IMPACT OF BRIDGE CONSTRUCTION ON MORPHOLOGY OF MAJOR RIVERS IN BANGLADESH

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ABSTRACT

In the context of Bangladesh, major rivers like the Brahmaputra, Ganges, and Meghna are thought to have undergone intriguing changes following the construction of bridges. This study explores if these infrastructural advancements have affected these essential rivers. Addressing the Brahmaputra case, the diffrences in the bank width, cross-sectiona area, thalweg level is found to be +3189m, +2419m^2 and
-0.403m respectively between the pre- and post-bridge periods. These differences are likely to be influenced by independent variables (water discharge, sediment discharge, hydraulic gradient, water level) or bridge construction. A correlation (0.15) was found only between water level and cross-sectional area. Hence, it is evident that construction of bridge has some impacts on the morphology of the Brahmaputra River. As to the Ganges River, the differences in the bank width, cross-sectional area and thalweg level between the post- and pre-bridge periods are found to be +792m, -1399m^2 and -3.56m, respectively. The correlation in post-bridge situation between peak sediment discharge and cross-sectional area was found to be 0.58, and that between hydraulic gradient and thalweg level was -0.40. But other dependent variables did not show any correlation with the independent variables. Therefore, the independent variables might have some influences on the morphology of the river. In the case of the Meghna, the diffrences between the post- and pre-bridge periods in the bank width, cross-sectional area, thalweg level and average bed level were found to be -42m, +1916m^2, -0.824m and -0.286m respectively. The correlation between peak water discharge and average bed level was -0.40, that between peak sediment discharge and thalweg level was -0.68, that between water level and thalweg level was 0.62, that between water level and average bed level was 0.65, and that between water level and cross-sectional area was -0.66. But other dependent variable like bank width did not show any correlation with the independent variables. Therefore, the independent variables have notable influence on the morphology of the river. Finally, these findings underline the intricate relationship between human interventions, such as bridge construction, and river morphology. However, understanding the full extent of this influence remains an engaging area for further exploration.

Keywords: *River morphology, water discharge, sediment discharge, hydraulic gradient, correlation*

1. INTRODUCTION

Hydraulic structures are constructed on rivers to protect the river banks, cross the rivers, maintain the flow, etc. Bangladesh, being a riverine country, has constructed many such structures on its rivers. Notable examples are the Bangabandhu bridge on the Brahmaputra in 1998, the Lalon Shah bridge on the Ganges in 2004, and the Bangladesh–UK Friendship Bridge on the Meghna in 2002. It is generally thought that the construction of such bridges would lead to morphological changes in the rivers (Islam et al., 2017). Generally, thalweg level, bed level, cross-sectional area, and width are considered while studying the morphological change of a river. These parameters are linked with water discharge, sediment discharge, and bed slope to see their impacts on morphology (Mondal et al., 2020). However, such kinds of studies are not widely available. Though a few available studies indicate that the construction of a bridge can alter a river's health locally and thus can have negative impacts. For example, bridge construction can impact the hydrology, morphology, and ecology (Merrill et al., 2005), can modify the channel size and shape (Gilvear et al., 2002), can increase the cross-sectional area in the downstream (Richardson et al., 1999). Moreover, the width of a river can decrease due to the construction of bridge piers (Biswas, 2010), can shift the thalweg line (Uddin et al., 2022). Above all, bridge construction, that is placed across the river's flow route is likely to have an impact not only on the hydrodynamic and morphology of the river but also on the stability of the bridge and the pattern of land use (Biswas et al., 2018). However, it is not clear if such construction leads to changes in general morphology of the rivers. In this study, we investigate if the morphology of the major rivers in Bangladesh, the Brahmaputra, the Ganges and the Meghna, has changed due to the construction of the major bridges, by linking the water and sediment flows as well as the slope with the morphological parameters of the rivers.

2. METHODOLOGY

Secondary data on water level, water discharge, sediment discharge, and river bathymetry were collected from the BWDB. Daily water level was available for 1985-2022 at Sirajganj, Kazipur and Bahadurabad on the Brahmaputra, at Hardinge Bridge and Talbaria on the Ganges, and at Bhairab Bazar on the Meghna. Daily discharge was available for 1985-2005 at Bahadurabad, 1985-2006 at Hardinge Bridge, and 1985-2019 at Bhairab Bazar. Observed discharge was available for 2006-2022 at Bahadurabad, 2007-2022 at Hardinge Bridge, and 2020-2022 at Bhairab Bazar. Observed sediment was available for 2000-2022 at Bahadurabad, for 2000-2020 at Hardinge Bridge, and for 2017-2022 at Bhairab Bazar. Bathymetry was available for 1976-2021 near the Bangabandhu Bridge, 1978-2021 near the Lalon Shah bridge, and 1973-2021 near Bangladesh-UK Friendship Bridge. The discharge rating curve of $Q=C(H-a)^n$ type was generated for the year without having the complete daily discharge. Also, the sediment rating curve of $Q_s=aQ^b$ type was generated for each year having sediment data. Then the daily water and sediment discharges were estimated from the rating curves. The average bed level of a cross-section of a river was obtained from the measured bathymetry at certain interval along the section within the banklines. The measurements were available at 40-200 m interval depending on the river. The maximum discharge, peak one-month average discharge, sediment discharge, thalweg level, average bed level, cross-sectional area, and bank-width time series were plotted to see the trend in each series. Finally, correlations were studied between the dependent (bank width, cross-sectional area, thalweg level, average bed level) and independent (water discharge, sediment discharge, hydraulic gradient, water level) variables.

3. RESULTS AND DISCUSSIONS

3.1 Brahmaputra River

For the Brahmaputra River, the dependent (bank width, cross-sectional area, thalweg level, average bed level) variables, which represent the morphology of the river, have been studied. In the pre-bridge period the average bank width was found to be 6678m, that in the post-bridge period was 9867m. The bank width downstream of the bridge was found to be increasing (R^2=0.97) in the pre-bridge period, that did not show any trend in the post-bridge period (Figure 1). In the pre-bridge period the average cross-sectional area was found to be 31574m^2, that in the post-bridge period was 33993m^2. Also, the cross-sectional area showed increasing trend both in pre- and post-bridge period to some extent. In the pre-bridge period the average thalweg level was found to be -2.688 m PWD, that in the post-bridge period was -3.091m PWD. Again, the thalweg level showed a deepening trend of 11cm/year (R^2=0.17) in the post-bridge period, but it was in a silting trend of 21 cm/year (R^2=0.12) in the pre-bridge period. In the pre-bridge period the average bed level was found to be 7.488 m PWD, that in the post-bridge period was 7.493m PWD. Also, the average bed level showed a silting trend of 18 cm/year (R^2=0.69) in the pre-bridge period, that showed a deepening trend of 24 cm/year (R^2=0.67)in the post bridge period (Figure 2). So, after analyzing the Brahmaputra River morphology in the downstream of the Bangabandhu Bridge, it is found that the morphology is showing a partially stable behavior after the bridge construction. Now, whether it is because of the independent variables (water discharge, sediment discharge, water level, hydraulic gradient) or bridge construction that can be identified after finding the correlation between the parameters for the post bridge period. In this case, the correlation between water level and cross-sectional area was 0.15 (Figure 3). But rest of the dependent variables did not show any correlation with the independent variables. Therefore, it is evident that other variables, like bank width, thalweg level and average bed level are changing because of the bridge impact.

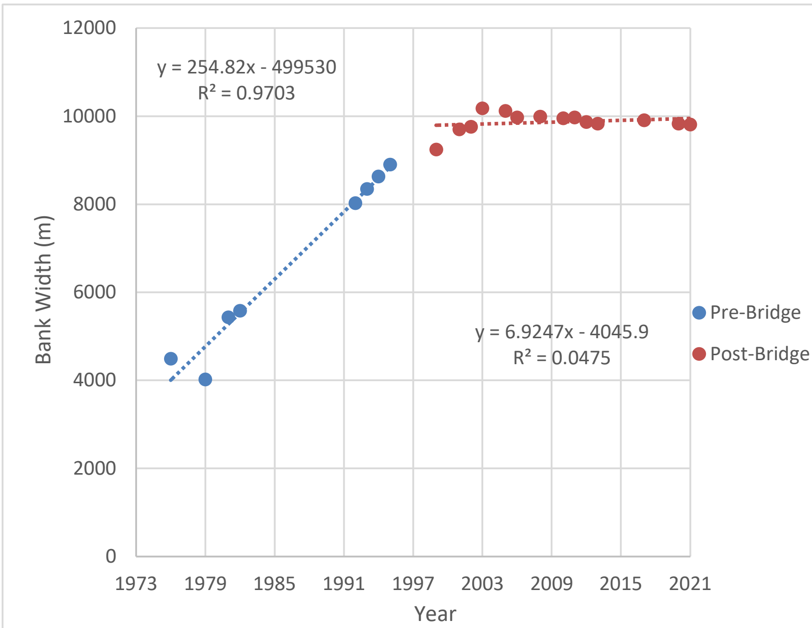

Figure 1: A typical time series plot of pre- and post-bridge bank width of the Brahmaputra River

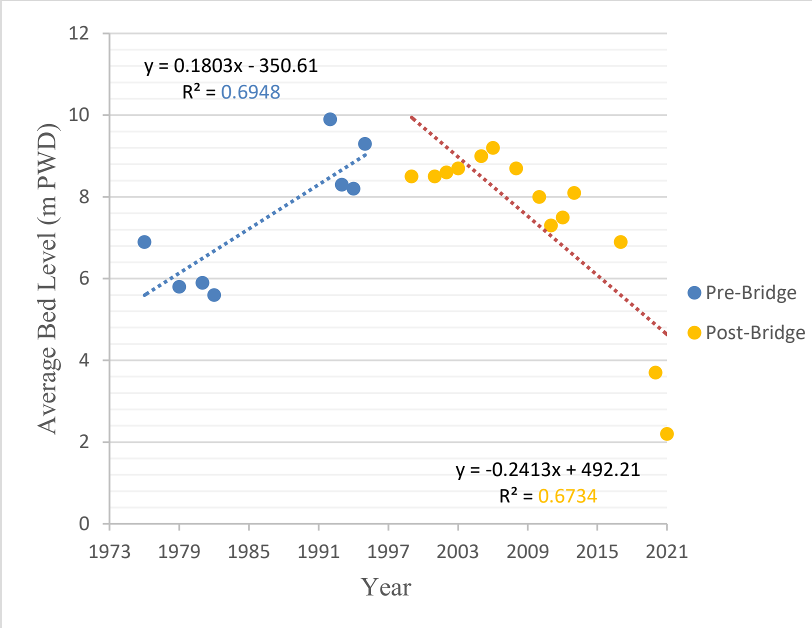

Figure 2: A typical time series plot of pre- and post-bridge average bed level of the Brahmaputra River near the Bangabandhu Bridge

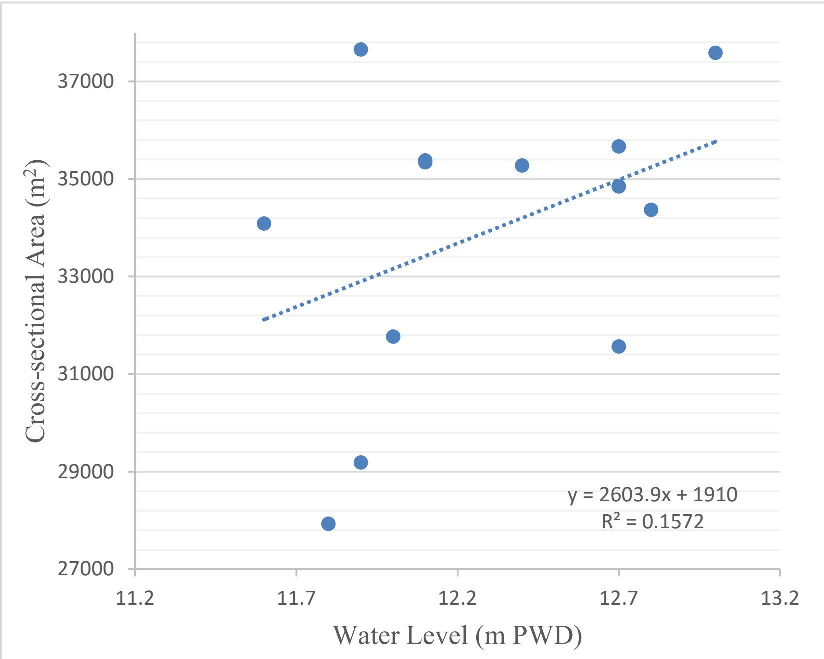

Figure 3: A typical plot of water level vs cross-sectional area for the post-bridge period (1999-2021) of the Bangabandhu Bridge

3.2 Ganges River

For the Ganges River, the average bank width was found to be 3449 m in the pre-bridge period, that in the post-bridge period was 4241m. Also, the bank width downstream of the bridge was found to be increasing (R^2=0.69) in the pre-bridge period and similar in the post-bridge period (Figure 4). A jump in the bank width is observed between 1984 and 1995, which is probably caused by bank erosion (Dewan et al., 2017) due to the major floods in 1987 and 1988. In the pre-bridge period the average cross-sectional area was found to be 19739m^2, that in the post-bridge period was 18340m^2. Also, the cross-sectional area was found to be decreasing (R^2=0.61) in the pre-bridge period and that did not show any trend in the post-bridge period (Figure 5). In the pre-bridge period the average thalweg level was found to be -1.215m PWD, that in the post-bridge period was -2.340m PWD. Also, the thalweg level, which did not show any trend in the pre-bridge period, showed a deepening trend of 15 cm/year (R^2=0.12) in the post-bridge period (Figure 6). In the pre-bridge period the average bed level was found to be 1.398m PWD, that in the post-bridge period was 1.295m PWD. Also, the average bed level did not show any notable trend in both pre- and post-bridge periods. So, after analyzing the Ganges River morphology for the downstream of the Lalon Shah Bridge, it is found that the morphology is showing a stable behavior after the bridge construction. Now, whether it is because of the independent variables (water discharge, sediment discharge, water level, hydraulic gradient) or bridge construction that can be identified after finding the correlation between the parameters for the post bridge period. In this case, the correlation between hydraulic gradient and average bed level was found to be -0.59 (Figure 7), that between hydraulic gradient and thalweg level was -0.4 (Figure 8), and that between peak sediment discharge and cross-sectional area was 0.58 (Figure 9). The dependent variables showed correlation with the independent variables to some extent. But, the correlations between the variables are not strong. Therefore, some bridge impact might be also there on the morphological changes of the river.

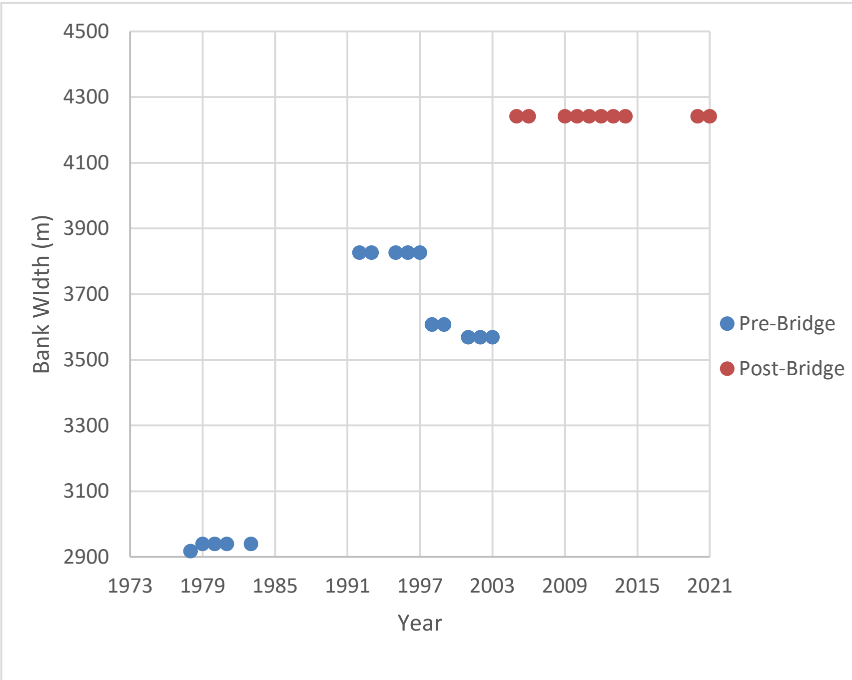

Figure 4: A typical time series plot of pre and post-bridge bank width of the Ganges River

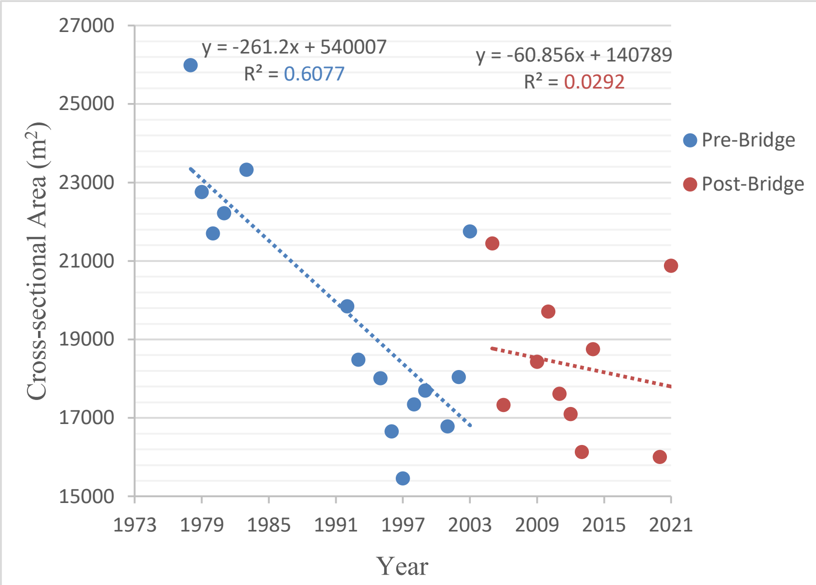

Figure 5: A typical time series plot of pre- and post-bridge cross-sectional area of the Ganges River

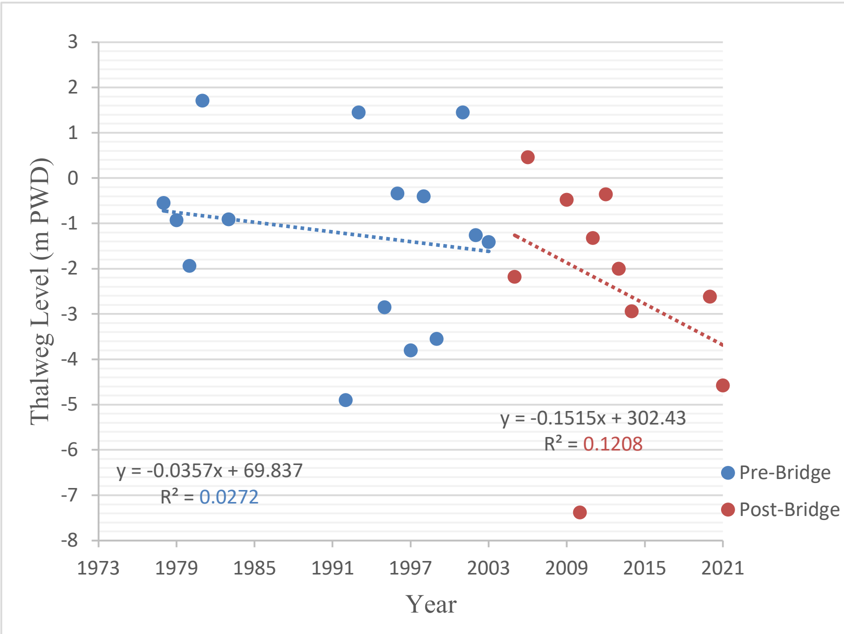

Figure 6: A typical time series plot of pre- and post-bridge thalweg level of the Ganges River

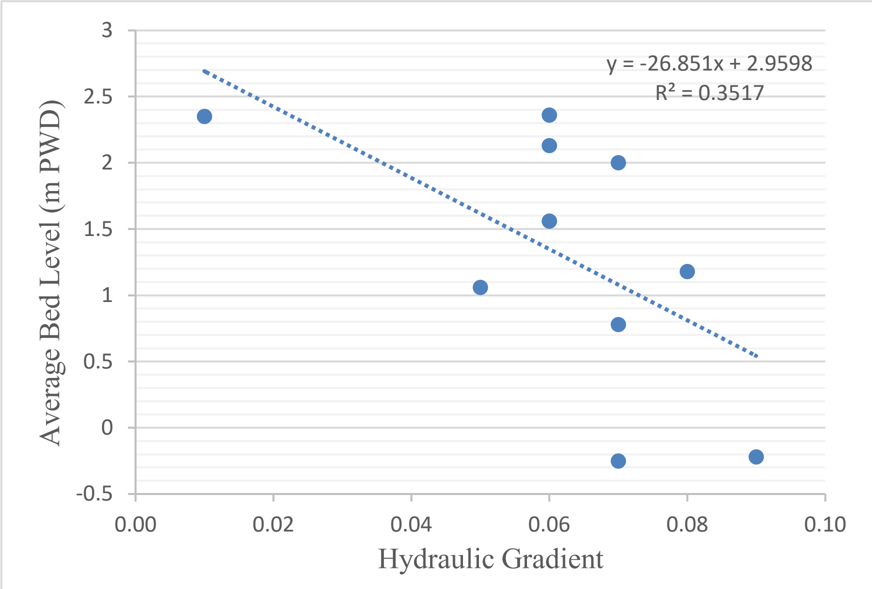

Figure 7: A typical plot of hydraulic gradient and average bed level of the Ganges River

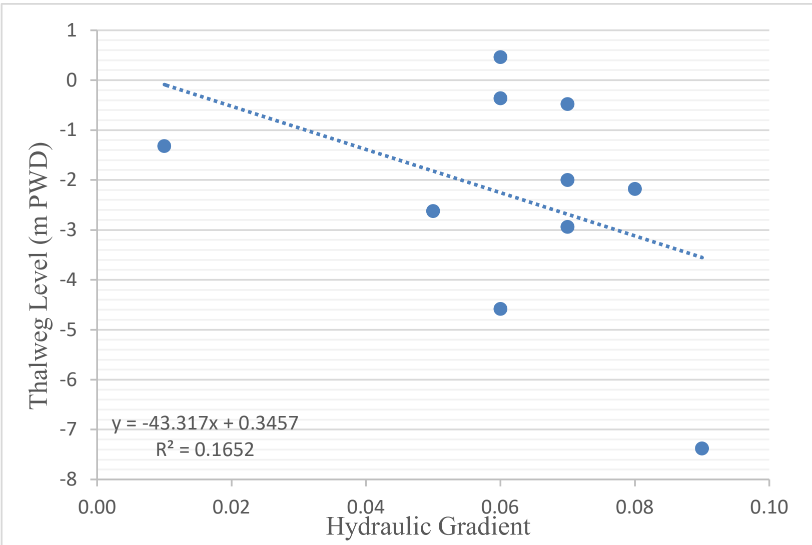

Figure 8: A typical plot of hydraulic gradient and thalweg level of the Ganges River

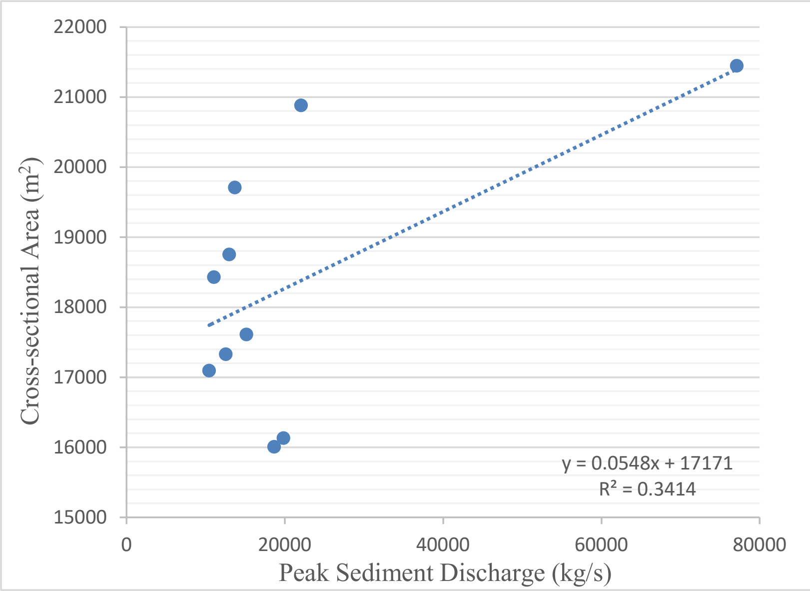

Figure 9: A typical plot of peak sediment discharge and cross-sectional area of the Ganges River

3.3 Meghna River

For the Meghna River, the average bank width was found to be 3229m in the pre-bridge period, that in the post-bridge period was 3187m. Also, the bank width downstream of the bridge was found to be increasing (R^2=0.43) in the pre-bridge period, that showed a more pronounced increase (R^2=0.52) in the post-bridge period (Figure 10). In the pre-bridge period the average cross-sectional area was found to be 19556m^2, that in the post-bridge period was 21472m^2. Also, the cross-sectional area was found to be decreasing (R^2=0.10) in the pre-bridge period but showed a drastic increase (R^2=0.72) in the post-bridge period (Figure 11). In the pre-bridge period the average thalweg level was found to be -7.929m PWD, that in the post-bridge period was -8.753m PWD. Also, the thalweg level showed a silting trend of 6 cm/year (R^2=0.28) in the pre bridge period but showed a deepening trend of 44 cm/year (R^2=0.66) in the post-bridge period (Figure 12). In the pre-bridge period the average bed level was found to be -0.814m PWD, that in the post-bridge period was -1.100m PWD. Also, the average bed level did not show any notable trend in the pre-bridge period but showed a drastic deepening trend of 33 cm/year (R^2=0.85) in the post-bridge period (Figure 13). So, after analyzing the Meghna River morphology for the downstream of Bangladesh–UK Friendship Bridge, it is found that the morphology is showing an unstable behavior after the bridge construction. Now, whether it is because of the independent variables (water discharge, sediment discharge, water level, hydraulic gradient) variables or bridge construction that can be identified after finding the correlation between the variables for the post bridge period. In this case, the colleration between peak water discharge and average bed level was -0.40 (Figure 14), that between peak sediment discharge and thalweg level was -0.68, that between water level and thalweg level was 0.62 (Figure 15), that between water level and average bed level was 0.65 (Figure 16), and that between water level and cross-sectional area was -0.66 (Figure 17). The dependent variables showed correlation with the independent variables to some extent. But, correlations between the parameters are not strong. Therefore, some bridge impact might be also there on the morphological changes of the river.

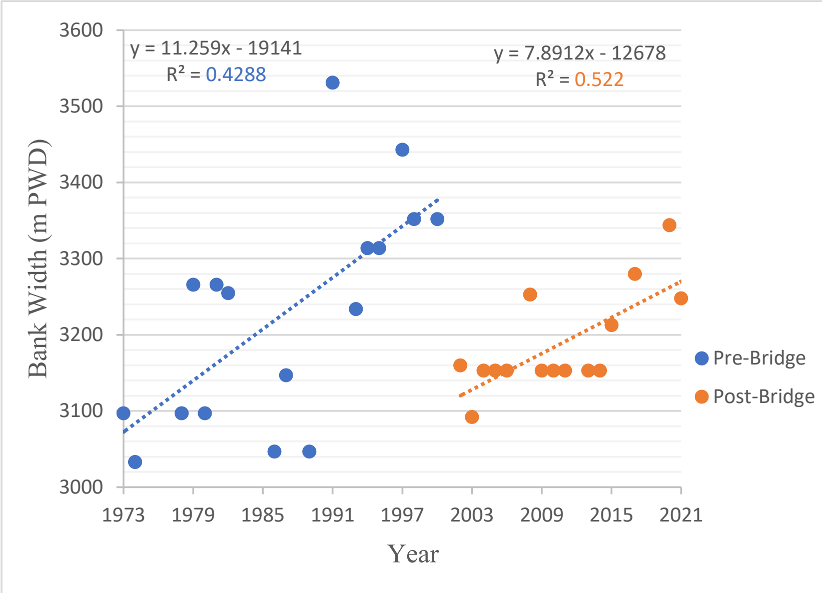

Figure 10: A typical time series plot of pre- and post-bridge bank width of the Meghna River

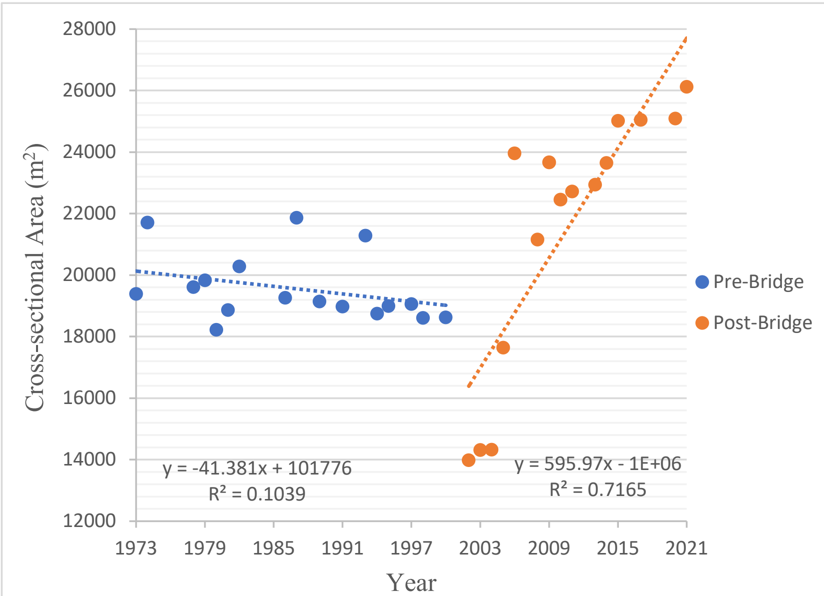

Figure 11: A typical time series plot of pre- and post-bridge cross-sectional area of the Meghna River

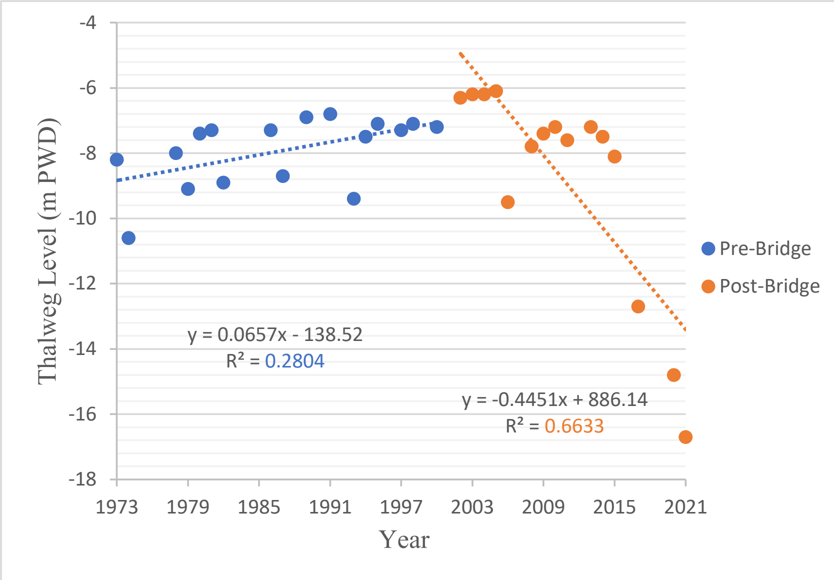

Figure 12: A typical time series plot of pre- and post-bridge thalweg level of the Meghna River

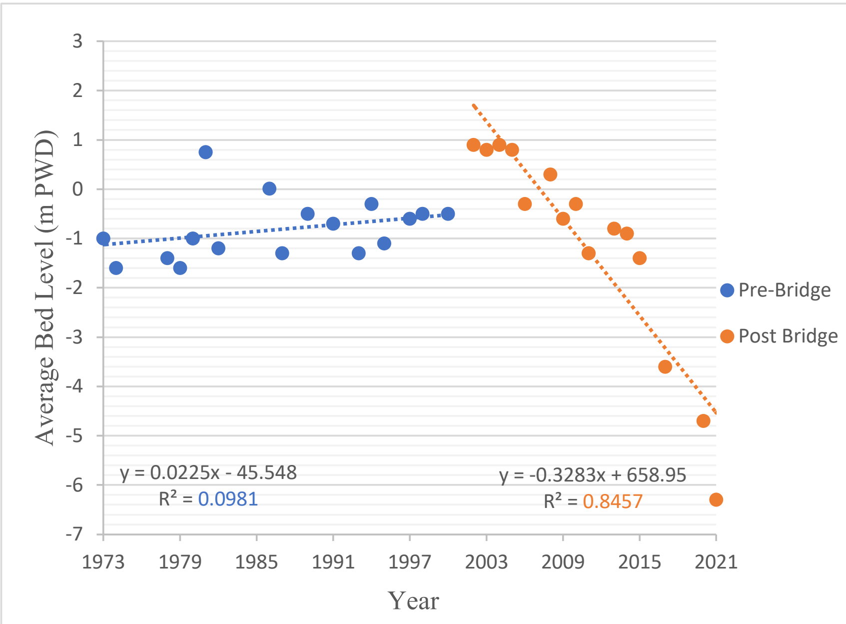

Figure 13: A typical time series plot of pre- and post-bridge average bed level of the Meghna River

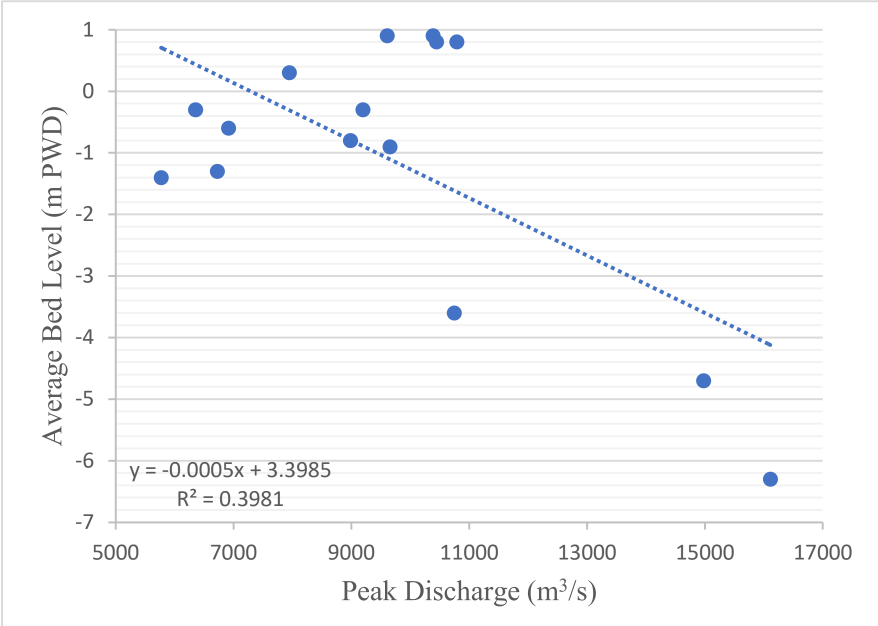

Figure 14: A typical plot of peak discharge and average bed level of the Meghna River

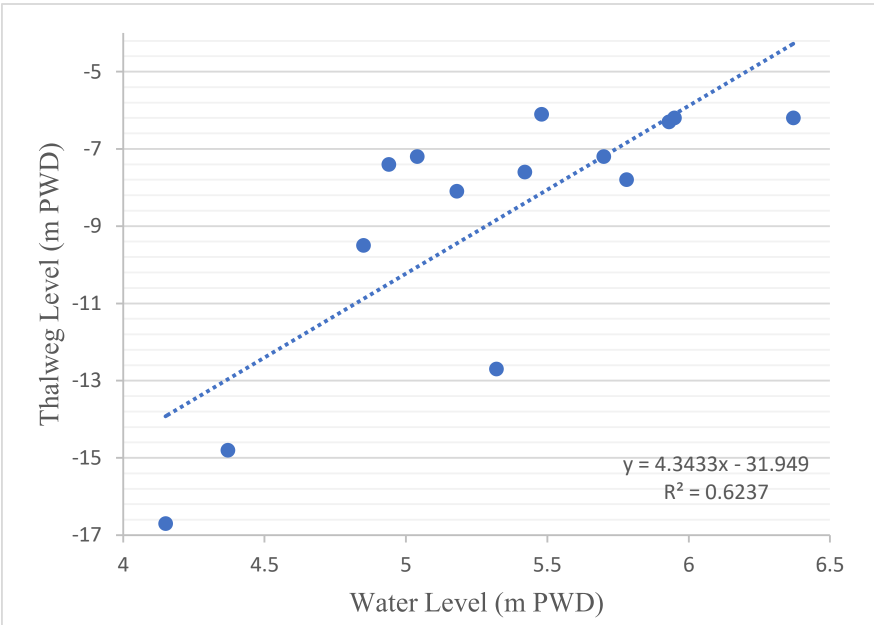

Figure 15: A typical plot of water level and thalweg level of the Meghna River

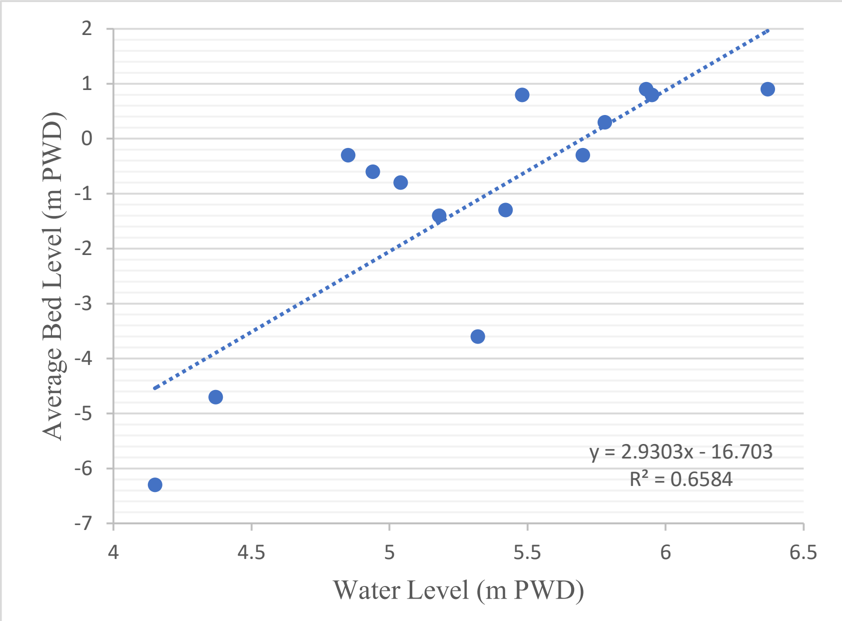

Figure 16: A typical plot of water level and average bed level of the Meghna River

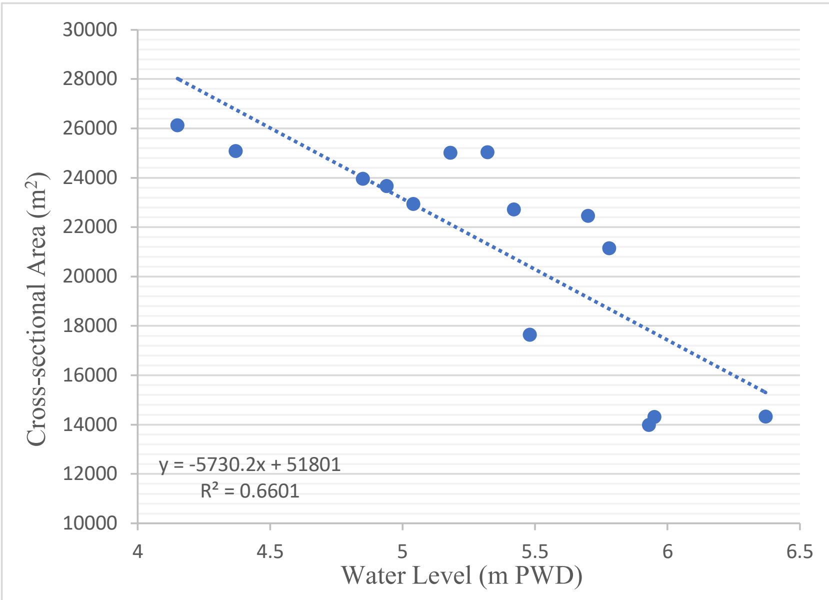

Figure 17: A typical plot of water level and cross-sectional area of the Meghna River

4. CONCLUSIONS

The observed morphological changes in the Brahmaputra, Ganges, and Meghna rivers post-bridge construction unveil a complex interplay between natural river dynamics and the interventions imposed by bridge infrastructure. In the case of the Brahmaputra River, the changes in bank width, thalweg level, and average bed level suggest partial stable behaviour. Correlations with peak water discharge hint at a nuanced relationship between hydrological factors and specific morphological alterations. Hence, bank width, thalweg level and average bed level are partially stable due to the bridge impact. Conversely, the Ganges River is showing a stable behavior in the post-bridge period. Correlations involving hydraulic gradient, sediment discharge, and morphological parameters also suggest a nuanced relationship between hydrological dynamics and the observed changes. So, there might be some impact of bridge construction. Again, the Meghna River is showing an unstable behaviour in the post-bridge period. Correlations between peak water and sediment discharge and morphological parameters imply an association between hydrological variables. However, the moderate correlations suggest a probable influence of the bridge construction, necessitating a more comprehensive investigation. Understanding these complexities is pivotal in managing and mitigating the impacts of such large-scale interventions on the delicate equilibrium of riverine ecosystems in Bangladesh.

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