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Research Article

A STUDY ON SUSPENDED SEDIMENT DISCHARGE AND BED LOAD GRAIN SIZE OF THE GUMTI RIVER OF TRIPURA AT SOME SELECTED TRIBUTARY CONFLUENCE POINTS

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ABSTRACT
The suspended sediment load refers to the fine sediment that is transported in suspension, with only infrequent contact with the bed, whereas bed load sediment is sediment that is transported along the bed. As a river flows downstream it receives lots of tributaries at regular intervals. The tributaries have their own sediment load and their meeting with the main stream leads to a significant increase in the load of the main stream. Gumti River is the largest river of Tripura which is regulated by the Dumbur Dam in its upstream. After 18.9 km away from the dam, the River Gumti started to receive its major tributaries from both sides, which influence the sediment discharge and grain size of the river. In this paper the researchers intend to identify the impact of five major tributaries on the suspended sediment discharge and grain size distribution of bed sediment of the Gumti River. For this purpose cross sections have been taken immediately before and after the tributary confluence points. Besides, suspended sediment concentration and mean grain size of bed sediment have also been measured. The result indicates that all five tributaries have their influence in increasing the suspended sediment discharge of the Gumti River by 20% to 138%. Besides, the mean grain size of bed load varies from fine sand to medium sand in each upstream and downstream of tributary junctions respectively.

Keywords: *Gumti River, Sediment Concentration, Suspended Sediment Discharge, Grain Size*

INTRODUCTION
Confluence of a tributary with its trunk stream is very much significant to change the water and sediment discharge of that river. Channel confluence is an important component of river system because it affects the morphology and hydrology of the reaches upstream and downstream from the confluence point (Roy and Sinha, 2007). The experimental works of Mosley, 1976; Best and Roy, 1991; Biron *et al.,* 1993a, 2002; Bristow *et al.,* 1993; Axtmann *et al.,* 1997; De Serres *et al.,* 1999; Rhoads and Sukhodolov, 2001, 2004; Stevaux *et al.,* 2009 etc. are very much effective in the study of river confluence. Moreover, during last ten years there has been large scale increase in the study of confluence dynamics (e.g., Parsons *et al.,* 2007, Szupiany *et al.,* 2009, Leite Ribeiro *et al.,* 2012 and Constantinescu *et al.,* 2012). Confluences are key features of river network which provide diverse flow conditions that influence physical channel processes and biological processes (Benda *et al.,* 2004). When two channels meet together, each of having independent flow and sediment discharge regimes creates unique erosional and depositional environments with consequent changes in channel morphology at confluences (Miller, 1958; Best, 1986 and 1988). Due to the abrupt introduction of sediment and organic materials at confluences, different types of changes in channel morphology in the vicinity of confluences takes place (Chakraborty and Mukhopadhyay, 2014).
Confluence is very much important for the influx of extra discharge and sediment load to the main stream. The flow structure of main stream goes through unique change at the junction of tributary. Tributaries have their own sediment load. When it is added to the main stream at tributary junction, it experiences sudden increase in sediment load. This sudden increase in load can change the overall channel profile. Higher the input of sediments from the tributaries, greater will be the changes in physical characteristics of the main stream. Besides, change in the mean size of the river bed sediment also took place at the tributary junction. The magnitude of this change depends on the energy level of the tributary to carry

load. Gumti River is the largest and longest river of Tripura. As the river approaches downstream from the Dumbur dam, it receives lots of tributaries from both the sides which change the overall sediment discharge and bed load grain size distribution of the river. The study area extends from 23° 25′ 16.91″ N to 23° 27′ 38.13″ N and from 91° 15′ 21.18″ E to 91°48′ 06.05″E i.e. a stretch of the Gumti River from Dumbur dam to Srimantapur border with Bangladesh.

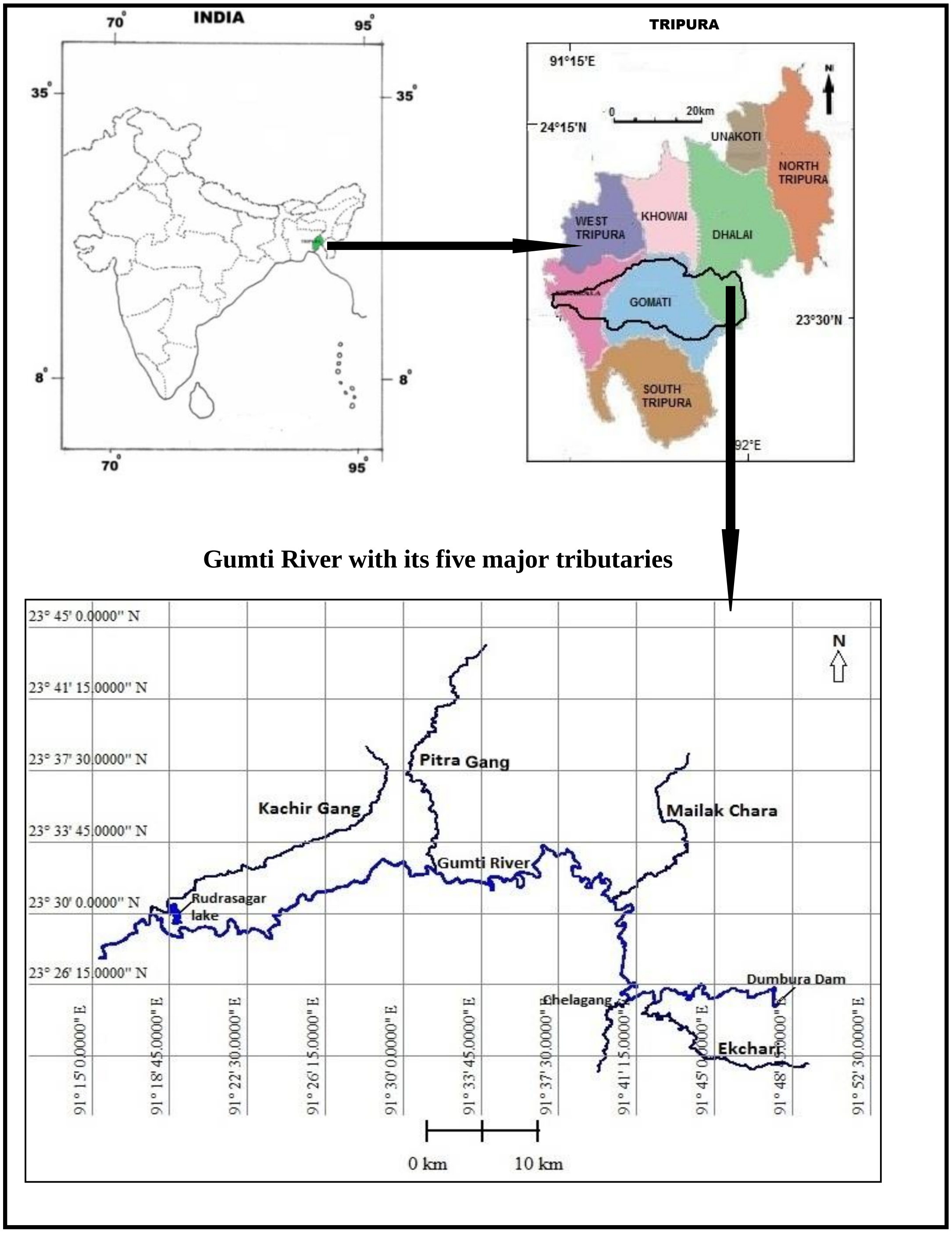


Figure 1: Location of the Study Area

In this paper the impact of five major tributaries, namely, Ekchari and Chela Gang (left bank) and Mailak Chara, Pitra Gang and Kachir Gang (right bank), on the suspended sediment discharge and bed load grain size of the Gumti River has been analyzed (Figure1).

MATERIALS AND METHODS

In order to prepare this research paper intensive field work has been carried out and modern technology has been used. Cross sections across the Gumti River have been taken at immediate upstream and downstream of the five confluence points in order to identify the changes that have taken place after each confluence. Cross sections have been taken in pre- monsoon period as it is very difficult to carry out hydrological measurements across the Gumti River in monsoon and post-monsoon periods due to high discharge and velocity of the river during these periods. Velocity has been measured by using Digital Current Meter. Discharge (Q) has been calculated using formula Q = A*V. Water samples from immediate upstream and downstream of the confluence points have been collected. The sediment concentration of the collected samples has been measured by using filter paper. Mean sediment concentration and standard deviation of each sample have been calculated. For calculation of suspended sediment discharge the following empirical formula (USGS, 1972) has been used:

$$Qs = Qw\ Cs\ k$$

Where, Qs = Suspended sediment discharge in metric tonnes.

Qw = Water discharge in m^3 / second.

Cs = Mean concentration of suspended sediment in the cross-section in mg/litre.

K = a coefficient based on the unit of measurement of water discharge which is 0.0864 when discharge is in m^3/second.

For grain size analysis, bed materials have been collected from immediate upstream and downstream of the confluence points and dried up in woven. Sieving technique is used to separate grains of various sizes and mean size has been calculated using the following formula suggested by Fork and Ward (1957):

$$M_{Z} = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

RESULTS AND DISCUSSION

Tributaries lead to a sudden change in channel bed morphology due to a significant increase in sediment load along the main stem river. Moreover, discontinuities in the fining of sediments are often observed at tributary junctions (Rice, 1998). It is observed that sediment concentration and discharge of the Gumti River has been charged at each tributary junction.

Table 1: Information about Five Major Tributaries of the Gumti River

Tributaries	Source Height (m)	Confluence Height (m)	Length (Km)	Confluence Point with Gumti River	Gradient from Source to Mouth (m/km)	Catchment Area (Km^2)
Ekchari	195	40	27.4	91° 42′ 13.70″E 23° 25′ 18.54″N	5.65	104
Chela Gang	100	40	13	91° 40′ 50.83″E 23° 25′ 30.75″N	4.62	32
Mailak Chara	271	38	27	91° 40′ 00.03″E 23° 30′ 40.58″N	8.63	65
Pitra Gang	183	27	34.7	91° 31′ 28.13″E 23° 32′ 17.19″N	4.49	174
Kachir Gang	78	18	37	91° 17′ 50.11″E 23° 29′ 53.95″N	1.62	163

Influence of Tributaries on Suspended Sediment Discharge of the Gumti River

The changes in hydraulic characteristics like velocity, cross sectional area water and sediment discharge, sediment concentration of the Gumti River have been identified after the confluence of each selected tributary. The field records show that the velocity was higher in the immediate downstream of the confluence in comparison to the immediate upstream (Table 2) in all the cases (ranges between 15-25% increase) except Kachir Gang which shows -4.88% decrease in downstream velocity. This anomaly may be due to 16.67% and 12.82% increase in sediment concentration and cross sectional area respectively after the confluence point.

Table 2: Variation in Hydraulic Parameters of the Gumti River Upstream and Downstream of the Tributary Confluences

Name of Tributary	Hydraulic Parameters	Before Confluence	After Confluence
Ekchari	Average Velocity	0.30 m/sec	0.37 m/sec
	Cross-sectional Area	18.83 m^2	18.02 m^2
	Discharge	5.65 Cumec	6.67 Cumec
	Suspended Sediment Concentration	82 ±2.65 mg/l (Mean ±SD)	84 ± 1.53 mg/l (Mean ±SD)
	Suspended Sediment Discharge	40.03 Metric tonnes/day	48.41 Metric Tonnes/Day
Chela Gang	Average Velocity	0.38 m/sec	0.46 m/sec
	Cross-sectional Area	16.00 m^2	16.25 m^2
	Discharge	6.56 Cumec	7.47 Cumec
	Suspended Sediment Concentration	85 ±1.73 mg/l (Mean ±SD)	90 ±2.64 mg/l (Mean ±SD)
	Suspended Sediment Discharge	48.18 Metric Tonnes/Day	58.12 Metric Tonnes/Day
Mailak Chara	Average Velocity	0.32 m/sec	0.37 m/sec
	Cross-sectional Area	21.43 m^2	19.45 m^2
	Discharge	6.86 Cumec	7.2 Cumec
	Suspended Sediment Concentration	96 ±1.70 mg/l (Mean ±SD)	110 ±2.61mg/l (Mean ±SD)
	Suspended Sediment Discharge	56.90 Metric Tonnes/Day	68.43 Metric Tonnes/Day
Pitra Gang	Average Velocity	0.30 m/sec	0.40 m/sec
	Cross-sectional Area	23.50 m^2	26.25 m^2
	Discharge	7.05 Cumec	10.50 Cumec
	Suspended Sediment Concentration	50 ±3.61 mg/l (Mean ±SD)	80 ±2 mg/l (Mean ±SD)
	Suspended Sediment Discharge	30.46 Metric Tonnes/Day	72.58 Metric Tonnes/Day
Kachir Gang	Average Velocity	0.41 m/sec	0.39 m/sec
	Cross-sectional Area	21.76 m^2	24.55 m^2
	Discharge	8.92 Cumec	9.57 Cumec
	Suspended Sediment Concentration	72 ±1 mg/l (Mean ±SD)	84 ±2.66 mg/l (Mean ±SD)
	Suspended Sediment Discharge	55.49 Metric Tonnes/Day	69.49 metric Tonnes/Day

Source: Calculated by the authors on the basis of field measurement

After computation of the cross sectional areas it was observed that the areas have been increased from 1.56%-12.82% except in case of Mailak Chara (-9.24%) and Ekchari (-4.3%) which is owing to the presence of point bar of 8.2m and 14.6m respectively. An increase in water discharge has also been identified in all the selected sites, ranging from 4.96%-48.94%. Moreover, an increase of about 2.44%-60% in suspended sediment concentration reveals the large scale influx of suspended sediment by the tributary streams with larger catchment area covered by loamy, red sandy and lateritic soil. Similarly, the sediment discharge show significant increasing trend from upstream to downstream of the confluence points ranging from 20.26%-138.28%.

The larger the tributary discharge as compared to the main stem discharge, the more sudden the increase in discharge will be, and the more permanent the change that occurs at confluence point (Benda *et al.*, 2004). Confluence plays a vital role in regulating the movement of sediment through the river networks (Rhoads and Kenworthy, 1995; Rice, 1998).

The fact to be mentioned here that the amount of both suspended sediment concentration and discharge are higher (110mg/l and 68.43metric tonnes/day) in downstream of the Mailak Chara whereas it becomes lower (50 mg/l and 30.46metric tonnes/day) in next immediate upstream of the Pitra Gang (Table 2, Figure 2 &3).

This difference is due to the presence of the Maharani Barrage, about 3 km upstream of the Pitra Gang confluence point, that used to trap the sediments and therefore, both the sediment concentration and sediment discharge show a significant change of about 60% and 138.28% respectively in downstream. Therefore, the study clearly indicates that the Pitra Gang (174 km^2 catchment area) contributes the highest amount of suspended sediment to the main River Gumti.

Kachir Gang, the last tributary received by the Gumti River, contributes lesser amount of suspended load to the main stream because before the confluence point, it passes through the Rudrasagar Lake (Figure 1) where it compels to drop its load. Thus, rising of the river bed and narrowing of the channel become normal activities of the River Gumti which in turn affect the socio-economic condition of the local people.

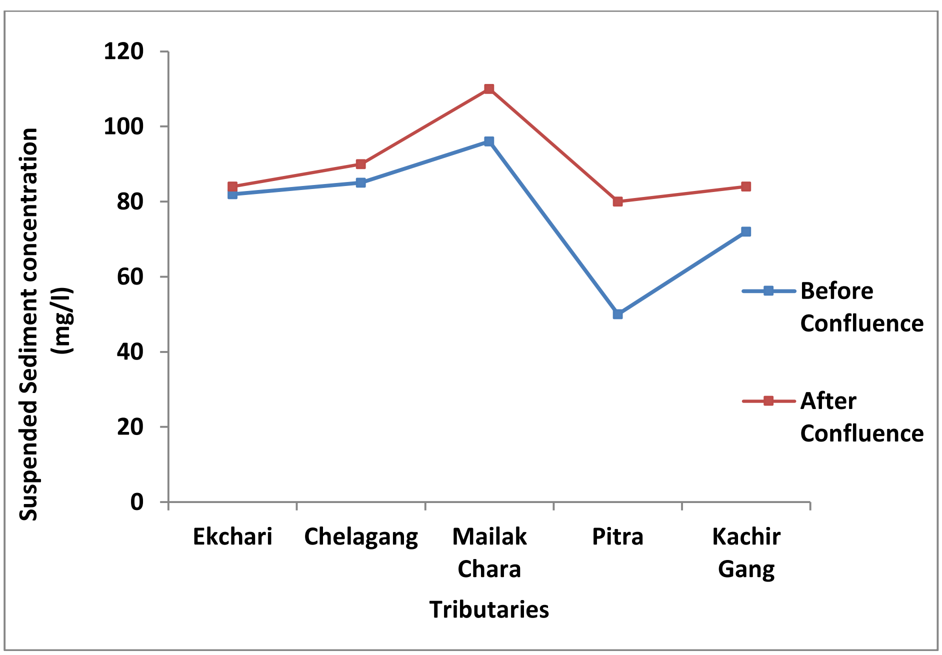


Figure 2: Variation in Suspended Sediment Concentration of the Gumti River Before and After Confluence with Five Major Tributaries

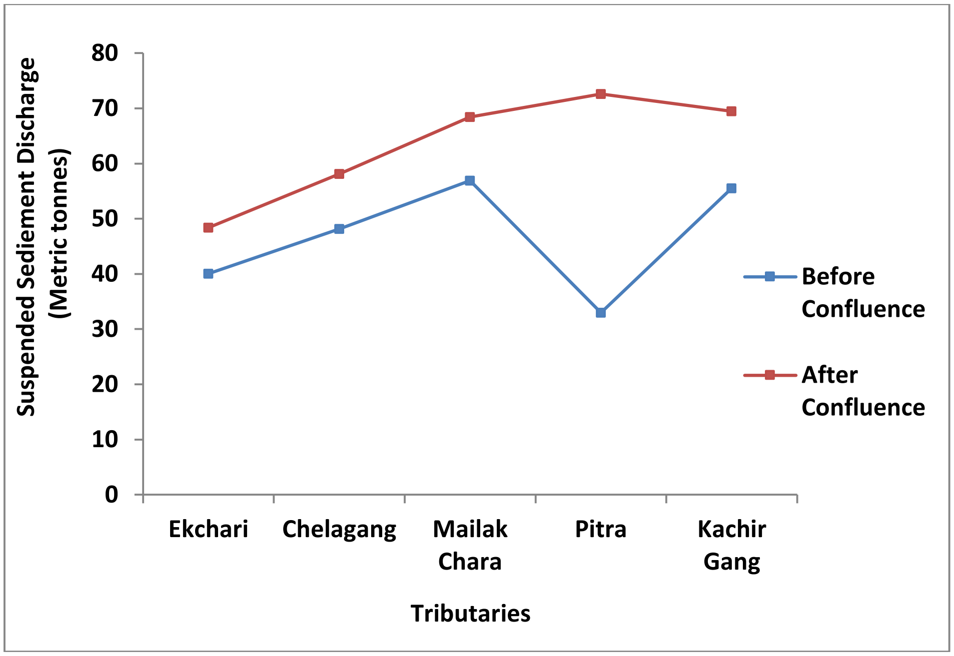


Figure 3: Variation in Suspended Sediment Discharge of the Gumti River Before and After Confluence with Five Major Tributaries

Figure 4 and 5 reveal that in downstream, starting from the first to last confluence of the large tributaries, correlation with water discharge (r=0.76) is positive and significant but suspended sediment load is not significant, only r=0.39. It is due to the fact that the normal distribution of sediment load was modified by the presence of barrage (anthropogenic) and lake (natural) in general and frequent bar formation in particular.

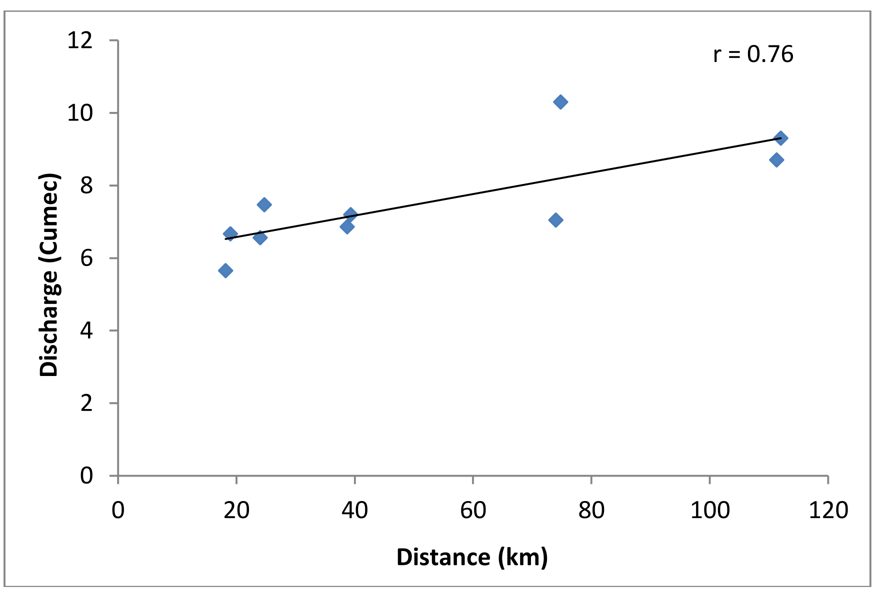


Figure 4: Correlation between Distance and Water Discharge of the Gumti River

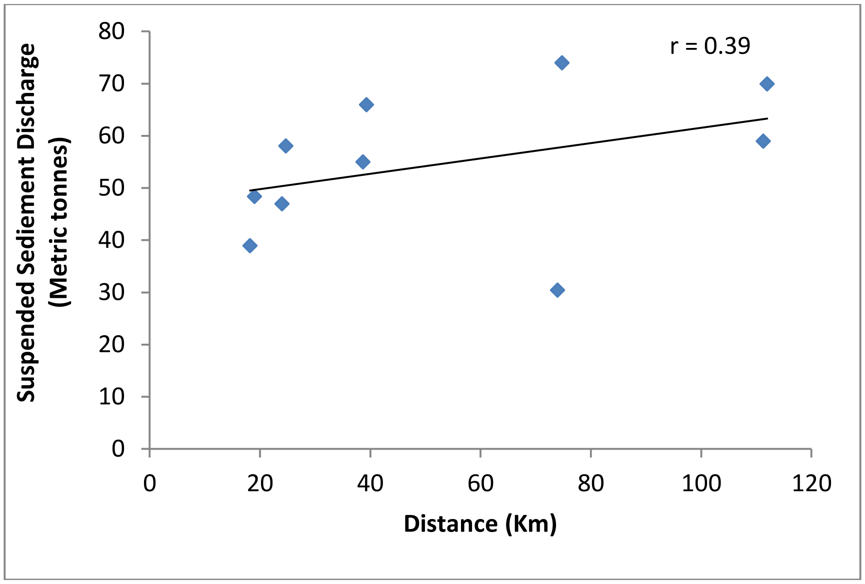
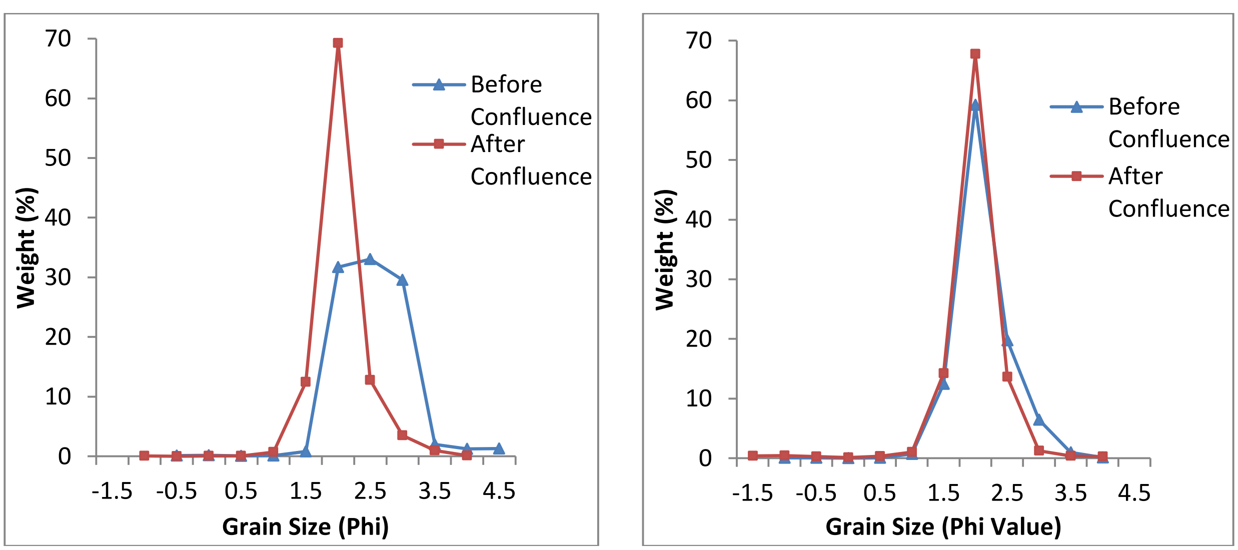


Figure 5: Correlation between Distance and Suspended Sediment Discharge of the Gumti River

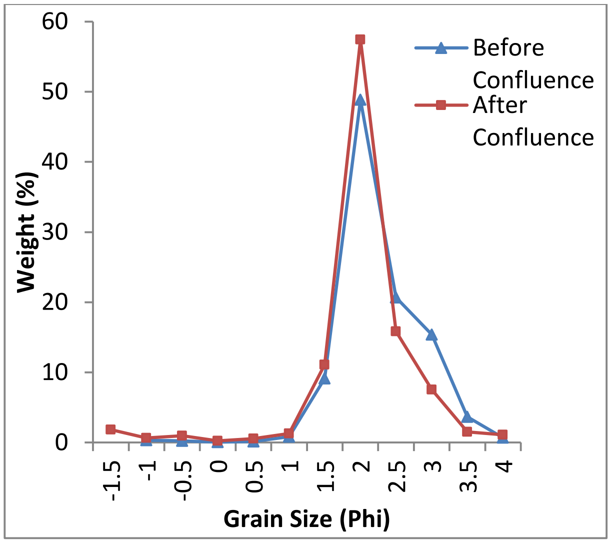
Influence of Confluence on Grain Size Distribution

An increase in the grain size of the Gumti River from fine to medium sand has been observed after the confluence of most of the tributaries (Table 3). It is due to the fact that the tributaries carry medium and large sized sediment from their hilly catchments which are directly added to the Gumti River (Table 3).

Figure 6 reveals that after confluence of the tributaries, the grain size has been increased downstream. The study identified the anomalies in grain size distribution which is purely due to the intervention of barrage and lake in the course of the tributaries like Pitra Gang and Kachir Gang respectively. Moreover, the increasing length and decreasing gradient of segment between two confluences also play significant role in variation in grain size between immediate upstream and downstream of each tributary confluences (Table 3). It initiates sedimentation problem in the lower reach of the Gumti River due to lack of competence to carry the bed load.



(I) **(II)**



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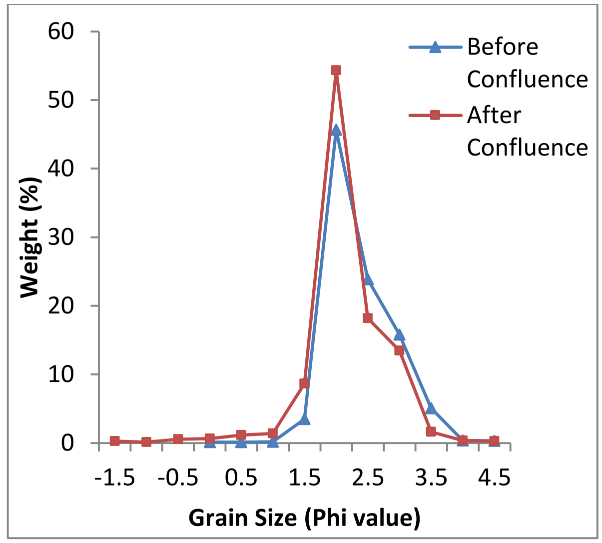

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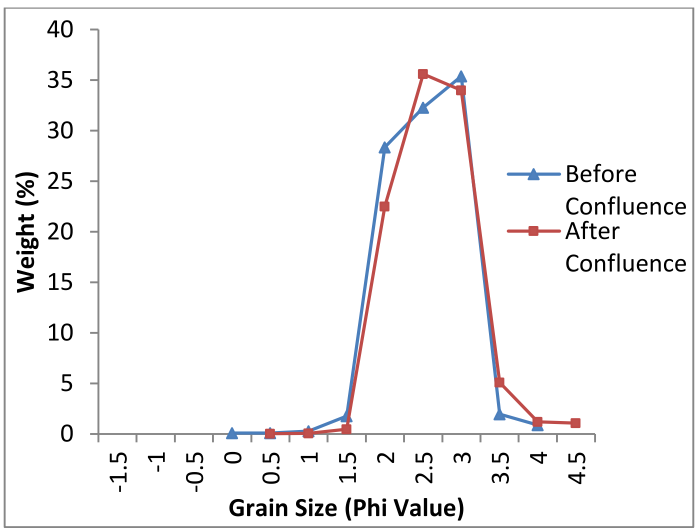

(V)

Figure 6: Variation in Bed Load Grain Size Distribution of the Gumti River Before and After the Confluence of Tributary (I) Ekchari, (II) Chela Gang, (III) Mailak Chara, (IV) Pitra Gang and (V)Kacir Gang

Impact of Influx of Sediment from the Tributaries to the Gumti River

The study indicates that the magnitude of sediment supply to the Gumti River at the confluence points depend on the size of the sub-catchments, length of the segments and the presence of obstruction. Now a day, with the increased rate of population pressure, large scale deforestation has taken place over the sub catchments of the Gumti River. Extra sediment influx from the tributaries has negative impact on the River Gumti through frequent bar formation (Figure 7). It indicates that the river has deficient competency to transport the medium sized load that has been brought by the tributaries, especially after Chela Gang confluence due to low gradient and velocity. As a result the navigability of the river is severely affected. Moreover, the suspended sediment load of the river settled down in downstream where buoyancy becomes lesser than the weight of load. The ultimate result is the increase in bed height.

Table 3: Variation in mean size of bed load of the Gumti River before and after the confluence of five major tributaries

Name of tributary	Mean Size (Phi)		Descriptive Term		Length of Segment (km)	Gradient
	Before Confluence	After Confluence	Before Confluence	After Confluence		
Ekchari	2.257	1.775	*Fine Sand	Medium Sand	4	1:1000
Chela Gang	1.88	1.863	Medium Sand	Medium Sand	18	1:3600
Mailak Chara	2.421	1.994	*Fine Sand	Medium Sand		
Pitra Gang	2.11	1.964	*Fine Sand	Medium Sand	35	1:3890
Kachir Gang	2.270	2.355	*Fine Sand	Fine Sand	37	1:4100

Source: Measured by the authors

[*medium sized grains settled down in lakes and barrages and length of the segment]

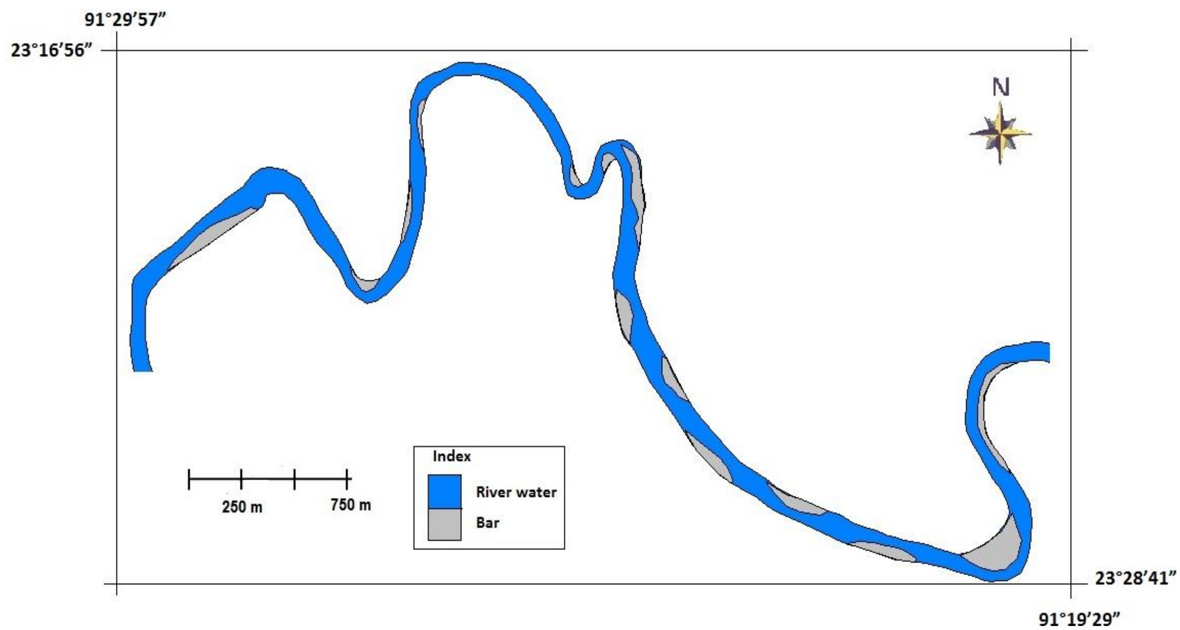

Figure 7: Frequent Bar Formation After the Pitra Gang Confluence in Downstream which Indicates Sedimentation Problem

Conclusion

The confluence of the major tributaries with the Gumti River has immense significance in terms of hydraulic and morphological perspectives. Abrupt changes in the physical characteristics of the river like velocity, cross sectional area, water and sediment discharge, sediment concentration have been observed at the confluence points. The study shows that lack of competency to carry the extra load influx results in the rising up of bed level and frequent bar formations in the Gumti River. Thus initiatives like afforestation in the sub catchments and dredging of the river bed should be taken to make the river navigable again.

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