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STUDY OF WATER AND BED LEVEL VARIATION IN THE GANGES-PADMA RIVER, BANGLADESH

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Abstract- This study investigated the water and bed levels together with thalweg profile variations in graphical and numerical analysis using MS Excel for the Ganges-Padma River between 1996 and 2014 at three different selected stations. It was found that there was no consistency in cross section profiles over the years. The cross section profiles varied rapidly at Mawa and Harding Bridge stations, whereas the changes at Baruria Transit were more consistent comparatively. The mean bed levels at Harding Bridge and Mawa stations gradually rose while at Baruria Transit station, it showed a dynamic behavior. Recently in most cases, the water and bed levels lowered or rose simultaneously, but in the years 1996 to 2009 they showed dissimilar patterns. The maximum water level variation was found at Harding Bridge station at 0.75m (rise). The shifting of thalweg points also varied significantly. The most frequent movement of thalweg vertically was found at Baruria Transit station and horizontally at Mawa station.

Keywords**:** Water level, Bed level, Thalweg, Ganges-Padma.

1.0 INTRODUCTION

Bangladesh is a land of rivers. The economic condition of Bangladesh is mostly connected with her rivers. The global consumption of water is doubling every 20 years, more than twice the rate of human population growth [1]. The Ganges-Padma River has a length of approximately 2,200 km from its source in the Himalayas in Nepal to its confluence with the Jamuna River in Bangladesh [2]. The Ganges-Padma river system is one of the three major river systems of Bangladesh which extends from Kustia to Chandpur. It is 120 km long and about 4 to 8 km wide in Bangladesh [3]. The rivers of Bangladesh are morphologically dynamic, characterized by erosion and sedimentation which results in changes in hydraulic geometry, plan form and longitudinal profile of the rivers [4]. Every year, thousands of people are affected by erosion that destroys standing crops, farmland and homestead land. Erosion and deposition statistics of the Ganges indicate that 57km^2 of land was lost along the right bank whereas around 59 km^2 has been gained along the left bank during the assessment period [5]. Aggradations (i.e., rising of the river bed by deposition) occur in a river if the amount of sediment coming into a given reach of a stream is greater than the amount of sediment going out of the reach. Part of the sediment load must be deposited and hence the bed level must rise [6]. Sediment deposition along streams or in reservoirs is a complex and troublesome process. It creates a variety of problems such as rising of river beds and increasing flood heights, meandering and over flow along the banks, chocking up navigation and irrigation canals and depleting the capacity of storage reservoirs [7]. River bank erosion and channel shifting are geo-morphological phenomena that have been studied by various researchers in the last few years [8], [9], [10], [11].

The main objective of this study was to observe bed level and thalweg profile variation in the study area. This gives a clear idea of possible changes in bed level in the last two decades.

Further study on this basis can contribute to future development of river training and resettlement in the estuarine region of Bangladesh in the context of Global Warming.

1.1 Study Area

The Ganges-Padma River is located in the North-Western part of Bangladesh and passes through Kushtia and Rajshahi districts to Chandpur. Geographically it lies between 88° 30´ 0" to 89° 05´ 0" E longitude and 24° 0´ 0" to 24° 25´ 0" N latitude. This area has tropical monsoon climate where mean annual rainfall is 2000 mm of which about 70% occurs during the monsoon season [3]. The study was carried out at 3 different selected stations i.e., Kustia (Harding Bridge), Baruria Transit and Mawa.

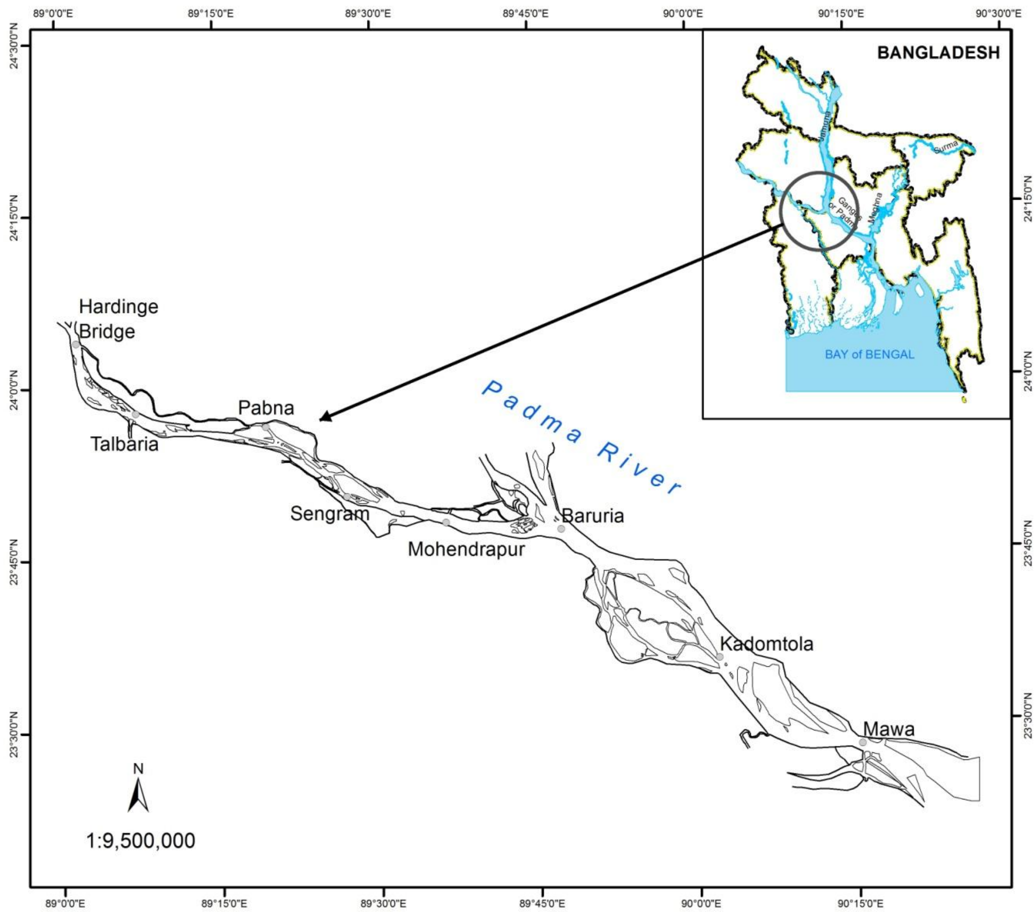


Figure 1 Location map of the stations in the Ganges-Padma River

2.0 Data Source And Methodology

Cross sectional and water level data were collected from Bangladesh Water Development Board (BWDB). They collected data by using the principle of resonance of sound. In every station, there was an imaginary reference point called chart datum (CD) which is known from the nearby PWD bench marks.

The following procedures were followed to complete the project:

2.1 Analysis Of Cross Sectional Profile

The cross sectional profile variations over the years for a particular station were analyzed graphically by superimposing the cross sections at a particular station for two successive selected years using Microsoft Excel software.

2.2 Analysis of Mean Bed Level

Analysis of mean bed level variations was carried out both graphically and numerically. In graphical analysis, superimposition of the bed profile for different years at different stations was done. For a particular river, it was convenient to assess the trend in bed topography including erosion and deposition along the course [12]. For numerical analysis, the mean bed level of the irregular cross sections was approximated by equivalent rectangular section. The mean bed level was calculated by using the following equation from [12]

$$MBL = \frac{1}{n}\sum_{i=1}^{n} y_i \text{ [12]} \qquad (1)$$

where n is the number of ordinates and y is the depth of water in meters.

2.3 ANALYSIS OF WATER LEVEL

Water level varies in a river one month to another. So, the data were collected every month of a year. To simplify the analysis, highest water levels were collected during wet seasons and lowest water levels at dry seasons.

2.4 ANALYSIS OF THALWEG PROFILE

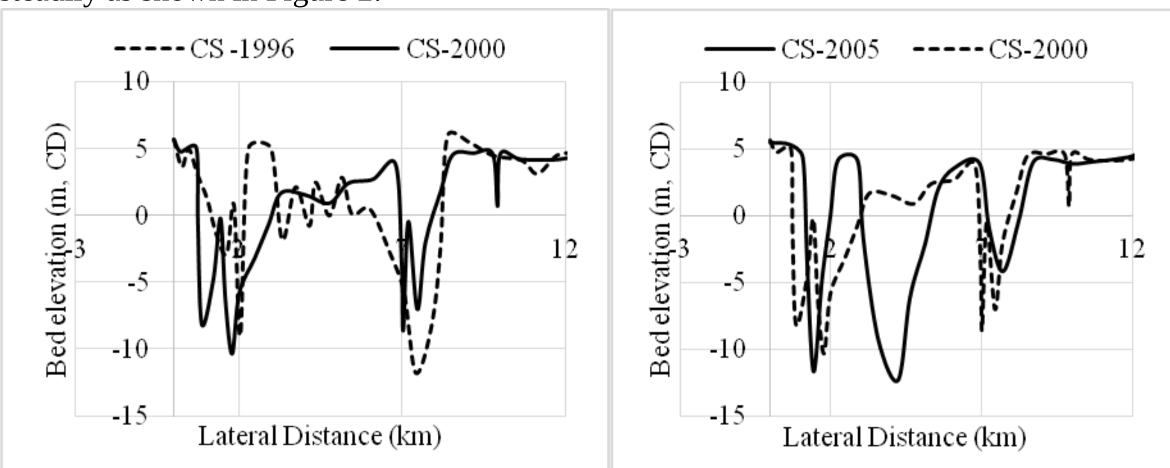
The joining line between the lowest points of a river channel is known as the thalweg line. Though thalweg profile does not give a strong idea about the mean bed level elevation, it definitely has impacts on it. Endeavors were made to evaluate the vertical as well as the horizontal deviations of thalweg lines. Vertical variation was obtained by comparing the longitudinal thalweg profile of the different years and horizontal migration was found by comparing the horizontal shifting of the thalweg line from a reference bank line.

3.0 RESULTS AND DISCUSSIONS

3.1 VARIATION IN CROSS SECTION

The analysis was carried out by graphical description for 5 different selected years (1996, 2000, 2005, 2009 and 2014) at a particular station that showed the changes in geometry of a river along the transverse direction from year to year. Observations are discussed below:

Cross section profile at Mawa: The cross sections over the different selected years varies steadily as shown in Figure 2:



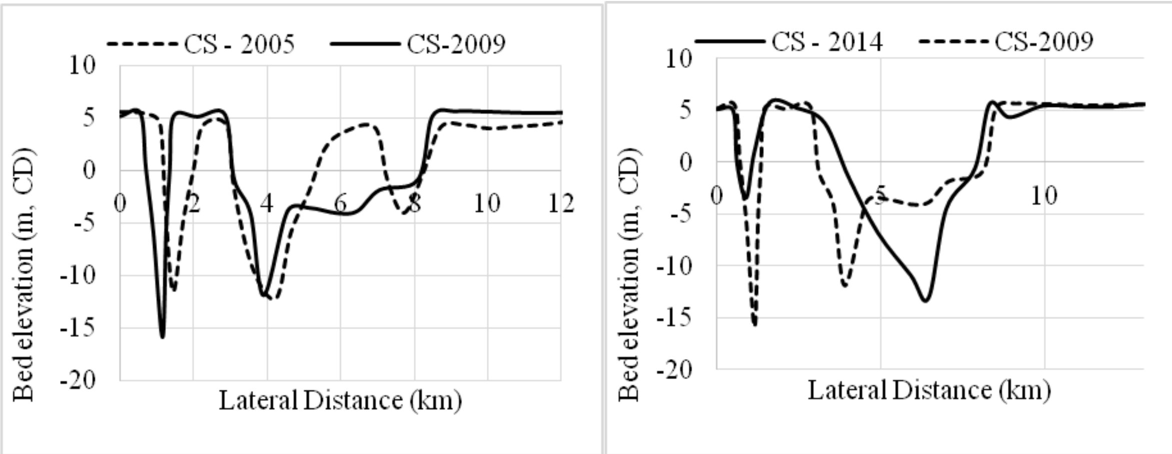


Figure 2 Cross section variations at Mawa station, 1996 to 2014

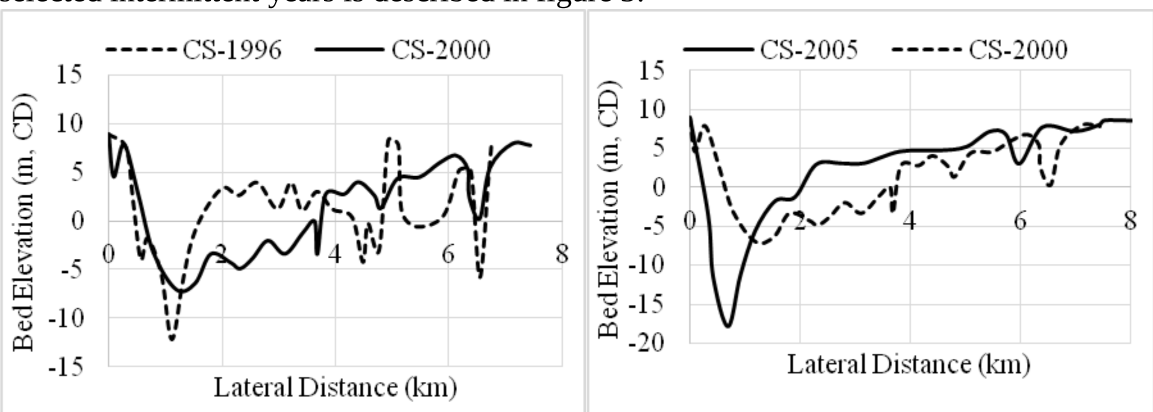
Year 1996 to 2000: There was no significant change in the right bank. The left bank was scoured and shifted slightly rightward. The middle portion of the bank was silted and no shifting was occurred.

Year 2000 to 2005: The left bank was highly eroded on both sides, silted at the middle and divided into two small banks. The right bank shifted rightward and the cross section increased. The middle bank was silted and became small over the cross section.

Year 2005 to 2009: The left bank was totally divided into two banks and the right of these was connected with the middle bank as the middle portion of the bank underwent enormous scouring.

Year 2009 to 2014: The left bank silted and become slender in width and depth. The middle bank shifted rightward, erosion occurred at the right side and siltation at the left. There was no change at the right portion of the bank.

Cross section at Harding Bridge: The variation of cross section from 1996 to 2014 and in the selected intermittent years is described in figure 3:



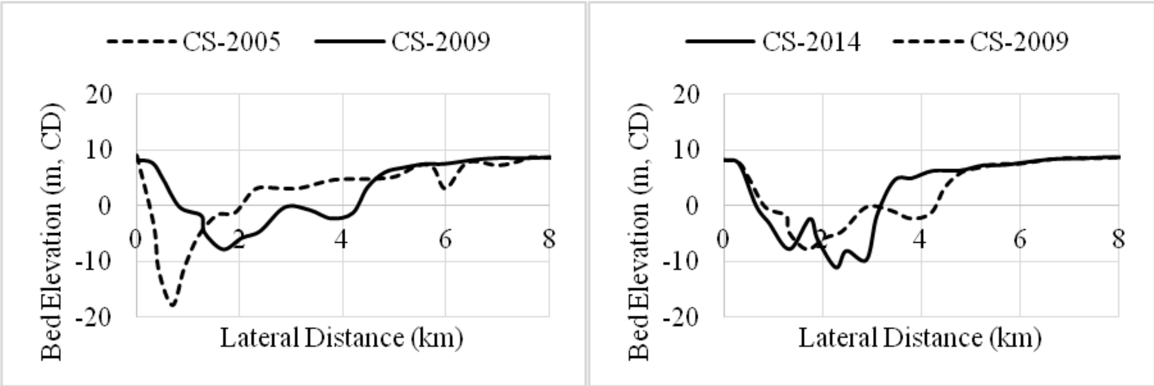


Figure 3 Cross section variations at Harding Bridge station, 1996 to 2014

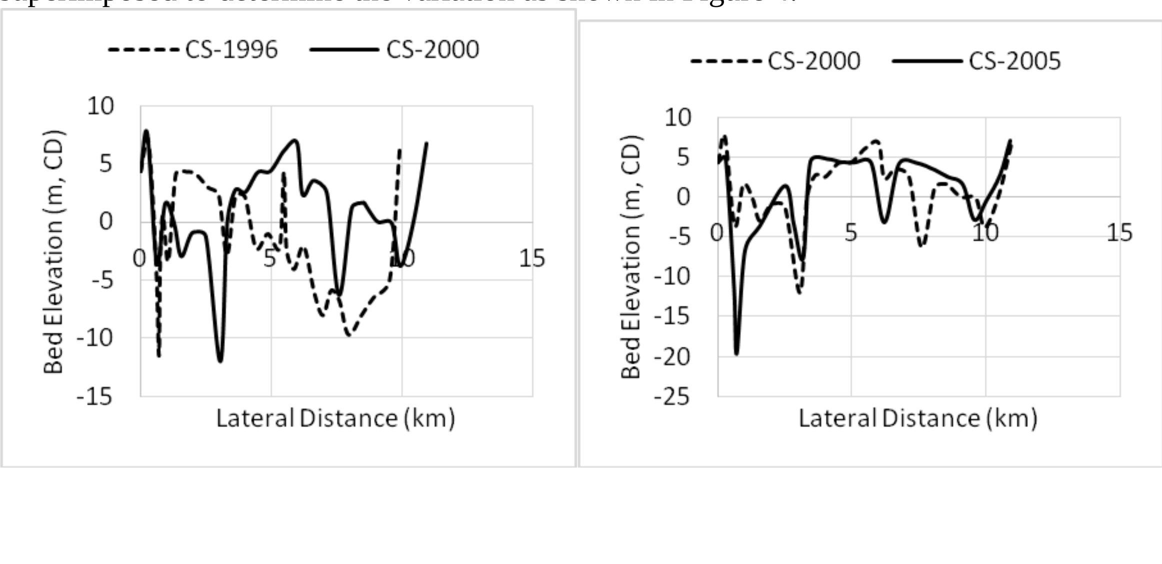
Year 1996 to 2000: There was no significant channel shifting in the horizontal direction. The left bank was eroded heavily and the right bank had sediment deposition. The thalweg point of the bank remained at left bank but had silted about 5m.

Year 2000 to 2005: There was large sediment deposition at the middle portion of the bank and there was very significant erosion at the left bank. The river bed level was raised due to the deposition of sediment. The average cross sectional area remained the same as before.

Year 2005 to 2009: There was noticeable variation at the left bank. The cross section that was observed in 2000 had been reshaped again in 2009. The bank regained its cross section.

Year 2009 to 2014: No significant changes were noticed. The thalweg point of the bank was lower than before, and the right bank seemed to be stable during the whole period from 1996 to 2014.

Cross section at Baruria Transit: The cross-section profiles over the years are plotted and superimposed to determine the variation as shown in Figure 4:



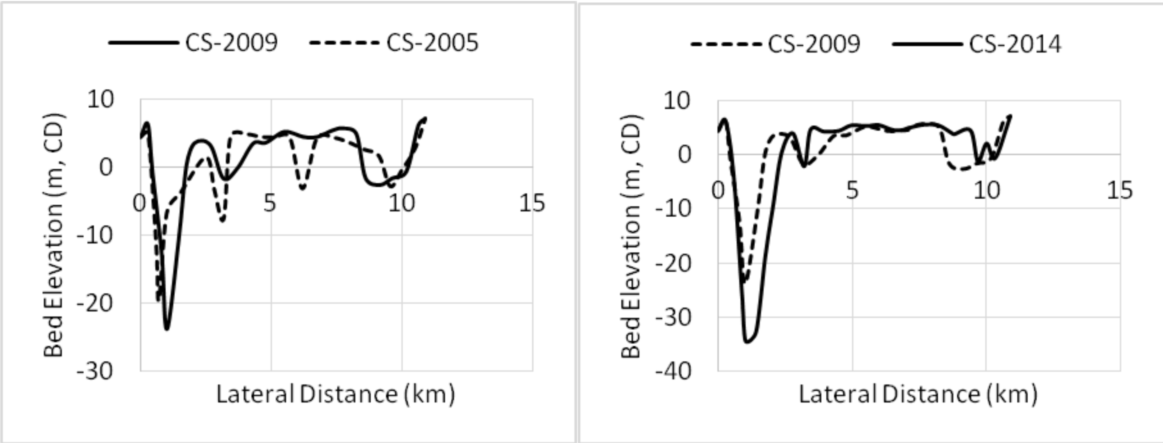


Figure 4 Cross section variations at Baruria, 1996 to 2014

Year 1996 to 2000: Enormous sediment was deposited at the right bank and shifted rightward. Noticeable erosion took place at the left bank. The average cross sectional area increased in 2000.

Year 2000 to 2005: There was no significant channel variation during these years. There was no continuous change throughout the bank. The bed level lines intersect at various points resembling a stationary wave.

Year 2005 to 2009: Very little variation of cross section was found, with cross sectional area also appearing the same. The thalweg point of the river lowered by 8m and shifted rightward.

Year 2009 to 2014: There was no noticeable variation both in the horizontal and vertical direction at the whole bank. The left bank scoured and shifted rightward. The thalweg point of the bank lowered by 12m. The right bank of the river remained almost as before.

3.2 VARIATION OF MEAN BED LEVEL (MBL)

The mean bed levels for every station and every selected year are shown in table 1. Table 2 shows the erosion/deposition of the mean bed level, where the preceding year was taken as the base year for the next consecutive year. From Tables 1 and 2, it is seen that the mean bed level of the Ganges-Padma River is very dynamic, with significant variation over the years. The amount of erosion and deposition is also large at Baruria Transit.

Table 1 Variation of mean bed level in the Ganges-Padma River at different stations (m, CD)

Stations	1996	2000	2005	2009	2014	Distance (km)
Harding Bridge	1.14	1.47	2.73	3.54	3.1	20
Baruria Transit	-1.55	1.08	0.13	0.45	-1.33	80
Mawa	0.96	0.21	0.67	0.48	1.09	200

Table 2 Erosion/Deposition of mean bed level of Ganges-Padma River (m)

Stations	1996	2000	2005	2009	2014
Harding Bridge	0	0.33	1.26	0.81	-0.44
Baruria Transit	0	2.63	-0.95	0.32	-1.78
Mawa	0	-0.75	0.46	-0.19	0.61

Figure 5 shows the mean bed level is higher at the first station (Harding Bridge) compared to the second station (Baruria Transit) downstream. The erosion/deposition at different stations is shown in the following Figures 6 (a), (b) and (c) respectively.

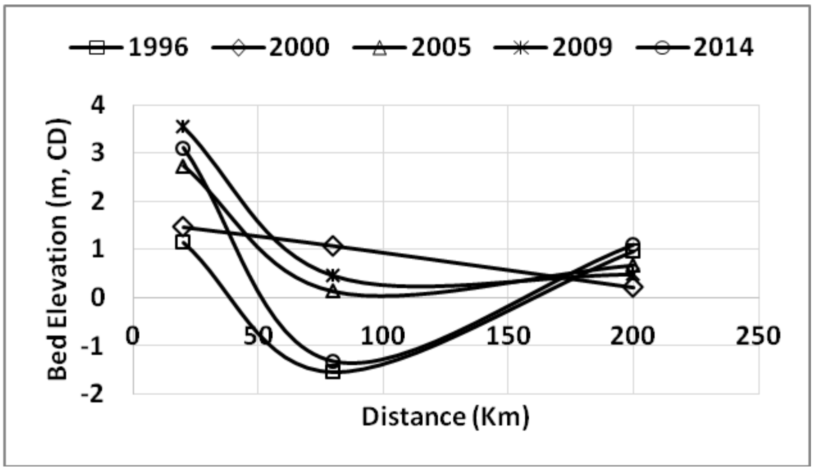
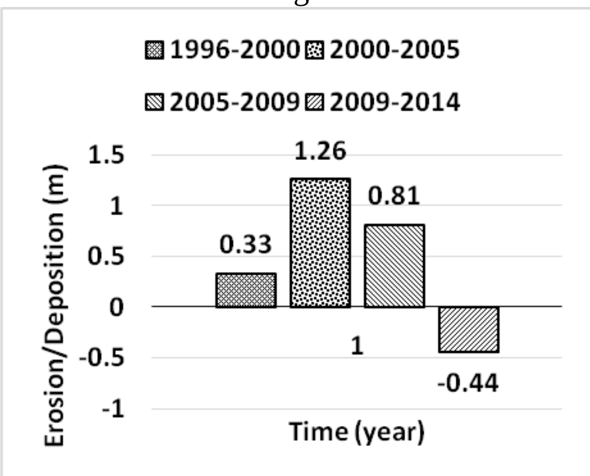
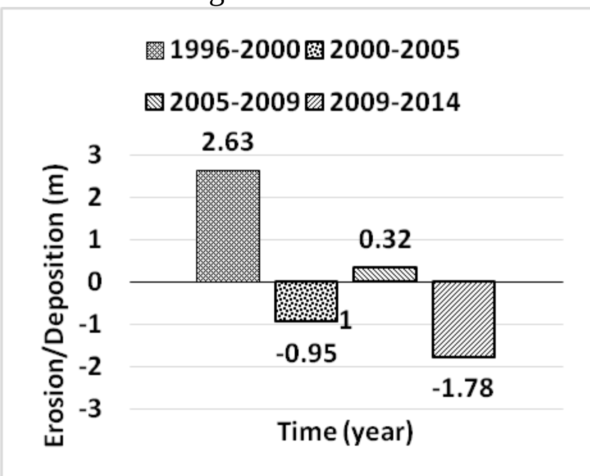


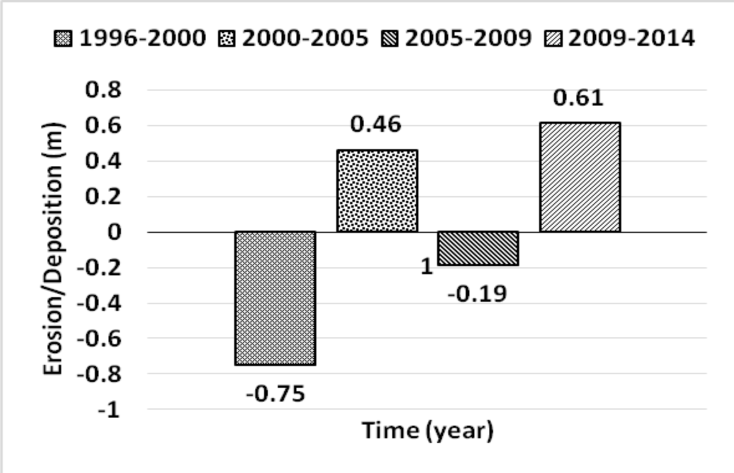
Figure 5 Variation of mean bed level along the river



(a)



(b)



(c)

Figure 6 Bar diagram for erosion/deposition: (a) Harding Bridge (b) Baruria Transit (c) Mawa

Harding Bridge, Figure 6 (a):
Mean bed level lowered successively from 1996 to 2009 as deposition occurred. Maximum deposition was calculated at 2005 with respect to 2000. From 2009 to 2014 results were different, with erosion occurring at the bank.

Baruria Transit, Figure 6 (b):
This station shows very dynamic characteristics. Erosion and deposition had occurred alternately with respect to previous years. Maximum deposition had taken place at 2000 with respect to 1996 with a value of 2.63m.

Mawa Station, Figure 6 (c):
This station also shows very dynamic behavior. Erosion and deposition had occurred alternately with respect to previous years. Maximum erosion had taken place at 2009 with respect to 2005 with a value of 1.09m.

3.3 CORRELATION BETWEEN MBL AND WL

The results from the analysis of the variations of water level (WL) and bed level (BL) are presented in Tables 3 to 6. The Chart Datums (CD) are to references. Negative BL values indicate erosion while positive BL values indicate deposition. Negative and positive WL values indicate drop or rise in water level respectively. HWL is the highest recorded water level during the dry season and LWL is for the lowest water level.

Table 3: Water level and bed level variations, 1996 and 2000

Stations	1996			2000			HWL Change (m)	LWL Change (m)	BL Change (m)
	HWL (m, CD)	LWL (m, CD)	BL (m, CD)	HWL (m, CD)	LWL (m, CD)	BL (m, CD)			
Harding Bridge	14.35	4.69	1.14	14.20	5.40	1.47	-0.15	0.71	0.33
Baruria Transit	8.18	2.04	-1.55	8.52	1.96	1.08	-0.29	-0.08	2.63
Mawa	6.26	3.5	0.96	6.15	3.67	0.21	-0.11	0.17	-0.75

From Table 3, HWL falls although bed material is deposited at Harding Bridge station. But HWL rose at Baruria Transit station due to deposition of bed materials. Erosion occurred at Mawa station to cause the river bed LWL to rise.

Table 4 Water level and bed level variations, 2000 and 2005

Stations	2000			2005			HWL Change (m)	LWL Change (m)	BL Change (m)
	HWL (m,CD)	LWL (m,CD)	BL (m,CD)	HWL (m,CD)	LWL (m,CD)	BL (m,CD)			
Harding Bridge	14.2	5.40	1.47	13.76	5.31	2.73	-0.44	-0.09	1.26
Baruria Transit	8.52	1.96	1.08	8.72	1.92	0.13	0.20	-0.04	-0.94
Mawa	6.15	3.67	0.21	5.88	3.10	0.67	-0.27	0.57	0.46

From Table 4, HWL and LWL both decreased although mean bed levels were eroded at Harding Bridge station and Mawa station (except LWL at Mawa) and LWL decreased due to erosion of river bed material at Baruria Transit.

Table 5 Water level and bed level variations, 2005 and 2009

Stations	2005			2009			HWL Change (m)	LWL Change (m)	BL Change (m)
	HWL (m,CD)	LWL (m,CD)	BL (m,CD)	HWL (m,CD)	LWL (m,CD)	BL (m,CD)			
Harding Bridge	13.76	5.31	2.73	13.69	4.74	3.54	-0.07	-0.57	0.82
Baruria Transit	8.72	1.92	0.13	7.76	1.69	0.45	-0.96	-0.23	0.32
Mawa	5.88	3.10	0.67	5.48	3.08	0.48	-0.4	-0.02	-0.19

In Table 5, despite bed level deposition, the overall water level of Harding Bridge and Baruria Transit station is lowered. On the other hand, at Mawa station as bed level lowered, water level is also lowered. So, it may be said that during these years the overall water level of the Ganges-Padma River was lowered.

Table 6 Water level and bed level variations, 2009 and 2014

Stations	2009			2014			HWL Change (m)	LWL Change (m)	BL Change (m)
	HWL (m,CD)	LWL (m,CD)	BL (m,CD)	HWL (m,CD)	LWL (m,CD)	BL (m,CD)			
Harding Bridge	13.69	4.74	3.54	12.99	5.49	3.10	-0.7	0.75	-0.45
Baruria Transit	7.76	1.69	0.45	8.26	1.84	-1.33	0.5	0.15	-1.78
Mawa	5.48	3.08	0.48	5.82	3.26	1.09	0.34	0.18	0.61

Table 6 shows that as bed level deposited HWL and LWL were both raised at Mawa station while at Harding Bridge and Baruria Transit station bed level eroded. Consequently HWL at Harding Bridge and LWL at Baruria Transit lowered but LWL at Harding Bridge and HWL at Baruria Transit rose.

3.4 VARIATION OF THALWEG PROFILE

The variation of thalweg in the vertical direction along the river for every year is shown in Table 7 and Figure 7. The deepest point of the cross section at Baruria Transit increased successively, while at Mawa station it remained almost steady. At Harding Bridge station the deepest thalweg point elevation was recorded as 17.78m for 2005 and shallowest point was recorded as 7.03m for 2000. An indirect indication of sediment erosion from 2000 to 2005 can be seen at Harding Bridge station.

Table 7 Variations of thalweg depth by year (m, CD)

Stations	Year-1996	Year-2000	Year-2005	Year-2009	Year-2014
Harding Bridge	-12.14	-7.03	-17.78	-7.72	-11.01
Baruria Transit	-11.484	-11.95	-19.57	-23.7	-34.47
Mawa	-11.809	-10.35	-12.25	-15.84	-13.08

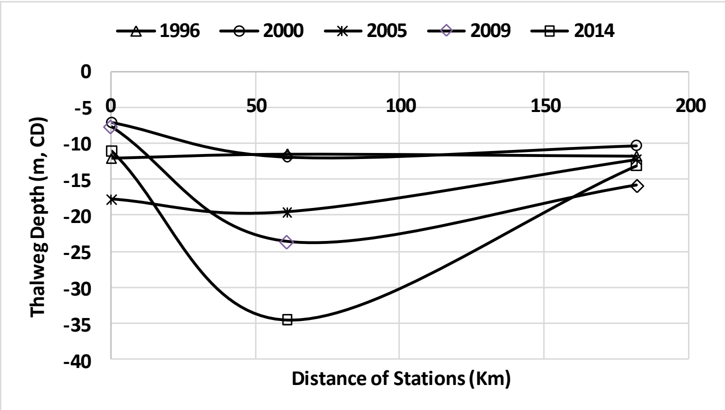


Figure 7 Variations of thalweg vertically along the river

Taking the left bank as reference line at each station the shifting of thalweg line horizontally over time is showed in Table 8 and Figure 8. Figure 8 shows the thalweg maintained a constant distance from the bank from 1996 to 2000 while in 2005, it came close to the left bank. Subsequently the line gradually shifted towards the right bank at Harding Bridge station. At Baruria Transit station the thalweg line remained close to the left bank from 1996 to 2014 except 2000. In 2000, it suddenly shifted rightward, i.e. at middle bank where erosion had taken place more than the left bank. At Mawa station the dominating position of the thalweg line was at the right bank. Only in 2000 and 2009 it came towards the left bank.

Table 8 Shifting of thalweg line from the left bank, 1996 to 2014

Location of the station	Distance (m)					
	1996	2000	2005	2009	2014	
Harding Bridge	1112.76	1190.55	690	1670	2260	0
Baruria Transit	698.35	3050	694	1000	1020	61
Mawa	7415.8	1781	4240	1150	6440	182

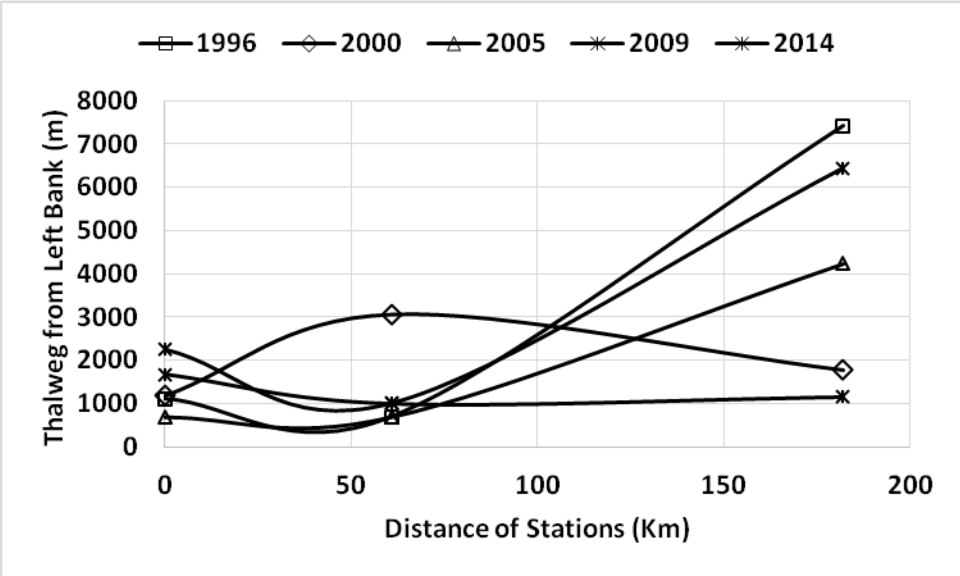


Figure 8 Lateral migration of thalweg line from left bank

4.0 CONCLUSION

This study highlights the water and bed level variations in the Ganges-Padma River. The river showed a dynamic behavior at Baruria Transit where the highest mean bed level variation was found to be 2.63m (deposition) in 2000 with respect to 1996. At Harding Bridge Station, mean bed level variation was steady along with the stations.

The variation of water level and bed level followed a typical trend with some deviations. From 2009 to 2014 in most cases the water level dropped as the bed level declined or the water level rose as a consequence of bed level rise. But from 1996 to 2009, different characteristics are apparent for all stations.

Shifting of the thalweg point also varied over time for different places. Vertically, the most frequent movement of thalweg was found at Mawa station, whereas horizontally the most frequent movement was at Baruria Transit. In this study, only cross sectional and water level data were analyzed to compare the bed level changes with respect to water level rise or fall. A further study might be taken by considering sediment transport data and also by using GIS (Geographic Information System) technology with detailed plans, sufficient data and satellite imagery.

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