Morphometric Analysis of Linear Aspects of Upper Neera River Basin, Maharashtra

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Abstract

Watershed managers require understanding and synthesizing hydrologic response of river basin for which they have started looking into its basin characteristics or morphologic features and establish connection of fluvial geomorphology to hydrology. According to Strahler (1968), the science of geomorphology treats the origin and systematic development of all types of landforms and is a major part of Physical Geography. Drainage basin is an ideal unit of the earth surface for the study of its landform. Therefore the present study deals with the quantitative analysis of selected drainage basin. Using drainage basin as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the drainage basin. Measurement of shape, or geometry, of any natural form- be it plant, animal, or relief feature- is termed as morphometry (Strahler, 1957). Systematic description of the geometry of a drainage basin and its stream channel system requires measurement of linear, areal and relief aspect of drainage network. In current research paper only linear aspects are analyzed such as stream order, Stream numbers, bifurcation ratio, stream length, mean stream length and stream length ratio.

KEYWORDS : Morphometric, drainage network, linear aspects.

Introduction

River basin and its characteristics are controlled by nature and its hydro-climatic parameters are mostly interrelated with each other. Watershed managers require understanding and synthesizing hydrologic response of such basin for which they have started looking into its basin characteristics or morphologic features and establish connection of fluvial geomorphology to hydrology. Geomorphology is the study of landforms (valley, gorge, waterfall, cavity, sand-dunes). Worcester defines geomorphology, the interpretative description of relief features. (Worcester, 1948) Drainage basin is an ideal unit of the earth surface for the study of its landform (Singh S. a., 1974). Therefore the present study deals with the quantitative analysis of selected drainage basin. (Singh S. a., 1974)Using drainage basin as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the drainage basin. The landscape as well as relief features play a dominant role to influence source of transportation, location of cities and agriculture field so their study is great importance and interest to geomorphologist. The aim of the watershed management is to conserve the soil and water resources, so as to achieve improvement in the agriculture. So the emphasis is on the development of regional resources.

Study Area

Upper Neera river basin upto Veer dam has been considered for the present study. The Neera River basin is part of the Bhima river basin situated in the Western part of Maharashtra state in India and it is a tributary of Bhima river. Karha is a tributary of Neera. The river Neera arises in Sahyadri near Shirgaon village at the height of 880 meters and runs eastward to meet Bhima river at Neera Narsingpur near Akluj. The dams built on Neera river are Devdhar and Veer dam in Pune District.

The geodetic location of the Neera basin is on the north western part of the Deccan shield. The latitudinal and longitudinal extension of the study basin is from 18^o 00' 30'' N to 18^o 24' 7'' N and 73^o 31' 47'' E to 74^o 7'14'' E respectively. The study river basin has 1749.99 sq. km. total geographical area. The eastern part of the basin is comparatively less rugged than Western part and possesses flat rolling topography. Topographically the basin shows high degree of slopes, high dissection index and typical features of Western Ghats.

The region experiences tropical type of climate and is characterized by monsoon rains. The Rainfall pattern is highly variable. About 85% of the rains occur in the months of June to September from south-west monsoon. The rainfall is above 1600 mm. Temperature is moderate and it goes up-to 45^0 C in summer and generally it varies between 20-30^0 C. The entire river basin area rather the western ghat portion is mainly formed during the Late Cretaceous to Palaeogene age (according to geological time scale). Predominantly the area is covered with thick red and black cotton soils. The most common patterns are dendritic drainage patterns.

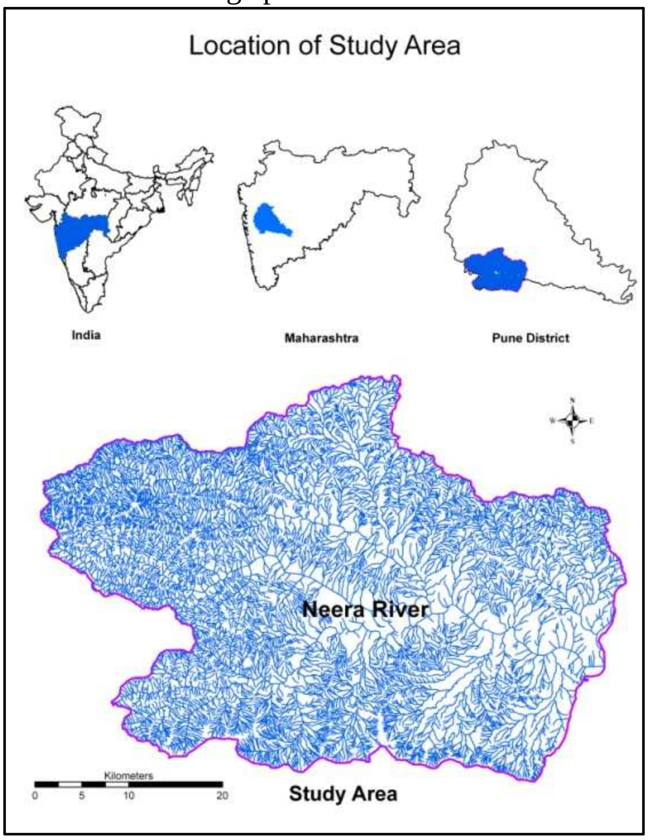

Fig 1. Location map of study area

Objectives

The goal of the present study is "to understand the morphometric linear aspects of the drainage basin". In order to understand this goal following objectives were outlined,

- To investigate the lithology and structure of selected drainage basin.
- To examine fluvial environment under different morphometric attributes and the role of lithology upon their development processes.
- To judge the impact of topography upon the drainage basin.
- To adopt various statistical techniques to standardize the morphometric parameter and to define statistically the association between morphometric variable.

Methodology

In the present investigation, the form approach has been mainly used to interpret and study the various kinds of landform e.g. number of stream, length ratio, drainage density, stream frequency. This method follows the form approach very common quantitative and empirical method followed by many American geomorphologists wherein various techniques have been developed for measuring the geometry of the landscape. Such investigation is usually based on a natural unit – the drainage basin being the most frequently selected and the relationship that can be established between the variables have been referred as the laws of morphometry(Chow, 1965). The above mentioned laws of morphometry based on measurable quantities such as number of stream, length ratio, drainage density, stream frequency and basin circularity ratio which can be related to one another quantitatively and dimension lessly (King, 1966).

1. Geological map for identifying various lithological formation and rock types.
2. Fluvial environment is examined under following aspect.
   a. Linear Aspects**:** Stream order, Stream number, bifurcation ratio, Stream length ratio etc. The linear aspects are studied using the methods of Horton (1945), Strahler (1952), and Chorley (1957).
3. Cartographic representation is done through the maps of location, lithology, structure, relief slope and drainage and terrain units. Correlation and regression models are illustrated through graphs.
4. Quantitative measurement: Central tendency mean, median, mode, dispersion, quartile deviation, standard deviation, mean deviation, range, skewness and kurtosis, correlation coefficients and regression models are computed by computer. The variables of fluvial morphometry are interrelated with the help of correlation analysis.

For the purpose of the morphometric analysis, the base map and a drainage map of the basin was prepared with the help of Survey of India topographic sheets on 1:50000 scale. The toposheets and digital data were geometrically rectified and geo-referenced to world space coordinate system using digital image processing software (ERDAS Imagine 9.1). Digitization work has been carried out for entire analysis of basin morphometry using the ERDAS Imagine 9.1 and Arc GIS software ver. 9.3. The orders were designated to each stream following Strahler (Chow, 1965) stream ordering technique. The attributes were assigned to create the digital data base for drainage layer of the basin. The fundamental parameters namely stream length, area, perimeter, number of stream, order and basin length were derived from the drainage layer. Drainage network map, Contour map, Stream ordering map, Location map of study area prepared with the help of Arc GIS software ver. 9.3, software was used for computing morphometric parameter.

Table-1 Formula adopted for computation of morphometric parameters

Sr. No.	Morphometric Parameters	Formula	Reference
1	Stream order (μ)	Hierarchical rank	Strahler (1964)
2	Stream Number (Nμ)	Hierarchical rank	Strahler (1964)
3	Bifurcation ratio (Rb)	Rb=Nμ/Nμ+1	Schumn(1956)
4	Stream length (Lμ)	Length of the stream	Horton (1945)
5	Mean stream length (Lsm)	Lsm=Lμ/Nμ	Strahler (1964)
6	Stream Length Ratio (Rl)	$Rl=Lsm^1/Lsm^2$	Horton (1945)
7	Mean bifurcation ratio (Rbm)	Average of bifurcation ratios of all orders	Strahler (1957)

Discussion and Results

Linear aspects of the basins are related to the channel patterns of the drainage network wherein the topological characteristics of the stream segments in terms of open links of the network system (streams) are analyzed. The drainage network, which consists of all of the segments of streams of a particular river, is reduced to the level of graphs, where stream junctions act as points (nodes) and streams, which connect the points (junctions), become links or lines wherein the numbers of all segments are counted, their hierarchical orders are determined, the lengths of all stream segments are measured and their different interrelationships are studied. The nature of flow paths in terms of sinuosity is equally important in the study of linear aspects of the drainage basins.

The liner aspects of drainage network such as Stream Orders (μ), Stream Number (Nμ), bifurcation ratio (R_b), Stream Length (Lu), Mean Stream Length (Lsm) and Stream Length Ratio (RL) results have been presented in the present study.

Stream Orders (μ)

In the drainage basin analysis the first step is to determine the stream orders and is based on a hierarchic ranking of streams. 'Stream order is defined as a measure of the position of a stream in the hierarchy of tributaries' (Leopold, 1964). Out of the four systems of ordering the streams that are available (Horton, 1945) (Strahler, 1957) and (Scheidegger, 1968), Strahler's system, which has in fact slightly modified Horton's, was followed because of its simplicity.

In the present study, the stream segments of the drainage basin have been ranked according to Strahler's stream ordering system (Strahler, 1968). The trunk stream through which all discharged of water and sediment passes is therefore the stream segment of the highest order. According to Strahler's method of ordering the Neera River Drainage basin with a drainage area of 1749.99 sq. km. is a 7^{th} order. It has observed that the maximum frequency is in the case of first order streams. It has also noticed that there is a decrease in stream frequency as the stream order increases (Fig. 2).

Stream Number (Nμ)

The order wise total number of stream segment is known as the stream number. Horton states that the number of stream segments of each order form an inverse geometric sequence with order number, (Horton, 1945) (Table 2). The number of the stream segment present in each order was counted and tabulated. The total number of 8688 streams were identified of which 6706 are 1st order streams, 1550 are 2nd order streams, 339 are 3rd order streams, 70 are 4th order streams, 17 are 5th order streams, 5 are 6th order streams and 1 is indicating 7th order streams. These figures show that, the number of the streams decreases as the stream order increases.

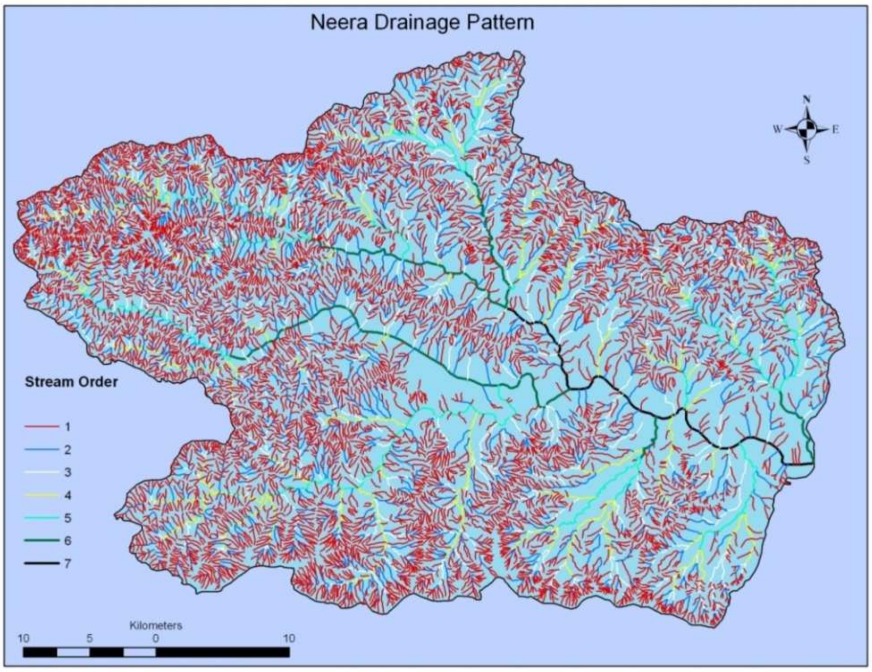

Fig 2. Drainage pattern of upper Neera river

Table 2: Stream Order and Number of Stream

Stream Order	Number of Stream
1st	6706
2nd	1550
3rd	339
4th	70
5th	17
6th	5
7th	1
Total Number of Stream	**8688**

Bifurcation Ratio (R_b)

Horton defined the bifurcation ratio (R_b) as the ratio between the numbers of streams of any given order to the number in the next lower order (Horton, 1945). The term bifurcation ratio (R_b) is used to express the ratio of the number of streams of any given order to the number of streams in next higher order (Schumm, 1956). Bifurcation ratio characteristically ranges between 3.0 and 5.0. For basins in which the geological structures do not distort the drainage pattern (Chow, 1965). Strahler demonstrated that bifurcation ratio shows a small variation for different regions or for different environment dominates (Strahler, 1957). The higher values of R_b (>10) indicate strong structural control in drainage pattern while the lower values are indicative of not affected by structural disturbances. According to Strahler the theoretical minimum possible ratio is 2, whereas the natural drainage systems are generally characterized by bifurcation values between 03 and 05. Bifurcation ratio which is related to the branching pattern of the drainage network, is defined as a ratio of the number of streams of a given order to the number of streams of the next higher order and is expressed in terms of the following equation

$$R_b = \frac{N\mu}{N\mu+1}$$

Where $N\mu$ = number of stream of a given order

$N\mu + 1$ = number of streams of the next higher order

For the present study, bifurcation ratio of the Neera river basin calculated and tabulated as follows

Table 3: Stream Order, Stream Number and Bifurcation ratio

Stream Order (μ)	**Number of Stream (Nμ)**	**Bifurcation ratio (R_b)**
1^{st}	6706	4.32
2^{nd}	1550	4.56
3^{rd}	339	4.77
4^{th}	70	3.89
5^{th}	17	2.83
6^{th}	5	2.50
7^{th}	1	-
Mean Bifurcation Ratio (Rbm)		**3.81**

The mean bifurcation ratio (Rbm) of the Neera river basin is 3.81, which indicates that geological structure are less disturbing the drainage pattern.

Stream Length (Lμ)

The length of the stream channel is a dimensional property, which reveals the size of the component of drainage lines. It is the total length of stream in a particular order. Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. Streams are relatively smaller length are characteristics of areas with larger slopes and finer textures, longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of the stream segment is maximum in first order streams and decreases as the stream order increases. The numbers of stream of various orders in a basin were counted and their lengths are measured with the help of the software.

Table 4: Stream Order, Number of Stream and Length of Streams

Stream Order (μ)	Number of Stream (Nμ)	Length of Streams in km. (Lμ)	Mean Stream Length in km. (Lsm)
1st	6706	3866.402	0.576559
2nd	1550	1096.152	0.707195
3rd	339	565.1306	1.667052
4th	70	284.9467	4.070666
5th	17	149.9746	8.822035
6th	5	74.20715	14.84143
7th	1	32.18965	32.18965
Total	**8688**	**6069.003**	**62.87459**

Relationship between logarithm of number of stream versus stream order and logarithm of length of stream versus stream order were measured (fig. 3 and 4) and calculated in Table 4. Plot of logarithm of stream length versus stream order (fig 4) showed the linear pattern which indicates the homogenous rock material subjected to weathering erosion characteristics of the basin. Deviation from its general behavior indicates that the terrain is characterized by variation in lithology and topography.

Mean Stream Length (Lsm)

The mean length of a channel is a dimensional property and reveals the characteristic size of drainage network components and its contributing basin surface (Chow, 1965). The mean stream lengths (Lsm) have been calculated by dividing the total stream of order (μ) and number of stream of segment of order (Nμ). Table 4 indicates that Lsm values of the basin is total 62.87 respectively.

Table 5: Relationship between logarithm of number of stream versus stream order and logarithm of length of stream versus stream order

River Basin	Stream Order (μ)	Number of Stream (Nμ)	Log. Number of Stream (Nμ)	Total Length of Streams in km. (Ls)	Log (Ls) Stream Length
Neera River Basin	1	6706	3.826464	3866.402	3.587307
	2	1550	3.190332	1096.152	3.039871
	3	339	2.5302	565.1306	2.752149
	4	70	1.845098	284.9467	2.454764
	5	17	1.230449	149.9746	2.176018
	6	5	0.69897	74.20715	1.870446
	7	1	0	32.18965	1.507716

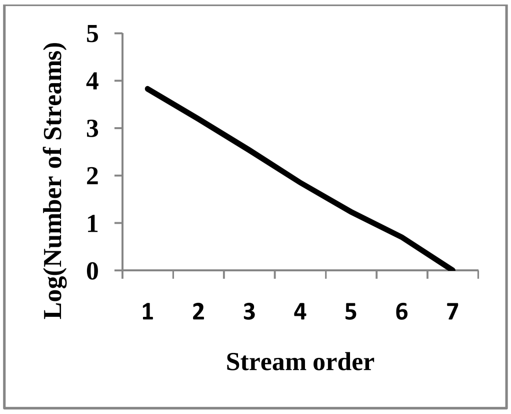

Fig 3: Relationship between Logarithm of Number of Streams versus Stream order

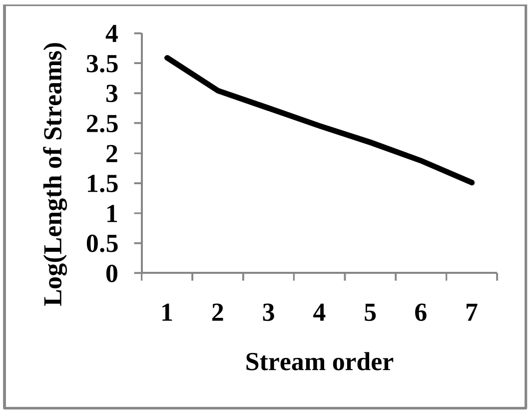

Fig 4: Relationship between Logarithm of Length of Stream versus Stream order

Stream Length Ratio (RL)

The stream length ratio, which is the ratio of the mean length of the streams of a given order to the mean length of the streams of the next lower order (Horton, 1945). Horton's law of stream lengths refers that the mean stream lengths of stream segments of each of the successive orders of a drainage basin tend to approximate a direct geometric sequence in which the first term (stream length) is the average length of segments of the first order (Table 6). Changes of stream length ratio from one order to another order indicate that their late youth stage of geomorphic development (Singh S. a., 1997).

Table 6: Stream Order and Stream Length Ratio

Stream Order (µ)	Number of Stream (Nµ)	Length of Streams (Ls)	Stream Length Ratio (RL)
1st	6706	3866.402	
2nd	1550	1096.152	0.283507
3rd	339	565.1306	0.515559
4th	70	284.9467	0.504214
5th	17	149.9746	0.526325
6th	5	74.20715	0.494798
7th	1	32.18965	0.433781
Total	8688	6069.003	2.758184

Table 7: Linear aspects of the drainage network of the study area

Sr. No.	Morphometric Parameters		Neera Basin
1	Stream order (μ)	I	6706
		II	1550
		III	339
		IV	70
		V	17
		VI	5
		VII	1
2	Total Number of Stream (N μ)		8688
3	Stream length (Lμ)	I	3866.402
		II	1096.152
		III	565.1306
		IV	284.9467
		V	149.9746
		VI	74.20715
		VII	32.18965
2	Total stream length		6069
3	Mean Stream Length (Lsm)		62.87
4	Bifurcation ratio (Rb)	I/II	4.32
		II/III	4.56
		III/IV	4.77
		IV/V	3.89
		V/VI	2.83
		VI/VII	2.50
5	Mean Bifurcation Ratio (Rbm)		3.81
6	Stream Length Ratio (RL)		2.7581

Conclusion :

Stream order and Stream number; In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. The study area Neera river basin is a 7^{th} order drainage basin (Fig 2). The total numbers of 8688 streams were identified of which 6706 are 1^{st} order streams, 1550 are 2^{nd} order, 339 are 3^{rd} order, 70 are 4^{th} order, 17 are 5^{th} order, 5 are the 6^{th} order and one is indicating 7^{th} order streams.

Bifurcation ratio of Neera river basin was 3.81 which indicate that geological structure is less disturbing the drainage pattern. It also indicates whether a basin is elongated or circular. Suresh has shown the high bifurcation ratio (Rb) is expected in the regions of steeply dipping rock strata, where narrow strike valleys are confined between the ridges (Suresh, 2000). According Kale and Gupta (Kale, 2001), the results of the present study ranged from 3 to 5 for the drainage basin indicating natural drainage system characteristics.

Stream length Relationship between logarithm of number of stream versus stream order and logarithm of length of stream versus stream order were measured (fig. 3 and 4) and calculated. Plot of logarithm of stream length versus stream order (fig. 4) showed the linear pattern which indicates the homogenous rock material subjected to weathering erosion characteristics of the basin. Deviation from its general behavior indicates that the terrain is characterized by variation in lithology and topography.

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