International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 4 Issue 7, July 2017

ISSN: 2394-4404

# Impact Of Channel Hydraulic Parameters On Channel Capacity: A Case Of Karatoya River Along The Rajganj Block, Jalpaiguri District, West Bengal

**Dr. Snehasish Saha**

Assistant Professor, Department of Geography and Applied Geography, University of North Bengal

**Kunal Chakraborty**

Ex. Student, Department of Geography and Applied Geography, University of North Bengal

***Abstract:** River is not only the vital resource for human activity but also it is the important physical agent to study the morphology of the region as well as. Basically sand-bed rivers are very complicated as they significantly change their bed forms (Jana & Paul, 2016). River Karatoya is one of the most important ancient rivers of North Bengal of that type. Over the several historical events the river has lost its natural course as well as its regime. At present significant variations in discharge and water head during summer and winter can be observed at places. Deposition of huge load during monsoonal months has enhanced the river bed aggradations over time. The aim of the present paper is to measure the in-channel hydraulic mechanism of the river along with the cross sections for a stretch of 13 Km (Balai-Gachh to Rajganj area). Field survey has been the main methodological approach to understand the riverine environment and the interrelations of the hydraulic parameters. The channel has been deteriorated temporally and hydraulic parameters as well their interrelations have been changing and that signifying the decay of the channel. The authors have also tried to put forward some suggestive measures to save the channel regime.*

***Keywords:** hydraulics, channel capacity, cross section, discharge, velocity, fluid density, friction*



## I. INTRODUCTION

Recent geographers in fluvial geomorphology include hydrological characteristics has become an important aspect to study the riverine regime. The present work signifies the hydraulic characters like velocity, discharge, water head calculations etc. of Karatoya river in Jalpaiguri District, West Bengal. Hydrological problems in the field of geomorphology are more concerned with identification of relationships and the impact of fluvial processes of a river basin. As the water flowing over the surface of the earth is a dominant agent of landscape sculpturing, a qualitative and quantitative study of stream discharges, stream velocity, and other hydraulic parameters also with the bank characters etc. will be necessary in understanding the nature of fluvial processes.

## II. HISTORICAL SIGNIFICANCE OF KARATOYA

The present Karatoya was at one time the main channel of the Tista, which lost its connectivity with Tista after the devastating flood of 1787-88 and changed its course and made its way to the Brahmaputra through the Rangpur district, thereby greatly diminishing the volume of water passing though the Karatoya and its sister channels Atrai and Punarbhaba (Chakraborty and Roy, 2010). Record reveals that up to 1787 the river Tista and Karatoya were the same river that flowed through the Atrai-Punarbhaba into the Ganga. Neo-tectonic activity coupled up with high intensity rainfall induced flash-flood caused massive shifting of the river (District Gazetteer, Jalpaiguri). The so-called whale backed subsurface ridge of the Baikunthapur-Fulbari became active to separate Tista and Tista migrated eastward bifurcating the river Karatoya. Major Rennel’s Atlas of 1770 shows the old course of the river and he states the Tista is a larger river which runs almost parallel to the Ganges by two distinct channels situated about twenty miles from each other, and a third channel at same time discharges itself into the Meghna but during the season of floods the Ganges runs into the Tista whose outlet is then continued to the channel that communicates with the Meghna. Thus, the once wide Tista-Karatoya valley dried up and only two narrow channels namely Karatoya and Sahu are still visible. During the flood of 1788-89, the Tista shifted further east and reached Per-Mekhliganj-Jaldhaka of present Bangladesh. Under orders of the Governor General in Council an attempt was made in June 1889 to restore the Tista to its original Channel (Balurghat Municipality,2009), however, it was abandoned six months later as impracticable. The river Karatoya has suffered further during the above mentioned flood years due to massive aggradations which is also noticeable in case of many Bengal rivers. The process has been hastened further by rising of the level of the river-bed during the earthquake in 1897(District Gazetteer, Jalpaiguri). Not only this, the channel also has been affected by human interferences causing loss of its vivacity.

## III. STUDY AREA

The present study area is located in the Rajganj Block delimiting the western boundary as river Karatoya from Balai-Gachh to Rajganj area of Jalpaiguri District. The location-wise extension of the selected reach of the river is 26°32'00"N to 26°36'00"N and 88°29'00"E to 88°31'00"E respectively covering an area of about 9.50 sq. km. The total perimeter of the basin area under study (part of upper Karatoya segment Figure 3.1) is about 13.17 km.

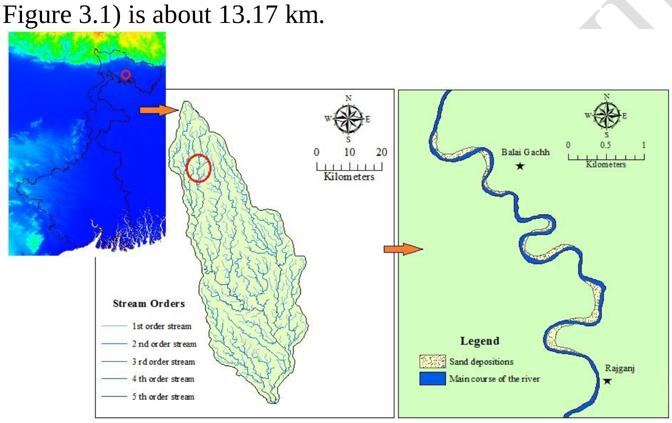



*Figure 3.1: Location of the study area*

## IV. OBJECTIVE OF THE STUDY

The present study aims to the following objectives:

- ✓ The hydraulic characteristics of the Karatoya river
- ✓ To analyse the progressive cross section characteristics.

## V. MATERIALS AND METHOD

The work is dominantly based on primary database collected during the field survey. The calculations of hydraulic parameters have been done using conventional methods and formulae gathered from literature studies. Cross sections have been drafted manually for selected sites to study progressive variations. Mapping has been carried out under GIS environment. For the measurement of density and viscosity of water, samples have been collected from selected depths of the channel and tested under laboratory treatment for assessing the results.

## VI. HYDRAULIC PARAMETERS AND PROGRESSIVE CHANGES

Progressive change detection has been noticed in different parameters namely cross-sectional area, channel width, channel average depth, channel wetted perimeter, hydraulic radius, channel velocity and channel discharge which have been summarized below under respective headings.

| Cross Sections | CS 1 | CS 2 | CS 3 | CS 4 | CS 5 | CS 6 |
|---|---|---|---|---|---|---|
| Width (m) | 40.5 | 42.9 | 51.8 | 43.4 | 44.6 | 37.2 |
| Average Depth (m) | 1.5 | 1.5 | 1.9 | 1.6 | 1.7 | 1.3 |
| Cross sectional Area (sq m) | 37.3 | 39.9 | 57.7 | 42.6 | 46.3 | 35.8 |
| Wetted Perimeter(m) | 24.7 | 26.5 | 47.4 | 28.5 | 39.3 | 22.3 |
| Hydraulic Radius (m) | 1.53 | 1.57 | 2.36 | 1.73 | 2.03 | 1.41 |
| Velocity (m/sec) | 0.61 | 0.57 | 0.55 | 0.56 | 0.56 | 0.72 |
| Estimated Discharge (cumecs) | 48.5 | 34.9 | 23.8 | 29.3 | 26.7 | 59.2 |

*Source: Field investigation during May'15*

*Table 6.1: CS-wise Calculations for Hydraulic Parameters*

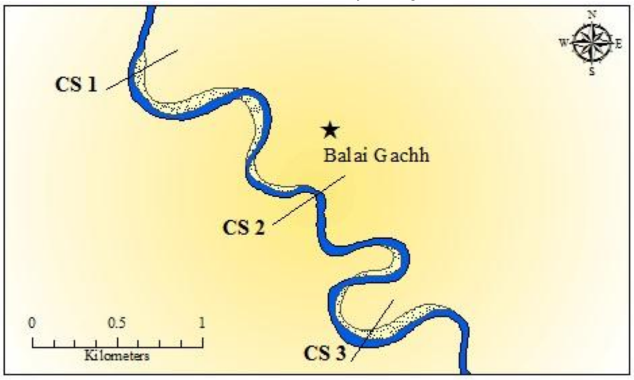



*Figure 6.1: Cross section- sites of River Karatoya, upper reach (08 Km selected Reach in the study area)*

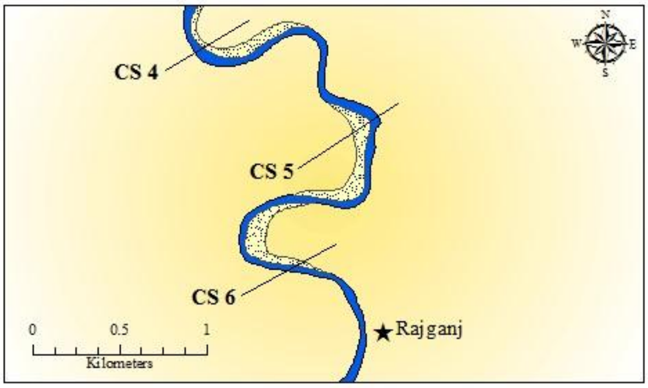



*Figure 6.2: Cross section- sites of River Karatoya, lower reach (08 Km selected Reach in the study area)*

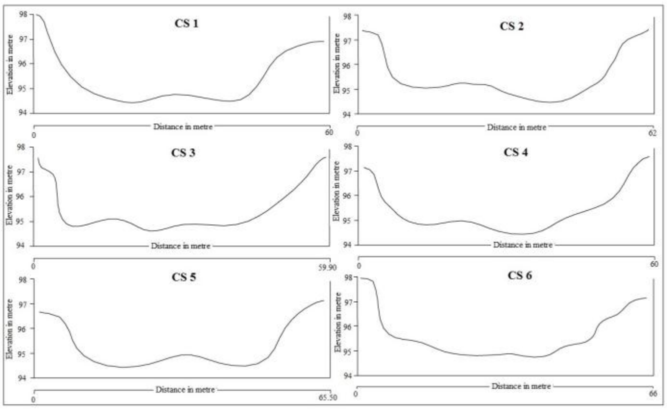
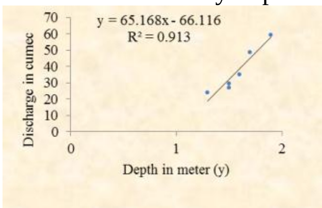



*Figure 6.3: (CS 1-6) Cross sections of selected sites of River Karatoya*

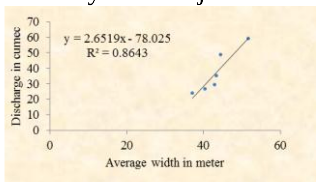
Six consecutive cross sections (Figure 6.1 and Figure 6.2) from north to south have been studied which shows variations from upstream to downstream. Maximum cross section area has been noticed for the 3rd cross section while the 6th records the lowest that reveals the systematic and conventional nature of river i.e. increasing tendency of hydraulic actions especially scouring of the bed and bank. Channel width is of increasing tendency from the upstream to the downstream segments. Cross-section wise measured channel widths prove that with the down slope advancement of the stream the width of the channel also get increased. Average channel velocity of River Karatoya is 0.57m/sec. In township areas channel velocity is very low as it is affected by anthropogenic interferences. Estimated Discharge (q) was calculated based on cross section area and channel velocity. The entire studied reach within the Jalpaiguri town areas is receiving low channel discharge as well as lesser expanses of channel width. Q-w relationship is proportionately and most positively correlated within the study reach. The average discharge of the river is 37.07 cumec. Channel depth along different sections is not changing remarkably except little variations. This reveals that river's vertical gradation process along those sections is almost equal. The wetted perimeter shows gradual increment with the increase in channel width. Hydraulic Radius is a function of cross sectional area /wetted perimeter. Hydraulic radius of the channel remains almost equal in all surveyed cross sections except for the 6th cross section.

## VII. HYDRAULIC PARAMETERS AND THEIR INTER-RELATIONSHIP

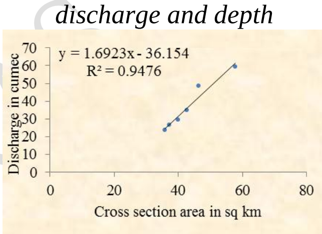
Progressive Hydraulic Parameters like cross sectional area (A), channel width (w), average channel depth(y), channel velocity (v), wetted perimeter (P), hydraulic radius (R) discharge and their inter-relationships have discussed. Here all the hydraulic parameters have been compared and cognitively analyzed with discharge. Depth versus discharge shows a high positive relationship of about 91% which indicates that discharge is directly related with depth i.e. with the increment of the depth of channel, the discharge also increases. Width is positively related to discharge and the relationship is 86% correlated as per $R^2$ value (0.864). This shows that with the increment of channel width discharge is proportionately increasing. The acceleration of discharge is experienced in case of the relation between cross sectional area and discharge signifies that with the increment of cross section area, discharge is progressively in increment. The relationship in normality is positively correlated with high significance of 94% and $R^2$ value is 0.947. On the other hand in the Hydraulic radius-Discharge relationship, the cluster of scatters shows high variation in relation to the best fit line with $R^2$ value being 0.995, this indicates that discharge is always been dependent on the hydraulic radius. High positive relationship is present here. The cluster of scatters in case of velocity-discharge relationship is comparatively compact and the scatters are compactly settled along the best fit line. Here the $R^2$value is 0.878 that means in case of increasing velocity discharge also increases. In case of perimeter and discharge relationship, high positive correlation is noticed i.e. 99% and $R^2$ value is 0.994, which means that if wetted perimeter increases discharge output also increases and the channel maintains a tendency to preserve fluvio-dynamic adjustments.



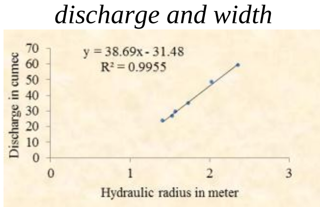

*(a) Relation between discharge and depth*



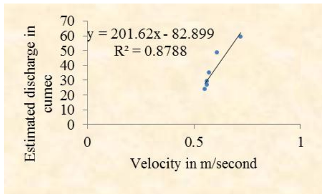

*(b) Relation between discharge and width*



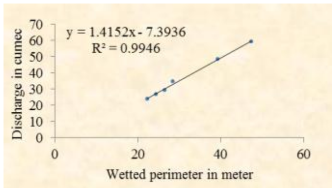

*(c) Relation between discharge and cross sectional area*




*(d) Relation between discharge and hydraulic radius*




*(e) Relation between discharge and velocity*




*(f) Relation between discharge and wetted perimeter*

*Figure 7.1: Interrelationship between hydraulic parameters (no. a-d)*

## VIII. COMPUTATION OF OTHER HYDRAULIC CHARACTERS

To study the other hydraulic characters (average) for the studied reach standard and conventional formula based calculations were carried out (Table 8.1)

| Hydraulic parameters | Formula | Results | Remarks |
|---|---|---|---|
| ($F_1$) Resistance force (τ) | $F_1$= γ * R * S here γ = ɭ * g// | 172.32 N m 3-1 | Moderate to create turbulence and frictional force |
| ($F_2$) Frictional | $F_2$= L * W * ɭ * | 679.61 N m 3-1 | **$F_1$: $F_2$** = 3.94 signifies low to |

ISSN: 2394-4404

| | | | |
|---|---|---|---|
| force | g * sin α | | moderate acceleration |
| Channel Capacity (C) | $C=b_1 * (s - б)^n$ | 2.35 | Low to entrain load as per standards |
| Shearing stress (τ) | $\tau = \mu * d^2 / dy$ | 7.78 | Moderate to detach bank materials |
| Average Fluid Density(D) | Laboratory assessment (gm/cc) | 1.005 gm/cc | Moderate |
| Kinematic viscosity (Ƞ) | Ƞ =(μ / ɭ) | 0.00824 poise | Low |
| Froude's number (Fr) | $Fr = V / \sqrt{g^{//}} * D$ | 0.15 | <1 signifying Low turbulence |
| Critical depth ($Y_c$) | $Y_c = V^2 / g^{//}$ | 0.037 m | low critical depth signifying good specific energy |
| Turbulent velocity ($V^{/}$) | $V^{/} = \sqrt{V - V}$ mean | 0.84 m / sec | Low |
| Settling velocity | $2 / 9 * r^2 * g * (d_1 - d_2) / \mu$ | $1.059\ m\ s^{-1}$ | Moderate to high |
| Specific weight of water (¥) | ¥ = p * g | 9.733 gm/l | Moderate |

*Table 8.1: Channel strength in relation to hydraulic characters of river Karatoya*

## IX. DISCUSSION

Fluid character in relation to channel competence always confronts to a difficult way of channel mechanism. Here the river Karatoya always reveals a moderate channel character in respect to its capacity and strength. As the mean computed resistance force of the river is moderate, it results into low fluid acceleration and thereby in-channel siltation (*plate c*). Hence bed roughness is always in challenge and consequent upon low angle of friction(s) which also signifies low competence of the river as already mentioned (table 2). Not only this, it also indicates incapacitation of the river as the shear stress (τ) decreases to about moderate magnitude. Cross section analysis and volume of bank materials produced as well bed load characters also depict the aforesaid channel character. The inclination of the bed plane is not even enough to carry the discharge with load towards downstream. The fluid characters especially the density and the viscosity of the river water has been calculated to that of moderate magnitude and hence impact on turbulence as well as settling velocity is high meaning thereby lowering of turbulence and increasing propensity of settling velocity of suspended and transitional fluid load. Thus the rolling friction along the channel bed is producing a very low turbulent velocity for the river which is also facilitating in channel deposition and formation of both point and mid channel bars (*plate a & c*). In this region actually the bed material character being comparatively huge in respect to the cross sectional area of the channel and fluid velocity, is highly responsible for this low rolling friction. Legacy to the past in relation to the channel capacity explicitly unshadows a competent character of the river and that has been seriously hampered due to its disconnectedness with the river Tista since 1787 flood. From then the channel is also facing the difficulties of regular head water supply and steady discharge leading to continuous deterioration.

*Plate 9.1: During field investigation (May, 2015)*

*Plate 9.2: Spur as human interference against channel regime*

*Plate 9.3: In channel siltation of bank material signifying Interruption against channel dynamics*

*Plate 9.4: Velocity measurement during field Survey*

*Plate 9.5: Huge supply of bank material reducing channel capacity*

*Plate 9.6: Clayey bed material offering low frictional and moderate Resistance energy*

## X. CONCLUDING REMARKS

Dependency of the local people on the river has been found very high from time immemorial in the form of human interventions on the riverine regime especially sand extraction is one of the common practices in the river bed. As a result of this simultaneously river bed aggradations is being artificially provoked instead of heavy bed deposition. Many meander loops have also been identified from satellite images and field investigations in this reach which has precisely held responsible for the declining capacity of the channel and has influenced the building-up of embankments to reduce bank failures. Embanking might have also been restricted the natural flow of the river during high spates than to overtop the banks. On the other hand low velocity and low depth characters would have been remarkably affected channel bed erosion. The results show continuous disruption of flow regime due to continuous and constant sedimentation and gradual channel infilling which consistently resulted into river bed upliftment. Most important to infer that the river has had shown a gradual decline in its competency as well as in its capacity to carry its discharge properly in the down slope direction.

LIST OF SYMBOLS USED

Q = Discharge in cumecs
V = velocity in m / second
W = width of the cross section (1 sq m)
L = length of the cross section (1 sq m)
g = site specific gravity α = channel bed inclination
ḽ = density of water gm / litre
R = hydraulic radius of the channel
S = slope of channel bed (from upstream to downstream)
Ꞷ = omega
H = height fro sea level
y or d = depth of the channel in meter
y or d = depth of the channel in meter
$d_1$ = density of the particle
$d_2$ = density of the water
p = site specific density
A = cross sectional area
ϴ = gradient angle
n = roughness coefficient
c = capacity of the river
$b_1$ = 01 (empirical constant)
б = competent slope
CS= cross section

REFERENCES

[1] Butzer, W. K. (1976): Geomorphology from the Earth. The University of Chicago; Pub: Harper and Row, March, Newyork, London, pp. 133-140.
[2] Chakraborty, T. And Ghosh, P. (2009): The geomorphology and sedimentology of the Tista megafan, Darjeeling Himalaya: Implications for megafan; *Geomorphology ELSEVIER*, Volume 115, Issues 3–4, 1 March 2010, pp. 252-266
[3] Comprehensive district agricultural plan of Jalpaiguri district (2010): http //CDAP plan of Jalpaiguri district, 2010, pp. 89-97.
[4] Doornkamp, John C. and King, Cuchlaine A. M. (1971): Numerical analysis in Geomorphology: An introduction; St. Martin’s Press, New York, USA, First Edition, pp. 28-96.
[5] Duari, M. Mazumder, A. and Maiti, P. (2014): Padartha Bidya; Revised Edition-March,’14, Pub: Chhaya Prakashani, Kolkata-07, pp. 430-443 and 479-487.
[6] Ghosh, D. and Saha, S. (2013): Channel bed aggradation in relation to channel morphometry: A case study of river Jainti, Jalpaiguri, West Bengal. *International Journal of Geomatics and Geosciences*, Volume 4, No 1, ISSN 0976 – 4380, pp. 201-206.
[7] Leopold, L.B., Wolman, M. Gordon and Miller, John P. (1970): Fluvial Processes in Geomorphology; S. Chand and Company Ltd., New Delhi, First Indian Reprint, pp.131 – 322.
[8] Morisawa, M. (1985): Rivers: Form and Process; Geomorphology Texts, Longman Group Ltd., New York, First Edition, pp. 25-36.
[9] Morisawa, M. (1968): Streams: their dynamics and morphology; Earth and Planetary Science Series, McGraw-Hill Book Company, New York, First Edition, pp. 152-166.
[10] Nageswara, Rao K. and Swarna, Latha, P. et al. (2010): Morphometric analysis of Gostani river basin in Andhra Pradesh state, India using spatial information technology. *International journal of geomatics and geosciences*; Volume 1, No 2, ISSN 0976 – 4380, pp. 181- 185.
[11] Raghunath, H. M. (2014): Hydrology: Principles, Analysis and Design. New International Publishers; 3rd Edition, ISBN- 978-81-224-3618-1, pp. 171-174.