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RESEARCH ARTICLE

Morphometric Analysis of Cauvery Sub-watershed of South Bangalore Metropolitan Region of Karnataka, India

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Abstract

Morphometric analysis is an important in any hydrological study in urban areas like Bangalore city for development and management of drainage basin. Morphometric analysis of fourteen sub-watersheds comprising part of River Cauvery of Bangalore district have been carried out using Geographic Information System(GIS) and Survey of India (SOI) Topo-sheets numbers (57G/4,8,12,16,57H,1,2,3,5,6,7,9,10,11 and 13). The present study terrain exhibits Trellis to dendritic drainage pattern. There are 14 sub watersheds are coming under the SBMR (South Bangalore Metropolitan Region) of study area. Morphometrical study of the watershed have been analyzed through measurement of linear, aerial and relief aspects of basins by using GIS techniques in the preparation of detail drainage map. The parameters such as Rb, Dd, Fs, T, Lof and Ccm are calculated by using standard formula and prioritization has been done by using raster calculator option of spatial analyst. The stream orders varies from first order to sixth order in the basin and the total number of stream segments of all orders cumulated to11,134. The maximum area covers under Dakshina Pinakinisub-basin about 892.70Sqkm and Minimum of 24.42Sqkm in Edakolada Halla. The morphometric parameters ranges between Rb (9.67 to 22.56), Dd (1.942 to 136.57), FS (1.372 to 9.36), T (0.009to 0.0092), Rf (0.3342 to 1.6485), Rc (0.0259 to 0.267), Re (0.2171 to 1.05), Lof (0.9701to 68.2653) and Ccm (0.0073 to 0.5153)..

Introduction

Development of a drainage system and the flowing pattern of a river over space and time are influenced by several variables such as geology, geomorphology, structural components, soil and vegetation of the area through which it flows. Geographical Information System (GIS) techniques have already been used for assessing various terrain and morphometric parameters of the drainage basins and watershed as they provide a flexible environment and a powerful tool for the manipulation and analysis of the spatial information, particularly for the future identification and extraction of the information for better understanding (Vijith, 2006). Morphometric analysis gives the information about characterization of linear and areal features, gradient of channel network and contributing ground slopes of the drainage basin. Geographic Information System techniques characterized by a very high accuracy of mapping and measurement prove to be a competent tool in morphometric analysis. Morphometric is the measurement and mathematical analysis of the configuration of the Earth's surface, shape and dimension of its landforms (Clarke, 1996). The morphometric analysis was carried out through measurement of linear, aerial and relief aspects for the14 watersheds of sixth order drainage in Cauvery sub basin of South Bangalore metropolitan region, Karnataka state, India.

Material and Methods

Study Area

The study area is situated in the Southern part of Bangalore, Karnataka and lies between the Longitude 77°3'57.66"E to 77°50'39.85" E and Latitude 13°7'1.33"N to 12°14'23.53"N. The study area covers about 4,137 Sq.km of Bangalore and Ramanagara district. The Catchment of South BMR Comprises parts of Cauvery, South Pennar and Palar basins (Figure 1). The SOI Topo-sheet numbers are 57G/4,8,12,16,57/H,1,2,3,5,6,7,9,10,11 and 13 are used to delineate the boundary and morphometric analysis.

Methodology

The base map used for morphometric analysis carried out through GIS Mapping using SOI topographical sheet of the area scale of 1:50000. The required GIS maps like location map, Drainage map, watershed map of the study area has been generated and morphometric spatial analysis tool is extensively used for calculation purpose.

Result and Discussion

The Morphometric parameters like Stream order maps, Stream Length and Mean Stream length, Bifurcation ratio, Drainage Density, Stream Frequency or Drainage Frequency, Circularity ratio, Texture ratio, Form Factor, Elongation ratio, Length of overland flow, Constant of Channel Maintenance and Compactness ratio maps were generated using the Table 1 and values are tabulated in Table 5.

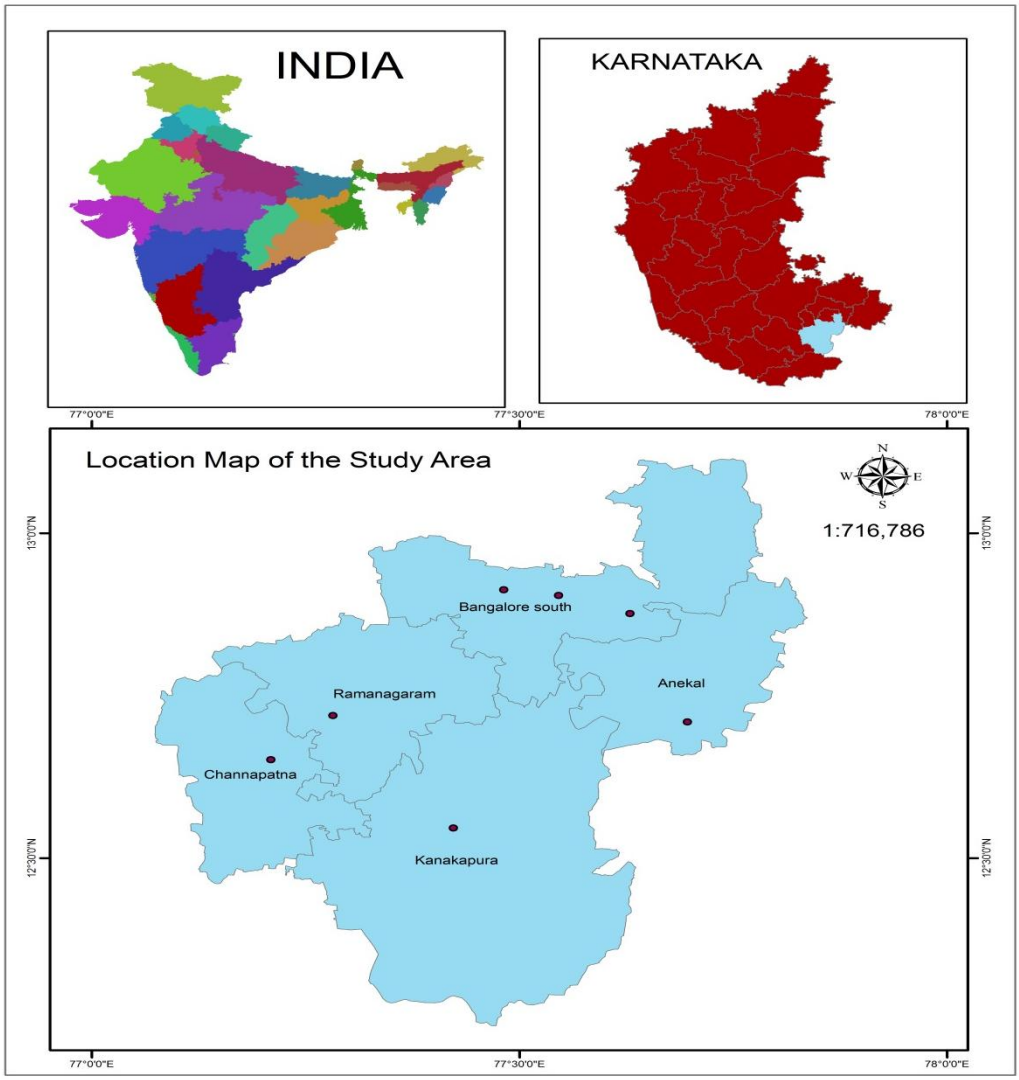


Figure 1: Location Map

Table 1: Formula adopted for computation of morphometric parameters for the study area

	Morphometric Parameters	Methods	References
LINEAR	Stream order (U)	Hierarchical order	Strahler,1964
	Stream length (Lu)	Length of the stream	Horton,1945
	Mean stream length (Lsm)	Lsm= Lu/Nu;where,Lu=Stream length of order'U'Nu=Total number of stream segments of order'U'	Horton,1945
	Stream length ratio (Rl)	Rl=Lu/Lu-1;whereLu=Total stream length of order'U',Lu-1=Stream length of next lower order	Horton,1945
	Bifurcation ratio (Rb)	Rb=Nu/Nu+1;where,Nu=Total number of stream segment of order'u';Nu+1=Number of segment of next higher order	Schumn,1956
ARIAL	Drainage density (Dd)	Dd=L/A where, L=Total length of streams ;A=Area of watershed	Horton,1945
	Stream frequency (Fs)	Fs=N/A; where, N=Total number of streams ;A=Area of watershed	Horton,1945
	Texture ratio (T)	T= N1/P;where,N1=Total number of first Order streams ;P=Perimeter of watershed	Horton,1945
	Form factor (Rf)	$Rf=A/(Lb)^2$;where,A=Area of watershed, Lb=Basin length	Horton,1932
	Circulatory ratio (Rc)	$Rc=4\pi A/P^2$;where,A=Area of watershed, π=3.14,P=Perimeter of watershed	Miller,1953
	Elongation ratio (Re)	$Re=2\sqrt{(A/\pi)}/Lb$; where, A=Area of watershed, π=3.14,Lb=Basin length	Schumn,1956
	Length of overland flow (Lof)	Lof=1/2Dd;where,Dd=Drainage density	Horton,1945
	Constant of channel maintenance (Ccm)	C=1/Dd; where, Dd=Drainage density	Schumn,1956
	Compactness ratio (Cc)	$Cc=0.2821*P/A^2$;where, P=Perimeter of the basin(km), A=Area of the basin (km^2)	Horton,1945

Watershed

A watershed is a natural or disturbed system that functions in a manner to collect, store, and discharges water from a common outlet, such as a larger stream and lakes. A watershed embraces all its natural and artificial (manmade) features, including its surface, subsurface features: climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. The science embraces a comprehensive understanding of the basic functions of a watershed as well as awareness that functions and physical characteristics may vary dependent on watershed size as well as proximity to neighboring watersheds that may drain into and be part of connected, larger and multiple watershed systems. The total area and perimeter of 14 Sub-watershed has been calculated using ArcGIS and values has been tabulated in Table 2. The total area of 14 sub-watersheds is 4371.73 Sqkm and total perimeter of the basin is 1449.37 km.

Table2: Sub-watersheds of Cauvery Basins

Sl.No	Watersheds	Area in Sq.km	Perimeter in km
1	Antaragange Hole	85.64	59.52

2	Arkavati River	889.33	244.24
3	Cauvery River	133.31	68.59
4	Chikkatore Halla	31.91	29.71
5	Dakshina Pinakini River	892.70	179.12
6	Dodda Halla	266.61	108.98
7	Doddaguli Halla	191.83	74.75
8	Edakolada Halla	24.42	23.02
9	Kanva Hole	609.22	144.09
10	Kutle hole	210.23	116.91
11	Rayatmala Hole	129.72	64.59
12	Shimsha River	114.73	111.26
13	Suvarnamukhi River	310.37	103.75
14	Vrishabavati River	481.71	120.84
	Total	**4371.73**	**1449.37**

Morphometric Parameters

Stream Order (Nu): The designation of stream order is the first step in the drainage basin analysis. The primary step in drainage basin analysis is to designate stream orders. As per the Strahler's (1964) ordering scheme, the study area ending with Sixth order drainage basin. The minimum length of the sixth order is 120.50Km in Kanva Holewatershed, Maximum length is 186.05 km in Doddaguli Halla watershed and total length of the sixth order is 518 km.

Stream length (Lu): Stream length measured from mouth of the river to drainage divided, the stream length of different order has been delineated from ArcGIS software. Hortons law of stream length supports the theory that geometrical similarity is preserved generally in the basin in the increasing order. The mean length of channel Lu of order U is the ratio of total length to the number of stream of the given order. Mean length of channel is the given order greater than that of the next lower order but less than that of the next higher order. In the study area table.3 showing total length of the stream order.

Table3: Stream orders of Cauvery sub basins

Sl. No	Drainage order	First	Second	Third	Fourth	Fifth	Sixth
1	Total. No. Drainage	8512	1959	520	118	22	3
2	Minimum (m)	4.67	20.65	22.01	126.03	158.38	120509.66
3	Maximum (m)	4529.16	6675.34	8548.98	16861.60	19479.93	211493.80
4	Sum (m)	5090939.42	1757827.11	975244.78	465548.73	148114.25	518056.84
5	Mean (m)	598.08	897.00	1875.47	3945.32	6732.46	172685.61

Mean stream length (Lu/Nu): Mean stream length of a stream channel system is a dimension less property reveling the characteristic of the size of the component of the drainage network and its contributing basin set

$$Lu=\sum Lu/Nu,$$

Where $\sum Lu$ = Total length of the order, Nu = Number stream of that order.

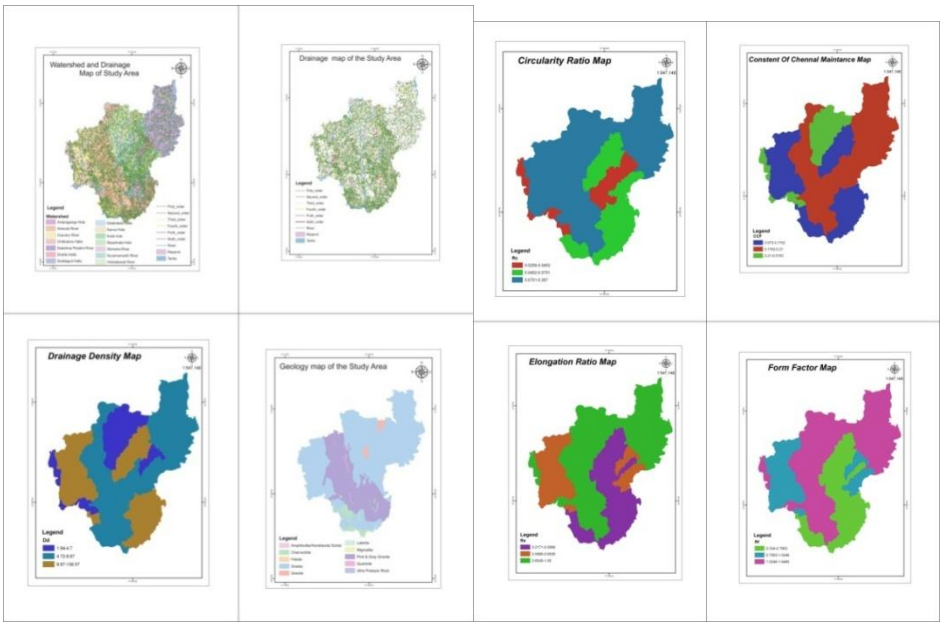
Mean stream length (Lsm) is a characteristic Property related to the drainage network components and its associated basin surface (Strahler, 1964). This has been calculated dividing the total stream length of the order (U) by the number of stream of segments in the order. The Total number of first to sixth order is 11,134; mean stream length of the study area is 0.75 km.

Stream Length ratio (RL): Stream length ratio (RL) is ratio of the mean length of the one order to the next lower order of the stream segment.

Bifurcation Ratio (Rb): Bifurcation Ratio is defined as the ratio of the number of stream of a given order to the number of stream to the next higher order which is expressed in terms of following equation closely related to the branching pattern of a drainage network. According to Schumn (1956), the term bifurcation ratio may be defined as the ratio of the number of stream segment of given order to the number of segments of the next higher orders. Bifurcation shows a small range of variation for different regions or for different environments except where full geological control dominants (Strahler, 1957).Rb = Nu/Nu+1 where, Rb= Bifurcation Ratio, Nu = number of Segments of the given order Segments. Nu+1= Number segments of the next higher order. Rb depends on the slop, Physiographic and Climate. Arial aspects includes different morphometric parameter, like drainage density texture ratio stream frequency, from factor, circularity ratio, elongation ratio and length of the overland flow, the value of this parameters area show in the table and discussed and interpreted. In the study area higher Rb greater than five indicates some sort of geological control (Agarwal, 1998). The bifurcation ratio low in Suvarnamukhi, Vrishabavati River & Antaragange Hole. High in Dakshina Pinakini River, Kanva Hole, Arkavathi River Dodda Halla & Kutle Hole. In the well developed drainage network bifurcation ratio is general between 2 to 5 (Strahler, 1964 and Horton,1932). In the study area bifurcation ration ranges between 9.67 to 22.56.

Drainage density: Drainage density is defined as the total length of streams of all orders per drainage area. Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, surface roughness has no significant correlation with drainage density. The drainage density indicates the closeness of spacing of channels (Horton, 1932). It may be considered as one of the methods of measurement of basin area. According to Horton, Drainage Density is defined ratio of total length of all stream segments in a given drainage basin to the total area of that basin. It is expressed by a formula DD=∑L/A Where,∑L = Totallength, A =Total area. The drainage density shows in the map Low in Shimsha River, Vrishabavati River & Antaragange Hole. High in Kanva Hole Dodda Halla, Doddaguli Halla & Suvarnamukhi River. In the study area drainage density has calculated, drainage density ranges between 1.942 to 136.57.

Stream frequency/channel frequency: The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). Hopefully, it is possible to have basins of same drainage density differing stream frequency and basins of the same stream frequency differing in drainage density. Stream Frequency is defined as the ratio between the number of stream segment per unit area which expressed by a formula, DF= ∑N/A where, ∑N= Total no of stream segment; A= Unit area in km^2 or m^2.Stream frequency low in Dakshina PinakiniRiver, Vrishabavati River Antaragange Hole and Kanva Hole. High in Dodda Halla, Cauvery River, Rayatmala Hole and Kutle Hole. It is a technique which is also used in planning and development to identify land quality for optimum utilization. The Stream frequency in the study area is 1.372 to 9.36.



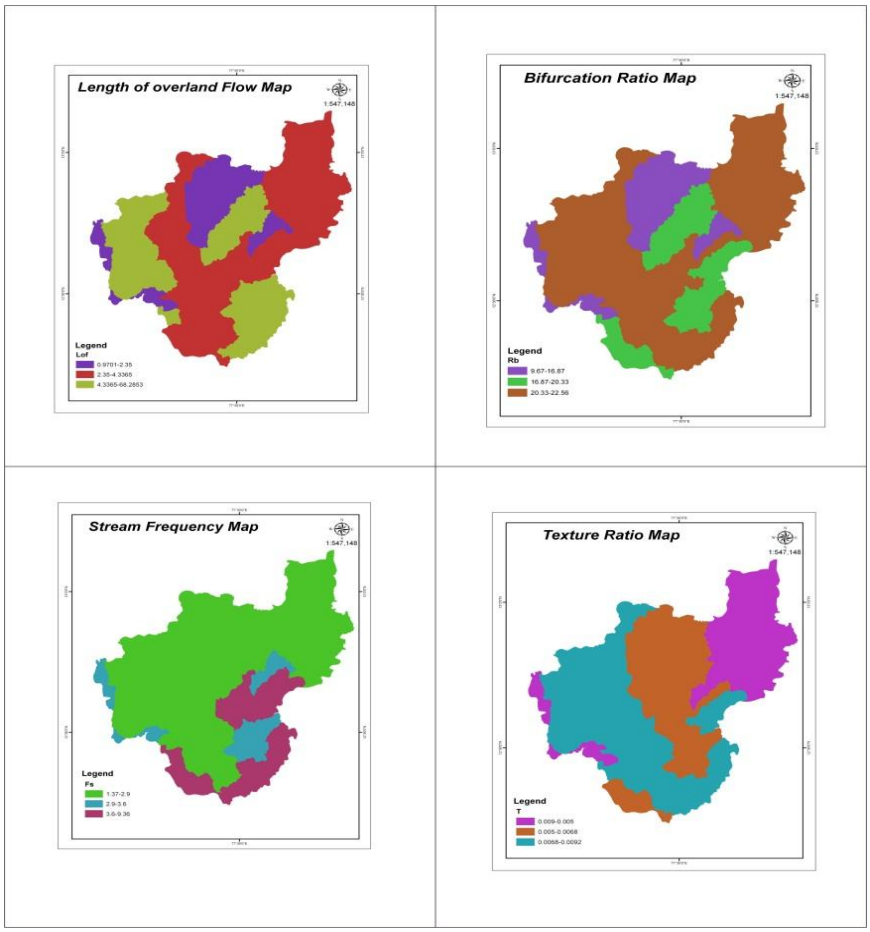


Figure 2: Spatial analysis of Morphometric Parameters

Drainage texture or Texture ratio: Drainage texture is the total number of stream segments of all orders per perimeter of that area (Horton, 1945). It is one of the important concepts of geomorphology which means that the relative spacing of drainage lines. Drainage lines are numerous over impermeable areas than permeable areas. According to Horton (1945), infiltration capacity as the single important factors which influences drainage texture and considered drainage texture which includes drainage density and stream frequency. The texture ratio in the study area low in Dakshina PinakiniRiver&Shimsha River, High in Kanva Hole Arkavati River Dodda Halla and Rayatmala Hole. The values of texture ratio of the study area varies between 0.009to 0.0092.

Aerial Aspects

Form factor (Rf) : Form factor may be defined as the ratio of the area of the basin and square of basin length (Horton, 1932). The value of form factor would always be greater than 0.78 for a perfectly circular basin. Smaller the value of form factor, more elongated will be the basin. The form factor in the study area noted that 0.187 and all the basin area observed that thy area sub circular and elongated, the form factor shows Low in Dodda Halla, Doddaguli Halla Cauvery River & Kutle Hole. High in Dakshina Pinakini River, Arkavati River, Vrishabavati River and Part of Shimsha River. The study area form factor ranges between 0.33 to 1.64.

Circularity ratio (Rc): The circularity ratio is mainly concentrated with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. It is the ratio of the area of the basins to the area of circle having the same circumstance as the perimeter of the basin. The circularity ratio show in the study area part of Dakshina Pinakine River, Vrishabhavathi River, Arkavathi River and Kanva Hole showing low circularity ratio. Kutle and Antergange Hole are showing high circularity ratio value. In the present study the circularity ratio its shows 0.026 to 0.27.

Elongation ratio (Re): Elongation ratio is the ratio between the diameter of the circle of the same area as the Drainage basin and the maximum length of the basin (Table4). The formula used to calculate Elongation Ratio is Re= (2/Lb)*(A/3.14*0.5).

Table 4: Elongation ratio and Shape of river

Elongation ratio	Shape of the basin
<0.7	Elongated
0.7 to 0.8	Less elongated
0.8 to 0.9	Oval
>0.9	Circular

Elongation ratio shows Low in Dodda Halla, Doddaguli Halla Cauvery River andKutle hole. High in Dakshina Pinakini River, ArkavatiRiver, Vrishabavati River and Part of Shimsha River. In the study area results indicate that 0.167 (<0.7) the basin is elongated area 0.2171 to 1.05.

Compactness constant (Cc): Compactness ratio is defined as the ratio between the area of the basin and the perimeter of the basin. $Cc=0.2821*P/A^2$. The study area Cc observed 0.187

Length of Overland Flow (Lof): It is the length of water over the ground before it gets concentrated in to definite streams channels3. This factor depends on the rock type, permeability, climatic regime, vegetation cover and relief as well as duration of erosion4. The length of overland flow approximately equals to half of the reciprocal of drainage density (Horton,1932). Length of overland flow Low in Vrishabavati River Antaragange Hole, Suvarnamukhi River.High in Dodda Halla, Doddaguli Halla Suvarnamukhi River & Kanva Hole. In the study area, it is observed that the length of overland flow in the study area 0.118 km and its varies between 0.9701to 68.2653.

Constant of Channel Maintenance (Ccm): Introduced the factor, constant of channel maintenance, as the inverse of drainage density5 is about 4.23 km and Low in Kanva Hole, Suvarnamukhi River, Dodda Halla and Cauvery River, High in Shimsha, Vrishabavati River and Ranges between 0.0073 to 0.5153.

Table 5: Morphometric Parameter of Cauvery Sub Basins

Sl.No	Watershed	Area (Km2)	Perimeter (km)	Basin Order	Basin Length (Lb) (Km)	Bifurgation Ratio(Rb)	Drainage density (Dd)(km2)	Strem Frequency (Fs)(km2)	Texture Ratio (T)(km)	Form Factor (Rf)	Circularity Ratio (Rc)	Elongation ratio (Re)	Length overland Flow (Lof)(Km)	Constent Of Channel Maintance (c)(Km)
1	Antaragange Hole	85.64	59.51	5	197.04	16.87	4.7	3.6	0.0041	0.869	0.0361	0.55	2.35	0.210
2	Arkavati River	889.33	244.24	5	1702.59	20.55	5.75	2.56	0.0072	1.044	0.0951	0.67	2.87	0.174
3	Cauvery River	133.31	68.59	5	371.51	18.70	8.67	4.57	0.0068	0.71767	0.0488	0.46	4.34	0.115
4	Chikkatore Halla	32.91	29.71	5	197.06	16.87	12.24	9.36	0.0082	0.334	0.0278	0.21	6.12	0.082
5	Dakshina Pinakini River	892.7	179.12	5	1083.04	20.71	4.84	1.37	0.005	1.6485	0.1252	1.05	2.42	0.207
6	Dodda Halla	266.61	108.98	5	756.75	22.56	9.81	3.99	0.0076	0.7046	0.0515	0.44	4.91	0.102
7	Doddaguli Halla	191.83	74.75	6	657.53	18.03	136.57	3.22	0.0063	0.5834	0.0645	0.37	68.29	0.007
8	Edakolada Halla	24.42	23.02	3	50.66	9.67	1.94	2.38	0.0019	0.964	0.267	0.61	0.97	0.515
9	Kanva Hole	609.22	144.09	6	1334.80	20.54	59.24	2.5	0.0079	0.9128	0.1062	0.58	29.62	0.017
10	Kutle hole	210.23	116.91	5	528.62	20.33	4.82	3.64	0.0051	0.79539	0.0452	0.51	2.41	0.208
11	Rayatmala Hole	129.72	64.59	5	312.70	20.33	5.34	5.91	0.0092	0.82967	0.0505	0.53	2.67	0.187
12	Shimsha River	114.73	111.26	4	223.93	13.47	2.55	2.97	0.0024	1.02467	0.0259	0.65	1.28	0.392
13	Suvarnamukhi River	310.37	103.75	6	881.00	19.41	127.21	2.9	0.0067	0.7038	0.0751	0.45	63.60	0.008
14	Vrishabavati River	481.71	120.84	5	806.37	16.20	4.66	2.02	0.0063	1.1947	0.1001	0.76	2.33	0.214

Discussion and Conclusion

GIS techniques characterized by very high accuracy of mapping and measurement prove to be a competent tool in morphometric analysis. The morphometric analysis were carried out through measurement of linear, areal and relief aspects of the watershed 14 morphometric parameters are analyzed of sixth order of Cauvery sub basin. The morphometric analysis of the drainage network of the watershed show trellis and dendric patterns. The bifurcation ratio in the study area ranges between 9.67 to 22.56. The bifurcation ratio low in Suvarnamukhi, Vrishabavati River

& Antaragange Hole.High in Dakshina Pinakini River, Kanva Hole Arkavati River Dodda Halla and Kutle Hole. The watershed indicates normal watershed category. The value of stream frequency indicate that the watershed show It is a technique which is also used in planning and development to identify land quality for optimum utilization. The Stream frequency in the study area is 1.372 to 9.36. With increasing stream population with respect to increasing drainage density. The value of form factor and circular ration suggest that Cauvery sub watershed is less circular to elongated (<0.7) the basin is elongated area 0.2171 to 1.05. Length of Overland Flow parameter to analyze types of rock, porosity and permeability, land use land cover concept. The length of overland flow, Low in Vrishabavati River Suvarnamukhi River, Antaragange Hole, High in Dodda Halla, Doddaguli Halla Suvarnamukhi River & Kanva Hole, The length of overland flow varies between 0.9701to 68.2653.

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