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Morphometric Analysis of Kumari River Basin Using Geospatial Approach in Purulia District of West Bengal, India

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Abstract— The morphometric analysis of the drainage basin plays an important role in the geohydrological nature of the drainage basin and it expresses the prevailing evolutionary history of the basin. Remote Sensing (RS) and Geographic Information System (GIS) have emerged as an important tool in demarcation of drainage basin, pattern and groundwater potential and its planning. Geospatial techniques can be used for the identification of morphological characteristics of the drainage basin. In this study, SRTM data has been used to extract the basin boundary and various morphometric parameters of Kumari river basin. The morphomeric parameters of the basin deals with linear, areal and relief features such as stream order (Nu), stream length (Lu), bifurcation ration (Rb), drainage density (Dd), stream frequency (Fs), elongation ratio (Re), circulatory ratio (Rc)), texture ratio (Rt), length of overland flow (Lg), and form factor ratio (Rf) etc. have been dealt in the present study. Morphometric analysis of Kumari drainage basin reveals that it is a 7th order and dendritic type of drainage basin thereby indicates homogeneity in texture and lack of structural control. In the Kumari watershed, total nuber of stream is 2087 whereas first order stream is 1577 and second order stream is 386, 87 third order stream, 28 fourth order stream, 6 fifth order stream, 2 sixth order stream and one seventh order stream. First order stream length is maximum and its decreases with increasing stream order. In this study, morphometric analysis is a useful tool for the sustainable development and planning strategies in control the soil erosion and conservation of water resources.

Abstract— Morphometric Analysis, RS & GIS, Water Resource, Management, Kumari River Basin

1 Introduction

The drainage basins are the most important fundamental units of the watershed management and in terms of geometric characteristics of fluvial landscape. Geographical Information System (GIS) and Remote Sensing (RS) have used for understanding the morphometric characteristics of river channel and its drainage network. Morphometry indices of the watershed interpret the hydrological characteristics of a river basin [1]. Morphometric analysis has been used to identify the relationship of various parameters in the watershed. It is a comparative morphometric parameters evaluation of various watersheds to know different geomorphological and topographical condition. Watershed is a natural is a natural hydrological entity from which surface runoff flows to defined drained, channel, stream at a particular point [2]. Morphometric parameters of the watershed is very important for watershed planning and management and it gives an idea about the basin characteristics such as slope, topography, soil condition, runoff characteristics, surface water potential etc. [3]. The most common morphometric parameters of the watershed are stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, drainage density, drainage texture, stream frequency, relief ratio, form factor, elongation ratio, circulatory ratio, length of overland flow etc. [4]. In many papers has defined the formula of each parameters as same. There is no complete classification for all parameters. Several papers have stated that resulted values of certain parameter are either high or low and it indicates condition but the range of value is not included. There are no statements of the implication of high and low value of a particular morphometric parameter. The quantitative analysis of morphometric parameters likes linear, relief and areal are immense utility in river basin evaluation, watershed prioritization for flood and water conservation and natural resource management [5. Drainage basin in the semi arid region is conductive to flash flood generation [6]. GIS helps to create data base for the watershed which is used for carrying out spatial analysis and decision makers informing appropriate measure for critically affected areas [7]. This study will help in better understanding the hydrological characteristics of the basin, flood potentiality, drainage management, groundwater potential and erosion for watershed planning and management.

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2 Methodology and Data Base

For the study of morphometric parameters of the basin are effective done using modern RS and GIS techniques. Kumari watershed map is a sub-watershed drainage basin of Kangsabati watershed was prepared with the help of Survey of India (SoI) toposheets and SRTM-DEM data and then it was digitized. SoI toposheets number 73E/15, 73E/16, 73I/3 and 73I/4 have been used to extract morphometry parameters for the present study. A geo-hydro processing model was used for evaluating the stream parameters of the basin. Stream order has been extracted using Strahler method. The cited formula has been used to implement the morphometric analysis as shown in the following tables 6, 7 and 8. Various morphometric parameters have been extracted from the watershed such as aerial, linear and relief aspects and derived formula was further proposed to eradicate detailed morphometric study with statistical methods and mathematical calculation using GIS software from the various authors. SRTM-DEM, Topposhhets, Geological map (SoI) were used to prepare various thematic maps using gis software ILWIS 3.0 such as stream ordering, physiographic, drainage density, slope and geological etc. toposheets and SRTM-DEM have been georeferenced and all morphometric parameters of Kumari watershed were extracted using RS & GIS platforms. Each morphometric parameter has been analysed in detail and try to discuss the importance of the calculating value. Author has calculated 48 morphometric parameters in the Kumari watershed and tries to find out the problems of the study area. This study will helpful for the planner, engineer and researcher for the further study.

3 Study Area

Kumari watershed is extended between latitude 22042/42// N to 23014/14// N and longitude 86009/38// E to 86044/37// E and located in southern part of Purulia District of West Bengal, India and covers an area of about 1920 sq. km. Kumari river flows from north west to south east direction and join with Kansai river where Kongsabati Dam is situated. Physiographically, the basin is a part of Chhotonagpur plateau and lies under laying granite gneiss hard rocks. Maximum and minimum elevation of this basin is 609 meter and 56 meter respectively. Administratively, Kumari river basin covers the CD block of Balarampur, Bundwan, Barabazar, Manbazar-I & II, Baghmundi, Arsha, Purulia-I of Purulia district and Ranibandh, Khatra and Hirbandh block of Bankura District in West Bengal and some part of situated in Jaharkhand. The climate of this region is dry hot in summer and dry cold in winter and is characterized by high evaporation and low precipitation. Most of the rainfall received from June to October by the south west monsoon. Average rainfall ranges from 1100 mm. to 1500 mm. while there is sparse rainfall between October to January. Geologically, the region lies under laying impermeable hard granite gneiss rocks with varying degree of weathering and limited soil cover. The elevation is higher in west and south west part of the basin and decreases towards east direction. This region is drought prone areas where the main source of water is rainfall with south west monsoon and agricultural activity depend on the south west monsoon. The study area is shown in figure 1.

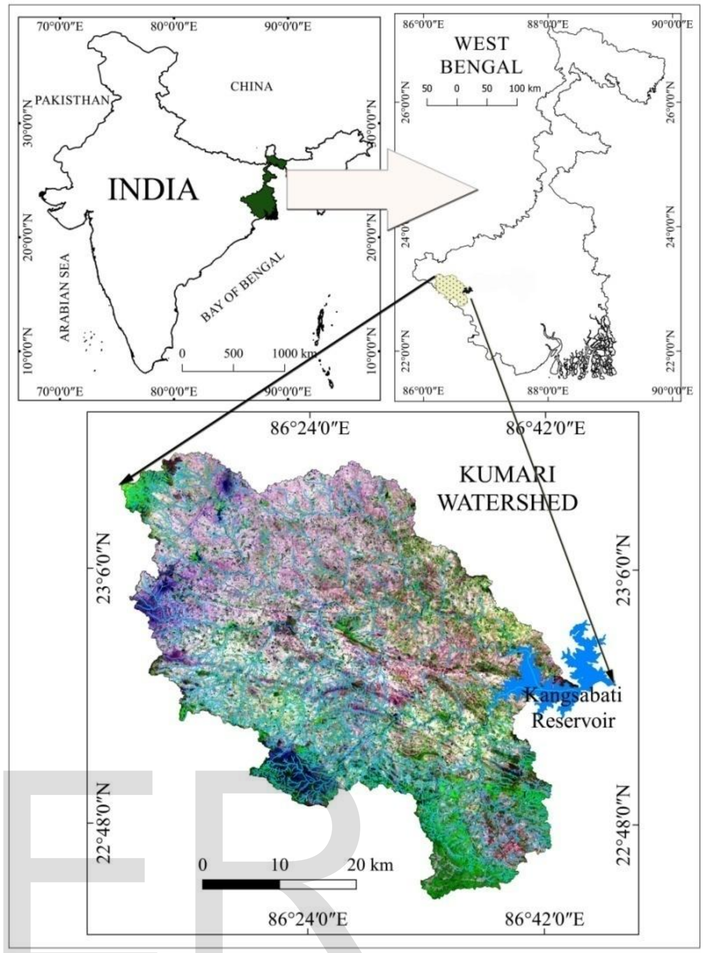


Fig. 1. Location of the study area

4 Geology

Geologically, Kumari river basin is a part of Chhotonagpur plateau granite gneiss complex in eastern India. Granite gneiss complex is a product of replacement origin [8]. This area is covered by soil which represents undulating topography with moderate and gentle slope. It has exposed metamorphic rocks of proterozoic age except for some linear belts where sedimentary of Gondowana rocks are predominant. Figure 2 shows the geological distribution of the study area where quartzite and quartzite schist covers an area of 41.68 percent and granite gneiss megmatite covers 35.77 percent area. Metamorphosed basis and intrusive granite rocks are covered 9.70 and 8.31 percent respectively. Mica schist, phyllite and mica schist, quartzite and clay with calche connection have covered small area of the study area. Table1 shows the shows the distribution percentage area covered by rocks of the basin.

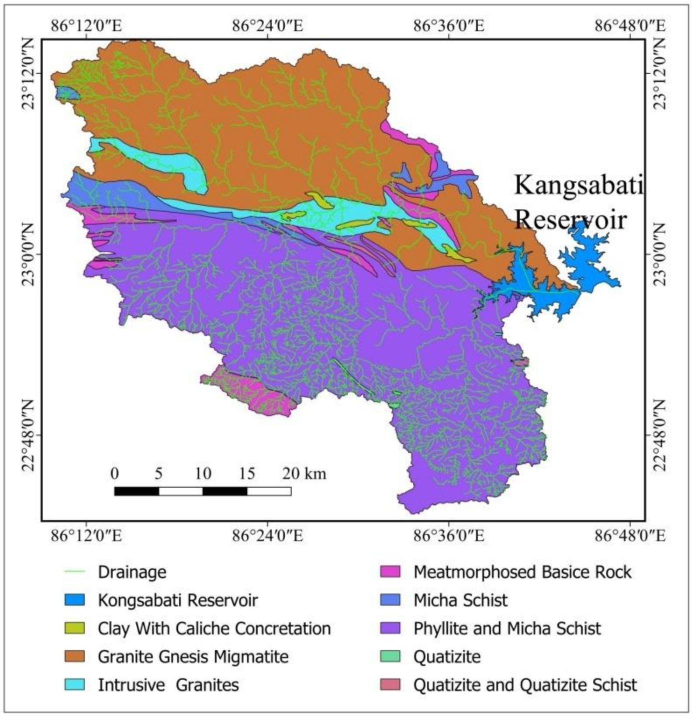


Fig. 2. Geological characteristics of the study area

TABLE 1
DISTRIBUTION OF ROCKS OF KUMARI WATERSHED

Rock	Area in sq. km.	Area (%)
Metamorphosed Basice Rock	186.16	9.70
Granite Gneiss Migmatitte	686.76	35.77
Mica Schist	64.38	3.35
Phyllite and Mica Schist	4.55	0.24
Quartizite	2.58	0.13
Quartizite and Quartizite Schist	800.23	41.68
Intrusive Granites	159.61	8.31
Clay with Calche Concretion	15.73	0.82
Total	1920.00	100.00

5 PHYSIOGRAPHY

Elevation is defined as the height from the sea level which represents the shape of the topography. Elevation of the study area ranges from 56 meter in outlet of the basin and 609 meter in the water divide from the sea level. It has been categorized into eleven zones at 50 meter interval. About 5.98 percent area is less than 100 meter and 27.88 percent area lies within 100 meter to 150 meter. 45.98 percent area is between 150 meter to 200 meter and 97.32 percent area lies below 200 meter from the sea level. Figure 3 and Table 2 show the distribution of elevation of Kumari river basin.

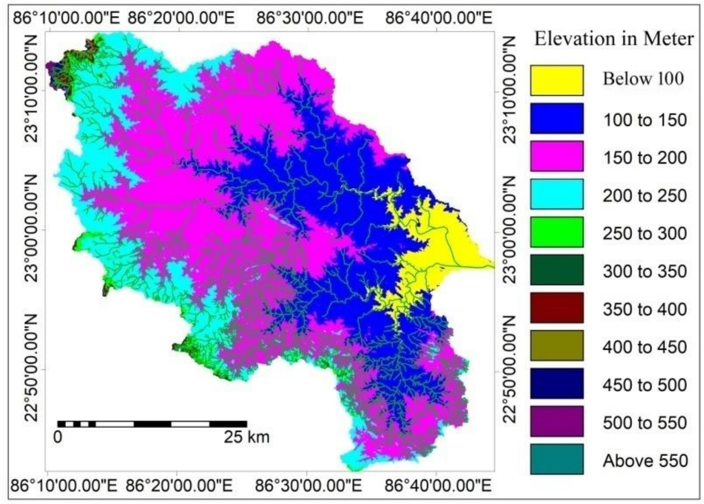


Fig. 3. Physiographic division of the study area

TABLE 2
PHYSIOGRAPHIC DISTRIBUTION OF THE STUDY AREA

Elevation (m)	Area sq. km.	Area covered (%)
Below 100	112.87	5.88
100 to 150	535.31	27.88
150 to 200	882.77	45.98
200 to 250	337.51	17.58
250 to 300	23.55	1.23
300 to 350	8.99	0.47
350 to 400	6.49	0.34
400 to 450	4.83	0.25
450 to 500	4.32	0.23
500 to 550	3.06	0.16
Aove 550	0.3	0.02
Total	1920	100

6 SLOPE

A slope is the rise and fall of the land surface. It is important for the planners and engineers. Slope map has been prepared from the SRTM (DEM) data using ILWIS 3.0 GIS software. Using the following formula, slope has been calculated as given below.

SLOPDEG = RADDEG(ATAN(SLOPEPCT/100)) (1)

Where, SLOPDEG = Slope in degree

RADDEG/ATAN = Internal map calculation of ilwis 3.0

SLOPEPCT = 100 * HYP(DX,DY)/Pixel size (DEM)

HYP = Internal map calculation

DX = Height difference in X-direction

DY = Height difference in Y-direction

Slope of Kumari river basin has been categorized in eleven zones at 20 intervals (figure 4). 95.86 percent area is less than 80 of slope of the basin. 4.14 percent area is above 80 of slope. Steep slope has been identified in the North West and southern part of the study area.

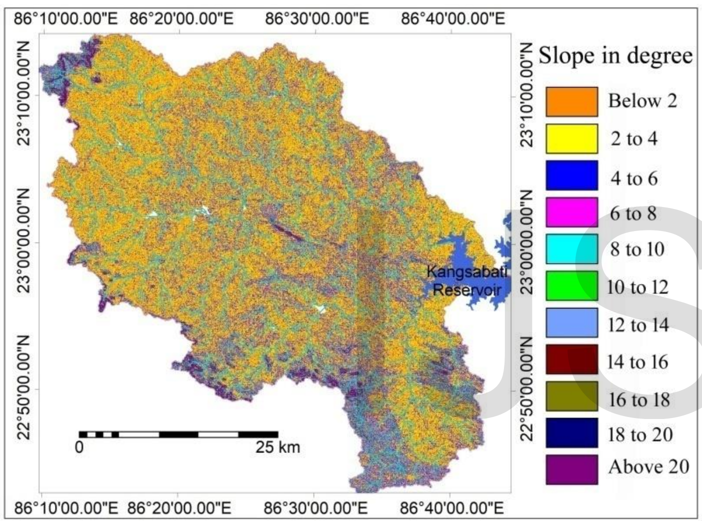


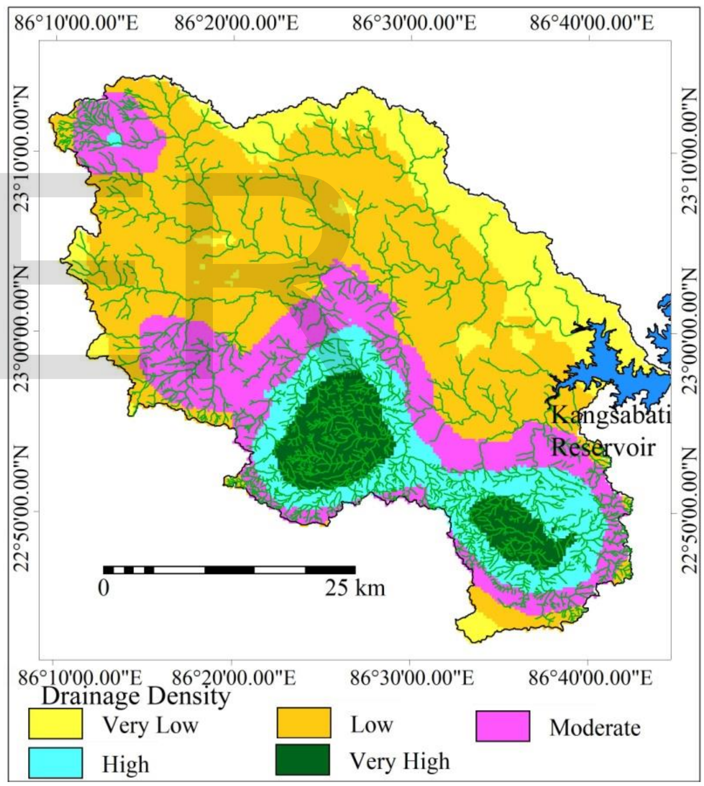
Fig. 4. Slope distribution of the study area

TABLE 3
SLOPE DISTRIBUTION

Slope (Degree)	Area (Sq. km.)	Area (%)
Below 2	643.11	33.50
2 to 4	688.4	35.85
4 to 6	315.72	16.44
6 to 8	113.42	5.91
8 to 10	51.44	2.68
10 to 12	28.42	1.48
12 to 14	17.81	0.93
14 to 16	12.32	0.64
16 to 18	8.61	0.45
18 to 20	6.6	0.34
Aove 20	34.15	1.78
Total	1920	100

7 DRAINAGE DENSITY

According to Strahler, drainage density id Dd=L/A, where L is the stream length in the watershed and A is the area of the watershed [9]. Figure 5 and table 4 shows the drainage distribution zones of the study area. It has been classified into very low, low, moderate, high and very high. 14.46 percent area is under very low drainage density zone. 44.38 and 21.04 percent area are covered by low and moderate drainage density respectively and high drainage density covers an area of 12.76 percent and 7.36 percent area is above very high drainage density zone. Low drainage density area is poorly drained basin with a slow hydrological response from watershed making it highly susceptible to flooding, gully erosion etc [10].



High drainage density area experience quick hydrological response to rainfall events and on the other hand, high drainage density area is characterized by impermeable subsoil material, sparse vegetation and high mountain relief.

Fig. 5. Drainage density distribution of Kumari Watershed

TABLE 4
DRAINAGE DENSITY DISTRIBUTION

Drainage Density	Area in sq. km.	Area (%)

Very Low	277.55	14.46
Low	852.06	44.38
Moderate	404.01	21.04
High	245.04	12.76
Very High	141.34	7.36
Total	1920	100

8 Morphometric Analysis

The morphometric analysis provides quantitative description of the basin geometry to understand the initial inequalities slope in the hardness of rock, structural controls, recent diastrophism, geological and morphological history of the drainage basin [9]. Drainage basin geomorphic characteristics confirms to Horton's (1932) 'Laws of stream number' which state that number of segments of an order decreases with increasing stream order of the drainage basin. Horton's (1932) 'Law of stream length' states that the average stream length of each stream order increases with increasing stream order of the drainage basin. The linear aspects were studied using the methods of Horton (1932), Strahler (1953), Chorley (1957), areal aspects using methods of Schumm (1956), Strahler (1956 & 1968), Miller (1953) and Horton (1932) and the relief aspects using the techniques of Horton (1945), Broscoe (1959), Melton (1957), Schumm (1954), Strahler (1952) and Pareta (2004). The results (Table 5) of the morphometric analysis have been discussed in the following suggested subheadings.

8.1 Drainage Network Analysis

8.1.1 Stream Order (Su)

Stream ordering is the first step of morphometric analysis of drainage basin. There are four different types of stream ordering system such as Gravilius, 1914; Horton, 1945; Strahler, 1964; Schiddeggar, 1970. The stream ordering system was first promoted y Horton (1945) but Strahler (1964) make some modification of this ordering system [11]. In the first order stream, there are no tributary. In the second order stream, there are only first order streams as tributaries. Similarly third order stream has first and second order stream as tributaries and so on. Higher number of stream segments of an order indicates that the region is still under erosion. In Kumari watershed, there are 1577 first order stream, 386 second order stream, 87 third order stream, 28 fourth order stream, 6 fifth order stream and 1 seventh order stream having total number of 2087 stream segment of different order spreading over an area of 1920 sq. km. in this watershed, first order stream segments are dominant in number and states that the basin is under active in erosion process.Topography is figured by the less number of streams in a given drainage basin where as large number of stream presence manifest the topography is still undergoing the erosion [12]. Figure 6 shows the stream ordering of Kumari river basin.

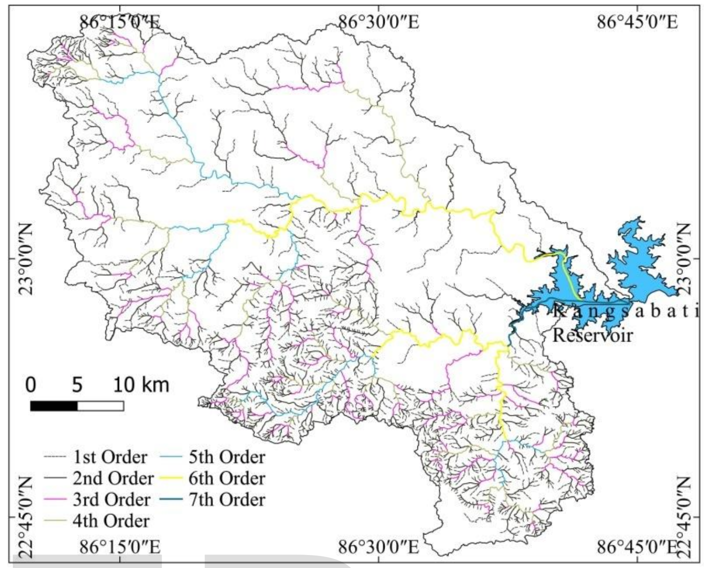


Fig. 6. Stream ordering of Kumari Watershed

8.1.2 Stream Number (Nu)

The total number of stream channel of each order is stream number. According to Horton's law, "number of streams of different orders of the basin tends closely to approximate as inverse geometric series of which the first term is unity and the ratio is the bifurcation ratio" [13].The number of stream decreases with increasing stream order. Kumari basin has seventh order drainage basin where as 1577 is first order stream and 386 is second order stream (Table 5). Higher number of stream indicates lesser permeability and infiltration.

8.1.3 Stream Length (Lu)

Stream length is defined as the total length of stream segment of each order. Stream length of each order increases exponentially with increasing stream order. Total length of first order stream is 1042.86 km., second order streams having length of 466.15 km., third order streams having length of 163.90 km., fifth order stream having length of 93.41 km., sixth order stream having length of 95.95 km., and 16.54 km. stream length of seventh order stream (Table 5). Stream length is most important morphometric parameters for getting information about surface runoff hydrological characteristics of the basin. Large number of smaller stream length of the stream represent that the bed rock is less permeable. Total stream length of all stream order in the Kumari river basin is 2109.21 km.

8.1.4 Mean Stream Length (Lsm)

Mean stream length is calculated by dividing length of stream of an order by total number of stream segments of the total order. It is a dimensionless property revealing the characteristics size of components of a drainage network and its contributing watershed surface [14]. It is a directly proportional related to the size and topography of drainage basin.

8.1.5 Stream Length Ratio (RL)

Stream length ratio is the ratio of the mean (Lu) of stream segments of an order to mean length segments of the next lower order (Lu-1), which is constant through the successive orders of a basin [15]. Mean stream length has been calculated based on the method proposed by Strahler (1964). Order wise mean stream length ratio of Kumari river basin ranges from 0.34 to 2.66 (Table 5). The stream length ratio is a important relevance with surface flow discharge and erosion stage of the basin [16].

8.1.6 Bifurcation Ration (Rb)

The bifurcation ratio is the ratio of the number of stream segments in the next higher order (Nu+1) (Table 5). Horton (1945) defined bifurcation ratio as an index of relief and dissection. According to Strahler (1954), bifurcation ratio displays a small range of variation for different regions or different environment except where the powerful geological control dominates. Inequalities of bifurcation ratio are dependent upon the geological and lithological characteristics of the watershed [14]. The bifurcation ratio generally varies from 3.0 to 5.0. Lower value of bifurcation ratio shows less structural disturbances and their drainage pattern has not been distorted due to geological and structural rocks of the watershed [17]. Strahler significantly noticed that geological structures do not affect the drainage pattern if the bifurcation ratio is in between 3.0 to 5.0. Lower bifurcation ratio indicates high possibilities of flooding as water will tend to accumulate rather than spreading out [18]. The human activity plays an important role to reduce bifurcation ratio within the basin [18].

8.1.7 Weighted Mean Bifurcation Ratio (Rbwm)

Strahler (1953) used a more representative bifurcation number as known as weighted mean bifurcation ratio. It is calculated by multiplying of each successive pair of orders by the total number of streams involved in the ratio and taking the mean of the sum of these values. Weighted mean bifurcation ratio of Kumari watershed is 4.11 (Table 5). This watershed is less structural disturbance.

8.1.8 Rho Coefficient (p)

The Rho coefficient defined as the ratio of stream length ratio and bifurcation ratio [19] and it is an important morphometric parameter relating drainage density and phyiographic development of the watershed. Rho value varies with changing climate, geology, biology, geomorphology and anthropology. Rho value of Kumari river basin is 0.17. Higher values of Rho coefficient indicate higher hydrological storage capacity during flood. Rho coefficient is more than 0.50 indicating higher hydrological storage during floods [20].

TABLE 5
STREAM ORDER, STREAM NUMBER AND BIFURCATION RATIOS

	Su	Nu	Lu	RL	Rb	Nu-r	Rb*Nu-r	Lsm	Lurm	Rbwm
Kumari River Basin	I	1577	1042.86	0.45	4.08	1963	8009.04	0.66	1.83	4.11
	II	386	466.15	0.49	4.44	473	2100.1	1.21	2.19	
	III	87	230.40	0.71	3.12	115	358.8	2.65	2.21	
	IV	28	163.90	0.57	4.67	34	158.8	5.85	2.66	
	V	6	93.41	1.03	3	8	24	15.57	3.08	
	VI	2	95.95	0.17	2	3	6	47.97	0.34	
	VII	1	16.54	-	-	-	-	16.5	-	
	Total	2087	2109.21	3.42	21.31	2596	10656.7	90.45	12.31	

Su: Stream order, Nu: Number of streams, Lu: Stream length, RL: Stream length ratio (RL=Lu/Lu-1), Rb: Bifurcation ratios, Nu-r: Number of stream used in the ratios, Lsm: Mean stream length, Lurm: Mean stream length ratio, Rbwm: Weighted mean bifurcation ratio

8.2 Basin Geometry

8.2.1 Basin Area (A)

Basin area is an important parameter in morphometric analysis of the watershed. It denotes the length of the stream of the watershed. According to Schumm (1956), there are interesting relation between the area of watershed and total stream lengths in the watershed which are supported by the water contributing areas. Basin area has been extracted by using ILWIS 3.0 GIS software having an area of 1920 sq. km. (Table 6).

8.2.2 BasinPerimeter (p)

Basin perimeter determines the outer boundary of the watershed and it is important parameter in morphometry analysis. It is identified along the watershed and may be used as an indicator of size and shape of the watershed. Perimeter of Kumari basin is 298.3 km. (Table 6).

8.2.3 Length of the Basin (Lb)

Schumm (1956) defined the length of the basin as the longest dimension of the basin parallel to the main drainage line. According to Gregory the basin is the longest length of the basin in which one end being the mouth. As per Gardinier (1975), the basin length is the length of the line of a basin from the mouth to a point on the perimeter equidistant from the basin outlet in either direction. Length of Kumari river basin has been determined approximately 65.22 km (Table 6).

8.2.4 Length of Main Channel (Cl)

The length of the main channel is the longest watercourse from the outflow of the designated watershed to the upper limit of the watershed boundary [15]. Main channel length has been calculated using ILWIS 3.0 GIS software. The length of the main channel is 95.98 km (Table 6).

8.2.5 Length Area Relation (Lar)

Hack (1957) stated that for a large number of basins, the stream length and basin area is associated with a simple power function as follows: Lar = 1.4*A0.6 [21]. Lar value of Kumari watershed is 130.64 (Table 6).

8.2.6 Leminiscate's (K)

Chorley (1957) has used the Leminicate's value to compute the slope of the basin. Leminiscate's formula is K = Lb2/A, where Lb is the basin length in kilometer. Leminicate's value of Kumari watershed has been found 2.21 which show the watershed area occupies maximum area with large number of higher order streams.

8.2.7 Form Factor (Ff)

Horton stated that form factor is the ratio of area of basin to square of the basin length and it ranges from 0 to 1 (1 for a perfectly circular watershed). Lower value shows the elongated shape with longer duration flow. On the other hand higher value indicates circular shape with high peak flows of shorter duration. In the Kumari watershed, form factor is 0.45 (Table 6). It is little elongated shape basin.

8.2.8 Elongation Ratio (Re)

According to schumm (1956), elongation ratio is the ratio of a diameter of circular of the same area of the basin to the maximum basin length. The Re value ranges from 0 (highly elongated shape) to 1.0 (Perfectly circular shape). Shape of watershed variation may be categorized with the help of elongation ratio index i.e., circular (0.90 to 1.0), Oval (0.8 to 0.9), less elongated (0.7 to0.8), elongated (0.5 to 0.7) and more elongated (<0.5) for tectonically high active, active, slightly active [22]. Higher value of elongation ratio will be the more circular shape of the basin and vice-versa. Values close to 1.0 are typical of region of very low relief, whereas that the values of 0.6 to 0.8 are usually associated with high relief and steep ground slope [9]. The elongation ratio of Kumari watershed is 1.24 which shows less elongated basin in shape (Table 6).

8.2.9 Texture Ratio (Rt)

Texture ratio is the ratio between the first order stream and perimeter of the basin i.e., Rt = N1/p. it determines the underlying lithology, infiltration capacity and relief aspects of topography [23]. It is also an important as a morphometric parameter to determine the underground water recharge capacity of the watershed. Texture ratio of Kumari watershed is 5.29 (Table 6).

8.2.10 Fitness Ratio (Rf)

According to Melton (1957), fitness ratio is the main channel length to the perimeter of watershed. It is used for measure the topographical fitness. The fitness value of Kumari river basin is 0.32 (Table 6).

8.2.11 Wandering Ratio (Rw)

Smart and Surkan (1967) defined the wandering ratio as the main channel length and the valley length. It is the straight line distance from outlet of the basin and the farthest point on the ridge of the watershed [15, 21]. The wandering ratio of Kumari watershed is 1.47 (Table 6).

8.2.12 Watershed Eccentricity (T)

According to Black (1972) watershed eccentricity equation is

defined as follows

$$T = \frac{[(Lcm^2 - Wcm^2)]^{\wedge}0.5}{WCM} \qquad (2)$$

Where, T = Watershed eccentricity.
Lcm = Straight line distance from the watershed mouth to the ridge of the watershed through centre of the mass.
Wcm = Width of the watershed which perpendicular to Lcm at the centre of the mass.
Watershed eccentricity indicates the shape of the watershed to an ellipse for which the major axis is twice the minor axis. Watershed eccentricity of Kumari watershed is 1.94 (Table 6).

8.2.13 Sinousity Index(Si)

Sinuosity index indicates the pattern of channel of a drainage basin. It is the ratio of channel length and valley length which various form 1 to 4 or more. Sinuosity has been categorized that river's nature like straight having SI<1.05, small meandering 1.05 to 1.3 and meandering >1.5 [9]. Mueller (1968) theory has been used to calculate the sinuosity index in this paper and 1.04 sinuosity index has been found for Kumari watershed (Table 6) having straight channel.

8.2.14 Channel Index (Ci) and Vally Index (Vi)

Mueller (1968) stated that the river channel has been number of segments for determination of sinuosity parameter. The computation of channel index and valley index required channel length, length of valley and shortest distance from source to the outlet (Air distance) of the watershed. Channel index and valley index of Kumari river basin are 1.51 and 1.45 respectively (Table 6). Geomorphologist, Hydrologist and Geologist used the sinuosity index for interpreting the significance of streams in the evaluation of landscapes. Mueller

(1968) stated that topographic, hydraulic and sinuosity index are the important parameter for the flow of natural stream coarse and the development of flood plains and it has been compared. Topographic, hydraulic and sinuosity index of Kumari river basin are 88.24%, 11.76% and 1.04 respectively (Table 6).

TABLE 6
BASIN GEOMETRY OF KUMARI WATERSHED

Sl No.	Stream Property	Formula/ Method	References	Kumari Watershed
1	Basin Length (Lb) in kms.	GIS Software	Schumm (1956)	65.22
2	Basin Width (W) in kms.	GIS Software	Schumm (1956)	40.51
3	Mean Basin Width (Wb) in kms.	GIS Software	Schumm (1956)	29.824
4	Basin Perimetre (P) in kms.	GIS Software	Schumm (1956)	298.3
5	Basin Area (A) in sq. kms	GIS Software	Schumm (1956)	1920
6	Relative Parametre (Pr)	Pr=A/P	Schumm (1956)	6.44
7	Length Area Relation (Lar)	$Lar=1.4*(A)^{0.6}$	Hack (1957)	130.64
8	Lemniscate's (k)	$k=(Lb)^2/A$	Chorely (1957)	2.22
9	Form Factor Ratio (Ff)	$Ff=A/(Lb)^2$	Horton (1932)	0.45
10	Shape Factor Ratio Sf)	$Sf=(Lb)^2/A$	Horton (1932)	2.22
11	Elongation Ration (Re)	$Re=2/Lb*(A/\pi)^{0.5}$	Schumm (1956)	1.24
12	Circulatory Ratio (Rc)	$Rc=12.57*(A/P^2)$	Miller (1960)	0.27
13	Compactness Coefficient (Cc)	$Cc=0.2841*P/A^{0.5}$	Gravelius (1914)	1.93
14	Fitness Ratio (Rf)	Rf=Cl/P	Melton (1957)	0.32
15	Wandering Ratio (Rw)	Rw=Cl/Lb	Smart & Surkan (1967)	1.47
16	Watershed Eccenticity (T)	$T=((Lb^2-W^2)^{0.5})/W$	Black (1972)	1.94
17	Down Vally distance (Vd)	GIS Software	Mueller (1968)	16.54 (7th order stream length)
18	Main Channel Length (Cl) in kms	GIS Software	-	95.98
19	Valley Length (Vl) in kms	GIS Software	-	93.262
20	Minimum Aerial Distance (ADM) in kms.	GIS Software	-	63.58
21	Channel Index (Ci)	Ci=Cl/ADM (H & TS)	Mueller (1968)	1.51
22	Valley Index (Vi)	Vi=Vl/ADM (TS)	Mueller (1968)	1.45
23	Standard Sinuosity Index (Ssi)	Ssi=Ci/Vi	Mueller (1968)	1.04
24	Hydraulic Sinuosity (Hsi) %	His=((Ci-Vi)/(Ci-1))*100	Horton (1945)	11.76
25	Topographic Sinuosity Index (Tsi) %	Tsi=((Vi-1)/(Ci-1))*100	Schumm (1965)	88.24
26	Length of Overland Flow (Lg) in kms.	Lg=(A/2)/Lu	Horton (1945)	0.45
27	Texture Ratio (Rt)	Rt=N1/P	Schumm (1965)	5.29

8.3 Drainage Texture Analysis

8.3.1 *Stream Frequency (Fs)*

Horton (1932) introduces the drainage frequency that means stream frequency. It is defined the number of stream segments per unit area. In the Kumari watershed, the stream frequency is 1.09 (Table 7). Higher drainage frequency represents larger surface runoff, steeper ground surface, impermeable surface, sparse vegetation and high relief condition. Lower drainage frequency indicates high permeable geology and low relief. Higher drainage frequency also indicates the early stage of the fluvial cycle or rejuvenated erosional activities [24].

8.3.2 *Drainage Density (Dd)*

Drainage density defined as the length of all stream order per unit basin [19]. It shows the landscape dissection index and runoff potential [25]. Drainage density represents the infiltration capacity and cover of vegetation of the catchment area [26]. Volume of water and sediment has been drained out from the catchments depending on drainage density [27]. Drainage density shows the groundwater potentiality of the catchment area because it is related with surface runoff and permeability. Lower drainage density indicates the permeable subsoil material, dense vegetation and low relief [28]. Higher drainage density shows the impermeable subsurface material, sparse vegetation and mountain relief. Lower to higher drainage density leads to coarse and fine drainage texture. The drainage density of the Kumari watershed is 1.09 km per sq. km (Table 7) which represents gentle to steep slope terrain, medium dense vegetation and less permeable wit medium rainfall.

8.3.3 *Drainage Texture (Dt)*

Drainage texture is the product of drainage density and drainage frequency and it is controlled by climate, rainfall, vegetation, lithology, soil type, infiltration capacity and stage of development by vegetation cover [29]. Drainage texture has been determined by vegetation cover, type and density [30]. Unprotected soft and weak rocks produce fine texture whereas massive and resistant rocks produce coarse texture. Vegetation and climate control the texture of rocks [31]. According to Horton (1945), infiltration capacity is an important factor which influences the drainage texture. It has been classified into five different classes such as very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8) [23, 29]. In the Kumari watershed, drainage texture was found 0.99 having very coarse drainage texture (Table 7).

8.3.4 Constant of Channel Maintenance (Cc)

Constant of channel maintenance defined as the requirement of units of watershed surface to bear one unit of channel length. Schumm (1956), Cc is the inverse relation with drainage density having the dimension of length as aproperty termed constant of channel maintenance. Higher value of Cc indicates lower the drainage density. Channel constant maintenance value of Kumari watershed is 0.95 which shows the strong control of lithology with a surface of high permeability and it also represents higher infiltration rates, moderate surface runoff and less dissection.

8.3.5 Drainage Intensity (Di)

Faniran (1968) defined drainage intensity as the ratio of the stream frequency and drainage density. Drainage density value of the study area is 1.03 (Table 7). Higher value of drainage intensity indicates little effect by the drainage density and frequency on the extent to which the surface has been lowered by agents of denudation Having lower values of drainage density, stream frequency and drainage intensity are not quickly removed water from watershed causes high flooding, gully erosion and landslide.

8.3.6 Infiltration Number (If)

The infiltration number is the product of drainage density and drainage frequency which gives an idea about the infiltration characteristics of the watershed. Higher value of infiltration number shows the lower infiltration and higher surface runoff. Infiltration number of Kumari watershed is 1.19% (Table 7) which indicates medium infiltration and medium surface runoff of this watershed.

8.3.7 Drainage Pattern (Dp)

Drainage pattern reflects the influence of slope, lithology and structure of the study area which helps to identify the stage in the cycle of erosion. Drainage pattern gives an idea about geology, the strike and dip of depositional rocks, existence of faults and other information about geological structures from the drainage pattern. Howard (1967) stated that drainage pattern has been controlled by the climate, permeability of rocks, vegetation and relief ration etc. Dendritic drainage pattern has been identified in the Kumari Watershed and it shows fairly homogeneous rock without control by the underlying geologic structures.

8.3.8 Length of Overland Flow (Lg)

Length of overland flow is the half of reciprocal of drainage density which is the length of water flow over the ground surface before it is localized into main stream. It effects the hydrological and physiographic development of the drainage basin [19]. When rainfall intensity exceeds than soil infiltration capacity of the ground surface, the excess water flows over the land surface as overland flow [32]. It is controlled by the type of rock permeability, climate regime, vegetation cover, relief and duration of erosion [33]. The calculated value of overland flow of this watershed is 0.45 (Table 8). Lower value of overland flow indicates low permeability steep to very steep slopes and high surface runoff [34]. As per overland flow value, Kumari watershed is under medium permeability, gentle slope and medium surface runoff.

TABLE 7

DRAINAGE TEXTURE OF KUMARI WATERSHED

Sl No.	Stream Property	Formula/Method	Refrences	Kumari Watershed
1	Drainage Density (Dd) in km/kms2	Dd=Lu/A	Horton (1932)	1.09
2	Drainage Texture (Dt)	Dt=Nu/P	Horton (1945)	0.99
3	Stream Frequency (Fs)	Fs=Nu/A	Horton (1932)	1.09
4	Length of Overland Flow (Lg) in kms	Lg=(A/2)/Lu	Horton (1945)	0.45
5	Infiltration Number (If)	If=Fs*Dd	Schumm (1956)	1.19
6	Constant of Channel Maintenance (kms2/km)	C=1/Dd	Schumm (1956)	0.95
7	Drainage Intensity (Di)	Di=Fs/Dd	Faniran (1968)	1.03
8	Drainage Pattern (Dp)	GIS Software	Horton (1932)	Dendritic

8.4 Relief Characteristics

8.4.1 Relief Ratio (Rhl)

Basin relief defined as between the elevation of highest point of the watershed and lowest elevation on the valley floor. Relief ratio is the ratio of total relief of a basin to the longest dimension of the basin parallel with the main drainage line [13]. Schumm (1956) stated that relief ratio is a close relation with the hydrological characteristics. Sediments loose deposited per unit area are associated with the relief ratio. Lower value of relief ratio indicates the resistant basement rocks of the drainage basin and low degree of gradient [23] and represents intensity of erosion progress operating on slopes of the basin [34]. Computed value of relief ratio is 8.48 of Kumari river basin (Table).

8.4.2 Relative Relief (Rhp)

Relative relief is the difference between highest elevation on the watershed perimeter and the lowest elevation on the mouth of the stream of the watershed. According to Schumm (1956), basin relief has been used for computation relief ratio. Melton's (1957) formula has been used for computing relative relief as give below.

$$Rhp = \frac{H*100}{p} \quad (3)$$

Where, Rhp = Relative relief
H = Total basin relief in meter
P =Perimeter of the watershed in meter

Relative relief of Kumari watersheds has been determined 185.38 meter (Table 8)

8.4.3 Absolute Relief (Ra)

Absolute relief is defined as the difference between elevation of the highest point of the watershed and sea level. Ra value of this warershed is 609 meter (Table 8).

8.4.4 Channel Gradient (Cg)

Channel gradient is an important morphometric parameter for study the geomorphological characteristics in drainage system. It is the total drops in elevation from source to the mouth in the river channel. It represents the longitudinal sequential change of river through the presence of waterfalls, step pools and ripple pools etc. channel gradient of Kumari river basin was calculated to be 3.67 (Table 8).

8.4.5 Ruggedness Number (Rn)

Ruggedness number is defined as the combines of slope steepness and drainage length indicating the extent of the instability of land surfaces [36]. Rn value of Kumari watershed has been calculated and to be found 0.61(Table 8). Lower Rn value represents less soil erosion prone area and has intrinsic structural complexity in association with relief and drainage density.

8.4.6 Melton Ruggedness Number (MRn)

MRn is a relief ruggedness that indicates the slope index within the watershed [37]. Lower value of MRn represents the normal flow in main stream without more debris flow and higher value represents rapid flow in the main stream with more debris in rugged hilly or mountain area. MRn value of Kumari watershed is 0.54 which indicates normal water flow in the main river with little debris (Table 8).

8.4.7 Dissection Index (Dis)

Dissection index is the ratio of relative relief made by the river and the highest elevation from the sea level of the study area. Morphometry physiographic attribute and magnitude of dissection has been determined by the dissection index [38]. Generally, dissection index value has been varied from 0 to 1 but there are some exceptional cases such as vertical cliffs, escarpment of hilly slope and at sea shore. Lower value of dissection indicates old stage [39] of basin and less degree of dissection. Dis value of Kumari watershed is 0.91 which represent late youth stage (Table 8).

8.4.8 Gradient Ratio (Rg)

Gradient ratio represents the channel slope and it has assessed the runoff volume and velocity of the watershed [40]. Calculation of gradient ratio formula has been given below.

$$Rg = \frac{(Es-Em)}{Lb} \quad (4)$$

Where, Rg = Gradient ratio
Es = Elevation at the source
Em = Elevation at the mouth
Lb = Basin length

Lower values of Rg indicate the moderate relief terrain and main stream flow through plateau. In the Kumari watershed, gradient ratio value is 6.2 which indicate moderate relief terrain of the study area (Table 8).

TABLE 8
RELIEF ASPECTS OF KUMARI WATERSHED

Sl No.	Relief Property	Formula/Method	References	Kumari Watershed
1	Maximum Height of the Basin in Meter (Z)	GIS Software	-	609
2	Height of Basin Mouth in Meter (z)	GIS Software	-	56
3	Total Basin Relief (H) in Meter	H=Z-z	Strahler (1952)	553
4	Rilef Ratio (Rhl)	Rhl=H/Lb	Schumm (1956)	8.48
5	Maximum Relief (ZI)	GIS Software		609
6	Absolute Relief (Ra)	GIS Software		609
7	Relative Relief Ratio (Rhp)	Rhp=H*100/p	Melton (1957)	185.38

8	Dissection Index (Dis)	Dis=H/Ra	Singh & Dubey (1994)	0.91
9	Gradient Ratio (Rg)	Rg=Es-Em/Lb	Sreedevi et al, (2009)	6.2
10	Watershed Slope (Sw)	Sw=H/Lb	Sreedevi et al, (2005)	8.48
11	Ruggedness Number (Rn)	Rn=Dd*(H/1000)	Patton & Baker (1976)	0.61
12	Melton Ruggedness Number (MRn)	$MRn=(H/A)^{0.5}$	Melton (1965)	0.54
13	Channel Gradient in m/kms. (Cg)	Cg=H/{(π/2)*Clp}	Broscoe (1959)	3.67

9 Conclusion

Remote sensing data and GIS based technique have been used for assessing the drainage morphometry in this study and it is more appropriate than conventional method. Drainage is the important element for the study of landform. Its distributional patterns, density, frequency and other basin parameters have been computed and analyzed quantitatively. Various morphometric parameters of Kumari river basin has been analyzed such as drainage density, drainage frequency, bifurcation ratio, stream order, basin slope, circulatory, sinuosity, infiltration and relief ratio etc. Kumari river basin represents dendritic drainage pattern with seventh order drainage. The bifurcation varies from 2 to 4.67 and weighted mean bifurcation ratio is 4.11 which indicate less structural disturbances and drainage pattern have not been distorted due to geological structural rocks of the watershed. Lower value of bifurcation ratio also indicates that the water will take longer time to reach the outlet. Drainage texture of the watershed is to be found 0.99 which indicates very coarse drainage texture having gentle to steep slope terrain, moderate vegetation and less permeable rocks with medium rainfall. Infiltration number of this watershed is 1.19 which shows the lower infiltration and high surface runoff. Rho value of Kumari watershed is 0.17 which indicates lower hydrology capacity during floods. Texture ratio of Kumari river basin is 5.29 which show moderate groundwater recharge capacity. Form factor ratio of this watershed is 0.45 which represents neither elongated nor circular shape having medium duration of flow of water. Length of overland flow is 0.45 which indicates medium permeability of rocks with medium surface runoff. All the morphometric parameters have been extracted from the SRTM base DEM data using Rs and GIS platform and it provides very important input parameters for the study of watershed prioritization and planning. The collected information from the watershed can be used for the management water harvesting and it also helps for planning decision and flood disaster risk reduction. This study reveals that the GIS is very useful for morphometric analysis of the basin.

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References

[1] P. K. Rai, V. H. Mishra and K. Mohan, “A Study of Morphometric Evaluation of the Son Basin, India Using Geospatial Approach”, Remote Sensing Applications: Society and Environment, vol. 7, pp. 9-2, Aug. 2017.

[2] S. S. Vittala, S. Gobindaiah and H. H. Gowda, “Morphometric Analysis of Sub-watersheds in the Pavagada Area of Tumkur District, South India using Remote Sensing and GIS Techniques”, Journal of the Indian Society of Remote Sensing, vol. 32, no. 4, pp. 351-362, Dec. 2004.

[3] H. Chandrashekar, K. V. Lokesh, M. Sameena, J.Roopa and G. Ranganna, “Proc. Int. Conf. on Water Resources, Coastal and Ocean Engineering (Mangalore)”, ed G S Dwarakish (Elsevier Procedia),vol. 4, pp. 1345-1353, 2015.

[4] J. Yangchan, A. K. Tiwari and Sood, “Morphometric Analysis of Drainage Basin through GIS: A Case Study of Sukhna Lake Watershed in lower Shiwalik, India”, International Journal of Science and Engineering Research, vol. 6, no. 2, pp. 1015-1023, Feb. 2015.

[5] H.Vijith and R. Satheesh, “GIS Based Morphometric Analysis of Two Major Upland Sub-Watersheds of Meenachil River in Kerala”, Journal of the Indian Society of Remote Sensing, vol. 34, no. 2, pp. 181-185, June 2006.

[6] E. Butter and R.E. “Marsell, Cloud Burst Floods in Utah 1939-69”, Utah Division of Water Resources Cooperative Investigation Report, Vol. 11, pp. 103. 1972.

[7] A. K. Thakkar and S. D. Dhiman, “Morphometric analysis and prioritization of miniwatersheds in Mohr Watershed, Gujarat Using Remote Sensing and GIS Techniques”, Journal of the Indian Society of Remote Sensing, vol. 35, no. 4, pp. 313-321, Dec. 2007.

[8]]. A. Dunn and A. K. Dey, “The Geology and Petrology of eastern Singhbhum and Surrounding Areas”. Geological Survey of India Mem, vol. 69, no. 2, pp. 281-456, 1942.

[9] A. N. Strahler, and V. T. Chow, “Quantitative Geomorphology of Drainage Basins and Channel Network” Edited In Ven Te Chow, Handbook of Applied Hydrology, McGraw Hill Book Company, New York. Pp. 39-76, 1964.

[10] S. N. Mura, “Identification of Water Resource Potential Zones of Karu River Basin Using Remote Sensing and GIS techniques in Purulia District, West Bengal, India”, Infokara Research Journal, vol. 9, no. 2, pp. 589-605, 2020.

[11] P. K. Rai, V.N. Mishra and K. A. Mohan, “Study of Morphometric Evaluation of the Son Basin, India Using Geospatial Approach”, Re-

mote Sensing Application: Society and Environment, vo. 7, pp. 9-20, Aug. 2017.

[12] D.R. Montgomeryand, W.E. DIETRICH, “Where do channel begins?” In:- Drainage basin morphometry for identifying zones for artificial recharge: A case study from Gagas River Basin, India”, 2011.

[13] R.E. Horton, “Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology” Bulletin of the Geological Society of America, vo. 56, pp. 275-370, 1945.

[14] E.B. Eze and j. Efiong, “Morphometric Parameters of the Calabar River Basin: Implication for hydrologic processes” Journal Geography and Geology, vol. 2, no. 1, pp. 18-26, Jan. 2010.

[15] K. Pareta, “Geo-environmental and Geo-hydrological Study of Rajghat Dam Sagar, Madhya Pradesh using Remote Sensing techniques”, International Journal of Scientific and Engineering Research, vol. 2, no. 8, pp. 1-8, Aug. 2011.

[16] G. P. Obi, G. P. Reddy, A. K. Maji and K. S. Gajbhiye, “GIS for Morphometric Analysis of Drainage Basin”, Journal of Geological Survey of India, vol. 11, no. 4, pp. 9-14, Sept. 2002.

[17] R. Chopra and D.D. Sharma, “Morphometric Analysis of Sub-Watersheds in Gurudaspur District, Punjab, using Remote Sensing and GIS Techniques”, Journal of Indian Society of Remote Sensin, vol. 33, no. 4, pp. 531-539, Dec. 2005.

[18] K.I. KELSON and S.G. WELLS, “Geologic influences on fluvial hydrology and bed-load transport in small mountainous watershed, northern New Mexico, USA. In:- Drainage basin morphometry for identifying zones for artificial recharges: A case study from Gagas River Basin, India”, 2011.

[19] R.E. Horton, “Erosional Development of Streams and their Drainage Basins; Hydrology Approach to Quantitative Methodology”, Bulletin of the Geological Society of America, vol. 56, pp. 275-370, Mar. 1945.

[20] S. Sandeep, “Assessment of Morphometric Characteristics of Chakrar Watershed in Madhya Pradesh India”, Applied Water Science, vol. 7, no. 5, pp. 2089-2102, Feb. 2016.

[21] K. Pareta and U. Pareta, “Quantitative Geomorphological Analysis of a Watershed of Ravi River Basin, HP India” International Journal of Remote Sensing and GIS, vol. 1, no. 1, pp. 41-56, May, 2012.

[22] S. K. Sharma, S. Gajbhiye, R.K. Nema and S.Tignath, “Assessing Vulnerability to Soil Erosion of a Watershed of Tons River Basin using Remote Sensing and GIS”, International Journal of Environmental Research and Development, vol. 4, no. 2, pp. 153-164, 2014.

[23] P. K. Rai, R. S. Chandel, V. N. Mishra and P. Singh, “Hydrological Inferences through Morphometric Analysis of lower Kosi River Basin of India for Water Resource Management Based on Remote Sensing Data”, Applied Water Science (Springer), vol. 8, no. 1, pp. 1-16, Jan. 2018.

[24] K. N. Singh, “Quantitative Analysis of Landforms and Settlement Distribution in Southern Uplands of Eastern Uttar Pradesh (India)”, Vimal Prakashan, Varanasi, 1980.

[25] R.J. Chorley, “Introduction to Physical Hydrology”, Methuen and Co. Ltd. Suffolk, pp. 211, 1969.

[26] Z. Macka, “Determination of Texture of Topography from Large Scale Contour Maps”, Geografski Vestnik, vol. 73, no. 2, pp. 53-62, Jan. 2001.

[27] H. Ozdemir and D. Bird, “Evaluation of Morphometric Parameters of Drainage Network Derived from Topographic Maps and DEM in Point of Floods”, Environmental Geology, vol. 56, no. 7, pp. 1405-1415, Feb. 2009.

[28] S. K. Nag, “Morphometric Analysis using Remote Sensing Techniques in the Chaka Sub-watershed, Purulia district, West Bengal”, Journal of Indian Society of Remote Sensing, vol. 26, no. 1&2, pp. 69-76. Mar. 1998.

[29] K. G. Smith, “Standard for Grading Texture of Erosional Topography”, American Journal of Science, vol. 248, no. 9, pp. 655-668, Sept. 1950.

[30] V. S. Kale and A. Gupta, “Introduction to Geomorphology” Academic (India) Publishers, New Delhi, 2001.

[31] J. C. Dornkamp and C. A. M. King, “Numerical Analyses in Geomorphology”, An introduction. St. Martins Press, New York, vol. 72, pp. 372, 1971.

[32] R. Suresh, “Soil and Water Conservation Engineering – Watershed Concept and Management” Standard Publishers Distributors, New Delhi, 2010.

[33] S. A. Schumm, “Evolution of Drainage Systems & Slopes in Badlands at Perth and Boy, New Jersey”, Bulletin of the Geological Society of America, vol. 67, pp. 597-646, pp. May, 1956.

[34] K. S. Muthukrishnan and K. K. Banu, “Drainage Morphometry Evaluation for Kodavanar Sub-basin to Understand the Interrelationship in Morphological Systems and in Process-Response Systems”, International Journal of Geomatics and Geoscience, vol. 3, no. 4, pp. 692-707, Dec. 2013.

[35] A. Javed, M.Y. Kanday and R. Ahmed, “Prioritization of Sub-watershed Based on Morphometric ad Landuse Analysis using Remote Sensing and GIS Techniques” Journal of Indian Society of Remote Sensing, vol. 37, no. 2, pp. 261. Oct. 2009.

[36] A. N. Strahler, “Quantitative Analysis of Watershed Geomorphology”, Transaction American Geophysical Union, vol. 38, no. 6, pp. 9013-920, Dec. 1957.

[37] M. A. Melton, “The Geomorphic and Paleoclimatic Significance of Alluvial Deposits in Southern Arizona” J Geol, vol. 73, no. 1, pp. 1-38, Jan. 1965.

[38] S. Singh and A. Dubey, “Geo-environmental Planning of Watersheds in India. Allahabad” Chugh Publication, pp. 28-69, 1994.

[39] M. Deen, “Geomorphology and Landuse: A Case Study of Mewat”, Thesis (PhD), JNU, New Delhi, 1982.

[40] P. D. Sreedevi, S. Owais, H. H. Khan and S. Ahmed, “Morphometric Analysis of a Watershed of South India using SRTM Data and GIS”, Journal of Geological Society of India, vol. 73, no. 4, pp. 543-552. May, 2009.

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