A STUDY ON GEOMETRIC AND SEDIMENT TRANSPORT CHARACTERISTICS OF THE RIVER SURMA

KAMRUNNESSA

DEPARTMENT OF WATER RESOURCES ENGINEERING
BUET, DHAKA

A STUDY ON GEOMETRIC AND SEDIMENT TRANSPORT CHARACTERISTICS OF THE RIVER SURMA

Submitted by

KAMRUN-NESSA

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

December, 1994

CERTIFICATE

This is to certify that this work has been done by me and this report nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

Counter Signed

Dr. M. Monowar Hossain

Supervisor

Signature

Kamrun nessa

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF WATER RESOURCES ENGINEERING

December 26 , 1994

We hereby recommend that the project work prepared

by

Kamrun-nessa

entitled " A STUDY ON GEOMETRIC AND SEDIMENT TRANSPORT CHARACTERISTICS OF THE RIVER SURMA " be accepted as fulfilling this part of the requirements for the degree of Master of Engineering (Water Resources).

Chairman of the Committee
(Supervisor) — (Dr. Monowar Hossain)

Member — (Dr. Ainun Nishat)

Member — (Dr. M. A. Matin)

Head of the Department — (Dr. M. Fazlul Bari)

ABSTRACT

A study was conducted to investigate geometric and sediment transport characteristics of the Surma. To carry out the investigation cross-sectional data at 42 sections of the Surma from Kanairghat to Markuli for the years 1970-1974 and 1988-89 were collected from the Bangladesh Water Development Board. Data on suspended sediment transport at Sylhet for the years 1957 to 1992 and mean daily discharge at Sylhet for the years 1970-1971 to 1992-1993 were also collected from the Bangladesh Water Development Board (BWDB) and analyzed.

Cross-sectional area at 24 sections for the years 1970 and 1988-1989 were analyzed to study the change in cross-sectional areas during the 19 years period. It was observed that the river was becoming wider and shallower.

Deepest point(thalweg) of 42 sections in 1970 and 1988-89 were plotted. Maximum rise in deepest point was found at section S-1 (4.75m) whereas maximum fall occurs at section S-11 (3.26m). Mean Bed Level at 24 different sections were computed and plotted for the years 1970 and 1988-89. The maximum rise in mean bed level occurs at section S-18 (4.84m) whereas the maximum fall in mean bed level occurs in section S-42 (1.65m) during 19 years.

Suspended sediment data of the Surma at Sylhet were analyzed and applicability of three well Known sediment transport equations against these data were tested. Of the three formulas viz. Engelund-Hansen, Yang and Hossain, examined in the current study, Hossain's formula provided relatively realistic results against present set of data followed by Engelund-Hansen formula. According to Hossain's equation the annual total sediment load was found to vary between 1.68 million tons and 3.924 million tons, with an average load of 2.739 million tons. A further analysis was under taken to estimate the annual suspended sediment load of the Surma at Sylhet and were found to vary between 1.563 million tons and 3.966 million tons, with an average annual suspended sediment load of 2.681 million tons.

Bed loads were computed using Meyer-Peter and Muller's equation as well as using Rottner's equation and were expressed as a percent of suspended load. Accordingly, this estimated bed load was found to vary between 1 percent and 10 percent, which indicates that this river carries a very small quantity of bed load.

ACKNOWLEDGEMENT

The author expresses sincerest gratitude and thanks to Dr. Monowar Hossain, Professor, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology (BUET), for his active support, advice, guidance and supervision throughout this study.

The author is also thankful to Dr. Ainun Nishat, Professor, Dr. M. Fazlul Bari, Professor and Dr. M. A. Matin, Associate Professor of the Department of Water Resources Engineering, Bangladesh University of Engineering and Technology (BUET), who were the members of the Board of Examiners for their useful comments.

Thanks are also due to the Bangladesh Water Development Board (BWDB) for their necessary approval to pursue graduate studies at the Bangladesh University of Engineering and Technology (BUET) and for providing all necessary data related to the study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOTATIONS AND ABBREVIATIONS

a	constant;
b	exponent;
B	average width of the channel;
c	constant;
C_t	total average sediment concentration in parts per million;
D	mean channel depth;
D_{50}	median diameter of bed material;
d_{50}	median diameter of bed material;
f	exponent;
g	acceleration due to gravity;
g_s	rate of bed load transport by weight/time/width;
H	average depth of flow;
k	constant
m	exponent;
M	Sediment flow rate, mass per unit width/time;
Q	discharge;
Q_c	assessed discharge;
q	discharge per unit width;
R_b	mean hydraulic radius of the bed;
S	average water surface slope;

S_s	relative density of sediment;
u_*	shear velocity
u_{*_c}	critical shear velocity according to the shields.
V	Average flow velocity;
V_{cr}	critical average water velocity;
W	channel width ;
τ_0	bed shear stress;
γ_s	specific weight of sediment particles;
γ	specific weight of water;
ω_r	settling velocity for a representative sediment size for which $D_{50} = 0.15$ mm at ambient temperature;
ω	settling velocity of the sediment load;
ν	kinematic viscosity;
ρ_S	density;
BWDB	Bangladesh Water Development Board;
BUET	Bangladesh University of Engineering and Technology;
EPWAPDA	East Pakistan Water and Power Development Authority;
FAP	Flood Action Plan;
GSB	Geological Survey of Bangladesh;
MBL	Mean Bed Level;
MPO	Master Plan Organization;

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The history of civilization is closely related to some major rivers of the world. Many of the noted ancient civilizations prospered in the fertile valleys of these rivers. During the ancient times, trade and commerce flourished using mostly river routes. While mankind benefits from rivers they also cause lots of sufferings through causing floods, land erosion, siltation etc. Therefore, engineers need to plan, design, operate and maintain projects for regulation, flood mitigation, water supply, navigation and irrigation. Hence they require adequate knowledge of river behaviour.

Rivers can be classified broadly in terms of channel pattern that include straight, meandering, braided or some combination of the three. An important characteristic of alluvial river is its flow in sinuous path, called meandering formed by the process of erosion and deposition. The meandering process usually causes the river to leave their original course, forces them to flow along new courses, and thus causes huge damage both to land and property. The proper understanding of meandering development and channel pattern changes of alluvial river is very important for all engineering projects which have linkage with the river.

The national territory of Bangladesh comprises an area of 148000 sq. km. (BBS, 1992), of which 120400 sq. km. lies within the world's largest delta formed by the sedimentary material brought down by the three great river systems - the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna (Surface Water Resources of North-east Region, FAP-6, 1993). The sediments carried down by these river systems are supplied by the erosion of their enormous catchment area. In Bangladesh most of the river studies included the behaviour and characteristics of only the major rivers. Apart from these three major rivers there are also numerous medium and minor rivers, which are interlaced throughout the country. Therefore, it is also important to understand the behaviour and characteristics of the medium and minor rivers.

The Surma is the third largest river of the Meghna region. It originates from the bifurcation of the Barak of India at Amalshed where it flows a westerly course through the north-east region of Bangladesh until it joins the Balui just north of Sukhdevpur. The most important feature of this river is that its catchment area includes the southern facing slope of Shillong plateau in Meghalaya, Cherapunji, which is the wettest place on the earth. The inflows during monsoon season causes flush floods with peak flows ranging up to 30 or more times than the average flows (BWDB). The massive flash flood and a large sediment load causes continual erosion and sedimentation which affects river banks stabilization, navigation, flood control, fisheries and agriculture. Accordingly, the Surma has been selected as a representative of the medium size rivers of Bangladesh for this study.

1.2 OBJECTIVE OF THE STUDY

The main objectives of the current study ars as follows:

(i) To study the geometric characteristics of the Surma for a reach from Kanairghat to Markuli.

(ii) To Study the sediment load transport characteristics of the Surma at Sylhet.

CHAPTER 2

THE SURMA SYSTEM

2.1 INTRODUCTION

The Surma originates from the bifurcation of the Barak of India at Amalshed, flows westerly through Bangladesh until it joins the Balui river. It collects inflows from the eastern 7540 km^2 or 56% of the area in Meghalaya tributary to the sub-region. This area occupies most of the southern slopes of Shillong Plateau, a massive hoist which rises to a maximum elevation of 2575 meters and is the focus of the world's heaviest rainfall region. Flow in the Surma has been measured by the Bangladesh Water Development Board (BWDB) in its upper reaches. Water balance studies indicate that the annual contribution of the Surma to the Balui amounts to 69.7 km^3/year (Surface Water Resources of Northeast Region, FAP-6, 1993). This flow identifies Surma as the third largest river in the Meghna Subregion. These inflows occur mainly in monsoon season as intense flash floods with peak flows ranging up to 30 or more times average flows. The Surma also collects 35% of the Barak inflows.

The Surma has seven significant tributaries all originating in Meghalaya and entering it from the north. They are: Lubha, Sarigowain, Piyain, Dhalai, Umium, Jhalukali and Jadukata. These tributaries all rise on the Shillong Plateau in Meghalaya, but the Jadukata also drains the eastern part of the northeast slope of Tura Range. The Surma system is shown in Figure 2.1.

The Barak bifurcated into the Surma and Kushiyara river at Amalshed. The Surma and Kushiyara rivers rejoin 300km downstream where they flow into the upper Meghna river. The Surma river has been subdivided into the Upper Surma river (Amalshed to Chhatak), the Lower Surma river (Chhatak to Old Surma offtake) and the Nawa river (Old Surma offtake to Balui river junction). The main geomorphic features of the Surma is summarized in Table 2.1 (River Sedimentation and Morphology, FAP-6, 1993).

The Rennel's Survey of 1768 shows that the Surma river is a direct continuation of the Barak river. The Surma was shown to be very close to its present alignment between Amalshed and Sunamganj. Near Sunamganj, it turns abruptly south until it joins the Kalni/Kushiyara near the town of Ajmiriganj. The course between Sunamganj and Ajmiriganj is called the ``Old Surma river'' and does not carry much of the flood flows of the Surma. The main flow now is through the Nawa river and in the southward flowing into the Balui river. The lower 30 km of the Balui river is called the Ghorautra river. The Ghorautra river flows into the upper Meghna river near the town of Dilpur.

2.2 HYDROLOGICAL OVERVIEW

An overview of hydrological, geological, landform and sediment problems in the Northeast region of Bangladesh is discussed in the following paragraphs:

The Northeast region of Bangladesh comprises an area of 24265 km^2 almost all of which is devoted to agriculture. This region can be divided into two distinct sub-regions: the larger Meghna Sub-region in the east, comprising 83.5% of area in the region and the smaller Old Brahmaputra Sub-region in the west comprising 16.7% of area of the region. The geological features of these two sub-regions are similar, hydrologic features are different. The Meghna Sub-region receives flash floods from the adjacent Indian states. This region gets flood affected during the wet season and is effected by soil moisture deficit in the dry season.

The Northeast region has a tropical monsoon climate. For about four months in winter (December through March). air flows from the northeast direction, while for another four months in summer (June through September) it flows from the southwest direction. The southwest monsoon brings moist air from the Bay of Bengal. Rainfall in this season increases north westwards across the region and reaches maximum on the southward facing slopes of the Shilong Plateau in Meghalaya, Cherrapunji, on this slope. It is well known as the wettest place on the earth, its mean annual rainfall being over 12 meters. Across the Northeast region rainfall during the southwest monsoon ranges from around 1500 mm in the southwest to around 4100 mm in the northwest at the border with Meghalaya. In contrast, the northeast monsoon brings dry air into the region from China and rainfall in this season ranges from around 80 mm in the southwest to around 220 mm in the northwest. In spring, the rainfall ranges from around 490 mm in the southwest to around 1290 mm in the northwest . In autumn, the rainfall ranges from around 170 mm in the southwest to around 320 mm in the northeast (Surface Water Resources of Northeast Region, FAP-6,1993). The mean annual rainfall in the northeast region is shown in Figure 2.2. A study of daily rainfall for the Northeastern zone of Bangladesh was carried out by Matin and Ahmed (1983). A generalized Rainfall Intensity-Duration-Frequency relationship for the north-eastern region of Bangladesh was developed by Matin and Ahmed (1984).

The principal rivers of the Meghna Sub-region are the Balui, the Kushiyara and the Surma. Many other channels, both natural and man made, interconnect these rivers making the drainage pattern very complex. Some of these channels are occasionally abandoned while the new one develops; some of them carry flow only in wet season while other can carry flow in either direction depending on water levels prevailing in the main rivers they connect.

Discharges in the Surma have been measured by the Bangladesh Water Development Board at Kanairghat and Sylhet. The 22 years of record for Kanairghat and Sylhet indicate a mean annual discharge of 549 m^3/s and 563 m^3/s respectively The hydrograph for Mean Daily Discharge for the Surma at Sylhet is shown in Figure 2.3.

The seasonal distribution of the runoff at Kanairghat and Sylhet are shown in Table 2.2. and Table 2.3 respectively. Water levels in the Surma observed by the BWDB at Kanairghat, Sylhet, Chhatak and Sunamganj are shown in Table 2.4. Table 2.5 shows the seasonal variation of water levels at Kanairghat, Sylhet, Chhatak and Sunamganj.

Between the many river channels of the Meghna Sub-region, there are interfluvial areas called *haors*. Static water found at the center of the *haor* in the dry season , is known as *beel*. The *haors* comprise an important part of the agricultural land of the region, but their seasonal inundation severely constraints the agriculture. The *haors* also comprise an important part of the fisheries environment. When the ground water table remains over the ground level in dry season, the *beels* are permanent, where it falls below the ground level, the *beels* are seasonal.

2.3 CHANNEL MORPHOLOGY

The upper Surma flows through Surma Flood plain deposits until a point downstream of Chhatak where it enters the *haor* areas of the central basin. Between Amalshed and Chhatak, the Surma flows in a single irregularly meandering sand bed channel. The river becomes noticeably wider downstream of Chhatak. During most water level conditions there are no bars exposed and no islands. The river narrows again in the Nawa reach, downstream of the old Surma uptake. The main geomorphic features of the Surma are given in Table 2.1 (River Sedimentation and Morphology, FAP-6, 1993).

2.4 GEOLOGY AND LANDFORMS

The Indian sub-continent, including Bangladesh has evolved since *Cretaceous* times as a result of a collision between the northward moving Indian plate and the stationary Eurasian plate. During *Oligocene* times (38-26 million years ago), a portion of the north Indian plate fractured and sank below the sea level. This portion was eventually filled with sediments to form the Bengal Basin. Since this time the land has been developed by a process of deltaic sedimentation into a slowly subsiding *tectonic* basin. (River Sedimentation and Morphology, FAP-6 , 1993).

The Sylhet Trough is a sub-basin of the Bengal Basin and consists of 13-20 km thickness of alluvial and deltaic sediments underlain by much older *gneiss* and *granite* rocks. This basin is bounded by the Shilong plateau on the north, by the Indian-Burma ranges on the east and by the Indian shield to the west. Rapid subsidence has occurred in this basin since the *Miocene* times (22 million years ago) as a result of encroachment of the Indo-Burma Ranges to the east and overthrusting by Shilong Plateau along the Dauki fault to the north (Johnson and Alam, 1991). It is reported that the rates of subsidence may reach in the order of two meters per century (MPO-1980). Typical water surface slope in this region is 2m-4m/100 km which could be affected by the land subsidence. But, the land subsidence will be partly offset by long term sedimentation.

Information on seismic activity in this region was derived from MPO (1987), BETS (1989) and Rahman (1990). More than 120 large earthquakes have been recorded in and around Bangladesh over the last 130 years. These earthquakes centered mainly in the Shillong Plateau in Assam, in the Arakan Yoma Ranges and in the Indo-Burma Ranges in Myanmer. Earthquakes have also included land sliding and slope failures in headwater catchments in the Shillong Plateau, which could greatly increase the amount of sediment supplied to the region for long period of time. Therefore, river processes and sedimentation patterns in the north-east region may be subjected to major disruptions following severe seismic events.

Most landforms in the region are of *Holocene* age (less than 10000 years old). Earlier sediments were eroded during *Pleistocene* time when sea levels were lower than the present time. All of the sediments in the region are derived from fluvial, lacutrine and deltaic sedimentation. Most of the lands have been created by infilling of an embayment from the Brahmaputra river on the west and the Barak on the east. This has produced a characteristic ``*bowl*-shaped basin''.

Approximately 25% of the area of North-east region lies below the elevation of 5m and 50% of the area lies below the elevation of 8m. It is believed that the low lying nature of the region is due to ongoing land subsidence in the Sylhet Basin and limited supply of sediment to the central part of the basin.

The main physio-graphic sub-divisions of the North East region as published by the Geological Survey of Bangladesh (GSB, 1990) and Rashid (1991) are: Flood basin, Low land Flood plains, Piedmont Floodplains, Alluvial Fans, Terraces, Uplands. The physiographic characteristics of the basin are summarized below:

Flood basins and *haors* are the dominant landforms throughout the Central Basin, Meghalaya Basin and Sylhet Lowland . These lands form a low lying, bowl shaped depression in the middle of the region and occupy an area of 6000 km^2. Virtually all of the land lies below the elevation of 8m PWD and is deeply flooded during the monsoon season.

Floodplains are landforms that have been created as a result of fluvial deposition and erosion. GSB (1990) mapped Surma/Kushiyara floodplains as mainly alluvial silts and clays, including flood basin silts and back-swamps silts and organic-rich.

Piedmont floodplains have been formed along the southern and northern margins of the region by relatively small, steep tributary streams. Surface gradients on piedmont floodplains are much steeper (typically 3m/km) than low lying mainstream floodplains, with elevations ranging between 8-16 m PWD

Alluvial funs are found along the northern border of the Meghalaya foothills. The funs are produced when steep mountainous streams exit from their canyons and spread over the flat, unconfined land of the lowland floodplains and Sylhet depression.

Terraces: Uplifted *Pleistocene* age deposits (Madhupur Tract) occur along the western edge of this region which occupies an area of 495 km^2, has been raised by uplifting and faulting so that it is no longer subjected to inundation by normal flooding activity.

Uplands total about 1970 km^2 of land in the region or 8% of the total area. These tilas and hills are composed of weathered, poorly consolidated sandstone, siltstone and conglomerate (GSB, 1990).

CHAPTER 3

STUDIES ON ALLUVIAL RIVERS

3.1 PREVIOUS STUDIES

Recent literature survey indicates that very few water resources development project, construction project or related studies were under taken on the river Surma. The most significant studies carried out on the river Surma is the Northeast Regional Water Management Project. However innumerable studies on the Ganges and Brahmaputra relating hydrology, morphology and sediment transport had been under taken. Some of these studies are described in the following sections:

3.1.1 HYDRO-MORPHOLOGICAL STUDY

Bangladesh Water Development Board (BWDB) normally collects hydrological data and they publish it in different reports like `Water Level and Discharge Observation Records´, `Water Level Records´ and `Gauge and Discharge Observation´ under water supply papers. Moreover, the Hydrological Year Book of the Bangladesh Water Development Board contains hydrological data including rainfall and evaporation.

The cross-sectional data of the Ganges were analyzed in details by Hossain (1987), Hossain (1989) and Das (1992). Master Plan Organization (MPO, 1984) and its consultants have done some studies on surface water availability of Bangladesh. Alam and Ahmed (1980) have conducted flood frequency analysis for the Ganges using mean monthly and annual maximum discharge at Hardinge Bridge for the years 1935 to 1959. Hossain (1987) had studied the maximum and minimum flow of the Ganges at Hardinge Bridge using data of 1952 to 1986 before and after the construction of Farakka barrage. A number of studies have been conducted on the Brahmaputra, of which some examples are those of Alam and Hossain (1988), Sultana (1989), Hossain (1992), Ullah (1987) and Bari (1979). As mentioned earlier, no such study had been undertaken for the case of the Surma.

Morphological aspects of some major and minor rivers of Bangladesh are those of the Arialkhan were studied by Ashrafuzzaman (1992), Hossain (1989) on the Ganges and Ullah (1987) on the Brahmaputra. Rahman (1978) had studied the erosion pattern, its migrating tendency and direction of movement, formation and movement of sand bars for the river Padma from the Ganges-Brahmaputra confluence to the Padma-Meghna confluence. The most promising work was done by Colemen (1969). However, morphological studies on smaller regional river like the Surma is yet to be done.

3.1.2 HYDRAULIC GEOMETRY STUDY

Attempts were made by numerous investigators to develop quantitative relationships for river geometry, notably by Leopold and Maddock, Leopold and Wolman, Blench, Langbein and Engelund and Hansen (after Lane, 1957). Regime formulas for rivers in the most general form were given as functions of the discharge as follows:

$$W = aQ^b\ ;\quad D = cQ^f\ ;\quad V = kQ^m\ ;$$

in which $W=$ channel width ; $D=$ mean channel depth: $V=$mean flow velocity ; $Q=$ discharge: a,c,k are constants and b,f,m are exponents. From the continuity consideration $b+f+m=1$. Coefficients and exponents were found to vary depending on the river data used, no unique relationship has been determined.

For an alluvial channel, the necessary and sufficient condition for equilibrium is when the stream power is minimum. Hence, an alluvial channel with a given water discharge and sediment flow tends to establish its width, depth and slope such that the stream power is minimum. Das (1992) studied the hydraulic geometry for the river Ganges from Indo-Bangladesh Border to Aricha confluence covering a reach length of about 125 km and developed correlation between width, depth and velocity with discharge.

3.1.3 SEDIMENT TRANSPORT STUDY

Bangladesh Water Development Board has been collecting Sediment data for the river Surma since 1958 and they published it in different annual reports like 'Report on Analysis of Suspended Materials of Different Rivers of Bangladesh for the year 1975', `Annual Report on General Suspended Sediment Studies for the year 1989, 1990 and 1991' and `Report on Analysis of Suspended Material of Different Rivers of East Pakistan for the year 1965' etc. Bangladesh Water Development Board sediment program uses a field suspended procedure to split finer sized sediment from the suspended load and the concentration values represent only the fraction coarser than 0.06 mm (suspended sand load). Bangladesh Water Development Board suspended sand concentrations neither represent the total suspended load nor do they represent the suspended bed material load. This reduces usefulness of their data. Generally Bangladesh Water Development Board data falls lower than the other Asian data. This is probably due to the fact that Bangladesh Water Development Board sediment load includes only sand fraction where as the other data includes the silt and clay fractions.

The North East Regional Water Management Project analyzed bed material loads at Sylhet and Kanairghat station using Acker's White sediment transport equation. This load corresponds to sand coarser than 0.12 mm, moving on bed load as well as in suspension. They noticed that the annual load at Kanairghat is higher than that at Sylhet indicating local aggradation. The lower transport capacity at Sylhet is partly due to the reduction in flood flows at Sylhet caused by overbank spills.

Sediment transport aspects have so far been mainly studied for the major rivers of Bangladesh. Bari (1978) has analyzed the sediment data of the Ganges at Kalikapur for the year 1970, 1972 and 1973. Alam and Ahmed (1980) have analyzed sediment data at Kalikapur for the year 1969 to 1972. The Gorai was studied by Khan (1986). The most dependable sediment transport equation for the Surma is yet to be analyzed. Similar works were done by Alam and Hossain (1988) for the Ganges and Jamuna.

3.2 SEDIMENT TRANSPORT

From the remote past men have been concerned with problems of sediment transport. Hydraulics, in general, was considered as the first advancement in sediment transport that developed some 4,000 years back. Notable contributions were made in the field of sediment transport study by people, like, Hippocrates (400 BC), Leonardo Da Vincii

(1452-1915), J. Dupuit (1804-1866), Duboys (1847-1924) and P. Forchheimer (1852-1933). R.G. Kennedy was the pioneer in India, who studied sediment problems in design of irrigation canals in Punjab that was reported in his paper ``The Prevention of Silting Irrigation Canals'' in 1885. Subsequent studies by Lindley, Lacey, Inglis, Blench and others led to development of the Regime theory.

3.3 SEDIMENT TRANSPORT EQUATIONS

The rate of sediment transport in rivers depends on many variables, such as water discharge, average flow depth, flow velocity, energy slope, shear stress, stream power, particle size and gradation as well as temperature. Some of these variables are interrelated and depends on each other. It is very difficult to incorporate all these variables simultaneously and to develop one equation. Different equations have been put forward on the basis of different dominant variables as the independent variables. In the following, a brief review is made on some well known sediment transport equations:

Engelund and Hansen's Equation (1967):

Engelund and Hansen's equation is based on the shear approach. In developing the equation, Engelund and Hansen relied on data from experiment in a specific series of tests on a large flume. The sediments used in this flume had a median diameter of 0.27 mm, 0.45 mm and 0.93 mm. This equation can be written as:

$$g_s = 0.05\gamma_s V^2 \sqrt{\frac{D_{50}}{g\left(\frac{\gamma_s}{\gamma} - 1\right)}} \left[\frac{\tau_0}{(\gamma_s - \gamma) D_{50}}\right]^{\frac{3}{2}}$$

where,

$g_s =$ sediment transport per unit time per unit width;

$\tau_0 =$ bed shear stress;

$V =$ Average flow velocity;

$D_{50} =$ median diameter of bed material;

$\gamma_s =$ specific weight of sediment particles;

$\gamma =$ specific weight of water;

$g =$ acceleration due to gravity;

Since the equation is dimensionally homogeneous it can be used with any consistent set of units.

Hossain's Equation (1987):

Based on the concept of dimensional analysis and similitude argument Hossain proposed that sediment concentration in a stream of steady water and sediment flow is a power function of:

(i) the product of Froude number and Slope of energy gradient;

(ii) the settling velocity ratio;

(iii) the discharge ratio.

The functional form of the equation could be expressed as follows:

$$C_t = A\left[X^a Y^b Z^c\right]$$

where,

C_t = total average sediment concentration in parts per million;

$A = 6.946*10^5$ for $\frac{B}{H} < 500$

$A = 6.946*10^6$ for $\frac{B}{H} > 500$

$X = \frac{VS}{(gH)^{\frac{1}{2}}}$ and $a = 0.745$

$Y = \frac{\omega_r}{\omega}$ and $b = 0.633$

$Z = \frac{Q}{Q_c}$ and $c = 0.50$

ω_r = settling velocity for a representative sediment size for which $D_{50} = 0.15$mm at ambient temperature;

ω = settling velocity of the sediment load;

Q = measured discharge;

Q_c = assessed discharge;

$$Q_c = \left[\left(2.15 + K\frac{B}{H}\right)H(gS)^{\frac{1}{5}}\right]^{\frac{5}{2}}$$

where,

B = average width of the channel;

H = average depth of flow;

S = average water surface slope;

g = acceleration due to gravity;

The value of K is proposed to be 0.055 when $Q <$ 15000 cumecs and 0.17 when $Q >$ 15000 cumecs. Settling velocities of the sediment particles have been computed using Rubey's equation. The constants and coefficients of Hossain's equation were collected from a trapezoidal flow cross-section flume. The median size particles from 0.15 mm to 0.3 mm, the discharge ranged from 0.0001-0.015 m^3/s and the width-depth ratio from 0.68-42.6. It may be worthwhile to mention that Hossain's equation has successfully been used to estimate sediment transport of many rivers of Bangladesh (Hossain 1982, Sultana 1989, Das 1992 and Alam and Hossain 1988).

Yang's Equation (1976):

Yang proposed a sediment transport formula based on the concept of unit stream power, which can be utilized for the prediction of total bed material concentration transported in sand bed flumes and rivers (Garde J. R., 1977). The formula is as follows:

$$\log C_t = 5.435 - 0.286\log\frac{\omega D_{50}}{\nu} - 0.457\log\frac{u_*}{\omega}$$

$$+\left(1.799 - 0.409\log\frac{\omega D_{50}}{\nu} - 0.314\log\frac{u_*}{\omega}\right)\log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right)$$

where,

$\frac{V_{cr}}{\omega} = \frac{2.5}{\log\frac{u_* D_{50}}{\nu} - 0.06} + 0.66$; when $1.2 < \frac{u_* D_{50}}{\nu} < 70$ and

$\frac{V_{cr}}{\omega} = 2.05$ when $70 \le \frac{u_* D_{50}}{\nu}$

$C_t =$ total average sediment concentration in parts per million;

$D_{50} =$ median diameter of bed material;

$S =$ water surface slope;

$u_* =$ shear velocity;

$V =$ average water velocity;

$V_{cr} =$ critical average water velocity;

$\nu =$ kinematic viscosity;

$\omega =$ terminal fall velocity;

This equation is dimensionally homogeneous and any consistent set of units can be used.

Engelund and Fredsoe Formula (1976):

Engelund and Fredsoe (1976) proposed a bed load transport relationship incorporating the probability p of particle movements in the surface layer which contains $1/d^2$ grains per unit area (Raudkivi, 1990). Their result is:

$$\Phi_B = 5p\left(\sqrt{\theta} - 0.7\sqrt{\theta_c}\right)$$

where,

$$p = \left\{1 + \left[\frac{(\pi/6)\beta}{(\theta - \theta_c)}\right]^4\right\}^{1/4}$$

$\beta = \tan 27^0$ is assumed to be constant.

The probabilistic approach, later, has been used by Kalinske (1942, 1947) and Frijlink (1952) who tried to determine the amount of shear taken by solid particles in motion.

Van Rijn Formula (1984):

Van Rijn (1984) developed an analytical relationship for bed load transport in terms of the saltation height, particle velocity and bed load concentration (Raudkivi, 1990). The transport equation was expressed in terms of the dimensionless particle size D_* and his transport parameters T as

$$\frac{q_B}{\left[(S_S-1)g\right]^{0.5} d_{50}} = 0.053\frac{T^{2.1}}{D_*^{0.3}}$$

for grain sizes from 0.2 to 2 mm,

where,

q_B =flow per unit width, m^2s^{-1};

$T = \left[\left(u_*'\right)^2 - u_{*c}^2\right] / u_{*c}^2$;

$D_* = \left[(S_S-1)g/v^2\right]^{1/3} d_{50}$ and

v = kinematic viscosity;

u_{*c} is the critical shear velocity according to the shields. The grain shear stress:

$\tau_0' = \rho g U^2 / \left(C'\right)^2$, or $u_*' = \sqrt{g} U / C'$

where,

$C' = 18\log(12R_b / 3d_{90})$

A verification analysis using published data shows that about 77% of the predicted bed load transport rates are within 0.5 to 2 times the observed values. A simplified formula when only the mean velocity, flow depth and particle size are known, was given as

$$\frac{q_B}{Uy_0} = 0.005\left\{\frac{U-U_c}{[(S_S-1)gd_{50}]^{1/2}}\right\}^{2.4}\left\{\frac{d_{50}}{y_0}\right\}^{1.2}$$

where,

$$Uc = 0.19 d_{50}^{0.1} \log\left[\frac{12R_b}{3d_{90}}\right] \; ; \qquad 0.1 \le d_{50} \le 0.5 \text{ mm}$$

$$Uc = 8.5 d_{50}^{0.6} \log\left[\frac{12R_b}{3d_{90}}\right]; \qquad 0.1 \le d_{50} \le 2.0 \text{ mm}$$

R_b = mean hydraulic radius of the bed;

Mayer-Peter and Muller Formula (1948) :

The Mayer-Peter and Muller formula is based on data from experiments in flumes with width 15 cm to 2 m, slope 0.004 to 0.02, water depth 1 cm to 120 cm. Sediment used ranged from coal (specific gravity 1.25) to river sediment. Some of the sediment were graded and some other sorted. The mean size of the sediment ranged from 0.4 to 30 cm (Vanoni, 1977). The Mayer-Peter and Muller formula may be simplified as follows (Vanoni, 1977):

$$g_s^{2/3} = 250 q^{2/3} S - 42.5 d_{50}$$

where,

g_s = rate of bed load transport by weight/time/width;

q = discharge per unit width in;

S = water surface slope;

d_{50} = median diameter of bed material;

Rottner's Equation (1959):

Rottner proposed the following bed load equation which has been derived by relating the parameters obtained by a dimensional analysis of the problem (Rottner, 1959):

$$\frac{M}{\rho_S\left[gH^3\left(S_S-1\right)\right]^{1/2}}=\left[\left\{0.667\left(\frac{D_{50}}{H}\right)^{2/3}+0.14\right\}\frac{V}{\left(S_S-1\right)^{1/2}\left(gH\right)^{1/2}}-0.778\left(\frac{D_{50}}{H}\right)^{2/3}\right]^3$$

Where,

M = Sediment flow rate, mass per unit width/time;

$S_S = 2.65$;

ρ_S = density;

H = depth;

D_{50} = median diameter of bed material;

V = velocity.

CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.1 DATA COLLECTION

Data collected for the present study were cross-sectional map, discharge, water level, velocity and observed suspended sediment load for the river Surma. Cross-sectional data for the river Surma at 42 different sections from Kanairghat to Markuli, for the years 1970-1977 and 1988-91 were collected from the Morphology Division, Bangladesh Water Development Board. The location of the cross sections are shown in Figure 4.1. Suspended sediment load and corresponding discharge and velocity data for the river Surma at Sylhet for the years 1957-91 were collected from the Surface Water Hydrology-2, Bangladesh Water Development Board (BWDB), Dhaka. Mean daily discharge of the river Surma at Sylhet for the years 1970-71 to 1992-93 were also collected from the Surface Water Hydrology-2, Bangladesh Water Development Board (BWDB), Dhaka.

4.2 DATA ANALYSIS

In the present study 24 number of sections of the river Surma were selected out of available 42 number of sections surveyed by the Bangladesh Water Development Board from

Indo-Bangladesh border near Kanairghat to Markuli, approximately at 4 miles interval, for the years 1970-74 and 1988-89 (Inventory of Works, BWDB, 1964-93). These are: S-1, S-3, S-5, S-7, S-9, S-10, S-12, S-14, S-16, S-18, S-20, S-21, S-23, S-25, S-27, S-29, S-30, S-32, S-34, S-36, S-38, S-40, S-41 and S-41. All the co-ordinates i.e. distance from a fixed reference point at left bank to right bank and corresponding reduced level data for each section were entered into worksheets using Microsoft Excel for Windows Package program. Cross-section of nine selected sections e.g., S-1, S-5, S-10, S-14, S-21, S-25, S-30, S-34 and S-42 for the year 1970 and 1988-89 were plotted to visualize change in cross-section in nineteen years (Figure 4.2 to Figure 4.10). Then the cross-sectional area, average depth, width, mean bed level and deepest point (thalweg) of 24 selected sections were computed for the year 1970 and 1988-89 (Table 1 and Table 2). Cross-sectional area at 24 selected sections for the year 1970 and 1988-89 were plotted in Figure 4.11 to evaluate change in cross section.

Variation of width at bank level for 24 sections for the year 1970 and 1988-89 were plotted in Figure 4.12 to evaluate change in width from 1970 to 1988-89. Deepest point (thalweg) elevation for all the 42 sections for the year 1970 and 1988-89 were plotted for the year 1970 and 1988-89 (Figure 4.13)

Mean bed level was computed for those selected 24 sections for the year 1970 and 1988-89 to determine the extent of change of mean bed level for the respective section over 19 years period (Figure 4.14). The mean bed level of an equivalent rectangular cross section having width and area equal to the width and area respectively of that particular section were computed such that the net erosion below and deposition above this level remain unchanged for a hydrological year. This level was measured from a fixed reference line. This procedure is correct when the channel is wider that is the width to depth ratio is greater than 20 (Das, 1992). Erosion or deposition at 24 selected sections from 1970 to 1988-89 is shown in Table 4.3.

Area-elevation relationships were also developed for these nine selected sections for the year 1970 and 1988-89. Area-elevation computations are shown in Table 4.4 and Table 4.5. Area-elevation curves are drawn to see whether the river bed is rising or falling. One of such typical plot at section S-25 is shown in Figure 4.15.

The various hydraulic ,geometric and sediment transport parameters needed in these computations have been obtained by considering the active portion of the channel section. Values of these parameters have been determined according to the following criteria :

(i) Width of the channel has been taken as surface width. Measured width includes the width of shoals whenever required.

(ii) Mean depth of the flow has been determined from equivalent rectangular channel section whose top lateral dimension equals the water surface width. Thus the water section area divided by the water surface width gives the average depth. Then average depth was deducted from the bank level with respect to PWD datum. As a result Mean Bed Level for the respective section was obtained.

(iii)Average slope of the river Surma and D_{50} size of the sediment particle have been taken from Specialist Study, River Sedimentation and Morphology done by Northwest Hydraulic Consultants.

(iv) Cross-sectional area was computed corresponding to the right or the left bank level which is lower.

Total sediment transport for the river Surma at Sylhet for the year 1970, 1975 and 1989 were computed. This analysis included estimation of suspended sediment load on the basis of tons per day and then tons per year. The measured suspended sediment discharges were compared with those calculated by formulas (Table 4.6 to Table 4.8). This has been felt necessary to get a preliminary idea about the performance of the selected sediment transport equations. Total sediment load of the Surma was determined utilizing three very well known sediment equations. These are the Engelund-Hansen's equation, Yang's equation and Hossain's equation. These equations have been selected on the basis of their performance on various rivers of Bangladesh (Hossain 1990, Sultana 1989).

Graphical relationship between computed sediment load and discharge (rating curves) were developed and power type trend line equations were obtained (Figure 4.16 to Figure 4.18). Relationships between the suspended sediment load and discharge at Sylhet were computed using data for the year 1961 to 1990 (Figure 4.19). Discrepancy ratio of various equations for the years 1970, 1975 and 1989 are shown in Table 4.9, Table 4.10 and Table 4.11. Sediment transport at various discharge level for the years 1970, 1975 and 1989 are shown in Table 4.12, Table 4.13 and Table 4.14 respectively. Annual sediment transport of the river Surma for the Year 1970-71 to 1992-93 were computed using those relationships (Table 4.15).

Bed load at Sylhet for the years 1970, 1975 and 1989 were computed using Meyer-Peter and Muller's equation and Rottner's equation respectively. Bed load at different discharge levels as a percentage of total load is shown in Table 4.16. Graphical relationship between computed bed load and discharge were developed and power type trendline equations were obtained (Figure 4.20).

Relationships between the suspended sediment load and discharge with velocity were also computed using data for the years 1961 to 1990 and those are shown in Figure 4.21 and Figure 4.22 respectively.

Sample calculations on various aspects of this study are given in Appendix-I.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 VARIATION OF CROSS-SECTIONS

The selected nine cross-sections of the river Surma e.g. S-1, S-5, S-10, S-14, S-21, S-25, S-30, S-34 and S-42 for the years 1970 and 1988-89 were plotted in a same scale to visualize the variations of cross-sectional shape, width, deepest point and its movement through out the nineteen years period (Figure 4.2 to Figure 4.10). From the plotted charts it was evident that the river was becoming wider and shallower.

The cross-sectional areas at 24 different sections for the years 1970 and 1988-89 were plotted (Figure 4.11). The cross-sectional areas at the bank level were found to decrease noticeably for the year 1988-89 in comparison to those for the year 1970 in sections S-20 ($358.21m^2$), S-25 ($710.8m^2$) and S-30 ($694.28m^2$), which indicate that degradation in these sections have taken place. Whereas the value of the cross-sectional areas increase noticeably at sections: S-16 ($1196.44m^2$), S-18 ($1576.84m^2$), S-27 ($1679.43m^2$) and S-36 ($931.06m^2$) during nineteen years. It was also observed that the cross-sectional area of the river

Surma increases gradually from Kanairghat to Sunamganj (S-42 to S-11) except at the reach between Sylhet and Chhatak (S-25 to S-21) where it rapidly decreases. The maximum cross-sectional area in 1970 was found to be 3055.54m^2 at the section S-20 and 3855.8m^2 in 1988-89 at the section S-18. It was also observe that the cross-sectional area in the downstream of Sunamganj, old Surma region (S-10 to S-1), is very small.

Figure 4.12 shows that the section S-16 is the widest section in 1970 (745.2m) and in 1988-89 (846.7m). The section S-42 is the narrowest section in 1970 (296m) and in 1988-89 (266m). Maximum increase and decrease in width at bank level in nineteen years is found at sections S-18 (334.95m) and S-40 (143.14m) respectively.

Deepest point (thalweg) of all available 42 sections in 1970 and 1988-89 were plotted in Figure 4.13. Noticeable rise in deepest point was found in sections S-1 (4.75m), S-19 (4.45m), S-25 (6.86m) and S-38 (4.54m) respectively. However, deepest point falls considerably in sections S-3 (2.23m), S-11 (3.26m) and S-31 (2.29m). In 1970 exceptional deep points were found in sections S-12 (16.31m), S-18 (16.61m) and S-20 (17.37m) and the shallower sections were S-1 (6.86m), S-9 (6.92m) and S-10 (5.26m). In 1988-89, exceptional deep points were S-12 (17.00m), S-16 (17.15m), S-18 (19.8m) and S-42 (15.54m). Cross-sectional area, width, average depth and deepest point in 1970 and 1988-89 are shown in Table 4.1 and Table 4.2 respectively.

5.2 VARIATION OF MEAN BED LEVEL

Mean Bed Level at 24 different sections were computed and plotted for the years 1970 and 1988-89 (Figure 4.14). This analysis was conducted with a view to observe the effects of erosion and deposition on Mean Bed Level at the selected sections during the long period between 1970 and 1988-89. The maximum rise in mean bed level occurs in sections S-1 (1.65m), S-10 (1.30m) and S-18 (4.84m) whereas mean bed level falls in sections S-3 (1.13m), S-14 (0.86m), S-41 (0.97m) and S-42 (1.65m). Due to data scarcity it was not possible to quantify the total amount of erosion and deposition throughout the reach, but an idea was obtained.

5.3 AREA-ELEVATION RELATIONSHIP

Area-elevation curves are plotted to clearly visualize the aggradation and degradation of a particular section over a period. For this reason area-elevation curves for nine selected sections were plotted. One of such typical plot at section S-25 is shown in Figure 4.15. This figure indicates that a significant aggradation has taken place over the period 1970 to 1988-89. This supports the comparison of cross-section area shown in Figure 4.7. Summary of area-elevation relationship are shown in Table 4.4 and Table 4.5.

5.4 PERFORMANCE OF SEDIMENT DISCHARGE FORMULA

The observations analyzed herein have been taken from the Surma at Sylhet during the years 1970, 1975 and 1988. Total sediment load was also computed using the three selected sediment transport equations. These are : Engelund-Hansen's equation, Hossain's equation and Yang's equation.

Comparative study was undertaken for the measured suspended sediment discharge with those calculated by formulas. This is felt necessary to get a preliminary idea about the performance of these formulas.

5.4.1 ENGELUND - HANSEN'S FORMULA

Results obtained by Engelund-Hansen's method were consistently good (Table 4.6 to Table 4.8). Plotting of data of computed sediment load in ton per day and discharge in cumec for the year 1970, 1975 and 1989 are shown in Figures. 4.16, 4.17 and 4.18 respectively. Best fit lines were drawn for these data.

Relationships were developed between calculated sediment load and observed discharge for the year 1970, 1975 and 1989. The co-efficient of correlation was found to be equal to 0.852 (1970), 0.907 (1975) and 0.875 (1989). Regression equations were developed as follows:

$$Q_s = 44.802Q^{0.7105}; \qquad R^2 = 0.7261 \quad (1970)$$

$$Q_s = 18.2Q^{0.7393}; \qquad R^2 = 0.8222 \quad (1975)$$

$$Q_s = 4.7177Q^{0.8525}; \qquad R^2 = 0.7659 \quad (1989)$$

Where Q_s is the sediment discharge in ton per day and Q is the water discharge and R is the coefficient of correlation. It is apparent that the Q_s is well correlated with Q for the river Surma.

The mean discrepancy ratios (ratio of calculated value to measured value of sediment discharge) were 1.91, 0.83, and 1.15 for the year 1970, 1975 and 1989 respectively (Table 4.9 through Table 4.11).

5.4.2 HOSSAIN'S FORMULA

Result obtained by Hossain's formula is very close to the measured value (Table 4.6 to Table 4.8). Plotting of data of computed sediment load in ton per day and discharge in cumec for the year 1970, 1975 and 1989 are shown in

Figures. 4.16, 4.17 and 4.18 respectively. Best fit lines were drawn for these data.

Relationships were developed between calculated sediment load and observed discharge for the year 1970, 1975 and 1989. The co-efficient of correlation was found to vary between 0.991 (1970), 0.994 (1975) and 0.985 (1989). Regression equations were developed as follows:

$$Q_s = 0.1946Q^{1.612}; \qquad R^2 = 0.9829 \quad (1970)$$

$$Q_s = 1.5502Q^{1.3764}; \qquad R^2 = 0.9885 \quad (1975)$$

$$Q_s = 7.3503Q^{0.1243}; \qquad R^2 = 0.9706 \quad (1989)$$

Where Q_s is the sediment discharge in ton per day and Q is the water discharge and R is the coefficient of correlation. It is apparent that the Qs is very well correlated with Q for the river Surma.

The mean discrepancy ratios were 0.91, 1.24, and 3.43 for the years 1970, 1975 and 1989 respectively (Table 4.9 to Table 4.11).

5.4.3 YANG'S EQUATION

The performance of this formula against the present set of data is disappointing (Table 4.6 to Table 4.8). Plotting of data of computed sediment load in ton per day and discharge in cumec for the year 1970, 1975 and 1989 are shown in Figures. 4.16, 4.17 and 4.18 respectively. Best fit lines were drawn for these data. Relationships were developed between calculated sediment load and observed discharge for the year 1970, 1975 and 1989. The co-efficient of correlation was found to vary between 0.969 (1970), 0.98 (1975) and 0.936 (1989). Regression equations were developed as follows:

$$Q_s = 0.0866Q^{1.4377}, \qquad R^2 = 0.9383 \quad (1970)$$

$$Q_s = 0.1581Q^{1.3334}, \qquad R^2 = 0.9595 \quad (1975)$$

$$Q_s = 0.1789Q^{0.2521}, \qquad R^2 = 0.8719 \quad (1989)$$

Where Q_s is the sediment discharge in ton per day and Q is the water discharge and R is the coefficient of correlation. The mean discrepancy ratios were 0.13, 0.10, and 0.16 for the year 1970, 1975 and 1989 respectively (Table 4.9 through Table 4.11).

5.5 COMPARATIVE STUDY

Formulas suitable for the river under study have been selected on the basis of previous studies about their performance on various rivers of Bangladesh (Hossain 1990, Sultana 1989, Alam and Hossain 1988). Of the three equations examined in the current study, the Engelund-Hansen's equation and Hossain's equation were able to predict sediment transport rates. The results obtained by Yang's formula are too low compared to the other two methods. Hossain's formula provided relatively realistic results against present set of data. Hossain's equation was developed using a trapezoidal flume with mobile bed which has reasonable resemblance with natural stream. The sediment size used in his experiments are typically similar to that of carried by Bangladeshi rives. More over this equation was developed based on stream Froude power approach, which is a vital parameter for determining the sediment transporting capacity of an alluvial stream. This parameter is missing in the other equations. The Engelund-Hansen's equation was derived using sediment sizes 0.93 mm on a small flume and the author recommended that this equation should not be used for cases where median size of the sediment is less than 0.15 mm. For the present cases the d_{50} of suspended sediment is less than 0.15 mm. Hence it is quite likely that Engelund-Hansen formula would yield a different transport values. Similar arguments could as well be valid for Yang's equation also. A general relationship was developed between water and sediment discharge combining data for the years 1970 , 1975 and 1989 as follows:

$Q_s = 1.1904Q^{1.3821}$; $R^2 = 0.9421$ (Using Hossain's equation),

$Q_s = 14.918Q^{0.8013}$; $R^2 = 0.7278$ (Using Engelund Hansen's equation),

$Q_s = 0.1246Q^{1.3663}$; $R^2 = 0.9334$ (Using Yang's Equation)

Where Q_s is the sediment discharge in ton per day and Q is the water discharge and R is the coefficient of correlation. Relationship between the suspended sediment load and discharge at Sylhet was computed using data for the year 1961 to 1990 (Figure 4.19) is as follows:

$$Q_S = 0.4959Q^{1.5166} \qquad R^2 = 0.8086$$

Where Q_s is the sediment discharge in ton per day and Q is the water discharge and R^2 is the coefficient of correlation.

Annual total sediment transport of the river Surma for the year 1970-71 to 1992-93 was computed using above relationships is shown in Table 4.15. Using suspended sediment load data, the annual suspended sediment transport for the Surma was found to vary from 1.563 million tons to 3.966 million tons, the average value is 2.681 million tons. The annual total sediment transport computed by Engelund-Hansen's method for the Surma varies from 0.654 million tons to 1.07 million tons, the average value being 0.863 million tons. Using Yang's equation, the annual total sediment transport varies from 0.17 million tons to 0.393 million tons, the average value being 0.215 million tons. Hossain's equation results the annual total sediment transport of the Surma ranging from 1.67 million tons to 3.924 million tons, the average value being 2.739 million tons. Therefore, it can be concluded that Hossain's equation is found to be best among three against the data of the Surma river followed by Engelund-Hansen's equation.

5.6 ESTIMATED BED LOAD

Bed load was computed using Meyer-Peter and Mueller's equation and Rottner's equation. A general relationship between water and the bed load for the river Surma at Sylhet was developed combining data for the years 1970 , 1975 and 1989 (Figure 4.20) as follows:

Using Meyer-Peter & Muller's Equation,

$$Q_b = 0.0034Q^{1.3771}; \quad R^2 = 0.9382$$

Using Rottner's Equation,

$$Q_b = 0.783Q^{0.9239}; \quad R^2 = 0.5186$$

Where Q_b is the bed load in ton per day and Q is the water discharge and R is the coefficient of correlation. The bed load as a percentage of suspended load for the river Surma at different discharge level is shown in Table 4.16.

5.7 RELATIONSHIP BETWEEN SUSPENDED SEDIMENT LOAD AND VELOCITY

Relationships between the suspended sediment load and velocity was computed using data from 1961 to 1990 (Figure 4.21). The data have been fitted roughly by power relations which are straight lines on logarithmic graph. From this figure it was observed that the sediment transport increases with the increase of velocity. Regression equation was developed as follows:

$$Q_s = 14293V^{2.3295}, \qquad R^2 = 0.6775$$

Where Q_s is the sediment transport in ton per day, V is the observed discharge in cumec and R is the coefficient of correlation. From the graph it is observed that sediment transport increases with velocity.

5.8 RELATIONSHIP BETWEEN DISCHARGE AND VELOCITY

Relationship between the observed discharge and velocity was computed using data from 1961 to 1990 (Figure 4.22). The data have been fitted roughly by power relations which is a straight line on logarithmic graph. Regression equation was developed as follows:

$$V = 428.34Q^{2.4763}, \qquad R^2 = 0.6884$$

Where Q is the water discharge in cumec, V is the observed discharge in cumec, ? and R is the coefficient of correlation. From this figure it was observed that the velocity increases with the increase of discharge.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions may be drawn from the present study :

1. It was observed that the river was becoming wider and shallower. In most of the sections the deepest point (thalweg) in 1970 was at a higher elevation than that of the year 1988-89 which indicates a depositing tendency. However, from section S-35 through section S-41 erosions have taken place during that specified period. An exceptional deep point was found at section S-12. It was also observed that there is a trend of rise in mean bed level in the whole study reach.

2. Three sediment transport equations were tested against the suspended sediment data collected from Bangladesh Water Development Board. Values predicted by Hossain's equation were found to be in' closer agreement with the measured values followed by Engelund-Hansen's equation. Results obtained from Yang's equation is very low.

3. The annual suspended sediment flow for the Surma at Sylhet shows a slightly increasing trend. The average annual suspended sediment flow of the Surma at Sylhet is estimated as 2.681 million tons. The peak suspended sediment flow is estimated as 3.966 million tons in the year 1991-91. Correlation between suspended sediment flow and water flow were developed for ready use. Correlation between total sediment flow and water flow were also developed.

4. Bed load has been estimated by Meyer-Peter and Muller's equation and Rottner's equation. Correlation between bed load and water discharge have been developed which have been used to compute bed load as a percentage of suspended load at various discharge levels.

5. Power type relationship has been developed between suspended sediment load and velocity. Similar relationship has been developed between discharge and velocity.

6.2 RECOMMENDATIONS

1. In the present study only 24 selected cross-sections were considered. Similar type of studies could be carried out for greater number of sections for further verification of relationships obtained here.

2. Cross-sectional data for most of the sections were discontinuous. Continuous data for a longer period should be studied for better prediction.

3. In the present study total sediment load has been computed for Sylhet only. For studying sediment transport characteristics of a river, data from a number of sections should be considered.

4. In the present study three sediment transport equations were used. Similar types of work could be done considering other sediment equations.

5. Similar types of work should be carried out on other small and medium size rivers.

REFERENCES

Alam, M.K. and Hossain, M.M. (1988) "Sediment Transport in the River Jamuna", Journal of the Institution of Engineers, Bangladesh, Vol. 16, No. 2, pp 19-26.

Ashrafuzzaman, A.K.M. (1992) "A Study on the Geometric aspect of the Arialkhan River", M.Sc. Engg. Thesis, BUET, Department of Water Resources Engineering, Dhaka.

Bari, M.F. (1978) "Applicability of Sediment Transport Formulas for the Ganges and Jamuna", M.Sc. Engg. Thesis, Department of Water Resources Engineering, BUET, Dhaka.

BWDB, Report on Analysis of Suspended Materials of Different Rivers of Bangladesh for the year 1970, Hydraulic Research Laboratory.

BWDB, Report on Analysis of Suspended Materials of Different Rivers of Bangladesh for the year 1975, Hydraulic Research Laboratory.

BWDB, Annual Report on General Suspended Sediment Studies for the year 1989, 1990 and 1991, Sediment, Chemical, Water Pollution and Ground Water utilization Division, Geotechnical Research Directorate, River Research Institute, Faridpur.

BWDB, Morphological Survey Data of the River Surma during 1988-89, Morphology Division, BWDB, Mymensingh.

BWDB, Morphological Survey Data of The River Surma, Period of Observation 1989-90, Morphology Division, BWDB, Jamalpur.

BWDB, Inventory of Works as on June, 1993, Period of Observation 1964-93. Morphology Division, BWDB, Mymensingh.

Coleman, J.M. "Brahmaputra River: Channel Processes and Sedimentation", Sedimentary Geology, Vol. 3, No. 2/3, pp. 129-239, 1969.

Das S.K. (1992) "Study of Hydraulic Geometry of the Ganges", M. Engg. Thesis, BUET, Department of Water Resources Engineering, Dhaka.

EPWAPDA, (1958) "Study of Materials in Suspension in Different Rivers of East Pakistan for the year 1957", Hydraulic Research Laboratory Report Number: Sediments-1(57), April, 1958.

EPWAPDA, (1959) "Study of Materials in Suspension in Different Rivers of East Pakistan for the year 1958", Hydraulic Research Laboratory Report Number: Sediments-1(58), April, 1959.

EPWAPDA, (1965) "Study of Materials in Suspension in Different Rivers of East Pakistan for the year 1965", Hydraulic Research Laboratory Report.

EPWAPDA, Flood and River Control, Surma River Range S#1 - S#42, Plan and Profile for the year 1969-71, Brahmaputra Circle, Dhaka.

FAP-6 (1993), Surface Water Resources of Northeast Region, Specialist Study.

FAP-6 (1993), River Sedimentation and Morphology, Specialist Study.

Garde, R. J. and Ranga Raju, K.G. (1985), ´´ Mechanics of Sediment Transport and Alluvial Stream Problems.´´, Willy Eastern Ltd., 2nd Edition, New Delhi.

Hossain, M.M. (1989) "Geomorphic Characteristics of the Padma up to Brahmaputra Confluence", Final Report, R 02/89, IFCDR, BUET

Hossain, M.M. (1992) "Total Sediment Load in the Lower Ganges and Jamuna´´, Journal of the Institution of Engineers, Bangladesh, Vol. 20, 1-2, January-April, 1992.

Hossain, M.M., Shahjahan, M and Ahmed, E (1990) "Assessment of Sediment Transport in the Teesta River", Journal of the Institution of the Engineers, Bangladesh, Vol. 18, No. 4, pp. 19-25.

Hossain, M. M. and Barr, D.I.H (1988) ``Sediment Transport Equation: An Evaluation.´´, Journal of Indian Water Resources Society, Vol. 8, No. 4, pp. 1-19

Khan W.(1986) "Study of Sediment Transport in the River Gorai-Modumoti", M.Sc. Engg. thesis, Department of Water Resources Engineering, BUET.

Matin, M.A. and Ahmed, S. M. (1983) "A Study of Daily Rainfall for the North-Eastern Zone of Bangladesh", Bangladesh Journal of Water Resource Research, Bangladesh, Vol. 4, No. 1, pp 11-17.

Matin, M.A. and Ahmed, S. M. (1984) "Rainfall Intensity-Duration-Frequency Relationship for North-Eastern Region of Bangladesh'', Bangladesh Journal of Water Resource Research, Bangladesh, Vol. 5, No. 1, pp 7-19.

Rahman, K. S. (1978) "A Study on the Erosion of the River Padma", M. Engg. Thesis, BUET, Department of Water Resources Engineering, Dhaka.

Raudkivi, A. J. (1990) ''Loose Boundary Hydraulics'', 3rd Edition, Pergamon Press.

Rottner, J. (1958) ``A Formula for Bed Load Transportation'', La Houille Blanche, Vol. 4, No. 3, pp 302-307.

Sultana, N. (1989) "Critical Review of Sediment Transport Studies of Jamuna River" M. Engg. Thesis, BUET, Department of Water Resources Engineering, Dhaka.

Ullah, M. H. (1987) "Computer Modelling of River Channel Changes in Alluvial Condition", First Interim Report, R 02/87, IFCDR, BUET, Dhaka.

Vanoni, V. A. (1977), Editor ``Sedimentation Engineering'', ASCE Manual No. 54, Newyork.

TABLE 2.1: THE MAIN GEOMORPHIC FEATURES OF THE SURMA

Extent of River Reach	Channel Pattern	Bars	Islands	Vertical Stability	Lateral Stability	Bed Material	Sinuosity	Slope (m/km)	Bankfull Dimension
						D_{65} (mm) D_{50} (mm) D_{35} (mm)		Average Pre-monsoon Monsoon	Top Width Mean Depth Area
Amalshed-Chhatak 0-164 km	Single; Irregular Meanders	Point Bars	Absent	Stable	Minor erosion due to progressive meander migration	0.23 0.20 0.16	1.51	0.040 0.040 0.050	172.0 8.4 1448.0
Chhatak-Old Surma 164-220 km	Single; Sinuous Meanders	Absent	Few	Degrading	Minor widening	0.18 0.16 0.13	1.58	0.005 0.005 0.026	251.0 10.3 2583.0
Old Surma-Baulai river 220-248 km	Single; Irregular Sinuous	Absent	Few	Degrading	Minor widening	0.100 0.095 0.080	1.24	0.008 0.030 0.014	177.0 11.3 1996.0

TABLE 2.2 : THE SEASONAL DISTRIBUTION OF THE RUNOFF AT KANAIRGHAT

Season	Mean Discharge (m^3/s)	Mean Runoff (MCM)	(%)
Pre-Monsoon	404	2130	12.3
Monsoon	1235	13018	75.3
Post-Monsoon	367	1935	11.2
Dry-Season	21	216	1.2
Year	549	17299	100.0

TABLE 2.3 : THE SEASONAL DISTRIBUTION OF THE RUNOFF AT SYLHET

Season	Mean Discharge (m^3/s)	Mean Runoff (MCM)	(%)
Pre-Monsoon	399	2104	11.9
Monsoon	1263	13312	75.0
Post-Monsoon	395	2082	11.7
Dry-Season	23	245	1.4
Year	563	17742	100.0

TABLE 2.4 : WATER LEVELS IN THE SURMA OBSERVED BY THE BWDB

Gauge	Record (years)	Mean (m PWD)	Water Level Minimum (m PWD)	Water Level Maximum (m PWD)	Range (m)
Kanairghat	26	8.32	3.93	15.04	11.11
Sylhet	11	6.34	1.99	11.94	9.95
Chhatak	25	5.43	1.10	11.16	10.06
Sunamganj	27	5.23	1.34	9.46	8.12

TABLE 2.5 : THE SEASONAL DISTRIBUTION OF WATER LEVELS IN THE SURMA

Season	Mean Water Level (m PWD)			
	Kanairghat	Sylhet	Chhatak	Sunamganj
Pre-Monsoon	7.81	6.10	5.19	5.06
Monsoon	12.27	9.74	8.32	7.68
Post-Monsoon	8.05	6.58	5.88	5.84
Dry-Season	4.71	2.93	2.43	2.50
Year	8.32	6.34	5.43	5.22

TABLE 4.1: CROSS-SECTIONAL AREA, WIDTH, AVERAGE DEPTH, MEAN BED LEVEL AND DEEPEST POINT AT VARIOUS SECTIONS (1970)

Section No.	Bank Level (m PWD)	Area (sq.m)	Width (m)	Average Depth (m)	MBL (m PWD)	Deepest Point (m PWD)
S-1	5.26	671.30	572.96	1.17	4.08	-1.60
S-3	4.57	713.86	239.59	2.98	1.59	-4.04
S-5	6.71	1094.80	643.66	1.68	5.02	-2.90
S-7	7.01	1016.75	434.54	2.34	4.67	-5.26
S-9	7.47	770.70	255.33	3.02	4.45	0.55
S-10	6.71	731.26	310.16	2.36	4.34	1.45
S-12	7.32	1961.75	495.65	3.96	3.36	-8.99
S-14	8.17	2490.90	606.37	4.11	4.06	-5.79
S-16	8.23	2119.68	745.20	2.84	5.39	-6.40
S-18	6.55	2278.96	309.43	7.37	-0.81	-10.06
S-20	10.06	3055.54	400.42	7.63	2.43	-7.32
S-21	8.69	1446.71	268.59	5.37	3.32	-4.57
S-23	9.08	750.47	170.44	4.40	4.68	-3.23
S-25	10.49	1804.68	546.28	3.39	7.10	-6.25
S-27	10.49	1196.85	243.49	4.92	5.57	-2.90
S-29	11.92	1474.63	287.13	5.14	6.78	-0.76
S-30	12.19	2629.94	614.89	4.20	7.99	-2.59
S-32	12.04	1594.27	598.93	2.66	9.38	-0.30
S-34	12.65	1256.33	229.67	5.47	7.18	-2.06
S-36	12.80	1616.76	471.03	3.43	9.37	2.59
S-38	13.59	1886.67	712.49	2.65	10.95	-1.52
S-40	14.33	1629.98	392.95	4.15	10.18	3.12
S-41	14.75	1723.79	602.90	2.86	11.89	3.63
S-42	15.54	1461.12	295.56	4.94	10.60	1.07

TABLE 4.2: CROSS-SECTIONAL AREA, WIDTH, AVERAGE DEPTH, MEAN BED LEVEL AND DEEPEST POINT AT VARIOUS SECTIONS (1988-89)

Section No.	Bank Level (m PWD)	Area (sq.m)	Width (m)	Average Depth (m)	MBL (m PWD)	Deepest Point (m PWD)
S-1	6.89	532.33	461.94	1.15	5.73	3.15
S-3	5.66	1275.72	245.46	5.20	0.46	-6.26
S-5	6.77	1276.26	608.07	2.11	4.66	-3.83
S-7	7.24	979.04	517.72	1.89	5.35	-4.79
S-9	7.56	762.00	254.42	3.00	4.56	1.65
S-10	7.35	610.63	357.23	1.71	5.64	2.04
S-12	7.64	2268.14	545.18	4.16	3.48	-9.36
S-14	7.89	2543.43	541.82	4.69	3.19	-5.18
S-16	8.85	3316.12	846.75	3.92	4.93	-8.30
S-18	10.01	3855.80	644.38	5.98	4.03	-9.78
S-20	9.77	2697.33	403.72	6.68	3.09	-3.41
S-21	8.84	1314.11	270.60	4.86	3.98	-1.45
S-23	8.98	881.59	179.51	4.91	4.07	-2.70
S-25	10.20	1137.28	478.66	2.38	7.82	0.62
S-27	10.96	2876.28	569.71	5.05	5.91	-3.34
S-29	11.86	1700.57	308.99	5.50	6.36	0.87
S-30	11.99	1889.42	654.01	2.89	9.10	1.31
S-32	12.14	1639.33	583.77	2.81	9.33	0.98
S-34	12.57	1385.49	233.82	5.93	6.64	-1.26
S-36	13.94	2547.82	579.97	4.39	9.55	1.46
S-38	14.04	2436.42	771.28	3.16	10.88	3.01
S-40	14.63	1729.60	461.21	3.75	10.88	1.51
S-41	15.14	1939.72	459.76	4.22	10.93	3.97
S-42	15.86	1840.97	266.14	6.92	8.95	0.33

TABLE 4.3: EROSION AND DEPOSITION OF THE SURMA

Section No.	Change in Area (sq.m)	Change in Width (m)	Change in Average Depth (m)	Change in MBL (m PWD)	Change in Deepest Point (m PWD)
S-1	-139.08	-111.02	-0.02	+1.65	+4.75
S-3	+561.86	+5.87	+2.22	-1.13	-2.23
S-5	+197.29	-35.59	+0.42	-0.36	-0.93
S-7	-37.71	+83.18	-0.45	+0.68	+0.47
S-9	-8.70	-0.91	-0.02	+0.11	+1.10
S-10	-121.99	+47.07	-0.65	+1.30	+0.59
S-12	+306.39	+49.53	+0.20	+0.12	-0.37
S-14	+50.93	-64.55	+0.58	-0.86	+0.61
S-16	+1196.44	+101.55	+1.07	-0.45	-1.90
S-18	+1576.84	+334.95	-1.38	+4.84	+0.27
S-20	-358.21	+3.30	-0.95	+0.67	+3.90
S-21	-128.15	+2.01	-0.51	+0.67	+3.12
S-23	+131.12	+9.07	+0.51	-0.61	+0.53
S-25	-710.80	-67.62	-1.01	+0.72	+6.86
S-27	+1679.43	+326.22	+0.13	+0.34	-0.44
S-29	+225.94	+21.86	+0.37	-0.42	+1.63
S-30	-694.28	+39.12	-1.31	+1.11	+3.90
S-32	+45.06	-15.16	+0.15	-0.05	+1.28
S-34	+129.16	+4.15	+0.46	-0.53	+0.80
S-36	+931.06	+108.94	+0.96	+0.18	-1.13
S-38	+549.75	+58.79	+0.51	-0.07	+4.54
S-40	+99.62	+68.26	-0.40	+0.70	-1.62
S-41	+214.88	-143.14	+1.36	-0.97	+0.34
S-42	+379.85	-29.42	+1.97	-1.65	-0.74

* '+' ve sign indicates increase in cross-sectional area/width or rise in elevation.

** '-' ve sign indicates decrease in cross-sectional area/width or fall in elevation.

TABLE 4.4: RELATIONSHIP BETWEEN CROSS-SECTIONAL AREA AND ELEVATION FOR THE SURMA (1970)

S-1														
Area (sq.m)	0.00	0.03	12.91	54.87	114.07	358.74	671.30							
Elevation (m PWD)	-1.60	-1.52	0.00	1.52	3.05	4.57	5.26							
S-5														
Area (sq.m)	0.00	34.39	132.38	271.55	447.27	639.89	851.80	1094.80						
Elevation (m PWD)	-2.29	-1.52	0.00	1.52	3.05	4.57	6.10	6.71						
S-10														
Area (sq.m)	0.00	2.00	106.91	250.50	544.11	731.26								
Elevation (m PWD)	1.45	1.52	3.05	4.57	6.10	6.71								
S-14														
Area (sq.m)	0.00	34.28	163.28	343.65	579.42	840.82	1131.34	1434.44	1747.10	2204.84	2490.90			
Elevation (m PWD)	-5.79	-4.57	-3.05	-1.52	0.00	1.52	3.05	4.57	6.10	7.62	8.17			
S-21														
Area (sq.m)	0.00	24.62	91.10	181.09	329.20	531.95	756.81	995.95	1241.32	1446.71				
Elevation (m PWD)	-4.57	-3.05	-1.52	0.00	1.52	3.05	4.57	6.10	7.62	8.69				
S-25														
Area (sq.m)	0.00	16.84	58.29	114.04	200.15	311.33	437.69	583.62	741.97	910.12	1084.38	1263.65	1447.91	1804.68
Elevation (m PWD)	-8.98	-7.62	-6.10	-4.57	-3.05	-1.52	0.00	1.52	3.05	4.57	6.10	7.62	9.14	10.49
S-30														
Area (sq.m)	0.00	5.60	35.64	110.01	231.23	430.24	685.97	963.98	1251.34	1564.82	2629.94			
Elevation (m PWD)	-2.59	-1.52	0.00	1.52	3.05	4.57	6.10	7.62	9.14	10.67	12.19			
S-34														
Area (sq.m)	0.00	1.53	21.38	54.18	108.60	215.78	375.56	562.53	758.78	964.50	1180.13	1256.33		
Elevation (m PWD)	-2.06	-1.52	0.00	1.52	3.05	4.57	6.10	7.62	9.14	10.67	12.19	12.50		
S-41														
Area (sq.m)	0.00	10.64	94.32	260.19	477.87	710.90	955.97	1214.48	1723.79					
Elevation (m PWD)	1.11	4.57	6.10	7.62	9.14	10.67	12.19	13.72	14.75					

TABLE 4.5: RELATIONSHIP BETWEEN CROSS-SECTIONAL AREA AND ELEVATION FOR THE SURMA (1988-89)

S-1											
Area(sq.m)	0.00	90.55	291.07	532.33							
Elevation (m PWD)	3.15	4.57	6.10	6.89							
S-5											
Area(sq.m)	0.00	22.78	101.03	211.22	349.68	518.24	714.89	967.79	1276.26		
Elevation (m PWD)	-3.92	-3.05	-1.52	0.00	1.52	3.05	4.57	6.10	6.77		
S-10											
Area(sq.m)	0.00	20.42	78.06	224.60	620.11						
Elevation (m PWD)	2.04	3.05	4.57	6.10	7.35						
S-14											
Area(sq.m)	0.00	11.48	163.82	407.68	671.15	954.21	1256.88	1579.17	1921.09	2274.09	2543.43
Elevation (m PWD)	-5.18	-4.57	-3.05	-1.52	0.00	1.52	3.05	4.57	6.10	7.62	7.89
S-21											
Area(sq.m)	0.00	65.04	218.59	415.99	634.19	859.44	1091.10	1314.11			
Elevation (m PWD)	-1.45	0.00	1.52	3.05	4.57	6.10	7.62	8.84			
S-25											
Area(sq.m)	0.00	13.37	115.80	298.08	490.69	687.41	888.59	1137.28			
Elevation (m PWD)	0.62	1.52	3.05	4.57	6.10	7.62	9.14	10.20			
S-30											
Area(sq.m)	0.00	0.64	58.15	241.06	486.90	753.85	1036.74	1333.35	1889.42		
Elevation (m PWD)	1.31	1.52	3.05	4.57	6.10	7.62	9.14	10.67	11.99		
S-34											
Area(sq.m)	0.00	25.57	91.31	181.31	302.52	469.26	667.49	876.69	1093.80	1320.78	1385.49
Elevation (m PWD)	-1.26	0.00	1.52	3.05	4.57	6.10	7.62	9.14	10.67	12.19	12.57
S-41											
Area(sq.m)	0.00	18.24	204.89	441.05	684.73	932.41	1191.09	1461.66	1939.72		
Elevation (m PWD)	3.97	4.57	6.10	7.62	9.14	10.67	12.19	13.72	15.15		

TABLE 4.6: COMPUTATION OF SEDIMENT TRANSPORT (1970)

Sl. No.	Sampling date	Observed Discharge cumec	Suspended Sediment Load ton/day	Total Load: Engelund Hansen's Formula ton/day	Total Load: Yang's Formula ton/day	Total Load: Hossain's Formula ton/day
1	11.02.70	4.08	46.86	360.34	1.55	2.94
2	26.02.70	7.31	76.38	736.40	4.87	9.01
3	11.03.70	6.40	58.06	340.47	2.33	5.68
4	25.03.70	3.31	32.35	236.51	0.93	2.00
5	08.04.70	149.99	466.54	281.39	32.95	329.52
6	07.05.70	168.46	465.75	472.78	50.89	382.46
7	01.07.70	1228.27	30244.96	7366.26	2683.33	26079.57
8	08.07.70	742.18	9875.21	7715.52	1584.25	7259.56
9	16.07.70	1822.56	57003.76	15465.22	5643.06	44897.3
10	22.07.70	1833.09	29458.51	16468.74	6317.79	50304.1
11	29.07.70	1713.51	39972.74	14674.30	5405.12	43397.4
12	05.08.70	1520.61	34684.61	12385.20	4441.36	36399.78
13	12.08.70	1443.93	25450.18	11652.00	4188.29	34657.51
14	19.08.70	1286.83	24793.63	10989.53	3849.08	33719.03
15	26.08.70	680.96	3647.79	4619.58	1011.07	5346.12
16	02.09.70	870.83	10834.49	6869.25	1689.76	8642.45
17	09.09.70	542.66	9517.89	3452.25	683.57	3754.63
18	17.09.70	1403.35	21097.47	10182.03	3873.15	35031.39
19	24.09.70	1208.65	6996.62	10510.76	3251.33	23813.73
20	01.10.70	1121.77	9692.11	11361.92	3015.16	14240.03
21	08.10.70	1893.21	25190.26	15972.81	7108.94	60223.9
22	15.10.70	1080.37	13908.29	9018.99	2497.56	12693.03
23	22.10.70	329.38	1735.97	1027.17	176.46	1272.97
24	29.10.70	411.50	5155.28	1835.45	330.75	2045.33
25	05.11.70	239.96	974.42	780.84	108.84	784.65
26	20.11.70	208.53	1657.53	638.35	87.50	689.23
27	04.12.70	37.21	118.95	33.40	0.95	22.71
28	16.12.70	18.80	48.74	250.96	4.53	19.62
29	30.12.70	10.51	68.08	378.70	3.80	10.58

TABLE 4.7: COMPUTATION OF SEDIMENT TRANSPORT (1975)

Sl. No.	Sampling date	Observed Discharge cumec	Suspended Sediment Load ton/day	Total Load: Engelund Hansen's Formula ton/day	Total Load: Yang's Formula ton/day	Total Load: Hossain's Formula ton/day
1	07-02-75	5.64	41.87	55.59	1.40	16.90
2	21-02-75	6.29	31.50	196.40	4.52	30.91
3	07.03.75	5.61	54.26	166.50	3.59	25.26
4	21-03-75	3.00	16.08	48.51	0.72	7.17
5	04-04-75	2.58	28.94	39.67	0.54	5.66
6	18-04-75	238.12	1625.29	190.36	68.93	1695.27
7	02-05-75	415.63	2441.94	727.37	283.00	4228.74
8	09-05-75	118.90	1561.52	57.46	12.44	439.40
9	23-05-75	775.54	9917.01	2671.22	1209.49	12994.07
10	30-05-75	707.61	11738.40	2156.92	973.90	11146.75
11	06-06-75	331.14	2660.75	478.57	164.79	2660.90
12	14-06-75	854.26	9521.27	3102.05	1486.06	15830.23
13	20-06-75	921.74	15529.50	4783.83	2058.69	18749.97
14	27-06-75	842.68	12522.91	3100.89	1420.68	15441.48
15	05-07-75	867.66	11619.66	3476.26	1590.21	16844.11
16	11-07-75	1074.99	22198.16	3590.33	1951.94	23571.27
17	18-07-75	1836.57	100603.12	6552.13	4809.51	68026.34
18	26-07-75	1925.63	96663.57	8712.23	5211.37	60374.00
19	02-08-75	1854.13	17781.85	9286.06	5211.01	58541.60
20	08-08-75	1245.46	20337.86	4249.32	2482.20	35654.13
21	22-08-75	1623.74	34932.59	6268.82	4205.32	57669.26
22	29-08-75	1001.31	6575.02	2916.65	1633.76	25562.11
23	05-09-75	1537.60	47559.96	6951.49	4391.54	57084.69

TABLE 4.8 COMPUTATION OF SEDIMENT TRANSPORT (1989)

Sl. No.	Sampling date	Observed Discharge cumec	Suspended Sediment Load ton/day	Total Load: Engelund Hansen's Formula ton/day	Total Load: Yang's Formula ton/day	Total Load: Hossain's Formula ton/day
1	01.01.89	27.24	40.01	5.12	0.51	98.61
2	11.01.89	20.50	38.97	37.50	5.38	184.68
3	25.01.89	12.63	16.37	52.83	6.29	155.72
4	07.02.89	9.87	35.82	45.88	5.04	124.27
5	22.02.89	32.63	59.20	85.81	19.77	572.33
6	08.03.89	8.18	16.25	103.00	6.92	98.25
7	22.03.89	6.23	32.84	64.99	4.46	74.74
8	05.04.89	269.21	907.13	657.43	277.06	5518.74
9	19.04.89	258.37	3370.77	380.76	141.24	3066.12
10	28.06.89	1198.19	19669.41	4457.69	2435.64	27044.58
11	12.07.89	1297.56	21637.07	4349.50	2423.89	27650.11
12	17.07.89	450.95	6233.88	1234.66	477.25	6859.98
13	26.07.89	1287.90	21921.06	3611.30	2425.71	31835.10
14	09.08.89	1680.76	74496.49	702.26	619.90	17443.68
15	27.12.89	10.71	88.85	20.88	2.03	75.31

TABLE 4.9: DISCREPANCY RATIO OF VARIOUS SEDIMENT TRANSPORT EQUATIONS (1970)

Sl. No.	Sampling date	Calculated Total Load / Measured Suspended Load		
		Engelund Hansen's Formula	Yang's Formula	Hossain's Formula
1	11.02.70	7.69	0.03	0.06
2	26.02.70	9.64	0.06	0.12
3	11.03.70	5.86	0.04	0.10
4	25.03.70	7.31	0.03	0.06
5	08.04.70	0.60	0.07	0.71
6	07.05.70	1.02	0.11	0.82
7	01.07.70	0.24	0.09	0.86
8	08.07.70	0.78	0.16	0.74
9	16.07.70	0.27	0.10	0.79
10	22.07.70	0.56	0.21	1.71
11	29.07.70	0.37	0.14	1.09
12	05.08.70	0.36	0.13	1.05
13	12.08.70	0.46	0.16	1.36
14	19.08.70	0.44	0.16	1.36
15	26.08.70	1.27	0.28	1.47
16	02.09.70	0.63	0.16	0.80
17	09.09.70	0.36	0.07	0.39
18	17.09.70	0.48	0.18	1.66
19	24.09.70	1.50	0.46	3.40
20	01.10.70	1.17	0.31	1.47
21	08.10.70	0.63	0.28	2.39
22	15.10.70	0.65	0.18	0.91
23	22.10.70	0.59	0.10	0.73
24	29.10.70	0.36	0.06	0.40
25	05.11.70	0.80	0.11	0.81
26	20.11.70	0.39	0.05	0.42
27	04.12.70	0.28	0.01	0.19
28	16.12.70	5.15	0.09	0.40
29	30.12.70	5.56	0.06	0.16
	Mean =	1.91	0.13	0.91

88/68

TABLE 4.10: DISCREPANCY RATIO OF VARIOUS SEDIMENT TRANSPORT EQUATIONS (1975)

Sl. No.	Sampling date	Calculated Total Load / Measured Suspended load		
		Engelund Hansen's Formula	Yang's Formula	Hossain's Formula
1	07-02-75	1.33	0.03	0.40
2	21-02-75	6.23	0.14	0.98
3	07.03.75	3.07	0.07	0.47
4	21-03-75	3.02	0.04	0.45
5	04-04-75	1.37	0.02	0.20
6	18-04-75	0.12	0.04	1.04
7	02-05-75	0.30	0.12	1.73
8	09-05-75	0.04	0.01	0.28
9	23-05-75	0.27	0.12	1.31
10	30-05-75	0.18	0.08	0.95
11	06-06-75	0.18	0.06	1.00
12	14-06-75	0.33	0.16	1.66
13	20-06-75	0.31	0.13	1.21
14	27-06-75	0.25	0.11	1.23
15	05-07-75	0.30	0.14	1.45
16	11-07-75	0.16	0.09	1.06
17	18-07-75	0.07	0.05	0.68
18	26-07-75	0.09	0.05	0.62
19	02-08-75	0.52	0.29	3.29
20	08-08-75	0.21	0.12	1.75
21	22-08-75	0.18	0.12	1.65
22	29-08-75	0.44	0.25	3.89
23	05-09-75	0.15	0.09	1.20
	Mean =	0.83	0.10	1.24

TABLE 4.11: DISCREPANCY RATIO OF VARIOUS SEDIMENT TRANSPORT EQUATIONS (1989)

Sl. No.	Sampling date	Calculated Total Load / Measured Suspended Load		
		Engelund Hansen's Formula	Yang's Formula	Hossain's Formula
1	01.01.89	0.13	0.01	2.46
2	11.01.89	0.96	0.14	4.74
3	25.01.89	3.23	0.38	9.51
4	07.02.89	1.28	0.14	3.47
5	22.02.89	1.45	0.33	9.67
6	08.03.89	6.34	0.43	6.05
7	22.03.89	1.98	0.14	2.28
8	05.04.89	0.72	0.31	6.08
9	19.04.89	0.11	0.04	0.91
10	28.06.89	0.23	0.12	1.37
11	12.07.89	0.20	0.11	1.28
12	17.07.89	0.20	0.08	1.10
13	26.07.89	0.16	0.11	1.45
14	09.08.89	0.01	0.01	0.23
15	27.12.89	0.24	0.02	0.85
	Mean =	1.15	0.16	3.43

TABLE 4.12: SEDIMENT TRANSPORT IN THE SURMA AT VARIOUS DISCHARGE LEVEL (1970)

Observed Discharge cumec	Suspended Sediment Load ton/day	Total Load: Engelund Hansen's Formula ton/day	Total Load: Yang's Formula ton/day	Total Load: Hossain's Formula ton/day
10	16.29	230.04	2.37	8.53
100	535.30	1181.13	65.00	374.23
200	1531.57	1932.77	176.08	1167.98
400	4382.06	3162.72	476.98	3645.23
600	8104.73	4218.65	854.41	7093.61
800	12537.77	5175.39	1292.08	11376.71
1000	17587.09	6064.53	1780.81	16411.29
1500	32527.76	8089.29	3189.95	31936.31
2000	50319.49	9923.83	4824.02	51219.35
2500	70584.59	11628.77	6648.69	73885.69
3000	93067.1	13237.08	8641.22	99672.63
4000	143972.1	16239.07	13067.71	159854.67
5000	201953.8	19028.98	18010.55	230595.90

TABLE 4.13: SEDIMENT TRANSPORT IN THE SURMA AT VARIOUS DISCHARGE LEVEL (1975)

		Total	Load	
Observed Discharge cumec	Suspended Sediment Load ton/day	Engelund Hansen's Formula ton/day	Yang's Formula ton/day	Hossain's Formula ton/day
10	16.29	99.86	3.41	36.88
100	535.30	547.86	73.41	877.38
200	1531.57	914.58	184.98	2277.85
400	4382.06	1526.77	466.14	5913.75
600	8104.73	2060.43	800.42	10333.21
800	12537.77	2548.74	1174.66	15353.27
1000	17587.09	3005.88	1581.73	20873.14
1500	32527.76	4056.54	2716.01	36472.01
2000	50319.49	5017.91	3985.89	54190.78
2500	70584.59	5917.91	5367.17	73673.68
3000	93067.1	6771.85	6844.24	94688.54
4000	143972.1	8376.73	10044.28	140689.96
5000	201953.8	9879.16	13525.04	191271.40

TABLE 4.14: SEDIMENT TRANSPORT IN THE SURMA AT VARIOUS DISCHARGE LEVEL (1989)

		Total Load		
Observed Discharge cumec	Suspended Sediment Load ton/day	Engelund Hansen's Formula ton/day	Yang's Formula ton/day	Hossain's Formula ton/day
10	16.29	34.37	3.20	97.86
100	535.30	250.46	57.12	1302.88
200	1531.57	455.37	136.06	2840.23
400	4382.06	827.96	324.08	6191.57
600	8104.73	1174.59	538.44	9767.43
800	12537.77	1505.38	771.91	13497.37
1000	17587.09	1824.86	1020.73	17346.23
1500	32527.76	2588.86	1695.88	27364.31
2000	50319.49	3317.94	2431.25	37814.0
2500	70584.59	4022.11	3214.93	48597.0
3000	93067.1	4707.03	4039.37	59653.0
4000	143972.1	6032.64	5790.95	82433.0
5000	201953.8	7312.94	7657.56	105939.3

TABLE 4.15: ANNUAL SEDIMENT TRANSPORT OF THE SURMA

Year	Annual Average Discharge (cumec)	Suspended Sediment Load (MT)	Total Sediment Load		
			Engelund Hansen's Formula (MT)	Yang's Formula (MT)	Hossain's Formula (MT)
1970-71	572	2.751	0.882	0.266	2.812
1972-73	394	1.563	0.654	0.160	1.680
1973-74	597	2.936	0.913	0.282	2.983
1974-75	614	3.064	0.934	0.293	3.101
1975-76	557	2.643	0.863	0.257	2.710
1976-77	550	2.593	0.855	0.252	2.663
1977-78	621	3.117	0.942	0.298	3.150
1981-82	437	1.829	0.711	0.184	1.938
1982-82	414	1.685	0.681	0.171	1.799
1983-84	681	3.585	1.014	0.338	3.578
1984-85	520	2.381	0.817	0.234	2.465
1985-86	561	2.672	0.868	0.259	2.737
1986-87	423	1.741	0.693	0.176	1.853
1987-88	519	2.374	0.816	0.233	2.458
1988-89	635	3.224	0.959	0.307	3.249
1989-90	611	3.041	0.930	0.291	3.080
1990-91	681	3.585	1.014	0.338	3.578
1991-92	728	3.966	1.070	0.370	3.924
1992-93	493	2.196	0.783	0.217	2.290
Average	558	2.681	0.863	0.259	2.739

TABLE 4.16: BED LOAD AS A PERCENTAGE OF SUSPENDED LOAD

Discharge	Suspended Sediment Load	Meyer-Peter & Muller's Equation		Rottner's Equation	
		Bed Load	Bed Load as a % of Suspended Load	Bed Load	Bed Load as a % of Suspended Load
cumec	ton/day	ton/day		ton/day	
10	16.3	0.08	0.497	6.57	40.334
100	535.3	1.93	0.361	55.15	10.303
250	2148.4	6.82	0.317	128.59	5.986
500	6146.8	17.71	0.288	243.97	3.969
750	11368.7	30.95	0.272	354.84	3.121
1000	17587.1	46.00	0.262	462.87	2.632
2000	50319.5	119.49	0.237	878.18	1.745
2500	70584.6	162.47	0.230	1079.24	1.529
3000	93067.1	208.84	0.224	1277.24	1.372
4500	172129.9	365.02	0.212	1857.65	1.079
5000	201953.8	422.02	0.209	2047.58	1.014

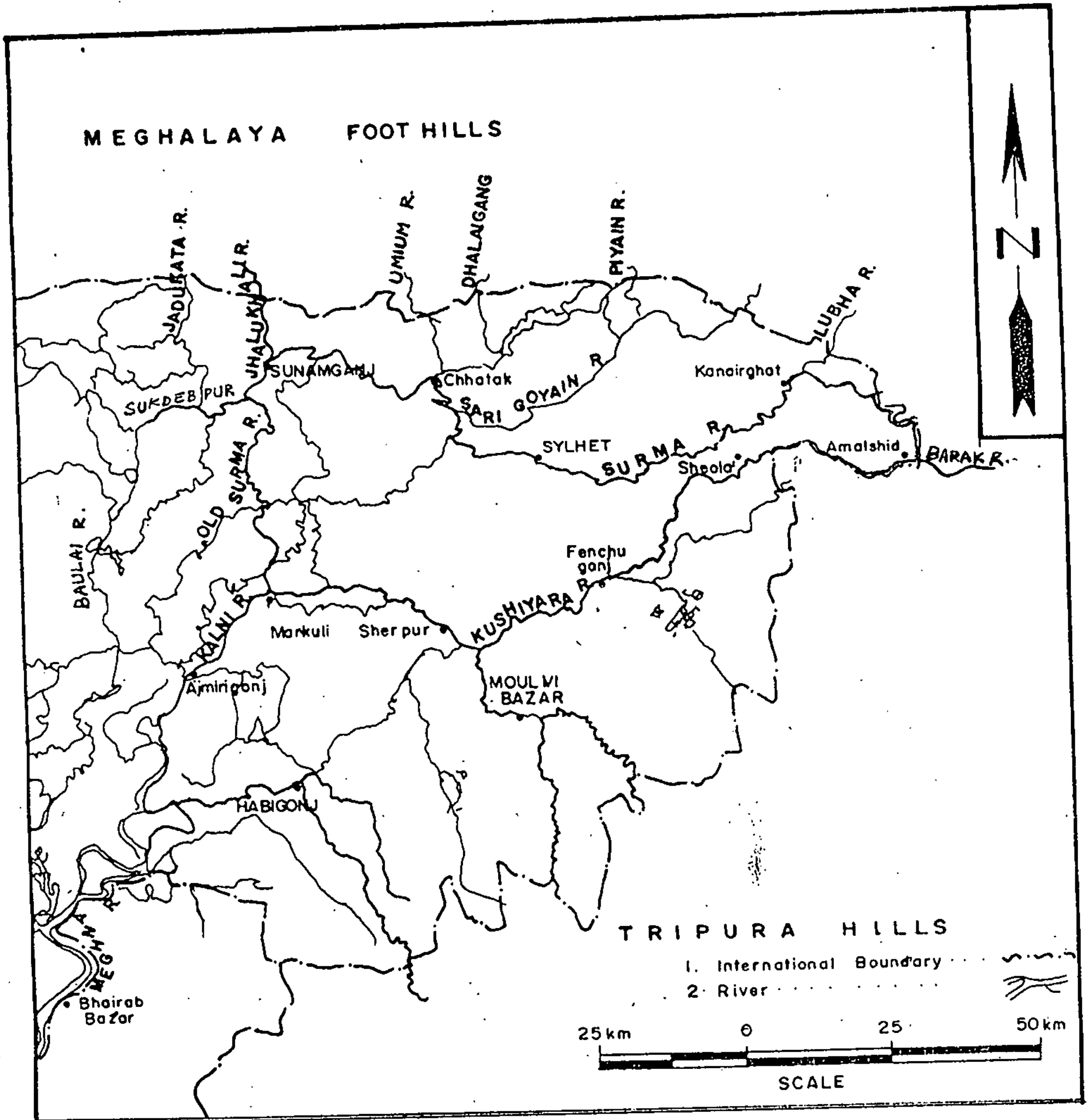

FIG. 2·1 THE SURMA SYSTEM

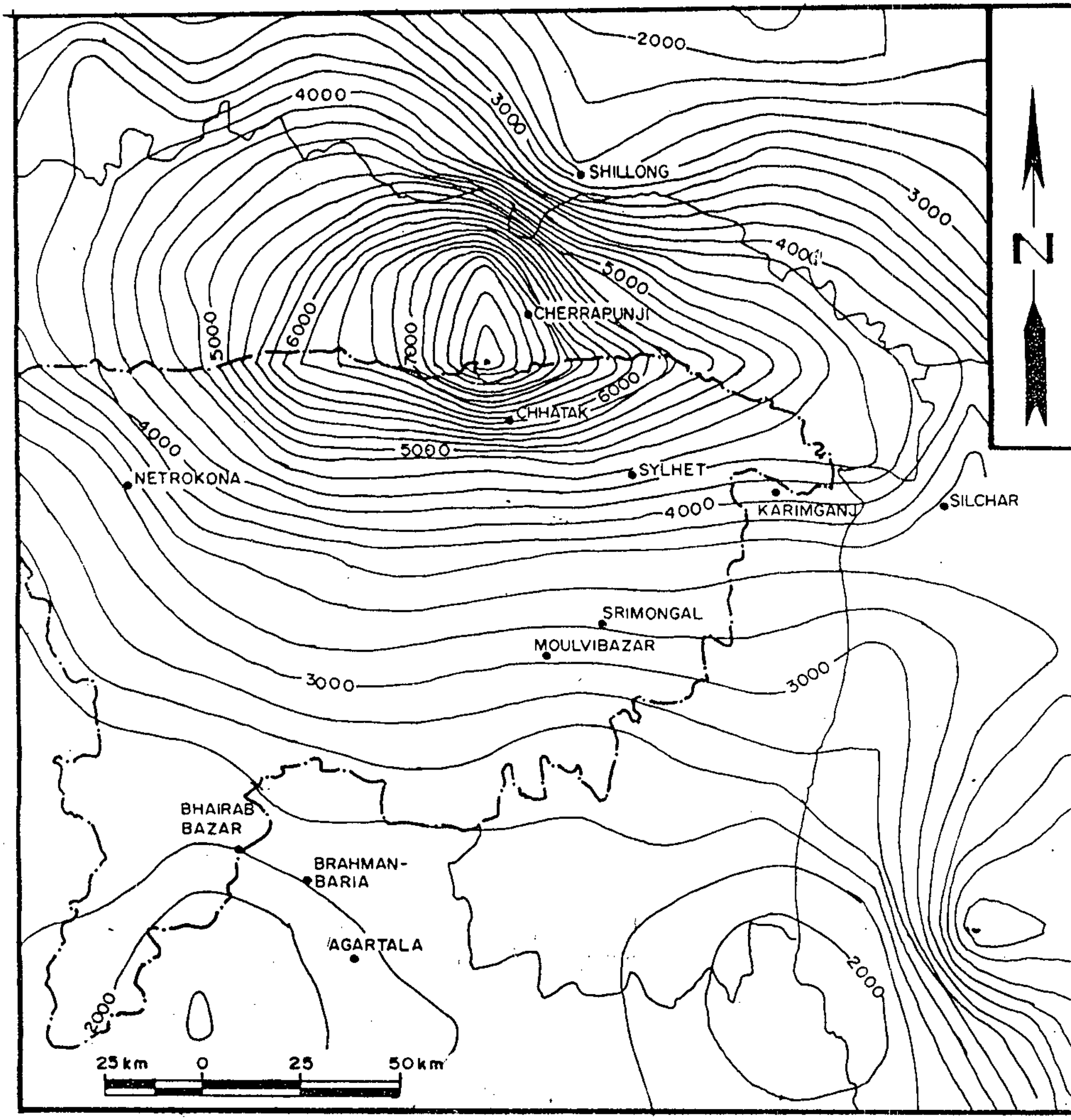

FIG. 2.2 MEAN ANNUAL RAINFALL OF THE STUDY AREA

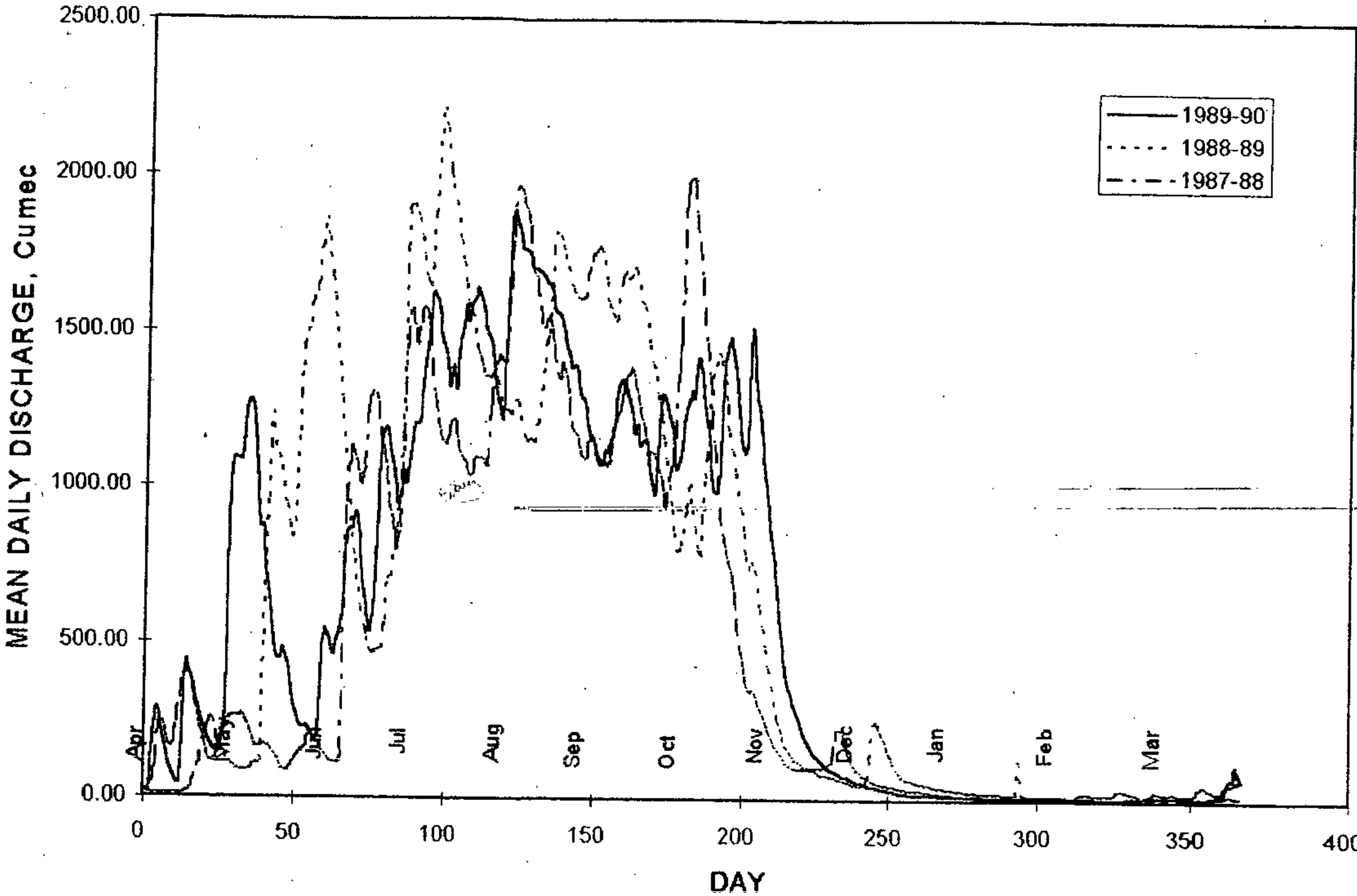

FIG. 2.3 HYDROGRAPH FOR MEAN DAILY DISCHARGE FOR THE SURMA AT SYLHET

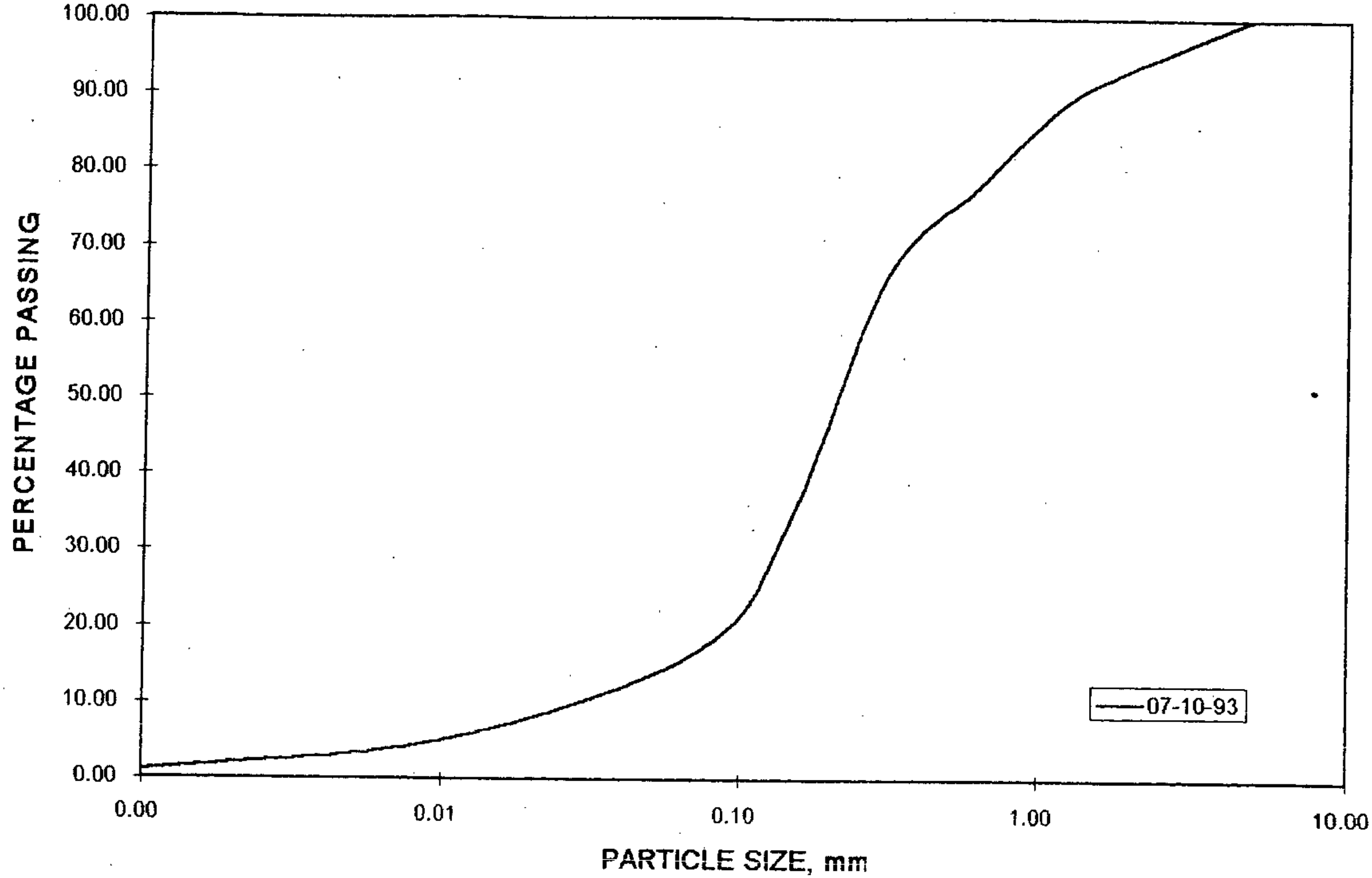

FIG. 3.1 GRAIN SIZE DISTRIBUTION CURVE OF THE SURMA AT SYLHET

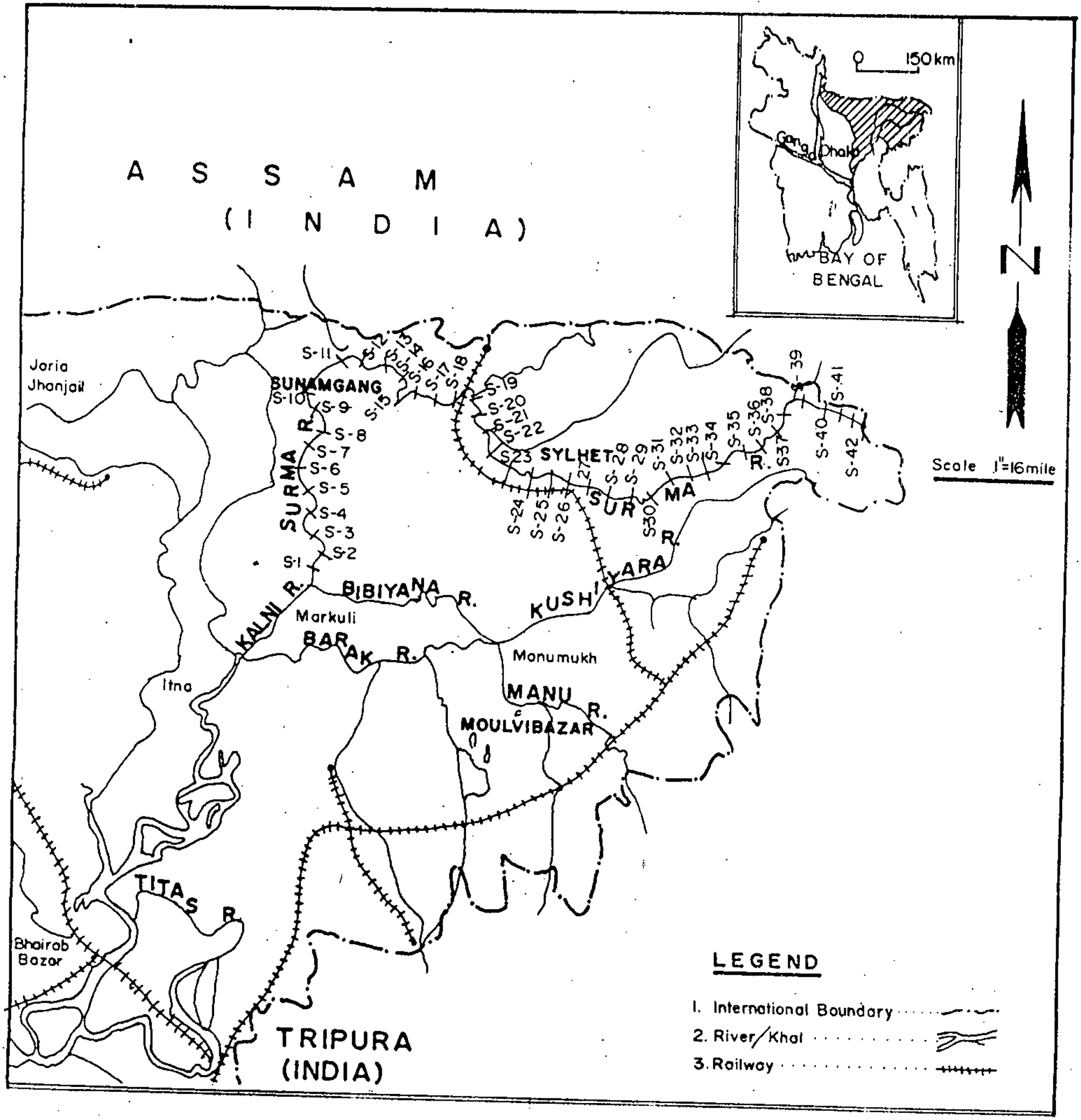

FIG. 4·1 INDEX MAP OF THE STUDY AREA

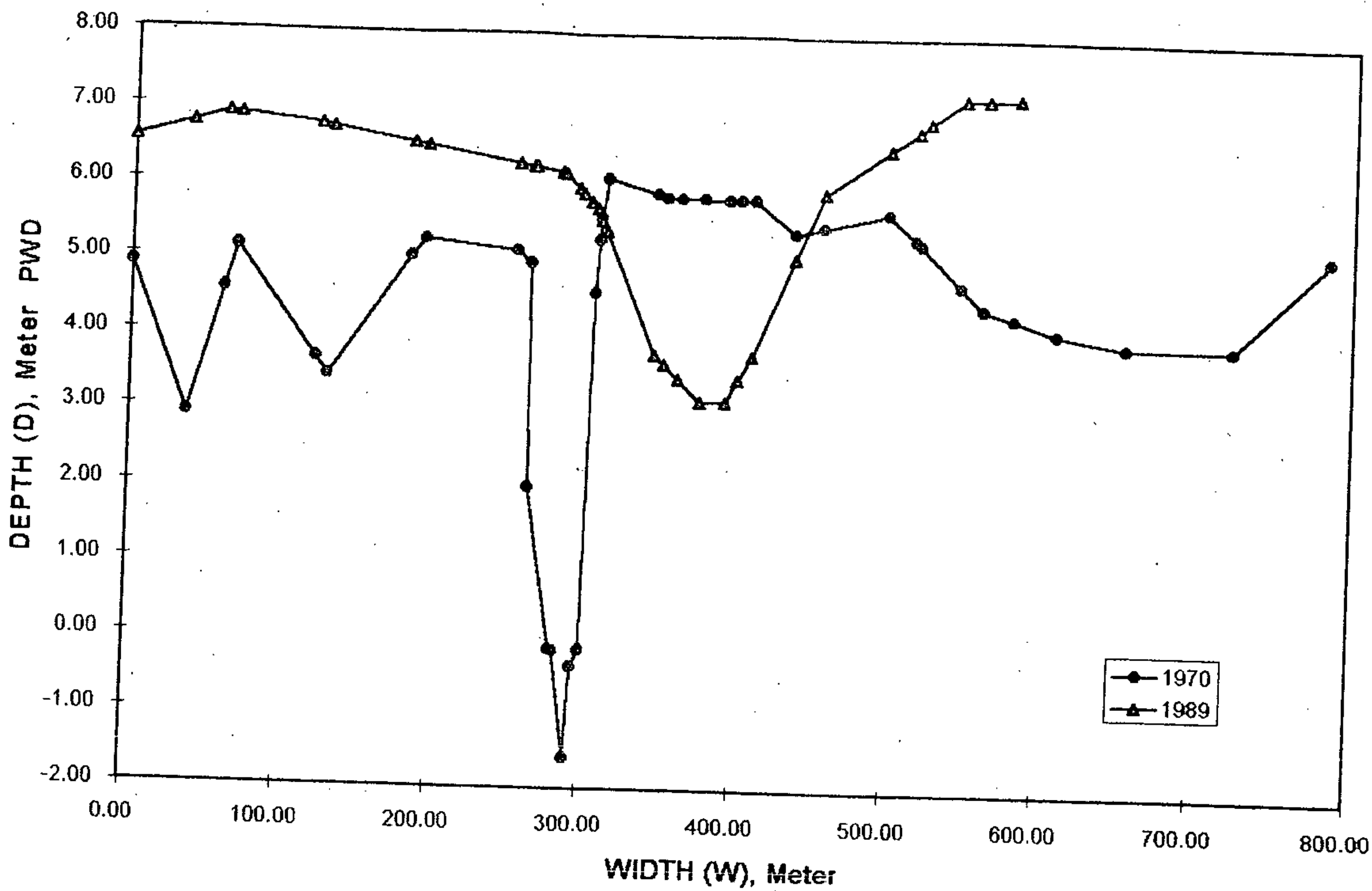

FIG. 4.2 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-1

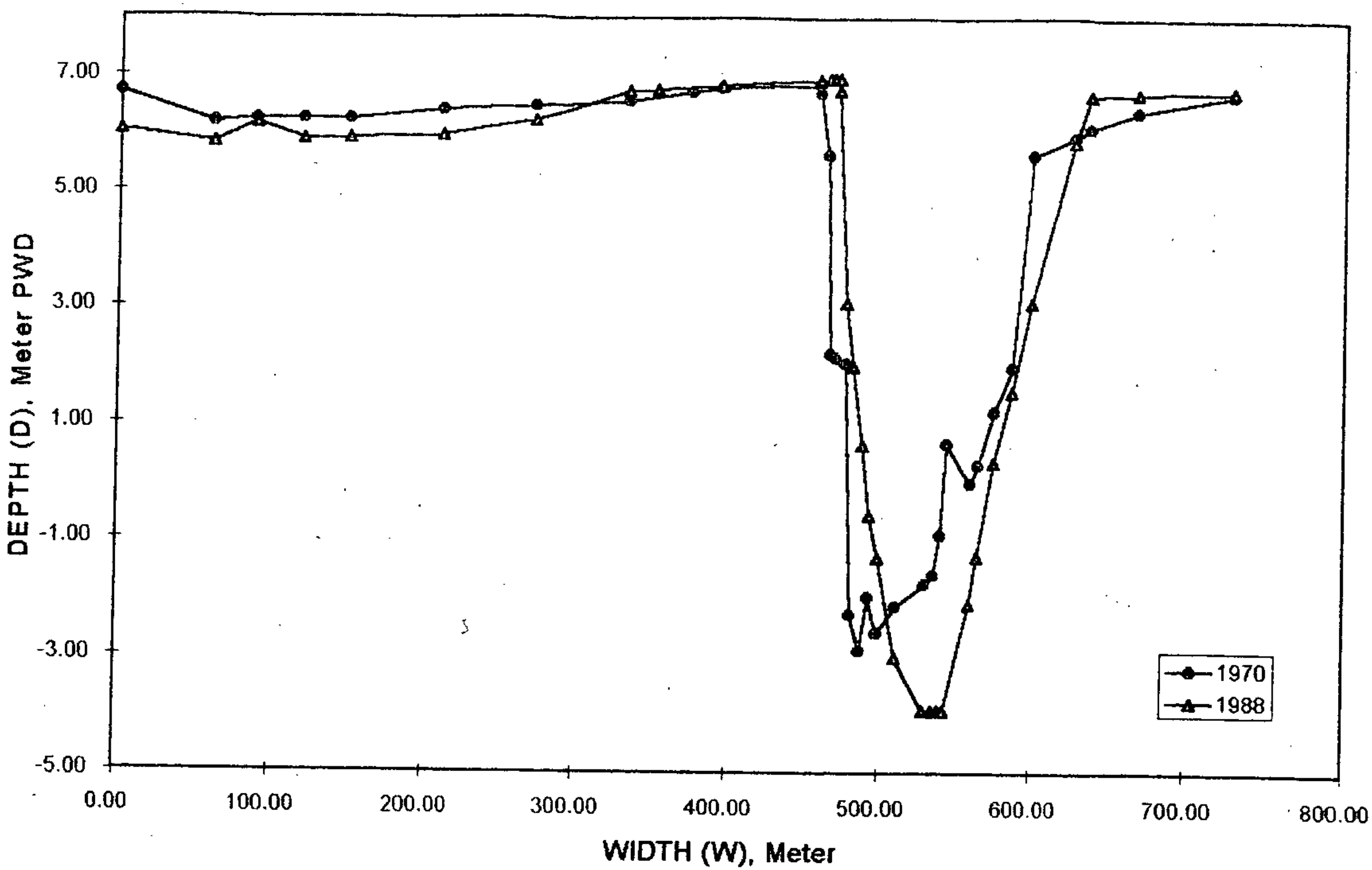

FIG. 4.3 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-5

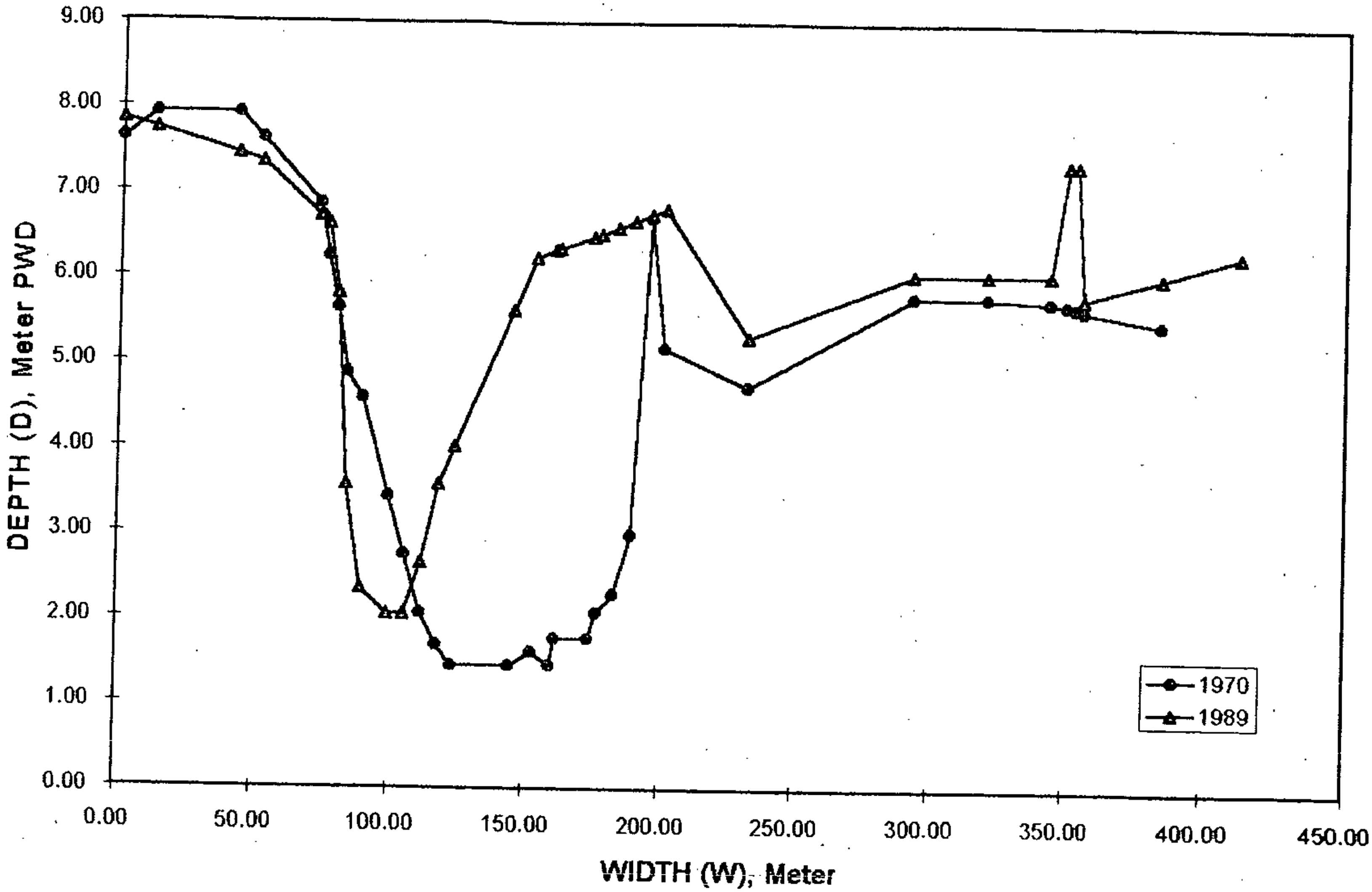

FIG. 4.4 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-10

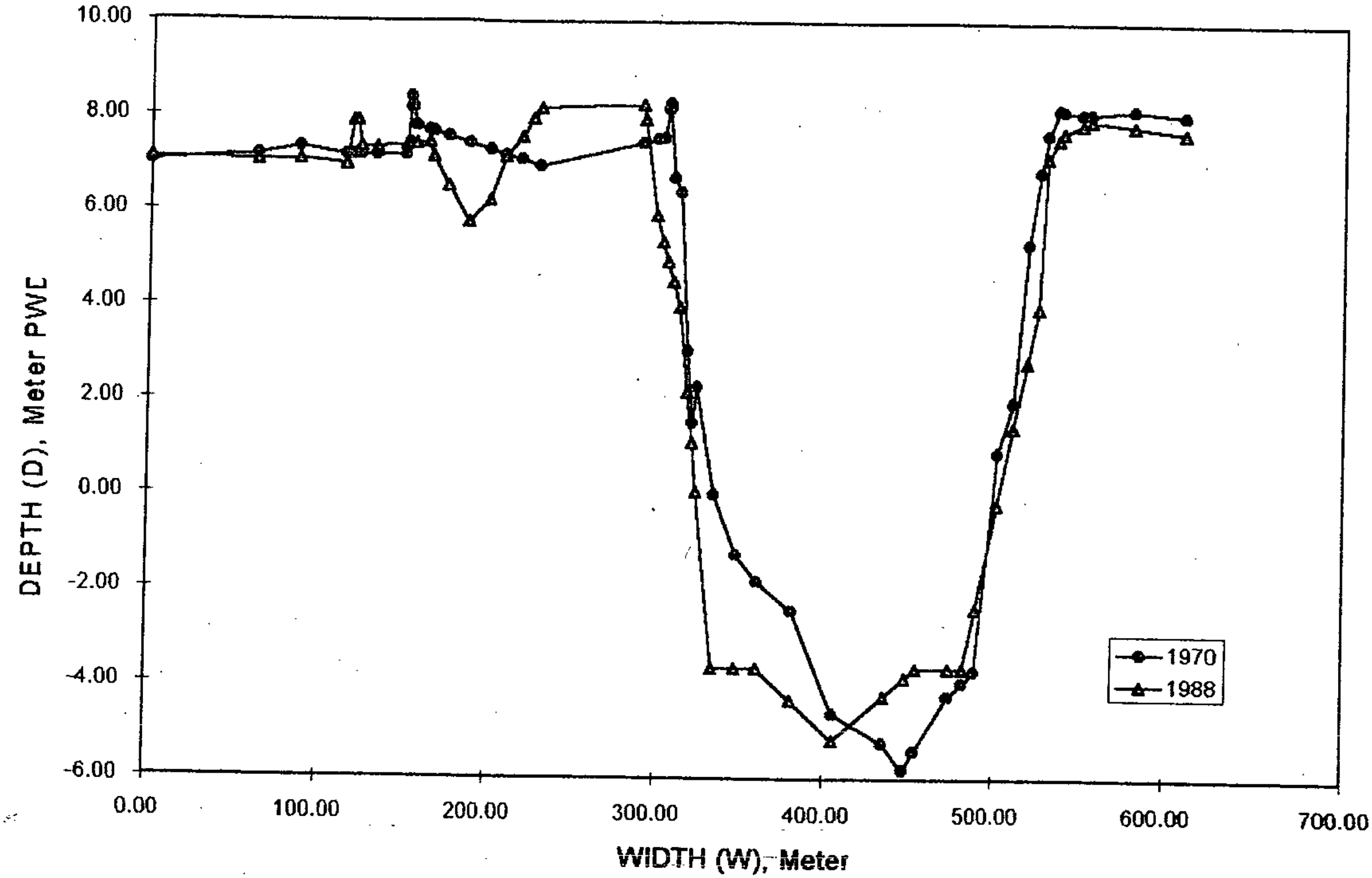

FIG. 4.5 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-14

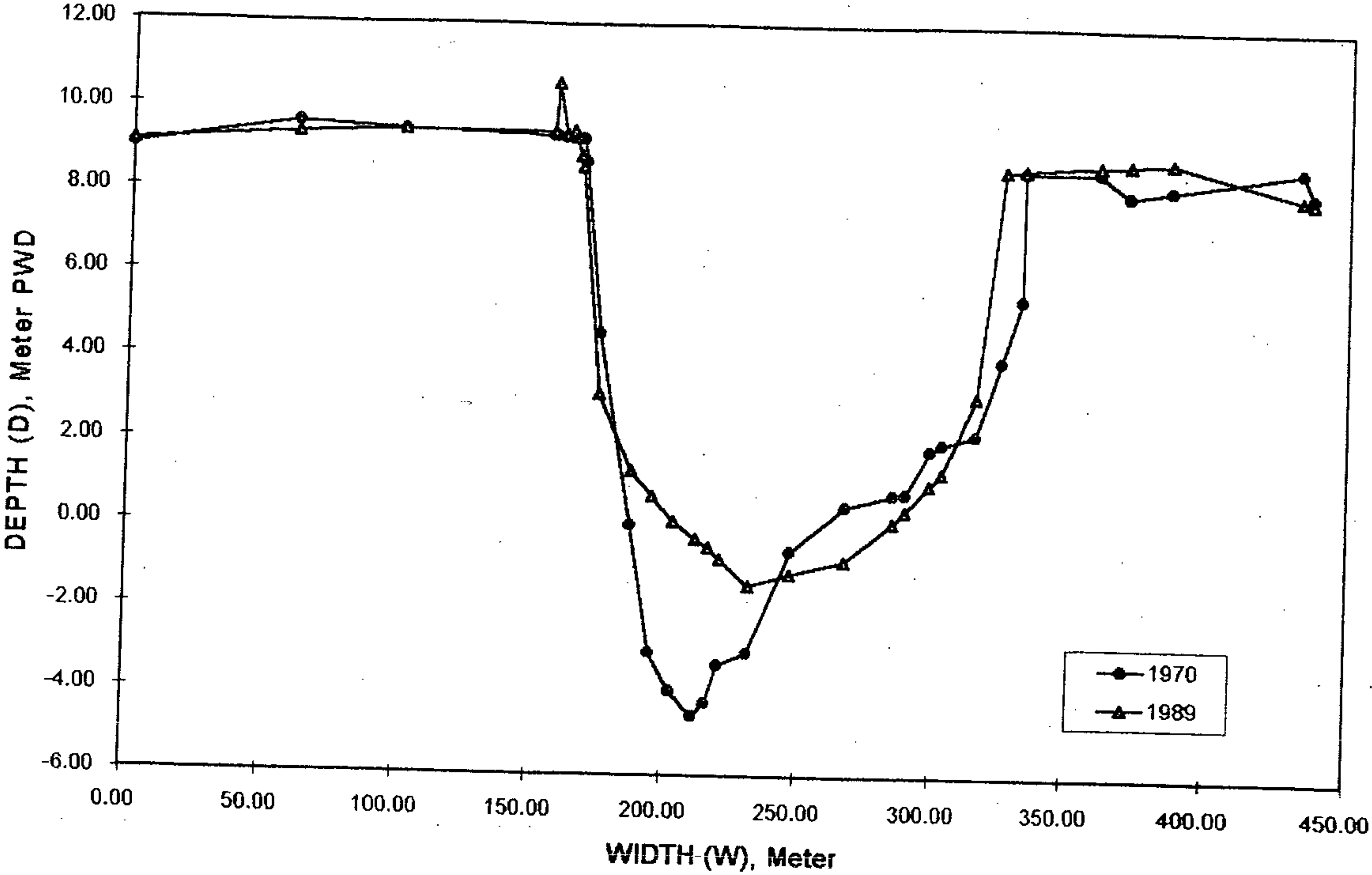

FIG. 4.6 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-21

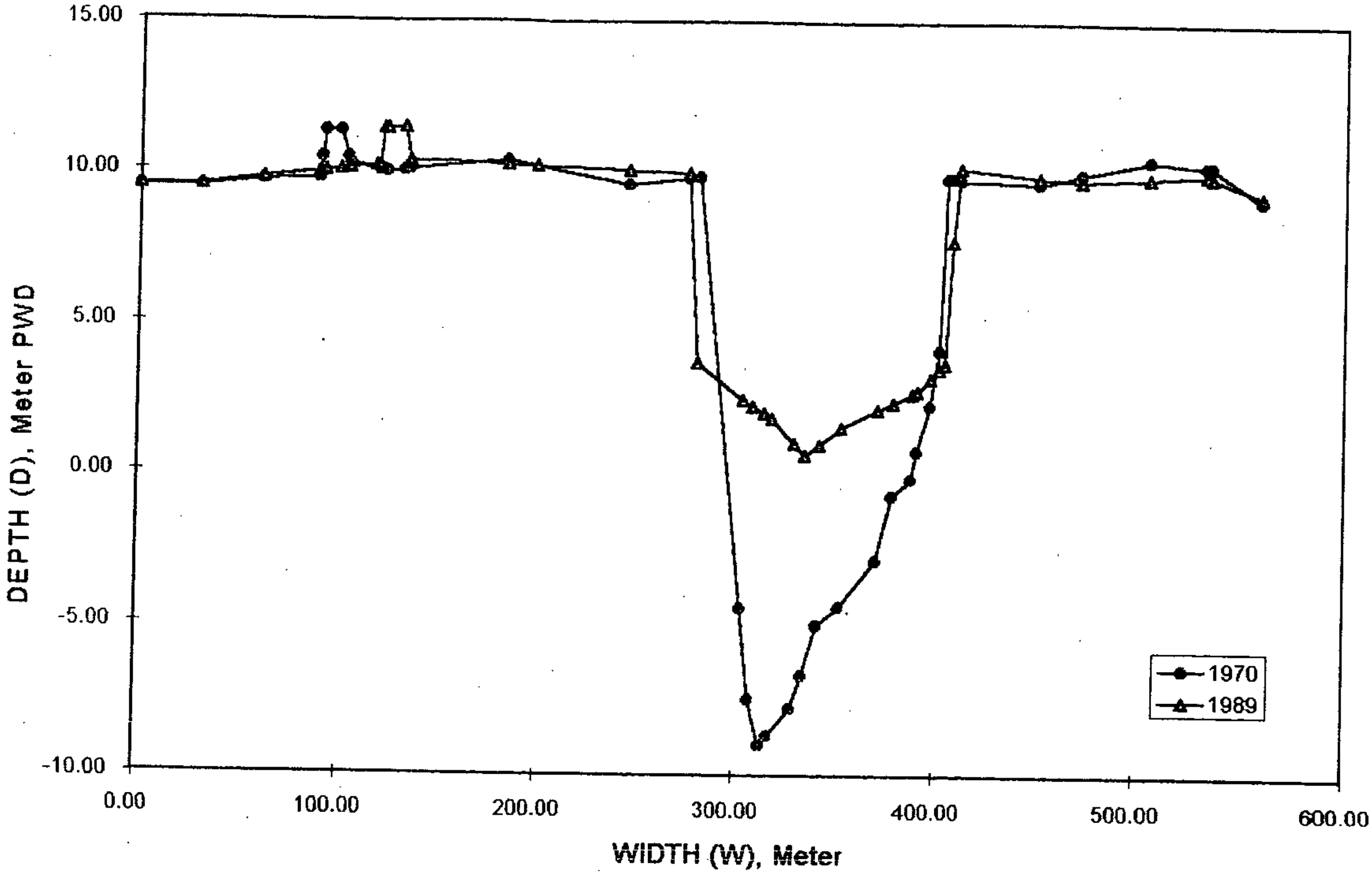

FIG. 4.7 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-25

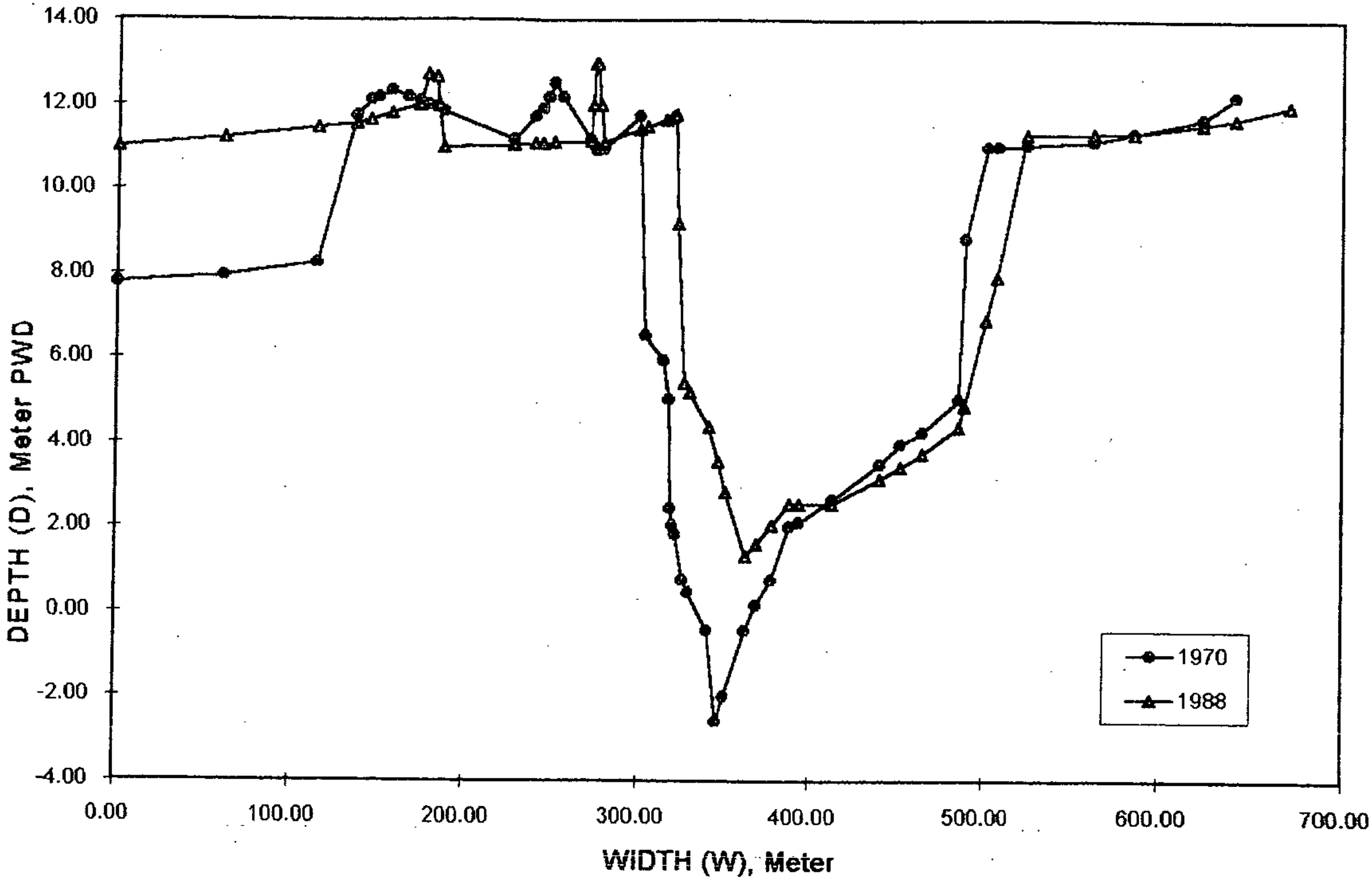

FIG. 4.8 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-30

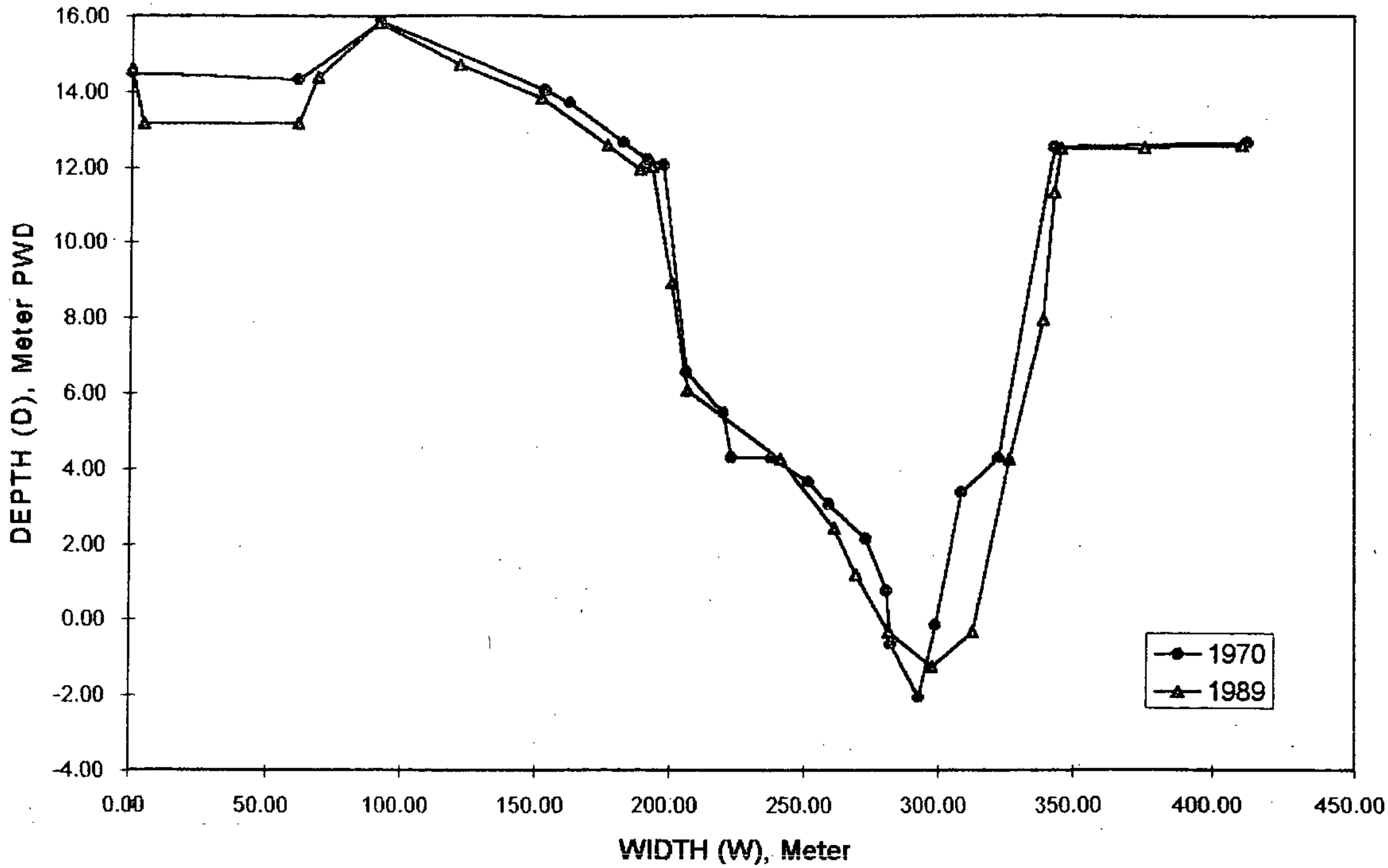

FIG. 4.9 VARIATION OF CROSS-SECTIONAL AREA AT SECTION S-34

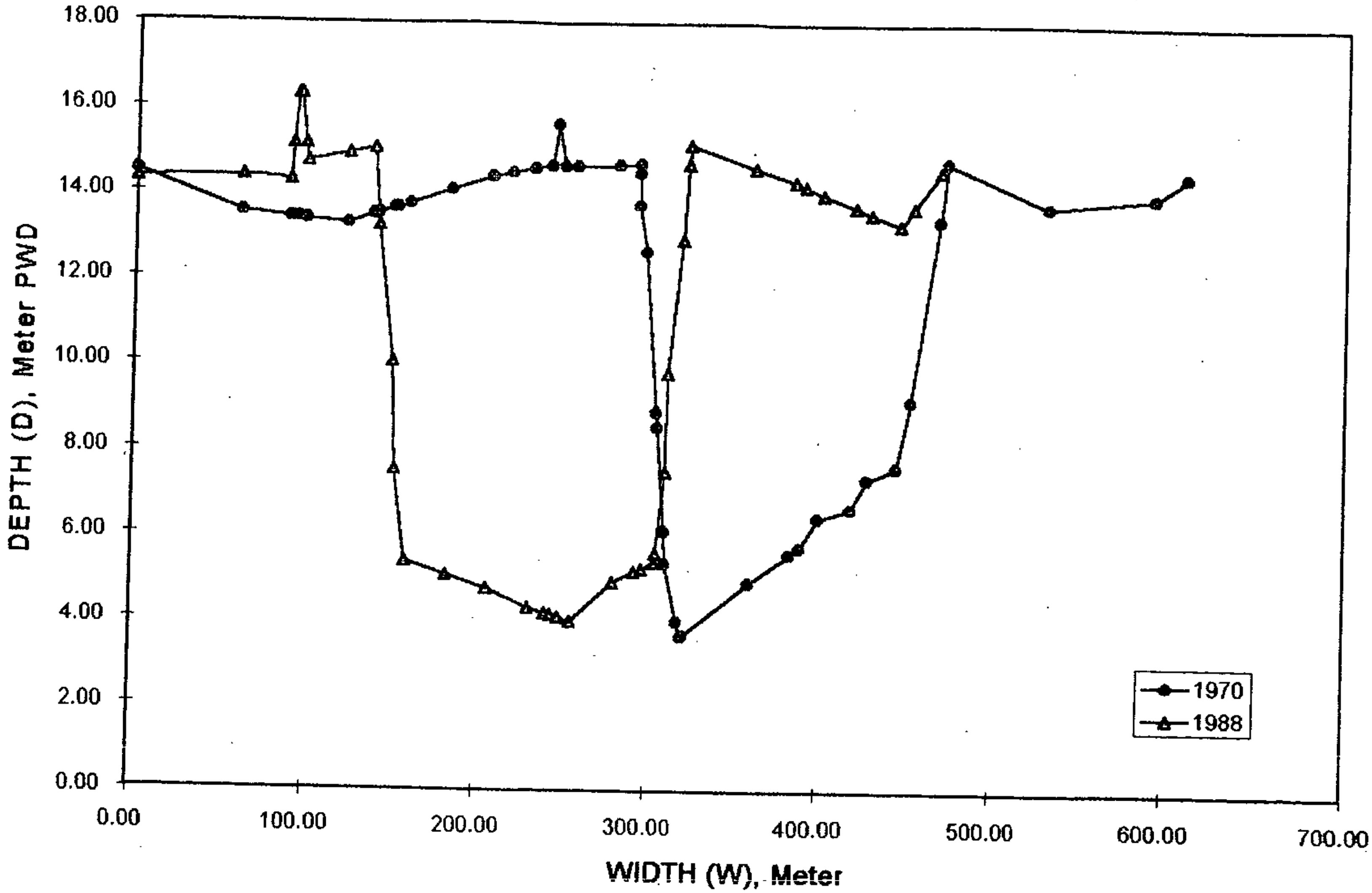

FIG. 4.10 VARIATION OF CROSS-SECTIONAL AREA AT SECTION #41

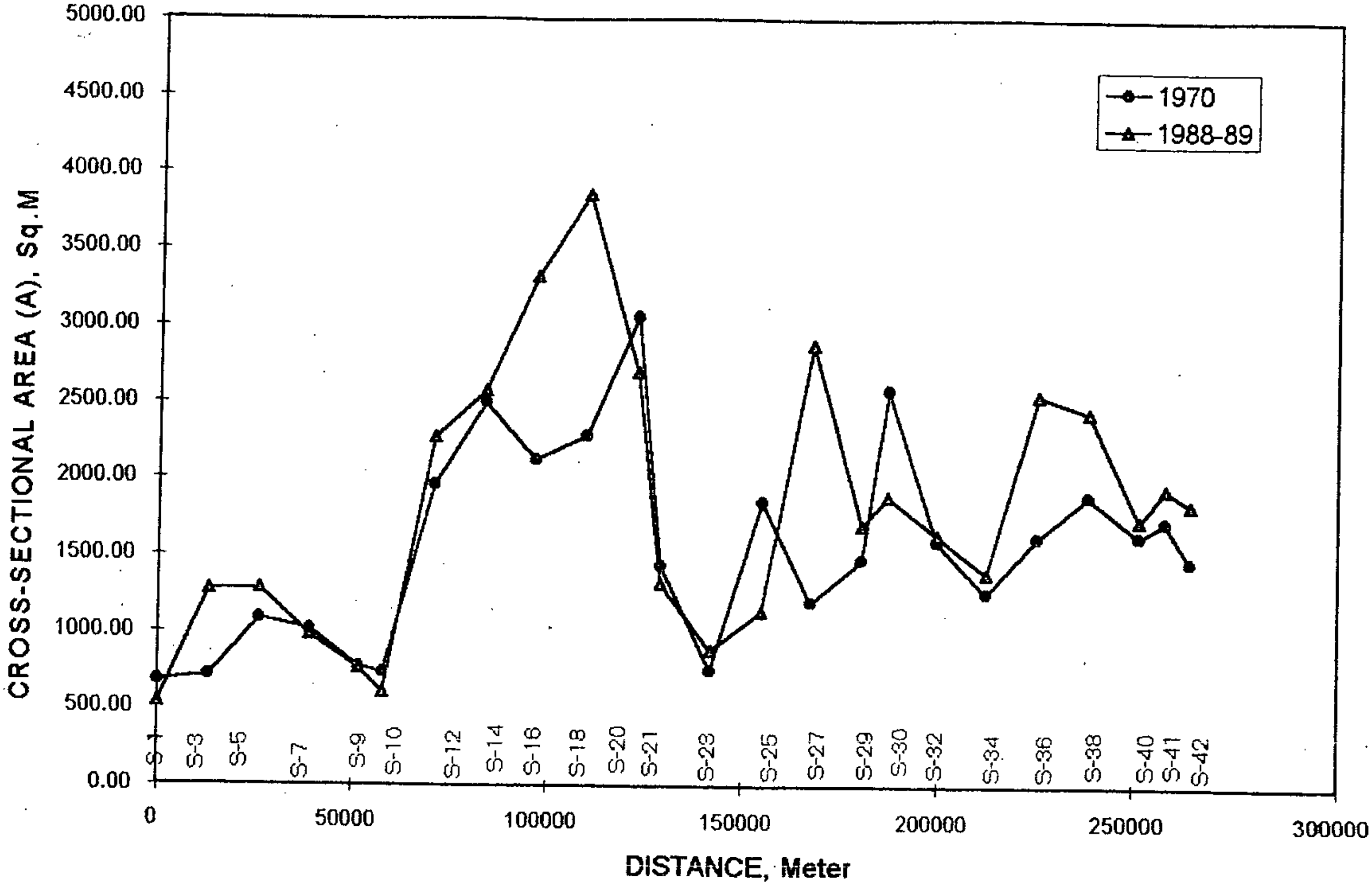

FIG. 4.11 VARIATION OF CROSS-SECTIONAL AREA FOR THE RIVER SURMA

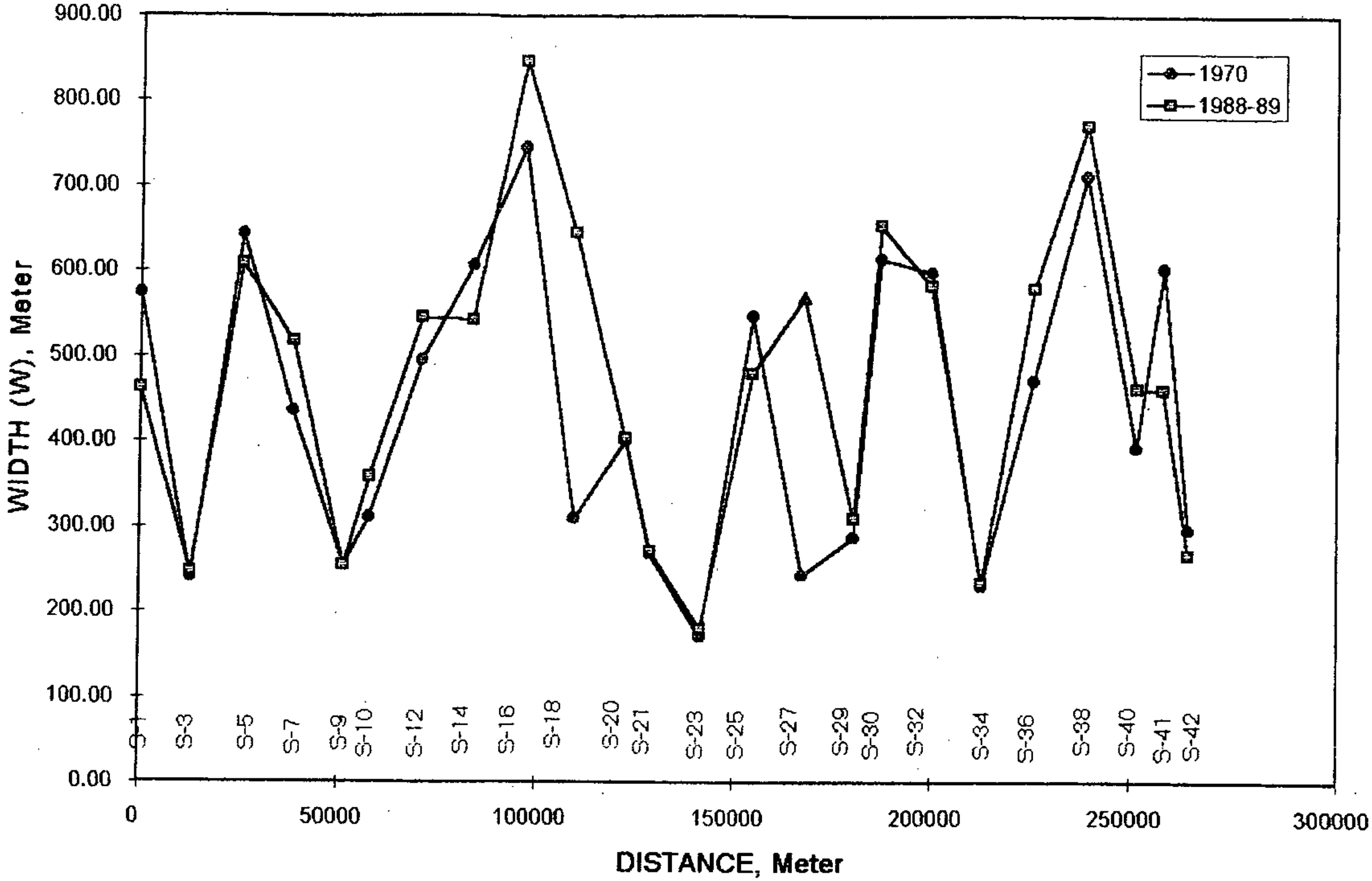

FIG. 4.12 VARIATION OF WIDTH FOR THE RIVER SURMA

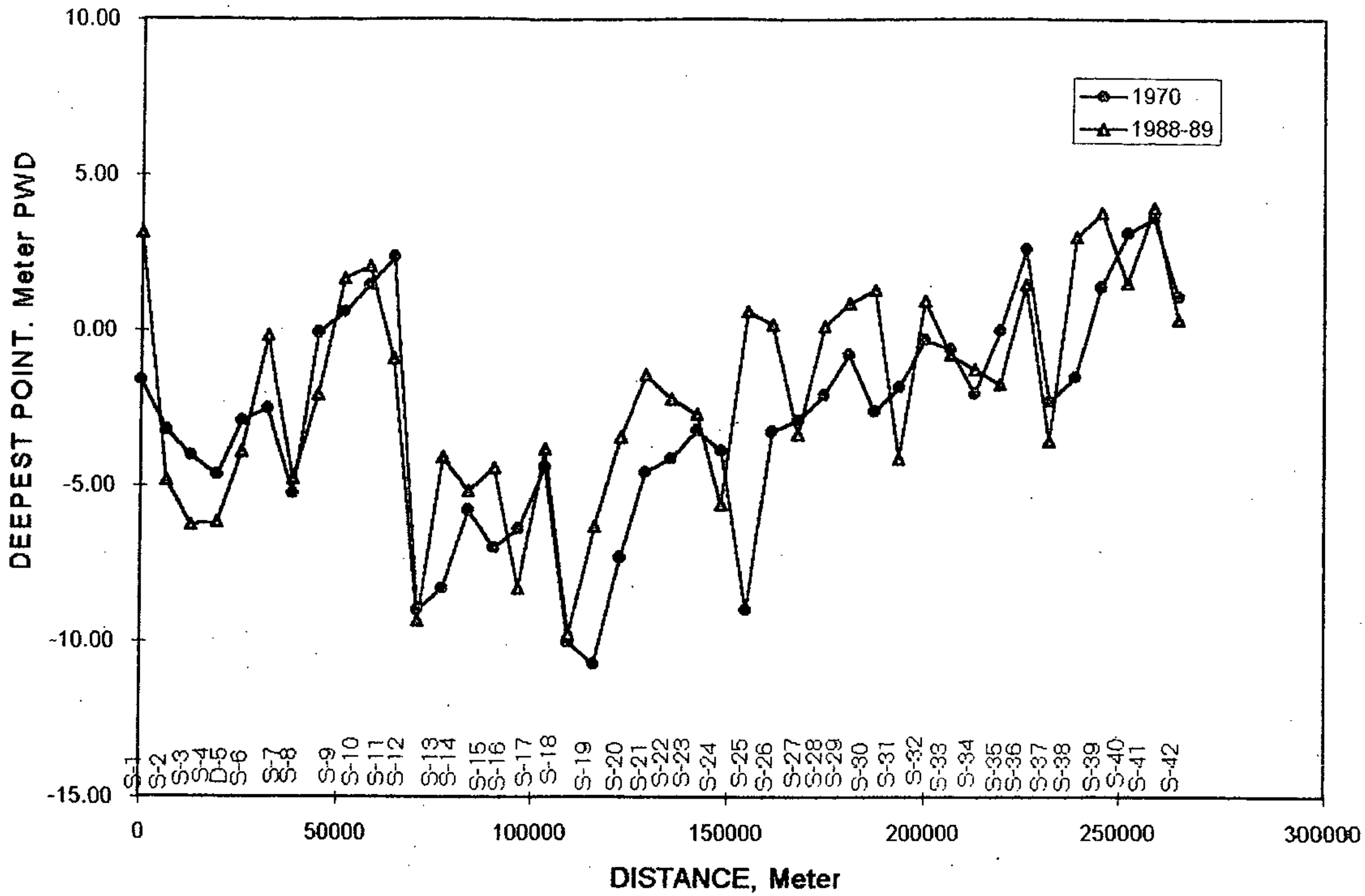

FIG. 4.13 VARIATION OF DEEPEST POINT (THALWEG) FOR THE RIVER SURMA

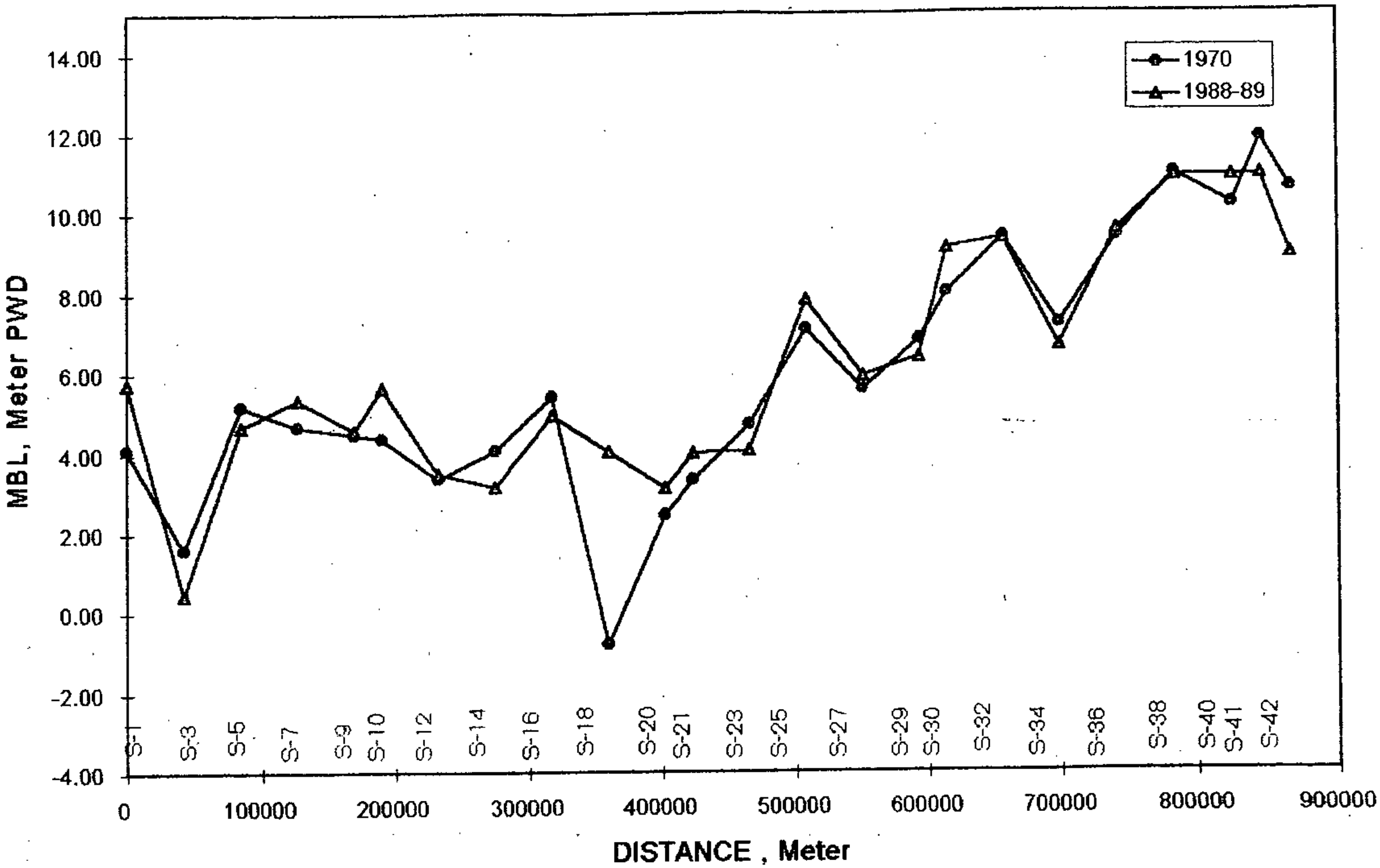

FIG. 4.14 VARIATION OF MBL FOR THE RIVER SURMA

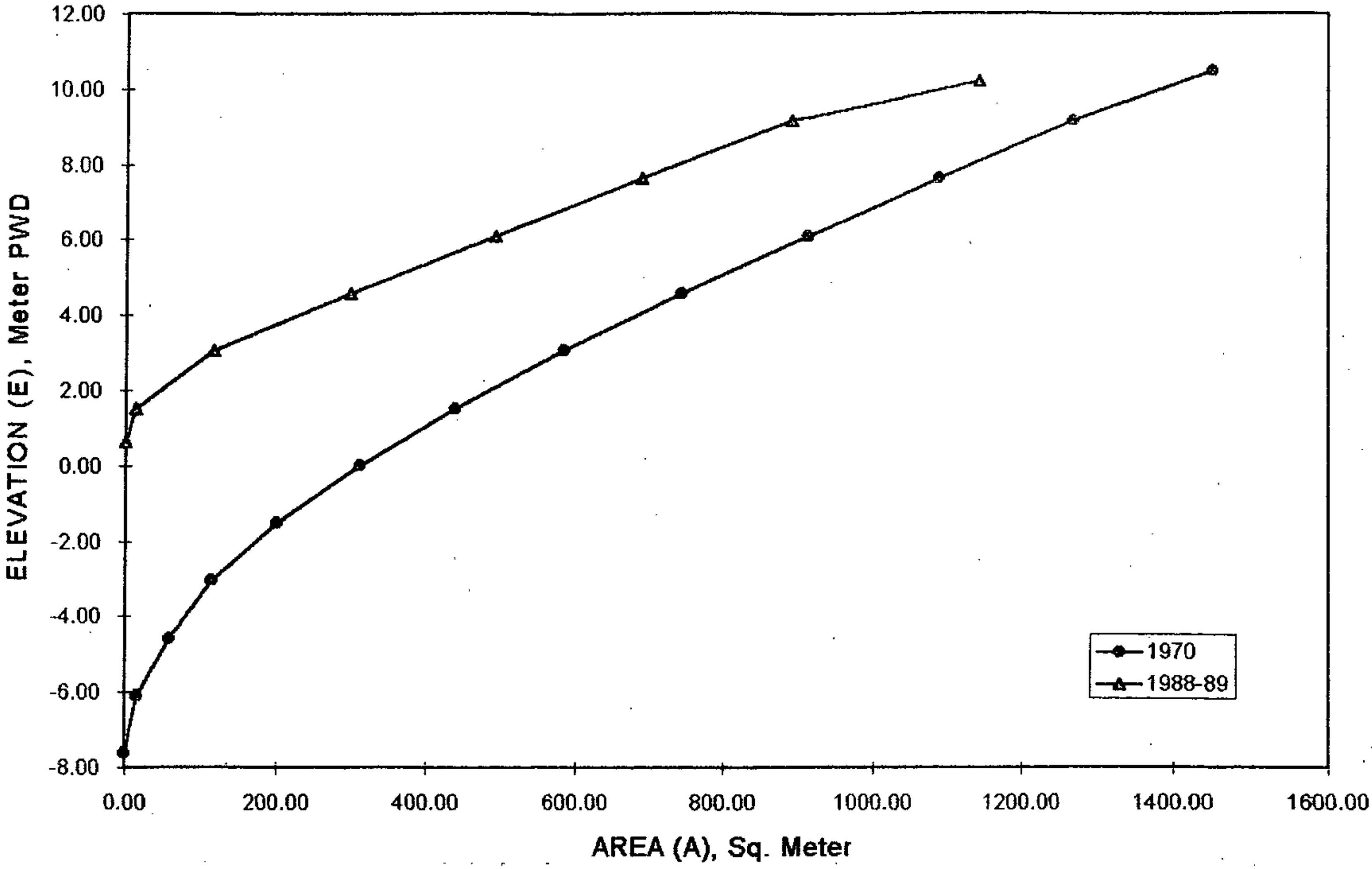

FIG. 4.15 RELATIONSHIP BETWEEN AREA AND ELEVATION FOR THE SURMA AT SECTION S-25

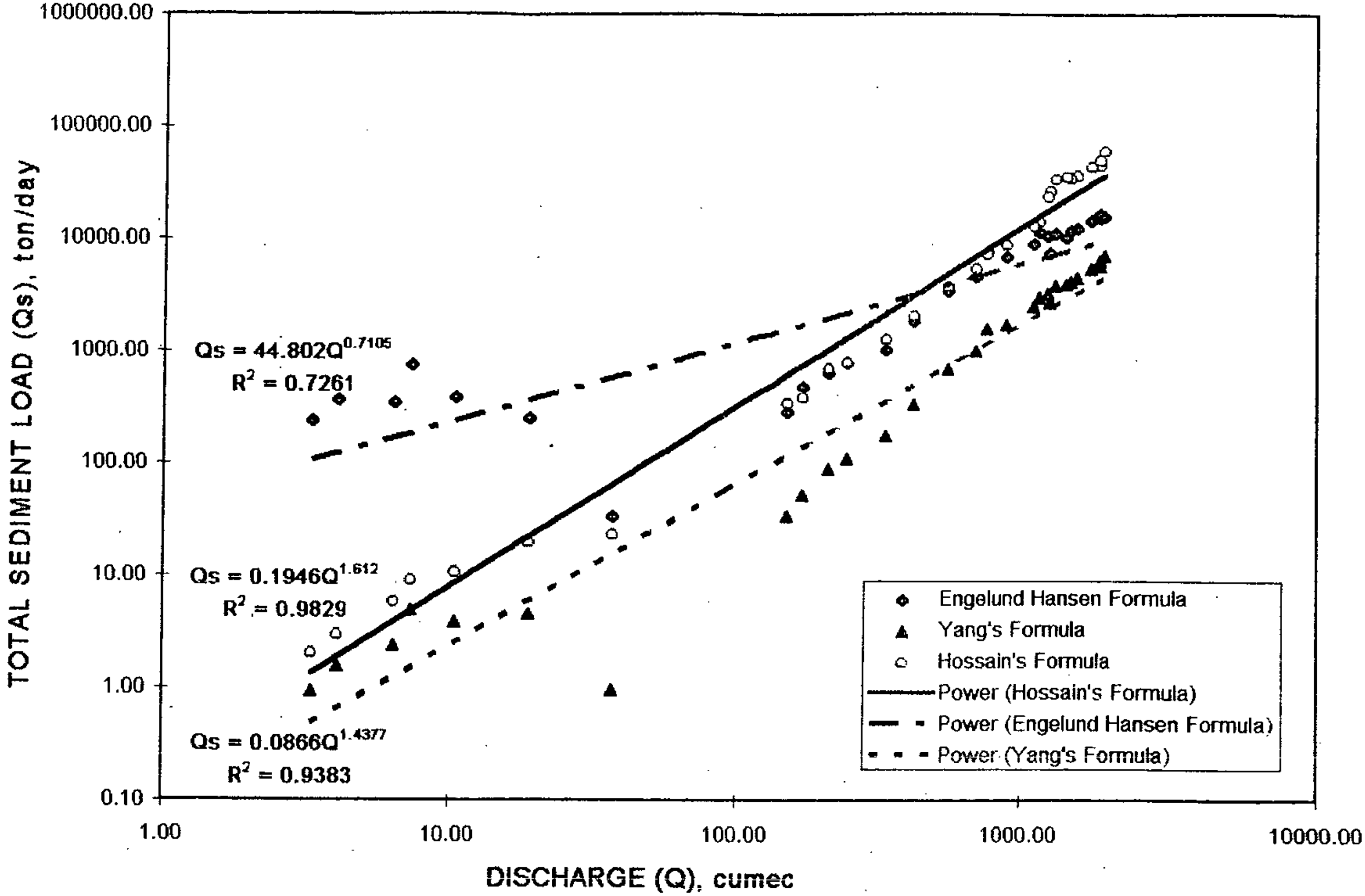

FIG. 4.16 RELATIONSHIP BETWEEN TOTAL SEDIMENT LOAD AND DISCHARGE AT SYLHET (1970)

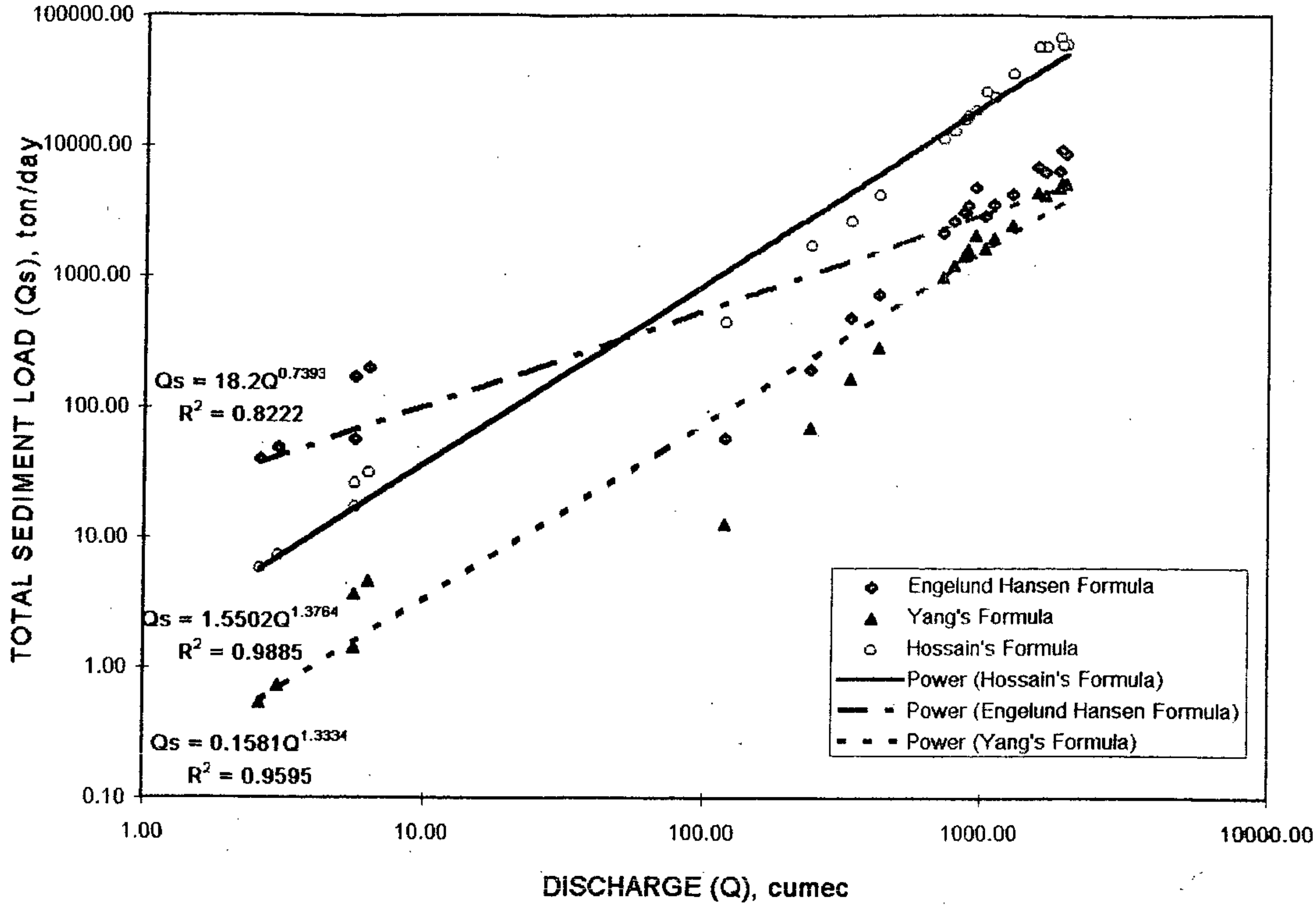

FIG. 4.17 RELATIONSHIP BETWEEN TOTAL SEDIMENT LOAD AND DISCHARGE AT SYLHET (1975)

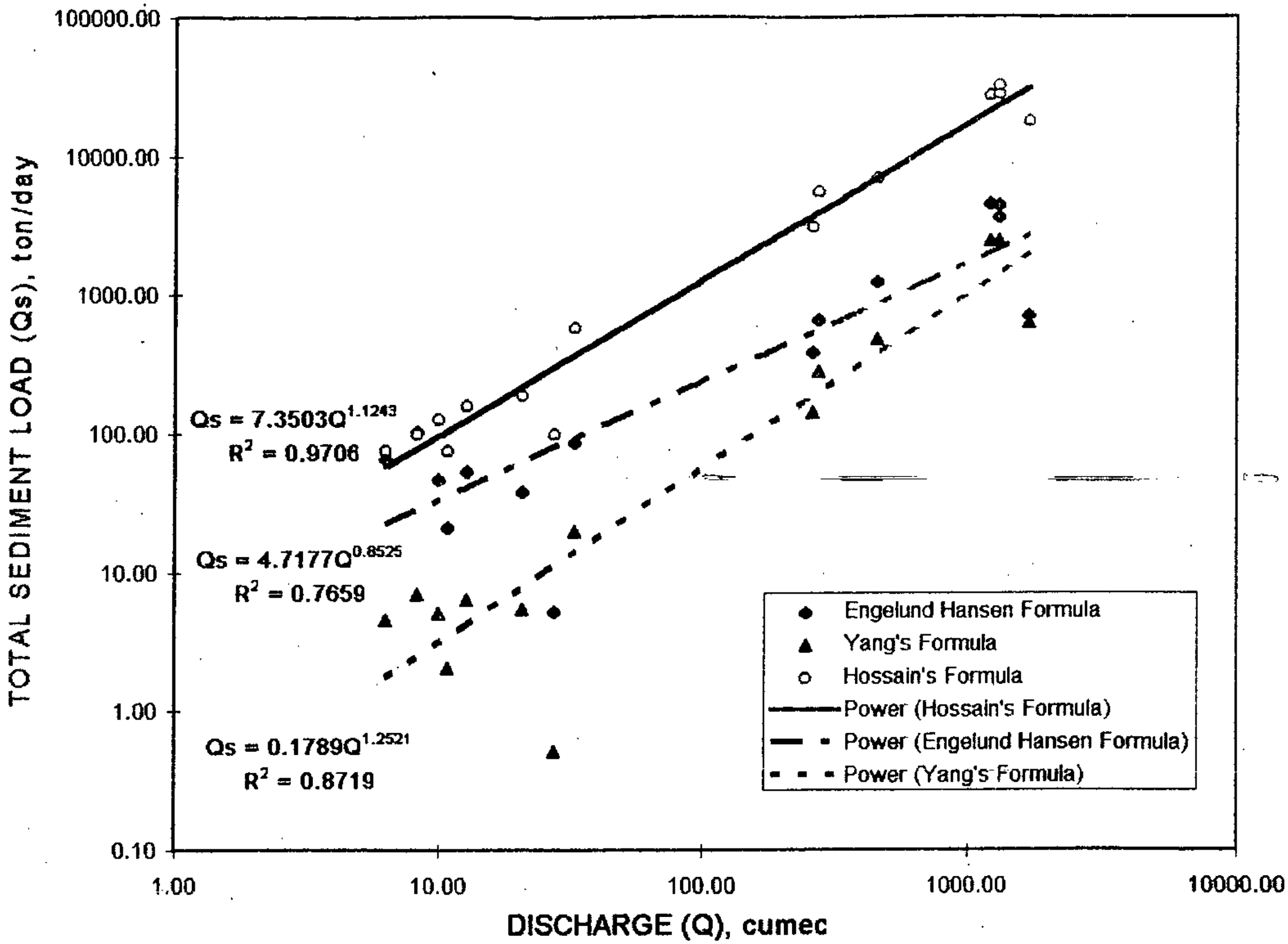

FIG. 4.30 RELATIONSHIP BETWEEN TOTAL SEDIMENT LOAD AND DISCHARGE (1989)

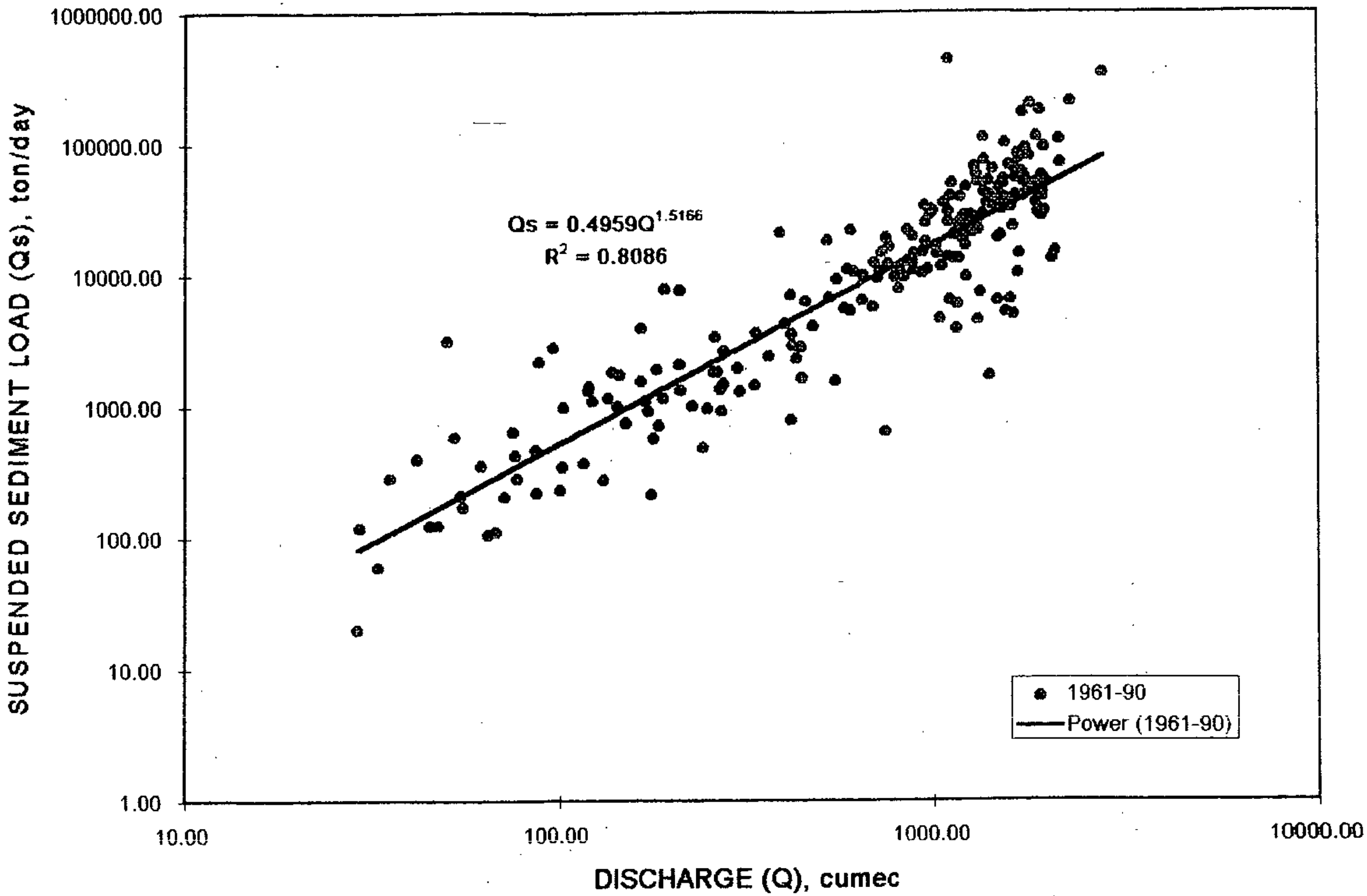

FIG. 4.19 RELATIONSHIP BETWEEN SUSPENDED SEDIMENT LOAD AND DISCHARGE AT SYLHET (1961-90)

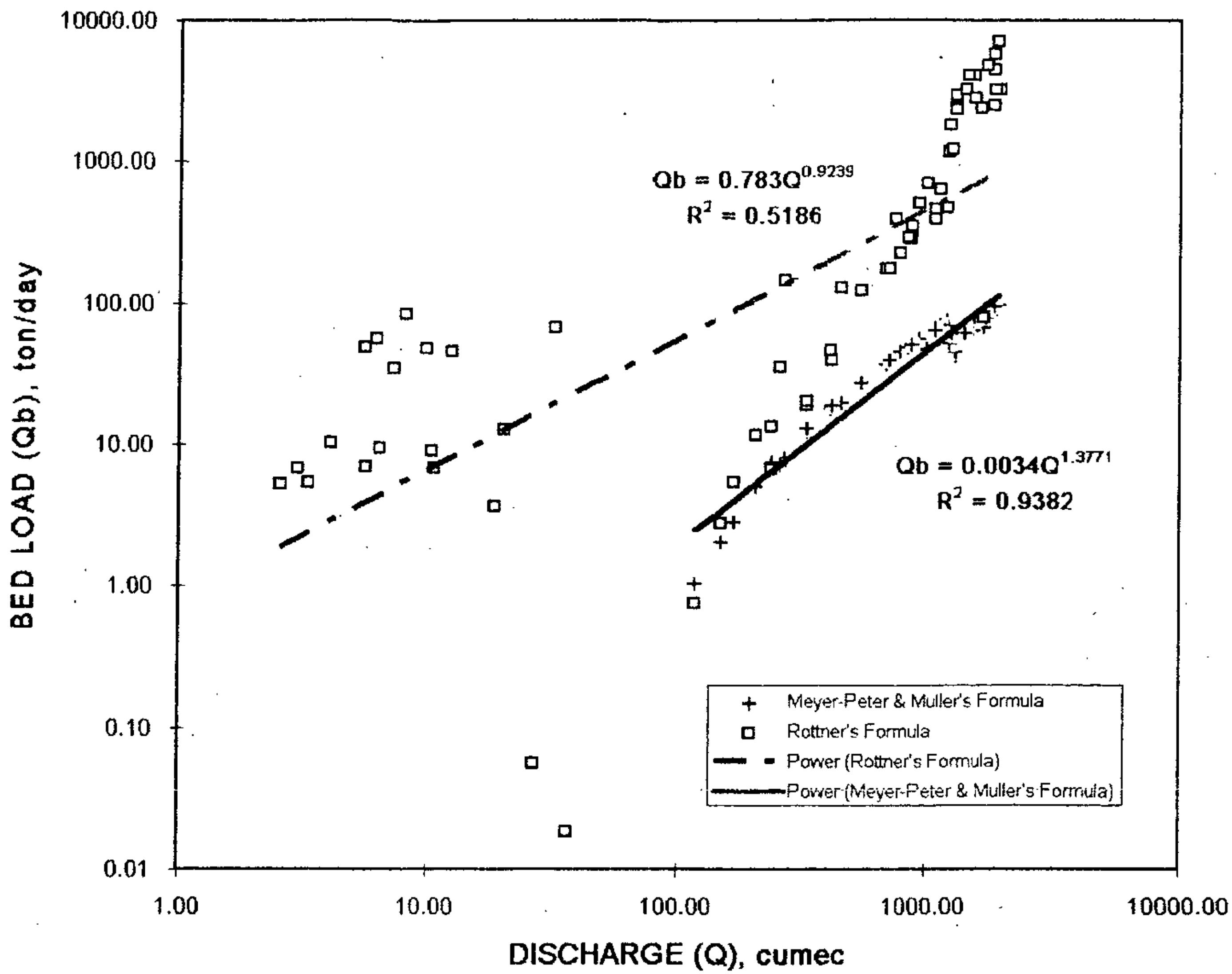

FIG. 4.20 RELATIONSHIP BETWEEN BED LOAD AND DISCHARGE

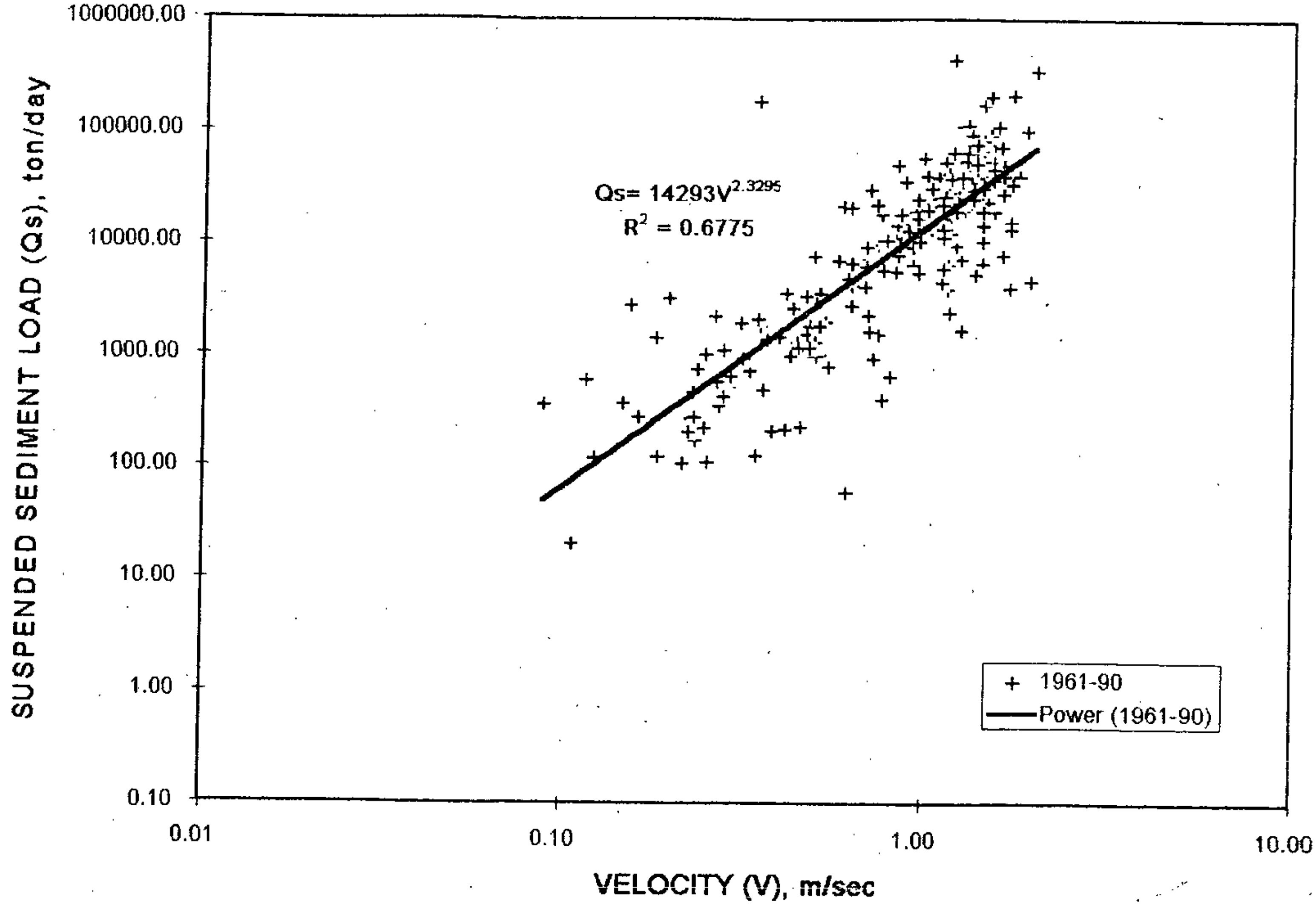

FIG 4.21 RELATIONSHIP BETWEEN SUSPENED SEDIMENT LOAD AND VELOCITY AT SYLHET (1961-90)

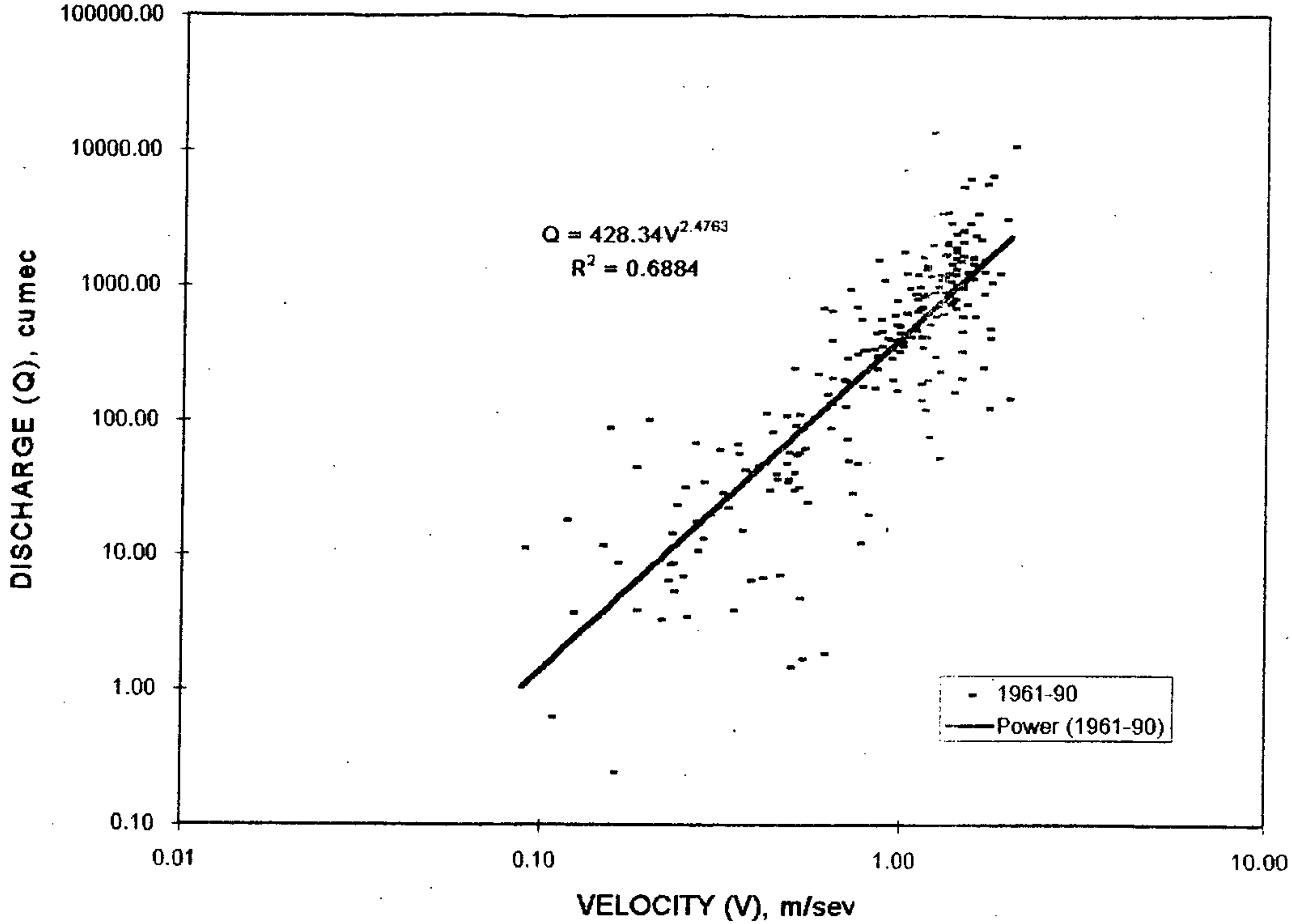

FIG. 4.22 RELATIONSHIP BETWEEN VELOCITY AND DISCHARGE AT SYLHET (1961-90)

APPENDIX - A

Sample Calculations

CALCULATIONS FOR CROSS-SECTIONAL AREA, WIDTH, AVERAGE DEPTH, MEAN BED LEVEL AND DEEPEST POINT AT SECTION S-14 FOR THE RIVER SURMA

DISTANCE (m)	R.L. (m PWD) (15-12-88)	Incremental Area (sq.m)		
0.00	7.11			
62.79	7.03	51.40		
87.17	7.07	20.48		
114.30	6.97	23.70		
117.65	7.89	1.55		
120.70	7.88	0.01		
122.22	7.36	0.41		
132.28	7.33	5.47		
149.35	7.39	9.03		
152.40	7.40	1.50		
155.45	7.41	1.47		
162.76	7.44	3.39	Bank Level =	7.89 m PWD
165.81	7.11	1.87	Area at Bank Level =	2543.45 sq.m
174.96	6.50	9.88	Width at Bank Level =	608.69-290.31+223.44-0.00
187.15	5.74	21.54	=	541.82 m
199.34	6.20	23.40	Average Depth =	2543.45/541.82
208.48	7.11	11.27	=	4.69 m
217.63	7.56	5.04	Mean Bed Level =	7.89-4.69
223.44	7.89	0.95	=	3.20 m PWD
228.60	8.18		Deepest Point (thalweg) =	-5.18 m
288.95	8.25			
290.31	7.89			
297.79	5.91	7.40		
301.75	5.36	8.93		
304.80	4.94	8.35		
307.85	4.51	9.64		
311.81	3.96	14.47		
316.99	2.16	25.01		
320.04	1.10	19.07		
323.09	0.05	22.29		
333.76	-3.66	103.43		
347.47	-3.66	158.39		
360.27	-3.66	147.83		
381.00	-4.35	246.50		
405.99	-5.18	316.30		
435.86	-4.24	376.42		
448.06	-3.86	145.58		
454.46	-3.66	74.56		
473.96	-3.66	225.26		

482.19	-3.66	95.03
489.20	-2.40	76.53
501.40	-0.20	112.05
510.54	1.44	66.49
518.16	2.81	43.92
524.56	3.96	28.82
528.83	7.16	9.93
534.92	7.55	3.26
537.36	7.70	0.65
548.64	7.87	1.19
553.82	7.94	-0.08
579.12	7.83	0.10
608.69	7.70	3.76
	Area =	2543.45

AREA-ELEVATION COMPUTATION FOR AT SECTION S-10 FOR THE SURMA

DISTANCE (m)	R.L. m PWD (1970)							
0.00	6.71							
60.96	6.17							16.26
88.39	6.25							13.59
118.87	6.25							13.94
149.35	6.25							13.94
210.31	6.40							23.23
271.27	6.48							16.26
332.23	6.55							11.61
372.87	6.71							3.10
393.19	6.78							
457.20	6.86							
457.96	6.71							
461.01	6.10							0.93
463.30	5.64						0.52	1.92
464.24	4.57						0.94	1.52
465.60	3.05					1.03	3.10	3.92
466.34	2.21				0.31	1.45	2.58	3.04
469.39	2.13				2.67	7.32	11.96	13.82
476.71	2.06				6.97	18.12	29.26	33.72
477.31	1.52				0.75	1.67	2.58	2.94
479.02	0.00			1.30	3.91	6.52	9.13	10.17
480.73	-1.52		1.30	3.91	6.52	9.13	11.74	12.78
481.58	-2.29	0.33	1.63	2.93	4.24	5.54	6.85	7.37
487.68	-2.90	6.50	15.79	25.08	34.37	43.66	52.95	56.67
493.17	-1.98	5.02	13.38	21.74	30.10	38.46	46.82	50.17
498.35	-2.59	3.95	11.85	19.74	27.64	35.54	43.43	46.59
510.54	-2.13	10.22	28.80	47.38	65.96	84.54	103.12	110.55
534.92	-1.60	8.36	45.52	82.68	119.84	157.01	194.17	209.03
535.43	-1.52	0.02	0.79	1.57	2.34	3.12	3.89	4.20
539.50	-0.91		4.95	11.15	17.34	23.54	29.73	32.21
557.78	0.00		8.36	36.23	64.10	91.97	119.84	130.99
563.88	0.30			8.36	17.65	26.94	36.23	39.95
579.40	1.52			9.46	33.11	56.76	80.40	89.86
585.22	1.98				7.54	16.41	25.27	28.82
588.77	3.05				1.90	7.32	12.74	14.90
593.85	4.57					3.87	11.61	14.71
597.41	5.64						3.52	5.69
624.84	5.94						8.36	25.08
638.56	6.10						1.05	9.41
665.99	6.40							12.54
727.56	6.71							9.38
Area	(sq.m)=	34.39	132.38	271.55	447.27	639.89	851.80	1094.80
Elevation	(m PWD)=	-1.52	0.00	1.52	3.05	4.57	6.10	6.71

AREA- ELEVATION COMPUTATION FOR SECTION S-25
FOR THE RIVER SURMA

DISTANCE (m)	R.L. m PWD (1-1-89)							
0.00	9.48							
30.48	9.50							21.46
60.96	9.77							17.05
116.29	10.20							11.80
118.26	10.21							
120.40	11.40							
131.06	11.46							
133.50	10.38							
199.07	10.20							
274.32	9.98							8.03
275.05	9.14							0.46
276.37	7.62						1.01	2.40
277.70	6.10					1.01	3.03	4.42
279.02	4.57				1.01	3.03	5.05	6.44
279.81	3.67			0.35	1.54	2.73	3.93	4.75
291.68	3.05			14.38	32.48	50.57	68.66	81.15
302.97	2.45		3.36	20.57	37.78	54.99	72.20	84.07
317.91	1.84		13.43	36.19	58.95	81.71	104.47	120.18
322.31	1.52		6.00	12.71	19.42	26.12	32.83	37.46
334.67	0.62	5.56	24.40	43.24	62.08	80.93	99.77	112.77
352.05	1.52	7.32	34.31	60.80	87.29	113.79	140.28	158.56
352.35	1.54		0.45	0.90	1.34	1.79	2.24	2.55
370.33	2.15		21.65	49.06	76.46	103.87	131.28	150.19
389.84	2.76		11.59	41.32	71.05	100.78	130.51	151.02
394.09	3.05		0.61	7.09	13.56	20.03	26.50	30.97
403.25	3.67			11.10	25.07	39.04	53.00	62.64
404.06	4.57			0.36	1.60	2.84	4.07	4.92
405.44	6.10				1.05	3.14	5.23	6.68
406.81	7.62					1.05	3.14	4.59
406.91	7.73						0.15	0.25
408.66	9.14						1.24	3.07
409.96	10.20							0.68
470.92	9.74							13.94
504.44	9.88							12.94
531.88	10.00							7.03
559.31	9.31							14.80
Area(sq.m) =		13.37	115.80	298.08	490.69	687.41	888.59	1137.28
Elevation (m PWD) =		1.52	3.05	4.57	6.10	7.62	9.14	10.20

River : Surma

Date : 11-01-89 **Station : Sylhet**

Engelund and Hansen's Equation (1967):

$$g_s = 0.05\gamma_s V^2 \sqrt{\frac{D_{50}}{g\left(\frac{\gamma_s}{\gamma}-1\right)}}\left[\frac{\tau_0}{(\gamma_s-\gamma)D_{50}}\right]^{\frac{3}{2}}$$

where,

g_s = sediment transport per unit time per unit width;

V = average flow velocity = 0.377 m/sec

D_{50} = median diameter of bed material = 0.0002 m

γ_s = specific weight of sediment particles

= 1000*2.65 kg/m^3

γ = specific weight of water = 1000 kg/m^3

g = acceleration due to gravity = 9.81 m/sec^2

S = slope = 0.00004

B = width = 109.55 m

τ_0 = bed shear stress = γ RS = 1000*1.262*0.00004 = 0.0548

$$g_s = 0.05*2.65*1000*(0.377)^2\sqrt{\frac{0.0002}{9.81*(2.65*1)}}\left[\frac{0.0548}{(2.65-1)*1000*0.0002}\right]^{3/2}$$

= 18.832*0.0035151*0.059828

= 0.00396 kg/m/sec

= 0.00396*60*60*24*109.55/1000

= 37.482 ton/day

COMPUTATION OF TOTAL SEDIMENT TRANSPORT
OF THE SURMA AT SYLHET

(Engelund- Hansen Method)

Sl. No.	Sampling date	Hydraulic Radius R (m)	Width B (m)	Velocity V m/sec	Discharge Q cumec	Bed shear stress To kg/sq.m	Total Sediment Load gs kg/m/sec	Total Sediment Load ton/day	Suspended Sediment Load ton/day	Suspended Sediment Load ppm
1	01.01.89	1.461	120.661	0.119	27.243	0.058435	0.000492	5.12	40.0	17
2	11.01.89	1.262	109.550	0.377	20.503	0.050491	0.003962	37.50	39.0	22
3	25.01.89	1.024	96.757	0.557	12.632	0.040960	0.006319	52.83	16.4	15
4	07.02.89	0.931	91.213	0.574	9.870	0.037256	0.005822	45.88	35.8	42
5	22.02.89	1.188	105.510	0.608	32.626	0.047533	0.009413	85.81	59.2	21
6	08.03.89	1.367	72.393	0.724	8.175	0.054678	0.016467	103.00	16.2	23
7	22.03.89	1.209	64.482	0.668	6.231	0.048375	0.011666	64.99	32.8	61
8	05.04.89	3.275	126.686	0.718	269.209	0.131005	0.060063	657.43	907.1	39
9	19.04.89	3.987	128.015	0.469	258.368	0.159490	0.034425	380.76	3370.8	151
10	28.06.89	7.169	134.838	1.007	1198.185	0.286770	0.382636	4457.69	19669.4	190
11	12.07.89	2.502	545.551	1.089	1297.560	0.100093	0.092276	4349.50	21637.1	193
12	17.07.89	5.238	130.378	0.682	450.946	0.209518	0.109604	1234.66	6233.9	160
13	26.07.89	2.288	501.335	1.107	1287.899	0.091524	0.083372	3611.30	21921.1	197
14	09.08.89	2.895	547.177	0.392	1680.756	0.115813	0.014854	702.26	74496.5	513
15	27.12.89	1.094	100.460	0.327	10.712	0.043771	0.002406	20.88	88.2	96
1	11.02.70	6.594	105.628	0.344	4.078	0.263772	0.039483	360.34	46.9	133
2	26.02.70	6.666	105.948	0.488	7.306	0.266626	0.080447	736.40	76.4	121
3	11.03.70	6.586	105.510	0.335	6.400	0.263459	0.037348	340.47	58.1	105
4	25.03.70	6.338	104.104	0.290	3.313	0.253512	0.026294	236.51	32.3	113
5	08.04.70	8.830	114.641	0.235	149.994	0.353216	0.028409	281.39	466.5	36
6	07.05.70	9.838	117.266	0.277	168.457	0.393534	0.046663	472.78	465.7	32
7	01.07.70	4.394	372.310	1.125	1229.272	0.175755	0.228996	7366.26	30245.0	285
8	08.07.70	11.501	121.691	0.978	742.185	0.460022	0.733823	7715.52	9875.2	154
9	16.07.70	4.708	449.580	1.408	1822.557	0.188318	0.398140	15465.22	57003.8	362
10	22.07.70	4.418	449.580	1.524	1833.091	0.176736	0.423974	16468.74	29458.5	186
11	29.07.70	4.431	449.580	1.436	1713.509	0.177223	0.377778	14674.30	39972.7	270
12	05.08.70	4.205	445.580	1.372	1520.615	0.168201	0.318847	12385.20	34684.6	264
13	12.08.70	4.037	449.580	1.372	1443.933	0.161496	0.299971	11652.00	25450.2	204
14	19.08.70	4.838	323.204	1.372	1286.831	0.193538	0.393540	10989.53	24793.6	223
15	26.08.70	11.429	121.252	0.762	680.964	0.457162	0.440959	4619.58	3647.9	62
16	02.09.70	11.620	122.133	0.914	870.828	0.464805	0.650971	6869.25	10834.5	144

17	09.09.70	10.911	119.921	0.686	542.664	0.436460	0.333192	3452.25	9517.9	203
18	17.09.70	4.232	395.420	1.320	1403.355	0.169271	0.298031	10182.03	21097.5	174
19	24.09.70	7.932	191.140	1.204	1208.648	0.317279	0.636456	10510.76	6996.6	67
20	01.10.70	12.008	123.069	1.143	1121.772	0.480333	1.068536	11361.92	9692.1	100
21	08.10.70	3.946	449.580	1.634	1893.208	0.157838	0.411207	15972.81	25190.3	154
22	15.10.70	11.852	122.642	1.030	1080.373	0.474065	0.851145	9018.99	13908.3	149
23	22.10.70	10.294	118.467	0.393	329.382	0.411743	0.100353	1027.17	1736.0	61
24	29.10.70	10.681	119.497	0.509	411.500	0.427252	0.177776	1835.45	5155.3	145
25	05.11.70	9.633	117.254	0.357	239.957	0.393331	0.077077	780.84	974.4	47
26	20.11.70	9.104	115.352	0.344	208.525	0.364169	0.064051	638.35	1657.5	92
27	04.12.70	7.946	112.380	0.088	37.208	0.317839	0.003440	33.40	118.9	37
28	16.12.70	7.468	110.469	0.256	18.602	0.298710	0.026293	250.96	48.7	30
29	30.12.70	7.114	108.459	0.329	10.506	0.284556	0.040412	378.70	68.1	75
1	07-02-75	2.183	93.675	0.329	5.635	0.087313	0.006869	55.59	41.9	86
2	21-02-75	2.223	93.919	0.610	6.286	0.088906	0.024203	196.40	31.5	58
3	07.03.75	2.179	93.838	0.570	5.607	0.087154	0.020536	166.50	54.3	112
4	21-03-75	2.009	92.603	0.329	3.002	0.080345	0.006063	48.51	16.1	62
5	04-04-75	1.927	92.132	0.308	2.577	0.077089	0.004984	39.67	28.9	130
6	18-04-75	4.980	106.432	0.308	238.116	0.199201	0.020701	190.36	1625.3	79
7	02-05-75	6.208	110.813	0.500	415.635	0.248331	0.075971	727.37	2441.9	68
8	09-05-75	4.625	105.192	0.180	118.902	0.184993	0.006322	57.46	1561.5	152
9	23-05-75	7.222	114.533	0.841	775.542	0.288862	0.269939	2671.22	9917.0	148
10	30-05-75	6.993	113.688	0.777	707.610	0.279732	0.219587	2156.92	11738.4	192
11	06-06-75	6.102	110.428	0.411	331.137	0.244070	0.050159	478.57	2660.8	93
12	14-06-75	7.233	114.579	0.905	854.263	0.289337	0.313352	3102.05	9521.3	129
13	20-06-75	7.534	119.707	1.067	921.742	0.301344	0.462533	4783.83	15529.5	195
14	27-06-75	7.017	124.020	0.890	842.681	0.280674	0.289389	3100.89	12522.9	172
15	05-07-75	7.002	124.559	0.942	867.656	0.280067	0.323015	3476.26	11619.7	155
16	11-07-75	6.680	138.039	0.942	1074.992	0.267214	0.301037	3590.33	22198.2	239
17	18-07-75	3.679	325.813	1.295	1836.574	0.147165	0.232756	6552.13	100603.1	634
18	26-07-75	3.780	400.824	1.320	1925.631	0.151187	0.251572	8712.23	96663.6	581
19	02-08-75	4.009	377.041	1.344	1854.130	0.160359	0.285056	9286.06	17781.9	111
20	08-08-75	3.856	285.445	1.076	1245.460	0.154246	0.172299	4249.32	20337.9	189
21	22-08-75	3.672	317.136	1.286	1623.745	0.146868	0.228785	6268.82	34932.6	249
22	29-08-75	3.920	249.456	0.942	1001.312	0.156806	0.135324	2916.65	6575.0	76
23	05-09-75	3.688	307.281	1.372	1537.605	0.147500	0.261835	6951.49	47560.0	358

River : Surma

Date : 11-01-89 **Station : Sylhet**

<u>Hossain's Equation (1987):</u>

$$C_t = A\left[X^a Y^b Z^c\right]$$

where,

C_t = total average sediment concentration in parts per million;

$A = 6.946*10^5$ for $\frac{B}{H} < 500$ and

$A = 6.946*10^6$ for $\frac{B}{H} > 500$

$K = 0.055$ when $Q < 15000$ cumecs and

$K = 0.17$ when $Q > 15000$ cumecs.

here, $A = 6.946*10^5$; $\frac{B}{H} = \frac{109.55}{1.262} = 86.806$ and

K = 0.055 ; $Q = 20.503$ cumec

$X = \frac{VS}{(gH)^{\frac{1}{2}}} = \frac{0.377*0.00004}{(9.81*1.262)^{\frac{1}{2}}} = 0.00000428$ and $a = 0.745$

$Y = \frac{\omega_r}{\omega}$ and $b = 0.633$

and $c = 0.50$

$\nu =$ kinematic viscisity = 0.000000864 m^2/sec

$\omega_r =$ settling velocity for a representative sediment size for

which $D_{50} = 0.15$mm at ambient temperature

$= 0.01551$ m/sec

$\omega =$ settling velocity of the sediment load

$$= \frac{\left(\frac{2}{3}g(S_S - 1)D_{50}^3 + 36\nu^2\right)^{0.5} + 6\nu}{D_{50}} = 0.027288$$

$Q =$ measured discharge = 20.503 cumec

$Q_c =$ assessed discharge;

$$Q_c = \left[\left(2..15 + K\frac{B}{H}\right)H(gS)^{\frac{1}{5}}\right]^{\frac{5}{2}}$$

where,

$B =$ average width of the channel =109.55 m

$H =$ average depth of flow 1.262 m

$S =$ average water surface slope = 0.00004

$g =$ acceleration due to gravity = 9.81 m/sec^2

$$Y = \frac{\omega_r}{\omega} = \frac{0.01551}{0.027288} = 0.5638$$

$$Q_c = \left[(2.15 + 0.055 * 86.806) * 1262 * (9.81 * 0.00004)^{\frac{1}{5}}\right]^{\frac{5}{2}} = 4.4715$$

$$Z = \frac{Q}{Q_c} = \frac{20.505}{4.4715} = 4.587$$

$$C_t = A\left[X^a Y^b Z^c\right]$$

$$= 6.946 * 100000 * \left[0.00000428^{0.745} * 0.56838^{0.633} * * 4.587^{0.5}\right]$$

$$= 6.946 * 100000 * 0.0001 * 0.69933 * 2.1473$$

$$= 104.408 \text{ ppm}$$

$$= 104.408 * 20.503 * 24 * 3600 / 1000000$$

$$= 184.95 \text{ ton/day}$$

COMPUTATION OF TOTAL SEDIMENT TRANSPORT
OF THE SURMA AT SYLHET

(Hossain's Method)

Sl. No.	Sampling date	Depth y (m)	Width B (m)	Velocity V (m/sec)	Discharge Q (cumecs)	Dc	X	Z	Calculated Total Sediment Load Ct (ppm)	(ton/day)
1	01.01.89	1.461	120.661	0.119	27.243	5.921	0.0000013	4.601	41.893	98.61
2	11.01.89	1.262	109.550	0.377	20.503	4.472	0.0000043	4.584	104.252	184.68
3	25.01.89	1.024	96.757	0.557	12.632	3.075	0.0000070	4.108	142.682	155.72
4	07.02.89	0.931	91.213	0.574	9.870	2.566	0.0000076	3.817	145.718	124.27
5	22.02.89	1.188	105.510	0.608	32.626	4.000	0.0000071	8.155	203.035	572.33
6	08.03.89	1.367	72.393	0.724	8.175	2.496	0.0000079	3.276	139.102	98.25
7	22.03.89	1.209	64.482	0.668	6.231	1.856	0.0000078	3.358	138.836	74.74
8	05.04.89	3.275	126.686	0.718	269.209	14.551	0.0000051	18.501	237.266	5518.74
9	19.04.89	3.987	128.015	0.469	258.368	19.081	0.0000030	13.540	137.353	3066.12
10	28.06.89	7.169	134.838	1.007	1198.185	49.332	0.0000048	24.288	261.242	27044.58
11	12.07.89	2.502	545.551	1.089	1297.560	147.544	0.0000086	8.794	246.636	27650.11
12	17.07.89	5.238	130.378	0.682	450.946	28.895	0.0000038	15.606	176.070	6859.98
13	26.07.89	2.289	501.335	1.107	1287.899	119.216	0.0000093	10.803	286.095	31835.10
14	09.08.89	2.895	547.177	0.392	1680.756	157.478	0.0000029	10.673	120.121	17443.68
15	27.12.89	1.094	100.460	0.327	10.712	3.451	0.0000040	3.104	81.375	75.31
1	11.02.70	6.594	105.628	0.344	4.078	35.379	0.0000017	0.115	8.348	2.94
2	26.02.70	6.666	105.948	0.488	7.306	36.141	0.0000024	0.202	14.267	9.01
3	11.03.70	6.586	105.510	0.335	6.400	35.276	0.0000017	0.181	10.270	5.68
4	25.03.70	6.338	104.104	0.290	3.313	32.635	0.0000015	0.102	6.987	2.00
5	08.04.70	8.830	114.641	0.235	149.994	63.718	0.0000010	2.354	25.427	329.52
6	07.05.70	9.838	117.266	0.277	168.457	79.290	0.0000011	2.125	26.277	382.46
7	01.07.70	4.394	372.310	1.125	1228.272	97.031	0.0000069	12.659	245.749	26079.57
8	08.07.70	11.501	121.691	0.978	742.185	109.611	0.0000037	6.771	113.210	7259.56
9	16.07.70	4.708	449.580	1.408	1822.557	142.017	0.0000083	12.833	285.118	44897.29
10	22.07.70	4.418	449.580	1.524	1833.091	135.759	0.0000093	13.503	317.618	50304.11

11	29.07.70	4.431	449.580	1.436	1713.509	136.019	0.0000087	12.598	293.132	43397.38
12	05.08.70	4.205	449.580	1.372	1520.615	131.256	0.0000085	11.585	277.055	36399.78
13	12.08.70	4.037	449.580	1.372	1443.933	127.781	0.0000087	11.300	277.803	34657.51
14	19.08.70	4.836	323.204	1.372	1286.831	83.498	0.0000080	15.412	303.277	33719.03
15	26.08.70	11.429	121.252	0.762	680.964	108.066	0.0000029	6.301	90.866	5346.12
16	02.09.70	11.620	122.133	0.914	870.828	112.081	0.0000034	7.770	114.866	8642.45
17	09.09.70	10.911	119.921	0.686	542.564	98.100	0.0000027	5.532	80.060	3754.63
18	17.09.70	4.232	395.420	1.320	1403.355	104.693	0.0000082	13.406	288.919	35031.39
19	24.09.70	7.932	191.140	1.204	1208.648	79.034	0.0000055	15.293	228.041	23813.73
20	01.10.70	10.308	123.069	1.143	1121.772	120.078	0.0000042	9.342	146.924	14240.03
21	08.10.70	3.946	449.580	1.634	1893.208	125.910	0.0000105	15.036	368.177	60223.92
22	15.10.70	11.852	122.642	1.030	1080.373	116.786	0.0000038	9.251	135.981	12693.03
23	22.10.70	10.294	118.467	0.393	329.382	87.008	0.0000016	3.786	44.731	1272.97
24	29.10.70	10.681	119.497	0.509	411.500	93.926	0.0000020	4.381	57.528	2045.33
25	05.11.70	9.833	117.254	0.357	239.957	79.207	0.0000015	3.029	37.847	784.65
26	20.11.70	9.104	115.352	0.344	208.525	67.746	0.0000015	3.076	38.255	689.23
27	04.12.70	7.946	112.380	0.088	37.208	51.714	0.0000004	0.720	7.064	22.71
28	16.12.70	7.468	110.469	0.256	18.802	45.644	0.0000012	0.412	12.080	19.62
29	30.12.70	7.114	108.459	0.329	10.506	41.284	0.0000016	0.254	11.658	10.58
1	07-02-75	2.183	93.675	0.329	5.635	6.025	0.0000028	0.935	34.708	16.90
2	21-20-75	2.223	93.919	0.610	6.286	6.177	0.0000052	1.018	56.910	30.91
3	07-03-75	2.179	93.838	0.570	5.607	6.025	0.0000049	0.931	52.147	25.26
4	21-03-75	2.009	92.603	0.329	3.002	5.393	0.0000030	0.558	27.641	7.17
5	04-04-75	1.927	92.132	0.308	2.577	5.100	0.0000028	0.505	25.418	5.66
6	18-04-75	4.980	106.432	0.308	238.116	22.109	0.0000018	10.770	82.402	1695.27
7	02-05-75	6.208	110.813	0.500	415.635	33.018	0.0000026	12.588	117.757	4228.74
8	09-05-75	4.625	105.192	0.180	118.902	19.436	0.0000011	6.118	42.771	439.40
9	23-05-75	7.222	114.533	0.841	775.542	44.084	0.0000040	17.592	193.922	12994.07
10	30-05-75	6.993	113.636	0.777	707.610	41.421	0.0000038	17.083	182.323	11146.75
11	06-06-75	6.102	110.428	0.411	331.137	31.965	0.0000021	10.359	93.005	2660.90
12	14-06-75	7.233	114.579	0.905	854.263	44.226	0.0000043	19.316	214.478	15830.23
13	20-06-75	7.534	119.707	1.067	921.742	49.068	0.0000050	18.785	235.439	18749.97
14	27-06-75	7.017	124.020	0.890	842.681	44.498	0.0000043	18.938	212.086	15441.48
15	05-07-75	7.002	124.559	0.942	867.656	44.483	0.0000045	19.506	224.691	16844.11
16	11-07-75	6.680	138.039	0.942	1074.992	44.740	0.0000047	24.028	253.784	23571.27
17	18-07-75	3.679	325.813	1.295	1836.574	67.169	0.0000086	27.343	428.701	68026.34
18	26-07-75	3.780	400.824	1.320	1925.631	99.052	0.0000087	19.441	362.880	60374.00
19	02-08-75	4.009	377.041	1.344	1854.130	92.497	0.0000086	20.045	365.435	58541.60
20	08-08-75	3.856	285.445	1.076	1245.460	55.841	0.0000070	22.304	331.334	35654.13
21	22-08-75	3.672	317.136	1.286	1623.745	64.008	0.0000086	25.368	411.067	57669.26
22	29-08-75	3.920	249.456	0.942	1001.312	45.732	0.0000061	21.895	295.470	25562.11
23	05-09-75	3.688	307.281	1.372	1537.605	60.848	0.0000091	25.270	429.696	57084.69

River : Surma

Date : 11-01-89 **Station : Sylhet**

Yang's Equation (1976):

$$\log C_t = 5.435 - 0.286 \log \frac{\omega D_{50}}{\nu} - 0.457 \log \frac{u_*}{\omega}$$

$$+ \left(1.799 - 0.409 \log \frac{\omega D_{50}}{\nu} - 0.314 \log \frac{u_*}{\omega}\right) \log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right)$$

where,

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{u_* D_{50}}{\nu} - 0.06} + 0.66; \qquad \text{when } 1.2 < \frac{u_* D_{50}}{\nu} < 70 \text{ and}$$

$$\frac{V_{cr}}{\omega} = 2.05 \qquad \text{when} \quad 70 \le \frac{u_* D_{50}}{\nu}$$

C_t = total average sediment concentration in parts per million

D_{50} = median diameter of bed material=0.0002 m

S = water surface slope = 0.00004

H = average depth = 1.262 m

u_* = shear velocity = $\sqrt{gHS} = \sqrt{9.81 * 1.262 * 0.00004} = 0.022253$

V = average water velocity = 0.377 m/sec

V_{cr} = critical average water velocity

ν = kinematic viscosity = 0.000000864 m^2/sec

ω = terminal fall velocity = 0.01551 m/sec

Q = discharge= 20.503 cumec

$$\frac{u_* D_{50}}{\nu} = \frac{0.022253 * 0.0002}{0.000000864} = 5.152$$

$$\frac{u_*}{\omega} = \frac{0.022253}{0.01551} = 1.43475$$

$$\frac{\omega D_{50}}{\nu} = \frac{0.01551 * 0.0002}{0.000000864} = 3.591$$

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{u_* D_{50}}{\nu} - 0.06} + 0.66 = \frac{2.5}{\log 5.152 - 0.06} + 0.06 = 4.495$$

$$\log C_t = 5.435 - 0.286 * \log 3.591 - 0.457 * \log 1.43475$$
$$+(1.799 - 0.409 * \log 3.591 - 0.314 * \log 1.43475)$$
$$\log\left(\frac{0.377 * 0.00004}{0.01551} - 4.495 * 0.00004\right)$$

= 5.20456+1/52269*(-3.101)

= 0.4827

C_t = 3.0387 ppm

= 3.0387*20.503*24*60*60/1000000

= 5.383 ton/day

COMPUTATION OF TOTAL SEDIMENT TRANSPORT
OF THE SURMA AT SYLHET

(Yang's Method)

Sl. No.	Sampling date	Depth D (m)	Velocity V (m/sec)	Discharge Q (cumecs)	Shear Velocity u*	u*D50/v	U*/w	Vcr/w	log C	Calculated Total Sediment Load C (ppm)	(ton/day)
1	01.01.89	1.461	0.119	27.243	0.0239	5.542	1.543	4.317	-0.6678	0.215	0.506
2	11.01.89	1.262	0.377	20.503	0.0223	5.152	1.435	4.495	0.4825	3.037	5.381
3	25.01.89	1.024	0.557	12.632	0.0200	4.640	1.292	4.782	0.7607	5.763	6.290
4	07.02.89	0.931	0.574	9.870	0.0191	4.425	1.232	4.927	0.7715	5.909	5.039
5	22.02.89	1.188	0.608	32.626	0.0216	4.999	1.392	4.573	0.8460	7.014	19.772
6	08.03.89	1.367	0.724	8.175	0.0232	5.361	1.493	4.395	0.9910	9.795	6.919
7	22.03.89	1.209	0.668	6.231	0.0218	5.043	1.404	4.550	0.9182	8.284	4.460
8	05.04.89	3.275	0.718	269.209	0.0358	8.298	2.311	3.570	1.0760	11.912	277.063
9	19.04.89	3.987	0.459	258.368	0.0396	9.156	2.550	3.432	0.8012	6.327	141.244
10	28.06.89	7.169	1.007	1198.165	0.0530	12.278	3.419	3.089	1.3716	23.527	2435.642
11	12.07.89	2.502	1.089	1297.560	0.0313	7.254	2.020	3.783	1.3349	21.621	2423.894
12	17.07.89	5.238	0.682	450.946	0.0453	10.495	2.922	3.262	1.0881	12.249	477.252
13	26.07.89	2.288	1.107	1287.699	0.0300	6.936	1.931	3.861	1.3384	21.799	2425.709
14	09.08.89	2.895	0.392	1680.756	0.0337	7.802	2.173	3.664	0.6303	4.269	619.905
15	27.12.89	1.074	0.327	10.712	0.0207	4.797	1.336	4.686	0.3406	2.191	2.027
1	11.02.70	6.594	0.344	4.078	0.0509	11.775	3.279	3.133	0.6447	4.413	1.555
2	26.02.70	6.666	0.488	7.306	0.0511	11.839	3.297	3.127	0.8878	7.723	4.875
3	11.03.70	6.586	0.335	6.400	0.0508	11.768	3.277	3.134	0.6254	4.220	2.334
4	25.03.70	6.338	0.290	3.313	0.0499	11.544	3.214	3.154	0.5135	3.262	0.934
5	08.04.70	8.830	0.235	149.994	0.0589	13.626	3.794	2.987	0.4053	2.543	32.953
6	07.05.70	9.238	0.277	168.457	0.0621	14.393	4.005	2.937	0.5436	3.496	50.890
7	01.07.70	4.394	1.125	1228.272	0.0415	9.612	2.676	3.369	1.4029	25.285	2683.333
8	08.07.70	11.503	0.978	742.185	0.0672	15.550	4.330	2.869	1.3928	24.706	1584.246
9	15.07.70	4.708	1.408	1822.557	0.0430	9.949	2.770	3.326	1.5543	35.836	5643.064
10	22.07.70	4.416	1.524	1833.091	0.0416	9.639	2.684	3.366	1.6009	39.890	6317.787

11	29.07.70	4.431	1.436	1713.509	0.0417	9.652	2.688	3.364	1.5624	36.509	5405.110
12	05.08.70	4.205	1.372	1520.615	0.0406	9.403	2.618	3.397	1.5290	33.805	4441.364
13	12.08.70	4.037	1.372	1443.933	0.0398	9.214	2.566	3.424	1.5260	33.572	4188.290
14	19.08.70	4.838	1.372	1286.831	0.0436	10.086	2.809	3.309	1.5393	34.620	3849.076
15	26.08.70	11.429	0.762	680.964	0.0670	15.502	4.317	2.872	1.2351	17.185	1011.068
16	02.09.70	11.620	0.914	870.828	0.0675	15.631	4.352	2.865	1.3514	22.458	1689.757
17	09.09.70	10.911	0.686	542.664	0.0654	15.147	4.218	2.891	1.1637	14.579	683.569
18	17.09.70	4.232	1.320	1403.355	0.0407	9.433	2.627	3.393	1.5044	31.944	3873.154
19	24.09.70	7.932	1.204	1208.648	0.0558	12.914	3.596	3.039	1.4932	31.135	3251.332
20	01.10.70	12.008	1.143	1121.772	0.0686	15.890	4.425	2.851	1.4929	31.109	3015.161
21	08.10.70	3.946	1.634	1893.208	0.0393	9.109	2.536	3.439	1.6381	43.460	7108.939
22	15.10.70	11.852	1.030	1080.373	0.0682	15.786	4.396	2.856	1.4274	26.756	2497.559
23	22.10.70	10.294	0.393	329.382	0.0636	14.712	4.097	2.917	0.7924	6.201	176.459
24	29.10.70	10.681	0.509	411.500	0.0647	14.986	4.173	2.901	0.9686	9.303	330.754
25	05.11.70	9.833	0.357	239.957	0.0621	14.379	4.004	2.937	0.7202	5.250	108.844
26	20.11.70	9.104	0.344	208.525	0.0598	13.836	3.853	2.973	0.6863	4.857	87.500
27	04.12.70	7.946	0.088	37.208	0.0558	12.925	3.599	3.038	-0.5294	0.296	0.950
28	16.12.70	7.469	0.256	18.802	0.0541	12.531	3.489	3.069	0.4457	2.791	4.533
29	30.12.70	7.114	0.329	10.506	0.0528	12.230	3.406	3.093	0.6224	4.192	3.805
1	07-02-75	2.183	0.329	5.635	0.0293	6.775	1.886	3.903	0.4572	2.866	1.395
2	21-02-75	2.223	0.610	6.286	0.0295	6.836	1.904	3.887	0.9204	8.325	4.522
3	07.03.75	2.179	0.570	5.607	0.0292	6.769	1.885	3.905	0.8698	7.410	3.590
4	21-03-75	2.009	0.329	3.602	0.0281	6.499	1.810	3.981	0.4447	2.784	0.722
5	04-04-75	1.927	0.308	2.577	0.0275	6.366	1.773	4.021	0.3843	2.422	0.539
6	18-04-75	4.980	0.308	238.116	0.0442	10.233	2.849	3.292	0.5251	3.350	68.925
7	02-05-75	6.208	0.500	415.635	0.0494	11.425	3.181	3.165	0.8966	7.881	283.003
8	09-05-75	4.625	0.180	118.902	0.0426	9.861	2.746	3.337	0.0831	1.211	12.438
9	23-05-75	7.222	0.841	775.542	0.0532	12.322	3.431	3.086	1.2565	18.050	1209.493
10	30-05-75	6.993	0.777	707.610	0.0524	12.126	3.377	3.102	1.2022	15.930	973.896
11	06-06-75	6.102	0.411	331.137	0.0489	11.327	3.154	3.175	0.7604	5.760	164.791
12	14-06-75	7.233	0.905	854.263	0.0533	12.333	3.434	3.085	1.3039	20.134	1486.057
13	20-06-75	7.534	1.067	921.742	0.0544	12.586	3.505	3.064	1.4125	25.850	2058.691
14	27-06-75	7.017	0.890	842.681	0.0525	12.147	3.382	3.100	1.2903	19.513	1420.675
15	05-07-75	7.002	0.942	867.656	0.0524	12.133	3.379	3.101	1.3266	21.213	1590.215
16	11-07-75	6.680	0.942	1074.992	0.0512	11.852	3.300	3.126	1.3225	21.016	1951.938
17	18-07-75	3.679	1.299	1836.574	0.0380	8.795	2.449	3.487	1.4816	30.309	4809.508
18	26-07-75	3.780	1.320	1925.631	0.0385	8.915	2.482	3.469	1.4959	31.323	5211.372
19	02-08-75	4.009	1.344	1854.130	0.0397	9.181	2.557	3.429	1.5123	32.529	5211.013
20	08-08-75	3.856	1.076	1245.460	0.0389	9.004	2.507	3.455	1.3630	23.067	2482.203
21	22-08-75	3.672	1.286	1623.745	0.0380	8.786	2.447	3.489	1.4768	29.976	4205.325
22	29-08-75	3.920	0.942	1001.312	0.0392	9.079	2.528	3.444	1.2761	18.884	1633.755
23	05-09-75	3.698	1.372	1537.605	0.0380	8.805	2.452	3.486	1.5193	33.057	4391.537

River : Surma

Date : 28-06-89 **Station : Sylhet**

Mayer-Peter and Muller Formula (1948) :

$$g_s^{2/3} = 250q^{2/3}S - 42.5d_{50}$$

where,

$g_s =$ rate of bed load transport by weight/time/width;

$S =$ water surface slope = 0.00004

$d_{50} =$ median diameter of bed material = 0.0002 m

$B =$ width = 134.808 m

$Q =$ discharge = 1198.185 cumec

$q =$ discharge per unit width = 1198.185/134.808

= 8.886 cumec/meter width

$g_s^{2/3} = 250q^{2/3}S - 42.5d_{50} = 250*8.886^{2/3}*0.00004-42.5*0.0002$

= 0.0344

$g_s = 0.00639$ kg/m/sec

= 0.00639*134.838*60*60*24/1000

= 74.4 ton/day

COMPUTATION OF BED LOAD TRANSPORT
OF THE RIVER SURMA AT SYLHET

(Meyer-Peter & Muller Formula)

Sampling date	Average Depth H (m)	Width B (m)	Velocilty V (m/sec)	Discharge Q (cumec)	gs^.667	Calulated Bed Load gs (kg/m/sec)	ton/day
05.04.89	3.275	126.686	0.718	269.209	0.0080	0.00072	7.88
19.04.89	3.987	128.015	0.469	258.368	0.0075	0.00065	7.14
28.06.89	7.169	134.838	1.007	1198.185	0.0344	0.00638	74.34
12.07.89	2.502	545.551	1.089	1297.560	0.0093	0.00090	42.40
17.07.89	5.238	130.378	0.682	450.946	0.0144	0.00172	19.41
26.07.89	2.288	501.335	1.107	1287.899	0.0103	0.00104	45.00
09.08.89	2.895	547.177	0.392	1680.756	0.0126	0.00142	67.11
08.04.70	8.830	114.641	0.235	149.994	0.0035	0.00020	2.02
07.05.70	9.838	117.266	0.277	168.457	0.0042	0.00028	2.79
01.07.70	4.394	372.310	1.125	1228.272	0.0137	0.00160	51.36
08.07.70	11.501	121.691	0.978	742.185	0.0249	0.00392	41.26
16.07.70	4.708	449.580	1.408	1822.557	0.0169	0.00220	85.52
22.07.70	4.418	449.580	1.524	1833.091	0.0170	0.00222	86.27
29.07.70	4.431	449.580	1.436	1713.509	0.0159	0.00200	77.88
05.08.70	4.205	449.580	1.372	1520.615	0.0140	0.00166	64.57
12.08.70	4.037	449.580	1.372	1443.933	0.0133	0.00153	59.37
19.08.70	4.838	323.204	1.372	1286.831	0.0166	0.00214	59.84
26.08.70	11.429	121.252	0.762	680.964	0.0231	0.00351	36.77
02.09.70	11.620	122.133	0.914	870.828	0.0285	0.00482	50.89
09.09.70	10.911	119.921	0.686	542.664	0.0189	0.00259	26.83
17.09.70	4.232	395.420	1.320	1403.355	0.0148	0.00179	61.31
24.09.70	7.932	191.140	1.204	1208.648	0.0257	0.00412	68.02
01.10.70	12.008	123.069	1.143	1121.772	0.0351	0.00659	70.03
08.10.70	3.946	449.580	1.634	1893.208	0.0176	0.00233	90.52
15.10.70	11.852	122.642	1.030	1080.373	0.0342	0.00631	66.88
22.10.70	10.294	118.467	0.393	329.382	0.0113	0.00120	12.25
29.10.70	10.681	119.497	0.509	411.500	0.0143	0.00171	17.66
05.11.70	9.833	117.254	0.357	239.957	0.0076	0.00067	6.74
20.11.70	9.104	115.352	0.344	208.525	0.0063	0.00050	5.03
18.04.75	4.980	106.432	0.308	238.116	0.0086	0.00080	7.34
02.05.75	6.208	110.813	0.500	415.635	0.0156	0.00196	18.73
09.05.75	4.625	105.192	0.180	118.902	0.0024	0.00011	1.04
23.05.75	7.222	114.533	0.841	775.542	0.0273	0.00451	44.62
30.05.75	6.993	113.688	0.777	707.610	0.0253	0.00403	39.61
06.06.75	6.102	110.428	0.411	331.137	0.0123	0.00136	13.01

14.06.75	7.233	114.579	0.905	854.263	0.0297	0.00511	50.58
20.06.75	7.534	119.707	1.067	921.742	0.0305	0.00532	55.07
27.06.75	7.017	124.020	0.890	842.681	0.0274	0.00453	48.53
05.07.75	7.002	124.559	0.942	867.656	0.0280	0.00468	50.35
11.07.75	6.680	138.039	0.942	1074.992	0.0308	0.00540	64.43
18.07.75	3.679	325.813	1.295	1836.574	0.0232	0.00353	99.30
26.07.75	3.780	400.824	1.320	1925.631	0.0200	0.00282	97.74
02.08.75	4.009	377.041	1.344	1854.130	0.0204	0.00292	95.04
08.08.75	3.856	285.445	1.076	1245.460	0.0182	0.00246	60.56
22.08.75	3.672	317.136	1.286	1623.745	0.0212	0.00309	84.62
29.08.75	3.920	249.456	0.942	1001.312	0.0168	0.00217	46.75
05.09.75	3.688	307.281	1.372	1537.605	0.0208	0.00299	79.39

River : Surma

Date : 28-06-89 **Station : Sylhet**

Rottner's Equation (1959):

$$\frac{M}{\rho_s\left[gH^3(S_s-1)\right]^{1/2}}=\left[\left\{0.667\left(\frac{D_{50}}{H}\right)^{2/3}+0.14\right\}\frac{V}{(S_s-1)^{1/2}(gH)^{1/2}}-0.778\left(\frac{D_{50}}{H}\right)^{2/3}\right]^3$$

Where,

M = Sediment flow rate, mass per unit width/time;

$S_s = 2.65$;

$\rho_s = \text{density} = {}^{\gamma s}\!/_{g}$

H = depth = 7.169 m

D_{50} = median diameter of bed material = 0.0002 m

V = velocity = 1.007 m/sec

$$A=\rho_s\left[gH^3(S_s-1)\right]^{1/2}=\frac{2.65*1000}{9.81}\left[9.81*7.169^3(2.65-1)\right]^{1/2}=20861.3$$

$$\left(\frac{D_{50}}{H}\right)^{2/3}=\left(\frac{0.0002}{7.169}\right)^{2/3}=0.000917$$

$$0.667*\left(\frac{D_{50}}{H}\right)^{2/3}+0.14=0.667*0.000917+0.14=0.14061$$

$$\frac{V}{(S_s-1)^{1/2}(gH)^{1/2}}=\frac{1.007}{(2.65-1)^{1/2}(9.81*7.169)^{1/2}}=0.093481$$

$$0.778\left(\frac{D_{50}}{H}\right)^{2/3}=0.778*0.000917=0.0007134$$

$$B=\left[\left\{0.667\left(\frac{D_{50}}{H}\right)^{2/3}+0.14\right\}\frac{V}{\left(S_s-1\right)^{1/2}\left(gH\right)^{1/2}}-0.778\left(\frac{D_{50}}{H}\right)^{2/3}\right]^3$$

or, $\left[0.14061*0.093481-0.0007134\right]^3=0.00000192$

Now, $\frac{M}{A}=B$

or, $M=A*B=208613*0.00000192$

$=0.04$ kg/m/sec

$=0.04*134.838*60*60*24/1000$

$=466$ ton/day

COMPUTATION OF BED LOAD TRANSPORT
OF THE RIVER SURMA AT SYLHET

(Rottner's Equation)

Sampling date	Average Depth H (m)	Width B (m)	Velocilty V (m/sec)	Discharge Q (cumec)	(d/D)^.667	A	B	Calculated Bed Load M kg/m/sec	ton/day
01.01.89	1.461	120.661	0.119	27.243	0.0027	1918.99	2.76E-09	0.0000	0.1
11.01.89	1.262	109.550	0.377	20.503	0.0029	1541.30	8.74E-07	0.0013	12.8
25.01.89	1.024	96.757	0.557	12.632	0.0034	1126.17	4.78E-06	0.0054	45.0
07.02.89	0.931	91.213	0.574	9.870	0.0036	976.29	6.09E-06	0.0059	46.9
22.02.89	1.189	105.510	0.609	32.676	0.0030	1407.27	5.20E-06	0.0073	66.7
08.03.89	1.367	72.393	0.724	8.175	0.0028	1737.03	7.61E-06	0.0132	82.7
22.03.89	1.209	64.482	0.668	6.231	0.0030	1444.75	6.97E-06	0.0101	56.1
05.04.89	3.275	126.686	0.718	269.209	0.0016	6441.61	2.05E-06	0.0132	144.5
19.04.89	3.987	128.015	0.469	258.369	0.0014	8652.96	3.68E-07	0.0032	35.3
28.06.89	7.169	134.838	1.007	1198.185	0.0009	20862.38	1.92E-06	0.0401	466.7
12.07.89	2.502	545.551	1.099	1297.560	0.0019	4302.01	1.17E-05	0.0505	2379.7
17.07.89	5.238	130.378	0.682	450.946	0.0011	13028.57	8.69E-07	0.0113	127.6
25.07.89	2.288	501.335	1.107	1287.899	0.0020	3761.52	1.41E-05	0.0531	2301.7
09.08.89	2.395	547.177	0.392	1680.756	0.0017	5354.25	3.09E-07	0.0017	78.3
27.12.89	1.094	100.460	0.327	10.712	0.0032	1244.06	6.23E-07	0.0008	6.7
11.02.70	6.594	105.628	0.344	4.078	0.0010	18403.74	6.08E-08	0.0011	10.2
26.02.70	6.666	105.948	0.482	7.306	0.0010	18703.29	2.00E-07	0.0037	34.3
11.03.70	6.586	105.510	0.335	6.400	0.0010	18371.04	5.53E-08	0.0010	9.3
25.03.70	6.338	104.104	0.290	3.313	0.0010	17340.50	3.42E-08	0.0006	5.3
08.04.70	8.830	114.641	0.235	149.994	0.0008	28518.35	9.75E-09	0.0003	2.8
07.05.70	9.838	117.266	0.277	168.457	0.0007	33537.99	1.58E-08	0.0005	5.4
01.07.70	4.394	372.310	1.125	1228.272	0.0013	10009.80	5.63E-06	0.0564	1813.7
08.07.70	11.501	121.691	0.978	742.185	0.0007	42386.88	8.71E-07	0.0369	388.1
16.07.70	4.708	449.580	1.408	1822.557	0.0012	11102.00	1.03E-05	0.1145	4447.7
22.07.70	4.418	449.580	1.524	1833.091	0.0013	10093.68	1.45E-05	0.1465	5691.2
29.07.70	4.431	449.580	1.436	1713.509	0.0013	10135.49	1.20E-05	0.1216	4721.9
05.08.70	4.205	449.580	1.372	1520.615	0.0013	9371.46	1.12E-05	0.1053	4091.1
12.08.70	4.037	449.580	1.372	1443.933	0.0013	8816.67	1.19E-05	0.1053	4089.5
19.08.70	4.838	323.204	1.372	1286.831	0.0012	11566.81	9.12E-06	0.1055	2945.3
26.08.70	11.429	121.252	0.762	680.964	0.0007	41992.13	3.96E-07	0.0166	174.3
02.09.70	11.620	122.133	0.914	870.828	0.0007	43049.58	6.92E-07	0.0298	314.4
09.09.70	10.911	119.921	0.686	542.664	0.0007	39172.33	3.02E-07	0.0118	122.5
17.09.70	4.232	395.420	1.320	1403.355	0.0013	9460.98	9.87E-06	0.0933	3188.7
24.09.70	7.932	191.140	1.204	1208.648	0.0009	24278.65	2.90E-06	0.0705	1164.5
01.10.70	12.008	123.069	1.143	1121.772	0.0007	45224.77	1.33E-06	0.0603	641.1

08.10.70	3.946	449.580	1.634	1893.208	0.0014	8518.85	2.13E-05	0.1819	7063.7
15.10.70	11.852	122.642	1.030	1080.373	0.0007	44342.51	9.80E-07	0.0435	460.7
22.10.70	10.294	118.467	0.393	329.382	0.0007	35892.43	5.14E-08	0.0018	18.9
29.10.70	10.681	119.497	0.509	411.500	0.0007	37939.33	1.17E-07	0.0044	45.8
05.11.70	9.833	117.254	0.357	239.957	0.0007	33512.07	3.90E-08	0.0013	13.2
20.11.70	9.104	115.352	0.344	208.525	0.0008	29855.00	3.85E-08	0.0011	11.5
04.12.70	7.946	112.380	0.088	37.208	0.0009	24342.99	7.81E-11	0.0000	0.0
16.12.70	7.468	110.469	0.256	18.802	0.0009	22178.75	1.71E-08	0.0004	3.6
30.12.70	7.114	108.459	0.329	10.506	0.0009	20621.24	4.64E-08	0.0010	9.0
07-02-75	2.183	93.675	0.329	5.635	0.0020	3504.97	2.44E-07	0.0009	6.9
21-02-75	2.223	93.919	0.610	6.286	0.0020	3602.16	2.10E-06	0.0076	61.5
07.03.75	2.179	93.838	0.570	5.607	0.0020	3495.36	1.72E-06	0.0060	48.8
21-03-75	2.009	92.603	0.327	3.002	0.0021	3093.88	2.74E-07	0.0008	6.8
04-04-75	1.927	92.132	0.308	2.577	0.0022	2907.72	2.25E-07	0.0007	5.2
18-04-75	4.780	106.432	0.308	238.116	0.0012	12078.17	6.00E-08	0.0007	6.7
02-05-75	6.208	110.813	0.500	415.535	0.0010	16811.66	2.41E-07	0.0041	38.9
09-05-75	4.625	105.192	0.180	118.902	0.0012	10809.27	7.63E-09	0.0001	0.7
23-05-75	7.222	114.533	0.841	775.542	0.0009	21091.04	1.07E-06	0.0226	223.4
30-05-75	6.953	113.688	0.777	707.610	0.0009	20099.07	8.70E-07	0.0175	171.7
06-06-75	6.102	110.428	0.411	331.137	0.0010	16380.77	1.27E-07	0.0021	19.9
14-06-75	7.233	114.579	0.905	854.263	0.0009	21143.12	1.35E-06	0.0285	282.6
20-06-75	7.534	119.707	1.067	921.742	0.0009	22472.77	2.14E-06	0.0481	497.8
27-06-75	7.017	124.020	0.890	842.681	0.0009	20200.66	1.34E-06	0.0270	289.5
05-07-75	7.002	124.559	0.942	867.656	0.0009	20135.20	1.61E-06	0.0324	348.3
11-07-75	6.360	138.039	0.942	1074.992	0.0010	18765.18	1.72E-06	0.0323	385.6
18-07-75	3.679	325.813	1.295	1836.574	0.0014	7669.59	1.15E-05	0.0879	2474.0
26-07-75	3.780	400.824	1.320	1925.631	0.0014	7986.12	1.17E-05	0.0932	3228.5
02-08-75	4.009	377.041	1.344	1854.130	0.0014	8723.74	1.13E-05	0.0988	3218.7
08-08-75	3.856	285.445	1.076	1245.460	0.0014	8229.70	5.94E-06	0.0489	1205.6
22-08-75	3.672	317.136	1.286	1623.745	0.0014	7546.32	1.12E-05	0.0859	2355.0
29-08-75	3.920	249.456	0.942	1001.312	0.0014	8435.47	3.79E-06	0.0320	689.1
05-09-75	3.689	307.781	1.372	1537.605	0.0014	7695.78	1.37E-05	0.1052	2792.8