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Morphometric Analysis in Varuna River Basin: A Geoinformatics Based Analysis

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Abstract: ***Varuna River is an important tributary of river Ganga. For the present study River Varuna has been chosen for the morphometric analysis and the demarcation of the basinal area of the river has been automatically done through Geospatial tool known as Arc Hydro. The study regarding the morphometry of the river lets us infer about the basin geometry, network system of the drainage and more of the river basin characteristics.***
Calculations of the morphometry will give us the quantitative description of the drainage system, which is an important aspect of the basins.
This will describe the shape, slope, elongation, drainage density and many more important values to further incorporate water management processes in the varuna river basin. GIS tools will help us achieving morphometric analysis. With the help of morphometric analysis we are able to gain knowledge regarding the basin geomorphology and its responses to various hydrological processes.
Keywords: Morphometric Analysis, Varuna River Basin, Arc Hydro, DEM, GIS.

I. INTRODUCTION

The Varuna river basin is a part of Indo Gangetic basin. Varuna river and its sub-watersheds are the ones which controls the drainage system of Varanasi city and also they control the flow of the groundwater over the adjoining area. Due to fast paced urbanization and immense pumping and usage, groundwater is depleting rapidly over parts of the basin. Discharge of pollutants into the different environmental components makes it difficult to control them from evacuating out of the system. Further, contamination of the rivers by domestic and industrial liquid waste has led to the deterioration of river health. The over exploitation of river resource takes us to the harsh reality of facing scarcity of water in coming future.

II. STUDY AREA

The Varuna River is a minor tributary of Ganges River in Uttar Pradesh, India. It originates at 25°27′N, 82°18′E, at a place called Malahan near Phulpur in the Prayagraj district and merges into the Ganges at 25°19′46″N, 83°02′40″E near Sarai Mohana in the Varanasi district (Fig. 1).
The 6 kilometres stretch between Sarai Mohana and Sadar, Varanasi, Uttar Pradesh is prone to flooding. The name Varanasi is originated from the name of two rivers, Varuna and Assi. The climate of the region is tropical monsoonal. Varuna River covers an area of about 3622 km^2 of the Ganga Plain. Varuna Plain is drained by Alluvial Soil.
Varuna river (Fig. 2) has been selected for the study as it has undergone severe pollution and presently almost a drying river which contribute to pollution of the river Ganga also when emphasis is being laid on cleaning the river Ganga it becomes imperative to make its tributaries pollution free to achieve the national objective of ensuring river Ganga free from pollution.
The river is currently facing tremendous pressure due to encroachments, discharge of untreated domestic and industrial waste, dumping of solid waste and illegal diversion of water. However, the river remains less examined with regard to important baseline information.
Depending on the level of deterioration, river rejuvenation aims at a new sustainable healthy river ecosystem. This can also be achieved by restoring the river health back to an accepted historical state of the river. Avoiding direct entry of domestic sewage and industrial effluents into the river will certainly improve the river health.

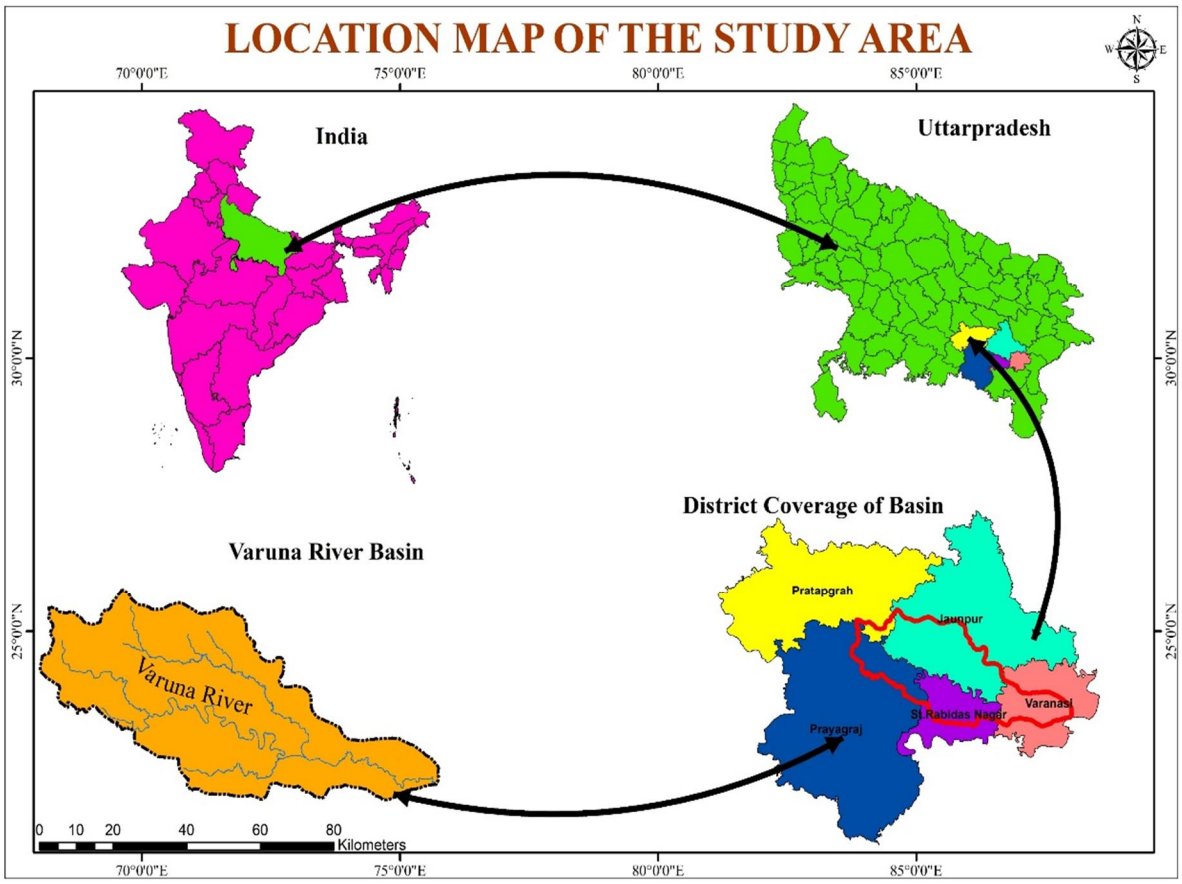

Fig. 1 Location Map Of Varuna River Basin

III. DATA USED

A. Survey Of India Toposheets

Toposheet provides us with information about an area like roads, railways, settlements, canals, rivers, highways, waterbodies, etc. Toposheets gives us information regarding the latitude and longitude of the area made on suitable projection for that area. The primary database of the study area has been generated with the help of Survey of India topographic maps on 1:50,000 scale. The toposheets on 1:50000 scale, which have been used for the study are mentioned here under in (Table 1)

S.NO.	TOPOSHEET NUMBER
1)	63G/14
2)	63K/1
3)	63K/2
4)	63K/3
5)	63K/5
6)	63K/6
7)	63K/7
8)	63K/10
9)	63K/11
10)	63K/15
11)	63O/3

TABLE 1 Toposheets of the Study Area

IV. METHODOLOGY

Toposheets are used to digitise Varuna River and its tributaries Basuhi & Morwa.

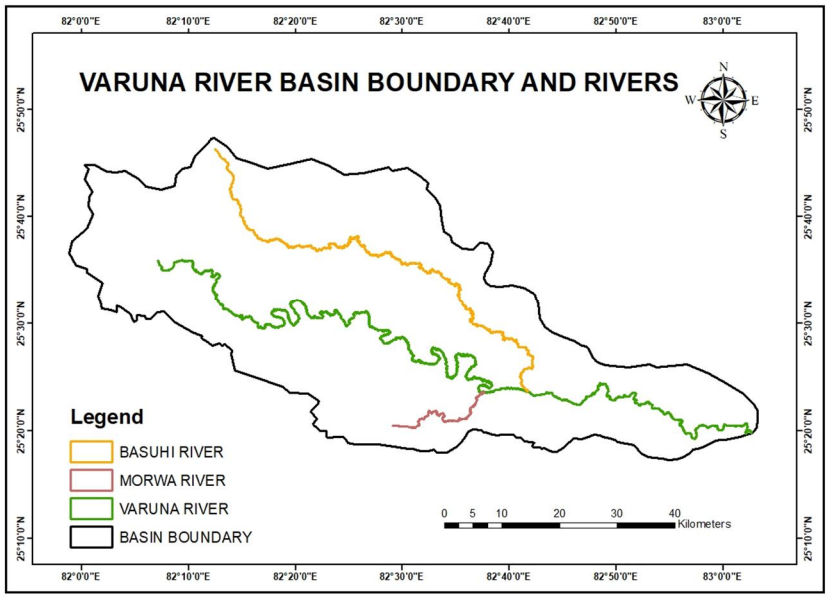

Fig. 2 Varuna River Basin Boundary and Rivers

Morphometric analysis of a drainage system requires delineation of all existing streams. The stream delineation is done in GIS environment using Digital Elevation Model (DEM). Using Digital Elevation Model (DEM) data from BHUVAN- NRSC (Fig. 3) for extraction of:

- Drainage Map (Fig. 7)
- Stream Classification (Fig. 8)

All these are derived using Arc Hydro Tool following the steps like creating fill sink map, flow direction map, catchment map etc. to get the desired result.

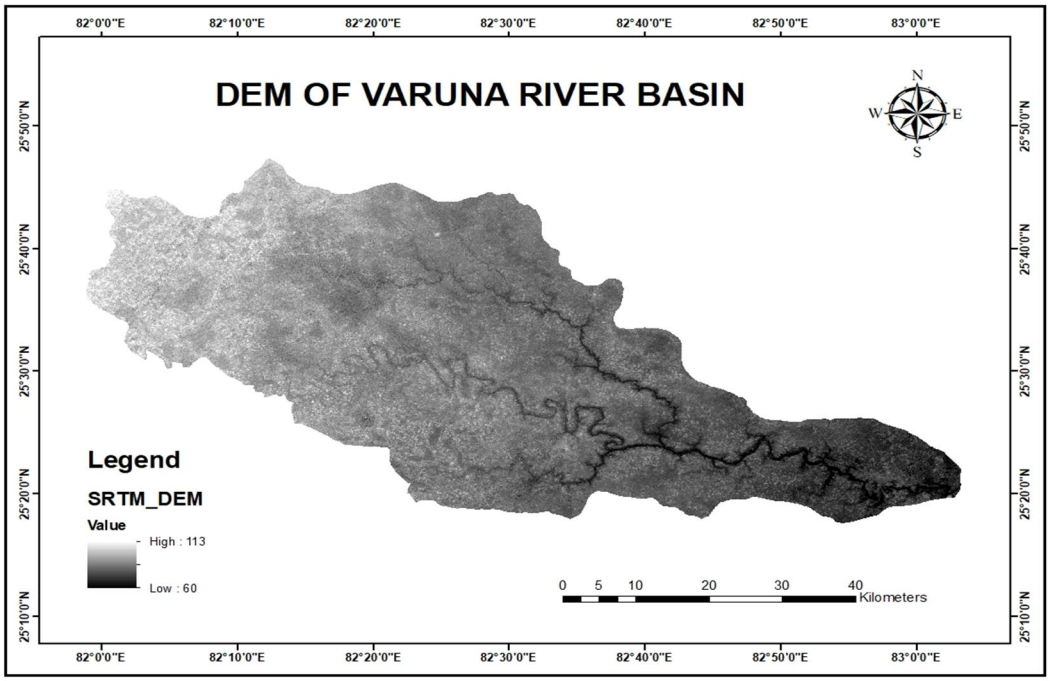

Fig. 3 DEM OF VARUNA RIVER BASIN (SOURCE OF DEM: BHUVAN NRSC)

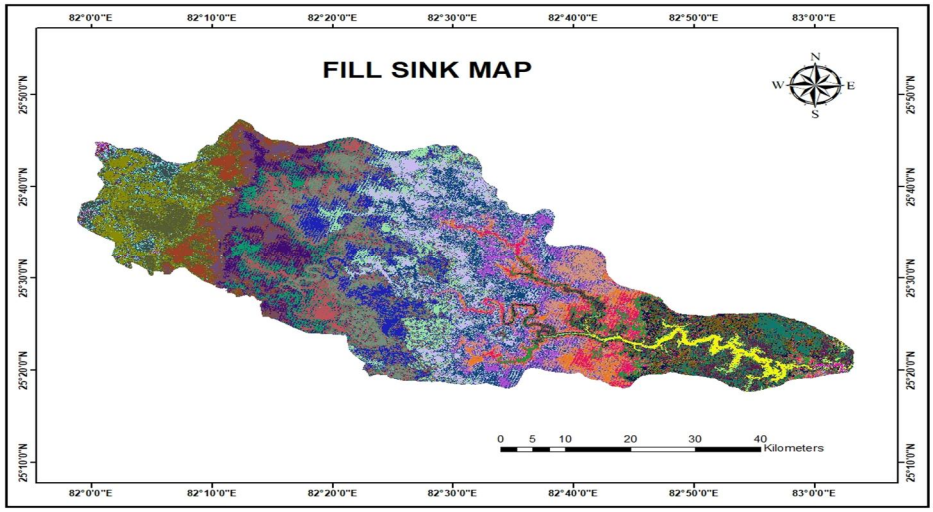

Fig. 4 FILL SINK MAP OF VARUNA RIVER BASIN

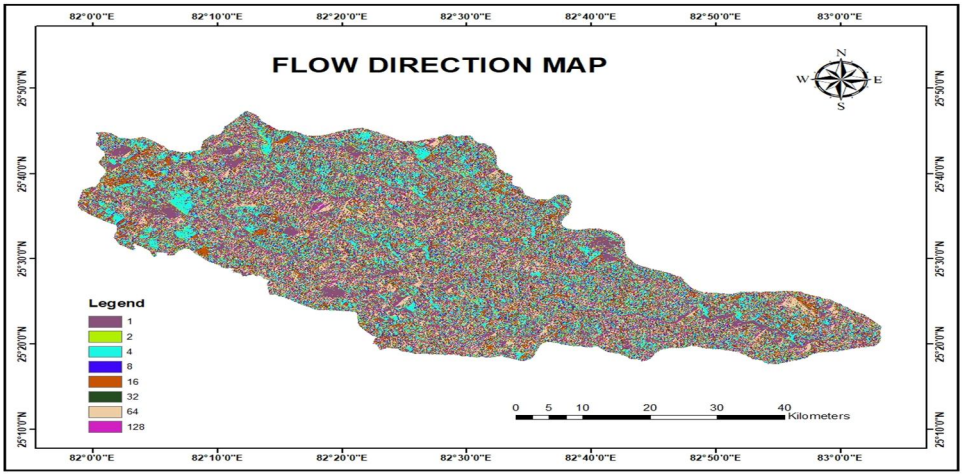

Fig. 5 FLOW DIRECTION MAP OF VARUNA RIVER BASIN

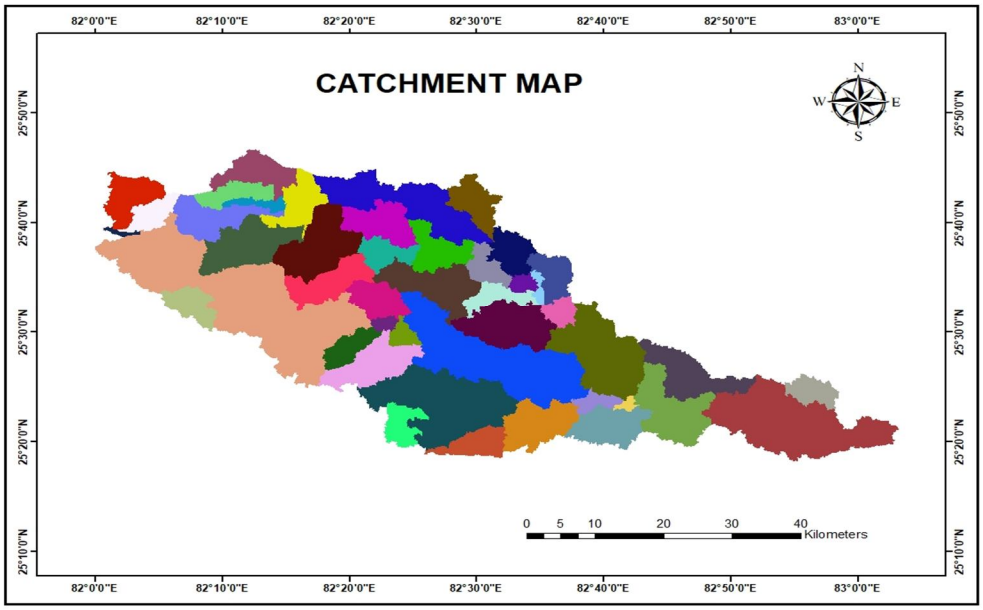

Fig. 6 CATCHMENT MAP OF VARUNA RIVER BASIN

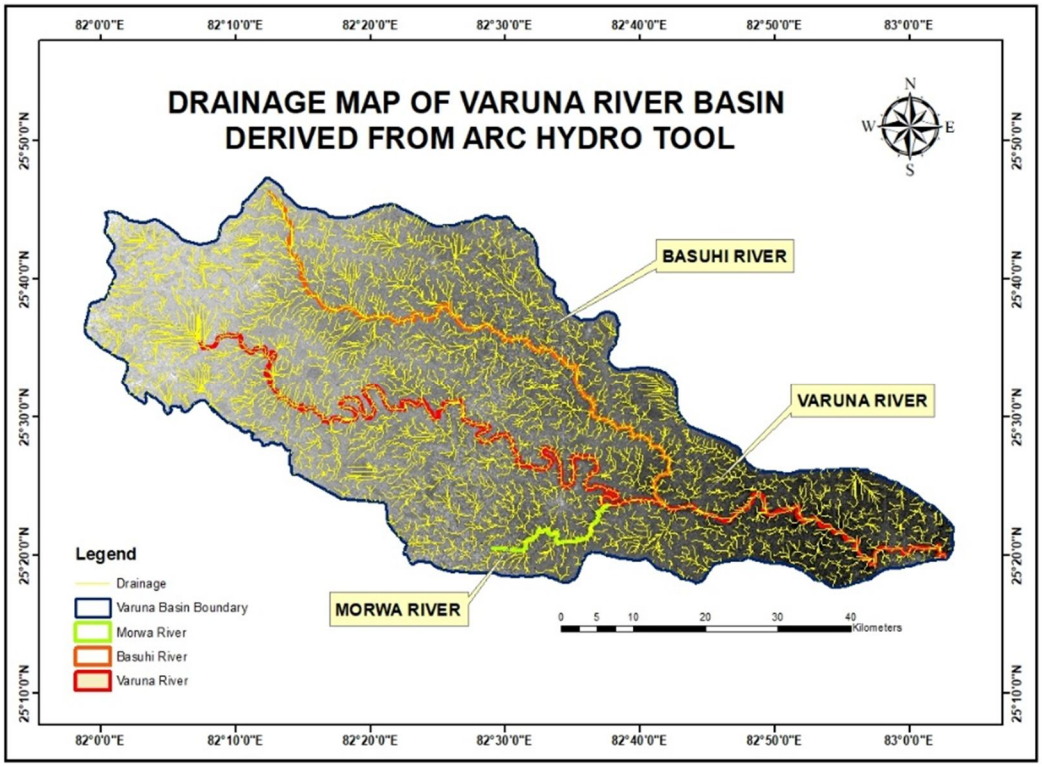

Fig. 7 DRAINAGE MAP OF VARUNA RIVER BASIN

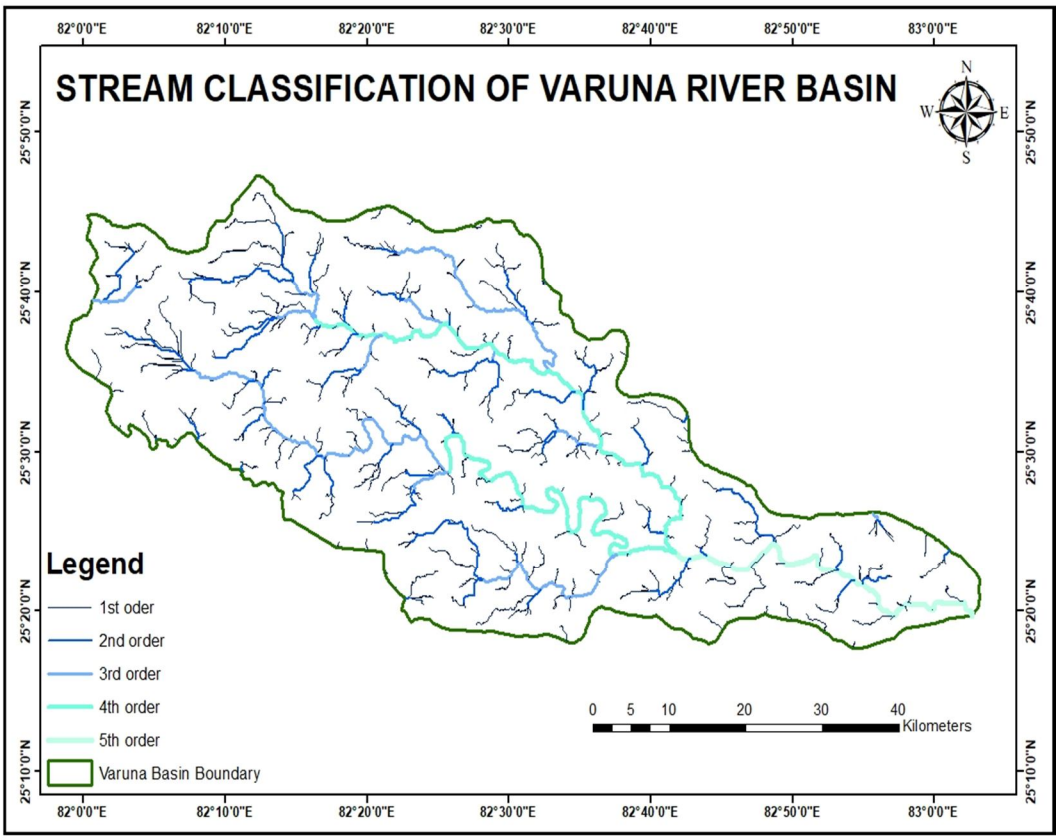

Fig. 8 STREAM CLASSIFICATION MAP OF VARUNA RIVER BASIN

The morphometric parameters have been determined as per the standard methodology as shown in (Table 2)

Morphometric Parameters	Formula	References
Stream order (Su)	Hierarchical order	Strahler,1952
Stream Length (Lu)	Length of the stream	Horton, 1945
Mean stream length (Lsm)	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order (km), Nu=Number of stream segment.	Horton, 1945
Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu1=The total stream length of its next lower order	Horton, 1945
Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments, present in the given order, Nu+1= Number of segments of the next higher order	Schumm, 1956
Drainage density (Dd)	Dd=L/A Where, L=Total length of stream, A= Area of basin	Horton, 1945
Stream frequency (Fs)	Fs=N/A Where, L=Total number of streams, A=Area of basin	Horton, 1945
Texture ratio (T)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of basin	Horton, 1945
Form factor (Rf)	$Rf=A/(Lb)^2$ Where, A=Area of basin, Lb=Basin length	Horton, 1945
Elongation ratio (Re)	$Re=\sqrt{(Au/\pi)}/ Lb$ Where, A=Area of basin, π=3.14, Lb=Basin length	Schumm, 1956
Circulatory ratio (Rc)	$Rc=4\pi A/P^2$Where A= Area of basin, π=3.14, P= Perimeter of basin	Miller,1953
Length of overland flow (Lg)	Lg=1/2Dd Where Dd= Drainage density	Horton, 1945
Constant of channel maintenance(C)	C=1/Dd Where, Dd= Drainage density	Horton, 1945
Basin relief (H)	Vertical distance between the lowest and highest points of basin	Schumm, 1956
Relief Ratio (Rh)	Rh = H / Lb Where, H=Basin relief, Lb=Basin length	Schumm, 1956
Ruggedness Number (Rn)	Rn=H×Dd Where, H= Basin relief, Dd=Drainage density	Schumm, 1956

TABLE 2 FORMULA FOR COMPUTING MORPHOMETRIC PARAMETERS

V. RESULT AND DISCUSSION

A. Morphometric Analysis

Morphometry will give us mathematical measurements about basinal surface and dimension of its terrain. This will help in planning, protecting and managing Watershed in Varuna River Basin. GIS tools will help us achieving morphometric analysis. With the help of morphometric analysis we are able to gain knowledge regarding the basin geomorphology and its responses to various hydrological processes.

Remote Sensing and GIS tools like Arc GIS software are used to proceed for the development of this study.

Morphometry of Varuna River Basin

S.NO.	PARAMETER	FORMULA	VALUE
	LINEAR		
1)	Area (A) (Km^2)	-	2921.43
2)	Perimeter (P) (Km)	-	308.26
3)	Basin Length (Lb)	-	173.73
4)	Stream Order (Su)		5
5)	Stream Number (Nu)	N1+N2+….. NN	413
6)	Stream Length (Lu)	L1+L2+….LU	1290.07
7)	Stream Frequency	Nu/A	0.141
8)	Drainage Density (Dd)	Lu/A	0.441
9)	Drainage Texture (Dt)	Nu/P	1.33
10)	Bifurcation Ratio (Rb)	Nu/Nu+1	4.64
11)	Length Of Overland Flow (Lg)	1/(Dd*2)	1.133
	SHAPE		
12)	Circularity Ratio (Rc)	$4\Pi A/(P^2)$	0.3861
13)	Elongation Ratio (Re)	$(2*(\sqrt{A/\Pi}))/Lb$	0.35
14)	Form Factor (Rf)	$A/(Lb^2)$	0.096
15)	Compactness Coefficient (Cc)	$0.28*P/\sqrt{A}$	1.596
16)	Shape Factor (Sf)	$(Lb^2)/A$	10.33
17)	Constant Of Channel Maintenance (C)	1/Dd	2.267
	RELIEF		
18)	Basin Relief (H)	HIGHEST-LOWEST	53
19)	Relief Ratio (Rh)	H/Lb	0.30

Table 3 Calculated Values of Morphometric Parameters

VI. CONCLUSION

Morphometry has been proved to be a very powerful tool in giving us the actual calculative parameters of the river basin. Morphometry done on the Varuna River Basin shows (in Table 3) that the calculated order of the river is 5 which tells us about the Dendritic Drainage Pattern of the basin which also indicates about the gentle slope of the area. Elongation ratio being 0.35 which shows that it is elongated telling us that it will take much more time for run off to reach the confluence. Also, bifurcation ratio measured to be 4.64 which is <5 and it means that the drainage is not controlled by any geological structures. Length of overland flow is calculated as 1.133 which is high and tells us about the gentle gradient, long flow paths, more infilteration and reduced runoff. The Drainage Density is low calculated to be 0.441 which indicates that basin has permeable soil. Low value of form factor which in 0.096 which assures us about having flatter peak flow of long duration and hence results as an elongated basin.

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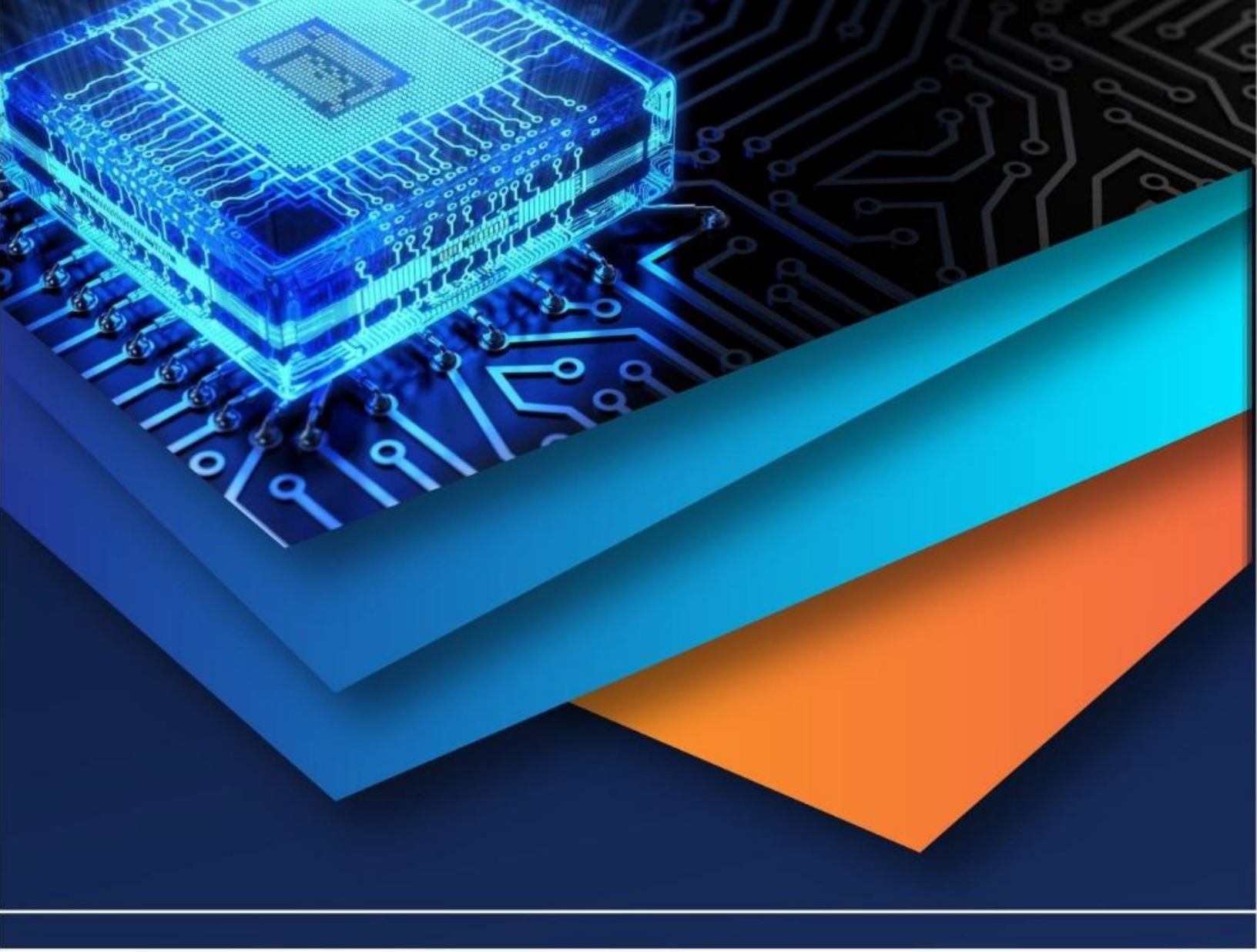

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