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Morphometric Analysis of Auranga River Basin: A GIS-based Approach

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Abstract: *Auranga River is a west flowing small river with an area of 800 sq.km. Auranga basin lies between Ambika river in the north and Par river in the south. It has six smaller basin i.e. Tan, Man Nirpan, Lower Tan, Lower Auragna and Vanki Nadi In the present investigation author attempted physiographical setup, linear and areal morphometric parameters such as steam order, stream length, bifurcation ratio and drainage density. Most of the drainage pattern identified are radical and dendric. The stream order of the basin is mainly controlled by physiographic and lithological conditions of the area. The study area is designated as seventh order basin with the drainage density value being as 3.31 km/km ^{2}. The increase in stream length ratio from lower to higher order shows that the study area has reached a mature geomorphic stage.*

Keywords: *Drainage morphometry, Aurang basin, GIS*

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I. Introduction:

Morphometric analysis is refers as the quantitative evaluation of form characteristics of the earth surface and any landform unit. This is the most common technique in basin analysis, as morphometry form an ideal areal unit for interpretation and analysis of fluvially originated landforms where they exhibits and example of open systems of operation. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke 1996; Agarwal 1998; Obi Reddy et al. 2002). Morphometry incorporates qualitative study of the area, altitude, volume, slope, profiles of the land and drainage basin characteristics of the area concerned (Savindra Singh, 1972). In fact, morphometric analysis is done successfully through measurement of linear, aerial, relief, gradient of channel network and contributing ground slope of the basin (Nautiyal 1994; Nag and Chakraborty, 2003; Magesh et al. 2012b). A widely acknowledged principle of morphometry is that drainage basin morphology reflects various geological and geomorphological processes over time, as indicated by various morphometric studies (Horton 1945; Strahler 1952, 1964; Muller 1968; Shreve 1969; Evans 1972, 1984; Chorley et al. 1984; Merritts and Vincent 1989; Ohmori1993; Cox 1994; Oguchi 1997; Burrough and Mc Donnell, 1998; Hurtrez et al. 1999). It is well established that the influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. The composition of the stream system of a drainage basin in expressed quantitatively with stream order, drainage density, bifurcation ration and stream length ratio (Horton, 1945). It incorporates quantitative study of the various components such as, stream segments, basin length, basin parameters, basin area, altitude, volume, slope, profiles of the land which indicates the nature of development of the basin. Besides, the quantitative analysis of drainage system is an important aspect of characteristic of watershed (Strahler, 1964). Drainage characteristics of many river basins and sub-basins in different parts of the globe have been studied using conventional methods (Horton 1945; Strahler 1957, 1964; Krishnamurthy et al. 1996). The morphometric analysis of the drainage basin is aimed to acquire accurate data of measurable features of stream network of the drainage basin. Various hydrological phenomena can be correlated with the physiographic characteristics of an drainage basin such as size, shape, slope of the drainage area, drainage density, size and length of the contributories, etc. (Rastogi and Sharma 1976; Magesh et al. 2012a). The fast emerging spatial information technology, remote sensing, GIS, and GPS have effective tools to overcome most of the problems of land and water resources planning and management rather than conventional methods of data process (Rao et al. 2010). GIS-based evaluation using Shuttle Radar Topographic Mission (SRTM) and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) data has given a precise, fast, and an inexpensive way for analysing hydrological systems (Smith and Sandwell 2003; Grohmann 2004). The geographic and geomorphic characteristics of a drainage basin are important for hydrological investigations involving the assessment of groundwater potential, etc. The present study aims at using GIS technology to compute various parameters of morphometric characteristics of the Auranga River basin. This is in consonance with the latest developments and researches as cited above.

Objective: Objectives of the present study is as follows:

1. To study linear morphometric parameters of Auranga river

II. Methods and Materials:

The present study is based on Survey of India (SOI) topographic maps of no.46D/15, 46H/2, 46H/3, 46H/6, 46H/7, 46H/10 and 46H/11 on the scale 1:50000. Topographical maps were rectified/referenced geographically and mosaiced and entire study area was delineated in GIS environment with the help of Arc- GIS 10.2 software assigning Universal Mercator (UTM), World Geodetic System (WGS dating from 1984 and last revised in 2004) and 43N Zone Projection System. Since, morphometric analysis of a drainage basin requires the delineation of all the existing streams, digitization of drainage basin was carried out for morphometric analysis in GIS environment using Arc- GIS 10.2 software. The attributes were assigned to create the digital data base for drainage layer of the basin. Linear morphometric parameters were computed.

III. Study area:

Auranga is a west flowing river with its catchment in Maharashtra and Gujarat. The river is known as Auranga after the confluence of its two tributaries viz., Man and Tan. The rivers Man and Tan originate in the Sahyadri hill ranges in Gavala Dongar near Surgana in Nashik district of Maharashtra. The length of Man and Tan rivers up to their confluence is 78 km and 49 km respectively. The Auranga River traverses a distance of about 30 km after the confluence of Man and Tan rivers before draining into the Arabian Sea. Auranga basin lies between north latitudes 20^0 30' and 20^0 42' and east longitudes 72^0 53' and 73^0 37' with effective drainage area of 800 km^2. A portion of Valsad, Navsari districts of Gujarat and Nasik district of Maharashtra falls in this basin. The basin forms part of the Western Ghats in Gujarat and Maharashtra.

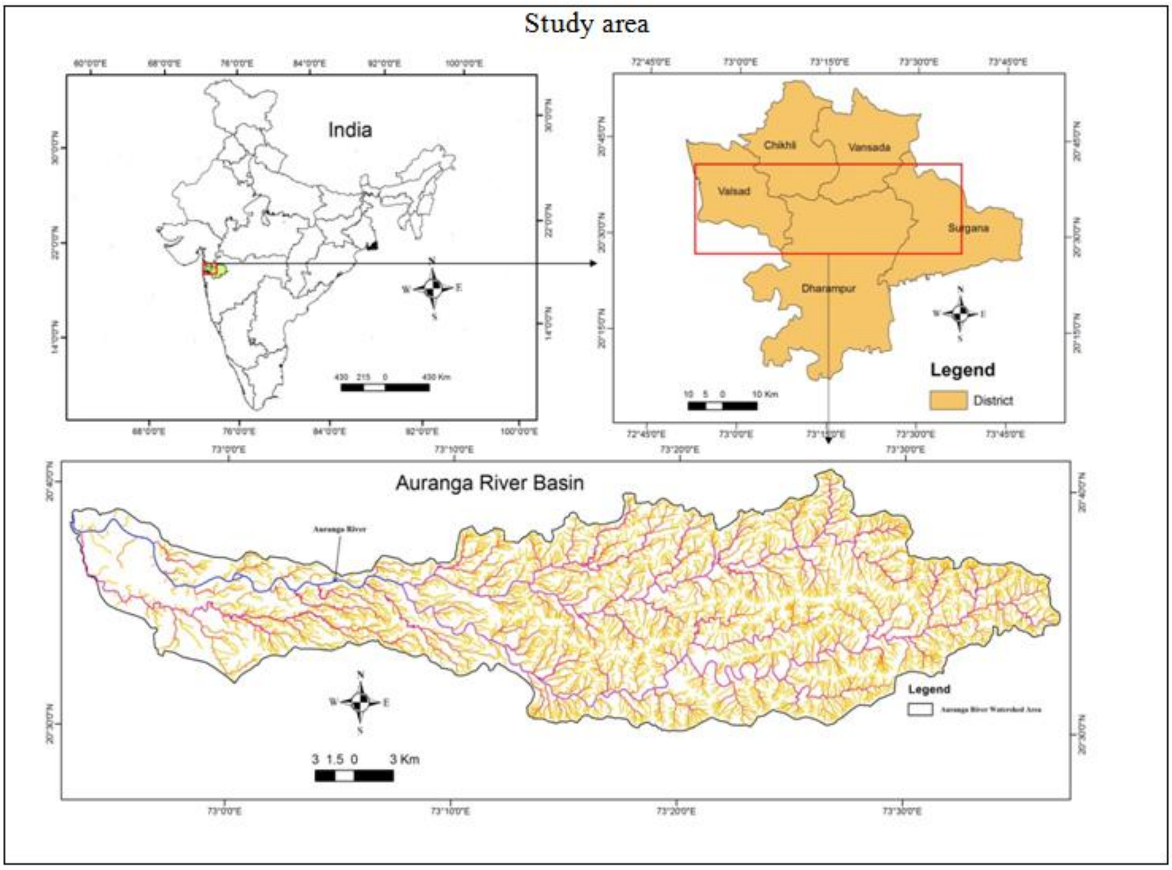

Fig: 1. Location Map

Physiographically, Auranga basin is divided into 5 groups namely, 1. Hill tops and hill slopes 2. Hill terraces and uplands 3. Upper and lower foot slopes (medium land), 4. Valley plains and local depressions (low lands) and 5. River and stream beds. Geological formations in the region belong to the Precambrian, Mesozoic, Tertiary and Quaternary ages. Deccan traps occupy major portion of the upper reaches. They are of two prominent types viz. dark grey to bluish black which are hard, compact and massive and the light brown to pink which are soft. Different morphometric parameters have been determined as shown in the Table 1.

IV. Result and Discussion:

The drainage basin is generally regarded as the most satisfactory basic unit for study because it is an aerial unit and drainage systems can be placed in orderly hierarchies. The systematic description of the geometry of a drainage basin and (gradient) aspects of the channel network and contributing ground slope (Strahler AN, Chow VT 1964). In the present study, the morphometric analysis has been carried out about parameters as stream order, stream length, mean stream length, stream length ratio, bifurcation ratio using mathematical formula given in table no.1. and result are summarized in Table 2.

Table 1. Morphoametric Parameters with formula

Sr. No.	Parameter	Methods	References
1.	Stream Order (U)	Hierarchical order	Strahler, (1964)
2.	Stream length (Lu)	Length of the stream	Horton (1945)
3.	Mean Stream length (Lsm)	Lsm = Lu/Nu, where, Lu= Stream length of order 'u' Lu= Number of stream segments of of order 'u'	Horton (1945)
4.	Stream length ratio (Rl)	Rl= Lu-1; where Lu= Total stream length of order 'u', Lu-1 = stream length of next lower order.	Horton (1945)
5.	Bifurcation ratio (Rb)	Rb= Nu/Nu+1; where Nu= Total number of stream segment of order 'u'; Nu+1= Number of stream segment of next higher order	Schumn (1956)

Linear morphometric parameters: The linear aspects of morphometric analysis of basin include stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

Stream Order:-

There are four different system of ordering streams that are available (Gravelius, 1914, Horton 1945, Strahler, 1952 and Schideggar,1970). Strahler's system, which is a slightly modified of Hortons system, has been followed because of its simplicity, where the smallest, un-branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. When two channel of different order join then the higher order is maintained. The trunk stream is the stream segment of highest order. It is found that Auranga river 7th order as shown in fig. 2.

In all 4181 streams were identified of which 3149 are first order, 786 are second order, 191 are third order, 45 in fourth order, 7 in fifth order, 2 are six order and 7st order one. Drainage patterns of stream network from the basin have been observed as mainly of dendritict type. The properties of the stream networks are very important to study basin characteristics (Strahler, 2002).

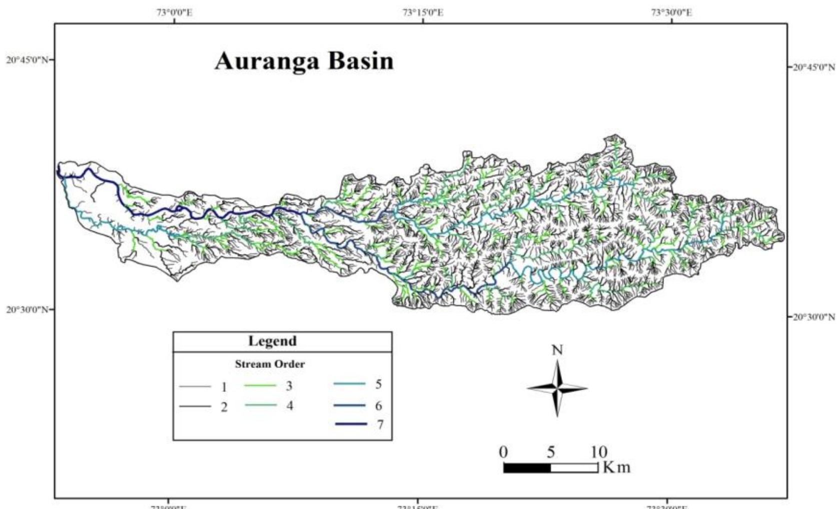

Figure: 2. Stream Order Map

Stream Number (Nu):

The total number of stream segments present in each order is the stream number (Nu). Nu is number of streams of order u. As per Horton's law (1945) of stream numbers, ''the number of streams of different orders in a given drainage basin tends closely to approximate as inverse geometric series of which the first term is unity and the ratio is the bifurcation ratio''. As per this law, the number of streams counted for each order is plotted on logarithmic scale on the y axis against order on arithmetic scale on the x axis. Number of streams of different orders and the total number of streams in the basin are counted and calculated in GIS platforms. During calculation it is identified that the number of streams gradually decreases as the stream order increases; the variation in stream order and size of tributary basins is largely depends on physiographical, geomorphological and geological condition of the region. Result of the study revealed that Auranga river is having 4181 streams link with 7 order as shown in Fig. 1. Out of which 75.3 % (3149) is 1st order, 18.7 % (786) 2nd order, 4.56 % (191) 3rd order, 1.07 % (45) 4th order, 0.01 % (07) 5th order, 0.047 % (2) 6th order and 0.002 % comprises 7th order stream (1). A higher stream number indicates lesser permeability and infiltration. Auranga stream basin shows a negative correlation (-745) among the stream order and stream number as shown fig. 3.

Stream Length (Lu) :

According to Horton (1945), streams lengths delineate the total lengths of stream segment of each of the successive orders in a basin tend to approximate a direct geometric series in which the first term is the average length of the stream of the first order. Stream length is indicative of chronological development of stream segments including interlude tectonic disturbances. When the bedrock and formation is permeable, only a small number of relatively longer streams are formed in a well-drained watershed, a large number of streams of smaller length are developed where the bedrocks and formations are less permeable (Sethupathi et al. 2011). In the present work the total length of stream segment is more in case of the first order streams and decreases with the increase in the stream order as shown in Table 2 and figure 4. It is noticed that stream segments up to 4^{th} order traverse part of high to moderate altitudinal zone characterised by steep to moderate slope while 5^{th}, 6^{th} and 7^{th} order stream segments shows plain lands.

Stream Order - Stream Number Relationship

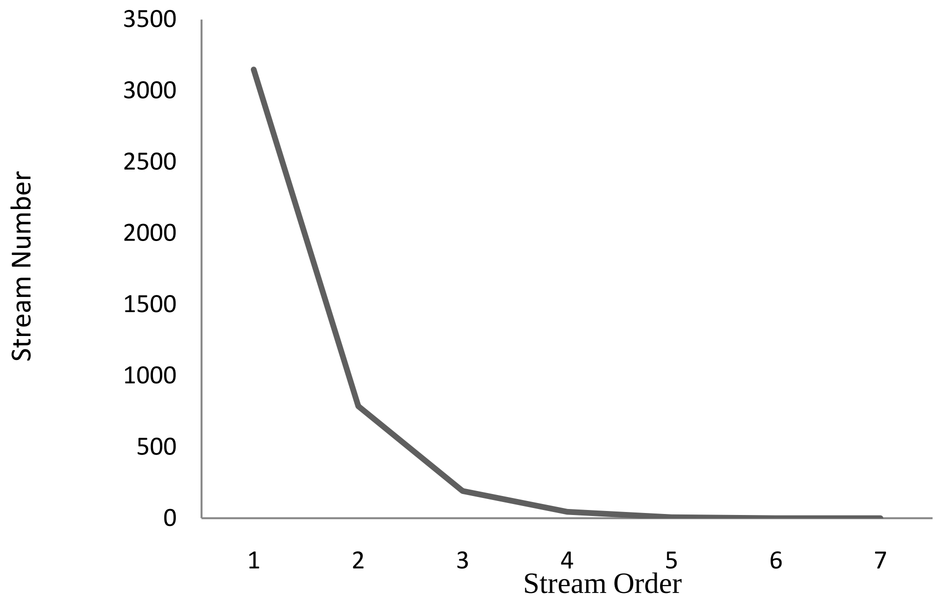

Figure 3 : Stream Order- Stream Number Relationship

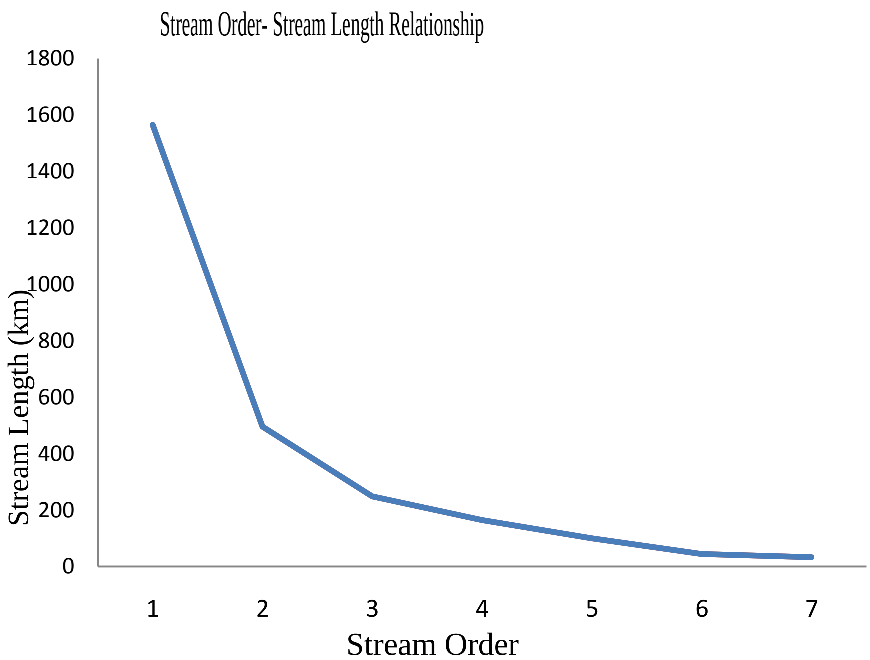

Figure 4: Stream Order- Stream Length Relationship

Stream length ratio:

Horton's law (1945) of stream length points out that mean stream length segments of each of the successive orders of a basin tend to approximate a direct geometric series with stream length increasing towards higher order of streams.

The stream length ratio of Auranga river showed an increasing trend. (Table 2). This change might be attributed to variation in slope and topography.

Bifurcation ratio:

Bifurcation ratio (Rb) may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumn 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. (Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. It is observed that Rb is change from one order to its next order. In the study area mean Rb varies from 2 to 6.4; the mean Rb of the entire basin is 4.04. Usually these values are common in the areas where geologic structures do not exercise a dominant influence on the drainage pattern.

Drainage Density:

Drainage density acts as important parameters for analysis of a drainage basin. The density of stream network in a basin has long been recognized as topographic characteristics of fundamental significance. Drainage density is a significant factor affecting the flow, infiltration capacity etc. It is defined as the ratio of the total length of channels of all orders in a basin to the area of the basin. It has been observed that low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. Lithology, climate and vegetation cover are the major factors for the varying density.

The drainage density of Auranga basin is 3.31. The density is high due to the regions of weak or impermeable surface materials and sparse vegetation.

Table: 2. Linear Morphometric Parameters of the drainage network of Auranga Drainage Basin.

Stream Order(U)	Stream Number(Nu)	Stream length (Lu)	Mean Stream length (Lsm)	Cumulative Stream Length	Stream length ratio (Rl)	Bifurcation ratio (Rb)
1st	3149	1564.520845	0.496831008	0.496831008		
2nd	786	495.311726	0.63016759	1.126998599	1.268374115	4.006361323
3rd	191	248.7460432	1.302335305	2.429333903	2.066649134	4.115183246

4th	45	164.0392096	3.645315769	3.645315769	2.799060853	4.244444444
5th	7	99.53687089	14.21955298	17.86486875	3.900774003	6.428571429
6th	2	43.7953395	21.89766975	39.7625385	1.539968927	3.5
7th	1	32.8742494	32.8742494	32.8742494	1.50126702	2
Total/Mean	4181	**2648.82**	**75.06**		2.17	
Mean Bifurcation Ratio = 4.04						

V. Conclusion:

GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation and their updation. It is inferred that the Auranga river falls under 7th order basin. The morphoetric analysis is carried by the measurement of linear aspect of the basin. The detail morphometric study shows radical and dendritic type of drainage pattern. There is negative relationship between stream order and total stream length. There is positive relationship between stream order and mean stream length. The bifurcation ratio differ from 2 to 6.4 shows that the high Rb means basin is controlled by geological structure and low Rb indicate that there is high possibility of flood as water tend to accumulate rather than spreading out. The used approaches in this study include a comprehensive morphometric analysis that can be applied for any drainage system elsewhere.

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