Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.3, 2015

Channel Avulsion Archives and Morphological Readjustment near the Bhagirathi-Mayurakshi Confluence in the Lower Gangatic Plain, West Bengal, India

Raghunath Pal
Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi-110067
Email: raghunath.geo17@gmail.com

Abstract
The morphology of an alluvial channel is a complex response phenomenon adjusted over geologic, climatic and anthropogenic controls and a number of morphologic and hydrologic factors have been involved for scientific and logical investigation. Channel geomorphic forms are the landforms within the landforms up to various extent in different spatial order that are develop according to the acted fluvial forces (e.g. turbulence, helicoidal and convective motions etc.) along with the incorporation of various causal factors i.e. tectonic tilting, channel geometry, sedimentological readjustments and discharge variability. The present study includes surface morphology of the floodplains and the channels avulsive characteristics in the past sixty years using LANDSAT and SRTM data. In this study topographical maps of 1955 help to construct the path to study the history of channel as well as floodplain morphology as there are no satellite data of 1955. Major outcomes of this paper are the Bhagirathi-Mayurakshi confluence shifting criticality, complex meandering pattern of Mayurakshi and Dwaraka River near the confluence, meandering abnormality in the Bhagirathi River and intra-channel formation (crevasse) which has breached right bank natural levee of the Bhagirathi River.
Keywords: Meandering, Avulsion, Floodplain, Confluence, Bhagirathi River, Natural levee, Over bank sedimentation, alluvial deposit

1. Introduction
The river channels are the open system in general, drain across the earth surface from higher to lower elevation under the force of gravity. The channels are the principal routes for transporting the products of weathering, probably has been paid more attention than any other geomorphic system by geomorphologists, geologists and civil engineers (Leopold, et al., 1964) (Schumm, 1977). In geomorphology channel dynamics and meandering are perhaps the dominant planform morphology, have ever been investigated in geomorphological research for decades (Xu, et al., 2011). In the study of floodplain morphology dynamics channel avulsion is a considerable complex response event which modify floodplain structure, channel geometry, meandering and sediment depositional characteristics of a river system (Keen-Zebert, et al., 2012). A single mechanism or a single cause can't be put forward to explain meandering events and floodplain formation. To understand the meander character of modern channels, scientific analysis and explanation of many palaeo sequences of mud-silt-clay dominated facies is most important. A single mechanism or a single cause can't be put forward to explain meandering-braiding events and floodplain formation. To understand the meander character of modern channels, scientific analysis and explanation of many palaeo sequences of mud-silt-clay dominated facies is most important (Tandon, 1991; Sinha, 1996). the explanations for meandering has been done based on autocyclic-stochastic movements (Wells et al., 1987), on sedimentation in a braided stream (Leopold & Maddock, 1955), on cone building activity (Gole et al., 1966), instability of channel that is a sudden movement around a concave point (divergence point) and vertical accretion (shallow or deep inundation) including large breaches during a flood with a magnitude near to avulsion threshold (extrinsic or intrinsic) (Schumm, 1977). For floodplain formation existing conceptual models are based on sediment load(Schumm et al.,1972;Carson,1984), on tectonically stable areas (Leopold, et al., 1964), on inherited antecedent conditions(Brown,1990), on lateral accretion and overbank deposition(Leopold et al.,1957; Leeder,1979), on conceptual model for cyclic floodplain wetland development (Tooth et al.,2004). Channel avulsion is mostly effective where rivers emerge from uplands and in the lower regime of a basin where channel moves across the unconsolidated or partly consolidated well sorted alluvial deposit.

The Bhagirathi River is a distributary of the Ganga River, connected with feeder canal after the Farakka barrage construction. Initially it was a highly flood affected river but after the barrage construction the channel flow remains under control and hence channel modification rate is probably slow. On the origin of this river there is an argument that before sixteenth century it was the main distributary of Ganga but after that the channel was shifted towards the east direction and formed today's Padma (Gupta, et al., 2014). Although there is no sufficient evidences to say that the Bhagirathi was the prior main channel of the Ganga River (Rudra, 2010). The objective of this paper are i) to understand the morphology of the Bhagirathi-Mayurakshi River's parallel flow orientation and ii) to examine channel planform modification and it's readjustment with adjoining floodplains over time (1955-2015).

2. Regional setting

Present study mainly concerns with the part of two rivers, one is Mayurakshi, plateaux in origin, flows south-eastwards and conflux with Bhagirathi at Kalyanpur; another is Bhagirathi itself, bifurcates from River Ganges (recently modified by feeder canal construction). The study area is a small part of Lower Gangatic Plain which is an ever considered track of extensive Quaternary alluvial sedimentation. Regional extension of the study area is (23.701579°N-24.015336°N and 88.071701°E-88.343249°E) and cover an area of about 945 km^2. The River Mayurakshi flows along with Bhagirathi parallely for a considerable distance before joining it (usually called *Yazoo* tributary). Both the rivers flow through valleys of variable width and heterogeneous lithology like many other river over the world. The area is under tropical savanna type climate (Koppen's classification, 1931), is a reasonable factor along with diverse lithology shrouded by new sedimentation for floodplain development and alluvial preservation (by avulsion) which vary temporally and spatially along the channel courses. The unconfined reach deposition of the area is commenced on a thick series of Eocene strata (>1000m) underlying a thick succession of estuarine and marine Oligocene and Pliocene formation (Wadia, 1975) (Singh, 1996). The unconfined reaches characterized by gently slope, low energy channels, flow across broad valley. Both the channels meandered across extensive floodplain characterized by slack water sedimentation. A noteworthy fact that the thickness and age of new alluvial deposition is not unvarying monotonous, in general increases towards both the sides of the channel bank. Further, the study area unvarying monotonously flat but with a southerly slope, as inferred from the direction of channel flow.

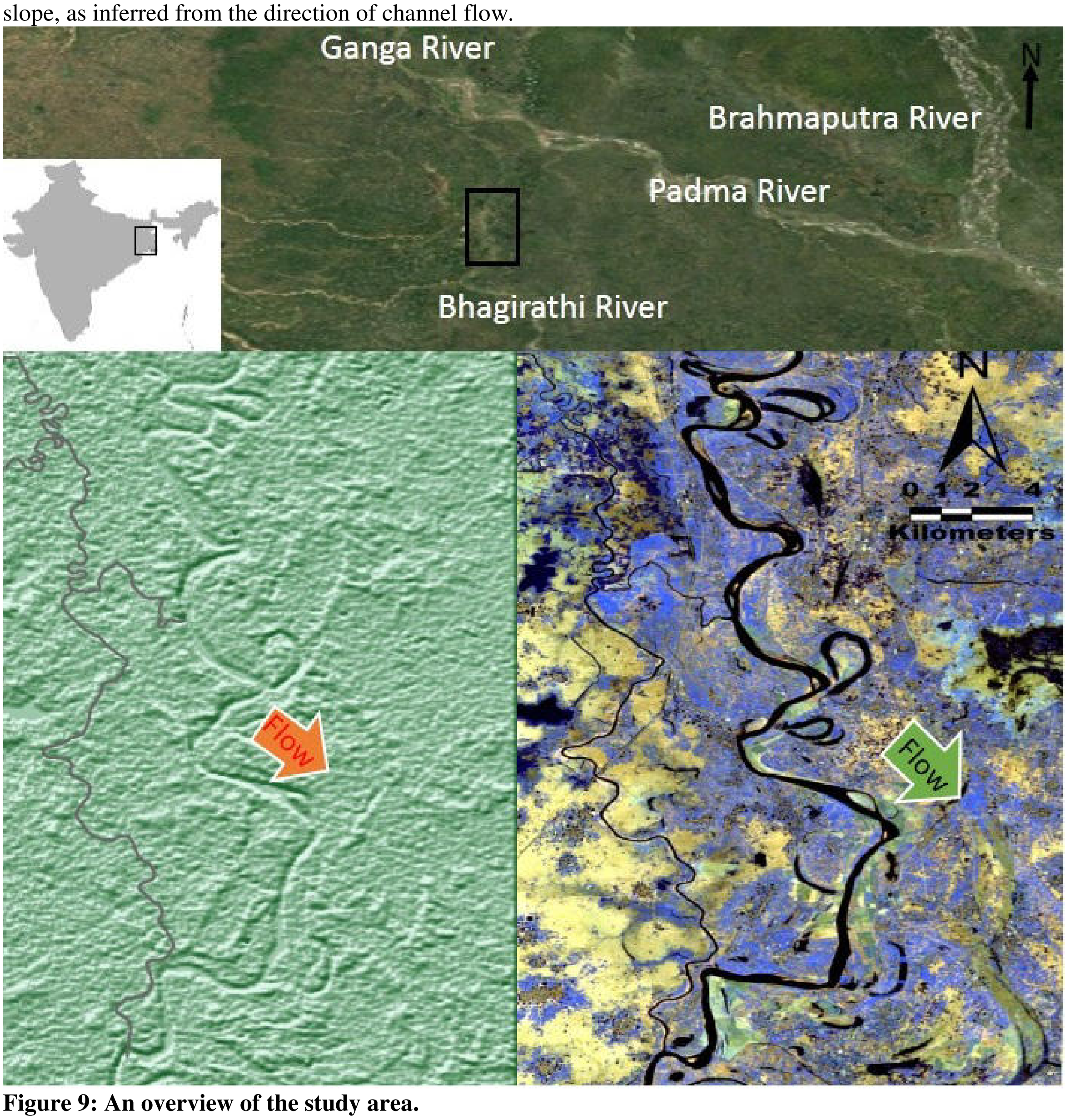

Figure 9: An overview of the study area.

3. Data Used and Methods:

In the present study, the topographic maps of 1955, covering the study portion by four sheets have taken from University of Texas Library website and all 1:250,000 scale topographic maps have georeferenced using and then a mosaic has prepared after subseting each map using ERDAS IMAGINE13 software considering EVEREST 1956 projection system and taking several ground control points. The Google Earth maps has also been used to visualize three dimensional form for the channel and adjoining landforms morphology. For this study, satellite images of LANDSAT MSS (1975), TM (1989), ETM (2001) and OLI (2015) had been taken from USGS Earth Explorer website. The problem of same year data unavailability has been removed by using same season nearest year images of the considering year's i. e., 1955, 1975, 2000 and 2015. Other problems are unavailability of data with continuous interval and interval maintaining. Hence, three intervals but irregular i.e. 20, 26 and 14 years have been taken under

Table 5: Data used in the study.

Data Types	Year & Scale	Source
Satellite Images		
I. Landsat-4 MSS	1975	USGS Earth Explorer
II. Landsat-5 TM	1989	,,
III. Landsat-7 ETM	2001	,,
IV. Landsat-8 OLI	2015	,,
Elevation data		
SRTM void filled	2000 (90 m resolution)	,,
Maps		
Topographical Maps	1955 (1:250,000)	University of Texas Library
Google Earth Images	2014	Google earth

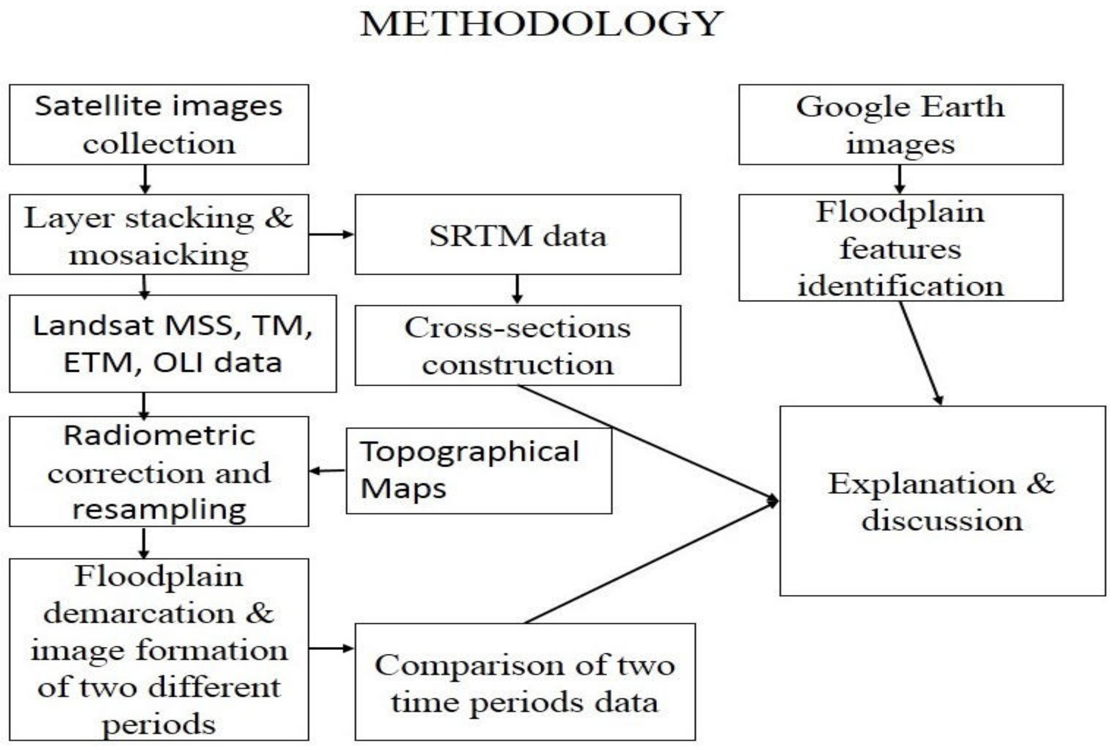

Figure 10: The flow chart indicates the way of the study that had been workout.

consideration to depict channel migration characteristics and because of dissimilarity in interval it is very difficult to calculate channel migration rate per year. To show the variations in topographic profiles of the river and adjoining active floodplain, SRTM (90 m ground resolution) based digital elevation model data has also used after some processing using ARC MAP10 software. To understand the changing channel course over the time period of 1955-2015 four channel maps of different period i.e. 1955, 1975, 2001and 2015 have been prepared and then superimposed all the maps. For a detail investigation of the channel planform morphology two slides of six different reaches of four different periods have been prepared. One more slide has been prepared to show the channel metamorphosis in the downstream after Farakka Barrage construction (1975).

4. Discussion and Explanation

4.1. Channel Migration

4.1.1. Bhagirathi Avulsive System

The Bhagirathi River is a distributary of The River Ganga, bifurcates at Dhulian and flows in southward direction. Significantly the river have a complex location where eastern side is under Great Bengal Delta and western part is the edges of Chotanagpur Plateau and shroud of partly

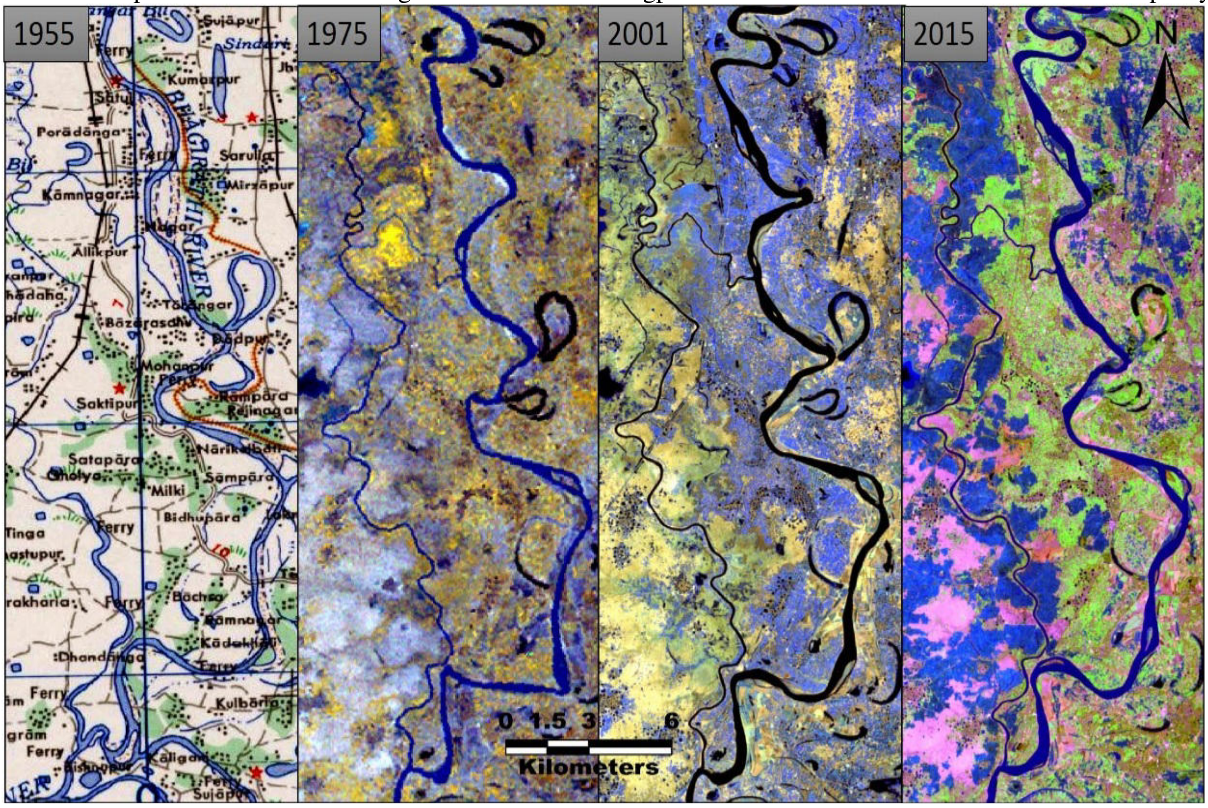

Figure 11: Changing channel morphology and surface floodplain structure from 1955 to 2015. In this figure toposheet (1955) and LANDSAT (1975, 89 and 2015) data have been used.

consolidated alluvium. Another important factor is that after Farakka Barrage construction in 1975, the flow of Bhagirathi River is largely controlled which affect the natural migration character of the river and its influencing factors also i.e., floodplain topography, local hydraulics, suspended sediment concentration flood duration, flood magnitude, flood frequency etc. Although, several tributaries from both but mainly west side confluxes at different location, which have significant contribution on floodplain formation and channel avulsion along with controlled main channel flow. For example, in 1978 during devastating flood in South Bengal a large amount of sediment and water discharge moves through the channel and floodplain areas which change the floodplain height, channel geometry, alluvium depth, avulsive characteristics of the channel etc.

In the study section of the river there are three latitudinal compression zone where the channel extensively migrate laterally in the east-west direction, at Sujapur, Rejinagar and Kaliganj. At kaliganj the channel moves towards west because of local north-west reverse slope respect to regional slope. The image shows the existence of palaeo-channels which reflects the direction and distance of shift. At Sujapur the channel migration is highly variable east and west in both the direction probably due to local unconsolidation of deposited alluvium over the unconfined floodplain reaches. The figure.3 shows four satellite images to reflect the changing location of channel in different time span from 1955 to 2015.

4.1.2. Mayurakshi Avulsive System

The Mayurakshi River is originate from western plateau and after joining with Dwaraka, it flows southward parallel to Bhagirathi River. Morphologically this system less dynamic relative to Bhagirathi System, because the first one is largely controlled by geology and in the study section it flows across consolidated alluvium deposit. The palaeo channels are less frequent in this system as frequent in Bhagirathi system in the study portion. Another important factor of less dynamicity is less volume of discharge which resist to erode the channel banks. Only peak monsoon season is effective for high rate of erosion and flood and rest of the months the channel flow remains constant. The wetted perimeter of the channel varies seasonally from 4-12 meter. The channel width ranges from 30-150 meter. The sinuosity index is relatively high for Mayurakshi River and where Dwaraka River meets to Mayurakshi, meandering is extremely high. From Uttar-hijal to Sujapur about 29 km both Bhagirathi and Mayurakshi river flow parallely from north to south direction which indicates Yazoo style of morphology. The studied section of the rivers is under less erosive western Bengal plain to the right and partly consolidated delta plain to the east. The channel planform elevation is greater for Mayurakshi as the channel flows across the Rarh plain.

4.1.3. The Confluences

From the satellite image analysis it is clear that near the confluence point and in its upper portion The Bhagirathi River shifts westward means towards Mayurakshi System significantly and it is also a zone of compression where the sinuosity is very high (>3.0). Furthermore, it can be said that increasing concave point erosion may change the confluence means both the river join together apart from present confluence point to the north after few years. The dynamism of the confluence zone reflects the local instability of the floodplain probably due to sedimentological readjustments and new fine suspended sediment deposit over the floodplain extensively mainly during large flood occurrences. Moreover, from 1955 to 2015 the confluence is remain consistent but it is also visible that in the near future the confluence will be shifted towards 3-5 km north and a large channel bar will come into existence after this conversion. There is another confluence in the study section that is Mayurakshi-Dwaraka confluence which is consistent in position. There are two other nodes which have formed crevasse joining Bhagirathi and Mayurakshi together (Fig.4).

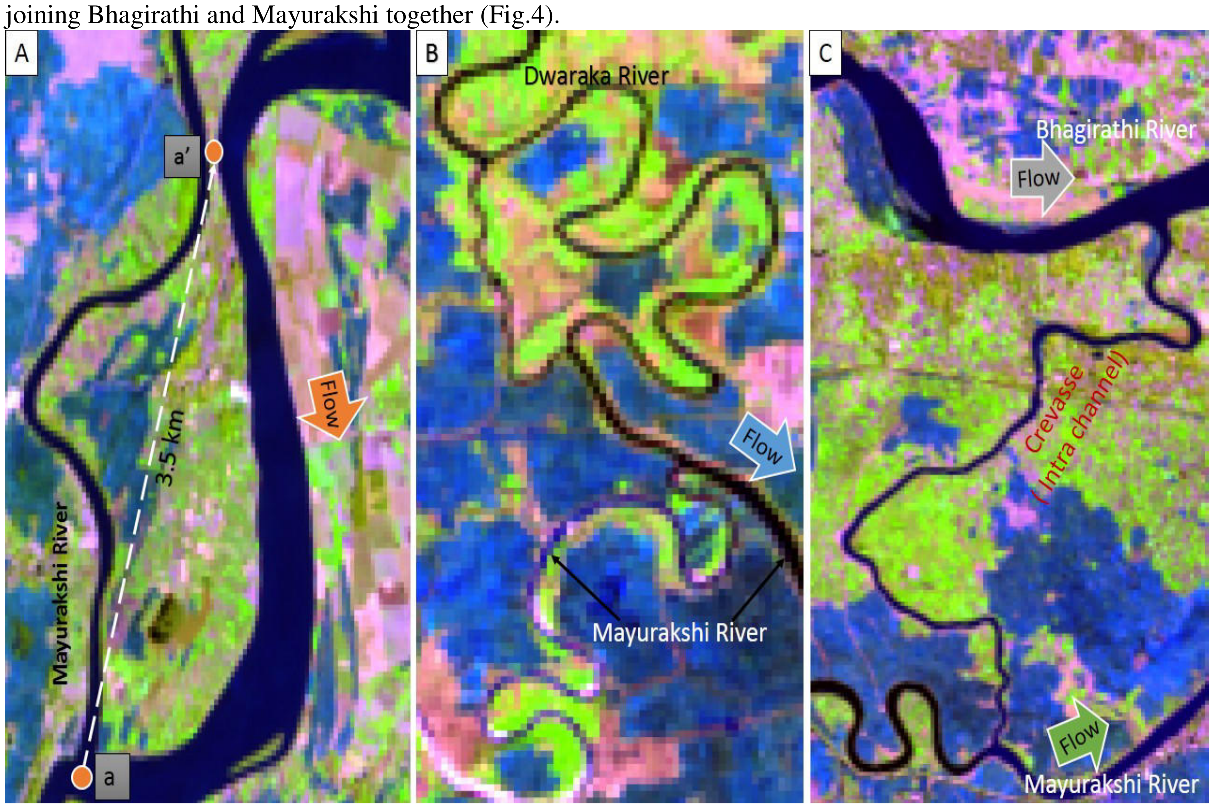

Figure 12: A. The Bhagirathi-Mayurakshi confluence morphology. In this figure aa’ indicates that the confluence location will change from a to a’ moving 3.5 km towards north. B. The extreme meandering nature of Mayurakshi and Dwaraka River near the confluence. C. Intra channel (crevasse) formation near Beldanga which connect Mayurakshi with Bhagirathi across the right bank natural levee.

4.2. Adjoining Floodplains Structure

Geomorphologically, a floodplain can be defined as “largely horizontally-bedded alluvial landform adjacent to a channel, separated from the channel by banks, and built of sediment transported by the present flow regime” (Nanson & Croke, 1992). The processes, which are cause of floodplain formation and evolution can be explained by the recent satellite image interpretation. In the study area existing floodplain features are interpreted in the following section. Large rivers’ floodplains are extensive in form and take long time to readjust and evolve. Floodplains are the most ubiquitous depositional massive landform of large river course especially where the river flows across the extensive plain area. The floodplains are form large extended alluvial deposit by vertical accretion directly and lateral accretion indirectly (Knighton, 1998) (Zwolinski, 1992).

4.2.1. Neck cut offs, Ox-bows and Palaeo channels

Abundant cut-offs, ox-bows and sinuous palaeochannels in the study section of deltaic plain are the imprints of laterally local movement of channels and bank erosion. These features are abundant in the compression zones of the study area. All the features are associated with past avulsive channels indicating present channel characteristics. Furthermore, palaeochannels and cut-offs are the evidences of reduction in channel length and sinuosity. To develop a complete cut-off after long time of 50-100 years is essential (Sinha, 1996). In the study section, near the confluence two palaeo channels have been identified from the satellite images, one of them (older one) is very large reflects the past extension of the channel. However, it can be said that these features are shows the channel alignment and morphology of the river in the study section.

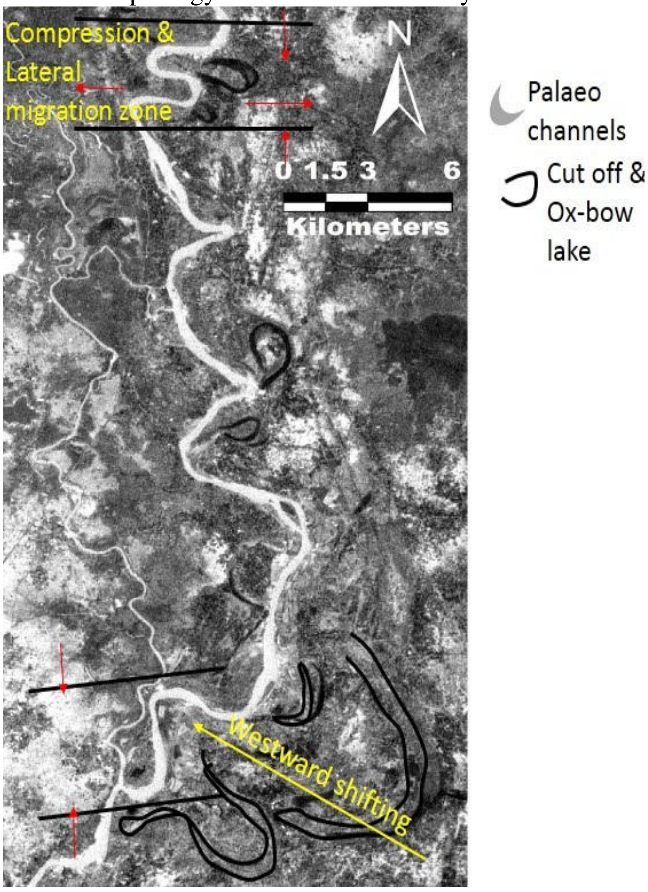

Figure 13: The upper portion of the river is showing compression and extension zone. Near the Bhagirathi-Mayurakshi confluence is shifted towards west direction.

4.2.2. Point bars, Channel bars and Natural levees:

Point bars are very significant features of meander channels, forms on the convex bank of channels due to lateral accretion of the floodplains. Many point bars are capped by scroll bars (shows the former channel margin during in early meander growth. All the point bars are formed by a large amount sediment concentration in the convex bank of the channel and the height of point bars increases from channel site to towards the topographic levels and floodplains. Of course it can be said that the height of the point bars is less than the floodplain. In the study section, a few number of channel bar has formed in the channel probably due to meandering character. Significantly, considerable channel bars are formed in those areas of the channel, where the channel is relatively straight means less sinuous, in case of Bhagirathi River. In the Mayurakshi River there is no channel bar formation because of its sinuous character and narrow weak water and sediment discharge flow.

4.2.3. Morphological Settings of the Cross sections:

The study section is an assemblage of unique channel network, two confluence, meandering with channel consistency etc. The upper portion of the study reach is indicating the vertical compression and lateral migration of the Bhagirathi River which is somewhere above normality (Fig.4). In the lower portion the channel is shifting towards west direction. The reason is not clear why the channel is shifting towards west direction. It may be possible that the channel is maintaining normal meandering pattern to adjust with both the deltaic and Rarh plain lithology because just above the Bhagirathi-Mayurakshi confluence the channel (Bhagirathi River) flow is relatively straight in comparison to rest portion which brake the normality. In the figure.8 six cross sections had been drawn to analyse surface morphological structure of the area. In the graphs sink portions indicate channel trough and levee elevation is ranging from 16 to 19 m to the left bank and 17-23 m to the right bank levee. From cross section one to six indicates that the channel valley is shifted towards west in the study reach from north to south (Fig.6). Both the natural levees are shaped by rail and road construction which cause to disrupted floodplain morphology. The cross section five is depicting well developed left bank terrace formation.

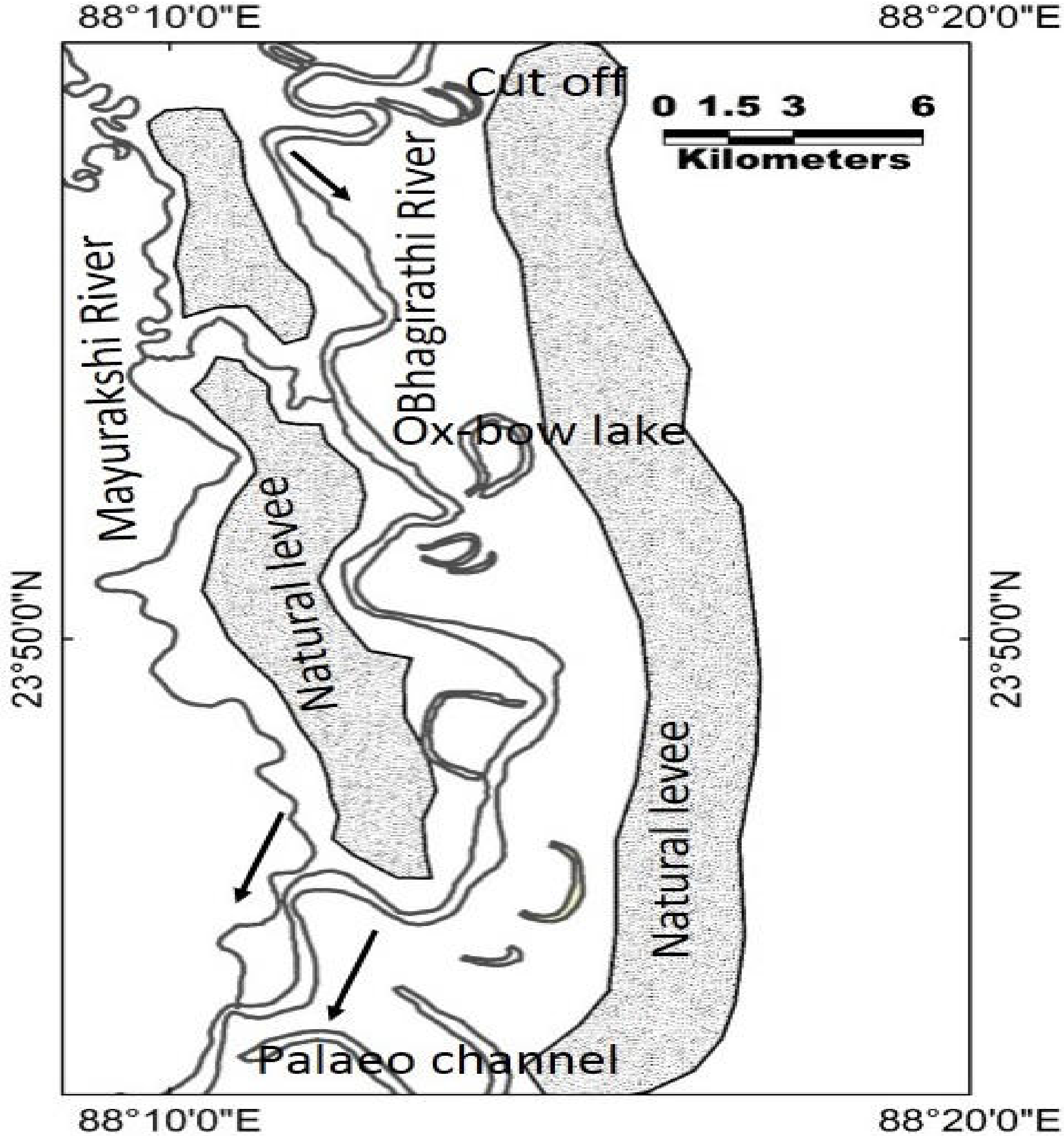

Figure 14: This figure indicates various geomorphic features of the studied section i.e. natural levee, ox-bows, palaeo channels etc.

4.2.4. Overbank Deposit and Back Swamps

Overbank deposition occurs during floods (shallow or deep inundation) due to vertical accretion and lasting for a few days to several months. In the study section, both the sides of Bhagirathi River, natural levees have formed of different elevation due to annual sediment deposition during flood. It has been found that the height of west side levee (16-22m) is greater than the left side levee (15-20m) mainly due to south-eastern regional slope of the study area. Areas between the levees and valley walls of the Bhagirathi River becomes poorly drained due

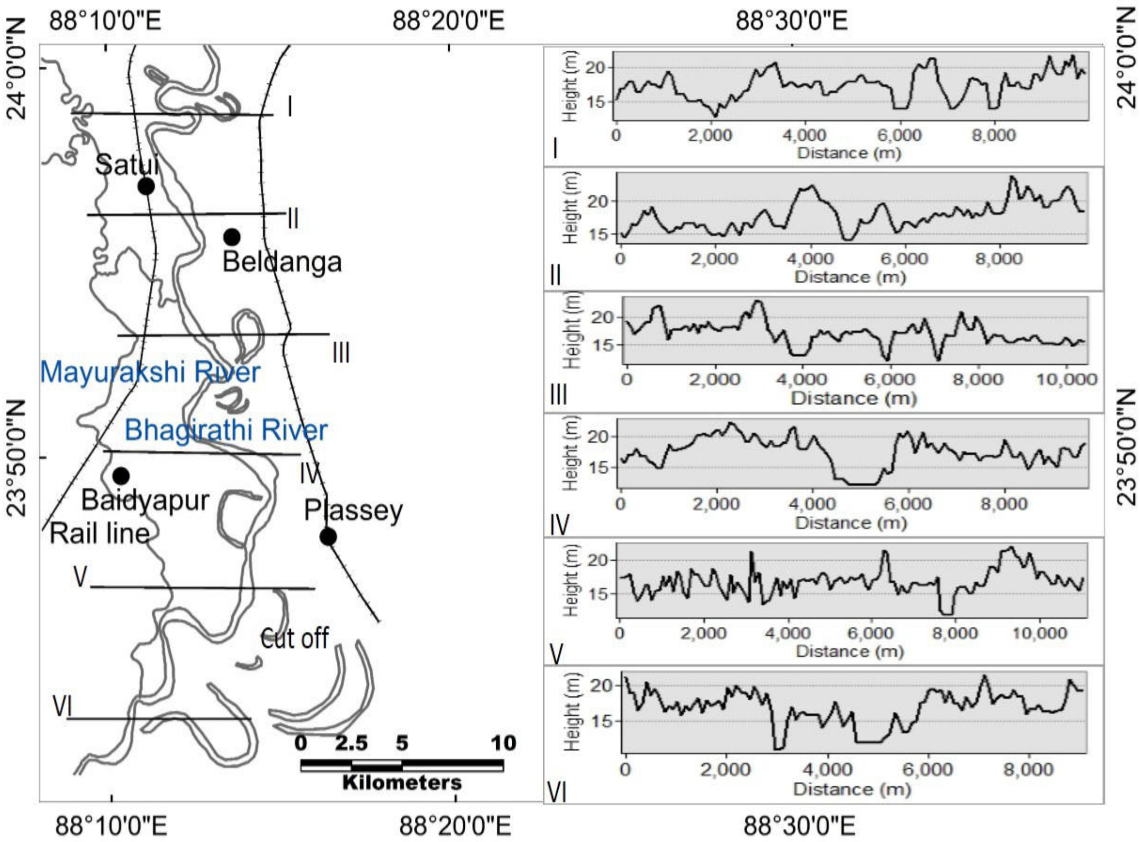

Figure 15: This figure indicates various geomorphic features of the studied section i.e. natural levee, ox-bows, palaeo channels etc.

to the levees height and more than eight back swamps have formed in the upper portion including intra-channel formation in the study area. As a result Mayurakshi River flow parallel to the Bhagirathi for the distance (straight) of 25km up to confluence (like *Yazoo* River).

Further, as distances increases from the river bank floodplain age and elevation of the floodplain increases but thickness of suspended load deposit decreases. The breach cut also develop (crevasse) in the upper portion of the study area where one channel join both the river laterally. The cause of breaching is probably due to high flood occurrence and the existence of long low zone

5. Conclusion

Floodplain archives and channel shifting processes working in the study area mainly controlled by regional sedimentological adjustments, water and sediment discharge volume, new tectonic subsidence and regional climatic variability. Although, large floods have intense effect on floodplain formation as well as channel migration. Fine sediment accumulation on floodplain increases its height and modify channel conveyance capacity. The limitation of this study are lack of information of field measurement, insufficient water and sediment discharge data and lack of very past morphologic information. Furthermore, hydrological analysis, suspended and bed load measurement, grain size distribution, floodplain facies analysis, channel flow hydraulics and channel modelling etc. can help to get more information to come to a conclusion and to find out the causes which are acting to dynamic the channel and its geometry.

Acknowledgements

The author is deeply indebted to his supervisor Dr. Padmini Pani, Assistant Professor and his teacher Prof. Milap Chand Sharma, CSRD, Jawaharlal Nehru University, New Delhi, for giving important ideas and guidance. The author is also thankful to his friends Sumantra Sarathi Biswas, Biswajit Mandal, Malay Pramanik and senior Prasenjit Acharya for their help in image analysis.

References

Gupta, N. et al., 2014. Geomorphology One-dimensional modeling of a recent Ganga avulsion : Assessing the potential effect of tectonic subsidence on a large river. *Geomorphology,* Volume 213, pp. 24-37.

Keen-Zebert, A. et al., 2012. Lata Quaternary Floodplain Reworking and the Preservation of Alluvial Floodplain Sedimentary Archavies in Confined and Unconfined River Valley in Eastern Interior of South Africa. *Geomorphology,* Volume 185, pp. 54-66.

Knighton, D., 1998. *Fluvial Forms And Processes.* 1st ed. New York: Arnold.

Leopold, L. B., Wolman, M. G. & Miller, J. P., 1964. *Fluvial Processes In Geomorphology.* New York: Dover Publications, INC..

Nanson, G. C. & Croke, J. C., 1992. A genetic classification of floodplain. *Geomorphology,* Volume 4, pp. 459-486.

Rudra, K., 2010. Dynamics of the Ganga in West Bengal, india (1764-2007): Implications for science policy interaction. *Quaternary International,* Volume 227, pp. 161-169.

Schumm, S. A., 1977. *The Fluvial System.* New York: John Wiley & Sons, Inc..

Singh, I. B., 1996. Geological Evolution of Ganga Plain- an overview. *Journal of Palaeontological Society of India,* Volume 41, pp. 99-137.

Sinha, R., 1996. Channel avulsion and floodplain structure in the Gandak-Kosi interfan, North Bihar Plain. *Z. Geomorph. N. F.,* Volume 103, pp. 249-268.

Wadia, D. N., 1975. *Geology of India.* 4th ed. New Delhi: Tata McGraw-Hill.

Xu, D., Bai, Y., Ma, J. & Tan, Y., 2011. Numerical investigation of long-term planform dynamics and stability of river meandering on fluvial floodplains. *Geomorphology,* pp. 195-207.

Zwolinski, Z., 1992. SEdimentology and geomorphology of overbank flows on meandering river floodplains. *Geomorphology,* Volume 4, pp. 367-379.

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar