PERFORMANCE OF SEDIMENT TRANSPORT EMPIRICAL EQUATIONS: IN THE MAJOR RIVERS OF BANGLADESH

Submitted By

MARZIA TABASSUM FARIA
193-47-259

DEWAN MD. JAKIRUL ISLAM
193-47-254

MD. MOHAIMINUL ISLAM RIDOY
193-47-262

MD. FATIN ISHTIAK
193-47-276

Supervised By

Dr. M. R. Kabir
Professor
Department of Civil Engineering
Daffodil International University

A Thesis Submitted to the Department of Civil Engineering, Daffodil International University in partial fulfillment of the requirements for the award of the Degree of
Bachelor of Science in Civil Engineering

Department of Civil Engineering

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DECLARATION

This is to certify that the following student worked on the project and thesis titled "**Performance of Sediment Transport Empirical Equations: In the Major Rivers of Bangladesh**" under my direct supervision in the laboratories of the department of Civil Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science. On February 2024, the work was presented.

Signature of the candidates

Faria

MARZIA TABASSUM FARIA

193-47-259

Jakir

DEWAN MD. JAKIRUL ISLAM

193-47-254

Ridoy

MD. MOHAIMINUL ISLAM RIDOY

193-47-262

Fatih

MD. FATIN ISHTIAK

193-47-276

Countersigned

Dr. M. R. Kabir
Professor
Supervisor
Department of Civil Engineering
Daffodil International University
Faculty of Engineering

The thesis titled "**Performance of Sediment Transport Empirical Equations: In the Major Rivers of Bangladesh**" Submitted by MARZIA TABASSUM FARIA (193-47-259), DEWAN MD. JAKIRUL ISLAM (193-47-254), MD. MOHAIMINUL ISLAM RIDOY (193-47-262), MD. FATIN ISHTIAK (193-47-276) Session: February 2024 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering in 12th February 2024.

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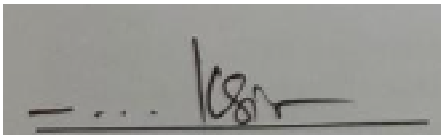

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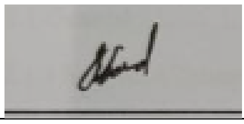

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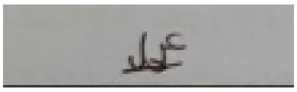

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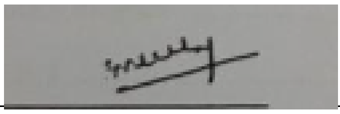
Daffodil International University



Dr. Muhammad Mukhlesur Rahman
Deputy Secretary — External Member
Ministry of Textiles for Jute

TABLE OF CONTENTS

LIST OF FIGURES viii

LIST OF TABLES ix

ABSTRACT xi

ACKNOWLEDGEMENT xii

CHAPTER 1 1

INTRODUCTION 1

1.1 Background 1

1.2 Objectives 2

CHAPTER 2 3

LITERATURE REVIEW 3

2.1 General 3

2.1.1 Sediment Transport Studies in the Rivers of Bangladesh 5

2.2 Sediment Transport Equation 8

2.2.1 Ackers and White (1973) 8

2.2.2 Engelund-Hansen (1967) 9

2.2.3 C.T. Yang (1976) 9

2.2.4 L.C Van Rijn (1989) 9

2.2.5 Meyer- Peter and Mueller (1948) 10

2.2.6 Hossain's Equation (1987): 10

2.3 Shields diagram 12

CHAPTER 3 13

MAJOR RIVERS IN BANGLADESH 13

3.1 The Padma River 14

3.2 The Meghna River 18

3.3 The Jamuna River 23

CHAPTER 4 28

DATA COLLECTION AND CALCULATION 28

4.1 Introduction 28

4.2.1 Discharge in Padma, Meghna and Jamuna River 30

4.2.2 Velocity in Padma, Meghna and Jamuna River 30

4.3 Cross-Sectional Representation of Padma, Meghna and Jamuna River 31

4.3.1 Cross-Section of Padma River 31

4.3.2 Cross-Section of Meghna River 32

4.3.3 Cross-Section of Jamuna River 33

4.3.4 Calculation of Area, Wetted Perimeter, and Maximum Depth of Padma, Meghna and Jamuna River 33

4.3.5 Slope of The Major River in Bangladesh 34

4.3.6 Bed Materials Sizes of The Major Rivers of Bangladesh 34

4.4 Grain Size Distribution Curve of Padma, Meghna and Jamuna Rivers 35

4.5 Calculation 38

4.5.1 Sediment Transport Rate Calculation in Padma River 38

4.5.1.1 Meyer- Peter and Mueller (1948) 38

4.5.1.2 C. T Yang's Equation (1976) 39

4.5.1.3 L.C Van Rijn (1989) 40

4.5.1.4 Engelund and Hansen (1967) 42

4.5.1.5 Hossain's Equation (1987) 43

4.5.1.6 Ackers and White (1973) 45

4.5.2 Sediment Transport Rate Calculation in Meghna River 47

4.5.3 Sediment Transport Rate Calculation in Jamuna River 48

CHAPTER 5 49

DATA ANALYSIS AND DISCUSSION 49
5.1 Data Analysis 49
5.2 Comparative Studies Among All the Sediment Transport Equations 49
5.3 Sensitivity Analysis 52
5.3.1 Sensitivity Analysis of Padma River 52
5.4 Most Sensitive Hydraulic Parameter of Padma River 56
5.5 Discussion 57
CHAPTER 6 59
CONCLUSION AND RECOMMENDATION 59
6.1 Conclusion 59
6.2 Recommendation 60
REFERENCE 61
BIBLIOGRAPHY 65
NOTATION AND ABBREVIATIONS 69
APPENDIX 72
Sample Calculation of Padma River 72
Perimeter Calculation of Padma River 76
Sample Calculation of Meghna River 77
Sample Calculation of Jamuna River 80
Comparison Among All Empirical Equations for Meghna River 84
Comparison Among All Empirical Equations for Jamuna River 84
Sensitivity Analysis of Meghna River 85
Most Sensitive Hydraulic Parameter of Meghna River 87
Sensitivity Analysis of Jamuna River 87
Most Sensitive Hydraulic Parameter of Jamuna River 89

LIST OF FIGURES

Figure 2.1: Shields Diagram 12
Figure 3.1: Schematic Water Balance for Average Year in Percent (Organisation-MPO, 1991) 13
Figure 3.2: Ganges-Padma River System Map (Banglapedia) 17
Figure 3.3: Surma-Meghna River System Map (Banglapedia) 22
Figure 3.4: Brahmaputra-Jamuna River System Map (Banglapedia)....................................26
Figure 4.1: Showing Hydrological Station Network by Bangladesh Water Development Board 29
Figure 4.2: Cross-Section of Padma River 32
Figure 4.3: Cross-Section of Meghna River 32
Figure 4.4: Cross-Section of Jamuna River 33
Figure 4.5: Grain Size Distribution of Padma River...36
Figure 4.6: Grain Size Distribution of Meghna River 36
Figure 4.7: Grain Size Distribution of Jamuna River 37

LIST OF TABLES

Table 4.1: Maximum Discharge in Padma, Meghna, and Jamuna (April 2016)......................30
Table 4.2: Maximum velocity in Padma, Meghna, and Jamuna (April 2016).........................31
Table 4.3: Area, Wetted perimeter in Padma, Meghna and Jamuna (April-2016)...................34
Table 4.4: Slope of the major rivers in Bangladesh 34
Table 4.5: Bed Materials size of the major rivers of Bangladesh 35
Table 4.6: Sediment Transport Rate Calculation in Meghna River 47
Table 4.7: Sediment Transport Rate Calculation in Jamuna River 48
Table 5.1: Comparison Among All Empirical Equations for Padma River 50
Table 5.2: Sensitivity Analysis of Hossain’s Equation in Padma River 52
Table 5.3: Sensitivity Calculation of C.T Yang’s Equation in Padma River 53
Table 5.4: Sensitivity Calculation of Engelund and Hansen’s Equation in Padma River 53
Table 5.5: Sensitivity Calculation of Mayer-Peter and Muller’s Equation in Padma River....54
Table 5.6: Sensitivity Calculation of L.C Van Rijn’s Equation in Padma River 54
Table 5.7: Sensitivity Calculation of Ackers and White’s Equation in Padma River.............55
Table 5.8: Most Sensitive Parameter of Padma River 56
Table 6.1: Estimated Sediment Transport of Three River...59
Table 7: Value of Distance and RL of Padma River 72
Table 8: Perimeter Calculation of Padma River 76
Table 9: Value of Distance and RL of Meghna River 77
Table 10: Value of Distance and RL of Jamuna River..80
Table 11: Comparison Among All Empirical Equations for Meghna River 84
Table 12: Comparison Among All Empirical Equations for Jamuna River.............................84
Table 13: Sensitivity Analysis of Hossain’s Equation in Meghna River 85
Table 14: Sensitivity Calculation of C.T Yang’s Equation in Meghna River..........................85
Table 15: Sensitivity Calculation of Engelund and Hansen’s Equation in Meghna River 85
Table 16: Sensitivity Calculation of Mayer-Peter and Muller’s Equation in Meghna River...86
Table 17: Sensitivity Calculation of L.C Van Rijn's Equation in Meghna River.....................86
Table 18: Sensitivity Calculation of Ackers and White's Equation in Meghna River 86
Table 19: Most Sensitive Parameter of Meghna River 87

Table 20: Sensitivity Calculation of Hossain’s Equation in Jamuna River 87
Table 21: Sensitivity Calculation of C.T Yang’s Equation in Jamuna River...........................87
Table 22: Sensitivity Calculation of Engelund and Hansen’s Equation in Jamuna River.......88
Table 23: Sensitivity Calculation of Mayer-Peter and Muller’s Equation in Jamuna River....88
Table 24: Sensitivity Calculation of L.C Van Rijn's Equation in Jamuna River......................88
Table 25: Sensitivity Calculation of Ackers and White's Equation in Jamuna River 89
Table 26: Most Sensitive Parameter of Jamuna River 89

ABSTRACT

The process of sediment transport in rivers is both significant and intricate. Understanding the characteristics and quantities of sediments carried by rivers is crucial for effective water management. Given the concentration of major projects along or near the riverbanks in the study area, there is a constant concern among decision-makers about the potential impact of sediment transport, and sedimentation on these projects. Consequently, there is a pressing need to enhance our understanding of applicable equations that can yield accurate results for monitoring sedimentation and transport processes in river courses, allowing us to anticipate changes along the river banks. This study was conducted to evaluate the reliability of various sediment transport formulas using data collected from three major rivers in Bangladesh: the Padma River, the Meghna River, and the Jamuna River. The objective was to identify the most suitable formula for these specific rivers. Hydrological data from the Bangladesh Water Development Board after WRE, BUET were utilized to calculate the total sediment load at a specified cross-section, employing widely recognized sediment transport formulas such as Ackers-White, C.T. Yang, Engelund-Hansen, Meyer-Peter and Mueller, L.C. van Rijn, and Alam and Hossain. The performance of these formulas was assessed based on the accuracy of predictions regarding observed sediment loads, along with a sensitivity analysis.

L.C. Van Rijn's equation is considered to be the most preferable choice depending on the following calculations and a comparison of six sediment transport equations. In the context of sediment transport rate estimation among the three rivers, this equation exhibits more accuracy and reduced dispersion in comparison to the empirical data. The equation established by L.C Van Rijn incorporates all hydraulic characteristics into its calculations, thereby facilitating the prediction of exceedingly precise sediment transport rates compared to the observed values. Velocity is identified as the most responsive factor, it becomes essential to precisely measure and monitor river velocities in order to assure precise forecasts of flow rates and sediment transportation.

Keywords: Bed load, Sediment transport, Suspended Sediment load, Sediment transport formulas.

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CHAPTER 1
INTRODUCTION

1.1 Background

Bangladesh is a country characterized by its abundance of rivers. Bangladesh is primarily influenced by three major rivers - the Brahmaputra-Jamuna, Ganga, and Meghna - which collectively contribute sediment to form one of the biggest deltas in the world, located in the Bay of Bengal(Best et al. 2008). Each year, the country has a range of 1000 to 5000 mm of rainfall in different places. The complex system of more than 200 major and minor rivers releases around 175 billion cubic meters of water into the Bay of Bengal (Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Year, and 1999 1999). The majority of rivers are naturally created, either by themselves or by alluvial processes.(Sui-ji and Jin-ren 2002). Streams and alluvial rivers transport and displace sediment, resulting in the formation of distinct pathways. The composition of alluvial channels, including both the channel boundaries and the water flow, directly influences the dimensions of the channel in terms of its width and depth. Rivers flowing through soft material often have higher sediment loads compared to rivers exposed to bedrock, as a significant portion of the sediment load originates from the channel's bottom and sides (Salih et al. 2020). The rivers of Bangladesh transport water from a combined drainage basin of approximately 1.7 million square kilometers, with just 8% of this area being inside the borders of Bangladesh. Moreover, these rivers transport around 2.4 billion tons of sediment each year to the Bay of Bengal. (Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning et al. 1999). At present, water resource managers are greatly concerned about the effects of bed load and suspended sediment movement on the resident aquatic creatures and the overall water quality. (Tao, Keshtegar, and Yaseen 2019). In addition, the majority of construction activities carried out near or on the riverbank can diminish the stability of adjacent riverbanks. These activities can also lead to an increase in the transportation of bed load and suspended sediment, as well as an elevation in turbidity. Gaining insight into the mechanics of sediment transportation, encompassing both bed load and suspended sediment load, is crucial for the development and efficient administration of river systems. 'Estimating the sediment transport capacity in rivers is a crucial aspect of planning and developing soil conservation and watershed management, river training, flood control, and hydraulic constructions. It is physically impossible to calculate the quantity of sediment transport'(Azarang 2015). So, it is important to use the empirical equation to estimate how much sediment is transported by the rivers. This study will explore the current state of sediment transport in major rivers in Bangladesh and analyze the potential impact of future developments on sediment discharge.

1.2 Objectives

Based on the given background, the primary objectives are:

- Summaries hydro morphological information of Padma, Meghna and Jamuna.
- Estimate sediment transport of the major rivers using different empirical equations.
- Review performance of these commonly used empirical equations and estimate sediment transport.
- Sediment transport load estimated by the different empirical equations will be compared among themselves.
- Sensitivity analyses of each parameter of each empirical equation.

CHAPTER 2
LITERATURE REVIEW

2.1 General

"In sediment transport, the choice of an appropriate formula is crucial in order to accurately predict and understand the movement of sediments in rivers and streams”. The question always arises from hydraulics and environmental engineers who are working with different sediment control projects such as river restoration, flood control, and erosion prevention measures in Bangladesh rivers. It is difficult to choose which formula will provide the most accurate predictions, as different formulas can yield varying results and may not accurately represent real-world conditions.

Researchers and engineers assess the performance of various sediment transport formulae by comparing their predictions with field measurements in order to overcome this difficulty. The two noteworthy individuals are:

1. (Task Committee for Preparation of Sediment Manual American Society of Civil Engineers 1971), who published a thorough review of sediment transport formulas and their applications in hydraulic engineering.

2. (White, Milli, and Crabbe 1973) Hydraulic Research Station (H.R.S), which carried out a thorough investigation and comparison of various sediment transport formulas.

Both of these studies emphasize the need to assess the precision and relevance of different sediment transport formulas for specific field sites by comparing them with real field data. Based on the study conducted by the task committee, the equations developed by Colby (1964), Englund-Hansen (1967), and Ackers & White (1969) demonstrated the highest level of accuracy in predicting sediment transport capacity among the thirteen formulae tested. The results indicate that these findings are not definitive conclusions, but rather recommendations for further investigation and collecting of field data. The investigations conducted by Wallingford are very comprehensive since they examine many sediment transport equations and evaluate their efficacy based on field observations. They subjected 19 transport equations to evaluation by comparing them against 270 field data and about 1000 laboratory experiments. The basis of this study was the possibility of using formulas, similar to those created by Colby

(1964), Englund-Hansen (1967), and Ackers & White (1973), to accurately forecast the pace at which sediment moves.

Various theoretical and semi-empirical models have been developed to predict the flow of silt in rivers and streams. Various researchers, including Einstein (1950), Yalin (1963), Bagnold (1966), Meyer-Peter and Müller, Yang (1973), and L. C. Van Rijn (1985), developed techniques to forecast the transport of sediment.

(Yang 1977)) developed a sediment transport equation using the concept of stream power. The individual evaluated 154 collections of field data and 1093 sets of laboratory data to his equation, as well as eleven supplementary sediment transport equations. Yang observed that his equation is more efficacious compared to other equations. He deduced that his formula was applicable to several additional equations, such as those of Shen-Hung, Ackers, and White.

(Nakato 1990) conducted a comparative analysis of eleven sediment transport formulas using field data gathered at two USGS gauging stations located along the Sacramento River in California. The bed sediments of these two rivers were classified into two categories: fine sand and coarse sand. The utilized formulas encompass those developed by Ackers and White, , Karim, Einstein-Brown, Inglis-Lacey, Engelund-Fredose, Meyer-Peter and Mueller, Van Rijn, Toffaleti, and Yang. The overall flow and sediment input variables of each transport function, together with the corresponding dependent parameters, were summed and discussed. Quantifiable hydraulic and sediment variables, such as the size distribution of bed materials, were also documented. According to the research, it is evident that precisely predicting sediment movement and discharge in rivers is a challenging endeavor.

The Special Committee of the National Research Council (NRC), in its 1983 evaluation, examined the effectiveness of six numerical models specifically designed to mimic the alterations in river beds caused by floods. The paper evaluates the sediment releases calculated by separate models for three distinct natural rivers. The NRC Committee (An Evaluation 1983) reports significant variations in sediment flows predicted using alternative sediment-transport functions, but having the same hydraulic and bed-material properties. In a study conducted by Nakato (1987), five sediment-discharge formulas were examined. These formulas included those developed by Ackers and White (1973), Engelund and Fredsoe (1976), Engelund and Hansen (1967), Inglis and Lacey (Inglis 1968), and Toffaleti (1969). The study focused on a specific section of the San Dieguito River that had been investigated by the NRC Committee.

Nakato then compared the results obtained from these formulas with the calculations made by Chang (1984) using the Graf formula (1971). The findings presented in Nakato's (1987) study reveal highly disconcerting disparities among the aforementioned expectations. The greatest disparity, exceeding a factor of one hundred, was seen within the Graf and Toffaleti formulas(Chang 1984; Nakato 1990).

(Van Den Berg 1993) looked at how the Yellow River's suspended bed materials were moved through slits and very fine sand. The study focused on three equilibrium sand transport equations developed by Ackers and White (1973), Engelund and Hansen (1967), and Van Rijn (1984b) to determine the rate at which suspended bed material is transported. Based on their investigation, the Van Rijn formula yielded an accurate result. The Engelund formula and the Ackers and White Overpredicted formula yielded significant results in the minimum state. It was suggested to adapt the Van Rijn formula for application in flows through extremely fine sand and silt.

2.1.1 Sediment Transport Studies in the Rivers of Bangladesh

Accurate prediction and understanding of sediment transport are of immense interest to coastal oceanographers, engineers, and coastal zone management authorities in Bangladesh. Many sediment transport equations have been tested in the past in Bangladesh Rivers. However, due to the complex nature of sediment transport processes, accurately predicting sediment transport in rivers remains a challenge. Furthermore, the intricate characteristics of the flood hydrograph in a braided river during the monsoon season have a significant impact on bank erosion and the subsequent movement of silt (Karmaker and Dutta 2010).

The literature study reveals that the Ganges, Brahmaputra, and Meghna rivers in Bangladesh transport a substantial quantity of sediment every year (Sarker et al. 2003).

In order to analyze the flow of sediment in the Gorai-Madhmati River (Waliuzzaman1986) applied five equations: Yang (1973), Ackers and White (1973), Engelund-Hansen (1967), Hossain (1985), and Mantz (1983). He concluded that the river Gorai-Madhumati provided more precise estimates of sediment transport through the use of the Engelund-Hansen equation.

(Bari 1978) used data collected from the Ganges River at Hardinge Bridge to employ the sediment prediction methodology. According to his study, the Engelund-Hansen formula provides dependable results, and the Colby equation's estimation of the sediment transport rate roughly corresponds to the actual numbers. He also discovered a power law correlation between sediment and water results.

(Dey 1995) developed a schematized sediment transport estimator and used it to analyze the Jamuna River in the context of alluvial rivers. The suitability of the Hossain (1985), Engelund and Hansen (1967), and Bagnold (1966) formulas as transport predictors for the Jamuna River has been determined.

Ahmed (1996) performed a study to assess the suitability of sediment transport predictors in the Jamuna River by quantifying shear velocity. He discovered a substantial enhancement in the accuracy of sediment transport equations by using observed shear stress (Islam and Akhter 2005).

(Hossain 1989) conducted a comparison analysis was carried out to evaluate the effectiveness of many established equations in predicting the sediment transport rate for the Jamuna River. Additionally, a quantitative assessment of the sediment transport rate was undertaken. The equation developed by Colby and Hossain yielded consistent results when compared to the other equations included in their investigation. They showed that sediment discharge may be accurately described by a function that considers both flow velocity and water discharge.

(Hossain 1989) used more recent data spanning from 1980 to 1988 to evaluate the Ganges data. Additionally, he found that the results obtained using the Hossain and Engelund-Hansen formula were more reliable and uniform. Nilufer (1989) found that Hossain's equation was more widely accepted than the data from the Brahmaputra.

In 1988, BUET-BWDB conducted an assessment on the sediment flow characteristics of the river Teesta in relation to the building of the Teesta Barrage Project. They selected the Yang, Engelund-Hansen, and Colby equations and determined that Yang's equation was the most efficient among the others.

(Hossain and Barr 1988) conducted a comparison of eight well recognized transport equations and data collected from various sources worldwide. By conducting a thorough analysis of 800 field data and 3480 laboratory data, the researchers evaluated the equations proposed by Yang, Colby, Engelund-Hansen, Einstein-Brown, Ackers and White, Toffaleti, Holtroff, and Hossain. The Hossain equation outperforms other equations when considering all testing parameters for performance in comparison to several independent data sets.

Based on non-dimensional considerations, a power-type equation using the regression technique was developed by Hossain (Hossain 1992). He implemented his methodology to analyze the data from the Ganges River at Hardinge-Bridge and the Jamuna River at Bahadurabad. The primary focus of his work was to evaluate the suitability of several widely recognized sediment transport equations using data from the Ganges and the Jamuna rivers. He stated that the sediment transport equations that yielded a satisfactory level of precision were the Hossain, Colby, and Engelund-Hansen equations.

More recently, some well-known sediment transport prediction formulae have been utilized and compared for application in Bangladesh for morphological study. (Galappatti and Olesen) used the Engelund-Hansen equation for the development of a one-dimensional morphological model for the Jamuna River.

FAP 24 (1996) formulated an equation to describe the movement of sediment in both the Ganges River at Hardinge Bridge and the Jamuna River at Bahadurabad. The dimensionless sediment transport formula proposed for the Jamuna River was calculated using observed data collected from the river between 1984 and 1987. The researchers used a separate data set obtained from the Bangladesh Water Development Board (BWDB) during the time frame of 1993-1994. The findings revealed that the proposed equation somewhat overestimates the rate of sediment movement. A correction factor of 0.75 was utilized to modify and account for this variance. The accuracy of the proposed equation and five selected sediment transport prediction methods may be ranked in the following descending order: The following equations are recommended: Bagnold (1966), Engelund and Hansen (1967), Yang (1973), van Rijn (1984), and Acker and White (1973). However, they did not assess the performance of the proposed equation by comparing it with the real data of the Ganges at Hardinge Bridge, as the data was deemed inaccurate (Islam and Akhter 2005).

(Matin, 1994) used measured data to create a simplified transport equation that may be used for the rivers in the north-west area of Bangladesh. The resultant connection was also compared with the simplified forms of the equations proposed by Engelund-Fredsoe (1976) and Van Rijn (1984). The study indicates that the Van Rijn predictor is deemed acceptable for predicting silt movement.

2.2 Sediment Transport Equation

The sediment transport equation is a fundamental tool used in various fields, including hydrology, geomorphology, and engineering, to study the movement of sediment particles in water bodies such as rivers. Several relationships have been developed indicating the magnitude of sediment discharge as a function of the various flow parameters. None of the available formulae for the calculation of sediment discharge has gained universal acceptance in confidently predicting the sediment transport rate. The calculated results from different equations often differ drastically from each other and the observed data.

Many theories have been put forward to provide the framework for sediment transport prediction. Only the sediment transport equations that are related to the present study have been outlined in the following sections.

2.2.1 Ackers and White (1973)

Based on the analysis of 925 sets of flume and field data, the following empirical formula was proposed:

$$q_t = k\, u d_{35} \left(\frac{u}{u_*}\right)^n \left(\frac{Y - Ycr}{Ycr}\right)^m \quad (2.1)$$

The particle mobility parameter, Y can be expressed as:

$$Y = \left(\frac{{u_*}^n}{\sqrt{(s-1)g d_{35}}}\right) \left(\frac{u}{5.66 \log\left(\frac{10h}{d_{35}}\right)}\right)^{1-n} \quad (2.2)$$

The particle diameter D_* can be defined as:

$$D_* = d_{35} \left(\frac{(s-1)g}{v^2}\right)^{\frac{1}{3}} \quad (2.3)$$

The coefficients k, n, m are defined as:

$$k = 10^{-3.53 + 2.06 \log(D_*) - (\log D_*)} \quad \text{For } 1 < D_* < 60 \quad (2.4)$$

$$n = 1 - 0.56 \log(D_*) \quad \text{For } 1 < D_* < 60 \quad (2.5)$$

$$m = \frac{9.66}{D_*} + 1.34 \quad \text{For } 1 < D_* < 60 \quad (2.6)$$

$$k = 0.025,\ m = 1.5,\ n = 0,\ Y_{cr} = 0.17 \quad \text{For } 1 > D_* > 60 \quad (2.7)$$

The k and m coefficients were later (Wallingford 1990) Revised:

$$Y_{cr} = \frac{0.23}{D_*^{0.5}} + 0.14 \quad \text{For } 1 < D_* < 60 \tag{2.8}$$

$$k = 10^{-3.46+2.79\log(D_*)-0.98(\log D_*)^2} \text{ For } 1 < D_* < 60 \tag{2.9}$$

$$m = \frac{6.83}{D_*} + 1.67 \quad \text{For } 1 < D_* < 60; \text{ m} = 1.78 \text{ For } D_* > 60 \tag{2.10}$$

2.2.2 Engelund-Hansen (1967)

The equation proposed by Engelund and Hansen is derived from the shear approach. Engelund and Hansen based their equation on data obtained from experiments conducted in a specific set of tests using a large flume. The sediments utilized in this flume had a median diameter of 0.27 mm, 0.45 mm, and 0.93 mm. This equation can be written as:

$$g_s = 0.05\gamma_s v^2 \sqrt{\frac{D_{50}}{g(\frac{\gamma_s}{\gamma}-1)}} \left[\frac{\tau_0}{(\gamma_s-\gamma)D_{50}}\right]^{\frac{3}{2}} \tag{2.11}$$

(Hossain 1994)

2.2.3 C.T. Yang (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 and Raju 2000). The formula is as follows:

$$\log C_t = 5.435 - 0.286\log\frac{\omega D_{50}}{v} - 0.457\log\frac{U_*}{\omega} + \left(1.799 - 0.409\log\frac{\omega D_{50}}{v} - 0.314\log\frac{U_*}{\omega}\right)\log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \tag{2.12}$$

Where,

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log\frac{U_* D_{50}}{v} - 0.06} + 0.66; \text{When } 1.2 < \frac{U_* D_{50}}{v} < 70 \tag{2.13}$$

$$\frac{V_{cr}}{\omega} = 2.05; \text{ When } 70 \leq \frac{U_* D_{50}}{v} \tag{2.14}$$

(Yang 1976)

2.2.4 L.C Van Rijn (1989)

Van Rijn's equation based on shear stress he expressed as:

$$q_s = q_b * \rho_s \tag{2.18}$$

Bed load sediment transport rate,

$$q_b = 0.053\left(\frac{T_*^{2.1}}{D_*^{0.3}}\right).(\rho'.g)^{1/2}\,(d_{50})^{3/2} \quad (2.19)$$

Transport stage parameter, $T_* = \frac{(u_*'^2 - u_{*cr}2)}{u_{*cr}2}$ (2.20)

Bed shear velocity related to grain roughness,

$$u_*' = \frac{U(g)^{1/2}}{C'} \quad (2.21)$$

Chezy's Coefficient with grain roughness,

$$C' = 18\log\left(\frac{12R}{3d_{90}}\right) \quad (2.22)$$

(Kabir and Ahmed 1996)

2.2.5 Meyer- Peter and Mueller (1948)

Based on laboratory results Meyer- Peter and Mueller formula may be simplified as follows:

$$g_s^{\frac{2}{3}} = 250q^{\frac{2}{3}}S - 42.5d_{50} \quad (2.23)$$

(Vanoni 2006)

2.2.6 Hossain's Equation (1987):

Hossain proposed that the sediment concentration in a stream with a constant flow of water and sediment may be described by a power function, based on the principles of dimensional analysis and similitude argument.

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:

$$C_t = A(X^aY^bZ^c) \quad (2.24)$$

Where,

$A = 6.496\times 10^5$ For $B/H < 500$ (2.25)

$A = 6.496\times 10^{6}$ For B/H > 500 (2.26)

The Product of Froud Number and Slope of Energy Gradient:

$X = \frac{VS}{(gH)^{\frac{1}{2}}}$ and a = 0.745 (2.27)

The Settling Velocity Ratio:

$Y = \frac{\omega_r}{\omega}$ and b = 0.633 (2.28)

The Discharge Ratio:

$Z = \frac{Q}{Q_c}$ and c=0.50 (2.29)

Assessed discharge,

$$Q_c = \left[\left(2.15 + k\frac{B}{H}\right) H(gS)^{\frac{1}{5}}\right]^{\frac{5}{2}} \quad (2.30)$$

The value of K is proposed to be 0.055 when Q< 15000 cumecs (2.31)

and 0.17 when Q> 15000 cumecs (2.32)

The settling velocities of particles of sediment have been calculated using Rubey's equation. The constants and coefficients of Hossain's formula were obtained using a trapezoidal flow cross-section flume. The median particle size ranges from 0.15 mm to 60.3 mm. The discharge varied between 0.0001 and 0.015 cubic meters per second, whereas the width-depth ratio ranged from 0.68 to 42.6. It is noteworthy to add that Hossain's formula has effectively been employed to predict the sediment movement of several rivers in Bangladesh (Hossain 1994; Hossain and Barr 1988; Sultana 1989).

2.3 Shields diagram

The Shields diagram is a graphical illustration used for the analysis of sediment transport to ascertain the critical conditions necessary for particle displacement. The diagram is designated as the Walter Shields diagram, as it was created by Walter Shields during the 1930s. The graph displays the relationship between the dimensionless shear stress, which quantifies the force exerted by the fluid on the particles, and the dimensionless particle size.

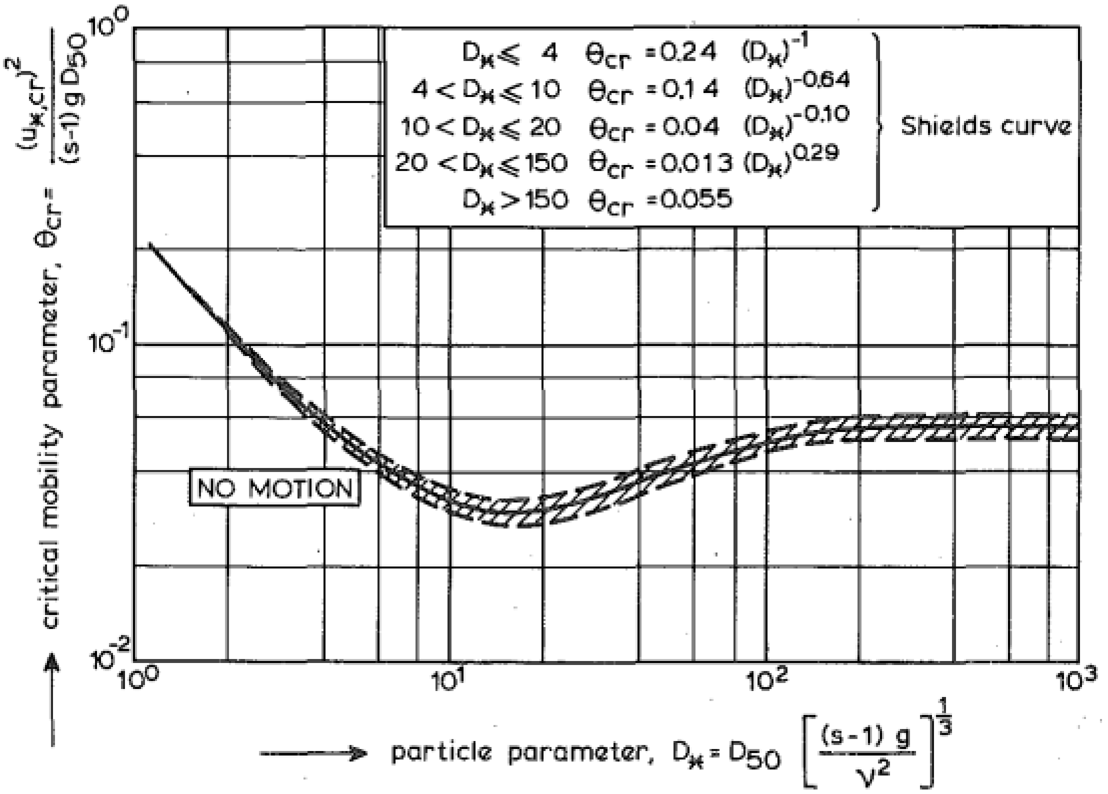

Figure 2.1: Shields Diagram

CHAPTER 3

MAJOR RIVERS IN BANGLADESH

Bangladesh is a country with many rivers has important consequences for its geography, economics, society, and culture. Bangladesh benefits from a copious supply of water resources due to its convergence of rivers and its proximity to an extensive marine region. The abundant presence of water has significantly influenced the topography of the nation, resulting in around 300 significant rivers, 400 subsidiary streams and tributaries, and an extensive interconnected system of water routes. Bangladesh's water resources are significantly influenced by 57 transboundary rivers that originate in neighboring India and Myanmar. The Ganga or Padma, Jamuna, Meghna, Teesta, Khoai, and Feni rivers are noteworthy within this group of rivers. Shangu and Halda are the only two internal rivers originated and finished within Bangladesh. Bangladesh's development and sustenance heavily rely on its rivers, which offer fertile soils, diversified flora, and aquaculture. However, they also pose a substantial flood danger and infrastructure risk for the country's enormous and expanding population (Best et al. 2008).

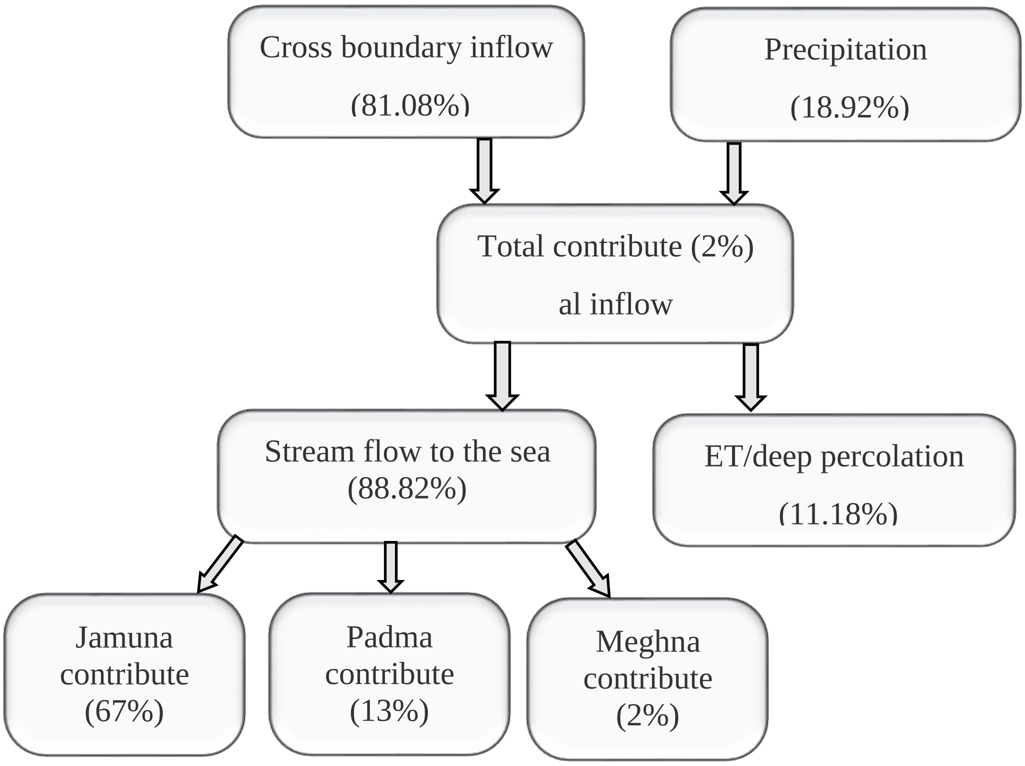

Figure 3.1: Schematic Water Balance for Average Year in Percent (Organisation-MPO, 1991)

Above, figure shows the water balance for the year of 1983 to 1990. The dependable cross boundary inflow is 81.08% and annually precipitation rate is 18.92%. Annually the rivers of Bangladesh discharge about 175 billion cubic meters of water (80%) to the Bay of Bengal. In evident the Jamuna river contributes about 67% of the total flow. The Padma river contributes 13% of the total flow and Meghna contributes 2% others contributes to the remain flow. As these three rivers contributes significant amount of the total flow bringing the dominant border inflow these rivers also carry the most sediment to the Bay of Bengal. For these, reason the selected rivers are the Padma, Meghna and Jamuna river. Below is a comprehensive depiction of these three rivers.

3.1 The Padma River

The Padma River is the second most extensive waterway in Bangladesh. The Ganges major distributary, which originates in the Gangotri glacier of the Himalayas, is the primary channel for the river's flow. The part of the Ganga River that flows into Bangladesh is referred to as the Padma. It enters Bangladesh from India's Murshidabad district and passes through Shibganj Upazila, namely the Manakosha and Durlavpur unions, in the Chapai Nawabganj district. The length of the river in Bangladesh measures 366 kilometers(Hossain ML, Mahmud J, Islam J 2005). The Padma River merges with the formidable Jamuna River (also known as Lower Brahmaputra), and the resulting amalgamation continues to flow eastward under the name Padma, reaching Chadpur. In Bangladesh, the Meghna River, which is the widest in the country, converges with the Padma River and then flows practically directly southward as the Meghna till it reaches the Bay of Bengal. The mainline passes the districts of Chapai Nawabganj, Rajshahi, Pabna, Kushtia, Faridpur, Rajbari, and Chandpur in Bangladesh. The river that runs from Goalanda to Chadpur is called Padma. It spans a length of 120 kilometers and has a width ranging from 4 to 8 kilometers. The river originates from Chapai Nawabganj and travels towards Goalanda, where it is known as the Ganga.(Chowdhury and Islam 2003).

The Ganges-Padma is a significant hydrodynamic system that created one of the biggest delta complexes in the world, spanning a substantial area of the country and a significant chunk of West Bengal in India. Over an extended period of time, the Ganges Delta underwent a process of southeastward movement and has ultimately settled in its current location inside the Bengal Basin. The hydrological and drainage networks of the Ganges Delta in southern Bangladesh are closely connected to the powerful Ganges River and the fluvial-hydrological conditions of the Bengal Basin. The deltaic estuary of the Ganges-Brahmaputra-Meghna network receives the combined flow of these river systems, which totals an average of 35,000 cubic meters per second. However, throughout the rainy season, the flow rate of the Padma River increases significantly to around 750,000 cubic meters per second, accompanied by a proportional increase in the amount of silt it carries. The river's discharge throughout the dry season is quite low, at 15,000 cubic meters per second. Consequently, there is a small amount of silt carried by the river throughout this time. The width of the river in the deltaic region varies between 1.6 and 8.0 km, occasionally exhibiting a braided pattern despite being a meandering river (Paszkowski et al. 2021).

1. Origin and flow:

    The Padma River originate at the intersection of the Ganges and Jamuna Rivers, located close to the India-Bangladesh border. The convergence is a pivotal location, signifying the commencement of the Padma's course as a separate and identifiable river. The Padma River flows in a southerly direction, passing through the middle and western parts of Bangladesh. It covers a significant extent and has a profound impact on the surrounding terrain

2. Geography and Delta:

    The Padma, in conjunction with both the Meghna and Jamuna rivers, contributes to the creation of the Ganges Delta. The Sundarbans, commonly referred to as this delta, holds the distinction of being the biggest river delta on Earth. The Sundarbans are famous for their mangrove forests, which provide a distinct ecosystem that sustains a wide variety of plant and animal life. The Bengal tiger, a species at risk of extinction, inhabits the Sundarbans, highlighting the ecological importance of the Padma River.

3. Economic Importance:

    The agriculturally significant lowlands next to the Padma River play a vital role in rice growing. Bangladeshi population mostly eat rice, and the river's waters are an essential resource for irrigation, which promotes the development of crops. The Padma River supports fishing as an economic activity, which plays a vital role in sustaining the livelihoods of populations residing along its banks.

4. Historical and Cultural Significance:

The Padma River has been a witness to the historical and cultural evolution of the region. Its banks are dotted with archaeological sites that unveil the rich heritage of the area. Settlements along the river date back centuries, showcasing the continuous human presence influenced by the river's flow. The Padma has also been a route for trade and cultural exchange, connecting communities along its course.

5. Challenges and Environmental Concerns:

Although the Padma River provides several advantages, it also poses difficulties. The erosion occurring along the banks of the river, particularly during the monsoon season, presents a significant danger to both human settlements and agricultural areas. The river's shifting trajectory might result in the relocation of settlements, emphasizing the intricate equilibrium within human progress and natural phenomena. The impact on the environment and long-term viability of human actions, such as the construction of dams and embankments, designed to exploit the river's capabilities, have become a subject of concern.

6. Infrastructure Development:

In recent years, there has been a focus on infrastructure development along the Padma River. The construction of the Padma Bridge is a notable project aimed at improving connectivity between different regions of Bangladesh. This bridge is expected to facilitate transportation, trade, and economic development, connecting areas that were previously isolated during certain seasons.

7. Urban settlements:

The riverbanks of the Padma River are home to a multitude of cities and villages, where societies have flourished for years. These villages are tightly interdependent with the river, depending on it for water, travel, and sustenance. The river has exerted a significant influence on the spatial distribution of human settlements, hence impacting the evolution of these communities throughout history.

To summarize, the Padma River is not only a waterway; it is a dynamic and essential component of the socioeconomic and cultural foundation of the region. The waters of this river have provided sustenance for civilizations, shaped cultural customs, and offered both advantages and difficulties for the inhabitants residing beside its shores. Ensuring the continuing well-being of the populations residing along the Padma River necessitates the careful equilibrium between resource exploitation and environmental protection.

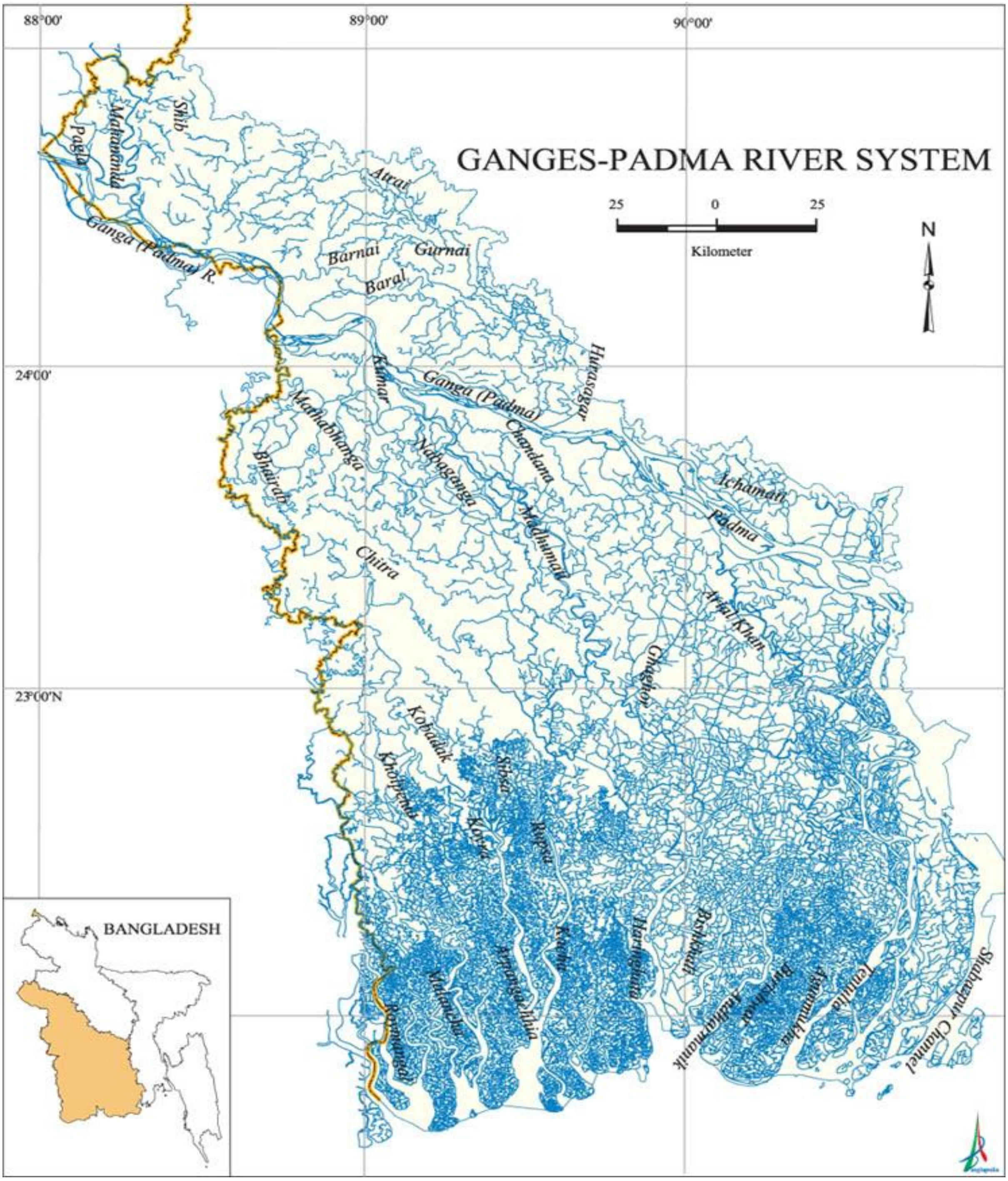

Figure 3.2: Ganges-Padma River System Map (Banglapedia)

3.2 The Meghna River

The Meghna River is a major waterway in Bangladesh, renowned for its significant estuary where the combined waters of the Ganges-Padma, the Brahmaputra-Jamuna, and the Meghna itself. The section of the Surma River that follows Ajmiriganj is commonly known as the Meghna. The situation would be less complex if it weren't for the fact that the Surma-Meghna River has a section called the Dhaleshwari, which spans approximately 26 km in a straight line from Madna downstream (Nabi et al. 2016). The waterway extending from Ajmiriganj to the point where it meets the Dhanu River is often known as the Surma. The confluence is located 5 kilometers to the east of Kuliarchar and to the north of Bhairab Bazar. After this location, the river is known as the Meghna.

The Meghna River is composed of two separate sections. The Upper Meghna, spanning from Kuliarchar to Shatnol, is a rather little river. The Lower Meghna, extending from Shatnol, is considered one of the world's greatest rivers due to its enormous estuary mouth. The Lower Meghna is occasionally regarded as an independent watercourse.

The Meghna river intersects with the old Brahmaputra river on its right side in Bhairab Bazar. Located somewhat upstream from the point where the Meghna River meets another river, there is a railway bridge called 'Bhairab Bridge' and a road bridge known as the 'Bangladesh-UK-Friendship Bridge' that span across the Meghna River. The river has a width of 0.75 kilometers. Multiple minor tributaries originating from the Meghna River and winding through the low-lying areas next to the Tippera Surface collect the water from various mountainous streams and merge back into the main river downstream. The most significant of these branches is the Titas, which originates south of Ghatalpar and, after winding through two extensive curves spanning 240 km, reconnects with the Meghna River through two channels near Nabinagar upazila. The Meghna river has several tributaries, including the Pagli, Kathalia, Dhonagoda, Matlab, and Udhamdi. The Meghna and its tributaries are supplied with water by many mountainous streams originating out of the Tripura Hills. The Kagni,, Kakrai, Gumti, Dakatia, Harimangal, Sonaiburi, Hawrah, Pagli,Balujuri,Kurulia,Handachora,Sonaichhari,Jangalia, and are some of the significant hill streams. All of these areas are susceptible to flash floods. The Hawrah, Gumti,and Kakrai, rivers are very detrimental. They have accumulated sediment in their beds to the point that they now flow above the average level of the ground when full. Multiple embankments have been constructed to confine them. However, every alternate year, either one of these streams exceeds its normal capacity, resulting in significant harm to agricultural produce, animals, and residential properties.

The Meghna River receives water from the Tipperary Surface streams coming from the east and the bigger Dhaleshwari River flowing from the west. The Meghna River is approximately five kilometers wide at the confluence located immediately north of Shatnol. The Dhaleshwari River descends in a flowing brown current and converges with the transparent blue-green Meghna River. Over a considerable distance, the waters appear to remain separate, as one-half of the river water retains a brown hue while the other half exhibits a blue-green color. The boatmen frequently highlight this distinctive characteristic.

The confluence of the Ganges and Brahmaputra-Jamuna rivers, together referred to as the Padma, occurs 16 kilometers away from Shatnol. This meeting point, which is 11 kilometers wide during the rainy season, is located near Chandpur where it joins the Meghna river. Starting from this location and extending towards the south, the Meghna River is identified as the Lower Meghna. It transforms into one of the widest rivers and biggest estuaries globally.

The Lower Meghna is formed by the confluence of the Padma and the Meghna (Upper Meghna), which is further strengthened by the Dhaleshwari. Each of those rivers are large river. At the point where they meet, the Dhaleshwari-Meghna and the Padma rivers have a width of 5 kilometers for each. The Lower Meghna has many very small CHARS (braid-bars) that form two primary channels, with the larger eastern channel measuring 5 to 8 kilometers in width. The breadth of the western channel is approximately 2 kilometers. The Safipur River, which is 1.5 km wide, branches off from the right bank at Muladi. To the south, the Lower Meghna divides into three channels: the Tentulia (Ilsha) river running from west to east, the Shahbazpur, and the Bamni. The Ilsha is a canal with a width ranging from 5 to 6.5 kilometers, which serves as a barrier between Bhola Island and the Barisal mainland.

The Rabnabad islands are located to the west of the Ilsha river's mouth. The Shahbazpur Channel, with a width ranging from 5 to 8 kilometers, serves as a separation between the Bhola and Ramgati and Hatiya islands. At the mouth of this channel, you may find the Manpura islands. Bamni is currently considered non-existent. Formerly, it traversed the space separating the islands of Ramgati and Char Lakshmi, in addition to the Noakhali mainland. It occasionally served as the primary channel for the Meghna River. The tides and their surges consistently had a significant impact on it, causing the channel to either contract or expand in an unexpected fashion. In the 1940s, a significant portion of the mainland eroded, causing a rapid increase in the shallowness of the water immediately west of Noakhali town. This resulted in the formation of a land bridge between the mainland and Ramgati Island during the winter season. To establish this as a lasting characteristic, a substantial earthen cross dam was constructed. In order to expedite the accumulation of sediment, a secondary barrier was constructed to connect the Noakhali mainland and Char Jabbar, resulting in the quick formation of around 260 square kilometers of new land.

The estuary of the Lower Meghna is commonly defined as extending from the Rabnabad islands to the Kumira shore, covering a total distance of 153 km. During half of the year, the water in this area is salty, extending as far north as a line drawn from the center of Bhola to the north of Sandwip. The estuary of the Lower Meghna may be defined as the area between the Ilsha (Tentulia) and Shahbazpur rivers, which collectively span around 40 kilometers in width at the point where they meet the sea. The precise amount of the estuary discharge is still unknown. However, in Chandpur, the average flow from June to October is approximately 2.5 million cubic feet per second. The average peak flow during this time of year is around 4 million cubic feet per second. During the winter, the river's flow is around one-eighth of its flow during other seasons, even though the river remains several kilometers wide. The reduced flow is a result of the stream's lack of energy. During peak flood conditions, the water discharge of the Lower Meghna River is a minimum of five million cubic feet per second. Additionally, it is approximated that during May and October, the river carries a daily sediment load of about four million tons. The river transports around 1,500 million tons of sediments annually and has an annual water flow of roughly 875 million acre-feet (MAF). By contrast, the yearly flow of the Congo, La Plata, and Yangtse rivers is 1,022, 636, and 559 million acre-feet (MAF) respectively. The Lower Meghna, being the primary discharge point for the combined Ganges, Brahmaputra, and Meghna rivers, has a little lower volume of water flowing out compared to the Congo River, which is the second largest river in terms of discharge after the Amazon.

The Lower Meghna spans a distance of 160 kilometers, extending from the southern region of Chandpur to the Tentulia area. The flow is calculated at a location equidistant between Chandpur and Mehendiganj. The Surma-Meghna has a total length of around 670 kilometers. The Upper Meghna's length is measured till Chandpur, while the discharge is recorded at Bhairab Bazar.

Both banks of the Meghna River have witnessed the emergence of numerous communities, cities, ports, and enterprises. Narsingdi, Barisal, Chandpur, and Bhola are the district towns situated along the banks of the Meghna River. Chandpur (Puran Bazar), Bhairab Bazar, Kuliarchar, Daulatkhan, Kalupur, and Ramdaspur serve as significant riverports and commercial hubs. The Ashuganj thermal power station and the Fenchuganj fertilizer industry are situated adjacent to this river.

The Bangladesh Water Development Board has implemented the Meghna Valley Project to protect the flood-prone Meghna River. This project involves building embankments along the riverbanks to safeguard the greater Comilla, Mymensingh, and Sylhet districts from flooding. Additionally, strategically placed dams enable the irrigation of 180,000 hectares of land. The coastal embankment project in the southern area of Bangladesh has resulted in the construction of around 125 kilometers of dams. These measures aid in flood management and prevent the accumulation of salt. Furthermore, these dams have a significant impact on the process of land reclamation (Chowdhury and Islam 2003).

Figure 3.3 shows the Meghna River system map.

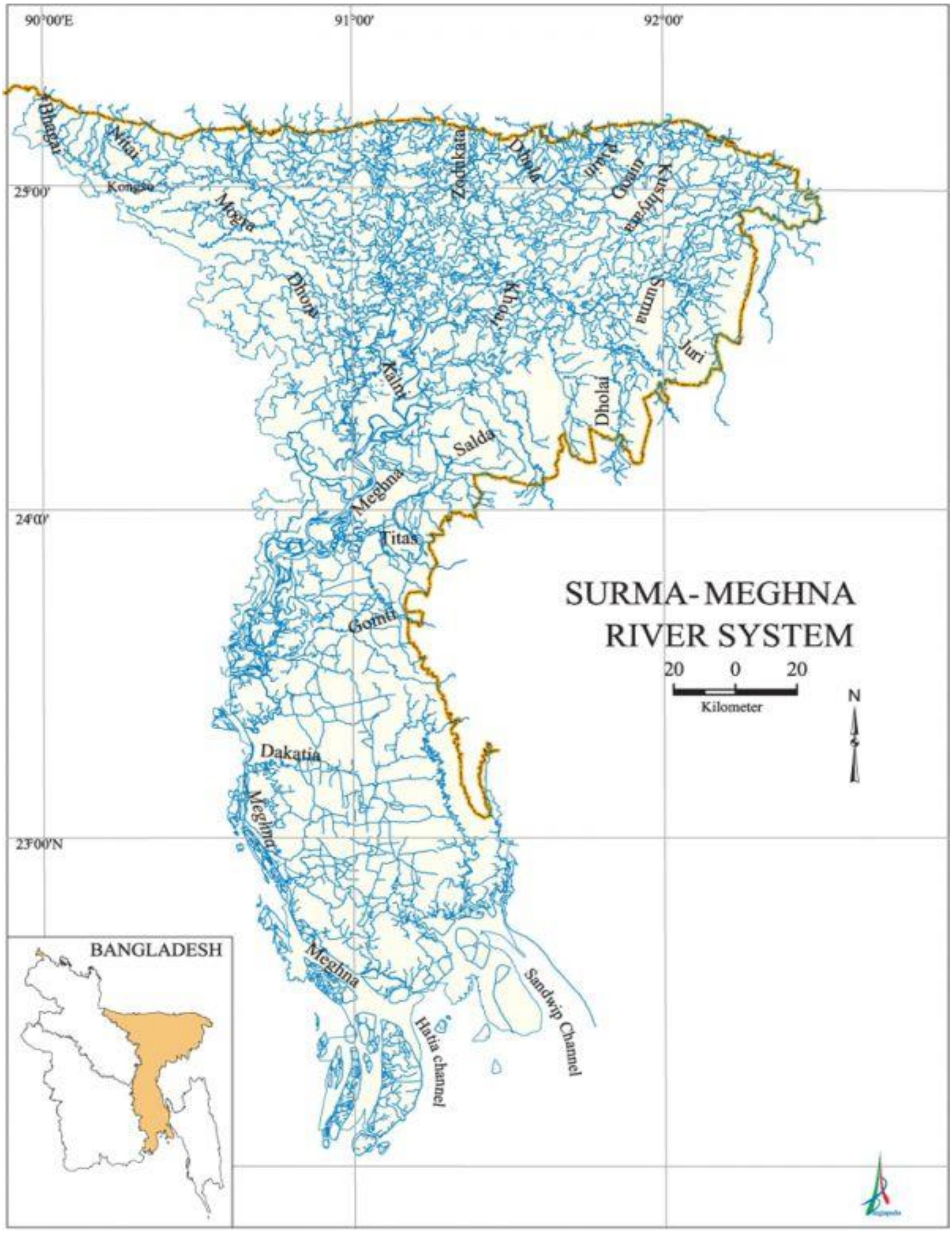

Figure 3.3: Surma-Meghna River System Map (Banglapedia)

3.3 The Jamuna River

The Jamuna River, which flows through Tibet, India, China and Bangladesh, is the second-biggest river in Bangladesh and among theworld's largest. Jamuna is the subsequent route of the Brahmaputra River that occurred following the occurrence of an earthquake and a severe flood between the years 1782 and 1787. Currently, the Brahmaputra River flows in a southeastern direction from Bahadurabad, specifically in the Dewanganj upazila of the Jamalpur district. However, beyond Bahadurabad and up till Aricha, the river is known as the Jamuna, not the Brahmaputra. The Hydrology Directorate of the Bangladesh Water Development Board (BWDB) designates the entire length as the Brahmaputra-Jamuna.

It starts in the Chemayung-Dung glacier, about 145 kilometers from Parkha, a significant trading hub situated between Lake Manassarowar and Mount Kailas, at around 31'30'N and 82'0'E. Before entering the Great Plains of Bengal, the Brahmaputra River is referred to as the Dihang in the Assam Himalayas. It penetrates into Bangladesh via the Kurigram district, namely along the boundary of Kurigram Sadar and Ulipur upazilas. The combined length of the Tsangpo-Brahmaputra-Jamuna River till it meets the Ganges is approximately 2,700 kilometers. The Brahmaputra-Jamuna River inside Bangladesh has a length of 276 kilometers, with the Jamuna section accounting for 205 kilometers.

The river's width varies between 3 km to 20 km, with an average width of around 10 km. During the wet season, the width of the river is always at least five kilometers. The river has a complex network of several interconnected channels, forming a braided pattern. The nation has channels of varying dimensions, ranging from hundreds of meters to kilometers wide, and exhibiting diverse patterns like braiding, meandering, and anastomosing. Throughout its trajectory in Bangladesh, the river is adorned with submerged sandbars, known as CHARS, which consolidate into a singular waterway during the rainy season. Therefore, based only on its width, this river meets the criteria to be considered one of the biggest in the world. The width-to-depth ratios of the different channels of the Brahmaputra River range from 50:1 to 500:1. The slope of the river in Bangladesh is 0.000077, which decreases to 0.00005 when it merges with the Ganges.

The total area of the Brahmaputra-Jamuna River basin is approximately 583,000 square kilometers, with 293,000 square kilometers located in Tibet, 241,000 square kilometers in India, and just 47,000 square kilometers inside Bangladesh. The catchment area upstream of

Bahadurabad is 536,000 square kilometers. This river system is the broadest in the country and flows in a north-south direction. At Bahadurabad, there exist records of gauges and discharges for this river. These records include the flow entering Bangladesh, as well as the flows of the Dudhkumar, the Dharla, and the Tista rivers. However, the records do not include the flows of the Old Brahmaputra and Bangal rivers. The river's flow during the rainy season is immense, with an average of 40,000 cubic meters per second. This places it among the seven greatest rivers in the world, alongside the Amazon, Congo, Yangtse, La Plata, Mississippi, and Meghna, based on this measurement. In August 1988, the flood reached a peak discharge of 98,600 cubic meters per second, which stands as the largest recorded flood to date.

The estimated annual average flow at Bahadurabad is 501 million acre-feet. Historically, August has consistently been the month with the highest probability of widespread floods. The occurrence of floods between May and July is typically attributed to the Brahmaputra-Jamuna and Meghna rivers. During August to October, the confluence of those rivers with the Ganges results in increased water flow. The flow of the Brahmaputra-Jamuna River is often more unpredictable compared to that of the Ganges River. The average slope of the Jamuna River is 1:11,850, which is somewhat higher than that of the Ganges River. The Jamuna River carries a substantial quantity of water while simultaneously transporting significant quantities of silt. In the rainy season, approximately 1.2 million tons of sediment are deposited daily, and the annual silt flow at Bahadurabad is estimated to be 735 million tons.

The Dharla, the Dudhkumar, the Tista, and the Karatoya-Atrai system are its four main tributaries. The initial trio of rivers have a rapid and sudden flow, originating from the steep drainage area located on the southern slope of the Himalayas, spanning from Darjeeling in India to Bhutan. The Old Brahmaputra is the longest of all the distributaries and served as the current route of the Brahmaputra River around 200 years ago.

Bangladesh's eastern and western regions are now connected by a new 4.8-kilometer bridge that spans the Jamuna. The eastern terminus of the 'BANGABANDU JAMUNA MULTIPURPOSE BRIDGE' is located in the Bhuapur upazila of the Tangail district, while the western terminus is situated in the Sirajganj Sadar upazila of the Sirajganj district. In addition to expediting the transportation of products and passengers via road and rail, it has also enabled the transfer of power and natural gas, as well as the integration of telecommunications systems. The bridge was inaugurated for vehicular passage on 23 June 1998. A significant amount of river training was conducted to confine the river within the bridge, rather than allowing it to spread over a flood width of 14 km at the bridge's location (Akhter 2005).

The Jamuna River has a braided nature. The Jamuna River is surrounded by several islands of varying sizes, known as chars, within its braided belt. Upon evaluating the Landsat picture from the dry season of 1992, it was determined that the Jamuna river possessed a collective count of 56 wide island chars, with each one measuring over 3.5 kilometers in length. There were 226 more tiny island chars, with lengths ranging from 0.35 to 3.5 kilometers. This encompasses both sandy regions and vegetation chars. During the period from 1973 to 2000, there has been a persistent presence of chars in the areas across from the Old Brahmaputra offtakes, namely to the north and east of Sirajganj. Additionally, chars have been observed in the southernmost area just before the point where the Jamuna River meets the Ganges River. Between 1981 and 1993, about 729,000 individuals in Bangladesh were relocated as a result of river bank erosion. The majority of the relocation occurred around the Jamuna River (Chowdhury and Islam 2003).

As one of the main distributaries of the Brahmaputra River, one of the largest rivers in the Indian subcontinent, the Jamuna River is an important waterway in Bangladesh. The Jamuna River traverses the northern and central parts of Bangladesh, making a substantial contribution to the country's physical and hydrological characteristics.

This grandiose river assumes a crucial function in the agricultural operations of the nation. The rich floodplains next to the river are essential for the production of several crops, so supporting a significant proportion of the population's livelihood. The river's yearly inundation is a mixed blessing, providing nourishment to the land through silt accumulation but also presenting periodic difficulties in the form of floods. Notwithstanding intermittent difficulties, the waters of the Jamuna River serve as a vital resource for farmers, facilitating the growth of rice, jute, and several other crops.

Furthermore, the Jamuna River plays a crucial role as a primary transportation artery, enabling the exchange of goods and fostering connections across various areas of Bangladesh. The river is easily navigable, and its waters are employed for the transportation of products and people, which promotes economic activity along its route. The junction of the Jamuna and Padma Rivers downstream creates the Meghna River, a prominent river system located in Bangladesh. The complex system of rivers has a crucial impact on the formation of the country's geography, exerting influence on its culture, economics, and day-to-day activities. The Jamuna River exemplifies the delicate connection between rivers and societal development, through its many contributions. Figure 3.4 shows the Jamuna River system map.

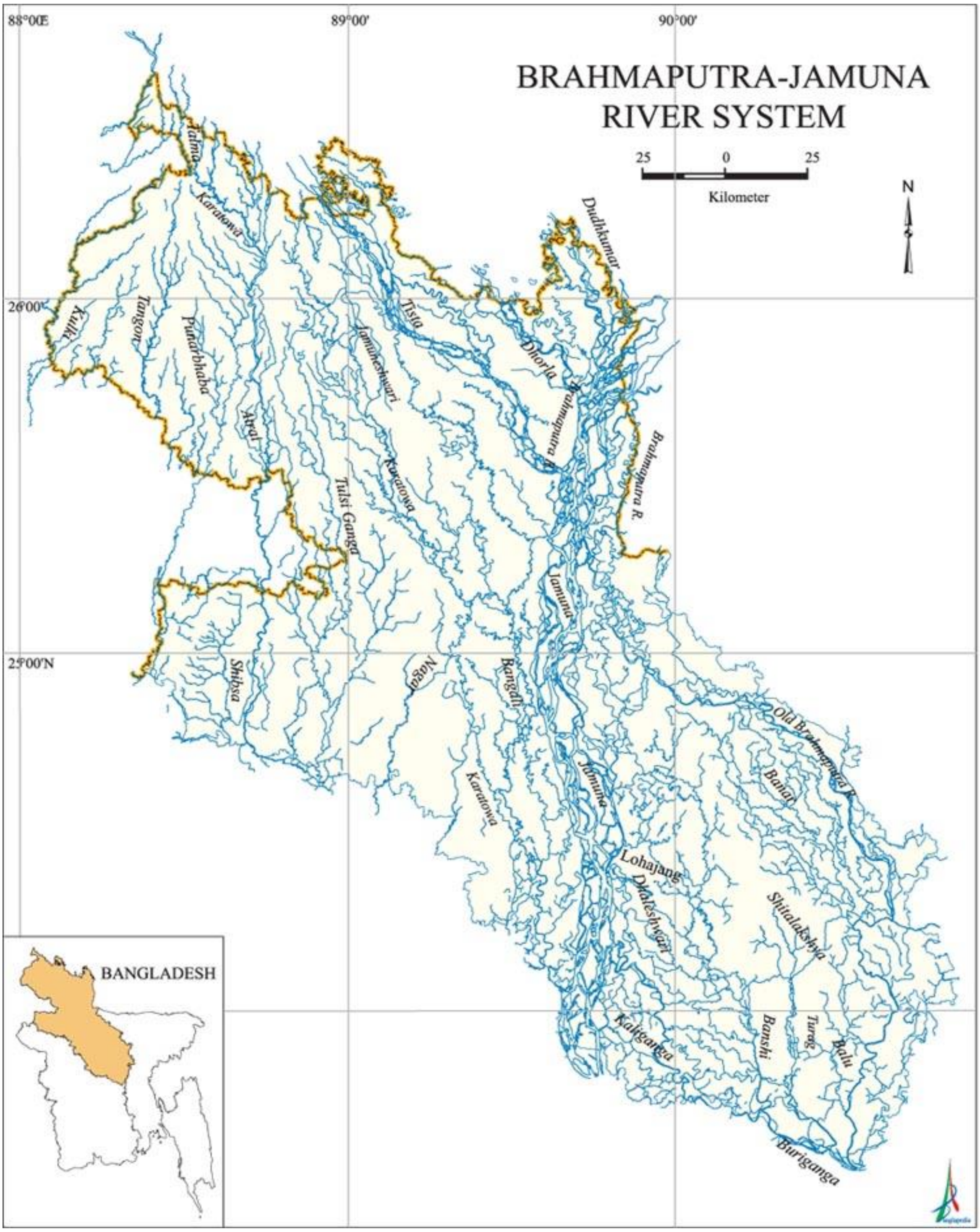

Figure 3.4: Brahmaputra-Jamuna River System Map (Banglapedia)

In conclusion, the Padma, Meghna, and Jamuna rivers of Bangladesh have a significant influence on the country's geography, culture, and economics. These rivers act as crucial conduits, enabling the transportation, irrigation, and agriculture that guarantee food security for millions. The livelihoods of a significant number of Bangladeshi inhabitants are dependent on these rivers, with as many as 600,000 individuals residing only on the riverine islands (Sarker et al. 2003). The intermingling rivers have catalyzed both economic growth and issues for the country. For generations, the inhabitants of Bangladesh have adjusted their way of life to live with river floods. They often relocate their temporary dwellings along the riverbanks, cultivate crops on newly formed river bars, and occasionally elevate their residences above the water level during flood seasons (Paul 1997).

Ultimately, the Padma, Meghna, and Jamuna rivers are essential components of Bangladesh's national identity.

CHAPTER 4

DATA COLLECTION AND CALCULATION

4.1 Introduction

Bangladesh is a country with many rivers has important consequences for its geography, economics, society, and culture. Bangladesh benefits from a copious supply of water resources due to its convergence of rivers and its proximity to an extensive marine region. The abundant presence of water has significantly influenced the topography of the nation, resulting in around 300 significant rivers, 400 subsidiary streams and tributaries, and an extensive interconnected system of water routes. The interconnected system of rivers and canals has not only enabled the movement of goods and people but has also shaped the distribution of human settlements and the utilization of land. Moreover, the rivers have served a crucial part in strengthening the country's agriculture, by providing irrigation for crops and sustaining the livelihoods of millions of individuals. Bangladesh's water resources are significantly influenced by 57 transboundary rivers that originate in neighboring India and Myanmar. The Ganga or Padma, Jamuna, Meghna, Teesta, Khoai, and Feni rivers are noteworthy within this group of rivers.

The Hydrological Water Network Map (BWDB) displays the water level stations. The three water level sites considered for computation, namely Padma (SW91.6L), Meghna (SW273), and Jamuna (SW46.9L), were picked based on the availability of data for April 2016. These stations are integral components of the Hydrological Water Network Map (BWDB) and offer vital data on the water levels of these prominent rivers. The station data has been obtained by the Water Resource Engineering Department at BUET.

Figure 4.1: Showing Hydrological Station Network by Bangladesh Water Development Board

4.2.1 Discharge in Padma, Meghna and Jamuna River

For the purpose of this thesis, maximum discharge data for the Padma, Meghna, and Jamuna rivers during the month of April 2016 has been collected from the Bangladesh Water Development Board (via WRE, BUET). The collected data corresponds to station SW91.6L for the Padma River at Baruria_Transit, SW273 for the Meghna River at Bairab Bazar, and SW46.9L for the Jamuna River at Bahadurbad_Transit. The highest discharge was observed on April 23rd in the Padma River, reaching 13,166.94 m3/s. Similarly, the Meghna River recorded its maximum discharge at 5,655.93 m3/s, while the Jamuna River observed a maximum discharge of 5,316.21 m3/s. Among these three rivers, the Padma River exhibits the highest discharge. Table 4.1 shows the detail data.

Table 4.1: Maximum Discharge in Padma, Meghna, and Jamuna (April 2016)

River Name	Station ID	Station Name	Maximum Discharge(m^3/s)	Date
Padma	SW91.6L (RMP -7)	Baruria_Transit	13166.94	23/04/2016
Meghna	SW273 (RMM-22)	Bairab Bazar	5655.93	23/04/2016
Jamuna	SW46.9L (RMJ- 12)	Bahadurbad_Transit	5316.21	27/04/2016

4.2.2 Velocity in Padma, Meghna and Jamuna River

To support this thesis, the highest recorded velocity measurements for the Padma, Meghna, and Jamuna rivers during April 2016. This data was obtained from the Bangladesh Water Development Board (via WRE, BUET). Data was collected from station SW91.6L for the Padma River at Baruria_Transit, SW273 for the Meghna River at Bairab Bazar, and SW46.9L for the Jamuna River at Bahadurbad_Transit. The Padma River displayed the maximum velocity, measured at 1 m/s. The Meghna River achieved a maximum velocity of 1.07 m/s, while the Jamuna River's velocity was recorded at 1.03 m/s. Table 4.2 shows the specific information.

Table 4.2: Maximum velocity in Padma, Meghna, and Jamuna (April 2016)

River Name	Station ID	Station Name	Maximum Velocity(m/s)	Date
Padma	SW91.6L (RMP -7)	Baruria_Transit	1	23/04/2016
Meghna	SW273 (RMM-22)	Bairab Bazar	1.07	23/04/2016
Jamuna	SW46.9L (RMJ- 12)	Bahadurbad_Transit	1.03	27/04/2016

4.3 Cross-Sectional Representation of Padma, Meghna and Jamuna River

In this section, for representing the cross-section of the Padma, Meghna, and Jamuna rivers cross-sectional data has been collected from has been collected from the Bangladesh Water Development Board (via WRE, BUET) for the month of April 2016.

4.3.1 Cross-Section of Padma River

The relationship between distance and reduced level is evident in the graph below. The x-axis represents distance, while the y-axis represents the equivalent lowered level. The graph depicts a vertical slice of the Padma River, specifically focusing on the data obtained in April from the water station SW96.6L (RMP -7), which is referred to as Baruria_Transit. This graphical depiction functions as a primary instrument for investigating cross-sectional characteristics. The comprehensive graph is displayed in Figure 4.2 below.

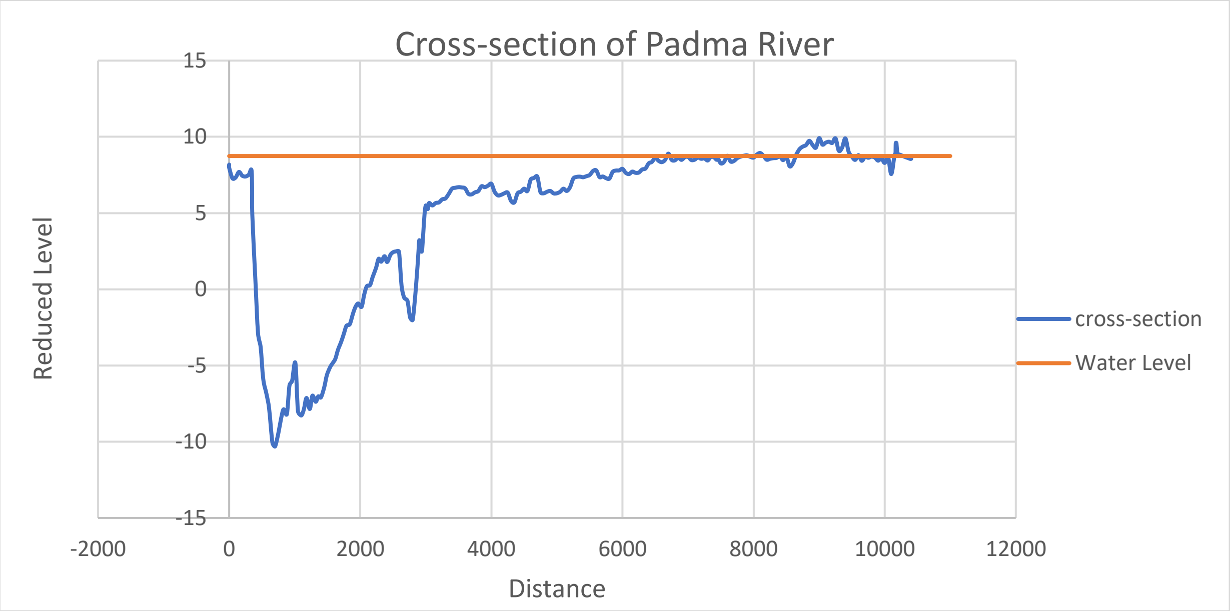

Figure 4.2: Cross-Section of Padma River

4.3.2 Cross-Section of Meghna River

The graph below depicts the relationship between distance and reduced level. The x-axis represents the distance, and the y-axis illustrates the corresponding reduced level. The graph showcases a cross-section of the Meghna River based on data collected in April from water station SW46.9L (RMJ -12), with the data collection station named Bahadurbad_Transit. This graphical representation serves as a fundamental tool for exploring cross-sectional properties. The detailed graph is presented in Figure 4.3 below.

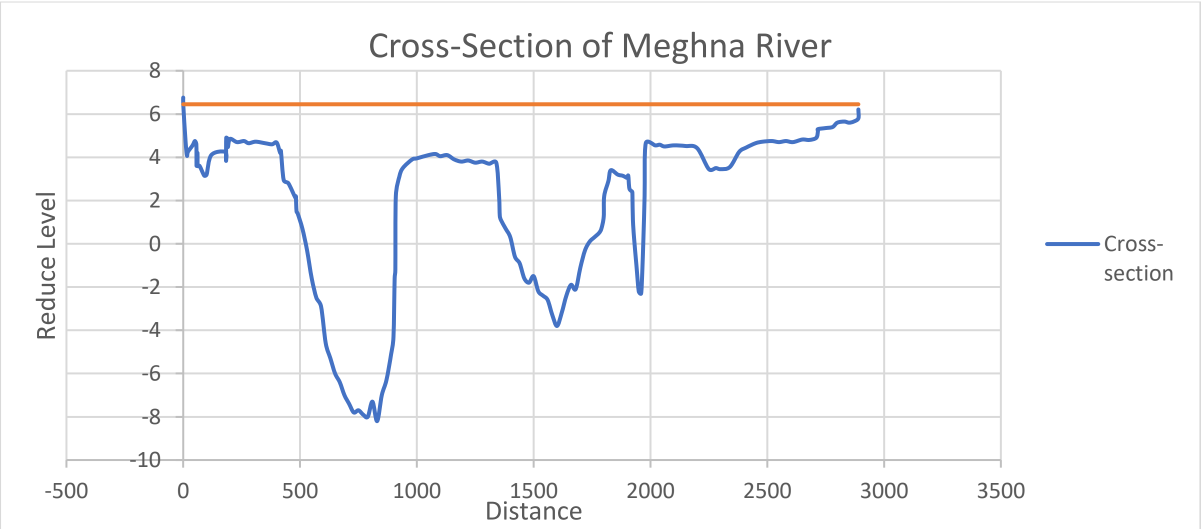

Figure 4.3: Cross-Section of Meghna River

4.3.3 Cross-Section of Jamuna River

The below graph presents the relationship between distance and reduced level. The x-axis represents the distance, while the y-axis illustrates the corresponding reduced level. The graph shows a cross-section of the Meghna river based on the data of April month for water station SW273 (RMM -22). The data collection water station's name is Bairab_Bazar. This graphical representation serves as a fundamental tool in the exploration of cross-sectional properties. The Figure 4.4 shown the detailed graph.

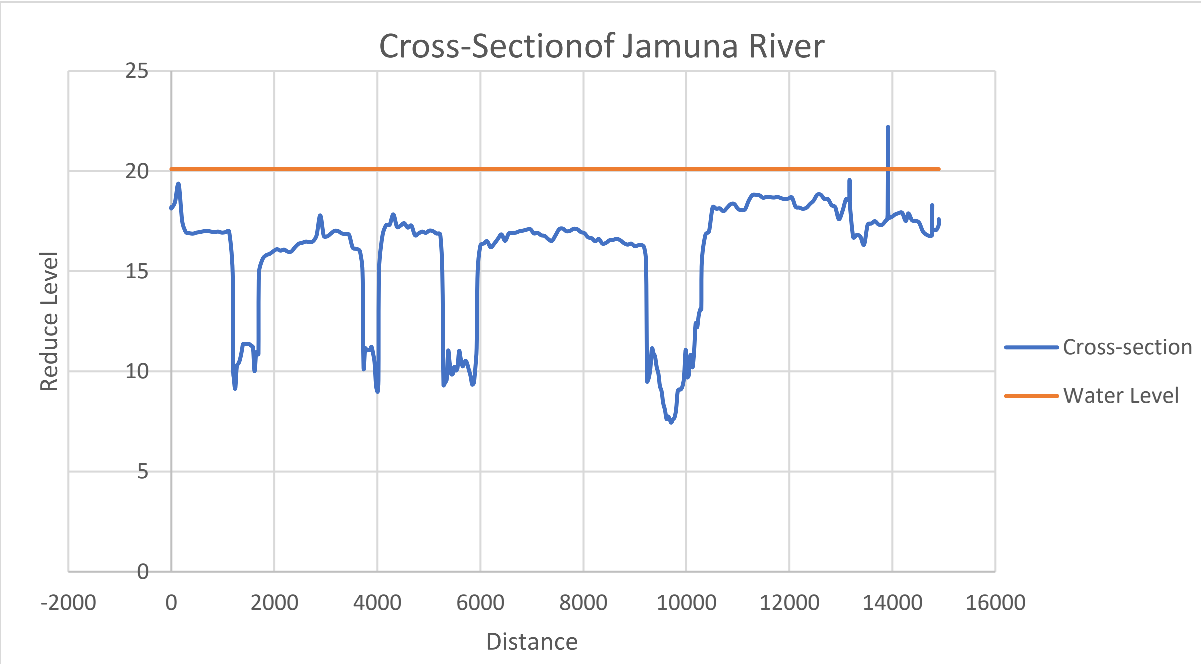

Figure 4.4: Cross-Section of Jamuna River

4.3.4 Calculation of Area, Wetted Perimeter, and Maximum Depth of Padma, Meghna and Jamuna River

From the above three graph area, wetted perimeter and maximum depth can be calculated for the Padma, Meghna, and Jamuna rivers for the month of April. The table presents data on the area, perimeter, and depth of the Padma, Meghna, and Jamuna rivers. The area, measured in square meters, reveals significant variations among the rivers. Padma has the largest area at 56,242.75 m², followed by Meghna with 5,284 m² and Jamuna with 190,223.55 m².

Examining perimeter data in meters, the figures show the lengths of the riverbanks. Padma and Jamuna have significantly larger perimeters at 9,300 m and 14,901.85 m, respectively, compared to Meghna with a perimeter of 3,000 m. The detailed table is shown below.

Table 4.3: Area, Wetted perimeter in Padma, Meghna and Jamuna (April-2016)

River Name	Area(m2)	Wetted perimeter
Padma	56242.75	9300
Meghna	5284	3000
Jamuna	190223.55	14901.85

4.3.5 Slope of The Major River in Bangladesh

Slope of each river collected from FAP 24 measurements (Kabir, 1996). Table 4.4 shows the slope of the major rivers that are considered for the computation in this study.

Table 4.4: Slope of the major rivers in Bangladesh

Name of The River	Slope m/m
Padma	0.000055
Meghna	0.000022
Jamuna	0.000077

4.3.6 Bed Materials Sizes of The Major Rivers of Bangladesh

The values of bed material size i.e. D_{50} and D_{90} are essential for the computation of the sediment transport equation used in the calculation (Kabir, 1996). The Table 4.5 shows the values of bed material sizes of the major rivers.

Table 4.5: Bed Materials size of the major rivers of Bangladesh

Name of the River	D_{50}(m)	D_{90} (m)
Padma	0.00015	0.00022
Meghna	0.00018	0.00025
Jamuna	0.00022	0.00034

4.4 Grain Size Distribution Curve of Padma, Meghna and Jamuna Rivers

In this thesis, the grain size distribution curve plays a pivotal role in understanding the composition of sediment particles within aquatic environments. The curve visually represents the distribution of particle sizes, unveiling insights into sediment dynamics. Total grain size distribution could not be found for those three rivers. However, d_{50}, d_{90}, and d_{35} three data have been collected and an approximate graph has been plotted for the Padma, Meghna, and Jamuna rivers. Using this grain size distribution curve any value for percent finer can be obtained for calculation purposes. The grain size distribution curve for Padma, Meghna, and Jamuna has been shown in Figure 4.5, Figure 4.6, and Figure 4.7

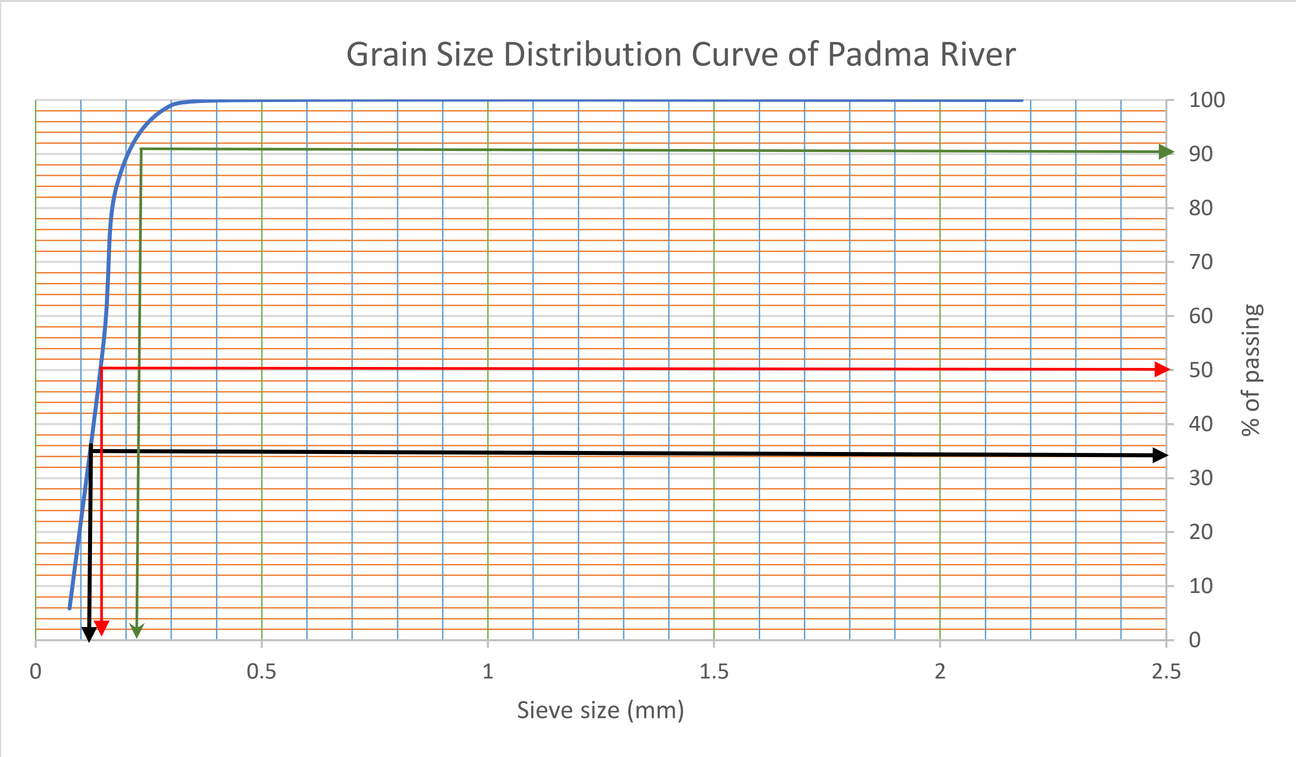

Figure 4.5: Grain Size Distribution of Padma River

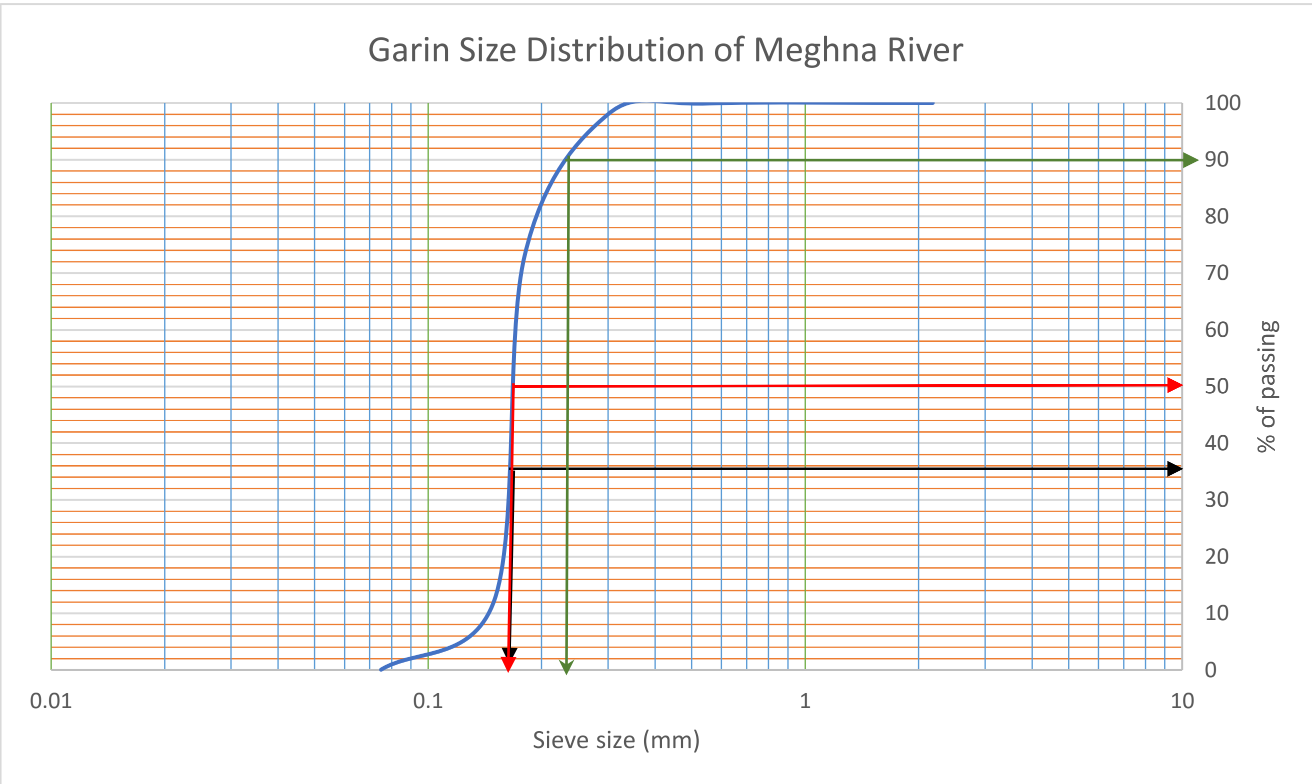

Figure 4.6: Grain Size Distribution of Meghna River

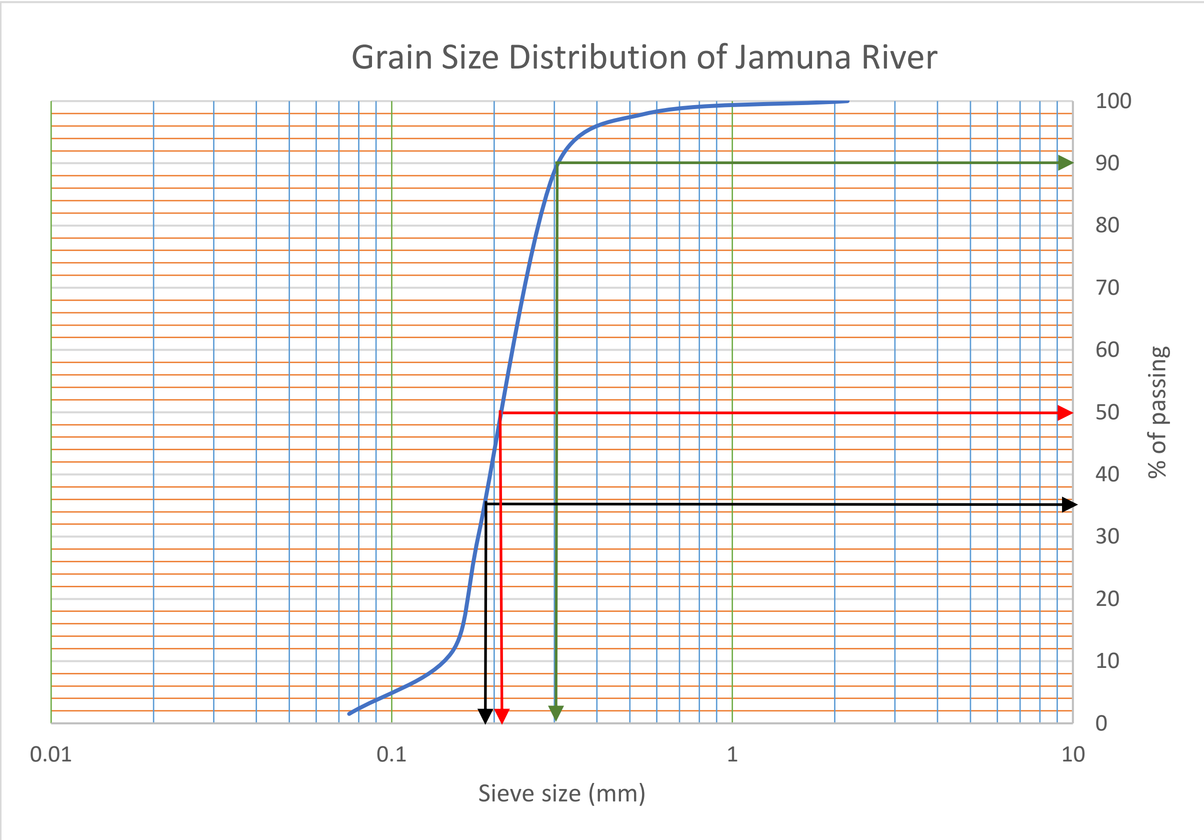

Figure 4.7: Grain Size Distribution of Jamuna River

4.5 Calculation

Using empirical equations to calculate sediment transport in rivers can provide a more comprehensive understanding of the processes involved. In many approached equations considering five equations for calculating sediment transport rate in Padma, Meghna, Jamuna.

4.5.1 Sediment Transport Rate Calculation in Padma River

4.5.1.1 Meyer- Peter and Mueller (1948)

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

Here,

S = 0.000055

d_{50} =0.00015 m

B = 6450 m

Q = 13166.94 cumec

$q = \frac{13166.94 \text{ cumec}}{6450 \text{ m}}$

$= 2.04 \text{ cumec/meter width}$

Now,

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

$$= (250\times 2.04^{\frac{2}{3}} \times 0.000055) - (42.5 \times 0.00015)$$

$$=0.0221168 - 0.006375$$

$$=0.0157418$$

$$g_s = 1.975\times 10^{-3} \text{ kg/m/s}$$

$$= \frac{(1.975\times10^{-3})\times6450\times24\times3600}{1000}$$

$$=1100.628 \text{ ton/day}$$

4.5.1.2 C. T Yang's Equation (1976)

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

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

Here,

D_{50} = 0.00015 m

S = 0.000055

A = 56242.75 m^2

B = 6450 m

H = 8.72 m

V = 0.85 m/s

μ = 10^{-6} m^2/sec

$\omega = 0.01551\, m/sec$

Q = 13166.94 cumec

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{U_* D_{50}}{v} - 0.06} + 0.66; \text{When } 1.2 < \frac{U_* D_{50}}{v} < 70 \text{(ok)}$$

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log 10.284 - 0.06} + 0.66$$

$$= 3.2856$$

$$\frac{U_* D_{50}}{v} = \frac{0.06856 \times 0.00015}{0.000001}$$

$$= 10.284$$

Shear Velocity,

$$u_* = \sqrt{gHS}$$

$$= \sqrt{9.8 \times 8.72 \times 0.000055}$$

$$= 0.06856 \text{ m/s}$$

$\log C_t$=5.435−0.286 log 2.3265 − 0.457 log 4.4204 + (1.799 −

$$0.409 \log 2.3265 - 0.314 \log 4.4204) \log(\frac{0.85\times0.000055}{0.01551} - 3.2856 \times 0.000055)$$

$\log C_t$= 5.0351+1.446343× −2.5477

=1.350312397

$C_t = 10^{1.350312397}$

= 22.4002 ppm

$= \frac{22.4002 \times 20.503 \times 24 \times 3600}{1000000}$

= 39.68 ton/day

4.5.1.3 L.C Van Rijn (1989)

Van Rijn equation based on shear stress he expressed as:

$$q_s = q_b \times \rho_s$$

Here,

D_{50} = 0.00015 m

S = 0.000055

A = 56242.75 m^2

B = 6450 m

R=6.0476 m

H = 8.72 m

V = 0.85 m/s

μ = 10^{-6} m^2/sec

D_{90}= 0.00022 m

Chezy's Coefficient with grain roughness,

$$C' = 18\log(\frac{12R}{3d_{90}})$$

$$= 18\log\left(\frac{12\times 6.0476}{3\times 0.00022}\right)$$

$= 90.7420\ m^{1/2}/s$

Bed shear velocity related to grain roughness,

$$u_*{}' = \frac{U(g)^{1/2}}{C'}$$

$$= \frac{0.85\times(9.8)^{1/2}}{90.7420}$$

$= 0.0293$ m/s

$$\theta_{cr} = 0.24\times(D_*)^{-1}$$

$$= 0.24\times(3.0345)^{-1}$$

$= 0.0791$

Critical bed shear velocity,

$$u_{*cr} = \sqrt{(s-1)\times g\times d_{50}\times\theta_{cr}}$$

$$= \sqrt{(2.65-1)\times 9.8\times 0.00015\times 0.0791}$$

$= 0.01385$ m/s

Transport stage parameter,

$$T_* = \frac{(u_*{}'^2 - u_{*cr}2)}{u_{*cr}2}$$

$$= \frac{(0.0293^2 - 0.01385^2)}{0.01385^2}$$

$= 3.4754$ m

Bed load sediment transport rate,

$$q_b = 0.053\left(\frac{T_*{}^{2.1}}{D_*{}^{0.3}}\right).(\rho'.g)^{1/2}\,(d_{50})^{3/2}$$

$$= 0.053\left(\frac{3.4754^{2.1}}{3.0345^{0.3}}\right)\times(0.605\times 9.8)^{1/2}\times\ (0.00015)^{3/2}$$

$= 2.3344\text{x}10^{-6}$ kg/m/s

Now,

$$q_s = q_b \times \rho_s$$

$= 2.3344\text{x}10^{-6}$ x 1600

$= 3.7351\text{x}10^{-3}$ kg/m/s

$= \frac{(3.7351\times10-3)\times6450\times24\times3600}{1000}$

= 2081.4709 ton/day

4.5.1.4 Engelund and Hansen (1967)

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

Here,

V = 0.85 m/s

D_{50} = 0.00015 m

$\gamma_s =$ 1000× 2.65 kg/m^3= 2650 kg/m^3

$\gamma = 1000$ kg/m^3

g = 9.8 m/sec^2

S = 0.000055

B = 6450 m

A = 56242.75 m^2

P = 9300 m

Bed Shear Stress,

$\tau_0 = \gamma$RS

=1000×6.05× 0.000055;

=0.3326

$$g_s = 0.05\times 2650 \times (0.85)^2 \sqrt{\frac{0.00015}{9.8(\frac{2650}{1000}-1)}} \left[\frac{0.3326}{(2650-1000)\times 0.00015}\right]^{\frac{3}{2}}$$

$= 0.4542 \text{ kg/m/sec}$

$= \frac{0.4542\times 6450\times 3600\times 24}{1000}$

$= 253116.576 \text{ ton/day}$

4.5.1.5 Hossain's Equation (1987)

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

$$C_t = A(X^a Y^b Z^c)$$

Here;

A = 56242.75 m2

B = 6450 m

H = 8.72 m

V = 0.85 m/s

$S_s = 2.65$

D_{50} = 0.00015 m

S = 0.000055

g = 9.8 m/sec^2

μ = 10^{-6} $\text{m}^2\text{/sec}$

ω_r = 0.01551 m/s

Q = 13166.94 cumec

$\frac{B}{H}$ = 739.695

A = 6.496× 10^6; B/H > 500 (ok)

K = 0.055 when Q < 15000 cumecs and

K = 0.17 when Q > 15000 cumecs

The Product of Froud Number and Slope of Energy Gradient:

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

$$X = \frac{0.85 \times 0.000055}{(9.8 \times 8.72)^{\frac{1}{2}}}$$

$X = 5.06 \times 10^{-6}$; and a = 0.745

The Settling Velocity Ratio:

$$Y = \frac{\omega_r}{\omega}$$

$$Y = \frac{0.01551}{3.3235}$$

Y = 0.00468; and b = 0.633

The Discharge Ratio

$$Z = \frac{Q}{Q_c}$$

$$Z = \frac{13166.94}{62594.896}$$

$Z = 0.2104$; and c = 0.5

Settling Velocity of the sediment load,

$$= \frac{(\frac{2}{3}g(S_s - 1)D_{50}^2 + 36v^2)^{0.5} + 6v}{D_{50}}$$

$$= \frac{(\frac{2}{3} \times 9.8(2.65 - 1) \times 0.00015^2 + 36 \times 0.000001^2)^{0.5} + (6 \times 0.000001)}{0.00015}$$

$= 3.3235$

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

$$= \left[(2.15 + 0.055 \times 739.695) \times 8.72 \times (9.8 \times 0.000055)^{\frac{1}{5}}\right]^{\frac{5}{2}}$$

$Q_c = 62594.896$

Now,

$$C_t = 6.496\times 10^6((5.06 \times 10^{-6})^{0.745} \times (0.00468)^{0.633} \times (0.2104)^{0.5})$$

$$C_t = 11.3245 \text{ ppm}$$

$$= \frac{11.3245\times20.503\times24\times3600}{1000000}$$

$$= 20.0609 \text{ ton/day}$$

4.5.1.6 Ackers and White (1973)

$$q_t = k\, ud_{35} \left(\frac{u}{u_*}\right)^n \left(\frac{Y-Ycr}{Ycr}\right)^m$$

Here,

A = 56242.75 m2

B = 6450 m

H = 8.72 m

P = 9300m

u = 0.85 m/s

g = 9.8 m/sec^2

d_{35} = 0.00012 m

s = 2.65kg/m^3

The particle diameter D_* can be defined as,

$$D_* = d_{35}\left(\frac{(s-1)g}{v^2}\right)^{\frac{1}{3}}$$

$$= 0.00012\left(\frac{(2.65-1)\times9.8}{(10^{-6})^2}\right)^{\frac{1}{3}}$$

$$= 3.0345$$

As $1 < D_* < 60$Now K, n, m Coefficient

$$k = 10^{-3.46+2.79l0g(D_*)-0.98(logD_*)^2}$$

$= 10^{-3.46+2.79log(3.0345)-0.98(log3.0345)^2}$

$= 4.5421\text{x}10^{-3}$

$n = 1 - 0.56\log(D_*)$

$= 1 - 0.56\log(3.0345)$

$= 0.7300$

$m = \frac{6.83}{D_*} + 1.67$

$= \frac{6.83}{3.0345} + 1.67$

$= 3.9208$

$Y_{cr} = \frac{0.23}{D_*^{0.5}} + 0.14$

$= \frac{0.23}{3.0345^{0.5}} + 0.14$

$= 0.2720$

The particle mobility parameter, Y can be expressed as,

$$Y = \left(\frac{u_*^n}{\sqrt{(s-1)gd_{35}}}\right)\left(\frac{u}{5.66\log\left(\frac{10h}{d_{35}}\right)}\right)^{1-n}$$

$$= \left(\frac{0.06856^{0.7300}}{\sqrt{(2.65-1)\times9.8\times0.00012}}\right)\left(\frac{0.85}{5.66\log\left(\frac{10\times8.72}{0.00012}\right)}\right)^{1-0.7300}$$

$= 1.1932$

$$q_t = k\,ud_{35}\left(\frac{u}{u_*}\right)^n\left(\frac{Y-Ycr}{Ycr}\right)^m$$

$$= 4.5421\text{x}10^{-3} \times 0.85 \times 0.00012 \times \left(\frac{0.85}{0.06856}\right)^{0.7300} \times \left(\frac{1.1932-0.2720}{0.2720}\right)^{3.9208}$$

$= 3.4768\text{x}10^{-4}$ kg/m/s

$= \frac{3.4768\text{x}10^{-4} \times6450\times3600\times24}{1000}$

$=193.7562$ ton/day

4.5.2 Sediment Transport Rate Calculation in Meghna River

Table 4.6: Sediment Transport Rate Calculation in Meghna River

Sediment Transport Rate Calculation in Meghna River					
Meyer- Peter and Mueller	C. T Yang	L.C Van Rijn	Engelund and Hansen	Hossain	Ackers and White
g_s(ton/day)	C_t (ton/day)	q_s (ton/day)	g_s(ton/day)	C_t (ton/day)	q_t (ton/day)
0.2363	3.5272	4796.984	4466.94	43.0185	1.659

The table provides a thorough summary of sediment transport rate estimations in the Meghna River, using the sediment transport equation. Each column represents a unique calculating method, such as Meyer-Peter and Mueller, C.T Yang, L.C Van Rijn, Engelund and Hansen, Hossain, and Ackers and White. The parameters being examined, namely g_s (ton/day), C_t (ton/day), q_s (ton/day), and q_t (ton/day), are thoroughly recorded for each approach. According to the Meyer-Peter and Mueller approach, the sediment transport rate (g_s) is calculated to be 0.2363 ton/day, along with corresponding values for (C_t) and (q_s). The C. T Yang sediment transport equation yields a sediment flux (g_s) of 4466.94 ton/day. The L.C Van Rijn technique yields a sediment transport rate (q_s) of 4769.984 ton/day. In accordance with the Engelund and Hansen technique, the (g_s) parameter is calculated to be 4466.94 ton/day. The Hossain approach produces a C_t value of 43.0185 ton/day, but the Ackers and White method generates a sediment transport rate (q_t) of 1.659 ton/day. The comprehensive analysis highlights the variety of results achieved by employing several calculation methods, providing insight into the complexities of sediment transport dynamics in the Meghna River. The data highlights the significance of methodological issues in riverine research and adds to a broader knowledge of how different methodologies describe and measure sediment transport rates.

4.5.3 Sediment Transport Rate Calculation in Jamuna River

Table 4.7: Sediment Transport Rate Calculation in Jamuna River

Sediment Transport Rate Calculation in Jamuna River					
Meyer- Peter and Mueller	C. T Yang	L.C Van Rijn	Engelund and Hansen	Hossain	Ackers and White
g_s(ton/day)	C_t (ton/day)	q_s (ton/day)	g_s(ton/day)	C_t (ton/day)	q_t (ton/day)
26.57	96.2878	8087.453	2006608.019	5.06	344.804

The table presents the outcomes of sediment transport rate computations in the Jamuna River, using several equations such as Meyer-Peter and Mueller, C. T Yang, L.C. Van Rijn, Engelund and Hansen, Hossain, and Ackers and White. Every column corresponds to a distinct technique, and the parameters g_s (ton/day), C_t (ton/day), q_s (ton/day), and q_t (ton/day) are specified for each method. According to the Meyer-Peter and Mueller technique, the sediment transport rate (g_s) is calculated to be 26.57 ton/day. The C. T Yang equation yields a C_t value of 96.2878 ton/day, but the L.C Van Rijn equation computes a (q_s) of 8087.453 ton/day. Conversely, the Engelund and Hansen method yields a much-elevated (g_s) value of 2006421.062 ton/day. The Hossain technique yields a sediment transport rate (C_t) of 5.06 ton/day, whereas the Ackers and White method calculates the sediment transport rate (q_t) to be 344.804 tons per day. The data provides a thorough overview of how sediment is transported in the Jamuna River. It demonstrates the variety of results obtained from using different calculating techniques and emphasizes the significance of choosing a suitable methodology for studying rivers.

CHAPTER 5
DATA ANALYSIS AND DISCUSSION

5.1 Data Analysis

In the present study, three water level stations have been selected for each three rivers. Data has been collected from the Bangladesh Water Development Board via (WRE, BUET). Three water level stations are SW91.6L for Padma River, SW273 for Meghna River, and SW46.9L for Jamuna River for April 2016. All the coordinates of these three stations corresponding reduced level data of each station were entered into Microsoft Excel. Cross-section data of three selected water level stations e.g., SW91.6L, SW273, and SW46.9L for the month of April were plotted (Figure 4.2 to Figure 4.4). Then the cross-sectional area, average depth, width, wetted perimeter, maximum velocity, and maximum discharge of each selected section were computed for the month of April 2016 (Table 4.1 to Table 4.3). Grain size distribution of three river has been plotted in the graph (Figure 4.5 to Figure 4.7).

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) The width of the channel has been taken as surface width.
(ii) Average velocity has computed maximum velocity multiplied by 0.85 because the velocity profile is missing.
(iii) The average slope of the three rivers and D_{50}, the D_{90} size of the sediment particle have been taken from BWDB.

5.2 Comparative Studies Among All the Sediment Transport Equations

The objective was to compare the accuracy of six sediment transport equations in calculating sediment transportation rates in three rivers. Determining which equation provides a more accurate result is crucial for understanding the reliability of these equations and their applicability to specific rivers.

Table 5.1: Comparison Among All Empirical Equations for Padma River

Comparison Among All Empirical Equations for Padma River		
Sediment Transport Equation	**Sediment Transport (ton/day)**	**Percent Variation**
Hossain’s	20.0609	99.03621521
C. T. Yang	25.1526	98.79159492
Engelund and Hansen	253116.576	12060.46672
Mayer-Peter and Muller	1100.628	47.12258528
L.C Van Rijn	2081.4709	0
Ackers and White	193.7562	90.69138079

Results in three rivers were calculated using six sediment transport equations. The primary task at present is to determine which equation provides the most precise results out of the six available equations. After considering the calculations described earlier, it is evident that L.C Van Rijn's equation is the most precise when compared to other models. This equation is significant because it provides the latest improvements to sediment transport equations, based on the insights obtained from previous research. L.C Van Rijn's method uses hydraulic parameters, including velocity, depth, D_{50}, and D_{90}, to calculate sediment transport rates in the Padma River, Meghna River, and the Jamuna River. The calculation portion for the Padma River demonstrates discrepancies, L.C Van Rijn's equation produces a value of 2081.4709 ton/day. Notably, Meyer-Peter and Mueller's equation differs by 99% from L.C Van Rijn's result for the same river. In addition, Acker and White's equation produces a sediment transport rate that is 90% less than L.C Van Rijn's equation in the Padma River. Likewise, the fluctuation in the Meghna and Jamuna Rivers remains unchanged. The Ackers and White’s equation deals with total sediment transport load. For these three rivers there is no bed load which means there is no motion of sediments in shields diagram (Figure 1) due to the low velocity in the April month which is the reason behind the inaccurate value. The equation proposed by Engelund-Hansen has considerably greater variability compared to L.C Van Rijn's equation, particularly in the Padma and Jamuna Rivers, where the values are 253116.576 ton/day and 2006608.019 ton/day, respectively, which are notably unusual. Errors in data collection for hydraulic parameters, such as water depth, velocity, and sediment diameter, might be another possible explanation for this variance.

The discrepancy in Meyer-Peter and Mueller's equation is ascribed to the observed disparities in sediment size, a pivotal component influencing computed outcomes. This formula is specifically designed for sediment with a size between 6.4mm to 30mm. However, the sediment size in the Padma, Meghna, and Jamuna Rivers is limited to a tighter range of 0.15mm to 0.25mm. The huge disparity in sediment size leads to discrepancies in computed results, since the equation proposed by Meyer-Peter and Mueller may not precisely account for the behavior of sediment movement in rivers with considerably lower grain sizes. Concerning Hossain's Equation, the study conducted on the major rivers in Bangladesh lacks accuracy in calculating their values. This is because the data collection took place in April, a month when sediment transport is minimal, and there may have been errors in assuming hydraulic parameters. The deviation of C.T Yang's equation in the Padma, Meghna, and Jamuna Rivers surpasses 90%, suggesting inaccuracies when utilized for Bangladesh rivers, maybe arising from deficiencies in the gathered hydraulic data.

After doing calculations and comparing six sediment transport equations, it is concluded that L.C Van Rijn's equation is the recommended choice. When it comes to estimating sediment transport rates between the three rivers, this equation predicts the findings more accurately and with less fluctuation than the actual data. The equation developed by L.C Van Rijn considers all hydraulic characteristics in its computations, which enables it to accurately forecast sediment transport rates that are very near to the actual values. It is noteworthy that, in the calculations, the remaining five equations, apart from L.C Van Rijn's equation, exhibit variations in the expected rates of sediment movement across the three rivers.

5.3 Sensitivity Analysis

Sensitivity Analysis of each six-sediment transport equation for Padma River has been shown below.

5.3.1 Sensitivity Analysis of Padma River

Table 5.2: Sensitivity Analysis of Hossain's Equation in Padma River

Sensitivity Calculation of Hossain's Equation in Padma River							
Sediment Transport Equation	Calculated C_t (ton/day)	Depth		Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Hossain	20.0154	18.8312	21.3407	20.7563	19.265	20.0227	20.0073
	Variation (%)	5.9165	6.621	3.702	3.749	0.0364	0.0405

The above table shows how the C_t value change according to increasing and decreasing velocity, depth and D_{50}.In specific terms, when the depth increases by more than 5%, the C_t value experiences a variation of 5.92%, suggesting an increase in sediment transport rate. Conversely, a decrease in depth by less than 5% results in variation of 6.62%, indicating a decrease in sediment transport rate. Similar variations are observed for velocity and diameter, with specific percentages denoting the sensitivity of the sediment transport equation to changes in these parameters. In Hossain's equation depth is not proportional to C_t when depth increased C_t value is decreased but when depth decreased C_t value increased but all the other parameters are proportional to C_t and shows linear variation. More sensitive parameter in Hossain's equation is the depth than velocity and D_{50}.

Table 5.3: Sensitivity Calculation of C.T Yang's Equation in Padma River

Sensitivity Calculation of C.T Yang's Equation in Padma River							
Sediment Transport Equation	Calculated C_t (ton/day)	Depth		Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Yang	39.6869	40.0528	39.305	42.7759	36.6704	41.2834	38.101
	Variation (%)	0.92196	0.96228	7.7834	7.6007	4.0227	3.9960

According to the above table shows that how the C_t value change according to increasing and decreasing velocity, depth and D_{50}. The table show when the depth increased by 5% the C_t value increased by 0.92% and when decreased 5% the depth C_t value also decreased 0.96%. Similarly, the velocity and D_{50} shows same variation in C_t value. Which indicate that the all parameters are proportional to C_t. In terms of sensitivity velocity is more sensitive than depth and D_{50}.

Table 5.4: Sensitivity Calculation of Engelund and Hansen's Equation in Padma River

Sensitivity Calculation of Engelund and Hansen's Equation in Padma River					
Sediment Transport Equation	Calculated g_s (ton/day)	Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Engelund and Hansen	253147.9612	279095.6272	228466.035	241093.2964	266471.5381
	Variation (%)	10.2499	9.7499	4.7619	5.2631

The table shows how the g_s value varies in relation to velocity and diameter increases and decreases. The g_s value increases by 10% with a 5% increase in velocity, while the g_s changes by 9.75% with a 5% increase in velocity. In a similar vein, the results show that the g_s value increases by 5.27% when the diameter is lowered relative to the real diameter and reduces by 4.76% when the diameter increases. The computed data clearly shows that velocity influences the g_s value more sensitively than diameter.

Table 5.5: Sensitivity Calculation of Mayer-Peter and Muller's Equation in Padma River

Sensitivity Calculation of Mayer-Peter and Muller's Equation in Padma River			
Sediment Transport Equation	Calculated g_s (ton/day)	Diameter	
		Increasing 5%	Decreasing 5%
Mayer-Peter and Muller	1101.7734	1068.5015	1135.3837
	Variation (%)	3.0198	3.0506

The table above reveals that the only sensitive parameter in Meyer-Peter and Muller's equation is the sediment diameter. The sediment diameter value is inversely proportional to the g_s value, signifying that an increase in diameter leads to a decrease in the g_s value, while a decrease in diameter results in an increased value in g_s calculation.

Table 5.6: Sensitivity Calculation of L.C Van Rijn's Equation in Padma River

Sensitivity Calculation of L.C Van Rijn's Equation in Padma River					
Sediment Transport Equation	Calculated q_s (ton/day)	Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
L.C Van Rijn	2081.464568	2700.1786	1570.6071	1960.9485	2211.750246
	Variation (%)	29.7249	24.5432	5.7899	6.2593

The table presents a sensitivity analysis of L.C Van Rijn's sediment transport equation in the Padma River, focusing on the calculated values for q_s (ton/day) under varying conditions of velocity and diameter. The calculated q_s values are shown for scenarios where each parameter experiences a 5% increase or decrease. For L.C Van Rijn's equation, the calculated q_s value is 2081.464568 ton/day. When the velocity increased by 5% almost 30% q_s value increased, while 5% decreased in velocity shows significant reduction of q_s 25% in q_s. Similarly, 5% increase in diameter leads to 5.78% reduction in q_s, whereas 5% decrease in diameter results in increased q_s value. Which indicate that, velocity is proportional to q_s and diameter is inversely proportional to q_s. In this sediment transport equation velocity is more sensitive than diameter.

Table 5.7: Sensitivity Calculation of Ackers and White's Equation in Padma River

Sensitivity Calculation of Ackers and White's Equation in Padma River					
Sediment Transport Equation	Calculated q_t (ton/day)	Velocity		Depth	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Ackers and White	193.6426	225.2450	165.1415	207.1605	180.3020
	Variation (%)	16.3199	14.7183	6.9808	6.8892

A sensitivity study of Ackers and White's sediment transport equation in the Padma River is shown in the table, with particular focus paid to the computed values of q_t (ton/day) under increasing and decreasing velocity and depth conditions. Calculated q_t value is 193.6426 (ton/day). When velocity increased or decreased q_t value increased or decreased accordingly. Similarly, depth also shows the same linear variation. Which means that both velocity and depth parameters are proportional to q_t. According to the presented data the velocity is more sensitive rather than depth.

5.4 Most Sensitive Hydraulic Parameter of Padma River

Table 5.8: Most Sensitive Parameter of Padma River

Equation	**Most sensitive parameter with variation of ± 5%**	
Hossain's	Depth	(6-7) %
C. T. Yang	Velocity	(7-8) %
Engelund and Hansen	Velocity	(9-10) %
Mayer-Peter and Muller	Sediment size	3%
L.C Van Rijn	Velocity	(24-30) %
Ackers and White	Velocity	(14-16) %

The equations mentioned in the study are frequently used in hydrological research to compute distinct characteristics of rivers, such as flow rate and sediment transport. The sensitivity analysis helped in identifying the parameters that exhibit the most significant influence on the outcomes of these equations. Comprehending the sensitivity of factors is essential for precise modeling and forecasting of river behavior.

The set of tables (Table 5.2 to Table 5.7) displays the findings of a sensitivity research for six sediment transport equations in the Padma River. With respect to depth, velocity, and diameter, the analysis focused on the values of C_t (ton/day), g_s (ton/day), q_s (ton/day), and q_t (ton/Day). The table is split into sections to show whether the parameter deviations are greater than or less than 5% from the baseline values. For each scenario, the calculated C_t, g_s, q_s, and q_t values demonstrate how changes in depth, velocity, and diameter impact the rate of sediment transport. In the equations used for the Padma River, the velocity is the parameter that has the most impact. At (Table 5.8) it evident that 5% increase in velocity leads to a substantial variance in the results, ranging from 10% to 30%. However, there is only a slight fluctuation of (3%-10%) in both the depth and diameter parameters, indicating that the resulting change is minimal. Likewise, the Meghna River (Table 19) has a velocity variation of (7%–30%), which is more than the depth and width variations in the computed results. In the sensitivity study of the Jamuna River (Table 26) it has been determined that the most sensitive parameter is velocity, compared to depth and diameter. But, Meyer-Peter-Mueller equation, used in the Meghna River and Jamuna River, calculates sediment transport in this equation, the sensitivity analysis reveals that the diameter parameter has the greatest impact on the calculated result, with a variation of (65%-100%) for increasing or decreasing diameter from the actual value which means while using the equation the diameter should be calculate carefully. But in other equation considerable sensitive parameter is velocity. Which means that to get the approximate sediment transport rate in rivers the velocity should be calculate accurately otherwise the result shows error value. In this study, velocity should be considered the most sensitive parameter while calculating sediment transport rate.

In conclusion by determining the most susceptible variables in six equations, it facilitated the prioritization of data gathering and monitoring efforts. Velocity is identified as the most responsive factor, it becomes essential to precisely measure and monitor river velocities in order to assure precise forecasts of flow rates and sediment transportation. Subsequently, this data may be utilized to guide river management tactics, such as ascertaining the most advantageous placement for constructions like dams or bridges.

Details calculation of sensitivity analysis in Meghna River and Jamuna River shown in the appendix section.

5.5 Discussion

In this thesis the three water level sites considered for computation, namely Padma (SW91.6L), Meghna (SW273), and Jamuna (SW46.9L), were picked based on the availability of data for April 2016. All the cross-sectional and hydrological parameter data has been collected from BWDB (WRE via BUET). The literature review identified six commonly employed equations for sediment transport, specifically Meyer-Peter and Mueller (1948), C.T. Yang (1976), Engelund-Hansen (1967), L.C. Van Rijn (1989), Ackers and White (1973), and Hossain (1987). Consequently, these equations were used in the computation method for the Padma, Meghna, and Jamuna Rivers, uncovering discrepancies in the outcomes. After analyzing the computed data, it is apparent that L.C. Van Rijn's equation is more appropriate for these rivers. The equation considers characteristics such as depth, velocity, and diameter, making it a recent and enhanced model that solves limitations encountered in previous equations. Engelund-Hansen's equation, however, tends to overestimate values when compared to actual data. The formula developed by C.T. Yang, Meyer-Peter and Mueller are not appropriate for the rivers in Bangladesh, considering the data that has been obtained. While Hossain's equation is designed particularly for rivers in Bangladesh, there are still some unidentified mistakes present in the obtained data.

During the sensitivity study, it was seen that all six equations share the same parameter that is highly sensitive, except for Meyer-Peter and Mueller's formula, which alone depends on the sediment diameter as the sensitive parameter. Based on the sensitivity analysis, an accurate determination of velocity is essential. Subsequent research should prioritize the reduction of mistakes and the improvement of precision in the computation of sediment transport rates. To do this, it is necessary to gather more data from water level stations for a prolonged duration to acquire precise cross-sectional measurements. Furthermore, the acquisition of velocity distribution profiles will enhance our overall comprehension of the dynamics, hence enhancing the accuracy of sediment transport rate estimations in river systems.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

After summarizing the morphological information of Padma, Meghna and Jamuna river in chapter three. The width of Padma River in dry season is 11km and in rainy season it is 13km. The depth of the Padma River is now 1.5 to 3 meters at different places. The velocity varies from 4.85m/s. Flow rate of the Padma River increases significantly to around 750,000 m^3/s and 15000m^3/s in winter. The average width of Meghna is 3400 meters and the average flow from June to October is approximately 2.5 million ft^3/s and 0.3 million ft^3/s in winter. The Jamuna river's width varies between 3 km to 20 km. The river's flow during the rainy season is immense, with an average of 40,000 m^3/s.

Using six sediment transport empirical equation the three major rivers estimated sediment transport rate is shown the below Table 6.1

Table 6.1: Estimated Sediment Transport of Three River

Sediment Transport Equation	Estimated Sediment Transport(ton/day)		
	Padma	**Meghna**	**Jamuna**
Hossain's	20.0609	43.1085	5.06
C. T. Yang	25.1526	3.5272	96.2878
Engelund and Hansen	253116.576	4466.94	2006608.019
Mayer-Peter and Muller	1100.628	0.2363	26.57
L.C Van Rijn	2081.4709	4796.984	8087.453
Ackers and White	193.7562	1.659	344.804

From the table it has been observed that the Meyer-Peter and Mueller formula shows the lowest value in sediment transport and the L.C Van Rijn equation shows most precise value in three rivers. Other equation shows unusual prediction in result.

In the study the L.C Van Rijn equation is considering standard and compared to others equation shown in Table 6.1 the variation is about (90-100) % in C.T Yang, Ackers and White, Meyer-Peter-Mueller and Hossain's equation. Engelund-Hansen equation performance shows unrealistic variation.

Now comparing the all the equation among themselves Hossain's and C. T Yang equation shows (1-2) % on the other hand the variation between Meyer-Peter and Mueller's and Ackers and White variation is 1%. These four-equation variation among themselves is minimum.

In conducting sensitivity analyses on the parameters of various sediment transport equations, it becomes evident that the performance of these equation is highly dependent on variables. The sensitivity analysis highlights those certain parameters exert a more significant influence on the model predictions than others. For example, in the Meyer-Peter and Mueller equation sediment diameter found to be highly sensitive parameters (80-100) %, emphasizing the importance of accurate measurement and consideration of these factors in applications. Similarly, in the Engelund-Hansen equation, L.C Van Rijn the velocity (10-20) % and in Hossain's equation depth (7-8) % plays pivotal role in determining its performance. The conclusion drawn from these analyses is that the choice of sensitive parameters varies across equations, and understanding the context-specific significance of each parameter is crucial for accurate sediment transport predictions. Moreover, the level of sensitivity may vary based on the specific conditions of the river being studied. Identifying these sensitive parameters allows researchers and practitioners to prioritize data collection and monitoring efforts for better estimation. In summary, sensitivity analyses contribute to the refinement of sediment transport equations by pinpointing the parameters that significantly influence the result.

6.2 Recommendation

1. Only three specific cross-sections were considered for the analysis of three rivers in this study. Additional investigations might be conducted on a larger number of sections to more accurately estimate the sediment transport rate.

2. The cross-sectional data for the majority of the sections exhibited discontinuity. It is recommended to analyze continuous data for an extended duration to enhance the accuracy of predictions.

3. In this study only, April month in 2016 which is a dry season data should be collected for the whole year.

4. The velocity distribution profile is missing results because of the one-month data collection a longer period of data should be collected.

5. "Thalweg" of each river should be known to understand the river morphology.

REFERENCE

Akhter, Farida. 2005. "Japan ODA : Cause of River Erosion , Displacement and Environmental Destruction in Bangladesh ?" 63–160.

Azarang, Farhang. 2015. "Mathematical Model for Evaluating of Sediment Transport (Case Study: Karkheh River in Iran)." *Indian Journal of Science and Technology* 8(23). doi: 10.17485/ijst/2015/v8i23/75246.

Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Publication Year, and 1999. 1999. *"Bangladesh Compendium of Environment Statistics 1997."*

Bari, M. F. 1978. "Applicability of Sediment Transport Formulas for the Ganges and the Jamuna, M. Sc. Engg."

van den Berg, Jan H., and André van Gelder. 1993. "Prediction of Suspended Bed Material Transport in Flows over Silt and Very Fine Sand." *Water Resources Research* 29(5):1393–1404. doi: 10.1029/92WR02654.

Best, James L., Philip J. Ashworth, Maminul H. Sarker, and Julie E. Roden. 2008. *The Brahmaputra-Jamuna River, Bangladesh*.

Chang, Howard H. 1984. "Modeling of River Channel Changes." *Journal of Hydraulic Engineering* 110(2):157–72. doi: 10.1061/(asce)0733-9429(1984)110:2(157).

Chowdhury, Momen, and Sirajul Islam. 2003. "Meghna River." *Banglapedia: The National Encyclopedia of Bangladesh*.

Chowdhury, Momen, and Sirajul Islam. n.d. "Jamuna River." *Banglapedia: The National Encyclopedia of Bangladesh*.

Dey, Krishna Chandra. 1995. "Schematised Sediment Transport Predictor for Study of Alluvial Rivers: An Application to the Jamuna."

Galappatti, Ranjit, and Kim Wium Olesen. n.d. "Schematizing Large Active Rivers for Morphological Computations : Experience From Bangladesh."

Garde, Ramchandra Janardan, and K. G. Ranga Raju. 2000. *Mechanics of Sediment Transportation and Alluvial Stream Problems*. Taylor & Francis.

Hossain, Dr M. Monowar. 1989. “Geomorphic Characteristics of the Ganges (Padma) up to Brahmaputra Confluence.” *Final Report* 2:158.

Hossain, Dr M. Monowar. 1994. *Study on Geometric and Sediment Transport Characteristics of the River Surma*.

Hossain, M. M. 1992. “Total Sediment Load in the Lower Ganges and Jamuna.” *Journal of IEB* 20(1&2):1–8.

Hossain, M. M., and D. I. H. Barr. 1988. “Sediment Transport Equation: An Evaluation.” *J. Ind. Wat. Resour. Soc* 8(4):1–19.

Hossain ML, Mahmud J, Islam J, Khokon ZH and Islam S. (eds. .. 2005. “Padma.” *Tatthyakosh* 1&2:182.

Islam, G. M. , and S. Akhter. 2005. “Sediment Transport Predictor in the Ganges River.” *J. Civ. Eng. (IEB)* 33(2):65–74.

Kabir, M. R., and Naur Ahmed. 1996. “Bed Shear Stress for Sediment Transportation in the River Jamuna.” *J. Civ. Eng. Inst. Eng. Bangladesh* 24:55–68.

Karmaker, Tapas, and Subashisa Dutta. 2010. “Generation of Synthetic Seasonal Hydrographs for a Large River Basin.” *Journal of Hydrology* 381(3–4):287–96. doi: 10.1016/j.jhydrol.2009.12.001.

Khan, Waliuzzaman. 1986. “Study of Sediment Transport in the River Gorai-Modhumoti.”

Nabi, Rejaun, Md Shahedur Rashid, Hossain Mohammad Ismail, Md Rejaun Nabi, and Mohammad Ismail Hossain. 2016. “Historical Bankline Shifting Since 1760s: A GIS and Remote Sensing Based Case Study of Meghna River Plate of Rennell’s Atlas Effect of Variation of Vegetation Species (Rubber and Natural Forest) on Enhanced Vegetation Index (EVI) View Project Disaster Pro.” *International Journal of Scientific and Research Publications* 6(12).

Nakato, Tatsuaki. 1990. “Tests of Selected Sediment-Transport Formulas.” *Journal of*

Hydraulic Engineering 116(3):362–79. doi: 10.1061/(asce)0733-9429(1990)116:3(362).

Paszkowski, Amelie, Steven Goodbred, Edoardo Borgomeo, M. Shah Alam Khan, and Jim W. Hall. 2021. “Geomorphic Change in the Ganges–Brahmaputra–Meghna Delta.” *Nature Reviews Earth & Environment* 2(11):763–80. doi: 10.1038/s43017-021-00213-4.

Paul, Bimal Kanti. 1997. “Flood Research in Bangladesh in Retrospect and Prospect: A Review.” *Geoforum* 28(2):121–31. doi: 10.1016/s0016-7185(97)00004-3.

Salih, Sinan Q., Ahmad Sharafati, Khabat Khosravi, Hossam Faris, Ozgur Kisi, Hai Tao, Mumtaz Ali, and Zaher Mundher Yaseen. 2020. “River Suspended Sediment Load Prediction Based on River Discharge Information: Application of Newly Developed Data Mining Models.” *Hydrological Sciences Journal* 65(4):624–37. doi: 10.1080/02626667.2019.1703186.

Sarker, Maminul Haque, Iffat Huque, Mustafa Alam, and Rob Koudstaal. 2003. “Rivers,Charsandchar Dwellers of Bangladesh.” *Intl. J. River Basin Management* 1(1):61–80.

Sui-ji, Wang, and Ni Jin-ren. 2002. “Straight River: Its Formation and Speciality.” *Journal of Geographical Sciences* 12(1):72–80. doi: 10.1007/bf02837430.

Sultana, Nilufer. 1989. “Critical Review of Sediment Transport Studies of Jamuna River.”

Tao, Hai, Behrooz Keshtegar, and Zaher Mundher Yaseen. 2019. “The Feasibility of Integrative Radial Basis M5Tree Predictive Model for River Suspended Sediment Load Simulation.” *Water Resources Management* 33(13):4471–90. doi: 10.1007/s11269-019-02378-6.

Task Committee for Preparation of Sediment Manual American Society of Civil Engineers, Committee on Sedimentation of the Hydraulics Division. 1971. “Sediment Transportation Mechanics: H. Sediment Discharge Formulas.” *Journal of the Hydraulics Division* 97(4):523–67.

Vanoni, Vito A. 2006. “Sedimentation Engineering.” American Society of Civil Engineers.

Wallingford, H. R. 1990. “Sediment Transport, the Ackers and White Theory Revised.” *Report SR237, HR Wallingford, England*.

White, W. R., H. Milli, and A. D. Crabbe. 1973. “Sediment Transport; an Appraisal of Available Methods, Rep. 119, UK Hydraulics Res.” *Stat., Wallingford, England*.

Yang, Chih Ted. 1976. “Minimum Unit Stream Power and Fluvial Hydraulics.” *Journal of the Hydraulics Division* 102(7):919–34.

Yang, Chih Ted. 1977. “The Movement of Sediment in Rivers.” *Geophysical Surveys* 3(1):39–68.

BIBLIOGRAPHY

Akhter, F. (2005). Japan ODA : Cause of river erosion , displacement and environmental destruction in Bangladesh ? 63-160.

ALAM, R. S. (2016). HAZARD CHARACTERISTICS OF NATURAL. *IMPACT: International Journal of Research in Applied*, 13-20.

Azarang, F. (2015). Mathematical Model for Evaluating of Sediment Transport (Case study: Karkheh River in Iran). *Indian Journal of Science and Technology, 8*(23). doi:10.17485/ijst/2015/v8i23/75246

Bangladesh Bureau of Statistics, S. D. (1999). *"Bangladesh compendium of environment statistics 1997".*

Bari, M. F. (1978). Applicability of Sediment Transport Formulas for the Ganges and the Jamuna, M. Sc. Engg.

Best, J. L. (2008). The Brahmaputra-Jamuna River, Bangladesh. *Large Rivers: Geomorphology and Management*, 395-433. doi:10.1002/9780470723722.ch19

Bolton, P. (1983). *Sediment discharge measurement and calculation.*

Britannica, T. E. ((2023, December 26). *Padma River*. Retrieved from Encyclopedia Britannica: https://www.britannica.com/place/Padma-River

Chang, H. H. (1984). Modeling of River Channel Changes. *Journal of Hydraulic Engineering, 110*(2), 157-172. doi:10.1061/(asce)0733-9429(1984)110:2(157)

Chowdhury, M. (2003). Meghna River. In S. Islam, *Banglapedia: the National Encyclopedia of Bangladesh* (p. 500). Asiatic Society of Bangladesh. Retrieved from https://en.banglapedia.org/index.php/Meghna_River

Dey, K. C. (1995). Schematised sediment transport predictor for study of alluvial rivers: An application to the Jamuna.

Dudkowska, A. &.-G. (2017). *Wave-induced bedload transport – a studyof the southern Baltic coastal zone.* doi:https://doi.org/10.1515/logos-2017-0001

Engelund, F. (1967). A monograph on sediment transport in alluvial streams. *Technical University of Denmark 0stervoldgade 10, Copenhagen K.*

Ferguson, R. I. (1986). *Hydraulics and hydraulic geometry.* (1 ed., Vol. 10). Progress in Physical Geography. doi:10.1177/030913338601000101

Galappatti, R. (1987). Schematizing Large Active Rivers for Morphological Computations : Experience From Bangladesh.

Garde, R. J. (2000). Mechanics of sediment transportation and alluvial stream problems.

Haddad, B. M. (2023). Watershed management. *Dictionary of Ecological Economics: Terms for the New Millennium*, 584-585. doi:10.4337/9781788974912.W.13

Hossain ML, M. J. (2005). Padma. *Tatthyakosh, 1&2*, 182.

Hossain, D. M. (1989). Geomorphic Characteristics of the Ganges (Padma) up to Brahmaputra Confluence. *Final report, 2*, 158.

Hossain, D. M. (1994). *Study on geometric and sediment transport characteristics of the river Surma.*

Hossain, M. M. (1988). Sediment transport equation: an evaluation. *J. Ind. Wat. Resour. Soc, 8*(4), 1-19.

Hossain, M. M. (1992). Total sediment load in the lower Ganges and Jamuna. *Journal of IEB, 20*(1&2), 1-8.

Islam, G. (2005). Sediment transport predictor in the Ganges river. *J. Civ. Eng. (IEB), 33*(2), 65-74.

Kabir, M. R. (1996). Bed shear stress for sediment transportation in the River Jamuna. *J. Civ. Eng. Inst. Eng. Bangladesh*, 55-68.

Karmaker, T. (2010). Generation of synthetic seasonal hydrographs for a large river basin. *Journal of Hydrology, 381*(3-4), 287-296. doi:10.1016/j.jhydrol.2009.12.001

Khan, W. (1986). Study of sediment transport in the river Gorai-Modhumoti.

Matin, M. A. (1994, April). Sediment characteristics of the rivers in Atrai basin. *Journal of Institution of Engineers,, 22*(2), 1-5.

Mclelland, S. J. (2009). Flow Structure and Transport of Sand-Grade Suspended Sediment around an Evolving Braid Bar, Jamuna River, Bangladesh. *Fluvial Sedimentology VI*(1990), 43-57. doi:10.1002/9781444304213.ch4

Nabi, R. (2016). Historical Bankline Shifting Since 1760s: A GIS and Remote Sensing Based Case Study of Meghna River Plate of Rennell's Atlas Effect of Variation of Vegetation Species (Rubber and Natural Forest) on Enhanced Vegetation Index (EVI) View project Disaster Pro. *International Journal of Scientific and Research Publications, 6*(12).

Nakato, T. (1990). Tests of Selected Sediment-Transport Formulas. *Journal of Hydraulic Engineering, 116*(3), 362-379. doi:10.1061/(asce)0733-9429(1990)116:3(362)

Organisation-MPO, M. P. (1991). National Water Plan Project Phase II. *Dhaka, Bangladesh*.

Paszkowski, A. (2021). Geomorphic change in the Ganges–Brahmaputra–Meghna delta. *Nature Reviews Earth & Environment, 2*(11), 763-780. doi:10.1038/s43017-021-00213-4

Paul, B. K. (1997). Flood research in Bangladesh in retrospect and prospect: A review. *Geoforum, 28*(2), 121-131. doi:10.1016/s0016-7185(97)00004-3

Pradhan, N. S. (2021). Sustainable management options for healthy rivers in south Asia: The case of Brahmaputra. *Sustainability (Switzerland), 13*(3), 1-23. doi:10.3390/su13031087

Profile, S. E. (2017, june). Applicability of Two Sediment Transport Predictors in the Rivers of Northwest Region of Bangladesh.

Razzak, M. M. (2015). *BAGLADESHER NODNODI: BORTOMAN GOTIPROKRITI.* Dhaka: Kathaprokash.

Salih, S. Q. (2020). River suspended sediment load prediction based on river discharge information: application of newly developed data mining models. *Hydrological Sciences Journal, 65*(4), 624-637. doi:10.1080/02626667.2019.1703186

Sankhla, M. S. (2016). Heavy Metals Contamination in Water and their Hazardous Effect on Human Health-A Review. *International Journal of Current Microbiology and Applied Sciences, 10*, 759-766. doi:10.20546/ijcmas.2016.510.082

Sarker, M. H. (2003). Rivers,charsandchar dwellers of Bangladesh. *Intl. J. River Basin Management, 1*(1), 61-80.

Sarker, M. H. (2011). River bank protection measures in the Brahmaputra-Jamuna River: Bangladesh Experience Living with floods in Bangladesh View project Levee effect View project River bank protection measures in the Brahmaputra-Jamuna River: Bangladesh Experience. (May). Retrieved from https://www.researchgate.net/publication/263125674

Sui-ji, W. (2002). Straight river: its formation and speciality. *Journal of Geographical Sciences, 12*(1), 72-80. doi:10.1007/bf02837430

Sulaiman, S. O. (2021). Evaluation of sediment transport empirical equations: case study of the Euphrates River West Iraq. *Arabian Journal of Geosciences, 14*(10), 1-11. doi:10.1007/s12517-021-07177-1

Sultana, N. (1989). Critical review of sediment transport studies of Jamuna river.

Sultana, R. (2016). Hazard Charecteristics of Natural Flood: A Case Study of Padma River. *4*(12), 13-20.

Tao, H. (2019). The Feasibility of Integrative Radial Basis M5Tree Predictive Model for River Suspended Sediment Load Simulation. *Water Resources Management, 33*(13), 4471-4490. doi:10.1007/s11269-019-02378-6

Task Committee for Preparation of Sediment Manual American Society of Civil Engineers, C. o. (1971). Sediment Transportation Mechanics: H. Sediment Discharge Formulas. *Journal of the Hydraulics Division, 97*(4), 523-567.

van den Berg, J. H. (1993). Prediction of suspended bed material transport in flows over silt and very fine sand. *Water Resources Research, 29*(5), 1393-1404. doi:10.1029/92WR02654

Vanoni, V. A. (2006). Sedimentation engineering.

Wallingford, H. R. (1990). Sediment transport, the Ackers and White theory revised. *Report SR237, HR Wallingford, England*.

White, W. R. (1973). Sediment transport; an appraisal of available methods, Rep. 119, UK Hydraulics Res. *Stat., Wallingford, England*.

Wikipedia. Retrieved from Meghna River (Bangladesh): https://en.m.wikipedia.org/wiki/Meghna_River

Wikipedia. Retrieved from Jamuna River (Bangladesh): https://en.m.wikipedia.org/wiki/Jamuna_River_(Bangladesh)

Yang, C. T. (1976). Minimum unit stream power and fluvial hydraulics. *Journal of the* Hydraulics Division, 102(7), 919-934.

Yang, C. T. (1977). The movement of sediment in rivers. Geophysical *surveys, 3*(1), 39-68.

NOTATION AND ABBREVIATIONS

Y	= Particle mobility parameter
D_*	=Sedimentological grain diameter
k, n, m	=Coefficient
V, u, U	= Average flow velocity
D_{50}	= Median
H	=Depth diameter of bed material
γ_s	=Specific weight of sediment particles
γ	= Specific weight of water
g	= Acceleration due to gravity
S	= Water surface slope
A	= Area
B	=Width
P	= Wetted perimeter
R	=Hydraulic radius

τ_0 = Bed shear stress

u_* = Bed shear velocity

V_{cr} =Critical average water velocity

μ = Kinematic viscosity

ω =Terminal fall velocity

Q = Measured discharge

Q_c = Assessed discharge

Z = The product Froud number and Slope of Energy Gradient Ratio

X = The settling velocity ratio

a, b, c = Coefficient

q_b =The bed load transport rate in volume

ρ' = Relative density of submerged solids

ρ_s = Density of sediment

ρ = Density of water

T_* = Transport stage parameter

S = Relative density of sediment

u_*' = Bed shear velocity related to grain roughness

u_{*cr} = Critical bed shear velocity

C' = Chezy's coefficient with grain roughness

q = discharge per unit width

ω_r = Settling Velocity for a representative Sediment size for which, D_{50} = 0.15mm at ambient temperature

ω = Settling Velocity of the sediment load

C_t = Total average sediment concentration in parts per million

g_s, q_s	= sediment transport per unit time per unit width
q_t	= Total sediment transport per unit time per unit width
BWDB	= Bangladesh Water Development Board
BUET	= Bangladesh University of Engineering and Technology
ASCE	= American Society of Civil Engineers
HRS	= Hydraulic Research Station
USGS	= United States Geological Survey
NRC	= National Research Council
FAP	= Flood Action Plan
MPO	= Master Plan Organization

APPENDIX

Sample Calculation of Padma River

Calculation of cross-sectional area, depth, width, and wetted perimeter at station SW91.6L for the river of Padma month of April (2016). The below graph data has been collected from BWDB (via WRE, BUET)

Table 7: Value of Distance and RL of Padma River

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW91.9L	0	8.18	1.91	SW91.9L	1230	-7.85	6.83
SW91.9L	0	7.98	1.91	SW91.9L	1270	-6.98	6.83
SW91.9L	50	7.28	1.37	SW91.9L	1320	-7.38	7.05
SW91.9L	100	7.34	1.37	SW91.9L	1360	-7.02	7.05
SW91.9L	150	7.7	1.35	SW91.9L	1400	-7.09	7.39
SW91.9L	200	7.45	1.35	SW91.9L	1450	-6.43	7.39
SW91.9L	250	7.4	1.34	SW91.9L	1490	-5.64	7.3
SW91.9L	300	7.52	1.34	SW91.9L	1540	-5.11	7.3
SW91.9L	340	7.83	1.82	SW91.9L	1580	-4.84	7.29
SW91.9L	350	6.6	1.82	SW91.9L	1620	-4.56	7.29
SW91.9L	353	4.9	1.8	SW91.9L	1660	-3.97	6.99
SW91.9L	400	0.63	1.8	SW91.9L	1710	-3.43	6.99
SW91.9L	440	-2.87	2.03	SW91.9L	1750	-2.91	6.6
SW91.9L	480	-3.78	2.03	SW91.9L	1790	-2.39	6.6
SW91.9L	520	-5.88	2.44	SW91.9L	1840	-2.29	6.72
SW91.9L	570	-6.88	2.44	SW91.9L	1890	-1.58	6.72
SW91.9L	610	-7.84	2.86	SW91.9L	1930	-1.13	7.41
SW91.9L	660	-10.06	2.86	SW91.9L	1970	-0.93	7.41
SW91.9L	700	-10.31	3.48	SW91.9L	2020	-1.15	7.45
SW91.9L	750	-9.45	3.48	SW91.9L	2060	-0.35	7.45
SW91.9L	790	-8.53	3.93	SW91.9L	2100	0.2	7.12
SW91.9L	830	-7.87	3.93	SW91.9L	2150	0.28	7.12
SW91.9L	880	-8.19	6.33	SW91.9L	2190	0.82	7.51
SW91.9L	920	-6.31	6.33	SW91.9L	2240	1.39	7.51
SW91.9L	960	-6.01	6.74	SW91.9L	2280	2	7.55
SW91.9L	1010	-4.84	6.74	SW91.9L	2320	1.81	7.55
SW91.9L	1050	-8	6.71	SW91.9L	2370	2.17	7.45
SW91.9L	1100	-8.28	6.71	SW91.9L	2410	1.79	7.45
SW91.9L	1140	-7.87	6.45	SW91.9L	2460	2.26	6.76
SW91.9L	1180	-7.13	6.45	SW91.9L	2500	2.43	6.76

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW91.9L	2540	2.48	6.39	SW91.9L	4250	6.34	7.32
SW91.9L	2590	2.47	6.39	SW91.9L	4300	5.8	7.32
SW91.9L	2630	0.23	5.59	SW91.9L	4350	5.7	1.59
SW91.9L	2670	-0.55	5.59	SW91.9L	4400	6.3	1.59
SW91.9L	2720	-0.76	4.71	SW91.9L	4450	6.4	1.72
SW91.9L	2760	-1.85	4.71	SW91.9L	4500	6.6	1.72
SW91.9L	2800	-2	4.32	SW91.9L	4550	6.45	2.08
SW91.9L	2850	0.18	4.32	SW91.9L	4600	7.2	2.08
SW91.9L	2890	2.61	3.49	SW91.9L	4650	7.3	2.39
SW91.9L	2900	3.22	3.49	SW91.9L	4700	7.4	2.39
SW91.9L	2920	2.79	2.96	SW91.9L	4750	6.36	3.14
SW91.9L	2940	2.5	2.96	SW91.9L	4800	6.3	3.14
SW91.9L	2960	3.6	2.51	SW91.9L	4850	6.4	3.35
SW91.9L	2980	4.9	2.51	SW91.9L	4900	6.45	3.35
SW91.9L	3000	5.5	2.23	SW91.9L	4950	6.29	3.94
SW91.9L	3030	5.26	2.23	SW91.9L	5000	6.3	3.94
SW91.9L	3050	5.66	1.74	SW91.9L	5050	6.4	4.49
SW91.9L	3100	5.5	1.74	SW91.9L	5100	6.6	4.49
SW91.9L	3150	5.66	1.71	SW91.9L	5150	6.45	4.85
SW91.9L	3200	5.7	1.71	SW91.9L	5200	6.7	4.85
SW91.9L	3250	5.9	1.71	SW91.9L	5250	7.27	6.32
SW91.9L	3300	5.96	1.71	SW91.9L	5300	7.37	6.32
SW91.9L	3350	6.26	1.39	SW91.9L	5350	7.39	6.87
SW91.9L	3400	6.6	1.39	SW91.9L	5400	7.35	6.87
SW91.9L	3450	6.66	1.75	SW91.9L	5450	7.42	7.76
SW91.9L	3500	6.7	1.75	SW91.9L	5500	7.5	7.76
SW91.9L	3550	6.68	1.76	SW91.9L	5550	7.76	8.25
SW91.9L	3600	6.62	1.76	SW91.9L	5600	7.8	8.25
SW91.9L	3650	6.26	1.84	SW91.9L	5650	7.36	8.1
SW91.9L	3700	6.23	1.84	SW91.9L	5700	7.4	8.1
SW91.9L	3750	6.36	3.15	SW91.9L	5750	7.29	8.42
SW91.9L	3800	6.44	3.15	SW91.9L	5800	7.26	8.42
SW91.9L	3850	6.76	4.67	SW91.9L	5850	7.7	8.74
SW91.9L	3900	6.7	4.67	SW91.9L	5900	7.79	8.74
SW91.9L	3950	6.8	4.9	SW91.9L	5950	7.8	7.2
SW91.9L	4000	6.92	4.9	SW91.9L	6000	7.9	7.2
SW91.9L	4050	6.39	5.76	SW91.9L	6050	7.64	6.88
SW91.9L	4100	6.16	5.76	SW91.9L	6100	7.56	6.88
SW91.9L	4150	6.2	7.04	SW91.9L	6150	7.72	5.95
SW91.9L	4200	6.3	7.04	SW91.9L	6200	7.64	5.95

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW91.9L	6250	7.66	4.6	SW91.9L	8150	8.76	3.77
SW91.9L	6300	7.86	4.6	SW91.9L	8200	8.5	3.77
SW91.9L	6350	7.92	4.05	SW91.9L	8250	8.56	3.21
SW91.9L	6400	8.26	4.05	SW91.9L	8300	8.6	3.21
SW91.9L	6450	8.36	3.25	SW91.9L	8350	8.62	2.95
SW91.9L	6500	8.63	3.25	SW91.9L	8400	8.74	2.95
SW91.9L	6550	8.43	3.09	SW91.9L	8450	8.47	2.37
SW91.9L	6600	8.34	3.09	SW91.9L	8500	8.7	2.37
SW91.9L	6650	8.49	2.7	SW91.9L	8550	8.07	2.08
SW91.9L	6700	8.9	2.7	SW91.9L	8600	8.27	2.08
SW91.9L	6750	8.49	2.44	SW91.9L	8650	8.82	1.86
SW91.9L	6800	8.46	2.44	SW91.9L	8700	9.19	1.86
SW91.9L	6850	8.64	2.27	SW91.9L	8750	9.36	1.77
SW91.9L	6900	8.49	2.27	SW91.9L	8800	9.46	1.77
SW91.9L	6950	8.66	1.9	SW91.9L	8850	9.74	1.64
SW91.9L	7000	8.69	1.9	SW91.9L	8900	9.47	1.64
SW91.9L	7050	8.48	1.69	SW91.9L	8950	9.29	1.85
SW91.9L	7100	8.5	1.69	SW91.9L	9000	9.92	1.85
SW91.9L	7150	8.65	4.21	SW91.9L	9050	9.49	1.92
SW91.9L	7200	8.56	4.21	SW91.9L	9100	9.62	1.92
SW91.9L	7250	8.59	4.81	SW91.9L	9150	9.68	2.54
SW91.9L	7300	8.45	4.81	SW91.9L	9200	9.6	2.54
SW91.9L	7350	8.7	7.08	SW91.9L	9250	9.9	3.63
SW91.9L	7400	8.64	7.08	SW91.9L	9300	9.09	3.63
SW91.9L	7433	8.5	5.99	SW91.9L	9350	9.29	5.64
SW91.9L	7433	8.55	5.99	SW91.9L	9400	9.9	5.64
SW91.9L	7450	8.63	7.27	SW91.9L	9450	9.02	4.3
SW91.9L	7500	8.26	7.27	SW91.9L	9500	8.7	4.3
SW91.9L	7550	8.36	7.76	SW91.9L	9550	8.49	5.91
SW91.9L	7600	8.76	7.76	SW91.9L	9600	8.8	5.91
SW91.9L	7650	8.38	7.23	SW91.9L	9650	8.43	5.92
SW91.9L	7700	8.42	7.23	SW91.9L	9700	8.69	5.92
SW91.9L	7750	8.6	6.77	SW91.9L	9750	8.63	6.52
SW91.9L	7800	8.7	6.77	SW91.9L	9800	8.7	6.52
SW91.9L	7850	8.76	6.32	SW91.9L	9850	8.64	7.24
SW91.9L	7900	8.79	6.32	SW91.9L	9900	8.44	7.24
SW91.9L	7950	8.69	6.67	SW91.9L	9950	8.6	7.61
SW91.9L	8000	8.64	6.67	SW91.9L	10000	8.29	7.61
SW91.9L	8050	8.84	5.09	SW91.9L	10050	8.7	7.55
SW91.9L	8100	8.94	5.09	SW91.9L	10100	7.56	7.55

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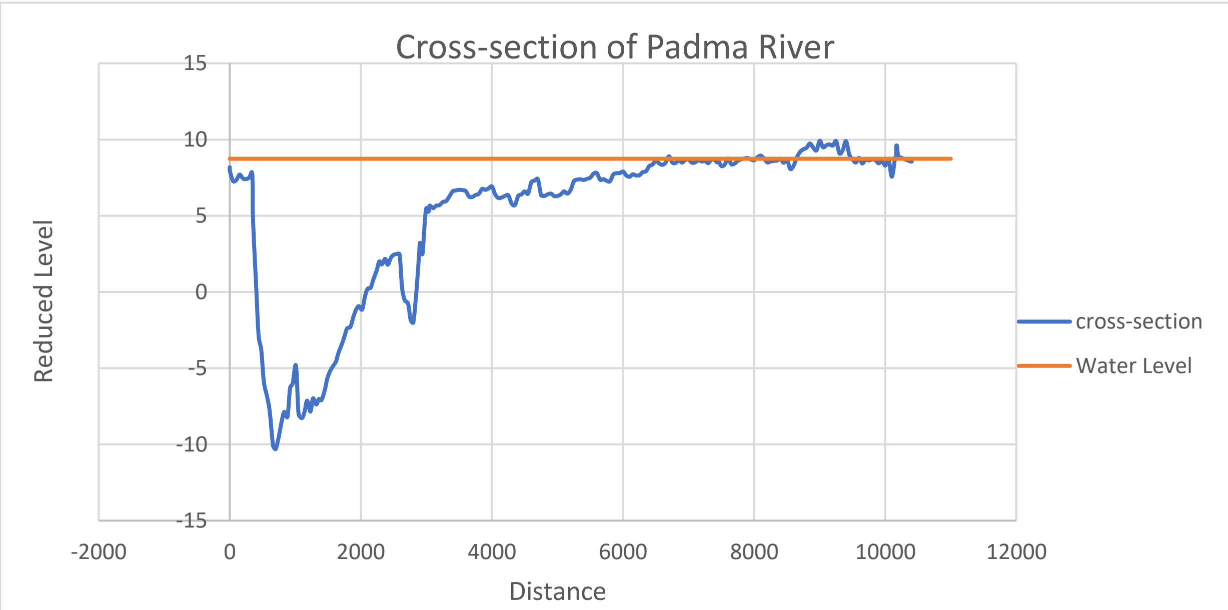
Station ID	Distance	Water Level	RL	Station ID	Distance	RL	Water Level
SW91.9L	10150	7.25	8.8	SW91.9L	10250	8.8	7.65
SW91.9L	10164	7.25	8.88	SW91.9L	10300	8.7	7.65
SW91.9L	10169	8.38	9.6	SW91.9L	10350	8.62	6.59
SW91.9L	10179	8.38	9.6	SW91.9L	10401	8.55	6.59
SW91.9L	10186	8.37	9.22	SW91.9L	10401	8.69	5.58
SW91.9L	10200	8.37	8.9	SW91.9L			

From using the above table data, the cross-section of the Padma River has been plotted in a graph which is shown below



Area calculation of Padma River

Area of Trapezoidal Rule

$$A = D\left(\frac{\text{Rl 1st value} + \text{RL last value}}{2} + \text{Rl all middle value}\right)$$

$= 56242.75 m^2$

Perimeter Calculation of Padma River

Table 8: Perimeter Calculation of Padma River

X1	Y1	X2	Y2	Y2-Y1	Y2-Y1^2	X2-X1	X2-X1^2	(x2-x1)2+(y2-y1)2	Perimeter	total perimeter
0	7.98	50	7.28	-0.7	0.49	50	2500	2500.49	50.0048998	9199.113675
50	7.28	150	7.45	0.17	0.0289	100	10000	10000.0289	100.000144	
200	7.45	340	783	775.55	601477.8	140	19600	621077.8025	788.084895	
340	7.83	600	-10.06	-17.89	320.0521	260	67600	67920.0521	260.614758	
600	-10.06	830	-7.87	2.19	4.7961	230	52900	52904.7961	230.010426	
830	-7.87	880	-8.19	-0.32	0.1024	50	2500	2500.1024	50.001024	
880	-8.19	1010	-4.84	3.35	11.2225	130	16900	16911.2225	130.043156	
1010	-4.84	1050	-8	-3.16	9.9856	40	1600	1609.9856	40.1246259	
1050	-8	1180	-7.13	0.87	0.7569	130	16900	16900.7569	130.002911	
1180	-7.13	1230	-7.85	-0.72	0.5184	50	2500	2500.5184	50.0051837	
1230	-7.85	1270	-6.98	0.87	0.7569	40	1600	1600.7569	40.0094601	
1270	-7.38	1790	-2.39	4.99	24.9001	520	270400	270424.9001	520.023942	
1790	-2.39	2020	-1.15	1.24	1.5376	230	52900	52901.5376	230.003343	
2020	-1.15	2100	0.2	1.35	1.8225	80	6400	6401.8225	80.0113898	
2100	0.2	2280	2	1.8	3.24	180	32400	32403.24	180.009	
2280	2	2540	2.48	0.48	0.2304	260	67600	67600.2304	260.000443	
2540	2.48	2760	-1.85	-4.33	18.7489	220	48400	48418.7489	220.042607	
2760	-1.85	2900	3.22	5.07	25.7049	140	19600	19625.7049	140.091773	
2900	3.21	3030	5.26	2.05	4.2025	130	16900	16904.2025	130.016162	
3030	5.26	3550	6.68	1.42	2.0164	520	270400	270402.0164	520.001939	
3550	6.68	3650	6.26	-0.42	0.1764	100	10000	10000.1764	100.000882	
3650	6.26	3950	6.8	0.54	0.2916	300	90000	90000.2916	300.000486	
3950	6.8	4350	5.7	-1.1	1.21	400	160000	160001.21	400.001512	
4350	5.7	4650	7.3	1.6	2.56	300	90000	90002.56	300.004267	
4650	7.3	5100	6.6	-0.7	0.49	450	202500	202500.49	450.000544	
5100	6.6	5250	7.27	0.67	0.4489	150	22500	22500.4489	150.001496	
5250	7.27	5550	7.76	0.49	0.2401	300	90000	90000.2401	300.0004	
5550	7.76	5750	7.29	-0.47	0.2209	200	40000	40000.2209	200.000552	
5750	7.29	5950	7.8	0.51	0.2601	200	40000	40000.2601	200.00065	
5950	7.8	6050	7.64	-0.16	0.0256	100	10000	10000.0256	100.000128	
6050	7.64	6550	8.43	0.79	0.6241	500	250000	250000.6241	500.000624	
6550	8.43	6650	8.49	0.06	0.0036	100	10000	10000.0036	100.000018	
6650	8.49	7500	8.26	-0.23	0.0529	850	722500	722500.0529	850.000031	
7500	8.26	8600	8.27	0.01	1E-04	1100	1210000	1210000	1100	

Calculated Perimeter of Padma =9199.11375m but considered as 9300m for the calculation purpose.

Sample Calculation of Meghna River

Calculation of cross-sectional area, depth, width, and wetted perimeter at station SW273 for the river of Meghna month of April (2016). The below graph data has been collected from BWDB (via WRE, BUET)

Table 9: Value of Distance and RL of Meghna River

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW273	0	6.76	5.01	SW273	490	1.4	4.25
SW273	0	6.46	5.27	SW273	510	0.7	3.54
SW273	10	4.72	5.34	SW273	530	-0.3	3.65
SW273	16	4.08	5.28	SW273	550	-1.6	3.55
SW273	20	4.25	5.22	SW273	570	-2.5	4.9
SW273	40	4.55	4.82	SW273	590	-2.9	4.91
SW273	50	4.75	4.74	SW273	610	-4.6	4.58
SW273	56	4.6	4.35	SW273	630	-5.3	4.43
SW273	57	3.6	4.4	SW273	650	-6	4.81
SW273	59	4.2	4.26	SW273	670	-6.4	4.97
SW273	61	4.2	4.51	SW273	690	-7	5.51
SW273	62	3.6	4.79	SW273	710	-7.4	6.02
SW273	70	3.6	4.65	SW273	730	-7.8	5.8
SW273	90	3.15	4.36	SW273	750	-7.7	5.47
SW273	100	3.2	4.07	SW273	770	-7.9	4.87
SW273	120	4.1	3.22	SW273	790	-8	4.85
SW273	179	4.25	2.86	SW273	810	-7.3	4.58
SW273	183	3.84	3.12	SW273	830	-8.2	4.36
SW273	184	4.9	4.45	SW273	850	-7	4.21
SW273	189	4.87	5.29	SW273	870	-6.3	4.15
SW273	191	4.47	5.51	SW273	890	-5.1	3.18
SW273	200	4.85	4.67	SW273	900	-4.3	4.66
SW273	230	4.7	5.19	SW273	905	-1.6	4.72
SW273	260	4.75	5.49	SW273	908	-1.2	5.08
SW273	280	4.65	5.69	SW273	910	2.2	5.24
SW273	310	4.72	5.98	SW273	925	3.1	5.78
SW273	350	4.65	5.95	SW273	940	3.5	5.85
SW273	380	4.6	5.75	SW273	980	3.9	5.72
SW273	400	4.68	6.01	SW273	1000	3.95	5.71
SW273	415	4.2	6.13	SW273	1050	4.1	5.65
SW273	418	4.3	6.39	SW273	1080	4.15	5.43
SW273	430	2.95	6.45	SW273	1100	4.05	5.22
SW273	450	2.8	6.06	SW273	1130	4.1	5.61
SW273	480	2.13	5.43	SW273	1160	3.9	5.77
SW273	482	2.2	4.88	SW273	1190	3.8	5.76
SW273	485	1.5	4.67	SW273	1220	3.85	5.89

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW273	1250	3.75	5.86	SW273	1923	2.2	5.25
SW273	1280	3.8	5.86	SW273	1925	1.1	4.84
SW273	1310	3.7	5.48	SW273	1930	0.25	4.98
SW273	1340	3.75	5.39	SW273	1940	-1	5.34
SW273	1352	2.2	4.82	SW273	1950	-2.2	5.29
SW273	1355	1.3	4.14	SW273	1960	-2.3	5.14
SW273	1360	1.1	3.2	SW273	1965	-1.3	4.81
SW273	1380	0.7	3.77	SW273	1970	0.3	3.85
SW273	1400	0.3	3.84	SW273	1975	2.2	3.55
SW273	1420	-0.6	3.84	SW273	1980	4.65	3.82
SW273	1440	-0.9	5.03	SW273	2020	4.55	3.53
SW273	1460	-1.6	5.3	SW273	2040	4.58	4.15
SW273	1480	-1.8	5.41	SW273	2060	4.5	4.25
SW273	1500	-1.5	5.43	SW273	2100	4.55	4.8
SW273	1520	-2.2	5.46	SW273	2150	4.52	5.03
SW273	1540	-2.4	5.66	SW273	2200	4.42	5.14
SW273	1560	-2.6	5.91	SW273	2250	3.45	5.09
SW273	1580	-3.3	6.06	SW273	2280	3.5	5.07
SW273	1600	-3.8	5.87	SW273	2300	3.45	5.23
SW273	1620	-3.2	5.48	SW273	2340	3.55	5.37
SW273	1640	-2.4	5.06	SW273	2380	4.25	5.25
SW273	1660	-1.9	5.05	SW273	2410	4.45	5.23
SW273	1680	-2.1	5.09	SW273	2450	4.65	5.51
SW273	1700	-1.1	4.82	SW273	2480	4.72	5.2
SW273	1720	-0.3	4.01	SW273	2520	4.75	4.57
SW273	1740	0.1	3.4	SW273	2550	4.7	4.02
SW273	1760	0.3	3.22	SW273	2580	4.75	4.08
SW273	1780	0.5	3.58	SW273	2610	4.7	4
SW273	1790	0.7	3.79	SW273	2650	4.82	3.75
SW273	1800	1.25	4.5	SW273	2680	4.8	3.18
SW273	1802	2.2	4.9	SW273	2710	4.9	2.86
SW273	1820	2.9	5.55	SW273	2717	5.2	3.26
SW273	1830	3.4	5.32	SW273	2717	5.3	3.6
SW273	1860	3.2	5.71	SW273	2750	5.35	4.31
SW273	1880	3.15	5.96	SW273	2780	5.4	4.79
SW273	1890	3.1	5.68	SW273	2800	5.6	4.83
SW273	1900	3.05	5.5	SW273	2830	5.65	5.17
SW273	1905	3.15	5.22	SW273	2850	5.6	4.9
SW273	1910	2.55	5.25	SW273	2870	5.65	4.92
SW273	1922	2.4	5.24	SW273	2890	5.8	4.62

Similar as Padma River calculation of Meghna River

Area = 190223.55 m^2

Width = 13914 m

Wetted perimeter = 14901.85 m

Depth = 13.67

Sample Calculation of Jamuna River

Calculation of cross-sectional area, depth, width, and wetted perimeter at station SW46.9L for the river of Jamuna month of April (2016). The below graph data has been collected from BWDB (via WRE, BUET)

Table 10: Value of Distance and RL of Jamuna River

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW46.9L	0	18.21	13.18	SW46.9L	1691	10.87	12.59
SW46.9L	0	18.14	13.16	SW46.9L	1700	14.9	12.57
SW46.9L	70	18.45	13.15	SW46.9L	1770	15.6	12.55
SW46.9L	140	19.36	13.12	SW46.9L	1840	15.8	12.52
SW46.9L	210	17.5	13.1	SW46.9L	1910	15.87	12.48
SW46.9L	280	16.96	13.07	SW46.9L	1980	16	12.47
SW46.9L	350	16.9	13.03	SW46.9L	2050	16.1	12.45
SW46.9L	420	16.88	13	SW46.9L	2120	16.03	12.43
SW46.9L	490	16.93	12.97	SW46.9L	2190	16.08	12.41
SW46.9L	560	16.96	12.97	SW46.9L	2260	15.98	12.39
SW46.9L	630	17	12.95	SW46.9L	2330	15.99	12.38
SW46.9L	700	17.02	12.93	SW46.9L	2400	16.2	12.36
SW46.9L	770	16.98	12.92	SW46.9L	2470	16.37	12.35
SW46.9L	840	16.96	12.91	SW46.9L	2540	16.42	12.33
SW46.9L	910	16.98	12.91	SW46.9L	2610	16.48	12.32
SW46.9L	980	16.93	12.89	SW46.9L	2680	16.46	12.31
SW46.9L	1050	16.95	12.89	SW46.9L	2750	16.5	12.3
SW46.9L	1120	16.99	12.87	SW46.9L	2820	16.8	12.28
SW46.9L	1190	14.9	12.85	SW46.9L	2890	17.79	12.26
SW46.9L	1200	10	12.84	SW46.9L	2960	16.76	12.25
SW46.9L	1210	9.71	12.82	SW46.9L	3030	16.75	12.25
SW46.9L	1240	9.14	12.81	SW46.9L	3100	16.89	12.25
SW46.9L	1271	10.27	12.79	SW46.9L	3170	17.02	12.24
SW46.9L	1304	10.4	12.78	SW46.9L	3240	17	12.24
SW46.9L	1332	10.6	12.78	SW46.9L	3310	16.89	12.23
SW46.9L	1361	10.94	12.76	SW46.9L	3380	16.86	12.22
SW46.9L	1391	11.36	12.76	SW46.9L	3450	16.82	12.21
SW46.9L	1421	11.36	12.75	SW46.9L	3520	16.18	12.21
SW46.9L	1456	11.36	12.74	SW46.9L	3590	16.12	12.22
SW46.9L	1484	11.36	12.73	SW46.9L	3660	16	12.25
SW46.9L	1516	11.36	12.72	SW46.9L	3711	15	12.27
SW46.9L	1549	11.28	12.7	SW46.9L	3731	10.2	12.29
SW46.9L	1584	11.21	12.67	SW46.9L	3761	11.15	12.32
SW46.9L	1615	10.01	12.66	SW46.9L	3795	11.06	12.37
SW46.9L	1646	10.95	12.64	SW46.9L	3826	11.06	12.41
SW46.9L	1675	10.84	12.6	SW46.9L	3856	11.07	12.47

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW46.9L	4005	8.98	12.47	SW46.9L	5874	9.44	13.33
SW46.9L	4021	9.55	12.47	SW46.9L	5907	10.33	13.35
SW46.9L	4031	15	12.44	SW46.9L	5927	11.16	13.43
SW46.9L	4100	16.8	12.42	SW46.9L	5947	15	13.45
SW46.9L	4170	17.3	12.42	SW46.9L	6000	16.28	13.49
SW46.9L	4240	17.33	12.42	SW46.9L	6070	16.39	13.5
SW46.9L	4310	17.84	12.45	SW46.9L	6130	16.5	13.5
SW46.9L	4380	17.22	12.47	SW46.9L	6200	16.2	13.48
SW46.9L	4450	17.28	12.44	SW46.9L	6270	16.38	13.46
SW46.9L	4520	17.4	12.43	SW46.9L	6340	16.62	13.45
SW46.9L	4590	17.18	12.43	SW46.9L	6410	16.84	13.45
SW46.9L	4660	17.28	12.44	SW46.9L	6480	16.52	13.5
SW46.9L	4730	16.8	12.46	SW46.9L	6550	16.88	13.55
SW46.9L	4800	16.89	12.5	SW46.9L	6620	16.92	13.56
SW46.9L	4870	16.98	12.55	SW46.9L	6690	16.93	13.61
SW46.9L	4940	16.92	12.56	SW46.9L	6760	17	13.64
SW46.9L	5010	17.03	12.55	SW46.9L	6830	17.03	13.69
SW46.9L	5080	17	12.54	SW46.9L	6900	17.08	13.75
SW46.9L	5150	16.88	12.56	SW46.9L	6970	17.1	13.82
SW46.9L	5220	16.84	12.59	SW46.9L	7040	16.89	14.05
SW46.9L	5261	15	12.61	SW46.9L	7110	16.92	14.15
SW46.9L	5284	9.31	12.62	SW46.9L	7180	16.8	14.24
SW46.9L	5314	9.44	12.67	SW46.9L	7250	16.76	14.26
SW46.9L	5345	9.59	12.77	SW46.9L	7320	16.6	14.3
SW46.9L	5374	11.03	12.88	SW46.9L	7390	16.52	14.54
SW46.9L	5404	10.4	12.96	SW46.9L	7460	16.8	14.77
SW46.9L	5435	9.86	12.96	SW46.9L	7530	17.1	14.85
SW46.9L	5464	9.87	12.91	SW46.9L	7600	17.13	14.82
SW46.9L	5494	10.23	12.89	SW46.9L	7670	17	14.95
SW46.9L	5523	10.04	12.84	SW46.9L	7740	17.02	15.69
SW46.9L	5555	10.16	12.83	SW46.9L	7810	17.12	16.12
SW46.9L	5587	11.02	12.87	SW46.9L	7880	17.1	16.2
SW46.9L	5619	10.62	13.04	SW46.9L	7950	16.96	16.19
SW46.9L	5654	10.26	13.31	SW46.9L	8020	16.9	16.26
SW46.9L	5678	10.35	13.44	SW46.9L	8090	16.7	16.21
SW46.9L	5711	10.53	13.47	SW46.9L	8160	16.65	16.12
SW46.9L	5743	10.39	13.42	SW46.9L	8230	16.5	16.16
SW46.9L	5776	10.07	13.37	SW46.9L	8300	16.61	16.29
SW46.9L	5808	9.78	13.33	SW46.9L	8370	16.38	16.25
SW46.9L	5841	9.34	13.32	SW46.9L	8440	16.42	16.2

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW46.9L	8510	16.55	16.2	SW46.9L	10120	10.2	18.5
SW46.9L	8580	16.57	16.32	SW46.9L	10150	11	18.61
SW46.9L	8650	16.62	16.57	SW46.9L	10180	12.4	18.54
SW46.9L	8720	16.54	16.91	SW46.9L	10210	12.2	18.5
SW46.9L	8790	16.4	17.22	SW46.9L	10240	12.8	18.33
SW46.9L	8860	16.33	17.31	SW46.9L	10270	13.1	18.27
SW46.9L	8930	16.38	17.25	SW46.9L	10290	13.1	18.17
SW46.9L	9000	16.25	17.24	SW46.9L	10300	15.5	18.07
SW46.9L	9070	16.3	17.34	SW46.9L	10370	16.82	17.92
SW46.9L	9140	16.3	17.37	SW46.9L	10440	17	17.75
SW46.9L	9180	16.19	17.2	SW46.9L	10510	18.2	17.59
SW46.9L	9217	15.5	17.01	SW46.9L	10580	18.12	17.46
SW46.9L	9237	9.5	16.99	SW46.9L	10650	18.14	17.43
SW46.9L	9270	9.68	16.99	SW46.9L	10720	18	17.41
SW46.9L	9301	10.16	17.08	SW46.9L	10790	18.17	17.43
SW46.9L	9330	11.13	17.13	SW46.9L	10860	18.35	17.47
SW46.9L	9363	10.89	17.19	SW46.9L	10930	18.36	17.6
SW46.9L	9391	10.74	17.18	SW46.9L	11000	18.12	17.58
SW46.9L	9424	10.21	17.05	SW46.9L	11070	18.05	17.63
SW46.9L	9457	9.88	17.03	SW46.9L	11140	18.1	17.74
SW46.9L	9485	9.28	17.08	SW46.9L	11210	18.52	17.77
SW46.9L	9519	9	17.11	SW46.9L	11280	18.8	17.73
SW46.9L	9549	8.43	17.2	SW46.9L	11350	18.82	17.7
SW46.9L	9584	8.07	17.33	SW46.9L	11420	18.79	17.42
SW46.9L	9615	7.62	17.69	SW46.9L	11490	18.67	17.3
SW46.9L	9646	7.75	18.12	SW46.9L	11560	18.72	17.27
SW46.9L	9677	7.6	18.27	SW46.9L	11630	18.7	17.11
SW46.9L	9705	7.44	18.24	SW46.9L	11700	18.68	17.16
SW46.9L	9739	7.6	18.45	SW46.9L	11770	18.71	17.38
SW46.9L	9770	7.7	18.8	SW46.9L	11840	18.65	17.6
SW46.9L	9800	8.09	18.88	SW46.9L	11910	18.6	17.99
SW46.9L	9831	9.01	18.89	SW46.9L	11980	18.63	18.21
SW46.9L	9860	9.1	18.87	SW46.9L	12050	18.68	18.4
SW46.9L	9892	9.1	18.85	SW46.9L	12120	18.22	18.65
SW46.9L	9924	9.26	18.84	SW46.9L	12190	18.18	18.82
SW46.9L	9954	9.69	18.71	SW46.9L	12260	18.12	19
SW46.9L	9987	11.08	18.51	SW46.9L	12330	18.17	19.04
SW46.9L	10016	9.71	18.45	SW46.9L	12400	18.36	19.03
SW46.9L	10045	9.8	18.35	SW46.9L	12470	18.53	19
SW46.9L	10076	10.8	18.28	SW46.9L	12540	18.82	19.1
SW46.9L	10098	10.82	18.38	SW46.9L	12610	18.82	19.28

Station ID	Distance	RL	Water Level	Station ID	Distance	RL	Water Level
SW46.9L	12680	18.61	19.38	SW46.9L	13914	22.2	13914
SW46.9L	12750	18.6	19.54	SW46.9L	13918	22.21	13918
SW46.9L	12820	18.3	19.62	SW46.9L	13924	17.7	17.35
SW46.9L	12890	18.2	19.65	SW46.9L	13990	17.72	17.27
SW46.9L	12960	17.6	19.81	SW46.9L	14050	17.83	17.16
SW46.9L	13030	18	19.95	SW46.9L	14120	17.9	17.14
SW46.9L	13100	18.6	20.1	SW46.9L	14190	17.92	17.08
SW46.9L	13165	18.55	20.13	SW46.9L	14260	17.51	16.87
SW46.9L	13167	19.56	20.06	SW46.9L	14310	17.89	16.72
SW46.9L	13170	19.55	19.79	SW46.9L	14380	17.55	16.54
SW46.9L	13172	18.47	19.44	SW46.9L	14450	17.52	16.43
SW46.9L	13240	16.7	19.12	SW46.9L	14520	17.42	16.36
SW46.9L	13310	16.82	18.92	SW46.9L	14590	17	16.33
SW46.9L	13380	16.72	18.81	SW46.9L	14660	16.83	16.26
SW46.9L	13450	16.33	18.62	SW46.9L	14730	16.76	16.2
SW46.9L	13520	17.33	18.49	SW46.9L	14770	16.81	16.27
SW46.9L	13590	17.38	18.4	SW46.9L	14772	18.3	16.6
SW46.9L	13660	17.5	18.3	SW46.9L	14775	18.3	16.63
SW46.9L	13730	17.34	18.19	SW46.9L	14777	17.12	16.51
SW46.9L	13800	17.32	18.04	SW46.9L	14850	17.06	16.39
SW46.9L	13870	17.52	17.87	SW46.9L	14900	17.32	16.35
SW46.9L	13900	17.6	17.69	SW46.9L	14900	17.6	16.34
SW46.9L	13907	17.82	17.57	SW46.9L			

Similar as Padma River calculation of Jamuna River

Area = 5284 m^2

Width = 3000 m

Wetted perimeter = 3000 m

Depth = 1.76 m

Comparison Among All Empirical Equations for Meghna River

Table 11: Comparison Among All Empirical Equations for Meghna River

Comparison Among All Empirical Equations for Meghna River		
Sediment Transport Equation	**Sediment Transport (ton/day)**	**Percent Variation**
Hossain's	43.1085	99.10134159
C. T. Yang	3.5272	99.92647047
Engelund and Hansen	4466.94	6.880239751
Mayer-Peter and Muller	0.2363	99.99507399
L.C Van Rijn	4796.984	0
Ackers and White	1.659	99.96541577

Comparison Among All Empirical Equations for Jamuna River

Table 12: Comparison Among All Empirical Equations for Jamuna River

Comparison Among All Empirical Equations for Jamuna River		
Sediment Transport Equation	**Sediment Transport (ton/day)**	**Percent Variation**
Hossain's	5.06	99.93743395
C. T. Yang	96.2878	98.8094175
Engelund and Hansen	2006608.019	24711.37163
Mayer-Peter and Muller	26.57	99.67146641
L.C Van Rijn	8087.453	0
Ackers and White	344.804	95.73655637

Sensitivity Analysis of Meghna River

Table 13: Sensitivity Analysis of Hossain's Equation in Meghna River

Sensitivity Calculation of Hossain's Equation in Meghna River							
Sediment Transport Equation	Calculated C_t (ton/day)	Depth		Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Hossain	42.9825	40.4394	45.8286	44.5738	41.3709	42.9956	42.9679
	Variation (%)	5.9165	6.6215	3.7022	3.74943	0.03047	0.03396

Table 14: Sensitivity Calculation of C.T Yang's Equation in Meghna River

Sensitivity Calculation of C.T Yang's Equation in Meghna River							
Sediment Transport Equation	Calculated C_t (ton/day)	Depth		Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Yang	7.2022	7.3082	7.0909	7.8462	6.5787	7.5793	6.8208
	Variation (%)	1.4717	1.5453	8.9417	8.65707	5.2359	5.2956

Table 15: Sensitivity Calculation of Engelund and Hansen's Equation in Meghna River

Sensitivity Calculation of Engelund and Hansen's Equation in Meghna River					
Sediment Transport Equation	Calculated g_s (ton/day)	Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Engelund and Hansen	4466.8278	4924.6776	4031.312	4254.1216	4701.9239
	Variation (%)	0.2499	9.7500	4.76190	5.2632

Table 16: Sensitivity Calculation of Mayer-Peter and Muller’s Equation in Meghna River

Sensitivity Calculation of Mayer-Peter and Muller’s Equation in Meghna River			
Sediment Transport Equation	Calculated g_s (ton/day)	Diameter	
		Increasing 5%	Decreasing 5%
Mayer-Peter and Muller	5.2583	1.7803	9.7979
	Variation (%)	66.1430	86.3320

Table 17: Sensitivity Calculation of L.C Van Rijn's Equation in Meghna River

Sensitivity Calculation of L.C Van Rijn's Equation in Meghna River					
Sediment Transport Equation	Calculated q_s (ton/day)	Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
L.C Van Rijn	4796.9846	6056.1419	3740.9655	4587.8317	5022.6548
	Variation (%)	26.2489	22.01422	4.36009	4.7044

Table 18: Sensitivity Calculation of Ackers and White's Equation in Meghna River

Sensitivity Calculation of Ackers and White's Equation in Meghna River					
Sediment Transport Equation	Calculated q_t (ton/day)	Velocity		Depth	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Ackers and White	1.6527	2.03642	1.3228	1.8088	1.4999
	Variation (%)	23.2161	19.9603	9.4453	9.2425

Most Sensitive Hydraulic Parameter of Meghna River

Table 19: Most Sensitive Parameter of Meghna River

Equation	Most sensitive parameter with variation of ± 5%	
Hossain's	Depth	(6-7) %
C. T. Yang	Velocity	(7-8) %
Engelund and Hansen	Velocity	(9-10) %
Mayer-Peter and Muller	Sediment size	(65-86) %
L.C Van Rijn	Depth	(22-26) %
Ackers and White	Velocity	(19-23) %

Sensitivity Analysis of Jamuna River

Table 20: Sensitivity Calculation of Hossain's Equation in Jamuna River

Sensitivity Calculation of Hossain's Equation in Jamuna River							
Sediment Transport Equation	Calculated C_t (ton/day)	Depth		Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Hossain	5.0672	4.7676	5.4027	5.2547	4.8772	5.0684	5.0657
	Variation (%)	5.9125	-6.6210	3.7002	3.7496	0.0236	0.029

Table 21: Sensitivity Calculation of C.T Yang's Equation in Jamuna River

Sensitivity Calculation of C.T Yang's Equation in Jamuna River							
Sediment Transport Equation	Calculated C_t (ton/day)	Depth		Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Yang	100.4566	101.2116	99.6679	107.4902	93.5416	103.9674	96.8895
	Variation (%)	-0.7515	0.7851	-7.0016	6.8835	-3.4948	3.5508

Table 22: Sensitivity Calculation of Engelund and Hansen's Equation in Jamuna River

Sensitivity Calculation of Engelund and Hansen's Equation in Jamuna River					
Sediment Transport Equation	Calculated g_s (ton/day)	Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Engelund and Hansen	2006608.019	2212285.341	1810963.737	1911055.256	2112218.967
	Variation (%)	10.25	9.7500	4.7619	5.2631

Table 23: Sensitivity Calculation of Mayer-Peter and Muller's Equation in Jamuna River

Sensitivity Calculation of Mayer-Peter and Muller's Equation in Jamuna River			
Sediment Transport Equation	Calculated g_s (ton/day)	Diameter	
		Increasing 5%	Decreasing 5%
Mayer-Peter and Muller	26.4718	6.821	53.3278
	Variation (%)	74.2329	101.4513

Table 24: Sensitivity Calculation of L.C Van Rijn's Equation in Jamuna River

Sensitivity Calculation of L.C Van Rijn's Equation in Jamuna River					
Sediment Transport Equation	Calculated q_s (ton/day)	Velocity		Diameter	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
L.C Van Rijn	8087.45333	10451.53404	6131.181432	7635.454853	8575.870377
	Variation (%)	29.2314	24.1889	5.5888	6.0391

Table 25: Sensitivity Calculation of Ackers and White's Equation in Jamuna River

Sensitivity Calculation of Ackers and White's Equation in Jamuna River					
Sediment Transport Equation	Calculated q_t (ton/day)	Velocity		Depth	
		Increasing 5%	Decreasing 5%	Increasing 5%	Decreasing 5%
Ackers and White	344.9521	401.9463	293.6002	358.8053	330.894
	Variation (%)	16.5223	14.8866	4.0159	4.0751

Most Sensitive Hydraulic Parameter of Jamuna River

Table 26: Most Sensitive Parameter of Jamuna River

Equation	**Most sensitive parameter with variation of ± 5%**	
Hossain’s	Depth	(6-7) %
C. T. Yang	Velocity	(7-8) %
Engelund and Hansen	Velocity	(9-10) %
Mayer-Peter and Muller	Sediment size	(70-100)-%
L.C Van Rijn	Depth	(24-30) %
Ackers and White	Velocity	(14-16) %