Int. J. of Geol. & Earth Sci., 2017

International Journal of Geology and Earth Sciences

ISSN 2395-647X www.ijges.com
Vol. 3, No. 4, December 2017

Research Paper

SHORT-TERM MORPHOLOGICAL CHANGE PREDICTION OF THE PADMA RIVER AT THE BRIDGE CONSTRUCTION LOCATION IN BANGLADESH

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Received on: 17th September, 2017 Accepted on: 13th November, 2017

This study has predicted the short-term morphological changes of the Padma river at the bridge crossing illustrating the development and migration of bars, channels shifting and bank erosion using time-series satellite images. The three mid-channel bars MCB1, MCB2, MCB3 initiated with an initial area of 1.03, 1.89, 2.25 km^2. After initiation, the MCB1 bar grew maximum size of 10 km^2. The size of MCB2, MCB3 bars increased 3 to 4 folds within 3 to 5 years. At the initiation, the sizes of the four attached bars AB1, AB2, AB3, AB4 were very close and ranged from 3 to 6.7 km^2. Among the four attached bars, the AB1, AB3 bars decreased in size and the AB2, AB4 bars increased from 4 to 10 folds in size. The three attached bars AB1, AB2, AB4 migrate with a very close rate of about 1.5 km/year while the AB3 bar showed no net migration within five years. Bathymetric surveys suggested the main channel has been continuing along the left channel close to Mawa and is going to take the shape of a single-channeled planform. The channels Ch1 and Ch2 along the right bank have not changed substantially from the previous years and the overall trend is decline in these two channels by 2011. The bar Br1 would move downstream and reach the bridge crossing by 2010. It is expected that the right flanking channel at the bridge crossing will be silted up; therefore, the bar Br2 would be an attached char.

Keywords: Bar development and migration, Channel shifting, Padma river, Bridge crossing

INTRODUCTION

The morphological change prediction is very significance to river training work. The rivers in Bangladesh have been frequently changing their courses (Bristow, 1987; Hasan *et al.*, 1997; Bridge, 2003; CEGIS, 2009; and Rahman *et al.*, 2016) and the Padma is the second ranking river because of its erosion intensity along the 100 km long reach (CEGIS, 2005a and 2005b; Sarker and Thorne, 2006; CEGIS, 2015; and Rahman *et al.*, 2016). The Padma is a very large sand-bed river having bankfull discharge that ranges from 75,000 to 80,000 m^3/s (CEGIS, 2009; Delft Hydraulics and DHI, 1996a and 1996g; and Rahman *et al.*,

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2016). The Padma river is not an intensely braided river like the Jamuna and it is not as dynamic as the Jamuna. Nevertheless, bank erosion of the river is a most common event the extent of which is comparable to that of the Jamuna river (Bristow, 1987; Delft Hydraulics and DHI, 1996c; and CEGIS, 2015). The banks of the river generally consist of highly erodible materials. A few kilometers along the left bank at the upstream of Mawa and along the right bank at Sureshwar have less erodible materials which play an important role in developing the planform historically (Leopold, 1957; Coleman, 1969; FAP 24, 1996b; Islam, 2006; CEGIS, 2009; and Rahman and Islam, 2017).

The channel abandonment/declination and migration of bifurcation or channel migration within the braid belt are not very frequent morphodynamics events in the Padma river but which are very common in the Jamuna river (Coleman, 1969; Bristow, 1987; Delft Hydraulics and DHI, 1996c; CEGIS, 2005a and 2005b; and Islam, 2006). It has been observed in the Padma river that in many cases small and low-level mid-channel bars disappear in the year following its emergence (Delft Hydraulics and DHI, 1996g; and CEGIS, 2005a). The development and migration of the bar are more uncertain. Moreover, there are a few examples of bar development and migration, which add further uncertainties in predicting bar development and migration (Delft Hydraulics and DHI, 1996b; and FAP 24, 1996a). An attempt has been made to predict the short-term planform and bank erosion at the bridge crossing through analysis of bar development and migration, meandering bend movement and bank erosion. Development and migration of both mid-channel and attached bars are crucial for short-term prediction of morphological changes (CEGIS, 2015). Even the study has predicted of bank erosion exceeds 50 m/yr at the present location of observation. Therefore, this morphological study at micro level would be an indicator for river training work.

MATERIALS AND METHODS

The prediction method is based on satellite images by CEGIS and field observation technique at ground level. Adebola *et al.* (2017) has emphasized on the remote sensing technique, as it is the convenient and scientific method for geomorphological analysis particularly, in the analysis of drainage basin morphology. The remote sensing data provide the accurate bird's-eye picture of a particular area at a particular time that is spatially corrected, and precise to real world situation (Laha and Bandyapadhyay, 2013). The development and migration of a few mid-channel and attached bars, and assessing the rate of meandering bend migration were analyzed using time-series satellite images from 1994 to 2009. The images used in this study were georeferenced using the CEGIS 1997 landsat image mosaic and the coordinates for the Ground Control Points (GCP) used in the georeferencing process were collected from the image mosaic (Rahman *et al.*, 2016). The primary software ERDAS Imagine was used for image processing and raster GIS analysis and the Windows NT based ArcInfo for vector analysis (Rahman *et al.*, 2016; and Rahman and Islam, 2017). Bathymetric surveys of August-September 2008 and August 2009 were performed for making a short-term prediction at the bridge location. Bathymetric surveys of the Padma river at bridge crossing have been utilized to predict channel development together with meandering bend movement. Planform predictions for the years 2010 and 2011 were done based on the planform of 2009. The result of the image interpretation integrating with the field observation phenomenon has applied to predict the short-term morphological changes of the river at bridge crossing.

RESULTS AND DISCUSSION

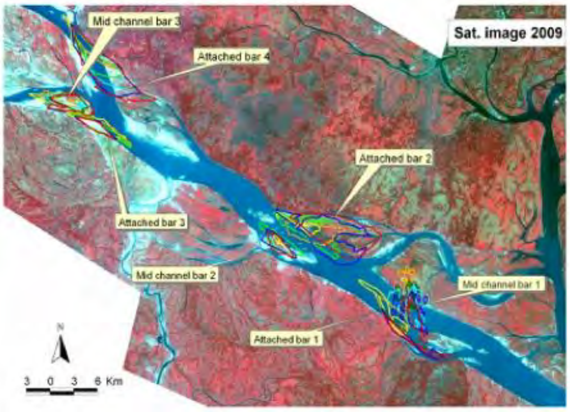
Development and Migration of Bars

The low-level sand covered mid-channel and attached bars were considered for assessing the development of bars and their migration. When the same bars were elevated and subsequently vegetation started to colonize over the bar, further development and migration of those bars were not analyzed. The locations of the studied bars are presented in Figure 1 and their years of initiation and corresponding characteristics are presented in Table 1.

Mid-Channel Bars

After initiation one mid-channel bar (MCB1) grew nine times larger within three years and the maximum size of the bar was 10 km^2 (Figure 2). Within the following two years the bar became reduced in size. The size of MCB2 and MCB3 bars increased 3 to 4 folds within 3 to 5 years. Enlargement of these bars were not unidirectional.

Figure 1: Location of the Studied Bars Shown on Satellite Image



Within five years after initiation, all these bars became vegetated and two of them became attached bars. The average size of the bars at that stage was about 6 km^2. In two cases the bars were found to be elongated initially and the length and width ratio was within a range 4 to 5. At the matured stage, the ratio of the length and breadth varied close to 3 (CEGIS, 2009). The migration of the leading and trailing edges as well as the center of the bar was analyzed. All three bars showed that their rate of migration was initially higher than at the later stage (Figure 3). In the first two years the average migration was 3.5 km and the average rate of migration was 1.75

Table 1: Description and Characteristics of Bars Used in the Analysis

Types of Bar	Name of Bar	Initiation of Bar	Initial Area (km^2)	Maximum Area (km^2)	Final Area (km^2)	Increase in Size (Nos. of Fold)
Mid channel bars	MCB 1	1995	1.03	9.53	5.12	4.97
	MCB 2	2003	1.89	6.86	4.15	2.2
	MCB 3	2005	2.25	8.46	8.46	3.76
Attached bars	AB 1	1999	5.23	7.26	3.6	0.69
	AB 2	2000	3.19	31.91	31.91	10
	AB 3	2005	6.69	6.69	3.1	0.46
	AB 4	1994	5.83	26.2	26.2	4.49

Figure 2: Development of Mid-Channel Bars Over Time

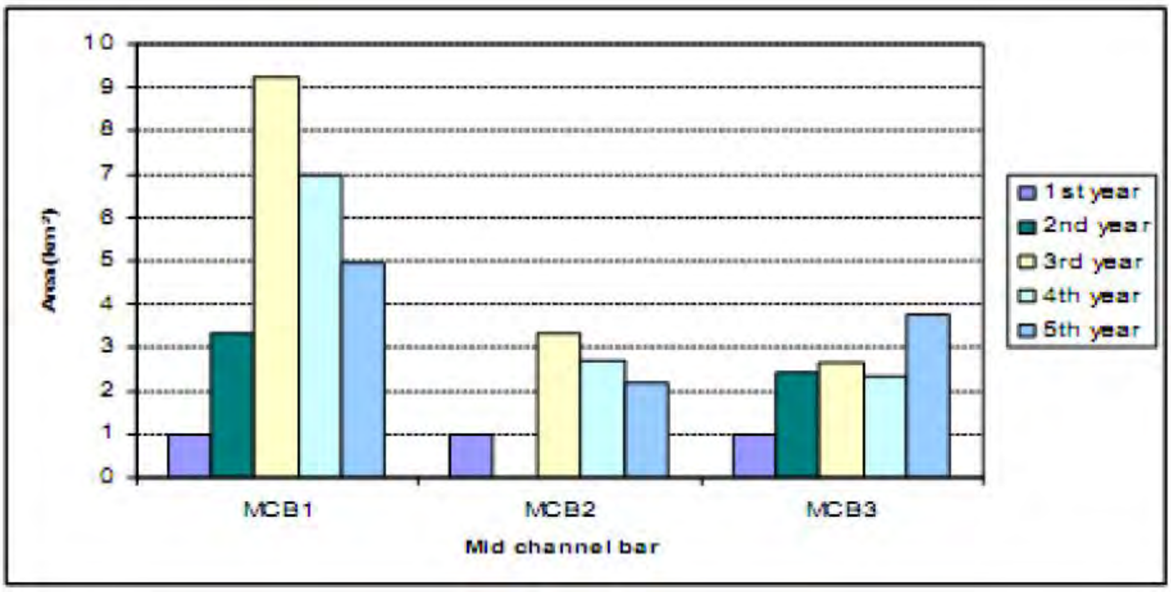
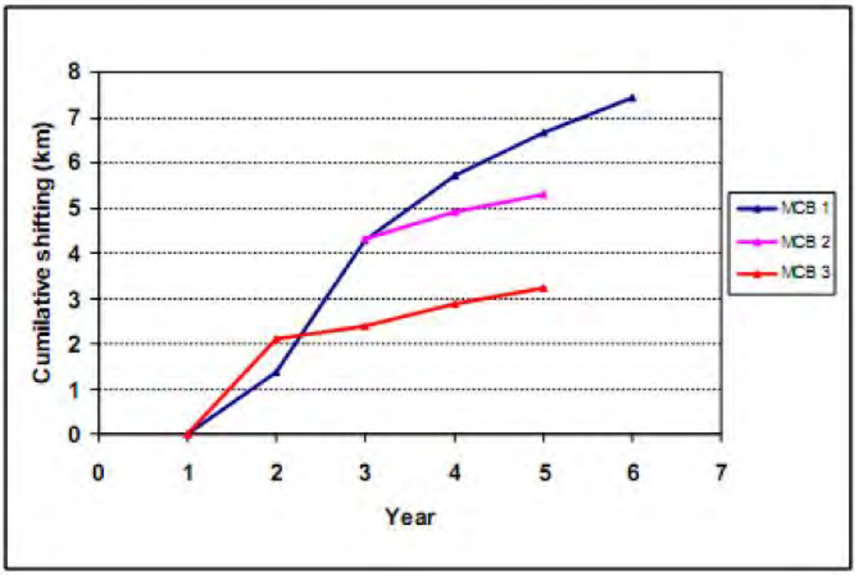


Figure 3: Downstream Migration of Mid Channel Bars



km/year. In the following two years the rate of migration reduced 0.8 km/year.

Attached Bars

The size of the attached bars varied over a wide range from 3 km^2 to 32 km^2. The rate of annual growth also varied widely. At the initiation, the sizes of the bars were very close and ranged from 3 to 6.7 km^2. Out of four, two of the studied bars decreased in size and the other two increased from 4 to 10 folds in size (Figure 4). The surface of the four attached bars became vegetated

Figure 4: Development of Attached Bars Over Time

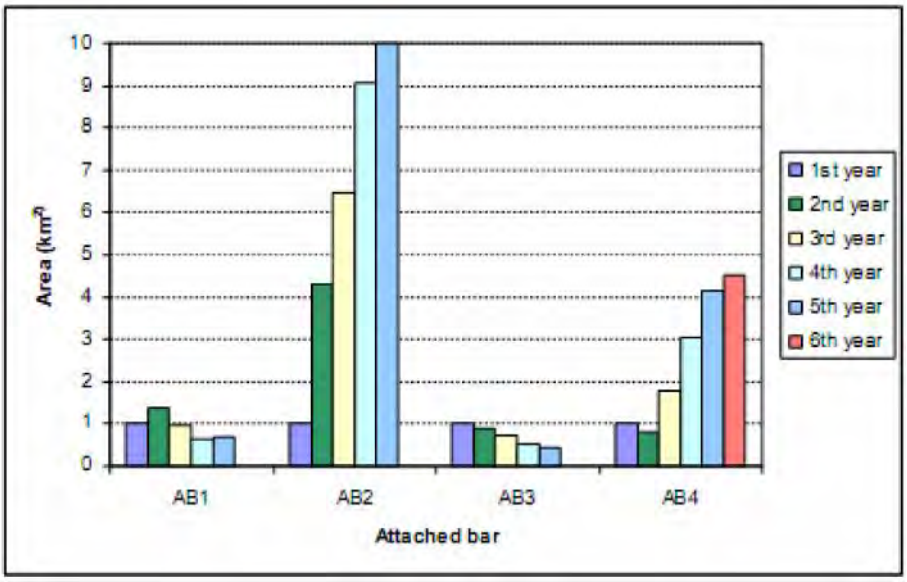
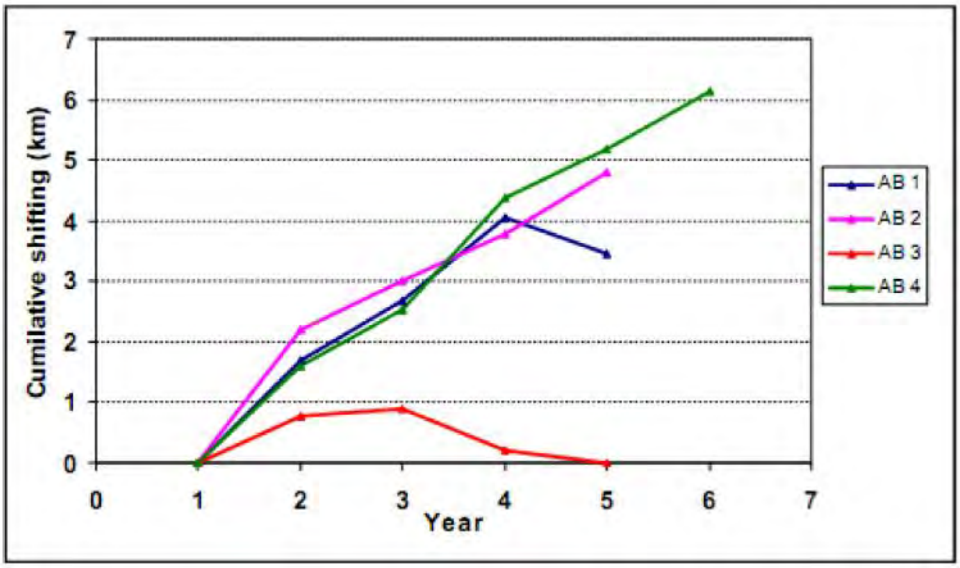


Figure 5: Downstream Migration of the Attached Bars



within five years, and the surface of only one bar becomes vegetated within six years. This finding concurs very closely with what was found for the mid-channel bars. It takes about five years for vertical accretion of a bar facilitating vegetation growth on the surface. The ratio of the length to width of the bars varied within a wide range between 2 and 16. The ratio was higher for the smaller bars and vise-versa. The average ratio for the smaller bars was 9 while it was 3.5 for the larger bars. Attached bars generally do not move downstream as a whole. In many cases the upstream end remains at the same position as during the formation of the bars. But as the bar growth continues downstream the center of the bars generally migrates downstream. Three attached bars out of four migrate with a very close rate of about 1.5 km/year (Figure 5). One bar showed no net migration within five years before it became vegetated.

Bank-erosion, Channel and Panform Change

Planform predictions for the years 2010 and 2011 are presented in Figures 7 and 8 based on the planform of 2009 (Figure 6). Bathymetry surveys and satellite images indicate that channels Ch1 and Ch2 have not changed substantially from the previous years. This does not also mean that one of these channels could not develop during the coming months. The probability of the development of channel Ch2 is less than 25%. In such consideration the maximum probable extent of bank erosion along the right bank at the bridge crossing would be 80 m (probability 20%). Bar Br1 would move downstream and reach the bridge crossing by 2010.

As it is expected that the planform at Mawa is going to take the shape of a single-channeled planform, the overall trend is decline in channels Ch1 and Ch2 in 2011, there is only 5 to 10% probability that Channel Ch2 or Ch1 will increase further. In such a case, the maximum extent of bank erosion at the bridge crossing would be 150 m from the present position (probability <10%) (Figure 8). Bar Br1 will move further down and reach the bridge crossing suggesting that a number of pier constructions should be done on the mid-channel bar in 2011. It is likely that the right flanking channel at the bridge crossing will

Figure 6: Planform of the Padma River at Bridge Crossing During January 2009

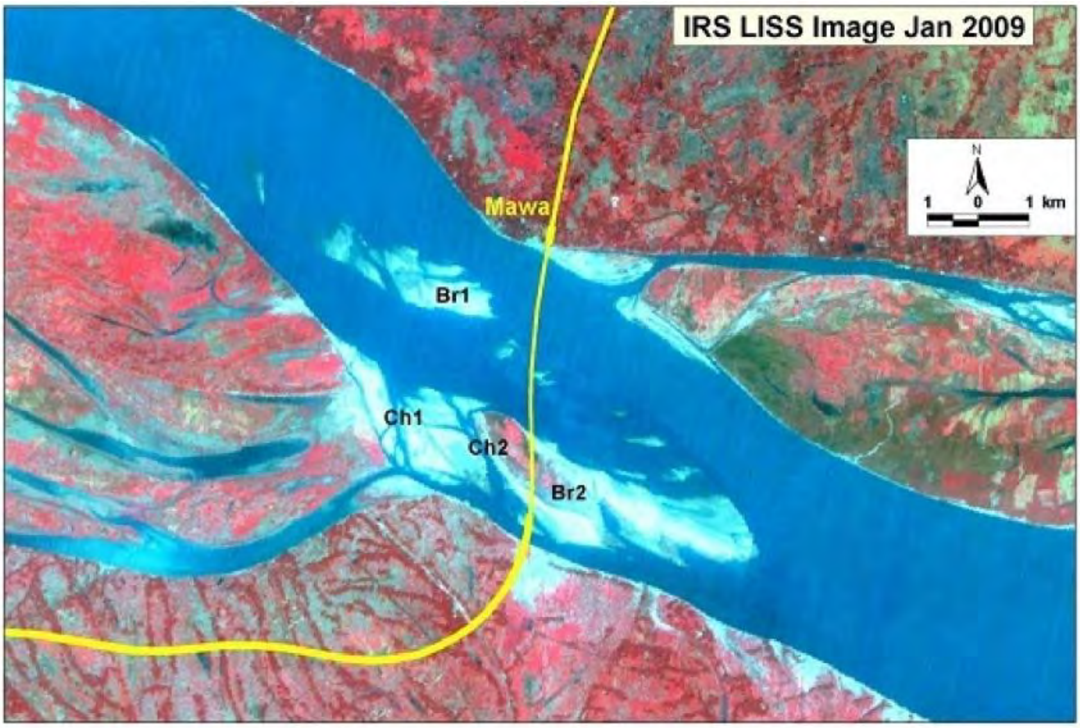


Figure 7: Bank Erosion Prediction of the Padma River at Bridge Crossing for 2010

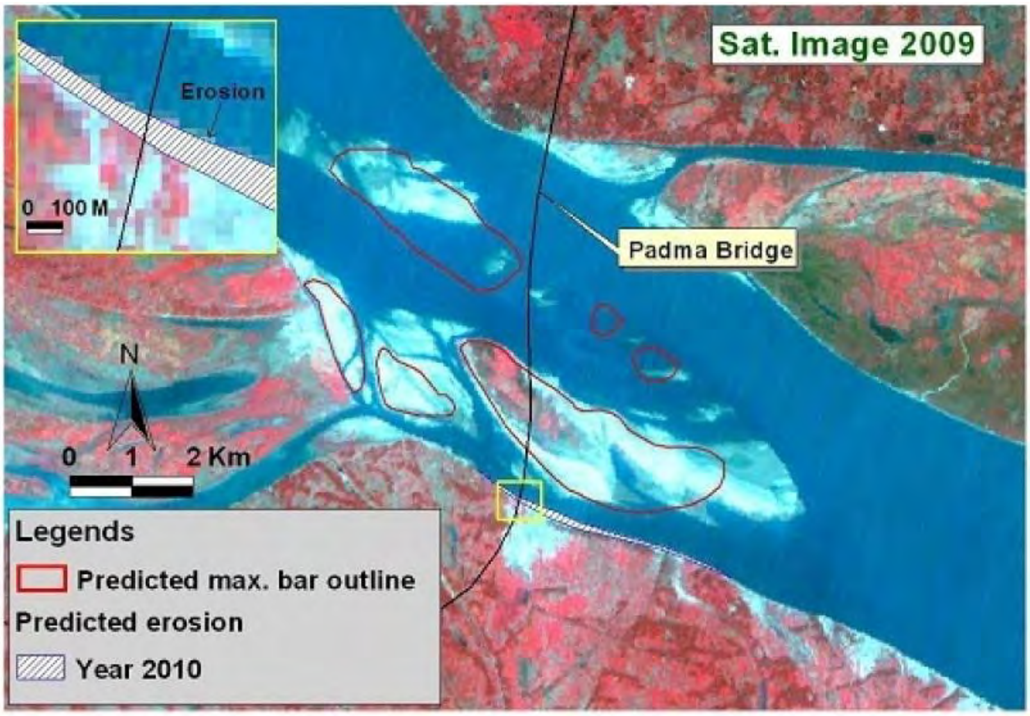


Figure 8: Bank Erosion Prediction of the Padma River at Bridge Crossing for 2011

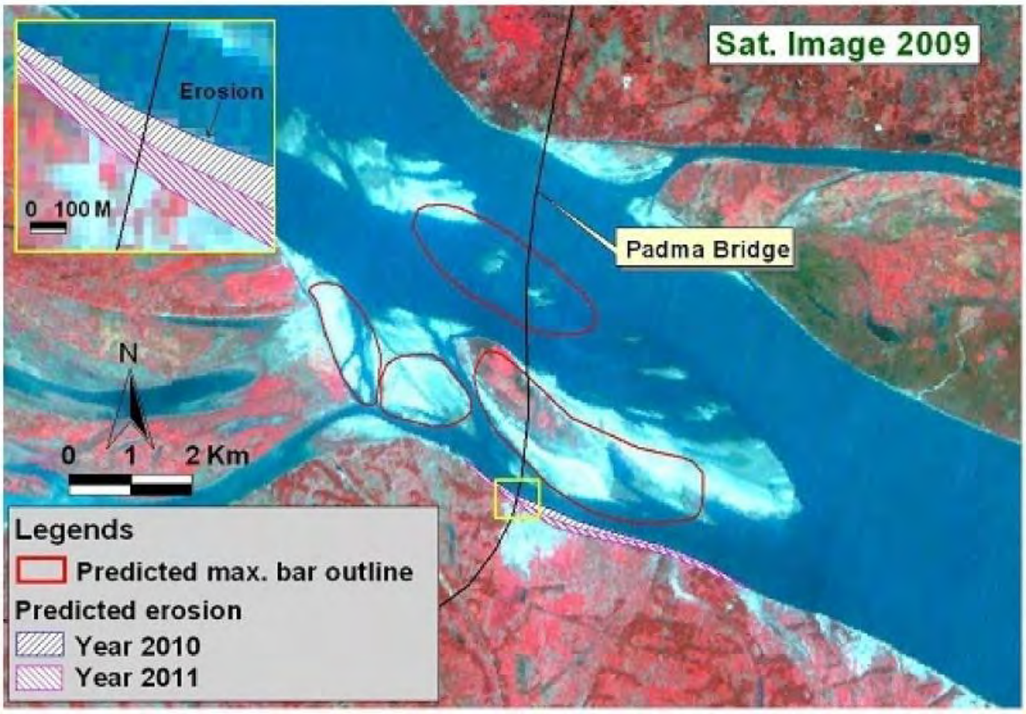


Figure 9: Bathymetric Survey of the River at Bridge Crossing, August/September 2008

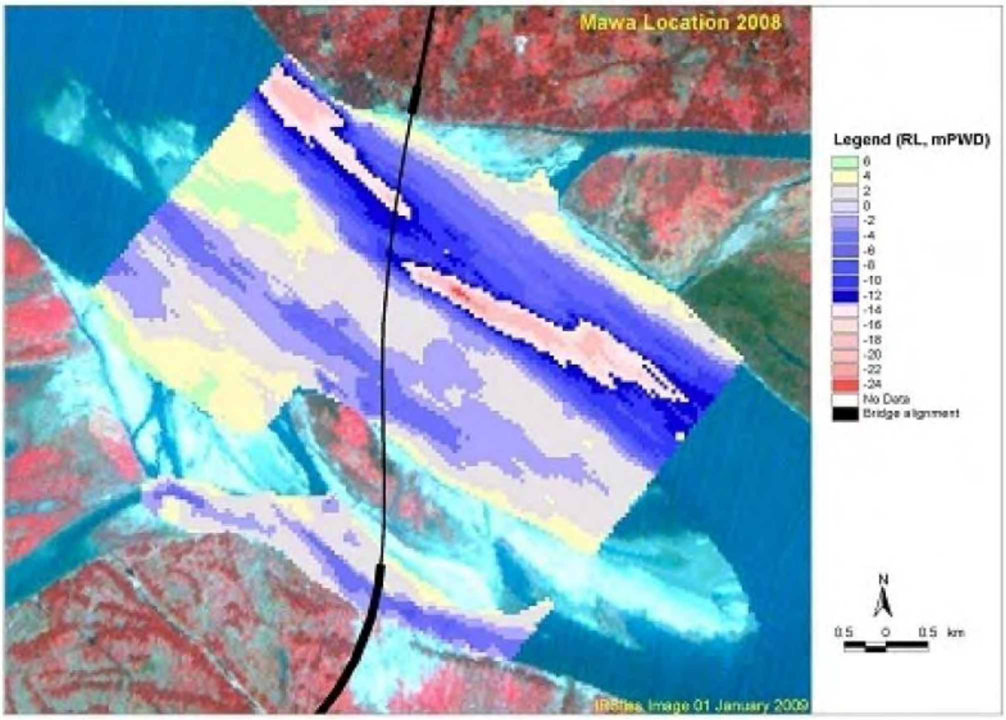


Figure 10: Bathymetric Survey of the Padma River at Bridge Crossing, August 2009

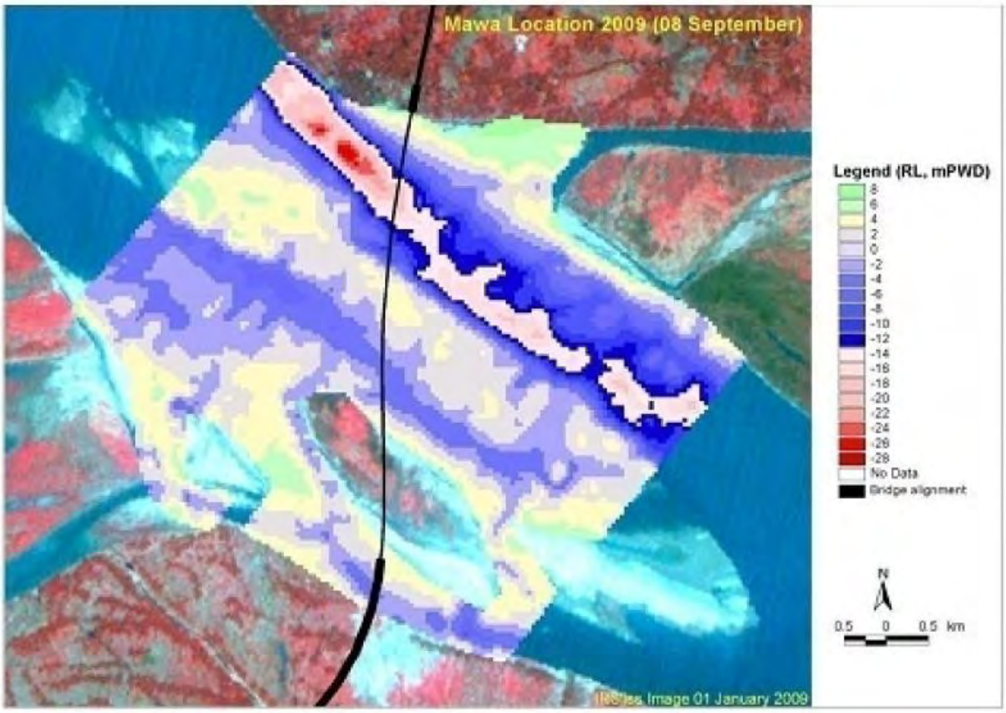
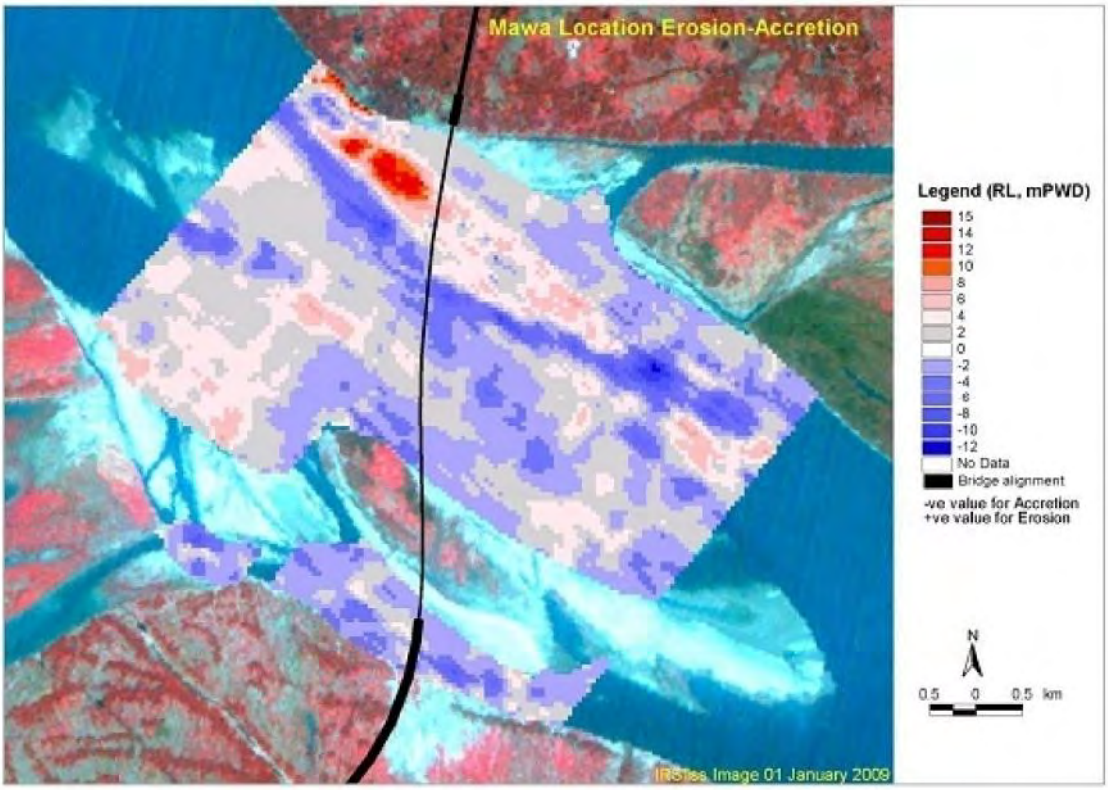


Figure 11: Riverbed Erosion and Deposition at Bridge Crossing August 2008 to August 2009



be silted up. In such case bar Br2 would be an attached char.

Bathymetric Survey and Morphological Prediction

Bathymetric surveys of August-September 2008 (Figure 9) and August 2009 (Figure 10) were used for making a short-term morphological prediction at the bridge location that has illustrated the erosion-accretion on the riverbed during this period (Figure 11). These figures suggested that the main channel has been continuing along the left channel close to Mawa. The channel flowing at the right side of bar Br1 has been maintaining its earlier status. The mid-channel bar Br1 and the attached bar Br2 migrated downstream and it appears that the bars have changed in size and shape. A cluster of bars was found to emerge at the downstream of Br1, which has been maintaining a division flow between the left and mid-channels.

CONCLUSION

This is expected that the river at Mawa would be a single channeled instead of a multi-threaded channel which is an indicative type of prediction. At the bridge location, the river is 5.2 km wide. The main channel is at the left bank where the bank materials are less erodible. On the other hand, the bank materials along the right bank are highly erodible, and a large bar in front of the bank has reduced the flow that may cause severe erosion (Figure 6). However, development of any shallow and narrow channels (Ch1 and Ch2 of figure 6) dissecting the bar may cause increased bank erosion along the right bank of the river at the bridge location. It is likely that in future a meandering bend that has already started to develop will continue to develop over the following decade. The right bank apex would be at the upstream of the bridge crossing and the left bank would be at Mawa and at the downstream. It is probable that the future planform over the next few years would be very close to what it was in the mid-1980s. Predictions of such development of channels or subsequent riverbank erosion at bridge location are crucial for designing the bridge length. Moreover, development and migration of the bar Br1 and Br2 are important for designing the construction methodology.

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