# CHARACTERIZATION OF OPEN CHANNEL FLOW PARAMETERS OF THE RIVER GORAI

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## ABSTRACT

*Gorai River is the principal right bank distributary of the Ganges River. It is an important provider of fresh water inflows to southwestern region of Bangladesh. Bangladesh is located in the lower part of the GBM delta having flat land formed mainly by the sediments deposited by the three largest rivers the Ganges, the Brahmaputra and the Meghna. Huge quantity of flow during monsoon coming from the upper catchments makes its way towards the sea through these rivers. Reliable stage and flood frequency estimates are vital for floodplain management and for the protection of public infrastructure. This study presents the results of trend and statistical analysis based on Gorai River. Required data for this study are processed by MIKE-11 and parameters like hydraulic radius, top width, conveyance and cross sectional area are determined at different water levels. An investigation of the behavior of various hydrologic parameters of Gorai is performed which includes frequency analysis for different return periods and goodness-of-fit test (chi-square test). It has been found that the chi square test fits the Log-Normal distribution mostly for the available data. From trend analysis, it has been found that flow and stage both have a decreasing or increasing trend in last few years. And for annual trend analysis of the station Gorai Railway Bridge, it has been seen that maximum, minimum water level have decreasing tendency, where as average water level has an opposite trend in last few years. Seasonal analysis is done for three different seasons (pre monsoon, monsoon and post monsoon) of Bangladesh and the results show that maximum water level of monsoon period of Gorai Railway Bridge station have decreasing trend, where as minimum and average water level have increasing trend in the last few years.*

**Keywords:** *G-K project, Ganges, Gorai, MIKK-11*

## 1. INTRODUCTION

Being the distributary of the Ganges, Gorai River is an important artery for Bangladesh. The river is used for navigation, fisheries, agriculture and domestic purposes. Besides this, the fresh water flow of the river is also important to the ecology and economy of the mangrove forests situated along the coast. To maintain the flow of the river, continuous struggle against natural forces in terms of dredging and river training would be necessary. Hydrologic parameters of the river could give an over view of hydrologic process of the river.

“Gorai River Restoration Project (GRRP)” is implemented by Bangladesh government to meet the urgent need of dredging Gorai River to restore the dry-season’s flow volume in SWR and the regional ecological balance. The article on “Irregularities cloud Gorai River dredging” states the present working condition of the restoration projects of the river. Phase-I of the restoration Project ended in November 2009. The Gorai River Restoration Project Phase-II, which began on December 2, 2010, is scheduled to be completed in June 2012. Islam & Gnauck (2012) developed study on “Water Shortage in the Gorai River Basin and Damage of Mangrove Wetland Ecosystems in Sundarban, Bangladesh” to investigate the shortage of fresh water in the Ganges-Gorai basins and their negative impacts on socio-economy and mangrove wetland ecosystems in the Sundarbans in Bangladesh after construction of Farakka Barrage on the Ganges River water flow has reduced significantly in the downstream.

“The Gorai river excavation project” was conducted to oppose the drying up of the Gorai River. The water flow in the Gorai River had gradually decreased and sedimentation had increased from 1980-1990, which causes the river to fall dry during increasingly longer periods. This, in combination with the increased salinity intrusion in the downstream part, had a negative impact on river-dependent activities such as agriculture, trade, transport, fisheries, logging, environment and domestic use. Paul (2010) discussed the impacts of these problems in the study “Gorai River and its Environmental Flow Problems, opportunities and threats”. Many development projects like- Sundarban Biodiversity project are being hampered due to low flow in Gorai.

Mirza (1998) carried out a research work on "Diversion of the Ganges Water at Farakka and Its Effects on Salinity in Bangladesh". India commissioned a barrage on the Ganges River at Farakka in April 1975 to divert water and make the Bhagirathi-Hooghly River navigable. The diversion has reduced the dry season discharge of the Ganges and Gorai rivers in Bangladesh. Reduced discharge in the Gorai River has induced accelerated sedimentation and increased salinity in the southwest region of Bangladesh. Empirical analyses demonstrate the relationship between discharge in the Gorai River and salinity. Analyses also determine the requirement of flow for the Ganges and Gorai rivers to keep salinity at threshold limits. Kader (2000) worked on " Effectiveness of Pilot Dredging in the Gorai River" considering a 30 km reach of Gorai which is studied to estimate changes in dredged bed levels and alignments at different discharge scenarios. The changes are computed using the MIKE21 hydro-morphological software which allows the study to estimate effective discharge responsible for low flow bed formation. Sarker et al. (2002) studied the morphological changes of the Gorai in response to the declining flow using remote sensing.

Naser, Bhuiyan, Dutta and Dushmanta (2012) presented a paper on "Assessing impacts of sea level rise on river salinity in the Gorai river network, Bangladesh". The outcomes of the study was conducted in the coastal area of Gorai river network in the South West region of Bangladesh for developing a comprehensive understanding of the possible effects of sea level rise with the aid of a hydrodynamic model. Islam and Karim (2005) developed a study on "Predicting downstream hydraulic geometry of the Gorai River" where the geometry of Gorai River in terms of bank full width, average flow depth & mean flow velocity had been examined.

The studies mentioned above mainly focused on many problem and their impacts on Gorai River. But this study mainly focused for in-depth analysis about Statistical distribution of design parameters and finds the best fit distribution pattern using Goodness of Fit test as well as seasonal trend analysis of Average, Maximum and Minimum Water Level; Average, Maximum and Minimum Discharge. To achieve these data are processed in MIKE 11 using cross sections as input data to obtain hydraulic radius (R), cross sectional area (A), top width (B), conveyance (K) as output. Trend analysis of hydraulic radius (R), cross sectional area (A), top width (B), conveyance (K) at same water levels are used for different points of the river.

## 2. METHODOLOGY

### 2.1 Study Area

Gorai-Madhumati River is the principal distributary of the Ganges. The same river has been named as the Gorai in the upper course and Madhumati in the lower course. The Gorai takes off from the Ganges at Talbaria, north of Kushtia town and 19 km downstream from Hardinge Bridge. South of Kushtia its first offshoot, the Kaliganga branches off to join the Kumar near Shailkupa. This river has been dammed by one of the primary canals of the Ganges-Kobadak irrigation project (G-K Project) and the lower half of the course is now almost a dry bed. The main river bifurcates and rejoins several times as it flows southeast to Mohammadpur upazila in Magura district. From here it changes its name to Madhumati. The Kumar, the nabaganga and the chitra join it through several channels south of Mollahat upazila. There it changes its name to Baleshwar, which in turn changes to Haringhata from the Bogi forest outpost of the Sundarban. The Gorai-Madhumati has a flood discharge of nearly 7,000 cumec but in winter its flow goes down to five cumec.

All the rivers between the Khulna-Ichamati, Ganges, Gorai-Madhumati and the Bay of Bengal are connected by cross-channels, which are especially numerous in the Sundarbans. They are of great importance for inland navigation in the delta. The Gorai is a very old river. Its early name was Gauri. The famous geographer and astronomer Ptolemy noticed about five estuarine mouths of the Ganges. One of those, the 'Kambari Khan', was perhaps the Gorai. The course of the Gorai-Madhumati is wide, long and meandering. From its originating point at Kamarkhali, it is navigable by boats in the monsoon, but in the dry season it becomes non-navigable. In the downstream it is navigable throughout the year. Maximum recorded flow at Kamarkhali is 7,932 cumec. The breadth of the river increases as it flows down and at the end it is about 3 km. Study area is shown in Figure 1.

### 2.2 Data Collection

Discharge and water level measurements of the Gorai River at the Gorai Railway Bridge station & Kamarkhali Transit station situated in Khulna division (Figure 2) are collected from Bangladesh Water Development Board (BWDB), were processed in this study. Yearly data of 22 years (from 1991 to 2012) of water level and stream flow of Gorai River for both stations were collected from BWDB. Cross sectional data includes forty two station ID's of Gorai named as RMGM1 to RMGM42 and the reduced levels are provided from a certain distance from the bank of the river. The hydrologic data includes water level data and discharge data. Water levels are in the form of mean daily water level (MDWL) and discharge data is obtained in the form of mean daily discharge (MDD). The provided data contains water level of 22 years from 1991 to 2012 of both the stations and discharge data is provided for 16 years in case of Gorai Railway Bridge station.

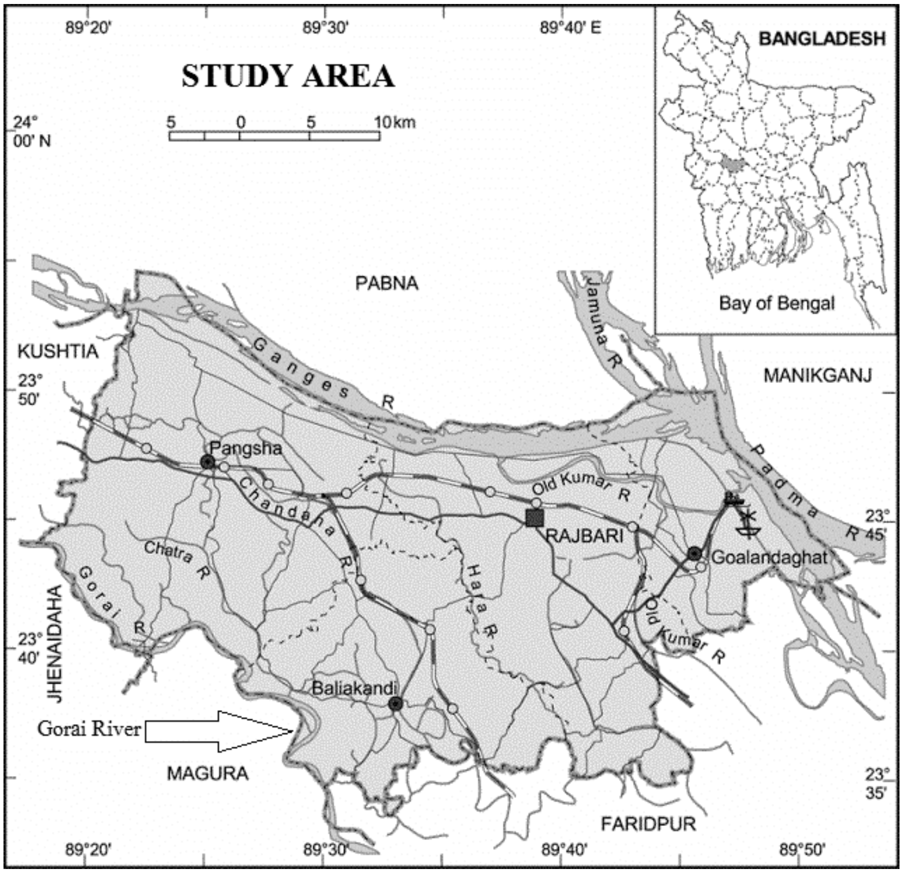



Figure 1: Study Area (http://mapofbangladesh.blogspot.com/)

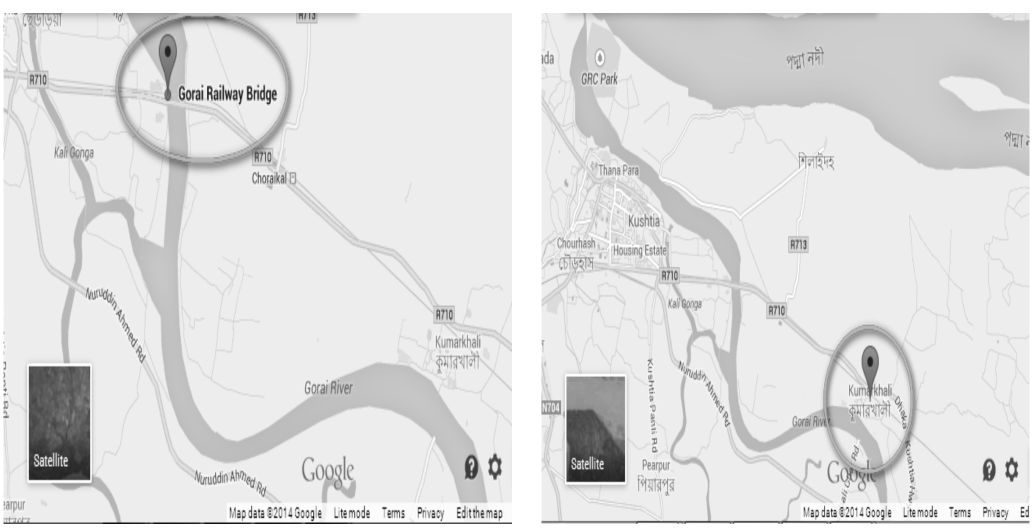



Figure 2: Two stations of Gorai River

## 2.3 Analysis

## 2.4 Processing of Data With Mike-11

The cross sectional data of Gorai River obtained from BWDB is processed through MIKE-11. Forty-two cross sections are provided in the data, denoted as RMGM1 to RMGM42. After the entry of bathymetry data into MIKE-11, data are processed (Figure 3 and 4) and for a definite water level, the corresponding values of cross sectional area, hydraulic radius, storage width, conveyance are determined by MIKE-11.

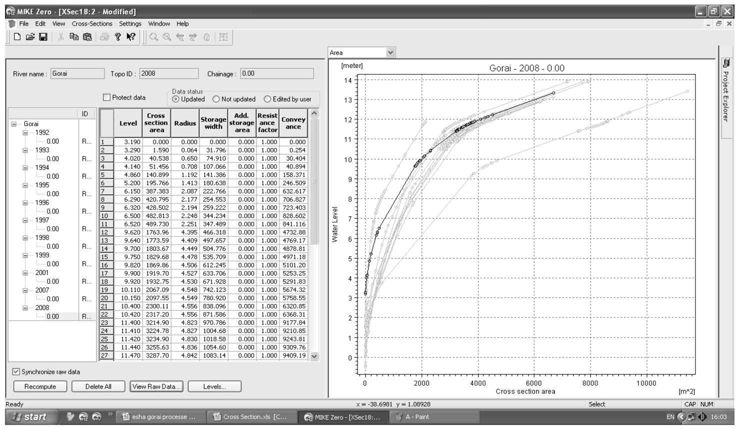



Figure 3: Water level vs Cross sectional area of Station RMGM9

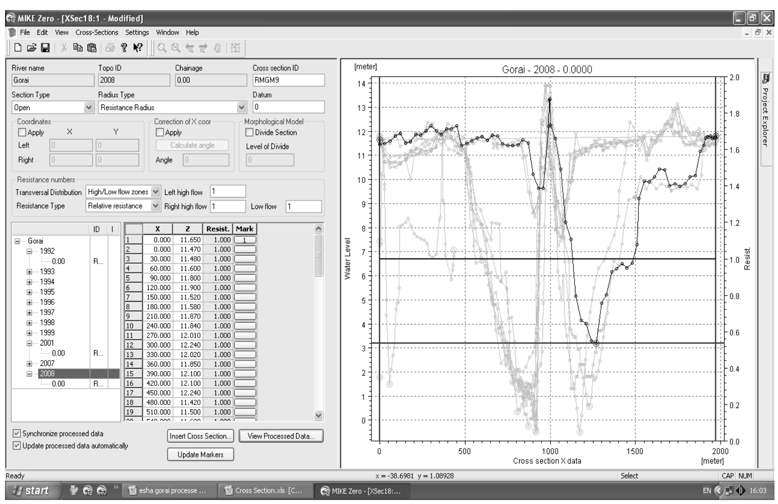



Figure 4: Water level vs Cross Section of Station RMGM9

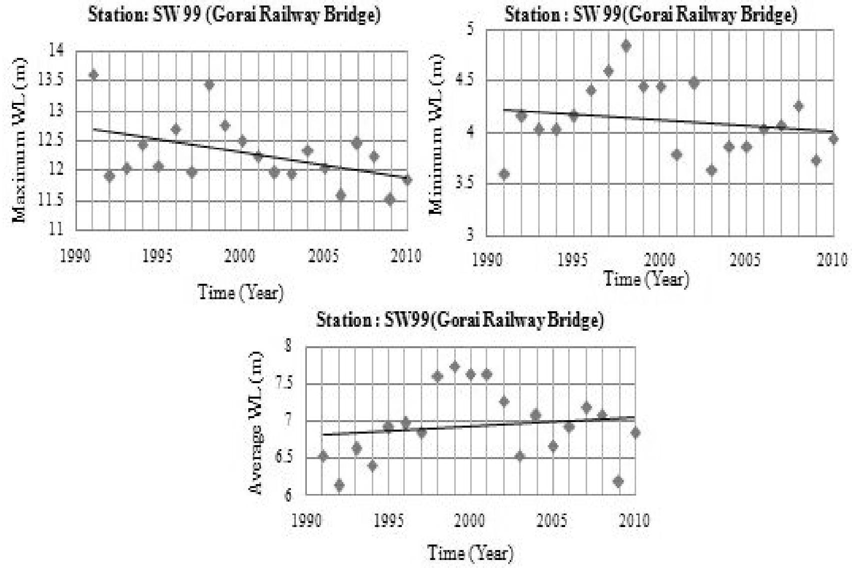
### 2.4.1 Trend Analysis

The data that are collected from BWDB are analyzed by trend analysis. Trend Analysis is the practice of collecting information and attempting to spot a pattern, or trend, in the information. Although trend analysis is often used to predict future events, it could be used to estimate uncertain events in the past.
Two types of trend analysis are done:

i) Annual trend analysis
ii) Seasonal trend analysis

#### *2.4.1.1 Annual trend analysis*

Annual trend analysis of water level and discharge of two stations are shown in Figure 5 and 6.

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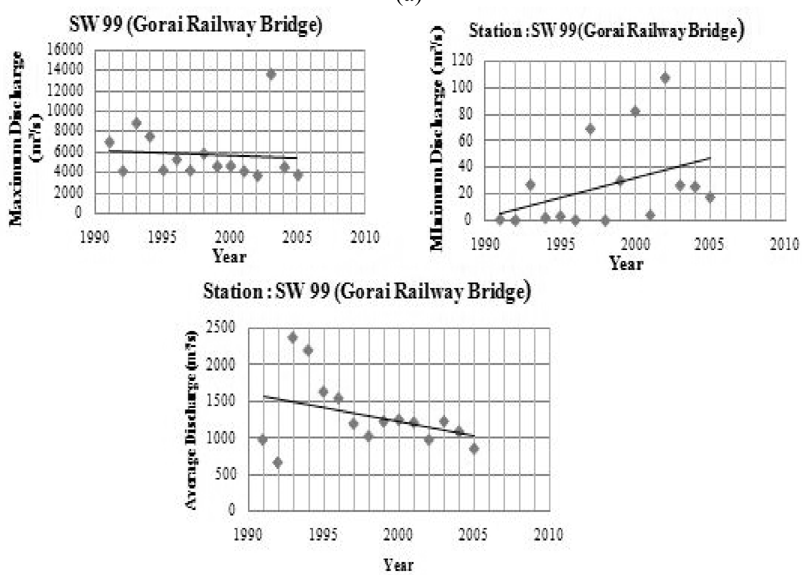



(b)

Figure 5: (a) Trends of Maximum, Minimum, and Average Water Level of Gorai Railway Bridge (b) Trends of Maximum, Minimum, and Average Discharge of Gorai Railway Bridge

From Figure 5 it is seen that (a) The trend line of maximum and minimum Water Level of Gorai Railway Bridge with time is decreasing average water level is increasing (b) The trend line of maximum and average Discharge of Gorai Railway Bridge with time is decreasing but for minimum discharge is increasing.

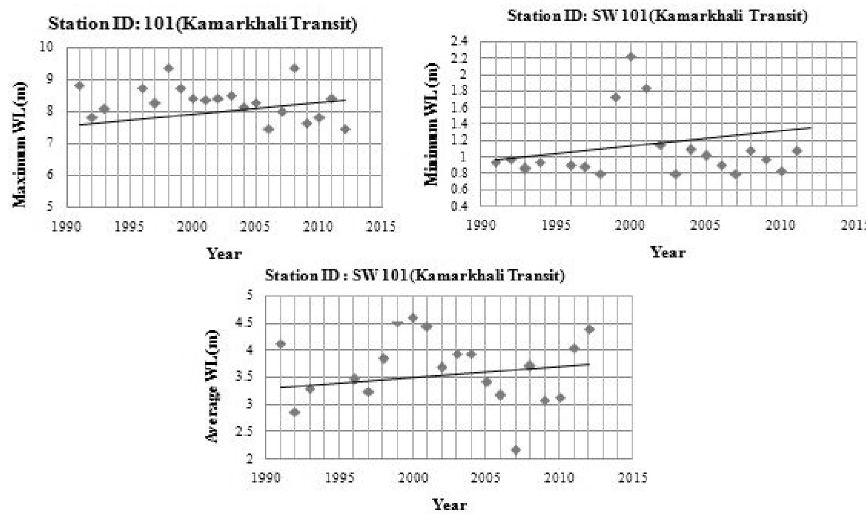



Figure 6: The trend line of maximum, minimum and average Water Level of Kamarkhali Transit

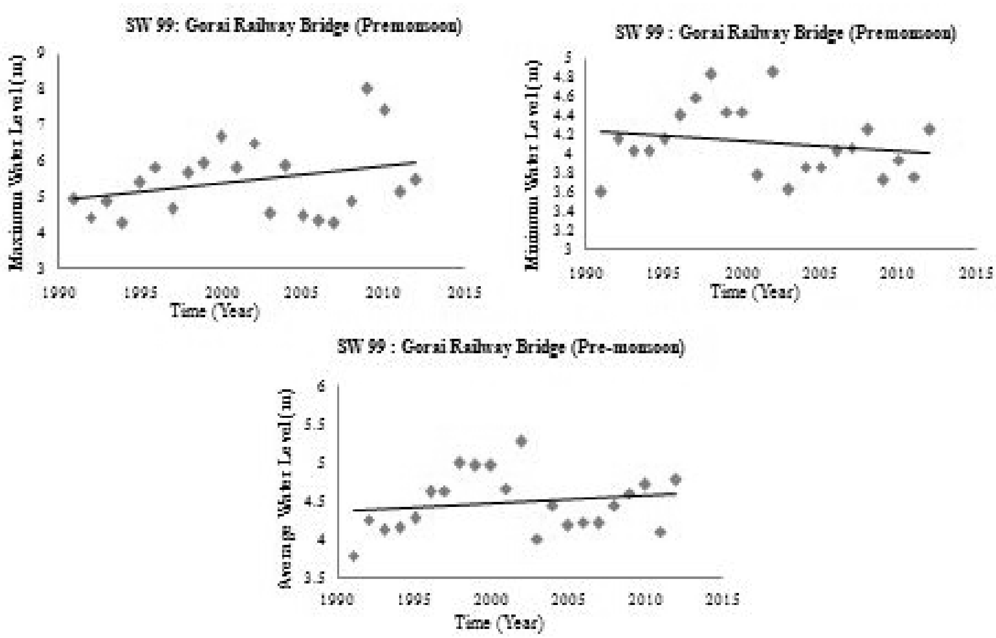
The trend line of maximum, minimum and average Water Level of Kamarkhali Transit Figure 6 with time is increasing.

### *2.4.1.2 Seasonal trend analysis*

There are 3 seasons in Bangladesh, they are:

- Premonsoon : February, March, April, May
- Monsoon : June, July, August, September
- Postmonsoon : October, November, December, Januar

Seasonal trend analysis of water level and discharge of two stations are shown in Figure 7, 8 and 9.

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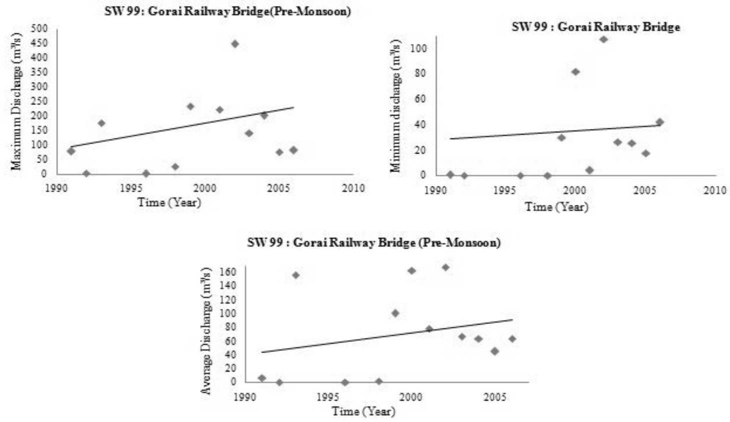
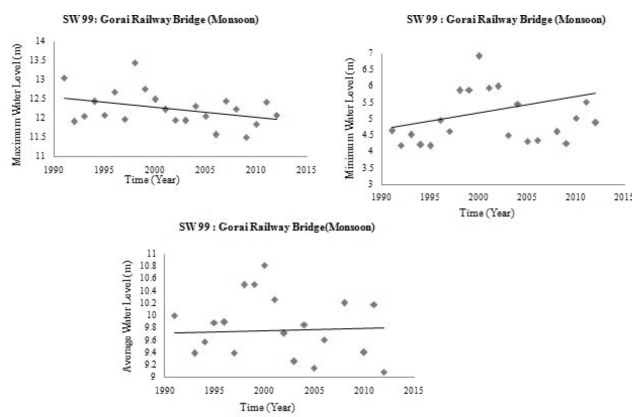


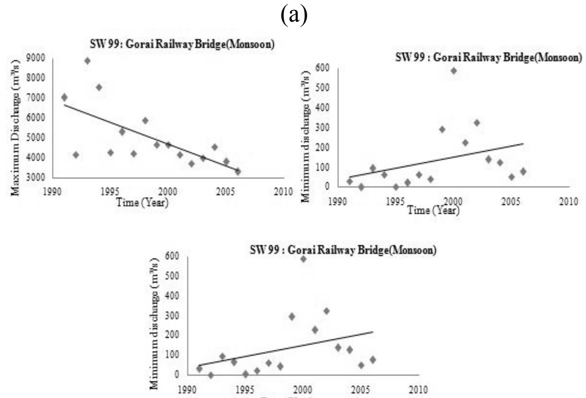

(b)

Figure 7: (a) Trends of Maximum, Minimum, and Average Water Level (Pre-Monsoon period) of Gorai Railway Bridge (b) Trends of Maximum, Minimum, and Average Discharge (Pre-Monsoon period) of Gorai Railway Bridge

From Figure 7, it is seen that (a) The trend line of maximum and average Water Level (Pre-Monsoon period) of Gorai Railway Bridge with time is increasing but minimum water level (Pre-Monsoon period) is decreasing (b) The trend line of maximum, minimum and average Discharge (Pre-Monsoon period) of Gorai Railway Bridge with time is increasing.



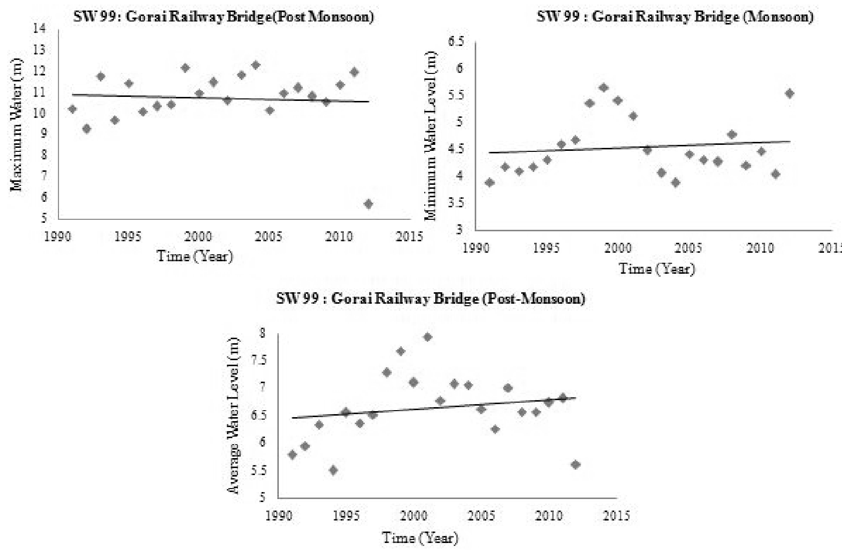

(a)



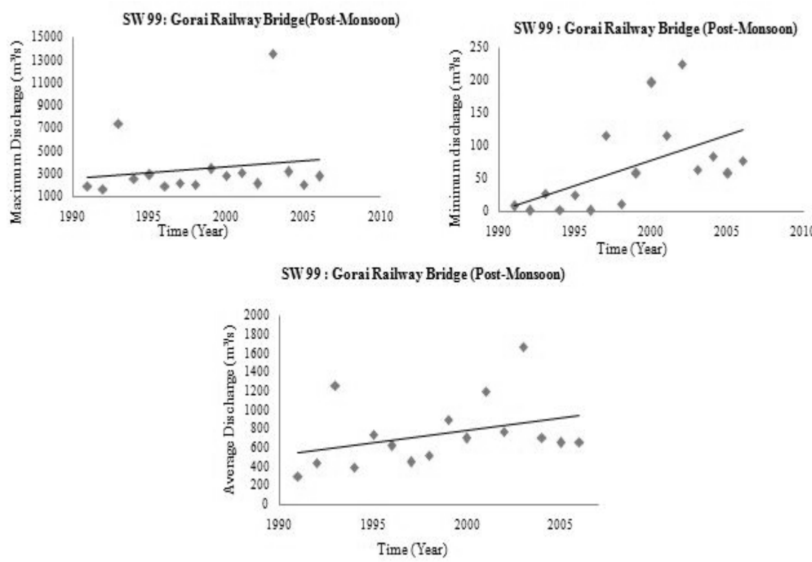

(b)

Figure 8: (a) Trends of Maximum, Minimum, and Average Water Level (Monsoon period) of Gorai Railway Bridge (b) Trends of Maximum, Minimum, and Average Discharge (Monsoon period) of Gorai Railway Bridge

From Figure 8, it is seen that (a) The trend line of minimum and average Water Level (Pre-Monsoon period) of Gorai Railway Bridge with time is increasing but maximum water level (Monsoon period) is decreasing (b) The trend line of minimum and average Discharge (Monsoon period) of Gorai Railway Bridge with time is increasing maximum Discharge (Monsoon period) is decreasing.




(a)




(b)

Figure 9: (a) Trends of Maximum, Minimum, and Average Water Level (Post-Monsoon period) of Gorai Railway Bridge (b) Trends of Maximum, Minimum, and Average Discharge (Post-Monsoon period) of Gorai Railway Bridge

From Figure 9, it is seen that (a) The trend line of minimum and average Water Level (Pre-Monsoon period) of Gorai Railway Bridge with time is increasing but maximum water level (Post-Monsoon period) is decreasing (b) The trend line of maximum, minimum and average Discharge (Post-Monsoon period) of Gorai Railway Bridge with time is increasing.

### 2.4.2 Statistical analysis

When confronted with data that needs to be characterized by a distribution, it is best to start with the raw data and answer four basic questions about the data that can help in the characterization. The first relates to whether the data can take on only discrete values or whether the data is continuous. The second looks at the symmetry of the data and if there is asymmetry, which direction it lies in. The third question is whether there are upper or lower limits on the data, there are some data items like revenues that cannot be lower than zero whereas there are others like operating margins that cannot exceed a value (100%). The final and related question relates to the likelihood of observing extreme values in the distribution. There are various types of distribution method can be adopted. Some of them are Normal distribution, Log-Normal Distribution, Exponential Distribution, Extreme Value Distributions, Triangular Distribution and Pearson Type III Distribution. For estimating high water level, average water level, peak flow, average discharge, maximum velocity, average velocity statistical distribution of hydrologic data are essentially required. In this case, three methods are considered. They are Extreme Value I Distribution, Normal Distribution and Log-Normal Distribution. From these distributions one can measure about the properties of hydrologic data. For that reason chi square test is done. The minimum value of chi square is calculated among these three methods for each data series represents its suitable distribution. Again from these analysis maximum values for different return period is predicted.

Station ID: SW 99 (Gorai Railway Bridge)

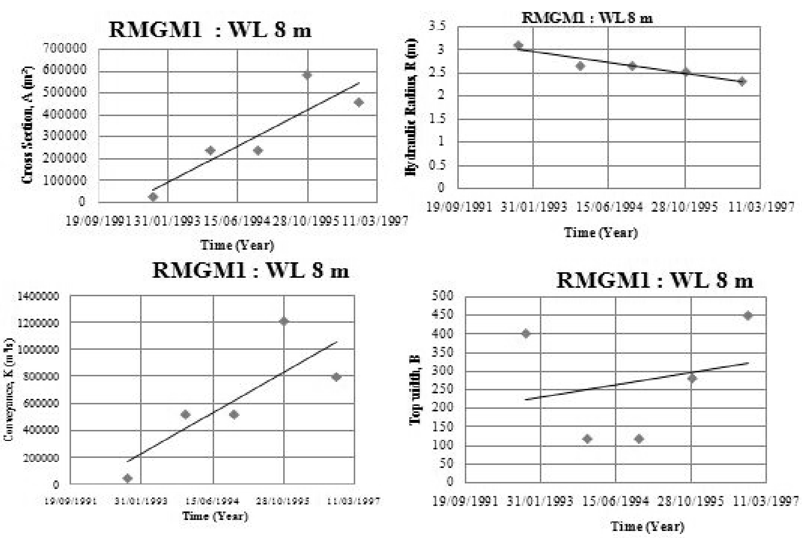
Table 1: Comparison of Values of $\chi 2$ of Maximum Water Level at SW 99

| Return Period | Gumbel's distribution | Log-Normal distribution | Normal distribution |
|---|---|---|---|
| $\chi^2$ | 0.22 | 5.42 | 9.34 |
| 25 | 13.33 | 13.18 | 13.18 |
| 50 | 13.61 | 13.35 | 13.33 |
| 100 | 13.89 | 13.5 | 13.47 |

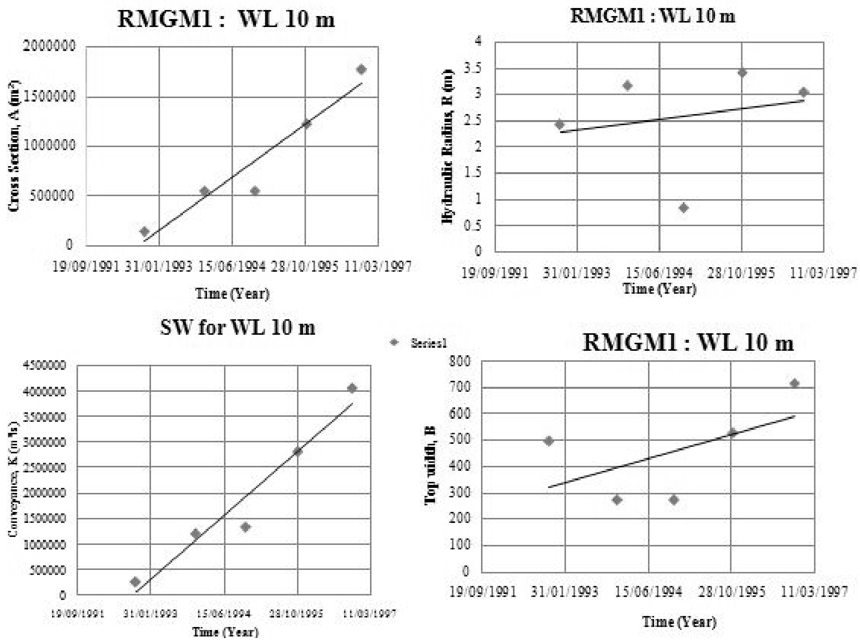
Maximum water level for return periods of 25, 50 and 100 years are determined (Table 1) using three types of distribution mainly normal distribution, lognormal, and EVI distribution. And it is observed for the same return period, that the value of $X_t$ obtained from EVI distribution is the highest among the three distribution types and value obtained from normal distribution is the lowest.

### 2.4.3 Trend analysis of data obtained from MIKE 11

Among all the cross-section here trend lines for 8m, 10m and 12m water level of Cross-section area A ($m^2$), Hydraulic Radius R(m), Conveyance k ($m^{3/s}$) and Top width B (m), Cross-section RMGM1 are shown in Figure 10.




(a)

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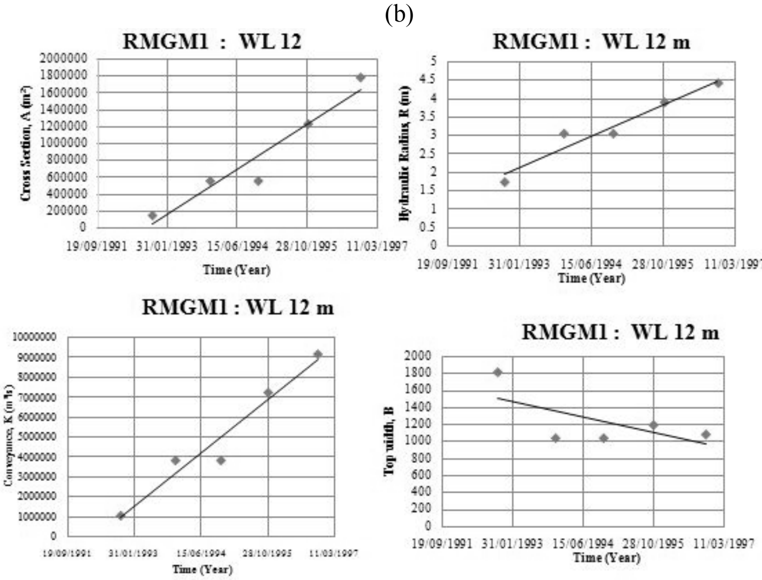


(c)

Figure 10: Trend lines for 8m (a), 10m (b) and 12m (c) water level of Cross-section area A ($m^2$), Hydraulic Radius R (m), Conveyance k ($m^{3/s}$) and Top width B (m).

From the Fgure 10, it is seen that the trend line of A with time is increasing. From Manning's equation we can predict that if the discharge increases, cross section will also increase. So, cross section area increases due to increase in Discharge. From trend line of R with time is decreasing for water level 8 m. And for water level 10 m & 12 m trend line is increasing. From Manning's equation we can predict that if the discharge increases, hydraulic radius will also increase and vise versa. From the trend line of K with time is increasing. Here, the conveyance is in positive trend, it means that due to increase in discharge, conveyance increases. And from the trend line of B with time for water level 8 m & 10 m is increasing and for water level 12 m it is decreasing. From Manning's equation we can predict that if the discharge decreases, top width will also decrease and vise versa.

## 3. CONCLUSIONS

In this study, trend analysis of hydrologic parameters is done for Gorai River. Frequency analysis for different return periods and goodness of fit test is performed for three types of distribution. Different parameters are computed at same water level using MIKE 11. From trend analysis, it has been found that flow and stage both have a decreasing or increasing trend in last few years. And for annual trend analysis of the station Gorai Railway Bridge, it has been seen that maximum, minimum water level have decreasing tendency, where as average water level has an opposite trend in last few years. Seasonal analysis is done for three different seasons (pre monsoon, monsoon and post monsoon) of Bangladesh and the results show that maximum water level of monsoon period of Gorai Railway Bridge station have decreasing trend, where as minimum and average water level have increasing trend in the last few years.

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