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MORPHMETRIC ANALYSIS OF UPPER SABARMATI DRAINAGE BASIN IN GUJARAT USING GEOGRAPHICAL INFORMATION SYSTEM

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ABSTRACT

The study of morphometric analysis of Sabarmati drainage basin has been conducted based on the secondary source, the SRTM data has been downloaded from GLCF website. The downloaded data has been analyzed using Arc GIS software, the study Linear, Relief and Arial aspects of drainage basin retrieved that, total numbers of streams are 1463, in that 4145 are first orders, 255are second orders, 56 are third orders and 8 are fourth order streams. The streams have been formed in dendritic drainage pattern. The length of stream segments is maximum for first order stream and decreases as the stream order increases. The result of drainage density shows the value 4.2 per square kilo meters in study area, which suggesting that the area has highly, density may indicate one or more of the following: a "mature", well developed channel system exists, surface runoff moves rapidly from hill slopes (overland flow) to channels, thin/deforested vegetation cover, basin rocks/soils/surface has generally low infiltration rate (highly impervious geology or abundant impervious manmade surfaces). It also describes the texture of a stream network.

KEYWORDS: Morphometric, Watershed, Drainage Basin, Flow Accumulation, Digital Elevation Model.

Morphometry is an essential means in geomorphic analysis of an area. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1966). Morphometric methods, though simple, have been applied for the analysis of area-height relationships, determination of erosion surfaces, slopes, relative relief and terrain characteristics as a whole. The morphometric analyses of different basins have been done by various scientists using conventional methods (Horton, 1945; Smith, 1950; Strahler, 1957) and earth observation data and GIS methods (Narendra and Rao, 2000,). The use of earth observation data and GIS techniques in morphometric analysis have emerged as powerful tools in recent years particularly for remote areas. In the present study using Earth Observation Data and GIS technology have been effectively used to compute basin morphometric characteristics by taking linear, areal and relief parameters of the Sabarmati river basin. Such analysis aided inunderstanding the hydrological, geological and topographical characteristics of the very complicated and unique. Geographical description of the basin Sabarmati River is one of the major West flowing Interstate Rivers in India, draining into the Gulf of Khambhat. The basin is bounded by Aravalli hills in the North and North-East, by ridge separating it from basins of minor streams and draining into Rann of Kachchh and Gulf of Khambhat in West and by Gulf of Khambhat in the South. The basin has a maximum length of 300 km and maximum width of 105 km. It is triangular in shape with the main river as the base and the source of the Watrak as the apex point. It originates in the Aravalli hills at latitude 240 40' N and longitude 730 20' E in the Rajasthan State at an elevation of 762 m above m.s.l. The Sabarmati River has a length of 371 kms and the drainage area is of 21674 sq km. The state wise distribution is shown below.

The Sabarmati River with its origin in Rajasthan flows generally in South - West direction. It enters the Gujarat State and passes through the plains and continues to flow in the same direction and joins the Gulf of Khambhat in the Arabian Sea.At the 51 km of its run, the river is joined by the Wakal on the left bank near village Ghanpankari. Flowing generally in the South - West direction at 67th km of its run, it receives the Sei on the right bank near Mhauri and then the Harnav on the left bank at about 103 km. From respective sources beyond this confluence, Sabarmati flows through the Dharoi gorge. Emerging from the gorge it passes through the plains and is joined on its left bank at about 170 km from its source by the Hathmati, which is its major tributary. Continuing to flow in South - West direction, the river passes through Ahmedabad and about 65 km downstream, another major tributary, Watrak joins it on the left bank, flowing for a further distance of 68 km, the river outfalls in the Gulf of Khambhat in Arabian Sea.

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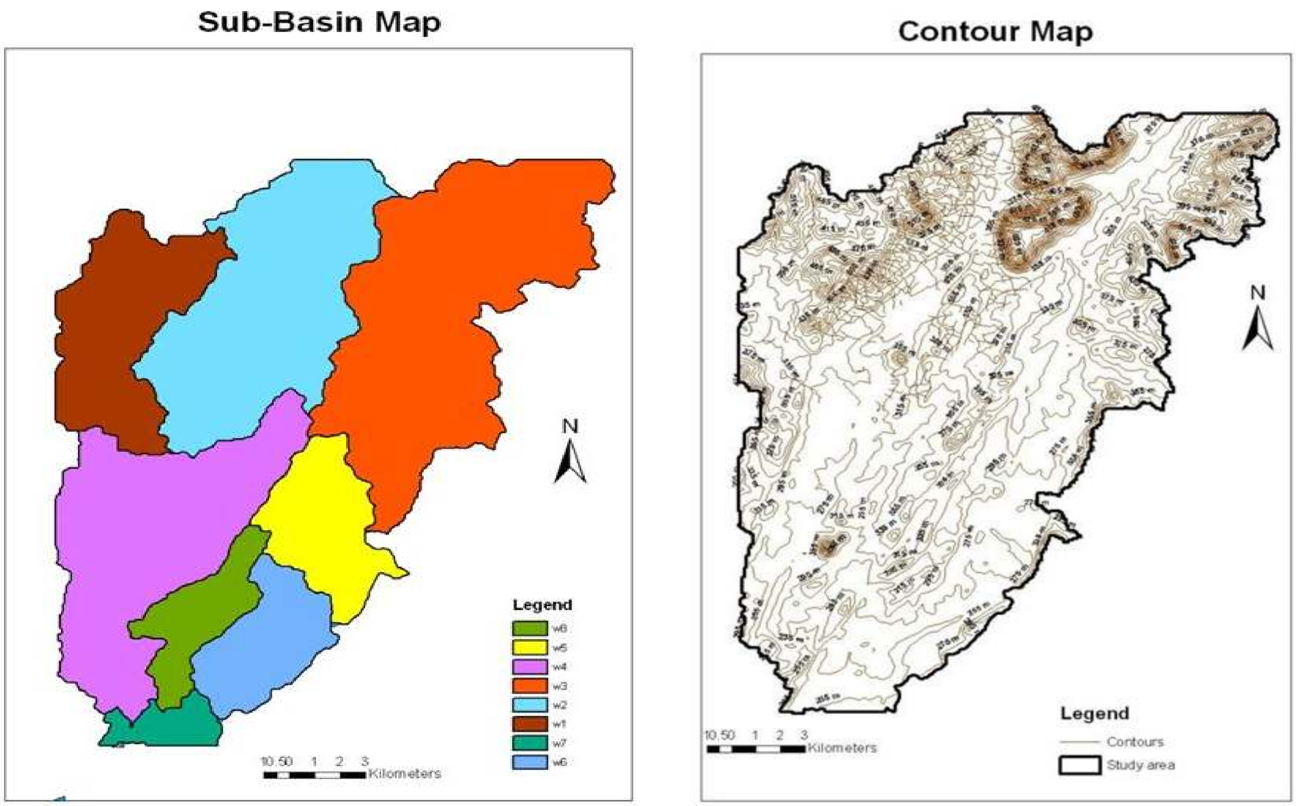

Figure 1: Sub-basin map and Contour map of study area

MATERIALS AND METHODS

Delineation of the Sabarmati river basin and preparation of drainage map is based on geo-codedResourcesat-1 LISS-III of 2005-06 on 1:50,000 scale and Digital Elevation Model (DEM)generated from Shuttle Radar Terrain Mapper (SRTM) data. Various morphometric parameters namely – stream order (Nu), stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb) mean bifurcation ratio (Rbm), drainage density (D),stream frequency (Fs), form factor (Rf), circulatory ratio (Rc), elongation ratio (Re) length ofoverland flow (Lg) have been computed (Table 1) using GIS tools.

RESULTS AND DISCUSSION

The various morphometric parameters of the Sabarmati river basin have been computed and summarized as follows:

Linear Aspects

Drainage network of the Sabarmati River basin is presented in Figure 1. Stream links (the different drainage lines) and the nodes (the stream junctions/confluences) characterise 'Linear aspects' of the basin. The linear aspects include the stream order (u), stream length (Lu), mean stream length (Lsm), stream length ratio (RL) and bifurcation ratio (Rb), were determined and results have been presented in Table 1.

Stream Order (u)

Table 1: Formulae adopted for computation of morphometric parameters

Sl. No	Morphometric Parameters	Formulae	Reference
1	Stream order (u)	Hierarchical rank	Strahler (1964)
2	Stream length (Lu)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm=? Lu /Nu Where, Lsm = Mean stream length ? Lu =Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'	Strahler (1964)
4	Stream length ratio (RL)	RL = Lu /Lu -1 Where, RL = Stream length ratio Lu =The total stream length of the 'u' Lu – 1 = The total stream length of its next lower order	Horton (1945)
5	Bifurcation ratio (Rb)	Rb = Nu / Nu +1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of the order 'u' Nu +1= Number of segments of the next higher order	Schumn (1956)
6	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
7	Stream frequency (Fs)	Fs = Nu /A Where, Fs = Stream frequency Nu = Total no. of streams of all orders A = Area of the basin (km2)	Horton (1932)
8	Drainage texture (Rt)	Rt = Nu / P Where, Rt = Drainage texture Nu = Total no. of streams of all orders P = Perimeter (km)	Horton (1945)
9	Form factor (Rf)	Rf = A / Lb2 Where, Rf = Form factor A = Area of the basin (km2) Lb2 = Square of basin length	Horton (1932)
10	Circularity ratio (Rc)	Rc = 4*Pi*/P2 Where, Rc = Circularity ratio Pi = 'Pi' value i.e., 3.14 A = Area of the basin (km2) P2 = Square of the perimeter (km)	Miller (1953)
11	Elongation ratio (Re)	Re = 2 / Lb Where, Re = Elongation ratio A = Area of the basin (km2) Pi = 'Pi' value i.e., 3.14 Lb = Basin length	Schumn (1956)

Ranking of streams has been carried out based on the method proposed by Strahler (1964). The smallest fingertip tributaries are designated as order 1. Where the two first-order channels join, a channel segment of 2nd order is formed and so forth. The trunk stream through which all discharge and sediments pass is therefore the stream segment of the highest order. Altogether, *1463* number of streams were identified, out of which *4145* are of 1st order, *255*are of 2nd order, *56* are of 3rd order.

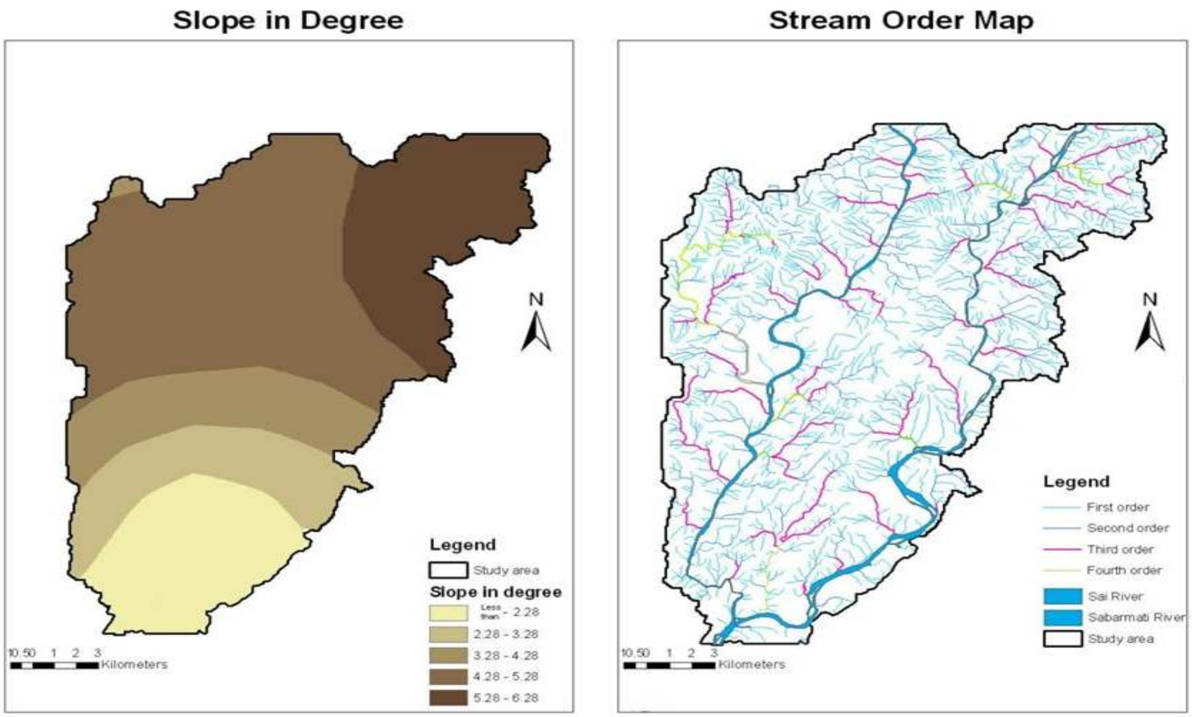

Figure 2: Slope map and Stream order map of study area

Stream Length (Lu)

Stream length is measured from the farthest drainage divide to the mouth of a river, based on the law proposed by Horton (1945). Stream length is one of the significant features of the basin as it reveals surface run-off characteristics. Streams of relatively smaller lengths indicate that the area is with high slopes. Longer lengths are indicative of flatter gradient. Usually, the total length of stream segments is highest in first order streams, and it decreases as the stream order increases in the present case. This brings out strong assumption that the basin is subjected to erosion and also that some areas of the basin are characterized by variation in lithology and topography (Singh and Singh, 1997; Vittala et al., 2004 and Chopraet al., 2005).

Table 2: Stream length in km (Lu)

Sr. No.	Watershed Name	First Order	Second Order	Third Order	Fourth Order	Fifth order	Total
1	Watershed 1	77.76	23.62	10.20	10.74	0	122.32
2	Watershed 2	126.17	41.45	17.53	0.00	0	185.16
3	Watershed 3	188.70	54.77	31.70	5.22	0	280.37
4	Watershed 4	107.97	36.82	22.32	3.39	0	170.50
5	Watershed 5	39.02	10.83	3.77	1.22	0	54.83
6	Watershed 6	24.61	5.91	4.66	0.00	0	35.18
7	Watershed 7	6.41	0.64	0.00	0.00	0	7.05
8	Watershed 8	29.29	5.90	9.00	4.78	0	48.96

Mean Stream Length (Lsm)

Mean stream length (Lsm) is a characteristic property related to the drainage network components and its associated basin surfaces (Strahler, 1964). This has been calculated by dividing the total stream length of order (u) by the number of streams of segments in that order (Table 3). It is seen that Lsm values exhibit variation from 1.28 to 43.72. This deviation might be due to change in topographic elevation and slope of the basin.

Table 3: Mean Stream Length (Lsm)

Sr. No.	Watershed Name	First Order	Second Order	Third Order	Fourth Order	Fifth order
1	Watershed 1	0.50	0.62	1.70	10.74	0
2	Watershed 2	0.56	0.74	1.35	0.00	0
3	Watershed 3	0.51	0.71	1.76	1.74	0
4	Watershed 4	0.49	0.82	2.23	1.70	0
5	Watershed 5	0.64	0.72	1.26	1.22	0
6	Watershed 6	0.60	0.74	1.55	0.00	0
7	Watershed 7	0.46	0.64	0.00	0.00	0
8	Watershed 8	0.47	0.42	3.00	4.78	0

Stream Length Ratio (RL)

Stream length ratio (RL) is the ratio of the mean length of the one order to the next order of the stream segments. Total stream length of a given order is inversely related to stream order,i.e., total stream length decreases from the lower order to the successively higher orders. This change might be a tribute to variation in slope and topography, indicating the youth stage of geomorphic development in the streams of the study area (Singh and Singh, 1997 and Vittala et al., 2004).

Table 4 Stream Length Ratio

Sr. No.	Watershed Name	II/I	III/II	IV/III	V/IV	Average
1	Watershed 1	1.23	2.73	6.32	0	3.43
2	Watershed 2	1.33	1.82	0.00	0	1.57
3	Watershed 3	1.39	2.48	0.99	0	1.62
4	Watershed 4	1.66	2.73	0.76	0	1.72
5	Watershed 5	1.13	1.74	0.97	0	1.28
6	Watershed 6	1.23	2.11	0.00	0	1.67
7	Watershed 7	1.39	0.00	0.00	0	1.39
8	Watershed 8	0.89	7.12	1.59	0	3.20

Bifurcation Ratio (Rb)

According to Schumm (1956), the term bifurcation ratio may be defined as the ratio of the number of the stream segments of given order to the number of segments of the next higher 651 orders. Bifurcation ratio shows a small range of variation for different regions or for different environments except where the powerful geological control dominates (Strahler, 1957). The Rb values of study area (Table 5) indicate that there is a uniform decrease in Rb values from the first order streams to the fourth order streams. But an increase in the Rb values is noticeable from the fourth to sixth order streams. The Rb values then suddenly decrease from the sixth to the eighth order. These differences are depending upon the geological and lithological development of the drainage basin (Strahler, 1964). In the study area, the higher values of Rb indicate a strong structural control in the drainage development whereas thelower values indicate that some of the area in the basin is less affected by structural disturbances (Stahler, 1964; Nag, 1998; Vittala et al., 2004 and Chopra etal., 2005). The Rbvalues in the study area range from 1.00 to 5.80 indicating that the basin is largely controlled by structure (Strahler, 1957).

Table 5: Linear Aspect of the Sabarmati

Sr. No.	Watershed Name	I/II	II/III	III/IV	IV/V	Bifurcation Ratio	Mean Bifurcation Ratio
1	Watershed 1	4.05	6.33	6.00	0.00	16.39	5.46
2	Watershed 2	4.04	4.31	0.00	0.00	8.34	4.17
3	Watershed 3	4.78	4.28	6.00	0.00	15.06	5.02
4	Watershed 4	4.87	4.50	5.00	0.00	14.37	4.79
5	Watershed 5	4.07	5.00	3.00	0.00	12.07	4.02
6	Watershed 6	5.13	2.67	0.00	0.00	7.79	3.90
7	Watershed 7	14.00	0.00	0.00	0.00	14.00	14.00

Areal Aspects

Area of a basin (A) and perimeter (P) are the important parameters in quantitative geomorphology. The area of the basin is defined as the total area projected upon a horizontal plane. Perimeter is length of the boundary of the basin. Areal aspects include differentmorphometric parameters, like drainage density (D), stream frequency (Fs), form factor (Rf), circulatory ratio (Rc), elongation ratio (Re) and length of the overland flow (Lg). The values of these parameters were calculated and results have been given in Table 3.

Drainage Density (D)

Drainage density is defined as the ratio of total length of streams of all orders with in the basin to the basin area or per unit area, which is expressed in terms of km/sq. km. It indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channels for the whole basin (Horton, 1932). The drainage density in the basin is 4.2 per km2 i.e., medium drainage density indicating that the basin has permeable rocks.

Table 6: Areal Aspects of the Sabarmati River basin

Sr. No.	Watershed Name	Drainage Density	Basin Parameter (P) in Km	Basin Parameter (P2) in Km	Total no of All stream orders	Stream Frequency	Basin Length Km	Circuity Ratio (Rc=4*Pi * A/P2)	Drainage Density* 2	Length of Overland Flow(Lg) 1/D*2
1	Watershed 1	3.02	37.24	1386.82	199	7.28	120.14	0.37	6.04	0.17
2	Watershed 2	2.58	46.83	2193.24	295	6.50	219.45	0.23	5.17	0.19
3	Watershed 3	2.91	75.60	5715.96	466	2.87	249.48	0.09	5.83	0.17
4	Watershed 4	2.51	49.90	2489.51	276	1.18	243.11	0.20	5.02	0.20
5	Watershed 5	2.16	26.70	713.00	80	2.05	77.83	0.71	4.32	0.23
6	Watershed 6	1.60	22.36	499.92	52	0.68	58.07	1.02	3.20	0.31
7	Watershed 7	0.95	15.20	231.04	15	10.81	20.09	2.20	1.90	0.53
8	Watershed 8	2.96	24.94	622.00	80	0.00	85.10	0.82	5.91	0.17

Stream Frequency /Drainage Frequency (Fs)

The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). The stream frequency (Fs) value of the basin is 3.9. The value of stream frequency (Fs) of the basin exhibits positive correlation with drainage density of the area. This indicates that with increase in stream numbers there is an increase in drainage density.

Form Factor (Rf)

Form factor (Rf) may be defined as the ratio of the area of the basin to the square of basin length (Horton, 1932). It is the quantitative expression of drainage basin outline form. Smaller the value of form factor, more elongated will be the basin. Form factor (Rf) value of the study area is 0.32. This indicates that the basin is elongated in shape. The elongated basin with low form factor indicates that the basin have a flatter peak of flow for longer duration.

Circulatory Ratio (Rc)

Miller (1953) defined a dimensionless circulatory ratio (Rc) as the ratio of basin area to the area of circle having the same perimeter as the basin. He described that the circularity ratios range from 0.2 to 0.8 which indicates strongly elongated and permeable homogenous geologic materials. Circulatory ratio (Rc) is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin.

Elongation Ratio (Re)

Elongation ratio (Re) is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. It is a very significant index in the analysis of the basin shape which helps to give idea about the hydrological character of a drainage basin. The elongation ratio value of the Sabarmati basin is 1.03, which indicates that the major part of basin is of high relief.

Length of Overland Flow (Lg)

The length of overland flow (Lg) approximately equals to half of reciprocal of drainage density (Horton, 1945). It is the length of water over the ground before it gets concentrated into definite stream channels. The length of overland flow (Lg values) of the study area is 0.24, indicating young topography.

Relief Aspects

Relief aspects of drainage basin relate to the three dimensional features of the basin involving area, volume and altitude of vertical dimension of landforms wherein different morphometric methods are used to analyze terrain characteristics. In this study, thus, relief aspect includes the analysis of average slope, relative reliefs, etc.

Average Slope

Slope is defined as the angular inclination of terrain between hill-tops and valley bottoms. Slope angle in degree of the drainage basin are tabulated and classified into convenient slope categories viz., (i) level slope = 00–100, (ii) gentle slope = 100–220, (iii) moderate slope = 220 – 300, (v) steep slope = 330 – 430 SS, and (vi) very steep slope = above 430.

Relative Relief

Relative relief termed as ‘amplitude of available relief’ or ‘local relief’ is defined as the difference in height between the highest and the lowest points (height) in a unit area. It is an important morphometric variable used for the overall assessment of morphological characteristics of terrain. Melton (1958) suggested calculating relative relief by dividing the difference of height between the highest and lowest points in the basin (H) with basin perimeter (P), thus relative relief = H/P. Relative relief is calculated on the basis of highest and lowest elevations and the data of relative relief so derived are tabulated and classified into three categories viz. (i) low relative relief = 0m – 100m, (ii) moderately relative relief 100m – 300 m and (iii) high relative relief = above 300m.

CONCLUSION AND FINDING

The morphometric analysis has been carried out through measurement of linear, areal and relief aspects of basins. It has been found that the study area is an 8th order drainage basin.

Dendritic drainage pattern is seen in the hilly and plateau parts of the drainage basin indicating the homogeneity in texture and lack of structural control. However, the piedmont zone of the basin is characterized by branching drainage pattern which is characterized by the Siwaliks deposits. From the study it can be concluded that areas drained by drainage orders of 1st, 2nd, 3rd, 7th and 8th have Bifurcation ratio between 3.0 to 5.0, indicating that these are not distorted by geological structures. The Bifurcation ratio in case of the 4th to the 6th drainage orders, it is more than 5.0. It is noted that, in the drainage basin that these areas are dominated by the presence of lineaments. The presence of the maximum number of the first order segments shows that the basin is subjected to erosion and also that some areas of the basin are characterised by variations in lithology and topography The deviation of the mean stream length values from 1.28 to 43.72 clearly indicates the change in topographic elevation and slope of the Sabarmati basin. The elongation ratio value of the Sabarmati basin is 1.47, which indicates that the major part of basin is of high relief. The length of overland flow (Lg values) of the study area is 0.64, indicating young topography. The slope of the basin ranges from a level slope in the plains (southern part) to a very steep slope in the northern part of the basin. Low relief to moderately relief is in the plains and high relative relief is in the hilly area.

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