

Single Beam Bathymetric Data Modelling for Identification of River Bank Erosion Prone Sites near Manikchak Region in Malda District, West Bengal

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Abstract : River Ganga is very much dynamic in the upstream segment of Farakka barrage near the Malda district. The Fluvial action of Ganga continuously eroded a large chunk of the landmass of the Diara tract of the Malda district every year. River Ganga is very much dynamic during the early monsoon and post-monsoon periods of a year. As a result, numerous char lands have emerged each year within the channel in this segment. In the present study, we have considered a specific extension of river Ganga adjacent to the Manikchak block of the Malda district. Firstly we have pointed out the thalweg position of the river bed across the given cross-segment between the mainland and both newly emerged and old stable mature Charland because thalweg position of channel influences on flow depth, flow velocity and flow direction of the channel which control bank erosion process and rate. Secondly, we have measured bottom relief characteristics between mainland and char lands along the given cross-sections through preparing river bed profiles on the basis of channel depth data deriving from the echo sounder survey. Basically, we have found that the maximum thalweg position is located adjacent to the Charland along the all given cross-sections which indicate that there has a chance of a large amount of erosion along Char lands compare to the mainland. Besides these above mentioning analysis, we have also tried to derive the bathymetry of the given river segment and point out the possible locations of bank erosion.

Keywords : Ganga river, Thalweg position, Single beam echo sounder, Bathymetry, Char land

Introduction

The determining factor in river development is the carrying capacity of the sediment load. When the waterway crosses a maximum value of sediment load, it becomes transformed into a braided channel from a single channel meandering river (Leopold et al., 1963). Bank erosion happens mainly in meandering rivers. The rate of channel migration is increasing rapidly with the increasing area of the meandering river. The rate of erosion and deposition depends on the size and flow of the river and the amount of sediments which it carries. Erosion occurs most rapidly during flood

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season, but bank slumping can continue through the dry season in places where rapid river flow continues to undermine river banks.

The river bank materials can be classified into cohesive and non-cohesive materials. The natural river bank is made with both cohesive and non-cohesive bank materials (Grissinger et al., 1963). However, there have sharp distinctions between the erosional behaviour of cohesive and non-cohesive sediments (Raudkivi, 1990; Mirtskhoulava 1991; Mitchener and Torfs, 1996; van Ledden et al., 2004). The erosional behaviour of non-cohesive bank sediments depends on the shape, size and density of soil particles. On the other hand, electrochemical bonding is a significant controlling factor that influences the erosion behaviour of cohesive bank sediments. But electrochemical bonding is more significant than the shape, size and density of soil particles in the context of riverbank failure.

India is also a significant river land among Asian countries. Numerous major rivers along with their numerous tributaries construct the Indian river system. The two most significant rivers which are subject to frequent bank erosion are the Ganga River and the Brahmaputra River which are braided rivers (Sharma 2013; Mili et al. 2013; Phukan et al. 2012). So far, various remedies like embankment have been constructed for flood control. The erosion problem of the embankment systems has been seen in some north-eastern states like West Bengal, Bihar, Assam, etc. (WRIS, 2014).

In case of West Bengal, Farakka Barrage has its special importance due to the existence of the Kolkata Port. The 2.64-km long Farakka Barrage was designed to divert 40,000 cusecs (or 1,133 cumecs) of Ganga water towards the Bhagirathi River to flush the sediment load into the deeper part of the estuary and rejuvenate the navigational status of the Kolkata Port (Banerjee, 1999; Rudra, 2004). It was built with the objective of inducing the excess water into the Hugli River. The obstruction seems to lead the river to carve out its own way, mainly in the upstream of Farakka barrage. Basically, the construction of the Farakka Barrage has resulted in the formation of a local base level, thereby disturbing the dynamic equilibrium of the fluvial system. Hence, the river is trying to remove the Barrage from its course. This can be done by increasing its sinuosity. In the process, a large chunk of land gets eroded and lost due to channel shifting (Rudra 2004). The main sufferers are the two districts of West Bengal, Malda and Murshidabad (Banerjee and Chakraborty 1983; Banerjee 1999). This change in the Ganga River course and resulting river bank failure is a long-term natural disaster in the state of West Bengal.

Since the river bank erosion in Malda districts has been a burning issue during the last few decades, a large number of papers have come out dealing with the hazard of bank erosion in the last few decades. Showkat (2010) studied the effect of flood and associated land erosion as well as the socio-economic aspects of this area. In the upstream of the Farakka Barrage, a major part of falls under Malda district, particularly in the four blocks viz Manikchak, Kaliachak-II, Kaliachak-III and Ratua-I. Iqbal (2010) observed that the rate of river bank erosion is very high and frequent, which causes a huge amount of river bank cutting and consequent population migration from the villages

near the river. Parua (2002) found that the change of river course was followed by the alteration in the river morphometry like its total width, sinuosity, braiding characteristics, etc. It also results in the change in the shape of the boundary between Malda and Murshidabad Districts, as well as the boundary between West Bengal and the Jharkhand States. It results in social and political conflict also. Since the 1950s, the pattern of the river channel was more or less straight, but later it continuously increases its sinuosity. The right bank of the river is underlain by erosion-resistant basalt rock of the Rajmahal Hills (Kent et al. 2002), which comes in eastern Jharkhand state, previously southern Bihar. They consist predominantly of quartz-normative tholeiites interbedded with thin bentonites or tuffs (Sengupta 1998). Along the left bank of the river Ganga, villages like Birnagar, Panchanandapur, and Manikchak Ghat, etc. which are made by a weak alluvial loose soil structure have become notorious in terms of these hazards due to channel shifting of the River Ganga and they have been in the news for wrong reasons. A large chunk of land has been lost due to continuous bank erosion by the river Ganga.

The basic objective of the present study to assess the bottom relief character of the river Ganga along Manikchak block near Malda district and to identify the thalweg position of the river channel which controls the riverbank erosion process. Beside this, we are also tried to derive channel bathymetry of the River Ganga adjacent to Manikchak Diara and identify the probable bank erosion sites within this segment.

The Study area

Malda is a central district of West Bengal which is situated Indo-Bangladesh border with extending an area of about 3733 sq. km approximately (Census of India, 2001). The western boundary of the district has bounded by the Ganga River where frequent bank erosion is continuously happening from the last few decades to till now. Malda district has 15 numbers of blocks, among these blocks Manikchak, Kaliachak II and Kaliachak III blocks are located at the western side of the district which are very much affected by bank erosion of Ganga. Basically, these three blocks are part of Diara physiographic division which is basically low lying new alluvial plain. Among them, the River bank segment along the Manikchak block has taken into consideration in the present study (Fig. 1). The geographical location of the study area is 24°51'N to 25°14'N and 87°46'E to 88°06'E. Manikchak block comprises 89 mouzas, among them 15 riverine mouzas are very much affected by the dynamic action of river Ganga in this upper segment. The emerging char lands within the river catchment are also being affected by riverbank erosion in this segment. So both mainland and char lands are affected by the dynamicity of river Ganga in this segment. Generally, within a year, mainly two times e.g. from the end of June to middle August which indicate the monsoon period and the second time is from the end of September to early November which indicates the post monsoon period. The causes of monsoon time river bank erosion has maximum water pressure on river bank site and on the other hand, the river water enters through the gap of the river bank materials, increase the water pressure on the material gap and collapse the riverbank site vertically. In this way, more or less amount of river bank erosion happened every year along with this Manikchak river bank site.

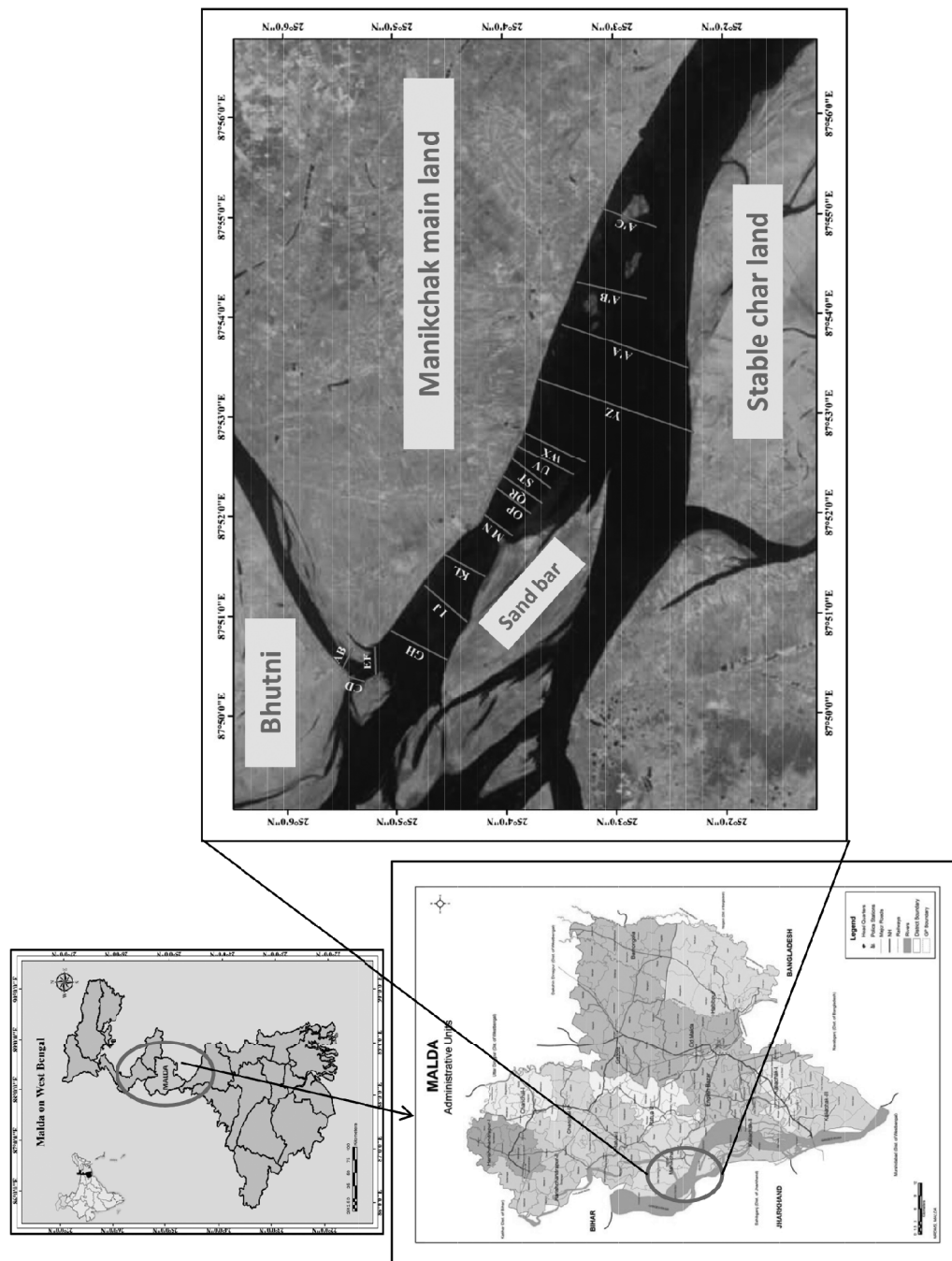


Fig. 1. Map of the study area

Data Source and Methodology

Techniques of data collection

The whole database in the present study has been collected through the field survey. At first, we have subdivided the whole river segment adjacent to the Manikchak block into three stretches. The first stretch is taken on the Ganga-Fulhar river junction point near Bhutni char land and here we have considered 4 cross sections namely AB, CD, EF and GH respectively. After the second stretch has been considered between a narrow river catchment between Manikchak main land and its adjacent newly emerged char land, here we have taken 8 cross sections namely IJ, KL, MN, OP, QR, ST, UV and WX towards downward from previous stretch. Finally, we have taken another four cross sections namely YZ, A'A, A'B and A'C at further downward section between Manikchak main land and old stable char lands where channel becomes relatively wider than the second stretch. The location of all given cross-sections have been shown in Fig. 1. Along each cross section, river depth has been measured through the single beam echo sounder instrument at 1 meter interval horizontally.

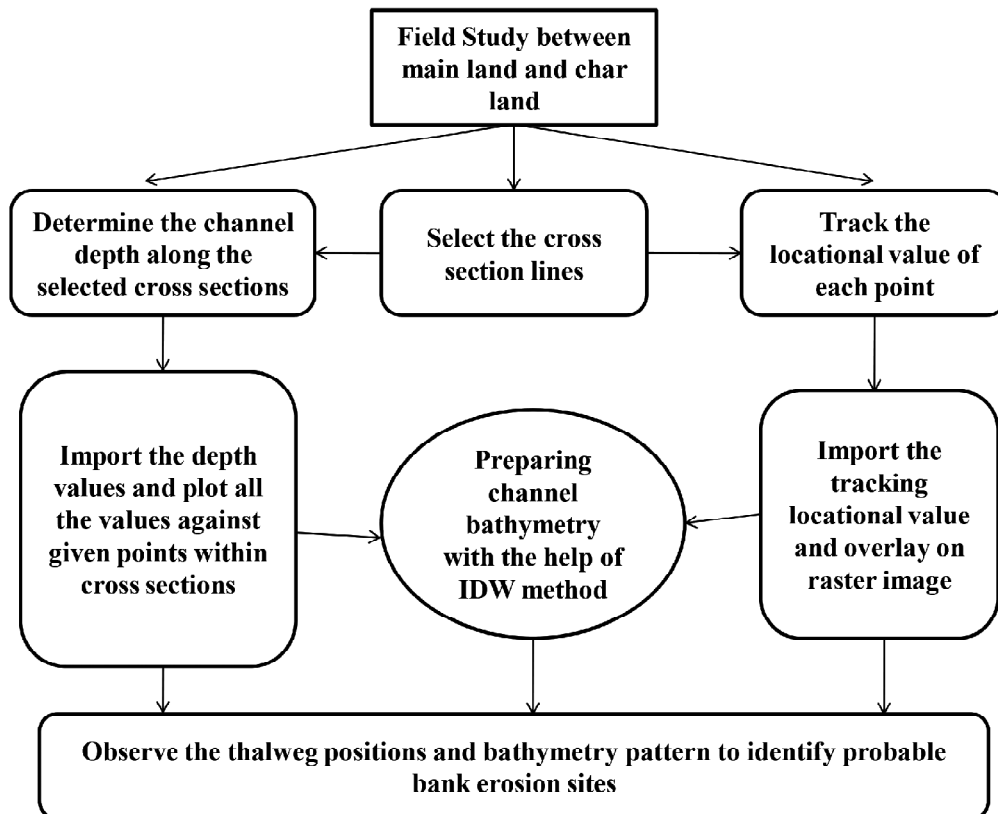


Fig. 2. Flow diagram of applying methodology

Determination of thalweg position and bottom relief character of the river channel

At the time of field survey using echo sounder instrument, all collecting channel depth data are stored as both tabular format and graph format in the internal storage of the instrument. The geographical location of both starting point and end point of each cross profile has been taken through GPS tracking. After completing the field study, we collected all tabulated channel depth data from internal storage of instrument and recorded these on MS Excel sheet and merge with their locational latitudinal and longitudinal extensions. On the basis of these datas, we have prepared cross profile on the basis of channel depth value (representing in Y axis) in respect to all points (representing on X axis) along each cross section and give suitable layout on it as required.

Preparation of channel bathymetry through single beam bathymetric data modelling

Single beam bathymetric data modelling has been applied to prepare channel bathymetry. At first we have derived a georeferenced study area map from Google Earth. All locational values, which are collected through GPS at the time of field survey, are merged with the georeferenced image through maintaining projection system and datum in Arc GIS 10.3 software environment. After that channel depth values have been joined with each point id and their locational extension in the attribute table of point-based vector layer (which containing individual geographical locational values) and extract the bathymetry map using Inverse Distance Weighting (IDW) method on the basis of depth value of each given point location in Arc GIS 10.3 software and give proper layout. The whole methodology has been shown through the flow diagram in Fig. 2.

Interpretation of the Results

Assessment of thalweg position between main land and char land

The river bank erosion is closely related with the position of channel thalweg along cross section of the river. Thalweg position influences depth, flow velocity and flow direction which ultimately promotes bank erosion processes. At Paschimnarayanpur Mouza, the thalweg position of the channel is very close to river bank which caused steep bank slope and high velocity of water and bank erosion (Fig.3a). Towards the south of Manikchak Ghat, thalweg position has been found close to the mid-channel bar/charland. This situation depicted the vulnerability condition of the mid-channel bar /charland (Fig.3b). The bottom relief of the channel bed is not smooth. There is a fluctuation of depth along the transects which revealed the variation of sediment deposition and transportations.

Bottom relief condition of the channel and associated bank erosion

Segment 1: Upper reaches near the meeting place of Ganga- Fulhar river

Several cross sectional studies have been made adjacent to Manikchak mainland to assess channel bottom relief, thalweg position and tendency of migration of channel and associated bank erosion. Bhutni Char is situated in the North West of Manikchak Block. The Fulhar river is passing between Bhutni Char and Manikchak mainland. From the confluence of the Fulhar river 14 transects

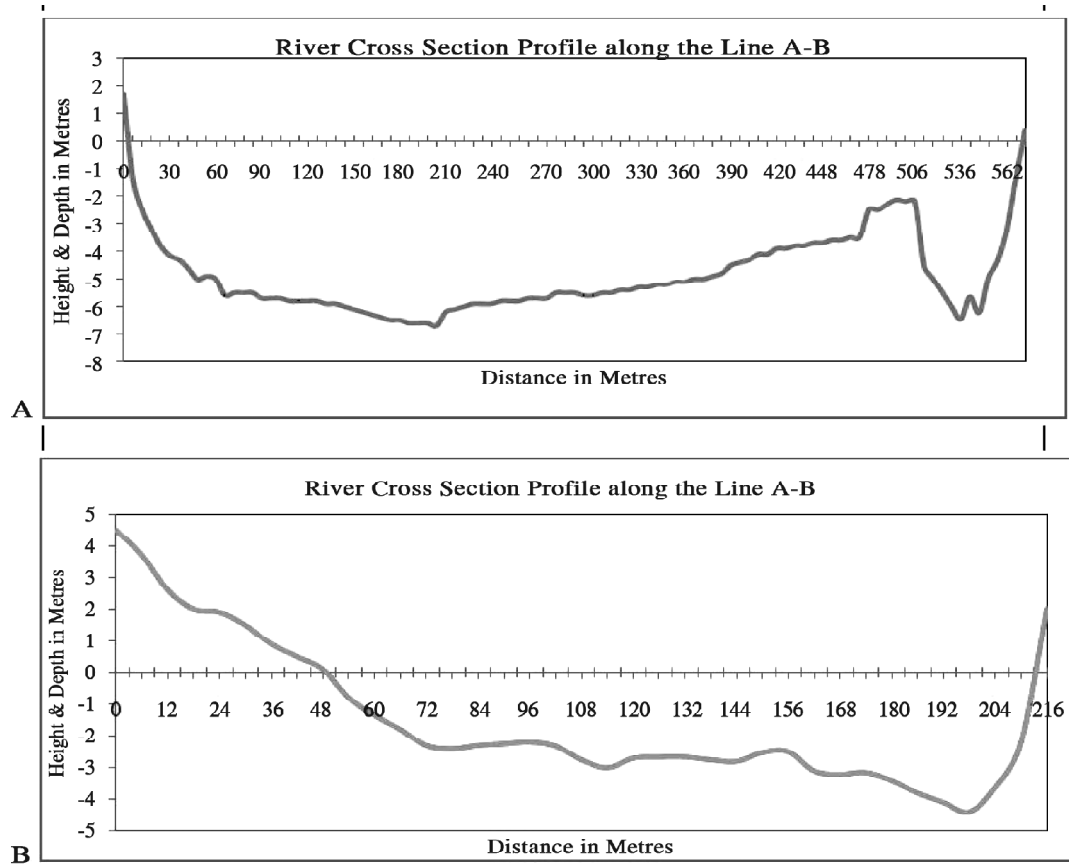


Fig. 3. River bed configuration of Ganga at **a** Paschim Narayanpur char, **b** near Manikchak

were considered and profile studies were being completed using single beam echo sounder. The study produced a significant result. The thalweg position of Fulhar river between Bhutni Char and Manikchak mainland (Transect AB) is towards the Bhutni Char (Fig.4a) where erosion is found. Between Bhutni Char and Ganga river bed charland (towards Rajmahal, Transect CD), the steep slope is found close to the Bhutni Char and it showed the propensity of Bhutni char erosion (Fig.4b). Along the transect EF, between river bed charland (confluence of Fulhar River) and Manikchak mainland, the position of channel thalweg is towards the charland which indicates the vulnerability of river bed charland (Fig.4c). Here, there is a tendency to develop new charland in near future. Between Manikchak mainland and River bed charland (along the profile GH), the river bank side slope is very steep and the depth of the water is very high for a long distance from the river bank (Fig.4d). The bed relief is not regular which depicts the continuous erosion and deposition of sediments over the river bed. The river bed is continuously increasing its height at a slow rate.

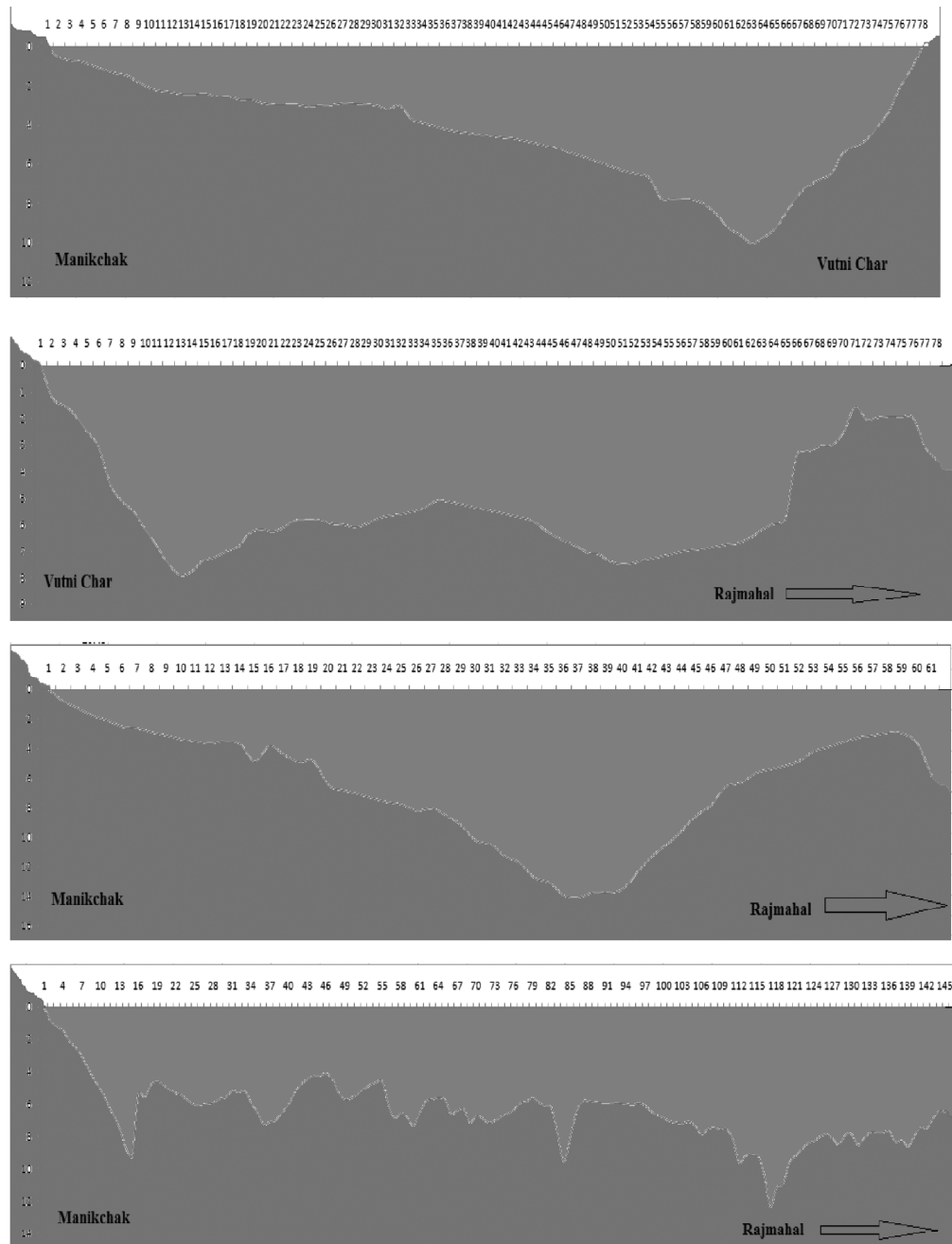


Fig. 4. Bottom relief character near the meeting place of Ganga- Fulhar river (a AB, b CD, c EF, d GH)

Segment 2: Middle reach between main land and new emerging char lands

The profile IJ between Manikchak mainland and Charland shows the regular removal of sediments which caused the bank slope steeper in character. Just immediate of IJ, along the profile KL between mainland and char land in Manikchak the river bed is more dynamic because of large scale transport of sediments due to scouring of the channel bed. As a result of large scale transportation of sediments the channel depth close to river bank is very high which has made the bank slope steep and making the mainland vulnerable to erosion (Fig. 5a& Fig.5b).

Along the transects of MN, OP, ORand ST, maximum depth area is being found very close to the bank line of Manikchak Diara. The situation reveals that the land areas exist close to the bank line are more susceptible to channel migration. The velocity of running water is very high in this area. The bank slope is also high which promotes undercutting and scouring processes and induce bank erosion hazards in Manikchak Diara (Fig.5c, 5d, 5e&5f).

Along the transects of UV and WX, the thalweg position is situated close to the bank line and the maximum wetted area between mainland and char land is being found towards the mainland of Manikchak Diara (Fig.5g&5h). The existence of greater depth and steep bank slope are the favorable conditions of bank erosion processes. Not only that the stratigraphie of the river bank plays an important role in bank erosion process.

Segment 3: Lower reach between main land and stable char lands

The profile (YZ) between Manikchak and Rajmahal based on the data derived from echo sounder survey depicted that the bottom topography of the river Ganga immediate lower section of Manikchak Ghat is characterized by sedimentation and development of several submerged chars (Fig.6a). The bank side slope is very steep and the uneven bottom relief towards the opposite bank showed erosion and deposition which regularly changed flow direction and flow velocity and helps to cause bank erosion. The depth is more or less uniform throughout the profile. Along the profile A/A between Manikchak mainland and towards River bed charland, there is a tendency to develop a big charland and this very situation has changed flow velocity and flow direction in this section and helped to cause river bank erosion (Fig.6b).

Along the profile A/B the downstream of ManikchakGhat, river bank side slope is very steep which is one of the major reasonsfor bank failure in this section. Towards the charland there is a well-developed submerged char that depicted the river bed is characterized by an active sedimentation process (Fig.6c). The immediate down of A/B, it was found that a huge amount of bottom sediments has been transported from the river bank sides and has the bank slope steeper which has also made the Manikchak mainland more vulnerable to the bank erosion process (Fig.6d).

Bathymetry of the River and probable locations of bank erosion

The bottom relief study with the help of echo-sounder survey along with several from north to south between Manikchak Mainland and towards Charland depicted some ideas for introducing

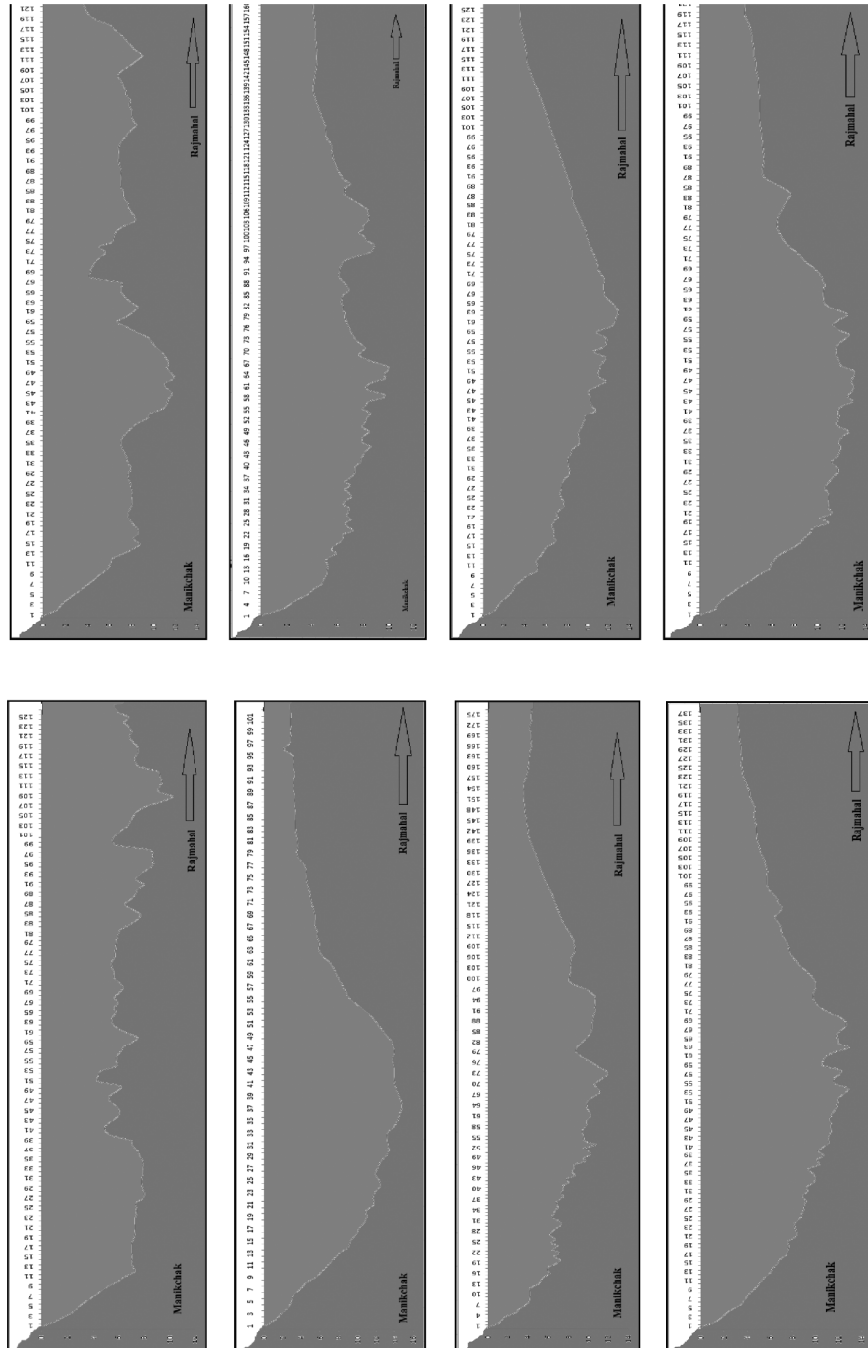


Fig. 5. Bottom relief character between main land and new emerging char lands (a JJ, b KL, c MN, d OP, e QR, f ST, g UV, h WX)

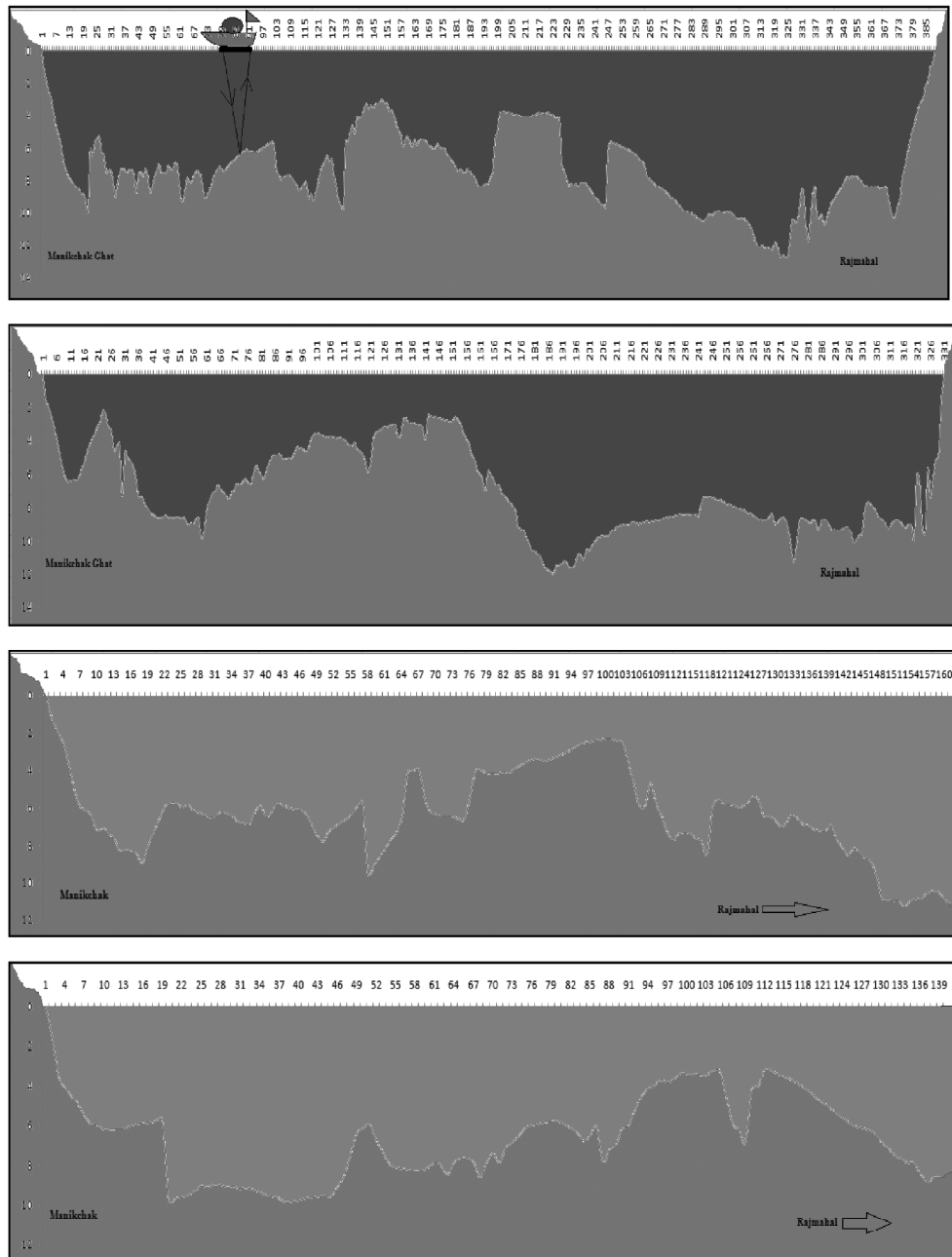


Fig. 6. Bottom relief character between main land and stable char lands (a YZ, b A'A, c A'B, d A'C)

bank erosion processes and associated land loss in Manikchak Diara of Malda district in West Bengal.

After analyzing single beam bathymetric data model, it shows that in most places the near bank depth and the slope are high which helps in undercutting, slab failure and scouring as well as land loss in Manikchak diara of Malda District, West Bengal. The position of channel thalweg is very close to the river bank which introduces much velocity of running water and promotes bank erosion mechanisms along Manikchak diara. The development of submerged char lands away from the river bank promotes and changes flow direction and flow velocity which ultimately narrows down the moving path of water and increases the velocity and bank erosion processes in Manikchak diara. The existence of cohesive and non-cohesive layers in the left bank of the river Ganga induces entrainment and piping process which causes tensional cracks on the surface and generates slab failures and land loss in Manikchak diara.

The channel bathymetry from Fulhar confluence to the Manikchak Ghat showed the variation of depth and erosion and deposition of sediments over the river bed. In the middlemost section of the study area, there are two well developed submerged chars and it is continuously extending towards the north (Fig.7). Such submerged chars may segment the main flow of the river and change the flow direction and flow velocity of running water. There is a probability of the formation of a narrow flow path close to the river bank and an increase in the velocity of water as well as river bank erosion in Manikchak Diara of Malda District. At Fulhar confluence area, there is a tendency of developing new charland which may cause the river more dynamic. The study reveals that there is a continuous change in the deposition of sediments and its removal from the river bed as well as the variation of depth which is caused as a result of variation of flow velocity, flow direction and sedimentology.

Conclusion

In this study, we have seen that how river encroachment is causing bank erosion problem at Manikchak block in Malda district, and the causes behind it through the bathymetric data modelling. If the present rate of bank erosion goes on a horrible situation will arise, then the entire left bank will be swallowed by the encroaching river. The uninterrupted encroachment of the river towards the left bank may outflank the barrage and open a new course through the present Ganga-Fulhar route. An indication of such a situation has been given in an unpublished report of the West Bengal state irrigation department. Along the maximum stretches, the water depth and slope of riverbank are very high and thalweg position near to the main left bank line and these all conditions indicate the probability of huge land loss along the left bank line of Ganga near Manikchak region. If such a situation happens in reality it is clear that the interfluvial land between Ganga and Fulhar will be completely eroded. It is very necessary to combat a hazardous situation induced by bank erosion. Many measures have already taken, some of those are working well in practical, but we should think about some more fruitful measures for combating the bank erosion. Some process-specific management strategies have been recommended here. Bank erosion in Manikchak has

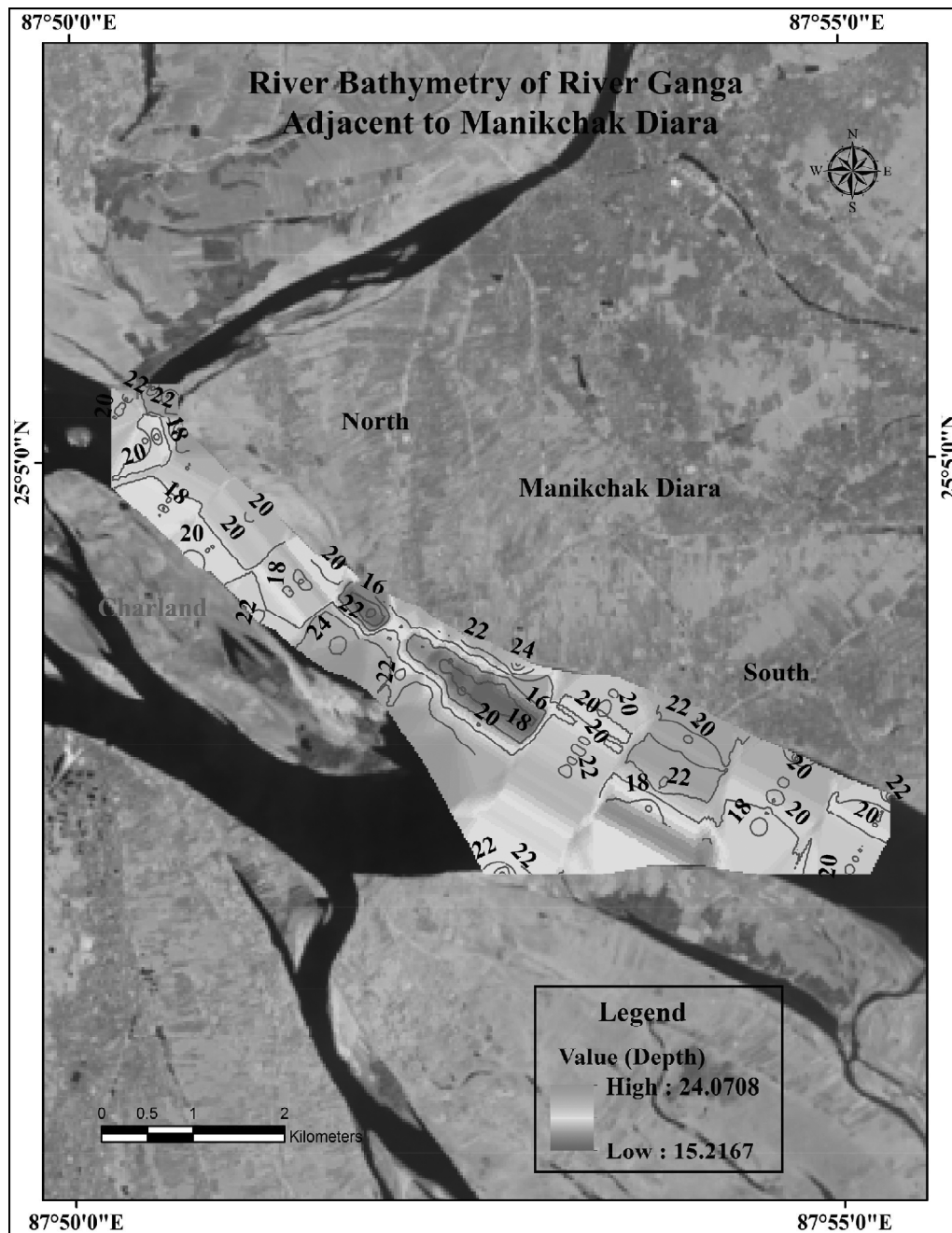


Fig. 7. Bathymetry map of the river Ganga adjacent to Manikchak Diara.

taken a form of hazard across the entire block, there some time it is difficult to install the process specific strategy in all fields and it is costly too. The deficit of funding is the major problem for management. Now a day's Government is allotting the maximum possible fund for combating bank erosion in this area. But only funding will not work, besides it is necessary to whether the management strategies are being executed properly, and then only the remaining villages along the bank side will be safe from the bank erosion.

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