Proceedings of the 6th International Conference on Civil Engineering for Sustainable Development (ICCESD 2022), 10~12 February 2022, KUET, Khulna, Bangladesh (ISBN-978-984-35-1972-6)

STUDY OF THE OFF-TAKE DYNAMICS FOR RESTORING THE OLD BRAHMAPUTRA RIVER

Jakia Akter*[1], Faria Nur[2] and Maminul Haque Sarker[3]

[1]*Senior Specialist, Centre for Environmental and Geographic Information Services (CEGIS), Bangladesh, e-mail: jakia_cegis@yahoo.com*
[2]*Research Consultant, Centre for Environmental and Geographic Information Services (CEGIS), Bangladesh, e-mail: faria.wre14@gmail.com*
[3]*Senior Advisor, Centre for Environmental and Geographic Information Services (CEGIS), Bangladesh, e-mail: msarker56@gmail.com*

*** Jakia Akter**

ABSTRACT

The present course of the Old Brahmaputra River is the former course of the Brahmaputra River. It was used to flow east of the Madhupur Tract even in the 18th century. Since the avulsion of the Brahmaputra into the present course of the Jamuna River, the Old Brahmaputra River has been declining, in return it is losing its conveyance capacity, and now it has become a mere spill channel of the Brahmaputra at present. The offtake is the most dynamic part of the river and its location has shifted large distances of about 15 kilometers since 1973. At present, serious deposition has been taken place at the mouth. This article aims at studying the offtake dynamics investigating the reasons for the declination of flow with possible interventions using time-series satellite images, old maps, and hydro-morphological data of Jamuna and Old Brahmaputra rivers. Large planform change of the parent river such as the lateral movement of the parent river directing opposite to the offtake location, frequent anabranch avulsion has made not only the increase of sediment load at the offtake but also has increased the distributary channel distance to the parent river. Study results show that if the existence of the main channel can be ensured at the offtake and the offtake can be fixed at the outer bank of the main channel, it will develop the flow diversion percentage to the distributary. It also shows that as the Jamuna River is a highly gradient river, only dredging in the Jamuna and Off-take of the Old Brahmaputra may not be sufficient to restore the Old Brahmaputra River if both of them are not properly trained. Continuous dredging along with river training works such as guide bund along the left bank of Jamuna River can be a possible intervention for reviving the Old Brahmaputra River.

Keywords: *Offtake dynamics, Bifurcation Angle, Channel Incidence, Dredging, River Training Work*

1. INTRODUCTION

The Brahmaputra-Jamuna is the largest river in Bangladesh in terms of discharge and sediment (CEGIS, 2012). It is a braided river with many anabranches between its east-west transverse expanses. It is one of the largest and youngest braided rivers on earth and is still in the process of development and as such, the river is highly unstable. Old Brahmaputra River (OBR) is a left bank distributary of Brahmaputra-Jamuna River which starts from Fulchuri Upazila of Gaibandha district (Rajshahi). This article aims at studying the offtake dynamics investigating the reasons for the declination of flow with possible interventions using time-series satellite images, old maps, and hydro-morphological data of Jamuna and Old Brahmaputra rivers. A certain reach of Jamuna River has been selected from Kortimari to Kulkandi which is about 30 km upstream and 15 km downstream from the off-take of the OBR (Figure 1).

Previously, SWMC and DHI (1999) jointly studied for High Point Rendell/ Mitsui to support the barge transportation in the Old Brahmaputra. Boskali (2000) investigated the technical feasibility of a standalone dredging intervention in the Old Brahmaputra to augment the dry season flows of the river. Ali (2010) investigated the siltation at the intake reach of the OBR. For this purpose, satellite images, cross-sectional data, water level, and discharge data of the OBR covering the period from 1973 to 2005 were collected. He found that in 1973, the percentage of Jamuna River flow to the OBR was 6.69% and in 2007 this percentage of flow is reduced to 0.70%. This reduction of flow reveals the siltation problem at the Intake reach of the OBR.

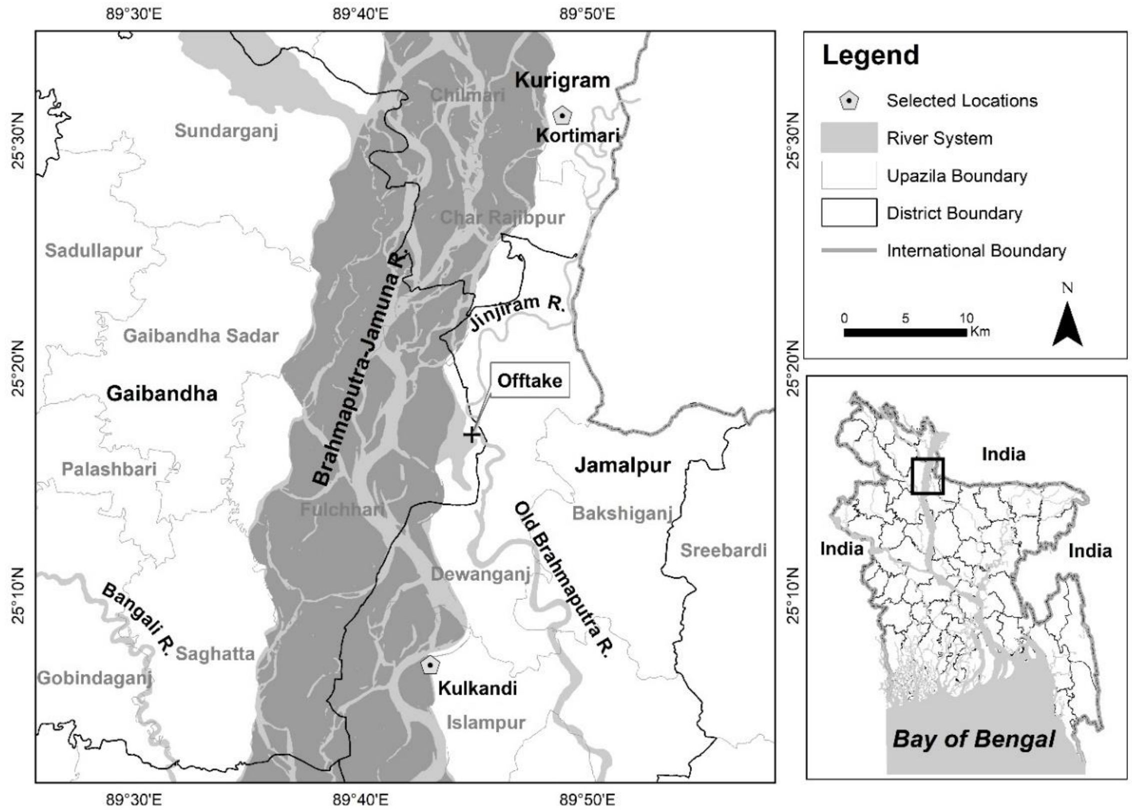


Figure 1: Study area

2. METHODOLOGY

Historical maps and time-series satellite images have been used for different years (1973-2020) to understand the ongoing morphological changes of the selected area of Jamuna River which is collected from the CEGIS archive. Moreover, time-series water level data at Bahadurabad and crosssection data of Jamuna and OBR vicinity have been collected from National Water Resources Database (NWRD). The outline of the methodology of the study is presented in Figure 2. The first column shows the inputs, the second column shows the processes and finally, the rightmost column shows the outputs.

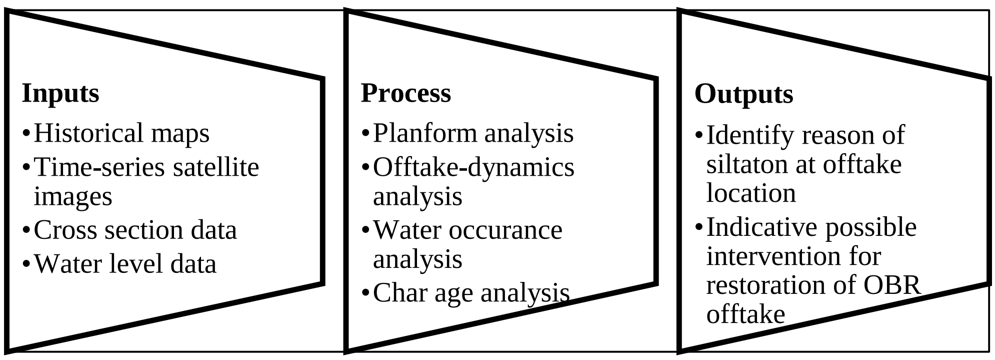


Figure 2: Methodology of the study

3. RESULTS AND DISCUSSION

3.1 Planform Analysis

3.1.1 Century-scale Changes

About 250 years ago, the Brahmaputra River flowed through the east side of the Madhupur Tract to meet the Meghna River and finally fell into the Bay of Bengal keeping Bhola district at its west (Figure 3). The Jennai River was found taking off from the Brahmaputra River to meet the Ganges. Huge water and sediment were carried through the Brahmaputra to the northeast region. About 170 years ago, a significant amount of the Brahmaputra flows diverted to the present Jamuna River to meet the Ganges. Two courses, namely the Jennai and Konai rivers, taking off from the Brahmaputra River met together and taking the name “Jamuna” met with the Ganges River at the then Jafarganj (presently Daulatpur). By the early 20th century, most of the Brahmaputra flow was diverted to the Jamuna River. Since then, the OBR has been declining day by day.

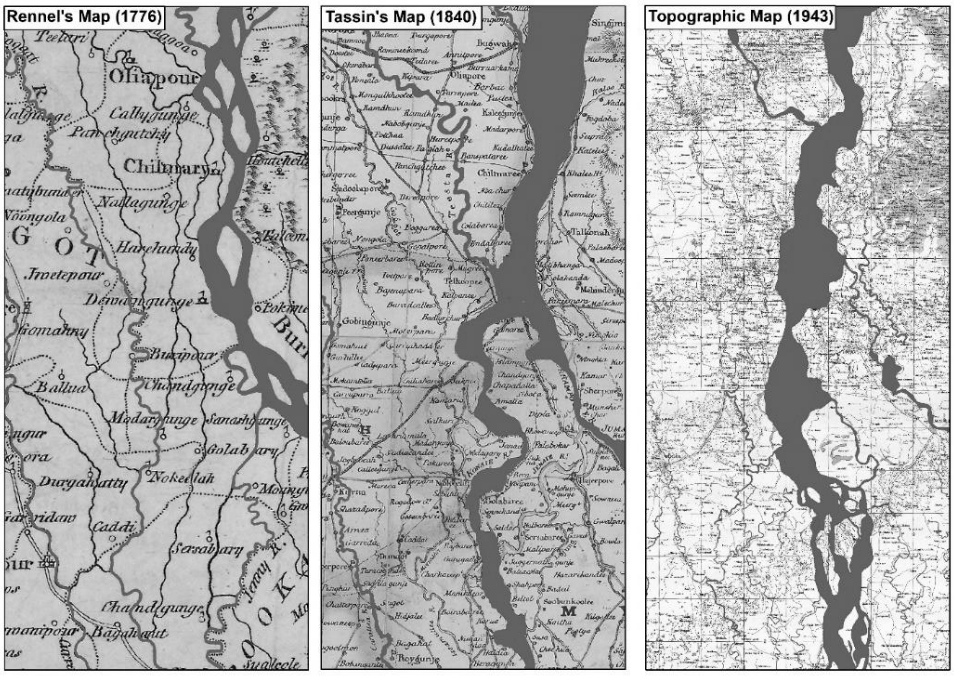


Figure 3: Century scale development of OBR

3.1.2 Decade-scale Changes

The movement of the banklines of the Jamuna River during the last 200 years was comprehensively studied by FAP 19 (Flood Action Plan, project 19) in Dhaka, and the results were published in ISPAN (1995). The ISPAN (1995) report reveals that in 1830 the Jamuna River had a meandering planform and followed a course that was for most of its length to the east of the line of the present east (left descending) bank. In 1914, the planform remained meandering, but the river had shifted noticeably. In the selected section, between 1914 and 1953, the river continued its westward migration (Figure 4), widening significantly (5.6 km to 9 km) (Figure 5) and hence metamorphosizing its planform from meandering to braiding. By 1973, the average width of the river had reduced to 8.3 km, but rapid westward migration had continued. Between 1973 and 1992, the rate of increase of the average width accelerated to a very high level (147 m/year), although the rate of westward migration slowed down. The river continued widening till 2009 (12 km in average width) while a sudden drop was observed in 2010 (11.6 km). From 2010, the river does not show any significant changes. Based on the available maps and images in CEGIS Archive from 1967 to 2020, a detailed description of the planform in the selected reaches is given below:

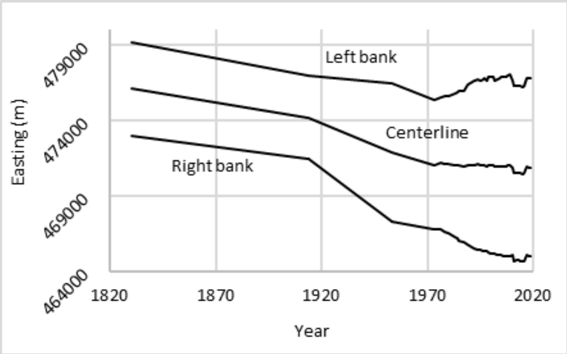


Figure 4: Lateral movement of the length-averaged bank lines and the centerline of the selected reach in the Jamuna River (1830–2017)

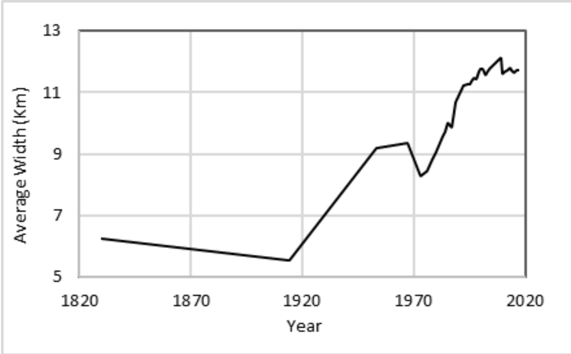


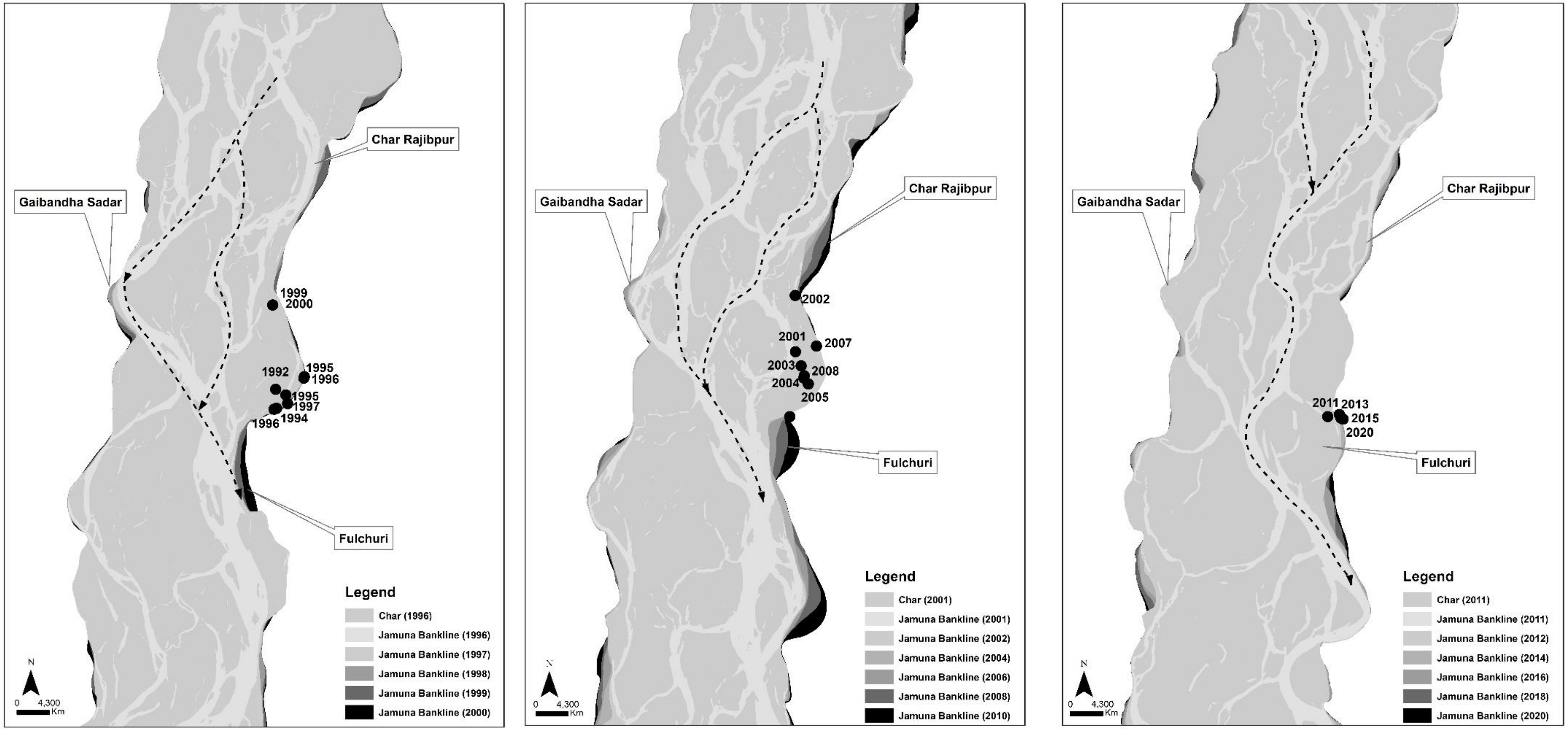
Figure 5: Time-series averaged width of Jamuna River (from Kortimari to Kulkandi)

3.1.2.1 Changes in 1991-2000:

Time series satellite images of the selected reach from 1991 to 2000 are shown in Figure 5. Char formation at the offtake was seen from 1994 when the main channel of the Jamuna River flowed from the left channel (Char Rajibpur) to the right channel (Gaibandha Sadar) and then to the left channel (Fulchuri) (the meandering direction of flow is shown by the dotted line in Figure 6). In this period, high erosion occurred along both banks of the main channel. Eroded material at Char Rajibpur might have been deposited immediately downstream where the offtake of the OBR was located. The low flow from the parent river, as well as westward migration of the Jamuna River and deposition from the upstream, led the offtake of the OBR to have less flow and siltation at the mouth.

3.1.2.2 Changes in 2001-2010:

All the channels were dominant in 2001. But the major part of the flow shifted to the left channel from 2006 (Figure 6). At the upstream of the offtake, a huge amount of erosion continued which deposited at the mouth of the OBR in the following years (Figure 6). But erosion along the riverbanks in the Gaibandha Sadar was observed reducing because the dominant channel shifted from the west to the east. Thus huge erosion downstream of the offtake was visible during this period. It is noticeable that the total amount of erosion in this decade is higher than the previous decade and the offtake of the OBR also shifts abruptly.



1990-2000 **2001-2010** **2011-2020**

Figure 6: Bankline shifting of Jamuna River in decade scale (1990-2020)

3.1.2.3 Changes in 2011-2020:

From 2011 to 2014, a large char was observed from Landsat Satellite images (Figure 6). From 2015, the channel adjacent to the offtake started to be dominant than other channels. Moreover, erosion was seen at the char located at the offtake of OBR (Figure 6). Though the parent river has enough flow, it is not able to feed the distributary. This is because of not only having a high bifurcation angle but also a high difference of elevation between the offtake of OBR and the Jamuna River.

3.2 Off-take Dynamics

Offtake of the river is the most dynamic and uncertain portion of the river. Often the location of the offtake shifted double from one place to the other. Moreover, on many occasions, it was found that the location of the off-take was not well defined or there might present more than one opening of a single river. The location of the offtake shifted along the left bank of the Brahmaputra-Jamuna River within a 15 km stretches of the river (1967-2020) (Figure 7).

3.2.1 Dynamics in 1967-1990

From 1967 to 1990, the offtake of Old Brahmaputra has shifted about 9.5 kilometers at a stretch. In 1973, the main channel of the Brahmaputra-Jamuna River was along the left bank at the Old Brahmaputra off-take. It was taking off from the Jamuna main channel at the crossing. In 1976, another spill developed 4 km downstream at the outer bank of the channel along with earlier off-take found in 1973. This location of 1976 off-take was the southernmost among other off-takes dated back to the 1970s. In 1983, the mouth of the north spill was deposited and from then flow continued through the southern offtake. In these years, a major portion of the Brahmaputra-Jamuna flow was flowing along the eastern channel of the Brahmaputra-Jamuna, close to the Old Brahmaputra off-take.

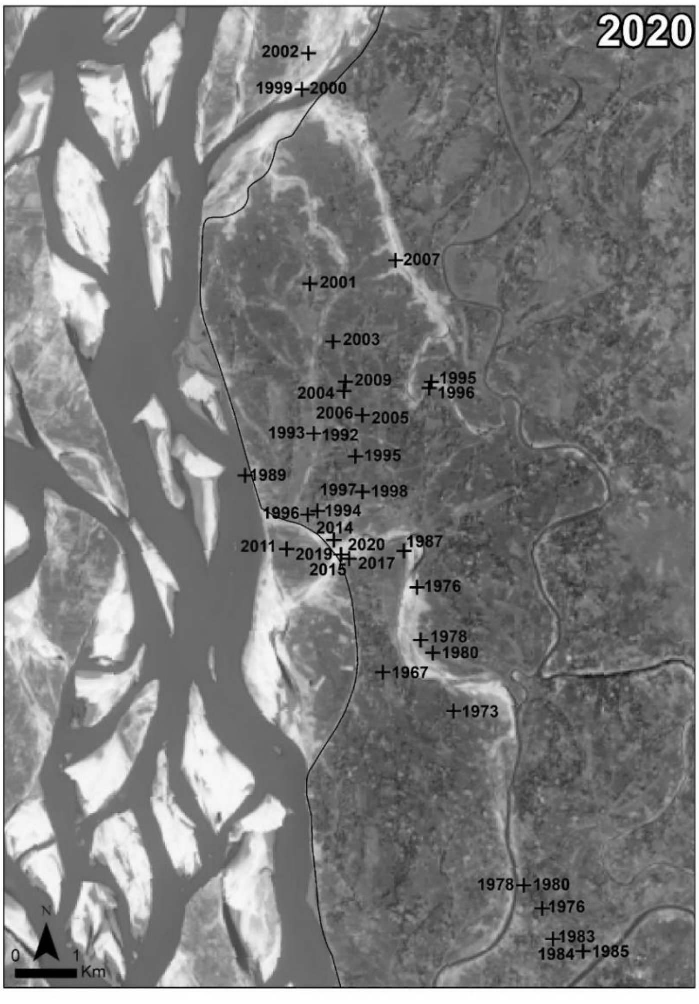


Figure 7: Offtake dynamics of OBR (1967-2020)

3.2.2 Dynamics in 1991-2000

From the early nineties to the twenties, the offtake of Old Brahmaputra did not show much variety in shifting compared to the previous two decades. In 1995, two offtake points have been identified while one of them closed again in 1997. A noticeable shift of about 7km towards north occurred in 1999 because of siltation at the former channel and the location continued till 2000.

3.2.3 Dynamics in 2001-2010

Locating the offtake points has been very difficult because of the high dynamicity of the Jamuna River in this decade. However, the offtake of Old Brahmaputra has shifted abruptly at about an 8 km stretch in this decade.

3.2.4 Dynamics in 2011-2020

From 2011 to 2020, the offtake of Old Brahmaputra has not shifted in any significant manner. This may happen because of the high bifurcation angle between the Parent River and the distributary. As other spill channels have been silted up and no other channel is suitable for continuing the flow, the river has been drying up day by day.

3.3 Role of Bifurcation angle in channel abandonment

In the Remote Sensing Study of Morphological Processes (Consulting Consortium FAP 21/22, 1993) of FAP 21/22 (Bank Protection and River Training Pilot Project) analysis was made on bifurcations in the Jamuna River. It was found that the deviation angle of a bifurcating channel could be a good indicator for predicting channel abandonment (EGIS, 2002). It has been observed that sedimentary features like sharpened bars, contraction bars, and sand wings within a reach of about 4 km upstream of any bifurcation generally affect the width and deviation angles and abandonment of the bifurcating channels. All channels having a deviation angle of more than 65° have a 100% probability of channel abandonment (EGIS, 2002).

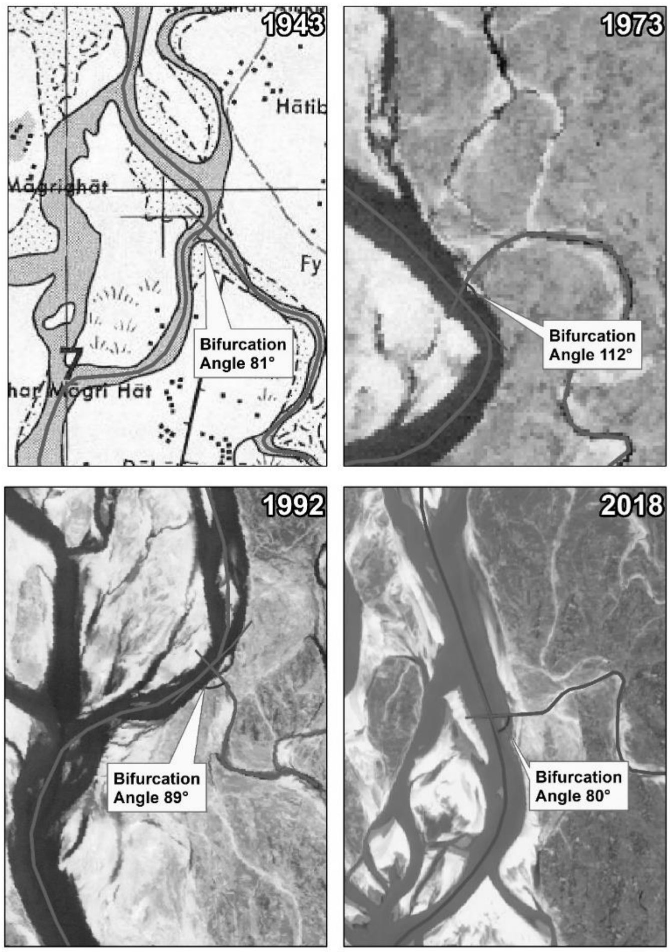


Figure 8: Time-series bifurcation angle variation of Jamuna and offtake of Old Brahmaputra

The bifurcation angle of Jamuna River and offtake of OBR has been calculated for the years 1943, 1973, 1942, and 2018 which is shown in Figure 8. The bifurcation angle of Jamuna River and offtake of OBR has been calculated for the years 1943, 1973, 1942, and 2018 which is shown in Figure 8. The bifurcation angle ranges from 80° to 112° which indicates a 100% probability of channel abandonment. Thus offtake of OBR is not in a suitable position to have enough flow from Jamuna River.

3.4 Water Occurrence Analysis

3.4.1 Channel Incidence

Channel incidence maps of Jamuna and OBRs have been prepared by superimposing the classified images in decade scale (1980-2020) which is represented in Figure 9.

Figure 9 represents the channel incidence map of 1980-1990 which shows that frequency of channel incidence is lower at the upstream reach of Jamuna River at Kortimari, which indicates high dynamicity of the river in this reach. Moreover, both left and right anabranches at Fulchuri are observed to be dominant equally. At the offtake of Old Brahmaputra, 40% to 60% of channel incidence has been perceived which confirms the continuation of flow in the river.

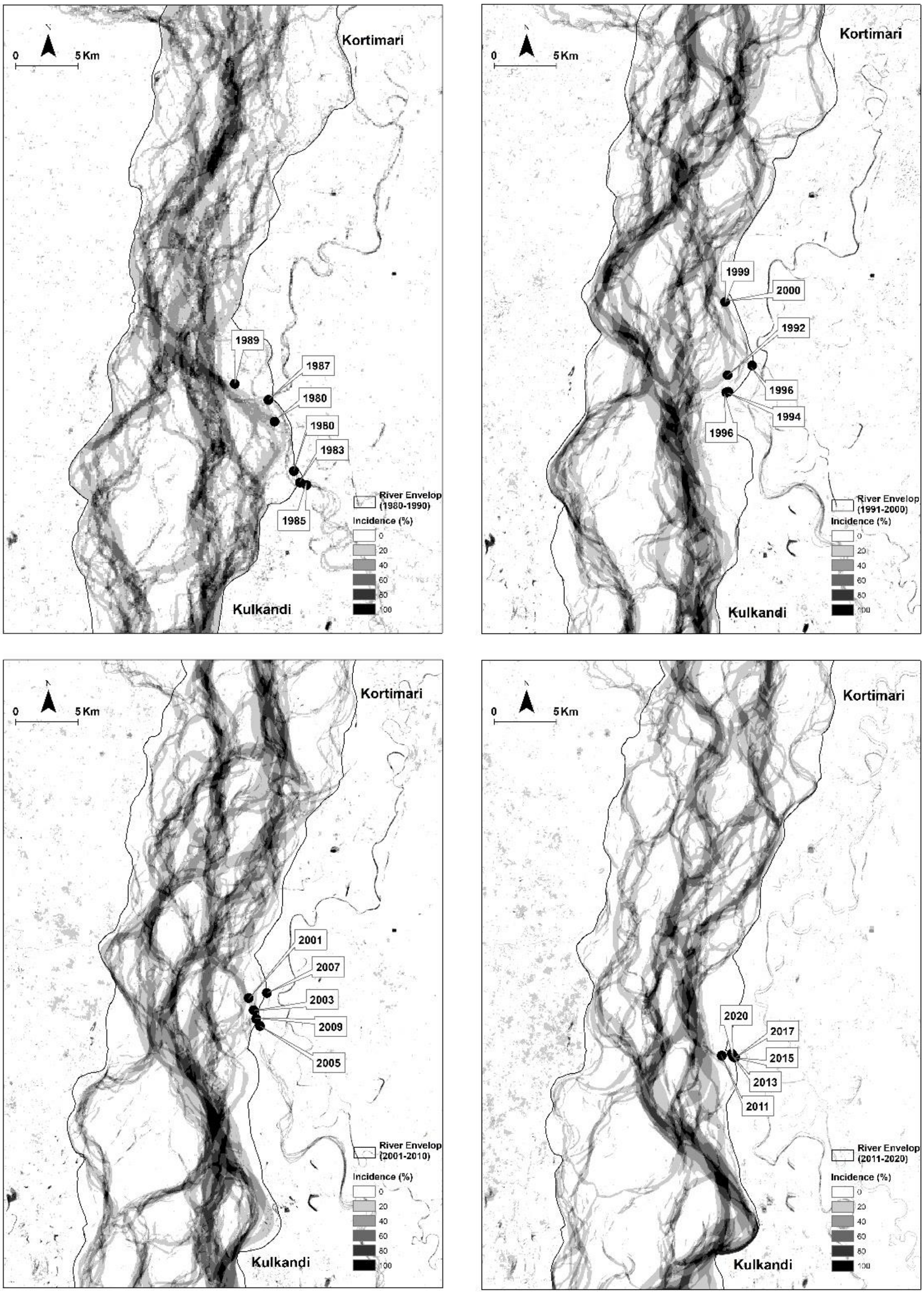


Figure 9: Channel incidence map (1980-2020)

The channel incidence map of 1991-2000 has also been shown in Figure 9. The map shows that the upstream reach of Jamuna River at Kortimari has become more braided than the previous decade. The right anabranch was dominant than the left anabranch at the Old Brahmaputra offtake reach while the left anabranch dominates at Fulcher. Consequently, the flow may decrease in the OBR in this decade because of the low flow in the parent river.

In 2001-2010 (Figure 9), the width of the Jamuna River at the upstream reach of offtake of Old Brahmaputra has increased and all the anabranches have become dominant equally. The left anabranch at Fulchuri has become fully dominated and the width of the right anabranch has decreased significantly. At the offtake of Old Brahmaputra, low frequency of channel incidence means char or sandbar formation which may result in a declination of flow in the OBR.

In the last decade (2011-2020) (Figure 9), Jamuna River looks to be more trained and a high frequency of channel incidence can be observed at left anabranches upstream of offtake. This may be the consequence of riverbank protection works along the right bank of the Jamuna River. Flow has completely shifted in the left anabranch at Fulchuri and low frequency can be observed at the offtake of the OBR.

3.5 Char Occurrence Analysis

The age of chars of study reach of Jamuna River has been analyzed for the last 25 years (1996-2020) which is shown in Figure 10. From this Figure, it is observed that the age of the most chars at the vicinity of the offtake of the OBR ranges from 2 to 5 years. This study confirms the dynamicity of the Jamuna River in this area. Moreover, char age at another offtake at the upstream of the present location is about 17-19 years which means permanent land formation in this location. Thus it can be concluded that this location may not be suitable in terms of restoration.

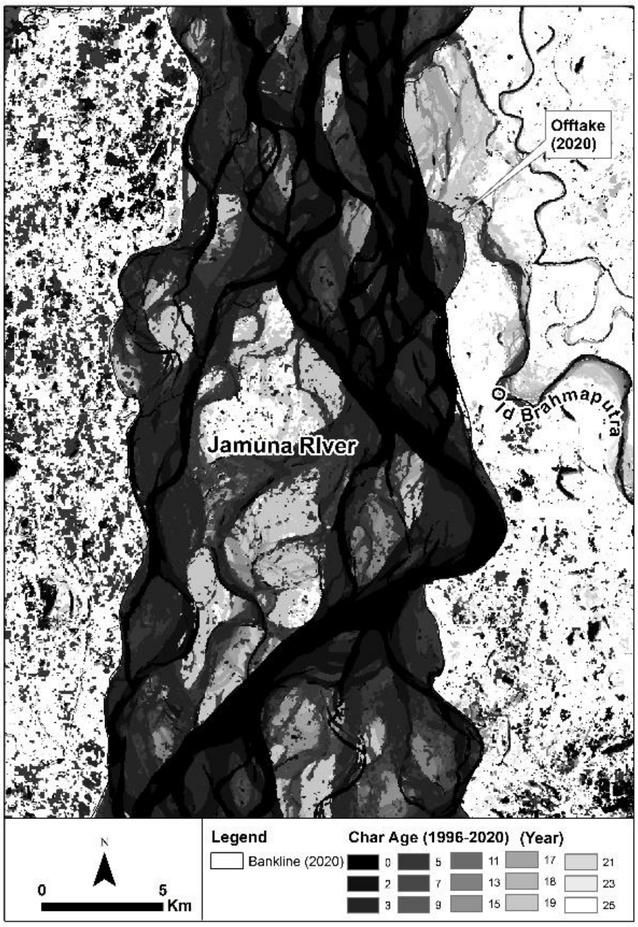


Figure 10: Char age analysis (1996-2020)

3.6 Elevation Difference at Offtake

Elevation difference at the offtake of Old Brahmaputra and Jamuna River has been analyzed from cross-section data that is shown in Figure 11. The Figure shows that the bed elevation at the offtake of OB is much higher than the bed elevation of Jamuna River. Moreover, the historical minimum water level of Bahadurabad is found about 11.7 mPWD which is below the bed level of the OBR. Thus elevation difference is the main reason for the offtake not having enough flow in the dry season. If the elevation difference can be minimized, offtake restoration is possible.

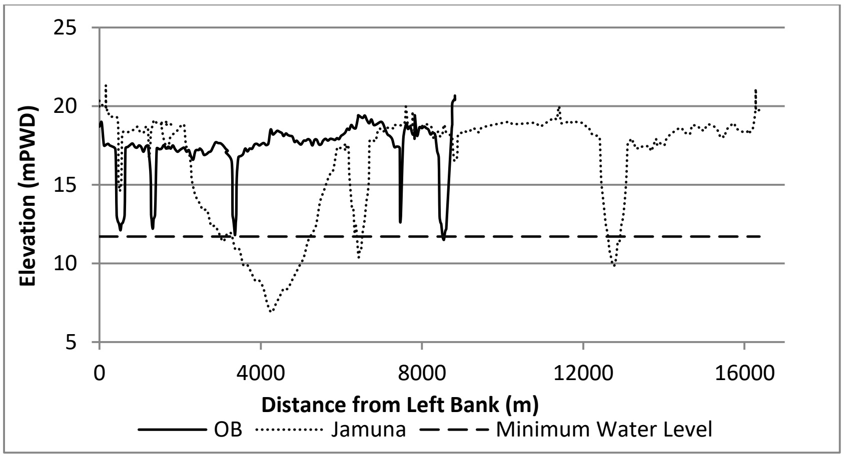


Figure 11: Bed Elevation of Jamuna and OBR at Offtake in 2005

3.7 Possible Intervention at Offtake

Since the Jamuna River is very dynamic and a huge amount of sediment is transported through the river, planned and sustainable intervention is necessary to restore the OBR based on the morphological understanding. An indication of possible interventions for restoring the OBR is given in Figure 12. Thus, guide bunds at both sides should be designed to attract the flow towards the off-take, considering the Jamuna Channelization plan for the future. In addition, it will also guide the flow to the main channel of the OBR without eroding the riverbanks for any natural modification. The length of the guide bund could be optimized based on model results. Few river training works in the OBR are also proposed for protecting the riverbank erosion and guiding the OBR flow. These interventions are also dependent on model results. For maintaining the flow, dredging should be done at the offtake, and maintain the channel with continuous dredging. The formation level of the dredging alignment at the OBR off-take should be less than the Lowest Low Water (LLW) level of the Jamuna River for year-round connectivity. The LLW at Bahadurabad is around 11.7 mPWD. Hence, the formation level of the dredging alignment should be lower than 11.7 mPWD. Here, we propose to keep the formation level at 10 mPWD at the off-take of the OBR. The bottom width of the dredging alignment would be 2-cut, i.e. 74 m; with a side slope of 1(V):7(H). The length of the dredging alignment is about 3 km. The bifurcation angle should not be greater than 65 degrees. All these indicative interventions can be finalized through a morphological modelling, which is under progress.

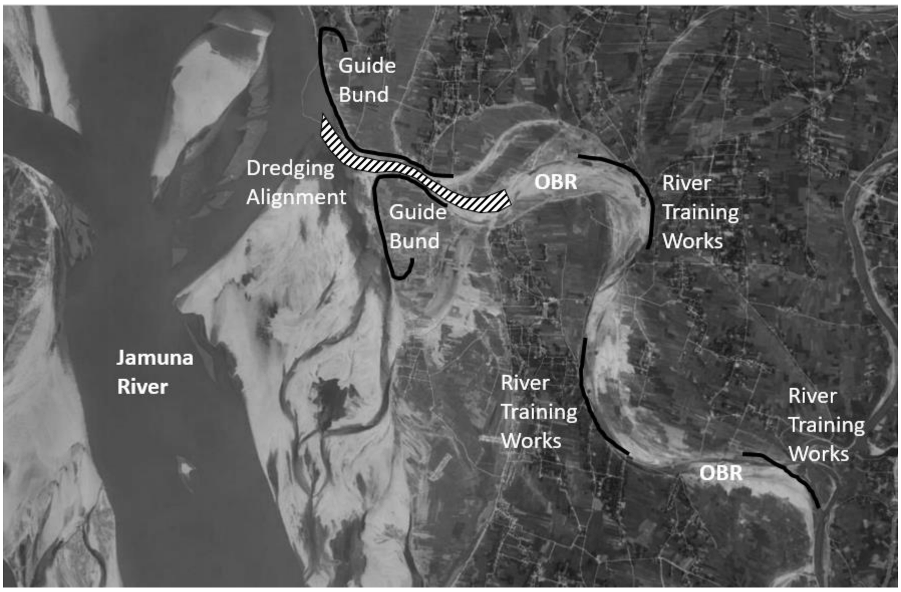


Figure 12: Indication of possible interventions for offtake-restoration

4. CONCLUSIONS

Being highly active, Jamuna and OBR rivers are still in the adjustment process. The study discussed above has confirmed the circumstances in the favour of abandonment of OBR without any intervention. The study concludes that

- The dominant channel of the Jamuna River shifts frequently. In the early nineties, the right channel used to be dominant when the left channel seems to be dominant in the last couple of years. Though the parent channel is flowing at the vicinity of the offtake, OBR is not having enough flow to revive.
- When avulsion started, the bifurcation angle between Jamuna and OBR was greater than 65° which was prone to channel abandonment. The angle varied through the years but always was in alignment with the channel abandonment process.
- A significant difference in elevation of the Jamuna and OBR bed level can be confirmed to be the main reason for channel abandonment.

The future is always uncertain. A lot of physical processes (such as extreme floods, earthquakes, tectonic activity, etc.) may interfere with the regular course of Jamuna and OBR in coming decades and the OBR may regain its flow naturally. But according to the study of the last 250 years, without intervention, restoration of OBR seems to be in an unfavorable condition. But planned and sustainable interventions with proper maintenance can help the river to revive again. Only dredging cannot restore the river, thus structural intervention like guide bund is also necessary to guide the flow to the OBR.

5. ACKNOWLEDGMENTS

The basic understanding of the Old Brahmaputra off-take was made during the activities done under the Flood and Riverbank Erosion Risk Management Investment Program (FRERMIP) financed by the Asian Development Bank (ADB). Later, The understanding was more enhanced and updated during the Joint Collaborative Program (JCP) activities funded by Dutch Partners.

REFERENCES

Ali. F., (2010), “A Study on siltation at the intake reach of the Old Brahmaputra River”, M.Engg Project, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

Boskalis-GRC, (2000), “Old Brahmaputra offtake area: Feasibility of Pilot Dredging”, Prepared for BWDB, Dhaka, Bangladesh

CEGIS. (2012). Geo-morphology and Planform of Bangladesh RIvers. Bangladesh Water Development Board.

EGIS. (2002). Developing and updating empirical methods for predicting morphological changes of the Jamuna River. environmental and GIS support project for water sector planning, EGIS-II. EGIS Technical Note Series 29.

ISPAN, (1995), “The dynamic physical environment of riverine charlands: Brahmaputra-Jamuna, Irrigation Support Project for Asia and near East (ISPAN)”, Prepared for Flood Plan Coordination Organisation (FPCO), Dhaka, Bangladesh.

SWMC and DHI (1999), “Navigabiliy of Old Brahmaputra River Survey and Modelling of River Condition”, Final Report, Prepared for Mitsui Engineering and Shipbuilding Co. Ltd.