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Estimation of geomorphological characteristics of raigad district using geospatial technology

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Abstract
Geographic information system (GIS) technique is a powerful tool that enables planners and decision makers to address current problems and future challenges effectively. GIS techniques have been adopted for the Estimation of Geomorphological characteristics and analyzing their properties of the Raigad district in Maharashtra, India. The study focuses mainly on the major six watersheds with an area of 6982.323 km^2 out of total area of Raigad district (7152 km^2). It is located between North 17º 51´ to 19º 80´ latitudes and East 72º 51´ to 73º 40´ longitudes. Annual rainfall over the district ranges from 2200 mm to more than 3000 mm in plains and it is above 5000 mm in the hills. The mean minimum temperature is 17.7ºC and mean maximum temperature is 31.8ºC. Various linear, areal and relief aspects of all the watersheds were calculated. The analysis revealed that the total number as well as total length of stream segments of first order stream is maximum than that of other higher order streams. The total number of streams and their length decreases as the order increases. Horton's law of stream numbers and stream length also holds good. The bifurcation ratio varies from 1.675 to 4.2 and the elongation ratio varying from 0.679 to 0.827, indicating that watersheds of elongated type have high relief and steep slopes.

Keywords: Geomorphological characteristics, Raigad district, GIS

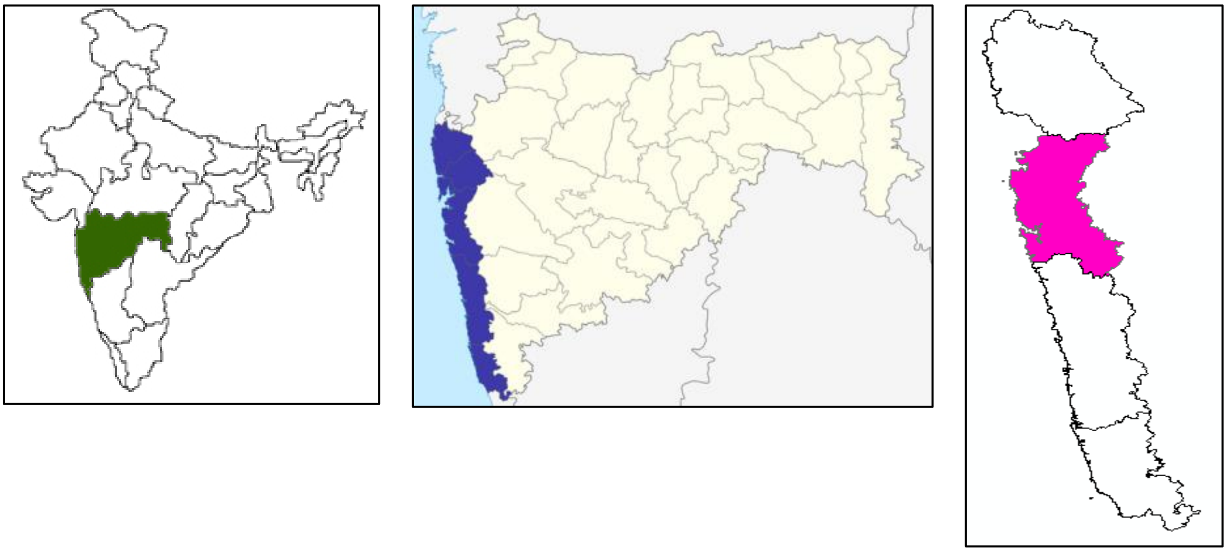
1. Introduction
Geographic information system (GIS) technique is a powerful tool that enables planners and decision makers to address current problems and future challenges effectively. There are many studies on GIS in the literature. Understanding hydrologic and geomorphologic characteristics of the region under study and preparing the required hydrologic and climatic datasets is a very important step in watershed planning and management. Watershed characteristics such Linear aspect of drainage network, Areal aspect of drainage basin, Relief aspect of drainage network are usually necessary for hydrologic analysis, planning, and management of watershed. Watershed is an ideal unit and accepted for planning, development and management of land and water resources. Watershed is also very useful for soil conservation and development of forest/vegetation. Healthy watershed is vital for a healthy environment and economy. Our watersheds provide water for drinking, irrigation and industry. Many people also enjoy lakes and streams for their beauty needs, healthy watersheds for food and shelter; it is effective and efficient way to sustain the local economy and environmental health. Scientists and leaders now recognized the best way to protect the vital natural resources is to understand and manage them on a watershed basis. Everything that is done in a watershed affects the watershed's system. So, the proper watershed protection is necessary for a community. (agritech.tnau.ac.in). A watershed provides a natural geohydrological unit for planning any developmental initiative for future. Man and his environment are independent; the changes in the environment directly affect the lives of the people. A degraded environment means a degraded quality of life in the people. Environmental degradation can be tackled effectively through the holistic development of the watershed. Development through watershed approach is one such developmental option.

1.1 Objective: To determine the geomorphological characteristics of Raigad district using Remote sensing and Geographic information System.

1.2 Study area
Raigad district is coastal district situated along the western coast of the state and is located between N 17º 51´ to 19º 80´ latitudes and E 72º 51´ to 73º 40´ longitudes.

It is bounded by Thane district in the north, Ratnagiri district in South, Pune district in the East and Arabian Sea forms the western boundary having a length of about 250 km. The district covers an area 7152 km^2 and has been divided into four revenue division's viz., Alibag, Panvel, Mahad and Managaon which are further divided into fourteen taluka's viz., Alibag, Panvel, Uran, Karjat, Khalapur, Pen, Sudhagad, Mahad, Roha, Managaon, Poladpur, Mahasala, Shriwardhan and Murud. Ulhas, Panvel and Patalganga are the three main rivers in northern part. Kundalika River is the main river in central part whereas in the southern part Savitri River is the main river (raigad.gov.in).

As per land use detail (2000-01) the district has an area of 1486 km^2 occupied by the forest. The cultivable area of district is 3286 km^2 whereas net sown area was 1356 km^2.



India Maharashtra Konkan: Raigad District

Fig 1.1: Location map of study area

2. Material and Methods

2.1 Data required: Digital Elevation Model (DEM) was required to calculate morphological properties of Raigad district. The DEM of Raigad district was downloaded from http://bhuvan.nrsc.gov.in. The downloaded DEM was obtained from Cartosat satellite of 30m resolution. The study area was categorized into different watersheds according to the flow accumulation of area. Then each watershed was selected for computing geomorphological properties. Accumulated flow is then classified according to the discharge occurring in the respective watershed. Stream order was then calculated using flow accumulation. Then length of each stream with its order was obtained. Hence all the geomorphological characteristics of different watersheds in this study area were estimated.

2.2 Geomorphological Characteristics

Morphological characterization was the systematic description of watershed geometry. Geometry of drainage basin and its stream channel system required the following measurements (Singh, et. al. 2003) [6]: -

1. Linear aspect of drainage network
2. Areal aspect of drainage basin
3. Relief aspect of channel network

3. Linear Aspects of Drainage Network

It also referred as linear aspect of channel system. Linear aspect of the 6sub watershed, related to the channel patterns of drainage network. Thisincludes the analysis of stream order, stream length and length of overland flow, mainly.

3.1 Stream network map: The stream network map was generated using DEM. Arc GIS tool was used to digitize the stream network.

3.2 Stream order: According to Strahler (1964) [8] it is classification system of stream/river in the watershed. The stream is the water flow path over the earth's surface. Streamordering is an important aspect for drainage basin analysis. It is defined as a measure of the position of a stream in the hierarchy of streams. The stream order provides a kind of stream classification, e.g. the smallest stream in the watershed has lower most order. On the other hand, the largest streams include highest order. The lowest order streams may be the tributaries or rivulets, while highest order stream is the outlet of watershed. Among the sub watershed, highest stream order (1^{th}order) is found in sub watershed1.The number of stream decreases as the order increases. The total numbers of all streams in all segments in this watershed are 49,618 of which first order streams are 26,288 which accounts for 48.85% to the total number of all streams. The Second order streams are 12,561 which account 25.32% to the total number of all streams. The Third order streams are 5704 which account 11.5% to the total number of all streams. The Fourth order streams are 3707 which account 7.47% to the total number of all streams. The Fifth order streams are 1358 which account 2.74% to the total number of all streams.

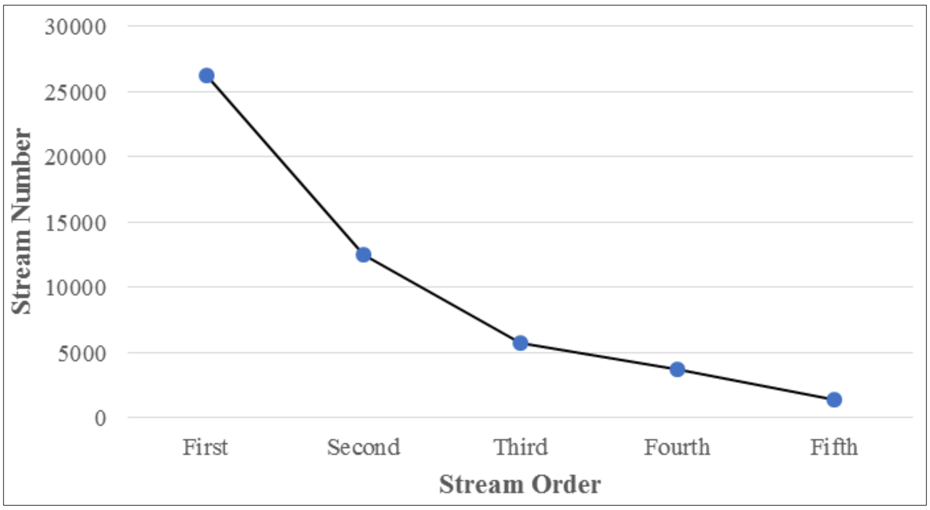


Fig 2: Stream segment of each order against Order number

3.3 Stream Length
According to Strahler (1964) [8], mean stream length describes the characteristic size of components of stream network.

$$L_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$$

Where,
L_u=Mean length of channel of order 'u'.
Nu= Total no. of stream segment of order 'u'.

3.4 Stream length ratio: According to Horton (1945) [2], It is the ratio of the mean length of the one order to the next lower order of the stream networks. Horton's law (1945) [2] of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geomorphic series with stream length towards higher order of streams.

3.5 Bifurcation ratio (R_b): Bifurcation ratio is computed on the basis of the law proposed by the Schumm, 1956 [5]. The term bifurcation ratio is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order.

$$R_b = \frac{N_u}{N_{u+1}}$$

N_u= Number of stream segments of order 'u'.
N_{u+1} = Number of stream segments of next higher order 'u+1'.
The lower bifurcation ratio values indicate the characteristics of the watersheds, which have suffered less structural disturbances, and the drainage pattern has not been distorted. Because of the structural disturbances the R_b values range from 3 to 5 in such areas (Biswas *et. al.* 1999). The bifurcation ratio is indicative of the shape of the basin also. An elongated basin is likely to have high bifurcation ratio, whereas a circular is likely to have a low bifurcation ratio.

3.6 Length of overland flow
Length of overland flow is computed on the basis of the law proposed by Horton, 1945 [2]. Over land flow refers to the flow of precipitated water which moves over the land surface leading to the stream channels. Length of over land flow is significant in small watershed and surface runoff is in bigger watershed.

The length of overland flow is calculated as a half of the reciprocal of drainage density, *i.e.*

$$L_g = \frac{1}{2D_d}$$

Where,
L_g= Length of overland flow.
D_d=Drainage density, km/km^2.

4. Areal aspects of drainage basin
The shape of basin, affects stream flow hydrographs and peak flow. The important parameters describing areal aspects are area (A), form factor (R_f), circulatory ratio (R_c), elongation ratio (R_e), drainage density (D_d) and constant channel maintenance (C).

4.1 Total basin area
The total area projected upon a horizontal plane, contributing overland flow to the stream segment of the given order and all the segment of lower order, e.g. the area of a 5th order basin would be the sum of all 1st order, 2nd order and 3rd order basin plus all inter basin areas between them.

4.2 Basin shape
It refers to the shape of boundary line of watershed or drainage basin. The basin shape is determined as the shape of projected surface on the horizontal plane of basin map. The evaluation of basin shape has importance to predict its effect on steam discharge relationship. The quantitative expression of drainage basin shape is predicted in different forms; the most common are outlined as, form factor, circulatory ratio, shape factor and elongation ratio.

4.3 Form factor
Form factor is computed on the basis of the law proposed by Horton, 1932 [1]. It is defined as the dimensionless ratio of the area (A) of a drainage basin to the square of its maximum length (L_b).

$$R_f = \frac{N_u}{L_b^2}$$

Where,
R_f=Form factor.
A_u= Basin area, km^2.
L_b^2=Basin length, km.

For a perfectly circular basin the value of form factor should always be less than 0.7854 (Horton, 1932) [1]. Smaller the value of form factor more elongated the basin. The basin with the high form factor has high peak flows for shorter duration, whereas elongated basin with low form factor will have a flatter peak flow for longer duration. Flood flows of elongated basins are easier to manage than that of the circular basins.

4.4 Circulatory ratio:
According to Miller (1953) [4], Circularity ratio is the ratio of the basin area (A) and the area of a circle with the same perimeter as that of the basin.

$$R_c = \frac{A_u}{A_c}$$

Where,
A_u=Area of basin, km^2.
A_c=Area of circle, km^2.

4.5 Elongation ratio:
According to Schumn (1956) [5], Ratio of diameter of a circle which has the area same to the basin, to the maximum basin length.

$$R_e = \frac{D_c}{L_{bm}}$$

Where,
R_L=Elongation ratio.
D_c=Diameter of circle which area is same to the given drainage basin.
L_{bm}=Maximum basin length, km.
Value of R_e ranges from 0.6 to 1. When R_e value approaches 1, the slope of the basin was nearly circular. For low relief value R_e was 1. For high relief value R_e ranges from 0.6 to 0.8.

4.6 Drainage Density
Drainage density is the ratio of total stream length of all the orders per unit basin area (Horton 1945) [2].

$$D_d = \frac{\sum_{i=1}^{k}\sum_{i=1}^{n} Lu}{Au}$$

Where,
D_d=Drainage density.
L_u=Length of stream segments.
A_u=Basin area, km^2.
k=Trunk order of the stream segment.
n=Total no. of streams.
The factors controlling drainage density are resistant to weathering, permeability of rock formations apart from the climatic condition and other factors like vegetation. Malik *et. al*. 2011 the watersheds can be grouped into four categories on the basis of drainage density as low (below 2.0 km/km^2), moderate (2.0 to 2.5 km/km^2), high (2.5 to 3.0 km/km^2) and very high (above 3.0 km/km^2). Low drainage density is observed in regions of highly resistant or permeable soil material under dense vegetation cover and low relief. High drainage density is observed in the regions of weak and impermeable subsurface material and sparse vegetation.

4.7 Constants of channel maintenance(C):
This parameter indicates the requirement of units of watershed surface to bear one unit of channel length. Schumm (1956) [5] has used the inverse of the drainage density having the dimension of length as a property termed as constant of channel maintenance.

$$C = \frac{1}{D_d}$$

Where,
C = Constant of channel maintenance.
D_d= Drainage density.
The value of C increases as the area of the land form unit increase.

4.8 Stream frequency
Stream frequency of a basin is defined as the number of streams per unit area (Horton 1945) [2].

$$F = \frac{\sum_{i=1}^{k} \mathrm{Nu}}{Au}$$

Where,
F = Stream frequency, km^{-2}
A_u = Basin area of the trunk order stream.
N_u= Number of streams.

5. Relief aspects of drainage basin and channel network
The parameters describing relief aspects of watershed are basin relief (H), maximum basin relief (H_m), relative ratio (R_h), ruggedness number (N) and geometric number (G). All are relief parameters depends on the elevation which was found by contour map.

5.1 Relief
It is elevation difference between the reference points located in the drainage basin.

5.2 Maximum Basin Relief
It is the elevation difference between basin outlet and the highest point located at the perimeter of basin.

5.3 Relief ratio (R_h)
Relief ratio is a dimensionless ratio of basin relief and basin length and effective measure of gradient aspects of the watershed.

$$R_h = \frac{H}{L}$$

Where,
R_h= Relative relief.
H= Relief (km).
L= Horizontal distance on which relief has been measured.

5.3 Relative Relief
Relative relief is computed on the basis of the law proposed by Melton, (1957) [3]. Relative relief is defined as the ratio of the maximum watershed relief to the perimeter length. It is computed using following expression.
$R_{hp} = \frac{H}{P} \times 100$
Where,
R_{hp}= Relative Relief (%).
H= Maximum basin relief (km).
P= Basin perimeter (km).
Relative relief increases with decrease in area.

5.4 Ruggedness No. (R_n)

Ruggedness number is computed on the basis of the law proposed by Strahler, 1957 [7]. It is a dimensionless number and is defined as the product of basin relief and drainage density.

$$R_n = H \times D_d$$

Where,
R_n= Ruggedness number
H= Relief (km)
Lower the R_n reveals the less fragmentation of relief and highly eroded surface and gentle slope.

5.5 Geometric number

The geometric number is the ratio of ruggedness number to the slope of ground surface.

$$\text{Geometric number} = H \times \frac{D_d}{S_g}$$

Where,
Sg= Slope of ground surface, (km km^{-1}).
D_d= Drainage density (km/km^2).

6. Result

It refers to the analysis of stream order, stream number, bifurcation ratio and stream length ratio. In this chapter estimated the values of linear aspects given in Table 1 are as follows:

Watershed 1: It has five stream orders. First order stream has highest streams i.e. 7601 number and fifth order stream has lowest number 209. Total numbers of streams of all order were 14712. Stream length of all orders was found to be 2054.73 km. Mean stream length of all orders was 0.704 km. Stream length ratio ranges from 0.994 to 1.071 and average stream length ratio 0.767. Bifurcation ratio ranges from 1.9 to 2 and average Bifurcation ratio was 2.475. Length of overland flow was 0.633 km.

Watershed 2: It has four stream orders. First order stream has highest streams i.e. 3190 number and fourth order stream has lowest number 590. Total numbers of streams of all order were 6292. Stream length of all orders was found to be 656.139 km. Mean stream length of all orders was 0.513 km. Stream length ratio ranges from 0.897 to 1.01 and average stream length ratio 0.980. Bifurcation ratio ranges from 1.1 to 3.7 and average Bifurcation ratio was 2.3. Length of overland flow was 0.554 km.

Watershed 3: It has four stream orders. First order stream has highest streams i.e. 2560 number and fourth order stream has lowest number 201. Total numbers of streams of all order were 4501. Stream length of all orders was found to be 470.908 km. Mean stream length of all orders was 0.525 km. Stream length ratio ranges from 0.964 to 1.084 and average stream length ratio 1.014. Bifurcation ratio ranges from 1.3 to 2.5 and average Bifurcation ratio was 2.05. Length of overland flow was 0.710 km.

Watershed 4: It has four stream orders. First order stream has highest streams i.e. 3741 number and fourth order stream has lowest number 600. Total numbers of streams of all order were 7325. Stream length of all orders was found to be 768.922 km. Mean stream length of all orders was 0.523 km. Stream length ratio ranges from 0.963 to 1.087 and average stream length ratio 1.012. Bifurcation ratio ranges from 1.1 to 2.4 and average Bifurcation ratio was 1.67. Length of overland flow was 0.840 km.

Watershed 5: It has four stream orders. First order stream has highest streams i.e. 7145 number and fourth order stream has lowest number 1063. Total numbers of streams of all order were 12888. Stream length of all orders was found to be 1356.51 km. Mean stream length of all orders was 0.524 km. Stream length ratio ranges from 0.990 to 1.019 and average stream length ratio 1. Bifurcation ratio ranges from 1 to 3 and average Bifurcation ratio was 1.725. Length of overland flow was 0.258 km.

Watershed 6: It has four stream orders. First order stream has highest streams i.e. 2051 number and fourth order stream has lowest number 361. Total numbers of streams of all order were 3900. Stream length of all orders was found to be 402.135 km. Mean stream length of all orders was 0.516 km. Stream length ratio ranges from 0.980 to 1.018 and average stream length ratio 1.004. Bifurcation ratio ranges from 2.1 to 6 and average Bifurcation ratio was 3.25. Length of overland flow was 0.631 km

Stream orders of Raigad district sub watershed.

S. No	Name of sub watershed	Stream orders (in number)					
		I	II	III	IX	V	Total
1	Watershed 1	7601	4193	1817	892	209	14712
2	Watershed 2	3190	1807	653	590	52	6292
3	Watershed 3	2560	1211	496	201	33	4501
4	Watershed 4	3741	1750	703	600	531	7325
5	Watershed 5	7145	2842	1402	1063	436	12888
6	Watershed 6	2051	758	633	361	97	3900
	Total	26288	12561	5704	3707	1358	49618

Stream Length of Raigad district sub watershed

S. No	Name of sub watershed	Stream orders Length (in Km)					
		I	II	III	IX	V	Total
1	Watershed 1	1063.32	583.046	252.440	124.642	31.289	2054.73
2	Watershed 2	331.03	188.501	68.807	62.832	4.967	656.139
3	Watershed 3	266.039	128.296	52.183	20.404	3.633	470.908

4	Watershed 4	391.690	184.351	73.775	60.700	58.403	768.922
5	Watershed 5	747.316	302.678	148.283	112.503	45.732	1356.51
6	Watershed 6	209.858	78.846	66.243	37.046	10.141	402.135
	Total	2709.53	1465.718	661.731	418.127	154.162	5709.344

Table 1: Linear aspect of watershed

S. No	sub watershed	Bifurcation Ratio	Stream Length Ratio	Mean Stream Length (Km)	Length of Overland flow (Km)
1	Watershed 1	2.475	0.767	0.704	0.633
2	Watershed 2	2.3	0.980	0.513	0.554
3	Watershed 3	2.05	1.014	0.525	0.710
4	Watershed 4	1.675	1.012	0.523	0.840
5	Watershed 5	4.2	1	0.524	0.258
6	Watershed 6	3.25	1.004	0.516	0.631
	Total	2.658	0.962	0.550	3.626

Under this aspect, the study revealed the relation between shape which affects stream flow hydrographs and peak flow. The important parameters that describe the shape of the watershed namely form factor, circulatory ratio and elongation ratio were computed. Values of areal aspects are given in Table 2.

Watershed 1: It has basin area 2604.37 km^2 and basin shape polygon. Form factor, circulatory ratio, elongation ratio, shape factor, drainage density and stream frequency were found to be 0.43, 0.25, 0.780, 1.24, 0.894 and 8.509, respectively. Elongation ratio reveals that this watershed was oval type.

Watershed 2: It has basin area 1102.97 km^2 and basin shape polygon. Form factor, circulatory ratio, elongation ratio, shape factor, drainage density and stream frequency were found to be 0.36, 0.22, 0.74, 1.49, 0.788 and 5.704, respectively. Elongation ratio reveals that this watershed was elongated type.

Watershed 3: It has basin area 243.16 km^2 and basin shape polygon. Form factor, circulatory ratio, elongation ratio, shape factor, drainage density and stream frequency were found to be 0.33, 0.29, 0.67, 1.55, 0.601 and 5.834, respectively. Elongation ratio reveals that this watershed was elongated type.

Watershed 4: It has basin area 859.84 km^2 and basin shape polygon. Form factor, circulatory ratio, elongation ratio, shape factor, drainage density and stream frequency were found to be 0.18, 0.29, 0.65, 1.64, 0.594 and 5.648, respectively. Elongation ratio reveals that this watershed was elongated type.

Watershed 5: It has basin area 1503.54 km^2 and basin shape polygon. Form factor, circulatory ratio, elongation ratio, shape factor, drainage density and stream frequency were found to be 0.62, 0.107, 0.88, 1.08, 1.936 and 8.571, respectively. Elongation ratio reveals that this watershed was oval type.

Watershed 6: It has basin area 668.42 km^2 and basin shape polygon. Form factor, circulatory ratio, elongation ratio, shape factor, drainage density and stream frequency were found to be 0.44, 0.17, 0.82, 1.22, 0.902 and 8.519, respectively. Elongation ratio reveals that this watershed was oval type.

S. No	sub watershed	Area (Km^2)	Perimeter (Km)	Length of basin (Km)
1	Watershed 1	2604.37	551.84	64.72
2	Watershed 2	1102.97	285.31	55.16
3	Watershed 3	243.16	115.95	26.96
4	Watershed 4	859.84	205.49	44.69
5	Watershed 5	1503.54	251.71	52.88
6	Watershed 6	668.42	167.86	38.91

Table 2: Aerial aspect of watershed.

S. No	Name of sub watershed	Form Factor	Circulatory Ratio	Elongation Ratio	Drainage Density	Stream Frequency
1	Watershed 1	0.43	0.25	0.780	0.894	8.509
2	Watershed 2	0.36	0.22	0.749	0.788	5.704
3	Watershed 3	0.33	0.29	0.679	0.601	5.834
4	Watershed 4	0.18	0.29	0.652	0.594	5.648
5	Watershed 5	0.62	0.10	0.889	1.936	8.571
6	Watershed 6	0.44	0.17	0.827	0.902	8.519

This refers to the analysis of relief aspects of drainage basin and channel networks. Estimated value of relief was 70 m interval, based on which relief ratio and relative relief were found. Further the ruggedness number and geometric number were computed. Values of relief aspects of drainage network are given in Table 3.
Relief was highest in WS5 i.e. 1050 m and lowest in WS4 i.e. 210 m. Maximum relief was highest in WS6 i.e. 936 m and lowest in WS4 i.e. 122 m. It revealed that WS5 has steep slope and WS4 was flatted as compared to another watershed.
Relief ratio was minimum in WS4 i.e. 0.008 and maximum in WS5 i.e. 0.065. Relative relief was minimum in WS4 i.e. 10.52% and maximum in WS5 i.e. 55.9%. Higher value of relief ratio indicate that intense erosion processes were taking place this indicate that WS5 was more susceptible to erosion and WS4 was the least among all the sub watersheds of the

study area.
Ruggedness number was lowest in WS5 i.e. 5 and highest in WS4 i.e. 30. Ruggedness number ranges from 5 to 11 this indicate that WS4 was least susceptible to erosion and WS5 was more susceptible among all the sub watersheds of the study area. Geometric number was lowest in WS4 i.e. 13 and highest in WS5 i.e. 26.
WS3 has highest elevation was 350 m and lowest elevation was 70 m as shown in Fig.4.9. Contour map of WS4 and WS6 has highest elevation was 980 m and lowest elevation was 70 m as shown in Fig.4.10 and Fig.4.12. Contour map of WS5 has highest elevation was 1020 m and lowest elevation was 70 m.
All contour map of watersheds shows contour lines are placed near to each other which indicates it has steep slope and contour lines are at distant from each other which indicates it has flattened slope.

Table 3: Relief aspect of watershed.

S. No	Name of sub watershed	Relief	Maximum relief	Relief ratio	Relative relief (%)	Ruggedness No	Geometric No
1	Watershed 1	700	678	0.032	35.6	15	18
2	Watershed 2	700	510	0.020	26.5	8	18
3	Watershed 3	280	297	0.012	24.5	6	16
4	Watershed 4	210	122	0.008	10.5	5	13
5	Watershed 5	1050	929	0.065	55.9	30	26
6	Watershed 6	910	936	0.045	45.3	23	23

7. Conclusions
The following conclusions were drawn from the work done with geographic information system.
1. The result indicated that the total watershed area was 6982.323km^2, perimeter 1578.183 km, number of streams of 1st order 26288, 2nd order 12561, 3rd order 5704 and 4th order 3707, 5th order 1358, respectively.
2. The presence of maximum number of first order segments shows that the basins were characterized due to variation in topography.
3. The values obtained for elongation ratios for different watersheds are in range of 0.652 to 0.889, suggest that the watersheds 2, 3 and 4 are of elongated type. Also this elongation ratio indicates that watershed has high relief and steep slope.
4. Geographic Information System is accepted to be powerful geospatial techniques in preparing the drainage map and understanding the watershed’s morphometric parameters.

8. References

1. Horton RE. Drainage basin characteristics. Transactions of the American Geophysical Union (AGU). 1932; 13:350-370.
2. Horton RE. Erosional development of streams and their drainage basins: Hydrological approach to quantitative morphology. Geological society of America Bulletin. 1945; 56(3):275-370.
3. Melton MA. Correlation structure of morphometric properties of drainage systems and their controlling Agents. Journal of Geology. 1957; 66(1):442-460.
4. Miller VC. A Quantitative geomorphic study of drainage basin characteristics in the clinch mountain area, Varginia and Tennessee, Project NR 389-042, Tech. Rept.3., Columbia University, Department of Geology, ONR, Geography Branch, New York, 1953.
5. Schumm SA. Evolution of drainage systems and slopes in badlands at Perth Amboy. New Jersey Bul Geol. Soc. Amer. 1956; 67:597-646.
6. Singh RK, Bhatt CM, Vajja HP. Morphological study of watershed using remote sensing and GIS techniques. Hydrology Journal. 2003; 26:1-2.
7. Strahler AN. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union. 1957; 38(6):913-920.
8. Strahler AN. Quantitative geomorphology of basin and channel networks. In: Chow, V.T. (Ed) Handbook of applied hydrology. Mcgraw Hill Company, New York, 1964.