DISCUSSIONS ON THE PAPER

"Assessment of planform changes of the Ganga River from Bhagalpur to Farakka during 1973–2019 using satellite imagery"

Author: Chandan Raj & Vivekanand Singh, Pub. ISH Journal of Hydraulic Engineering,
DOI: 10.1080/09715010.2020.1812123

Discusser: S.K Mazumder
Former AICTE Emeritus Professor of Civil Engg.
Delhi Technology University/Delhi College of Engg.
E-mai:somendrak64@gmail.com

Using Landsat data, authors have found the variation of width, shifting of bank lines, sinuosity and areas subjected to scouring and silt deposition in river Ganga for a stretch 175 km long from Bhagalpur to Farakka during the period 1973–2019. Information furnished by the authors will be beneficial not only for future planning of hydraulic structures like bridges, barrages etc. but also for river training, navigation and other river improvement works of river Ganga. Such Landsat data/imageries are now-a-days used in deciding locations and fixing waterways for bridges across rivers. Fig.1 illustrates the use of satellite imageries for determining location and waterway for a bridge on river Ganga at Phaphamau (u/s of Allahabad City). Considering the shift of the main channel during 2007-16 and the impact of the proposed bridge on the existing bridges about 2 km downstream near Allahabad (renamed as Prayag), it was decided to provide a waterway of 3.7 km (in red colour) with approach embankments (in blue colour) .

Fig.1 Historical Sattelite Imageries Showing Changes of Ganga River Course During 2007-2016

at Phaphamau near Allahabad/ Prayag (Red Line Indicate Bridge Waterway)

(Mazumder and Bagde 2019)

Ganga River has been shifting its bank line significantly under the combined action of erosion, deposition and meandering over the years as illustrated by the authors in figures 3 to 8 in their paper for the stretch Bhagalpur to Farakka. Fig.2 illustrates similar features of river Ganga in the stretch lying between Mongher (d/s of Patna) and Kahalgaon (u/s of Sahebganj) in Bihar during the period 1780 to 1978. Similar changes in river course are observed in most of the rivers originating from Nepal in the Himalayas. River Kosi, for example, migrated 112 km in 200 years (CBIP, 1989) westward before jacketing it in its current course with 123km long flood embankments on either side. Rivers Gomti, Bagmati, Ghagra, Gandak, Sarda, and other tributaries of Ganga have undergone similar morphological changes over the years due to several factors like tectonic movement of the sub-Himalayan region, periodic floods and huge sediment loads brought by the rivers (Garde, 2006).

Fig.2 Meandering of river Ganga near Mansi and Sultan Ganj Sites in Bihar During

1780 to 1978. (Mazumder and Bagde 2019)

Schumm (1980) studied different plan forms of a river (Fig.3) and termed them as autogenic and allogenic changes. Autogenic changes lead to change in river regime and involve braiding, meandering, cut-offs, channel migration, flow avulsion etc. Allogeneic changes occur due to system change caused by climate variation, fluctuations of flood discharges and sediment load and human activity in the flood plains. Different parameters governing the various flow regimes in a river are shown in Fig.3

Fig.3 Illustrating Effect of Different Parameters Governing Flow Regimes of a River

(Schumm, 1980)

Bhagalpur- Farakka reach of Ganga River is found to be in meandering regime as observed from Figures 1 to 4 in the paper. Regime diagrams by Lane (1957) and Leopold Wolman (1964) also confirm that Ganga river with a mean annual flow of 14000 cumec and a bed slope of 1.in 20,000 at Farakka lies in meandering flow regime as indicated in Fig.4 (Mazumder,2004).

Fig.4 Showing Regime Diagram of Lane (1957) and Leopold and Wolman (1964)

Farakka (Full circle) is seen to be Lying in Meandering Regime.

Several river engineers in India and abroad have investigated the cause of river meandering. Leopold &Wolman et al (1964) introduced the concept of minimization of energy principle. Yang (1971) questions the validity of the theory that Streams dissipate excess energy by meandering. Indian engineers (Chitale, 1970) believe that flood flow with excessive sediment load brought by streams during floods cause meandering. Asymmetric formation of shoals/chars on bed results in flow angularity, bank attack, and erosion of one bank and deposition of eroded materials on the other bank lead to development of flow curvature and meander formation due to secondary flow (Fig.5).

Fig.5 Development of a typical meander and river cross section (Mazumder and Bagde 2019)

Mazumder (2010) proved that critical tractive stress due to secondary flow may be zero and the river banks may collapse even under zero shear/tractive stress. Fridkin (1945) in his lab experiments demonstrated alternate bar formations in a sediment laden stream causing angular flow and erosion of banks leading to river meandering.

Authors' contention regarding shifting of meander upstream of Farakka barrage due to "the formation of pool and stagnation of water" and consequent flooding of areas on the east bank from the backwater effect "depending upon the elevation of the flood plains from Bhagalpur to Farakka" is not correct. On the basis of imageries during 1973-75 only (in pre barrage state), Authors' conclusion that construction of Farakka barrage is responsible for the autogenic changes in planform of Ganga observed during 1975-2019 (in post barrage state) is far from truth. Farakka barrage has very little solid obstruction and designed for a maximum afflux of 0.5m at design flood of 70,900 cumec at Farakka. The barrage is 2246 m long provided with 109 gates including sluices where the sill height is zero. Most of the sediments are in suspended form which is released along with flood water since flow diverted to Hoogly is 1135 cumec only. Backwater reach is very little due to limited afflux of 0.5 m at design flood of 73.500 cumec. Flow in Ganga River is normal upstream of Kaliachak/Rajmahal about 30 km upstream of Farakka and the river continues to flow in its own normal regime as in pre-barrage state.

Meanders move both laterally (at faster rate) and longitudinally downstream (at very slow rate) in a natural stream. As mentioned by the authors, Farakka barrage constructed at the end of reach EF has altered this natural movement of meander after the construction of the barrage. A new meander pattern has developed over the years with barrage as a fixed point, Malda district in West Bengal on the outer side of upstream bend and Murshibad district in West Bengal on the outer side of downstream bend as shown in Fig.6. In pre-historic days, river Hoogly was the main Ganga flowing by the side of Kolkata. Gradually, main course of parent Ganga (known as Padma in Bangladesh) was shifting towards the east side resulting in silting of the Hoogly offtake on right bank near Jangipur town(Fig.6) thereby cutting off of Hoogly river upland flow during lean season. Farakka barrage was constructed to forcibly divert 1135 cumec flow from Ganga to Hoogly through a 30 km long feeder canal (Fig.6) for improving navigability of river Hoogly serving Kolkata port, desalination of water of Hoogly river (a tidal river) supplying drinking and industrial water to Kolkata and other townships on the bank of Hoogly. NTPC super-thermal power project receives cooling water from feeder canal. The B.G. railway and the National Highway (NH-34) which are important links to north-east India cross Ganga passing over the barrage. Both National Waterways NW-1(from Prayag to Haldia) and NW-2 (from Sadia to Haldia) meet at Farakka and pass through feeder canal linking Ganga with Hoogly (Fig.6). Farakka site was selected for the barrage after a prolonged investigation and model study by eminent river engineers like Sir Arthur Cotton from UK, Dr.Hensen from West Germany, Dr.K.L.Rao and Joglekar from India (Parua, 2010). Considering the immense importance of the barrage, the Central Govt has taken over the river training works to tackle the present problem arising due to Char formation, flow meandering and left bank erosion upstream and right bank erosion downstream of Farakka barrage.

Fig.6 Showing Meanders U/S & D/S of Farakka Barrage, Feeder Canal and Jangipur Barrage, Hoogly River, Feeder Canal,NH-34, Rly Line. (Mazumder 2004)

REFERENCES

CBIP (1989) "River Bhaviour, Management and Training, Vol.I",Central Board of Irrigation and Power, MalchaMarg, New Delhi

Chiale,S.V.(1970) "River Channel Patterns", J. of Hyd. Divn., Proc. ASCE, Vol.96,pp.201-221

Friedkin, J.F.(1945) "Laboratory Study of the Meandering of Alluvial Rivers" USWES, Vicksburg, MIssipi, USA.

Garde, R.J.(2006) "River Morphology", New Age International Publisher, Ansari Road, Daryganj, New Delhi-2

Lane, E.W.(1957) “A Study of the Slope of Channels Formed by Natural Stream Flowing in Erodible Material” U.S. Army Corps of Engineers, Missouri River Division, Omaha, Sediment series- 9.

Leopold.L.B., Wolman L.G. and Miller, J.P.(1964) “Fluvial Processes in Geo-Morphology” pub.W.H. Freeman& Co., San Fransisco, USA

Mazumder, S.K.(2004) “Analysis and Control of Erosion of River Ganga Upstream and Downstream of Farakka Barrage” by MOWR, CWC & CWPRS, 12-13 Feb., New Delhi

Mazumder, S.K. (2010) ”critical tractive stress in straight and curved channels with non- cohesive soil” Paper pub, in ISH J. Of Hyd. Engg.,Vol. 16, No.2, Sept.2010.

Mazumder, S.K. and Sunil Bagde(2019) "Waterway for A Bridge in Meandering and Braiding Flood Plain of A River-Some Case Studies" Pub. in the journal "Indian Highways", Vol.47, No.3, March,pp.11-19, Indian Roads Congress,New Delhi.

Parua, P.K. (2010) “The Ganga”, Water Science and Technology Library 64, 283 DOI 10.1007/978-90-481-3103-7_15, C _ Springer Science+Business Media B.V. 2010

Schumm, S.A.(1980) ,“Plan form of Alluvial Rivers” Proc. of the International Workshop on Alluvial River Problems held at Univ. of Roorkee, March 18-20.

Yang, C.T.(1971) “On River Meanders”, J. of Hydrology, vol.13, pp.231-253