STUDY OF TIDAL CHARACTERISTICS OF THE MEGHNA DELTA

by

IQBAL MATIN

In partial fulfillment of the requirements
for the degree of Master of Engineering
(Water Resources)

DEPARTMENT OF WATER RESOURCES ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DHAKA

AUGUST - 1984

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

WE HEREBY RECOMMEND THAT THE PROJECT REPORT PREPARED BY

IQBAL MATIN

ENTITLED "STUDY OF TIDAL CHARACTERISTICS OF THE MEGHNA DELTA" BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (WATER RESOURCES).

Chairman of the Committee — (Dr. J.U. Chowdhury)

Member — (Dr. A. Hannan)

Member — (Dr. M.A. Halim)

Head of the Department — (Dr. A. Hannan)

August 16, 1984

ACKNOWLEDGEMENT

i

The author expresses his indebtedness and deep sence of graditude to Dr. J.U. Chowdhury, Assistant Professor, Department of Water Resources Engineering, Bangladesh University of Engineering & Technology, Dhaka for his continuous guidance, valuable suggestions and constant encouragement throughout the course of this work.

The author wishes to express his sincere gratitude to Dr. A. Hannan, Professor and Head, Department of Water Resources Engineering and Dr. M.A. Halim, Associate Professor, Department of Water Resources Engineering for their encouragement and advice during this work.

Sincere thanks are due to Mr. Abdur Rahim, Lecturer, Department of Naval Architecture and Marine Engineering and Mr. Liaqat Ali Khan, Lecturer, Department of Water Resources Engineering with whom the author had many fruitful discussion.

The author wishes to thank Mrs. Hasina Khandaker, Assistant Tidal Analysts, Hydrographic Department, BIWTA and Mr. Mustaqur Rahman, Assistant Engineer, BWDB, for their assistance in data collection.

Gratitude is also expressed to computer centre staff for their co-operation in ensuring fast turn around of jobs submitted The assistance of Mr. M. Mofser Ali and Mr. Md. Shahid Uddin for their help in typing the scripts and for helping in the preparation of sketches are gratefully acknowledged.

NOTATIONS

This table presents the definitions of the symbols in common use in this project. When other symbols have been used they are defined in the test.

A	cross-sectional area of a channel
A'	surface area between any two adjacent depth contours
b	mean water surface width
C_o	celerity
E	tidal excursion
g	acceleration due to gravity
h	elevation of water surface with respect to horizontal datum
n	roughness coefficient
Q	tidal discharge
Q_R	residual discharge
S	water surface slope
t	time
v	average tidal velocity
Δx	length between longitudinal segments of the estuary
Y	water depth
Y'	contour depth from mean tide level.

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Contd.)

CONTENTS

CONTENTS (Contd.)

CHAPTER - 1

INTRODUCTION

1.1 General:

Tidal characteristics of delta are mainly dependent on topographical feature, freshwater flow from upland and tidal variation at the estuary entrance. Information on tidal characteristics are vital in the planning and design of water development projects. A number of irrigation, flood control, drainage and navigation projects are in the execution stage in the Meghna Delta. Several more project are in the planning stage. Hence study on tidal characteristics of the Meghna Delta will be useful in the planning and design of future projects.

Tides in the ocean and seas is the result of gravitational pull of the moon, the sun and the plannets and of the local meteorological disturbances. Fluctuation of sea level at the mouth of an estuary causes tides in the estuary. The tides in the Meghna estuary originates in the Indian Ocean. It travels through the Bay of Bengal and finally arrives at the estuary mouth. In the Meghna Delta (Fig.1.1) the main channel divides into a number of distributaries and it has three main ocean outfalls namely Shahabazpur channel, Hatiya channel and Tetulia channel. The main flow carrying channel is the Shahabazpur channel to the east of Bhola Island. The freshwater discharge mainly comes from the river Padma and the Meghna. Network type geometry fed with large freshwater flow during monsoon while small flow during dry season makes the tidal characteristics of the Meghna Delta unique.

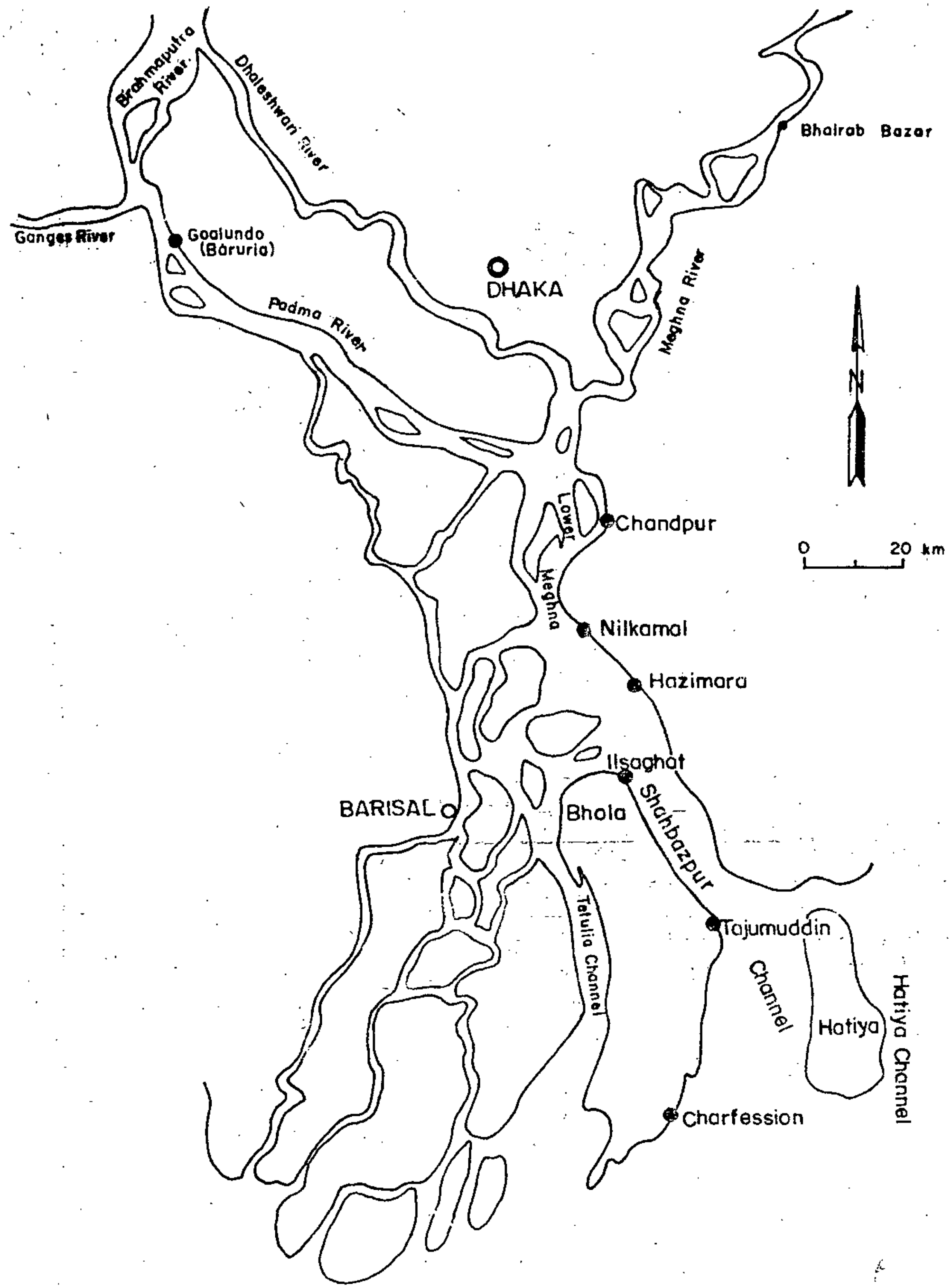


FIG. 1.1 THE MEGHNA DELTA

1.2 Objective:

In order to study the tidal characteristics of a complex river network like the Meghna Delta, topographical and hydraulic data are needed covering a long period of time. Unfortunately, data available from the study area is very limited. Further, the available records are not continuous. After painstaking scrutiny, continuous hydraulic data for the periods 7th April '77 to 18th April '77 and 12th April '79 to 26th April '79 were obtained. The objective of this project is to study the tidal characteristics of the Meghna Delta using those data.

CHAPTER - 2

THEORY

2.1 Tides in estuaries:

Rise and fall of sea level at the entrance of an estuary causes surface gradients which results in the propagation of gravity waves into the estuary[2]. The rate of propagation depends primarily on the depth of water and, in consequence, on the tidal range at the mouth.

The amplitude of tidal wave progressing upstream is influenced by the complexity of the estuarine geometry. Slow convergence of the estuarine geometry may tend to increase the tidal amplitude while rapid convergence is likely to produce continuous reflection from side walls and frictional dissipation of energy from the boundary eventually leading to considerable attenuation of the amplitude with the progress of the wave upland. Freshwater inflow and lateral run-off as well as frictional resistance cause the symmetrical tide of the open sea to become asymmetrical with the progress of tide upstream.

2.2 Terminologies:

Several terminologies are used in the tidal hydraulics. Some of them are described below:

Flood tide: The landward tidal flow during rising stage is known as flood tide.

Ebb tide : The seaward tidal flow during falling stage is known as ebb tide.

Highwater : The highest level reached by water surface at a section in one tidal oscillation is called the high water at that section.

Low water : The lowest level reached by water surface at a section in one tidal oscillation is called the low water at that section.

Mean tide level: The average of the highwater and low water is called the mean tide level.

Range : The difference between consequetive high and low water levels at a section is the range at that section.

Spring tide: Spring tides are the highest range tides occurring twice each month when the sun, earth and moon lie in a straight line. In Bangladesh this occurs about two days after full and new moon.

Neap tide : Neap tides are the lowest range tides occurring twice each month when the sun-earth moon angle is 90^{o}. In Bangladesh this occurs roughly 9 days after full and new moon.

Slack water: Slack water is the temporary stagnancy of tidal flow occurring at the turning of the tide from flood to ebb ar ebb to flood. High water slack occurs during the turning of the tide from flood to ebb whereas low water slack occurs during the turning of the tide from ebb to flood.

Synodic periods: A synodic period is the time over which the tide almost repeats itself. The main synodic periods are approximately 12½ hours, 25 hours, 14 days, 15 days, one month and one year.

Tidal wave velocity: The velocity at which the tidal wave travels is called the tidal wave velocity or celerity. It is given by,

$$\text{celerity } C_o \approx (gy)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (2.1)$$

where, g = acceleration due to gravity

y = water depth.

Tidal velocity: The velocity with which the water particle moves is called the tidal velocity. The average tidal velocity in a section is computed from

$$V = \frac{Q}{A} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.2)$$

where V = average tidal velocity

Q = tidal discharge

A = cross-sectional area

Tidal excursion: Tidal excursion is defined as the distance travelled by a percel of water during the period of the flood tide. Using cross-sectional average velocity, it may be estimated by the following formula

$$E = \int_{t_1}^{t_2} v \, dt \quad \ldots \quad \ldots \quad (2.3)$$

where E = tidal excursion

t_1 and t_2 = time limits

$\bar{v}$ = mean cross-sectional velocity.

Residual discharge : Residual discharge is the average discharge over a synodic period, preferably a fortnight. It may be expressed as

$$Q_R = \frac{1}{(t_e - t_s)} \int_{t_s}^{t_e} Q \, dt \quad \ldots \qquad (2.4)$$

where, Q_R = residual discharge

Q = tidal discharge

t_s = starting time of the synodic period

t_e = ending time of the synodic period.

Tidal pumping: In a network of tidal rivers, some portion of flood tide water entered through one branch may return through another branch during ebb. This phenomenon is known as tidal pumping. This can generate significant residual flows in a looped system of channel networks.

2.3 Continuity Equation:

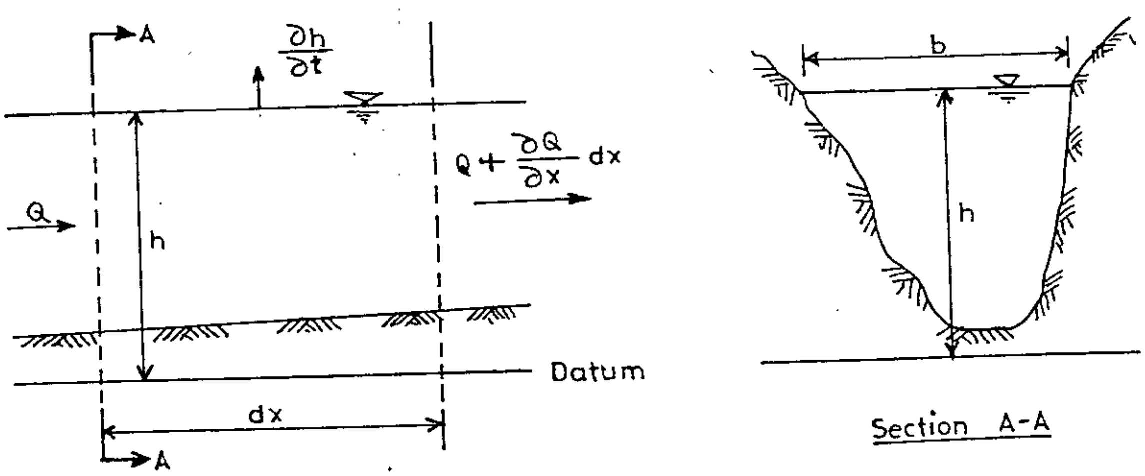


Fig. 2.1 Continuity principle applied to flow through a reach.

The equation of continuity for unsteady flow in tidal rivers may be established by considering the conservation of mass in an infinitesimal space between two channel sections shown in Fig. 2.1[1]. Let the channel be divided into short reaches having length dx between the cross-sections.

At a particular instant of time, t, let the mean surface width over the reach be 'b', such that the plan area of the water surface is 'bdx'.

If dx is so small that the whole water surface can be assumed to rise or fall at the same rate, the volume of water needed to change the surface level in time dt is

$$\left(\frac{\partial h}{\partial t}\right) dt\ bdx$$

where h is the elevation of water surface with respect to horizontal datum.

The volume of water flowing out of the reach is

$$\left(\frac{\partial Q}{\partial x}\right) dx\ dt$$

where Q is the flow rate.

Since the water is incompressible, the net change in discharge plus the change in storage should be zero, that is,

$$\left(\frac{\partial Q}{\partial x}\right) dx\ dt + \left(\frac{\partial h}{\partial t}\right) dt\ bdx = 0$$

Simplifying,

$$\frac{\partial Q}{\partial x} + b\ \frac{\partial h}{\partial t} = 0 \quad \ldots \quad \ldots \quad (2.5)$$

Eqn. 2.5 is known as the continuity equation.

2.4 Method of Cubatures:

Eqn. 2.5 can be used to compute discharges at various sections in an estuary if tide level data at every section and discharge data at one of the boundary section are known. The method is known as the method of cubature.

Integrating the continuity equation 2.5,

$$\int dQ = - \int b\left(\frac{\partial h}{\partial t}\right) dx \quad \ldots \quad \ldots \quad \ldots \quad (2.6)$$

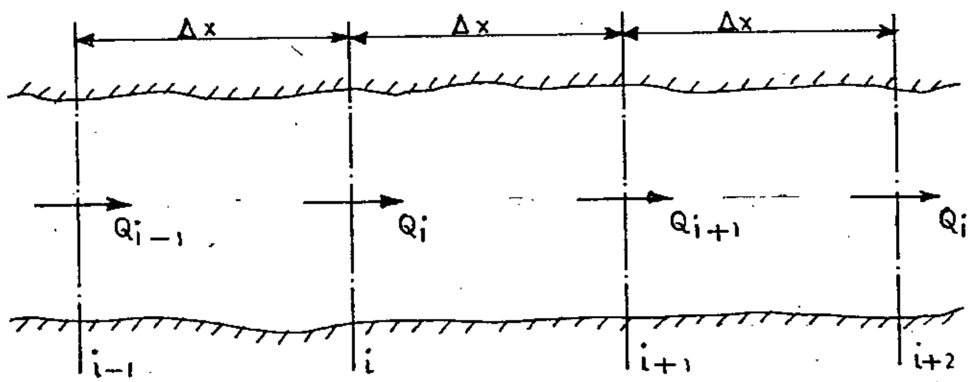


Fig. 2.2 Schemalization of a river reach

Figure 2.2 shows the plan of a channel portion. Variation of water level with time at every section is known. At section i-1, variation of discharge with time is known. The discharges at various time at the other sections Q_i, Q_{i+1}, Q_{i+2}......etc., are to be computed.

From equation 2.6 considering the channel reach between sections i-1 and i, we can write,

$$Q_i^2 - Q_{i-1}^2 = - \bar{b} \; \frac{\bar{\Delta h}}{\Delta t} \quad (x_i - x_{i-1}) \quad \ldots \qquad \ldots \qquad (2.7)$$

and hence,

$$Q_i^2 = Q_{i-1}^2 - \bar{b} \, \Delta x \, \frac{\bar{\Delta h}}{\Delta t} \qquad \ldots \qquad \ldots \qquad (2.8)$$

where, the subscripts indicate section number, the superscripts indicate time level and

$\bar{b}$ = average water surface width in the reach

Δx = length of the reach = $x_i - x_{i-1}$

$\bar{\Delta} h$ = average change in water level in time interval Δt.

The water surface width 'b' changes both with time and with distance. The average water surface width b is computed from

$$\bar{b} = \frac{b_{i-1}^1 + b_{i-1}^2 + b_i^1 + b_i^2}{4} \quad \ldots \qquad \ldots \quad (2.9)$$

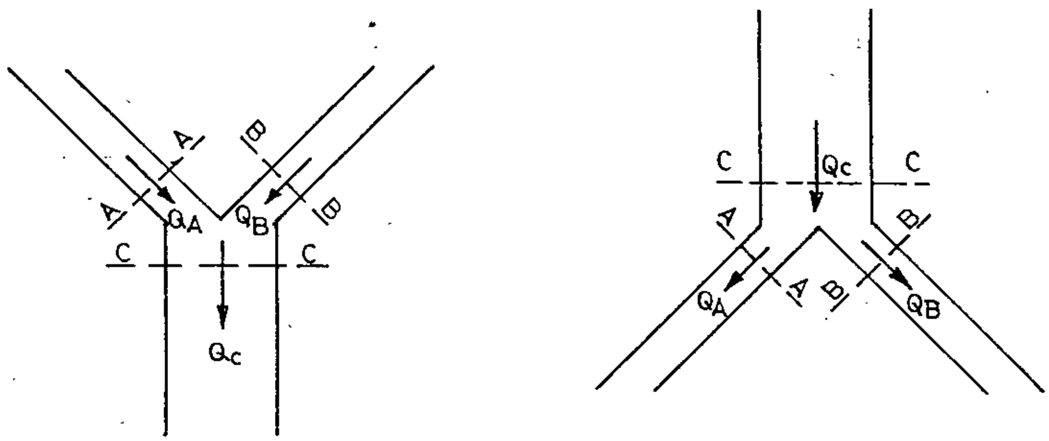
The average change in water level in the reach is computed from

$$\bar{\Delta} h = \frac{\left(h_{i-1}^2 - h_{i-1}^1\right) + \left(h_i^2 - h_i^1\right)}{2} \quad \ldots \qquad \ldots \quad (2.10)$$

From equation 2.8, the discharges at section i can be computed when the discharge at section i-1 is known. Using the computed discharge at section, i, discharge at the next section, i+1, can be computed and so on.

2.5 Computation of flow at a junction:

By the method of cubature, the discharge at successive sections in a branch can be calculated. To be able to continue the cubature computation beyond a junction, division of flow among the branch end sections has to be determined. Present study is restricted to a three-way junction. At a threeway junction either flows Q_A and Q_B from two channels combine to give Q_c in the third channel as shown in Fig. 2.3(a), or the flow Q_c from a channel divide into Q_A and Q_B into two branches as shown in Fig. 2.3(b).



(a) Addition (b) Division

Fig. 2.3 Division of flow at a junction

In the first case(Fig.2.3a), the discharge Q_c can be easily found by simply adding the two discharges, i.e.

$$Q_c = Q_A + Q_B \tag{2.11}$$

where Q_A and Q_B are determined by applying the method of cubature.

In the second case, Q_c from the upstream branch is divided into two downstream branches. A simple method is adopted here where the steady flow formula is applied. If the time interval is kept small, application of steady formula to gradually varied unsteady flow is acceptable.

Using Manning's formula for a rectangular channel we have

$$Q = \frac{1.486}{n} \; b.y^{1.67} \; S^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (2.12)$$

$$= \frac{1.486}{n} F$$

where $F = by^{1.67} \; S^{\frac{1}{2}}$

y = depth of flow

S = water surface slope

n = roughness coefficient

Assuming similar roughness coefficient for branched sections

$$Q_A = K \; F_A$$

and $Q_B = K \; F_B$

where F_A and F_B are values of $(by^{1.67} S^{\frac{1}{2}})$ at branch end sections A and B respectively.

$$Q_A = Q_c \frac{F_A}{F_A + F_B} \quad \ldots \quad \ldots \quad (2.13)$$

and $$Q_B = Q_c - Q_A \quad \ldots \quad \ldots \quad (2.14)$$

The water surface width, b, and the depth of flow, y, are known. The water surface slope, S, can be computed from water level data. Hence Q_A and Q_B can be computed from equations (2.13) and (2.14). Once the discharges at the branch-end sections are known, the discharges at successive sections can be determined by the method of cubature.

CHAPTER - 3

DATA COLLECTION AND ANALYSIS

3.1 Description of the project area:

The Meghna Delta shown in Figure 1.1 is the main ocean outfall of the Ganges-Brahmaputra-Meghna river system. It has about 712 km of channel divided into 15 reaches connected at 8 junctions. It has 3 ocean outfalls. The largest contribution of freshwater flow comes from the Brahmaputra[6]. The main flow carrying channel is the Shahbazpur channel to the east of the Bhola Island. The other important flow carrying channels are Hatiya channel and Tetulia channel. The Shahabazpur channel is also connected from the east by the Sandwip channel. The tide is mainly semi-diurnal in character but there are strong shallow water effects which distort the shape of the tidal hydrograph and create a fortnightly tide.

During the wet season the Ganges and the Brahmaputra rivers discharge enormous quantities of water which with the addition of local rainfall causes flooding in a large part of the delta. In the dry season there is a negligible amount of local rainfall and the low freshwater inflow allows saline seawater to penetrate into the upland.

3.2 Collection of data:

For the present study, data needed are the channel dimensions throughout the study area, variations of tide level with time at various locations, measurements of the freshwater inflow at Goalundo, Bhairab Bazar and Taraghat. Sounding charts of the rivers have been collected from Bangladesh Inland Water Transport Authority (BIWTA) and a list of them is given in the Table 3.1. Half hourly tide level recordings(3) are collected for 10 stations for the periods between 12th and 26th April, 1977 and 7th and 18th April, 1977 and the source of data is BIWTA. Mean daily discharge data from non-tidal rivers at Goalundo, Bhairab Bazar and Taraghat are collected from Bangladesh Water Development Board (BWDB)(4) for the same periods. Locations of discharge and water level gage stations are shown in Fig. 3.1. The discharge hydrographs are shown in Fig. 3.2. It is seen that the freshwater discharge in 1979 is significantly low compared to that in 1977. It further shows that freshwater flow from the Meghna basin is negligible compared to that from the Ganges and the Brahmaputra basins.

The periods between 12th and 26th April of 1979 and 7th and 18th April of 1977 have been taken because in these periods simultaneous water level and discharge data are available for all gaging stations in the study area. The quality of data is also better in those periods when compared to other available periods. The informations about the condition of the selected water level and discharge data are given in Table 3.2 and Table 3.3.

3.3 Estimating the missing water level data:

In the half hourly water level records, some data were missing due to the absence of gage reader, unfavourable condition of weather etc. To estimate the missing data, water level hydrographs have been plotted using available data and the missing data have been interpolated graphically as illustrated in the Fig.3.3.

TABLE - 3.1

LIST OF SOUNDING CHARTS

Sl. No.	River	Sheet No.	Year of Survey	Scale	Prepared by
1.	Shahbazpur Channel	E $\frac{27}{70}$ B	Jan '70	1/50000	BIWTA
2.	Shahbazpur Channel	E $\frac{27}{70}$ A	Jan '70	1/50000	BIWTA
3.	Meghna/Ganespur	E $\frac{60}{82}$ B	May '82	1/50000	BIWTA
4.	Meghna	E $\frac{60}{82}$ C	Nov '81 & Apr '82	1/50000	BIWTA
5.	Meghna & Padma	G $\frac{98}{77}$ A	Apr '77 & May '77	1/50000	BIWTA
6.	Padma	G $\frac{98}{77}$ B	,,	1/50000	BIWTA
7.	Padma	G $\frac{98}{77}$ C	,,	1/50000	BIWTA
8.	Padma	G $\frac{104}{78}$ C	Apr '78	1/25000	BIWTA
9.	Padma/Ganges Confluence	G $\frac{104}{78}$ D	May '78	1/25000	BIWTA
10.	Padma	G $\frac{104}{78}$ B	Apr '78	1/25000	BIWTA
11.	Meghna	C $\frac{32}{82}$ B	Apr '82	1/25000	BIWTA
12.	Meghna/Sitalakhya	C $\frac{32}{82}$ C	Apr '82	1/25000	BIWTA
13.	Meghna	S $\frac{196}{78}$ A	Jul '78	1/25000	BIWTA
14.	Meghna	S $\frac{196}{78}$ B	Jul '78	1/25000	BIWTA
15.	Meghna	S $\frac{196}{78}$ C	Jul '78	1/25000	BIWTA
16.	Meghna	S $\frac{196}{78}$ D	Jul '78	1/25000	BIWTA
17.	Tetulia to Nalchiti	-	1968-69	1/100000	EPIWTA
18.	Shabazpur Channel (South Hatiya to Amani Bazar)	E $\frac{60}{82}$ A	Feb '82	1/50000	BIWTA
19.	Hatiya Channel (Sandwip to South Hatiya)	E $\frac{55}{81}$ B	Mar '81	1/50000	BIWTA
20.	Sandwip & Hatiya Channel from Chittagong to Hatiya	BD HATIA 82 100 01	Nov '82	1/100000	BIWTA

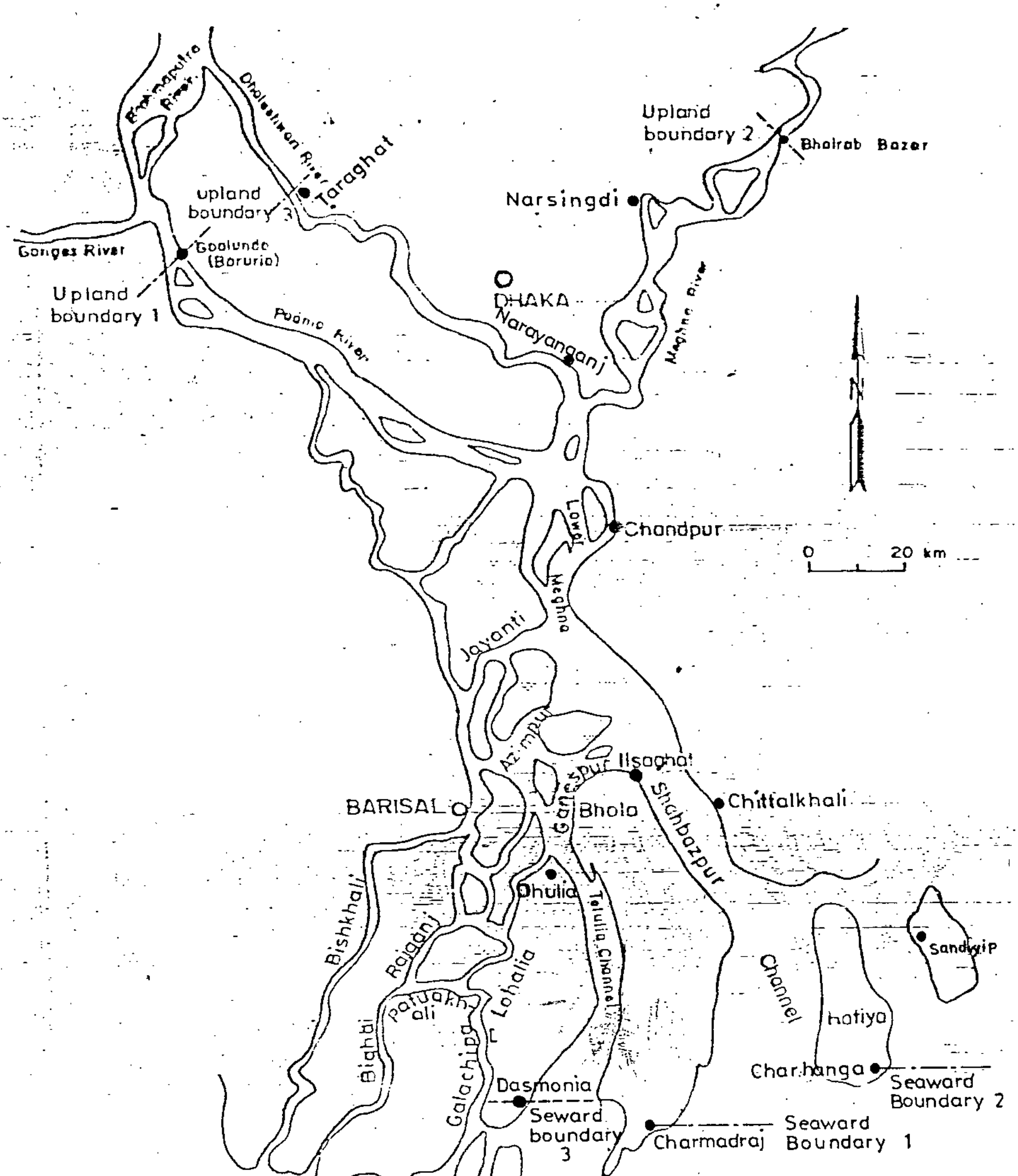


FIG. 3.1 MEGHNA DELTA SHOWING THE LOCATION OF DISCHARGE AND WATER LEVEL GAGE STATIONS.

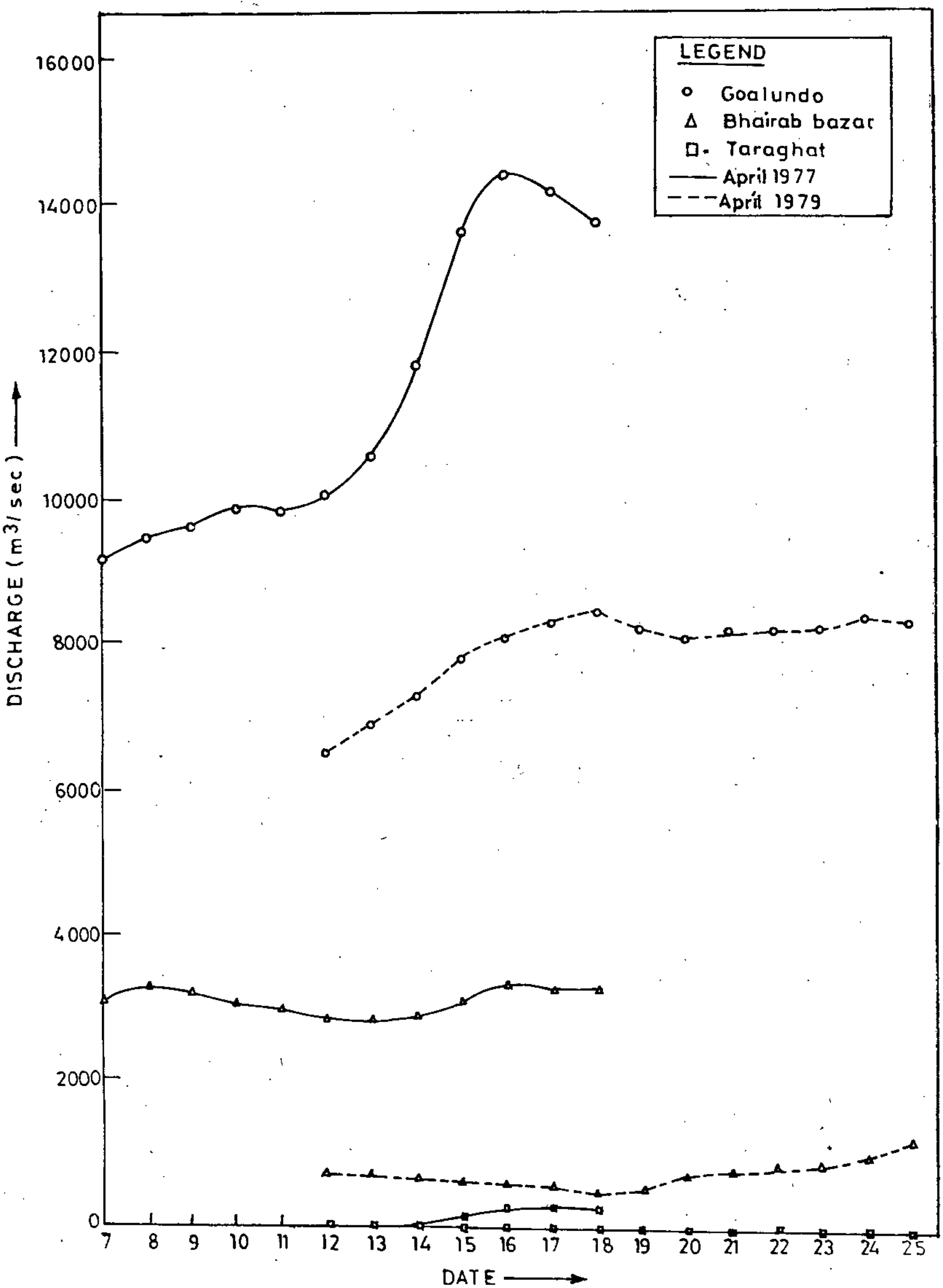


FIG. 3.2 HYDROGRAPH OF THREE UPLAND BOUNDARIES.

TABLE - 3.2

CONDITION OF WATER LEVEL DATA

No.of the gage station	Name of the station	Source of data	Condition of data	
			For April 1977	For April 1979
1	Narayanganj	BIWTA	Irregular	Irregular
2	Narsingdi	BIWTA	Irregular	Irregular
3	Chandpur	BIWTA	Irregular	Regular at ½ hour interval
4	Ilshaghat	BIWTA	Regular at ½ hour interval	Regular at ½ hour interval
5	Chittalkhali	BIWTA	Regular at ½ hour interval	Regular at ½ hour interval
6	Char Madraj	BIWTA	Irregular	1 hour interval
7	Dhulia	BIWTA	Regular at ½ hour interval	Regular at ½ hour interval
8	Dasmonia	BIWTA	Regular at ½ hour interval	Irregular
9	Sandwip	BIWTA	Regular at ½ hour interval	Irregular
10	Char Changa	BIWTA	Regular at ½ hour interval	Irregular

TABLE - 3.3

CONDITION OF FRESHWATER DISCHARGE DATA

Name of the station	Source of Data	Year	Condition of data
Goalundo	BWDB	1977	Available
Goalundo	BWDB	1979	Available
Bhairab Bazar	BWDB	1977	Estimated from the rating curve
Bhairab Bazar	BWDB	1979	Estimated from the rating curve
Taraghat	BWDB	1977	Estimated from the rating curve
Taraghat	BWDB	1979	Available

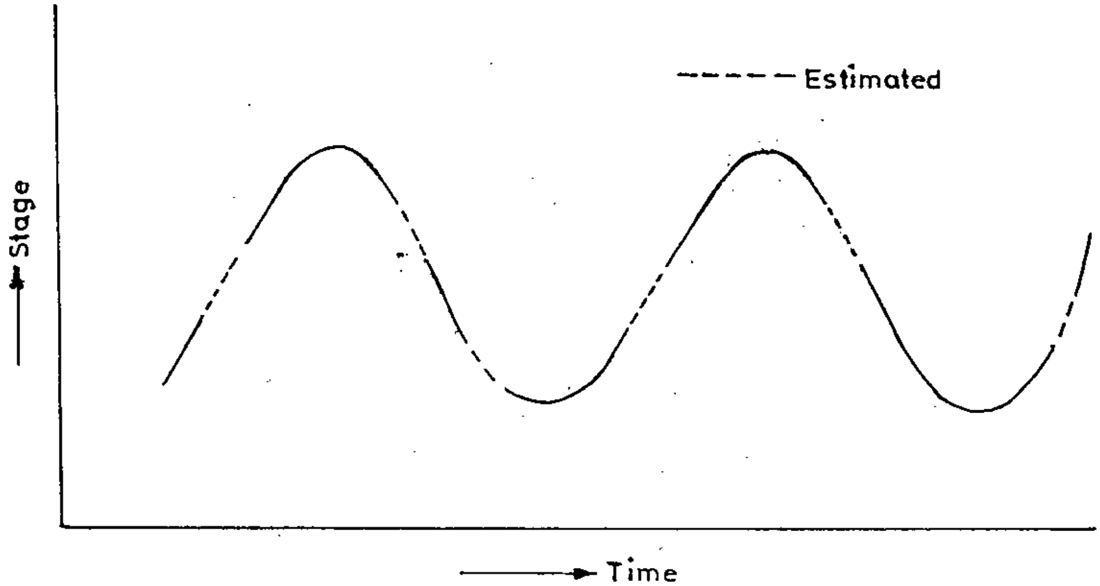


Fig. 3.3 Estimation of missing water level data.

3.4 <u>Estimating the missing discharge data:</u>

In the period of April 1977, the daily discharge data of Goalundo, and in April 1979, the daily discharge data of Goalundo and Taraghat were available from BWDB. But the discharge data of Bhairab Bazar and Taraghat in April 1977 and that of Bhairab Bazar in April 1979 were not available. However daily stage data were available for those stations. The missing discharge data have been estimated by drawing rating curves for those stations. The rating curves are shown in Fig. 3.4. The errors in the estimated discharge will have insignificant effect on the results of this study. This is because the combined discharges of Meghna and Dhaleshwari is very low compared to that of Padma at Goalundo as can be seen from the Fig. 3.2. A study by IECO[8] shows that the discharge of Meghna falls within standard deviation of the discharge of the Padma.

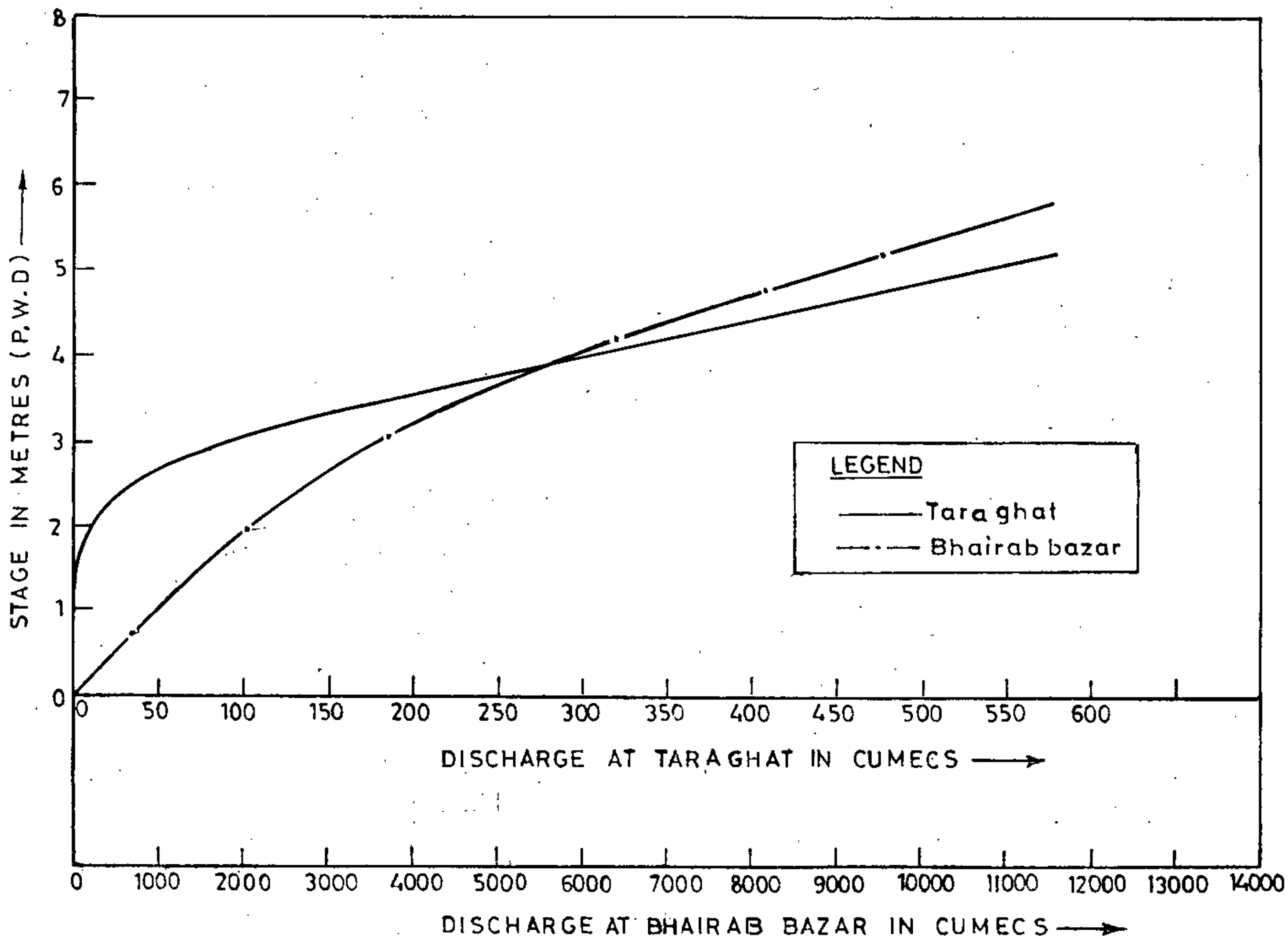


FIG. 3.4 RATING CURVES

3.5 <u>Adjustment for datum:</u>

Out of 10 gage stations, water level records at 5 station were recorded with respect to PWD datum. The stations were Narayangang, Narsingdi, Chandpur, Dhulia and Dasmonia. At remaining 5 stations water levels were recorded with respect to local chart datums. But for present study, water level data with respect to a common datum is needed and PWD datum is selected. The relation between the chart datum and PWD datum at Ilshaghat and Sandwip are known. But the same are not known at Charmadraj, Charchanga and Chittalkhali.

To find out the relationship between the PWD and chart datum at the 3 stations, mean tide levels with respect to chart datums are plotted against distance along Hatiya channel-Lower Meghna, Shahbazpur-Lower Meghna and Tetulia-Ganespur-Lower Meghna as shown in the Fig. 3.5. Similar curves were also drawn using available mean tide levels with respect to PWD datum. Then the vertical difference between the two curves gives the adjustment necessary in water level records at a gage station. This process is illustrated in the Fig. 3.5.

It is seen from the figure that the mean level at Dhulia is significantly deviated from mean level curve although the records were mentioned to be with respect to PWD datum. In the present study the datum of that station was also adjusted.

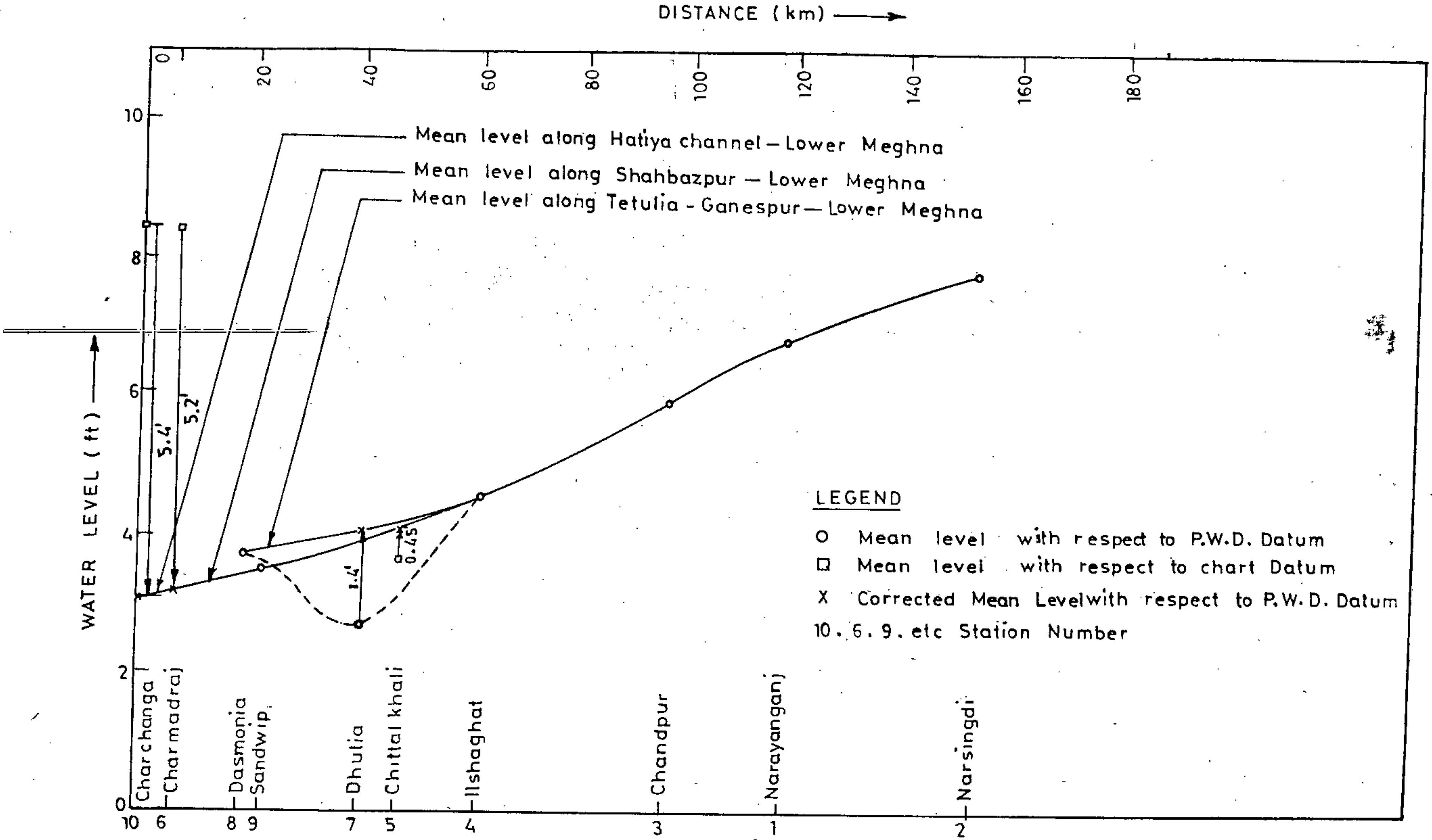


FIG. 3.5 ADJUSTMENT FOR DATUM

3.6 Schematization:

In a one dimensional finite difference formulation it is necessary to divide the estuary into a discrete number of longitudinal segments and to assign representative geometric characteristics to these segments. The required geometric quantities include the surface width, cross-sectional area and the mean depth. Since the number of segments which can be considered is limited, some degree of simplification and averaging is necessary; the process is called schematization[5].

The Meghna Delta has been schematized by dividing the branches into small reaches of length, $\Delta x = 10$ km. The schematized portion of the Meghna Delta has 3 upland discharge boundaries at Goalundo, Bhairab Bazar and Taraghat and 3 seaward boundaries at charMadraj, Char changa and Dasmonia. It has 15 branches and 8 junctions. The schematization resulted in a total of 85 computational sections. Obviously, branch lengths were not exact multipile of the chosen Δx and the nearest whole number was selected in such a way that the increased length in one branch was approximately compensated by decreases in other branch lengths[6]. Actual branch lengths and their schematized lengths are presented in Table 3.4 while details of the schematization have been shown in Fig.3.6.

3.7 Determination of representative geometric parameters:

After schematization the geometric parameters of an elemental reach extending $\Delta x/2$ on either side of a section was extracted by extensive analysis of sounding charts of the rivers. The cross-sections were represented by equivalent rectangular sections. The

TABLE - 3.4

LENGTHS OF VARIOUS BRANCHES OF THE MEGHNA DELTA

Branch No.	Name of the river	Actual length (km)	Schematrised length in numbers of Δx(= 10 km)
1	Padma River	96.5	10
2	Meghna River	80.5	8
3	Dhaleswari River	86.6	9
4	Meghna River	21.8	2
5	Lower Meghna	38.5	4
6	Lower Meghna	7.5	1
7	Lower Meghna	27.5	2
8	Lower Meghna	45.0	4
9	Shahbazpur Channel	45.0	5
10	Hatiya Channel	60.0	6
11	Ganespur River	27.5	2
12	Tentulia River	56.0	6
13	Azimpur Dharmaganj River	46.5	5
14	Tentulia River	15.8	1
15	Jayanti River	56.7	5
		711.4	70

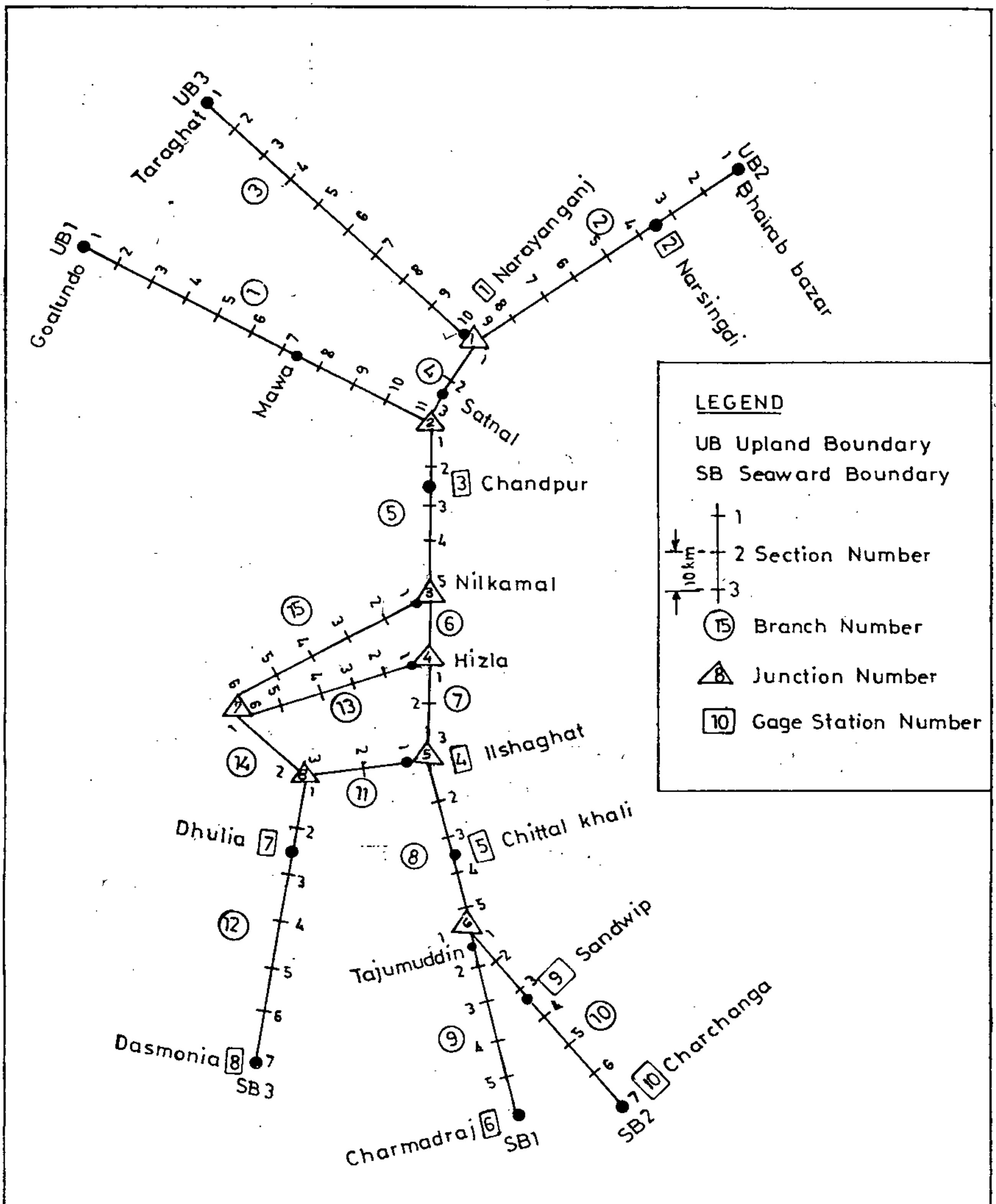


FIG. 3.6 SCHEMATIC REPRESENTATION OF THE MEGHNA DELTA.

width and the mean depth at a section must represent average topographical characteristics of a reach. This is best achieved by determining the volume of water contained between adjacent sections and lying below a given water level, together with the plan surface area between sections[1]. The volume was determined from depth contours drawn on sounding charts. A representative area was then obtained by dividing the volume by the reach length which may be expressed as

$$A = \frac{\sum_i \Delta A'_{i,i+1}\left(Y'_i + Y_{i+1}\right)}{2\Delta x} \qquad (3.1)$$

Representative mean depth was obtained by dividing the volume by the surface area

$$Y = \frac{\sum_i \Delta A'_{i,i+1}\left(Y'_i + Y_{i+1}\right)}{2\sum_i \Delta A'_{i,i+1}} \qquad (3.2)$$

Width of the section was obtained by dividing the surface area by the section length.

$$b = \frac{\sum_i \Delta A'_{i,i+1}}{\Delta x} \qquad (3.3)$$

where, $\Delta A'$ = surface area between any two adjacent depth contours

Y' = contour depth from mean tide level

i = contour number

A = Area of the section

b = width of the section

Y = mean depth of the section

Variation of computed mean depth, cross-sectional area and width along channels are presented in Fig.3.7. It shows that the area and width decrease with distance from sea ward boundary towards upland but the variation of depth with distance does not follow that rule.

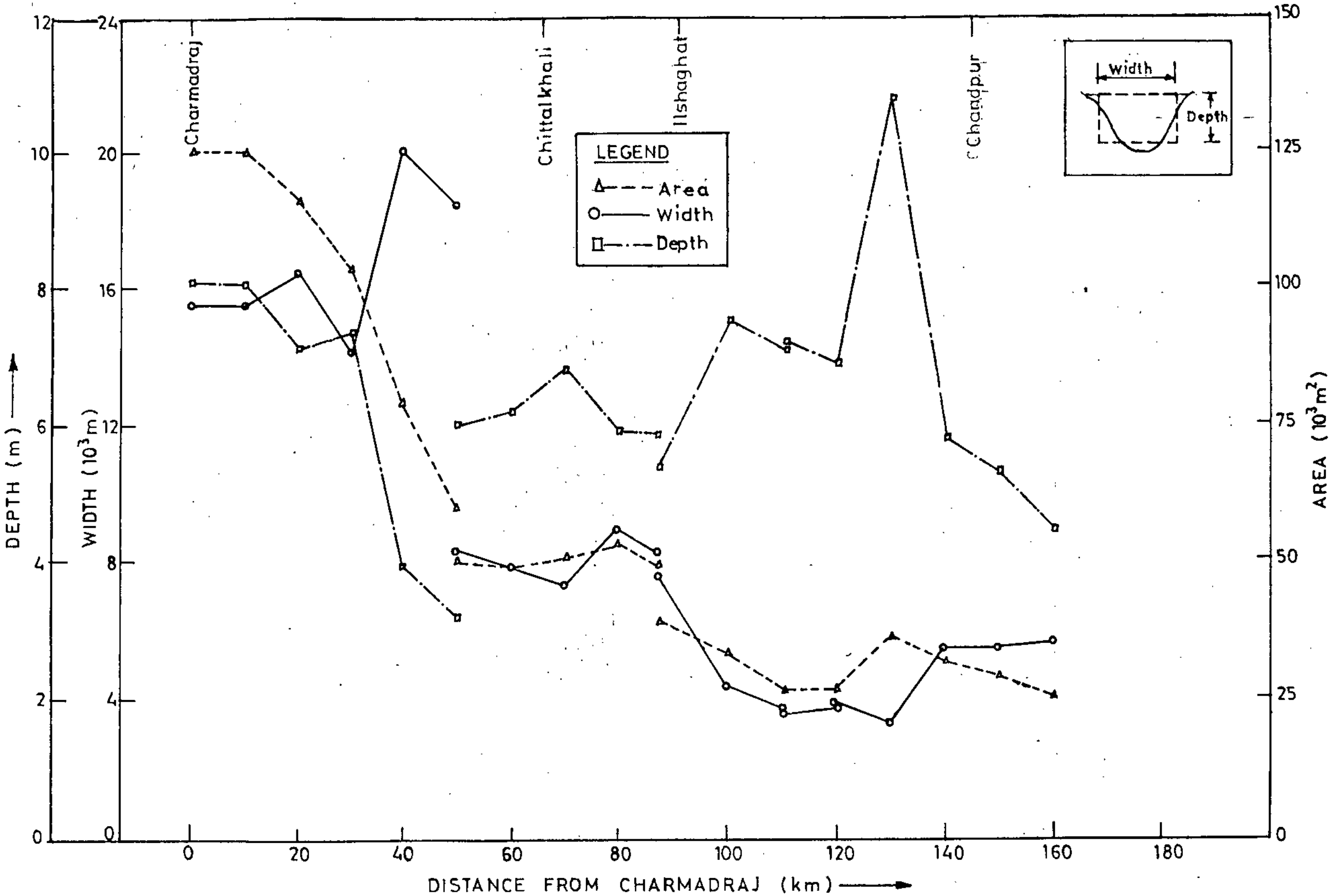


FIG. 3.7 VARIATION OF MEAN DEPTH, WIDTH AND AREA WITH DISTANCE.

CHAPTER - 4

DETERMINATION OF TIDAL CHARACTERISTICS

4.1 General:

Tidal characteristics of an estuary can be studied directly if extensive data on discharge hydrograph for a tidal period, tide level hydrographs, depth of flow, water surface width and water area are available at various locations for a continuous period. The data available from the Meghna Delta was very limited. As described in the previous chapter, only the daily discharge data were available at three upland boundary sections and tidal hydrographs were available only at ten gaging stations. This did not permit direct study of the tidal characters based on field data. An indirect approach has been followed here by applying the method of cubature. The method gave discharges at various sections and tidal characteristics were determined by analysing the computed discharges.

4.2 Cubature Calculation:

Application of the method of cubature requires observed tide level hydrographs at every computational section of the schematization. Tide level hydrographs were available only at 10 gage stations as shown in Figure 3.1. Tide level at intermediate sectionswere determined by linear interpolation from two gage stations. The computation starts from the upland boundary section using observed discharge data. The discharge at boundary section was assumed constant for two tidal cycles in a day. This is not introduced serious error into the computations as the discharge boundary sections were situated on non-tidal reach of the rivers. Then the cubature calculations were performed using the IBM 370/115 computer at BUET. A computer programme, for this purpose, was developed by Chowdhury earlier.[7] Typical computed discharge hydrographs are shown in Figure 5.11 . Using the computed discharges at various sections, mean tidal velocity, tidal excursion and residual discharges were determined.

4.3 Tidal Velocity:

Tidal velocity can be computed directly from $V = Q/A$ using the computed discharge. Both discharge and water area at a section change with time. Due to insufficient geometric data, variation in water area with respect to time could not be determined. Constant water area corresponding to mean depth has been used in the computations. In other words, tidal velocity has been assumed directly proportional to the computed discharge, the constant of proportionality being inverse of the mean water area. As a result of this simplification, computed velocity will be greater during high water while smaller during low water periods.

4.4 Tidal Excursion:

Tidal excursion has been computed by approximating the equation 2.3 in the following form

$$E = \sum_{j=1}^{n} V^{j}_{i} \, (t^{j} - t^{j-1}) \tag{4.1}$$

where, E = Tidal excursion

V_i^j = Tidal velocity at the ith section at jth time level

t^{j-1}, t^j = time levels.

n = number of time intervals

In the present study, a constant time interval of 30 minutes has been used i.e., $\Delta t = t^j - t^{j-1}$ = 30 minutes. In equation 4.1, velocity at the end of the time interval has been used.

4.5 Residual Discharge:

In order to compute residual discharge, eqn. 2.4 is approximated by

$$Q_R = \frac{1}{n\,\Delta t} \sum_{j=1}^{n} Q_i^j \, \Delta t \qquad (4.2)$$

where, Q_i^j = Discharge at ith section and jth time

$\Delta t = (t^j - t^{j-1})$ = time interval

n = number of time interval

Q_R = residual discharge at the end of the period $(t^n - t^0)$ i.e., $n\,\Delta t$.

In the present study, residual discharge has been computed over the periods of spring to neap, neap to spring and spring to spring using eqn. 4.2.

CHAPTER - 5

RESULTS AND DISCUSSIONS

The Meghna Delta has three main ocean outfalls namely the Hatiya channel, Shahbazpur channel and Tetulia channel. The Hatiya channel is on the east while the Tetulia channel is on the west side, the Shahbazpur channel being in the middle. Observed spring and neap tidal ranges in April of 1977 and 1979 at the mouth of those three estuaries are presented in the Table 5.1. It shows that the tidal ranges decrease from east to west along the coast of the Meghna Delta.

Levels of highwater and lowwater occurred in spring and neap tides in April of the years 1977 and 1979 are given in Table 5.2. It shows that highwater levels decrease and lowwater levels increase from east to west along the coast of the Meghna Delta.

Present study shows that the maximum flood velocity in the Meghna Delta reached as high as 6.53 m/sec and 7.81 m/sec in the month of April of 1977 and 1979 respectively. Maximum ebb velocities were 4.61 m/sec and 3.71 m/sec in the month of April 1977 and 1979 respectively.

At the mouth of Shahbazpur channel, the maximum flood velocity in spring tide was found to be about 1.57 m/sec and 2.32 m/sec in the month of April of 1977 and 1979 respectively and the maximum ebb velocity in spring was found to be about 1.49 m/sec and 1.41 m/sec in the month of April of 1977 and 1979 respectively. Whereas at the same location the largest among the

TABLE - 5.1

SPRING AND NEAP RANGES IN APRIL 1977 AND 1979 NEAR ESTUARY ENTRANCES

Name of the estuary	Gage Station	Spring range (m)		Neap range (m)	
		1977	1979	1977	1979
Hatiya Channel	Char Changa	3.261	2.941	1.844	2.499
Shahbazpur Channel	Char Madraj	2.509	2.493	1.585	2.179
Tetulia Channel	Dasmonia	1.767	1.905	1.128	1.310

TABLE - 5.2

SPRING AND NEAP HIGHWATER AND LOW-WATER LEVELS IN APRIL 1977 AND 1979 NEAR ESTUARY ENTRANCES

Name of the estuary	Gage Station	HWL (m)		LWL (m)		Type of Tide
		1977	1979	1977	1979	
Hatiya Channel	Char Changa	2.865	2.310	- 0.396	-0.631	Spring
Shahbazpur Channel	Char Madraj	2.280	2.124	- 0.229	-0.369	
Tetulia Channel	Dasmonia	2.057	1.859	0.290	-0.046	
Hatiya Channel	Char Changa	1.814	2.295	- 0.030	-0.204	Neap
Shahbazpur Channel	Char Madraj	1.585	2.085	0.000	-0.094	
Tetulia Channel	Dasmonia	1.570	1.737	0.442	0.427	

maximum flood velocities in the whole synodic period was found to be about 1.96 m/sec and 2.57 m/sec which occurred 1 day and 4 days after spring in April 1977 and in April 1979 respectively. The largest among the maximum ebb velocities was found to be about 2.25 m/sec and 1.86 m/sec which occurred 1 day and 6 days after spring in the month of April of 1977 and 1979 respectively.

As expected, the maximum flood velocity increases with the decrease of freshwater discharge and maximum ebb velocity increases with the increase of freshwater discharge. Fig.5.6 shows that the maximum flood velocity of spring in April 1979 is greater than that of spring in April 1977, and the maximum ebb velocity of spring in April 1977 is greater than that of spring in April 1979. Fig. 3.2 shows that the freshwater discharge is greater in April 1977 than that in April 1979.

Normally, maximum flood velocity and maximum ebb velocity decrease with distance from the mouth of the Shahbazpur channel towards upstream but at the junction they increase. For example, variations of maximum flood and ebb velocities with distance of four typical tides are shown in Fig. 5.5.

The tidal excursion increases with the increase in tidal range. But it decreases upland with distance from the mouth of the Shahbazpur channel. Variation of excursion with distance for 4 tides viz. spring, mid of spring and neap, neap and mid of neap and spring are shown in Fig. 5.8. Here at CharMadraj, the excursion was found to be about 20.7 km and 17.3 km where the range was found to be about 2.49 m and 2.18 m in spring and neap of April 1979 respectively. At the same station, the excursion was found to be about 13.3 km and 10.2 km where the range was found to be about 2.50 m and 1.59 m in spring and neap of April 1977 respectively. The tidal excursion at Ilshaghat was found to be about 4.6 km and 3.6 km where the range was found to be about 2.20 m and 2.00 m in spring and neap of April 1979 respectively. At that station, the excursion was found to be about 6.4 km and 2.4 km where the range was found to be about 2.26 m and 1.37 m in spring and neap of April 1977 respectively. These values are significant compared to the lengths of the estuary. Ilshaghat is about 90 km upland from CharMadraj and the confluence of Padma-Meghna is about 70 km upland Ilshaghat.

Tidal excursion is a measure of the horizontal tide. The figures 5.8 and 5.9 indicate that horizontal tide becomes insignificant at Padma-Meghna confluence. On the other hand, the vertical tide crosses Mawa and Narsingdi in the Padma and the Meghna rivers respectively.

The tidal excursion varies inversely with the freshwater discharge. For example in Fig. 5.9, the variation of excursion with distance for spring and neap in April 1977 and in April 1979 are shown. From the figure it shows that in spring of April 1979, the excursion is greater than that of spring in April 1977, and it is seen from Fig. 3.2 that the freshwater discharge is smaller in April 1979 than that of April 1977.

In Figures 5.13a, 5.13b and 5.13c residual discharge are shown for the periods between spring to neap, neap to spring and spring to spring in April 1977 and in April 1979. From the figures, it is seen that residual discharges are larger over the period between neap and spring while smaller over the period between spring and neap. The figures also indicate that the residual discharge increases with the increase in freshwater discharge. It is further seen that significant tidal pumping occurs between the Hatiya channel and the Shahbazpur channel.

Various simplifications are made in the present study. Hence results of this study are to be used keeping some degree of allowances. The simplifications made in the present study are discussed below:

The cross-section have been represented by equivalent rectangular sections. The minimum width-depth ratio out of all cross-sections is 34.5:1. Hence use of rectangular section is justified.

Due to insufficient geometric data, mean depth of flow at a section has been assumed constant. But the total depth of flow changes with time and the actual depth should be used in the computation of velocity. Hence, as a result of the simplifications, the computed velocity will be greater during high water and smaller during low water. However, the simplification is acceptable as the tidal range is small compared to the mean depth.

Division of flow at a junction has been computed by applying steady flow formula i.e., the Manning's formula. But the flow is a gradually varied unsteady flow. Further, the computational time interval Δt, of 30 minutes is about 4% of the tidal period. Hence, the simplification is not un-reasonable.

The freshwater discharges at the three upland boundary sections have been assumed constant for a day. As those boundaries are at non-tidal reaches of the rivers, it will not introduce serious error into the computation.

The water level elevations at intermediate sections between two gage stations have been determined by linear interpolation. As the tidal propagation is gradually varied and slope of the water level is very small, the simplification is reasonable. In the absence of extensive field data, the study is not possible without this simplification.

The basis of the cubature method is the continuity equation where flow is assumed one dimensional. In reality, the flow is two dimensional or even three dimensional. However, the assumption of one dimensional flow is a standard practice in all such studies.

Finally, in spite of the above simplifications, present study gives an idea about the order of magnitudes of various parameters of tidal characteristics of the Meghna Delta. The results of present study will be of immense value in any future study on numerical modelling, sediment transport, salinity etc.

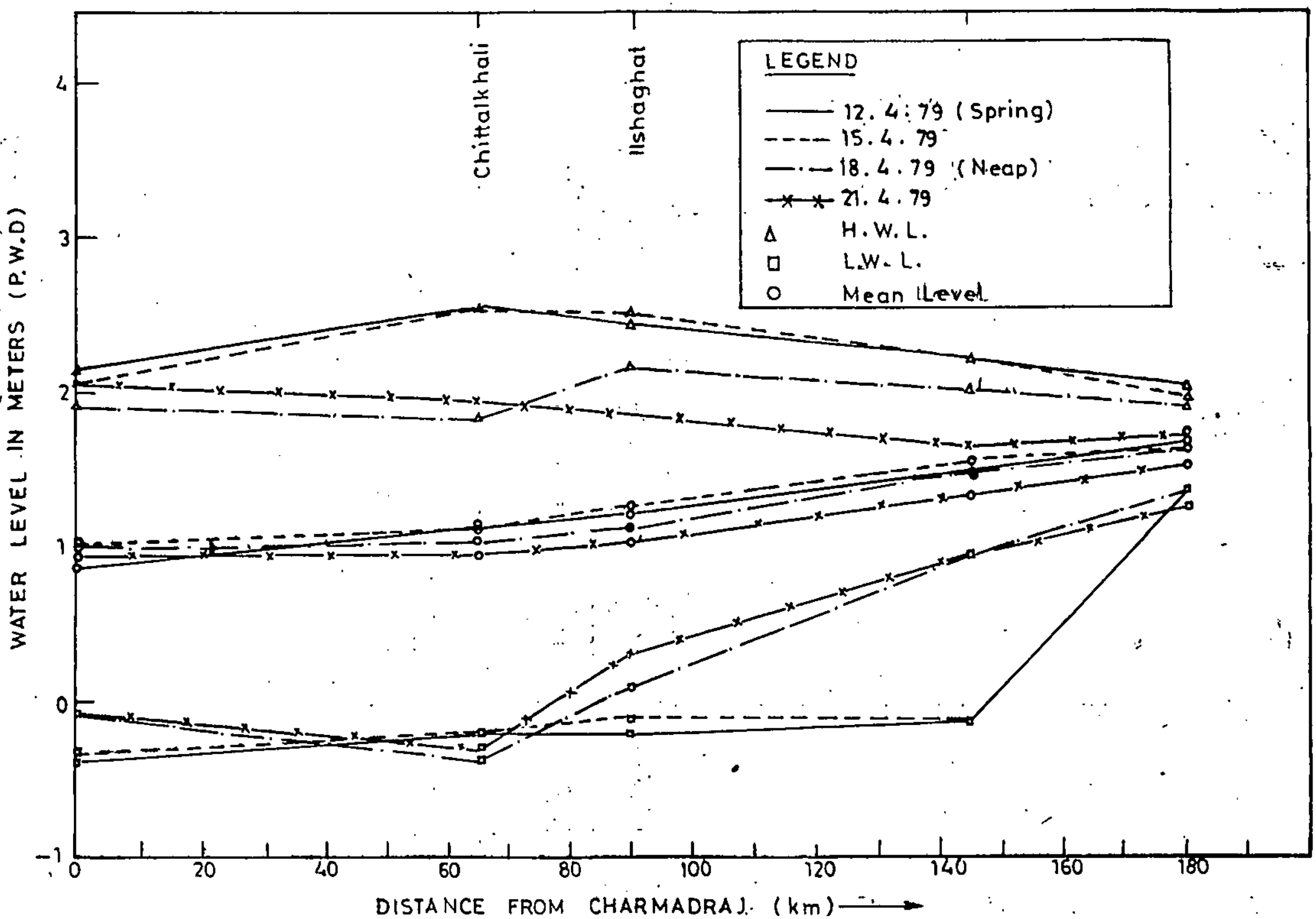


FIG. 5.1 VARIATION OF H.W.L. L.W.L. AND MEAN LEVEL WITH DISTANCE.

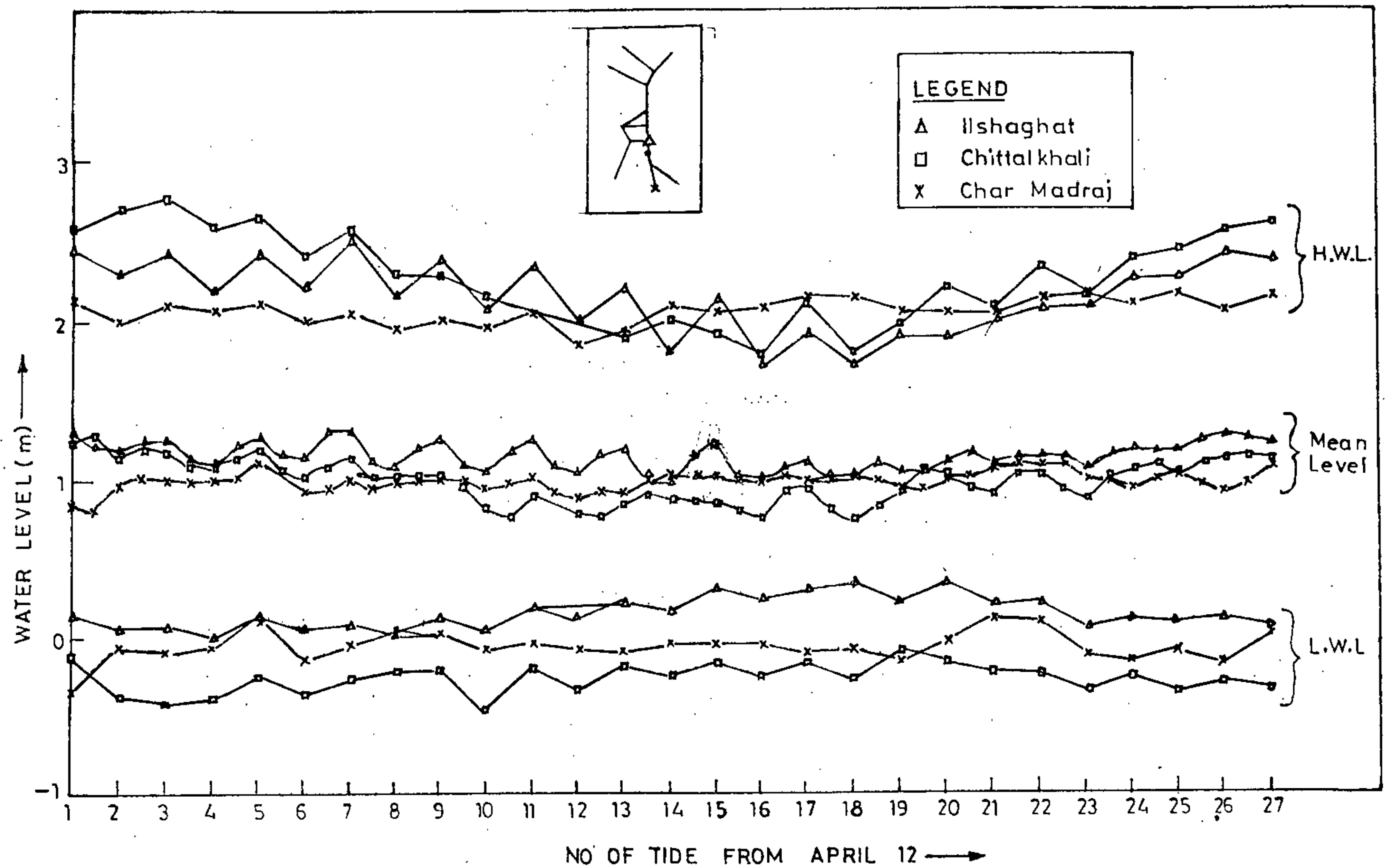


FIG. 5.2 VARIATION OF H.W.L., L.W.L. AND MEAN LEVEL FROM APRIL 12 TO APRIL 26, 1979

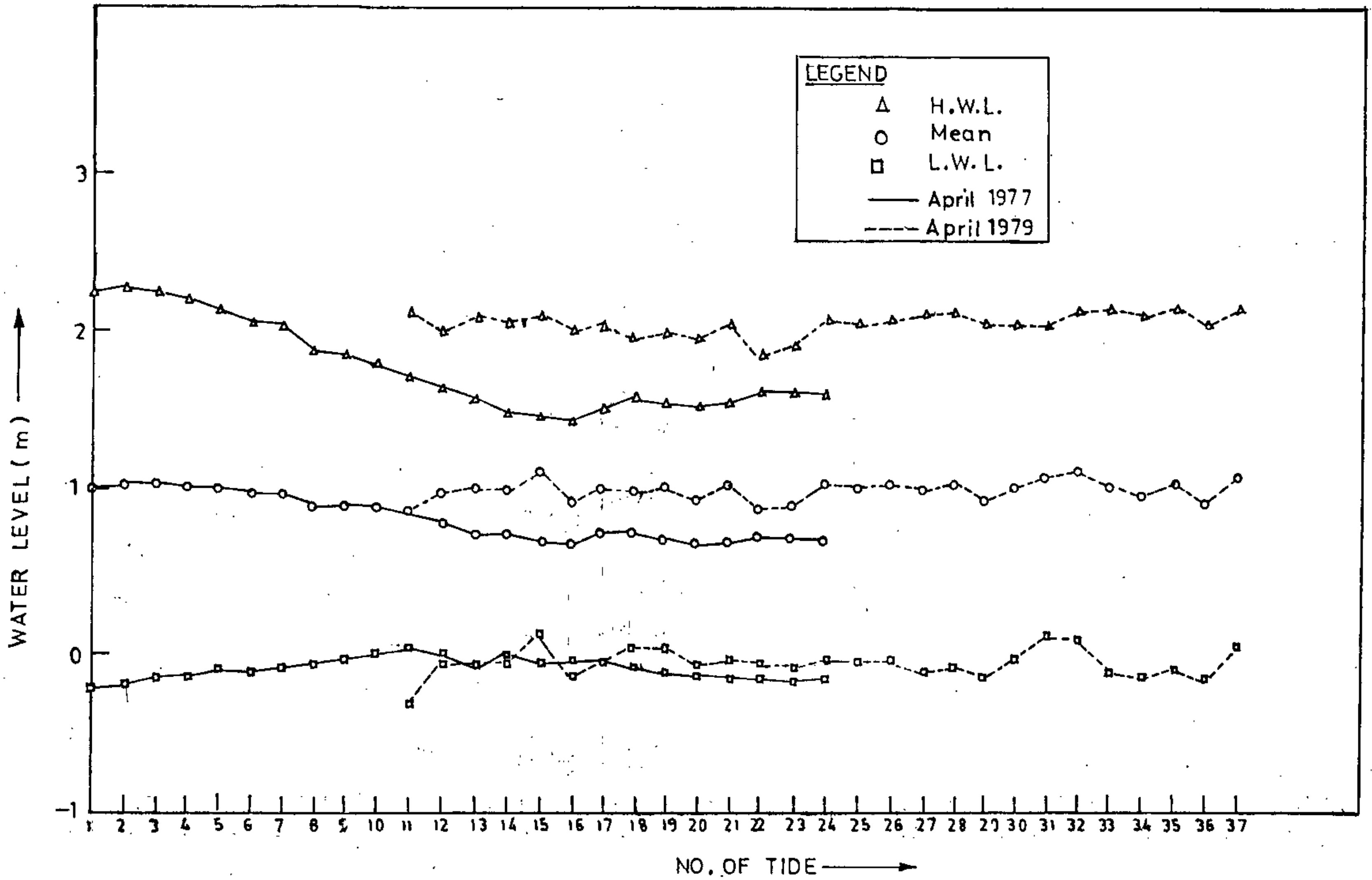


FIG.5.3 H.W.L., L.W.L. AND MEAN LEVEL OF EACH TIDE FROM SPRING TO SPRING.

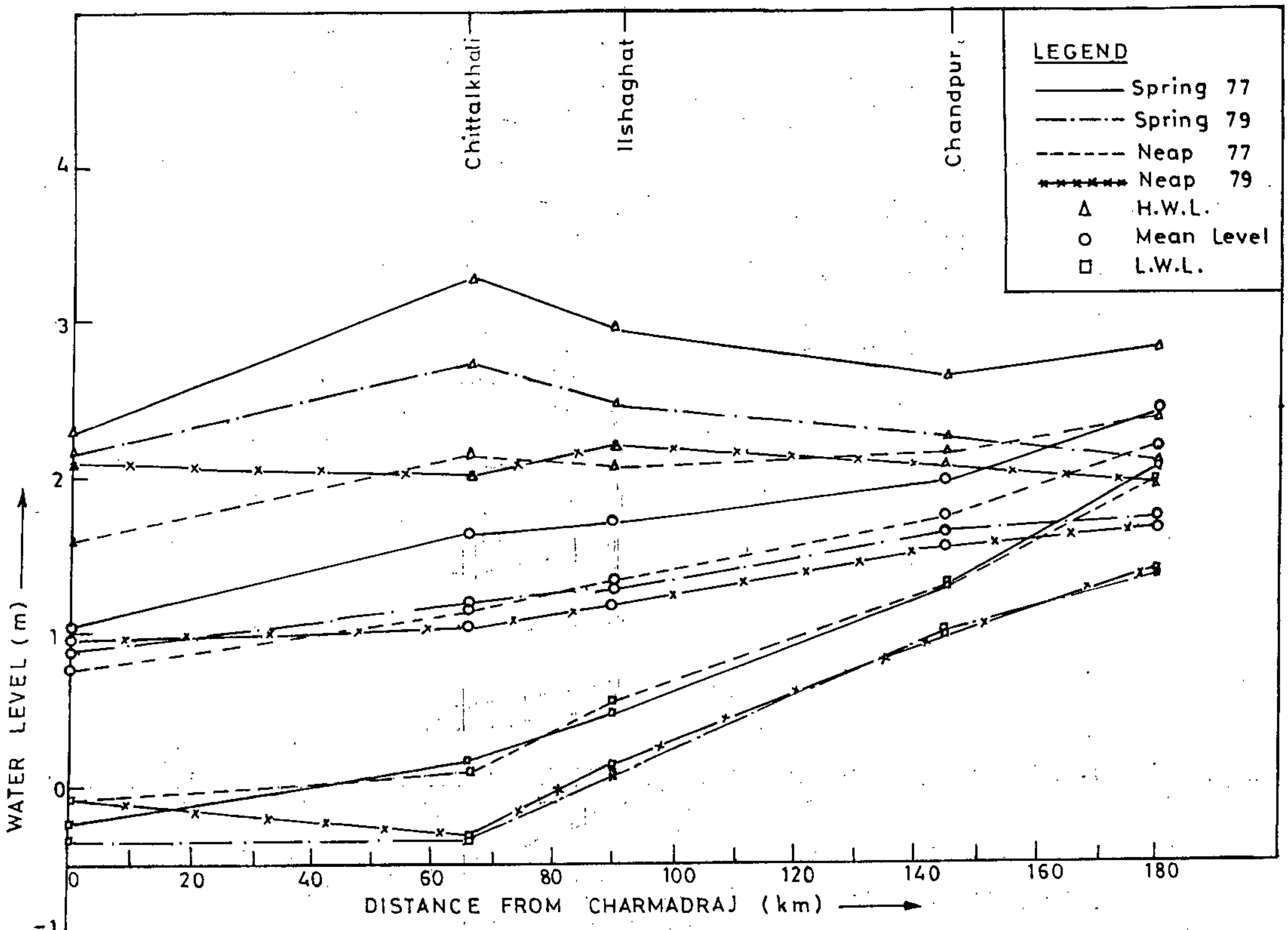


FIG. 5.4 VARIATION OF H.W.L, L.W.L. AND MEAN LEVEL WITH DISTANCE IN SPRING AND NEAP TIDES (April 1977, 1979)

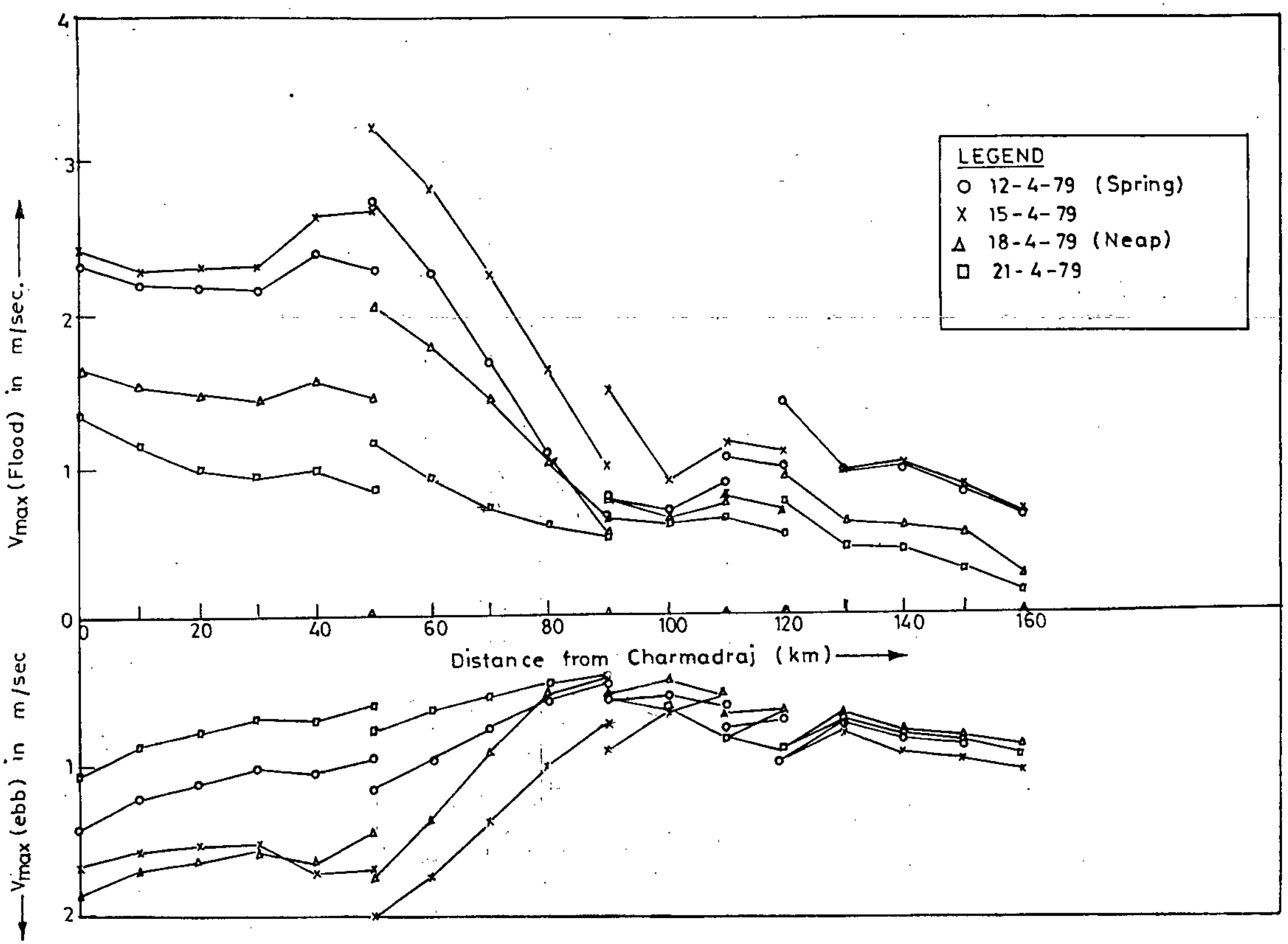


FIG. 5.5 VARIATION OF MAXIMUM FLOOD AND EBB VELOCITIES WITH DISTANCE.

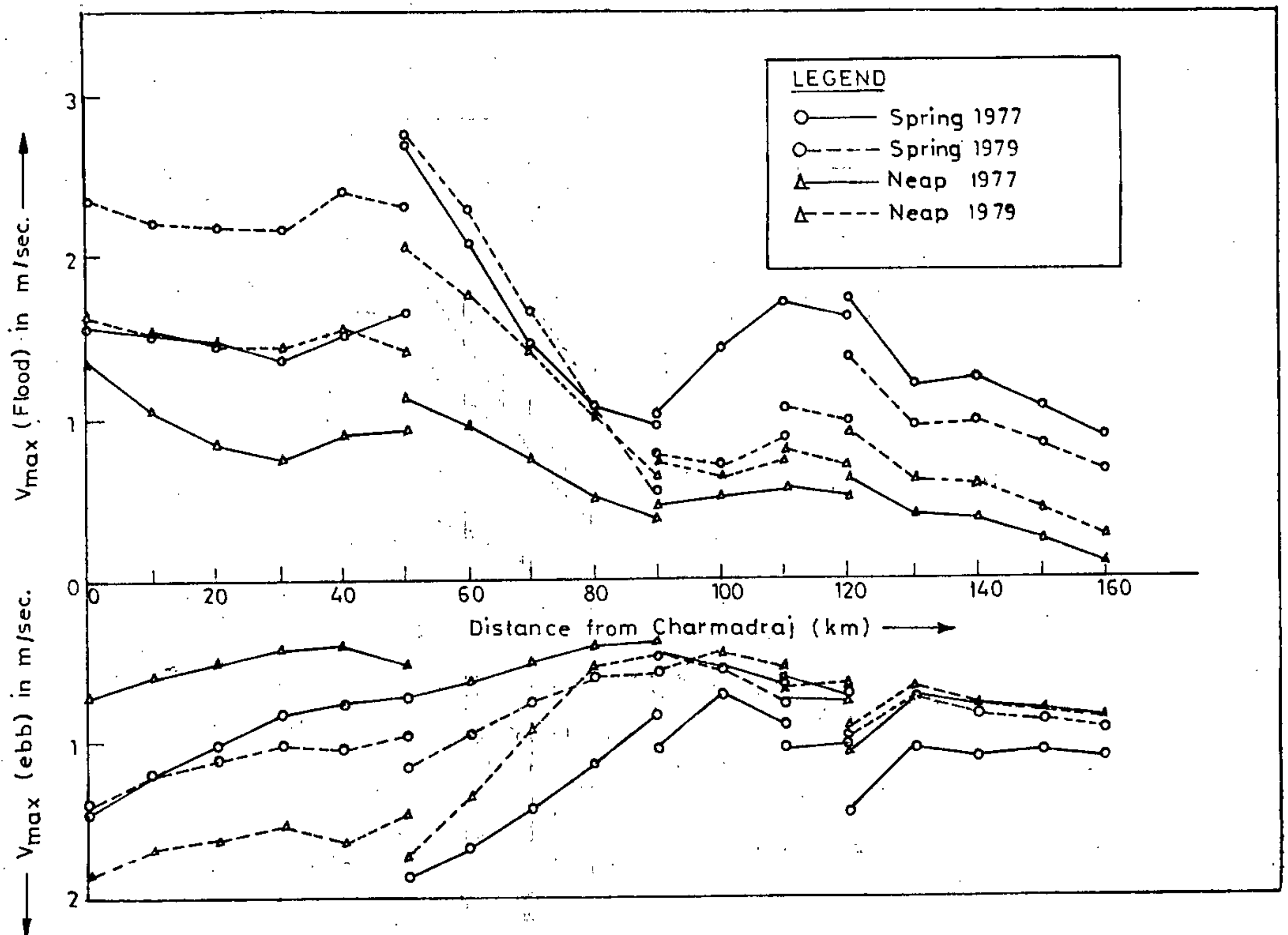


FIG. 5.6 VARIATION OF MAXIMUM FLOOD AND EBB VELOCITIES WITH DISTANCE IN SPRING AND NEAP TIDES.

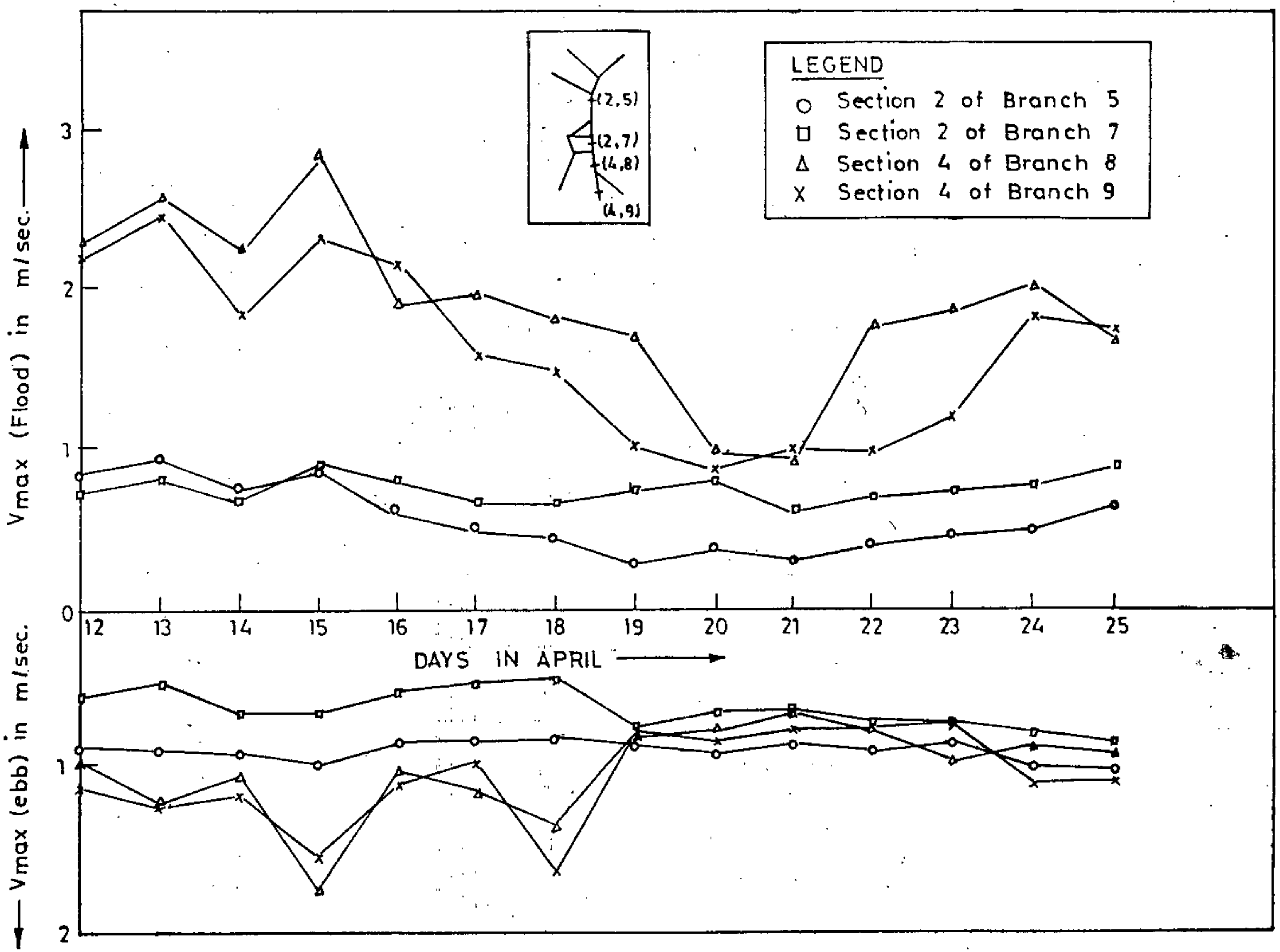


FIG. 5.7 VARIATION OF MAXIMUM FLOOD AND EBB VELOCITIES WITH TIME IN APRIL 1979

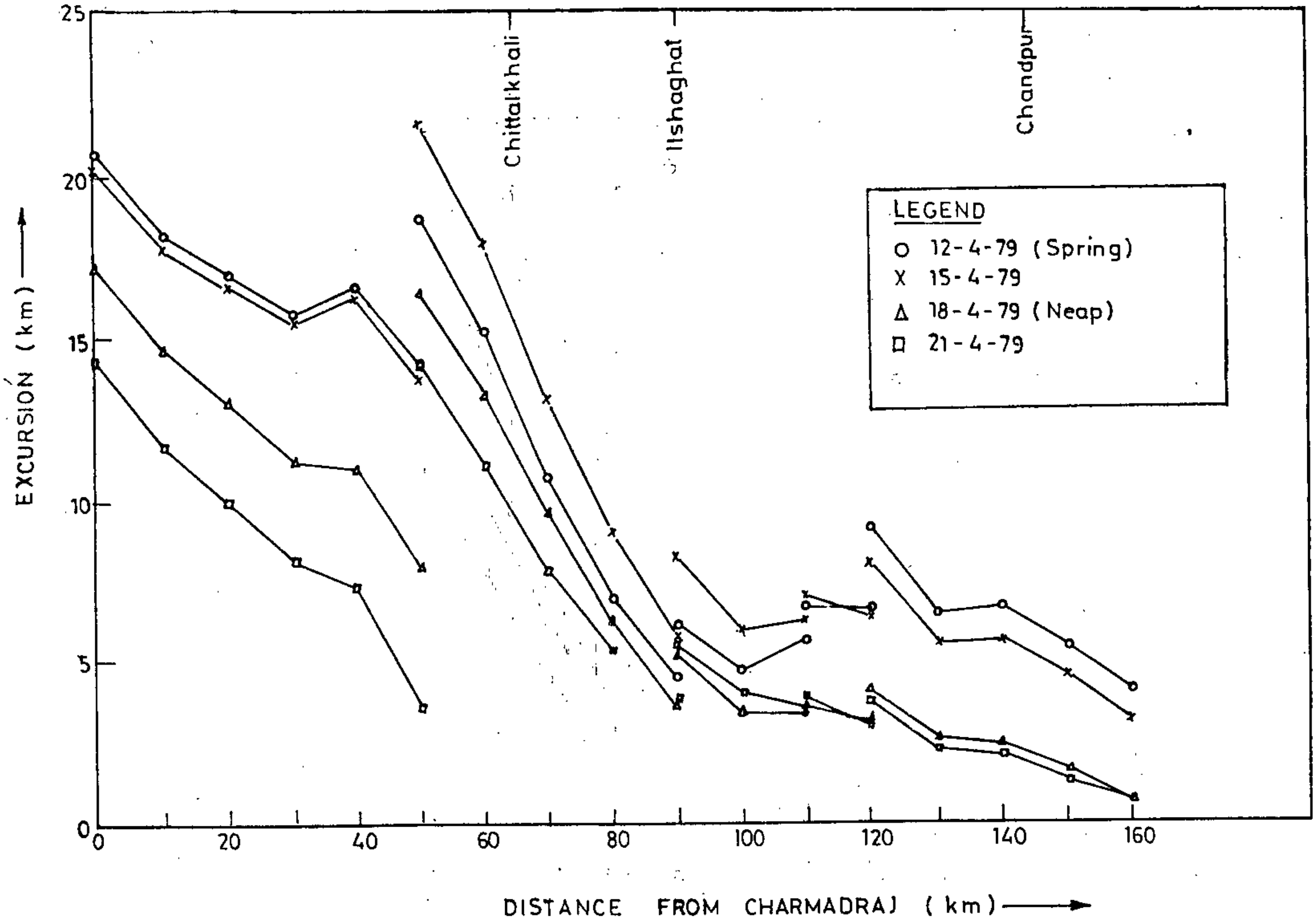


FIG. 5.8 VARIATION OF EXCURSION WITH DISTANCE

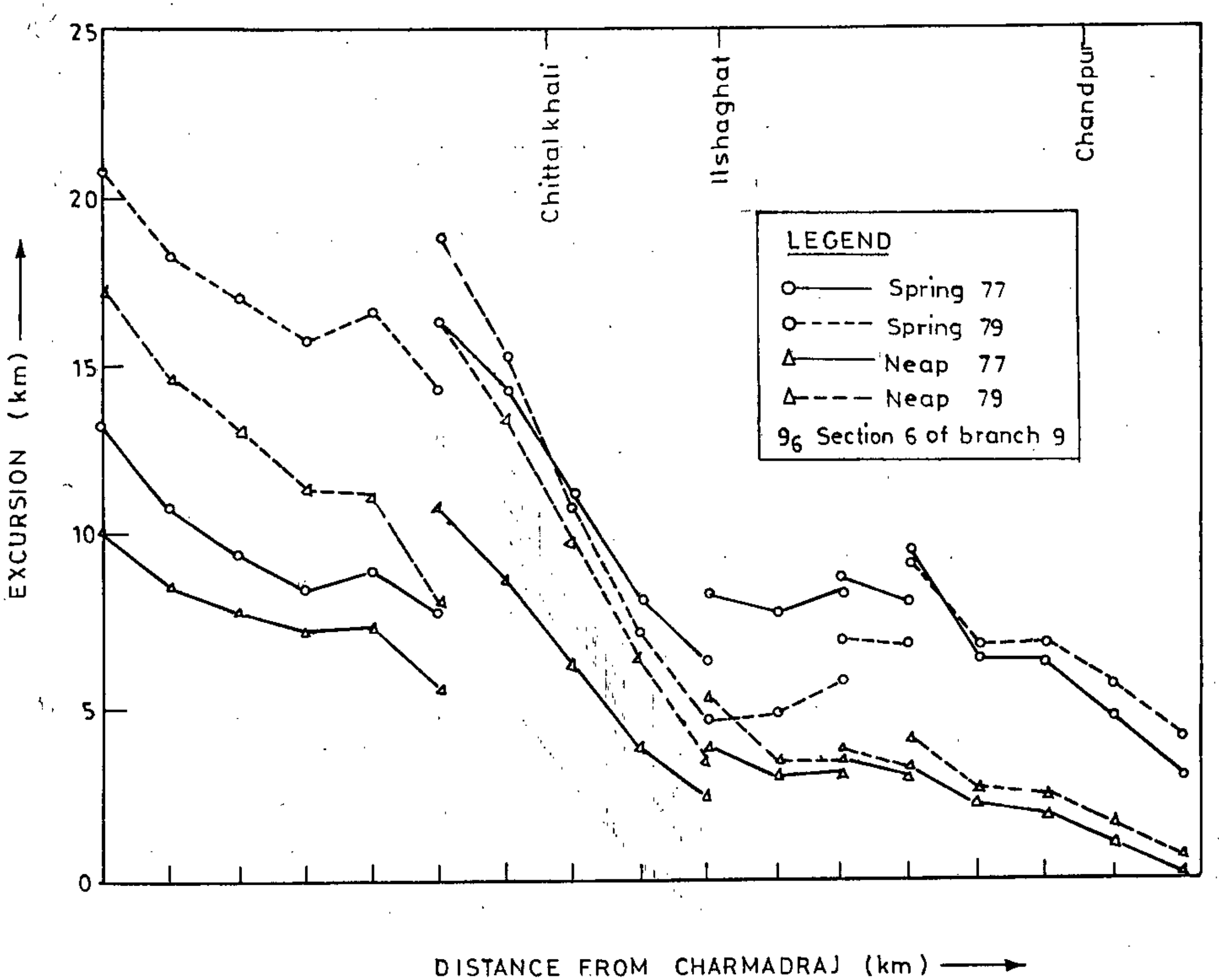


FIG. 5.9 VARIATION OF EXCURSION WITH DISTANCE IN SPRING AND NEAP TIDES (April 1977, 1979)

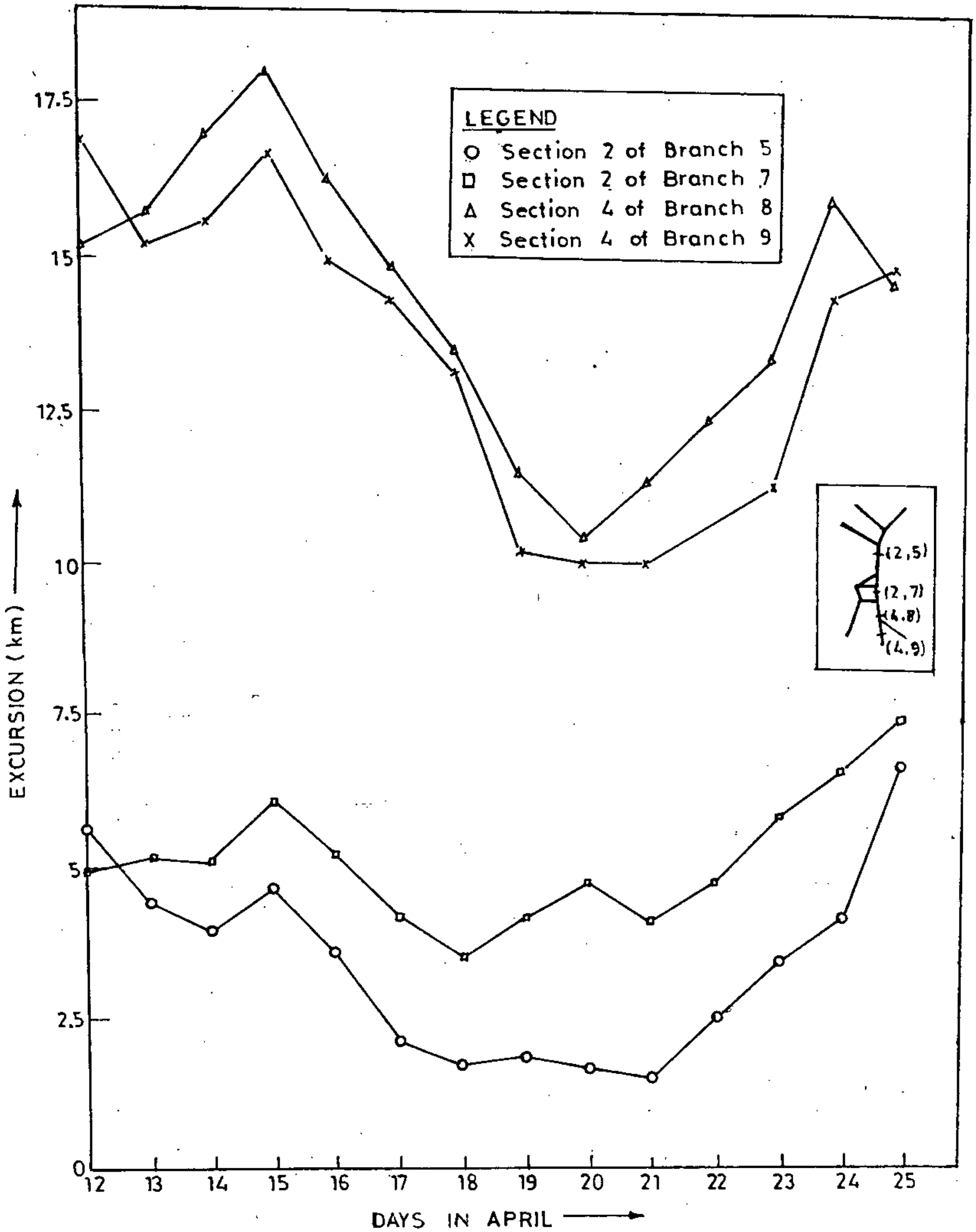


FIG. 5.10 VARIATION OF EXCURSION WITH TIME IN APRIL 1979

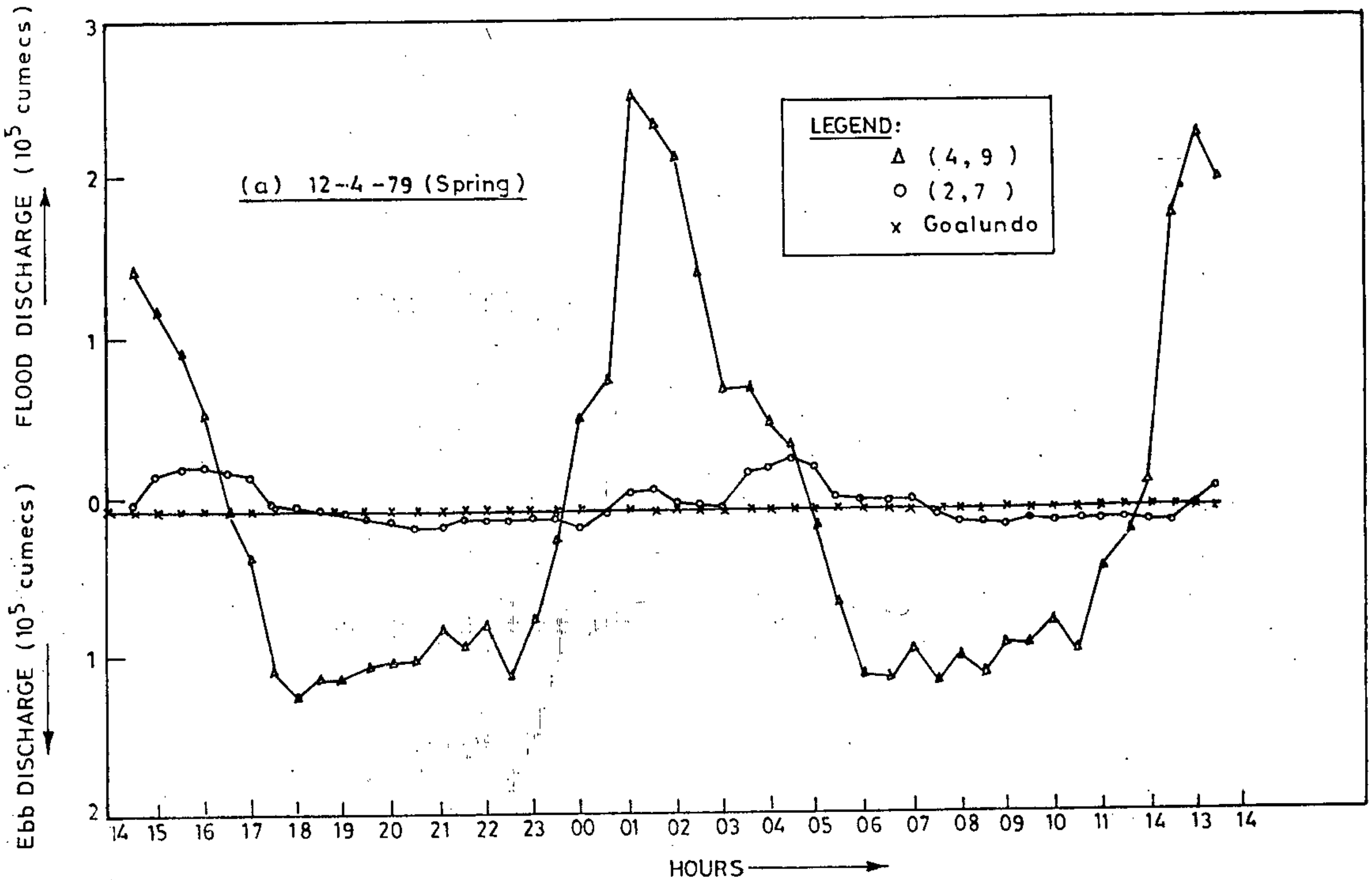


FIG. 5.11 VARIATION OF COMPUTED DISCHARGE WITH TIME.

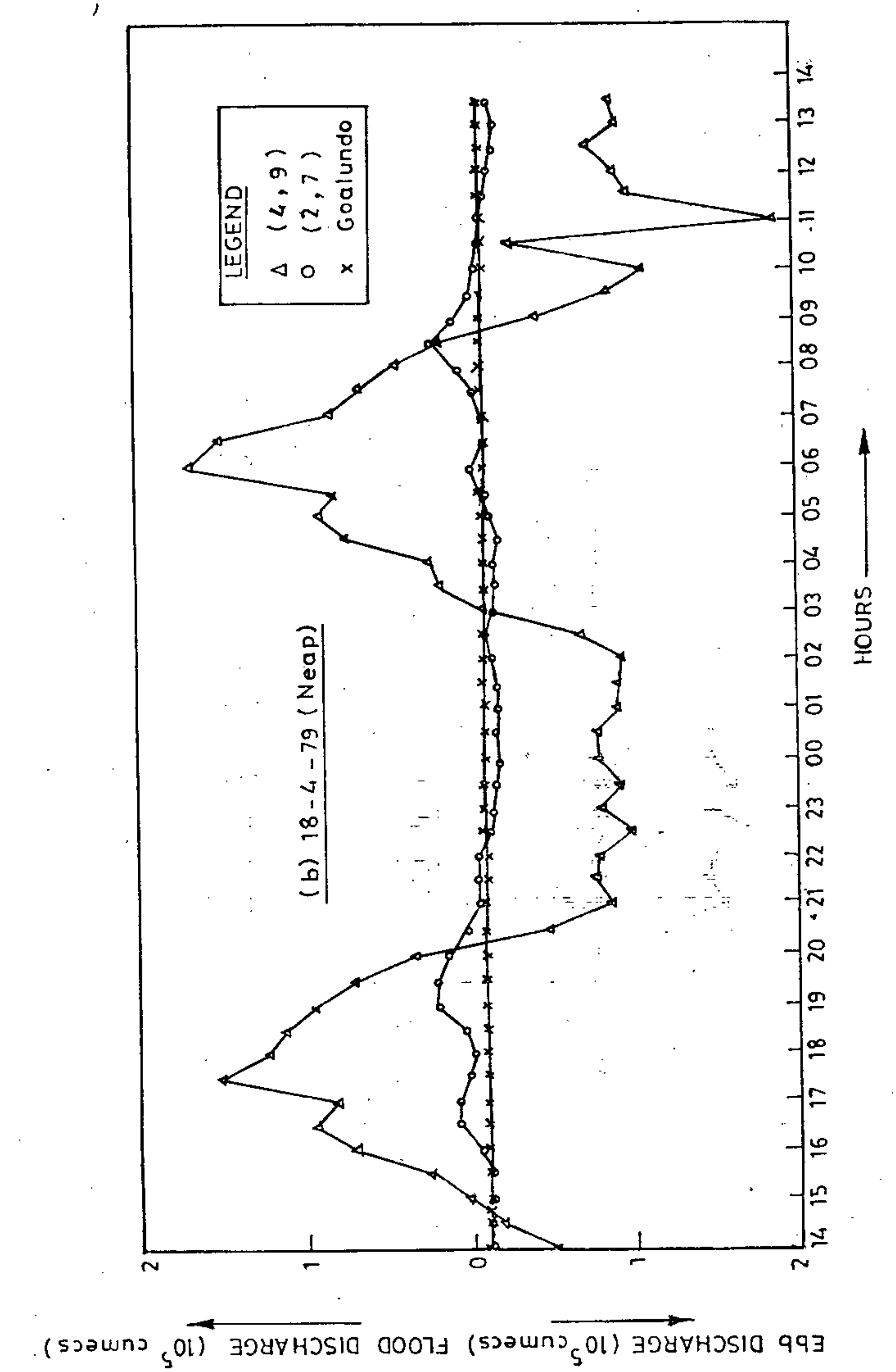


FIG. 5.11 (CONTINUED)

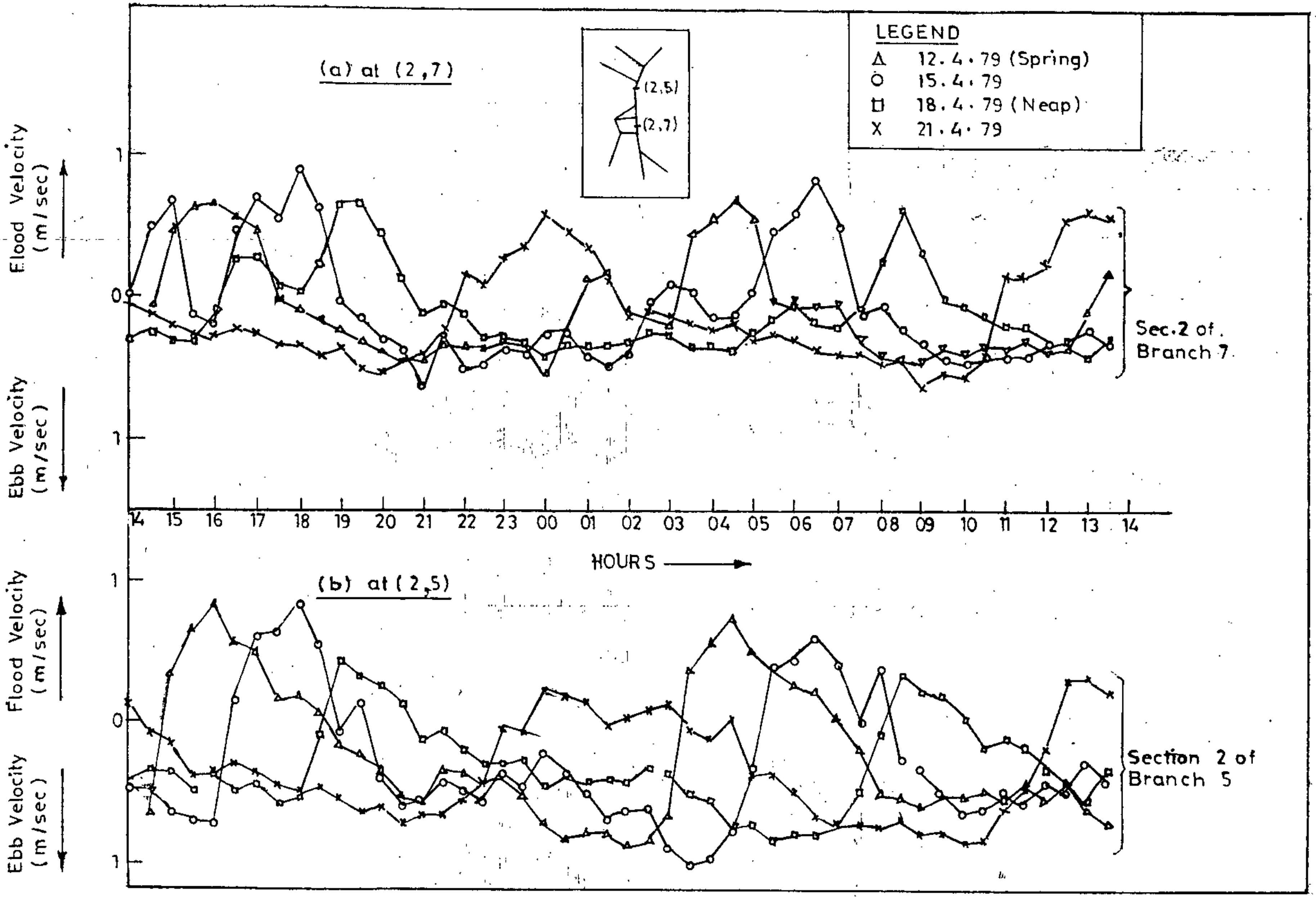


FIG. 5.12 VARIATION OF VELOCITY WITH TIME..

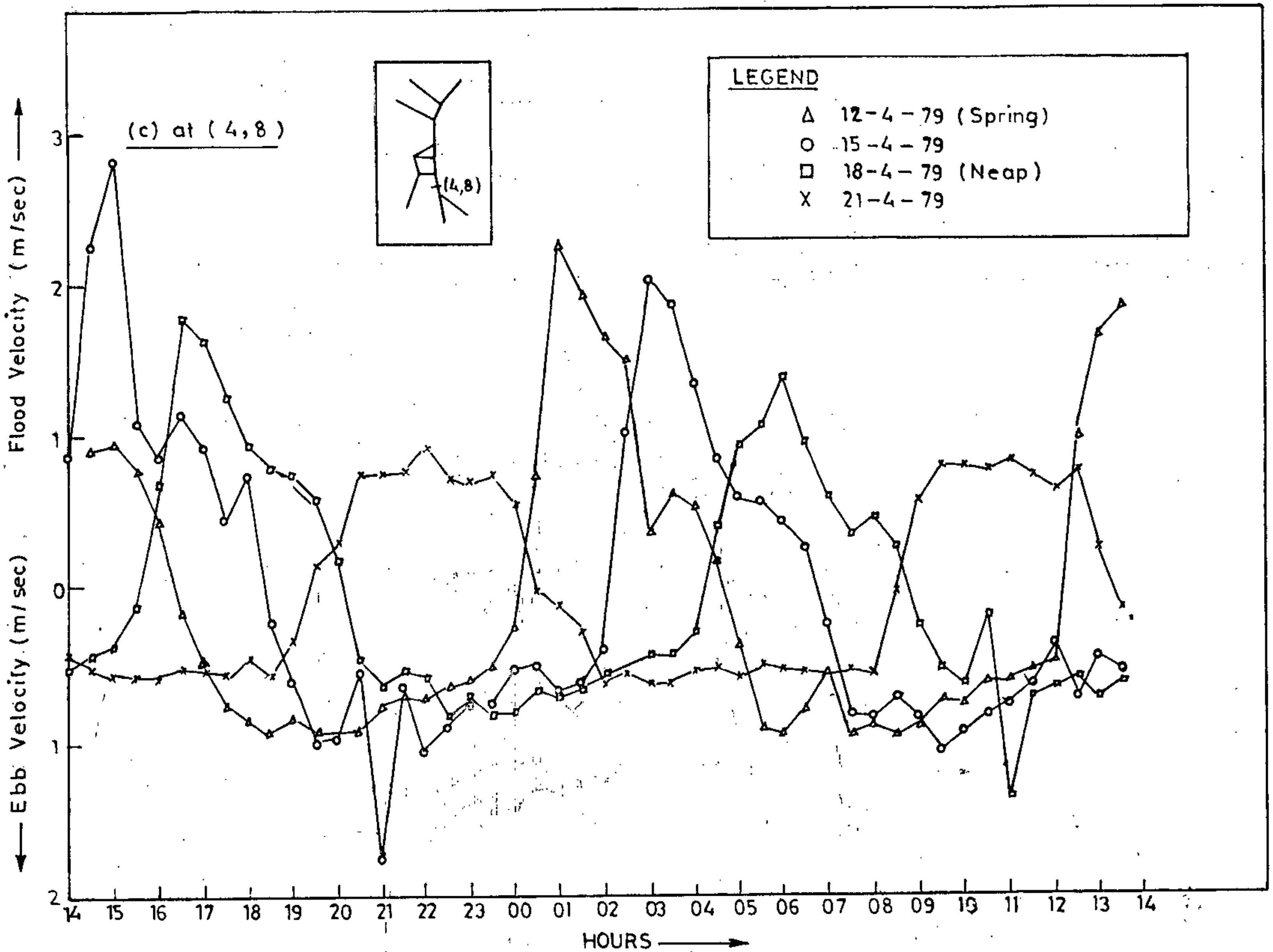


FIG.5.12 (CONTINUED)

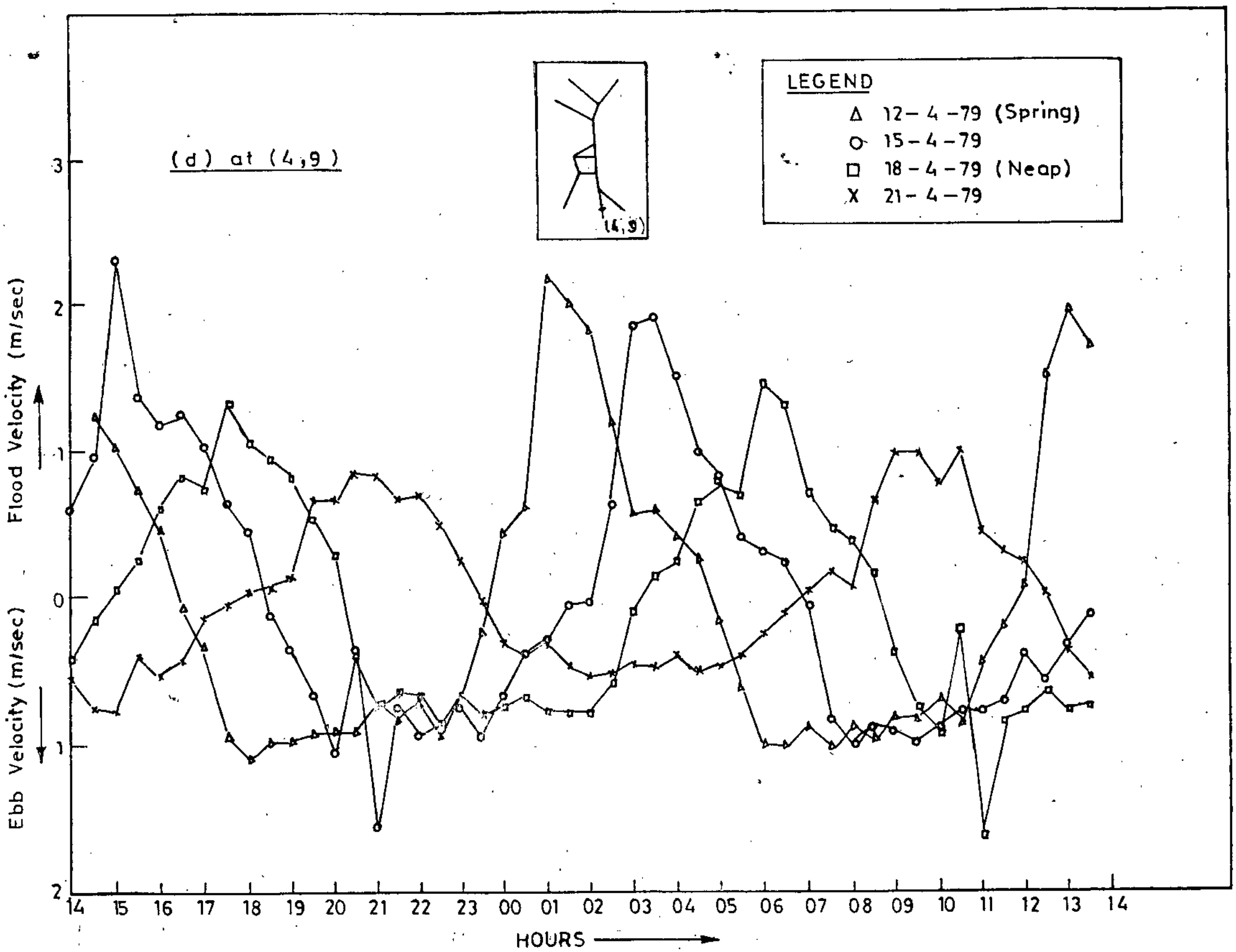


FIG. 5.12 (CONTINUED)

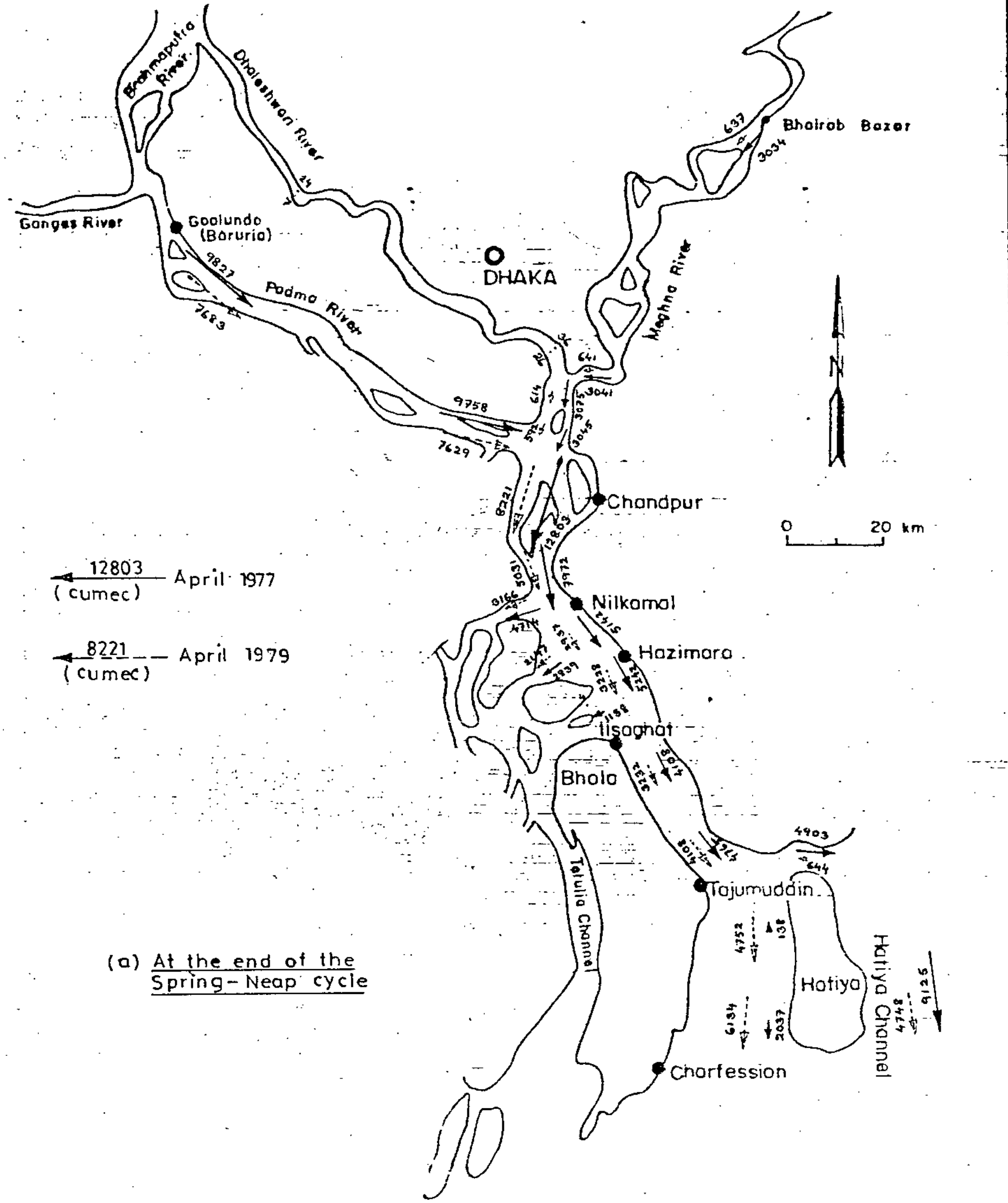


FIG. 5.13. RESIDUAL DISCHARGES

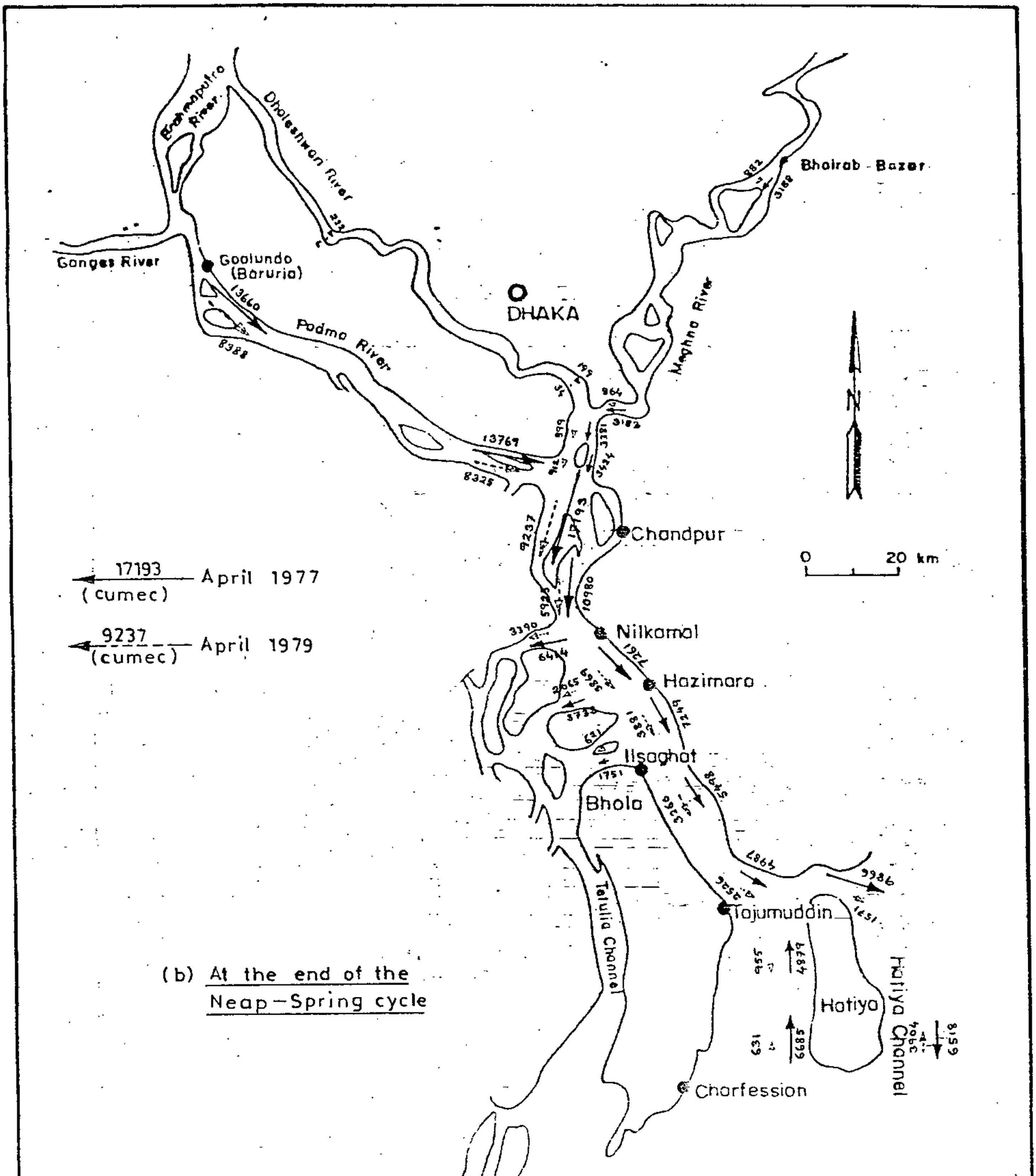


FIG. 5.13 (CONTINUED)

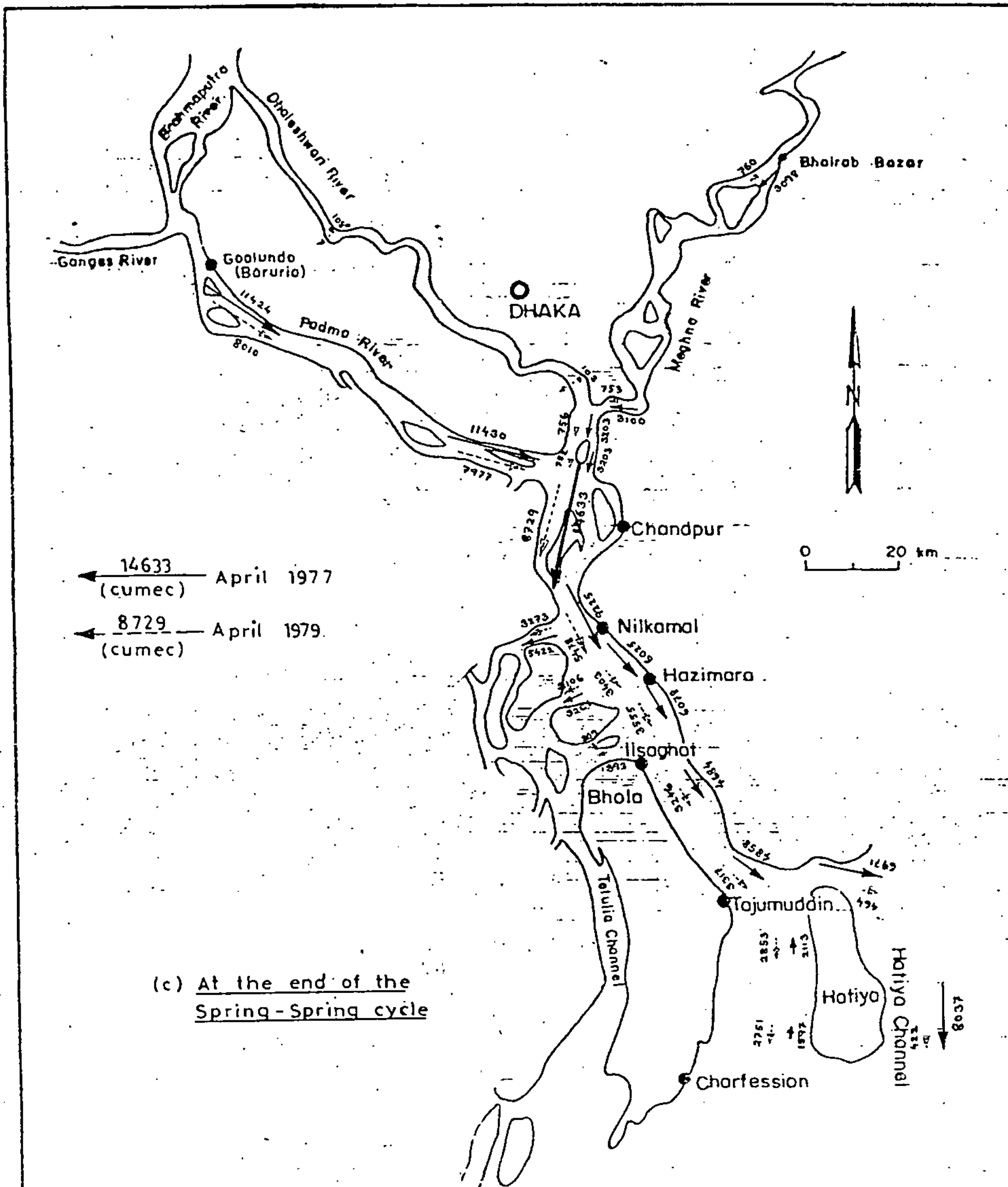


FIG.5.13 (CONTINUED)

CHAPTER - 6

CONCLUSIONS

Conclusions from this study are summerized below:

Spring and neap ranges decrease from east to west along the coast of the Meghna Delta.

Spring and neap high water levels decrease and low water levels increase from east to west along the coast.

Maximum flood velocity as high as 7.81 m/sec has been found in the study period while the maximum ebb velocity is 4.61 m/sec.

Tidal excursion increases with the decrease in combined freshwater flow from Padma and Meghna.

Tidal excursions of about 22 km and 18 km from the estuary entrance along the Shahbazpur channel has been found during spring and neap tides in the study period.

The horizonral tide becomes insignificant at the Padma-Meghna confluence while the vertical tide crosses beyond Mawa and Narsingdi in the Padma and the Meghna rivers respectively.

Residual discharge is larger over the neap-spring period while smaller over the spring-neap period.

Residual discharge increases with the increase in fresh-water discharge.

Significant tidal pumping occurs between the Hatiya channel and the Shahbazpur channel.

REFERENCES

1. McDowell, D.M., and Connor, B.A. (1977), "Hydraulic Behaviour of Estuaries". The Macmillan Press Ltd.

2. Odd, N (1982), "A One-dimensional Analysis of the Tidal Hydraulics of Deltas". Report no. OD 44, Hydraulic Research Station, U.K.

3. BIWTA. (1977,1979) "Weekly Water Level Record", Department of Hydrography. Tidal Investigation and Research Section.

4. BWDB, (1977,1979) "Mean Daily Discharge Record". Department of Hydrology.

5. Harleman, D.R.F. and Lee, C.H.(1969), "The Computation of Tides and Currents in Estuaries and Canals". Technical Bulletin No.16, Committee on Tidal Hydraulics, Corps of Engineers, U.S. Army.

6. Chowdhury, A.K.M. Jahir Uddin (1982) "Numerical Models for Shallow Water Tides in x-t river Networks and x-y-t Space" Ph.D. Thesis, University of Strathclyde, U.K.

7. Chowdhury, A.K.M. Jahir Uddin (1983), "Saline Intrusion in the Meghna Delta". A pilot mathematical model study. Bureau of Research Testing and Consultation, BUET, Dhaka.

8. IECO (1980), Southwest Regional Plan, Supplement E, "Saline Intrusion and Tidal Hydraulics". Special Studies Directorate, BWDB.