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A MORPHOMETRIC STUDY OF THE SONAI RIVER BASIN, BARAK VALLEY, NE INDIA

* **Nandita Dutta and J.N. Sarma**
Department of Applied Geology, Dibrugarh University,
Dibrugarh, Assam, PIN- 786004
**Corresponding author*: nanditadutta7@gmail.com; jnsdu@yahoo.com

ABSTRACT

An attempt has been made to study drainage basin morphometry of Sonai River Basin, Barak Valley NE India. This study reveals that the Sonai River is an eighth order river. The study area covers an area of about 2874 km^2. GIS techniques are used a tools for carrying out the morphometric analysis of the basin. The study is mainly focused on basin morphometric parameter such as linear aspects [Stream Order (Nu), Bifurcation Ratio (Rb), Stream length (Lu), Stream frequency and areal aspects [Form factor (Rf), Circulatory Ratio (Rc), Elongation Ratio (Re) and Drainage density] and Relief aspects [Relief, Relative relief (R_r), Relief ratio (R_R) and Ruggedness Number (R_D)]. During the study, relationships among the linear morphometic indices hold true for Horton's Law of drainage composition. Concave type of longitudinal profile of Sonai basin reflects high incision and knick points in the profile produced by uplift or erosion.

Key words: Morphometry, Sonai River, GIS

INTRODUCTION

Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimension of its landforms (Agarwal 1998; Obi Reddy et al. 2002). A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behaviour of surface drainage networks (Horton 1945; Leopold & Maddock 1953; Abrahams 1984). Geographic Information System (GIS) technique are now a days used for assessing various morphometric and morphotectonic parameters of the drainage basins and used as a powerful tool for the manipulation and analysis of spatial information (Malik et al. 2011).

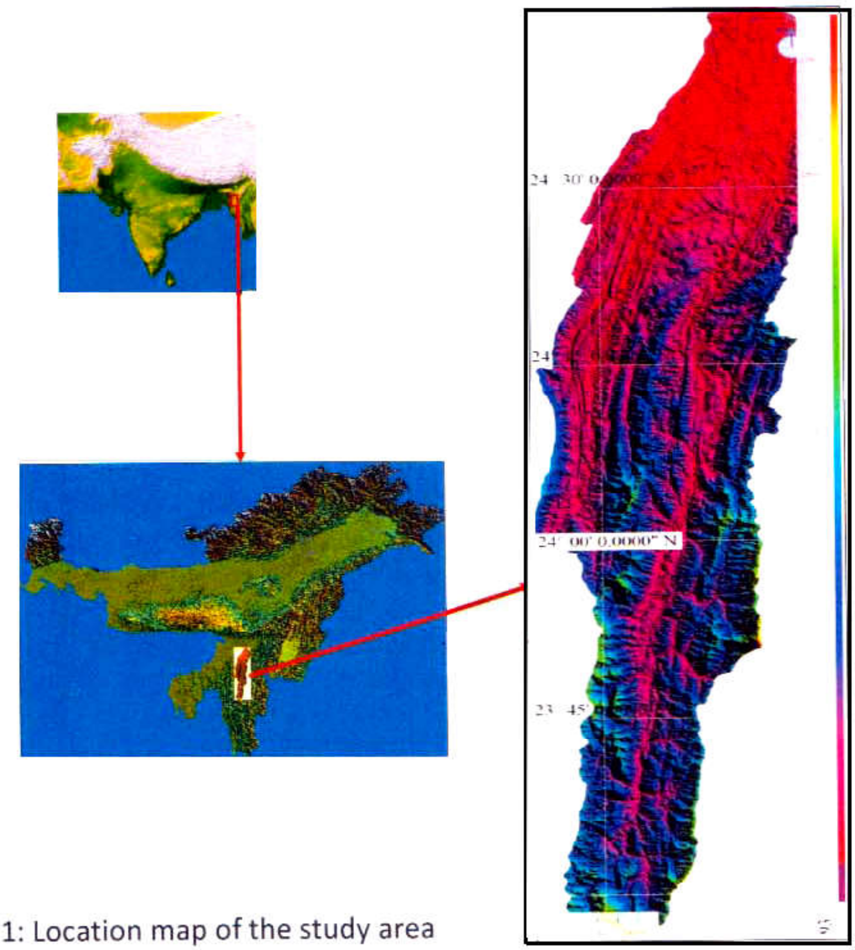

Fig. 1: Location map of the study area

STUDY AREA

The Sonai is one of the major south-bank tributaries of the Barak River. The river Sonai originates from the point (23.437^{0} N and 92.766^{0} E) within dense mixed jungle at Mizoram and falls at Sonaimukh on the east of the Silchar town. The Sonai River basin comprises a major part of the Barak Valley, which forms a part of the Cachar district of Assam and a part of the states of Mizoram. The area undertaken for morphometric analysis of drainage basin is bounded within the north latitudes from $23^{0}\,25^{/}\,33^{//}$ to $24^{0}\,44^{/}\,18^{//}$ and east longitude from $92^{0}\,41^{/}\,11^{//}$ to $92^{0}\,56^{/}\,59^{//}$ and covers an area of about 2875 km^{2} (Fig. 1).

DATABASE AND METHODOLOGY

The morphometric analysis of the drainage basin of the Sonai river was carried for the most part on the Survey of India Topographical maps nos. 83 D/10, 83D/11, 83D/12, 83D/13, 83D/14, 83D/15, 83H/2, 83H/3, 83H/4, 84A/9, 84A/10, 84A/11, 84A/

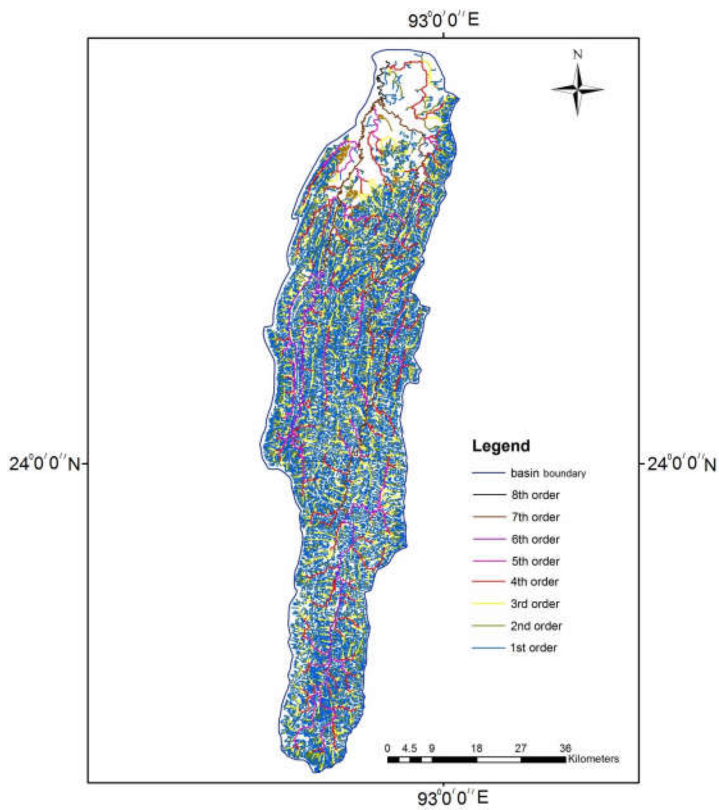

Fig 2: Sonai River basin with streams orders

13, 84A/14, 84A/15 on the scale of 1:50,000, surveyed during 1972. These maps are georeferenced in the Arc-GIS 9.3 software in the UTM projection system. The measurement of basic parameters of drainage basin, viz. length, area, number of streams and perimeters of the basins are calculated using the Arc-GIS software. For this study the lengths of the streams, areas of the drainage basin of the various orders were measured using the measuring tool of Arc GIS 9.3 software. Topographic contours at 20 m intervals and SRTM DEM of 30 m resolution of USGS are used for measuring the relief aspects.

RESULTS & DISCUSSION

Linear Aspects

Stream Order (Nu)

Stream order is the measure of position of a stream in the hierarchy of tributaries. Out of the six systems of ordering the streams that are available (Gravelius 1914; Horton 1945; Strahler 1952; Scheidegger 1965; Shreve 1957 and Smart 1978), Strahler's system, which is a slight modification of Horton's, was followed here because of its simplicity. For ordering the stream all finger-tip tributaries are considered as 1st order, the one formed by the merging of two such first order segments is the second order stream and so on.

The data of stream number of the Sonai River basin and is given in Table1.

Mean stream length

The mean stream length is a dimensionless property, characterizing the size aspects of drainage network and its associated surface (Strahler 1964). It is obtained by dividing the total length of streams of an order by the total number of segments in that order.

Stream length ratio

It is the ratio between the mean lengths of streams of any two consecutive orders. Horton's law (1945) of stream length states that the mean length of stream segments of each of the successive orders of a basin tends to approximate a direct geometric series, with stream lengths increasing towards higher stream order. All the subbasins in study area show variation in stream length ration between streams of different orders. Changes of stream length ratio from one order to another order indicate their late youth stage of geomorphic development (Singh and Singh 1997). The data of stream length and stream length ratio of the Sonai River basin and is given in Table 1.

Bifurcation Ratio (Rb)

According to Horton (1932), the ratio between the numbers of stream segments of any given order to the number of segments of the next higher order, a proportional ratio designated as the "bifurcation ratio", (R_b) is obtained. Hence, bifurcation ratio between successive orders is defined as $R_b = N_u/N_{(u-1)}$.

The data of stream length and stream length ratio of the Sonai River basin and is given in Table 1.

Table 1: Total stream length, Mean stream length, Bifurcation Ratio and length ratios of the Sonai River basin.

Basin Name	Stream order	Number of streams	Bifurcation Ratio	Total length of segments (km)	Mean Stream length (km)	Length ratio (km)	Mean Basin Area
SONAI RIVER	1	14152		6685.593	0.472		0.129
	2	2802	5.05	1624.409	0.58	1.23	0.271
	3	646	4.34	836.027	1.29	2.22	2.321
	4	147	4.39	512.850	3.49	2.70	15.069
	5	36	4.08	232.350	6.45	1.85	45.741
	6	5	7.2	139.126	27.825	4.31	278.238
	7	2	2.5	195.560	97.78	3.51	1350.944
	8	1	2	16.362	16.362	0.167	2874.123

Mean=4.22 ΣL_k=10242.277

Basin length and Basin width

The drainage basin length was measured as the longest basin diameter between the mouth of the basin to the most distant point on the perimeter. Basin length may or may not be equal to the length of the main channel. The length of Sonai Basin is 145.813 km. The width of the basin is measured as the longest diameter perpendicular to the length. The width of Sonai Basin is 27.818 km.

Areal Aspects

Basin area

The area of a basin is defined as a total area of surface contributing to all the channels in the basin along with all the inter-basin areas. The area of a basin is determined from the adjacent basin by the drainage divide. The drainage divide is demarcated on the basis of extension of first order streams, contour lines and topographic features. The basin area of Sonai river is about 2874 km^2 (Table 1).

Form factor (Ff)

The ratio of the basin area to the square of basin length is called the form factor. It is a dimensionless property and is used as a quantitative expression of the shape of basin form. Lower values of form factor are observed in subbasins leads to circular in shape (Mahadevaswamy 2011). The value of form factor is always less than 0.7854 for a perfectly circular basin. Smaller the value of form factor, more elongated is the basin. The basin with high Ff have high peak flows of shorter duration, whereas elongated sub basin with low form factor have lower peak flow of longer duration (Chopra et al. 2005). The Ff of the Sonai River Basin is 0.135 which infers that the basin is elongated in nature (Table 2).

Circularity ratio (R_c)

The circulatory ratio (Rc) has been used as a quantitative measure and is expressed as the ratio of the basin area (A) to the area of a circle having the same perimeter as the basin (Miller 1953, Strahler 1964). Circulatory ratio of Sonai basin is 0.292, which infers that it is an elongated basin (Table 2).

Elongation ratio (Re)

Schumm (1956) defined elongated ratio as the ratio of diameter of the circle of the circle of the same area in the basin to the maximum basin length. Values near to 1.0 are typical of regions of very low relief, whereas values in the range from 0.6 to 0.8 are generally associated with strong relief and steep ground slope. Elongation ratio of Sonai basin is 0.415 which infers that it is an elongated basin occurring on very low relief area (Table 2)

Table 2. Form factor, Circularity ratio, Elongation ratio of Sonai River

Sr. No.	Morphometric parameter	Formula	Sonai River Basin	Remarks
1.	Form factor	$F= A/L^2$	0.135	Elongated basin
2.	Circularity ratio	$C = 4\pi A / P^2$	0.292	Elongated basin
3	Elongation ratio	$E = 2* (A/\pi)^{0.5}/B_L$	0.415	Elongated basin

Drainage Density (D_d)

Drainage density is the ratio of total channel segment lengths cumulative for all orders within a basin to the basin area (Horton 1932). The drainage density indicates the closeness of spacing of channels, thus providing a quantitative measure of the mean length of river network for the whole basin. Drainage density is dependent on several factors like presence of exposed bedrocks, surface ruggedness, permeability or impermeability of the substratum etc. In the present study, the drainage density of Sonai River basin is 4.01 km^2/km, which belongs to high drainage density (Table 3). Sonai River basin is situated at the Cachar-Tripura-Mizoram fold belt which consists of a series of north-south trending, en-echelon anticlines and synclines, the former being generally associated with faults. So, High drainage density in this area may be due to the highly ruggedness topography.

Stream frequency (F_s)

Stream frequency was introduced by Horton (1945) and it is obtained by dividing the total number of streams (N) by the total drainage basin area (A). The stream frequency for the entire Sonai river basin is found to be 6.19 per km^2 , which is a high value (Table 3) indicating that stream frequency maintain a positive relationship with drainage density.

Constant of channel maintenance (C)

It is the inverse of drainage density (Schumm, 1956)). It may be simply defined as the area of basin surface needed to sustain a unit length of stream channel which is expressed as km^2/km. Constant of channel maintenance depends upon the rock type and permeability, climatic regime, vegetation cover, relief, the duration of erosion and climatic history. The constant is extremely low in areas of close dissection. The constant of channel maintenance of Sonai River is 0.249 (Table 3), which also indicates a very low value inferring close dissection.

Drainage texture (T)

Drainage texture is defined as the total number of stream segments of all orders per perimeter of the area (Horton 1945). The drainage texture depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith 1950).

Smith (1950) classified drainage texture into five different textures i.e., very coarse (<2), coarse (2–4), moderate (4–6), fine (6–8), and very fine (>8). Texture of the entire Sonai River Basin is 50.54 and it indicates that the Sonai basin has very fine texture which shows that both erosion and dissection rates are high (Table 3).

Table 3: Texture properties of Sonai River basin

Sr. No.	Morphometric parameter	Formula	Units	Sonai Basin
	Texture Properties			
1	Total stream length	ΣL	km	10242.277
2	Total number of streams	(N)	-	17791
3	Drainage Density	$Dd = \Sigma L / A$	km/km^2	4.01
4	Stream Frequency	$SF = N / A$	$No./km^2$	6.19
5	Constant of Channel Maintenance	$C = 1/ Dd$	km^2	0.249
6	Drainage texture	$T = N_u / P$	km	50.64

Interrelation between Morphometric Characteristics

Stream Order and number of stream

The number of streams of each order is plotted against the corresponding stream order on a semi-log graph paper for the basin as shown in Fig. 3.

It is apparent from the graph that the number of streams of a given order decreases systematically with increase in order, i.e. the relationship shows a negative correlation and this is in conformity to the law of stream numbers. All the points of a particular stream fall in almost straight line when the bifurcation ratio of the different orders is of similar magnitude.

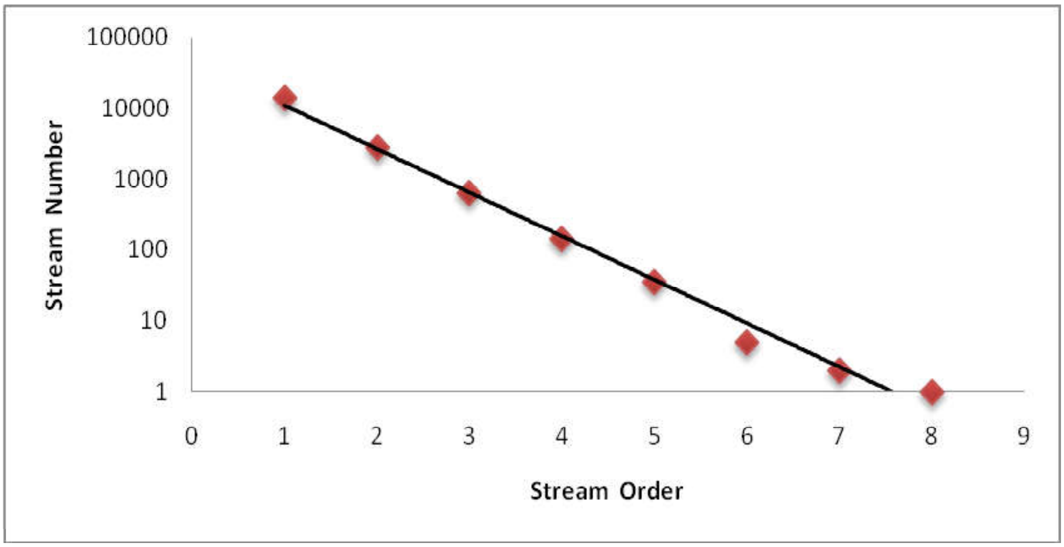

Fig. 3: Relation between Stream Order and Stream Number

Stream Order and Mean stream length

The mean length of stream of a given order is plotted against the corresponding stream order on a semi-log graph paper for the different sub-basins as shown in Fig. 4. It is evident from the plot that the mean length of the streams of a given order increases systematically with increase in order and thus conforms well to the law of stream length. The graph shows positive correlation.

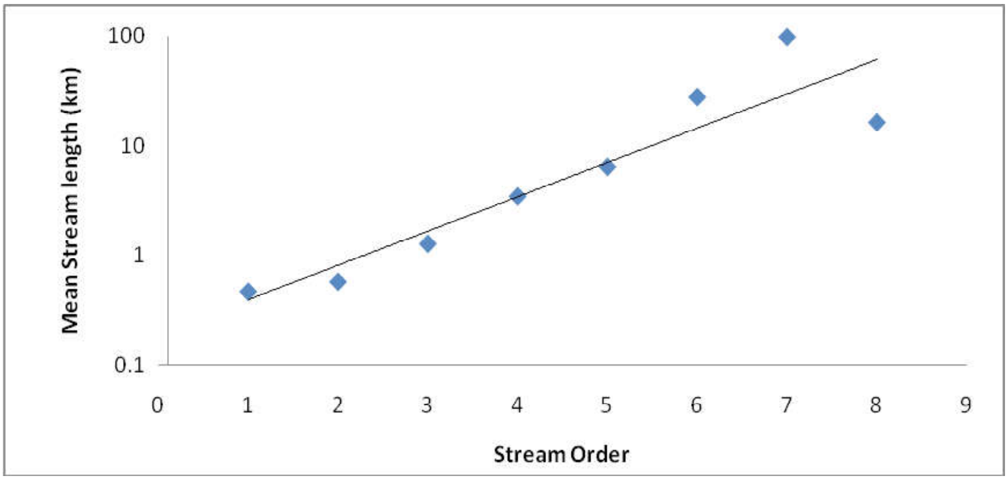

Fig. 4: Relationship between Stream Order and Stream Length

Stream Order and Mean Basin Area

The mean basin area of the streams of a given order for basin is plotted on semi-log graph paper against corresponding order as shown in Fig. 5. The relationship shows that the mean basin area of corresponding order increases systematically with increase in stream order and this is in conformity to Schumm's (1956) law of basin area.

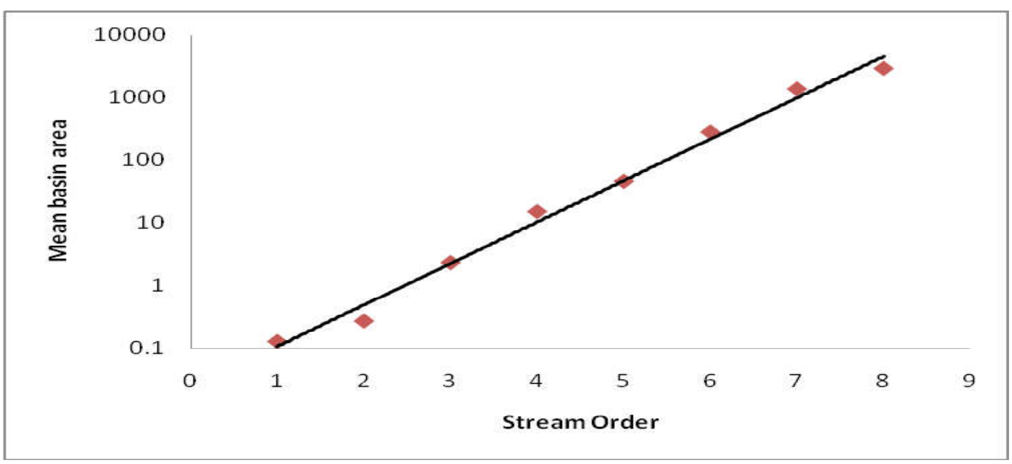

Fig. 5: Relationship between Stream Order and Mean basin area

Stream Length and Basin Area

The length of stream channel of each river is plotted against the corresponding drainage area on a log-log graph paper for the basin as shown in Fig 6. The relationship shows a linear pattern, length increasing with increasing area. This relationship conforms to the Morisawa's (1959) law of channel maintenance.

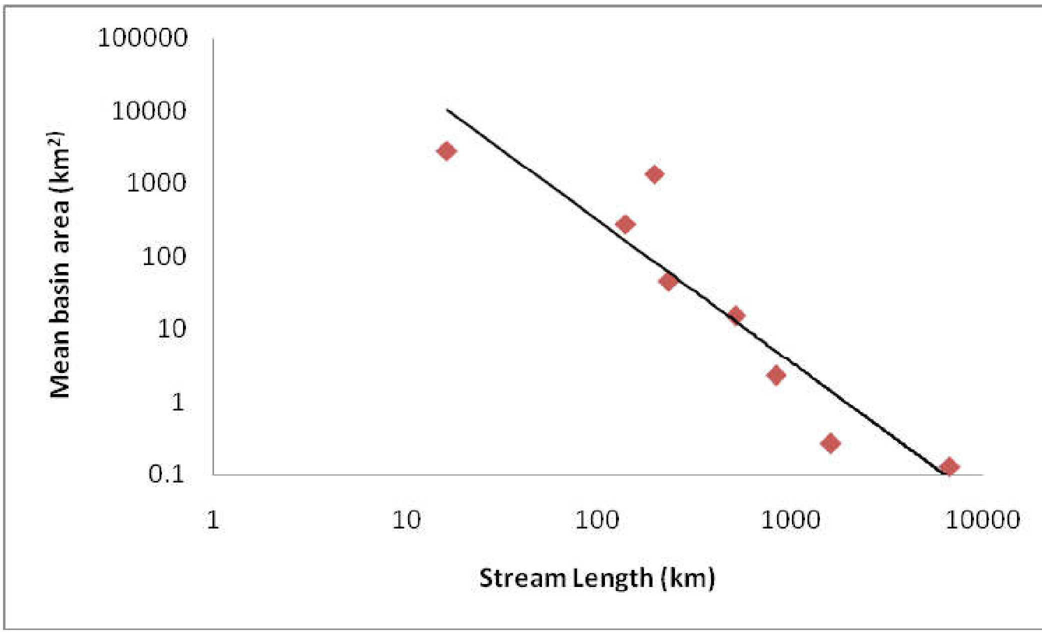

Fig. 6: Relationship between Stream Length and Mean basin area

Relief Aspects

Relief

The maximum basin relief (Strahler 1954, Schumm 1954), calculated as the difference between the maximum and minimum absolute heights, provides information on the relative rejuvenation of an area. The relief map (Fig. 7) of the basin shows that southern part of the Sonai River basin has higher elevation than the northern part. The highest and the lowest relief of the basin are 1620 m and 20 m, respectively (Table 4).

Relief ratio (Rr)

The relief ratio (Schumm 1954, 1956), representing the mean slope of a basin, is particularly useful for elongated basins (Morisawa 1962). The relief ratio of the Sonai basin is 0.00011 (Table 4). Value of relief ratio decreases while the length of the basin increases. Sonai basin is highly elongated, it indicates the length of the basin is high for which value of relief ratio is low.

Table 4: Relief properties of Sonai basin

Sr. No.	Morphometric parameter	Formula	Units	Sonai Basin
	Relief Properties			
1	Absolute Relief in the basin (A)	-	m	1620
2	Lowest point in the basin (L)	-	m	20
3	Mean Height of the basin (M)	-	m	820
4	Relative relief (Rr)	H-L	m	1600
5	Relief Ratio (R_R)	$R_R = (H - L) / B_L$		0.00011

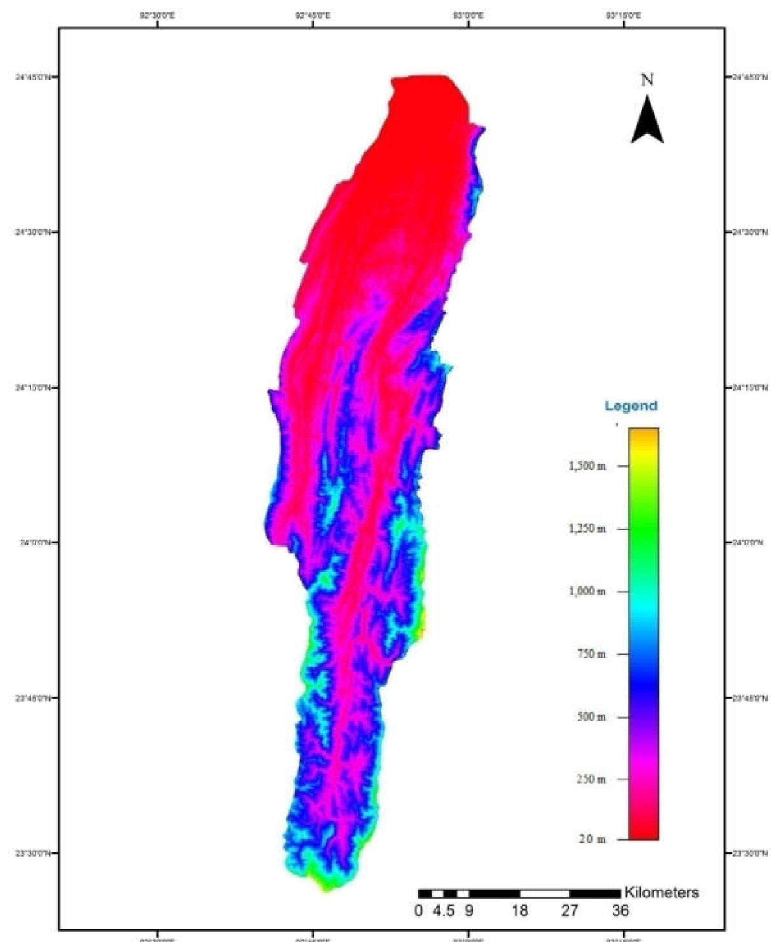

Fig. 7: Relief map of the Sonai River basin. The map is generated from the SRTM DEM.

Longitudinal profile

The longitudinal profile is a graph of elevation versus distance. Factors such as discharge, size of debris, velocity, width and slope, upon which the longitudinal profile depends are significantly variable within a short distance along hilly course of river. (Sarma et al. 1986)

The longitudinal profile of the Sonai River is prominent concave type and this curve is fairly steep in the upstream hilly catchment. The graph indicates that the rate of decrease in slope is quite high in the initial course. The profile consists of four subzones by three distinct knick points P, Q and R (Fig. 8). The knick point P coincides with the position of the river at which the river takes an abrupt turn. The point Q represents the position of the junction of the hills and plains and the point R represents the area when it cuts across the low ridge within the plains.

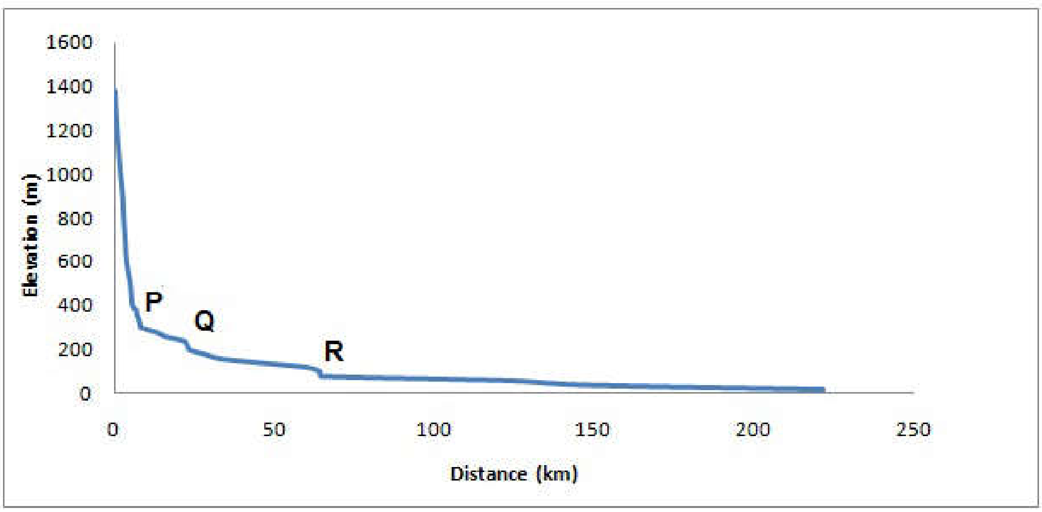

Fig. 8: Longitudinal profile of the Sonai River basin

CONCLUSIONS

This study reveals that the relationship among the linear morphometic indices holds true for Horton's law of drainage composition. The bifurcation ratio (Rb) is indicative of shape of the basin. The high R_b value of Sonai River basin indicates that it is elongated nature. Among areal indices, low form factor value of Sonai River basin also depicts elongated basin, which represents lower peak flow of longer duration.

High drainage density in the study area may be due to ruggedness topography of the region. Fine drainage texture of Sonai shows erosion and dissection rate is high. Low value of constant of channel maintenance also represents close dissection in the area. Lower relief ratio represents Sonai basin is an elongated one. Elongated nature of Sonai basin indicates that the basin is influenced by structure and tectonics. Concave type of longitudinal profile of Sonai basin reflects high incision and knick points in the profile produced by uplift or erosion.

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