Engineering/Science/Technology Civil/WR/EE/GIS

A Preliminary, Empirical, Morphological Analysis of River Ganga at the Kahalgaon Constriction

Dokka. Yagna Vamshi*, Ms. Syed Ameena**, Ms. Darsana P Sathian***
Assistant Professor*, Graduate Engineer Trainee**, Project Assistant***
Vignan's University, Vadlamudi, Guntur – 522213*
ATKINS,Bangalore**
Indian Institute of Science (IISc),Bangalore***
yvdokka@gmail.com

ARTICLE HISTORY
Received: 02 Apr 2017
Revised: 10 Apr 2017
Accepted: 20 Apr 2017
Available online: 10 Jun 2017

GRAPHICAL ABSTRACT

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Any water body that experiences inflow and outflow, especially during floods/storm events, usually encounters sedimentation. The amount of deposition or erosion occurring along the length of a river, varies from time to time and depends mainly on the velocity of water flow and the amount of sediment carried by the incoming stream. The current study attempts to determine whether or not, a permanent morphological characteristic is responsible for the meandering of the river Ganges within the study area. This is a preliminary investigation attempting to prove that the constriction at Kahalgaon is capable of causing enough deposition upstream, so as to cause a mirroring of the existing meander/movement of the meander crest to the trough portion and vice versa. The study is an empirical one and involves the inclusion of various assumptions, and is based on the Schoklitschs' Equation.

***Keywords*—Bed Load Transport, Fluvial Morphology, Kahalgaon Constriction on the Ganga, Meander, Sediment Transport.**

2455-2062 | http://dx.doi.org/xx.xxx/xxx.xxx.xxx |

I. Introduction

River morphology or fluvial geomorphology describes the shapes of river channels and their change over time. The morphology of a river channel is mainly a function of the sediment transport rate and the rate of deposition on the floodplain. If a river is flowing in an alluvial valley over a bed composed mainly of unconsolidated sand or gravel, it is probable that the river and its channel are essentially in equilibrium.

The size, shape and slope of the channel vary with the amount of discharge and its variation and the supply of sediment of those sizes that make up its bed. If some artificial change is introduced to the flow characteristics, sediment supply or shape and slope of the channel, the river will tend to make adjustments to reach a new equilibrium. It will do so by scouring or filling its bed, widening or narrowing its channel, increasing or decreasing its bed slope [1].

The Farakka Barrage built across the Ganga, in West Bengal has been mired in controversies. It was built with the sole purpose of flushing the sediment that is steadily accumulating in the Kolkata Port. The engineers who designed it however, did not plan for such a heavy silt load in the river. This detail, on being overlooked, caused a catastrophic failure of the project, leading to formation of an island of sediment due to deposition within the reservoir.

Most of the people residing on the banks of the Ganga, who experience the after effects of flooding of the river, have observed that the river has begun to swing wildly, more rapidly and extensively than it used to. This has caused much damage to life and property and the flood plain of the Ganga has increased even further.

The swinging of the river/meandering is a natural phenomenon, which may sometimes be accelerated by human interference as seen, in the case of the Farakka. Though the project was a complete failure in terms of not being able to achieve its objective and causing further damage to its surroundings, blaming it for damages due to some other natural phenomenon far away from the actual site is not logical.

The case of the stretch of Ganga between the cities of Kahalgaon and Bhagalpur is one such scenario. This study attempts to determine the cause behind the morphological changes that the river experiences and attempts to prove that the Farakka barrage is not one to blame here.

II. Data and Study Area

A. Area of Study

The area of study is the stretch of the Ganga between the two cities of Kahalgaon and Bhagalpur in the state of Bihar, approximately 28 km long. The reasons behind choosing this study area are as follows.

A naturally occurring constriction in the river is present across the cross-section near the city of Kahalgaon (hereafter referred to as "the constriction") and the river does not change in width at this place under any natural circumstances. This has remained so for as fas observations were made.

The region experiences change in the pattern of the meanders. It has been reported that the meander has changed its course by moving a stretch of nearly 60 km across and mirroring itself.

The Farakka Barrage present nearly 160 km away along the course of the river. The dam is blamed for the changes observed in the morphology of the river.

Fig. 1. Location of Study Area:

B. Data

The Landsat 8 (Operational Land Imager) OLI-TRIS (Thermal Infrared Sensor) images of the selected stretch for Low Flow and Flood Flow were collected for the study. The data was sourced from earthexplorer.usgs.gov.

The following averaged values were obtained from literature and various project reports available at (CWPRS) the Central Water and Power Research Station, Pune:

(i) The flood discharge was taken to be 50,000 cumecs.

(ii) The average grain size of the sediment particles was taken to be 0.25 mm.

(iii) The average specific gravity of the sediment particles was found to be 2.65.

(iv) The approximate bed slope was found to be 1 in 20,000

C. Assumptions made to perform the study

Since the study taken up is only a preliminary one, extensive collection of data and rigorous validation techniques were not used. Averaged data sets (other than the actual satellite images) and logical assumptions, were made, to assess the validity of the proposed theory.

The following is a list of all assumptions that had to be made, so as to ensure that the study could be performed with reasonable accuracy.

(i) The depth of the river is taken to vary between 12 metres to 16 metres; occurring at the constriction.

(ii) The grain size is assumed to be uniform and homogenous at the averaged size of 0.25 mm

(iii) At any given section only one of the processes of sedimentation and erosion can occur. Both will not occur simultaneously.

(iv) To calculate rate of Meander, the sediment deposition and erosion were assumed to occur along any one side of the channel, as applicable.

(v) The river section is assumed to be trapezoidal with a side slope of 1:5, for ease of calculations.

III. Methodology

In order to determine the rate of deposition, erosion and the rate of movement of the meander, the bed load transport rate needs to be determined. For this purpose, the Schoklitsch's Bed Load equation has been used.

The Landsat images obtained from the USGS website for both flood flow and lean flow were Geo-referenced and and digitized to form shape files of the river.

The shape files thus generated were then divided into many fine sections, manually, based on their observable widths. Each section is divided in such a manner that the width of the section is same on both the ends. Each section is chosen in such a manner that the top width of each section is nearly equal to half of the perimeter of each such section.

The Schoklitsch's Equation for Bed-Load Discharge was used to determine the critical discharge rate and Bed Load Transport Rate per Unit width for every section.

$$q_b = \frac{\{86.7 * (S^{3/2}) * (q - q_c)\}}{\{d^{\frac{1}{2}}\}}$$

[Eq.1]

Where,

q_B = Rate of bed load transport in weight per unit width,

S = Water surface or Bed slope,

q = Fluid discharge rate per unit width of channel,

q_C = Fluid discharge rate per unit width which yields critical conditions for a given sediment size and slope

$$qc = \frac{0.00532 * d}{S\hat{}(\frac{4}{3})}$$

[Eq. 2]

d = Mean diameter of sediment particle in mm

The input for each section is the output from the preceding section. The bed load transport rate per unit width is calculate for every section. The sediment transport rate per unit width thus obtained is converted from Kg/m/s to total bed load transported in MT/yr. The difference between the incoming bed load and the outgoing bed load for every section gives the amount of sediment deposited or eroded at that section.

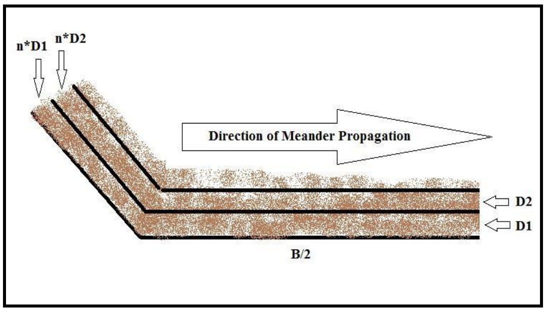

Fig. 2. Meander propagation:

The rate of meander is calculated from the depth of sediment deposited/eroded as described in the figure 1.

The distance traversed by the meander depends on the depth of sediment deposited on one side and the amount of sediment eroded on the other. The figure 2, describes the process. Here n represents the side slope and the depths of deposition are represented by D1, D2 and so on.

Over a period of 70 years the possible distance traversed by the river from across its path is determined.

IV. Results and Conclusion

A. Results and Discussions

The preliminary study yields the following results:

The Rate of Deposition in the river 9.808 MT/yr. The Rate of Erosion is found to be 9.710 MT/yr. The net rate of Deposition in the river stretch is found to be 0.098 MT/yr.

The average rate of meander is found to be 112.035 metres per year, which extends to nearly 7.8 kms in a period of 70 years. Nearly the same amount has been experienced in real life by those who live by the shores of these waters.

The result shows that the constriction is the major cause behind the traversing of the river's meander.

Images of lean and flood flows show that the constriction in the river is a permanent natural structure that does not change in response to floods and instead causes the meander to traverse across the flood plain upstream of it.

The Farakka Barrage, a dam 160 kms downstream of the river does not have a major part to play in the river's morphology at the study region. Its behavior is governed by a more local phenomenon.

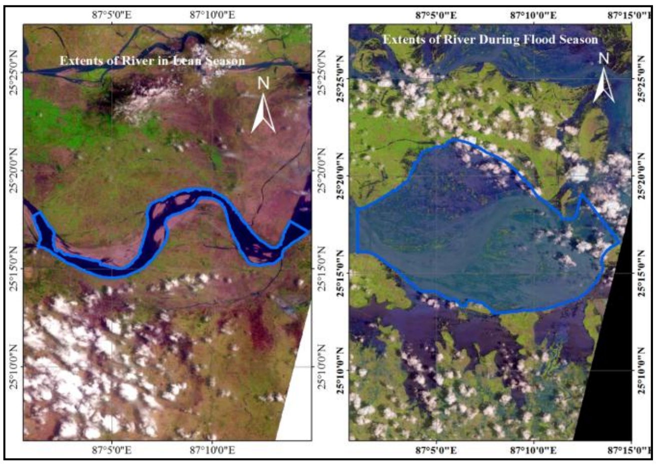

Fig. 3. The constriction on the Ganges.

B. Limitations

Like any other work, this study too has its own limitations. Being a preliminary study, the results of this work can be only used to give direction, to a more detailed study. The results obtained in this study are only qualitative and thus require further detail and validation.

The assumptions made in this study, though logical, require a valid proof with actual on-site data backing them. The study is based on averages of various values and the results obtained are error prone. Actual, discrete sets of data, will help us to further deepen, the understanding of the results and help relieve errors.

Acknowledgment

The authors wish to acknowledge Dr. R.G. Patil, Scientist – 'D' of the River Hydraulics division of CWPRS, Pune, without whose guidance this work would never have come into existence. This preliminary study was inspired and guided by him and the authors are very grateful.

References

[1] Hans Albert Einstein, "The Bed-Load Function for Sediment Transportation in Open Channel Flows" Technical Bulletin No. 1026, Soil Conservation Service, United States Department of Agriculture, Sep 1950.

[2] K.G. Ranga Raju, "Sedimentation of Rivers, Reservoirs and Canals", Fresh Surface Water – Vol III, EOLSS Publications, 25-Aug-2009.

[3] Mazumder, S.K. "River Behaviour Upstream and downstream of Hydraulic Structures", Proc. Int. Conf. On "Hydraulic Engineering Research and Practice (ICON-HERP-2004) org. by Deptt. Of C.E., IIT, Roorkee, Oct 26-28, 2004

[4] Choudhary U.K., "The five theories of river management", 1st Edition, Ganga Scientific and Technical Council, The Ganga 11Research Centre, I.T., B.H.U., 2008

[5] Anoop Nr. Singh, A.K. Upadhyay, U.K. Choudhary, J.P. Sonkar, "Interrelationship Between River Sedimentation And Meandering: A Case Study of Ganga at Varanasi," J. Name Stand. Abbrev., in press.

[6] Parineeta Dandekar, SANDRP, "Lessons from Farakka as we plan more barrages on Ganga," https://sandrp.wordpress.com/2014/11/25/lessons-from-farakka-as-we-plan-more-barrages-on-ganga/ , Accessed on 29/01/2017.