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# Morphometric Analysis of Bashistha and Bahini-Bharalu Drainage Basins in Assam and Meghalaya, India

**Abstract**

Morphometric analysis of Drainage basin is an important aspect of basin study. The morphometric analysis of Bashistha and Bahini-Bharalu river basins has been carried out through the measurements of linear and areal parameters of the basins. The study analyzes the morphometric characteristics of Basistha and Bahini-Bharalu drainage basins for river basin evaluation and assessing the hazard vulnerability of the basins as well as Guwahati city.

**Keywords:** Drainage Basin, Morphometric Analysis, Linear Parameters, Areal Parameters

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## Introduction

A.N. Strahler (1969) defines morphometry as "the measurement of the shape, or geometry, of any natural form-be it plant, animal or relief features" (S. Singh). Drainage basin is an area drained by the stream and its tributaries. It is bounded by a divide. Drainage basin is also sometimes called watershed or catchment. (Garde).Morphometric analysis of drainage basin encompasses the quantitative study of shape, size, dimension etc. of the drainage basin. Bashistha and Bahini-Bharalu are two significant river basins of southern bank of the river Brahmaputra which constitute a part of Kamrup and Kamrup Metro districts of Assam and Ri Bhoi district of Meghalaya. The length of Bashistha River is 33.12 km, while the length of Bahini-Bharalu River is 30.02 km.

## Objectives and Methodology

The main objectives of the study are : (1) to delineate and map the watershed boundary of Bashistha and Bahini –Bharalu river basins, (2) to measure the morphometric parameters of Bashistha and Bahini-Bharalu river basins and to analyze their Morphometric characteristics. A base map of the study area is prepared using GIS software (Arc GIS 9.3) on 1:50000 scale from Survey of India topographical sheets. After delineating the basin boundary the linear and areal parameters of Bashistha and Bahini-Bharalu river basins are measured and calculated using Arc GIS 9.3 software (through Attribute table).

## Morphometric Analysis and Findings

### Linear Aspects of the Basins

The topological characteristics of the stream segments of a drainage network are analyzed by the study of linear parameter (S. Singh). Under the above heading stream order (u), stream number(Nu), bifurcation ratio (Rb), stream length (Lu), mean stream length ($\bar{L}u$), length ratio (RL), sinuosity indices (S I), length of over land flow (Lg), law of stream number and law of stream length for Bashistha and Bahini-Bharalu drainage basins have been measured ,computed and analyzed.

### Strahler's (1952) Stream Ordering

The head water streams which do not have tributary are called first order streams. When two first order streams join, a second order stream develops. Similarly when two second order streams join, a third stream develops. If two streams of different order, say one is of first order and the other is of second order joins, the united stream is identified as the second order stream. Both the Bashistha as well as the Bahini-Bharalu river basins are of $5^{th}$ order status.

### Stream Number (Nu)

It is the total number of stream segments under a definite order of a drainage basin. In table1 and in table2 the order wise stream segments of Bashistha and Bahini-Bharalu rivers are shown respectively.

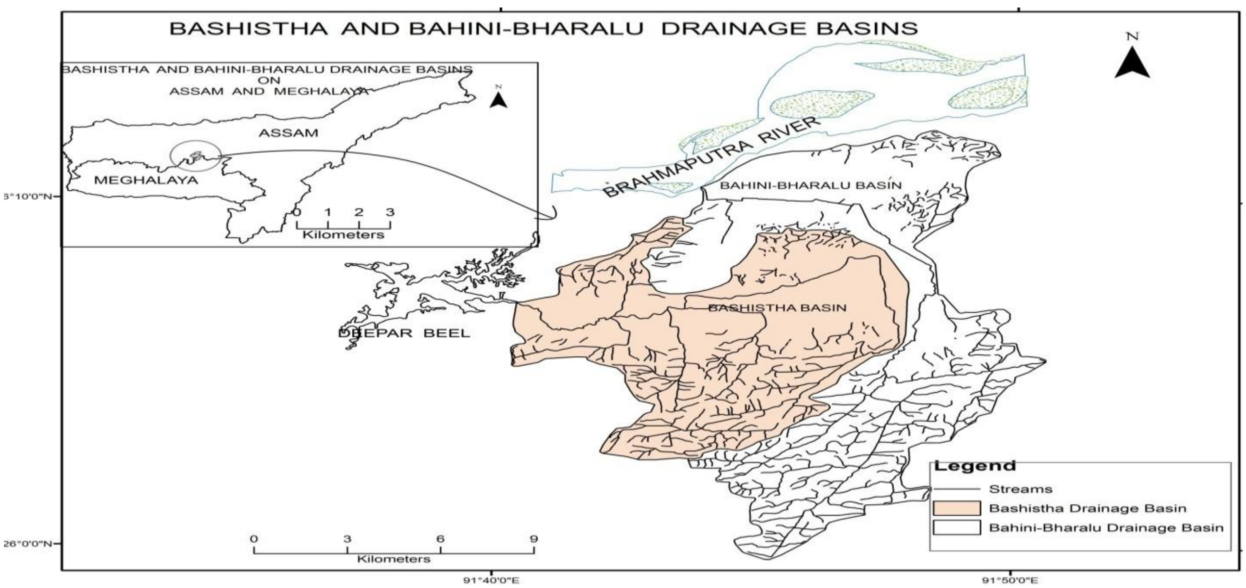


**Fig: 1 Location Map of the Study Area**

**Schumm's (1956) Bifurcation Ratio ($R_b$)**

It is the ratio of stream number of a given order to its next higher order. The formula is $R_b$=Nu/Nu+1
Where, Nu=Total Number of Streams of Order u
Nu+1=Total Number of Streams of the next higher order.

In general, it has irregular tendency from one order to the next order. The irregularities of Bifurcation ratio is dependent upon the lithological and geological development of drainage basin (C. P. Singh). In case of Bahini-Bharalu river basin, such irregular tendency of Bifurcation ratio is observed. Generally, the bifurcation ratio is affected by variations in the physiographic, lithologic and climatic conditions prevailing in individual basin. Thus, a basin with similar rocks and tectonic history, uniform climatic conditions and in similar stage of development is characterized by more or less similar values of the bifurcation ratio. (C. P. Singh).

Lower $R_b$ values are the characteristics of structurally less disturbed watersheds without any distortion in drainage pattern (Chopra). In Bashistha and Bahini-Bharalu river basins high $R_b$ values are not found. The mean bifurcation ratio of Bashistha (i.e. 3.82) and the mean bifurcation ratio of Bahini-Bharalu (i.e. 4.29) indicate strong structural control on the development of both the river basins.

**Table1: Stream Order, Stream Number, Bifurcation Ratio, Stream Length, Mean Stream Length and Stream Length Ratio Of Bashistha River Basin**

| stream Order (U) | Stream Number (Nu) | Bifurcation Ratio ($R_b$=Nu/Nu+1) | Stream Length (in km) (Lu) | Mean Stream Length ($\bar{L}u$= ∑Lu/Nu) | Stream Length Ratio ($R_L$=$\bar{L}u$/$\bar{L}u$-1) |
|---|---|---|---|---|---|
| 1st | 203 | 4.61 | 101.72 | .50 | ----- |
| 2nd | 44 | 4 | 39.80 | .90 | 1.8 |
| 3rd | 11 | 3.67 | 16.72 | 1.52 | 1.69 |
| 4th | 3 | 3 | 29.96 | 9.99 | 6.57 |
| 5th | 1 | ----- | 7.61 | 7.61 | 0.76 |

**Table2: Stream Order, Stream Number, Bifurcation Ratio, Stream Length, Mean Stream Length And Stream Length Ratio of Bahini-Bharalu River Basin**

| Stream Order (u) | Stream Number(Nu) | Bifurcation Ratio ($R_b$=Nu/Nu+1) | Stream Length (in km ) (Lu) | Mean Stream Length ($\bar{L}u$= ∑Lu/Nu) | Stream Length Ratio ($R_L$=$\bar{L}u$/$\bar{L}u$-1) |
|---|---|---|---|---|---|
| 1st | 246 | 3.97 | 136.92 | .56 | ----- |
| 2nd | 62 | 5.17 | 35.44 | .57 | 1.01 |
| 3rd | 12 | 6 | 22.62 | 1.88 | 3.29 |
| 4th | 2 | 2 | 11.60 | 5.8 | 3.08 |
| 5th | 1 | ------ | 17.43 | 17.43 | 3.01 |

**Horton's (1945) Stream Length (Lu)**

The total length of streams in a definite order is called stream length. In general, the total stream length decreases as stream order increases. Thus, these two variables are inversely related. However, in Bashistha river basin, the total length of 3rd order stream segments (16.72 km) is less than the total length of 4th order stream segments (29.96 km) and in Bahini-Bharalu river basin the total length of 4th order stream segments (11.60 km) is less than the total length of 5th order stream segments (17.43 km). Variations in relief may be the cause of these anomalies. But, mean stream length increases as stream order increases and thus, directly related. The mean stream lengths of Bashistha and Bahini-Bharalu river basins are found accordingly.

**Horton's (1945) Stream Length Ratio (RL)**

It is the ratio of mean stream length of a given order to its previous order. The formula is RL=L̄u/L̄u-1 where,L̄u=Mean Length of all stream segments of Order u

L̄u-1= Mean Length of all stream segments of the Previous Lower Order

**Horton's (1945) First Law of Stream Number**

It is the relationship between stream orders and stream numbers. It is based on the negative exponential function model. The regression equation is

log y= log a-bx

Where, y =Number of streams, x=order of streams, b= regression coefficient, a=constant. The regression line shows a highly negative relationship among stream number and stream order in case of Bashistha (r= -0.998 ) and Bahini-Bharalu river basin (r = -0.992) and validates Horton's law of Stream Number.

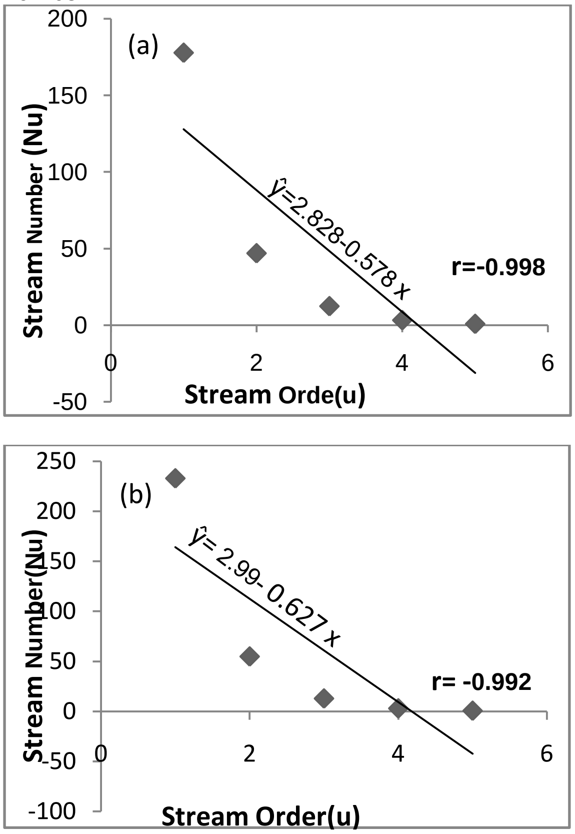


**Fig .1: Law of Stream Number: Regression line of Stream Number Vs Stream Order for (a) Bashistha and (b) Bahini- Bharalu river Basins**

**Horton's (1945) second Law of Stream Length**

It is the relationship between stream order and cumulative mean stream length. It is based on the positive exponential function model. The regression equation is log y= log a + bx

Where, y=cumulative mean stream length, x=order of streams, b=regression coefficient, a=constant

The regression lines show a highly positive relationship among mean stream length and stream order in case of Bashistha (r= 0.991 ) and Bahini-Bharalu river basin (r = 0.996) and validate Horton's law of Stream length

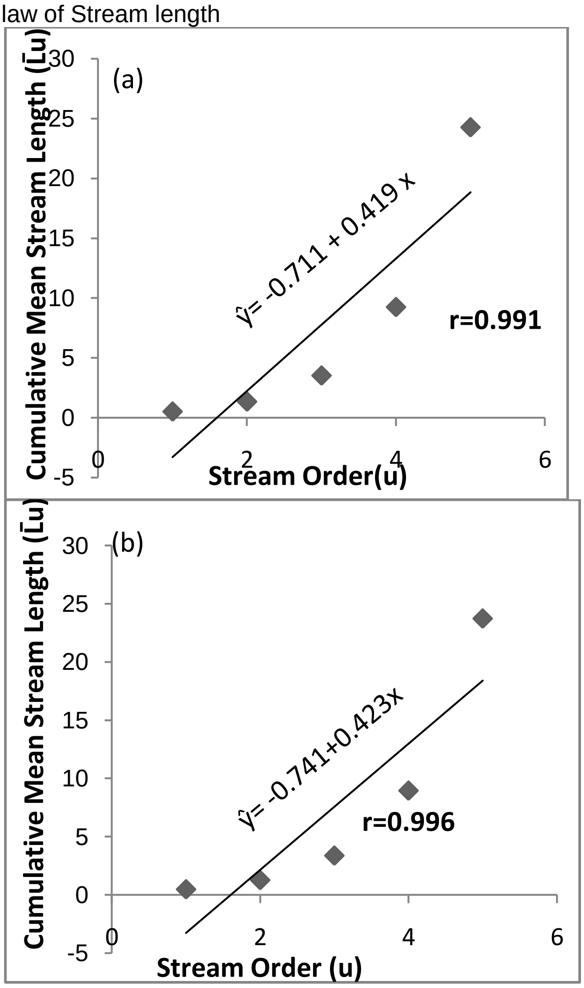


**Fig .2: Law of Stream Length: Regression line of Cumulative mean Stream Length Vs Stream Order for (a) Bashistha and (b) Bahini- Bharalu river basins**

**Schumm's (1963) Channel Sinuosity Index (S I)**

Sinuosity of a stream denotes the degree of deviation of its actual path from expected theoretical path/course (S. Singh). Sinuosity helps in studying the effect of terrain characteristics of the river course, stage of basin development etc. When the S I value is 1.0 it is straight course , then transitional course , regular course, irregular course and when it is more than 2.0 it is tortuous course. The tortuous course indicates highest deviation of the river from its expected straight path, while a river of straight course has no deviation. The Bashistha river basin found to be tortuous course, while the Bahini-Bharalu river basin is characterized by transitional to regular course.

**Table: 3 Sinuosity Indices of Bashistha And Bahini-Bharalu River Basins**

| Channels | Actual/ Observed Length (OL) in km. | Expected Straight Length (EL) in km. | Channel Sinuosity Index (CSI= OL/EL) | Course |
|---|---|---|---|---|
| Bashistha | 33.12 | 8.46 | 3.91 | Tortuous |
| Bahini-Bharalu | 30.02 | 19.47 | 1.54 | Transitional to Regular |

**Areal Aspects of the Basins**

Under this heading maximum basin length (Lo) ; basin area (Au) ; geometry of basin shape, stream frequency (Fs) ; drainage density ( Dd ) ; constant of channel maintenance ( C ) for Bashistha and Bahini-Bharalu drainage basins have been studied.

**Maximum Basin Length (Lo)**

It is the length of the longest basin diameter from the basin mouth to the most distant point on the basin perimeter (Chorley). The maximum basin length of Bashistha basin is 14.04 km and of Bahini-Bharalu basin is 23.42 km.

**Basin Area (Au)**

It is the total area projected upon a horizontal plane which contributes overland flow to the channel segments of a given order and all the tributaries of the lower order (Garde). Basin area is hydrologically important because it directly affects the size of the storm hydrograph, and the magnitude of mean and peak flows (Chorley). The Bashistha basin drains an area of 97.43sq km. while Bahini-Bharalu basin drains an area of 113.26 sq km.

**Geometry of Basin Shape**

Basin shape study is most important to know the fluvio geomorphic behavior and some other important characteristics of the basins. The present research work follows Horton's form factor (Rf), Miller's circulatory ratio (C) and Schumm's elongation ratio ( E) to study the shape of Bashistha and Bahini-Bharalu river basins.

A long narrow basin gives a low but sustained peak, whereas circular basins with low bifurcation ratio would give a sharply peaked hydrograph (Garde). A circular basin is more efficient in run-off discharge than an elongated basin (Chopra). Thus, a circular basin has more flood probability than a linear or elongated basin.

**Table:4 Shape Geometry of Bashistha and Bahini-Bharalu River Basins**

| River Basins | Basin Area (Au) | Basin Length (L) | Basin Perimeter (P) | Form Factor (F) | Basin Circulatory Ratio (C) | Elongation Ratio (E) |
|---|---|---|---|---|---|---|
| Bashistha | 97.43 | 14.04 | 55.41 | 0.49 | 0.40 | 0.79 |
| Bahini-Bharalu | 113.26 | 23.42 | 86.06 | .02 | 0.19 | 0.51 |

**Horton's (1932) Form factor (F)**

**F=** Basin area /( basin length)² Or, $F = Au/L^2$
where, Au=Basin area**,** L=Basin length

The value of F ranges from 0 (elongated) to 1 (circular). In the present study, the F=0.49 indicates that the Bashistha river basin is moderately circular while the F =0.02 indicates that the Bahini-Bharalu river basin is elongated. Flood flows of such elongated basin are easier to manage than of the circular basin (Narendra).

**Miller's (1952) Basin circulatory ratio (C)**

C= area of the basin (A) ÷area of the circle with same
Perimeter as the basin ( $\pi r^2$ ) Where, $r=p/2\pi$
Or, $C=4\pi A / p^2$ where, p= basin perimeter

The value of C varies from 0 (linear shape) to 1 (circular shape). For homogeneous basins of 1st and 2nd order C =0.6 to 0.7 and for non homogeneous basin C=0.4 to 0.5 (Garde). For Bashistha basin C is found 0.40, which depicts that the Bashistha basin is a non homogeneous basin. The Bashistha river basin is found to be moderately circular and the Bahini-Bharalu river basin is found to be almost linear. Hence, Bahini-Bharalu river basin has gemorphologically less chance for creating flood hazard. However, Bashistha river basin carries a little.

**Schumm's (1956) Elongation ratio (E)**

E=diameter of the circle with same area as basin $(2\sqrt{A}/\sqrt{\pi}) \div$ basin length(L) Or, $E=2\sqrt{A}/\sqrt{\pi}/L$
where, A= Basin area**,** L= Basin Length

Normally, the value of E varies from 0.6 to 1.0. Lower value indicates strong relief and steep slope (Garde). Lower the value more the shape is elongated. Values near 1.0 are of regions of high relief while values from 0.6 to 0.8 are associated with strong relief and steep ground slope (C. P. Singh). The E =0.79 of Bashistha river basin indicates that the basin is near circular while the E =0.51 of Bahini-Bharalu river basin indicates that the basin is elongated and is characterized by strong relief and steep slope.

**Horton's (1932) Stream Frequency (Fs)**

It is the total number of streams per unit area (S. Singh). Fs= total number of stream segments of all orders within a given basin/ the basin area.

High stream frequency or drainage density indicates increased channel development and high sediment yield (Garde). The high stream frequencies of Bashistha and Bahini-Bharalu river basins i.e. 2.69 and 2.85 respectively indicate that the sediment yield in the basins is high and consequently high sediment yield increases the chances of siltation in both the river beds during rainy season.

**Table: 5 Stream Frequency, Drainage Density and Constant of Channel Maintenance of Bashistha and Bahini-Bharalu River Basins**

| River Basins | Total Number of Streams | Total Length of Streams (km) | Basin Area (sq km) | Stream Frequ-ency(Fs) | Drainage density (Dd) | Constant of Channel Maintena-nce (C) |
|---|---|---|---|---|---|---|
| Bashistha | 262 | 195.81 | 97.43 | 2.69 | 2.01 | 0.50 |
| Bahini-Bharalu | 323 | 224.02 | 113.26 | 2.85 | 1.98 | 0.51 |

**Horton's (1945) Drainage Density (Dd)**

It is the total stream length per unit area (S. Singh). Dd= total length of all stream segments in a basin/ the basin area.

Greater drainage density indicates more channels per unit area or more closeness of channel spacing . High drainage density gives more sediment yield. Drainage density varies over a wide range from 2 km $^{-1}$ to 800 km $^{-1}$. Drainage density is mostly depends on subsoil material, vegetation, relief and climate.Osborn's study also shows that mean annual flood $Q_{2.33}$ is proportional to Dd 2.0 (Garde). In the present study, both Bashistha and Bahini-Bharalu river basins show high drainage density i.e. 2.01 km/km² and 1.98 km/k m² respectively. High drainage densities indicate that the basins are highly permeable subsoil and thick vegetation Cover (Narendra) or vice versa.

**Schumm's (1956) Constant of Channel Maintenance (C)**

It is an inverse of drainage density. It is the drainage area (in sq km) required to maintain one km of drainage channel. A basin with relatively impermeable strata requires smaller drainage area to maintain a permanent channel. A permeable strata requires larger drainage area. It is a measure of basin erodibility (Garde). The calculation of C shows that 0.50 sq. km area is required to maintain one km of drainage channel in Bashistha river basin while the 0.51 sq. km area is needed to maintain one km of drainage channel in Bahini-Bharalu river basin.

**Conclusion**

The bifurcation ratio of the rivers is indicating strong structural control on the development of both the river basins. Both the basins are high sediment yielding, lowly permeable but covered with thick vegetation. The morphometric analysis shows that the Bashistha river basin is a moderately circular which carries a little flood probability, while the Bahini-Bharalu river basin is nearly an elongated basin with less flood probability. Hence the present state of flood and water logging problems in Guwahati are not only due to natural characteristics of the rivers but human induced factors are also predominant in the basins.

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