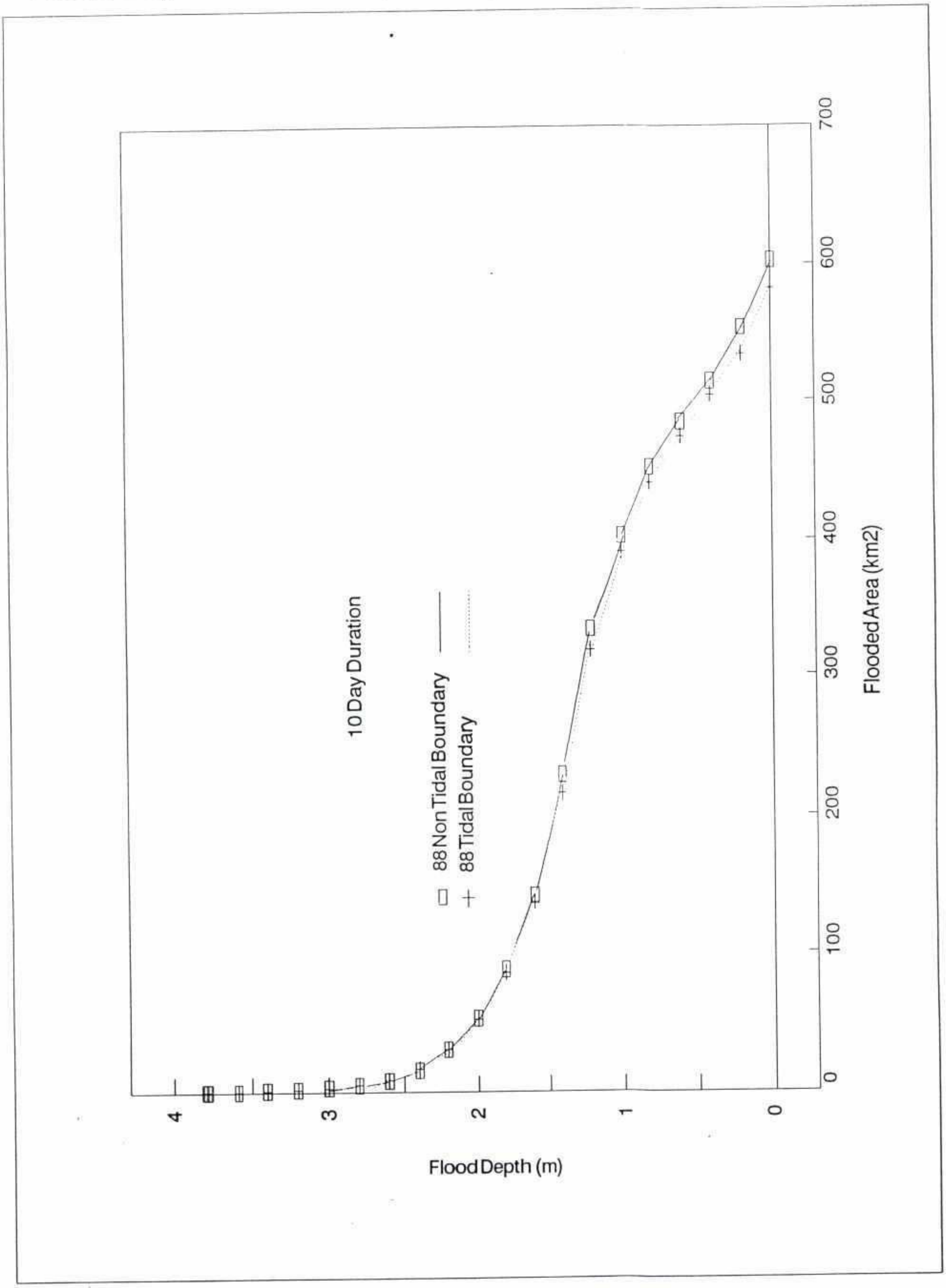

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Figure VI.4.4

Flood Depth Distribution, Dakatia Planning Unit, 1988 Flood

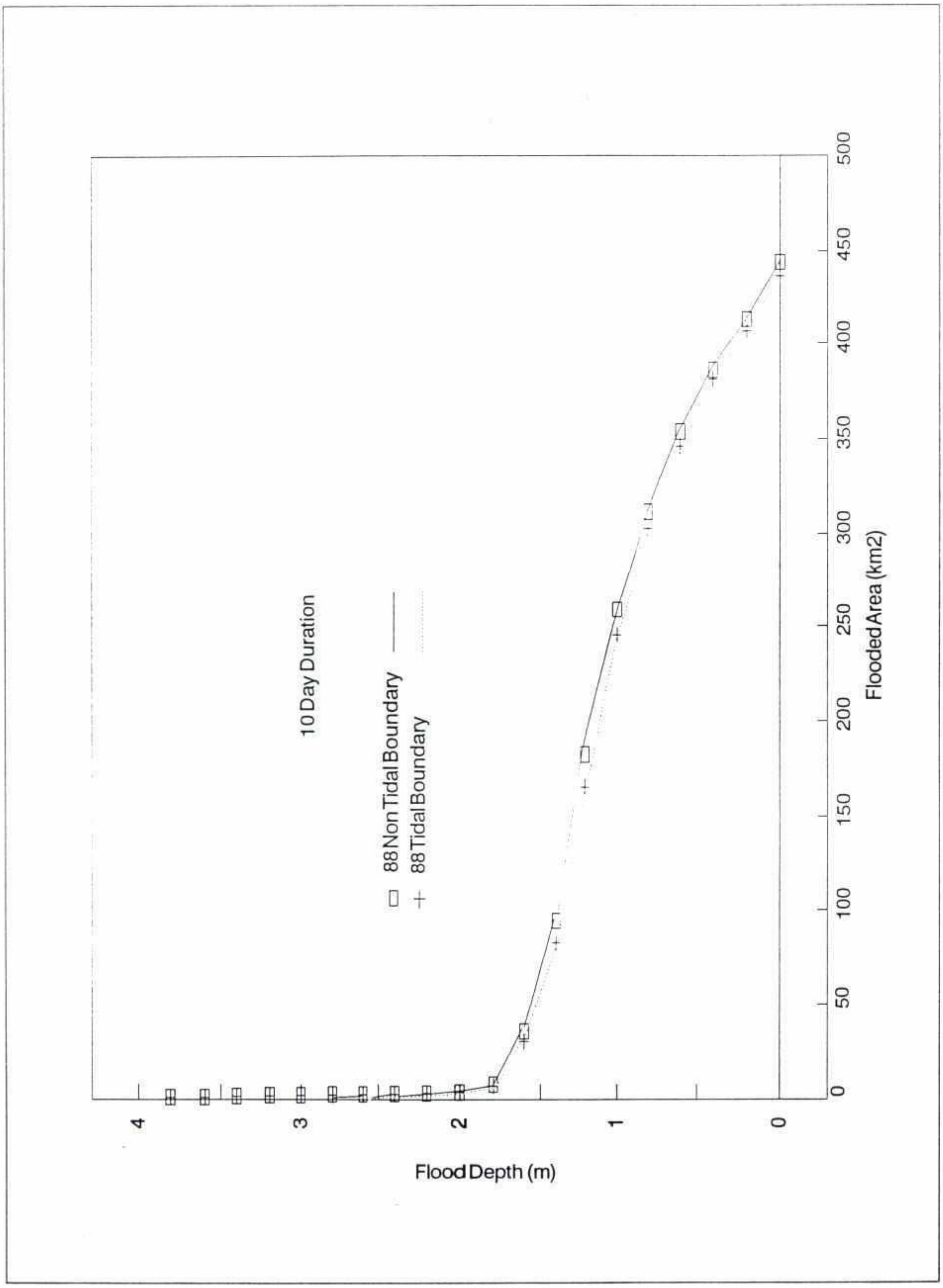

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Figure VI.4.5

Water Surface Profiles in Dakatia River, Option 34a5

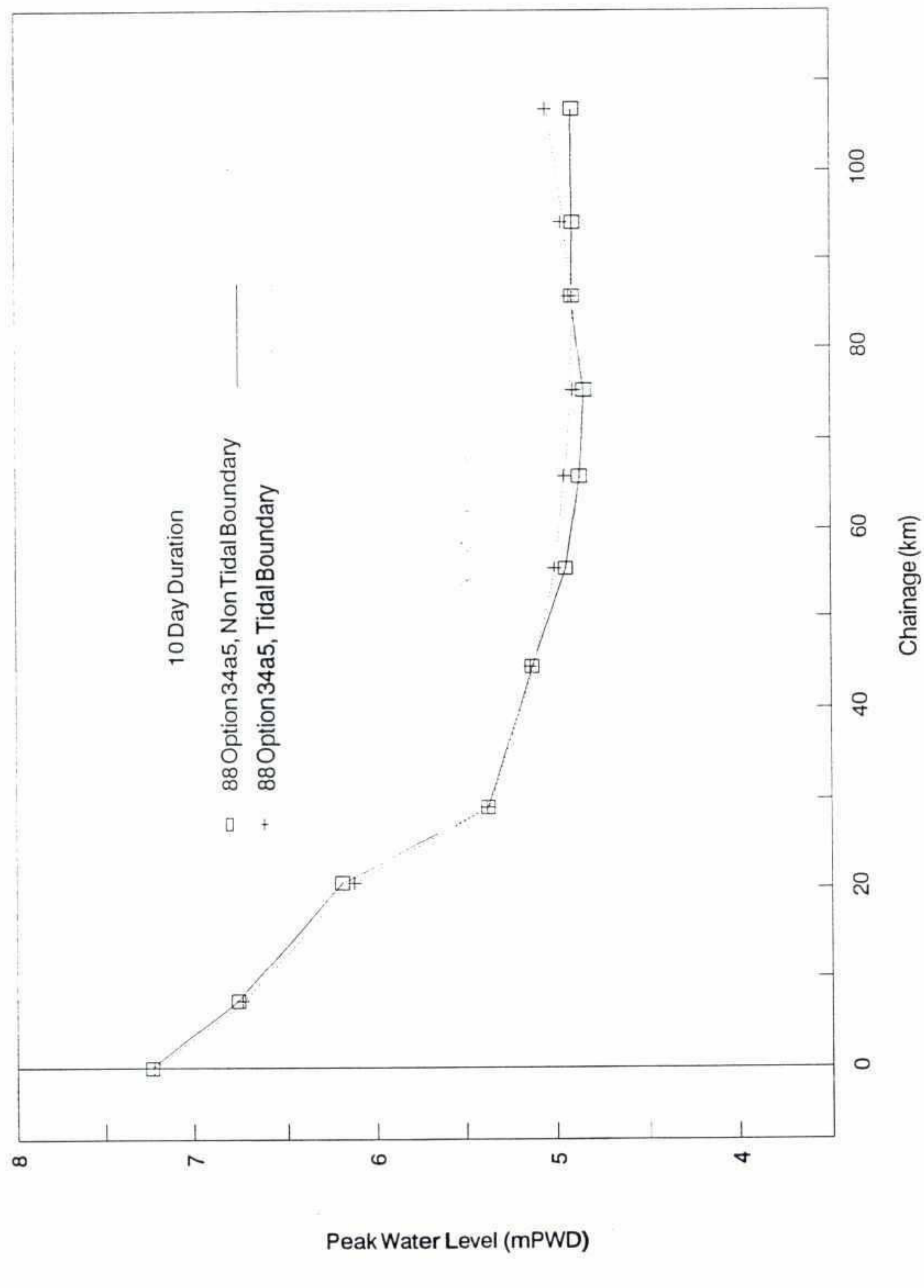

Figure VI.4.6(i)

Project Sreening, Dakatia Planning Unit, 1988 Flood

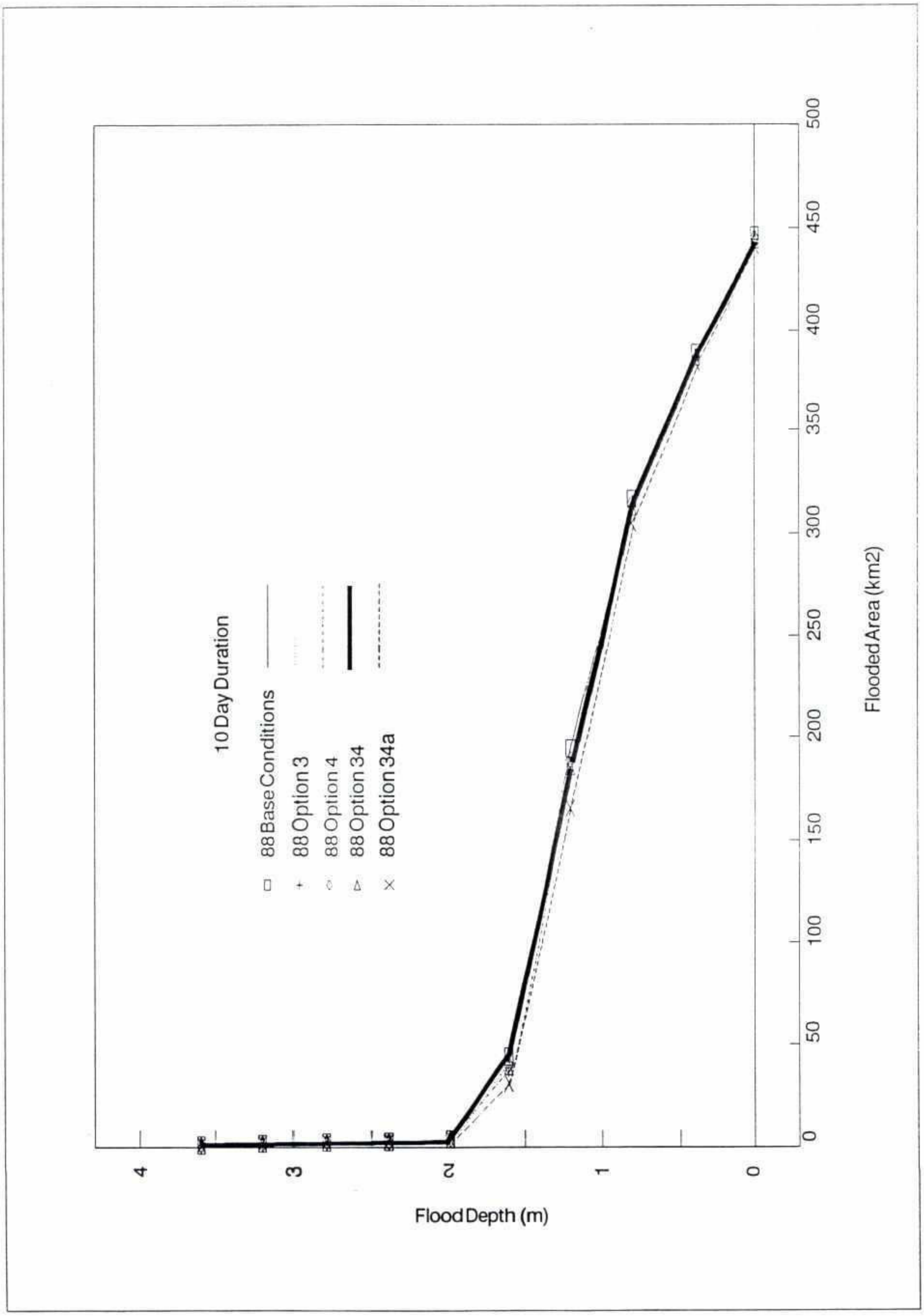

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Figure VI.4.6(ii)

Project Screening, Dakatia Planning Unit, 1988 Flood

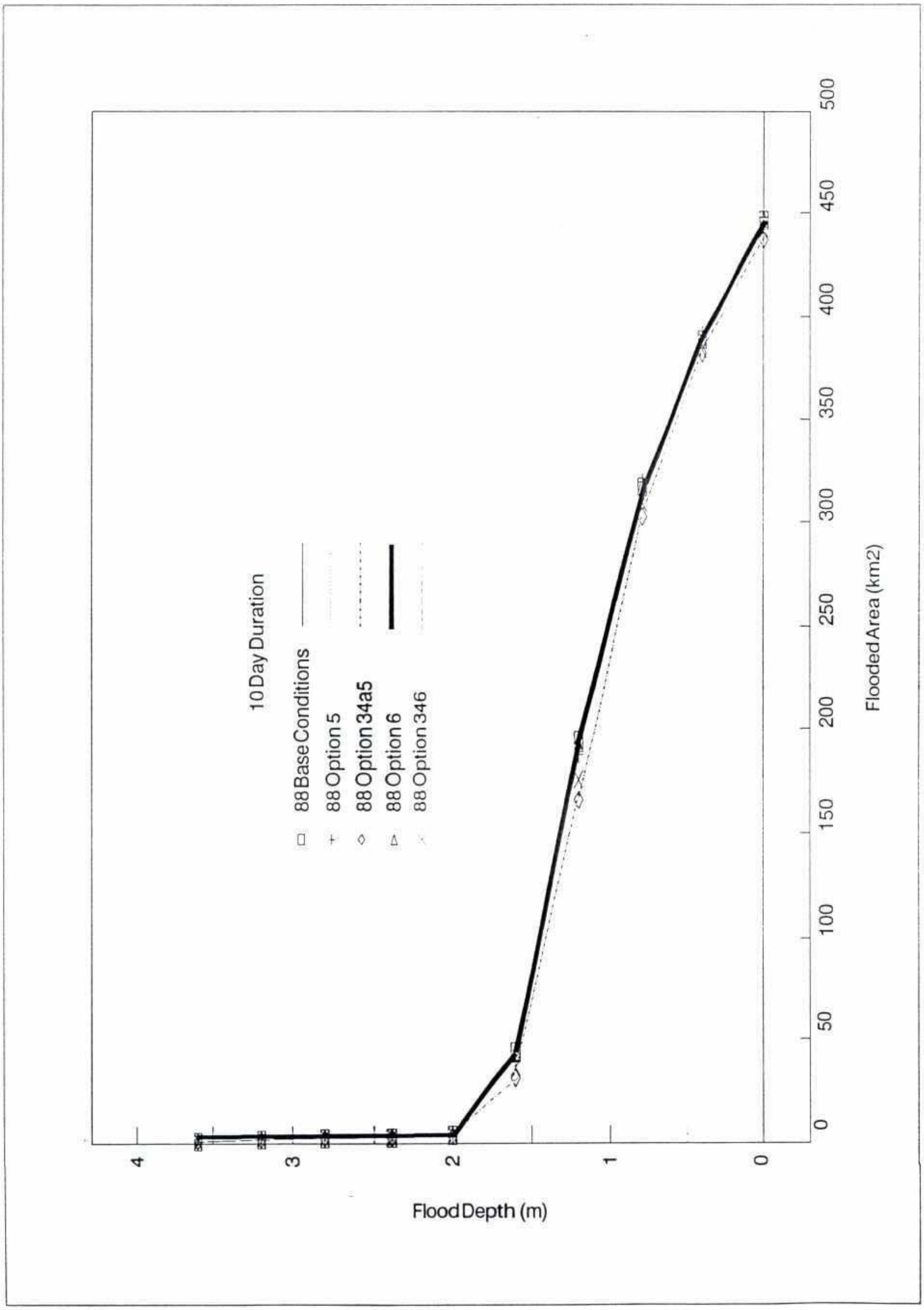

Figure VI.4.7

Project Screening, Noakhali North Planning Unit, 1985 Flood

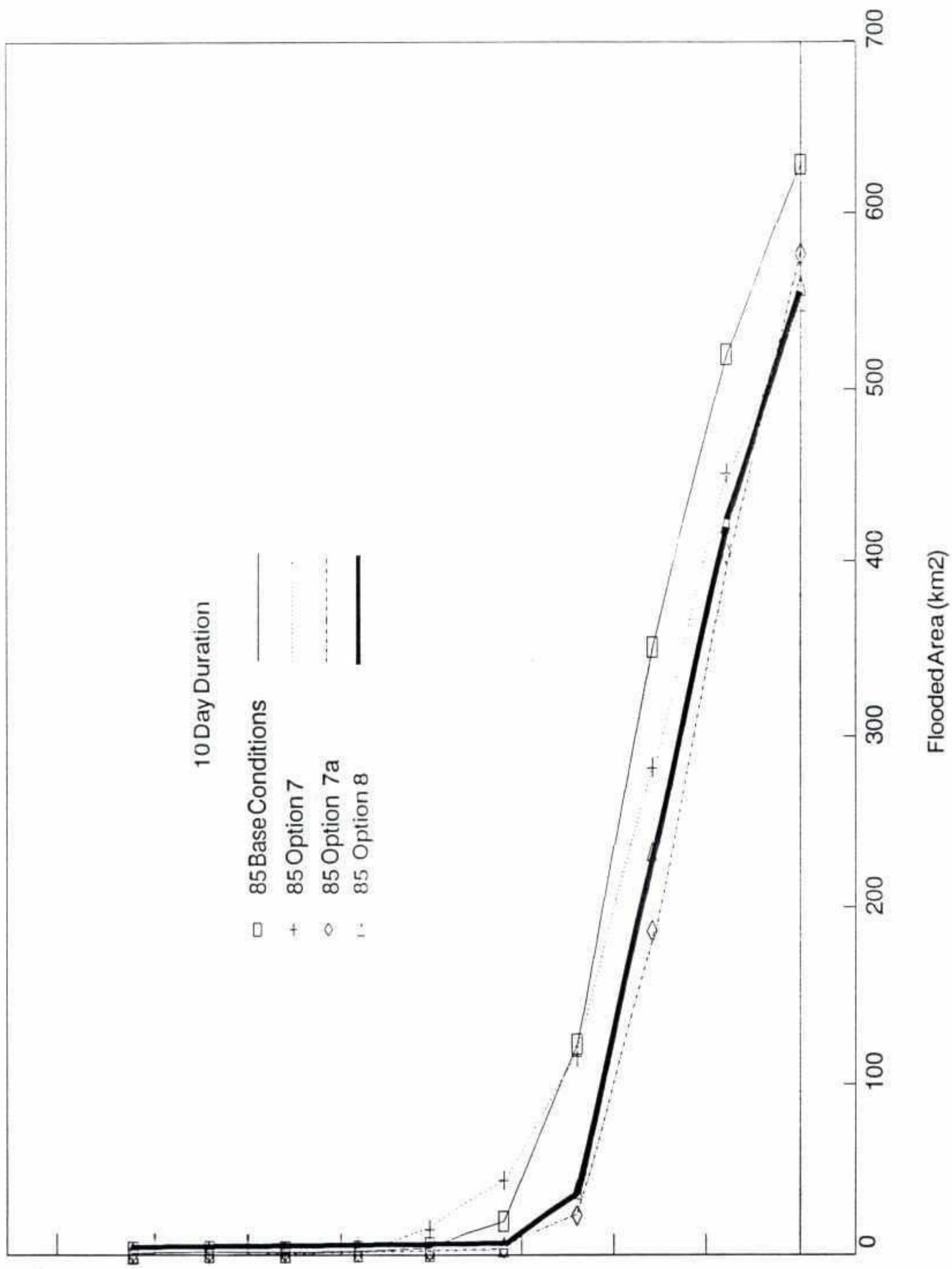

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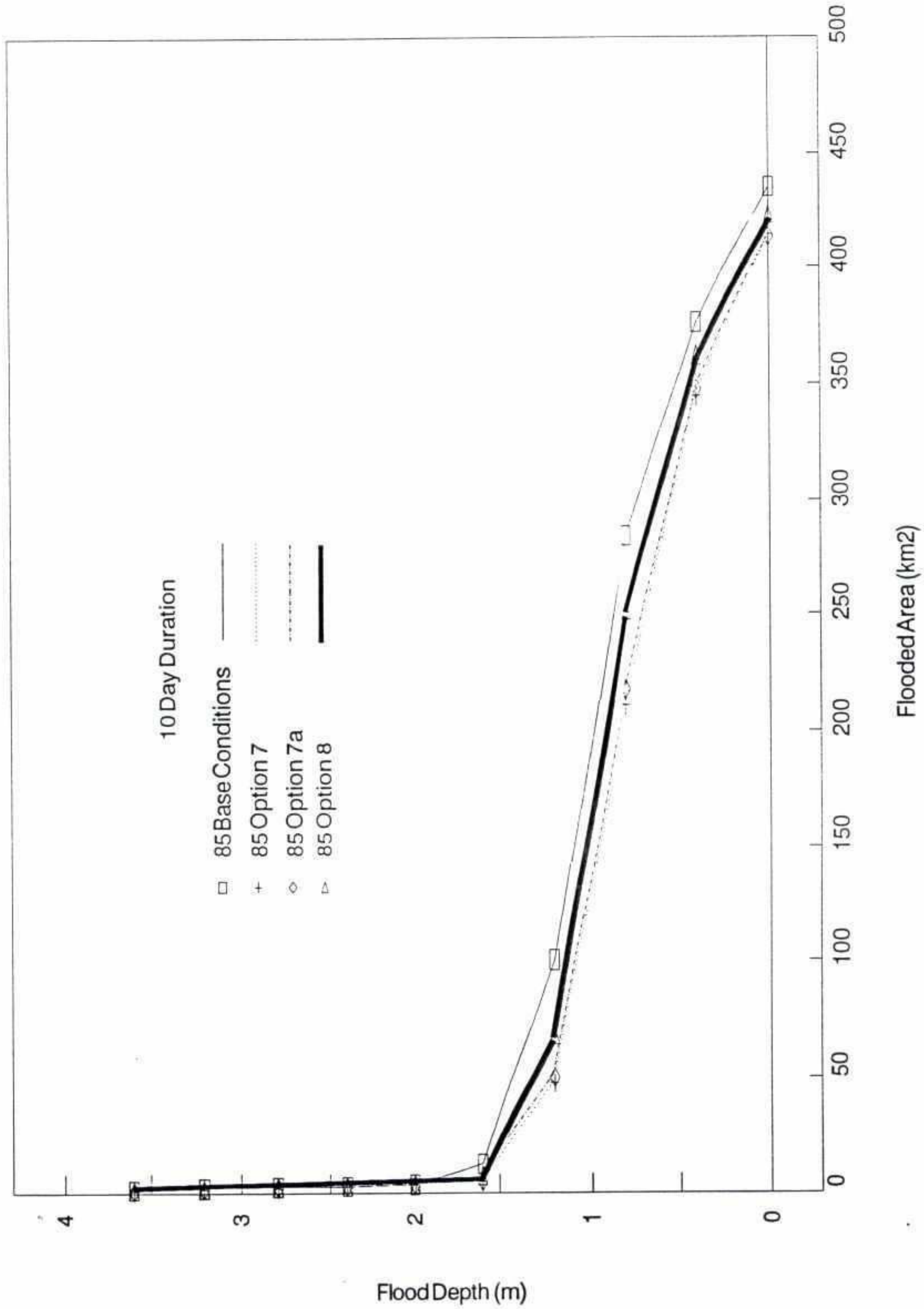
Figure VI.4.8

Project Screening, Dakatia Planning Unit, 1985 Flood



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VI.4.4 Project Evaluation

The evaluation of flood mitigation options in Bangladesh has for some time been based on classifications of flood depth on a thana or planning unit basis. Flood phases are categorised as follows:

F0	-	flood depths of < 0.3 m
F1	-	flood depths of 0.3 - 0.9 m
F2	-	flood depths of 0.9 - 1.8 m
F3	-	flood depths of >1.8 m for less than nine months
F4	-	flood depths of >1.8 m for more than nine months

The classification system has been extremely useful in broad level planning, and has served its purpose well. Crop statistics and cropping distributions have been related to flood phases, and they have become an important planning parameter. The introduction of hydrodynamic modelling techniques does, however, now offer a higher level of analysis and evaluation to planners, and reconsideration of how the flood phase classification is used may be appropriate. The results presented below indicate that it is important to adopt a more physically based process oriented approach to the consideration of flood inundation characteristics and flood impacts.

It is understood that flood phases defined by the Soils Research and Development Institute (SRDI), have been based on flood level inundation maps prepared from observed groundwater levels. Effectively the procedure was to assume that peak groundwater levels coincided with general flood levels. By a process of contouring and superposition on topographic maps, flood depth classifications could be derived. The availability of computational hydraulic models, and the computerised land level data base prepared under the present project, permits a more objective approach to determination of flood phases, and permits them to be related to duration and frequency of flooding. A much more extensive physically based data base is now available and must be incorporated in the planning process.

A drawback of the present classification, for other than broad level planning, is that it relates to neither the duration of flooding nor the frequency with which the inundation occurs. It was thought originally that the classification in its broadest sense ought to apply to average year conditions. Crop statistics have, however, been related to flood phases, and although many farmers plant at the margins, it is not thought generally likely that many would risk crop losses at frequencies of less than once in five years. It was therefore considered appropriate for the present investigations to relate flood phases to the inundation experienced with a return period of about five years. This has been justified to some extent through comparison of notional flood phases determined from the model for the present base case conditions, with the flood phase classifications. There is, however, poorer correlation than would have been expected.

The selection of representative years for modelling purposes has been discussed in Chapter VI.3. For each of these years, flood depth duration area characteristics have been computed using Mike11 and the land level data base through a series of post processing programs. A typical processed model output is shown in Table VI.4.1. Notional flood phases have been computed in order to indicate the sensitivity of the classification to the year on which it is based, and to the duration for which certain water levels are exceeded. On the basis of the approach adopted by the SRDI, and from consideration of the full model outputs in the form of Table VI.4.1, a 10 day duration was considered most appropriate for classification of the flood phases. The classifications are summarised in Figures VI.4.9 to VI.4.14, and in Table VI.4.2. These are for the planning units in which there is both hydrodynamic model and land level data.

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TABLE VI.4.1

Post Processed Model Output Format

Base Run, 1983 Conditions
DAKATIA Planning Unit

Flood Depth/Area Characteristics

Area Flooded (km²)

Flood Depth (m)	2 Day	5 Day	10 Day	20 Day	40 Day	60 Day	90 Day
0.0	374.9	370.9	366.8	357.7	352.4	349.6	310.8
0.2	356.1	351.5	345.6	335.0	330.6	327.0	277.8
0.4	339.5	334.3	325.7	310.6	303.1	298.1	230.8
0.6	316.6	306.9	295.6	279.2	271.6	265.1	147.9
0.8	283.6	272.0	257.3	231.2	219.4	210.5	77.8
1.0	227.1	211.7	196.3	160.4	143.8	130.3	25.8
1.2	153.8	133.1	112.4	84.9	76.9	68.5	6.1
1.4	83.4	68.8	53.1	26.1	18.9	16.3	3.5
1.6	27.4	17.6	11.7	6.0	5.1	5.0	3.1
1.8	6.9	5.1	4.2	3.4	3.2	3.2	2.8
2.0	3.5	3.3	3.2	3.0	2.9	2.9	2.6
2.2	3.0	2.9	2.8	2.8	2.8	2.7	2.4
2.4	2.8	2.7	2.7	2.7	2.6	2.6	2.2
2.6	2.6	2.6	2.5	2.4	2.3	2.3	2.0
2.8	2.3	2.3	2.3	2.2	2.2	2.1	1.5
3.0	2.2	2.1	2.1	2.0	1.9	1.9	1.2
3.2	1.9	1.7	1.7	1.4	1.3	1.2	1.1
3.4	1.2	1.2	1.2	1.2	1.2	1.2	0.9
3.6	1.2	1.2	1.1	1.1	1.0	1.0	0.6
3.8	1.0	1.0	0.9	0.9	0.8	0.8	0.2

Flood Phase Distributions (%)
Mapped Area = 594.2 km2

Flooded Phase	2 Day	5 Day	10 Day	20 Day	40 Day	60 Day	90 Day
F0	41.5	42.3	43.5	45.7	46.7	47.4	57.2
F1	15.6	17.0	18.3	21.4	22.8	23.9	34.1
F2	41.8	39.8	37.5	32.4	30.0	28.1	8.2
F3 & F4	1.2	0.9	0.7	0.6	0.5	0.5	0.5

Figure VI.4.9

Flood Phase Distributions, Dhonagoda Planning Unit

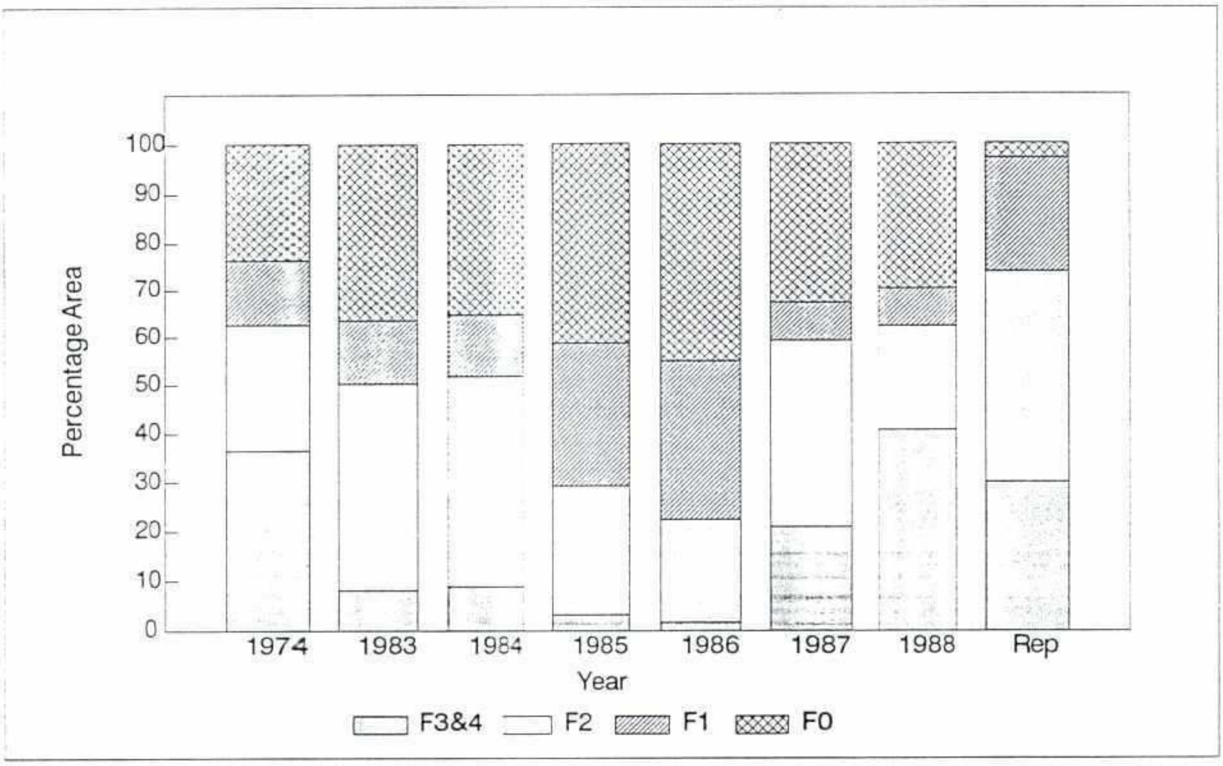

Figure VI.4.10

Flood Phase Distributions, Sonaichari Planning Unit

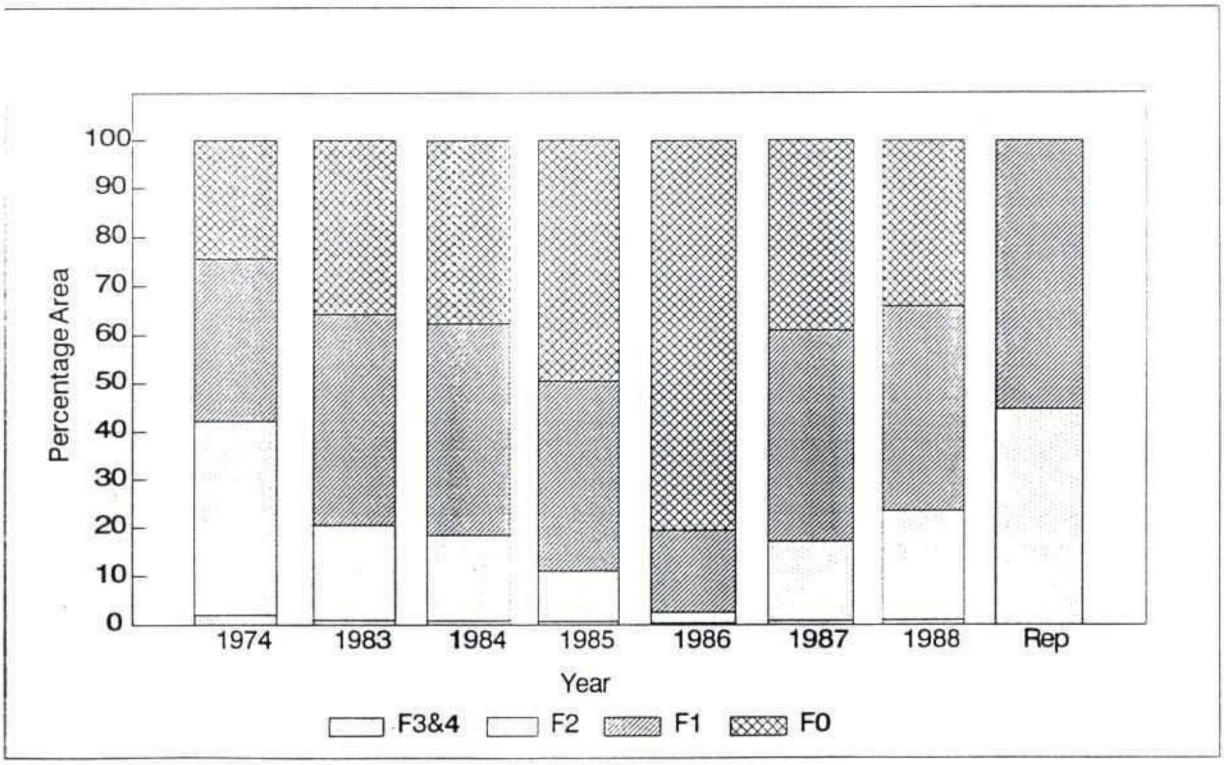

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Figure VI.4.11

Flood Phase Distributions, Noakhali North Planning Unit

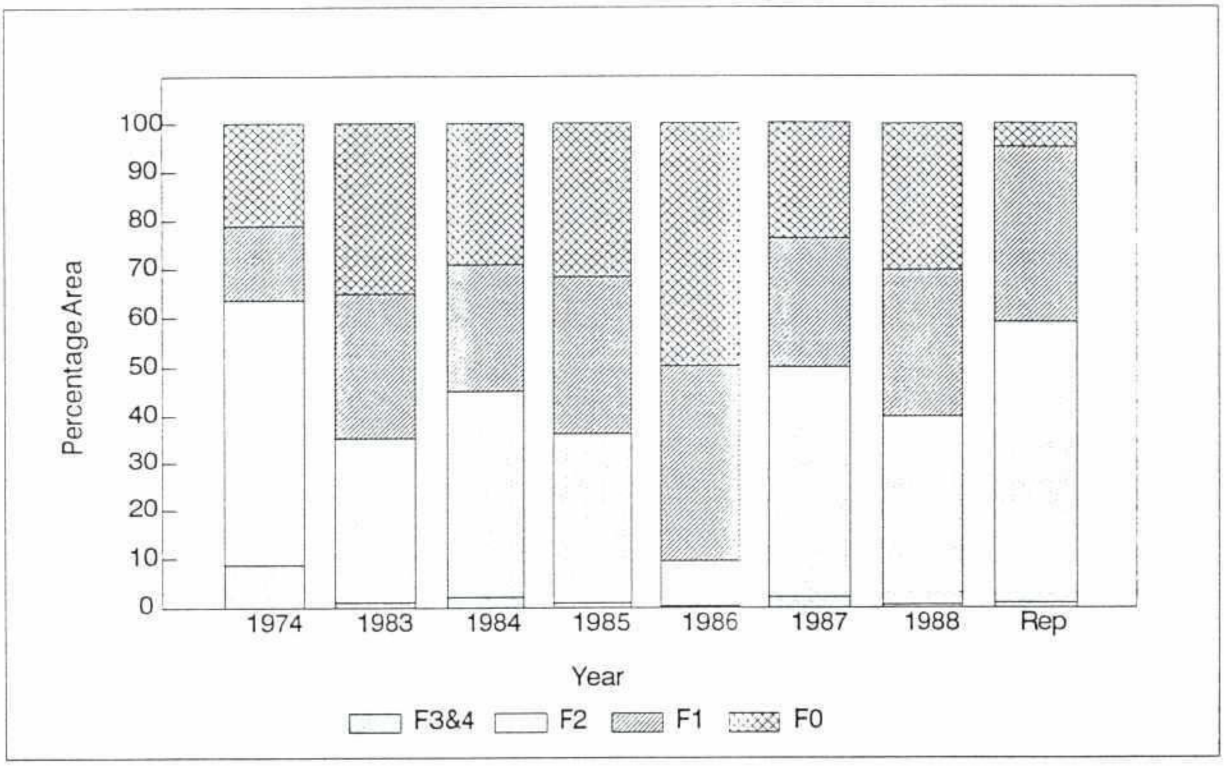

Figure VI.4.12

Flood Phase Distributions, South Sudharam Planning Unit

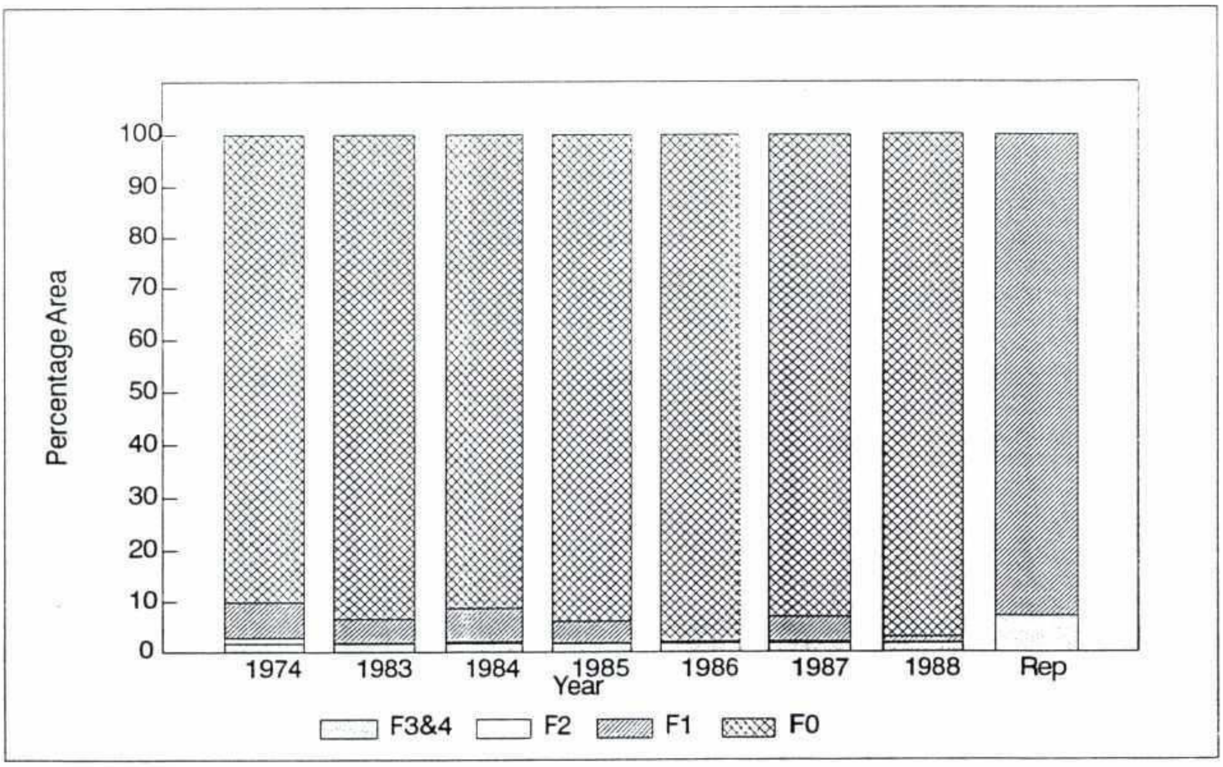

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Figure VI.4.13

Flood Phase Distributions, Little Feni Planning Unit

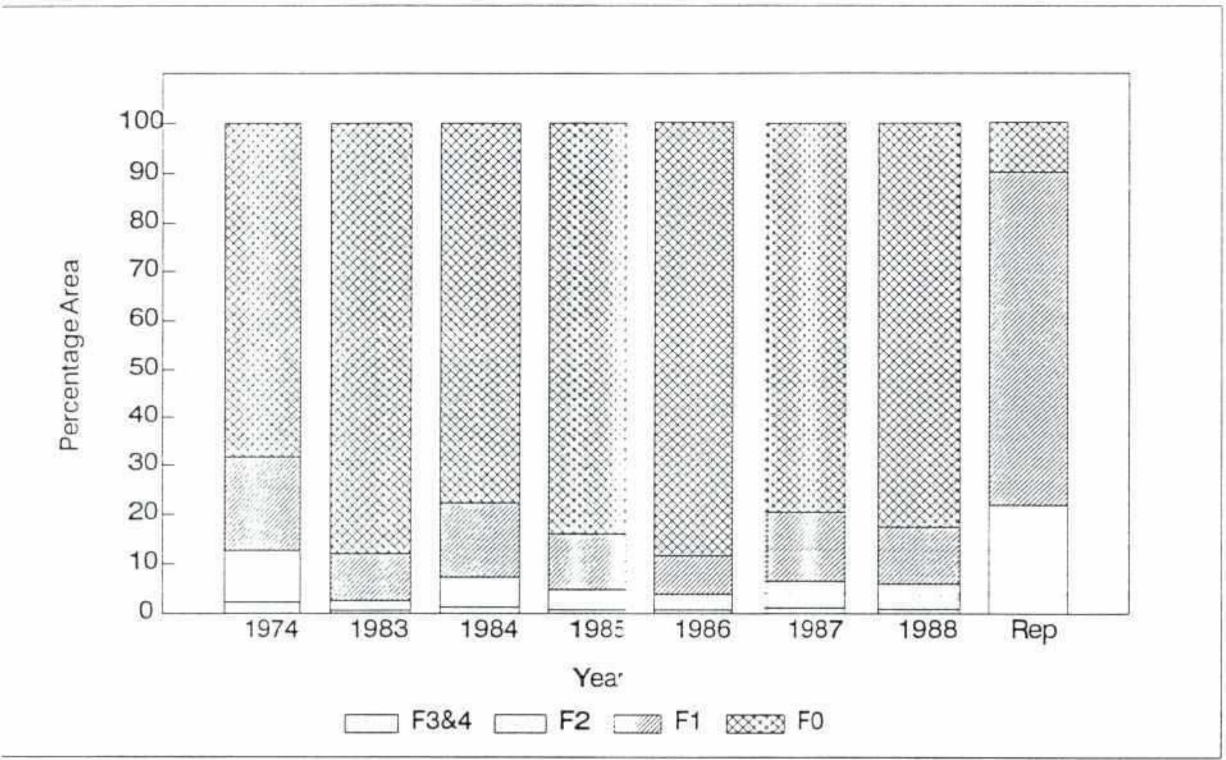

Figure VI.4.14

Flood Phase Distributions, Dakatia Planning Unit

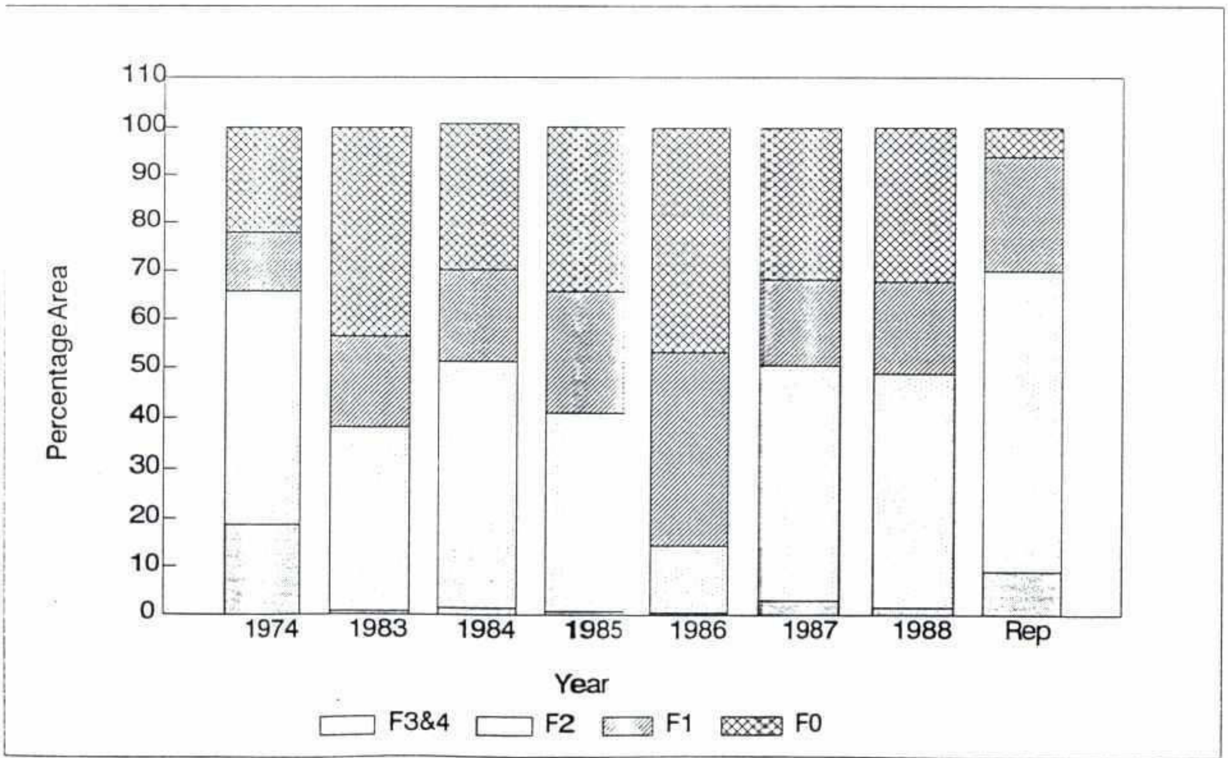

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TABLE VI.4.2

Modelled Flood Phases as Percentage of Mapped Area

Dhonagoda Planning Unit

Flood Phase	1974	1983	1984	1985	1986	1987	1988	Reported
F0	23.8	26.3	35.2	41.3	45	32.6	29.5	3
F1	13.7	13.5	12.9	29.5	32.7	8.1	8.1	23
F2	26	42.1	43	26	20.6	38.4	21.5	44
F3 & 4	36.6	8.1	8.8	3.2	1.7	20.9	40.9	30

Sonaichari Planning Unit

Flood Phase	1974	1983	1984	1985	1986	1987	1988	Reported
F0	24.5	35.7	37.6	49.5	80.5	39.1	34	0
F1	33.2	43.8	44	39.4	16.9	43.7	42.4	55
F2	40.2	19.5	17.5	10.3	2.2	16.3	22.5	45
F3 & 4	2.1	1	0.9	0.8	0.4	0.9	1	0

Noakhali North Planning Unit

Flood Phase	1974	1983	1984	1985	1986	1987	1988	Reported
F0	21.1	35.1	29.2	31.7	49.8	23.9	30.2	5
F1	15.2	29.6	25.6	32.1	40.7	26.2	30	36
F2	55	34.1	43	35.2	9.2	47.8	39	58
F3 & 4	8.7	1.2	2.2	1	0.3	2.2	0.7	1

South Sudharam Planning Unit

Flood Phase	1974	1983	1984	1985	1986	1987	1988	Reported
F0	90.1	93.4	91.3	93.9	97.9	93	97.1	0
F1	7.1	4.8	6.7	4.3	0.4	5	1.2	93
F2	1.1	0.1	0.3	0.1	0	0.3	0.1	7
F3 & 4	1.7	1.7	1.7	1.7	1.7	1.7	1.7	0

Little Feni Planning Unit

Flood Phase	1974	1983	1984	1985	1986	1987	1988	Reported
F0	68.4	88	77.7	83.9	88.4	79.4	82.3	10
F1	18.9	9.4	15	11.3	7.8	14	11.6	68
F2	10.3	2	6	4	3.1	5.4	5.1	22
F3 & 4	2.4	0.7	1.3	0.8	0.8	1.2	0.9	0

Dakatia Planning Unit

Flood Phase	1974	1983	1084	1985	1986	1987	1988	Reported
F0	22.1	43.5	30.5	34.2	46.4	31.7	32.1	6
F1	12.2	18.3	19	24.9	39	17.5	18.7	24
F2	47	37.5	49.9	40.3	14	47.8	47.7	61
F3 & 4	18.7	0.7	1.4	0.7	0.5	2.9	1.5	9

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Comparison of the computed and published flood phase distributions shows variations particularly between F0 and F1 land. It is clear from the land level elevation area characteristics presented in Appendix VIII, however, that small changes in water level can result in considerable changes in the extent of flooding. The sensitivity to inaccuracies in either flood or land levels is therefore high. Generally the published flood phase information indicates deeper levels of flooding than do the hydrodynamic model results. It is likely that groundwater observation well data used by the Soil Survey Data Processing System (SODAPS), relates to wells on higher non-flooded land, under which a groundwater mound would be expected to form even during the peak flood season. An over estimation of flood depths could therefore be anticipated.

For project evaluation purposes, the adopted approach has been to evaluate flood phase distributions in each planning unit for pre- and post-project situations. The approach is comparative, based on model simulation results, and modelled flood phase distributions. The requirement has been therefore, to select an appropriate year of record for each planning unit on which the comparisons can be made, this approximating most closely to a five year peak flood condition. On the basis of Table VI.3.1, and the system sensitivity analysis discussed in section VI.3.4, the most appropriate representative years of data on which to evaluate land enhancement benefits are:

Dhonagoda	1984
Sonaichari	1984
Noakhali North	1983
South Sudharam	1983
Little Feni	1988 (1983 was close)
Dakatia	1984

These have been determined simply by interpolating between ranks.

The above years of data have been used in the appraisal of pre- and post-project flood phase distributions, and hence land enhancement benefits. For each planning unit, a complete set of outputs in the form presented in Table VI.4.1 has been prepared for each of the identified flood mitigation options. A sample of the summary form in which these are utilised in the planning process is indicated in Table VI.4.3.

VI.4.5 Agricultural Flood Damages

An objective appraisal of agricultural flood damages requires that flood depths and durations be related to the stage of growth of the crop. Standard yield loss estimates are given in Table VI.4.4, although these do need to be expanded to relate to flood duration.

Because of the critical nature of the stage of crop growth to flood damage, the evaluation of damage frequency on the basis of specific years of data may not be quite as appropriate as for land enhancement benefits. The requirements for the evaluation are however fairly simple, being a cropping calendar and the distribution of the crop between various land categories. Time series water level results from Mike11 would be used with the land level data base and the cropping calendar to estimate yield losses. A thorough analysis would, however, require a long term simulation. This level of analysis is appropriate at full feasibility level, but for regional planning, a simplified approach based on recorded flood losses has been adopted.

TABLE 4.3

Typical Summary Results for Project Evaluation

Dakatia Planning Unit, 1984 Conditions
Flood Phase Distributions (%)

Option 5							
Flood Phase	2 Day	5 Day	10 Day	20 Day	40 Day	60 Day	90 Day
F0	28.9	29.9	30.8	32.2	34.4	34.6	38.9
F1	18.5	19.0	19.7	20.7	21.7	22.7	30.5
F2	50.6	49.5	48.3	46.1	43.1	41.9	30.0
F3 & 4	2.0	1.6	1.2	1.0	0.8	0.8	0.6
Option 34a5							
Flood Phase	2 Day	5 Day	10 Day	20 Day	40 Day	60 Day	90 Day
F0	28.5	29.3	30.3	31.4	33.3	33.5	38.2
F1	17.7	18.4	18.7	19.6	20.7	21.3	29.3
F2	50.7	49.9	49.4	47.5	44.9	44.2	31.9
F3 & F4	3.0	2.5	1.6	1.4	1.1	1.0	0.6
Option 7A							
Flood Phase	2 Day	5 Day	10 Day	20 Day	40 Day	60 Day	90 Day
F0	31.4	31.8	33.4	35.2	37.6	38.1	43.5
F1	23.4	25.0	25.7	26.4	27.6	29.8	36.6
F2	44.1	42.3	40.1	37.7	34.2	31.4	19.3
F3 & F4	1.0	0.9	0.8	0.7	0.6	0.6	0.5
Option 8							
Flood Phase	2 Day	5 Day	10 Day	20 Day	40 Day	60 Day	90 Day
F0	30.7	31.6	32.6	34.2	36.6	36.9	42.7
F1	23.6	24.7	25.4	26.6	28.9	29.3	38.9
F2	44.6	42.7	41.0	38.5	33.8	33.2	17.8
F3 & F4	1.2	1.0	0.9	0.9	0.7	0.7	0.6

TABLE VI.4.4

Probable Crop Damage at Critical Flood Depths

Crop	Land Type	Crop Growth Stage	Critical Flood Depth (m)			Vulnerable Period for Flood Damage
			20%	50%	80%	
HYV Boro	F3	Tending to Maturity	0.6	0.8	1.0	1st May to 30th June
HYV Boro	F2	Tending to Maturity	0.6	0.8	1.0	15th May to 30th June
Local Boro	F4	Tending to Maturity	0.8	1.0	1.3	15th April to 15th May
B. Aus	F2	Tending to Maturity	0.8	1.3	1.5	1st June to 31st July
B.Aman	F3	Vegetative	-	-	1.5	1st July to 15th Aug
T.Aman (HYV)	F1	Seeding Establishment	-	-	0.3	1st July to 30th Aug
T.Aman (HYV)	F1	Tillering	-	-	0.45	1st Aug to 30th Sep.
T.Aman (Local)	F1	Seedling Establishment	-	-	0.45	1st Aug to 15th Sep.
T.Aman (Local)	F1	Tillering	-	-	0.6	1st Aug to 30th Sep.

Estimates of crop flood damage are available from the Bangladesh Bureau of Statistics over the period 1983 to 1988. On the basis of the model runs for the years 1974, 1983, 1984, 1986, 1987 and 1988, which may be considered to be the 6 highest ranked events in the past 20 years, return periods can simply be attached to the damages by considering the rank of the events from the F3 and F4 flood phase classification in the summary model outputs. Table VI.4.5 summarises the results of the analysis, from which return periods can be attached to the BBS damage figures, and average damages computed.

TABLE 4.5

Estimated Flood Return Periods

Dhonagoda Planning Unit			
Rank	Year	F3 & F4 (%)	Return Period
1	1988	40.9	8.3
2	1974	36.6	5.9
3	1987	20.9	1.9
4	1984	8.8	1.1
5	1983	8.1	1.1
6	1985	3.2	1.0
7	1986	1.7	1.0
Sonaichari Planning Unit			
Rank	Year	F3 & F4 (%)	Return Period
1	1974	2.1	18.5
2	1983	1.0	1.5
3	1988	1.0	1.5
4	1984	0.9	1.3
5	1987	0.9	1.3
6	1985	0.8	1.2
7	1986	0.4	1.0
Noakhali North Planning Unit			
Rank	Year	F3 & F4 (%)	Return Period
1	1974	8.7	21.5
2	1984	2.2	1.5
3	1987	2.2	1.5
4	1983	1.2	1.2
5	1985	1.0	1.2
6	1988	0.7	1.1
7	1986	0.3	1.1

TABLE 4.5 (Contd.)

South Sudharam Planning Unit			
Rank	Year	F3 & F4 (%)	Return Period
1	1974	1.7	1.0
2	1983	1.7	1.0
3	1984	1.7	1.0
4	1985	1.7	1.0
5	1986	1.7	1.0
6	1987	1.7	1.0
7	1988	1.7	1.0
Little Feni Planning Unit			
Rank	Year	F3 & F4 (%)	Return Period
1	1974	2.4	18.9
2	1984	1.3	2.0
3	1987	1.2	1.7
4	1988	0.9	1.2
5	1986	0.8	1.1
6	1986	0.8	1.1
7	1983	0.7	1.1
Dakatia Planning Unit			
Rank	Year	F3 & F4 (%)	Return Period
1	1974	18.7	23.1
2	1984	2.9	1.4
3	1987	1.5	1.3
4	1988	1.4	1.2
5	1986	0.7	1.2
6	1986	0.7	1.2
7	1983	0.5	1.2

CHAPTER VI.5

SURFACE WATER RESOURCES

VI.5.1 Introduction

The seasonality in surface water resource availability in Bangladesh is extreme, and clearly demonstrated in Table VI.5.1 which presents a summary of simulated mean monthly dry season flows for catchment areas in the South East Region. The simulated flows are from the Water Balance Model as used in the National Water Plan Phase II (Ref. 11), and relate to the catchment areas delineated in Figures VI.5.11 and VI.5.12 . Between the months of October and March there is effectively no dependable rainfall (Chapter VI.1). Crop production in this period is thus totally dependant upon residual soil moisture and irrigation.

In considering the surface water resources available to the South East Region, and planning their utilisation, the following distinctions must be made:

- the internal resources comprising locally generated rivers and khals, and the larger Titas, Gumti and Muhuri rivers which have significant catchment areas in India;
- the resources of the Meghna.

The indications of previous investigations (Ref. 11) have been that the internal surface water resources of the region are effectively fully utilised, and that any future surface water irrigation would be dependant upon transfers from the Meghna. There is competition for Meghna resources from potential projects in other parts of the country, and this, coupled with the potential impacts of saline intrusion and morphological change induced by such development, requires careful consideration at the national level. This is a function of the WRPO which is the successor of the MPO. Issues such as this have been addressed in the National Water Plan Phase I and Phase II.

VI.5.2 Internal Resources

VI.5.2.1 General

The inter-linkages in the drainage system of the region have been outlined in Chapter VI.2. The system is complex, and in terms of surface water resources development and evaluation, a holistic view is required. Developments in one area are likely to impact on water users in another. Further complications relate to the nature of the hydrological system, the extent of existing water use and irrigation, and the lack of long term reliable streamflow records in the region. It must be said, however, that even were such records available, the dynamic nature of the river systems, and of changing irrigation demands and practices, would have made their analysis particularly difficult.

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TABLE VI.5.1

Mean Monthly Catchment Outflows

Discharge ($M^3/_s$)

Catchment	Area M^2	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Northeast Model							
72	337	60.0	37.1	25.6	15.5	14.7	30.1
73	3 616	3 075.0	968.0	383.0	103.0	356.0	2 060.0
Southeast Model							
3	261	7.7	4.6	2.0	0.6	3.5	11.5
5	1 251	21.5	11.3	- 1.3#	-6.9#	-11.0#	4.5
6	236	11.0	6.8	3.7	1.6	2.3	10.1
11	532	6.4	0.5	-1.7#	-4.2#	-5.7#	0.4
12	206	3.3	2.0	0.5	-0.4#	-1.1#	1.6
13	449	18.7	6.9	1.2	-3.1#	-3.9#	10.7
14	354	16.1	9.6	4.9	1.0	1.7	18.0
15 *	405	18.0	1.7	3.5	0.0	-0.5#	20.2

* For corrected water use in Table VI.5.8

\# **Negative flows indicate that a flow reversal from the** Meghna is required or that demand exceeds reverses. The model does not pass negative flows downstream.

Evaluation of the internal surface water resources of the region has been based on the results of the water balance model, as recently updated by the MPO (Ref. 11). The water balance model was originally developed in 1982 for water balance studies of the northern regions of the country, and extended to cover the southern regions in 1985 under the MPO. In Phase II of the National Water Plan, the model was updated to include hydrological data up to the 1988/89 water year, and the calibration verified with more recent data which included higher levels of water use.

VI.5.2.2 Analysis of Streamflow Records

At this regional planning level of study, only limited frequency analysis of dry season flows has been carried out. Some of the problems with streamflow records in the region have been discussed in Chapter VI.2. The following stations have been considered;

158.1	Shaistaganj;
114	Jibanpur;
110	Comilla;
212	Parshuram;
84.1	Kaliachari.

The objective of the analysis has been to establish data reliability and to provide an indication of the inter-annual variations that can occur. These stations measure cross boundary inflows to the region from India and, with the exception of station 114, form a significant input to the water resources model for the region.

Twenty five years of data are available at stations 158.1, 114, 110, and 212, at which records commence in 1964/65, whilst only fifteen years of data is available at station 84.1, which commenced in 1974 (Table VI.2.1). Data for 1971 is absent from the records at all stations.

Normal distributions were fitted to the mean of January to March flows and to mean March flows, for each station record. These are presented in Figures VI.5.1 to VI.5.5, and Figures VI.5.6 to VI.5.10 respectively. Statistical parameters derived from the analysis are presented in Tables VI.5.2 and VI.5.3.

It can be seen from Figures VI.5.1 to VI.5.5 that the plotted data do in general follow normal distributions. However, stations 158.1, 114, 110, and 212, have several extreme high mean flows, caused primarily by high flows recorded in March of 1969 and in 1989 in particular. These extreme values are particularly pronounced when the mean March flows are considered in isolation as can be seen from Figures VI.5.6 to VI.5.10. Table VI.5.3 indicates excessive skew at stations 158.1, 114, 110 and 212, which is also as a result of bias from the two high mean March flows in 1969 and 1989.

It may be concluded that the available data conform to a normal distribution and are sufficiently reliable for the purposes of providing inputs to the water balance model under low flow conditions. However a more detailed analysis of the minimum low-season flows would be required where stations are of particular relevance to projects being studied at feasibility level. Note should be taken, for example of the recent trend of higher dry season flows in the Gumti, which are unlikely to continue.

Figure VI.5.1

Station 158.1 - Shaistaganj
Frequency Distribution of Mean January to March Flows

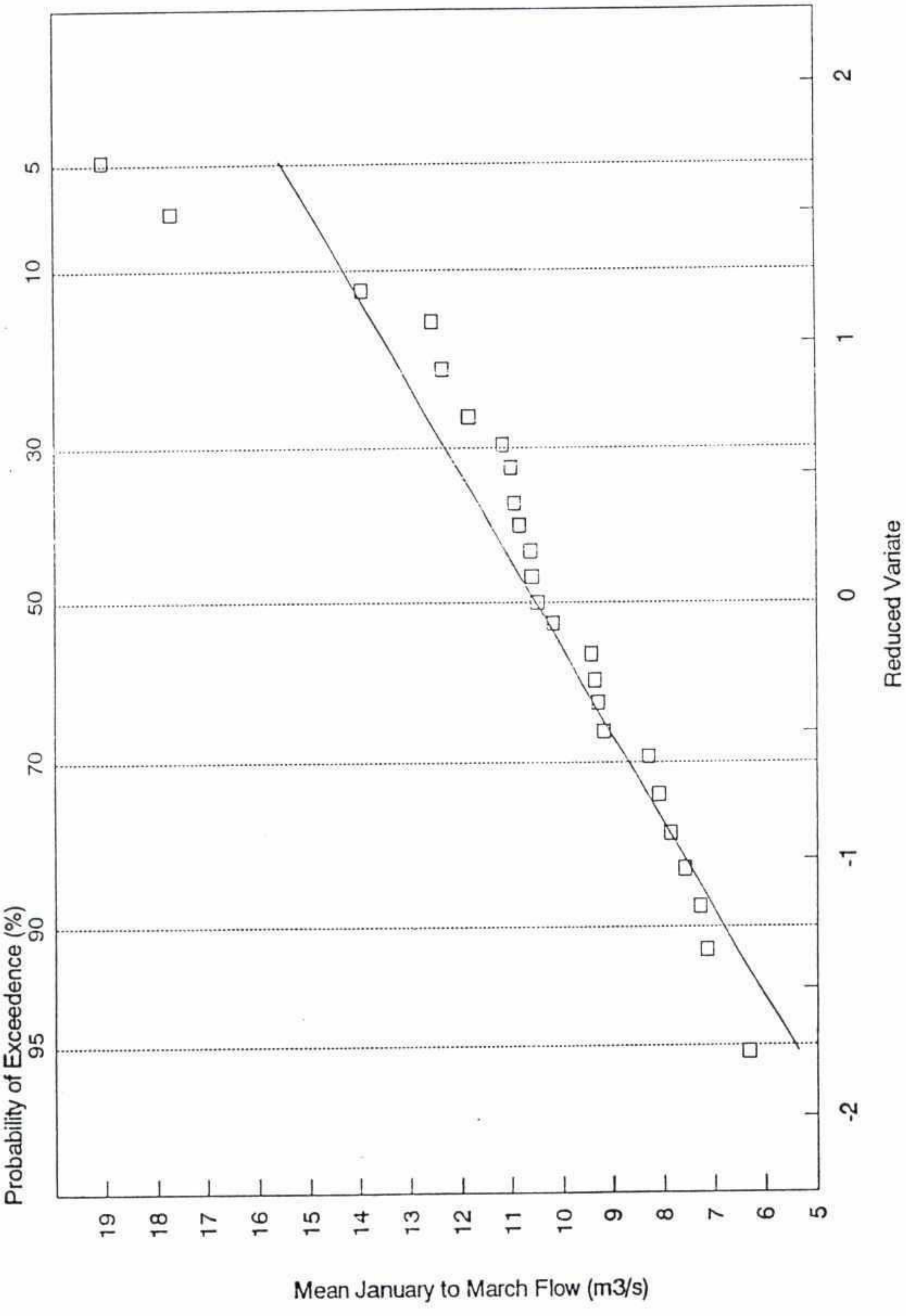

Figure VI.5.2

Station 114 - Jibanpur
Frequency Distribution of Mean January to March Flows

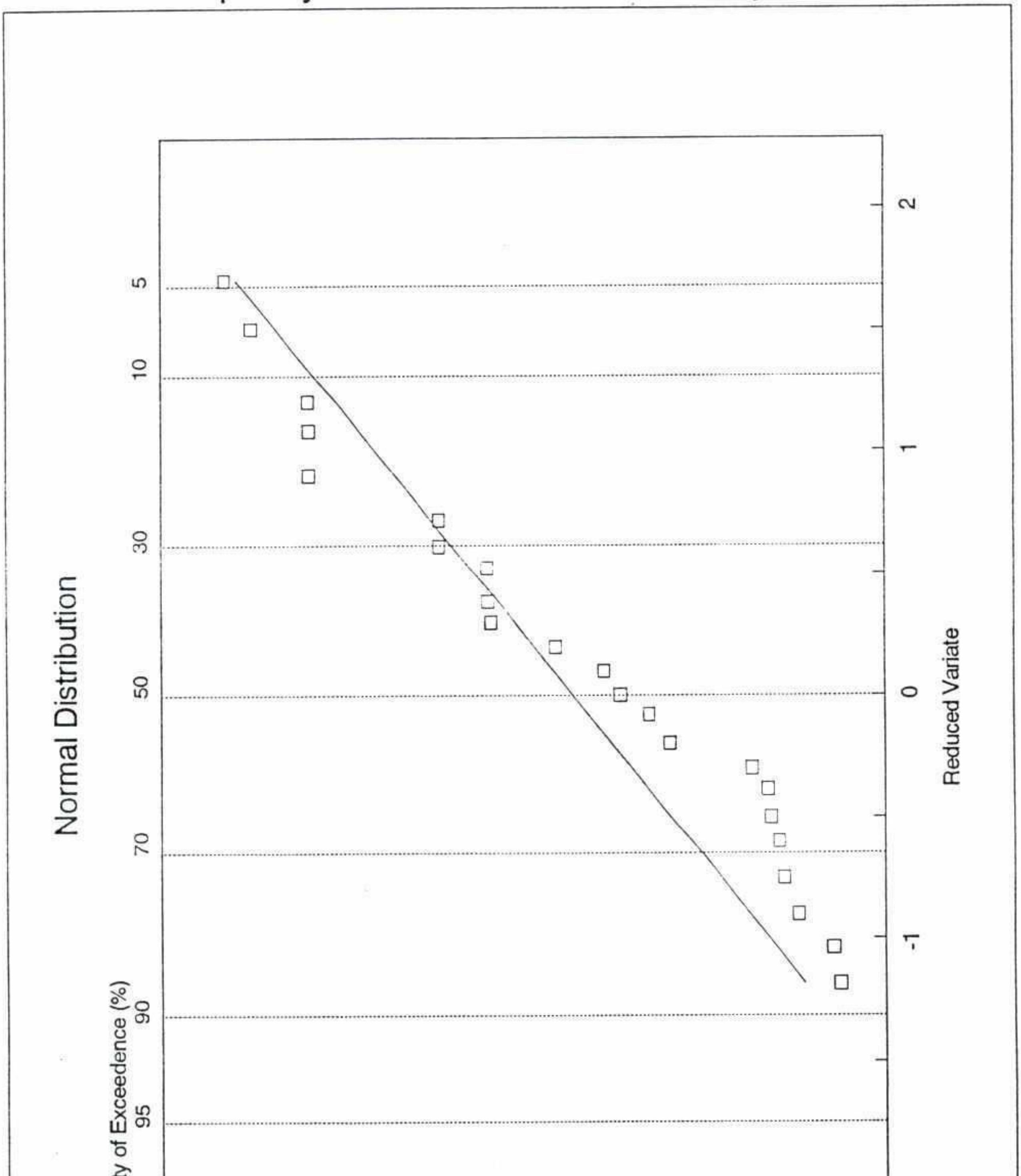

Figure VI.5.3

Station 110 - Comilla
Frequency Distribution of Mean January to March Flows

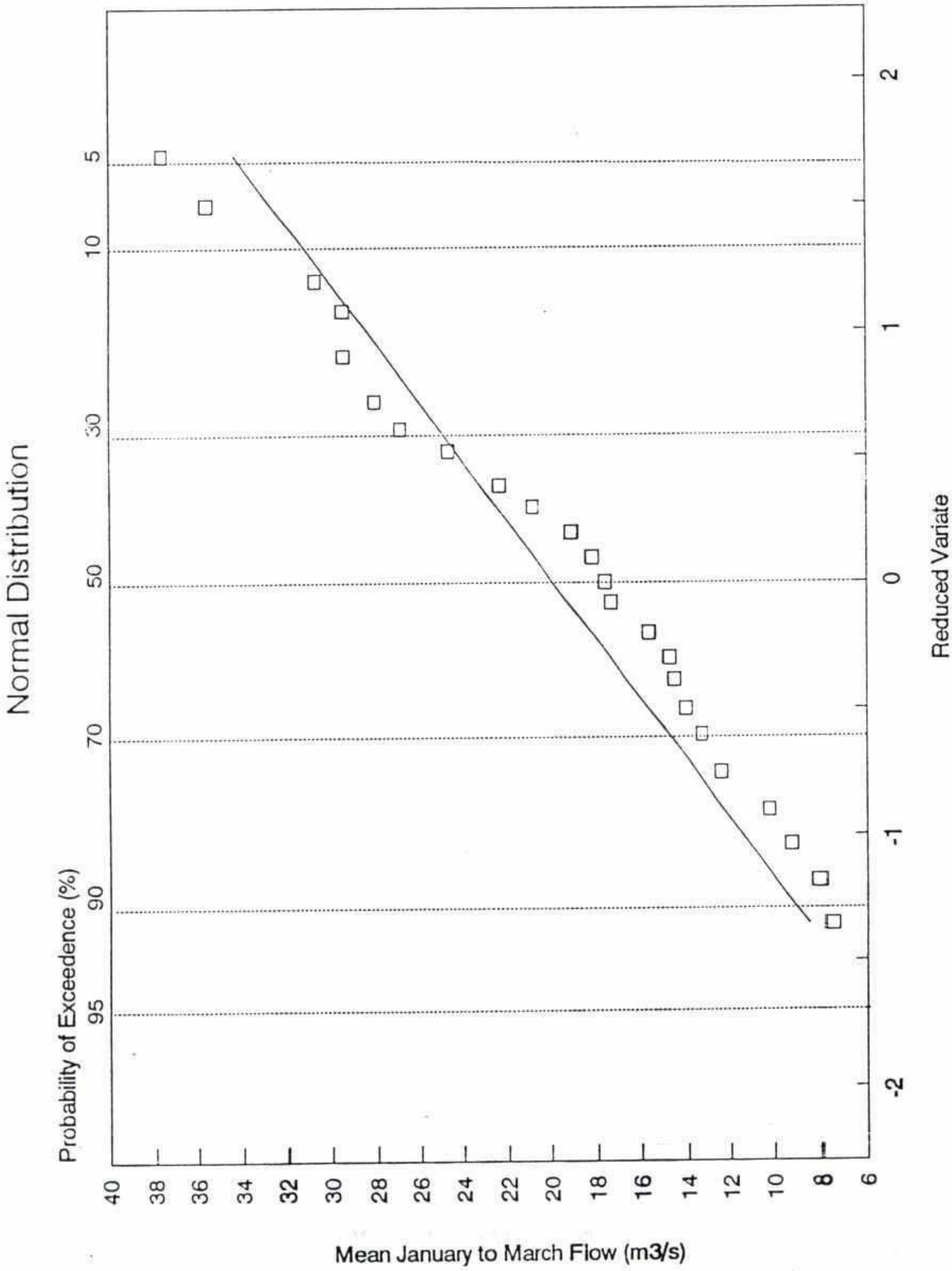

Figure VI.5.4

Station 212 - Parshuram
Frequency Distribution of Mean January to March Flows

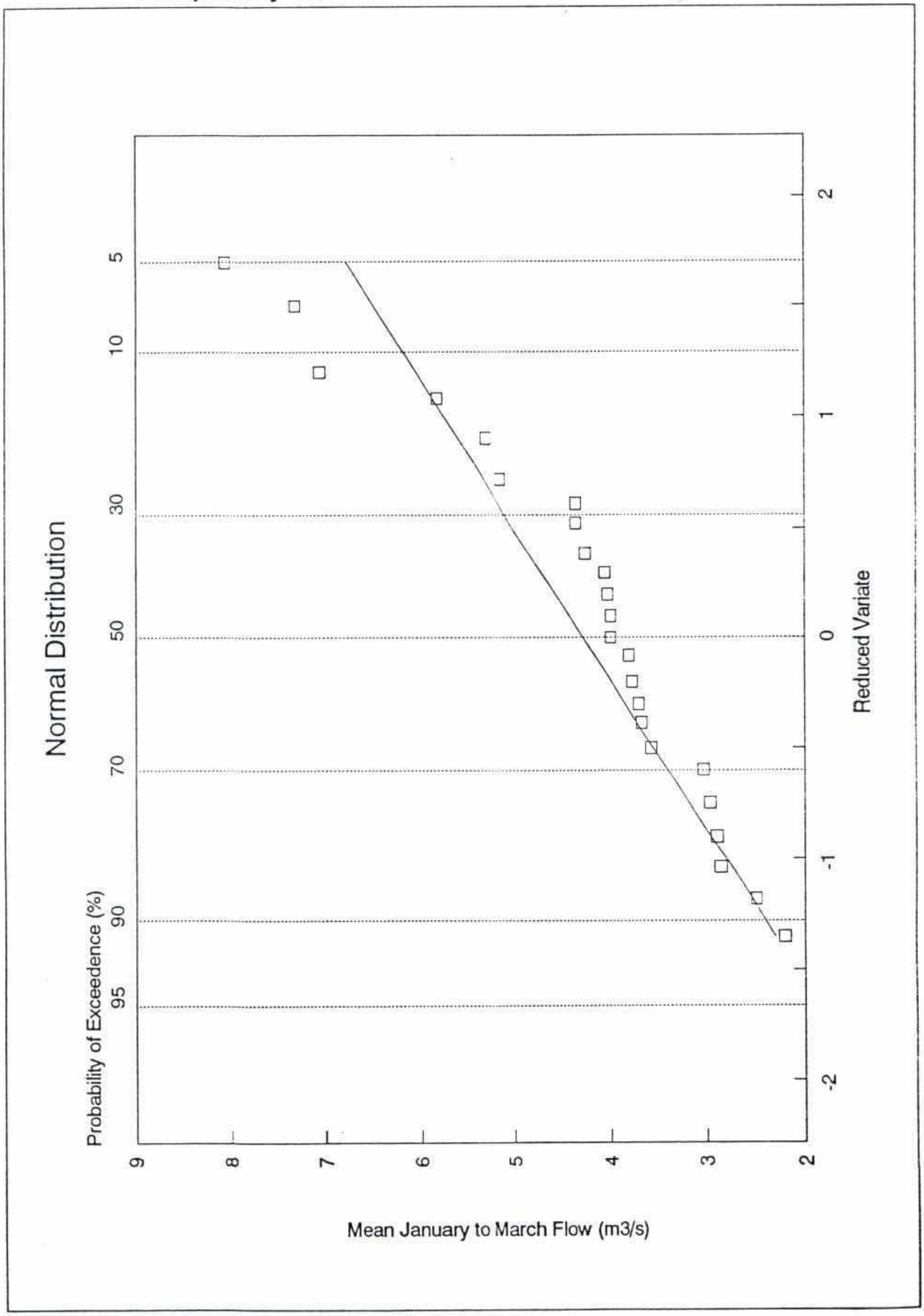

Figure VI.5.5

Station 84.1 - Kaliachari
Frequency Distribution of Mean January to March Flows

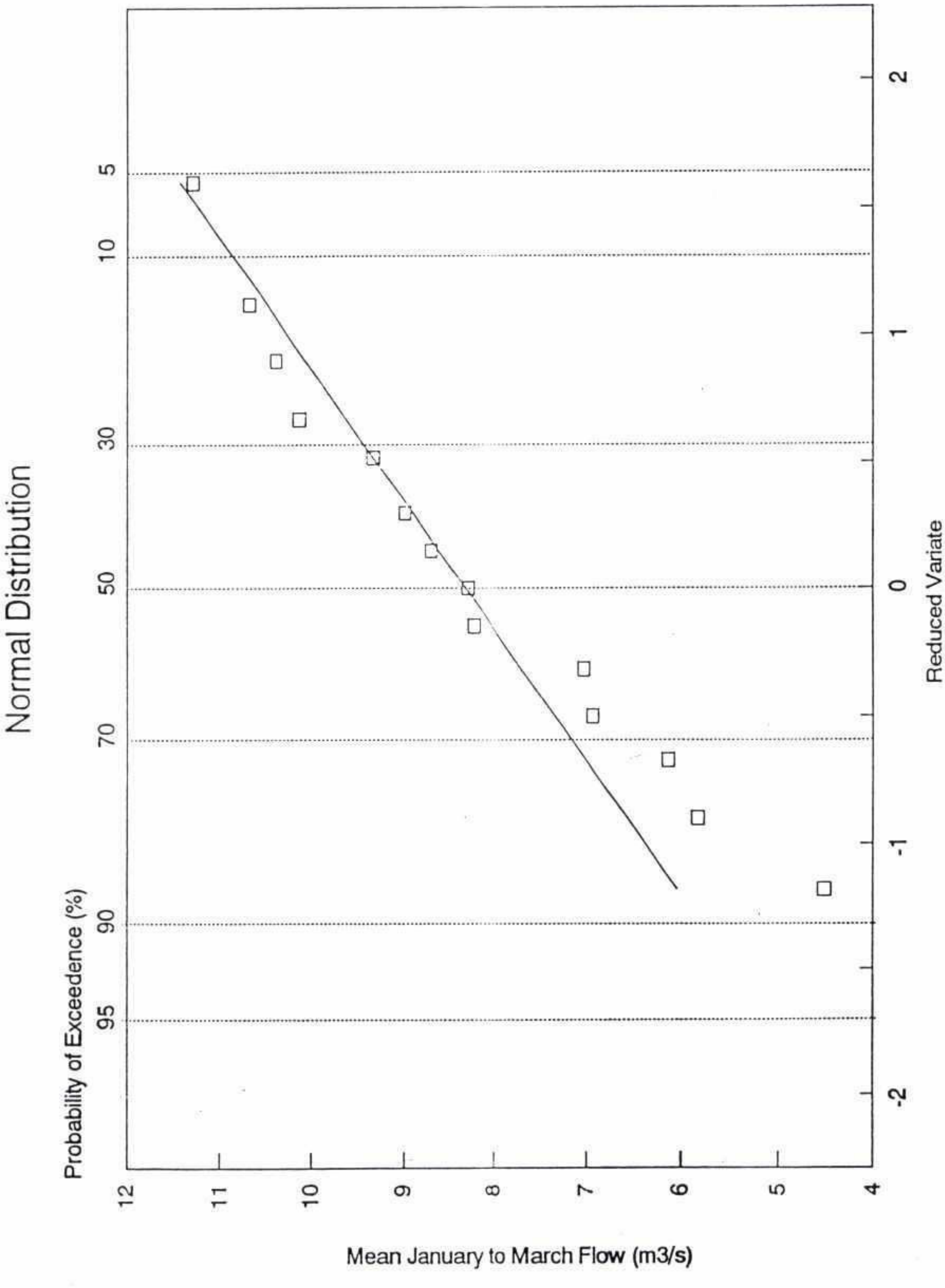

Figure VI.5.6

Station 158.1 - Shaistaganj
Frequency Distribution of Mean March Flows

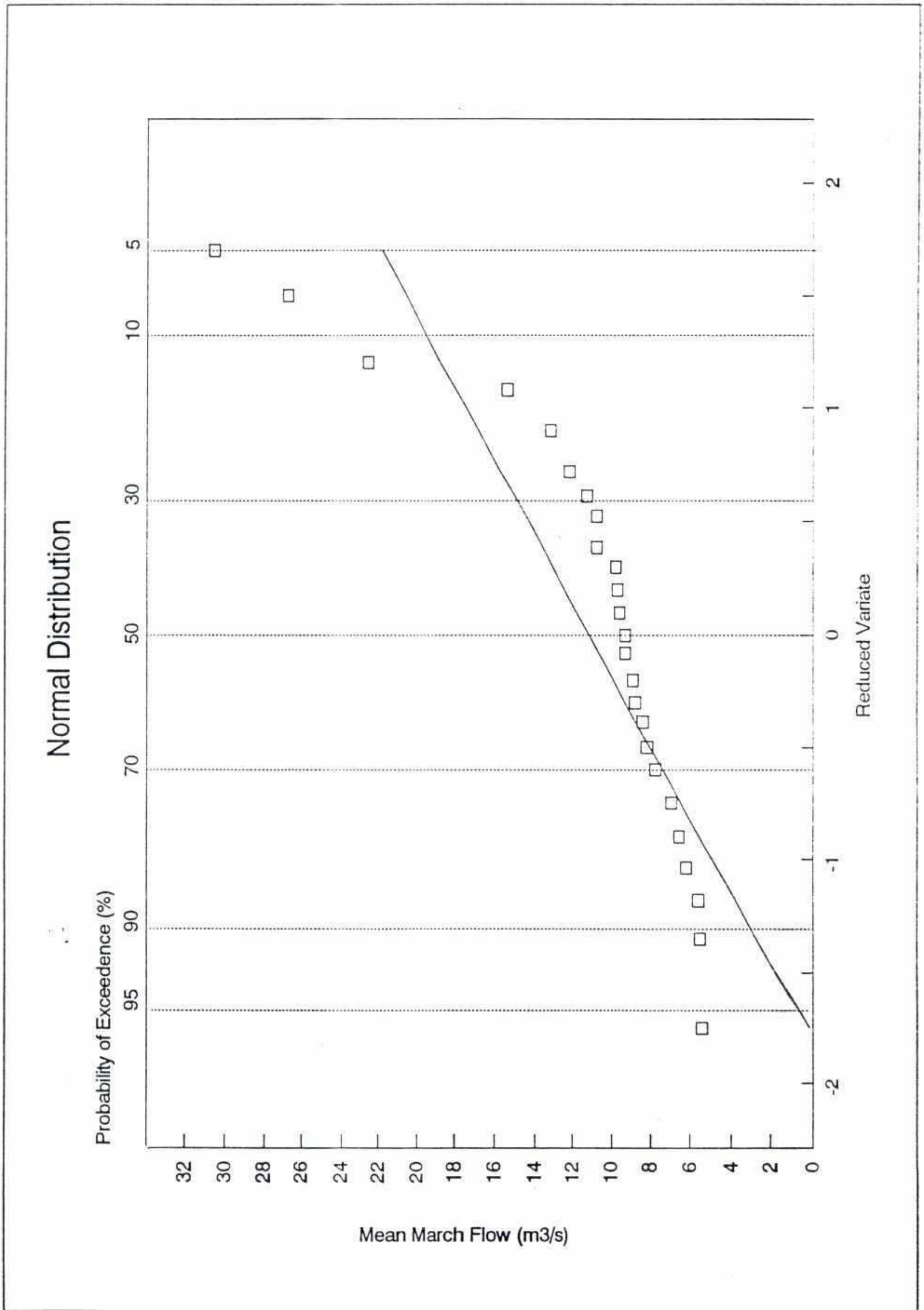

Figure VI.5.7

Station 114 - Jibanpur
Frequency Distribution of Mean March Flows

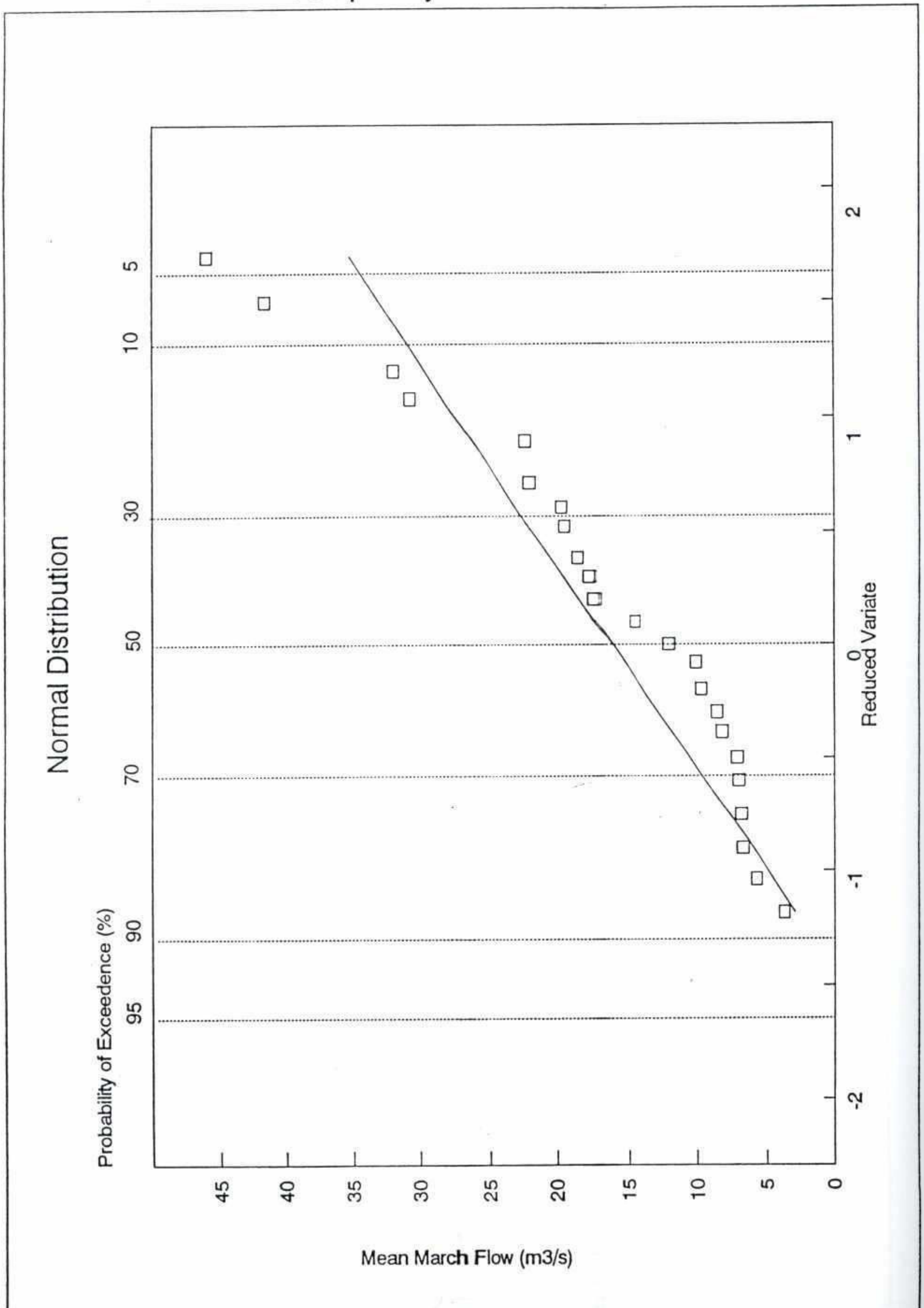

Figure VI.5.8

Station 110 - Comilla
Frequency Distribution of Mean March Flows

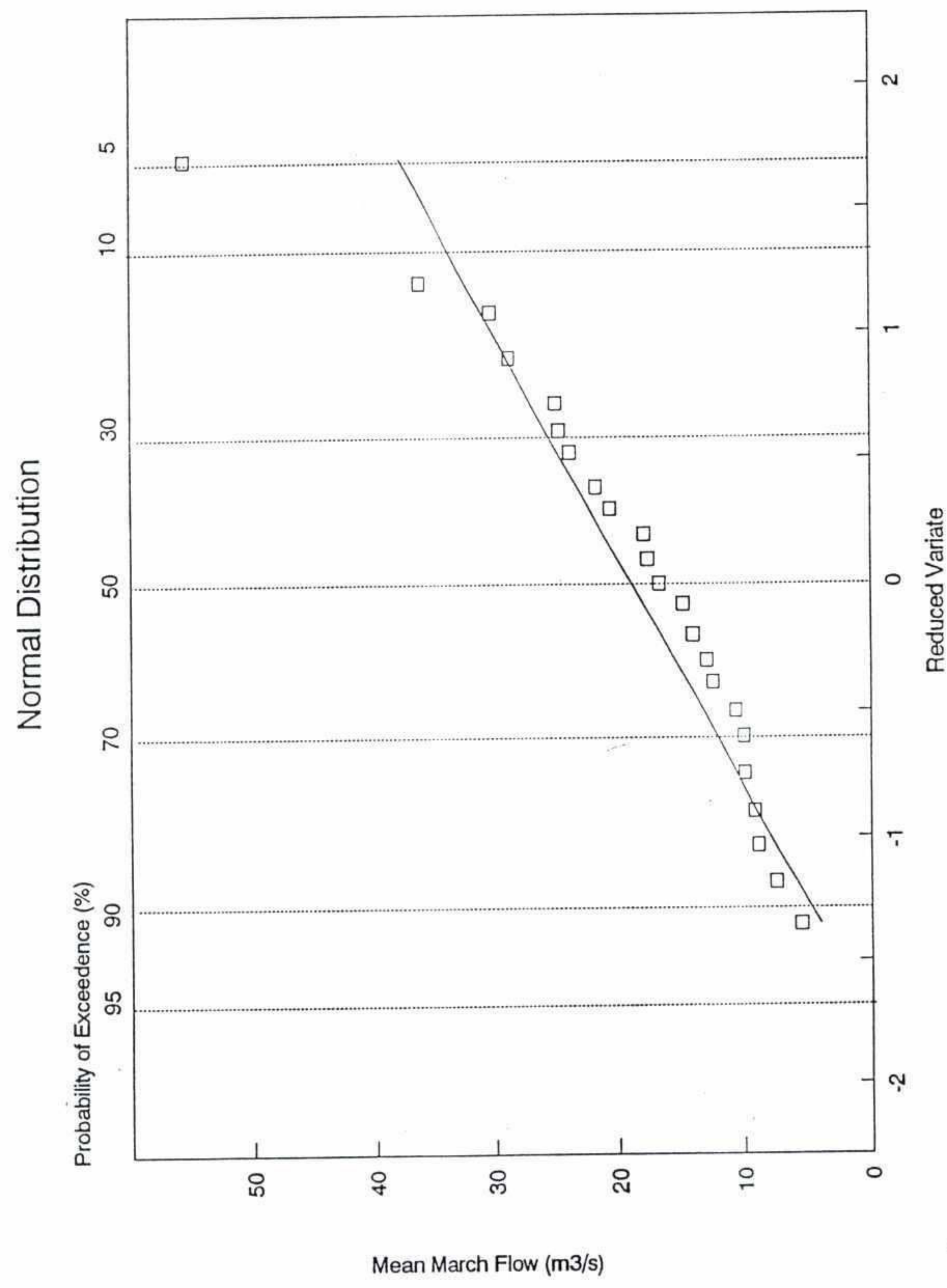

Figure VI.5.9

Station 212 - Parshuram
Frequency Distribution of Mean March Flows

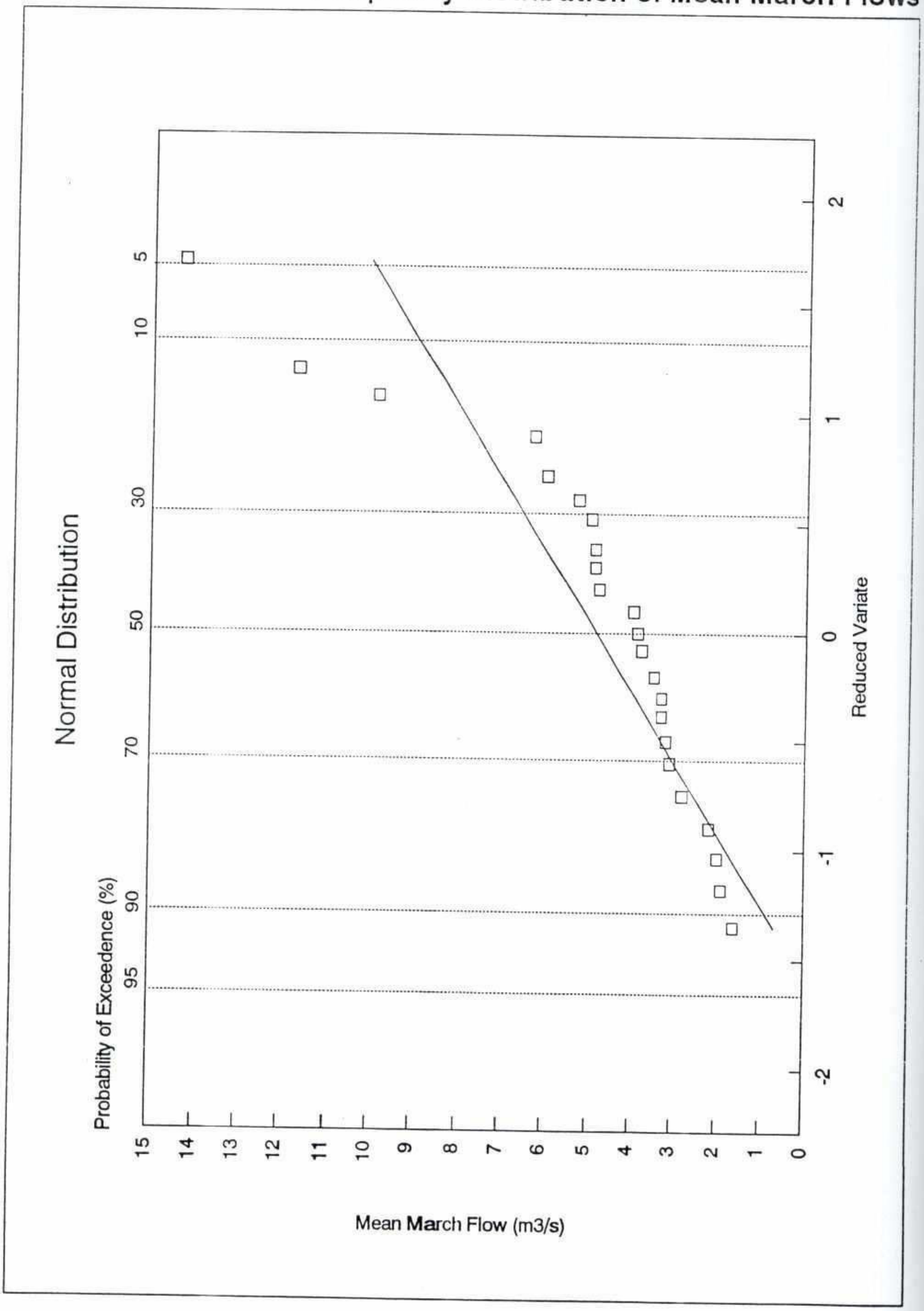

Figure VI.5.10

Station 84.1 - Kaliachari
Frequency Distribution of Mean March Flows

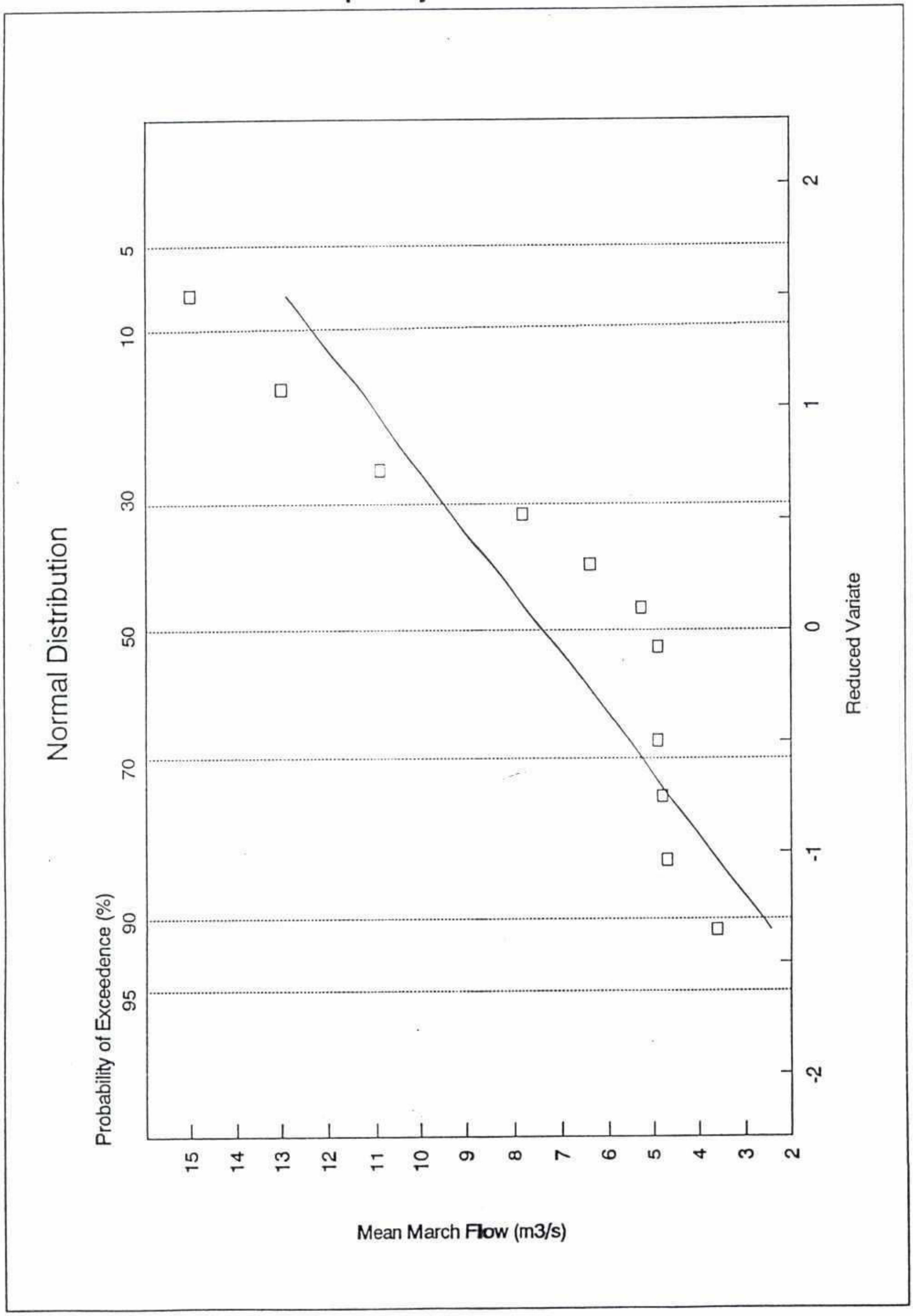

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TABLE VI.5.2

Statistical Parameters of Mean January to March Flows

Parameter	Station 158.1	114	110	212	84.1
Mean (m^3/s)	10.5	16.9	19.9	4.3	8.3
Standard (m^3/s) Deviation	2.9	8.2	8.5	1.5	1.9
Coefficient of Variance	3.57	2.06	2.34	2.9	4.28
Coefficient of Skewness	1.44	0.31	0.55	1.23	-0.67

TABLE VI.5.3

Statistical Parameters of Mean March Flows

Parameter	Station 158.1	114	110	212	84.1
Mean (m^3/s)	11.2	16.2	18.9	4.86	7.4
Standard (m^3/s) Deviation	6.3	11.3	11.1	3.1	3.7
Coefficient of Variance	1.78	1.43	1.7	1.57	2.01
Coefficient of Skewness	13.41	16.88	19.86	6.07	4.8

VI.5.2.3 The Water Balance Model

The water balance model comprises two principal components:

- a catchment model;
- a river systems or network model.

The model has been established for the north-east, north-west, south-east and south-west regions of the country. Of relevance to the South East Regional Study, are the north-east and south-east models. The catchment delineations for these are shown in Figures VI.5.11 and VI.5.12 respectively, and the network links between them in Figures VI.5.13 and VI.5.14.

Figure VI.5.11

Modelled Catchment Areas, North East Region

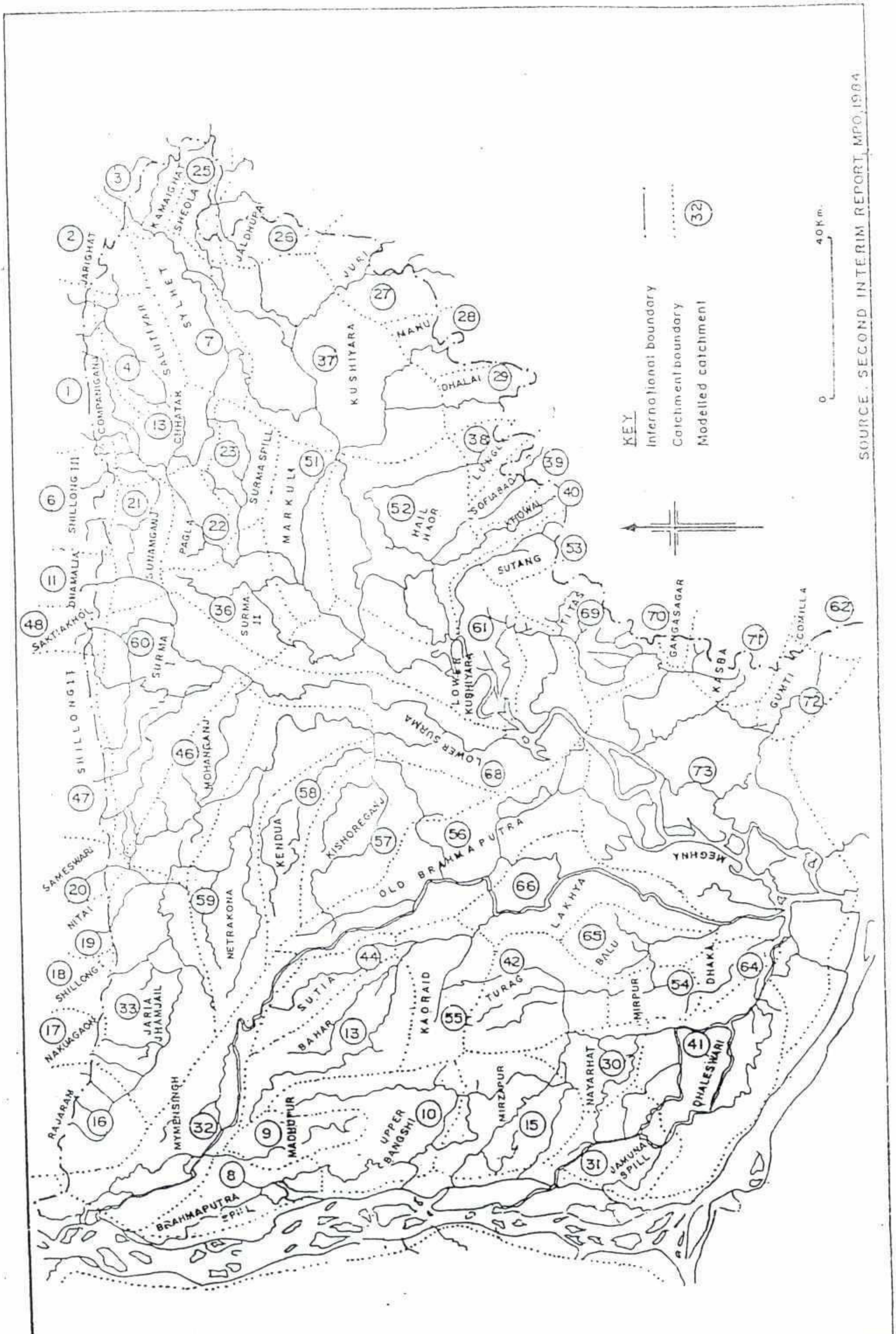

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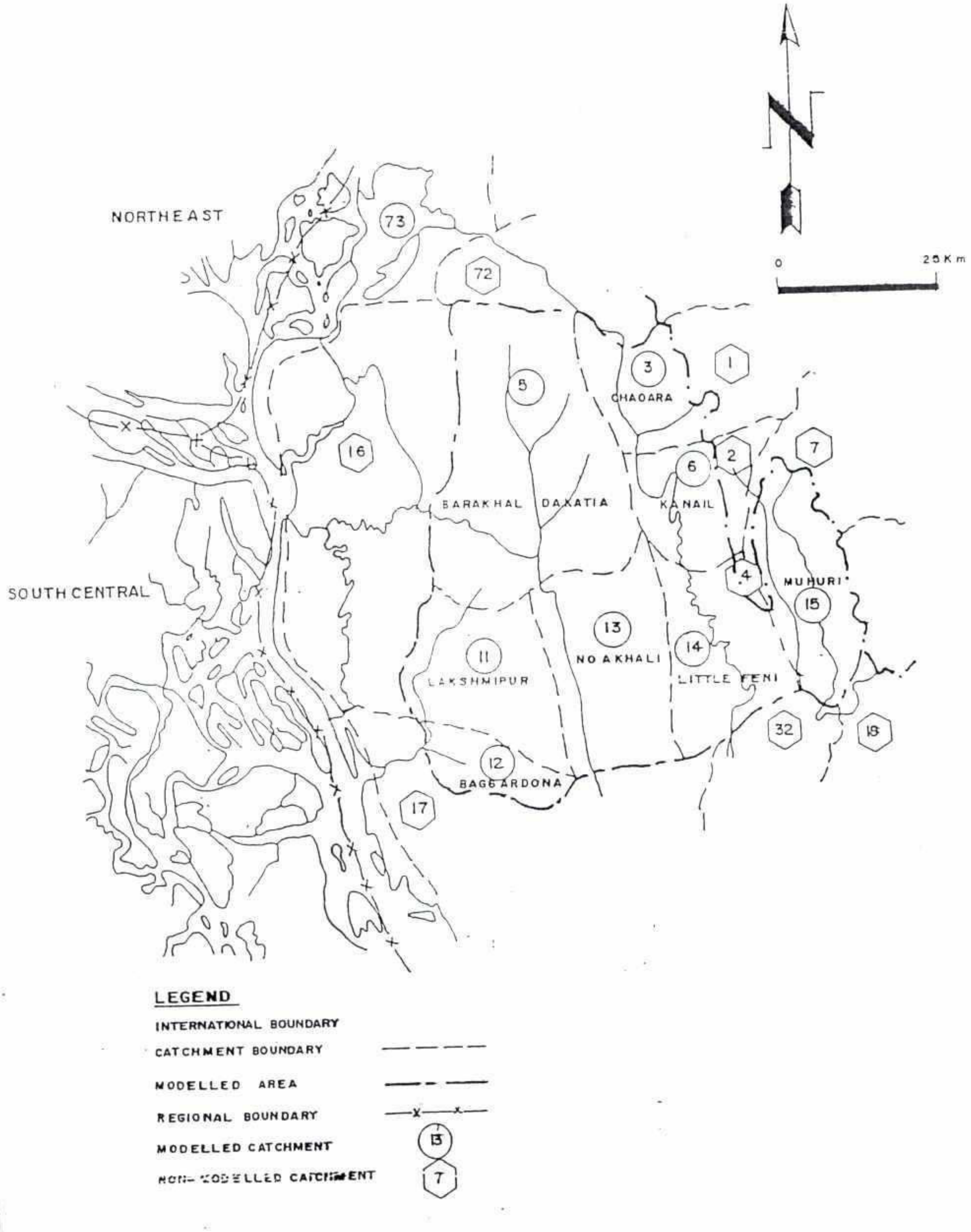
Figure VI.5.12

Modelled Catchment Areas (Southeast Region)



Source : TR 10, MPO, 1987

Network Diagram for the North/East

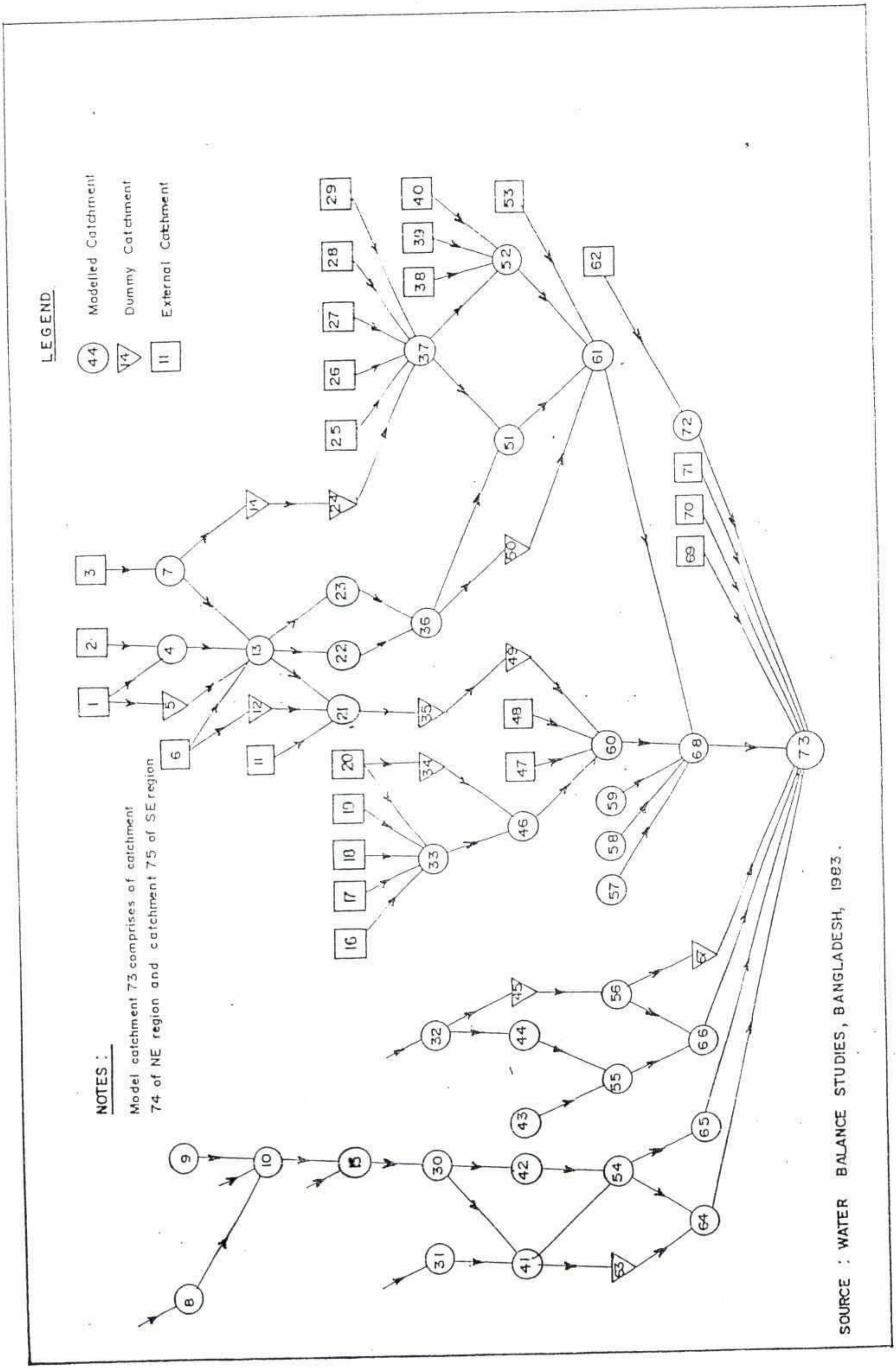
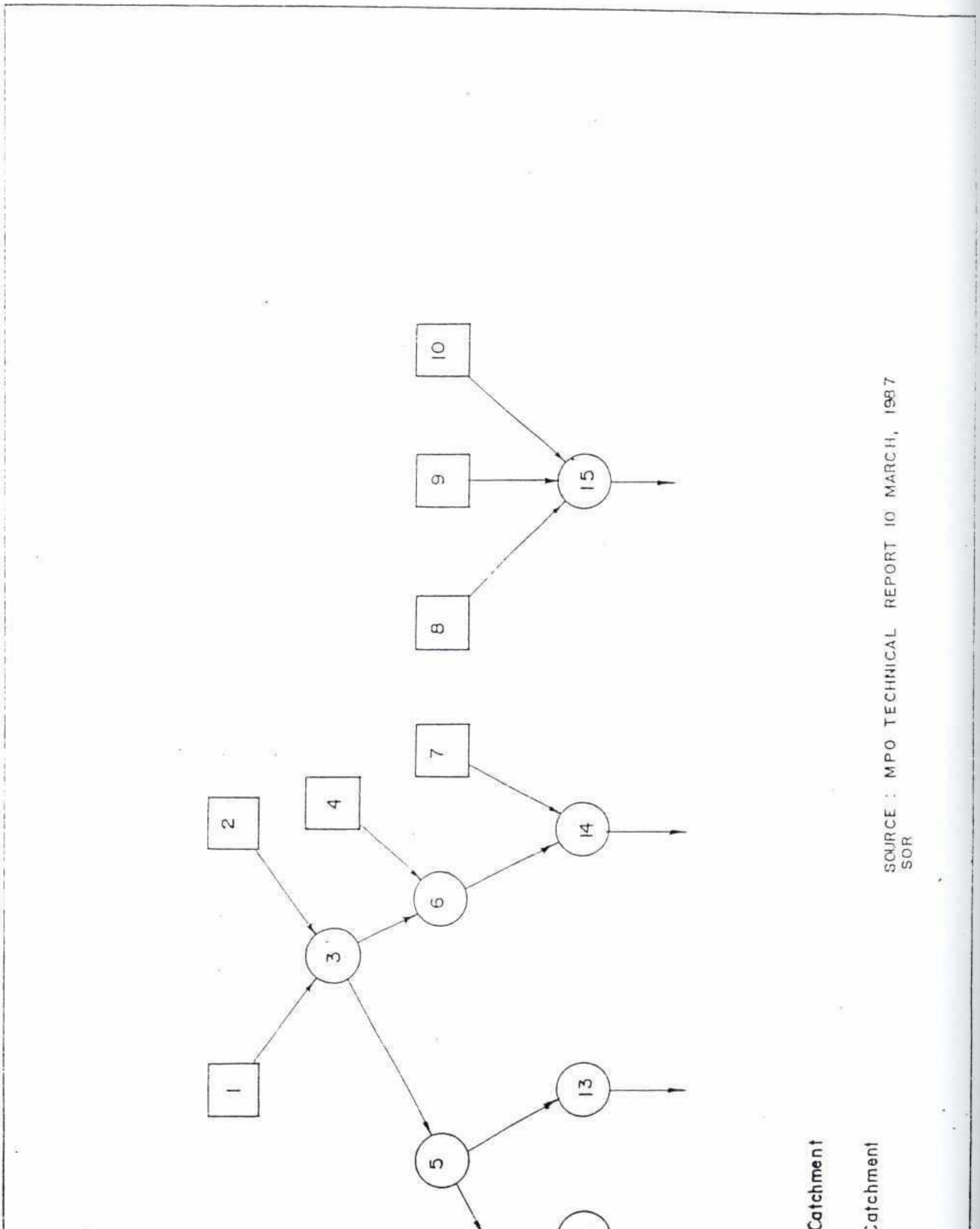


Figure VI.5.14

Network Diagram for the South/East



The model operates on a monthly basis and has been discussed in some detail in a number of previous reports (Ref. 3). The catchment model has a well founded deterministic base, and encompasses the entire water cycle. The basic driving parameters of the model are historical rainfall, potential evapotranspiration, and cross boundary flows into the regional models from India. With these, the impacts of various combinations of water use and cropping on water resource availability can be assessed.

For the purposes of the present study, the MPO model results utilising 1989 water use and cropping data have been considered to be representative of present resource availability.

VI.5.2.4 Water Balance Model Results

All of the water balance model results from the South East model are of relevance to the present study, and from the North East model the results for catchments 69, 70, 71, 72, and 73 are of relevance, although 69, 70 and 71 are classified as external catchments (Figures VI.5.11 and VI.5.12).

Mean monthly catchment outflows for the months of November to April are summarised in Table VI.5.1. The catchment outflows equalled or exceeded in 80 per cent of years are summarised in Table VI.5.4. The existence of negative flows indicates that either a flow reversal is required from the Meghna to meet irrigation demands, or that demands exceed estimated resource availability. It should be noted that although the model does flag negative flows, and outputs them, the network model will not pass a negative flow to a downstream catchment, and deficits cannot therefore be translated downstream through the system.

In catchment 5, it is expected that most of the existing deficits are satisfied by back flow in the Dakatia from the Meghna. It is clear, however, that even in average conditions, there is effectively no surplus surface water resource in the south-east region, and that any future irrigation development based on surface water resources will require water transfers from the Meghna.

It should be noted in the results for catchment 15, the Muhuri catchment, that the model does not include Muhuri reservoir, and in this respect, Tables VI.5.1 and VI.5.4 are somewhat misleading. Muhuri reservoir is discussed in more detail in section VI.5.4.

The results of the model are dependant to a large degree on the accuracy with which cropping and water use statistics are defined. The MPO put considerable effort into ensuring consistency, and model outputs have been prepared in a manner which helps to identify anomalies. Samples of a network balance output from the model are shown in Tables VI.5.7 and VI.5.8 and discussed in Section VI.5.4.3 (c)

VI.5.3 Major River Sources

The river system comprising the Jamuna, Ganges, and Meghna, provide an average annual fresh water outflow to the Bay of Bengal of approximately 800000 Mm^3. Any analysis of the availability of water in the Meghna to meet potential requirements in the south-east region would be beyond the scope of the present study. Potential availability and constraints have, however been defined by the MPO under the NWP Phase II study (Ref. 11).

TABLE VI.5.4

Catchment Outflows Equivalent or Exceeded in 80% of Years

Discharge (M^3/s)

Catchment	Area M^2	November	December	January	February	March	April
Northeast Model							
72	337	39.3	28.1	17.7	8.5	7.0	10.3
73	3 616	2 035.0	687.0	298.0	40.0	85.0	965.0
Southeast Model							
3	261	5.1	2.9	0.9	-0.2	0.2	5.4
5	1 251	13.9	6.9	-4.7	-8.8	-14.8	-13.2
6	236	8.1	5.2	2.3	0.8	0.3	3.5
11	532	4.5	-0.2	-2.3	-4.5	-6.5	-6.8
12	206	2.8	1.6	0.0	-0.7	-1.5	-1.7
13	449	12.5	3.3	-0.8	-3.6	-5.2	-4.3
14	354	12.3	7.5	3.0	-0.2	-1.2	-3.5
15 *	405	9.4	-3.9	0.2	-1.8	-3.7	0.1

* For revised water use in Table VI.5.8

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In general, the potential availability from major rivers is constrained to a greater or lesser degree by salinity levels, which increase during January through to March as fresh water inflows reduce. Salinity levels to the south of the Ganges and west of the Lower Meghna have worsened, whilst salinity levels in the Lower Meghna generally remain low due to its high inflows, even during March. It was found by the MPO (Ref. 11) that the 80 per cent reliable flow in the Lower Meghna during March, over and above that required to maintain salinity within desired limits, is approximately 3500 m^3/s. Future anticipated development diversions in the Lower Meghna will reduce this figure to 1500 m^3/s.

VI.5.4 The Water Resources of Muhuri Irrigation Project

VI.5.4.1 Introduction

The Muhuri Irrigation Project (MIP) is strictly speaking not within the study area of the South East Region Water Resources Development Programme. It lies just outside its south-eastern boundary. However, the Terms of Reference require the Consultants to *'make an operational study of the reservoir for the existing cropping pattern and the post-project recommended cropping pattern to determine the augmentation requirements of the reservoir for the original command area of 20 000 ha, the additional area that could be taken up above the project boundaries and for flushing requirements to keep the outfall canal free of silt to facilitate operation of the regulator gates at the onset of the monsoon'*. This need for augmentation is based upon the assertion that *'irrigation withdrawals by riparians above the Muhuri Irrigation Project boundaries and the dry season discharge requirements for flushing of tidal silts led to inadequate water in the reservoir during February/March to command the irrigable area of 20 000 ha'*.

These topics are addressed through an evaluation of the water resources of the Muhuri/Feni basin within Bangladesh and their need for augmentation.

VI.5.4.2 The Existing Muhuri Irrigation Project

(a) Project Planning

The Muhuri Irrigation Project was a component of the Meghna-Muhuri Water Transfer, as detailed in the 1972 Planning Report (Rahman and Associates Ltd and International Engineering Co Ref. 12). A feasibility study was prepared by the same consultants (Feasibility Study, Comilla-Noakhali Project, Muhuri Unit, December 1973 Ref. 13) based upon the identical project area, but with adjustments to the irrigation details and phasing. The feasibility study envisaged development in two phases:-

- Phase I (37 636 ha gross, 27 115 ha NCA, 23 068 ha net irrigated area) relying on the dry season flows of the Muhuri, Feni and Selonia Rivers, impounded by Feni Regulator. Irrigation is by low lift pumps (LLP) drawing from the reservoir and a network of improved distribution khals.

- Phase II (29 219 ha gross, 21 004 ha NCA, 18 413 ha net irrigated area) relying on the transfer of Meghna water and local groundwater (3 642 ha of the total net irrigated area).

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The Phase II planning also allowed for the supply of surface irrigation water to the proposed Chittagong North Project (9 308 ha net irrigated area) on the coastal plain towards Chittagong. The latter project was the final component of the 1972 Planning Report proposals.

(b) Present Development

Construction of the Phase I development, including Feni Regulator, was completed with World Bank (IDA), Canadian (CIDA) and EEC assistance in 1987. The area expected to be irrigated was reduced from 23 068 ha to 20 000 ha by the 1974 IDA appraisal mission, to take account of possible water abstractions in India. The project area is shown on Figure VI.5.15.

The FAO/World Bank Project Completion Report (March 1987, amended and updated April 1989 Ref. 14) estimates that the dry season flows in the Muhuri River at Parsuram and the Feni River at Kaliachari, in conjunction with the reservoir storage, are sufficient to irrigate only 14 500 ha, with 75% reliability. Estimates of the actual area currently irrigated (by both surface water and groundwater), in the Muhuri Reservoir catchments within Bangladesh range from 17 025 ha (from agriculture statistics for 1987/88, according to Project Completion Report) to 23 174 ha (SERWRDP Consultants' estimate). It is apparent, however, that a substantial proportion of this irrigation takes place outside the designated MIP Phase I area. Indeed, there is a separate FCDI project (Kahua-Muhuri Embankment, see Figure VI.5.15) in the upper reaches of the Muhuri River. According to the FAP 12 Rapid Rural Appraisal of this project (September 1991) some 1750 ha of irrigated boro were cultivated in 1990/91 by means of 80 LLP, 3 deep tubewells (DTW) and 17 shallow tubewells (STW). The gross area of the Kahua-Muhuri Embankment Project is about 2 600 ha. The spatial distribution of all irrigation (including groundwater), as interpreted from 1989 SPOT satellite imagery, is shown in Figure VI.5.16. The distribution by irrigation mode, based upon the 1991 AST data (Census of Lift Irrigation, prepared by the Bangladesh-Canada Agriculture Sector Team, for the Ministry of Agriculture) is shown in Table VI.5.5.

VI.5.4.3 Muhuri Reservoir

(a) General

The reservoir has an active storage capacity of 25.7 million m^3, and a surface area at full supply level of about 21 km^2. The range in operating levels is only 1.2m.

The concerns raised about the operation of Muhuri Reservoir, may be summarised as follows:

i) loss of active storage within the reservoir through siltation;

ii) increased abstraction by low lift pumps from the river system upstream of the reservoir, thereby potentially reducing inflows;

iii) the instability of the outfall channel downstream of the regulator and the dynamic nature in which this is changing and land accreting;

Figure VI.5.15

Muhuri Irrigation Project

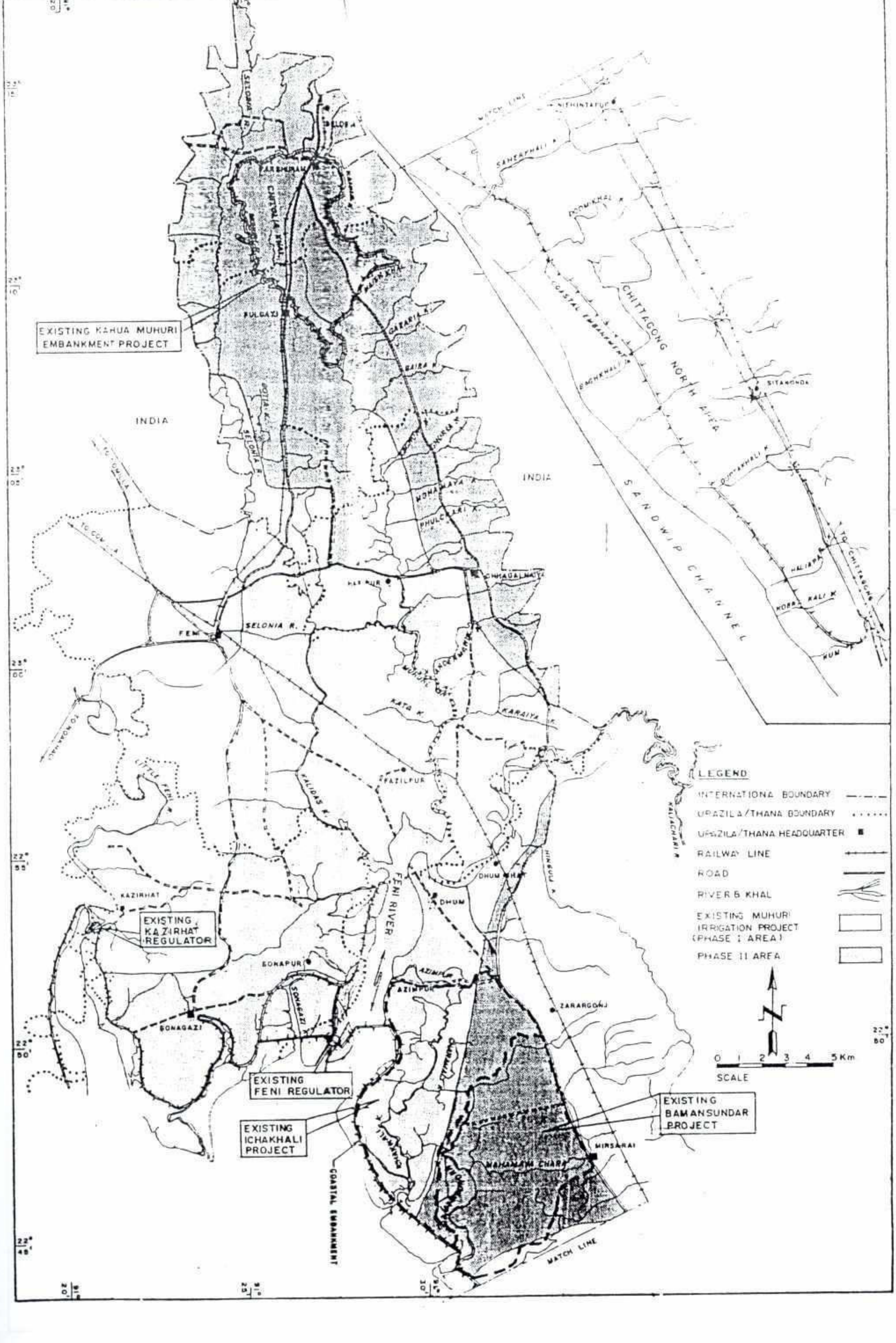

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Figure VI.5.16

Muhuri Irrigation Project
Existing Irrigation

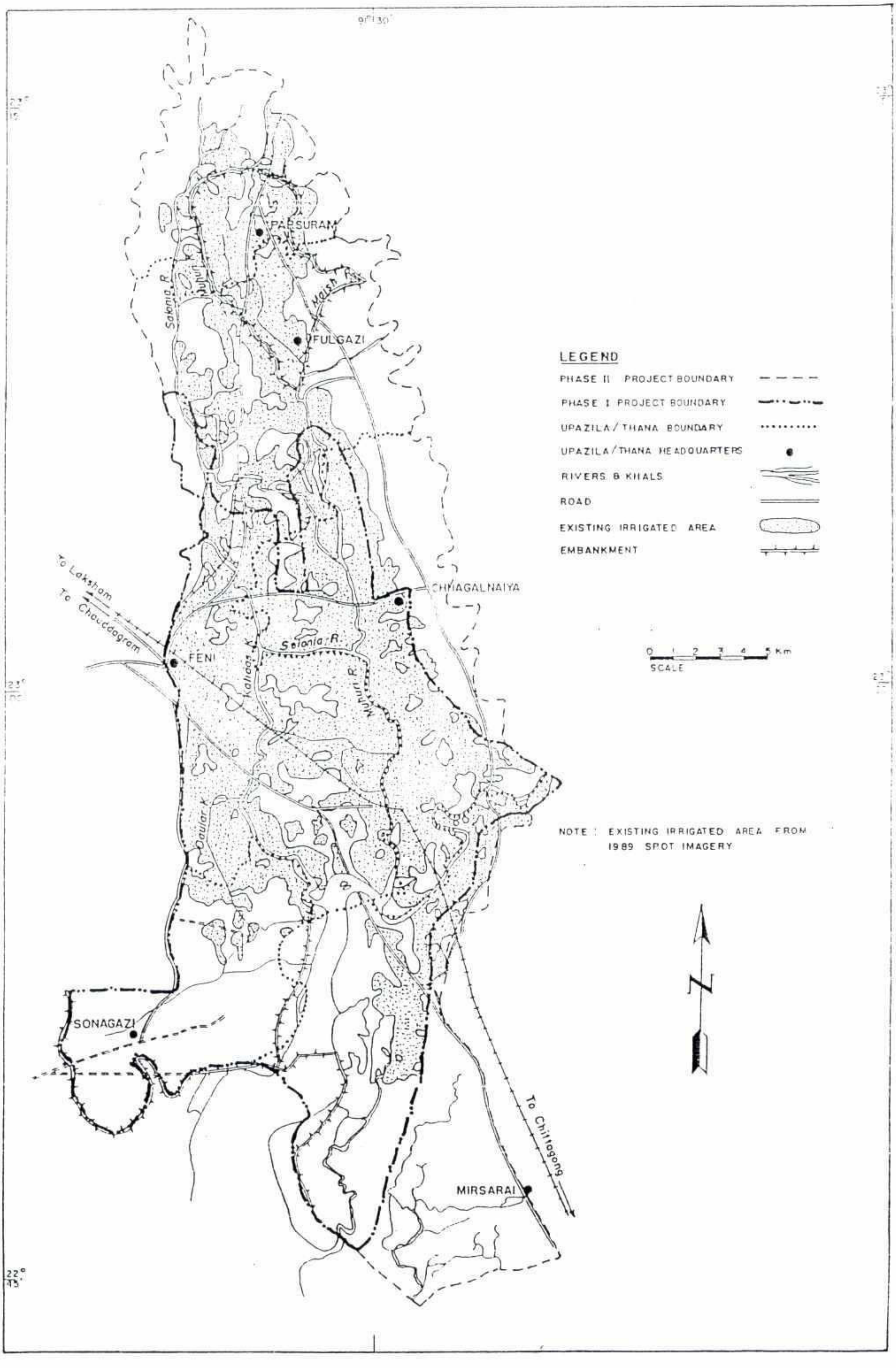


TABLE VI.5.5

Existing (1991) Irrigation within Muhuri Irrigation Project

Thana	Gross Area (ha)	NCA (ha)	Existing Irrigated Area (ha)				
			Surface	STW/ DSSTW	DTW	Total	% of NCA
PHASE I AREA							
Feni	11 655	8 268	3 563	499	758	4 820	58.3%
Sonagazi	8 256	6 039	759	2	48	810	13.4%
Chhagalnaiya	8 463	6 191	4 650	62	0	4 713	76.1%
Mirsarai	8 854	5 017	982	10	0	993	19.8%
Fulgazi	2 185	1 598	782	138	31	950	59.4%
Total Phase I	39 413	27 115	10 736	711	838	12 284	45.3%
PHASE II AREA							
Parsuram	7 073	4 952	2 422	426	96	2 943	59.4%
Fulgazi	10 392	7 276	3 558	626	41	4 225	59.4%
Chhagalnaiya	4 780	3 347	2 514	34	0	2 547	76.1%
Mirsarai	7 754	5 429	1 063	11	0	1 074	19.8%
Total Phase I	29 999	21 004	9 556	1 097	236	10 889	51.8%
TOT. PHASE I&II	69 412	48 118	20 292	1 808	1 074	23 174	48.2%

Source: AST Census of Lift Irrigation (1991)

iv) the requirement for gate opening to control siltation immediately downstream of the reservoir during the dry season;

v) through the above, the potential loss of irrigation command from the reservoir.

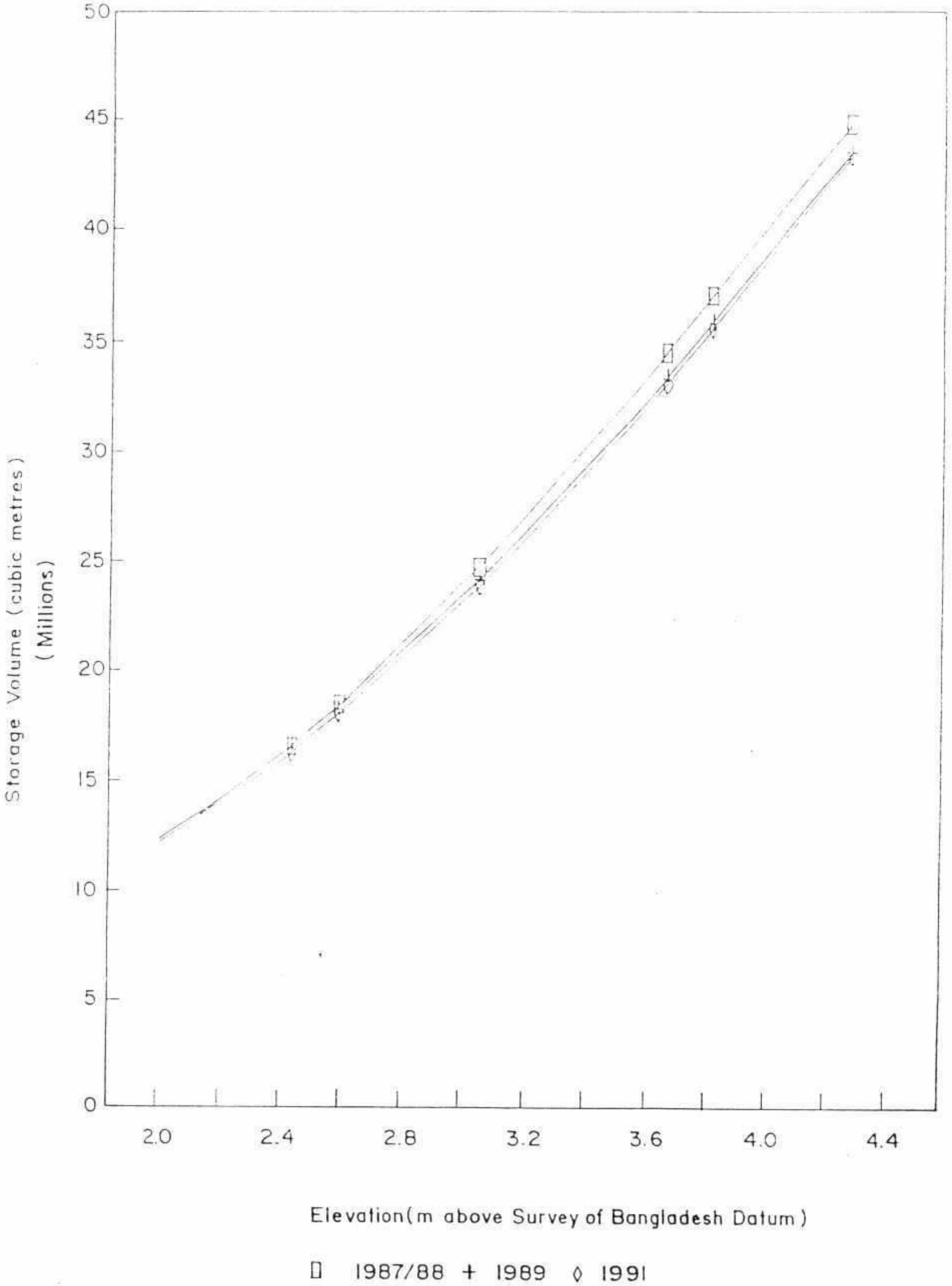
Hydrological reservoir operation studies have been carried out in order to address some of the above issues, and to determine more precisely the total area which may be irrigated by existing surface water resources.

(b) Reservoir Siltation

In order to assess reservoir siltation, an evaluation was made of changes in storage over the years 1987, 88, 1989 and 1991. Cross sections have been taken for each of these years on established survey lines across the reservoir, and are thus directly comparable between surveys. Elevation-storage curves have been calculated from these cross sections, and are presented in Figure VI.5.17. Details of the changes in storage are given in Table VI.5.6. Unfortunately, the cross sections do not cover the whole extent of the reservoir, and Figure VI.5.17 and Table VI.5.6 do not therefore represent the whole reservoir and cannot be compared with the elevation-storage characteristics prepared before construction (see Table VI.5.9 in Section (c) below). In particular, the upstream portions of the reservoir are omitted, and it is here that any siltation is likely to be most significant.

Figure VI.5.17

Muhuri Reservoir Storage Capacity



Note: These curves represent only that part of the reservoir covered by Surveyed cross-sections.

However, although some loss in live storage due to sedimentation is apparent, at the present rate it would take nearly 50 years to halve the present capacity within the portion covered by the cross sections. Even then, 75 % of the dead storage would remain.

TABLE VI.5.6

Changes in Storage of Muhuri Reservoir, 1987/88 to 1991

	1987/88	1989		1991	
	Mm^3	Mm^3	% of 1987/88	Mm^3	% of 1987/88
Total Storage below 3.81 m	37.02	35.86	96.9	35.54	96.0
Live Storage (2.59 m to 3.81 m)	18.64	17.58	94.3	17.57	94.3
Dead Storage below 2.59 m	18.38	18.28	99.5	17.97	97.7

There are no sediment rating curves available for either the Feni or Muhuri rivers, and there is insufficient data at this time to attempt to model rates of loss of storage. On the basis of a sediment yield of 800 tonnes/km²/year, and assuming a bulk density of sediments of 1.6 tonnes/m³, annual sediment inflow could be of the order of 3 Mm^3. Continued monitoring is essential, but as already noted, the general indicators are that there is no great cause for concern. Rates of reservoir sedimentation are related to the ratio of reservoir storage to annual inflow, and the manner in which the reservoir is operated. For a given annual sediment concentration in the reservoir inflows, the larger the reservoir, the greater will be the rate of sedimentation. The gross storage of the Muhuri reservoir at full supply level is only about 60 Mm^3, whilst mean annual inflow is of the order of 3 800 Mm^3. The trap efficiency during the main monsoon season should not therefore be high.

The greatest sediment inflows will occur during the months of June to September. Irrigation demand in these months is low, and operational policy should be to keep reservoir levels as low as possible during these months, thereby minimising loss of active storage. Such a policy is obviously also advantageous from a flood control point of view, although it is understood that some fisheries interests may be affected. There can, however, be no supportable fisheries argument as reservoir siltation would also limit the sustainability of fisheries. The implications of such a policy on reliability of supply levels is discussed in Section (c) below.

(c) Reservoir Operation Studies

The objective of the reservoir operation studies has been to assess the reliable yields from the reservoir for irrigation supply. Over 50% of the Muhuri Reservoir catchment area lies in India. Inflows on the Muhuri River are gauged at Parsuram, with records dating from 1965. The Feni River is gauged at Kaliachari, and records data from 1975.

Part of the Muhuri reservoir catchment area is represented in the MPO water balance model prepared for the National Water Plan (NWP) Phase I and is delineated as catchment Nr 15 (See Figure VI.5.18). This is effectively all of the catchment upstream of the confluence of the Feni and Muhuri Rivers. Inflows to the Muhuri catchment at Parsuram, and from other minor streams, have been infilled and extended under the NWP Phase II, using a combination of correlation and stochastic techniques. The same approach has been used as part of the present study to extend and infill flow records on the Feni River at Kaliachari. Such an approach is in fact the only one feasible, in view of the absence of hydrological, topographic or land use data for the Indian part of the catchment.

The Muhuri reservoir was not incorporated in the water balance model, but the model does include irrigation from the reservoir within catchment Nr 15. The model can therefore provide net inflows to Muhuri Reservoir from catchment Nr 15 and the upstream catchments in India.

The mean annual water balance for catchment Nr 15 is summarised in Table VI.5.7. Outputs from the model also include time series net catchment outflows, and these have been used as inflows for the reservoir operation studies. The deficits generated by the water balance model in catchment outflows assume that there is no storage in the catchment. By utilising this output for operational studies, the outcome is the additional reservoir yield that can be obtained, over and above existing water use from the reservoir for irrigation.

It will be noted from Table VI.5.7 that crop deficits are indicated in the months of November, December, January and February. There may in fact be some good reason for this, but for the purposes of the present investigations, surface water abstractions in the catchment have been increased to a level that satisfies the deficits, and the model re-run. The revised mean annual water balance is summarised in Table VI.5.8. Some minor deficits in crop water supply still remain, but they are in part related to tree and dry land crops, rather than the boro crop.

In addition to the water balance model outflows for catchment Nr 15, the infilled and extended flow records for the Feni River at Kaliachari have been used directly as a further inflow to the reservoir.

Simulation of the reservoir operation has been carried out using the program ONRES1, which carries out a continuous simulation using a time series of monthly inflows and rainfall, and specified monthly evaporation and releases. The reservoir model has been used to assess:

i) Whether full wet season drawdown is feasible.

ii) What additional releases are possible from the reservoir, while maintaining 80% reliability of supply in each month of the irrigation season.

Figure VI.5.18

Southeast Region Catchment Delineation for the Water Balance Model

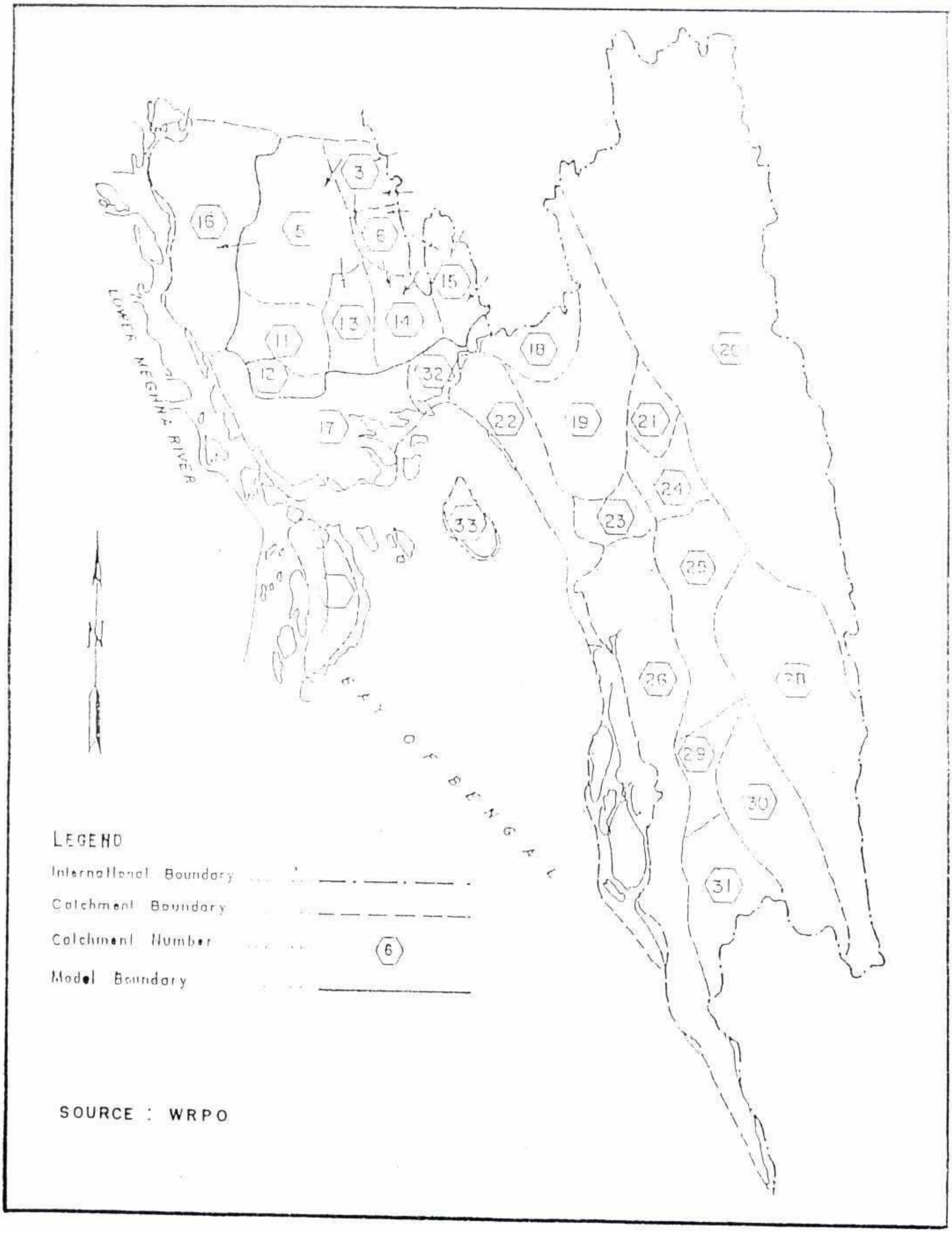


TABLE VI.5.7

Mean Annual Water Balance, Muhuri Catchment

Catchment 015 Southeast
Network Balances
Mean monthly balance components
Catchment Area: 405.0 (sq. km)
Cultivable Area: 265.0 (sq. km)

Depth in metres

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total	
Rainfall	0.206	0.344	0.510	0.664	0.543	0.307	0.157	0.047	0.016	0.008	0.020	0.055	2.877	
Actual Evap-trans	0.111	0.132	0.103	0.106	0.103	0.094	0.088	0.061	0.036	0.052	0.066	0.095	1.046	
Local Runoff	0.022	0.173	0.405	0.626	0.440	0.248	0.114	0.040	0.019	-0.010	-0.020	-0.050	2.007	
Inflow	0.081	0.258	0.406	0.685	0.534	0.341	0.225	0.095	0.061	0.040	0.033	0.041	2.800	
Outflow	0.104	0.431	0.812	1.311	0.973	0.590	0.339	0.135	0.079	0.030	0.013	-0.009	4.807	
Cropping														
Proportion of Area														
B. Aus													0.03	
M.B. Aus													0.27	
B. Aman													0.00	
T. Aman													0.73	
Boro													0.54	
Wheat													0.00	
Jute													0.00	
Sugar													0.01	
Others													0.03	
Tree													0.01	
Cropping Intensity	0.32	0.32	0.32	0.32	0.75	0.75	0.75	0.75	1.32	0.59	0.59	0.56	1.06	
Crop requirement over cropping area														
Crop Requirement	0.165	0.185	0.130	0.113	0.144	0.135	0.129	0.099	0.102	0.099	0.132	0.141		(Over cropped area)
Irrigation Appl.	0.325	0.123	0.011	0.003	0.000	0.000	0.000	0.001	0.013	0.091	0.102	0.198		(Over cropped area)
Crop Deficit	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.058	0.016	0.020	0.000		(Over cropped area)
Crop requirement over catchment														
Crop Requirement	0.034	0.039	0.027	0.024	0.070	0.066	0.063	0.049	0.067	0.038	0.051	0.052	0.579	
Irrigation Appl.	0.068	0.025	0.002	0.001	0.000	0.000	0.000	0.000	0.009	0.035	0.039	0.072	0.251	
Crop Deficit	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.038	0.006	0.008	0.000	0.061	
Catchment water use														
S.W. Abstraction	0.058	0.022	0.002	0.001	0.000	0.000	0.000	0.000	0.008	0.030	0.034	0.062	0.218	
G.W. Abstraction	0.010	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.006	0.006	0.011	0.047	

Source: MPO Water Balance Model

TABLE VI.5.8

Revised Muhuri Catchment Water Balance

Catchment 015 Southeast
Network Balances
Mean monthly balance components
Catchment Area: 405.0 (sq. km)
Cultivable Area: 265.0 (sq. km)

Depth in metres

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Rainfall	0.206	0.344	0.510	0.664	0.543	0.307	0.157	0.047	0.016	0.008	0.020	0.055	2.877
Actual Evap-trans	0.111	0.133	0.103	0.106	0.103	0.094	0.088	0.068	0.073	0.057	0.074	0.094	1.104
Local Runoff	0.049	0.207	0.428	0.628	0.440	0.248	0.114	0.020	-0.050	-0.016	-0.033	-0.044	1.991
Inflow	0.081	0.258	0.406	0.685	0.534	0.341	0.225	0.095	0.061	0.040	0.033	0.041	2.800
Outflow	0.129	0.465	0.834	1.313	0.973	0.590	0.339	0.115	0.011	0.023	0.000	-0.003	4.790

Cropping

Proportion of Area

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
B. Aus	---	---	---										0.03
M.B. Aus	---	---	---										0.27
B. Aman	---	---	---	---	---								0.00
T. Aman				---	---	---	---						0.73
Boro								---	---	---	---		0.54
Wheat								---	---	---	---		0.00
Jute	---	---	---										0.00
Sugar	---	---	---	---	---	---	---	---	---				0.01
Others								---	---	---			0.03
Tree	---	---	---	---	---	---	---	---	---	---			0.01
Cropping Intensity	0.32	0.32	0.32	0.32	0.75	0.75	0.75	0.75	1.32	0.59	0.59	0.56	1.06

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Crop requirement over cropping area													
Crop Requirement	0.165	0.185	0.130	0.113	0.144	0.135	0.129	0.099	0.102	0.099	0.132	0.141	(Over cropped area)
Irrigation Appl.	0.325	0.123	0.011	0.003	0.000	0.000	0.000	0.057	0.130	0.126	0.142	0.198	(Over cropped area)
Crop Deficit	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.002	0.001	0.002	0.000	(Over cropped area)
Crop requirement over catchment													
Crop Requirement	0.034	0.039	0.027	0.024	0.070	0.066	0.063	0.049	0.067	0.038	0.051	0.052	0.579
Irrigation Appl.	0.068	0.025	0.002	0.001	0.000	0.000	0.000	0.028	0.085	0.048	0.055	0.072	0.384
Crop Deficit	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.001	0.000	0.004
Catchment water use													
S.W. Abstraction	0.058	0.022	0.002	0.001	0.000	0.000	0.000	0.028	0.083	0.043	0.050	0.062	0.349
G.W. Abstraction	0.010	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.006	0.006	0.011	0.047

Source: MPO Water Balance Model

B:ANX-VI-5

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The reservoir characteristics used in the operation studies are summarised in Table VI.5.9

TABLE VI.5.9

Muhuri Reservoir Characteristics

Elevation		Storage		Reservoir Area
feet	metre	1000's Acre ft.	Mm^3	(km^2)
6	1.83	14.5	7.9	14
6.5	1.98	16.3	20.1	15
7	2.13	18.3	22.6	19
8	2.44	23.5	29.0	21
8.5	2.59	26.1	32.2	21
9	2.74	28.7	35.4	21
10	3.05	33.9	41.8	21
11	3.35	39.1	48.2	21
12	3.66	44.3	54.6	21
12.5	3.81	46.9	57.9	21

Notes:

1. Minimum supply level 8.5 feet.
2. Maximum operating level 12.5 feet.
3. Reservoir Area approximate only - derived from slope of elevation-storage curve.

Source: Muhuri Irrigation Project Operation and Maintenance Manual for Project Major Works IECO/Muhuri Design Cell (BWDB), March 1983.

It has been found that the reservoir can be kept at its lower operation level of 8.5 (2.59m) feet during the months of June to September, and will fill reliably in October. Although model results have indicated that the reservoir will remain full through November, the variability in October flows is such that any delay in filling beyond the end of September is not recommended.

The results of the simulation using the program ONRES1 are given in Table VI.5.10. The prescribed minimum monthly releases have been set on the basis of:-

- a gate flushing allowance of 3.0 m^3/s (see Section (d) below)
- irrigation water requirements for an additional 6 000 ha of irrigated area, on the basis of the irrigation duty implicit in the water balance model (0.75 l s/ha).

The minimum release for the critical month of March is 7.5 m^3/s (20.1 Mm^3). It is found that this release can be achieved with 80.9% reliability, based upon the inflow data for 1965/66 to 1988/89.

TABLE VI.5.10

Simulation of Muhuri Reservoir Operation
Minimum Release in March For Gate Flushing and Additional Irrigation
7.5 m3/s. Minimum Dry Season Operating Level 8.5 feet (2.59 m) Above SOB Datum.

Gross Capacity 57.9 Million Cubic Metres

Units-million cubic metres unless stated

	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Prescribed minimum	32.2	32.2	32.[illegible]	32.2	32.2	32.[illegible]	32.2	32.2	32.2	32.2	32.[illegible]	32.2	month-end storage
Prescribed minimum	27.2	16.11	296.[illegible]	339.21	339.21	296.[illegible]	10.7	11.7	16.1	16.1	16.[illegible]	20.1	monthly release
Monthly evaporation(mm)	183.0	183.0	135.[illegible]	140.0	140.0	134.[illegible]	131.0	108.0	96.0	103.0	123.[illegible]	[illegible]69.0	
Monthly rainfall(mm)	0.0	0.0	0.[illegible]	0.0	0.0	[illegible]	0.0	0.0	0.0	0.0	0.[illegible]	0.0	
Assumed monthly seepage	0.0	0.0	0.[illegible]	0.0	0.0	[illegible]	0.0	0.0	0.0	0.0	0.[illegible]	0.0	

Full Inflow Sequence

Year	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1965/66	34.2	87.0	462.9	932.9	1224.8	499.5	[illegible].4	103.7	40.7	39.6	19.4	8.8	3718.0
1966/67	16.8	92.7	411.4	497.4	1084.2	623.4	[illegible]3.7	110.7	95.6	58.4	25.9	33.7	3384.4
1967/68	57.0	176.8	347.1	763.6	695.3	507.3	3[illegible].2	73.1	22.2	25.2	12.8	22.5	3014.1
1968/69	59.6	369.4	1153.4	1276.8	668.5	377.9	[illegible].5	79.1	23.8	28.1	14.5	15.3	4227.9
1969/70	129.9	90.3	675.0	883.6	1151.4	482.6	[illegible]6.2	84.8	27.3	29.5	14.5	6.2	3751.2
1970/71	49.8	139.8	415.2	1065.7	735.2	355.1	3[illegible]6.7	134.8	41.5	37.2	17.2	3.53	392.2
1971/72	93.8	292.5	531.6	961.8	880.7	466.8	2[illegible].5	106.0	35.6	31.1	16.8	16.6	3703.8
1972/73	45.4	109.3	403.3	467.6	1009.5	204.0	[illegible]35.3	53.1	11.2	16.9	6.3	9.9	2471.8
1973/74	49.8	712.2	682.5	719.7	590.1	362.9	[illegible].8	234.6	91.9	52.5	18.4	15.3	3721.4
1974/75	66.6	318.2	702.4	1752.7	1072.2	723.4	6[illegible]8.5	168.7	74.7	58.7	36.3	24.1	5606.6
1975/76	11.7	72.6	167.4	1021.0	419.7	430.8	552.3	219.5	71.0	46.9	19.5	29.2	3061.6
1976/77	25.9	136.1	813.6	734.7	618.7	267.5	[illegible]0.0	76.5	28.4	23.8	15.7	4.8	2895.7
1977/78	410.1	428.8	916.8	923.0	673.3	361.6	2[illegible]3.6	91.8	22.0	31.3	15.2	7.0	4114.4
1978/79	20.7	637.2	988.1	731.5	424.0	611.2	[illegible].8	78.0	29.5	25.7	14.3	6.4	3762.3
1979/80	30.6	66.2	280.7	1258.3	857.6	515.5	2[illegible].8	116.1	51.7	31.9	16.0	29.5	3462.0
1980/81	10.1	371.8	311.8	437.9	753.7	464.5	2[illegible]3.8	73.9	3.2	6.4	10.2	18.5	2755.8
1981/82	261.5	341.2	498.7	2035.6	711.7	257.1	[illegible]2.2	39.7	1.3	8.8	8.2	-4.8	4271.3
1982/83	43.3	35.9	593.0	317.4	3106.7	994.3	[illegible].7	77.2	26.2	30.5	33.1	60.8	5483.3
1983/84	293.7	763.3	289.5	1019.1	1454.9	296.3	4[illegible].2	99.3	57.6	55.2	25.6	1.6	4820.2
1984/85	10.1	666.4	460.1	1452.2	597.0	553.1	2[illegible].1	75.4	31.1	30.5	19.8	19.8	4205.7
1985/86	87.9	285.0	712.8	771.1	754.5	273.2	[illegible]5.3	52.6	14.7	21.4	8.0	-3.5	083.0
1986/87	127.3	132.0	269.0	774.9	417.6	433.4	4[illegible]3.9	284.6	45.0	40.7	14.3	38.6	3011.2
1987/88	260.2	89.7	336.2	1130.0	1359.0	804.6	22[illegible].3	113.3	35.1	25.4	15.3	51.2	4449.3
1988/89	43.8	688.3	727.1	1624.2	792.5	700.9	5[illegible]5.4	129.6	60.5	47.4	26.1	10.7	5356.6
Mean	93.3	295.9	547.9	981.4	918.9	482.0	2[illegible]2.8	111.5	39.2	33.5	17.7	17.7	3821.8
CV	1.13	0.80	0.46	0.43	0.59	0.39	[illegible].50	0.54	0.65	0.43	0.42	0.92	0.23
Skew	1.8	0.8	0.7	0.8	3.0	0.9	[illegible].9	1.6	0.8	0.2	0.9	1.1	0.7

Values Equalled or exceeded 80% of the time (Not an homogeneous sequence)

X(I)	21.9	89.83	17.37	22.36	01.93	09.51	[illegible]2.27	4.2	22.02	4.1	13.1	5.1	3024.8

TABLE VI.5.10 (Contd)

Month-end Storage
Million Cubic metres

Year	Apr	May	June	Ju.y	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1965/66	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	57.7	43.9	577.9
1966/67	32.2	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	57.9	57.9	566.3
1967/68	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	51.7	53.6	581.5
1968/69	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	52.9	46.9	576.0
1969/70	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	53.9	38.4	568.5
1970/71	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	56.5	36.4	569.1
1971/72	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	55.5	48.5	580.3
1972/73	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	51.1	50.0	37.5	32.2	531.2
1973/74	53.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	56.8	50.8	579.8
1974/75	57.9	57.9	32.2	57.9	32.2	32.2	57.9	57.9	57.9	57.9	57.9	57.9	617.7
1975/76	40.2	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	57.9	57.9	574.3
1976/77	54.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	55.9	37.1	566.3
1977/78	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	53.7	37.7	567.6
1978/79	32.2	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	52.8	35.7	539.0
1979/80	35.7	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	55.2	57.9	567.1
1980/81	38.1	57.9	32.2	32.2	32.2	32.2	57.9	57.9	43.0	32.2	32.2	32.2	480.3
1981/82	57.9	57.9	32.2	57.9	32.2	32.2	57.9	57.9	41.4	32.2	32.2	32.2	524.1
1982/83	50.6	57.9	32.2	32.2	57.9	32.2	57.9	57.9	57.9	57.9	57.9	57.9	610.4
1983/84	57.9	57.9	32.2	32.2	57.9	32.2	57.9	57.9	57.9	57.9	57.9	35.9	595.7
1984/85	32.2	57.9	32.2	57.9	32.2	32.2	57.9	57.9	57.9	57.9	57.9	55.6	589.7
1985/86	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	54.5	57.9	46.4	32.2	551.4
1986/87	57.9	57.9	32.2	32.2	32.2	32.2	57.9	57.9	57.9	57.9	52.7	57.9	586.8
1987/88	57.9	57.9	32.2	32.2	57.9	32.2	57.9	57.9	57.9	57.9	54.3	57.9	614.1
1988/89	57.9	57.9	32.2	57.9	32.2	32.2	57.9	57.9	57.9	57.9	57.9	45.2	605.0
Mean	51.6	57.9	32.2	36.5	35.4	32.2	57.9	57.9	56.2	55.4	52.6	45.8	571.7
CV	0.1	90.0	00.0	00.2	70.2	50.0	00.0	00.0	00.0	80.1	30.1	50.2	20.35
Skew	-1.2	-1.1	-1.1	1.9	2.4	-1.1	-1.1	-1.1	-2.8	-3.0	-2.0	0.0	-1.1

Nr of months in the sequence 288
Nr of months the reservoir spilled 149
Nr of months the reservoir emptied 100

Nr of years in the sequence 24
Nr of years the reservoir spilled 24
Nr of years the reservoir emptied 24

Average monthly inflow 318
Average monthly losses-2.(-0.7%)

Average monthly outflow 321
Average monthly spill 72 (22.6%)

TABLE VI.5.10 (Contd)

Total Reservoir Outflow

million cubic metres

Year	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1965/66	30.6	85.2	498.4	946.3	1237.2	504.6	240.2	102.4	39.3	37.9	16.9	20.1	3759.2
1966/67	25.3	66.5	445.8	502.41	1C0.5	629.5	310.1	109.3	96.1	56.5	23.3	32.1	3397.5
1967/68	56.8	177.7	378.0	775.2	704.3	515.5	286.8	70.8	20.2	23.0	16.9	20.1	3045.4
1968/69	54.7	374.7	1198.2	1288.1	674.9	381.0	133.7	76.9	21.8	26.0	16.9	20.1	4267.1
1969/70	121.8	88.2	714.3	895.7	1166.2	486.1	148.5	82.6	25.3	27.7	16.9	20.1	3793.4
1970/71	29.6	140.6	447.3	1078.5	742.5	356.8	375.5	134.5	39.5	35.1	16.9	20.1	3416.9
1971/72	72.8	293.5	564.1	969.9	888.8	468.4	244.3	106.2	33.6	28.9	16.9	20.1	3707.7
1972/73	34.7	109.6	435.4	471.8	1020.4	202.5	109.7	50.9	16.1	16.1	16.9	14.0	2498.0
1973/74	27.2	718.3	719.5	727.0	592.5	367.2	165.1	237.1	91.6	50.4	16.9	20.1	3732.9
1974/75	59.1	322.6	735.5	1749.1	1103.8	727.6	585.8	167.3	72.7	56.5	34.0	20.6	5634.6
1975/76	27.2	53.9	195.0	1035.1	421.7	434.6	532.6	220.2	69.0	45.2	17.3	26.1	3077.8
1976/77	27.2	134.5	855.3	741.8	629.0	269.5	125.1	74.3	26.4	21.9	16.9	20.1	2941.9
1977/78	399.6	434.0	952.4	933.4	678.4	362.9	207.4	90.7	20.0	29.2	16.9	20.1	4145.0
1978/79	24.9	619.4	1022.0	739.0	428.3	617.6	169.5	75.8	27.4	23.5	16.9	20.1	3784.4
1979/80	27.2	44.0	313.9	1270.6	870.3	517.2	181.0	115.8	50.2	29.7	16.9	24.3	3461.3
1980/81	27.2	360.4	339.5	442.2	760.7	467.8	270.9	71.6	16.1	16.0	8.1	16.3	2796.8
1981/82	240.1	347.2	530.7	2025.9	742.4	258.5	83.9	37.4	16.1	15.9	5.9	0.0	4304.0
1982/83	27.2	27.2	629.5	322.9	3092.9	1024.6	136.6	75.6	24.3	28.9	31.8	59.4	5480.9
1983/84	300.1	771.2	319.1	1031.0	1442.7	324.2	443.4	97.5	56.6	53.2	23.0	20.1	4882.1
1984/85	11.5	652.7	491.5	1446.0	627.6	556.6	265.0	73.2	29.7	28.4	17.6	20.1	4220.0
1985/86	84.9	288.9	747.7	779.4	76-.9	275.3	77.4	50.51	6.1	16.1	16.9	7.2	3125.4
1986/87	106.6	132.8	298.1	784.4	422.1	437.7	409.2	285.4	-3.0	38.6	16.9	32.0	3006.8
1987/88	265.0	88.73	65.4	1143.9	1345.3	836.3	202.0	111.5	33.3	23.3	16.9	45.2	4476.8
1988/89	44.0	698.7	757.7	1612.0	823.8	707.3	479.5	129.2	58.5	45.2	24.1	20.1	5400.1
Mean	88.6	292.9	581.4	988.0	928.4	488.7	257.6	110.3	39.3	32.2	18.3	22.4	3848.2
CV	1.1	70.8	20.4	40.4	20.5	80.4	00.5	60.5	50.6	00.4	00.3	20.5	10.22
Skew	1.9	0.8	0.7	0.8	3.0	1.0	0.9	1.6	1.2	0.6	0.9	1.5	0.7

Values Equalled or Exceeded 80 percent of the time (Not an Homogeneous Sequence)

X(1)	27.2	85.9	345.3	729.7	627.9	331.6	134.4	72.0	20.0	22.2	16.9	20.1	3052.7

Percent of time p. the specified value of X is equalled or exceeded

X(I)	27.2	16.1	1296.0	1339.2	1339.2	1296.0	10.7	11.7	16.1	16.1	16.9	20.1	5405.2
P(I)	85.1	100.0	0.3	17.7	11.1	-3.4	100.0	100.0	100.0	89.2	89.2	80.9	10.6

The reservoir has a substantial dead storage capacity, and if it were possible to utilise the storage down to 6.5 feet (1.98 m) rather than 8.5 feet (2.59 m), the dependable releases may be increased. A revised analysis on this basis showed that 8.5 m^3/s (22.8 Mm^3) could then be released in March, with 80.9% reliability. Allowing 3.0 m^3/s for gate flushing the balance of 5.5 m^3/s is sufficient to irrigate some 7 300 ha.

From Table VI.5.8, the irrigated area included in the water balance model is 14 300 ha (265 km^2 at 54% intensity of boro). Assuming this is split between surface water and groundwater in the ratio 0.062 to 0.011 in March (last two lines of Table VI.5.8), the area irrigated by surface water is 12 150 ha. Adding the additional irrigable area from the reservoir simulation, the total area irrigable from existing surface water resources is between 18 150 ha and 19 450 ha. This compares with existing surface water irrigation of 20 292 ha from Table VI.5.5. Examination of the water level records for recent years indicates that the reservoir is almost always maintained at or near 12.5 feet (3.81 m) elevation throughout the irrigation season. It is therefore concluded that existing surface water resources are sufficient for the irrigation of the existing 20 292 ha, but there is no additional potential.

(d) **Land Accretion and Outfall Siltation**

The rate of land accretion following the closure of the cross-dam at Feni Regulator has been quite dramatic. Prior to closure, the channel invert had been at -10 m, and there was open estuary downstream of the regulator. The channel bed is now often at −1m or −2m immediately downstream of the regulator, and about 3 km of land has accreted south of the closure. Drainage from the regulator has changed its path, and with high velocities during flood, the channel is extremely mobile. Serious bank erosion was caused immediately downstream of the regulator in 1990 and 1991, and prediction or control of the movement of the channel will be extremely difficult. This aspect cannot be addressed as a part of the South East Regional Study, but needs to be given serious attention. Regular monitoring of the situation is essential.

Siltation at the outfall of the regulator occurs during flood tides. An observably heavy silt load is carried by the tide, some of which is deposited during slack water at the tidal peak. The sediments deposited appear to be in the very fine silt fractions, and are cohesive. Once deposition has occurred it is very difficult to achieve re-suspension, and classical sediment transport theory for non-cohesive materials no longer applies.

Rates of sedimentation downstream of the regulator cannot be predicted. A monitoring programme is required to assist in management of the problem and may lead to a better understanding of future means of control.

With regard to the requirements for gate operation to control siltation in the dry season, there is no means by which this can be determined analytically. The desilting procedure laid down in the "Operation and Maintenance Manual for Project Major Works" (IECO Muhuri Design Cell (BWDB) March 1983 Ref. 14) is as follows:

"Silt deposition in the area downstream of the flap gates should be monitored constantly. It should be observed visually on a daily basis especially during the dry season. Heavy silt accumulation is expected to occur behind the flap gates. As the flow of the tide water or tidal bore is stopped by the regulator structure, the suspended sediments in the tide water drop in the area downstream of the structure. This silting condition has been observed to occur in the existing Little Feni Regulator during the dry season due to infrequent and minimal

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release of water through the regulator to flush the sediments deposited behind the flap gates. The flap gates are being blocked by the heavy silt deposits and could not operate normally. The same situation will occur in the Feni Regulator if full attention is not given to the silt deposition behind the flap gates. An operating plan should be followed to prevent the silt from accumulating to an extent that will prevent the flap gates from opening.

The radial gates should be opened when the silt level behind the flap gates is observed to be at about 4.0 feet elevation. With this condition, the reservoir water pressure can overcome the passive resistance of the silt behind the flap gates. The gate opening should not be more than 2 feet. The sluicing or flushing operation should be done for a period of not more than 15 minutes. It is not necessary to open all the gates at the same time. Gates to be opened should correspond to the areas where heavy silt deposit is observed. If it is necessary to operate all the gates, alternate gates should be opened with the remaining set of gates to be operated only after sluicing operation on the first set of gates is completed. This operating condition has the advantage of disturbing and loosening the silt deposits in adjacent bays due to turbulence and eddying effect of the discharging water. If for any reason, the flap gates would not open, portable pumps should be used with water jets to loosen the silt deposits behind the flap gates. If necessary, a mobile crane may be needed to help in initially opening or lifting the flap gates to allow water to discharge through the gates and flush the sediments. It is important to make sure that the flap gates will function properly at the end of the dry season. The flap gates should be prepared and should be ready to pass flood flows before the flood season arrives.

The responsibility for monitoring silt deposition in the discharge channel and in the downstream area of the regulator belongs to the O&M Supervisor assigned to the Feni Regulator. Careful planning of the sluicing operation should be made by the O&M Supervisor to avoid wasting the valuable water in the reservoir during the dry season".

In the "Evaluation of Muhuri Irrigation Project, Bangladesh" (Keith Project Management Inc. for Canadian International Development Agency, June 1990 Ref. 15), it is stated that, *"in order to ensure that the radial gates remain free and operable, the BWDB is continuing a previously established program of flushing water through each of the radial gates for periods of about 2 to 3 minutes every other day. As noted in the 1986 report, the process seems to be working effectively although it is monotonous and time consuming. The entire process takes about 2 hours to complete but there appears to be no reasonable alternative and physical solutions would be extremely expensive. A calculation to determine the amount of water required annually for flushing indicates the volume is not excessive and does not detract from the reservoir's major objective of providing water for irrigation".*

On the basis of the above two sources, the equivalent continuous discharge required to be released for gate flushing lies between 0.5 m^3/s and $3m^3/s$. The higher more conservative figure has been used in the reservoir simulation in section VI.3.3 above. It is apparent however that much less may be needed, in which case more water would be available for irrigation.

It is only through operational experience that any fine tuning of current practice can be made. Careful monitoring of current practice along with the monitoring of downstream conditions is recommended. Regular survey in the reach downstream of the regulator must be carried out, possibly at weekly or fortnightly intervals through the dry season. Physical modelling could be considered to investigate certain aspects of gate operation and siltation, were it found that conditions were deteriorating. BUET have already been involved in the preparation of a physical model of the regulator to study the effects of scour on the downstream apron (Ref. 16). While uncertainty does exist over the discharges required for flushing, and the manner in which it is best carried out, flushing must take priority over irrigation supply in view of the possible consequence of reduced flood discharge capacity at the start of the wet season.

River training works will be required to arrest the erosion being caused by the current northward migration of the outfall channel from the regulator. A longer term solution involving the reclamation of the lands already accreted downstream of the regulator is also a possibility, and could be investigated by the Land Reclamation Project.

Operation of the regulator during the wet season, in particular to control downstream scouring, is covered by the "Second Flood Damage Rehabilitation Project, Feni Regulator: Downstream Scour, Report on Hydraulic Model Study and Design" (Ref. 16 - Sir William Halcrow and Partners Ltd. March 1991).

5.4.4 Summary of Findings

The findings of the investigations into the Muhuri Irrigation Project may be summarised as follows:

- the water resource of the Muhuri Reservoir is considered to adequate for the irrigation of about 20,000 ha, which is in fact the estimate of existing surface water irrigation from the reservoir: 80% reliability in supply can be achieved, but there is no scope for increased reservoir yield beyond this;

- maintaining the reservoir at as low a level as possible throughout the monsoon season will minimise sedimentation; the reservoir can be refilled at the end of September;

- river training works are required downstream of the regulator in order to stabilise the outfall channel; a detailed investigation of these requirements should be carried out as soon as possible, and could be linked to wider considerations of land reclamation and permanent channel formation.

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APPENDIX I

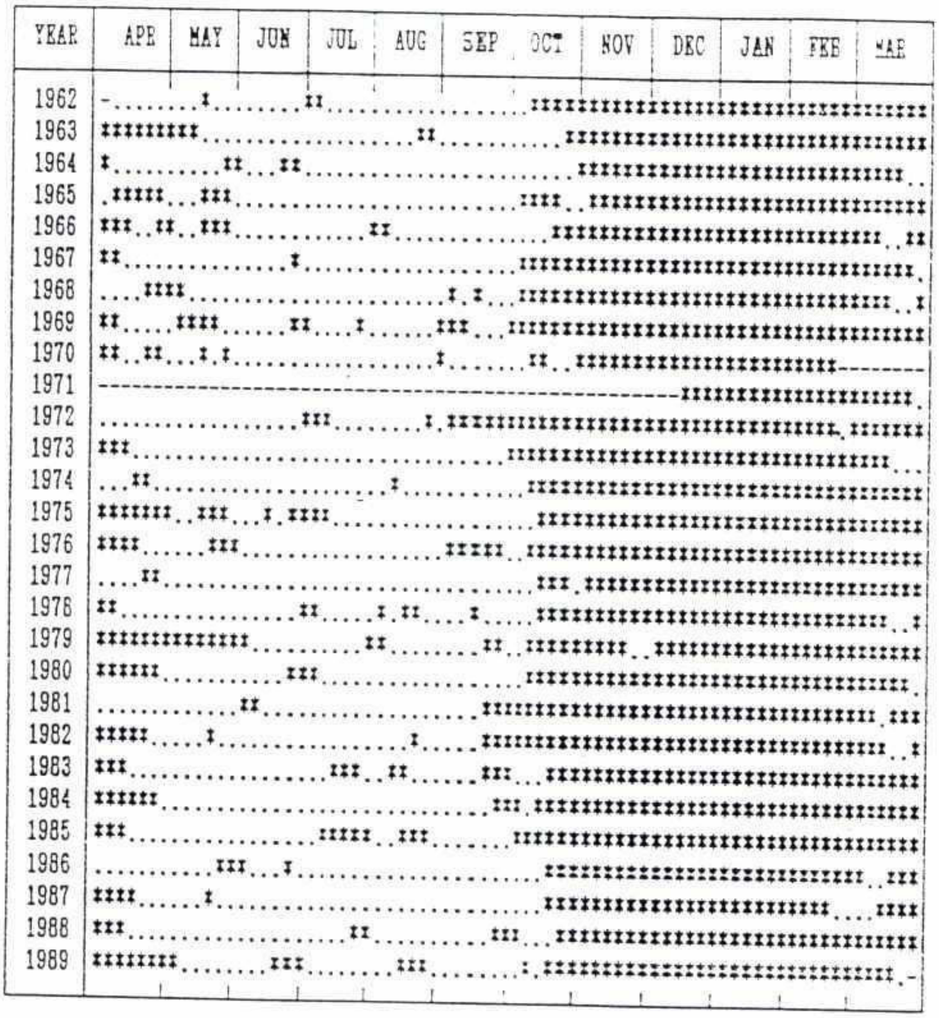
RESULTS OF PENTAD ANALYSIS

Analysis of Pentades
R-076, Narsingdi;

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-*.*...**..........*..........*......***********************************
1963	***...***.....................***..**..**..*****************************
1964	*..........**................---..........******************************
1965	*******..***.........................****...****************************
1966	**.......**..............................**************************...**
1967	**........**.....*...**................******************************...
1968	.....**..............................********************************..*
1969	**.....***.............................*********************************
1970	*...**...*........*...............**......******************************
1971	**..............................***...****..***************************.
1972	..................................*.*..*************************.*.*****
1973	***....................................*.****.************************..
1974	...**.........*..........----.........**********************************
1975	**...****......*****......***...........********************************
1976	****.......................*....**..************************************
1977	....*....................**....*****..**********************************
1978	***................*.....****..****..***********************************
1979	***...***..**............*.......**...*********..***********************
1980	***......................................*******************************
1981	*...***......****.****............**********************************.***
1982	***......**........****.............******************************....**
1983	***........***.......*............**....********************************
1984	.****..............................**....****************************...
1985	.*.*.................................**..*******************************
1986	............*...........................****************************.***
1987	*.......*.............................*.*************************..*..**
1988	***....*...............**................***********************..*****-
1989	--

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-101, Bhairab Bazar; Daily Rainfall (mm)



Note: : represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-103, Brahmantaria; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-III..............II.........IIIIII...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII-
1963	-------------------........II....III......IIIIIIIIIIIIIIIIIIIIIIIIIIIIII-
1964	---
1965	-IIIIII..III.........II..............IIII.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1966	III..II.................II..............IIIIIIIIIIIIIIIIIIIIIIIIIIIII..II
1967	II.......III.....I.....................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.
1968	....IIII......................II...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII..I
1969	III....IIII..............II.........IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.
1970	....IIII.III...........................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII-
1971	----------I.......III...................II..IIIIIIIIIIIIIIIIIIIIIIIIIIIII
1972	.....IIII..........I............IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1973	III..................................IIIIII...IIIIIIIIIIIIIIIIIIIIIIIII..
1974	...II....................III....I....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1975	IIII...........IIIII.......II.....III.IIIII..IIIIIIIIIIIIIIIIIIIIIIIIIIII
1976	IIII............................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1977	.........................II.......II...II...IIIIIIIII---IIIIIIIIIIIIIIIII
1978	II................II.............II.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1979	IIIIIIIIIIIII................II..II....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1980	III..............II.....................IIIIIIIIIIIIIIIIIIIIIII.IIIIIIIII
1981	I....III.....II...................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.III
1982	I.III.....................IIII....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.I...I
1983	............III......III.................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1984	.III...............................II...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1985	II..............II..II....IIIIII.....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1986	...........III..........................III..IIIIIIIIIIIIIIIIIIIIIIIIIIII
1987	I.......III.....I........II...........I.IIIIIIIIIIIIIIIIIIIIIIIII...I.III
1988	III....................II............I...IIIIIIIIIIIIIIIIIIIIIIII..IIIIII
1989	IIIIIIII................................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.-

Note: I represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-105. Chandpur Bagan: Daily Rainfall

```
YEAR | APR  MAY   JUN  JUL  AUG  SEP  OCT  NOV  DEC  JAN  FEB  MAR
1962 |-........x........................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xx
1963 |xx.......................................xxxxxxxxxxxxxxxxxxxxx..xxx...
1964 |..........xx......................x......xxxx...xxxxxxxxxxxxxxxxxxxxxxxx
1965 |xxxxx....xx......................x....xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966 |xx......................................xxxxxxxxxxxxxxxxxxxxxxxxxxx....x
1967 |xx........xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968 |x...xxx............................xxxx....xxxxxxxxxxxxxxxxxxxxxxx..x
1969 |xx.....xxx.............xxx.........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1970 |.x.xxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1971 |....x.............xx...................xxx..xxxxxxxxxxxxxxxxx..xxxxxxxxx.
1972 |...x...xx..................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1973 |xxx................................x.xxxx....xxxxxxxxxxxxxxxxxxxxxxxxx.
1974 |...xx..................................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975 |xx.............xxxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976 |xx..............................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977 |.....................x.....x..............x.x...xxxxxxxxxxxxxxxxxxxxxxxxxxx-
1978 |-------------------------------------------------------------------------
1979 |-..x...xxxxxx...........................xxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxx
1980 |xx......................................xxxxxxxxxxxxxxxxxxxxxxx.xxxxxxxx..
1981 |.....x....................xx......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982 |x..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx....x
1983 |x...........xxx.......xx.................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984 |xxxxx..............................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1985 |xx.....................................xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986 |...........xxx.............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987 |x................xxxx.................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1988 |xx........................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989 |xxxxx..............x........................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxx-
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-110 Habiganj; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-x.x.....x.....................xx.---------xxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1963	-------..................-------......xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1964	.........xxxx......................x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1965	.xxxxx....xx........xx.......x.......xxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xx.............................x....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1967	xx..............x...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1968	.....xx...............xxxxxxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1969	xx....xxxxx....---x xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1970	xx..xxxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxx.xxxxxxx.
1971	....xxx..xx......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1972	.xxxxxxxx........................xxxxxxxxxxxxxxxxxxxxxxxxxxx.x.xxxxx
1973	xx...............................xxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1974	....xx..............x.xxxxxx........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xx....xxx........xxxx..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xxxx............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx
1977	.........................xx.....----x...xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	xx............xx...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979	..xxx...xxxxxx..... ....xxx........xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1980	x..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1981	.....xx.......x.... xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	xx................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.....
1983	xxx.........x..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxx...............................xx....xxxxxxxxxxxxxxxxxxxxx..xxxxxxx...
1985	.x................................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	............xxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	xxxx............x....................x.xxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx
1988	xx...x.................x............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxx.xxxx.x-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-111, Itakhola(Baikunthapur): Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-......XXX.........X...X.........XX...XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1963	XX.....................................XX---------XXXX---------XXXXXXXXXX
1964	...........XX...X....................XXX..XXXX..XXXXXXXXXXXXXXXXXXXXXXXXX
1965	XX..XX...XX....................XX....XXXX...XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1966	XX...XX..........................X.....XXXXXXXXXXXXXXXXXXXXXXXXXXXXX...XX
1967	XX.....XXX......XX.....................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX...
1968	....XXXX..............................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX..X
1969	XX....XXXXXX.....XX....X...........XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1970	XXXXXXX..........XX..........XXXXX.....XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1971	X...XXX..XXX.......XX...........XXXX...XXXXXXXXXXXXXXXXXXXXXX..XXXXXXXXX-
1972	---
1973	-XXXX.................................XXXX.XXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
1974	...XX....................XX....XXXXX..XXX..XXXXXXXXXXXXXXXXXXX..XXXXXXXXX
1975	XXX...XXX......XXXXXX..............X....XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1976	X................---.............X...XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1977	.......................XXX.............X....XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1978	XX........................X...........X.XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
1979	..XXX.XXXXXXX......................X...XXXXXXXX..XXXXXXXXXXXXXXXXXXXXXXXX
1980	XXX...................................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
1981	....XXXX........XX................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1982	X.......XXXX......................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.....
1983	X..........XXXX.......X...........XXX....XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1984	XXXXX...................XX.........XXX.XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1985	XX......XX.........X.X........XX.....XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1986	.........X....XXX.......................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1987	XXX...................................X.XXXXXXXXXXXXXXXXXXXXXXXXX......XX
1988	XX...........X.........XX....X.......XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1989	XXXXXXXX..................................XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX-

Note: X represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-131, Sarail; Daily Rainfall (mm)

```
YEAR | APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  JAN  FEB  MAR
-----+-------------------------------------------------------------------------
1962 |-II......I............................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII..I-
1963 |-------II...................I...........II.IIIIIIIIIIIIIIIIIIIIIIIIIIIII.
1964 |..........II..II........................IIIIIIIIIIIIIIIIIIIIIIIIIIIII..
1965 |.I.III....I..........II.........I....III...IIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1966 |III..II..IIIIII.....................I...IIIIIIIIIIIIIIIIIIIIIIIIIIIII..II
1967 |II..............III....................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1968 |I...III..............................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII..I
1969 |II....IIIII..................II....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.
1970 |.I..IIII...............................IIIIIIIIIIIIIIIIIIIIIIIIIIIIII----
1971 |-------------------------------------------------------------------------
1972 |---..IIII.........III...........IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1973 |III...................................IIII....IIIIIIIIIIIIIIIIIIIIIIIIII.
1974 |...II.........I......................III..IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1975 |IIII.IIII.....IIIIIII....I...........II..IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1976 |III........II.......IIII........III...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1977 |...................II...IIII............I....IIIIIIIIIIIIIIIIIIIIIIIIIIII
1978 |II................................I.....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1979 |II.II.IIIIIIII....................II....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1980 |III...............II..................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.
1981 |...................................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII.III
1982 |IIII..............................I..IIIIIIIIIIIIIIIIIIIIIIIIIIIII......I
1983 |III..........III...................IIII..IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1984 |IIIII.....I.........................II....IIIIIIIIIIIIIIIIIIIIIIIIIIIII..
1985 |III...............I......I............IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1986 |............III..II.....................IIII..IIIIIIIIIIIIIIIIIIIIIIIIIII
1987 |IIII...III.............................I.IIIIIIIIIIIIIIIIIIIIIII.....IIII
1988 |III.....................II.....I..........IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1989 |IIIIIIIII....................II........I.IIIIIIIIIIIIIIIIIIIIIIIIIIIIII.-
```

Note: I represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-132, Nasirnagar: Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-*.......*........................*..***********************************
1963	**......................................*.***************************...
1964	..........***............................*****..************************
1965	*...*****...........................****...*****************************
1966	**.*.*.................................****************************...**
1967	**.......****.........................*******************************...
1968	...****.............................*********************************..*
1969	**.....*****.....................***************************************
1970	**..****.....................***......***.*****************************.
1971	...**.............*...................***..****************----********-
1972	---..****........***...........***
1973	***.....................**............******.**************************.
1974	........................**....**...****..*******************************
1975	***..*****...*******...............*.******..***************************
1976	*.........**..................******.***************************..******
1977	.....................**...............*....*****************************
1978	***.......................--------------******************************..
1979	****...*******...................*....**********************************
1980	**...................................********************************.*.
1981	....***......**...................********************************...***
1982	*..................................******************************......*
1983	***...............................**....********************************
1984	*****.............................**...***********************.*.****...
1985	**.......................**.........************************************
1986	........*.***..**..**..................*********************************
1987	****......................***..........************************...*...**
1988	**..................................*...********************************
1989	********...............................*******************************.-

Note: * represents a dry pentad
Note: . represents a wet pentad
 - represents missing data

Analysis of Pentades
S-260, Bhola; Daily Rainfall (mm)

```
YEAR | APR   MAY   JUN   JUL   AUG   SEP   OCT   NOV   DEC   JAN   FEB   MAR
1962 |-III....II.........I..................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1963 |II..............II....................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII-
1964 |-------------------------------------------------------------------------
1965 |-IIIIII..II..........I..............IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1966 |IIIIII..III.........II.................IIIIIIIIIIIIIIIIIIIIIIIIIIIIII..II
1967 |IIIIIIIIIIIII...........................IIIIIIIIIIIIIIIIIIIIIIIII..III..I
1968 |I.IIIIII.......................II.......IIIIIIIIIIIIIIIIIIIIIIIIIIIIII..I
1969 |III...IIIII.........................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1970 |IIIIIIIIII.......................II......II---IIIIIIIIIIIIIIIIIIIIIIIIIII
1971 |I..III...II...........................IIII..IIIIIIIIIIIIIIIII..IIIIIIIIII
1972 |IIIIIIIIIIIII.....................II....IIIIIIIIIIIIIIIIIIIIIIIIII...IIII
1973 |IIIIII.I..............................IIII...IIIIIIIIIIIIIIIIIIIIIIIII...
1974 |..IIII...II...........................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1975 |IIIIIIII................................II....IIIIIIIIIIIIIIIIIIIIIIIIIII
1976 |IIII................................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1977 |....................II.............IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1978 |I....I................................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1979 |II.IIIIIIIIII.....................II...IIIIIIIIIIIIIIIIIIIIIIII.III..IIII
1980 |IIIIIII............................I...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII...
1981 |.....III.I........................IIIIIIIIIIIIIIIIIIIIIIIIIIIII..IIIIIIII
1982 |II....IIIII.........I.............III.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1983 |I..................................II....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1984 |IIII......I........................II....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1985 |IIII........II................II.....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1986 |IIII.......III..........................III..IIIIIIIIIIIIIIIIIIIIIIIIIIII
1987 |III....IIII.........................III.IIIIIIIIIIIIIIIIIIIIIIIII..I.I.II
1988 |III..II.............................III..IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1989 |IIIIIIII....................I.........I...IIIIIIIIIIIIIIIIIIIIII...IIII.-
```

Note: I represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-261. Daulatkhan: Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-xxxx...xx.........xx........xx.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1963	xxx......x.---------.........---------xxx---------------xxxxxxxxxxxxxxx-
1964	---
1965	-xxxxx.....x.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxxxxx...xx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1967	xxx...xxxxxxx...xx.....................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1968	xxxxxxxx..............x........x.xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1969	xxxxxxxxxxxx........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1970	xx.....------..................xxxx..xx..xx---xxxxxxxxxxxxxxxxxxxxxxxxxxx
1971	xxxxx..........................xx..xxx------------------------xxxxxxxx
1972	xxx..xxxxxxxxx...xx.............xxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1973	xxxxx.................................xxxx....xxxxxxxxxxxxxxxxxxxxxxxxxxx.
1974	..xxxx...x..............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xxxxxxxx...........................xxxxxxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xxxxxx....xx...........xx---..xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxx
1977	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	.....xx...........................x.x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979	xxxxxxxxxxxx........................xx...xxxxxxxxxxxxxxxxxxxxxxxxx.xxx..xxxx
1980	xxxxxx...........................xxx.....xxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1981	....xxxxx........................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	xx....xxxxx.......................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1983	x.....x............................xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxx...............................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1985	xx.x.....xx........................xxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	xxxx....................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	xxxx....xxxx...........................x...xxxxxxxxxxxxxxxxxxxxxxxxxxx..xx
1988	xxxxx...................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxxx...x..............................xxxxxxxxxxxxxxxxxxx........xxx.-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-301. Antali!

```
YEAR | APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  JAN  FEB  MAR
-----+-------------------------------------------------------------------------
1962 |-.xxx..xxxxx.............x............xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1963 |x.....xxx...................xxxxx...xxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1964 |-------------------------------------------------------------------------
1965 |-xxxxxxxx.x....xx....xx..........xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1966 |xxxxxxxxxx...........xxx............x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1967 |xxxx....xxxxxx........xxx..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1968 |xxxxxxxx....x..................x.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x|
1969 |xx...xxxxx.............................xxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx|
1970 |x...xxxxx.............................xx......xxxxxxxxxxxxxxxxxxxxxxxxxx-
1971 |---------------------------------------------xxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1972 |----xxxxx..........x.........x...xx....xxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxx|
1973 |xxxx.................................xxxxx....xxxxxxxxxxxxxxxxxxxxxxxx...
1974 |.xxxx....x........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1975 |xx..xxx..................xx.............x....xxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1976 |x..xxxx..xxx......................x..x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1977 |....xx............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1978 |xxxxxxxx..........x........xx......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1979 |xxxxx.....xxx..........xxx.......xxx.xxxxxxxxxxx..xxxxxxxxxxxxxxx---xxxx-
1980 |-------------------------------------------------------------------------
1981 |-------------------------------------------------------------------------
1982 |-------------------------------------------------------------------------
1983 |-xx............................x.xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1984 |xxxxx...................x........xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x|
1985 |xxxxx.......................xxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1986 |xx.....................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1987 |xxx.x.xxxxx......x.......xx.....x..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1988 |xxxxxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1989 |xxxxxxxx....x................xx...........xxxxxxxxxxxxxxxxxxxxxxxxxx : x-
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-311, Patiachari:

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-xxxx....x.x......xx....x.............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1963	-------....................x.x.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1964	---
1965	-xxxx....xxx.....................x.xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxxxxxx..xx..........xx...............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx....
1967	xxxx....xxxxx.........xx..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1968	x.xxxxxx.............x.xxx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1969	xx...xxxxxx........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1970	xx..xxxxx............................xx......xxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971	x...xx...xx.....................xx...xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1972	....xxxxx...x.................xxxx.x..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1973	xxxx..............x.................xxxxx....xxxxxxxxxxxxxxxxxxxxxxxxx...
1974	.xxxx....x....................x.........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xx...xx......xxx...........x.x..........xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xxxxxxx..xx.......................xxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	xxxxxxx......xx...x..................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979	xxxxx......xx.........xxxx.....x.x...xxxxxxxxx...xxxxxxxxxxxxxxxxx----xxx
1980	xxxxx......x.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1981	x...xxxx........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	x....xxxxxx......x...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.....
1983	x.................................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxx.....xxxx...................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1985	xxxxxx............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	xx.....x....x.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	x......xxx......x...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx....xxxx
1988	xx...xxx................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxxx...............xxxxxx...........xxxxxxxxxxxxxxxxxxxxxxxxxxx.x..-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-315, Kaptai (Chowdhury Chara): Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-xxxxxxxxx............................xxxxxxxxx---------xxxx-------------
1963	---
1964	---
1965	-xxxx.x.xxx..........................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxx..xx..xx............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx....
1967	xxxx...xxxxxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1968	x.xxxxx.............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1969	xxx..xxxxxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1970	xxxxxxxxx......................---...xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971	....xxx..xxx...........................xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1972	xxxxxxxxxx.......xxx..........xxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1973	xxxx.................................xxx......xxxxxxxxxxxxxxxxxxxxxxxx...
1974	..xxx....x..............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xx...xxxx..............................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xxxxx..............................xxxxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxx
1977	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	xx...x................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979	xxxxx....xxx.........................xxxxxxxxxx.xxxxxxxxxxxxxxxxx...xxxxx
1980	xxxxx.............x......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1981	x...xx...........................xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	xx......xxx...........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xxx
1983	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxx.....xx.......................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1985	xx.x...xxx.........................xxxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxx
1986	xx.x......xx......................x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	x.....xxxx....xxx...................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1988	xxxxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxx...xx...................---xx.....xxxxxxxxxxxxxxxxxxxxxxx..xxx.-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
E-320. Mirsari; Daily Rainfall (mm)

```
YEAR | APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  JAN  FEB  MAR
-----+-------------------------------------------------------------------------
1962 |-xxxxxxxxx........x....................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1963 |xxxxxx........................x........x.x.xxxxxxxxxxxxxxxxxxxxxx...xxxx-
1964 |-------------------------------------------------------------------------
1965 |-xx.................xx...............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966 |xx................................xxx...xxxxxxxxxx..xxxxxxxxxxxxxxxx...xx
1967 |x.xxxx.....xx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1968 |xx....xx...---........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1969 |x...xxxxx............................xxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx
1970 |xxxxxxxxx.............................xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971 |x...x.xxx.............................xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxx
1972 |xxxx...xx..xxx....xx............xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxx...xxxxx
1973 |xxxxx.......----......................xxxx....xxxxxxxxxxxxxxxxxxxxxxxx...
1974 |xx......xxx.......................xx.....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975 |xxxxxxxx..................x.............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976 |.........xxx.......................xx.x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977 |xx..xx................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978 |xxxxxx.............x.................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979 |xxxxx.x.xxxxx....................xx...xxxxxxxxxx.xxxxxxxxxxxxxxxxxxx..xxx
1980 |x...xx................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1981 |xxx.xxxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982 |......xxxxxx...........---............xxxxxxxxxxxxxxxxxxxxxxxxxxxx.....xx
1983 |xxxx.....xxxx....................xxxx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984 |..xx..............................xx.....xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1985 |xxx.....................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1986 |-------------------------------------------------------------------------
1987 |-x...x..xxx.....xx...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxx.
1988 |.xxxx....................................xxxxxxx..xxxxxxxxxxxxxxxxxxxxxx-
1989 |-------xx.................x...............xxxxxxxxxxxxxxxxxxxxxx...x.x..-
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-323, Narayanhat;

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-xxxx..xxx.......xx....xxx............x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1963	-------....................x.........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1964	---
1965	-xxxx....xx........................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxxxxx...xx..........xxx...........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx....
1967	xxxx...xx..xxx........xxx.......xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968	...xxxxx..............xx..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1969	xx...xxxxxx...........................xxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx
1970	x...xxxxx...........................xx......xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971	...xxxx...xxx.....xx................xxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1972	.x.x.xxxx...xx....xxx.........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.x.xxxxx
1973	xxxx...............xxx...............xxxxx.....xxxxxxxxxxxxxxxxxxxxxxxx...
1974	..xxx...xxx.............................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xxx..xxxx......x...........................xxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xxx.xx..........................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	xx..xxx..........................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979	xxxxxxx...xxx..........xx..........x.xxxxxxxxxx.xxxxxxxxxxxxxxxxx---xxxxx
1980	xxxxx.....................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1981	.....xxx.......x......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	xx....xxx----.....x.........................x.xxxxxxxxxxxxxxxxxxxxxxxx....xxxx
1983	............xxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxx.............................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xx
1985	xxxxx......................xxx..xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	xx...............................x.....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	xxx.....xxx...............xx..........x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xxxx
1988	xx...xxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxx....x..............xxxx............xxxxxxxxxxxxxxxxxxxxxxxxx.x.x..-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-327, Ramgarh; Daily Rainfall (mm)

```
YEAR | APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  JAN  FEB  MAR
-----+------------------------------------------------------------------------
1962 |-xxxx..xxx.......xx.....x............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxx
1963 |.....xxxx...................---------.....xxxx---------xxxxxxxxxxx.xxxx-
1964 |------------------------------------------------------------------------
1965 |-xxxxxx..xxx........................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966 |xxxxxxx..xxx.x......xxxx............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xxx
1967 |xxxx...xxxxxx.........xx..........x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968 |xxxxxxxx.............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1969 |xx....xxx...........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1970 |xxxxxxxxxx...........................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971 |...xx------------------------------------------------------xxxxxxxxxxxx.
1972 |...x...xxx.......xxx........x.xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxxx
1973 |xxxx...............x.................xxx.....xxxxxxxxxxxxxxxxxxxxxxxx...
1974 |.xxxxx...x................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975 |xxx..........................................xxxxxxxxxxxxxxx..xxxxxxxxxx
1976 |xxxxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977 |.......................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978 |xxxxxxx................................xx---xxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979 |xxxxxxx...xxx..........................xxxxxxx..xxxxxxxxxxxxxx.xxx..xxxx
1980 |xxx.x..............................x.x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1981 |....xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982 |xx....x..xxx......xxx.............xx...xxxxxxxxxxxxxxxxxxxxxxxxxxx.....x
1983 |............xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984 |xxxx..............................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1985 |xx.x...........................xxx..xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1986 |------------------------------------------------------------------------
1987 |-xx....xxx.....x...............xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxx
1988 |xx...xx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989 |xxxxxxxx..xxx..xx.........xxx............xxxxxxxxxxxxxxxxxxxxxxxxxxx.x.-
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-351, Bancharampur; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-x x....xxx......................x---------------xxxxxxxxxxxxxxxxxxxxxxx
1963	xx....x.....................xxxx.......xx---------xxxxxxxxxxxxxxxxxxxxxx-
1964	---
1965	-x...xx.xxx........................xxxxxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxx...xxxxxx............xx.............xxxxxxxxxxxxxxxxxxxxxxxxxxxxx....x
1967	xxxx......xxx...xx.....x..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1968	xx..xxxx....xx.......xx..xx....x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1969	xx.....xxxxxx.................xxx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1970	.xxxxxxxxxxx.....xx...................xx..xx..xxxxxxxxxxxxxxxxxxxxxxxxxx.
1971	...................xx..........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1972	xxxx.xxxxxxxxxx..----.........xxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xxxxx
1973	xxxxxx...............x..........xx...xxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1974	..xxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xxxxxxx..........xxxxx..xxxxxx...........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xxxxx......---........x......---xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977	..................xx.....xx......xxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1978	.xx...............xxx....xxx.....x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979	xxxx.xxxxxxx.....x.x.xxxxxxxx........xxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxx
1980	xxx..xx.......xxxxxx.................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx---xxxxx
1981	....xxxxx...xxxxx............xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	xxxxx.x.xxxxxx................x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1983	xxx.......xxx.......xxxx.......x.xxxx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxxx.............xx................xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1985	xxxxxxx.....................x.xxxxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	x...xxx.xxxxxxxxx.xxxx...xxxx...........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	xxx......................xxxx.........x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1988	xx...xx..............xxxx.......xxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxxxx..........x.x....xxxxx.....x...xxxxxxxxxxxxxxxxxxxxxxxxx......-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-352, Barura; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-IIIII..III---------------...---------------IIIIIIIIIIIIIIII------------
1963	-I........................IIIII..II..II---------IIIIIIIIIIIIIIIIIIIIIIII-
1964	--
1965	-IIIII...III......................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1966	IIIIIII..............II...............IIIIIIIIIIIIIIIIIIIIIIIIIIIII...II
1967	IIII...IIIIIII...I.....................IIIIIIIIIIIIIIIIIIIIIIIIIIIIII...
1968	I.IIIII........................I....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1969	II....IIII..........................IIIIIIIIIIIIIIIIIIIIIIIIIII---IIIII.
1970	....IIIIII.............................I..IIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1971	....I.....II.....................IIIIIIIII..IIIIIIIIIIIIIIIIIIII---IIIII
1972	...I.I.III...I....II...........IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII...IIIII
1973	IIII..................................IIIII...IIIIIIIIIIIIIIIIIIIIIIII..
1974	..III..................................I.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1975	IIII.III......IIIIII.....I........III...II..IIIIIIIIIIIIIIIIIIIIIIIIIIII
1976	IIIIII.I.III.........II........IIIIIII.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1977	..........I.....I............II..IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1978	II..II...........II......I......III.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII--
1979	-IIIIIIIIIIII..........II......I...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1980	III..II........IIII......IIII.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1981	II..IIIII...III................IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1982	IIII..IIIIIIII............III...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII...I
1983	I..........IIII.................II....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1984	IIIII....II.......................III.IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1985	IIIII..III..................I....IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1986	I........II--------..........I.......IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1987	III.....IIIII...I.......II..........I.IIIIIIIIIIIIIIIIIIIIIIIIIII.I.IIII
1988	III...III........................I.I...IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
1989	IIIIIIIII...............II..............IIIIIIIIIIIIIIIIIIIIIIIIIIIIII.-

Note: I represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-353. Basurhat: Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	------	------	------	------	------	------	-----x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1963	....x.	.....-	------	------	------	------	------	-xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxx-
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	-xxxx.	x.xxx.	......	......	......	...xx.	.xxx..	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1966	xxxxxx	x.....	......	......	......	......	xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xx...x
1967	xxxx..	.xx...	......	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxx...
1968	x.xxxx	xx....	......	......	......	.xx...	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1969	xx....	xx	......	xx	......	......	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx..	xxxxxx
1970	x...xx	xxx...	......	......	......	......	..xxx.	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1971	x..xx.	......	......	......	......	..xx..	..xxxx	..xxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1972	x	xxx...	xx....	.x....	......	xxxxxx	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxx.	..xxxx
1973	xxxxxx	......	......	......	x	......	..xxxx	xx	xxxxxx	xxxxxx	xxxxxx	xxx...
1974	..xxxx	......	......	......	......	......	..xxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1975	xxx..x	xxx.xx	xxxxx.	......	......	x	xx...x	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1976	xxxxxx	...xx.	......	...xx.	x	x.....	xx	xxxxx.	.xxxxx	xxxxxx	xxxxxx	xxxxxx
1977	......	x.....	......	......	......	......	..xxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1978	xx..xx	......	......	......	......	x	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1979	xxxxxx	x.xxxx	x.....	......	......	xx	..xxxx	xxxxx.	xxxxxx	xxxxxx	xxxxx-	--xxxx
1980	xxxxxx	xx....	......	......	...xx.	..xxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	..xxxx	xxxx..
1981	xx	x.....	..xx..	......	.----.	x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1982	x.....	xxxxxx	x.....	..x...	....x.	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx.x
1983	......	......	......	......	......	x	x...xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1984	xxxx..	......	......	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxx...
1985	.xx...	......	......	......	......	x	xxx..x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1986	x.....	......	xx....	......	......	...x..	...xxx	..xxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1987	xxx...	.xxx..	......	......	......	......	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxx.	..xxxx
1988	xx...x	x.....	......	......	......	x	xx...x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1989	xxxxxx	xxxxxx	x.....	......	....x.	......	x	xxxxxx	xxxxxx	xxxxxx	xxxxx.	x.x..-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-354, Chandpur: Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-x.......x........xx.........---------xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxx
1963	xx..............xx.......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1964	---
1965	-xxxx....xxx.........x..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxxxxx..xxx.........xx............xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xx
1967	xxxx...xxxxxx....x.....................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968	..xxxxxx..........................xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1969	xxx..xxxxxxx..........xxxxx...xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1970	..xxxxxxxx.......................xxx..xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971	xxx......xxx......................x...xxxx..xxxxxxxxxxxxxxxxxx.xxxxxxxxx.
1972	...x.xxxxx..xx.................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxxx
1973	xxxxxx.............x.......x...x......xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxx..
1974	.xxxx....xx...............x............xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1975	---
1976	-xxxxxxxx.............xx.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx
1977	...................xxx.....xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1978	.xx..xx............x........x....xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1979	xxxxxxx.x.........................xx...xxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxx
1980	xxxxx...........xx...x............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1981	....xxxx.....xxxx.......xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxxxxx
1982	xx.......xxx........x...............xxxxxxxx..xxxxxxxxxxxxxxxxxxxx.....xx
1983	x...........xxx.....xx.............x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxxx....xx........................xxx.x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1985	xx.x....x............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	xxxx...x.x.xxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	x.......x................xx.........xxx.xxxxxxxxxxxxxxxxxxxxxxxxx..x.xxxx
1988	xx....xx..........................xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxx....................xxx.......x..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-355, Chhagalnaya; Daily Rainfall (mm)

```
YEAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR

1962 |-.xxx..xxx.........................---------xxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1963 |xx.........---------........x.xxx......x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx-|
1964 |-------------------------------------------------------------------------|
1965 |-xxxxx...xx.........xx...............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1966 |xxxxxxx..xx...........x................xxxxxxxxx.x.xxxxxxxxxxxxxxxxx...xx|
1967 |xxxxxxxxx..xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...|
1968 |x.xxxxxx..................xx.xxx......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x|
1969 |xx....xxxxxx..........xx.............xxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxx.|
1970 |.xx..xxx...............................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx-|
1971 |--.xxxx............................xxx..xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1972 |......xxx...xx.....xx..........xxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxx...xxxxx|
1973 |xxxx---............xx..-.............xxxxx...xxxxxxxxxxxxxxxxxxxxxxxxx...|
1974 |..xxxx....................xx...xxxxx...x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1975 |xxx......xxx..xxxxxx....x..........xx....x....xxxxxxxxxxxxx..xxxxxxxxxxxx|
1976 |xxxxxx................xx......xx.........xxxxxxxxxxxxxxxxxxxxxxxxx..xxxxx|
1977 |...................................x...xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1978 |xxxxxx.......................x......x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1979 |xxxxxxx...xxx..........................xxxxxxxxx.xxxxxxxxxxxxxxx.xxxxxxxx|
1980 |xxx.x...............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..|
1981 |....xxxx...........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1982 |x.......xxx........................xx..xxxxxxxxxxxxxxxxxxxxxxxxxx...xxx.x|
1983 |............xxxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1984 |xxxx...............................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...|
1985 |.x.x...--------..................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1986 |x..........xxxxxx.......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xx|
1987 |xxx....xxxx....xx..............xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1988 |xx....x.x................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1989 |xxxxxxxxxx......xx.......xxxxxx............xxxxxxxxxxxxxxxxxxxxxxxxxxxx.-|
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-356, Comilla; Daily Rainfall (mm)

```
YEAR | APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  JAN  FEB  MAR
1962 |-****...**.........*..............*.************************************-
1963 |-------------................***.......*.****---------******************-
1964 |-------------------------------------------------------------------------
1965 |-******..***........................*************************************
1966 |***..**...*.........*...................****************************...**
1967 |***....*.****..***.........*...........********************************..
1968 |*....***.......................*....**********************************..*
1969 |**.....***............***.......**..************************************.
1970 |...*********......................*...**...*..**************************.
1971 |...***...*........**.............*......---..*****************.**********
1972 |------.***.........*...........*-----------------*************-------****
1973 |****.........................****.....****...**************************..
1974 |...**...*.............................**.********************************
1975 |****..**.......*.*.......***.......---.****..****************************
1976 |******.........................******.*.*************************...*****
1977 |.........................**........*.******.*****************************
1978 |***..*............**..................***********************************
1979 |.************............*............*********.******************---****
1980 |***...................................************************.********..
1981 |....***...........................***************************************
1982 |*.........**......................**..******..*****************---*.....*
1983 |*...................**...................********************************
1984 |****...............................*.....*****************************..*
1985 |***.................................*************************************
1986 |...........***..........................*********************************
1987 |***.....***.........................***.****************************..***
1988 |**................................****...******.*************************
1989 |*********.......**........*.**........*.****************************.*..-
```

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-357, Daudkandi; Daily Rainfall (mm)

```
YEAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN  FEB | MAR
-----------------------------------------------------------------------------
1962 |-x.x.....x.......xxx.....xx..xxxx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1963 |xxxxxxx......................xxxxx......xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1964 |-------------------------------------------------------------------------
1965 |-...x.x.xxxx.................xx....xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1966 |xxx......xx..........................xxxxxx..xxxxxxxxxxxxxxxxxxxx....x|
1967 |xxx......x.xxx.......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968 |x.xxx........................xxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x|
1969 |xx......xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx--|
1970 |-...xx...xxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1971 |................................x....xxx.-----------------xxxxxxxxxx|
1972 |...xx..----..xxxx....----x......xx..x.xxxxxxxxxxxxxxxxx----xxxxxx.x.xxxxx|
1973 |xxx.x.............xx..........xx......xxxxx...xxxxxxxxxxxxxxxxxxxxxxxxx..
1974 |..xxx.........xxx..........x...........xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1975 |xx.x.xxx.................xxx..........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1976 |xxxx..............................xxxxxxxxxx..xxxxxxxxxxxxxxxx---xxxx.
1977 |..............................x.xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1978 |.xx..............................xxxxxxxxxxxxxxxxxxxx xxxxxxxxxx|
1979 |xxxxx.................xxx.............xxxxxxxx...xxxxxxxxxxxxx.xxxxxxxxx|
1980 |xxx.................................xxxxxxxxxxxxxxxxxxxxxxx...xxxxxx...
1981 |.....xx.......xx...................xxx.xxxxxxxxxxxx..xxxxxxxxxxxxxx...xxx|
1982 |x........xx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxx..xx..xx|
1983 |x..........xx.....................x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1984 |xxxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1985 |xxxxx.........................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1986 |..........xxxx.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1987 |xx....xxxxxxx....------...x..........xx.xxxxxxxxxxxxxxxxxxxxxxxxxxx.x...xx|
1988 |xx...xxx....xx...............------......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1989 |xxxxxxxx...................x...........x.xxxxxxxxxxxxxxxxxxxxxxxxxx.xxxx.-|
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analyeis of Pentades
R-358, Feni: Daily Rainfall (mm)

```
YEAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR
1962 |-..x...xxxx............---------xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1963 |x...---....................xxxxxxx----------------------xxxxxxxxxxxxxx..-
1964 |------------------------------------------------------------------------
1965 |-xxxxxx..xxxx.........................xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966 |xxxxxxx..xx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xx
1967 |xxxx........x..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968 |...xxxxx..............x.......xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1969 |xx....xxx..............xx.......xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1970 |.xxxxxxxx...........................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1971 |x........x........xx...........xxxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1972 |xxxxxxxxxx..xx....xxx..........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxx
1973 |xxxx..............xx........x......xxxxx.....xxxxxxxxxxxxxxxxxxxxxxxxxx..
1974 |.xxxx....x...............xx.......xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975 |xxxxxxx..xxx..xx...............x...........xxx...xxxxxxxxxxxxxxxxxxxxxx.xxxx
1976 |xxxxxx............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxxxx
1977 |...............................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1978 |.xx...............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1979 |xxxxxxxxxxxxx...........................xxxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxx
     |xxxxx        xx                  --   xxxxxxxx              xx.xxxxxxx.x.
     |                                                                 xxxxxxxxx
1983 |x..................................................................xxxxx
1984 |xxxxx..........................................xxxxxxxxxxxxxxxxx xxxxxxxxx
1985 |xx.x...............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
     |                                 ....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xx
     |                                 ..xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxx.xxxxxx
1988 |xx...xx...............................     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989 |xxxxxxxx..................xx.....                                xx..xxx.-
```

Note: x represents a dry pentad.
Note: . represents a wet pentad.

Analysis of Pentades
R-359, Gunabati; Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	-‡‡‡..	.‡‡‡..	......	‡‡....	......	......	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1963	‡‡‡...	......	......	......	......	......	......	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	.‡‡‡‡-
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	-‡‡‡‡‡	...‡‡‡	......	......	......	......	.‡‡‡..	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1966	‡‡‡.‡‡	‡‡‡‡‡.	......	......	......	......	....‡‡	‡‡‡‡‡‡	.‡.‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1967	‡‡‡‡..	.‡‡...	‡‡....	......	......	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡...
1968	‡.‡‡‡‡	‡‡....	......	..---.	......	......	..‡‡‡‡	.‡.‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡..‡
1969	‡‡...‡	‡‡‡‡‡‡	......	...‡..	......	‡...--	-‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡..	‡‡‡‡‡‡
1970	‡‡‡‡‡‡	‡‡‡‡..	......	......	......	......	..‡‡..	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1971	‡‡‡‡‡‡	...‡‡.	.-----	------	---‡‡-	---...	...‡‡.	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1972	‡‡‡‡‡.	.‡‡‡..	.....‡	‡‡.‡.‡	......	..‡‡..	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	‡‡‡‡‡‡
1973	‡‡‡‡..	......	......	......	.....‡	....‡.	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.
1974	..‡‡‡‡	‡‡‡‡‡.	......	‡.....	......	....‡‡	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1975	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	......	‡‡‡‡‡‡	......	....‡‡	‡..‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡-
1976	------	------	------	------	------	------	------	------	------	------	------	------
1977	------	------	-.....	......	......	.....‡	‡..‡‡‡	‡...‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1978	‡‡‡‡‡‡	......	......	.‡....	......	...‡.‡	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1979	‡‡‡‡‡‡	‡‡‡‡‡‡	‡.....	......	‡‡....	...‡‡‡	..‡‡‡‡	‡‡‡‡‡.	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1980	‡‡‡‡‡.	......	....‡‡	......	......	......	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡..‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.
1981	....‡‡	‡.....	......	......	.‡‡...	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1982	‡.....	...‡‡.	......	......	...‡‡.	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡..	.‡‡‡‡-
1983	------	------	------	------	------	------	------	------	------	------	------	------
1984	-‡‡‡‡‡	......	......	......	......	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡..‡
1985	‡‡‡‡‡‡	......	......	......	......	......	‡‡‡..‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1986	......	...‡.‡	‡‡‡‡..	......	......	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1987	‡.....	...‡‡‡	......	......	......	......	..‡.‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	..‡‡‡‡
1988	‡‡...‡	‡‡....	......	......	......	......	..‡...	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1989	‡‡‡‡‡‡	‡‡..‡‡	......	......	.‡‡...	......	‡‡‡.‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡.-

Note: ‡ represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
E-360. Rajigang; Daily Rainfall (BE)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-xxx...xxx.........x.....x............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1963	xx............................xx.........xxxxxxxxxxxxxxxxxxxxxxxxx..xxxx-
1964	---
1965	-xxxxx...xxx.......................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxx.xxxxxxx.............................xxxxxxxx.x.xxxxxxxxxxxxxxxxxxxxxx
1967	xxxxxxxxxx..xx........xx...............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968	...xxxxx..............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xx
1969	xx....xxxx......................x......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1970	....xxxxxxxx...........................x..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1971	------xxxxx...........................xxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxx.
1972	..xxx..xxx..x......x..xx......xxxx..x.xxxxxxxxxxxxxxxxxxxxxxxxxxx....xxxx
1973	xxxxx.............xx...................xxx....xxxxxxxxxxxxxxxxxxxxxxxxx..
1974	.xxxx................................xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1975	xxxx.xxx.................xxx.......x....xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	x..xxx................x...........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977	.............x.................xx..xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	xxxxxxx..........x..........x...xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1979	xxxxxxxxxxxxxx.........xxxx.......x...xxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxx
1980	xxxxx....xx..........x.x.x.x......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1981	....xxxxxx....x..........x.........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982	xx.....xxxxxx..............xx.....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxxx
1983	x.........xxxxx.....xx....xx............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxxx..............................xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1985	xx.x.............x.......xxxx...xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	x...x.xxxxxxxxxxx............xxx.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	xxx....xxxxx....xxx......xx..........xxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxx
1988	xx...xxx.............................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1989	xxxxxxxxxx........xxxx...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx.x-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-361, Hatia; Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	------	-****.	......	......	.....*	*.....	.*****	******	******	******	******	******
1963	......	.***..	..**..	......	......	.....*	.*****	******	******	******	******	*****-
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	-*****	*...*.	......	......	......	......	.*....	.*****	******	******	******	******
1966	******	..***.	......	......	......	......	...***	******	******	******	******	***.**
1967	****..	.*****	*.....	......	......	......	...***	******	******	******	******	***...
1968	*.****	**....	......	......	......	......	..****	******	******	******	******	******
1969	******	**....	......	......	......	......	...***	******	******	******	******	******
1970	******	*****.	......	......	......	......	..**..	**---*	******	******	******	******
1971	....*.	......	......	---...	......	...***	..***-	--.***	******	******	******	******
1972	**....	.***..	**....	......	......	...**.	..****	******	******	******	*****.	.*****
1973	*****.	......	......	......	......	......	..****	....**	******	******	******	***...
1974	.*****	******	......	......	.....-	---...	.....*	******	******	******	******	******
1975	******	**....	......	......	......	......	....**	*...**	******	******	******	******
1976	******	......	......	......	......	......	.*****	******	******	******	****..	******
1977	......	......	......	......	......	......	.*****	******	******	******	******	******
1978	**..**	*.....	......	......	......	.....*	...***	******	******	******	******	******
1979	******	******	*.....	......	......	...**.	..****	******	******	******	****--	-*****
1980	******	**....	......	......	......	....**	..****	******	******	*..***	******	****..
1981	....**	*.....	......	......	......	....**	******	******	******	******	******	******
1982	***...	******	......	......	......	......	..****	******	******	******	*****.	***..*
1983	*...*.	....*.	......	..**..	......	......	.....*	******	******	******	******	******
1984	****..	....*.	......	......	......	....**	**...*	******	******	******	******	******
1985	**.*..	......	......	......	......	......	.*****	******	******	******	******	******
1986	**....	....**	*.....	......	......	...*..	..****	******	******	******	******	******
1987	****..	.***.*	......	......	......	......	.***.*	******	******	******	******	******
1988	******	*.....	......	......	......	......	.....*	*****.	******	******	******	*****-
1989	------	------	------	------	------	------	------	------	------	------	------	------

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-362, Kasba; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-xxx.....x.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1963	x.....x....x...........xx..xxxxxx.........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1964	---
1965	-xxxxxx..xxx.........................xxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966	xxx...................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xx
1967	xxxx.......xx...xxx....x..............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1968	x...xxxx.................x....xxxx.x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1969	xxx...xxxxxx....................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1970	xxxxxxxxxx......................xxxxxx...x...x..xxxxxxxxxxxxxxxxxxxxxxx----
1971	---xxxxxxxxxxxxxxxxxxx.
1972	...x....x.........x........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xxxxx
1973	xxxx......................xxxxxxx....xxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxx..
1974	....x.....xx..xxx.......xx.x.xxxx....xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1975	xxx...........xxxxxxx..x.x....x....xx.xxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxx
1976	xx....................xxx....xxxxxxxxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977	...................................xx...xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978	xx...............xx.....xxx.....xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1979	xxxxxxxxxxxxxx..........xxxx..xx..xx...xxxxxxxxx..xxxxxxxxxxxxxxxxxxxxxxx
1980	xx..............xxxxx.....xxxxx......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1981	....xxxx.....xxx...................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xxx
1982	xxxx......xxx......xx......xxx.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.x....x
1983	xxx..................xxx...xx......xx.x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984	xxxxx..............x...............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1985	xxxx......................x....x.....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986	.............xxxxx.................x.......xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxx
1987	xxxx....xxx.....x..........x...........xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xx
1988	xx.....x.....xx......xxxxx...............xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1989	---

Note: x represents a dry pentad.
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-363, Laksam; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	-.....****.......********...**....---------**********--------------------
1963	--------------------------------....************************************-
1964	---
1965	-*****...****......****........*.**
1966	***********.........**...........************************************..**
1967	****...***..**.........................*******************************...
1968	*.******..........................***..**********************************
1969	**....*.*.*.........................*****************************..******
1970	...*******.......................**...*..********************************
1971	*........***......**...........***.....**..******************************
1972	*..*******..**...............*******..**************************.*******
1973	***...............**.................****....*************************..
1974	..***....**..............*...........***********************************
1975	****---------------------..*...........**...****************************
1976	******.............................**...*********************************
1977	.................................***.*****..*****************************
1978	**..**................................********************************..
1979	*******.*****.........**.........**..*********..***************---*****
1980	****.................................*******************************...
1981	.....***.........................**
1982	**.......***.......*.............********************************.....**
1983	*..................**....................********************************
1984	*****....*......................***********************************..*
1985	*****...*............................************************************
1986	..........******.......................**********************************
1987	***....***.....*........*........******************************....***
1988	***................................**************************************
1989	*********..................***........****************************.*..-

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-364. Lakshmipur: Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	-xx...	..xx..	......	......	x	xx....	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1963	x...--	-.....	......	......	......	......	..x.--	-xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxx-
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	-xx.x.	...xxx	......	......	......	x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1966	xxxxx.	..xxx.	......	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	x..xxx
1967	xxxxxx	xxxxxx	......	......	......	..---.	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxx...
1968	..xxxx	xx....	......	......	x	x...x.	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxx..x
1969	xxx...	..x...	......	......	......	x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1970	x...xx	xxx...	......	......	......	...x..	x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1971	x...x.	...xxx	......	......	......	......	.xxxx.	.xxxxx	xxxxxx	xxxxxx	..xxxx	xxxxxx
1972	xx...x	xxx...	xx....	......	......	..x...	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx..	.xxxxx
1973	xxxxxx	......	......	......	......	......	.xxxx.	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxx..
1974	..xxx.	..x...	......	......	......	......	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1975	xxxxxx	xxx.x.	......	......	x.....	...xx.	...xx.	..xxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1976	xxxx..	.x....	......	......	......	..x.xx	xx.xxx	xxxxxx	xxxxxx	xxxxxx	xxxx..	xxxxxx
1977	......	......	......	......	......	.x....	..xxx.	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1978	xxxxxx	......	......	......	......	.xx...	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1979	.x....	xxxxxx	......	......	......	..xxx.	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx--	-.xxxx
1980	xxxxxx	x.....	...xx.	......	....x.	......	xxxxxx	xxxxxx	xxxxxx	xxxxxx	x.xxxx	xxxx..
1981	......	x.....	......	......	......	...xx.	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1982	xx....	x.x...	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxx.	.xxxxx
1983	......	xx	x.....	xx....	......	......	xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1984	xxxxxx	x...x.	......	......	......	xx	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1985	xxxxxx	xxxxx.	......	......	......	x.....	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1986	xxxxxx	...x.x	......	......	......	......	...xxx	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1987	x.....	.xxxx.	......	......	......	x	x...xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1988	xxxxxx	xx....	......	......	......	......	.x..xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1989	xxxxxx	xx....	......	......	xxxx..	......	......	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxx..-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-365, Munshiganj; Daily Rainfall (mm)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	---
1963	-*..........---.............*.*.......*...*********************..*****-
1964	---
1965	-*****---***........**.........---..*****.*******************************
1966	*****---***.............---...........*.****************************..***
1967	**---......**..**.....*..............********************************...
1968	*.******..---................*.*.****..*******************************..*
1969	**.....****............---...**.....**********************************..
1970	....********.....................**..**..**..**************************
1971	.....-----*..-------------------********---*********************----****-
1972	--------------------------------******************************----****
1973	*-----------------------------------**---*-----*********************
1974	*-----------------*----------------*************************---*******--
1975	-**----------------------------.........********************************
1976	***---*...----------------------**************************************------***
1977	--------..---....----------**********---*********************************
1978	******---.------..***.---**---*****..**-----*****************************
1979	************-------------.-------------************************************-
1980	---
1981	-....**.......*......................************************************
1982	**....---****...---.*...---..*..---*********---***************************---*
1983	*...-----..**------***....**-----.***------******************************
1984	.*****.........---...-----.*...---.*************************************
1985	*****............*......*...........************************************
1986	..*.*.**.*...****...---...**...***.....******************************
1987	**..---.***---....---------------***********************************-----**
1988	***...***.........------*..---.---.***...*****************************
1989	*********.......***.**...*******...----.*******************************-

Note: * represents a dry pentad
Note: . represents a wet pentad.
- represents missing data

Analysis of Pentades
E-366, Muradnagar: Daily Rainfall (mm)

```
YEAR | APR   MAY   JUN   JUL   AUG   SEP   OCT   NOV   DEC   JAN   FEB   MAR
-----+-------------------------------------------------------------------------
1962 |-------------------------------------------------------------------------
1963 |-------------------------------------------------------------------------
1964 |-------------------------------------------------------------------------
1965 |-------------------------------------------------------------------------
1966 |-------------------------------------------------------------------------
1967 |-------------------------------------------------------------------------
1968 |-*******...***...*....*......---..************************************..*
1969 |*****...***............................**********************************
1970 |**...*****..................................*..**************************
1971 |*........***.......*....................**..*****************************
1972 |******.*******....**.............**..****************---****---**.*..****
1973 |****........*..........-......**...*******...**************************..
1974 |...**..................---------....*************************************
1975 |***..***.......*.*....******....***.*.***********************************
1976 |****......**.........*****.*------------*********************************
1977 |....................**...........*....**..**********************************
1978 |**................**......*.*....************************************.*.*
1979 |*************.....................*...********...**************.*********
1980 |***.............**...................*...*********************.*********.
1981 |....****......*...........*......***********************************.***
1982 |*.......*****..............**.........****************************.......
1983 |..**........***.......*............***...********************************
1984 |****...............................***********************************..*
1985 |***.......................*****..*..*************************************
1986 |..**........**................**.....*****..*****************************
1987 |***...***.*...............*..............**************************....**
1988 |**...****....................------..*...********************************
1989 |********..............................*.********************************-
```

Note: * represents a dry pentad

Note: . represents a wet pentad

\- represents missing data

Analysis of Pentades
R-367, Nabinagar;

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	-x.x..	...x..	......	......	.x....	......	xxxxxx	xxxxxx	xxxxxx	xxx---	------	------
1963	------	------	------	------	------	------	------	------	------	------	------	------
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	------	------	------	------	------	------	------	------	------	------	------	------
1966	------	------	------	------	------	------	------	------	------	------	------	------
1967	------	------	------	------	------	------	------	------	------	------	------	------
1968	------	------	------	------	------	------	------	------	------	------	------	------
1969	------	------	------	------	------	------	------	------	------	------	------	------
1970	------	------	------	------	------	------	------	------	------	------	------	------
1971	------	------	------	------	------	------	------	------	------	------	------	------
1972	------	------	------	------	------	------	------	------	------	------	------	------
1973	------	------	------	------	------	------	------	------	------	------	------	------
1974	------	------	------	------	------	------	------	------	------	------	------	------
1975	------	------	------	------	------	------	------	------	------	------	------	------
1976	------	------	------	------	------	------	------	------	------	------	------	------
1977	------	------	------	------	------	------	------	------	------	------	------	------
1978	------	------	------	------	------	------	------	------	------	------	------	------
1979	------	------	------	------	------	------	------	------	------	------	------	------
1980	------	------	------	------	------	------	------	------	------	------	------	------
1981	-...xx	x.....	.xxxx.	xxx...	......	xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xx.xxx
1982	xxxxx.	....x.	......	..xx..	..xxx.	xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	x...xx
1983	x.....	x	xxx...	...xx.	......	xx	x...xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1984	xxxxx.	......	......	......	......	xx	x...xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx..
1985	xx...x	x.....	......	......	xxx...	.x....	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1986	......	......	xxxxx.	..xx..	......	......	xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1987	xxxx..	..xxx.	......	x.....	.xxx..	...x..	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxx.	x...xx
1988	xxxx..	......	xx....	x	x...xx	x	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1989	xxxxxx	xx....	......	......	xx	x.....	..x.xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx.-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
B-369, Noakhali; Daily Rainfall (mm)

```
YEAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR
-----+-----------------------------------------------------------------------
1962 |-xxx...xxx.........x.................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1963 |-------..............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxxx-
1964 |-------------------------------------------------------------------------
1965 |-xxxx....xx.........................xxxxx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1966 |xxxxxxxxxx..........xx.................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx...xx
1967 |xxxx...xxx.............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968 |x.xxxxxx...........................x...xx..xxxxxxxxxxxxxxxxxxxxxxxxxxx..x
1969 |xxx...xxx...........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1970 |x...xxxxx............................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1971 |x..xxx...xx......................xx....xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1972 |xx...xxxx...xx...................xxxx..xxxxxxxxxxxxxxxxxxxxxxxxxx....xxxx
1973 |xxxxx.................................xx.....xxxxxxxxxxxxxxxxxxxxxxxxx...
1974 |.xxxx....xx............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1975 |-------------------------------------------------------------------------
1976 |-xxxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1977 |...................................xxxxxxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1978 |x...xx...........................x.x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1979 |xxxxxxx.xxxxx.....................xx..xxxxxxxx...xxxxxxxxxxxxxx.x---xxxxx
1980 |xxxxx.................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
1981 |....xxx..............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1982 |xx....xxxxxx........x................xxxxxxxxxxxxxxxxxxxxxxxxxxx---xxxx.x
1983 |............x......................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1984 |xxxxx..............................xx....xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1985 |xx.x................................xxx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1986 |..xx.........x.........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
1987 |xxx....xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.x.xxxx
1988 |xx....x..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.x
1989 |xxxxxxxxx..xx.............................xxxxxxxxxxxxxxxxxxxxx.....xxx.-
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-370, Parshuram; Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	-***..	.***..	......	......	......	......	.*****	******	******	******	******	*..***
1963	......	......	......	......	......	......	..*...	.*****	******	******	******	*****-
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	-*****	...***	......	......	......	......	******	******	******	******	******	******
1966	******	******	......	......	......	....**	******	******	******	******	******	*..***
1967	****..	..****	**....	......	......	......	..****	******	******	******	******	***...
1968	*.****	**....	......	...---	......	.*...*	.*****	******	******	******	******	***..*
1969	**....	****..	......	......	......	..**..	******	******	******	******	******	*****.
1970	.*.***	***...	......	......	......	..*...	..**..	.*..**	******	******	******	******
1971	...***	..---.	......	......	......	...*..	..****	******	******	******	******	******
1972	****.*	****..	**...*	*.....	......	.*****	...***	******	******	******	****..	.*****
1973	****..	......	......	......	.....*	......	..****	...***	******	******	******	****..
1974	.****.	....--	-..---	......	......	......	****..	.*****	******	******	******	******
1975	***..*	***.*.	...***	......	.*....	......	..*.**	*...**	******	******	******	****--
1976	-*****	....**	......	....**	......	*****.	.*****	******	******	******	******	******
1977	......	......	......	......	......	...***	...***	*.****	******	******	******	******
1978	**...*	......	......	......	......	.....*	.*.***	******	******	******	******	******
1979	**.***	******	*.....	.....*	***...	...**.	..****	****..	.*****	******	******	******
1980	****..	......	....**	......	......	....**	.*****	******	******	******	******	*****.
1981	....**	**....	.**...	......	......	....**	******	******	******	******	******	******
1982	***..*	*..***	......	......	......	.....*	..***-	------	------	------	------	------
1983	-.....	......	......	..**..	......	......	.....*	******	******	******	******	******
1984	****..	......	*.....	......	......	......	..****	******	******	******	******	***..*
1985	**....	......	......	......	......	.....*	******	******	******	******	******	******
1986	......	....**	**....	......	......	......	....**	******	******	******	******	******
1987	***...	..***.	.....*	......	.**...	..*...	..*.**	******	******	******	*****.	..****
1988	**...*	*.....	......	......	......	.....*	**...*	******	******	******	******	******
1989	******	***...	......	...**.	..*.**	*.....	.....*	******	******	******	*****.	*.*..-

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-372, Raipur (Noakhali): Daily Rainfall (mm)

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YEAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR
-----+-----------------------------------------------------------------------
1962 |-.......xx........xx..........xx......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1963 |xxxxx......xx...xxx..................xxx.---------xxxxxxxxxxxxxxxxxxxxxx-
1964 |-------------------------------------------------------------------------
1965 |-xxxx....xxxxxx......................xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1966 |xxxxx...xxx...........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx..xxx|
1967 |xxxx....xxxxxx........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...
1968 |x.xxxxxx..---........xx.....----.x.x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..x|
1969 |xxx...xxxxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1970 |x...xxxxxxx...........................xx..xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1971 |x...x....xxx......................xx....xx...xxxxxxxxxxxxxxxxxx.xxxxxxxxx|
1972 |.....xxxx..xxxx...................xx...xxxxxxxxxxxxxxxxxxxxxxxxxx....xxxx|
1973 |xxxxx...............x..........xx.....xxxxxx...xxxxxxxxxxxxxxxxxxxxxxx...
1974 |..xxxx..................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1975 |xxxxxxxxx.x.............................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1976 |xxxxxx..........................xxxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1977 |................................xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1978 |xxxxxxx.......................x....xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1979 |.x....x.xxxx...........xxx........xx..xxxxxxxxxxxxxxxxxxxxxxxxx.xxx..xxxx|
1980 |xxx.x..............................x.xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
1981 |.....xxxxx...xxx.........xx.......xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1982 |xx...................................xxxxxxxxxxxxxxxxxxxxxxxxxxxxx.xxxxxx|
1983 |xxxxx......xxx..........................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1984 |xxxxx.....xx.......x................xx...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1985 |xx.x....xx............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1986 |x..........xxxx............................xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
1987 |.......xxx.............................xxx.xxxxxxxxxxxxxxxxxxxxxxxxxxx.xxxx|
1988 |xxx..xxxx.....................x...xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx-
1989 |-------------------------------------------------------------------------
```

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-375, Rangati; Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	------	------	------	------	------	------	------	------	------	-xxxxx	xxxxxx	xxxxx-
1963	------	------	------	------	------	------	------	------	------	------	------	------
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	------	------	------	------	------	------	------	------	------	------	------	------
1966	-xxxxx	xxxxxx	......	......	......	x	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1967	xxxxxx	xxxxxx	x.....	......	......	......	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xx..xx	xxx..x
1968	x.xxxx	xx....	......	......	......	......	.xxxx.	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxx..x
1969	xxx..x	xxxxxx	......	......	......	x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1970	xxxxxx	xxxx..	......	......	......	......	.xx...	x---xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1971	...xxx	.....-	--....	......	......	.xxx.x	xxxxx.	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1972	x.....	.xxxxx	xx....	......	......	xxxxxx	x..xxx	xxxxxx	xxxxxx	xxxxxx	xxxxx.	..xxxx
1973	xxxxxx	......	......	......	x	......	xx	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxx..
1974	..xxx.	..xxx.	......	......	......	......	xxx.xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1975	xxxxxx	xx....	......	......	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1976	xx----	......	xx	......	......	......	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx..	xxxxxx
1977	......	......	......	......	......	x	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxx.
1978	......	......	......	......	......	......	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1979	------	x.xxxx	......	......	......	..xx..	xxxxxx	xxxxxx	xxxxxx	xxxxxx	x.x.xx	x..xxx
1980	xxxxx.	......	......	......	......	......	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxx...
1981	xx	xxx...	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1982	xx....	...xx-	--....	......	......	......	.xxxxx	x..xxx	xxxxxx	xxxxxx	xxx...	.xxx.x
1983	......	......	x.....	......	......	......	x	xx..xx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1984	xxxxx.	......	......	......	......	xx	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1985	xx.x..	x	x.....	......	......	......	...xxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1986	..xx..	...x..	......	......	......	x.x...	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1987	xxx...	.xxx..	......	......	......	x	xx.xxx	xxxxxx	xxxxxx	xxxxxx	xxxx..	..xxxx
1988	xx..xx	x.....	......	......	......	......	.xxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx
1989	xxxxxx	xxx...	......	...x..	......	......	......	xxxxxx	xxxxxx	xxxxxx	xxxx..	.xxx.-

Note: x represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
B-376, Senbag;

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YEAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR

1962 |-.......***........*...............----------****************-------*****|
1963 |**..*****.....................**...***.*...***********************..****-|
1964 |-------------------------------------------------------------------------|
1965 |-*****...**..........----------......***********************************-|
1966 |-------------------------------------------------------------------------|
1967 |-***...**...**.........................*******************************...|
1968 |...*****..............---.............***---*****************************|
1969 |**....******..........**............*************************************|
1970 |*...*****.............................**...******************************|
1971 |*...*---------..........................**...****************************|
1972 |*.....****..**...**............******..***************************.******|
1973 |***..........................*......****...**************************..|
1974 |.*****...**...........................***********************************|
1975 |********................***.............***..****************************|
1976 |*********............................---------*******************..******|
1977 |.............*...................****************************************|
1978 |******...........................*.*...**********************************|
1979 |*****...*****...........**...**..**************..***************---*****|
1980 |*****.................................********************************.*.|
1981 |....****..........................**************************************-|
1982 |-------------------------------------------------------------------------|
1983 |-.........*****.........................*********************************|
1984 |*****..............................***.*******************************..*|
1985 |****....*.*.........................*************************************|
1986 |*****....*.***.........................*********************************-|
1987 |-------------------------------------------------------------------------|
1988 |-*...***...........................****..********************************|
1989 |*************.............................*********************.****.*..-|
```

Note: * represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-377, Sonaimuri; Daily Rainfall (mm)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1962	------	------	------	------	------	------	-‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1963	‡‡‡‡‡‡	......	......	......	......	‡.....	.‡‡‡..	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	.‡‡‡‡-
1964	------	------	------	------	------	------	------	------	------	------	------	------
1965	-‡‡‡‡‡	...‡‡‡	......	......	......	......	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1966	‡‡‡‡‡‡	‡‡‡‡..	......	......	......	.-----	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1967	‡‡‡‡..	.‡‡‡..	......	......	......	......	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1968	‡.‡.‡‡	‡‡....	......	......	......	......	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡..‡
1969	‡‡...‡	‡‡‡‡‡.	......	......	......	.....‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1970	‡...‡‡	‡‡‡...	......	......	......	......	.‡‡..‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1971	‡..‡‡‡	..‡‡‡‡	......	......	......	...‡..	.‡‡‡..	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1972	‡‡‡‡.‡	‡‡‡‡..	‡‡....	......	......	‡‡‡...	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡..	.‡‡‡‡‡
1973	‡‡‡‡‡.	......	......	......	......	......	.‡‡‡..	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡..
1974	.‡‡‡‡.	...‡‡.	......	......	......	......	.‡‡...	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1975	‡‡‡‡‡‡	‡‡‡‡..	..‡‡..	......	......	.....‡	...‡‡.	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1976	‡‡‡‡‡‡	...‡..	...---	......	......	....‡.	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1977	......	......	......	......	......	......	.‡‡‡‡.	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1978	‡‡..‡‡	......	......	......	......	..‡‡..	..‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡..
1979	.‡‡‡‡‡	‡‡‡‡‡‡	‡.....	......	......	..‡‡..	‡‡‡‡‡‡	‡‡‡.‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡.‡‡‡	‡‡‡‡‡‡
1980	‡‡‡‡‡.	......	......	......	......	...‡‡.	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡.‡.
1981	....‡‡	‡.....	.‡‡...	......	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1982	‡‡...‡	‡‡‡‡‡.	......	.‡....	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	....‡‡
1983	‡.....	.....‡	‡‡....	......	......	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1984	‡‡‡‡‡.	......	......	......	......	....‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1985	‡‡‡‡..	..‡...	......	......	......	.....‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1986	‡.‡‡‡.	..‡.‡‡	‡.....	......	......	......	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1987	‡‡‡...	.‡‡‡..	......	......	......	......	...‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡.	.‡‡‡‡‡
1988	‡‡...‡	‡‡‡...	......	......	......	....‡.	.‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡
1989	‡‡‡‡‡‡	‡‡‡‡..	......	......	‡‡....	......	....‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡‡‡‡	‡‡‡..-

Note: ‡ represents a dry pentad
Note: . represents a wet pentad
- represents missing data

Analysis of Pentades
R-402, Bhagyakul; Daily Rainfall (EE)

YEAR	APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1962	---
1963	-....---------..‡‡.........‡‡‡‡‡.....‡‡‡‡‡.‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡.-
1964	---
1965	-..‡‡....‡‡‡.........‡............‡.‡.‡.‡.‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1966	‡‡‡‡‡...‡‡‡..........‡‡...........‡‡...‡.‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡.‡.‡
1967	‡‡‡‡...‡‡‡‡‡‡‡...‡....‡...............‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡...
1968	..‡---‡‡...‡‡‡........‡......‡...‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1969	‡‡‡...‡‡‡‡‡‡.................‡‡‡‡‡....‡‡‡‡‡‡..‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1970	‡‡..‡‡‡‡.‡......................‡‡...‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1971	‡..---...‡‡....‡‡................‡‡...‡‡‡...‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1972	..‡‡‡..‡‡‡..‡‡...............‡.........‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1973	‡‡....................‡..........‡‡‡.........‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡..
1974	..‡‡‡.........‡‡..........‡‡...‡........‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1975	‡‡‡‡‡‡‡‡......‡‡............‡‡........‡....‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1976	‡‡‡‡‡............‡‡..........‡.......‡‡..‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡..‡‡‡‡‡‡
1977	...................................‡‡‡‡.‡‡‡..‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡.
1978	........‡..........................‡‡..‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1979	‡‡‡...‡‡‡.‡‡‡...‡‡‡....‡‡..........‡‡..‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1980	‡‡‡‡‡.......................‡...........‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡.‡.
1981	.....‡........‡‡‡.‡................‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡..‡‡‡‡‡.‡‡‡
1982	‡....‡........‡‡‡.‡................‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡..‡‡‡...‡‡‡
1983	‡‡‡‡‡......‡‡‡‡.....‡‡.............‡‡....‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1984	.‡‡‡‡...............................‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡...
1985	.‡.‡...‡...................‡‡.....‡...‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1986	...............‡..........................‡‡‡‡..‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡
1987	‡‡‡.....‡‡‡................‡.........‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡.....‡-
1988	---
1969	-‡‡‡‡‡‡‡.............‡......‡‡........‡.‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡‡-

Note: ‡ represents a dry pentad
Note: . represents a wet pentad
- represents missing data

APPENDIX II

ANNUAL MAXIMUM RAINFALL FREQUENCY ANALYSIS

Annual Maximum Pre-Monsoon Rainfall
R-076, Narsingdi; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	114	153	179	204	236
2	169	217	250	281	321
3	206	271	315	357	411
4	234	311	361	410	473
5	254	335	388	439	505
7	306	415	487	557	646
10	358	487	572	653	759

Annual Maximum Mid-Monsoon Rainfall
R-076, Narsingdi; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	127	167	193	219	251
2	184	237	272	305	349
3	216	280	323	364	417
4	249	323	372	419	480
5	270	355	412	466	536
7	305	401	465	526	605
10	361	459	525	588	669

Annual Maximum Post-Monsoon Rainfall
R-076, Narsingdi; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	90	128	153	177	208
2	122	176	212	246	291
3	144	210	254	297	351
4	163	236	285	332	392
5	172	249	301	350	414
7	189	277	334	390	462
10	221	314	376	436	512

Annual Maximum Rainfall
R-076, Narsingdi; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	150	187	212	236	266
2	214	259	289	318	356
3	262	321	360	398	447
4	303	368	412	453	507
5	326	401	451	499	561
7	374	473	539	602	684
10	434	541	612	679	767

Annual Maximum Pre-Monsoon Rainfall
R-101. Bhairab Bazar; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	107	138	158	178	204
2	147	191	220	249	285
3	176	238	279	318	369
4	203	274	321	366	424
5	224	303	355	405	471
7	263	353	413	470	544
10	311	409	474	536	616

Annual Maximum Mid-Monsoon Rainfall
R-101, Bhairab Bazar; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	111	158	189	219	258
2	150	222	269	315	374
3	178	254	304	351	413
4	200	282	336	387	454
5	217	303	360	414	485
7	243	334	395	453	529
10	284	375	435	492	567

Annual Maximum Post-Monsoon Rainfall
R-101, Bhairab Bazar; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	87	134	165	194	233
2	117	179	220	260	311
3	134	200	244	286	340
4	147	216	261	305	361
5	156	227	275	321	380
7	167	243	294	342	405
10	195	284	343	400	474

Annual Maximum Rainfall
R-101, Bhairab Bazar; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	138	185	216	247	285
2	187	260	309	356	416
3	223	302	354	404	468
4	250	333	388	440	508
5	275	359	415	469	538
7	314	405	465	523	598
10	360	462	531	596	680

Annual Maximum Pre-Monsoon Rainfall
R-103, Brahmanbaria; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	116	153	178	202	233
2	156	208	243	276	319
3	189	257	302	345	401
4	214	295	349	400	466
5	233	324	385	443	517
7	268	376	447	515	603
10	310	422	496	567	659

Annual Maximum Mid-Monsoon Rainfall
R-103, Brahmanbaria; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	119	164	193	222	258
2	152	212	252	290	339
3	182	260	312	361	426
4	200	291	352	410	484
5	217	318	385	449	531
7	248	349	417	481	565
10	279	374	437	497	576

Annual Maximum Post-Monsoon Rainfall
R-103, Brahmanbaria; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	75	120	149	177	214
2	100	156	193	229	275
3	117	184	228	270	325
4	128	197	244	288	345
5	140	219	271	321	385
7	157	246	305	362	435
10	177	270	332	392	469

Annual Maximum Rainfall
R-103, Brahmanbaria; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	156	193	217	241	271
2	203	252	285	316	356
3	246	316	362	407	465
4	275	358	412	464	532
5	300	392	453	512	587
7	334	438	506	572	657
10	370	473	541	606	691

Annual Maximum Pre-Monsoon Rainfall
R-105, Chandpur Bagan; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	112	157	187	215	252
2	154	214	254	293	343
3	187	266	319	369	434
4	214	302	360	416	489
5	237	333	397	458	537
7	277	380	448	514	598
10	321	434	509	581	674

Annual Maximum Mid-Monsoon Rainfall
R-105, Chandpur Bagan; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	97	138	166	192	226
2	139	203	245	286	338
3	167	241	290	337	398
4	183	259	309	357	420
5	194	278	333	386	455
7	214	296	350	402	470
10	247	329	384	436	504

Annual Maximum Post-Monsoon Rainfall
R-105, Chandpur Bagan; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	72	113	140	166	200
2	97	145	178	209	249
3	114	171	208	245	291
4	124	180	217	253	299
5	134	194	233	271	320
7	149	213	255	295	347
10	171	240	286	330	387

Annual Maximum Rainfall
R-105, Chandpur Bagan; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	141	187	218	248	286
2	193	259	303	345	400
3	238	316	367	416	480
4	261	344	399	452	520
5	287	377	437	494	569
7	319	412	474	534	610
10	361	465	533	599	684

Annual Maximum Pre-Monsoon Rainfall
R-110 Habiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	128	167	194	219	251
2	179	237	274	311	358
3	221	289	335	378	434
4	242	321	374	425	490
5	272	358	415	470	541
7	312	413	487	554	641
10	360	469	542	611	702

Annual Maximum Mid-Monsoon Rainfall
R-110 Habiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	90	127	151	174	204
2	133	193	232	269	318
3	159	224	267	308	361
4	178	251	299	346	406
5	197	280	335	387	456
7	222	307	363	417	487
10	259	354	417	478	556

Annual Maximum Post-Monsoon Rainfall
R-110 Habiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	73	110	135	158	189
2	97	149	183	215	258
3	115	169	205	239	283
4	128	183	220	255	301
5	141	203	243	283	333
7	154	219	262	303	357
10	179	262	316	368	436

Annual Maximum Rainfall
R-110 Habiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	145	177	198	219	245
2	207	255	287	317	357
3	247	307	347	385	434
4	272	343	390	435	494
5	305	380	430	478	540
7	342	435	496	556	632
10	399	490	551	609	684

Annual Maximum Pre-Monsoon Rainfall
R-111, Itakhola(Baikunthapur); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	117	157	183	208	240
2	161	222	262	301	351
3	200	267	311	354	409
4	226	302	353	401	464
5	246	331	387	441	510
7	278	368	428	485	560
10	322	416	479	539	616

Annual Maximum Mid-Monsoon Rainfall
R-111, Itakhola(Baikunthapur); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	109	165	202	237	283
2	150	227	277	326	389
3	182	273	333	390	465
4	199	298	364	427	509
5	215	315	381	445	527
7	243	345	412	476	560
10	273	385	459	529	621

Annual Maximum Post-Monsoon Rainfall
R-111, Itakhola(Baikunthapur); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	72	101	121	139	164
2	100	137	161	185	216
3	121	162	189	215	248
4	133	175	203	230	265
5	140	187	218	248	286
7	150	202	236	269	312
10	177	248	295	341	399

Annual Maximum Rainfall
R-111, Itakhola(Baikunthapur); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	148	199	232	264	306
2	207	278	324	369	427
3	251	328	379	428	492
4	280	364	419	473	542
5	305	390	446	500	569
7	335	423	482	538	611
10	385	476	536	594	669

Annual Maximum Pre-Monsoon Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	117	155	179	203	234
2	156	205	237	268	308
3	188	253	296	337	390
4	220	300	353	404	471
5	236	323	380	435	506
7	271	367	430	491	570
10	329	434	503	570	656

Annual Maximum Mid-Monsoon Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	107	163	201	237	283
2	145	212	257	299	355
3	172	250	302	352	417
4	188	269	323	375	441
5	202	287	343	397	467
7	232	324	385	444	520
10	261	353	415	474	550

Annual Maximum Post-Monsoon Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	77	102	119	136	157
2	100	137	161	185	215
3	113	152	177	201	233
4	123	168	198	226	263
5	134	179	209	237	274
7	146	192	223	252	289
10	172	227	263	297	342

Annual Maximum Rainfall
R-131, Sarail; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	145	192	224	254	293
2	195	249	284	318	362
3	233	298	341	383	437
4	265	338	387	434	494
5	285	360	410	458	521
7	321	402	456	508	575
10	362	460	525	587	668

Annual Maximum Pre-Monsoon Rainfall
R-132, Nasirnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	111	149	175	199	230
2	154	205	238	271	312
3	193	254	294	332	382
4	221	285	327	367	419
5	239	306	351	394	450
7	284	369	426	480	550
10	336	451	526	599	694

Annual Maximum Mid-Monsoon Rainfall
R-132, Nasirnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	102	137	160	183	212
2	148	206	244	281	329
3	181	250	296	340	397
4	201	283	338	390	458
5	219	307	365	421	493
7	249	341	403	461	537
10	276	373	437	498	577

Annual Maximum Post-Monsoon Rainfall
R-132. Nasirnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	75	108	131	152	179
2	100	147	178	208	247
3	121	185	227	267	319
4	137	208	255	301	359
5	148	221	270	316	376
7	171	260	319	375	448
10	198	305	376	444	531

Annual Maximum Rainfall
R-132, Nasirnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	132	166	189	211	240
2	191	240	272	304	344
3	235	293	331	367	415
4	266	329	371	411	463
5	287	352	396	437	491
7	334	414	466	517	583
10	389	494	563	629	715

Annual Maximum Pre-Monsoon Rainfall
R-260, Bhola; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	109	141	162	183	209
2	150	188	213	236	267
3	179	228	261	292	332
4	203	270	314	357	412
5	223	302	355	405	470
7	258	353	416	476	553
10	314	415	481	545	628

Annual Maximum Mid-Monsoon Rainfall
R-260, Bhola; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	109	145	169	193	223
2	151	205	241	276	321
3	181	252	300	345	404
4	205	289	345	398	467
5	223	315	373	428	500
7	266	360	422	481	558
10	315	423	495	564	653

Annual Maximum Post-Monsoon Rainfall
R-260, Bhola; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	104	148	177	205	242
2	140	196	233	268	314
3	156	222	266	308	363
4	167	232	275	317	370
5	175	244	289	333	389
7	192	274	328	380	447
10	216	311	373	433	511

Annual Maximum Rainfall
R-260, Bhola; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	154	185	205	225	250
2	205	248	277	305	340
3	241	299	338	375	422
4	266	338	386	433	492
5	292	370	421	470	534
7	343	427	483	537	606
10	402	495	557	616	692

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Annual Maximum Pre-Monsoon Rainfall
R-261, Daulatkhan; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	97	128	149	169	195
2	135	182	212	241	279
3	165	222	260	296	343
4	195	261	304	346	400
5	217	294	346	395	459
7	262	355	416	475	552
10	310	423	498	570	663

Annual Maximum Mid-Monsoon Rainfall
R-261, Daulatkhan; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	105	140	163	185	214
2	168	231	272	312	364
3	215	298	354	407	476
4	246	341	404	465	543
5	271	373	441	507	591
7	317	438	517	594	693
10	389	515	599	679	782

Annual Maximum Post-Monsoon Rainfall
R-261, Daulatkhan; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	102	153	187	219	261
2	152	257	327	394	480
3	180	296	372	446	541
4	196	321	404	483	586
5	210	338	423	504	609
7	232	358	442	522	626
10	264	401	491	578	690

Annual Maximum Rainfall
R-261, Daulatkhan; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	134	177	206	233	268
2	212	298	356	411	483
3	259	359	426	490	573
4	299	406	476	544	632
5	325	437	511	582	674
7	378	495	572	647	743
10	449	574	657	737	840

Annual Maximum Pre-Monsoon Rainfall
R-301, Amtali; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	151	235	290	343	411
2	214	325	398	469	560
3	261	414	515	612	738
4	297	480	600	716	866
5	324	518	647	771	931
7	366	575	714	846	1018
10	417	642	791	934	1120

Annual Maximum Mid-Monsoon Rainfall
R-301, Amtali; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	153	202	235	266	306
2	230	315	370	424	493
3	301	406	476	543	629
4	357	486	571	653	759
5	395	540	636	728	848
7	459	629	741	849	989
10	537	752	895	1031	1208

Annual Maximum Post-Monsoon Rainfall
R-301, Amtali; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	78	124	154	183	220
2	105	157	191	224	266
3	122	193	240	285	343
4	130	206	257	305	367
5	140	219	271	322	387
7	151	234	288	341	409
10	173	260	318	374	446

Annual Maximum Rainfall
R-301, Amtali; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	184	262	313	362	426
2	264	374	446	516	607
3	336	486	585	680	804
4	393	575	694	809	958
5	425	626	759	887	1052
7	486	700	842	978	1155
10	568	813	976	1132	1333

Annual Maximum Pre-Monsoon Rainfall
R-311, Fatikchari; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	129	185	222	257	303
2	179	255	304	352	414
3	223	325	392	457	541
4	257	381	463	542	644
5	282	417	507	593	704
7	316	471	574	673	801
10	361	526	636	741	877

Annual Maximum Mid-Monsoon Rainfall
R-311, Fatikchari; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	134	177	205	232	268
2	212	279	324	366	422
3	268	364	428	489	569
4	311	418	489	557	645
5	343	453	525	595	685
7	396	519	600	678	779
10	446	579	666	750	859

Annual Maximum Post-Monsoon Rainfall
R-311, Fatikchari; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	80	125	155	184	221
2	110	175	218	259	313
3	126	204	255	305	369
4	135	215	268	319	384
5	141	225	280	334	402
7	154	244	304	361	435
10	177	274	338	400	480

Annual Maximum Rainfall
R-311, Fatikchari; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	165	209	238	266	302
2	244	310	354	396	450
3	313	411	475	537	617
4	365	475	547	617	708
5	392	512	592	668	767
7	442	584	678	769	886
10	507	656	754	848	970

Annual Maximum Pre-Monsoon Rainfall
R-315, Kaptai (Chowdhury Chara); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	136	217	271	322	389
2	189	305	382	456	551
3	232	369	460	547	659
4	262	411	509	603	725
5	280	444	552	656	790
7	307	476	588	695	834
10	347	516	628	736	875

Annual Maximum Mid-Monsoon Rainfall
R-315, Kaptai (Chowdhury Chara); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	138	198	238	276	325
2	208	313	382	449	535
3	252	379	463	544	649
4	286	450	559	663	798
5	306	483	600	712	857
7	338	520	640	755	905
10	389	579	705	825	981

Annual Maximum Post-Monsoon Rainfall
R-315, Kaptai (Chowdhury Chara); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	83	115	136	156	183
2	106	143	168	192	222
3	124	164	190	215	247
4	141	188	219	249	288
5	150	198	230	260	299
7	173	227	263	298	343
10	195	257	297	336	387

Annual Maximum Rainfall
R-315, Kaptai (Chowdhury Chara); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	182	254	302	347	406
2	269	384	460	533	627
3	323	461	552	639	753
4	368	538	650	758	898
5	394	582	706	826	980
7	431	621	748	869	1026
10	475	670	798	922	1081

Annual Maximum Pre-Monsoon Rainfall
R-320, Mirsari; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	155	212	250	287	334
2	221	303	357	410	477
3	259	352	413	472	548
4	295	395	461	524	606
5	329	434	504	571	658
7	366	482	559	632	728
10	430	578	675	768	889

Annual Maximum Mid-Monsoon Rainfall
R-320, Mirsari; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	153	197	227	255	291
2	245	323	375	424	489
3	302	405	473	539	623
4	355	475	554	630	729
5	391	520	605	686	792
7	453	586	674	759	868
10	526	674	772	866	988

Annual Maximum Post-Monsoon Rainfall
R-320, Mirsari; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	119	178	218	255	304
2	169	240	287	332	391
3	197	279	333	385	452
4	219	310	371	429	504
5	234	333	399	462	543
7	258	380	461	538	638
10	282	415	503	587	696

Annual Maximum Rainfall
R-320, Mirsari; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	203	251	283	314	354
2	289	366	417	465	529
3	354	450	514	575	654
4	407	518	591	662	753
5	446	560	636	708	802
7	511	626	702	774	868
10	592	723	809	892	1000

Annual Maximum Pre-Monsoon Rainfall
R-323, Narayanhat; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	138	191	226	259	302
2	195	265	311	355	413
3	237	318	372	424	491
4	268	355	413	469	541
5	291	390	455	518	600
7	316	430	505	578	671
10	359	494	584	671	782

Annual Maximum Mid-Monsoon Rainfall
R-323, Narayanhat; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	145	185	211	237	270
2	224	299	349	397	459
3	282	381	447	510	592
4	325	436	510	581	673
5	357	476	555	630	728
7	407	545	637	726	840
10	472	630	735	835	965

Annual Maximum Post-Monsoon Rainfall
R-323, Narayanhat; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	93	139	169	198	236
2	132	207	256	304	365
3	153	233	286	338	404
4	161	242	296	347	414
5	169	251	305	357	424
7	184	271	328	383	454
10	204	290	347	401	472

Annual Maximum Rainfall
R-323, Narayanhat; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	175	218	246	273	308
2	264	330	373	415	468
3	330	412	466	518	585
4	374	463	522	578	652
5	402	499	564	625	705
7	449	570	650	727	827
10	512	658	754	847	967

Annual Maximum Pre-Monsoon Rainfall
R-327. Ramgarh; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	145	204	243	280	328
2	196	269	317	363	422
3	238	343	413	480	566
4	268	399	485	569	676
5	292	444	545	642	767
7	330	496	605	710	846
10	374	558	680	797	948

Annual Maximum Mid-Monsoon Rainfall
R-327, Ramgarh; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	150	203	239	273	317
2	237	336	401	464	545
3	291	416	499	579	682
4	324	462	554	642	756
5	357	506	604	699	821
7	405	577	691	800	941
10	467	651	773	890	1041

Annual Maximum Post-Monsoon Rainfall
R-327, Ramgarh; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	89	122	144	165	192
2	120	172	206	238	281
3	140	203	245	285	337
4	151	218	262	304	359
5	158	226	272	316	372
7	175	245	292	336	394
10	198	282	338	392	461

Annual Maximum Rainfall
R-327, Ramgarh; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	184	239	276	311	357
2	274	360	416	471	541
3	336	457	537	614	713
4	372	515	610	701	819
5	402	568	678	783	920
7	460	641	762	877	1026
10	519	714	842	966	1126

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Annual Maximum Pre-Monsoon Rainfall
R-351, Bancharampur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	90	132	160	187	222
2	118	170	204	237	279
3	144	204	244	282	332
4	167	245	297	347	411
5	185	274	334	390	464
7	217	324	395	462	550
10	254	385	472	555	663

Annual Maximum Mid-Monsoon Rainfall
R-351, Bancharampur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	101	151	185	216	258
2	136	210	259	306	367
3	158	258	324	388	470
4	179	284	353	419	505
5	194	303	375	444	534
7	216	332	409	483	579
10	252	372	452	528	627

Annual Maximum Post-Monsoon Rainfall
R-351, Bancharampur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	59	104	133	162	199
2	75	131	168	203	249
3	84	152	197	240	296
4	93	168	218	266	328
5	99	177	230	280	344
7	109	203	265	325	402
10	128	235	306	373	461

Annual Maximum Rainfall
R-351, Bancharampur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	129	174	204	232	269
2	178	241	283	323	374
3	216	302	359	413	484
4	248	340	401	460	536
5	270	368	433	496	577
7	309	420	494	564	656
10	356	478	560	637	738

Annual Maximum Pre-Monsoon Rainfall
R-352, Barura; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	97	144	176	206	245
2	126	192	235	277	331
3	151	229	280	330	393
4	174	266	327	386	462
5	194	298	367	433	519
7	221	341	420	496	595
10	262	390	474	555	661

Annual Maximum Mid-Monsoon Rainfall
R-352, Barura; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	92	124	146	167	194
2	137	179	207	233	268
3	159	204	234	263	300
4	179	228	260	291	331
5	196	250	286	320	364
7	228	288	328	365	415
10	268	349	403	455	522

Annual Maximum Post-Monsoon Rainfall
R-352, Barura; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	74	114	140	165	198
2	106	174	218	261	316
3	124	215	276	334	409
4	137	234	298	360	440
5	143	240	303	365	444
7	160	261	327	391	474
10	184	287	355	421	505

Annual Maximum Rainfall
R-352, Barura; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	124	168	197	225	261
2	174	242	287	330	386
3	201	291	351	408	482
4	226	328	395	459	542
5	247	354	424	491	579
7	279	396	474	548	645
10	324	449	532	611	714

Annual Maximum Pre-Monsoon Rainfall
R-353, Basurhat; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	131	173	201	228	262
2	193	251	290	327	375
3	236	323	381	436	508
4	261	359	425	487	568
5	286	401	477	550	645
7	322	452	538	620	727
10	381	528	625	718	839

Annual Maximum Mid-Monsoon Rainfall
R-353, Basurhat; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	148	199	232	265	306
2	226	300	349	396	456
3	283	369	426	481	552
4	329	421	481	540	615
5	361	452	513	571	646
7	423	526	594	659	743
10	516	639	720	798	899

Annual Maximum Post-Monsoon Rainfall
R-353, Basurhat; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	113	175	215	254	304
2	158	250	311	369	445
3	188	298	370	439	529
4	207	324	402	477	574
5	218	339	419	495	595
7	245	372	457	538	642
10	277	410	499	584	693

Annual Maximum Rainfall
R-353, Basurhat; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	172	227	263	297	342
2	254	334	387	437	503
3	322	422	488	552	634
4	364	471	542	609	697
5	389	505	582	656	751
7	444	573	659	741	847
10	534	683	782	877	999

Annual Maximum Pre-Monsoon Rainfall
R-354, Chandpur; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	98	137	163	188	220
2	128	168	195	220	253
3	154	199	229	257	294
4	182	241	280	317	366
5	199	265	309	351	405
7	230	302	350	395	454
10	270	340	387	431	489

Annual Maximum Mid-Monsoon Rainfall
R-354, Chandpur; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	92	131	156	180	211
2	131	187	224	260	306
3	149	211	252	291	342
4	173	238	281	322	375
5	188	253	296	337	391
7	216	289	337	383	443
10	254	340	397	452	524

Annual Maximum Post-Monsoon Rainfall
R-354, Chandpur; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	73	126	161	194	238
2	93	160	204	246	301
3	106	181	230	278	339
4	116	193	243	292	355
5	123	203	256	307	373
7	133	223	282	339	413
10	156	263	334	402	491

Annual Maximum Rainfall
R-354, Chandpur; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	132	176	205	233	269
2	175	231	267	303	348
3	200	263	304	343	395
4	225	294	340	384	441
5	238	312	362	409	471
7	274	355	408	460	527
10	326	410	466	519	588

Annual Maximum Pre-Monsoon Rainfall
R-355, Chhagalnaya; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	118	154	178	201	230
2	170	220	253	284	325
3	209	267	305	342	390
4	229	290	330	369	419
5	250	317	361	404	459
7	284	367	421	473	541
10	331	421	480	537	611

Annual Maximum Mid-Monsoon Rainfall
R-355, Chhagalnaya; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	143	203	242	280	329
2	217	296	349	399	465
3	268	359	420	478	553
4	307	399	460	519	594
5	332	419	477	532	604
7	382	483	550	614	698
10	443	559	635	709	804

Annual Maximum Post-Monsoon Rainfall
R-355, Chhagalnaya; Daily Rainfall (mm

Duration Days	Return Period (years) 2	5	10	20	50
1	97	153	191	227	273
2	127	209	263	314	381
3	148	233	288	342	411
4	162	248	305	359	430
5	173	260	317	372	444
7	197	292	354	414	492
10	223	319	382	442	521

Annual Maximum Rainfall
R-355, Chhagalnaya; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	171	229	267	303	350
2	248	327	380	430	495
3	298	383	439	493	562
4	334	416	471	523	591
5	353	434	487	538	604
7	406	497	558	616	691
10	470	573	642	708	794

Annual Maximum Pre-Monsoon Rainfall
R-356, Comilla; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	102	141	168	193	225
2	138	187	219	250	290
3	164	220	257	293	339
4	192	258	301	343	397
5	209	278	324	368	425
7	241	328	386	441	512
10	283	380	444	505	585

Annual Maximum Mid-Monsoon Rainfall
R-356, Comilla; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	97	130	152	173	200
2	144	192	224	255	295
3	173	231	270	307	355
4	196	264	309	352	407
5	220	287	331	374	429
7	256	330	379	425	486
10	297	372	421	468	530

Annual Maximum Post-Monsoon Rainfall
R-356, Comilla; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	72	106	129	150	178
2	100	150	183	215	256
3	112	166	201	236	280
4	126	185	225	262	311
5	135	197	237	276	327
7	150	213	255	295	347
10	168	235	280	323	378

Annual Maximum Rainfall
R-356, Comilla; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	125	164	189	213	245
2	180	229	261	292	333
3	211	269	306	343	389
4	241	305	347	388	440
5	263	326	368	408	460
7	302	375	424	470	530
10	339	423	478	531	600

Annual Maximum Pre-Monsoon Rainfall
R-357, Daudkandi; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	90	111	126	139	157
2	139	170	191	211	237
3	171	219	251	282	322
4	199	261	302	341	392
5	221	296	346	393	454
7	273	374	441	505	587
10	332	456	538	616	718

Annual Maximum Mid-Monsoon Rainfall
R-357, Daudkandi; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	94	137	166	194	230
2	149	203	239	274	319
3	184	254	301	346	404
4	213	300	357	412	483
5	242	337	401	461	539
7	284	391	462	530	618
10	336	458	539	616	717

Annual Maximum Post-Monsoon Rainfall
R-357, Daudkandi; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	74	104	124	142	167
2	109	142	164	185	212
3	128	170	198	225	259
4	143	191	223	253	292
5	159	212	248	282	326
7	176	240	283	323	376
10	207	292	349	404	474

Annual Maximum Rainfall
R-357, Daudkandi; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	119	153	175	196	224
2	186	224	249	273	305
3	229	284	320	354	399
4	263	333	378	422	479
5	296	374	426	476	540
7	348	443	506	567	645
10	414	526	599	670	761

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Annual Maximum Pre-Monsoon Rainfall
R-358, Feni; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	130	172	200	227	261
2	187	247	287	325	375
3	225	293	337	380	435
4	253	337	393	447	516
5	278	376	441	504	585
7	324	443	521	597	694
10	386	526	619	709	824

Annual Maximum Mid-Monsoon Rainfall
R-358, Feni; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	156	202	232	261	299
2	241	311	358	403	461
3	293	377	433	486	556
4	336	432	497	558	638
5	365	472	542	610	698
7	432	553	633	709	809
10	501	663	770	874	1007

Annual Maximum Post-Monsoon Rainfall
R-358, Feni; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	94	137	165	192	226
2	132	187	224	259	305
3	164	238	288	335	396
4	184	267	322	374	443
5	197	285	344	400	473
7	219	311	373	431	507
10	245	342	406	467	547

Annual Maximum Rainfall
R-358, Feni; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	179	218	244	268	300
2	262	319	357	394	441
3	315	386	434	479	538
4	361	444	498	551	619
5	396	490	552	611	688
7	458	564	635	703	790
10	547	693	790	883	1003

Annual Maximum Pre-Monsoon Rainfall
R-359, Gunabati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	104	136	156	176	202
2	146	200	236	271	315
3	175	247	294	339	398
4	207	297	357	414	488
5	234	335	402	467	550
7	272	401	487	569	675
10	318	456	548	635	749

Annual Maximum Mid-Monsoon Rainfall
R-359, Gunabati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	127	171	200	228	264
2	180	245	288	329	383
3	218	307	365	421	494
4	250	350	416	480	562
5	272	380	451	519	607
7	319	437	515	589	686
10	390	550	655	757	888

Annual Maximum Post-Monsoon Rainfall
R-359, Gunabati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	96	151	187	222	268
2	138	225	282	337	409
3	163	270	341	409	497
4	178	295	372	446	541
5	192	310	388	463	559
7	219	344	427	507	610
10	235	363	448	530	635

Annual Maximum Rainfall
R-359, Gunabati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	161	197	221	243	273
2	234	302	348	391	448
3	282	376	438	497	574
4	314	424	497	567	657
5	340	456	533	607	702
7	392	521	607	689	795
10	456	604	702	797	918

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Annual Maximum Pre-Monsoon Rainfall
R-360, Hajigang; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	89	122	144	164	191
2	124	162	188	213	245
3	151	192	219	245	279
4	178	229	262	295	337
5	196	255	294	331	379
7	231	303	350	396	455
10	276	357	411	462	528

Annual Maximum Mid-Monsoon Rainfall
R-360, Hajigang; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	92	143	177	209	251
2	130	188	227	264	312
3	156	216	256	294	343
4	175	236	277	316	366
5	194	263	309	352	409
7	226	311	366	420	489
10	264	358	421	481	558

Annual Maximum Post-Monsoon Rainfall
R-360, Hajigang; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	70	99	118	136	160
2	104	154	187	219	259
3	125	184	222	259	307
4	139	207	252	295	351
5	149	226	277	326	389
7	170	267	332	393	473
10	190	303	378	449	542

Annual Maximum Rainfall
R-360, Hajigang; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	115	161	192	221	259
2	168	219	252	285	327
3	196	250	285	319	363
4	226	281	318	353	398
5	251	314	355	395	447
7	293	374	428	480	547
10	341	430	489	546	619

Annual Maximum Pre-Monsoon Rainfall
R-361, Hatia: Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	121	169	200	230	268
2	174	237	278	318	370
3	212	279	323	365	420
4	240	313	362	409	470
5	269	356	414	470	542
7	313	411	475	538	618
10	367	487	566	642	741

Annual Maximum Mid-Monsoon Rainfall
R-361, Hatia; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	138	177	203	228	260
2	214	282	327	370	426
3	266	351	408	462	532
4	297	392	455	515	594
5	334	440	511	578	666
7	393	508	585	659	754
10	464	588	670	748	850

Annual Maximum Post-Monsoon Rainfall
R-361, Hatia: Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	108	157	189	220	260
2	157	227	274	318	376
3	192	276	331	385	454
4	208	295	353	408	480
5	221	313	374	432	507
7	246	343	406	468	547
10	268	369	436	500	583

Annual Maximum Rainfall
R-361, Hatia; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	174	222	253	283	323
2	257	323	367	409	463
3	308	388	442	493	559
4	338	425	482	537	609
5	375	470	533	593	671
7	427	527	593	657	739
10	505	614	687	756	846

Annual Maximum Pre-Monsoon Rainfall
R-362, Kasba; Daily Rainfall (mm

Duration Days	Return Period (years) 2	5	10	20	50
1	89	113	128	143	163
2	130	177	209	239	279
3	153	209	246	281	327
4	179	245	289	331	385
5	196	266	313	358	416
7	231	319	378	434	506
10	269	358	417	474	548

Annual Maximum Mid-Monsoon Rainfall
R-362, Kasba; Daily Rainfall (mm

Duration Days	Return Period (years) 2	5	10	20	50
1	94	141	173	203	242
2	134	193	233	271	320
3	162	231	277	322	379
4	183	265	319	370	437
5	202	286	342	396	465
7	232	321	380	437	510
10	263	355	416	475	551

Annual Maximum Post-Monsoon Rainfall
R-362, Kasba; Daily Rainfall (mm

Duration Days	Return Period (years) 2	5	10	20	50
1	70	114	143	171	207
2	99	154	190	224	269
3	117	186	232	275	332
4	126	198	246	292	351
5	135	211	261	309	371
7	148	225	277	326	390
10	161	240	292	343	408

Annual Maximum Rainfall
R-362, Kasba; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	119	165	196	225	263
2	170	232	274	313	365
3	203	277	326	373	434
4	231	314	369	421	489
5	253	337	393	447	516
7	293	383	442	499	573
10	325	419	481	541	618

Annual Maximum Pre-Monsoon Rainfall
R-363, Laksam; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	101	142	168	194	227
2	149	194	224	253	290
3	182	243	283	322	372
4	204	278	327	375	436
5	232	320	378	433	505
7	273	379	448	515	602
10	326	446	525	601	700

Annual Maximum Mid-Monsoon Rainfall
R-363, Laksam; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	97	133	157	180	209
2	158	211	246	279	322
3	194	260	304	346	401
4	220	296	345	393	455
5	242	322	375	426	492
7	283	376	438	497	573
10	329	433	501	567	652

Annual Maximum Post-Monsoon Rainfall
R-363, Laksam; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	72	107	131	153	183
2	107	161	198	232	277
3	135	207	254	299	358
4	149	239	298	355	429
5	161	254	315	374	451
7	177	272	335	395	474
10	202	310	381	449	537

Annual Maximum Rainfall
R-363, Laksam; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	126	166	193	219	252
2	190	241	274	306	347
3	236	304	349	392	448
4	271	356	412	465	535
5	302	391	449	506	579
7	352	449	514	576	656
10	408	518	590	659	749

Annual Maximum Pre-Monsoon Rainfall
R-364, Lakshmipur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	87	122	146	168	197
2	124	168	197	225	261
3	153	211	249	285	332
4	174	238	280	321	374
5	200	271	317	362	420
7	240	333	395	454	531
10	289	398	470	538	627

Annual Maximum Mid-Monsoon Rainfall
R-364, Lakshmipur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	91	131	158	183	217
2	141	205	247	287	339
3	177	256	309	359	424
4	201	288	346	401	473
5	223	320	384	446	526
7	264	380	456	530	625
10	315	455	548	637	752

Annual Maximum Post-Monsoon Rainfall
R-364, Lakshmipur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	85	127	155	182	217
2	124	180	217	253	299
3	150	214	256	296	349
4	170	244	292	339	399
5	189	271	325	377	444
7	215	311	374	434	512
10	243	347	416	481	567

Annual Maximum Rainfall
R-364, Lakshmipur; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	119	162	191	218	253
2	182	240	279	316	364
3	224	298	347	394	454
4	255	335	388	439	505
5	282	372	432	489	563
7	333	447	523	595	689
10	395	531	621	707	819

Annual Maximum Pre-Monsoon Rainfall
R-365, Munshiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	95	132	157	180	211
2	138	202	244	285	338
3	163	235	283	329	388
4	186	271	327	381	450
5	206	310	378	443	528
7	241	363	444	522	622
10	280	417	508	595	708

Annual Maximum Mid-Monsoon Rainfall
R-365, Munshiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	94	142	174	205	244
2	144	217	265	310	370
3	176	270	333	392	470
4	200	311	384	455	546
5	212	334	414	491	592
7	238	377	469	557	671
10	276	440	548	653	787

Annual Maximum Post-Monsoon Rainfall
R-365, Munshiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	78	122	151	178	214
2	109	178	224	268	325
3	127	205	257	306	370
4	136	221	278	333	403
5	145	236	296	353	428
7	162	268	338	405	492
10	188	308	387	464	562

Annual Maximum Rainfall
R-365, Munshiganj; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	129	173	202	229	266
2	195	267	314	360	419
3	230	314	369	423	491
4	262	364	432	497	582
5	285	399	474	547	641
7	317	449	537	621	730
10	361	512	611	706	830

Annual Maximum Pre-Monsoon Rainfall
R-366, Muradnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	84	129	160	189	226
2	115	180	223	265	318
3	134	211	262	310	374
4	159	249	309	366	441
5	174	272	338	400	481
7	196	320	402	481	583
10	237	368	456	539	648

Annual Maximum Mid-Monsoon Rainfall
R-366, Muradnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	82	140	179	216	263
2	116	198	253	306	374
3	145	255	327	397	486
4	164	278	354	426	520
5	180	297	374	448	543
7	204	325	406	483	582
10	235	362	446	527	632

Annual Maximum Post-Monsoon Rainfall
R-366, Muradnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	50	82	103	124	150
2	73	123	156	188	229
3	85	146	186	225	275
4	93	161	206	249	304
5	104	179	229	276	338
7	118	209	269	327	402
10	138	234	299	360	440

Annual Maximum Rainfall
R-366, Muradnagar; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	106	161	197	232	277
2	147	226	278	328	393
3	179	286	357	425	513
4	202	313	386	457	548
5	222	337	414	487	581
7	249	384	473	559	670
10	289	427	518	606	719

Annual Maximum Pre-Monsoon Rainfall
R-367, Nabinagar; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	103	136	158	180	207
2	137	167	187	206	231
3	157	192	215	237	265
4	178	219	246	273	307
5	197	250	285	319	362
7	224	284	324	362	411
10	274	344	390	435	492

Annual Maximum Mid-Monsoon Rainfall
R-367, Nabinagar; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	91	132	159	184	218
2	122	185	227	267	318
3	140	213	262	309	369
4	162	230	275	319	375
5	177	251	300	346	407
7	200	276	326	374	436
10	229	309	362	413	478

Annual Maximum Post-Monsoon Rainfall
R-367, Nabinagar; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	63	107	136	164	200
2	82	134	169	203	246
3	90	145	181	216	261
4	100	154	189	224	268
5	112	170	208	245	293
7	130	213	268	320	389
10	155	236	290	341	408

Annual Maximum Rainfall
R-367, Nabinagar; Daily Rainfall (mm).

Duration Days	Return Period (years) 2	5	10	20	50
1	125	168	196	224	259
2	164	216	250	283	325
3	187	246	285	322	370
4	206	263	300	336	383
5	227	285	323	360	407
7	264	315	349	381	423
10	310	357	388	418	457

Annual Maximum Pre-Monsoon Rainfall
R-369, Noakhali; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	130	176	207	236	275
2	174	235	276	315	365
3	205	279	328	375	436
4	226	309	364	417	485
5	253	346	407	467	543
7	296	410	486	558	651
10	351	477	561	641	745

Annual Maximum Mid-Monsoon Rainfall
R-369, Noakhali; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	135	175	202	228	261
2	197	239	266	292	326
3	235	287	322	355	398
4	268	322	357	392	436
5	293	350	388	424	472
7	341	405	448	489	542
10	421	520	585	648	730

Annual Maximum Post-Monsoon Rainfall
R-369, Noakhali; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	124	171	202	232	270
2	167	235	281	324	380
3	194	269	319	366	428
4	215	300	356	410	480
5	226	316	375	432	506
7	243	337	398	458	534
10	280	383	451	517	601

Annual Maximum Rainfall
R-369, Noakhali; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	183	220	244	267	298
2	253	293	320	345	378
3	292	345	380	414	457
4	324	387	428	468	520
5	352	425	474	521	582
7	405	494	553	610	683
10	488	594	663	730	816

Annual Maximum Pre-Monsoon Rainfall
R-370, Parshuram; Daily Rainfall (mm)

Duration Days	Return Period (years				
	2	5	10	20	50
1	130	169	195	221	253
2	175	231	267	303	348
3	204	276	325	371	430
4	227	306	358	408	473
5	245	332	390	445	517
7	272	367	431	491	570
10	324	433	505	575	664

Annual Maximum Mid-Monsoon Rainfall
R-370, Parshuram; Daily Rainfall (mm)

Duration Days	Return Period (years				
	2	5	10	20	50
1	128	166	191	215	246
2	186	240	276	310	355
3	231	302	348	393	451
4	258	329	377	422	481
5	284	365	419	471	538
7	331	417	473	528	598
10	385	485	551	615	698

Annual Maximum Post-Monsoon Rainfall
R-370, Parshuram; Daily Rainfall (mm)

Duration Days	Return Period (years				
	2	5	10	20	50
1	68	100	120	140	166
2	95	141	173	202	241
3	113	174	214	252	302
4	127	191	233	274	327
5	136	200	243	283	336
7	150	216	260	302	356
10	168	238	285	330	388

Annual Maximum Rainfall
R-370, Parshuram; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	153	189	212	235	265
2	212	268	306	342	388
3	259	331	379	424	484
4	284	358	407	454	515
5	312	396	452	505	574
7	357	443	500	555	626
10	417	512	576	636	715

Annual Maximum Pre-Monsoon Rainfall
R-372, Raipur (Noakhali); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	91	137	167	196	233
2	127	183	220	256	302
3	158	219	259	298	348
4	182	250	295	339	395
5	199	273	321	367	428
7	232	312	365	415	481
10	274	364	423	479	553

Annual Maximum Mid-Monsoon Rainfall
R-372, Raipur (Noakhali); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	83	111	130	147	170
2	132	176	206	234	270
3	156	209	244	277	321
4	185	248	289	328	380
5	201	271	317	361	419
7	234	313	365	415	480
10	281	369	426	482	554

Annual Maximum Post-Monsoon Rainfall
R-372, Raipur (Noakhali); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	78	117	143	168	201
2	107	154	185	215	253
3	128	183	220	255	301
4	138	195	232	268	314
5	146	206	245	283	333
7	168	235	280	323	378
10	190	271	324	375	442

Annual Maximum Rainfall
R-372, Raipur (Noakhali); Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	115	156	184	210	244
2	166	217	251	283	324
3	199	250	283	316	358
4	226	284	322	359	407
5	250	313	355	395	447
7	289	363	411	458	518
10	336	420	476	530	600

Annual Maximum Pre-Monsoon Rainfall
R-375, Ramgati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	108	141	163	185	212
2	176	232	269	305	351
3	221	300	352	402	467
4	266	366	432	496	578
5	307	428	508	584	684
7	370	524	626	724	851
10	450	649	781	907	1071

Annual Maximum Mid-Monsoon Rainfall
R-375, Ramgati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	124	159	183	205	234
2	218	275	313	349	396
3	296	375	427	477	541
4	357	454	518	580	660
5	412	530	608	683	780
7	499	653	755	853	979
10	604	800	931	1055	1217

Annual Maximum Post-Monsoon Rainfall
R-375, Ramgati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	99	134	157	179	207
2	165	235	282	327	385
3	204	292	350	406	478
4	239	345	415	482	569
5	259	371	446	517	609
7	282	398	475	548	644
10	318	454	544	630	741

Annual Maximum Rainfall
R-375, Ramgati; Daily Rainfall (mm)

Duration Days	Return Period (years) 2	5	10	20	50
1	136	174	200	224	256
2	231	300	345	389	446
3	300	392	453	511	587
4	359	472	547	619	712
5	415	552	643	729	842
7	516	691	807	919	1063
10	633	845	986	1121	1296

Annual Maximum Pre-Monsoon Rainfall
R-376, Senbag; Daily Rainfall (mm).

Duration Days	Return Period (years)				
	2	5	10	20	50
1	120	167	199	229	267
2	159	212	247	230	323
3	193	262	307	351	407
4	216	303	361	416	488
5	236	331	394	455	533
7	282	395	471	543	637
10	337	470	558	643	752

Annual Maximum Mid-Monsoon Rainfall
R-376, Senbag; Daily Rainfall (mm).

Duration Days	Return Period (years)				
	2	5	10	20	50
1	151	213	254	293	344
2	215	289	338	385	446
3	263	356	418	477	554
4	294	394	461	525	608
5	318	426	498	566	655
7	378	488	560	630	720
10	439	565	649	729	833

Annual Maximum Post-Monsoon Rainfall
R-376, Senbag; Daily Rainfall (mm).

Duration Days	Return Period (years)				
	2	5	10	20	50
1	105	164	202	240	288
2	145	225	279	330	396
3	170	268	333	396	477
4	186	291	360	426	512
5	196	305	377	447	536
7	215	329	404	475	568
10	237	359	440	517	618

Annual Maximum Rainfall
R-376, Senbag; Daily Rainfall (mm).

Duration Days	Return Period (years)				
	2	5	10	20	50
1	178	231	266	299	342
2	243	310	354	396	451
3	298	391	452	511	588
4	331	440	511	580	669
5	356	475	554	630	728
7	410	537	620	701	805
10	481	625	721	812	931

Annual Maximum Pre-Monsoon Rainfall
R-377, Sonaimuri; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	106	148	176	203	238
2	149	203	240	275	320
3	176	237	277	316	366
4	198	266	312	355	411
5	223	300	352	401	465
7	260	350	409	466	540
10	320	434	509	581	674

Annual Maximum Mid-Monsoon Rainfall
R-377, Sonaimuri; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	132	175	203	230	264
2	184	245	284	323	372
3	222	291	337	381	438
4	247	323	373	421	483
5	272	351	403	452	517
7	330	439	512	582	672
10	400	534	623	708	818

Annual Maximum Post-Monsoon Rainfall
R-377, Sonaimuri; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	102	141	167	193	225
2	141	198	236	272	319
3	168	240	288	334	393
4	183	252	298	341	398
5	195	263	308	350	406
7	218	296	348	397	461
10	243	323	377	428	495

Annual Maximum Rainfall
R-377, Sonaimuri; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	156	197	224	250	283
2	219	277	315	352	399
3	258	327	373	417	473
4	286	357	405	450	509
5	314	393	445	495	560
7	373	475	543	608	692
10	447	577	664	746	854

Annual Maximum Pre-Monsoon Rainfall
R-402, Bhagyakul; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	121	174	210	243	287
2	154	213	252	290	338
3	173	234	274	313	363
4	192	257	300	341	394
5	214	296	351	403	473
7	238	327	385	442	515
10	280	370	430	487	561

Annual Maximum Mid-Monsoon Rainfall
R-402, Bhagyakul; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	83	118	141	163	192
2	113	159	189	218	255
3	135	195	235	273	322
4	150	216	258	298	351
5	167	239	285	330	383
7	191	270	322	372	433
10	221	314	376	436	513

Annual Maximum Post-Monsoon Rainfall
R-402, Bhagyakul; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	80	140	180	218	267
2	98	173	223	270	331
3	110	188	240	289	354
4	121	199	251	300	365
5	128	208	260	311	376
7	137	222	278	332	402
10	160	258	324	386	467

Annual Maximum Rainfall
R-402, Bhagyakul; Daily Rainfall (mm)

Duration Days	Return Period (years)				
	2	5	10	20	50
1	146	200	236	271	315
2	185	251	295	337	392
3	215	282	326	368	422
4	234	301	346	388	444
5	259	338	391	441	506
7	283	371	428	484	556
10	338	424	480	535	605

APPENDIX III

STORM REDUCTION FACTORS

The Key station in the analysis is:
R-363. Lassam; Daily Rainfall (mm)

Aerial Reductions on 1 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0
1962	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1963	**************** 0.00	**************** 0.00	1.16 1.26***** 0.00	1.16 1.26***** 0.00
1964	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1965	0.57 0.54 0.48 0.00	1.15*********** 0.00	0.50 0.58 0.40 0.00	1.15*********** 0.00
1966	0.33*********** 0.00	0.63*********** 0.00	0.76*********** 0.00	0.76*********** 0.00
1967	0.44 0.31 0.30 0.00	0.68 0.70 0.61 0.00	0.63 0.67 0.78 0.00	0.44 0.31 0.30 0.00
1968	0.72 0.69 0.73 0.00	0.62 0.59 0.62 0.00	0.81 0.65 0.81 0.00	0.72 0.69 0.73 0.00
1969	0.88 0.35 1.16 0.00	0.61 0.49 0.49 0.00	0.89 0.87 0.78 0.00	0.88 0.35 1.16 0.00
1970	0.25 0.13 0.17 0.00	0.86 0.72 0.53 0.00	1.20 0.83 1.31 0.00	0.25 0.13 0.17 0.00
1971	0.49*********** 0.00	0.71*********** 0.00	0.70 0.45 0.40 0.00	0.71*********** 0.00
1972	0.96 0.86 0.98 0.00	0.54 0.42 0.43 0.00	0.47 0.31 0.43 0.00	0.54 0.42 0.43 0.00
1973	0.75 0.63 0.65 0.00	0.52 0.52 0.51 0.00	0.64 0.67 0.57 0.00	0.75 0.63 0.65 0.00
1974	1.29 0.95 0.95 0.00	0.52 0.58 0.47 0.00	1.12 1.12 1.28 0.00	0.52 0.58 0.47 0.00
1975	1.16*********** 0.00	1.58*********** 0.00	0.62*********** 0.00	0.62*********** 0.00
1976	0.35*********** 0.00	0.68*********** 0.00	0.28*********** 0.00	0.85*********** 0.00
1977	1.02*********** 0.00	0.38 0.39 0.32 0.00	0.24 0.13 0.08 0.00	1.02*********** 0.00
1978	0.53 0.36 0.31 0.00	0.98 0.97 0.95 0.00	0.69 0.46 0.47 0.00	0.53 0.36 0.31 0.00
1979	0.74 0.34 0.70 0.00	0.44 0.35 0.34 0.00	0.42 0.27 0.21 0.00	0.74 0.34 0.70 0.00
1980	0.54 0.70 0.79 0.00	0.64 0.41 0.39 0.00	0.59 0.39 0.38 0.00	0.54 0.70 0.79 0.00
1981	0.29 0.29 0.32 0.00	0.89 0.77 0.66 0.00	0.33 0.21 0.29 0.00	0.29 0.29 0.32 0.00
1982	0.58*********** 0.00	1.01*********** 0.00	0.73*********** 0.00	1.01*********** 0.00
1983	0.60*********** 0.00	0.79*********** 0.00	1.10*********** 0.00	0.79*********** 0.00
1984	0.53 0.43 0.61 0.00	0.90 0.81 0.87 0.00	0.64 0.65 0.53 0.00	0.53 0.43 0.61 0.00
1985	0.50 0.47 0.44 0.00	0.81 0.64 0.74 0.00	0.34 0.54 0.61 0.00	0.81 0.64 0.74 0.00
1986	**************** 0.00	0.73 0.60 0.64 0.00	1.19 1.01 1.03 0.00	0.74 0.62 0.58 0.00
1987	0.59*********** 0.00	0.81*********** 0.00	0.90*********** 0.00	0.81*********** 0.00
1988	0.96 0.79 0.84 0.00	0.49 0.26 0.23 0.00	0.24 0.15 0.13 0.00	0.49 0.26 0.23 0.00
1989	0.73*********** 0.00	0.68*********** 0.00	0.82*********** 0.00	0.47*********** 0.00
Mean	0.70 0.59 0.63 0.00	0.75 0.58 0.56 0.00	0.69 0.59 0.59 0.00	0.70 0.56 0.55 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

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The Key station in the analysis is:
R-363. Laksam: Daily Rainfall (mm)

Aerial Reductions on 2 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	2121	4090	6409	0	2121	4090	6409	0	2121	4090	6409	0	2121	4090	6409	0
1962	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1963	1.16	1.26	*****	0.00	1.16	1.26	*****	0.00	0.79	0.87	*****	0.00	0.79	0.87	*****	0.00
1964	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1965	0.70	0.63	0.55	0.00	1.31	*****	*****	0.00	1.37	1.41	1.53	0.00	1.31	*****	*****	0.00
1966	0.90	*****	*****	0.00	0.76	*****	*****	0.00	0.69	*****	*****	0.00	0.69	*****	*****	0.00
1967	0.44	0.31	0.30	0.00	0.62	0.63	0.65	0.00	0.70	0.72	0.82	0.00	0.70	0.72	0.82	0.00
1968	0.96	0.94	1.10	0.00	0.66	0.70	0.66	0.00	0.90	0.64	0.52	0.00	0.66	0.70	0.66	0.00
1969	0.76	0.67	0.87	0.00	1.07	0.93	0.98	0.00	0.84	*****	*****	0.00	0.76	0.67	0.87	0.00
1970	0.34	0.26	0.25	0.00	0.78	0.60	0.61	0.00	1.42	1.14	1.57	0.00	0.78	0.60	0.61	0.00
1971	0.50	*****	*****	0.00	0.69	*****	*****	0.00	0.50	0.48	0.40	0.00	0.69	*****	*****	0.00
1972	0.93	0.89	1.00	0.00	0.57	0.48	0.50	0.00	0.61	0.46	0.63	0.00	0.57	0.48	0.50	0.00
1973	0.55	0.44	0.43	0.00	0.47	0.45	0.46	0.00	0.59	0.56	0.54	0.00	0.55	0.44	0.43	0.00
1974	0.70	0.65	*****	0.00	0.52	0.49	0.46	0.00	0.95	0.84	0.87	0.00	0.52	0.49	0.46	0.00
1975	0.73	*****	*****	0.00	1.44	*****	*****	0.00	0.67	*****	*****	0.00	0.67	*****	*****	0.00
1976	0.96	*****	*****	0.00	0.76	*****	*****	0.00	1.07	*****	*****	0.00	0.76	*****	*****	0.00
1977	0.74	0.80	0.97	0.00	0.56	0.44	0.41	0.00	0.30	0.25	0.24	0.00	0.56	0.44	0.41	0.00
1978	0.71	0.57	0.57	0.00	1.18	1.01	1.05	0.00	0.91	0.69	0.69	0.00	0.71	0.57	0.57	0.00
1979	0.59	0.71	0.61	0.00	0.84	0.91	1.01	0.00	0.47	0.35	0.33	0.00	0.84	0.91	1.01	0.00
1980	0.57	0.61	0.61	0.00	0.77	0.63	0.79	0.00	0.56	0.58	0.66	0.00	0.57	0.61	0.61	0.00
1981	0.37	0.42	0.40	0.00	1.02	0.87	0.76	0.00	0.38	0.26	0.33	0.00	0.37	0.42	0.40	0.00
1982	0.69	*****	*****	0.00	1.04	*****	*****	0.00	0.86	*****	*****	0.00	0.69	*****	*****	0.00
1983	0.75	*****	*****	0.00	0.69	*****	*****	0.00	0.68	*****	*****	0.00	0.69	*****	*****	0.00
1984	0.61	0.49	0.57	0.00	0.89	0.74	0.84	0.00	0.62	0.78	0.65	0.00	0.61	0.49	0.57	0.00
1985	0.70	0.76	0.84	0.00	0.70	0.60	0.80	0.00	0.67	0.87	0.77	0.00	0.70	0.76	0.84	0.00
1986	*****	*****	*****	0.00	0.75	0.66	0.79	0.00	1.23	1.01	1.01	0.00	0.78	0.75	0.76	0.00
1987	1.00	*****	*****	0.00	0.73	*****	*****	0.00	0.77	*****	*****	0.00	0.73	*****	*****	0.00
1988	0.56	0.45	0.58	0.00	0.75	0.65	0.69	0.00	0.77	0.71	0.76	0.00	0.75	0.65	0.69	0.00
1989	0.84	*****	*****	0.00	0.71	*****	*****	0.00	0.88	*****	*****	0.00	0.84	*****	*****	0.00
Mean	0.71	0.64	0.64	0.00	0.82	0.71	0.72	0.00	0.78	0.70	0.72	0.00	0.70	0.62	0.64	0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-353. Laksam; Daily Rainfall (mm)

Aerial Reductions on 3 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0
1962	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1963	0.79 0.87***** 0.00	0.79 0.87***** 0.00	1.04 1.05***** 0.00	1.04 1.05***** 0.00
1964	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1965	0.79 0.67 0.60 0.00	1.11********** 0.00	1.76 1.54 1.59 0.00	1.11********** 0.00
1966	0.99********** 0.00	0.74********** 0.00	*************** 0.00	*************** 0.00
1967	0.46 0.35 0.33 0.00	0.73 0.77 0.77 0.00	0.71 0.76 0.87 0.00	0.73 0.77 0.77 0.00
1968	0.85 0.90 1.03 0.00	0.74 0.76 0.80 0.00	0.95 0.66 0.52 0.00	0.85 0.90 1.03 0.00
1969	0.77 0.73 0.91 0.00	0.89 0.77 0.86 0.00	0.76********** 0.00	0.77 0.73 0.91 0.00
1970	1.21 1.10 0.99 0.00	0.84 0.68 0.67 0.00	1.25 1.19 1.41 0.00	0.84 0.68 0.67 0.00
1971	0.48********** 0.00	0.68********** 0.00	0.71********** 0.00	0.68********** 0.00
1972	0.99 1.04 1.17 0.00	0.57 0.47 0.46 0.00	0.61 0.58 0.71 0.00	0.57 0.47 0.46 0.00
1973	0.52 0.43 0.40 0.00	0.46 0.49 0.52 0.00	0.66 0.59 0.61 0.00	0.52 0.43 0.40 0.00
1974	0.58 0.51***** 0.00	0.75 0.60 0.58 0.00	0.83 0.71 0.72 0.00	0.75 0.60 0.58 0.00
1975	0.69********** 0.00	0.52********** 0.00	0.73********** 0.00	0.73********** 0.00
1976	0.94********** 0.00	0.61********** 0.00	0.78********** 0.00	0.94********** 0.00
1977	0.70 0.74 0.84 0.00	0.65 0.52 0.47 0.00	0.30 0.28 0.24 0.00	0.65 0.52 0.47 0.00
1978	0.90 0.79 0.78 0.00	1.18 1.01 1.06 0.00	0.91 0.79 0.78 0.00	0.90 0.79 0.78 0.00
1979	0.61 0.76 0.67 0.00	0.82 0.83 0.88 0.00	0.56 0.43 0.37 0.00	0.82 0.83 0.88 0.00
1980	0.66 0.81 0.86 0.00	0.80 0.72 0.91 0.00	0.67 0.68 0.73 0.00	0.66 0.81 0.86 0.00
1981	0.84 0.83 0.72 0.00	0.95 0.88 0.90 0.00	0.46 0.33 0.51 0.00	0.84 0.83 0.72 0.00
1982	0.74********** 0.00	1.10********** 0.00	0.82********** 0.00	0.74********** 0.00
1983	0.83********** 0.00	0.81********** 0.00	0.62********** 0.00	0.81********** 0.00
1984	0.58 0.48 0.55 0.00	0.69 0.77 0.93 0.00	0.61 0.79 0.68 0.00	0.58 0.48 0.55 0.00
1985	0.56 0.68 0.77 0.00	0.59 0.51 0.72 0.00	0.70 0.95 0.35 0.00	0.59 0.51 0.72 0.00
1986	*************** 0.00	0.78 0.66 0.78 0.00	1.22 0.98 1.00 0.00	0.78 0.66 0.78 0.00
1987	1.02********** 0.00	0.78********** 0.00	0.91********** 0.00	0.78********** 0.00
1988	0.60 0.48 0.58 0.00	0.80 0.71 0.80 0.00	0.40 0.41 0.35 0.00	0.60 0.48 0.58 0.00
1989	0.37********** 0.00	0.73********** 0.00	0.79********** 0.00	0.79********** 0.00
Mean	0.76 0.72 0.75 0.00	0.79 0.71 0.76 0.00	0.79 0.75 0.75 0.00	0.76 0.68 0.70 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-363, Laksam; Daily Rainfall (mm)

Aerial Reductions on 4 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0
1962	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1963	1.04 1.05***** 0.00	1.04 1.05***** 0.00	0.97 0.97***** 0.00	0.97 0.97***** 0.00
1964	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1965	0.87 0.70 0.64 0.00	1.09********** 0.00	2.06 1.65 1.80 0.00	1.09********** 0.00
1966	1.00********** 0.00	0.83********** 0.00	*************** 0.00	*************** 0.00
1967	0.45 0.31 0.30 0.00	0.69 0.74 0.76 0.00	0.71 0.76 0.87 0.00	0.69 0.74 0.76 0.00
1968	0.91 0.98 1.10 0.00	0.74 0.79 0.84 0.00	0.78 0.55 0.42 0.00	0.91 0.98 1.10 0.00
1969	0.75 0.73 0.86 0.00	1.03 0.85 0.88 0.00	0.77********** 0.00	0.75 0.73 0.86 0.00
1970	1.21 1.14 1.01 0.00	0.78 0.66 0.65 0.00	1.17 1.14 1.38 0.00	0.78 0.66 0.65 0.00
1971	0.46********** 0.00	0.69********** 0.00	0.66********** 0.00	0.69********** 0.00
1972	0.67 0.62 0.64 0.00	0.57 0.50 0.49 0.00	0.70 0.53 0.70 0.00	0.57 0.50 0.49 0.00
1973	0.50 0.45 0.44 0.00	0.43 0.45 0.48 0.00	0.63 0.59 0.60 0.00	0.50 0.45 0.44 0.00
1974	0.61 0.61***** 0.00	0.78 0.69 0.68 0.00	0.80 0.71 0.74 0.00	0.78 0.69 0.68 0.00
1975	0.64********** 0.00	0.52********** 0.00	0.75********** 0.00	0.75********** 0.00
1976	0.95********** 0.00	0.84********** 0.00	0.78********** 0.00	0.56********** 0.00
1977	0.72 0.78 0.87 0.00	0.71 0.55 0.50 0.00	0.30 0.28 0.24 0.00	0.71 0.55 0.50 0.00
1978	0.89 0.78 0.76 0.00	1.14 0.89 0.90 0.00	0.88 0.77 0.80 0.00	0.89 0.78 0.76 0.00
1979	0.60 0.78 0.70 0.00	0.80 0.82 0.90 0.00	0.53 0.42 0.36 0.00	0.80 0.82 0.90 0.00
1980	0.65 0.78 0.84 0.00	0.80 0.71 0.90 0.00	0.71 0.71 0.85 0.00	0.65 0.78 0.84 0.00
1981	0.88 0.85 0.73 0.00	0.85 0.79 0.80 0.00	0.50 0.46 0.60 0.00	0.88 0.85 0.73 0.00
1982	0.75********** 0.00	1.13********** 0.00	1.06********** 0.00	1.13********** 0.00
1983	0.77********** 0.00	0.75********** 0.00	0.64********** 0.00	0.75********** 0.00
1984	0.56 0.52 0.55 0.00	0.82 0.80 0.93 0.00	0.57 0.71 0.64 0.00	0.56 0.52 0.55 0.00
1985	0.68 0.69 0.78 0.00	0.59 0.55 0.75 0.00	0.74 1.00 0.92 0.00	0.59 0.55 0.75 0.00
1986	*************** 0.00	0.78 0.68 0.73 0.00	1.55 1.25 1.27 0.00	0.78 0.68 0.73 0.00
1987	0.72********** 0.00	0.76********** 0.00	1.12********** 0.00	0.76********** 0.00
1988	0.63 0.55 0.63 0.00	0.79 0.78 0.87 0.00	0.60 0.59 0.49 0.00	0.79 0.78 0.87 0.00
1989	0.87********** 0.00	0.73********** 0.00	0.79********** 0.00	0.79********** 0.00
Mean	0.75 0.72 0.72 0.00	0.80 0.72 0.76 0.00	0.83 0.77 0.79 0.00	0.76 0.71 0.73 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-363, Laksam Daily Rainfall (mm)

Aerial Reductions on 5 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0	2121 4090 6409 0
1962	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1963	0.97 0.97***** 0.00	0.97 0.97***** 0.00	0.97 0.98***** 0.00	0.97 0.98***** 0.00
1964	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1965	1.05 1.37 0.76 0.00	1.08********** 0.00	2.31 1.99 2.34 0.00	1.08********** 0.00
1966	0.91********** 0.00	0.87********** 0.00	*************** 0.00	*************** 0.00
1967	0.47 0.36 0.34 0.00	0.63 0.67 0.66 0.00	0.71 0.76 0.87 0.00	0.63 0.67 0.66 0.00
1968	0.97 1.04 1.18 0.00	0.72 0.75 0.81 0.00	0.80 0.62 0.51 0.00	0.97 1.04 1.18 0.00
1969	0.81 0.76 0.88 0.00	0.93 0.76 0.79 0.00	0.77********** 0.00	0.81 0.76 0.88 0.00
1970	1.20 1.20 1.06 0.00	0.80 0.71 0.72 0.00	1.22 1.20 1.51 0.00	0.80 0.71 0.72 0.00
1971	0.47********** 0.00	0.71********** 0.00	0.65********** 0.00	0.71********** 0.00
1972	0.63 0.60 0.61 0.00	0.61 0.53 0.51 0.00	0.62 0.54 0.66 0.00	0.61 0.53 0.51 0.00
1973	0.52 0.49 0.49 0.00	0.50 0.50 0.53 0.00	0.65 0.60 0.61 0.00	0.52 0.49 0.49 0.00
1974	1.03 0.97***** 0.00	0.78 0.69 0.70 0.00	0.79 0.71 0.75 0.00	0.78 0.69 0.70 0.00
1975	0.59********** 0.00	0.76********** 0.00	0.70********** 0.00	0.70********** 0.00
1976	0.98********** 0.00	0.86********** 0.00	0.78********** 0.00	0.98********** 0.00
1977	0.69 0.75 0.82 0.00	0.68 0.53 0.51 0.00	0.30 0.34 0.27 0.00	0.68 0.53 0.51 0.00
1978	0.86 0.76 0.75 0.00	1.04 0.90 0.93 0.00	0.92 0.80 0.86 0.00	0.86 0.76 0.75 0.00
1979	0.60 0.30 0.72 0.00	0.87 0.79 0.85 0.00	0.50 0.39 0.34 0.00	0.87 0.79 0.85 0.00
1980	0.60 0.67 0.71 0.00	0.76 0.67 0.85 0.00	0.67 0.67 0.75 0.00	0.60 0.67 0.71 0.00
1981	0.93 0.86 0.76 0.00	0.86 0.82 0.86 0.00	0.46 0.39 0.49 0.00	0.93 0.86 0.76 0.00
1982	0.75********** 0.00	0.47********** 0.00	0.86********** 0.00	0.47********** 0.00
1983	0.71********** 0.00	0.73********** 0.00	0.63********** 0.00	0.73********** 0.00
1984	0.66 0.59 0.63 0.00	0.60 0.63 0.67 0.00	0.59 0.71 0.67 0.00	0.66 0.59 0.63 0.00
1985	0.50 0.44 0.48 0.00	0.59 0.54 0.74 0.00	0.78 1.02 0.93 0.00	0.59 0.54 0.74 0.00
1986	*************** 0.00	0.83 0.71 0.78 0.00	1.16 0.98 1.06 0.00	0.83 0.71 0.78 0.00
1987	0.72********** 0.00	0.75********** 0.00	1.05********** 0.00	0.75********** 0.00
1988	0.72 0.62 0.69 0.00	0.85 0.84 0.91 0.00	0.66 0.65 0.59 0.00	0.85 0.84 0.91 0.00
1989	1.05********** 0.00	0.73********** 0.00	0.73********** 0.00	0.73********** 0.00
Mean	0.78 0.75 0.73 0.00	0.77 0.71 0.74 0.00	0.81 0.79 0.83 0.00	0.76 0.71 0.74 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-363, Laksar; Daily Rainfall (mm)

Aerial Reductions on 7 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	2121	4090	6409	0	2121	4090	6409	0	2121	4090	6409	0	2121	4090	6409	0
1962	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1963	0.97	0.98	*****	0.00	0.97	0.98	*****	0.00	1.02	1.04	*****	0.00	1.02	1.04	*****	0.00
1964	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1965	1.05	0.91	0.83	0.00	1.17	*****	*****	0.00	2.37	2.01	2.35	0.00	1.17	*****	*****	0.00
1966	0.89	*****	*****	0.00	0.69	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1967	0.46	0.35	0.35	0.00	0.61	0.63	0.62	0.00	0.71	0.76	0.87	0.00	0.61	0.63	0.62	0.00
1968	0.95	1.02	1.17	0.00	0.80	0.81	0.89	0.00	0.80	0.62	0.51	0.00	0.80	0.81	0.89	0.00
1969	0.79	0.76	0.87	0.00	0.91	0.75	0.81	0.00	0.81	*****	*****	0.00	0.79	0.76	0.87	0.00
1970	1.11	1.09	0.98	0.00	0.63	0.72	0.75	0.00	1.35	1.30	1.62	0.00	0.63	0.72	0.75	0.00
1971	0.53	*****	*****	0.00	0.71	*****	*****	0.00	0.68	*****	*****	0.00	0.71	*****	*****	0.00
1972	0.73	0.72	0.80	0.00	0.63	0.54	0.57	0.00	0.62	0.56	0.66	0.00	0.63	0.54	0.57	0.00
1973	0.58	0.56	0.55	0.00	0.59	0.57	0.59	0.00	0.68	0.60	0.59	0.00	0.58	0.56	0.55	0.00
1974	0.91	0.83	*****	0.00	0.87	0.78	0.78	0.00	0.78	0.74	0.78	0.00	0.87	0.78	0.78	0.00
1975	0.59	*****	*****	0.00	0.80	*****	*****	0.00	0.74	*****	*****	0.00	0.74	*****	*****	0.00
1976	0.99	*****	*****	0.00	0.82	*****	*****	0.00	0.78	*****	*****	0.00	0.99	*****	*****	0.00
1977	0.89	*****	*****	0.00	0.75	0.58	0.55	0.00	0.88	0.86	1.06	0.00	0.75	0.58	0.55	0.00
1978	0.77	0.66	0.55	0.00	0.95	0.85	0.88	0.00	0.82	0.66	0.72	0.00	0.77	0.66	0.55	0.00
1979	0.65	0.84	0.79	0.00	0.95	0.88	0.98	0.00	0.87	0.67	0.63	0.00	0.95	0.88	0.98	0.00
1980	0.65	0.72	0.76	0.00	0.89	0.77	0.89	0.00	0.61	0.58	0.56	0.00	0.65	0.72	0.76	0.00
1981	0.68	0.68	0.61	0.00	0.86	0.82	0.87	0.00	0.63	0.49	0.60	0.00	0.68	0.68	0.61	0.00
1982	0.75	*****	*****	0.00	0.92	*****	*****	0.00	1.23	*****	*****	0.00	0.92	*****	*****	0.00
1983	0.84	*****	*****	0.00	0.70	*****	*****	0.00	0.66	*****	*****	0.00	0.70	*****	*****	0.00
1984	0.66	0.59	0.64	0.00	0.85	0.87	1.13	0.00	0.60	0.72	0.70	0.00	0.66	0.59	0.64	0.00
1985	0.53	0.51	0.56	0.00	0.56	0.55	0.71	0.00	0.74	0.95	0.87	0.00	0.56	0.55	0.71	0.00
1986	*****	*****	*****	0.00	0.84	0.72	0.79	0.00	1.57	1.22	1.20	0.00	0.84	0.72	0.79	0.00
1987	0.72	*****	*****	0.00	0.75	*****	*****	0.00	1.03	*****	*****	0.00	0.73	*****	*****	0.00
1988	0.82	0.73	0.78	0.00	0.94	0.90	0.98	0.00	0.67	0.75	0.78	0.00	0.94	0.90	0.98	0.00
1989	1.12	*****	*****	0.00	0.79	*****	*****	0.00	0.73	*****	*****	0.00	0.73	*****	*****	0.00
Mean	0.79	0.75	0.73	0.00	0.81	0.75	0.80	0.00	0.90	0.85	0.91	0.00	0.78	0.71	0.72	0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
E-363, Laksam; Daily Rainfall (mm)

Aerial Reductions on 10 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	2121	4090	6409	0	2121	4090	6409	0	2121	4090	6409	0	2121	4090	6409	0
1962	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1963	1.02	1.04	*****	0.00	1.02	1.04	*****	0.00	1.02	1.06	*****	0.00	1.02	1.06	*****	0.00
1964	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1965	0.96	0.86	0.76	0.00	1.46	*****	*****	0.00	2.51	2.15	2.55	0.00	1.46	*****	*****	0.00
1966	0.95	*****	*****	0.00	0.78	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1967	0.46	0.33	0.39	0.00	0.62	0.67	0.73	0.00	0.76	0.75	0.82	0.00	0.62	0.67	0.73	0.00
1968	0.92	1.01	1.16	0.00	0.84	0.84	0.91	0.00	0.84	0.67	0.71	0.00	0.92	1.01	1.16	0.00
1969	0.95	0.88	1.01	0.00	0.94	0.81	0.84	0.00	0.83	*****	*****	0.00	0.95	0.88	1.01	0.00
1970	1.10	1.13	1.06	0.00	0.62	0.64	0.66	0.00	1.33	1.29	1.50	0.00	0.62	0.64	0.66	0.00
1971	0.30	*****	*****	0.00	0.53	*****	*****	0.00	1.01	0.98	0.95	0.00	0.53	*****	*****	0.00
1972	0.78	0.80	0.86	0.00	0.65	0.60	0.61	0.00	0.77	0.69	0.84	0.00	0.65	0.60	0.61	0.00
1973	0.58	0.57	0.55	0.00	0.65	0.63	0.66	0.00	0.64	0.59	0.57	0.00	0.58	0.57	0.55	0.00
1974	1.00	0.90	*****	0.00	0.90	0.86	0.83	0.00	0.78	0.74	0.78	0.00	0.90	0.86	0.83	0.00
1975	0.80	*****	*****	0.00	0.76	*****	*****	0.00	0.86	*****	*****	0.00	0.86	*****	*****	0.00
1976	1.01	*****	*****	0.00	1.00	*****	*****	0.00	0.78	*****	*****	0.00	0.78	*****	*****	0.00
1977	0.91	*****	*****	0.00	0.75	0.60	0.59	0.00	0.95	0.89	1.14	0.00	0.75	0.60	0.59	0.00
1978	0.64	0.51	0.53	0.00	0.89	0.75	0.76	0.00	0.82	0.71	0.76	0.00	0.64	0.51	0.53	0.00
1979	0.64	0.70	0.60	0.00	0.95	0.91	1.03	0.00	0.81	0.65	0.51	0.00	0.95	0.91	1.03	0.00
1980	0.63	0.70	0.72	0.00	0.81	0.69	0.92	0.00	0.65	0.69	0.72	0.00	0.63	0.70	0.72	0.00
1981	0.64	0.65	0.57	0.00	0.87	0.83	0.88	0.00	0.73	0.59	0.75	0.00	0.64	0.65	0.57	0.00
1982	0.72	*****	*****	0.00	1.00	*****	*****	0.00	1.61	*****	*****	0.00	0.72	*****	*****	0.00
1983	0.81	*****	*****	0.00	0.76	*****	*****	0.00	0.64	*****	*****	0.00	0.76	*****	*****	0.00
1984	0.65	0.64	0.66	0.00	0.89	0.88	1.19	0.00	0.57	0.64	0.63	0.00	0.65	0.64	0.66	0.00
1985	0.53	0.53	0.57	0.00	0.57	0.57	0.74	0.00	0.67	0.91	0.87	0.00	0.57	0.57	0.74	0.00
1986	*****	*****	*****	0.00	0.82	0.77	0.83	0.00	1.47	1.13	1.11	0.00	0.82	0.77	0.83	0.00
1987	0.72	*****	*****	0.00	0.88	*****	*****	0.00	1.06	*****	*****	0.00	0.86	*****	*****	0.00
1988	0.78	0.64	0.69	0.00	1.01	0.95	1.07	0.00	0.83	0.84	0.95	0.00	0.78	0.64	0.69	0.00
1989	1.08	*****	*****	0.00	0.77	*****	*****	0.00	0.73	*****	*****	0.00	0.73	*****	*****	0.00
Mean	0.78	0.75	0.72	0.00	0.84	0.77	0.83	0.00	0.95	0.89	0.96	0.00	0.78	0.72	0.74	0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali; Daily Rainfall (mm)

Aerial Reductions on 1 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0
1962	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1963	0.91*********** 0.00	0.67*********** 0.00	0.81*********** 0.00	0.81*********** 0.00
1964	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1965	0.46*********** 0.00	**************** 0.00	0.89*********** 0.00	**************** 0.00
1966	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1967	1.22 0.89 0.75 0.00	0.69 0.79 0.60 0.00	0.99 1.01 0.88 0.00	0.99 1.01 0.88 0.00
1968	0.77 0.63 0.47 0.00	0.93 0.66 0.41 0.00	0.46 0.15 0.08 0.00	0.77 0.63 0.47 0.00
1969	0.88 0.76 0.57 0.00	0.78 0.66 0.64 0.00	0.61 0.60***** 0.00	0.88 0.76 0.57 0.00
1970	0.70 0.59 0.52 0.00	0.63 0.29 0.25 0.00	0.55 0.45 0.32 0.00	0.55 0.45 0.32 0.00
1971	0.66 0.73***** 0.00	0.97 0.79***** 0.00	0.95 0.57***** 0.00	0.95 0.57***** 0.00
1972	0.82 0.88 0.68 0.00	0.99 0.69 0.56 0.00	0.73 0.85 0.62 0.00	0.99 0.69 0.56 0.00
1973	0.63 0.38 0.33 0.00	0.78 0.75 0.78 0.00	0.76 0.66 0.57 0.00	0.63 0.38 0.33 0.00
1974	0.88 0.72 0.93 0.00	1.04 0.59 0.46 0.00	1.38 1.38 0.99 0.00	1.04 0.59 0.46 0.00
1975	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1976	1.13 1.39***** 0.00	1.26 1.16***** 0.00	**************** 0.00	1.26 1.16***** 0.00
1977	0.69 0.73 0.63 0.00	0.83 0.56 0.42 0.00	0.73 0.70 0.58 0.00	0.69 0.73 0.63 0.00
1978	1.10 0.71 0.74 0.00	0.85 0.48 0.33 0.00	0.80 0.45 0.32 0.00	1.10 0.71 0.74 0.00
1979	0.91 0.50 0.59 0.00	1.01 0.85 0.71 0.00	0.81 0.45 0.43 0.00	1.01 0.85 0.71 0.00
1980	0.86 0.57 0.55 0.00	0.74 0.43 0.33 0.00	0.76 0.44 0.32 0.00	0.74 0.43 0.33 0.00
1981	0.85 0.69 0.49 0.00	0.60 0.51 0.41 0.00	0.67 0.67 0.51 0.00	0.60 0.51 0.41 0.00
1982	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1983	0.59 0.29***** 0.00	0.96 1.06***** 0.00	0.48 0.45***** 0.00	0.96 1.06***** 0.00
1984	0.75 0.68 0.55 0.00	0.53 0.37 0.29 0.00	0.75 0.62 0.63 0.00	0.75 0.68 0.55 0.00
1985	0.72 0.69***** 0.00	0.94 0.67 0.45 0.00	0.68 0.33 0.31 0.00	0.94 0.67 0.45 0.00
1986	0.63 0.46 0.35 0.00	0.79 0.60 0.61 0.00	0.76 0.62 0.48 0.00	0.63 0.46 0.35 0.00
1987	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1988	0.47 0.36 0.24 0.00	0.69 0.54 0.42 0.00	0.61 0.45 0.40 0.00	0.47 0.36 0.24 0.00
1989	0.87 0.73***** 0.00	0.68 0.44***** 0.00	0.71 0.56***** 0.00	0.71 0.56***** 0.00
Mean	0.79 0.67 0.56 0.00	0.83 0.64 0.48 0.00	0.76 0.60 0.50 0.00	0.83 0.66 0.50 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali; Daily Rainfall (mm)

Aerial Reductions on 2 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	1195	3988	8044	0	1195	3988	8044	0	1195	3988	8044	0	1195	3988	8044	0
1962	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1963	0.86	*****	*****	0.00	1.09	*****	*****	0.00	0.88	*****	*****	0.00	0.88	*****	*****	0.00
1964	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1965	0.64	*****	*****	0.00	*****	*****	*****	0.00	0.89	*****	*****	0.00	*****	*****	*****	0.00
1966	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1967	0.77	0.64	0.62	0.00	0.74	1.06	0.80	0.00	0.98	0.93	0.79	0.00	0.98	0.93	0.79	0.00
1968	0.79	0.66	0.56	0.00	0.83	1.17	1.13	0.00	0.46	0.17	0.09	0.00	0.79	0.66	0.56	0.00
1969	0.88	0.81	0.62	0.00	0.89	0.98	0.89	0.00	0.99	0.95	*****	0.00	0.88	0.81	0.62	0.00
1970	0.90	0.79	0.75	0.00	0.67	0.40	0.41	0.00	0.55	0.51	0.35	0.00	0.55	0.51	0.35	0.00
1971	0.75	0.82	*****	0.00	0.87	0.75	*****	0.00	0.93	0.63	*****	0.00	0.93	0.63	*****	0.00
1972	0.79	0.98	0.78	0.00	0.85	0.78	0.81	0.00	0.79	0.97	0.77	0.00	0.85	0.78	0.81	0.00
1973	0.64	0.42	0.35	0.00	0.90	0.78	0.74	0.00	0.84	0.87	0.75	0.00	0.64	0.42	0.35	0.00
1974	0.91	0.36	0.96	0.00	1.12	0.62	0.53	0.00	1.27	1.43	1.02	0.00	1.12	0.62	0.53	0.00
1975	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1976	1.28	1.50	*****	0.00	1.20	0.94	*****	0.00	*****	*****	*****	0.00	1.20	0.94	*****	0.00
1977	0.81	0.90	0.73	0.00	0.84	0.69	0.53	0.00	0.74	0.71	0.59	0.00	0.81	0.90	0.73	0.00
1978	0.36	0.55	0.52	0.00	0.96	1.07	0.86	0.00	0.68	0.42	0.28	0.00	0.86	0.55	0.52	0.00
1979	0.97	0.83	0.86	0.00	1.02	0.83	0.72	0.00	0.79	0.52	0.47	0.00	1.02	0.83	0.72	0.00
1980	0.95	0.59	0.69	0.00	0.87	0.56	0.45	0.00	0.70	0.43	0.49	0.00	0.87	0.56	0.45	0.00
1981	0.68	0.46	0.43	0.00	0.60	0.52	0.44	0.00	0.71	0.79	0.53	0.00	0.60	0.52	0.44	0.00
1982	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1983	0.57	0.36	*****	0.00	1.10	1.25	*****	0.00	0.55	0.65	*****	0.00	1.10	1.25	*****	0.00
1984	0.83	0.84	0.81	0.00	0.82	0.65	0.58	0.00	0.70	0.63	0.71	0.00	0.83	0.84	0.81	0.00
1985	0.79	0.75	*****	0.00	0.77	0.62	0.48	0.00	0.77	0.61	0.48	0.00	0.77	0.62	0.48	0.00
1986	0.75	0.49	0.36	0.00	0.85	0.91	0.86	0.00	0.76	0.71	0.58	0.00	0.75	0.49	0.36	0.00
1987	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1988	0.47	0.45	0.34	0.00	0.65	0.51	0.41	0.00	0.77	0.61	0.55	0.00	0.47	0.45	0.34	0.00
1989	0.94	0.58	*****	0.00	0.84	0.60	*****	0.00	0.79	0.69	*****	0.00	0.79	0.69	*****	0.00
Mean	0.81	0.72	0.63	0.00	0.88	0.78	0.66	0.00	0.79	0.70	0.56	0.00	0.84	0.70	0.55	0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali; Daily Rainfall (mm)

Aerial Reductions on 4 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	1195	3988	8044	0	1195	3988	8044	0	1195	3988	8044	0	1195	3988	8044	0
1962	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1963	1.06	*****	*****	0.00	0.97	*****	*****	0.00	0.87	*****	*****	0.00	0.87	*****	*****	0.00
1964	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1965	0.76	*****	*****	0.00	*****	*****	*****	0.00	0.77	*****	*****	0.00	*****	*****	*****	0.00
1966	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1967	0.90	1.06	0.83	0.00	0.95	1.00	1.02	0.00	0.95	1.00	0.89	0.00	0.95	1.00	0.89	0.00
1968	0.86	0.74	0.67	0.00	0.86	1.09	1.06	0.00	0.76	0.29	0.24	0.00	0.86	0.74	0.67	0.00
1969	0.89	0.78	0.60	0.00	0.86	0.93	0.87	0.00	0.94	0.89	*****	0.00	0.89	0.78	0.60	0.00
1970	0.78	0.76	0.73	0.00	0.71	0.56	0.52	0.00	0.82	0.87	0.68	0.00	0.82	0.87	0.68	0.00
1971	0.72	0.88	*****	0.00	0.92	0.91	*****	0.00	0.93	0.63	*****	0.00	0.92	0.91	*****	0.00
1972	0.82	1.07	0.95	0.00	0.83	0.73	0.77	0.00	1.21	1.25	1.02	0.00	0.83	0.73	0.77	0.00
1973	0.67	0.48	0.44	0.00	0.84	0.85	0.82	0.00	0.85	0.94	0.82	0.00	0.67	0.48	0.44	0.00
1974	0.85	0.98	*****	0.00	1.14	0.64	0.58	0.00	1.16	1.11	0.85	0.00	1.14	0.64	0.58	0.00
1975	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1976	1.34	1.66	*****	0.00	1.18	0.99	*****	0.00	*****	*****	*****	0.00	1.18	0.99	*****	0.00
1977	0.84	1.01	0.88	0.00	0.74	0.63	0.48	0.00	0.74	0.71	0.61	0.00	0.84	1.01	0.88	0.00
1978	0.88	0.64	0.60	0.00	0.95	1.21	0.94	0.00	0.94	0.59	0.46	0.00	0.88	0.64	0.60	0.00
1979	1.02	1.01	0.84	0.00	1.09	0.88	0.79	0.00	0.78	0.60	0.57	0.00	1.09	0.88	0.79	0.00
1980	0.96	0.79	0.81	0.00	0.88	0.69	0.59	0.00	0.81	0.51	0.54	0.00	0.88	0.69	0.59	0.00
1981	0.72	0.54	0.53	0.00	0.68	0.64	0.54	0.00	0.77	0.88	0.65	0.00	0.68	0.64	0.54	0.00
1982	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1983	0.86	0.71	*****	0.00	1.10	1.36	*****	0.00	0.89	0.70	*****	0.00	1.10	1.36	*****	0.00
1984	0.96	0.93	0.90	0.00	0.96	0.90	0.70	0.00	0.64	0.55	0.59	0.00	0.96	0.90	0.70	0.00
1985	0.81	0.71	*****	0.00	0.92	0.91	0.70	0.00	0.98	0.66	0.56	0.00	0.92	0.91	0.70	0.00
1986	0.73	0.57	0.45	0.00	0.97	0.92	0.84	0.00	0.84	0.87	0.75	0.00	0.73	0.57	0.45	0.00
1987	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1988	0.52	0.60	0.52	0.00	0.67	0.34	0.29	0.00	0.78	0.63	0.54	0.00	0.67	0.34	0.29	0.00
1989	0.87	1.02	*****	0.00	0.82	0.70	*****	0.00	0.85	0.75	*****	0.00	0.85	0.75	*****	0.00
Mean	0.86	0.85	0.69	0.00	0.91	0.84	0.72	0.00	0.87	0.76	0.65	0.00	0.89	0.79	0.63	0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali: Daily Rainfall (mm)

Aerial Reductions on 3 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0
1962	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1963	0.85********** 0.00	1.16********** 0.00	0.87********** 0.00	0.87********** 0.00
1964	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1965	0.98********** 0.00	*************** 0.00	0.78********** 0.00	*************** 0.00
1966	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1967	0.88 1.06 0.79 0.00	0.75 1.19 0.92 0.00	0.95 0.94 0.84 0.00	0.95 0.94 0.84 0.00
1968	0.90 0.69 0.61 0.00	0.83 1.10 1.02 0.00	0.47 0.18 0.10 0.00	0.90 0.69 0.61 0.00
1969	0.85 0.87 0.63 0.00	0.84 0.88 0.80 0.00	0.95 0.85***** 0.00	0.85 0.87 0.63 0.00
1970	0.76 0.77 0.77 0.00	0.69 0.48 0.49 0.00	0.74 0.77 0.55 0.00	0.74 0.77 0.55 0.00
1971	0.74 0.88***** 0.00	0.90 0.82***** 0.00	0.93 0.74***** 0.00	0.93 0.74***** 0.00
1972	0.80 1.05 0.86 0.00	0.95 0.95 0.92 0.00	1.16 1.19 0.91 0.00	0.95 0.95 0.92 0.00
1973	0.65 0.46 0.40 0.00	0.85 0.82 0.78 0.00	0.86 1.01 0.89 0.00	0.65 0.46 0.40 0.00
1974	0.83 0.31***** 0.00	1.14 0.64 0.56 0.00	1.21 1.04 0.81 0.00	1.14 0.64 0.56 0.00
1975	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1976	1.30 1.50***** 0.00	1.22 0.93***** 0.00	*************** 0.00	1.22 0.93***** 0.00
1977	0.83 0.97 0.82 0.00	0.88 0.80 0.64 0.00	0.74 0.71 0.59 0.00	0.83 0.97 0.82 0.00
1978	0.90 0.65 0.61 0.00	0.96 1.18 0.92 0.00	0.31 0.49 0.36 0.00	0.90 0.65 0.61 0.00
1979	0.85 0.65 0.70 0.00	1.02 0.87 0.75 0.00	0.77 0.57 0.55 0.00	1.02 0.87 0.75 0.00
1980	0.92 0.64 0.69 0.00	0.91 0.64 0.52 0.00	0.66 0.47 0.50 0.00	0.91 0.64 0.52 0.00
1981	0.73 0.53 0.50 0.00	0.66 0.59 0.50 0.00	0.76 0.83 0.61 0.00	0.66 0.59 0.50 0.00
1982	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1983	0.64 0.51***** 0.00	1.11 1.36***** 0.00	0.80 0.65***** 0.00	1.11 1.36***** 0.00
1984	0.98 0.97 0.91 0.00	0.78 0.71 0.57 0.00	0.73 0.71 0.74 0.00	0.78 0.71 0.57 0.00
1985	0.80 0.72***** 0.00	0.91 0.88 0.60 0.00	0.97 0.68 0.56 0.00	0.91 0.88 0.60 0.00
1986	0.74 0.52 0.40 0.00	0.84 0.85 0.76 0.00	0.76 0.81 0.68 0.00	0.74 0.52 0.40 0.00
1987	*************** 0.00	*************** 0.00	*************** 0.00	*************** 0.00
1988	0.50 0.55 0.45 0.00	0.62 0.29 0.25 0.00	0.80 0.70 0.64 0.00	0.50 0.55 0.45 0.00
1989	0.88 0.83***** 0.00	0.83 0.62***** 0.00	0.89 0.73***** 0.00	0.89 0.73***** 0.00
Mean	0.83 0.79 0.65 0.00	0.90 0.83 0.69 0.00	0.84 0.74 0.62 0.00	0.88 0.77 0.61 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali; Daily Rainfall (mm)

Aerial Reductions on 5 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0
1962	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1963	1.15*********** 0.00	1.01*********** 0.00	0.87*********** 0.00	0.87*********** 0.00
1964	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1965	0.80*********** 0.00	**************** 0.00	0.89*********** 0.00	**************** 0.00
1966	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1967	0.84 0.88 0.66 0.00	0.96 1.03 1.02 0.00	0.95 1.00 0.89 0.00	0.96 1.03 1.02 0.00
1968	0.88 0.81 0.75 0.00	0.86 1.07 1.02 0.00	0.76 0.31 0.25 0.00	0.88 0.81 0.75 0.00
1969	0.88 0.90 0.67 0.00	0.93 1.11 0.95 0.00	0.94 0.93****** 0.00	0.88 0.90 0.67 0.00
1970	0.88 1.04 0.88 0.00	0.74 0.59 0.54 0.00	0.79 0.86 0.66 0.00	0.79 0.86 0.66 0.00
1971	0.78 1.03****** 0.00	0.89 0.87****** 0.00	0.93 0.73****** 0.00	0.89 0.87****** 0.00
1972	0.83 1.04 0.95 0.00	0.83 0.73 0.80 0.00	1.10 1.24 0.96 0.00	0.83 0.73 0.80 0.00
1973	0.82 0.72 0.59 0.00	0.81 0.84 0.80 0.00	0.86 1.06 0.95 0.00	0.82 0.72 0.59 0.00
1974	0.98 1.11****** 0.00	0.88 1.00 0.92 0.00	1.08 1.04 0.79 0.00	0.88 1.00 0.92 0.00
1975	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1976	1.15 1.39****** 0.00	1.15 0.99****** 0.00	**************** 0.00	1.15 0.99****** 0.00
1977	0.86 1.05 0.91 0.00	0.78 0.72 0.56 0.00	0.74 0.71 0.61 0.00	0.86 1.05 0.91 0.00
1978	0.89 0.68 0.65 0.00	0.94 0.83 0.59 0.00	0.83 0.66 0.50 0.00	1.04 0.83 0.68 0.00
1979	0.84 0.83 0.88 0.00	1.06 0.87 0.76 0.00	0.76 0.56 0.54 0.00	1.06 0.87 0.76 0.00
1980	0.90 0.65 0.66 0.00	0.90 0.66 0.54 0.00	0.95 0.85 0.69 0.00	0.90 0.66 0.54 0.00
1981	0.78 0.65 0.57 0.00	0.80 0.73 0.60 0.00	0.81 0.90 0.67 0.00	0.80 0.73 0.60 0.00
1982	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1983	0.90 0.79****** 0.00	1.13 1.36****** 0.00	0.89 0.79****** 0.00	1.13 1.36****** 0.00
1984	0.87 0.83 0.65 0.00	0.94 0.96 0.76 0.00	0.67 0.62 0.62 0.00	0.94 0.96 0.76 0.00
1985	0.80 0.71****** 0.00	0.92 0.92 0.69 0.00	0.98 0.72 0.60 0.00	0.92 0.92 0.69 0.00
1986	0.74 0.58 0.46 0.00	1.01 1.01 0.94 0.00	0.84 0.98 0.83 0.00	0.74 0.58 0.46 0.00
1987	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1988	0.51 0.58 0.52 0.00	0.77 0.45 0.35 0.00	0.80 0.65 0.57 0.00	0.51 0.58 0.52 0.00
1989	0.96 0.98****** 0.00	0.81 0.73****** 0.00	0.85 0.76****** 0.00	0.85 0.76****** 0.00
Mean	0.86 0.86 0.70 0.00	0.91 0.87 0.74 0.00	0.88 0.81 0.68 0.00	0.89 0.86 0.71 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali; Daily Rainfall (mm)

Aerial Reductions on 7 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0	1195 3988 8044 0
1962	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1963	1.29********** 0.00	0.79********** 0.00	0.92********** 0.00	0.92********** 0.00
1964	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1965	0.84********** 0.00	**************** 0.00	0.88********** 0.00	**************** 0.00
1966	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1967	0.86 0.87 0.68 0.00	0.96 1.03 1.05 0.00	0.95 1.00 0.89 0.00	0.96 1.03 1.05 0.00
1968	0.88 0.82 0.76 0.00	0.92 1.18 1.16 0.00	0.81 0.87 0.70 0.00	0.88 0.82 0.76 0.00
1969	0.88 0.86 0.65 0.00	0.98 1.19 1.02 0.00	0.88 0.85***** 0.00	0.88 0.86 0.65 0.00
1970	0.85 1.01 0.88 0.00	0.85 1.07 1.01 0.00	0.80 0.92 0.70 0.00	0.74 0.55 0.51 0.00
1971	0.78 1.03***** 0.00	0.86 0.83***** 0.00	0.93 0.74***** 0.00	0.86 0.83***** 0.00
1972	0.82 0.96 0.87 0.00	0.88 0.86 0.86 0.00	1.26 1.19 1.02 0.00	0.82 0.96 0.87 0.00
1973	0.78 0.66 0.55 0.00	0.88 1.01 0.93 0.00	0.89 1.02 0.93 0.00	0.78 0.66 0.55 0.00
1974	0.96 0.95***** 0.00	0.88 1.03 0.94 0.00	1.05 1.05 0.82 0.00	0.88 1.03 0.94 0.00
1975	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1976	1.11 1.35***** 0.00	1.17 1.06***** 0.00	**************** 0.00	1.17 1.06***** 0.00
1977	0.83 1.06 0.94 0.00	0.94 1.01 0.81 0.00	0.60 0.48 0.39 0.00	0.94 1.01 0.81 0.00
1978	0.89 0.66 0.61 0.00	0.93 0.84 0.64 0.00	0.93 0.67 0.51 0.00	0.94 0.80 0.62 0.00
1979	0.93 1.01 1.00 0.00	1.24 1.04 0.93 0.00	0.76 0.63 0.59 0.00	1.24 1.04 0.93 0.00
1980	1.09 0.90 0.93 0.00	0.90 0.75 0.63 0.00	0.95 0.85 0.72 0.00	0.90 0.75 0.63 0.00
1981	0.97 0.97 0.74 0.00	0.77 0.75 0.61 0.00	0.74 0.78 0.60 0.00	0.77 0.75 0.61 0.00
1982	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1983	0.90 0.79***** 0.00	1.12 1.30***** 0.00	0.92 0.82***** 0.00	1.12 1.30***** 0.00
1984	1.02 1.03 1.00 0.00	0.93 0.95 0.79 0.00	0.68 0.62 0.63 0.00	0.93 0.95 0.79 0.00
1985	0.80 0.75***** 0.00	0.93 1.00 0.77 0.00	1.07 0.83 0.69 0.00	0.93 1.00 0.77 0.00
1986	0.78 0.65 0.50 0.00	0.88 0.79 0.74 0.00	0.83 0.97 0.79 0.00	0.78 0.65 0.50 0.00
1987	**************** 0.00	**************** 0.00	**************** 0.00	**************** 0.00
1988	0.52 0.62 0.56 0.00	0.76 0.49 0.43 0.00	0.79 0.72 0.63 0.00	0.52 0.62 0.56 0.00
1989	0.93 0.91***** 0.00	0.80 0.74***** 0.00	0.85 0.76***** 0.00	0.85 0.76***** 0.00
Mean	0.90 0.89 0.76 0.00	0.92 0.95 0.83 0.00	0.88 0.83 0.71 0.00	0.90 0.88 0.73 0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-369, Noakhali; Daily Rainfall (mm)

Aerial Reductions on 10 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	1195	3988	8044	0	1195	3988	8044	0	1195	3988	8044	0	1195	3988	8044	0
1962	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1963	1.19	*****	*****	0.00	1.20	*****	*****	0.00	0.94	*****	*****	0.00	0.94	*****	*****	0.00
1964	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1965	0.75	*****	*****	0.00	*****	*****	*****	0.00	0.81	*****	*****	0.00	*****	*****	*****	0.00
1966	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1967	0.81	0.64	0.71	0.00	0.94	1.11	1.01	0.00	0.92	0.79	0.65	0.00	0.94	1.11	1.01	0.00
1968	0.89	0.86	0.79	0.00	0.91	0.66	0.49	0.00	0.91	0.72	0.69	0.00	0.89	0.86	0.79	0.00
1969	0.95	0.88	0.69	0.00	0.93	1.02	0.99	0.00	0.85	0.82	*****	0.00	0.95	0.88	0.69	0.00
1970	0.92	0.82	0.76	0.00	0.82	0.72	0.65	0.00	0.76	0.83	0.63	0.00	0.76	0.83	0.63	0.00
1971	0.87	0.83	*****	0.00	0.90	0.87	*****	0.00	0.93	0.71	*****	0.00	0.86	0.83	*****	0.00
1972	0.76	1.10	0.94	0.00	0.82	0.94	0.88	0.00	1.21	1.24	1.07	0.00	0.82	0.94	0.88	0.00
1973	0.79	0.73	0.63	0.00	0.88	1.03	0.96	0.00	0.86	1.04	0.92	0.00	0.79	0.73	0.63	0.00
1974	0.94	0.97	*****	0.00	0.99	0.90	0.80	0.00	1.05	1.08	0.84	0.00	0.99	0.90	0.80	0.00
1975	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1976	1.05	1.23	*****	0.00	1.09	1.00	*****	0.00	1.20	1.24	*****	0.00	1.09	1.00	*****	0.00
1977	0.85	1.11	0.98	0.00	0.85	0.95	0.75	0.00	0.66	0.52	0.42	0.00	0.85	0.95	0.75	0.00
1978	1.08	0.85	0.77	0.00	0.57	0.85	0.64	0.00	1.00	0.79	0.66	0.00	0.94	0.85	0.66	0.00
1979	0.96	0.99	0.90	0.00	1.22	1.15	0.99	0.00	0.81	0.77	0.70	0.00	1.22	1.15	0.99	0.00
1980	1.07	1.03	1.00	0.00	0.88	0.74	0.59	0.00	0.86	0.63	0.69	0.00	0.88	0.74	0.59	0.00
1981	1.06	1.02	0.81	0.00	0.84	0.86	0.69	0.00	0.74	0.86	0.63	0.00	0.84	0.86	0.69	0.00
1982	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1983	0.89	0.84	*****	0.00	1.15	1.28	*****	0.00	0.68	0.89	*****	0.00	1.15	1.28	*****	0.00
1984	0.86	0.67	0.71	0.00	0.97	1.02	0.85	0.00	0.67	0.62	0.63	0.00	0.97	1.02	0.85	0.00
1985	0.80	0.75	*****	0.00	0.92	0.96	0.75	0.00	1.10	0.84	0.71	0.00	0.94	0.93	0.72	0.00
1986	0.74	0.61	0.47	0.00	0.91	0.86	0.81	0.00	0.87	1.06	0.93	0.00	0.74	0.61	0.47	0.00
1987	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00	*****	*****	*****	0.00
1988	0.53	0.63	0.60	0.00	0.73	0.56	0.43	0.00	0.82	0.75	0.65	0.00	0.73	0.56	0.43	0.00
1989	0.90	0.93	*****	0.00	0.75	0.70	*****	0.00	0.87	0.83	*****	0.00	0.87	0.83	*****	0.00
Mean	0.89	0.89	0.77	0.00	0.93	0.91	0.77	0.00	0.89	0.85	0.72	0.00	0.91	0.89	0.72	0.00

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377, Sonaimuri; Daily Rainfall (mm)

Aerial Reductions on 1 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475
1962	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1963	1.04	1.02	*****	*****	0.81	0.86	*****	*****	0.97	0.80	0.58	*****	0.97	0.80	0.58	*****
1964	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1965	1.01	0.82	0.67	*****	*****	*****	*****	*****	1.01	1.00	0.83	*****	*****	*****	*****	*****
1966	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1967	1.09	0.88	1.12	0.61	1.16	1.09	0.91	0.67	1.00	0.97	0.99	0.87	1.00	0.97	0.99	0.87
1968	1.11	1.10	1.17	0.95	0.82	0.55	0.47	0.41	0.79	0.77	0.69	0.24	1.11	1.10	1.17	0.95
1969	0.93	0.82	0.87	0.74	0.75	0.59	0.36	0.26	1.05	1.27	0.96	0.70	0.93	0.82	0.87	0.74
1970	0.88	0.75	0.73	0.74	0.73	0.53	0.46	0.29	0.92	0.92	0.57	0.59	0.92	0.92	0.57	0.59
1971	0.94	0.70	0.73	0.61	0.83	*****	*****	*****	1.01	0.74	0.68	0.53	1.01	0.74	0.68	0.53
1972	0.86	0.90	0.99	0.34	1.02	0.73	0.75	0.59	0.68	0.45	0.24	0.18	1.02	0.73	0.75	0.59
1973	0.86	0.62	0.54	0.39	0.90	0.84	0.74	0.51	1.02	0.95	1.29	1.01	0.86	0.62	0.54	0.39
1974	0.68	0.45	0.50	0.28	1.08	1.09	0.85	0.50	1.13	1.12	0.81	0.69	1.08	1.09	0.85	0.50
1975	0.78	0.64	*****	*****	0.95	0.86	*****	*****	0.97	1.21	*****	*****	0.95	0.86	*****	*****
1976	0.68	*****	*****	*****	1.03	*****	*****	*****	*****	*****	*****	*****	0.68	*****	*****	*****
1977	1.00	*****	*****	*****	1.00	0.83	0.99	0.64	0.87	0.73	0.99	0.94	1.00	*****	*****	*****
1978	0.80	0.72	0.74	0.42	0.70	0.54	0.50	0.50	0.92	0.75	0.60	0.36	0.80	0.72	0.74	0.42
1979	0.99	0.82	0.72	0.45	1.09	1.00	0.91	0.73	0.69	0.55	0.63	0.43	1.09	1.00	0.91	0.73
1980	0.73	0.48	0.24	0.07	0.99	0.67	0.69	0.31	1.17	0.94	1.03	0.72	0.99	0.67	0.69	0.31
1981	0.70	1.31	1.23	0.92	1.30	1.06	0.69	0.56	0.70	0.47	0.38	0.38	1.30	1.06	0.69	0.56
1982	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1983	0.70	*****	*****	*****	1.19	*****	*****	*****	0.81	*****	*****	*****	1.19	*****	*****	*****
1984	0.90	0.85	0.99	0.39	0.81	0.96	0.79	0.64	0.73	0.84	0.92	0.76	0.81	0.96	0.79	0.64
1985	1.00	0.90	0.44	*****	0.89	0.75	0.76	0.49	0.73	0.80	0.62	0.28	0.89	0.75	0.76	0.49
1986	0.94	0.71	0.76	*****	0.83	0.68	0.45	0.36	0.89	0.75	0.99	0.82	0.80	0.96	1.25	0.86
1987	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1988	0.68	0.45	0.28	0.11	1.01	0.85	0.81	1.00	0.94	0.63	0.63	0.66	0.68	0.45	0.28	0.11
1989	0.69	0.46	0.33	*****	0.80	0.80	1.06	*****	0.91	0.70	0.74	*****	0.91	0.70	0.74	*****
Mean	0.87	0.77	0.72	0.59	0.94	0.80	0.72	0.53	0.91	0.83	0.76	0.60	0.95	0.84	0.77	0.58

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377. Sonaimuri: Daily Rainfall (mm)

Aerial Reductions on 2 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	642 969 2023 7475	642 969 2023 7475	642 969 2023 7475	642 969 2023 7475
1962	********************	********************	********************	********************
1963	0.98 0.93**********	0.88 0.89**********	0.92 1.21 1.03*****	0.92 1.21 1.03*****
1964	********************	********************	********************	********************
1965	0.92 0.80 0.65*****	********************	1.03 1.02 0.85*****	********************
1966	********************	********************	********************	********************
1967	1.09 0.88 1.13 0.62	1.19 1.15 1.00 0.90	0.96 0.89 0.90 0.76	0.96 0.89 0.90 0.76
1968	1.17 1.25 1.34 1.07	1.08 0.78 0.78 0.44	0.79 0.77 0.69 0.24	1.17 1.25 1.34 1.07
1969	0.87 0.76 0.78 0.62	0.81 0.71 0.49 0.47	1.09 1.18 1.00 0.73	0.87 0.76 0.78 0.62
1970	1.02 0.96 1.05 0.99	0.93 0.71 1.04 0.85	1.04 1.16 0.75 0.77	1.04 1.16 0.75 0.77
1971	0.89 0.65 0.65 0.60	0.83***************	1.07 0.77 0.82 0.67	0.83***************
1972	0.87 0.93 0.97 1.03	1.02 1.07 0.98 0.66	0.68 0.47 0.44 0.38	1.02 1.07 0.98 0.66
1973	0.95 1.08 0.94 0.59	0.94 0.93 0.92 0.71	1.00 0.80 1.07 0.98	0.94 0.93 0.92 0.71
1974	1.08 0.98 1.08 1.29	1.01 1.08 0.81 0.48	0.99 0.91 0.71 0.57	1.01 1.08 0.81 0.48
1975	0.80 0.74**********	1.03 0.91**********	1.01 1.34**********	1.03 0.91**********
1976	0.70***************	1.25***************	********************	0.70***************
1977	0.94***************	1.04 0.92 1.01 0.82	0.86 0.74 0.98 0.92	0.94***************
1978	0.86 0.79 0.78 0.52	0.78 0.61 0.66 0.75	1.08 0.80 0.89 0.51	0.86 0.79 0.78 0.52
1979	0.92 0.87 0.76 1.01	1.00 0.90 0.85 0.67	0.69 0.56 0.68 0.52	1.00 0.90 0.85 0.67
1980	0.73 0.60 0.55 0.37	0.99 0.91 0.94 0.58	0.97 0.83 0.86 0.46	0.99 0.91 0.94 0.58
1981	1.06 1.53 1.30 0.87	1.10 0.85 0.61 0.57	0.71 0.47 0.50 0.43	1.10 0.85 0.61 0.57
1982	********************	********************	********************	********************
1983	0.70***************	1.01***************	0.94***************	1.01***************
1984	0.76 0.52 0.43 0.40	0.81 0.85 0.78 0.71	0.80 0.80 0.79 0.55	0.81 0.85 0.78 0.71
1985	0.92 1.14 1.23*****	0.99 0.84 0.84 0.63	0.74 0.85 0.65 0.29	0.99 0.84 0.84 0.63
1986	0.90 0.66 0.98*****	1.05 1.07 1.03 0.79	0.91 0.79 1.05 0.97	0.90 0.66 0.98*****
1987	********************	********************	********************	********************
1988	0.71 0.47 0.28 0.15	0.87 0.71 0.61 0.73	0.97 1.02 1.06 0.87	0.87 0.71 0.61 0.73
1989	1.09 0.75 0.90*****	1.47 1.41 1.58*****	1.03 0.99 1.17*****	1.03 0.99 1.17*****
Mean	0.91 0.86 0.88 0.72	1.01 0.91 0.88 0.67	0.92 0.87 0.84 0.62	0.96 0.93 0.89 0.68

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377, Sonaimuri; Daily Rainfall (mm)

Aerial Reductions on 3 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475
1962	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1963	1.02	0.99	*****	*****	0.82	0.89	*****	*****	0.91	1.18	1.02	*****	0.91	1.18	1.02	*****
1964	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1965	0.92	0.88	0.78	*****	*****	*****	*****	*****	0.79	0.61	0.55	*****	*****	*****	*****	*****
1966	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1967	0.94	1.01	0.86	0.91	1.03	1.11	1.06	1.02	0.96	0.91	0.91	0.84	0.96	0.91	0.91	0.84
1968	1.20	1.20	1.16	0.88	0.82	0.77	0.67	0.40	0.95	0.76	0.80	0.91	1.20	1.20	1.16	0.88
1969	0.87	0.87	0.84	0.67	0.86	0.75	0.64	0.60	1.08	*****	*****	*****	0.87	0.87	0.84	0.67
1970	1.02	0.96	1.05	0.99	0.89	0.86	0.77	0.69	1.01	1.13	1.05	0.97	1.01	1.13	1.05	0.97
1971	0.92	0.66	0.69	0.69	0.88	*****	*****	*****	1.05	0.76	0.80	0.65	0.88	*****	*****	*****
1972	0.86	0.86	1.00	1.18	0.93	0.97	1.10	0.90	0.73	0.54	0.54	0.63	0.93	0.97	1.10	0.90
1973	1.02	1.32	1.32	1.23	0.91	0.87	0.88	0.70	1.01	0.80	1.10	1.05	1.02	1.32	1.32	1.23
1974	1.18	1.25	1.31	*****	0.99	1.14	0.84	0.48	0.94	0.84	0.74	0.57	0.99	1.14	0.84	0.48
1975	0.84	0.73	*****	*****	1.07	1.01	*****	*****	1.00	1.33	*****	*****	1.07	1.01	*****	*****
1976	0.73	*****	*****	*****	1.35	*****	*****	*****	*****	*****	*****	*****	0.73	*****	*****	*****
1977	0.94	*****	*****	*****	1.04	0.91	1.03	0.86	0.68	0.45	0.22	0.23	0.94	*****	*****	*****
1978	0.88	0.80	0.88	0.57	0.78	0.61	0.66	0.80	1.45	1.15	1.06	0.61	0.88	0.80	0.88	0.57
1979	1.01	0.91	0.80	0.65	0.93	0.86	0.78	0.58	0.69	0.56	0.72	0.59	0.93	0.86	0.78	0.58
1980	0.72	0.62	0.76	0.59	1.03	0.94	0.93	0.62	0.97	0.84	0.90	0.56	1.03	0.94	0.93	0.62
1981	1.05	1.42	1.24	0.96	1.23	0.99	0.73	0.63	0.71	0.47	0.77	0.59	1.23	0.99	0.73	0.63
1982	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1983	0.70	*****	*****	*****	0.98	*****	*****	*****	0.89	*****	*****	*****	0.98	*****	*****	*****
1984	0.95	0.86	1.04	0.99	0.85	0.88	0.77	0.78	0.81	0.79	0.69	0.56	0.95	0.86	1.04	0.99
1985	0.86	1.06	1.16	*****	1.05	0.93	0.91	0.75	0.85	1.14	0.96	0.51	1.05	0.93	0.91	0.75
1986	0.90	0.66	0.98	*****	1.01	1.08	1.00	0.89	0.98	0.87	0.97	0.94	0.90	0.66	0.98	*****
1987	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1988	0.74	0.49	0.30	0.17	0.87	0.71	0.66	0.71	0.82	0.78	0.70	0.60	0.87	0.71	0.66	0.71
1989	0.81	0.67	0.67	*****	1.39	1.29	1.51	*****	1.09	1.15	1.17	*****	1.09	1.15	1.17	*****
Mean	0.92	0.91	0.93	0.81	0.99	0.93	0.88	0.71	0.93	0.85	0.82	0.67	0.97	0.98	0.96	0.77

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377, Sonaimuri; Daily Rainfall (mm)

Aerial Reductions on 4 Day Annual Maxima

Year	Pre-Monsoon	Mid-Monsoon	Post-Monsoon	Annual
	642 969 2023 7475	642 969 2023 7475	642 969 2023 7475	642 969 2023 7475
1962	********************	********************	********************	********************
1963	1.01 1.00**********	0.87 0.96**********	0.97 1.32 1.18*****	0.87 0.96**********
1964	********************	********************	********************	********************
1965	0.95 0.94 0.85*****	********************	0.82 0.64 0.62*****	********************
1966	********************	********************	********************	********************
1967	1.03 1.19 1.04 0.99	1.02-1.08 1.03 1.02	0.96 0.91 0.93 0.89	0.96 0.91 0.93 0.89
1968	1.18 1.26 1.22 1.01	1.05 0.86 0.78 0.52	0.98 0.78 0.80 1.02	1.18 1.26 1.22 1.01
1969	1.00 0.98 0.99 0.79	0.99 0.96 0.92 0.93	1.10***************	1.00 0.98 0.99 0.79
1970	1.18 1.13 1.14 1.06	0.87 0.84 0.76 0.80	1.05 1.18 1.15 1.06	1.05 1.18 1.15 1.06
1971	0.93 0.72 0.75 0.80	0.87***************	1.03 0.74 0.78 0.64	0.87***************
1972	0.86 0.90 0.92 1.01	0.92 0.93 1.08 0.88	0.81 0.76 0.65 0.59	0.92 0.93 1.08 0.88
1973	1.03 1.27 1.27 0.92	0.92 0.89 0.97 0.80	1.00 0.78 1.10 1.06	1.03 1.27 1.27 0.92
1974	1.14 1.36 1.47*****	0.99 1.20 0.89 0.50	0.95 0.84 0.75 0.60	0.99 1.20 0.89 0.50
1975	0.92 0.65**********	1.01 0.98**********	1.12 1.55**********	1.01 0.98**********
1976	0.78***************	1.37***************	********************	0.78***************
1977	0.92***************	1.08 0.95 1.04 0.88	0.68 0.45 0.23 0.23	1.08 0.95 1.04 0.88
1978	0.88 0.80 0.89 0.58	0.79 0.63 0.68 0.84	1.42 1.14 1.16 0.68	1.07 0.87 0.76 0.67
1979	1.00 0.93 0.84 0.75	0.92 0.84 0.75 0.57	0.70 0.56 0.71 0.59	0.92 0.84 0.75 0.57
1980	0.73 0.65 0.72 0.53	1.01 0.92 0.94 0.69	1.25 1.03 1.03 0.84	1.01 0.92 0.94 0.69
1981	1.08 0.75 0.66 0.66	1.15 0.93 0.71 0.60	0.84 0.56 0.85 0.75	1.15 0.93 0.71 0.60
1982	********************	********************	********************	********************
1983	1.01***************	0.99***************	1.16***************	0.99***************
1984	0.94 0.86 1.07 0.99	1.16 1.14 0.95 0.95	0.80 0.77 0.65 0.58	0.94 0.86 1.07 0.99
1985	0.85 1.01 1.09*****	1.04 0.98 1.01 0.84	0.87 1.07 0.86 0.51	1.04 0.98 1.01 0.84
1986	0.89 0.70 1.00*****	0.96 0.98 0.95 0.83	0.97 0.87 0.98 1.03	0.96 0.98 0.95 0.83
1987	********************	********************	********************	********************
1988	0.74 0.49 0.31 0.20	0.86 0.72 0.65 0.73	0.85 0.89 0.95 0.76	0.86 0.72 0.65 0.73
1989	0.84 0.77 0.78*****	1.39 1.29 1.54*****	1.09 1.16 1.21*****	1.09 1.16 1.21*****
Mean	0.95 0.92 0.95 0.79	1.01 0.95 0.92 0.78	0.97 0.90 0.87 0.74	0.99 0.99 0.98 0.80

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377, Sonaimuri; Daily Rainfall (mm)

Aerial Reductions on 5 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475
1962	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1963	1.00	0.97	*****	*****	0.89	1.01	*****	*****	0.90	1.18	0.96	*****	0.89	1.01	*****	*****
1964	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1965	0.95	0.94	0.86	*****	*****	*****	*****	*****	0.84	0.64	0.66	*****	*****	*****	*****	*****
1966	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1967	0.89	0.89	0.82	0.77	1.02	1.15	1.10	1.00	0.96	0.31	0.93	0.39	1.02	1.15	1.10	1.00
1968	1.22	1.28	1.22	1.02	0.99	0.84	0.73	0.47	0.98	0.33	0.86	1.08	1.22	1.28	1.22	1.02
1969	0.95	0.91	0.91	0.70	0.88	0.87	0.67	0.69	1.10	*****	*****	*****	0.95	0.91	0.91	0.70
1970	1.19	1.10	1.07	1.01	1.14	1.43	1.04	0.87	1.04	1.16	1.11	1.12	1.04	1.16	1.11	1.12
1971	1.03	0.73	0.84	0.78	0.84	0.56	0.61	0.51	1.03	0.33	0.84	0.74	0.84	0.56	0.61	0.51
1972	0.86	0.85	0.95	1.13	0.94	0.94	1.15	0.94	0.82	0.77	0.66	0.60	0.94	0.94	1.15	0.94
1973	1.06	1.43	1.51	1.21	0.94	0.93	1.03	0.89	0.99	0.73	1.10	1.07	1.06	1.43	1.51	1.21
1974	1.03	1.20	1.20	*****	0.98	1.13	0.85	0.49	0.99	0.39	0.80	0.69	0.98	1.13	0.85	0.49
1975	0.92	0.55	*****	*****	1.06	1.07	*****	*****	1.20	1.43	*****	*****	1.06	1.07	*****	*****
1976	0.79	*****	*****	*****	1.08	*****	*****	*****	*****	*****	*****	*****	0.79	*****	*****	*****
1977	1.26	1.22	1.31	1.49	1.08	0.98	1.00	0.97	0.69	0.49	0.25	0.29	1.08	0.98	1.00	0.97
1978	0.88	0.80	0.88	0.57	0.80	0.64	0.71	0.87	1.42	1.18	1.19	0.79	1.11	0.88	0.86	0.69
1979	0.99	0.93	0.85	0.79	0.91	0.83	0.73	0.56	0.70	0.56	0.71	0.60	0.91	0.83	0.73	0.56
1980	0.77	0.65	0.67	0.53	1.12	0.96	0.89	0.63	1.15	0.97	0.96	0.81	1.12	0.96	0.89	0.63
1981	1.06	0.74	0.72	0.74	1.15	0.93	0.71	0.60	0.83	0.56	0.80	0.73	1.12	0.94	0.73	0.57
1982	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1983	0.90	*****	*****	*****	0.96	*****	*****	*****	1.17	*****	*****	*****	0.96	*****	*****	*****
1984	0.91	0.86	0.97	0.91	1.27	1.23	1.02	0.98	0.79	0.74	0.64	0.57	0.91	0.86	0.97	0.91
1985	0.84	0.97	1.03	*****	0.96	1.07	0.98	0.76	0.86	1.06	0.85	0.49	0.96	1.07	0.98	0.76
1986	0.89	0.70	1.01	*****	0.94	0.91	0.92	0.85	0.91	0.84	0.88	0.95	0.94	0.91	0.92	0.85
1987	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1988	0.74	0.49	0.32	0.30	0.89	0.86	0.77	0.90	0.84	0.86	0.89	0.73	0.89	0.86	0.77	0.90
1989	0.84	0.77	0.85	*****	1.39	1.29	1.55	*****	1.09	1.16	1.25	*****	1.09	1.16	1.25	*****
Mean	0.95	0.91	0.95	0.85	1.01	0.98	0.92	0.76	0.97	0.89	0.86	0.76	0.99	1.00	0.98	0.81

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377. Sonaimuri: Daily Rainfall (mm)

Aerial Reductions on 7 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475
1962	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1963	1.06	0.97	*****	*****	0.93	1.08	*****	*****	0.98	0.90	0.69	*****	1.06	0.97	*****	*****
1964	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1965	0.98	1.05	0.95	*****	*****	*****	*****	*****	0.84	0.64	0.66	*****	*****	*****	*****	*****
1966	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1967	0.94	1.04	0.95	0.80	1.02	1.14	1.08	1.02	0.96	0.91	0.93	0.89	1.02	1.14	1.08	1.02
1968	1.15	1.18	1.11	0.95	0.94	0.80	0.76	0.49	0.85	0.69	0.51	0.63	1.15	1.18	1.11	0.95
1969	0.91	0.85	0.83	0.76	0.90	0.84	0.67	0.65	1.11	*****	*****	*****	0.91	0.85	0.83	0.76
1970	1.17	1.11	1.13	1.02	1.13	1.29	0.91	0.81	1.03	1.14	1.09	1.06	1.03	1.14	1.09	1.06
1971	*****	*****	*****	*****	1.03	*****	*****	*****	1.03	0.88	0.90	0.77	1.03	*****	*****	*****
1972	0.86	0.97	0.98	1.05	0.95	0.94	1.19	1.04	0.79	0.71	0.61	0.52	0.86	0.97	0.98	1.05
1973	1.00	1.37	1.35	1.13	1.12	1.11	1.27	1.23	1.05	1.05	1.32	1.20	1.00	1.37	1.35	1.13
1974	1.05	1.23	1.30	*****	0.99	1.03	0.91	0.69	1.01	0.89	0.86	0.78	0.99	1.03	0.91	0.69
1975	0.92	0.65	*****	*****	1.05	1.07	*****	*****	1.13	1.33	*****	*****	1.05	1.07	*****	*****
1976	0.78	*****	*****	*****	1.13	*****	*****	*****	*****	*****	*****	*****	0.78	*****	*****	*****
1977	0.93	*****	*****	*****	1.05	0.98	1.01	0.94	0.70	0.52	0.47	0.41	1.05	0.98	1.01	0.94
1978	0.87	0.77	0.85	0.55	0.82	0.66	0.74	0.90	1.01	0.93	1.01	0.77	1.11	0.90	0.93	0.77
1979	1.01	0.92	0.92	0.93	0.92	0.83	0.70	0.59	0.69	0.61	0.76	0.56	0.92	0.83	0.70	0.59
1980	0.78	0.65	0.67	0.57	0.86	0.65	0.66	0.58	1.15	0.97	0.96	0.81	0.86	0.65	0.66	0.58
1981	1.05	0.75	0.74	0.76	1.15	0.93	0.71	0.60	0.81	0.54	0.79	0.74	1.17	0.97	0.74	0.60
1982	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1983	0.92	*****	*****	*****	0.92	*****	*****	*****	1.10	*****	*****	*****	0.92	*****	*****	*****
1984	1.00	0.91	1.09	1.01	1.21	1.24	1.00	0.93	0.83	0.82	0.78	0.66	1.00	0.91	1.09	1.01
1985	1.17	1.15	0.82	*****	0.95	1.04	0.97	0.75	0.89	1.13	0.90	0.55	0.95	1.04	0.97	0.75
1986	0.88	0.68	0.91	*****	0.92	0.90	0.91	0.88	0.89	0.82	0.91	1.04	0.92	0.90	0.91	0.88
1987	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1988	0.76	0.56	0.62	0.61	0.89	0.89	0.79	0.86	0.89	1.01	0.97	0.84	0.89	0.89	0.79	0.86
1989	0.83	0.82	0.86	*****	1.00	0.90	1.07	*****	1.09	1.16	1.26	*****	1.09	1.16	1.26	*****
Mean	0.96	0.93	0.95	0.84	0.99	0.96	0.90	0.81	0.95	0.88	0.86	0.76	0.99	1.00	0.97	0.85

Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

The Key station in the analysis is:
R-377, Sonaimuri; Daily Rainfall (mm)

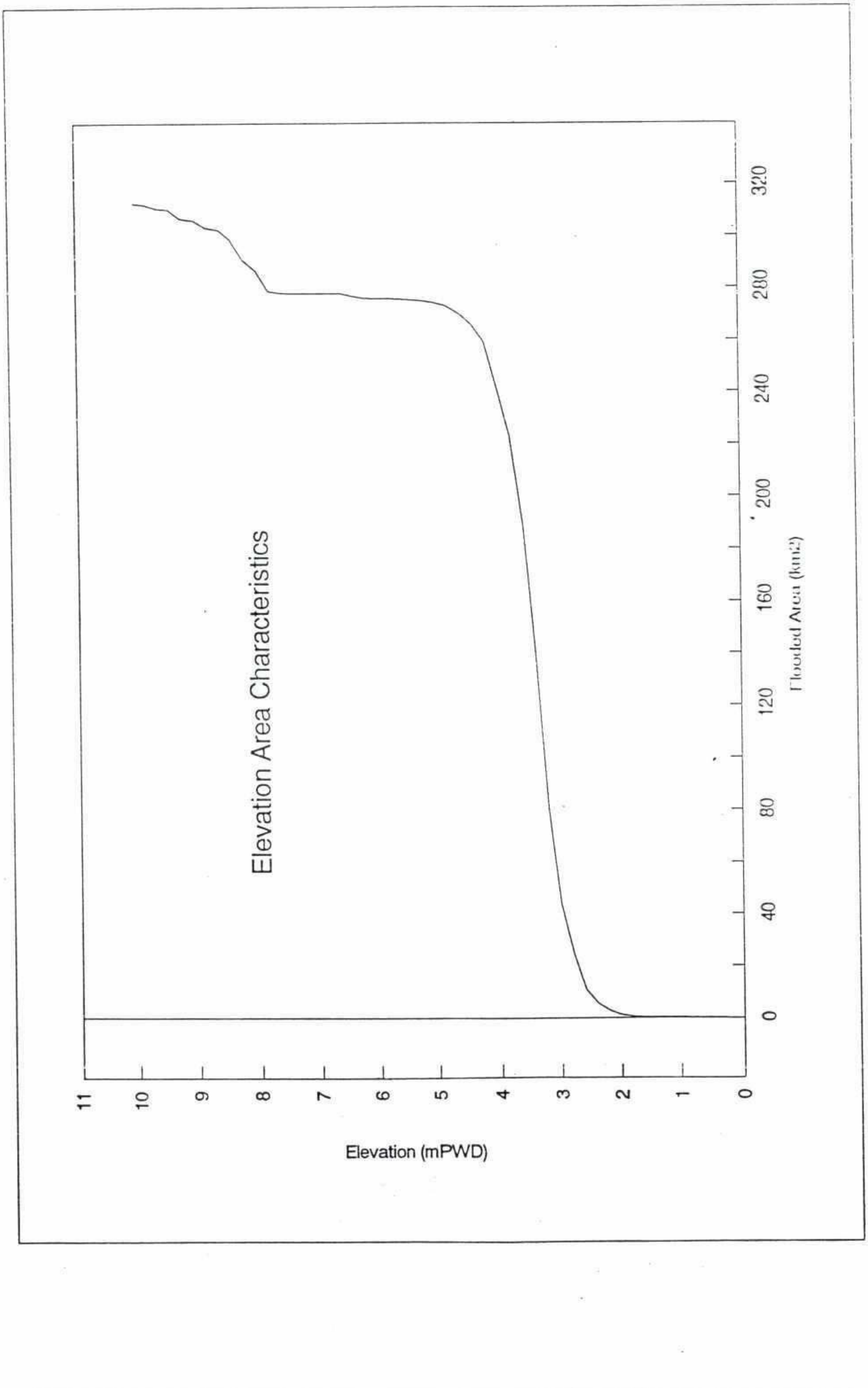
Aerial Reductions on 10 Day Annual Maxima

Year	Pre-Monsoon				Mid-Monsoon				Post-Monsoon				Annual			
	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475	642	969	2023	7475
1962	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1963	1.04	1.02	*****	*****	1.04	1.16	*****	*****	0.96	0.92	0.72	*****	1.04	1.16	*****	*****
1964	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1965	1.03	1.05	1.01	*****	*****	*****	*****	*****	0.80	0.64	0.53	*****	*****	*****	*****	*****
1966	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1967	0.97	1.06	1.04	0.98	1.05	1.10	1.17	1.12	0.94	0.77	0.85	0.72	1.05	1.10	1.17	1.12
1968	1.11	1.15	1.11	1.03	0.94	0.79	0.31	0.54	0.88	0.71	0.65	0.76	1.11	1.15	1.11	1.03
1969	0.94	0.88	0.86	0.74	0.93	0.93	0.78	0.76	1.10	*****	*****	*****	0.94	0.88	0.86	0.74
1970	1.13	1.10	1.13	1.05	1.02	0.93	1.01	0.94	1.05	1.16	1.15	1.19	0.95	0.87	0.97	0.84
1971	*****	*****	*****	*****	0.86	0.57	0.66	0.64	1.00	0.82	0.88	0.68	0.86	0.57	0.66	0.64
1972	0.86	0.97	0.98	1.05	0.97	0.91	1.12	0.98	0.79	0.71	0.62	0.52	0.97	0.91	1.12	0.98
1973	0.98	1.30	1.30	1.07	0.89	0.96	1.17	1.06	1.00	0.80	1.03	1.14	0.98	1.30	1.30	1.07
1974	1.12	1.23	1.22	*****	0.97	1.06	0.93	0.74	1.01	0.89	0.86	0.79	0.97	1.06	0.93	0.74
1975	0.83	0.68	*****	*****	1.06	1.10	*****	*****	1.18	1.43	*****	*****	1.06	1.10	*****	*****
1976	0.79	*****	*****	*****	1.29	*****	*****	*****	*****	*****	*****	*****	0.79	*****	*****	*****
1977	0.91	*****	*****	*****	1.03	1.07	1.05	1.02	0.71	0.61	0.55	0.53	1.03	1.07	1.05	1.02
1978	0.98	0.87	0.89	0.63	0.84	0.66	0.80	0.89	1.29	1.16	1.12	0.82	0.98	0.87	0.89	0.63
1979	1.10	0.97	1.05	1.02	0.90	0.81	0.68	0.61	0.70	0.63	0.78	0.63	0.90	0.81	0.68	0.61
1980	0.77	0.66	0.60	0.53	0.99	0.82	0.38	0.67	1.10	1.12	1.15	0.88	0.87	0.65	0.66	0.64
1981	1.26	0.93	0.88	0.89	1.14	0.92	0.74	0.67	0.79	0.53	0.75	0.74	1.16	0.95	0.75	0.65
1982	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1983	0.91	*****	*****	*****	0.87	*****	*****	*****	1.06	*****	*****	*****	0.87	*****	*****	*****
1984	0.98	0.89	1.00	0.93	1.11	1.24	1.08	1.00	0.83	0.83	0.78	0.69	0.98	0.89	1.00	0.93
1985	0.89	0.94	0.82	*****	1.03	1.13	1.02	0.80	0.90	1.11	0.88	0.55	1.07	1.10	1.01	0.84
1986	0.88	0.68	0.96	*****	0.95	0.88	0.88	0.81	0.88	0.83	0.90	1.07	0.95	0.88	0.88	0.81
1987	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1988	0.77	0.57	0.64	0.66	0.92	0.90	0.82	0.90	0.88	0.95	0.99	0.80	0.92	0.90	0.82	0.90
1989	0.88	0.80	0.89	*****	1.09	1.07	1.28	*****	1.06	1.07	1.13	*****	1.06	1.07	1.13	*****
Mean	0.96	0.93	0.96	0.88	1.00	0.95	0.94	0.83	0.95	0.88	0.86	0.78	0.98	0.96	0.94	0.83

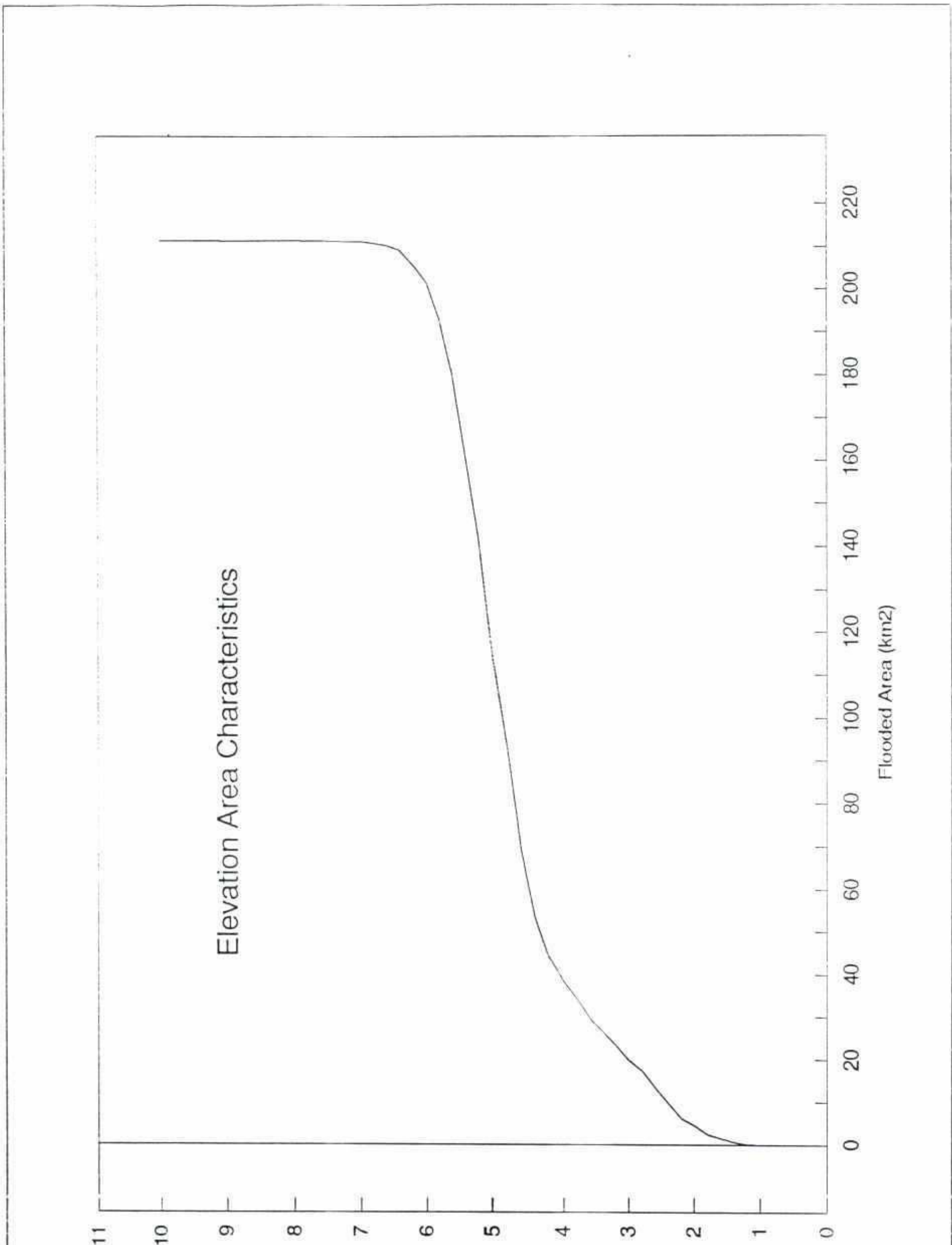
Notes: 1. ** indicates missing data at one or more station.
2. Second row of numbers are areas for the computed reductions.

APPENDIX IV

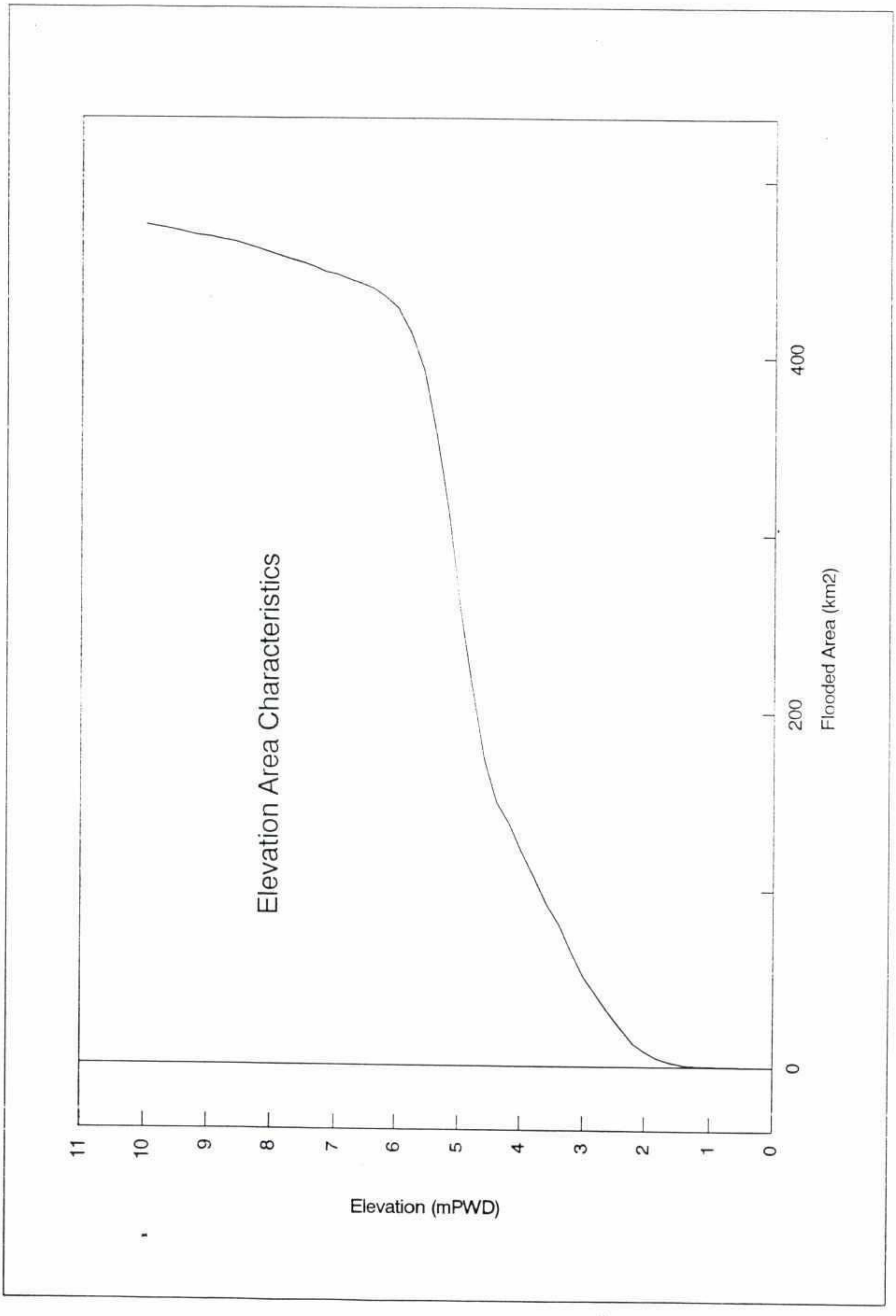
10 DAY WATER LEVEL RECORDS


Elevation Area Characteristics
Elevation (mPWD)
Flooded Area (km2)
0
1
2
3
4
5
6
7
8
9
10
11
0
40
80
120
160
200
240
280
320

Ashuganj Planning Unit



Titas Planning Unit



W-110, Comilla ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1965	7.440	7.445	7.965	9.455	7.815	7.380	10.245	11.310	10.880	11.935	12.715	10.800	11.150	11.795	10.855	10.670	9.820	10.285	9.645	8.495	9.545	12.715
1966	7.905	7.710	7.765	7.765	8.885	7.925	7.955	11.120	10.810	11.470	9.735	8.990	9.175	9.965	12.250	10.825	11.915	11.815	10.385	10.720	9.550	12.250
1967	7.320	8.745	8.685	9.100	8.310	7.895	7.985	9.725	9.145	11.380	11.515	9.100	10.150	9.580	9.425	9.420	9.365	9.690	10.270	11.440	9.110	11.515
1968	8.400	9.650	8.125	7.515	8.700	9.300	9.770	12.055	12.650	11.970	12.960	10.660	9.550	8.975	10.230	9.480	9.740	8.965	8.635	8.190	8.435	12.960
1969	7.325	8.310	8.675	8.100	7.465	7.695	10.965	10.660	11.790	10.615	10.575	9.960	9.090	11.985	12.485	10.150	9.235	9.430	8.560	8.580	8.300	12.485
1970	7.330	7.800	7.525	7.175	8.200	8.225	8.940	9.520	9.580	8.820	10.565	10.995	10.310	9.875	9.120	8.955	8.920	9.155	9.865	8.565	8.700	10.995
1971	8.600	-99.000	-99.000	9.000	9.385	8.270	.9.745	10.485	9.730	9.530	9.115	10.850	9.725	10.005	10.245	10.285	9.310	9.135	8.895	8.645	8.190	-99.000
1972	7.685	7.300	8.210	7.765	7.185	7.865	7.450	10.115	9.530	7.995	10.480	9.975	9.560	9.625	10.505	8.675	8.240	8.215	8.210	8.225	7.550	10.505
1973	7.090	7.045	8.800	11.740	12.235	10.105	10.550	10.610	10.270	9.840	9.735	11.080	11.035	9.620	8.930	8.690	8.715	8.920	9.290	8.685	8.540	12.235
1974	9.495	8.000	7.560	10.200	9.655	8.980	11.600	9.520	11.455	11.560	11.345	11.755	11.535	9.830	10.560	11.645	10.800	10.410	10.710	9.390	9.490	11.755
1975	7.350	8.545	7.745	7.465	8.490	9.430	11.135	10.045	8.740	7.970	11.830	12.200	11.495	9.990	10.150	10.455	10.630	9.920	9.255	10.210	8.905	12.200
1976	7.390	8.365	7.725	8.410	9.715	8.960	11.445	12.095	11.510	12.440	12.205	10.365	10.160	10.610	11.115	10.090	10.220	8.865	9.115	8.660	8.775	12.440
1977	9.090	9.575	8.930	9.380	10.265	9.980	11.305	9.975	11.485	11.090	10.305	9.635	9.535	10.575	9.525	9.405	9.555	8.910	10.190	9.160	8.560	11.485
1978	7.693	8.019	7.718	8.169	9.059	10.848	11.253	11.226	12.207	10.775	10.360	10.196	9.918	9.296	9.607	10.458	9.805	10.052	9.693	8.940	8.540	12.207
1979	7.711	7.687	7.742	8.275	7.790	7.745	7.910	8.790	8.315	10.336	10.080	9.432	9.000	10.050	11.640	9.600	10.964	9.954	9.660	9.080	8.415	11.640
1980	7.730	7.740	7.800	10.200	9.900	9.700	10.140	9.175	8.830	8.410	9.535	10.115	9.310	9.365	10.075	9.405	10.710	10.225	9.725	9.020	9.150	10.710
1981	8.570	10.090	9.800	8.445	10.000	9.575	10.410	8.740	9.500	11.690	10.405	10.045	9.625	9.365	10.395	9.620	9.120	8.630	8.705	8.295	8.210	11.690
1982	8.100	8.012	8.318	8.226	9.045	8.092	8.056	10.031	10.205	9.478	8.782	8.751	12.498	10.182	8.940	9.653	10.260	9.311	8.886	8.381	8.224	12.498
1983	7.978	9.068	9.956	11.426	10.424	10.096	9.490	10.471	9.598	12.050	9.980	9.026	13.218	12.488	11.068	10.116	9.374	9.270	9.712	9.970	9.662	13.218
1984	7.707	7.690	7.844	9.114	12.298	9.860	8.830	12.194	10.982	10.162	11.256	10.682	10.150	9.966	9.778	10.470	11.184	10.482	9.572	8.882	9.022	12.298
1985	8.716	8.576	8.198	8.872	8.384	11.638	10.212	10.576	9.600	12.192	11.784	9.470	9.228	9.250	10.112	9.054	8.878	9.324	9.304	8.404	8.376	12.192
1986	7.882	8.608	8.388	8.788	8.560	8.480	8.290	7.904	8.710	9.898	8.464	10.692	9.116	9.018	8.720	9.464	9.120	10.228	10.682	10.028	8.578	10.692
1987	7.758	7.868	9.252	8.910	8.154	7.796	9.622	8.912	8.700	8.228	9.298	11.394	12.158	9.082	12.382	10.294	9.120	10.956	9.830	9.222	9.180	12.382
1988	7.824	8.440	8.474	9.388	9.756	11.276	10.674	9.016	9.926	12.778	11.724	10.590	9.772	11.554	11.328	11.448	10.906	10.718	10.320	10.234	10.068	12.778
1989	8.082	7.936	8.630	8.526	8.508	8.510	8.872	10.656	8.916	10.478	9.730	11.092	10.442	9.302	8.556	9.658	9.888	9.234	10.068	11.532	9.668	11.532

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W-113. Kangsanagar : Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1960	4.120	4.130	4.070	4.000	4.055	6.890	6.735	8.885	8.215	7.665	9.045	8.425	6.860	7.015	7.310	7.725	7.865	7.735	7.855	8.505	6.760	9.045
1961	3.945	4.080	4.385	4.180	4.390	4.045	7.255	9.020	8.155	6.660	8.265	7.840	8.015	8.060	6.295	6.200	6.235	6.070	5.540	5.350	5.135	9.020
1962	3.650	3.430	5.450	5.440	4.000	5.350	6.605	8.405	7.675	7.610	7.285	7.245	5.830	6.660	7.435	6.835	6.600	6.025	5.715	5.020	5.485	8.405
1963	3.375	4.445	5.115	4.985	4.810	6.975	7.300	8.390	8.785	7.085	8.990	8.475	7.695	7.200	6.445	6.425	6.385	6.445	7.910	7.895	9.245	9.245
1964	4.890	5.945	5.930	6.125	6.015	6.750	5.015	8.255	6.990	8.640	8.535	7.935	8.075	7.375	7.130	7.300	6.735	6.935	7.770	7.500	7.720	8.640
1965	3.705	3.640	4.360	6.365	4.354	3.520	7.100	8.200	8.060	8.625	8.930	7.740	8.060	8.685	7.650	7.665	6.895	7.000	6.695	5.545	6.600	8.930
1966	3.625	3.445	4.175	4.265	5.790	4.450	4.630	7.970	7.880	8.320	6.795	6.375	6.355	7.070	8.960	7.770	8.320	8.365	7.315	7.545	6.460	8.960
1967	3.475	5.150	5.560	6.050	5.365	4.525	3.960	6.825	6.095	8.105	8.290	6.185	7.085	6.925	6.430	6.280	6.475	6.555	7.195	8.410	6.095	8.410
1968	5.335	6.145	5.285	3.810	5.500	6.335	6.810	8.950	9.490	8.655	9.360	7.390	6.705	6.310	7.210	6.530	6.610	5.950	5.555	5.310	5.145	9.490
1969	3.470	4.585	5.240	4.460	3.710	3.900	7.655	7.695	8.660	7.620	7.620	7.160	6.270	8.785	9.050	7.125	6.490	6.505	5.640	5.585	5.075	9.050
1970	3.575	4.215	4.030	3.350	4.760	4.805	5.750	6.365	6.740	5.830	7.795	7.965	7.490	7.235	6.740	6.435	6.095	6.210	7.125	6.150	5.890	7.965
1971	5.575	7.075	4.695	6.655	6.640	5.155	6.875	7.455	7.010	6.835	6.350	7.910	7.100	7.230	7.445	7.490	6.935	6.640	6.290	6.125	5.535	7.910
1972	4.345	3.860	5.000	4.695	3.565	5.315	4.080	7.180	6.765	5.425	7.590	7.310	6.850	6.735	7.660	6.035	5.505	5.120	5.085	5.230	4.145	7.660
1973	3.280	3.125	5.655	8.700	9.205	7.420	7.880	7.895	7.590	7.270	7.085	8.075	8.200	6.995	6.415	6.200	6.080	6.960	6.600	5.990	5.455	9.205
1974	6.795	4.955	4.155	7.430	6.675	6.870	8.840	6.825	8.675	8.765	8.505	8.880	8.710	7.595	7.730	8.610	7.785	7.480	7.670	6.515	6.400	8.880
1975	3.595	5.235	4.500	4.115	5.370	6.735	8.355	7.530	5.875	4.795	8.855	9.145	8.460	7.250	7.215	7.685	7.895	7.240	6.465	7.435	6.035	9.145
1976	3.990	5.320	4.480	5.455	6.890	6.310	8.400	9.245	8.510	9.410	8.990	7.590	7.405	7.755	8.370	7.315	7.340	5.985	6.340	5.720	5.755	9.410
1977	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1978	4.625	5.275	5.205	5.480	6.660	8.355	8.560	8.535	8.670	8.155	7.390	7.415	7.025	6.475	6.535	7.635	7.035	7.390	6.355	6.070	5.685	8.670
1979	4.340	4.310	4.480	5.160	4.400	4.400	4.630	5.730	5.380	7.620	7.300	6.800	6.290	7.570	8.850	6.970	8.320	7.210	6.980	6.350	5.520	8.850
1980	4.410	4.410	4.590	7.090	7.750	6.810	7.490	6.290	5.930	5.310	6.550	7.420	6.970	6.800	7.770	6.870	8.140	7.450	7.270	6.590	6.710	8.140
1981	5.507	7.776	7.605	5.471	7.593	7.123	7.794	6.422	5.837	9.942	7.483	7.452	7.117	7.239	7.666	6.843	6.758	6.200	6.080	5.482	5.300	9.942
1982	4.690	4.960	5.398	5.398	6.206	5.266	6.886	7.428	7.802	6.402	6.006	6.072	9.293	7.504	7.183	7.307	7.448	7.350	6.579	5.790	7.270	9.293
1983	7.026	7.632	9.335	9.375	9.333	9.375	8.321	9.299	9.271	9.350	9.227	8.707	9.556	8.612	8.022	7.600	7.078	7.420	7.292	7.582	7.502	9.556
1984	4.724	4.690	4.986	6.864	9.356	7.532	6.432	9.064	8.392	7.678	9.166	7.564	7.454	7.152	7.136	7.462	8.148	7.614	6.976	6.434	6.692	9.356
1985	5.646	6.198	5.628	6.284	5.872	9.150	8.278	8.574	7.634	9.484	9.388	8.474	8.176	8.204	9.136	7.544	7.350	7.440	6.398	5.834	5.806	9.484
1986	4.932	5.698	5.848	6.136	5.928	5.968	5.196	4.920	5.038	7.614	5.720	8.304	6.702	6.528	6.052	6.854	6.520	7.740	8.200	7.692	5.882	8.304
1987	4.490	4.796	6.512	5.878	5.454	4.742	6.844	6.228	6.246	5.550	6.856	8.534	9.348	7.158	9.476	7.830	6.876	8.556	7.568	7.010	6.636	9.476
1988	4.706	5.732	5.796	6.532	7.246	8.928	8.722	6.668	7.640	10.038	9.142	7.860	7.170	8.518	8.494	8.576	8.120	7.866	7.654	7.896	7.840	10.038
1989	5.060	4.810	5.348	5.740	5.540	5.706	6.540	8.318	6.888	8.242	7.256	8.532	8.130	6.906	5.958	6.490	7.596	6.466	7.146	8.966	7.188	8.966

W-114, Jibanpur (Gumti) ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1977	5.550	6.523	5.621	6.108	6.523	6.437	7.303	6.126	7.455	7.175	6.578	6.340	6.166	6.779	6.443	6.288	6.312	5.767	6.578	5.764	5.060	7.455
1978	4.084	4.795	4.724	4.865	5.694	6.949	7.620	7.266	7.467	6.840	6.303	6.462	6.340	5.870	6.328	6.523	6.157	6.431	5.907	5.288	5.072	7.620
1981	6.160	6.950	6.890	5.150	6.880	6.720	7.070	5.620	5.320	7.520	6.730	7.170	6.380	6.300	6.800	6.370	6.270	5.910	5.570	5.050	4.860	7.520
1982	4.862	4.456	4.926	4.718	5.928	4.732	4.418	6.382	6.982	6.261	5.665	5.695	7.185	6.619	5.919	6.403	6.662	6.399	5.875	5.193	4.833	7.185
1983	4.405	5.906	6.967	7.515	6.859	6.587	6.287	6.903	6.513	7.327	6.495	5.839	7.161	6.975	6.765	6.627	6.505	6.505	6.639	6.651	6.515	7.515
1984	4.324	4.298	4.614	6.276	7.768	6.656	6.004	7.370	6.822	6.878	7.108	6.644	6.678	6.494	6.350	6.492	6.932	6.712	6.232	5.908	6.066	7.768
1985	4.880	5.592	5.142	5.814	5.300	7.456	7.310	7.510	7.030	7.792	7.744	6.636	6.464	6.358	6.960	6.182	5.992	6.294	6.066	5.308	5.270	7.792
1986	4.304	4.822	5.202	5.476	5.274	5.320	4.626	4.314	4.208	6.926	5.390	7.456	6.220	5.920	5.670	6.288	6.130	7.072	7.406	6.806	5.530	7.456
1987	3.882	4.222	5.944	5.362	4.914	4.070	6.196	5.584	5.688	5.270	6.286	7.380	7.608	6.724	7.674	6.960	6.440	7.454	6.930	6.472	5.810	7.674
1988	4.110	5.076	5.210	5.698	6.496	7.728	7.520	6.094	6.832	7.452	7.110	6.706	6.324	6.770	7.064	7.246	7.056	6.678	6.690	7.068	7.030	7.728
1989	4.678	4.458	4.936	5.348	5.422	5.464	6.182	7.534	6.506	7.412	6.884	7.536	7.302	6.648	5.878	6.302	7.046	6.200	6.464	7.794	6.636	7.794

W 123, Ganga Sagart Railway Bridge ; Maximum 10 day levels, Apr. Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1965	4.375	3.935	4.805	4.100	4.345	3.800	4.775	5.900	4.775	5.015	5.170	5.260	5.415	5.930	6.020	6.020	5.595	5.505	5.230	4.740	4.680	6.020
1966	4.115	4.135	4.345	4.775	4.620	4.270	4.590	5.320	5.415	5.720	6.025	5.990	5.595	5.750	6.370	6.415	6.445	6.110	5.595	5.210	4.630	6.445
1967	4.040	4.600	4.570	4.665	4.160	4.540	4.540	4.935	4.360	5.575	5.500	5.775	5.775	5.425	5.255	5.090	4.935	5.305	5.290	5.135	4.390	5.775
1968	4.875	5.115	4.110	4.015	4.930	5.055	4.885	5.420	5.895	5.670	6.140	6.375	6.310	6.230	5.925	5.850	5.570	5.150	5.080	5.030	4.355	6.375
1969	3.900	4.870	5.030	3.985	3.720	4.465	5.220	5.225	5.225	5.205	5.500	5.680	5.595	5.960	6.165	6.225	6.030	5.686	5.090	5.090	4.130	6.225
1970	3.990	4.840	3.840	3.765	4.625	4.480	4.650	4.275	4.890	5.255	5.500	6.235	6.475	6.615	6.395	5.865	5.440	5.485	5.775	5.715	5.235	6.615
1971	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1972	4.510	4.390	4.290	4.110	3.565	4.720	3.870	4.955	5.105	5.265	5.145	5.265	5.615	5.585	5.360	4.960	5.040	4.705	4.415	3.975	3.735	5.615
1973	4.205	3.430	4.360	5.775	4.695	4.510	4.435	4.785	5.545	5.990	5.865	5.275	5.850	5.975	5.975	5.625	5.560	5.700	5.610	5.210	4.495	5.990
1974	4.860	4.130	3.795	4.970	4.890	3.945	4.680	4.600	5.105	5.975	5.975	6.935	7.160	7.055	6.570	6.215	6.325	6.185	5.895	5.595	4.770	7.160
1975	4.375	4.380	3.845	3.655	4.830	4.905	4.730	4.695	4.145	3.690	4.790	5.730	6.040	5.860	5.610	5.545	5.455	5.410	5.225	4.900	4.585	6.040
1976	4.480	4.800	3.810	4.740	4.955	4.085	4.770	5.225	5.295	5.880	6.465	6.355	5.720	5.670	5.730	5.675	5.380	4.970	4.785	4.250	4.085	6.465
1977	4.890	4.235	4.570	4.625	4.780	4.540	5.085	5.100	5.575	5.525	5.600	5.625	5.610	5.745	5.920	5.980	5.745	5.235	5.320	4.750	4.870	5.980
1978	4.890	5.195	4.385	5.150	5.210	5.295	5.115	5.025	5.175	5.205	5.305	5.390	5.410	5.435	5.435	5.240	5.090	5.060	4.985	4.725	4.205	5.435
1979	4.570	5.050	5.030	5.135	4.265	3.960	4.860	4.905	5.105	5.440	5.440	5.700	5.880	5.685	5.640	5.515	5.775	5.670	5.250	5.045	4.630	5.880
1980	4.650	4.695	4.690	5.335	5.350	5.120	5.240	5.210	5.135	5.225	5.275	5.545	5.485	5.820	5.915	5.915	5.615	5.380	5.225	4.875	4.920	5.915
1981	4.975	4.815	4.330	3.810	5.150	5.455	4.805	4.000	5.030	5.610	5.080	5.395	5.900	5.900	5.625	5.655	5.775	5.685	5.820	4.465	4.070	5.900
1982	5.246	3.840	3.900	3.832	4.870	3.680	3.762	4.700	4.980	5.063	5.245	5.458	5.944	5.960	5.516	5.256	5.100	5.180	4.954	-99.000	-99.000	-99.000
1983	4.800	4.464	5.512	5.785	5.450	5.180	4.587	5.770	5.456	5.862	5.436	5.280	6.075	6.010	6.100	6.150	6.280	6.290	6.176	5.718	5.236	6.290
1984	-99.000	-99.000	-99.000	5.858	5.978	4.704	4.800	5.800	5.646	5.160	6.000	6.430	6.416	6.050	5.610	5.618	6.280	6.390	6.034	5.370	5.544	-99.000
1985	4.524	4.916	4.644	4.830	4.540	5.280	5.340	5.260	5.300	5.512	5.282	5.710	5.862	5.766	5.250	5.230	5.144	5.138	5.184	4.576	4.474	5.862
1986	4.640	4.808	4.368	5.252	4.526	4.260	3.758	3.982	4.186	5.270	4.200	5.576	5.170	5.230	5.342	5.204	5.416	6.410	5.860	5.434	5.040	6.410
1987	-99.000	3.822	5.000	4.524	3.810	3.600	4.452	4.268	4.026	5.030	5.216	5.560	6.360	6.420	6.344	6.042	5.832	5.950	5.970	5.712	5.248	-99.000
1988	5.100	4.212	3.978	5.342	5.098	5.850	5.300	5.140	5.670	6.450	6.900	6.784	6.100	6.100	6.906	7.026	6.960	6.508	5.566	5.508	5.104	7.026
1989	-99.000	-99.000	-99.000	4.336	4.042	5.126	5.698	5.764	4.500	5.038	5.532	5.756	5.926	5.800	5.632	5.364	5.416	5.520	5.216	5.380	5.190	-99.000

W-157, Ballah ; Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1960	-99.000	-99.000	-99.000	18.860	19.030	21.360	21.910	23.590	21.580	22.320	23.240	22.230	20.800	21.850	21.550	21.760	22.740	22.120	21.470	22.950	20.170	23.590
1961	19.340	19.570	21.970	20.010	19.530	20.490	23.100	24.290	20.770	19.920	21.910	21.970	20.860	20.540	20.620	19.850	20.160	20.230	20.310	19.870	19.660	24.290
1962	19.340	19.350	20.040	20.070	19.280	20.190	22.170	24.020	22.250	20.500	22.380	20.740	19.920	23.490	22.510	20.860	21.030	21.270	20.120	19.500	22.310	24.020
1963	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1964	20.860	21.380	20.070	21.380	20.350	22.270	20.790	22.420	20.200	23.600	22.330	24.940	21.920	20.850	20.470	20.640	20.410	20.520	20.870	21.700	21.090	24.940
1965	19.440	19.450	19.400	20.280	19.550	19.250	20.490	23.730	20.720	22.230	22.720	21.380	22.060	23.700	22.370	20.910	21.420	21.200	20.690	19.690	20.140	23.730
1966	19.260	21.000	21.270	20.970	21.520	21.030	20.050	24.730	21.710	23.620	20.890	20.680	20.650	21.500	23.410	20.800	24.680	20.750	23.130	22.350	20.070	24.730
1967	19.430	21.750	20.740	21.110	19.950	20.270	20.260	23.180	20.650	24.880	21.530	20.310	21.590	22.090	20.860	20.910	20.190	22.600	21.050	21.930	20.000	24.880
1968	21.060	21.440	20.700	19.470	20.360	21.290	21.600	22.680	23.280	22.910	23.830	21.500	20.260	20.260	21.400	21.750	20.680	20.740	20.550	20.520	20.080	23.830
1969	19.420	20.490	20.560	19.680	19.440	19.780	21.960	21.410	21.850	21.490	21.110	20.190	19.900	24.490	21.090	21.000	21.100	20.220	21.070	21.460	19.760	24.490
1970	19.430	19.450	19.360	19.310	21.050	19.850	20.510	20.230	20.250	21.360	21.320	22.990	20.930	22.390	19.930	19.700	19.640	20.270	21.100	19.720	20.160	22.990
1971	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1972	19.280	19.580	20.640	19.690	19.220	20.300	19.450	20.270	20.270	19.240	20.060	19.280	19.660	20.300	19.950	19.500	19.720	19.720	19.700	19.700	19.690	20.640
1973	19.830	19.830	19.850	23.080	22.560	23.540	21.860	21.960	21.580	21.450	21.450	21.120	21.320	21.040	20.310	21.350	20.650	-99.000	-99.000	-99.000	-99.000	23.540
1974	20.120	20.110	20.230	21.480	21.560	20.320	21.950	21.210	22.630	21.880	23.660	21.690	20.910	21.070	21.090	22.250	21.870	21.220	20.790	19.850	19.840	23.660
1975	19.660	20.860	19.930	19.750	20.170	21.330	22.520	20.220	19.990	19.500	22.260	22.420	21.550	20.510	21.530	20.990	22.260	21.120	20.140	19.930	19.900	22.520
1976	19.470	20.310	20.110	20.120	21.200	19.570	24.840	24.590	23.310	23.070	22.160	20.810	21.030	21.380	21.310	21.750	21.380	20.270	20.740	20.370	20.410	24.840
1977	21.310	21.420	23.100	22.710	22.330	21.720	22.570	21.190	22.710	20.960	20.810	20.810	20.670	21.510	21.060	21.100	20.740	20.320	22.290	20.420	20.560	23.100
1978	19.960	19.950	19.960	21.160	22.150	24.790	24.180	22.520	23.070	22.470	22.800	22.410	20.550	21.250	21.190	21.390	20.640	21.420	21.230	21.040	20.130	24.790
1979	19.910	19.820	19.880	20.460	19.910	19.860	20.090	20.100	20.910	22.170	21.800	20.520	20.710	21.710	20.630	20.470	24.220	21.070	20.320	20.200	19.910	24.220
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	21.100	21.320	20.800	20.010	21.920	23.130	21.200	21.620	20.770	23.250	20.950	20.810	20.290	20.280	22.210	20.900	21.100	20.510	20.540	20.170	20.060	23.250
1982	19.760	20.184	20.949	20.632	20.946	19.891	20.750	21.930	21.363	21.019	21.287	20.988	24.268	21.494	20.367	21.308	21.693	20.336	20.470	19.980	19.940	24.268
1983	20.330	20.510	21.208	23.716	22.180	21.204	20.286	24.748	21.266	22.486	20.522	20.306	26.104	25.276	24.220	22.918	20.950	21.108	21.240	21.596	20.750	26.104
1984	19.820	19.816	20.104	21.180	-99.000	-99.000	20.218	25.308	23.648	21.056	21.540	21.534	20.840	21.224	21.068	23.034	22.658	21.322	20.826	20.766	21.958	-99.000
1985	20.420	21.154	20.808	21.200	20.970	24.090	21.880	22.504	21.920	21.890	21.244	22.004	21.036	21.476	21.076	21.586	21.252	21.400	21.392	21.300	20.630	24.090
1986	20.844	20.880	20.752	21.580	21.112	20.620	19.980	20.202	20.716	20.822	20.170	21.244	20.496	21.660	21.288	21.564	21.168	22.010	23.092	21.512	20.382	23.092
1987	19.718	19.910	21.170	20.710	20.398	20.070	21.500	21.084	20.468	20.536	20.182	23.834	23.442	20.740	23.092	20.636	20.586	23.234	20.680	20.762	20.782	23.834
1988	19.820	20.268	20.336	20.814	20.980	24.344	21.212	20.578	23.362	23.570	21.996	20.766	20.840	24.850	21.252	21.662	22.366	21.094	21.830	21.962	20.974	24.850
1989	20.068	19.960	21.092	20.788	20.344	21.174	22.180	21.966	20.444	21.474	21.250	22.978	21.648	20.850	21.094	21.094	20.984	21.136	21.520	21.690	20.750	22.978

W-15B, Chunarghat : Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1960	12.210	12.500	12.240	12.180	12.330	14.230	14.520	15.690	13.240	14.840	15.720	16.010	13.980	14.730	13.860	14.220	16.230	15.120	15.080	15.860	13.420	16.230
1961	12.710	12.740	12.740	13.610	12.920	13.090	14.140	16.650	14.460	13.510	15.190	15.310	13.660	14.030	13.570	13.350	13.650	13.830	13.300	13.310	13.170	16.650
1962	13.010	12.750	13.870	13.550	12.680	13.620	16.290	16.660	15.880	14.570	16.390	14.700	14.140	16.550	16.520	14.520	14.480	14.490	13.350	13.130	12.970	16.660
1963	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1964	13.910	13.870	13.500	14.430	13.910	14.050	13.980	16.640	13.650	16.670	16.290	16.750	16.700	14.710	14.560	14.390	14.280	14.550	14.750	15.670	14.820	16.750
1965	12.800	12.660	13.100	14.000	13.040	12.600	15.020	14.540	14.670	15.720	14.220	15.210	15.510	16.640	16.080	14.570	14.750	15.150	14.080	13.190	13.470	16.640
1966	12.720	14.380	14.780	13.830	15.820	15.720	13.930	17.370	17.740	16.670	14.870	14.720	14.690	16.300	16.610	14.630	16.700	14.410	16.430	16.150	13.650	17.740
1967	12.950	16.210	14.570	15.020	13.560	13.770	14.140	16.640	13.960	16.820	15.270	14.050	15.690	16.400	14.900	13.990	14.090	16.460	16.060	16.940	13.420	16.940
1968	14.350	15.630	14.000	13.070	13.930	15.360	15.440	15.600	16.850	16.360	17.360	15.530	14.540	16.160	16.470	15.010	16.350	14.660	14.200	14.020	13.710	17.360
1969	13.030	14.450	14.540	13.170	12.930	13.190	13.190	15.540	16.270	14.460	14.190	13.550	13.260	17.110	15.590	14.690	13.980	14.010	14.500	15.720	13.190	17.110
1970	12.780	12.860	12.670	12.710	14.480	13.620	14.770	14.310	14.110	16.100	15.270	16.830	14.310	16.200	13.910	13.800	14.000	14.110	14.970	13.560	13.560	16.830
1971	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1972	13.060	12.900	14.870	13.120	12.850	14.310	12.900	16.020	13.910	13.290	14.580	15.070	14.880	14.160	14.750	13.670	13.420	13.380	13.190	12.980	12.810	16.020
1973	12.600	12.680	14.840	17.840	16.330	16.740	16.490	15.500	15.290	14.870	15.190	14.140	14.710	14.090	14.820	14.360	13.510	13.790	14.840	13.700	13.550	17.840
1974	14.430	13.960	13.650	15.640	14.690	13.650	16.620	15.050	16.880	16.330	17.100	15.770	14.700	14.350	15.040	16.520	15.330	15.510	14.730	14.040	14.190	17.100
1975	12.780	14.490	13.360	12.890	13.930	15.570	16.880	14.520	13.830	13.010	15.570	16.600	14.760	14.010	14.760	14.530	16.180	14.200	13.830	14.480	13.360	16.880
1976	12.910	13.740	13.690	14.100	14.900	13.910	16.940	16.660	16.440	16.360	16.290	14.550	15.260	15.710	15.020	15.880	14.880	13.580	14.210	13.690	13.650	16.940
1977	15.780	15.340	16.390	15.680	16.240	15.770	16.430	15.150	17.110	14.790	14.820	14.300	13.840	15.640	14.580	15.000	14.690	13.700	16.540	13.970	13.980	17.110
1978	13.280	13.500	13.430	14.370	15.040	17.020	16.140	16.650	17.110	14.940	15.890	17.130	15.530	15.280	15.430	15.170	14.350	14.830	14.760	14.640	13.710	17.130
1979	13.910	13.820	13.830	14.450	13.820	13.830	13.910	14.550	14.430	16.780	16.100	14.470	14.830	16.040	17.650	15.430	17.880	15.600	15.190	14.940	14.390	17.880
1980	13.550	13.970	13.960	17.110	16.950	15.860	15.970	14.610	15.200	14.490	13.820	16.020	14.000	14.410	14.040	15.220	16.080	15.280	14.800	14.380	15.030	17.110
1981	14.440	15.150	14.440	13.430	17.540	17.570	16.260	15.300	14.350	17.330	14.750	14.550	15.410	14.010	15.130	13.780	15.030	13.690	14.170	13.370	13.310	17.570
1982	13.730	13.646	14.301	13.704	15.362	13.527	13.598	15.567	15.135	15.692	15.277	14.796	17.882	14.316	14.015	15.380	15.308	14.572	14.003	13.475	13.327	17.882
1983	13.350	13.758	15.660	17.144	15.642	14.818	14.594	17.236	15.038	17.878	14.268	13.946	18.140	15.564	15.976	14.138	14.042	14.160	16.002	14.984	14.388	18.140
1984	12.910	12.838	12.954	15.130	17.648	15.796	14.392	18.032	15.856	14.296	15.350	15.186	14.476	15.012	13.686	16.774	16.984	14.820	13.922	13.960	16.076	18.032
1985	13.378	14.980	14.118	14.976	14.610	18.012	15.812	16.294	16.276	15.354	14.216	15.156	14.056	16.654	14.320	14.788	14.586	14.724	14.512	14.706	13.730	18.012
1986	13.410	14.124	14.318	15.704	14.370	13.700	13.120	13.500	13.646	14.380	13.376	14.728	13.938	15.432	14.744	15.590	14.706	16.050	17.010	15.402	13.764	17.010
1987	13.010	13.486	15.080	13.934	14.128	13.664	15.548	14.778	14.010	14.176	13.474	17.618	16.804	14.570	16.458	14.092	14.182	17.012	14.236	14.546	14.494	17.618
1988	12.960	13.494	13.438	14.290	14.556	17.784	15.020	14.468	17.714	17.882	15.660	14.342	14.600	18.170	14.874	15.782	15.750	14.932	15.580	14.802	14.366	18.170
1989	13.432	13.370	14.444	14.442	14.544	14.974	16.712	15.894	13.878	15.106	14.868	17.170	15.858	14.690	14.614	15.096	15.006	15.256	15.600	15.636	14.094	17.170

T-3A , Brahmanbaria Railway Bridge : Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1964	2.180	3.200	3.185	3.580	3.690	3.780	3.335	4.630	5.180	5.575	6.185	6.735	7.160	7.085	6.675	6.505	6.570	6.290	6.005	5.760	5.305	7.160
1965	1.600	1.890	1.875	2.300	2.605	2.710	3.400	4.570	4.615	5.135	5.500	5.485	5.790	6.325	6.460	6.445	5.975	5.865	5.610	4.935	4.265	6.460
1966	1.815	1.815	2.055	2.245	2.955	2.530	3.155	5.545	5.805	6.140	6.490	6.460	6.000	6.095	6.905	6.935	6.840	6.645	5.960	5.255	5.075	6.935
1967	1.765	2.710	2.970	3.320	3.305	3.050	3.110	3.750	4.295	5.000	5.895	6.250	6.185	5.865	5.760	5.530	5.255	5.485	5.545	5.365	4.905	6.250
1968	1.920	2.680	2.660	2.135	2.760	3.215	3.520	4.405	5.180	5.820	6.545	6.750	6.680	6.555	6.250	6.250	5.990	5.615	5.500	5.425	4.830	6.750
1969	1.760	2.150	2.445	2.390	2.110	2.675	3.505	4.205	5.055	5.310	5.935	6.070	6.005	6.265	6.575	6.630	6.425	6.045	5.480	4.900	4.205	6.630
1970	2.180	2.545	2.530	2.680	3.185	3.565	3.725	4.235	5.320	5.645	5.665	6.690	6.960	7.080	6.850	6.290	5.880	5.915	6.185	6.170	5.640	7.080
1971	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1972	1.950	2.225	2.250	2.430	2.880	3.275	3.385	3.880	5.510	5.700	5.575	5.710	6.050	6.050	5.770	5.410	5.410	5.105	4.725	4.200	3.690	6.050
1973	1.680	2.050	2.590	4.455	4.580	4.360	4.170	4.945	6.005	6.445	6.370	5.790	6.295	6.425	6.415	6.150	6.000	6.125	6.030	5.545	5.045	6.445
1974	2.455	2.440	2.605	3.445	3.520	3.585	3.825	4.070	5.255	6.600	6.690	7.560	7.710	7.590	7.070	6.735	6.780	6.660	6.265	5.990	5.240	7.710
1975	1.525	2.150	2.375	2.345	2.745	3.345	4.055	4.040	3.810	4.100	5.090	6.200	6.485	6.370	5.990	5.945	5.915	5.895	5.610	5.210	5.030	6.485
1976	1.555	2.110	2.375	2.880	3.415	3.305	4.160	5.395	5.575	6.875	6.980	6.810	6.310	6.170	6.215	6.185	5.880	5.425	5.150	4.435	3.370	6.980
1977	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	99.000	99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1978	1.560	2.040	2.190	2.530	3.510	4.710	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	4.710
1979	1.680	1.680	1.830	2.130	2.420	2.700	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	5.680	5.380	5.030	5.680
1980	1.400	1.810	2.270	3.610	3.860	3.810	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	5.580	5.200	4.860	5.580
1981	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1982	2.018	2.346	2.748	2.886	3.980	2.014	2.860	3.708	5.002	5.416	5.800	5.792	6.236	6.292	5.876	5.516	5.492	5.576	5.362	4.616	3.782	6.292
1983	2.300	2.365	2.990	3.500	3.410	3.590	3.550	3.900	4.510	5.420	5.660	5.690	6.420	6.380	6.460	6.540	6.640	6.700	6.470	5.920	5.500	6.700
1984	1.720	1.960	2.050	2.740	4.410	4.430	4.980	5.280	5.600	5.550	6.480	6.930	6.930	6.560	5.980	5.920	6.840	6.930	6.520	5.810	4.850	6.930
1985	2.260	2.570	2.840	3.020	2.910	3.550	4.320	5.060	5.270	5.520	5.860	6.340	6.460	6.160	5.890	5.890	5.750	5.630	5.470	5.060	4.590	6.460
1986	1.700	2.160	2.720	2.930	2.910	2.700	2.480	2.780	3.560	4.120	4.570	5.240	5.570	5.540	5.140	5.240	5.230	5.460	5.460	5.570	5.490	5.570
1987	1.650	2.210	2.520	2.550	2.430	2.480	3.240	3.660	4.170	5.430	5.620	6.160	6.680	6.750	6.640	6.410	6.260	6.510	6.570	6.200	5.240	6.750
1988	1.890	2.190	2.280	2.590	3.270	5.020	5.510	5.340	5.870	7.020	7.350	6.950	6.530	6.510	7.370	7.590	7.590	6.800	6.060	5.590	5.140	7.590
1989	2.460	2.520	2.720	2.850	2.780	3.320	3.900	4.600	4.840	5.500	5.990	6.090	6.360	6.270	6.020	5.810	5.810	5.780	5.610	5.580	5.500	6.360

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W-181, Gunabati Railway Bridge (d/s) ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1983	-99.000	-99.000	-99.000	5.430	5.388	4.862	4.250	4.858	4.912	5.092	5.004	4.790	5.878	5.610	4.998	4.850	4.754	4.760	4.527	4.838	4.610	-99.000
1984	1.910	1.850	2.090	3.950	5.610	5.388	4.290	4.720	5.010	5.230	5.626	5.288	4.826	4.864	4.858	4.836	4.776	4.728	3.940	3.810	3.706	5.626
1985	-99.000	-99.000	-99.000	2.920	3.160	4.746	5.368	5.430	4.860	5.310	5.328	4.620	4.630	4.650	5.160	4.774	4.380	4.266	3.900	3.290	3.470	-99.000
1986	-99.000	-99.000	-99.000	4.138	4.240	4.278	4.156	4.254	4.760	5.034	5.038	5.484	5.310	4.836	4.696	4.346	3.792	4.558	4.720	4.688	3.910	-99.000
1987	-99.000	-99.000	4.620	4.620	4.362	3.410	3.858	3.968	3.810	4.620	5.058	5.508	5.586	4.880	5.608	5.486	4.746	5.050	4.900	4.218	3.774	-99.000
1988	3.186	3.438	3.522	3.470	4.240	5.292	5.326	5.016	4.810	5.618	5.716	5.120	4.430	5.068	5.046	5.386	5.302	4.730	4.040	3.910	4.098	5.716
1989	-99.000	-99.000	-99.000	-99.000	4.080	4.080	4.160	5.190	5.166	5.312	4.940	4.700	4.720	3.850	3.180	4.010	4.426	4.276	4.850	5.470	5.120	-99.000

T-58 , Hazigang ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1978	1.768	1.737	2.027	2.286	2.499	3.475	3.719	3.749	4.054	4.039	4.039	4.161	4.237	4.343	4.404	4.282	4.222	4.206	4.115	3.810	3.429	4.404
1979	1.981	1.920	2.072	2.072	2.499	2.560	2.346	3.124	3.474	3.688	3.764	3.932	4.175	4.267	4.175	4.145	4.160	3.840	3.932	3.855	3.489	4.267
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	2.225	3.322	3.277	2.743	2.972	3.139	3.337	3.261	3.444	3.962	4.099	4.343	4.526	4.496	4.435	4.373	4.237	4.145	3.977	3.535	3.048	4.526
1982	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1983	2.150	2.700	2.850	3.350	3.250	3.290	3.050	3.290	3.630	3.750	3.840	4.050	4.510	4.540	4.490	4.570	4.650	4.700	4.620	4.510	4.130	4.700
1984	2.050	2.370	2.310	3.110	3.550	3.510	3.750	3.930	4.180	4.180	4.510	4.650	4.820	4.700	4.550	4.570	4.570	4.650	4.500	4.080	3.700	4.820
1985	2.200	2.250	2.220	2.310	2.250	3.100	3.450	3.480	3.650	3.930	4.060	4.160	4.420	4.290	4.270	4.300	4.280	4.180	3.940	4.030	3.810	4.420
1986	2.060	2.300	2.550	2.420	2.360	2.700	2.350	2.600	3.320	3.590	3.680	4.080	4.180	4.230	4.070	4.040	4.080	4.170	4.170	4.110	3.900	4.230
1987	1.650	2.520	2.770	2.390	2.290	2.190	2.990	3.080	3.300	3.850	4.080	4.390	4.540	4.700	5.060	4.950	4.910	4.820	4.680	4.510	3.960	5.060
1988	2.080	2.640	2.360	2.220	3.060	3.490	3.600	3.730	3.830	4.110	4.510	4.510	4.620	4.600	4.990	5.520	5.490	5.160	4.600	4.200	3.940	5.520
1989	2.000	1.950	2.050	2.200	2.570	2.990	3.160	3.690	3.780	3.810	4.020	4.180	4.230	4.140	4.050	3.960	4.070	3.990	4.020	4.170	4.050	4.230

T-79 ,Matlab Bazar ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1959	-99.000	-99.000	-99.000	-99.000	-99.000	3.220	3.250	3.580	4.130	4.260	4.350	4.130	4.350	4.530	4.740	4.410	4.190	4.100	4.010	3.950	3.920	4.740
1960	1.090	1.210	1.420	1.450	1.660	1.660	2.550	2.670	3.280	3.680	3.650	4.220	4.830	4.860	4.770	4.770	4.740	4.990	4.900	4.560	3.980	4.990
1961	2.420	2.300	2.260	3.880	2.780	3.240	3.420	3.450	3.790	3.720	4.050	4.050	3.990	4.420	4.820	4.630	4.480	4.330	4.210	4.150	3.810	4.820
1962	2.590	2.130	2.320	2.560	2.650	3.230	3.260	3.510	3.780	4.360	4.420	4.360	4.360	4.690	5.090	5.090	5.060	4.880	4.540	3.870	3.320	5.090
1963	1.950	2.010	2.380	2.380	2.380	2.800	3.660	3.900	3.960	4.210	4.510	4.630	4.750	4.750	4.770	4.980	4.790	4.340	4.150	3.540	3.350	4.980
1964	2.160	2.820	2.380	3.050	3.190	2.870	3.200	3.630	3.960	4.360	4.450	4.750	5.360	5.440	4.880	4.790	4.690	4.910	4.690	4.010	3.930	5.440
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	2.070	2.680	2.410	2.560	2.990	3.050	3.380	3.570	4.070	4.570	4.600	5.060	5.040	4.820	4.600	4.400	4.340	4.080	4.330	4.250	3.660	5.060
1969	2.180	2.530	2.230	2.560	2.360	3.050	3.140	3.630	4.020	4.040	4.570	4.940	4.880	4.710	5.000	4.950	4.770	4.630	4.240	3.960	3.190	5.000
1970	2.470	2.440	2.470	2.960	3.260	3.380	3.540	3.660	4.270	4.300	4.720	4.970	5.110	5.240	5.150	4.790	4.560	4.590	4.850	4.390	4.210	5.240
1971	2.190	2.470	2.440	2.960	2.740	2.800	3.250	4.020	4.270	4.190	4.600	4.750	5.180	5.180	5.330	5.380	5.110	4.910	4.790	4.280	4.150	5.380
1972	2.350	2.670	2.610	2.680	3.000	3.170	3.280	3.290	4.180	4.270	4.160	4.510	4.800	4.690	4.360	4.510	4.570	4.270	3.610	3.410	3.260	4.800
1973	2.220	2.620	2.550	2.990	3.110	3.260	3.200	4.150	4.960	4.750	4.360	4.630	4.790	5.180	5.000	4.630	4.630	5.090	4.570	4.600	3.750	5.180
1974	2.440	2.440	2.580	3.140	3.030	3.320	3.320	3.600	4.160	4.560	4.720	5.090	5.530	5.610	5.360	5.040	4.910	4.690	4.680	4.070	3.520	5.610
1975	2.240	2.550	2.800	2.940	2.910	2.960	3.290	3.310	3.730	3.950	4.270	4.540	4.940	4.880	4.400	4.770	4.590	4.590	4.300	4.130	3.660	4.940
1976	2.010	2.700	2.390	2.620	2.960	2.960	3.230	3.600	3.720	4.510	4.600	4.360	4.330	4.540	4.800	4.630	4.510	4.500	3.660	3.340	3.410	4.800
1977	2.880	2.530	2.510	3.020	3.600	3.320	3.580	3.870	4.110	4.180	4.420	4.740	4.690	4.770	4.920	4.950	4.540	4.050	3.930	3.960	3.140	4.950
1978	-99.000	2.073	2.377	2.499	3.246	3.414	3.322	3.795	4.054	4.115	4.176	4.404	4.496	4.816	4.816	4.267	4.496	4.420	4.313	3.551	3.261	-99.000
1979	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1982	-99.000	-99.000	-99.000	99.000	99.000	99.000	-99.000	99.000	99.000	99.000	99.000	99.000	-99.000	99.000	99.000	99.000	99.000	99.000	99.000	99.000	99.000	99.000
1983	2.340	2.640	2.820	2.920	3.040	2.960	3.190	3.250	3.750	4.140	4.190	4.210	4.630	4.640	4.420	4.720	4.830	4.890	4.630	4.290	3.960	4.890
1984	2.450	2.820	2.650	2.720	3.200	3.630	3.860	3.970	4.270	4.280	4.880	5.000	5.190	4.670	4.530	4.490	4.700	4.980	4.440	4.210	3.640	5.190
1985	2.560	2.410	2.580	2.800	2.440	3.000	3.660	3.660	3.980	4.260	4.390	4.600	4.850	4.460	4.580	4.600	4.600	4.260	4.180	4.480	3.780	4.850
1986	2.320	2.340	2.860	2.580	2.550	2.910	2.560	3.130	3.480	3.780	4.080	4.410	4.490	4.450	4.100	4.260	4.300	4.510	4.130	3.960	3.790	4.510
1987	2.220	2.680	2.760	2.520	2.730	2.880	3.250	3.450	3.710	4.570	4.650	4.750	4.890	5.200	5.330	5.090	5.140	5.050	4.650	4.350	3.640	5.330
1988	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1989	2.290	2.110	2.300	2.870	2.850	3.490	3.530	4.070	4.160	4.110	4.590	4.980	4.610	4.530	4.490	4.410	4.510	4.360	4.260	4.510	3.760	4.980

T-115, Duadkandi ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1957	1.800	2.190	2.100	2.410	3.050	3.080	3.110	3.160	4.000	4.150	4.260	4.560	4.870	5.020	4.970	4.510	4.310	4.310	3.670	3.570	3.140	5.020
1958	2.070	1.890	2.040	2.680	2.770	3.080	3.340	3.110	3.470	3.900	3.980	4.000	-99.000	-99.000	-99.000	5.480	5.120	4.780	-99.000	-99.000	-99.000	5.480
1959	1.950	2.130	2.500	2.590	2.710	3.020	3.280	3.660	4.790	4.620	4.550	4.550	4.620	5.000	5.080	4.670	4.420	4.270	4.400	4.190	3.890	5.080
1960	1.710	1.980	1.950	1.950	2.320	2.900	3.020	3.350	3.450	3.830	4.390	5.070	5.050	4.970	4.820	4.970	5.120	5.230	5.000	4.580	3.990	5.230
1961	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1962	2.440	2.260	2.410	2.530	2.560	3.140	3.540	3.780	4.110	4.880	4.910	4.800	4.750	5.060	5.670	5.760	5.520	5.300	4.850	4.270	3.660	5.760
1963	1.890	1.920	2.320	2.260	2.230	2.590	3.540	4.110	4.420	4.540	4.880	5.090	5.150	5.180	5.210	5.380	5.290	4.850	4.570	4.150	3.690	5.380
1964	2.010	2.670	2.680	2.830	3.260	3.200	3.260	3.900	4.270	4.660	4.880	5.360	5.880	5.930	5.470	5.350	5.180	5.170	5.170	4.750	4.420	5.930
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1969	2.010	2.320	2.410	2.410	2.470	3.130	3.350	3.870	4.150	4.330	4.880	5.210	5.240	5.090	5.430	5.460	5.270	5.000	4.750	4.110	3.410	5.460
1970	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1971	2.190	2.130	2.230	2.440	2.740	3.690	3.630	4.130	4.340	4.610	4.920	5.210	5.350	5.500	5.620	5.650	5.500	5.130	4.970	4.830	4.520	5.650
1972	2.100	2.590	2.530	2.640	3.080	3.140	3.230	3.960	5.070	4.620	4.680	4.680	5.070	4.980	4.480	4.720	4.740	4.430	3.860	3.370	3.310	5.070
1973	2.150	2.650	2.640	2.850	3.150	3.400	3.380	4.450	4.950	5.090	4.820	4.750	5.030	5.460	5.360	4.910	4.850	5.060	4.880	4.750	4.080	5.460
1974	2.390	2.320	2.590	3.000	2.970	3.320	3.400	3.630	4.400	4.970	5.270	5.650	6.050	6.000	5.820	5.430	5.300	5.170	4.970	4.390	3.840	6.050
1975	2.880	2.530	2.510	3.020	3.600	3.320	3.580	3.870	4.110	4.180	4.420	4.740	4.690	4.770	4.920	4.950	4.540	4.050	3.930	3.960	3.140	-99.000
1976	-99.000	2.073	2.377	2.499	3.246	3.414	3.322	3.795	4.054	4.115	4.176	4.404	4.496	4.816	4.816	4.267	4.496	4.420	4.313	3.551	3.261	-99.000
1977	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1978	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1979	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	2.340	2.640	2.820	2.920	3.040	2.960	3.190	3.250	3.750	4.140	4.190	4.210	4.630	4.640	4.420	4.720	4.830	4.890	4.630	4.290	3.960	-99.000
1982	2.450	2.820	2.650	2.720	3.200	3.630	3.860	3.970	4.270	4.280	4.880	5.000	5.190	4.670	4.530	4.490	4.700	4.980	4.440	4.210	3.640	-99.000
1983	2.750	2.250	2.500	2.500	2.950	3.300	3.200	3.550	4.400	4.750	4.900	4.800	5.300	5.200	5.250	5.300	5.500	5.530	5.370	4.890	4.320	5.530
1984	2.440	2.840	2.620	2.970	3.520	3.600	4.010	4.370	4.750	4.870	5.200	5.250	5.520	5.200	4.670	4.720	5.350	5.460	5.200	4.590	-99.000	-99.000
1985	2.820	2.370	2.140	2.370	2.050	2.770	3.870	3.830	4.210	4.310	4.560	4.650	4.950	4.540	4.660	4.710	4.670	4.380	4.650	4.950	4.430	4.950
1986	2.460	2.570	3.080	2.880	2.960	3.280	3.030	3.710	4.230	4.510	4.750	5.110	5.400	5.400	5.230	5.080	5.170	5.320	4.980	4.950	4.720	5.400
1987	2.000	2.320	2.550	2.340	2.650	2.520	2.830	2.820	3.250	4.670	4.730	5.310	5.610	6.060	6.020	5.510	5.570	5.460	5.230	4.770	3.870	6.060
1988	2.270	2.350	2.460	3.360	3.350	3.430	4.020	4.080	4.210	5.100	5.550	5.490	5.470	5.420	6.270	6.340	6.120	5.380	4.400	4.240	3.820	6.340
1989	2.710	2.640	2.720	2.600	2.250	-99.000	3.060	3.710	4.240	4.480	4.860	5.080	5.000	4.780	4.740	4.660	4.760	4.740	4.560	4.540	3.980	-99.000

T-230 , Bhairab Bazar Railway Bridge ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	6.735	7.130	7.100	6.675	6.505	6.490	6.265	5.990	5.730	5.305	7.130
1965	1.765	2.085	2.025	2.530	2.745	2.895	3.490	4.295	4.815	5.225	5.655	5.595	5.945	6.400	6.490	6.475	6.020	5.912	5.610	4.920	3.940	6.490
1966	2.165	1.980	2.150	2.300	2.375	2.680	3.520	5.715	5.820	6.155	6.430	6.370	6.035	6.140	6.825	6.890	6.765	6.505	5.975	5.195	4.630	6.890
1967	1.785	2.055	2.302	2.390	2.725	3.065	3.155	3.720	4.570	5.030	6.095	6.250	6.185	5.880	5.730	5.530	5.255	5.530	5.530	5.365	4.755	6.250
1968	1.690	2.520	2.120	2.095	2.915	3.130	3.580	4.275	5.410	5.990	6.620	6.810	6.750	6.615	6.285	6.240	6.000	5.570	5.510	5.485	4.805	6.810
1969	2.010	2.410	2.440	2.420	2.260	2.990	3.255	4.430	5.240	5.490	6.025	6.110	6.080	6.255	6.690	6.705	6.485	6.080	5.504	4.840	4.060	6.705
1970	2.530	2.530	2.350	2.990	3.290	3.630	4.025	4.435	5.585	5.655	6.120	6.745	7.035	7.090	6.840	6.300	5.920	5.945	6.220	6.160	5.550	7.090
1971	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1972	2.130	2.590	2.590	2.680	3.200	3.320	3.475	3.880	5.770	5.815	5.585	5.850	6.080	6.080	6.695	5.450	5.455	5.050	4.660	4.180	3.630	6.695
1973	2.040	2.440	2.500	3.410	3.760	3.950	4.290	5.280	6.125	6.445	6.305	5.825	6.350	6.445	6.425	6.090	6.105	6.200	6.040	5.550	4.940	6.445
1974	2.440	2.300	2.870	3.440	3.550	3.670	3.990	4.310	5.410	6.505	6.630	7.480	7.620	7.500	7.040	6.645	6.690	6.600	6.230	5.910	5.120	7.620
1975	2.130	2.470	2.820	2.820	2.990	3.380	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	5.670	5.300	5.000	5.670
1976	1.890	2.560	2.380	2.590	2.990	2.830	3.680	5.560	5.680	6.835	6.950	6.750	6.200	6.125	6.340	6.215	5.785	5.380	4.980	4.220	3.690	6.950
1977	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1978	1.950	1.980	2.320	2.440	2.680	4.020	4.465	5.060	5.640	5.755	5.730	5.945	6.005	6.020	5.945	5.600	5.560	5.545	5.255	4.770	4.155	6.020
1979	2.010	2.170	2.110	2.210	2.840	2.990	2.605	2.605	3.780	5.120	5.595	6.225	6.265	6.000	5.700	5.860	6.185	6.125	5.520	5.430	5.000	6.265
1980	1.830	2.350	2.650	3.170	3.570	3.690	3.975	4.955	5.135	5.150	5.305	5.895	5.990	6.020	6.385	6.335	6.020	5.755	5.590	5.190	4.600	56.290
1981	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1982	2.134	2.316	2.713	2.926	2.926	2.987	2.938	3.670	5.285	5.675	5.913	5.944	6.492	6.471	6.947	5.602	5.590	5.715	5.331	4.621	3.652	6.947
1983	2.220	2.555	2.730	2.880	3.415	4.105	4.020	4.655	5.775	6.510	6.770	6.910	7.780	7.475	7.265	7.255	7.710	7.995	7.415	7.125	5.815	7.995

T-239 , Laksh-mipur ; Maximum 10 day levels, Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1978	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	3.200	3.048	3.353	3.231	3.170	3.261	3.231	3.200	3.353	3.444	3.231	3.109	3.170	2.652	2.957	-99.000
1979	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	2.317	2.865	3.353	3.170	3.139	3.536	3.597	3.292	3.231	3.231	3.292	2.987	3.079	-99.000
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	1.494	2.835	2.743	1.829	2.530	3.200	0.000	0.000	0.000	3.536	3.353	3.322	3.353	3.353	3.231	3.353	3.200	3.048	3.048	3.109	2.987	3.536
1982	0.975	1.036	0.300	1.180	1.260	1.640	2.130	2.780	2.980	2.890	3.020	3.180	3.770	3.680	3.490	3.330	3.350	3.280	-99.000	2.730	2.790	-99.000
1983	1.340	1.890	2.660	3.020	2.890	2.510	2.660	2.590	2.780	3.240	3.110	3.450	3.780	3.680	3.680	3.670	3.710	3.780	3.610	3.580	3.360	3.780
1984	1.460	1.410	1.450	1.890	2.390	2.470	3.420	3.420	3.520	3.520	3.500	3.600	3.690	3.710	3.720	3.720	3.680	3.570	3.520	3.170	2.790	3.720
1985	1.270	1.700	1.600	1.520	1.510	2.770	3.080	3.060	3.080	3.280	3.290	3.250	3.250	3.500	3.620	3.530	3.420	3.280	3.270	3.220	2.940	3.620
1986	1.450	1.490	1.530	1.880	2.400	2.380	2.330	2.330	3.210	3.310	3.100	3.820	3.530	3.360	3.340	3.250	3.260	3.380	3.630	3.560	3.270	3.820
1987	1.280	1.990	1.840	1.710	1.670	1.710	1.850	1.840	1.830	2.360	2.840	3.590	3.640	3.630	4.360	4.230	3.980	3.740	3.620	3.570	3.400	4.360
1988	1.150	1.190	2.000	1.350	0.840	2.760	2.770	2.770	3.030	3.100	3.490	3.470	3.620	3.670	3.730	3.810	4.000	3.990	3.740	3.340	3.360	4.000
1989	1.260	0.880	0.850	2.380	2.340	2.940	2.830	3.170	3.330	2.860	2.840	3.260	3.020	2.850	2.740	3.340	3.530	3.350	3.580	3.770	3.550	3.770

T-240 , Bhawaniganj ; Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1960	1.830	2.290	2.290	1.980	2.690	3.200	2.500	3.290	2.500	2.690	3.200	3.390	3.600	3.780	3.780	3.840	3.690	3.690	3.810	3.420	2.990	3.840
1961	2.530	2.380	2.440	2.930	2.360	3.520	3.220	3.730	3.730	4.130	3.920	4.160	4.220	4.250	4.280	4.160	4.280	3.830	3.790	3.760	3.670	4.280
1962	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1963	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	2.470	2.960	2.680	2.620	3.470	3.660	3.600	3.930	3.960	3.960	3.960	3.790	3.760	3.580	3.730	3.400	3.490	3.580	3.940	3.060	3.280	3.960
1969	2.500	2.960	2.190	2.590	2.530	2.870	3.200	3.510	3.570	3.630	3.750	4.080	4.050	3.930	3.840	3.690	3.960	3.810	3.350	3.380	3.200	4.080
1970	2.800	2.500	2.650	3.050	2.800	3.080	3.110	3.170	3.200	3.320	3.660	4.020	3.810	3.870	3.840	3.810	3.750	3.440	3.440	3.470	3.600	4.020
1971	2.230	2.410	2.290	2.440	2.410	2.440	3.230	3.230	3.350	3.230	3.870	3.600	3.840	3.660	3.960	4.080	3.840	3.750	3.660	3.630	3.350	4.080
1972	2.160	2.960	2.680	2.870	2.960	3.080	2.620	2.800	2.560	3.350	3.050	3.440	3.260	3.840	3.750	3.440	3.350	2.870	2.680	2.590	2.500	3.840
1973	1.800	2.440	2.740	2.960	2.960	2.960	2.950	3.140	3.230	3.510	3.660	3.690	3.600	3.930	3.810	3.690	3.410	3.510	3.320	3.600	3.290	3.930
1974	2.740	2.530	2.530	2.900	2.990	2.990	3.290	2.990	3.290	3.630	3.660	3.930	4.020	4.360	4.420	3.900	3.660	3.570	3.750	3.350	3.320	4.420
1975	2.070	2.440	2.620	2.960	3.080	2.900	2.900	3.020	3.020	3.020	3.350	3.750	3.780	3.750	3.840	3.990	3.510	3.470	3.350	3.630	3.410	3.990
1976	1.920	1.890	1.800	1.860	1.860	1.740	2.230	2.990	3.200	3.170	3.230	3.870	3.870	3.600	3.840	3.870	3.690	3.750	3.660	3.600	3.570	3.870
1977	3.080	3.140	2.830	2.620	3.080	2.680	2.900	2.900	3.020	3.140	3.080	3.290	3.690	3.440	3.900	3.900	3.600	3.780	3.690	3.630	3.380	3.900
1978	-99.000	1.341	1.311	1.615	2.317	3.322	3.353	3.200	3.353	3.231	3.200	3.292	3.109	3.109	3.139	3.231	3.048	3.261	3.109	2.926	2.926	-99.000
1979	0.792	0.732	0.762	0.671	0.853	0.823	0.945	1.158	1.341	1.554	2.621	3.322	3.079	2.835	2.804	2.804	2.713	2.469	2.134	1.829	1.768	3.322
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	1.311	1.219	1.311	1.372	1.341	2.042	2.347	2.195	2.317	2.499	2.652	2.652	2.652	3.139	3.261	3.322	3.170	3.139	2.774	2.225	2.103	3.322
1982	1.460	1.300	2.300	2.300	2.100	2.120	2.390	2.940	3.490	4.360	4.200	3.680	3.410	3.400	3.260	3.180	3.060	3.020	3.000	2.950	2.910	4.360
1983	2.070	1.420	1.370	1.520	1.260	1.060	1.020	1.000	0.980	1.090	1.930	2.050	2.820	2.340	2.320	3.400	2.900	2.600	2.800	2.800	2.570	3.400
1984	1.200	1.140	1.140	1.160	1.470	1.220	1.970	2.020	2.160	2.120	2.120	2.080	2.090	2.200	2.170	2.140	2.200	2.120	2.170	2.120	2.100	2.200
1985	1.720	1.370	1.170	1.020	0.920	3.020	2.690	2.690	2.800	3.120	3.180	3.200	3.410	3.370	3.380	3.350	3.310	3.350	3.390	3.320	3.330	3.410
1986	2.170	2.100	2.060	1.920	2.030	2.070	2.030	2.060	2.100	2.450	2.930	3.900	3.700	3.410	3.380	3.380	3.330	3.450	3.550	3.370	3.170	3.900
1987	1.200	1.220	1.550	1.180	1.180	1.230	1.270	1.200	1.170	2.350	3.270	3.640	3.800	3.680	4.000	3.930	3.800	3.690	3.620	3.590	3.580	4.000
1988	1.250	1.270	1.230	1.260	1.300	1.740	2.200	2.650	2.720	3.350	3.550	3.600	3.700	3.750	3.640	3.650	3.700	3.720	3.530	3.070	2.550	3.750
1989	2.150	2.080	1.720	2.100	2.130	2.530	2.410	2.730	2.980	2.830	2.730	2.830	2.730	2.630	2.640	2.940	3.450	3.380	3.180	3.830	3.170	3.830

T-275 , Baldyer Bazar ; Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1959	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	4.750	4.820	4.750	5.270	5.390	5.030	4.720	4.480	4.720	4.300	4.180	5.390
1960	1.800	1.800	2.010	2.070	2.530	3.030	3.050	3.320	3.660	4.100	4.540	5.300	5.260	5.170	4.940	5.040	5.270	5.460	5.150	4.570	3.960	5.460
1961	2.130	1.950	2.040	3.290	2.500	2.740	3.380	3.630	3.750	3.840	3.870	4.180	4.180	4.540	4.910	4.910	4.720	4.390	4.320	4.290	3.950	4.910
1962	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1963	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	1.730	2.250	1.960	2.020	2.600	2.690	3.180	3.670	4.400	4.860	5.130	5.620	5.650	5.370	5.050	5.010	4.730	4.340	4.640	4.610	3.790	5.650
1969	1.870	2.180	2.060	2.120	2.000	2.760	2.970	3.750	4.150	4.390	4.910	5.180	5.180	5.150	5.490	5.490	5.270	4.910	4.540	4.050	3.140	5.490
1970	2.320	2.130	2.190	2.770	3.050	3.410	3.470	3.630	4.480	4.540	4.910	5.550	5.820	5.780	5.730	5.180	4.850	4.880	5.120	4.910	4.450	5.820
1971	1.980	2.230	2.230	2.500	2.500	2.620	3.020	3.990	4.240	4.510	4.910	5.060	5.270	5.490	5.640	5.640	5.360	5.150	4.910	4.630	4.360	5.640
1972	1.860	2.190	2.260	2.380	2.900	2.930	3.170	3.610	4.430	4.470	4.370	4.740	5.010	4.920	4.860	4.680	4.590	4.250	3.830	3.310	2.940	5.010
1973	1.800	2.260	2.230	2.830	2.850	3.140	3.150	4.040	4.940	5.150	4.940	4.720	5.150	5.430	5.270	4.940	4.910	4.910	4.850	4.690	4.180	5.430
1974	1.860	2.550	3.120	2.970	2.960	3.410	3.350	3.540	4.390	5.000	5.150	5.700	6.160	6.130	5.760	5.460	5.360	5.180	4.970	4.660	4.020	6.160
1975	1.860	2.230	2.530	2.500	2.680	2.930	3.080	3.450	3.690	3.840	4.420	4.940	5.270	5.240	4.940	4.850	4.820	4.630	4.540	4.300	3.810	5.270
1976	1.870	2.330	2.270	2.180	2.410	2.650	3.350	4.050	4.390	5.180	5.260	4.980	4.800	4.860	4.890	4.980	4.860	4.470	3.950	3.540	2.990	5.260
1977	2.451	2.573	2.481	2.969	3.274	3.368	3.947	4.252	4.572	4.694	4.923	5.045	5.075	5.136	5.380	5.410	5.014	4.587	4.176	4.176	3.414	5.410
1978	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1979	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	1.524	1.615	1.433	2.225	2.438	2.652	3.505	3.170	3.353	4.572	4.603	4.999	5.304	5.426	5.426	4.999	4.938	4.633	4.420	4.115	2.835	5.426
1982	2.190	2.100	2.190	2.500	2.320	2.440	2.650	3.490	4.090	4.440	4.740	4.940	5.090	4.940	4.700	4.610	4.740	4.710	4.340	3.720	3.100	5.090
1983	2.030	2.080	2.480	2.280	2.780	3.030	2.980	3.230	3.380	4.680	5.880	5.980	5.000	4.950	4.900	5.000	5.500	5.600	5.000	4.450	3.950	5.980
1984	1.990	2.540	2.390	2.570	3.390	3.940	4.490	4.300	4.700	4.650	5.400	-99.000	5.770	5.100	4.800	5.100	5.430	5.650	5.200	4.150	3.700	-99.000
1985	2.010	2.060	2.130	2.850	2.500	3.000	3.350	3.800	4.400	4.550	5.050	5.250	5.700	5.300	5.200	4.900	5.000	4.700	4.550	4.650	4.150	5.700
1986	2.330	2.430	3.030	2.880	2.830	3.430	2.780	3.660	4.060	4.610	4.800	5.100	5.390	5.190	4.890	5.040	4.940	5.040	4.910	4.960	4.730	5.390
1987	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1988	2.440	2.840	2.540	2.940	3.690	4.410	4.640	4.490	4.820	5.740	6.500	6.300	5.850	5.750	6.830	6.980	6.870	6.050	5.220	4.830	4.380	6.980
1989	2.610	2.530	2.760	3.180	3.080	3.630	3.780	4.630	4.730	4.930	5.250	5.500	5.350	5.120	5.060	5.080	5.150	5.110	5.060	4.970	4.720	5.500

T-276 . Satnal : Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1958	1.930	1.690	1.780	2.330	2.690	3.240	3.240	2.940	3.360	3.570	3.610	3.700	4.660	4.820	5.070	5.100	4.730	4.340	4.060	4.090	3.670	5.100
1959	1.800	1.950	2.650	2.650	2.620	2.960	3.140	3.750	4.450	4.390	4.360	4.330	4.420	4.850	4.880	4.390	4.300	4.080	4.300	3.870	3.690	4.880
1960	1.890	2.260	2.100	2.130	2.190	2.960	3.170	3.350	3.350	3.750	4.080	4.750	4.720	4.660	4.570	4.750	4.750	4.970	4.570	4.020	3.750	4.970
1961	2.190	2.130	2.130	4.050	2.870	3.320	3.540	3.570	3.870	3.810	4.150	4.210	4.180	4.600	4.940	4.910	4.820	4.570	4.420	4.420	4.050	4.940
1962	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1963	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	1.870	2.410	2.160	2.440	2.830	2.830	3.470	3.660	4.360	4.850	4.940	5.390	5.490	5.150	4.940	4.790	4.630	4.330	4.570	4.510	3.670	5.490
1969	1.900	2.270	2.030	2.180	2.000	2.850	2.970	3.700	4.020	4.110	4.690	5.030	5.030	4.880	5.210	5.180	4.970	4.720	4.330	3.990	3.200	5.210
1970	2.330	2.150	2.210	2.800	3.140	3.290	3.460	3.640	4.370	4.370	4.680	5.170	5.460	5.350	4.920	4.920	4.620	4.650	4.850	4.470	4.310	5.460
1971	1.940	2.240	2.240	2.870	2.740	2.930	3.350	4.330	4.510	4.690	5.120	5.240	5.460	5.520	5.700	5.700	5.460	5.210	5.060	4.690	4.750	5.700
1972	2.160	2.560	2.380	2.440	2.800	3.050	3.110	3.110	4.110	4.330	4.210	4.510	4.820	4.790	4.360	4.510	4.570	4.270	3.570	3.410	3.110	4.820
1973	2.090	2.550	2.210	2.910	2.940	2.970	3.140	4.020	4.720	4.750	4.360	4.600	4.850	5.240	5.030	4.660	4.630	4.850	4.630	4.600	3.750	5.240
1974	2.270	2.240	2.330	2.760	2.760	2.790	3.550	3.440	4.150	4.660	4.790	5.380	5.670	5.670	5.430	5.090	5.790	4.850	4.690	4.080	3.580	5.790
1975	2.180	2.150	2.390	2.190	2.620	2.700	3.010	3.250	3.740	3.920	4.320	4.650	5.050	4.870	4.470	4.750	4.620	4.560	4.140	3.950	3.650	5.050
1976	1.630	2.270	1.910	2.420	2.530	2.590	3.140	3.700	3.730	4.590	4.710	4.470	4.310	4.470	4.830	4.710	4.590	4.530	3.760	3.350	3.140	4.830
1977	2.710	2.530	2.440	2.870	3.570	3.410	3.840	3.930	4.220	4.190	4.430	4.920	4.860	4.940	5.110	5.200	4.680	4.160	4.070	4.150	3.440	5.200
1978	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1979	2.040	2.010	2.230	2.040	2.770	2.800	2.620	2.930	3.540	4.150	4.180	4.720	5.150	4.910	4.510	4.630	4.540	4.270	4.270	4.240	3.470	5.150
1980	1.960	2.450	2.610	2.760	2.970	3.090	2.970	3.890	3.990	4.080	4.270	4.970	4.880	5.150	5.490	5.210	5.000	4.540	4.210	3.870	3.750	5.490
1981	2.743	2.621	2.469	2.530	2.713	2.804	3.383	3.383	3.475	4.511	4.511	4.907	5.182	5.243	4.968	4.968	4.785	4.603	4.267	3.719	2.926	5.243
1982	2.377	2.256	2.804	2.530	2.621	3.018	3.109	3.871	3.993	4.145	4.420	4.481	4.816	4.633	4.603	4.663	4.694	4.724	4.115	3.200	2.987	4.816
1983	1.900	1.900	2.840	2.740	3.770	2.960	3.740	3.990	4.420	4.710	4.470	4.480	4.930	4.880	4.720	4.930	5.160	5.260	4.800	4.330	4.130	5.260
1984	2.330	2.600	2.400	2.600	3.350	3.780	3.920	4.160	4.470	4.420	5.130	5.290	5.620	4.940	4.570	4.670	5.020	5.210	4.590	4.190	3.730	5.620
1985	2.630	2.420	2.520	3.220	2.810	3.130	3.720	3.720	4.170	4.470	4.470	4.820	4.990	4.490	4.620	4.690	4.670	4.320	4.250	4.520	4.000	4.990
1986	2.200	2.100	2.970	2.950	2.750	3.000	2.300	3.050	3.500	3.840	4.160	4.490	4.710	4.610	4.280	4.340	4.370	4.600	4.210	4.050	3.810	4.710
1987	1.850	2.290	2.290	2.190	2.390	2.540	2.790	3.180	3.560	4.430	4.630	4.880	5.330	5.570	5.610	5.250	5.320	5.250	4.750	4.280	3.540	5.610
1988	2.170	2.670	2.150	2.400	3.050	3.950	3.870	3.840	4.020	4.800	5.170	4.920	5.070	5.030	5.940	6.040	5.690	4.760	4.120	3.970	3.610	6.040
1989	2.200	2.000	2.280	2.680	2.430	3.170	3.370	3.980	4.030	4.330	4.550	4.910	4.690	4.490	4.460	4.400	4.530	4.370	4.270	4.460	3.560	4.910

T-277 , Chandpur ; Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1959	2.120	2.150	2.660	2.760	2.790	2.970	3.210	3.940	4.400	4.400	4.400	4.400	4.370	4.710	4.680	4.340	4.340	4.070	4.430	3.730	3.760	4.710
1960	1.930	1.900	1.870	1.870	2.080	3.210	3.370	3.520	3.520	4.010	3.910	4.580	4.680	4.520	4.460	4.580	4.430	4.710	4.340	4.100	3.790	4.710
1961	2.260	2.010	2.040	4.360	2.710	3.570	3.510	3.570	3.380	3.630	3.870	4.210	4.150	4.270	4.600	4.510	4.480	4.150	3.930	3.840	3.630	4.600
1962	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1963	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	1.580	2.380	2.290	2.070	3.080	2.960	3.540	3.690	3.990	4.540	4.400	4.830	4.750	4.540	4.450	4.270	4.270	4.050	4.250	4.130	3.790	4.830
1969	2.210	2.610	2.150	2.390	2.380	3.170	3.910	3.580	4.040	3.950	4.460	4.830	4.770	4.590	4.850	4.710	4.570	4.540	4.070	4.010	3.320	4.850
1970	2.450	2.470	2.480	2.940	2.960	3.520	3.490	3.780	4.270	4.180	4.560	4.800	4.850	4.970	4.920	4.630	4.390	4.280	4.470	4.160	4.280	4.970
1971	2.450	2.470	2.480	3.000	3.370	3.490	3.550	3.780	4.270	4.160	4.250	4.250	4.280	4.240	5.070	5.170	4.820	4.690	4.690	4.590	4.360	5.170
1972	2.330	2.670	2.640	2.670	3.090	3.280	3.350	3.940	3.870	4.190	4.220	4.400	4.590	4.570	4.370	4.470	4.540	4.210	3.630	3.200	2.350	4.590
1973	2.190	2.620	2.440	2.930	3.200	3.260	3.320	4.050	4.600	4.510	4.240	4.330	4.560	4.970	4.750	4.360	4.390	4.510	4.390	4.570	3.570	4.970
1974	2.100	2.290	2.530	2.800	2.900	3.140	3.350	3.660	4.020	4.270	4.510	4.820	5.120	5.240	4.940	4.690	4.790	4.330	4.390	3.780	3.290	5.240
1975	2.030	1.420	1.660	2.320	2.620	2.990	3.320	3.320	3.540	4.050	4.050	4.240	4.920	4.630	4.240	4.630	4.300	4.210	4.330	4.180	3.600	4.920
1976	1.910	2.680	2.550	2.410	3.280	2.940	3.100	3.600	3.660	4.210	4.390	4.210	4.020	4.330	4.450	4.150	4.270	4.330	3.380	3.260	3.540	4.450
1977	2.870	2.510	2.390	2.970	3.230	3.340	3.750	3.840	3.960	4.020	3.990	4.990	4.480	4.420	4.690	4.820	4.420	3.990	3.840	3.990	3.110	4.990
1978	2.087	1.996	2.453	2.499	3.246	3.581	3.398	3.855	4.130	4.008	4.191	4.099	4.312	4.617	4.602	4.251	4.312	4.160	4.404	3.642	3.398	4.617
1979	2.027	2.271	2.576	2.819	2.941	3.063	2.880	3.124	3.185	3.871	4.054	3.901	4.785	4.328	3.871	4.130	4.084	3.658	4.145	3.444	3.307	4.785
1980	1.981	2.682	2.713	2.926	3.230	3.200	3.185	3.474	3.871	4.023	3.901	4.480	4.297	4.389	4.876	4.480	4.572	4.115	3.810	3.596	3.932	4.876
1981	2.529	2.770	2.438	2.865	2.774	2.926	3.444	3.414	3.444	3.947	3.962	4.389	4.541	4.572	4.450	4.267	4.236	4.358	3.840	3.689	2.987	4.572
1982	2.290	2.200	2.900	2.780	2.660	2.920	3.070	3.590	3.980	3.880	4.120	4.340	4.570	4.500	4.340	4.530	4.480	4.480	4.040	3.400	3.150	4.570
1983	2.207	2.634	2.862	2.725	2.999	2.908	3.304	3.289	3.792	3.853	4.127	4.020	4.462	4.478	4.301	4.499	4.590	4.682	4.468	4.139	3.883	4.682
1984	2.530	2.850	2.670	2.870	3.800	3.670	3.800	4.110	4.330	4.220	4.350	4.520	4.960	4.340	4.410	4.380	4.410	4.550	3.930	4.070	3.790	4.960
1985	2.460	2.400	2.460	3.140	2.550	3.110	3.690	3.830	4.050	4.150	4.280	4.420	4.720	4.220	4.380	4.280	4.380	4.000	3.980	4.560	3.540	4.720
1986	2.300	2.490	2.680	2.610	2.510	2.930	2.610	3.140	3.530	3.700	3.950	4.410	4.240	4.150	4.030	4.070	4.050	4.070	3.990	3.750	3.610	4.410
1987	2.080	2.640	2.570	2.240	2.740	2.690	2.940	3.380	3.390	4.440	4.600	4.440	4.600	4.660	4.770	4.570	4.670	4.640	4.270	4.090	3.490	4.770
1988	2.140	2.660	2.160	2.560	3.020	3.720	3.790	3.740	3.810	4.110	4.590	4.530	4.590	4.410	5.160	5.140	4.870	4.320	4.000	3.770	3.590	5.160
1989	2.260	2.080	2.280	3.050	2.590	3.260	3.550	4.140	4.090	3.920	4.300	4.660	4.310	4.300	4.180	4.060	4.160	4.050	3.860	4.450	3.260	4.660

T-296 , Akhaura ; Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1959	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	5.335	5.270	5.880	6.110	5.850	5.490	5.340	5.200	5.155	5.005	6.110
1960	1.235	1.450	1.580	1.555	1.800	3.165	3.165	4.165	4.250	4.570	5.685	6.225	6.180	5.980	5.735	5.800	6.415	6.490	6.410	5.875	5.180	6.490
1961	2.250	2.080	2.095	2.430	2.605	3.125	4.025	5.025	5.005	4.795	4.870	5.085	5.130	5.290	5.540	5.525	5.465	5.280	5.160	5.145	5.025	5.540
1962	1.930	1.930	2.295	2.585	2.585	3.260	3.805	4.130	4.665	5.975	6.965	6.090	5.600	5.835	6.610	6.730	6.610	6.270	5.890	5.320	4.585	6.965
1963	1.685	1.860	2.080	2.265	2.235	2.830	4.085	4.785	5.680	5.725	6.080	6.320	6.320	6.255	6.305	6.445	6.365	6.075	5.570	5.360	4.810	6.445
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	2.040	2.880	2.830	2.270	2.990	3.380	3.600	4.510	5.285	5.930	6.640	6.875	6.750	6.675	6.350	6.335	6.075	5.710	5.590	5.515	4.980	6.875
1969	1.820	2.290	2.600	2.460	2.150	2.690	3.610	4.275	5.130	5.395	5.990	6.155	6.075	6.365	6.660	6.720	6.515	6.165	5.600	5.040	4.310	6.720
1970	2.190	2.620	2.560	2.670	3.200	3.550	3.810	4.735	5.475	6.005	6.080	6.810	7.070	7.180	6.975	6.430	6.015	6.065	6.325	6.325	5.775	7.180
1971	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1972	2.130	2.740	2.270	2.500	3.140	3.380	3.520	3.990	5.680	5.865	5.745	5.830	6.155	6.165	5.905	5.510	5.515	5.220	4.855	4.345	3.805	6.165
1973	1.750	2.090	2.900	4.710	4.790	4.470	4.265	4.875	6.020	6.475	6.430	5.820	6.310	6.490	6.415	6.155	6.050	6.185	6.065	5.670	5.135	6.490
1974	2.550	2.550	2.680	3.570	3.660	3.630	3.945	4.295	5.100	6.690	6.645	7.560	7.770	7.605	7.130	6.780	6.810	6.735	6.265	6.188	5.275	7.770
1975	1.570	2.270	2.470	2.470	2.900	3.350	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	3.350
1976	1.768	2.286	2.576	3.079	3.566	3.490	4.331	5.441	5.672	6.919	7.071	6.892	6.535	6.401	6.462	6.462	6.099	5.508	-99.000	4.542	3.780	-99.000
1977	3.292	3.597	3.277	3.536	3.886	4.222	5.233	5.526	5.938	5.989	6.075	6.127	6.127	6.264	6.471	6.538	6.288	5.767	5.395	5.212	4.862	6.538
1978	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1979	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1980	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1982	2.150	2.170	2.630	2.770	3.450	3.120	2.882	3.796	5.140	5.658	5.970	6.028	6.506	6.520	6.096	5.600	5.620	5.800	5.570	4.940	4.030	6.520
1983	2.330	2.225	3.105	3.765	3.575	3.545	3.565	4.145	4.570	5.430	5.700	5.635	6.560	6.520	6.630	6.675	6.785	6.840	6.685	6.040	5.680	6.840
1984	1.980	2.215	2.350	3.100	4.520	4.630	5.050	5.330	5.630	5.589	6.500	6.950	6.940	6.570	5.900	5.960	6.830	6.950	6.570	5.850	4.930	6.950
1985	2.180	2.560	2.800	3.000	2.950	3.580	4.300	5.050	5.220	5.490	5.820	6.300	6.400	6.230	5.860	5.830	5.710	5.600	5.440	5.100	4.680	6.400
1986	2.060	2.390	2.990	3.100	3.040	2.880	2.680	2.850	3.560	4.240	4.670	5.350	5.670	5.670	5.280	5.370	5.380	5.580	5.620	5.670	5.600	5.670
1987	1.720	2.320	2.700	2.720	2.570	2.580	3.430	3.760	4.300	5.550	5.770	6.340	6.880	6.980	6.880	6.610	6.420	6.590	6.610	6.320	5.360	6.980
1988	1.930	2.290	2.360	2.580	3.350	5.060	5.660	5.150	6.020	7.180	7.400	7.060	6.620	6.630	7.480	7.600	7.600	7.060	6.210	5.730	5.250	7.600
1989	1.860	1.920	2.440	2.880	2.060	3.440	4.040	4.690	4.960	5.610	6.140	6.270	6.490	6.500	6.180	6.000	5.980	5.980	5.760	5.760	5.660	6.500

T-297 , Gokorna Ghat : Maximum 10 day levels. Apr. - Oct.

YEAR	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1977	2.896	2.896	2.865	3.460	3.764	4.023	4.974	5.316	5.724	5.761	5.855	5.913	5.944	6.038	6.297	6.340	6.008	5.535	5.090	4.938	4.465	6.340
1978	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1979	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1980	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1981	2.408	2.926	2.911	2.682	3.002	3.231	3.731	3.783	3.859	5.337	5.499	5.925	6.309	6.218	6.011	6.035	6.096	6.023	5.441	4.709	3.841	6.309
1982	2.225	2.290	2.940	2.780	2.880	2.920	2.854	3.868	5.020	5.468	5.680	5.744	6.240	6.244	5.854	5.486	5.514	5.590	5.340	4.560	3.640	6.244
1983	2.410	2.500	2.900	3.190	3.410	3.550	3.550	3.920	4.540	5.500	5.630	5.660	6.370	6.350	6.420	6.480	6.610	6.640	6.440	5.930	5.440	6.640
1984	2.230	2.620	2.530	2.720	3.730	4.670	4.890	5.160	5.470	5.450	6.300	6.680	6.680	6.350	5.770	5.760	6.570	6.660	6.300	5.530	4.580	6.680
1985	2.310	2.510	2.740	2.970	2.660	3.030	4.240	4.830	5.020	5.320	5.610	6.030	6.150	5.920	5.600	5.590	5.450	5.350	5.200	4.810	4.470	6.150
1986	2.090	2.300	2.940	2.710	2.710	2.910	2.510	2.930	3.580	4.240	4.600	5.240	5.540	5.490	5.130	5.210	5.250	5.390	5.380	5.410	5.310	5.540
1987	2.000	2.520	2.620	2.560	2.590	2.610	3.120	3.640	4.390	5.450	5.590	6.170	6.680	6.770	6.700	6.430	6.210	6.370	6.370	6.010	5.020	6.770
1988	2.200	2.600	2.390	2.530	3.500	4.960	5.380	5.160	5.740	6.850	7.070	6.780	6.340	6.340	7.240	7.410	7.420	6.750	5.840	5.370	5.000	7.420
1989	2.220	2.140	2.480	3.020	2.890	3.430	3.880	4.680	4.880	5.480	5.930	6.060	6.260	6.220	5.940	5.730	5.700	5.700	5.540	5.470	5.400	6.260

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T-298, Nabinagar ; Maximum 10 day levels, Apr. - Oct.

YEAR	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1959	1.760	2.040	2.370	2.530	2.710	3.170	3.750	4.810	5.850	5.880	5.790	5.540	5.240	5.940	6.060	5.790	5.450	5.300	5.210	5.060	4.930	6.060
1960	1.670	2.070	2.070	1.950	2.250	2.950	3.410	3.960	4.230	4.660	5.570	6.090	6.030	5.820	5.610	5.910	6.280	6.310	6.060	5.510	4.810	6.310
1961	2.370	2.150	2.120	2.460	2.730	3.280	3.830	4.530	4.560	4.440	4.680	4.770	4.830	5.050	5.290	5.260	5.140	4.900	-99.000	99.000	99.000	5.290
1962	2.350	1.980	2.160	2.470	2.530	3.170	3.570	4.050	4.630	5.700	5.760	5.670	5.300	5.580	6.370	6.460	6.310	5.970	5.550	4.880	4.020	6.460
1963	1.680	1.950	2.070	2.160	2.290	2.830	3.720	4.690	5.360	5.460	5.910	6.070	6.070	5.970	5.990	6.130	5.970	5.640	5.090	4.750	4.240	6.130
1964	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	99.000	-99.000	-99.000	-99.000	99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000
1965	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1966	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1967	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000
1968	1.830	2.410	2.070	2.070	2.680	2.990	3.475	4.305	4.985	5.390	6.380	6.620	6.490	6.325	6.010	5.965	5.695	5.320	5.170	5.120	4.540	6.620
1969	1.980	2.320	2.350	2.320	2.260	2.930	3.215	4.205	4.945	5.180	5.770	5.915	5.860	5.990	6.415	6.430	6.170	5.775	5.270	4.720	3.930	6.430
1970	2.500	2.350	2.350	2.990	3.200	3.540	3.885	4.220	5.255	5.350	5.820	6.490	6.765	6.825	6.600	6.020	5.685	5.730	5.970	5.880	5.270	6.825
1971	2.100	2.420	2.320	2.800	2.960	3.000	3.305	4.130	4.630	5.045	5.485	5.670	5.830	6.140	6.340	6.320	6.250	5.975	5.650	5.430	5.150	6.340
1972	2.150	2.380	2.410	2.350	3.030	3.280	3.336	3.750	5.450	5.555	5.310	5.570	5.845	5.840	5.450	5.230	5.260	4.830	4.480	3.990	3.440	5.845
1973	2.000	2.440	2.460	3.290	3.660	3.840	4.035	4.970	5.820	6.170	6.035	5.530	6.050	6.185	6.140	5.775	5.775	5.915	5.760	5.270	4.750	6.185
1974	2.330	2.270	2.560	3.200	3.310	3.520	3.795	4.040	5.075	6.200	6.325	7.115	7.315	7.180	6.780	6.370	6.400	6.310	5.970	5.640	4.880	7.315
1975	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	5.350	5.010	4.740	5.350
1976	1.810	2.420	2.270	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	99.000	-99.000	-99.000	-99.000	-99.000	-99.000	5.140	4.210	3.610	5.140
1977	2.743	2.774	2.713	3.322	3.627	3.871	4.938	5.243	5.669	5.669	5.791	5.867	5.883	6.005	6.188	6.248	5.944	5.426	5.029	4.877	4.389	6.248
1978	1.920	1.859	2.225	2.530	2.987	3.841	4.191	4.770	5.349	5.410	5.410	5.608	5.685	5.700	5.685	5.974	5.380	5.410	5.029	4.557	3.932	5.974
1979	2.027	1.920	2.118	2.118	2.667	2.637	2.286	2.804	3.658	4.923	5.227	5.959	6.020	5.944	5.502	5.624	5.928	5.898	5.288	5.197	4.831	6.020
1980	1.783	2.347	2.682	3.079	3.383	3.597	3.719	4.724	4.907	4.938	5.075	5.730	5.807	6.111	6.233	6.188	5.867	5.563	5.380	4.968	4.435	6.233
1981	2.393	2.789	2.758	2.667	2.911	3.216	3.764	3.734	3.780	5.258	5.395	5.837	6.157	6.066	5.852	5.883	5.928	5.822	5.273	4.511	3.658	6.157
1982	2.270	2.270	2.630	2.750	2.790	2.840	2.930	3.780	4.960	5.350	5.550	5.640	6.110	6.100	5.705	5.350	5.410	5.480	5.160	4.420	3.480	6.110
1983	2.350	2.480	2.900	3.000	3.260	3.510	3.510	3.680	4.450	5.430	5.485	5.570	6.200	6.180	6.250	6.290	6.450	6.490	6.300	5.710	5.270	6.490
1984	2.320	2.580	2.450	2.650	3.470	4.590	4.810	5.040	5.370	5.360	6.210	6.610	6.620	6.280	5.650	5.690	6.500	6.600	6.220	5.430	4.410	6.620
1985	2.300	2.450	2.620	3.050	2.590	2.870	4.220	4.770	4.970	5.160	5.560	6.010	6.100	5.870	5.460	5.490	5.430	5.300	5.170	4.770	4.420	6.100
1986	2.120	2.280	2.880	2.650	2.650	2.830	2.550	2.950	3.600	4.170	4.530	5.150	5.430	5.380	5.040	5.130	5.170	5.290	5.270	5.310	5.180	5.430
1987	2.050	2.570	2.670	2.520	2.610	2.580	3.100	3.590	4.350	5.380	5.540	6.120	6.540	6.680	6.610	6.290	6.140	6.290	6.290	5.940	4.950	6.680
1988	2.130	2.580	2.340	2.450	3.480	4.900	5.340	5.040	5.710	6.770	7.000	6.700	6.300	6.280	7.160	7.340	7.320	6.630	5.720	5.280	4.880	7.340
1989	2.180	2.100	2.420	2.960	2.840	3.350	3.800	4.580	4.780	5.380	5.780	5.910	6.080	6.000	5.780	5.570	5.570	5.580	5.420	5.330	5.220	6.080

APPENDIX V

REGIONAL WATER LEVEL FREQUENCIES

Annual Maximum Water Levels
W-110, Comilla ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	7.27	7.43	7.59	7.61	7.71	7.71	8.31	8.97	8.78	8.92	9.26	9.33	9.01	9.00	9.08	9.07	8.84	8.77	8.82	8.17	8.17	11.17
1.25	7.44	7.64	7.78	7.93	8.07	8.04	8.66	9.28	9.12	9.33	9.59	9.58	9.33	9.27	9.40	9.29	9.09	9.00	9.01	8.44	8.34	11.37
2	7.83	8.13	8.22	8.67	8.92	8.83	9.50	10.01	9.92	10.28	10.38	10.17	10.09	9.90	10.14	9.79	9.68	9.55	9.46	9.08	8.73	11.85
5	8.36	8.80	8.81	9.67	10.05	9.88	10.63	11.00	11.00	11.57	11.44	10.96	11.11	10.75	11.13	10.47	10.48	10.28	10.05	9.94	9.26	12.50
10	8.70	9.25	9.20	10.33	10.80	10.58	11.38	11.65	11.72	12.43	12.15	11.48	11.78	11.31	11.79	10.92	11.01	10.77	10.45	10.50	9.61	12.93
20	9.04	9.67	9.58	10.97	11.52	11.25	12.10	12.28	12.41	13.25	12.82	11.98	12.43	11.85	12.42	11.36	11.51	11.23	10.83	11.05	9.95	13.34
50	9.47	10.22	10.06	11.79	12.46	12.12	13.03	13.08	13.29	14.31	13.69	12.63	13.27	12.54	13.23	11.91	12.17	11.84	11.32	11.75	10.39	13.87

Annual Maximum Water Levels
W-113, Kangsanagar ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	3.45	3.70	4.04	4.18	4.17	4.40	5.30	6.41	6.13	6.13	6.72	6.90	6.47	6.62	6.44	6.41	6.26	6.09	5.90	5.38	5.09	8.30
1.25	3.72	4.03	4.35	4.56	4.62	4.85	5.70	6.73	6.46	6.52	7.03	7.12	6.74	6.81	6.71	6.60	6.47	6.31	6.13	5.69	5.38	8.46
2	4.36	4.81	5.09	5.48	5.68	5.90	6.63	7.49	7.25	7.45	7.74	7.62	7.37	7.25	7.35	7.05	6.97	6.83	6.67	6.42	6.07	8.85
5	5.21	5.85	6.07	6.71	7.11	7.31	7.88	8.50	8.31	8.69	8.71	8.31	8.22	7.85	8.21	7.65	7.64	7.53	7.39	7.41	6.99	9.37
10	5.77	6.54	6.72	7.52	8.06	8.25	8.71	9.18	9.01	9.52	9.34	8.76	8.78	8.25	8.78	8.04	8.08	8.00	7.87	8.06	7.61	9.71
20	6.31	7.21	7.35	8.30	8.96	9.14	9.50	9.82	9.68	10.31	9.96	9.19	9.32	8.63	9.33	8.42	8.51	8.44	8.33	8.68	8.19	10.04
50	7.01	8.07	8.16	9.31	10.14	10.31	10.53	10.66	10.55	11.34	10.75	9.76	10.02	9.12	10.04	8.91	9.06	9.02	8.92	9.49	8.95	10.47

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Annual Maximum Water Levels
W-114, Jibanpur (Gumti) ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	3.91	4.17	4.58	4.81	5.13	4.93	5.20	5.31	5.35	6.21	5.84	6.03	6.15	6.11	5.88	6.16	6.08	5.96	5.81	5.13	4.85	7.39
1.25	4.10	4.43	4.80	5.03	5.38	5.25	5.51	5.60	5.62	6.41	6.02	6.20	6.29	6.21	6.04	6.25	6.19	6.10	5.96	5.38	5.07	7.44
2	4.55	5.04	5.34	5.54	5.95	6.00	6.23	6.26	6.28	6.87	6.46	6.61	6.63	6.44	6.43	6.46	6.44	6.41	6.31	5.97	5.57	7.56
5	5.15	5.86	6.06	6.23	6.73	7.02	7.21	7.16	7.15	7.49	7.05	7.16	7.08	6.75	6.96	6.75	6.77	6.84	6.78	6.77	6.25	7.73
10	5.55	6.40	6.53	6.68	7.24	7.69	7.85	7.75	7.73	7.91	7.44	7.53	7.37	6.96	7.31	6.94	6.99	7.12	7.09	7.29	6.70	7.84
20	5.93	6.93	6.99	7.12	7.73	8.33	8.47	8.32	8.29	8.30	7.82	7.88	7.66	7.16	7.64	7.12	7.20	7.40	7.39	7.80	7.14	7.94
50	6.43	7.60	7.58	7.68	8.37	9.17	9.27	9.05	9.01	8.82	8.30	8.33	8.03	7.41	8.07	7.35	7.48	7.75	7.77	8.45	7.69	8.08

Annual Maximum Water Levels
W-123, Ganga Sagart Railway Bridge ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	4.16	3.96	3.90	3.93	4.05	3.96	4.22	4.42	4.50	4.83	4.91	5.27	5.43	5.49	5.38	5.21	5.12	5.06	4.92	4.54	4.17	5.69
1.25	4.26	4.10	4.03	4.12	4.21	4.12	4.35	4.57	4.65	4.98	5.07	5.40	5.55	5.60	5.50	5.34	5.26	5.20	5.04	4.67	4.30	5.81
2	4.51	4.41	4.34	4.57	4.59	4.52	4.67	4.92	4.98	5.32	5.43	5.72	5.83	5.85	5.79	5.66	5.59	5.53	5.33	4.98	4.60	6.10
5	4.84	4.83	4.76	5.17	5.10	5.05	5.09	5.40	5.43	5.77	5.92	6.14	6.21	6.20	6.17	6.08	6.04	5.97	5.71	5.40	5.01	6.49
10	5.06	5.10	5.03	5.57	5.43	5.40	5.38	5.71	5.73	6.08	6.25	6.42	6.46	6.42	6.43	6.37	6.33	6.26	5.96	5.68	5.29	6.74
20	5.28	5.37	5.29	5.95	5.76	5.74	5.65	6.01	6.01	6.37	6.56	6.69	6.70	6.64	6.68	6.64	6.62	6.54	6.21	5.95	5.55	6.99
50	5.55	5.72	5.63	6.45	6.17	6.18	6.00	6.40	6.38	6.74	6.96	7.04	7.02	6.93	7.00	6.99	6.98	6.91	6.52	6.29	5.89	7.30

Annual Maximum Water Levels
W-157, Ballah ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	19.28	19.58	19.70	19.50	19.54	19.50	20.04	20.52	20.30	20.35	20.57	20.16	19.74	20.23	20.24	20.27	20.02	20.17	20.13	19.75	19.67	22.75
1.25	19.45	19.78	19.92	19.82	19.84	19.94	20.40	20.98	20.62	20.73	20.85	20.50	20.13	20.62	20.53	20.50	20.36	20.39	20.36	20.02	19.85	23.04
2	19.86	20.26	20.45	20.56	20.52	20.96	21.25	22.04	21.36	21.62	21.52	21.30	21.04	21.54	21.20	21.04	21.15	20.92	20.91	20.65	20.28	23.72
5	20.41	20.90	21.15	21.56	21.44	22.35	22.39	23.47	22.36	22.81	22.41	22.37	22.27	22.78	22.11	21.77	22.21	21.62	21.64	21.49	20.86	24.65
10	20.77	21.32	21.62	22.22	22.05	23.26	23.15	24.42	23.02	23.61	23.00	23.09	23.08	23.60	22.70	22.25	22.91	22.08	22.13	22.05	21.24	25.26
20	21.12	21.73	22.07	22.86	22.64	24.14	23.87	25.33	23.65	24.36	23.56	23.77	23.86	24.38	23.28	22.71	23.58	22.53	22.59	22.59	21.60	25.84
50	21.57	22.26	22.65	23.68	23.40	25.28	24.81	26.51	24.48	25.35	24.30	24.66	24.86	25.40	24.02	23.31	24.45	23.11	23.19	23.28	22.07	26.60

Annual Maximum Water Levels
W-158, Chunarghat ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	12.52	12.76	13.02	12.89	13.02	13.17	13.72	14.50	13.74	13.99	14.09	14.08	13.69	14.17	13.95	13.88	13.77	13.74	13.69	13.33	13.08	16.60
1.25	12.73	13.03	13.27	13.28	13.42	13.60	14.07	14.80	14.12	14.36	14.37	14.39	14.02	14.48	14.23	14.11	14.09	13.99	13.97	13.62	13.27	16.76
2	13.21	13.67	13.88	14.18	14.36	14.60	14.89	15.52	15.02	15.23	15.03	15.11	14.81	15.21	14.90	14.66	14.83	14.57	14.62	14.30	13.73	17.14
5	13.87	14.53	14.69	15.40	15.63	15.95	16.00	16.48	16.23	16.41	15.91	16.08	15.87	16.19	15.80	15.40	15.83	15.34	15.49	15.22	14.34	17.65
10	14.30	15.10	15.23	16.21	16.48	16.84	16.73	17.11	17.03	17.19	16.50	16.73	16.57	16.84	16.40	15.89	16.49	15.86	16.07	15.82	14.75	17.99
20	14.72	15.65	15.74	16.99	17.28	17.70	17.44	17.72	17.80	17.93	17.06	17.34	17.24	17.46	16.97	16.36	17.12	16.35	16.63	16.40	15.14	18.31
50	15.26	16.36	16.41	17.99	18.33	18.80	18.34	18.51	18.79	18.90	17.78	18.14	18.11	18.26	17.72	16.96	17.94	16.99	17.35	17.16	15.65	18.73

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Annual Maximum Water Levels

W-181, Gunabati Railway Bridge (d/s) ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	112.57	112.67	113.43	3.12	3.53	3.80	3.82	4.21	4.28	4.83	4.90	4.66	4.46	4.24	3.95	4.24	4.08	4.31	3.93	3.51	3.46	115.69
1.25	84.65	84.75	85.51	3.37	3.76	4.00	3.99	4.35	4.40	4.92	4.98	4.77	4.61	4.39	4.16	4.38	4.21	4.39	4.05	3.72	3.62	87.77
2	18.97	19.07	19.84	3.94	4.30	4.46	4.39	4.69	4.69	5.12	5.19	5.01	4.97	4.74	4.67	4.73	4.52	4.58	4.34	4.20	4.00	22.10
5	-69.39	-69.29	-68.53	4.72	5.04	5.09	4.92	5.15	5.08	5.40	5.47	5.34	5.44	5.20	5.34	5.19	4.93	4.83	4.73	4.85	4.51	-66.27
10	-127.89	-127.80	-127.03	5.23	5.52	5.50	5.27	5.45	5.34	5.58	5.66	5.56	5.76	5.51	5.79	5.50	5.20	4.99	4.98	5.27	4.85	-124.77
20	-184.01	-183.92	-183.15	5.73	5.99	5.89	5.61	5.74	5.58	5.75	5.84	5.77	6.06	5.80	6.22	5.79	5.47	5.15	5.23	5.69	5.17	-180.89
50	-256.65	-256.56	-255.79	6.36	6.59	6.41	6.05	6.11	5.90	5.97	6.07	6.04	6.46	6.19	6.78	6.17	5.80	5.35	5.55	6.22	5.59	-253.53

Annual Maximum Water Levels

T 3A , Brahmanbaria Railway Bridge ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.53	1.87	2.09	2.21	2.51	2.55	2.94	3.61	4.27	4.78	5.30	5.65	5.91	5.92	5.73	5.57	5.45	5.43	5.26	4.79	4.16	5.76
1.25	1.62	1.97	2.19	2.37	2.69	2.76	3.13	3.81	4.46	4.99	5.48	5.81	6.04	6.04	5.88	5.73	5.62	5.58	5.39	4.93	4.33	5.95
2	1.82	2.20	2.42	2.75	3.10	3.26	3.59	4.28	4.91	5.49	5.91	6.19	6.36	6.34	6.23	6.10	6.03	5.93	5.69	5.28	4.74	6.39
5	2.09	2.50	2.74	3.27	3.65	3.92	4.21	4.91	5.51	6.16	6.48	6.70	6.80	6.74	6.70	6.60	6.57	6.41	6.10	5.75	5.29	6.99
10	2.27	2.71	2.94	3.60	4.02	4.36	4.63	5.33	5.91	6.60	6.86	7.04	7.08	7.01	7.01	6.94	6.92	6.72	6.37	6.06	5.66	7.39
20	2.44	2.90	3.14	3.93	4.37	4.78	5.02	5.73	6.29	7.03	7.22	7.37	7.36	7.27	7.31	7.26	7.27	7.02	6.63	6.36	6.01	7.77
50	2.66	3.16	3.40	4.35	4.82	5.33	5.53	6.25	6.78	7.58	7.69	7.79	7.72	7.60	7.69	7.67	7.71	7.41	6.97	6.74	6.46	8.26

Annual Maximum Water Levels

T 79 ,Matlab Bazar ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.88	2.02	2.13	2.28	2.40	2.65	2.97	3.23	3.62	3.92	4.11	4.27	4.39	4.47	4.43	4.40	4.39	4.22	3.96	3.68	3.32	4.75
1.25	1.98	2.12	2.22	2.40	2.51	2.75	3.06	3.32	3.72	4.00	4.18	4.36	4.49	4.56	4.52	4.48	4.45	4.31	4.06	3.78	3.41	4.82
2	2.20	2.36	2.41	2.69	2.78	3.01	3.25	3.54	3.94	4.18	4.36	4.56	4.73	4.78	4.74	4.67	4.61	4.53	4.29	4.02	3.61	4.99
5	2.50	2.67	2.67	3.07	3.14	3.34	3.52	3.84	4.23	4.42	4.61	4.84	5.05	5.07	5.03	4.93	4.83	4.82	4.60	4.34	3.88	5.22
10	2.70	2.88	2.85	3.32	3.38	3.57	3.69	4.04	4.43	4.58	4.77	5.02	5.26	5.26	5.23	5.10	4.97	5.01	4.81	4.55	4.05	5.37
20	2.90	3.08	3.01	3.56	3.61	3.78	3.86	4.23	4.61	4.74	4.92	5.19	5.46	5.44	5.41	5.26	5.11	5.20	5.01	4.75	4.23	5.52
50	3.14	3.34	3.23	3.88	3.91	4.06	4.08	4.47	4.85	4.94	5.12	5.42	5.72	5.68	5.66	5.47	5.29	5.44	5.26	5.01	4.45	5.70

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Annual Maximum Water Levels
T-115, Duadkandi ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1.11	1.90	2.06	2.18	2.30	2.41	2.84	3.04	3.30	3.72	4.11	4.31	4.46	4.70	4.69	4.59	4.54	4.57	4.45	4.17	3.85	3.36	5.08
1.25	1.99	2.14	2.26	2.39	2.53	2.92	3.13	3.41	3.85	4.21	4.42	4.58	4.82	4.81	4.74	4.68	4.69	4.57	4.30	3.98	3.49	5.19
2	2.21	2.32	2.43	2.59	2.81	3.13	3.34	3.68	4.14	4.45	4.66	4.84	5.08	5.10	5.07	5.01	4.98	4.86	4.60	4.28	3.79	5.45
5	2.50	2.57	2.66	2.86	3.18	3.40	3.63	4.03	4.53	4.76	4.99	5.21	5.44	5.48	5.53	5.45	5.38	5.24	5.00	4.69	4.19	5.81
10	2.70	2.73	2.81	3.05	3.43	3.58	3.81	4.26	4.80	4.97	5.21	5.45	5.68	5.73	5.83	5.74	5.64	5.49	5.27	4.96	4.45	6.04
20	2.89	2.89	2.96	3.22	3.66	3.75	3.99	4.49	5.05	5.17	5.42	5.68	5.91	5.97	6.11	6.02	5.89	5.74	5.52	5.21	4.71	6.27
50	3.13	3.09	3.15	3.44	3.97	3.98	4.23	4.78	5.37	5.43	5.69	5.98	6.20	6.28	6.49	6.38	6.22	6.05	5.85	5.55	5.04	6.56

Annual Maximum Water Levels
T-230 , Bhairab Bazar Railway Bridge ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1.11	1.79	2.10	2.15	2.26	2.55	2.83	3.07	3.57	4.69	5.19	5.57	5.77	5.84	5.89	6.02	5.66	5.46	5.27	5.04	4.50	3.89	6.10
1.25	1.85	2.16	2.22	2.37	2.66	2.96	3.21	3.79	4.86	5.35	5.71	5.92	6.01	6.04	6.15	5.80	5.63	5.46	5.21	4.70	4.07	6.26
2	2.01	2.30	2.40	2.64	2.94	3.26	3.55	4.32	5.24	5.73	6.03	6.26	6.40	6.39	6.44	6.15	6.03	5.90	5.61	5.18	4.52	6.63
5	2.21	2.49	2.63	3.00	3.32	3.66	4.00	5.04	5.76	6.24	6.47	6.71	6.92	6.86	6.84	6.61	6.56	6.49	6.14	5.81	5.11	7.13
10	2.35	2.61	2.79	3.24	3.57	3.93	4.30	5.51	6.11	6.57	6.76	7.01	7.27	7.17	7.10	6.91	6.92	6.89	6.50	6.23	5.50	7.47
20	2.48	2.73	2.94	3.47	3.81	4.18	4.58	5.96	6.44	6.89	7.03	7.30	7.60	7.47	7.36	7.20	7.26	7.26	6.84	6.64	5.88	7.78
50	2.65	2.89	3.13	3.76	4.12	4.52	4.95	6.55	6.86	7.31	7.39	7.68	8.04	7.86	7.68	7.58	7.70	7.75	7.28	7.16	6.37	8.20

Annual Maximum Water Levels
T-240 , Bhawaniganj ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.32	1.22	1.28	1.27	1.32	1.54	1.73	1.86	1.90	2.18	2.62	2.82	2.91	2.86	2.88	3.01	2.94	2.85	2.74	2.58	2.45	3.29
1.25	1.49	1.42	1.46	1.47	1.54	1.77	1.94	2.08	2.13	2.40	2.78	2.98	3.05	3.02	3.04	3.14	3.06	2.98	2.88	2.73	2.60	3.42
2	1.88	1.89	1.88	1.96	2.05	2.31	2.42	2.59	2.65	2.90	3.16	3.35	3.39	3.38	3.43	3.45	3.36	3.28	3.21	3.09	2.95	3.73
5	2.40	2.52	2.44	2.62	2.74	3.04	3.07	3.28	3.36	3.59	3.67	3.86	3.85	3.87	3.94	3.86	3.75	3.69	3.65	3.58	3.41	4.14
10	2.75	2.93	2.82	3.05	3.19	3.53	3.50	3.74	3.83	4.04	4.00	4.19	4.16	4.19	4.28	4.14	4.01	3.96	3.94	3.90	3.72	4.42
20	3.09	3.33	3.18	3.47	3.63	3.99	3.91	4.18	4.28	4.48	4.33	4.52	4.45	4.50	4.61	4.40	4.27	4.22	4.22	4.21	4.02	4.68
50	3.52	3.85	3.64	4.00	4.20	4.59	4.44	4.75	4.86	5.04	4.75	4.93	4.83	4.91	5.03	4.74	4.59	4.56	4.58	4.61	4.40	5.02

Annual Maximum Water Levels
T-275 , Baidyer Bazar ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.73	1.93	1.90	2.18	2.32	2.57	2.80	3.34	3.72	4.15	4.37	4.67	4.80	4.86	4.71	4.62	4.56	4.39	4.24	3.87	3.21	5.05
1.25	1.80	2.01	2.01	2.29	2.43	2.70	2.94	3.45	3.85	4.27	4.52	4.80	4.92	4.96	4.84	4.76	4.70	4.52	4.35	4.00	3.37	5.18
2	1.99	2.20	2.25	2.54	2.70	3.03	3.28	3.72	4.16	4.56	4.88	5.12	5.21	5.19	5.16	5.08	5.02	4.83	4.62	4.30	3.75	5.47
5	2.23	2.45	2.59	2.88	3.05	3.47	3.73	4.08	4.56	4.96	5.36	5.54	5.61	5.50	5.59	5.51	5.45	5.25	4.98	4.70	4.26	5.87
10	2.40	2.62	2.81	3.10	3.29	3.75	4.03	4.32	4.83	5.22	5.68	5.82	5.87	5.71	5.87	5.80	5.73	5.53	5.22	4.97	4.60	6.14
20	2.55	2.78	3.02	3.31	3.51	4.03	4.32	4.54	5.09	5.47	5.98	6.09	6.12	5.91	6.14	6.07	6.00	5.80	5.45	5.23	4.92	6.39
50	2.76	2.98	3.30	3.59	3.81	4.39	4.70	4.84	5.43	5.79	6.38	6.44	6.44	6.16	6.50	6.43	6.36	6.15	5.74	5.56	5.34	6.72

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Annual Maximum Water Levels
T-276 , Satnal ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1.11	1.82	1.99	2.03	2.17	2.37	2.68	2.84	3.19	3.57	3.93	4.10	4.34	4.55	4.58	4.44	4.46	4.42	4.26	3.98	3.67	3.20	4.84
1.25	1.90	2.06	2.11	2.28	2.48	2.78	2.95	3.30	3.68	4.03	4.20	4.45	4.65	4.67	4.57	4.57	4.52	4.36	4.07	3.78	3.31	4.93
2	2.09	2.23	2.29	2.56	2.73	2.99	3.21	3.55	3.94	4.26	4.44	4.70	4.91	4.89	4.86	4.83	4.77	4.59	4.30	4.03	3.58	5.16
5	2.34	2.45	2.54	2.93	3.07	3.28	3.56	3.89	4.29	4.57	4.76	5.05	5.25	5.20	5.25	5.18	5.11	4.89	4.60	4.38	3.95	5.47
10	2.50	2.59	2.71	3.17	3.30	3.47	3.79	4.12	4.52	4.77	4.97	5.28	5.48	5.40	5.50	5.41	5.34	5.09	4.80	4.60	4.19	5.68
20	2.66	2.73	2.87	3.41	3.52	3.66	4.01	4.33	4.74	4.97	5.17	5.50	5.70	5.59	5.75	5.64	5.55	5.28	4.99	4.82	4.42	5.87
50	2.87	2.92	3.08	3.71	3.80	3.90	4.30	4.61	5.02	5.23	5.44	5.79	5.98	5.83	6.07	5.92	5.83	5.53	5.24	5.10	4.72	6.13

Annual Maximum Water Levels
T-277 , Chandpur ; Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April 1	April 2	April 3	May 1	May 2	May 3	June 1	June 2	June 3	July 1	July 2	July 3	August 1	August 2	August 3	September 1	September 2	September 3	October 1	October 2	October 3	Annual
1.11	1.93	2.03	2.12	2.23	2.51	2.89	3.04	3.34	3.49	3.83	3.98	4.15	4.26	4.24	4.20	4.16	4.20	3.99	3.78	3.50	3.08	4.55
1.25	2.00	2.12	2.20	2.36	2.61	2.97	3.12	3.42	3.59	3.90	4.04	4.22	4.34	4.31	4.29	4.24	4.26	4.07	3.86	3.60	3.19	4.61
2	2.17	2.34	2.39	2.67	2.85	3.15	3.33	3.61	3.83	4.05	4.19	4.40	4.51	4.48	4.50	4.43	4.40	4.24	4.06	3.86	3.47	4.76
5	2.40	2.63	2.65	3.08	3.17	3.39	3.60	3.86	4.14	4.26	4.39	4.64	4.75	4.70	4.78	4.69	4.59	4.48	4.34	4.21	3.83	4.95
10	2.55	2.83	2.82	3.35	3.39	3.55	3.78	4.02	4.35	4.39	4.52	4.80	4.91	4.85	4.97	4.86	4.71	4.63	4.52	4.44	4.07	5.08
20	2.69	3.01	2.98	3.61	3.60	3.71	3.95	4.18	4.56	4.52	4.65	4.95	5.06	5.00	5.15	5.02	4.83	4.78	4.69	4.66	4.30	5.20
50	2.88	3.25	3.19	3.94	3.86	3.91	4.17	4.38	4.82	4.69	4.82	5.15	5.26	5.18	5.38	5.23	4.98	4.98	4.91	4.94	4.60	5.36

Annual Maximum Water Levels
T 296 , Akhaura : Maximum 10 day levels, Apr. - Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.57	1.84	2.13	2.13	2.33	2.80	3.13	3.77	4.45	4.95	5.38	5.55	5.68	5.82	5.74	5.63	5.57	5.44	5.26	4.88	4.30	5.50
1.25	1.68	1.96	2.24	2.32	2.53	2.97	3.34	3.95	4.63	5.16	5.56	5.73	5.85	5.96	5.89	5.78	5.73	5.60	5.41	5.04	4.46	5.75
2	1.95	2.25	2.49	2.75	3.01	3.39	3.83	4.41	5.06	5.63	6.00	6.14	6.25	6.30	6.24	6.14	6.10	5.97	5.75	5.39	4.84	6.33
5	2.32	2.63	2.83	3.33	3.66	3.95	4.48	5.01	5.63	6.28	6.59	6.69	6.79	6.75	6.72	6.63	6.60	6.46	6.22	5.87	5.36	7.13
10	2.56	2.89	3.05	3.72	4.09	4.32	4.92	5.41	6.01	6.70	6.98	7.06	7.14	7.05	7.03	6.95	6.93	6.79	6.53	6.19	5.70	7.65
20	2.79	3.13	3.27	4.08	4.50	4.68	5.33	5.80	6.38	7.11	7.36	7.41	7.48	7.34	7.34	7.26	7.24	7.10	6.82	6.49	6.02	8.15
50	3.08	3.45	3.55	4.56	5.03	5.14	5.87	6.29	6.85	7.64	7.84	7.86	7.93	7.71	7.73	7.66	7.65	7.51	7.21	6.89	6.45	8.80

Annual Maximum Water Levels
T 298, Nabinagar ; Maximum 10 day levels, Apr. Oct.

Return Period (YEARS)	April			May			June			July			August			September			October			Annual
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1.11	1.82	2.04	2.15	2.23	2.46	2.70	2.95	3.56	4.19	4.77	5.08	5.35	5.45	5.58	5.45	5.41	5.34	5.21	4.97	4.52	3.88	5.63
1.25	1.90	2.11	2.22	2.34	2.57	2.86	3.14	3.73	4.37	4.92	5.23	5.49	5.60	5.70	5.59	5.55	5.48	5.34	5.10	4.66	4.04	5.78
2	2.08	2.27	2.38	2.59	2.85	3.23	3.59	4.15	4.79	5.28	5.57	5.83	5.94	5.99	5.92	5.87	5.81	5.67	5.40	4.99	4.42	6.13
5	2.31	2.50	2.60	2.93	3.22	3.73	4.19	4.71	5.35	5.76	6.03	6.26	6.39	6.37	6.37	6.30	6.26	6.11	5.79	5.42	4.93	6.60
10	2.47	2.64	2.75	3.16	3.46	4.06	4.59	5.08	5.73	6.08	6.33	6.58	6.70	6.62	6.66	6.59	6.56	6.39	6.06	5.71	5.26	6.90
20	2.62	2.78	2.89	3.37	3.69	4.38	4.97	5.44	6.09	6.39	6.63	6.86	6.99	6.86	6.95	6.86	6.84	6.67	6.31	5.99	5.58	7.20
50	2.82	2.96	3.08	3.65	4.00	4.79	5.47	5.90	6.55	6.79	7.00	7.23	7.36	7.18	7.31	7.22	7.21	7.03	6.64	6.35	6.00	7.59

APPENDIX VI

FLOOD LEVEL FREQUENCY DURATION TABLES

Flood Level Duration / Frequency
W-110, Comilla ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	9.63	9.84	10.34	11.01	11.45	11.88	12.43
30	9.27	9.50	10.02	10.72	11.18	11.64	12.21
40	9.16	9.36	9.84	10.49	10.91	11.32	11.86
50	9.05	9.21	9.59	10.10	10.44	10.76	11.18
60	8.87	9.03	9.42	9.95	10.29	10.63	11.06
80	8.71	8.86	9.21	9.68	10.00	10.30	10.68
100	8.59	8.73	9.06	9.50	9.79	10.07	10.43
120	8.28	8.42	8.74	9.17	9.46	9.73	10.09
150	7.73	7.87	8.21	8.66	8.97	9.25	9.63

Flood Level Duration / Frequency
W-113, Kangsanagar ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	7.10	7.28	7.69	8.25	8.62	8.97	9.43
30	6.84	7.03	7.48	8.08	8.46	8.86	9.35
40	6.71	6.87	7.27	7.80	8.16	8.50	8.93
50	6.48	6.65	7.03	7.54	7.88	8.21	8.63
60	6.19	6.37	6.80	7.38	7.76	8.13	8.60
80	5.93	6.12	6.55	7.13	7.51	7.88	8.36
100	5.78	5.97	6.40	6.99	7.38	7.75	8.24
120	5.33	5.53	6.01	6.66	7.08	7.49	8.02
150	4.31	4.57	5.13	6.01	6.55	7.08	7.75

Flood Level Duration / Frequency
W-114, Jibanpur (Gumti) ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	6.56	6.63	6.81	7.05	7.21	7.36	7.56
30	6.20	6.30	6.54	6.86	7.06	7.27	7.53
40	6.14	6.23	6.45	6.75	6.95	7.14	7.39
50	5.97	6.07	6.32	6.65	6.86	7.07	7.35
60	5.98	6.07	6.27	6.55	6.73	6.91	7.14
80	5.76	5.85	6.05	6.33	6.51	6.69	6.91
100	5.51	5.61	5.83	6.13	6.33	6.53	6.78
120	4.98	5.15	5.54	6.07	6.42	6.76	7.19
150	4.45	4.65	5.12	5.75	6.17	6.57	7.09

Flood Level Duration / Frequency
W-123, Ganga Sagar: Railway Bridge : Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	5.42	5.58	5.84	6.24	6.50	6.75	7.08
30	5.34	5.45	5.71	6.05	6.27	6.49	6.77
40	5.28	5.37	5.57	5.94	6.02	6.19	6.41
50	5.23	5.32	5.52	5.79	5.96	6.13	6.36
60	5.17	5.26	5.47	5.75	5.94	6.12	6.35
80	4.96	5.05	5.26	5.54	5.72	5.90	6.13
100	4.70	4.79	5.01	5.30	5.50	5.68	5.92
120	4.24	4.36	4.67	5.07	5.34	5.60	5.94
150	3.79	3.93	4.23	4.65	4.93	5.19	5.53

Flood Level Duration / Frequency
W-157, Ballah : Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	20.71	20.97	21.59	22.42	22.97	23.49	24.17
30	20.50	20.72	21.25	21.96	22.43	22.89	23.47
40	20.39	20.56	20.95	21.49	21.84	22.18	22.62
50	20.15	20.32	20.71	21.25	21.60	21.94	22.38
60	20.11	20.27	20.65	21.16	21.50	21.82	22.23
80	19.99	20.12	20.41	20.81	21.07	21.32	21.64
100	19.88	20.00	20.28	20.66	20.91	21.15	21.46
120	19.78	19.89	20.17	20.54	20.79	21.03	21.33
150	19.52	19.65	19.94	20.34	20.61	20.86	21.19

Flood Level Duration / Frequency
W-158, Chunarghat : Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	14.86	15.04	15.48	16.07	16.45	16.83	17.31
30	14.26	14.47	14.97	15.63	16.08	16.50	17.05
40	14.05	14.23	14.63	15.18	15.54	15.88	16.33
50	13.99	14.13	14.46	14.91	15.20	15.49	15.85
60	13.92	14.05	14.36	14.78	15.05	15.32	15.66
80	13.72	13.85	14.14	14.53	14.79	15.04	15.36
100	13.55	13.68	13.99	14.40	14.67	14.94	15.28
120	13.34	13.46	13.74	14.13	14.38	14.62	14.94
150	13.09	13.21	13.49	13.87	14.12	14.36	14.68

Flood Level Duration / Frequency
W-181, Gunabati Railway Bridge (d/s) ; **Maximum** 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	115.14	87.22	21.55	-66.82	******	******	******
30	115.07	87.15	21.47	-66.89	******	******	******
40	114.83	86.91	21.24	-67.13	******	******	******
50	114.83	86.91	21.24	-67.13	******	******	******
60	114.83	86.91	21.24	-67.13	******	******	******
80	114.45	86.53	20.86	-67.51	******	******	******
100	114.45	86.53	20.86	-67.51	******	******	******
120	114.45	86.53	20.86	-67.51	******	******	******
150	113.93	86.01	20.34	-68.03	******	******	******

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Flood Level Duration / Frequency
T-3A , Brahmanbaria Railway Bridge ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	5.86	6.02	6.36	6.82	7.12	7.41	7.79
30	5.80	5.92	6.19	6.56	6.81	7.04	7.35
40	5.68	5.78	6.01	6.32	6.53	6.72	6.98
50	5.58	5.69	5.93	6.27	6.49	6.70	6.98
60	5.49	5.60	5.87	6.22	6.45	6.68	6.97
80	5.28	5.39	5.65	6.01	6.24	6.47	6.76
100	4.92	5.03	5.29	5.64	5.87	6.09	6.37
120	3.98	4.15	4.53	5.05	5.40	5.73	6.15
150	2.54	2.74	3.20	3.82	4.23	4.62	5.13

Flood Level Duration / Frequency
T-79 ,Matlab Bazar ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	4.52	4.59	4.75	4.98	5.12	5.26	5.45
30	4.39	4.46	4.64	4.87	5.02	5.17	5.36
40	4.35	4.42	4.58	4.81	4.95	5.10	5.28
50	4.31	4.37	4.52	4.71	4.84	4.97	5.13
60	4.27	4.32	4.45	4.62	4.74	4.85	4.99
80	4.10	4.15	4.29	4.47	4.58	4.70	4.84
100	3.80	3.86	4.00	4.19	4.31	4.43	4.58
120	3.47	3.54	3.71	3.93	4.08	4.23	4.42
150	2.76	2.84	3.02	3.27	3.44	3.59	3.80

Flood Level Duration / Frequency
T-115, Duadkandi ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	4.71	4.83	5.11	5.46	5.73	5.97	6.26
30	4.63	4.73	4.98	5.30	5.52	5.72	5.99
40	4.55	4.66	4.90	5.22	5.44	5.65	5.91
50	4.50	4.60	4.84	5.15	5.37	5.57	5.83
60	4.46	4.56	4.79	5.10	5.30	5.50	5.76
80	4.31	4.39	4.58	4.84	5.01	5.17	5.39
100	3.98	4.07	4.28	4.55	4.74	4.91	5.14
120	3.49	3.59	3.84	4.18	4.40	4.61	4.89
150	2.79	2.88	3.08	3.34	3.52	3.69	3.91

Flood Level Duration / Frequency
T-230 . Bhairab Bazar Railway Bridge ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
-	1.11	1.25	2	5	10	20	50
20	5.99	6.12	6.44	6.86	7.14	7.41	7.76
30	5.76	5.89	6.20	6.60	6.87	7.13	7.47
40	5.64	5.76	6.03	6.40	6.65	6.89	7.19
50	5.55	5.68	5.97	6.36	6.62	6.87	7.19
60	5.42	5.55	5.87	6.30	6.58	6.85	7.20
80	5.26	5.38	5.67	6.07	6.33	6.58	6.91
100	4.90	5.03	5.34	5.75	6.02	6.28	6.62
120	3.98	4.16	4.58	5.15	5.52	5.88	6.35
150	2.80	2.94	3.26	3.68	3.97	4.24	4.59

Flood Level Duration / Frequency
T-240 . Bhavaniganj ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
-	1.11	1.25	2	5	10	20	50
20	2.98	3.12	3.45	3.88	4.17	4.45	4.80
30	2.96	3.09	3.40	3.82	4.10	4.36	4.71
40	2.94	3.07	3.37	3.78	4.06	4.32	4.66
50	2.85	2.99	3.30	3.73	4.01	4.28	4.63
60	2.74	2.88	3.21	3.65	3.94	4.22	4.58
80	2.63	2.77	3.11	3.57	3.87	4.16	4.53
100	2.39	2.54	2.89	3.37	3.69	3.99	4.39
120	1.84	2.05	2.54	3.20	3.64	4.06	4.61
150	1.48	1.68	2.16	2.81	3.24	3.65	4.18

Flood Level Duration / Frequency
T-275 , Baidyer Bazar ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
-	1.11	1.25	2	5	10	20	50
20	4.77	4.90	5.20	5.61	5.88	6.14	6.48
30	4.72	4.81	5.05	5.36	5.57	5.77	6.03
40	4.68	4.76	4.96	5.22	5.39	5.56	5.77
50	4.62	4.70	4.90	5.16	5.34	5.51	5.72
60	4.52	4.61	4.81	5.09	5.27	5.44	5.67
80	4.31	4.41	4.64	4.94	5.15	5.35	5.60
100	3.97	4.06	4.29	4.59	4.80	4.99	5.24
120	3.44	3.56	3.84	4.22	4.47	4.70	5.01
150	2.53	2.65	2.95	3.35	3.62	3.87	4.20

Flood Level Duration / Frequency
T-276 . Satnal ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	4.54	4.63	[illegible]	5.16	5.36	5.55	5.79
30	4.42	4.51	[illegible]	4.99	5.17	5.35	5.58
40	4.39	4.47	[illegible]	4.93	5.10	5.27	5.49
50	4.34	4.42	[illegible]	4.85	5.02	5.17	5.38
60	4.27	4.34	[illegible]	4.74	4.88	5.03	5.21
80	4.06	4.14	[illegible]	4.56	4.72	4.88	5.08
100	3.77	3.85	4.04	4.25	4.45	4.61	4.81
120	3.34	3.44	[illegible]	3.98	4.19	4.39	4.64
150	2.62	2.71	[illegible]	3.22	3.41	3.59	3.83

Flood Level Duration / Frequency
T-277 . Chandpur ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	4.21	4.27	[illegible]	4.64	4.78	4.91	5.08
30	4.16	4.22	[illegible]	4.54	4.66	4.78	4.93
40	4.13	4.18	[illegible]	4.49	4.60	4.71	4.85
50	4.10	4.16	[illegible]	4.46	4.58	4.69	4.84
60	4.06	4.11	[illegible]	4.38	4.48	4.57	4.70
80	3.90	3.95	[illegible]	4.22	4.33	4.43	4.55
100	3.70	3.75	[illegible]	4.06	4.18	4.29	4.44
120	3.37	3.45	[illegible]	3.85	4.01	4.16	4.35
150	2.85	2.92	[illegible]	3.34	3.50	3.65	3.85

Flood Level Duration / Frequency
T-296 , Akhaura ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years) 1.11	1.25	2	5	10	20	50
20	5.88	6.02	6.35	6.85	7.16	7.46	7.85
30	5.75	5.89	6.20	6.63	6.91	7.18	7.53
40	5.65	5.76	6.03	6.38	6.62	6.84	7.14
50	5.57	5.69	5.96	6.32	6.56	6.79	7.09
60	5.50	5.62	5.89	6.27	6.51	6.75	7.06
80	5.35	5.46	5.73	6.08	6.31	6.53	6.82
100	4.99	5.11	5.38	5.74	5.98	6.22	6.52
120	4.17	4.32	4.66	5.13	5.44	5.74	6.12
150	2.73	2.91	3.36	3.95	4.35	4.73	5.21

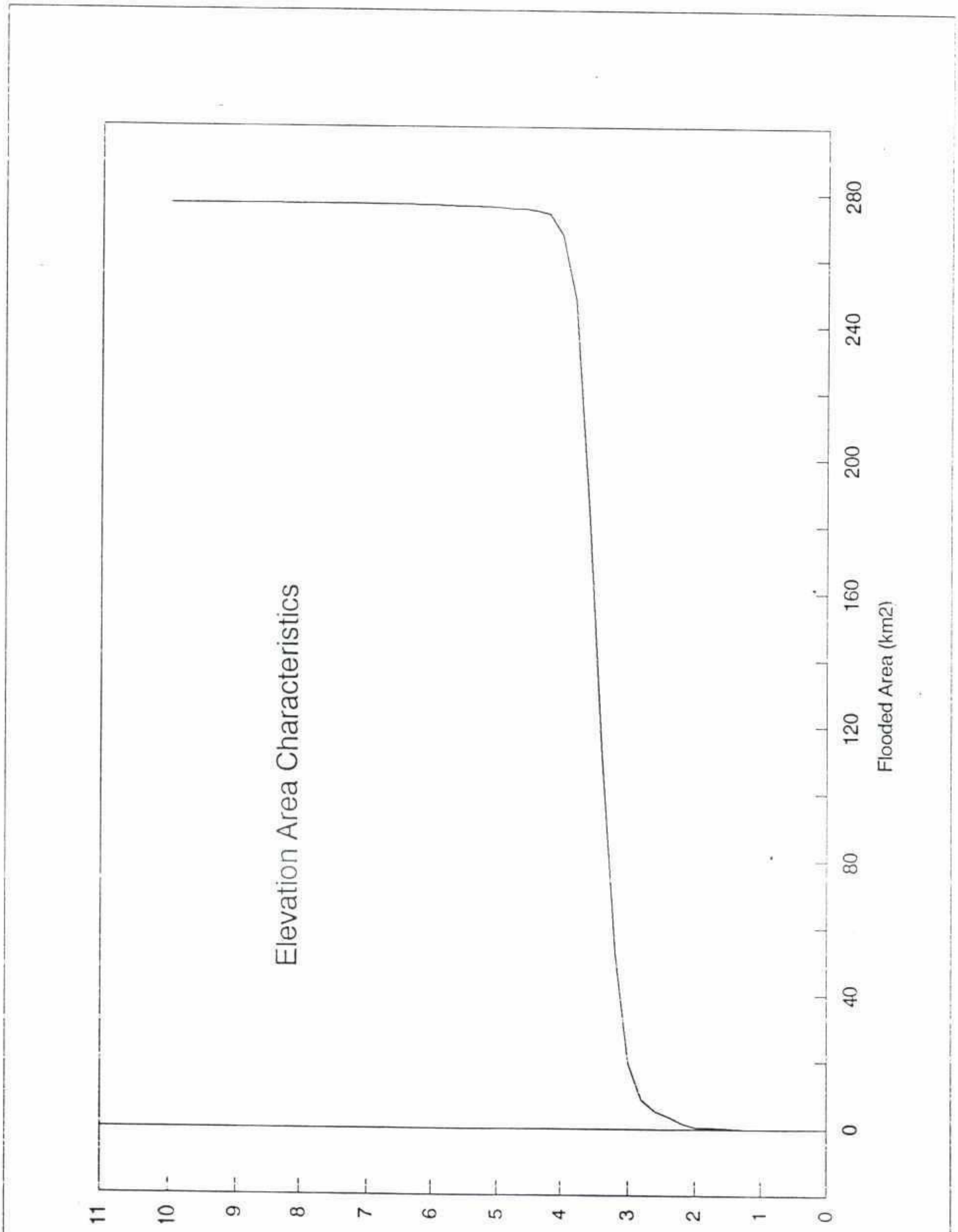
Flood Level Duration / Frequency
T-298, Nabinagar ; Maximum 10 day levels, Apr. - Oct.

Duration Days	Return Period (years)						
	1.11	1.25	2	5	10	20	50
20	5.64	5.76	6.05	6.44	6.69	6.94	7.26
30	5.52	5.63	5.88	6.23	6.46	6.68	6.96
40	5.43	5.52	5.73	6.01	6.19	6.37	6.60
50	5.36	5.46	5.67	5.96	6.15	6.34	6.58
60	5.30	5.39	5.61	5.91	6.10	6.29	6.53
80	5.12	5.21	5.42	5.70	5.89	6.06	6.29
100	4.74	4.83	5.05	5.35	5.54	5.73	5.97
120	3.95	4.09	4.42	4.86	5.15	5.43	5.79
150	2.66	2.83	3.21	3.74	4.08	4.41	4.84

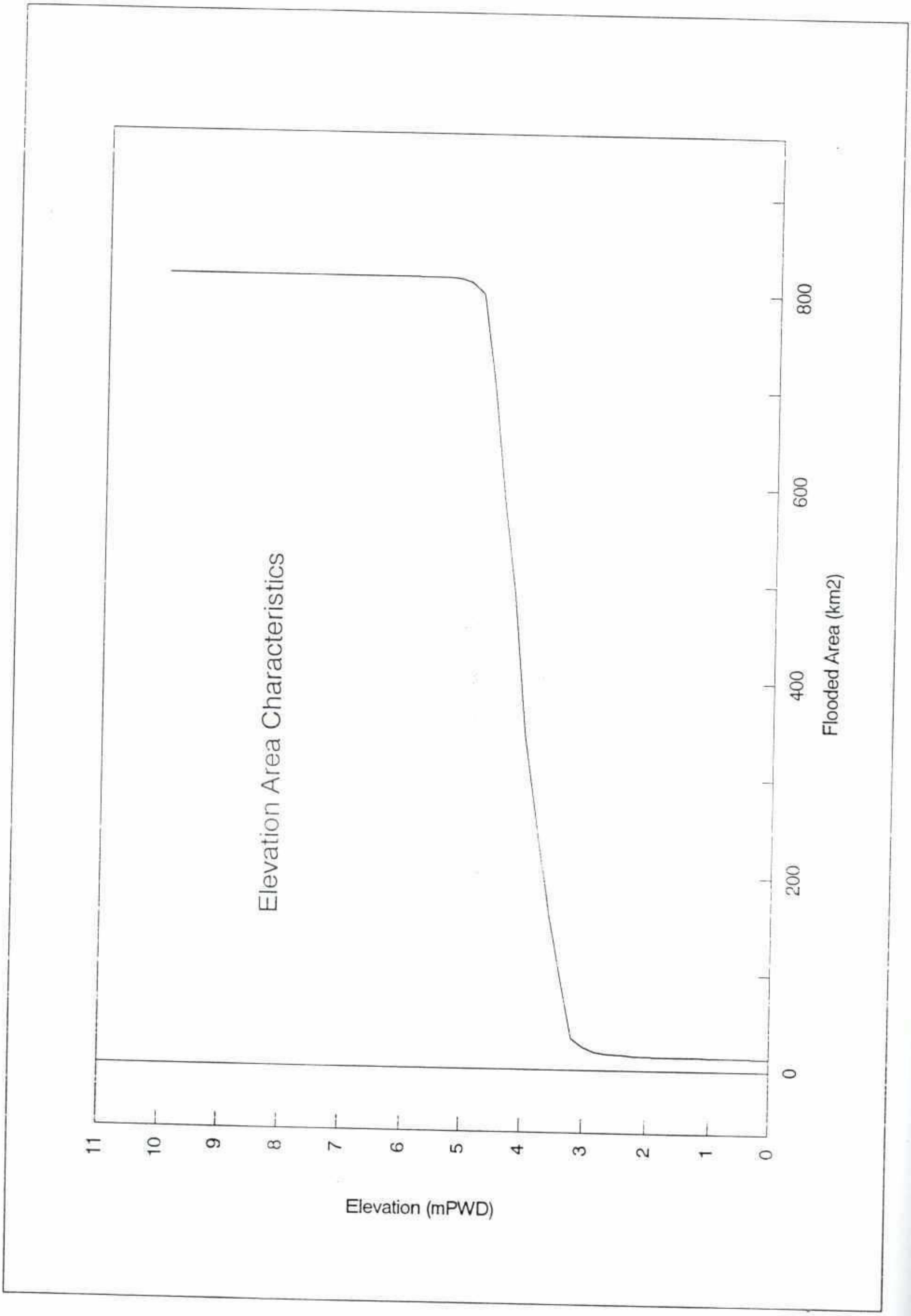
APPENDIX VII

PLANNING UNIT ELEVATION AREA CHARACTERISTICS

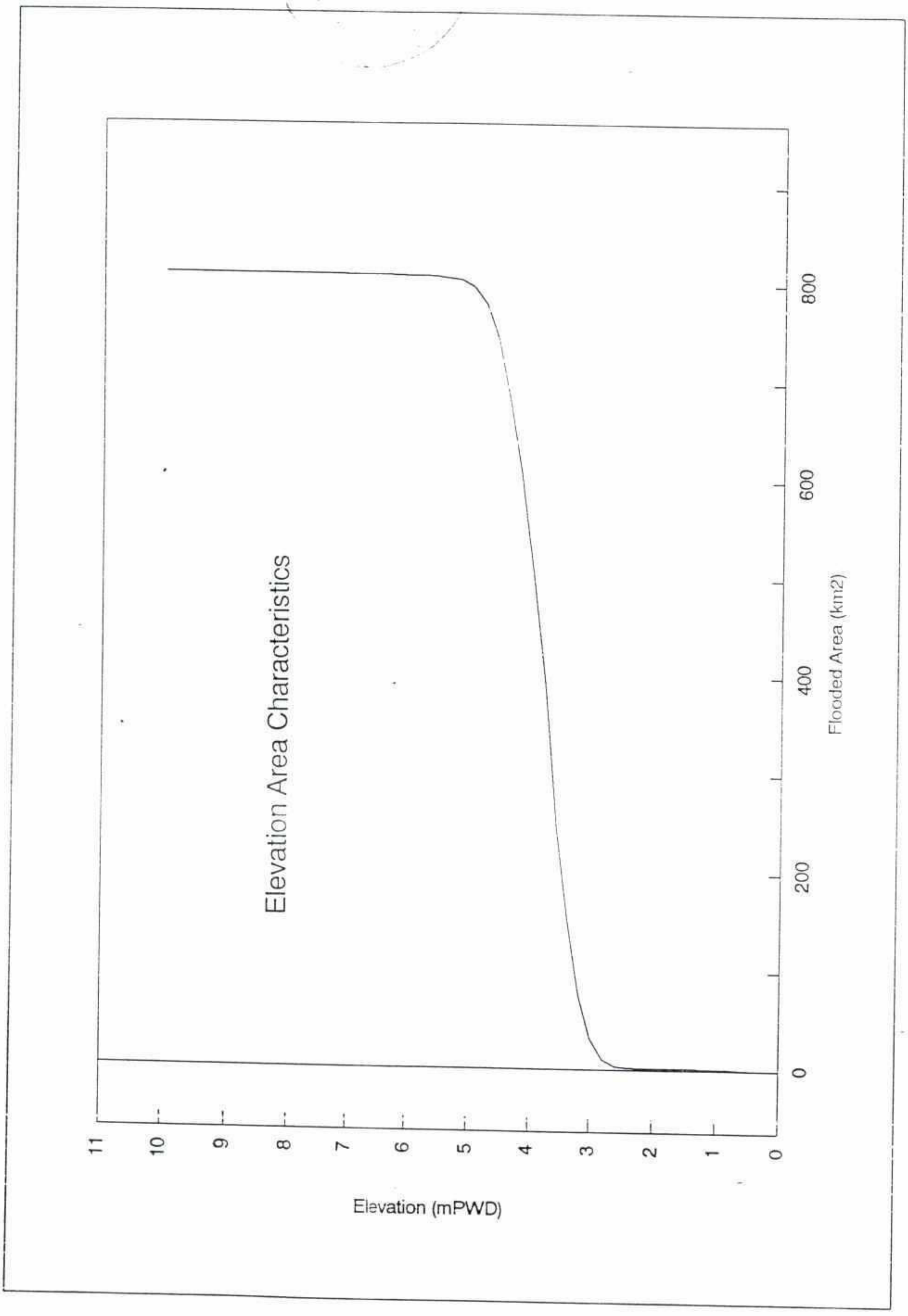
Polder 59/2 Planning Unit



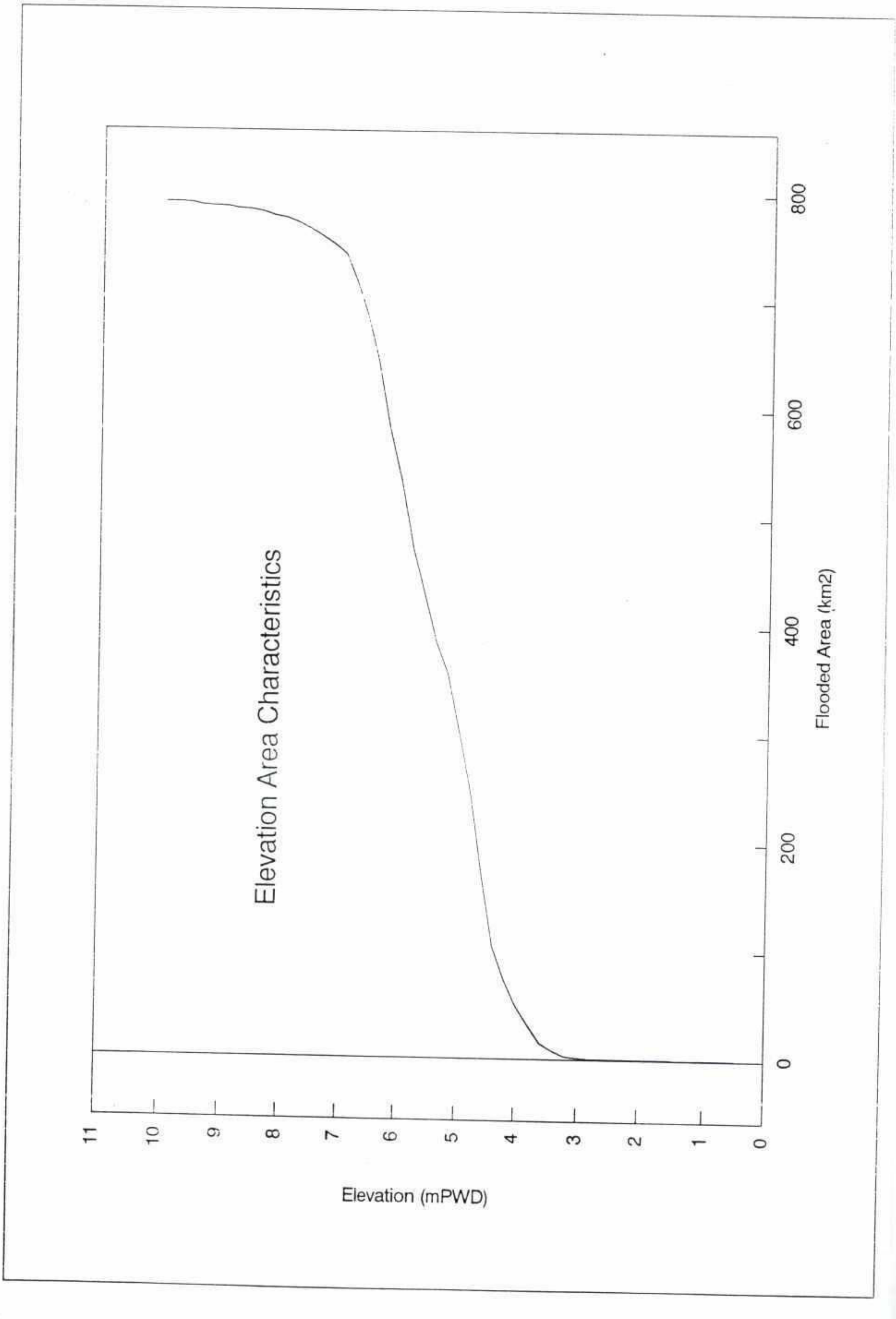
South Sudharam Planning Unit

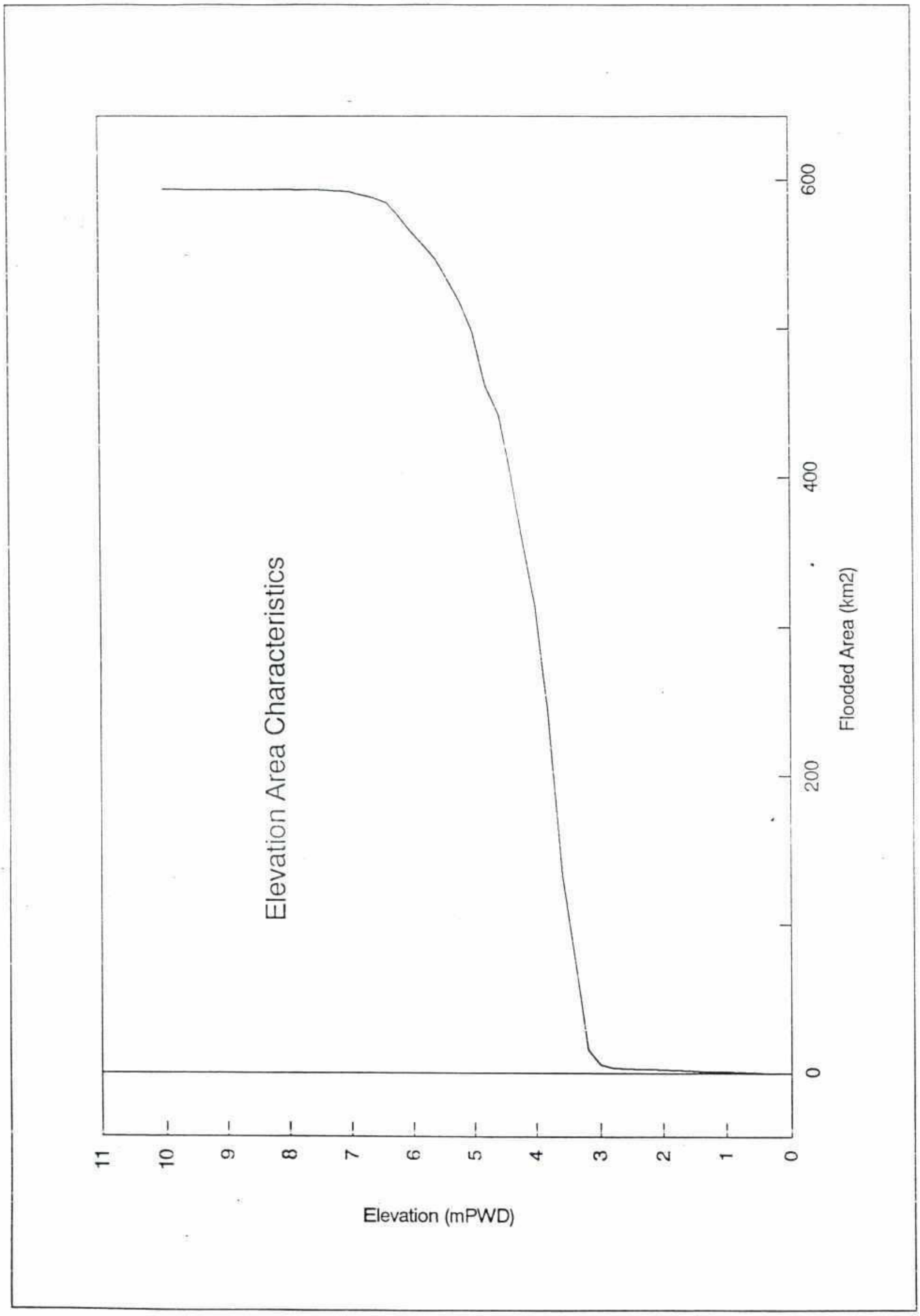


Noakhali North Planning Unit

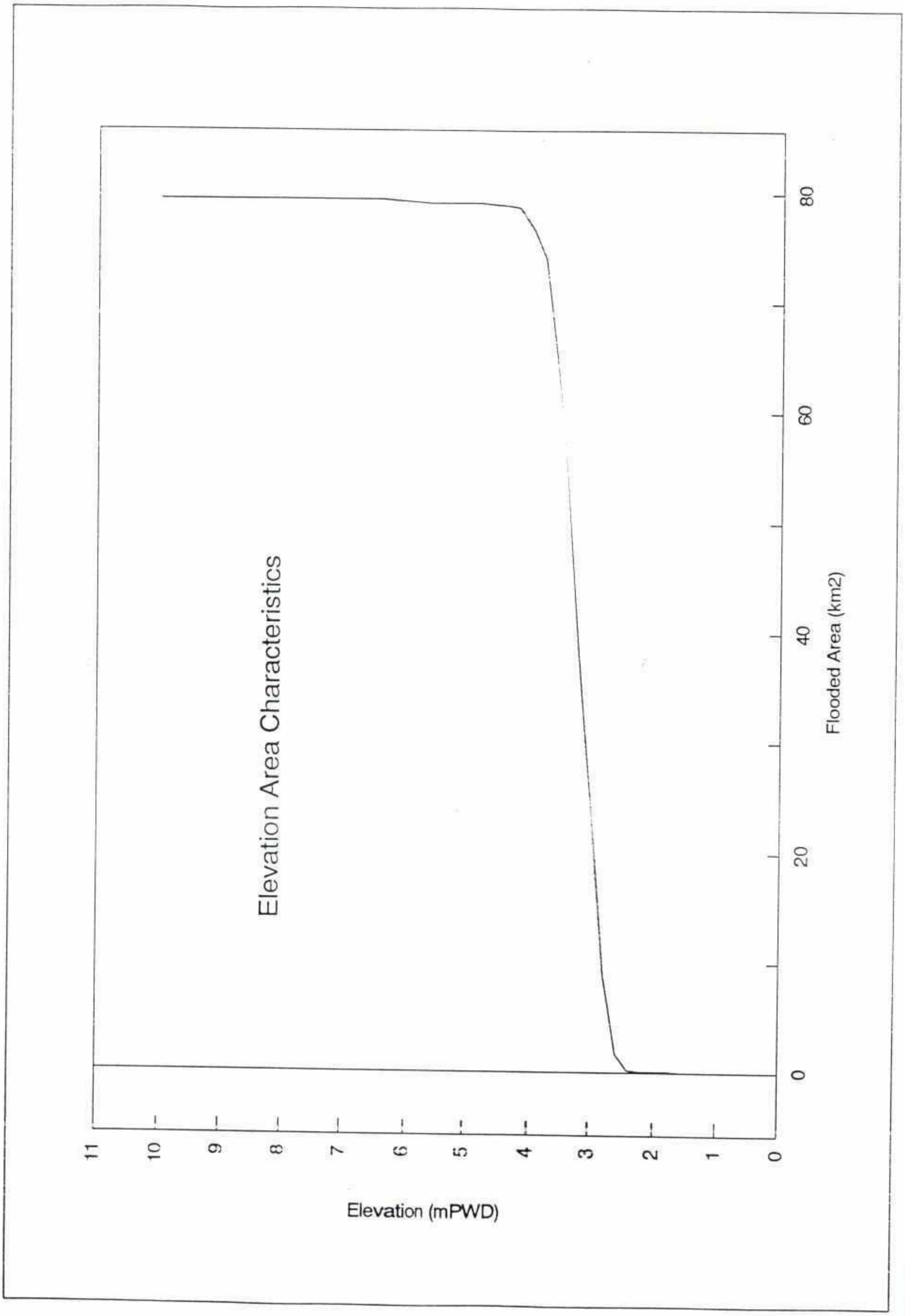


Little Feni Planning Unit

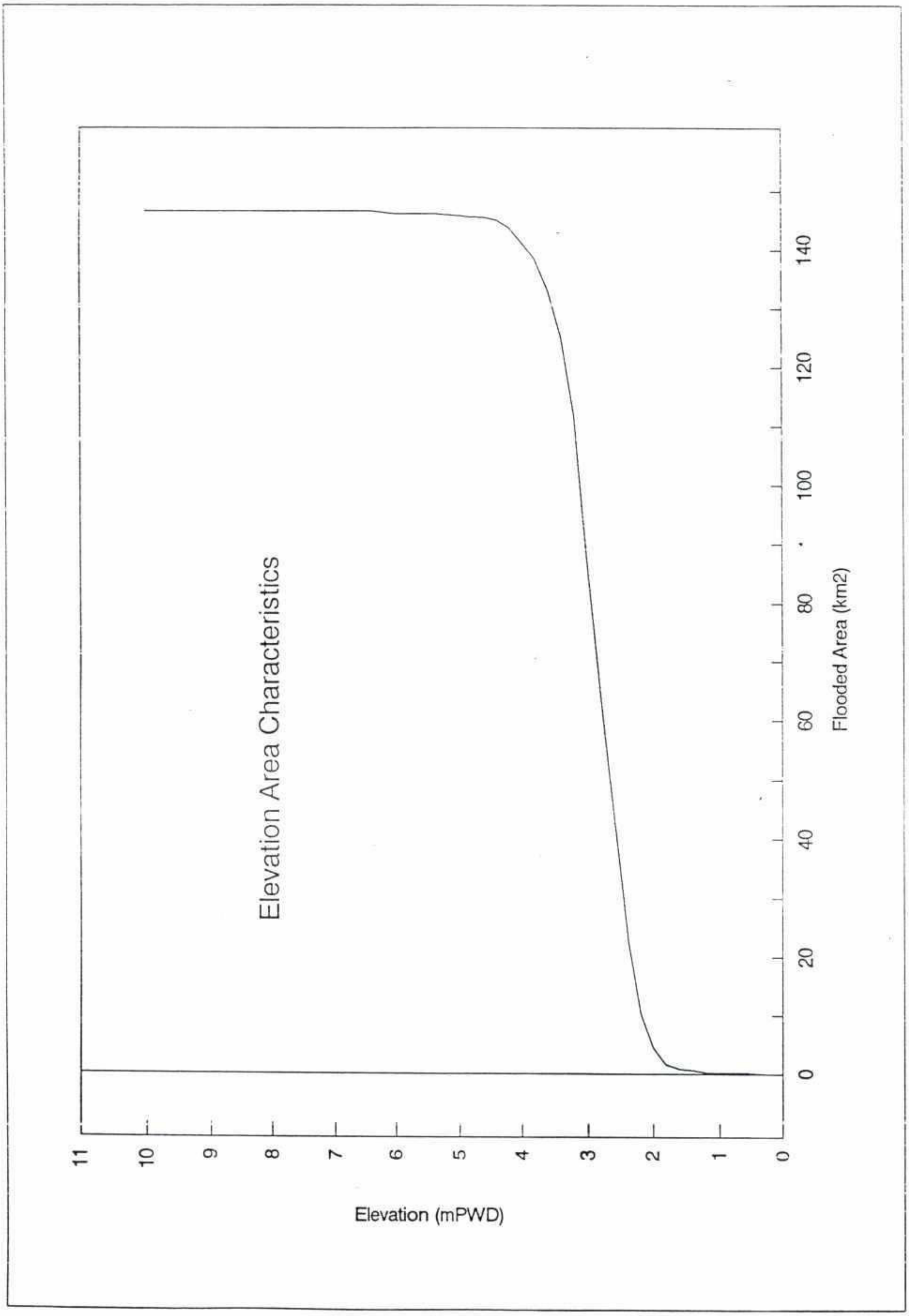



Elevation Area Characteristics
Elevation (mPWD)
0
1
2
3
4
5
6
7
8
9
10
11
Flooded Area (km2)
0
200
400
600

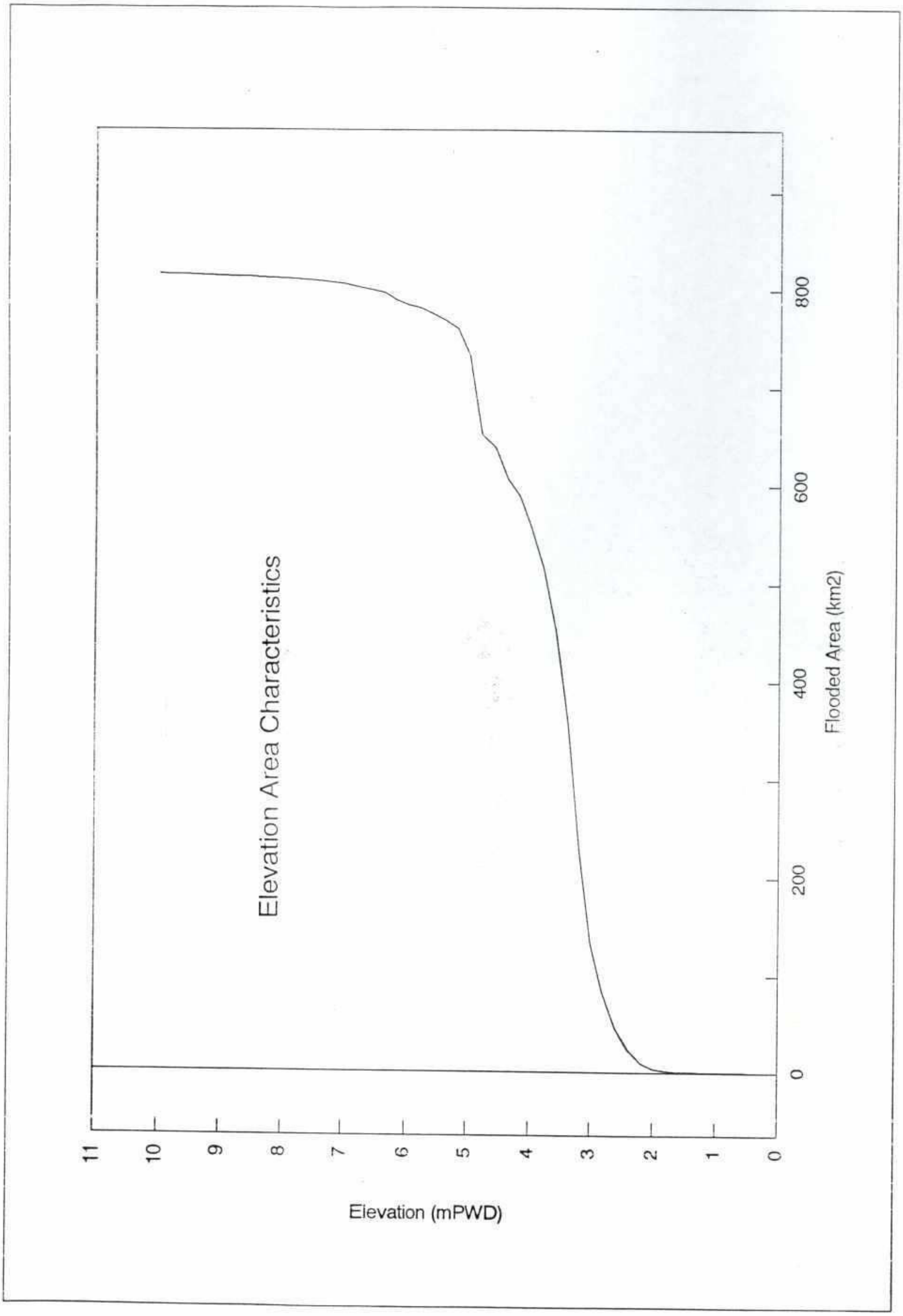
Chandpur Planning Unit



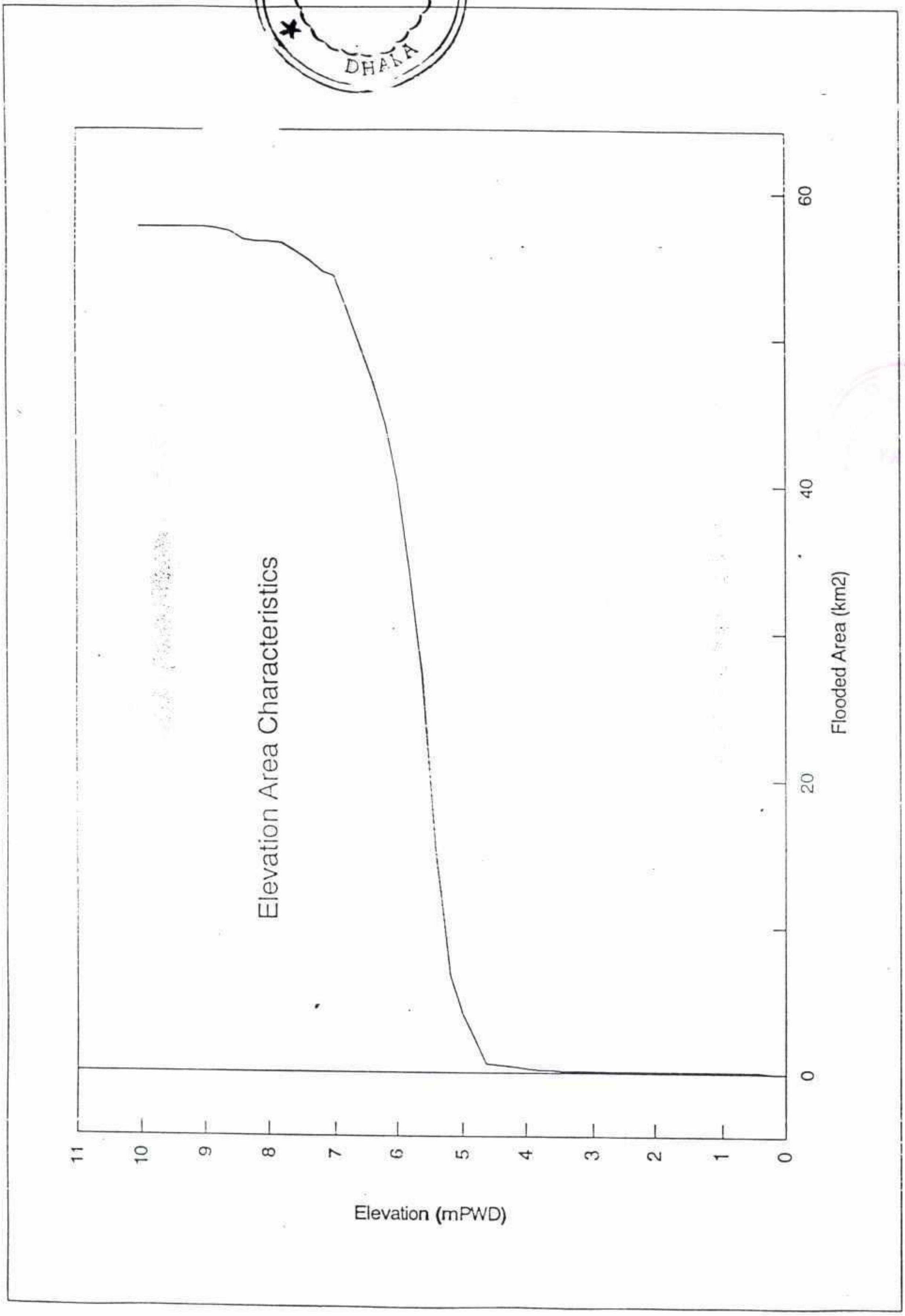
Megna-Dhonagoda Planning Unit



Dhonagoda Planning Unit



Sonaichari Planning Unit



Gumti-1 Planning Unit