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Geomorphometric Analysis of Sub Watersheds from Panjhara River Basin in Dhule Taluka, District Dhule, Maharashtra (India) using GIS and Remote Sensing Techniques

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Abstract

Groundwater is main source for drinking and irrigation, in year mostly the one third months are depends on groundwater. The study area is belongs to drought prone area. Geomorphometric analysis of Panjhara river basin in Dhule taluka is carried out to hydrogeological point of view. GIS and Remote sensing techniques are used to stream network analysis like, stream ordering, stream length is done. Study area is divided in to seven watershed names as TE-89, TE-77 and TE-65 are at left side of basin whereas TE-91A, TE-78, TE-66 and TE-56 are at right side of basin. The watershed names are given by GSDA (GSDA 2014). The Panjhara basin is 6th order basin which having 4170 number of stream segments having total length is 3425.77 km^2. Total area of the basin is 1288.43 km^2 and basin perimeter is 207.93 km. The length area relation is 6.2087 × A$^{0.4654}$ and regression constant is 0.7894. As elongation ratio is concern most of watersheds show elongated in nature except TE-90 is oval and TE-65 is circular in nature. Only TE-65 is circular and all are slightly elongated as form factor is concerns. This is due to most of the linear trend lines or fractures are East-West direction in study area, except TE-65 watershed. Drainage Texture of area is moderate to very fine category, where as stream frequency is low due to impermeable lithology, drainage density is high in all watersheds due to presence of lineament in basaltic terrain and intrusion of dykes.

Keywords: *Watershed, Morphometry, Deccan Volcanic Province, Panjhara River Sub-basin, Tapi Bain.*

INTRODUCTION

Watershed plays an important role in the natural functioning of the earth. Watershed considered as one of the primary planning units in the field of natural resource management. Remote sensing and GIS techniques are semi-automated techniques were used to calculate quantitative and qualitative morphometric parameters of watershed in parts of Panjhara sub-basins in Dhule Taluka. Also geology plays an important role in geomorphology and present topography is the residual hills of Sahyadri's and intrusion of dykes. The study area is under water scarcity zone and rainfall shadow zone. For surface water and groundwater management point of view the morphometric parameters study is important. The important parameters such as lithology, lineaments, bifurcation ratio, drainage density, drainage frequency, drainage texture are useful for surface water and groundwater management as well as constructions of the water conservation structures. Watershed wise calculation of geomorphometric parameters is most considered approach for development of water resources as studies in parts of Deccan Volcanic Province. Morphometric analysis is carried out based on watershed which belongs to the Dhule Taluka. The outcome of this study is help to the local administration for implementation of different water and soil conservation programs in Panjhara sub-basin.

Study Area

The Panjhara river basin is about 1288.43km^2 which is part of Dhule taluka, in Dhule district of Maharashtra State. River Panjhara is the main left side tributaries of Tapi River. As per WRIS-India watershed atlas of India, the study area is a part of "Tapi Middle" Sub-Basin (Code: B13TAM) around 31766.67 km^2, out of which further delineated in to 47 number of watershed. Out of 47 watersheds in Tapi middle sub-basin the study area has covered part of 32nd and 33rd (Panjhara) watersheds. The watersheds are further divided in to 7 sub-watersheds by GSDA, as per GSDA those seven sub-watersheds are called as 'Elementary Watersheds' (GSDA, 2014). Geographically the study area is situated in between 74˚26'00'' to 74°58'59'' E longitude and 20˚° 45'52'' N to 21˚06'08''N latitude as shown in figure 1.

Climate

The average annual rainfall in Dhule Taluka is 684 mm, maximum rainfall received in the monthly of July. Temperature is varies from 21°C to 32.9°C. The highest temperature in summer season (Month of May) and lowest in winter season (month of December) as shown in figure 2. As per geomorphological point of view this temperature and precipitation indicates, weak to moderate chemical and slightly mechanical weathering zone.

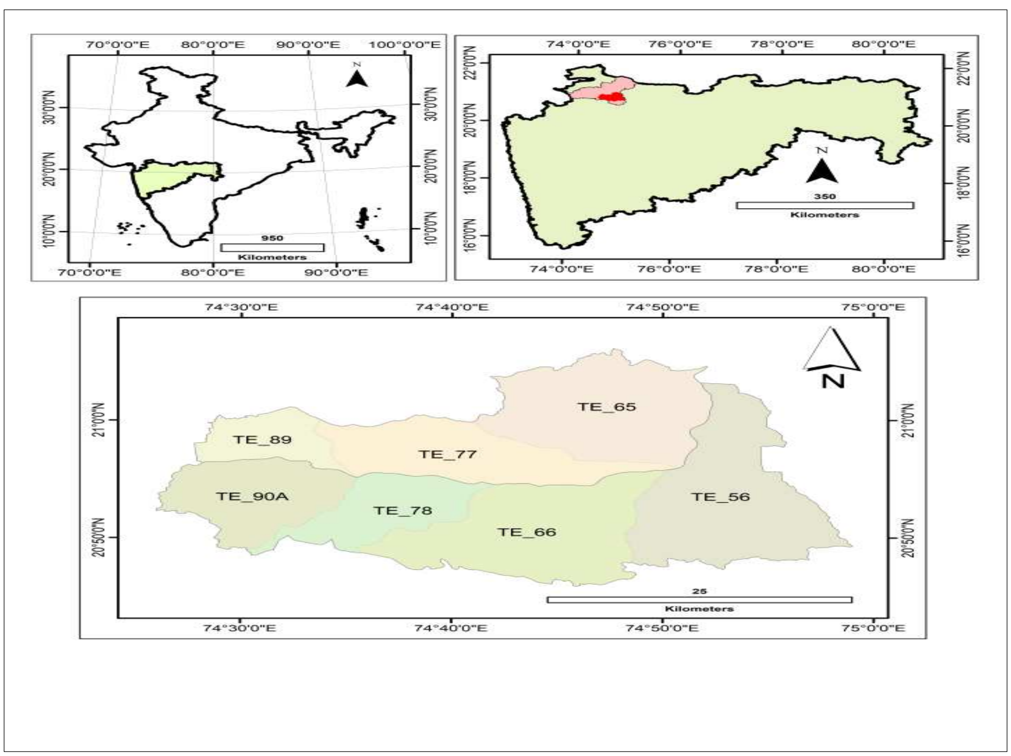

Figure 1: Location of study area

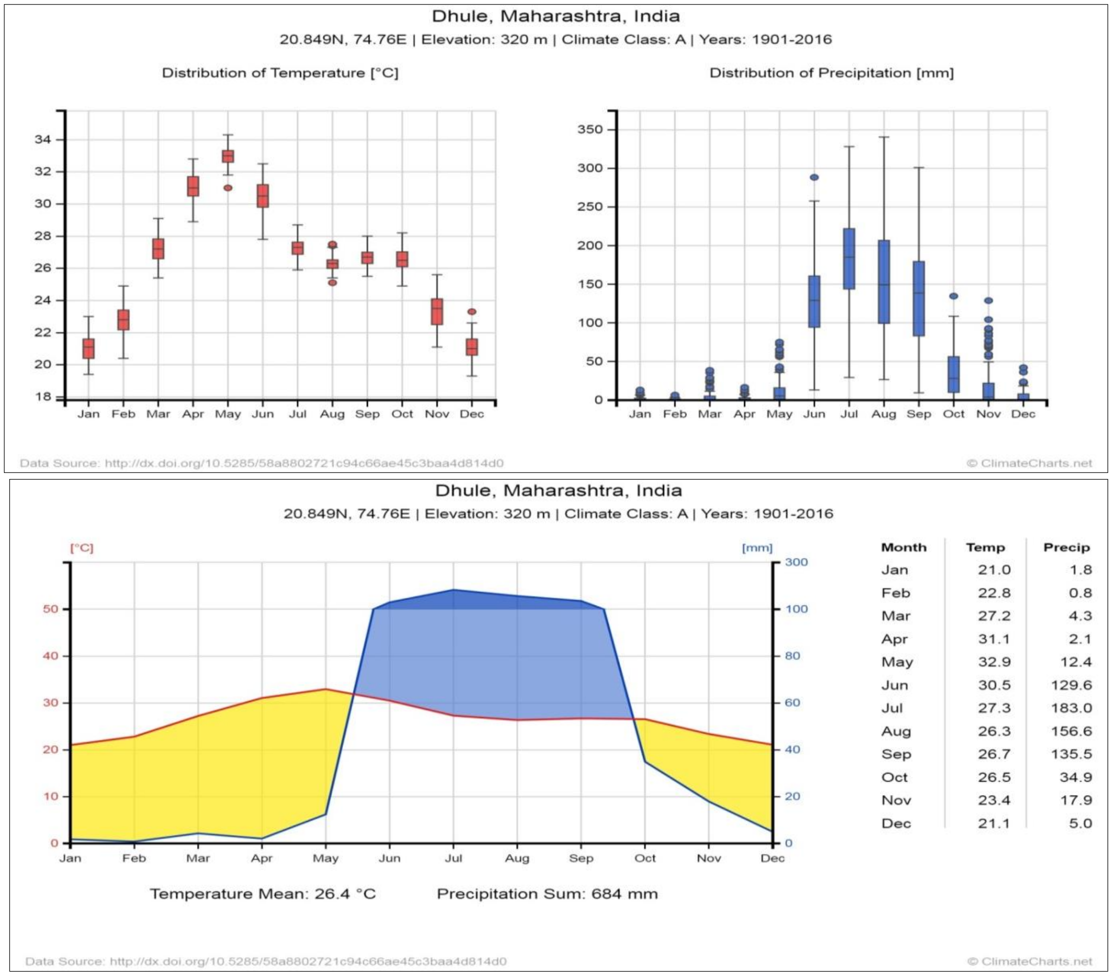

Figure 2: Climate of Study area
Source: [ClimateChart.net, http://dx.doi.org/10.5285/58a8802721c94c66ae45c3baa4d814d0.accessed on 31 March 2020]

Geology

The study area is covered by Deccan Volcanic Province or Deccan Trap Basalt of Cretaceous (65 m.a. ± 5 m.a.) to Eocene age. The lava flows are categorized in to 'Pahoehoe' or compound and 'aa' or simple type (GSI, 1989; 2001). Stratigraphically flows are under Sahyadri group (Deccan Trap) (Fig. 3). Based on the megascopic characteristics and presence of different marker magacryst flows, the lave pile in the area has been divided into two different formations. The lower most Salher formation is exposed around Pimpalner Taluka Sakri, along Panjhara River. Along Panjhara River (near Dhule) and along Bori river (Near Borkund and Shirud) marker horizon (Giant Phenocryst Basalt, M2) is exposed (20-70 m thickness) and overlain by Upper Ratangarh formation (of ~360 m thickness). The most part of the study area is covered by Upper Ratangarh formation. The Basalt rock in hand specimen is dark green to dark gray colour, fine grained and sparsely to moderately porphyritic. Local alluvium of recent age is deposited along Panjhara River at 184 m elevation. The dykes swarms are exposed in study area trending E-W direction with few meter thickness and few km lengths. The few dykes are dolerite in nature with three sets of joints having North-South trending while few dykes are gabbroic in nature and having E-W trending. Most of the fracture/Lineament is along 90° and 135°-140° and remaining are in between 0° to 180°. Most of dykes are showing trends East-West direction. The trend lines are mostly along 180° and 0° means South and North respectively.

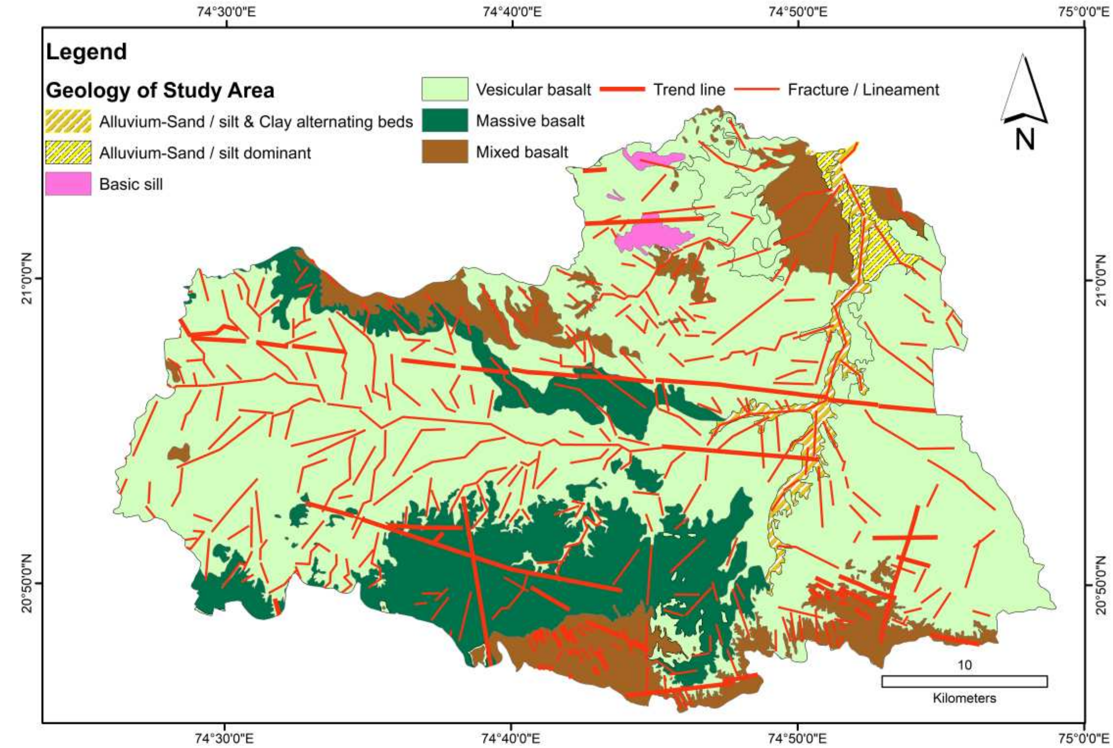

Figure 3: Geological Map of Dhule Taluka

Soil

Soil is vital natural resources supporting life systems and socio-economic development (Rajan, 2013). In Tapi valley, the soils are deep black and extremely fertile except in some portions near the main river and its tributaries, which have cut down the land very badly and removed the top soil. Otherwise the soils grade from the deep fertile soils to coarse shallow to stony soils (regur soil) towards residual hills and dykes (CGWB, 2013). Soil erosion is a major problem in rain-fed area. Erosion of the top soil layer leads to constant land degradation and decline of soil quality and productivity (Farhan and Anaba, 2016). Soil characteristics (Capodici et al., 2013) like texture, structure, organic matter content and permeability are useful to interpret the soil erosion (Shinde et al., 2010).

METHODOLOGY

Morphometric analysis of Panjhara river basin is carried out as per flow chart mentioned IN Fig. 4. As per different researchers studied reveal the fact that SRTM-DEM (Shuttle Radar Topography Mission-Digital Elevation Model) data are much more reliable and give better accuracy instead of other DEM data for morphometric analysis (Farr et al., 2007). From http://earthexplorer.usgs.gov/ website 30m resolution SRTM-DEM data is downloading and process under different GIS base platform software's like Arc GIS v10.1, Global Mapper v.19 and free software QGIS v3.16. With help of SoI Toposheets (1:50000 scale) viz. half part of 46L/5, 46L/9, 46L/10, 46L/13, 46L/13, 46L/14, 46K/12, 46K/16 and very little part of 46K/8. Scanned the same and digitized points, line and polygon of different features. Geological map are referred as District Resource map which is also digitized (GSI, 2001).

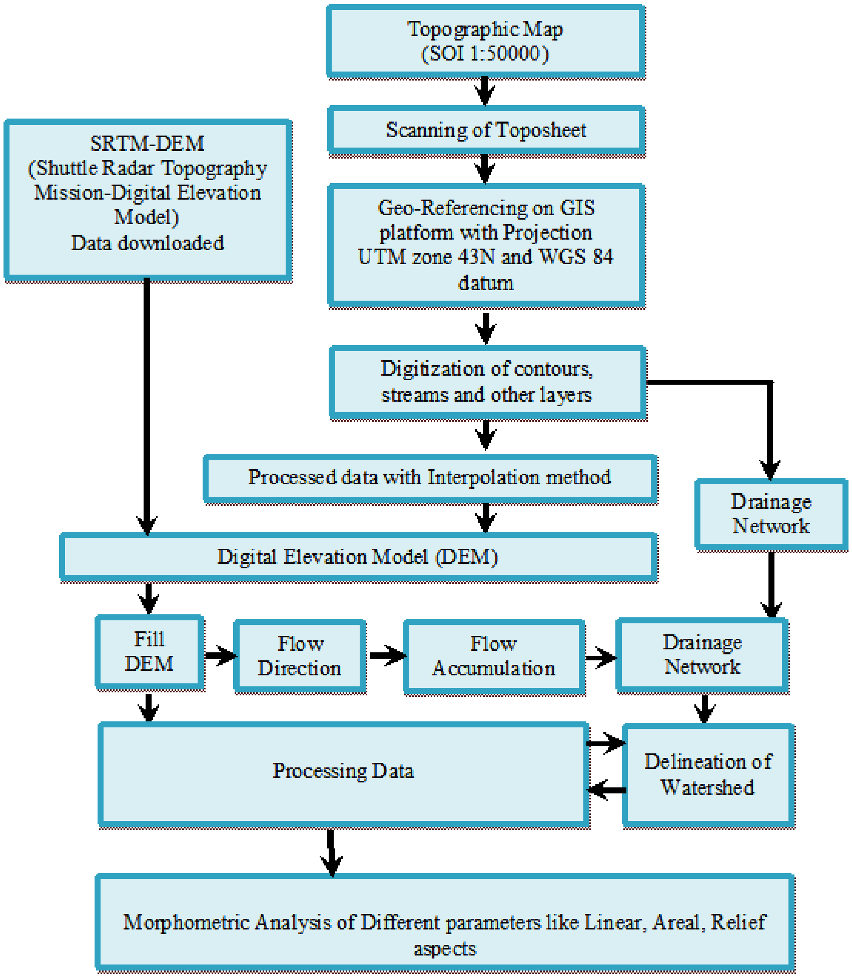

Figure 4: Flow chart of Methods

RESULTS AND DISCUSSION

The watershed wise analysis of morphometric parameters of study area was done with GIS software's, and data is tabulated as Table 1.

Linear aspect or Drainage Network

Stream Order (S_o)

Count of stream channels or branches in a watershed or sub-basin. Stream segments in toposheet of SOI have been digitized in GIS platform, order and counted. The term first-order stream originates from ideas initially proposed by R.E. Horton in the 1930s (Horton 1932, 1945).Streams orders are assigned in GIS based software, Arc GIS 10.1. In study area 6th order is highest order of streams of all watersheds in Panjhara River basin as shown in Fig. 5. Steam order indicate lithology, physiography and structure in the watershed (Horton, 1945; Strahler 1954, 1964; Singh and Singh, 2011; Chitra et al 2011; Zende et al 2013; Vandana, 2013; Ali U. et al, 2014).

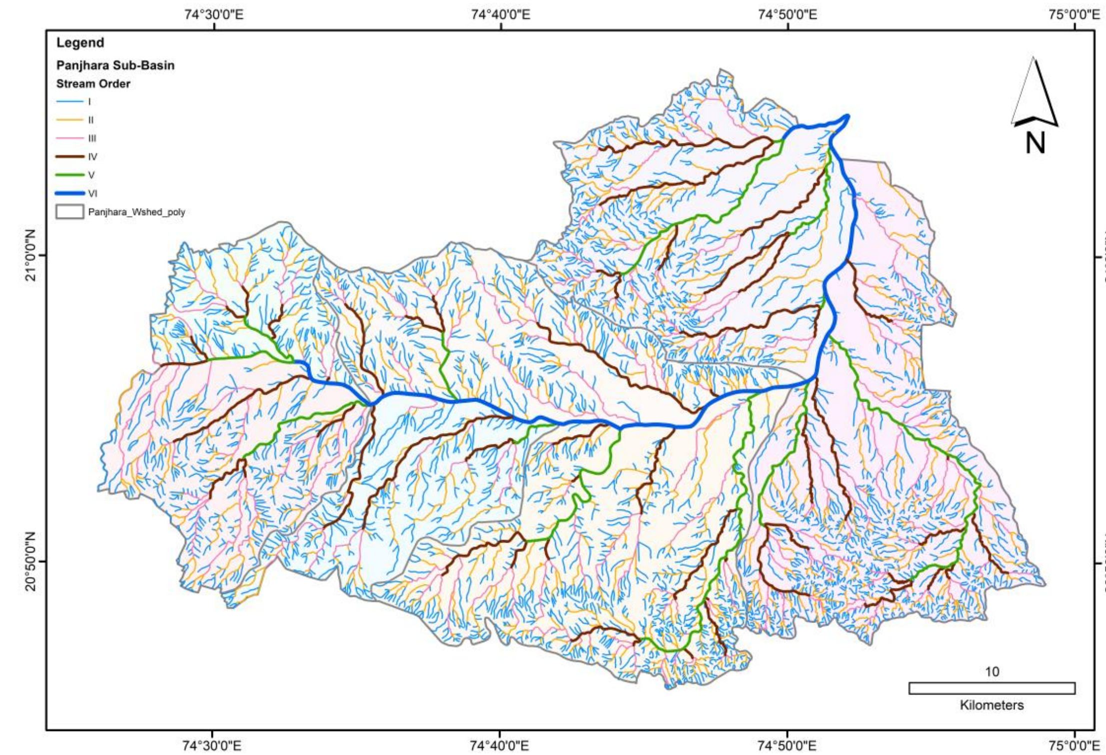

Figure 5: Stream order map of Study area (as per Strahler, 1945)

Stream Number (N_u)

The total of order wise stream segments is known as stream number. N_u is number of streams of order u. (as tabulated in Table 1 and 2). Stream number (Nu) observed that the number of streams exponentially decreases as the ordering of the streams increase. In study area total 4170 stream segments are counted. Out of which, maximum 74.65% of stream segments viz. 3113 are of 1^{St} order stream, 18.73% of stream segments viz. 781 are of 2^{nd} order stream. Remaining ~6.62% viz.198, 56, 14 and 8 are of 3^{rd}, 4^{th}, 5^{th} and 6^{th} order stream, respectively (Table 2).

Bifurcation Ratio (R_b):

The ratio between the total number of first order streams (Nu) to that of the next higher order (Nu+1) streams is defined as Bifurcation ratio (Strahler, 1952; Schumm, 1956; Pareta and Pareta, 2011; Iqbal and Sajjad, 2014). According to Horton (1945) stated that The Bifurcation ratio varies from min of 2 in 'Flat rolling drainage basins' to 3 to 4 in 'mountainous or highly dissected drainage basin' (Giusti and Schneider, 1965). Average bifurcation ratio of I/II streams of study area is varies from 2.89 to 4.07(as shown in Table 3 and 4). This indicates that the more surface runoff as well as geological and structural controlled drainage system developed. Higher the ratio values shows an elongation basin with geological structural disturbances play an important role (Chow, 1964), whereas lesser represents circular basin (Chow, 1964; Chitra et al., 2011, Khare et al., 2014). The lesser values indicate less structural disturbances (Strahler, 1964) with stable drainage (Pareta and Pareta, 2011) and greater chance of flooding (Prabhakaran and Raj, 2018) where as more values indicate a strong structural control over drainage system (Chitra et al., 2011). Bifurcation ratio is categories as shown in Table 4.

Table 1: Results of parameters of Watersheds in study area

S N	Parameter	*Symbol*	*Reference*	Formula	TE-56	TE-66	TE-65	TE-77	TE-90A	TE-78	TE-89	Panjhara	Max	Min
A) Drainage Network:														
1	Stream Order	*(u)*	Strahler (1952)	Hierarchical Rank	1 to 6	1 to 6	1 to 6	1 to 6	1 to 6	1 to 6	1 to 6	1 to 6	0	0
2	Stream number	*(Nu)*	Horton (1945)		1117	899	681	486	424	311	252	4168	1117	252
3	First Order Stream	*(Sof)*	*Strahler (1952)*	Sof=N1	837	673	506	360	632	234	180	3113	837	180
4	Bifurcation Ratio	*(Rb.n)*	Schumm (1956)		4.07	3.99	3.14	3.7	3.31	3.35	2.89	3.8	4.07	2.89
5	Weighted Bifurcation Ratio		Horton (1945)		4	4.01	3.91	3.87	4.21	4.06	3.53	3.95	4.21	3.53
6	Stream Length	*(Lu)*	Horton (1945)		797.4	692.7	596.13	455.73	392.51	281.52	209.78	3367.46	797.4	209.78
7	Stream length ratio	*(Rsl)*		Rsl=Lu/(Lu-1)	0.52	0.56	0.66	1.5	0.53	1.12	0.58	0.5	1.5	0.52
8	Weighted Average or Mean of Stream length ratio		Horton (1945)		0.5	0.49	0.54	0.71	0.5	0.57	0.47	0.47	0.71	0.47
9	Average or Mean Stream Length	*(Lsm)*	Strahler (1964)	Lsm=Lu/Nu	0.71	0.77	0.88	0.94	0.93	0.91	0.83	0.81	0.94	0.71
10	ratio of Average stream length	*(Rsl)*		Rsl=Lu/(Lu-1)	2.22	2.48	1.95	2.57	1.79	2.18	1.66	1.92	2.57	1.66
11	Weighted Average or Mean of Stream length ratio		Horton (1945)		1.87	1.79	2.08	1.59	1.89	1.63	1.45	1.72	2.08	1.45
12	Maximum of Stream Length				23.57	22.76	18.03	28.18	9.79	13.04	5.8	50.46	28.18	5.8
13	Minimum of Stream Length				0.04	0.05	0.03	0.02	0.01	0.01	0.02	0.01	0.05	0.01

14	Standard Deviation of Stream Length				1.18	1.27	1.4	1.6	1.21	1.32	0.77	1.36	1.6	0.77
15	Rho Coefficient	*r*	Horton (1945)	R=Rb.l/Rbn	0.14	0.15	0.24	1.26	0.17	0.84	0.21	0.13	1.26	0.14
B) Basin Geometry														
16	Basin length	*(Lb)*	*Schumm (1956)*	The straight line from the mouth of the basin of the basin to the farthest point on the basin perimeter	29.15	28.14	17.58	30.29	15.84	22.89	14.07	54.49	30.29	14.07
17	Mean basin width	*(Wb)*	*Horton (1932)*	Wb=A/Lb	9.62	9.03	13.75	5.73	9.32	5.06	5.34	23.64	13.75	5.06
18	Basin area	*(A)*	*Strahler (1964)*	Area from which water drain to a common stream and boundary determined by opposite ridges	280.48	254	241.78	173.59	147.64	115.81	75.12	1288.43	280.48	75.12
19	Length area Relation	*(Lar)*	*Hack (1957)*	Lar=1.4 × A^0.6	41.2	38.82	37.69	30.89	28.03	24.23	18.69	102.84	41.2	18.69
20	Basin perimeter	*(P)*	*Schumm (1956)*	Outer boundary of drainage basin measured in kilometer	93.19	85.71	74.19	73.13	55.73	61.96	45.84	207.93	93.19	45.84
21	Relative Perimeter	*(Pr)*	*Schumm (1956)*	Pr=A/P	3.01	2.96	3.26	2.37	2.65	1.87	1.64	6.2	3.26	1.64
22	Lemniscate's	*(k)*	*Chorley (1957)*	*k*=Lb^2/A	3.03	3.12	1.28	5.29	1.7	4.52	2.63	2.3	5.29	1.28
23	Form Factor	*(Ff)*	*Horton (1945)*	F=A/Lb^2 A=Basin area, Lb=Basin Length	0.33	0.32	0.78	0.19	0.59	0.22	0.38	0.43	0.78	0.19
24	Shape Factor	*(Sf)*	-	Sf=Lb^2/A	3.03	3.12	1.28	5.29	1.7	4.52	2.63	2.3	5.29	1.28
25	Elongation Ratio	*(Re)*	*Schumm (1956)*	Re=(2/Lb)×((A/p)^0.5)	0.65	0.64	1	0.49	0.87	0.53	0.7	0.74	1	0.49
26	Elongation Ratio	*(Re)*	*Schumm (1956)*	Re=2R/Lb Where, R=Radius of circle whose area equal to basin area. Re =(2×(SQRT(A/3.14)))/Lb	0.65	0.64	1	0.49	0.87	0.53	0.7	0.74	1	0.49
27	Texture Ratio	*(Rt)*	-	Rt=N1/P	8.98	7.85	6.82	4.92	11.34	3.78	3.93	14.97	11.34	3.78
28	Circularity Ratio	*(Re)*	*Miller (1953)*	Re=12.57×(A/P^2)	0.41	0.43	0.55	0.41	0.6	0.38	0.45	0.37	0.6	0.38
29	Circularity Ration	*(Rcn)*	*Strahler (1964)*	Rcn=A/P	3.01	2.96	3.26	2.37	2.65	1.87	1.64	6.2	3.26	1.64
30	Drainage Texture	*(Dt)*	*Horton (1945)*	Dt=Nu/P	11.99	10.49	9.18	6.65	7.61	5.02	5.5	20.05	11.99	5.02
31	Compactness	*(Cc)*	*Gravelius*	Cc=0.2841×P/A^0.5	1.58	1.53	1.36	1.58	1.3	1.64	1.5	1.65	1.64	1.3

	Ratio		*(1914)*											
32	Main Channel Length	*(Cl)*		GIS Analysis=(Longest River Length)	45.83	40.88	26.62	38.26	24.71	30.41	18.74	64.95	45.83	18.74
33	Valley length	*(Vl)*		GIS Analysis=(minimum areal distance)	25.7	29.23	25.91	30.28	17.28	22.73	14.68	41.13	30.28	14.68
34	Sinuosity Index	*(Si)*		Si=Cl/Vl	1.78	1.4	1.03	1.26	1.43	1.34	1.28	1.58	1.78	1.03
C) Drainage Texture of Basin														
35	Stream Frequency	*(Sf)*	*Hroton (1932)*	Fs=Nu/A	3.98	3.54	2.82	2.8	2.87	2.69	3.35	3.23	3.98	2.69
36	Drainage Density	*(Dd)*	*Hroton (1932)*	Dd=Lu/A	2.84	2.73	2.47	2.63	2.66	2.43	2.79	2.61	2.84	2.43
37	Constant of Chanel maintenance	*C*	*Schumm(1956)*	C=1/Dd	0.35	0.37	0.41	0.38	0.38	0.41	0.36	0.38	0.41	0.35
38	Drainage Intensity	*(Di)*	*Faniran (1968)*	Di=Fs/Dd	1.4	1.3	1.14	1.07	1.08	1.1	1.2	1.24	1.4	1.07
39	Infiltration Number	*(If)*	*Faniran (1968)*	If=Fs*Dd	11.32	9.65	6.94	7.35	7.64	6.53	9.37	8.45	11.32	6.53
40	Length of Overland flow	*(Lg)*	*Hroton (1945)*	Lg=A/(2×Lu)	0.18	0.18	0.2	0.19	0.19	0.21	0.18	0.19	0.21	0.18
41	Basin-scale Ruggedness	*(Rbs)*	-	Rbs=A/Dd	98.66	93.13	98.07	66.12	55.53	47.64	26.9	492.97	98.66	26.9
42	First Order Stream Frequency	*(Fst)*	*Miller (1953)*	Fst=N1/A	2.98	2.65	2.09	2.07	4.28	2.02	2.4	2.42	4.28	2.02
43	Fineness Ratio	*(Rfn)*	*(Rfn)*	Rfn=Lb/P	0.31	0.33	0.24	0.41	0.28	0.37	0.31	0.26	0.41	0.24
44	Drainage Pattern	*(Dp)*	*Hroton (1932)*	-	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	0	0
D) Relief Characteristics of Basin														
46	Minimum Height of Basin	*(Zmax)*	GIS Analysis		193	226	187	227	309	268	309	187	309	187
47	Maximum Height of Basin	*(Zmin)*	GIS Analysis		388	649	370	404	566	529	461	649	649	370
48	Mean Height of Basin	*(Hmean)*	GIS Analysis		278.56	342.7	256.23	313.6	389.57	356.45	361.27	316.27	389.57	256.23
49	Orientation of Basin (as	*(° in Horizontal*	GIS Analysis		87.43	21.6	165.99	166.81	15.51	31.62	171.87		171.87	15.51

	per Geometry)	view)												
50	Height of Basin Mouth	(Zbm)	GIS Analysis		193	226	187	227	309	268	309	187	309	187
51	Total basin relief	(H)	Strahler (1952)	H = Zmax-Zbm	195	423	183	177	257	261	152	462	423	152
52	Relief ratio	(Rhl)	Schumm (1956)	Rhl = (H/Lb)/100	1.66	3.95	1.65	1.47	2.41	2.38	1.38	4.08	3.95	1.38
53	Relative relief ratio	(Rhp)	Melton (1957)	Rhp = (H×100)/P	209.24	493.52	246.65	242.04	461.17	421.25	331.57	222.19	493.52	209.24
54	Average Divide Elevation	(Eda)	-	Eda = H / Rhl	117.58	107.13	110.63	120.65	106.57	109.61	110.2	113.37	120.65	106.57
55	Gradient Ratio	(Rg)	Sreedevi, 2004)	Rg=(Zmax × Zmin)/Lb	6.69	15.03	10.41	5.84	16.22	11.4	10.81	8.48	16.22	5.84
56	Slope Index or Watershed slope	(Sin)	Taylor AND Schwarz (1952)	Sin = H / Lb	6.69	15.03	10.41	5.84	16.22	11.4	10.81	8.48	16.22	5.84
57	Ruggedness number	(Rn)	Patton AND Baker (1976)	Rn = Dd × (H/1000)	0.07	0.16	0.07	0.07	0.1	0.11	0.05	0.18	0.16	0.05
58	Melton Ruggedness number	(MRn)	Melton (1957)	MRn = H / A0.5	11.64	26.54	11.77	13.43	21.15	24.25	17.54	12.87	26.54	11.64
59	Hypsometric Index	(Hi)	-	Hi = (Hmv-Zmi) / (Zmax-Zmin)	0.44	0.28	0.38	0.49	0.31	0.34	0.34	0.28	0.49	0.28
60	Total contour length	(Ctl)		GIS Analysis	960.46	732.84	397.3	298.76	418.82	296.3	136.37	2757.68	960.46	136.37
61	Contour interval	(Cin)		GIS Analysis	1	1	1	1	1	1	1	1	1	1
62	Mean slope of overall basin	(0s)	Chorley (1969)	0s=(Ctl x Cin)/A	3.42	2.89	1.64	1.72	2.84	2.56	1.82	2.14	3.42	1.64

Table 2: Number of streams in study area

Sr. No.	Watershed / Basin	Stream Numbers						
		I	II	III	IV	V	IV	Grand total
1	TE_56	837	211	54	12	2	1	1117
2	TE_65	506	128	31	10	4	2	681
3	TE_66	673	165	44	14	2	1	899
4	TE_77	360	96	23	5	1	1	486
5	TE_78	234	58	13	4	1	1	311
6	TE_89	180	48	15	6	2	1	252
7	TE_90A	323	75	18	5	2	1	424
	Panjhara	3113	781	198	56	14	8	4170

Table 3: Bifurcation ratio and distribution

Sr. No.	Watershed / River Basin	Bifurcation Ratio					
		I/II	II/III	III/IV	IV/V	V/VI	Average
1	TE_56	3.97	3.91	4.5	6	2	4.076
2	TE_65	3.95	4.13	3.1	2.5	2	3.136
3	TE_66	4.08	3.75	3.14	7	2	3.994
4	TE_77	3.75	4.17	4.6	5	1	3.704
5	TE_78	4.03	4.46	3.25	4	1	3.348
6	TE_89	3.75	3.2	2.5	3	2	2.89
7	TE_90A	4.31	4.17	3.6	2.5	2	3.316
	Panjhara	3.97	3.94	3.62	4.23	3.25	3.802

Table 4: Bifurcation ratio Category

Bifurcation ratio	Description of indicator	Reference	Study area	Watersheds
<3	Flat region	Horton (1945)	All watershed has <3 value of V/VI order streams	TE-89
3-5	Geological structures do not distort the drainage pattern	Chow (1964) and Nautiyal (1994)	All watershed has value 3-5 of I/II, II/III and most of III/IV order Streams ratio	TE-56, TE-66, TE-65, TE-77, TE-90A, TE-78 and Panjhara
>5	Lithologically and structurally control	Strahler (1964)	Watershed TE-56 and TE-66 of IV/V streams ratio has value 6 and 7 respectively	

Stream Length (L_u):

Stream length has been measured with GIS software ArcGIS 10.1 and calculations of total streams have been done. Horton 1945 method have been used to compute stream length and tabulated as shown in Table 5. The maximum stream lengths were observed is 28.18 km of 6th order stream in TE-77 watershed of Panjhara sub-basin. While minimum 0.49km stream length were observed 1st order streams in TE-56 watershed. Total segment of streams has length about 3425.77 km, out of which 53.43% stream length is of 1st order streams viz. 1830.56 km and having average length of 0.59 km. Stream length of river basin is characteristic parameter of runoff and hydrological parameter. Mostly longer the stream length indicates gentle slope with fine texture (Strahler 1964). In terms of the overall network, first-order channels defined by a Strahler ordering scheme commonly represent 50–60 per cent of the total stream length in a third-order drainage basin (Strahler 1964). The stream length is increases with the increase in stream order, this indicate that watershed evolution follows erosion lows acting on geologic material with homogenous weathering erosion characteristics (Nag and Chakraborty, 2003).

Table 5a: Stream Length of Study area

Sr. No.	Watershed / Basin	Stream Length						
		I	II	III	IV	V	IV	Grand Total
1	TE_56	413.62	176	108.86	50.05	33.98	14.9	797.4
2	TE_65	307.18	125.28	55.73	61.95	23.61	22.39	596.13
3	TE_66	368.27	149.52	84.04	39.58	35.2	16.1	692.7
4	TE_77	255.49	87.97	53.85	25.46	4.78	28.18	455.73
5	TE_78	157.99	51.37	30.79	26.01	3.28	12.08	281.52
6	TE_89	117.05	39.33	26.39	11.27	9.94	5.8	209.78
7	TE_90A	210.96	73.57	66.54	20.89	14.74	5.8	392.51
	Panjhara	1830.56	703.04	426.2	235.21	125.53	105.25	3425.77

Table 5b: Average Stream Length of Study area

Sr. No.	Watershed / Basin	Average Stream Length						
		I	II	III	IV	V	IV	Average Length of Total Streams
1	TE_56	0.49	0.83	2.02	4.17	16.99	14.90	0.71
2	TE_65	0.61	0.98	1.80	6.20	5.90	11.20	0.88
3	TE_66	0.55	0.91	1.91	2.83	17.60	16.10	0.77
4	TE_77	0.71	0.92	2.34	5.09	4.78	28.18	0.94
5	TE_78	0.68	0.89	2.37	6.50	3.28	12.08	0.91
6	TE_89	0.65	0.82	1.76	1.88	4.97	5.80	0.83
7	TE_90A	0.65	0.98	3.70	4.18	7.37	5.80	0.93
	Panjhara	0.59	0.90	2.15	4.20	8.97	13.16	0.82

Stream Length Ratio (R_l):

It is an ratio of stream length of particular order (Lu of S_{o1}) to next of that particular order of stream (Lu of S_{o2}). New formation of geomorphic landforms is highly correlated with higher stream length values (Kaliraj et al., 2014). Changes in R_l value from order to order illustrated that landforms development is in the youthful stage (Rai et al., 2014). Topographic properties and fluctuation in slope are the causes for differences in Rl values (Mangesh et al., 2012, 2013; Shreedevi et al., 2005; Mangesh and Chandrasekar, 2012). In study area R_l values are ranges from 0.13 to 5.90. The maximum R_l value 5.90 observed in ratio between 6th /5th order streams of TE-77 watershed, while minimum 0.13 in ratio between 5th/4th order streams of TE-78 watershed. The ratio in between 2nd/1storder varies from 0.33 to 0.43 (as shown in Table 6). These values indicate the topographic and lithological and geological structure control over the drainage network. The maximum value in study area is 5.9, 3.68 of TE-77 and TE-78 watersheds indicate mostly the structural or lineament controlled the higher order of streams, i.e. linear fractures are observed along Panjhara river near War village.

Table 6: Stream Length Ratio of study area

Sr. No.	Watershed / Basin	Stream length ratio				
		II/I	III/II	IV/III	V/IV	VI/V
1	TE_56	0.43	0.62	0.46	0.68	0.44
2	TE_65	0.41	0.44	1.11	0.38	0.95
3	TE_66	0.41	0.56	0.47	0.89	0.46
4	TE_77	0.34	0.61	0.47	0.19	5.90
5	TE_78	0.33	0.6	0.84	0.13	3.68
6	TE_89	0.34	0.67	0.43	0.88	0.58
7	TE_90A	0.35	0.9	0.31	0.71	0.39
	Panjhara	0.38	0.61	0.55	0.53	0.84

Rho (ρ) Factor or coefficient:

It is the ratio in between stream length ratio (R_l) and bifurcation ratio (R_b). Rho coefficient (ρ) is an important factor in relation both to drainage composition and physiographic development of drainage basin. As will be shown later, the value of the ratio $\rho = r_l / r_b$ is determined by precisely those factors-hydrological, physiographic, cultural and geological which determine the ultimate degree of drainage development in a given drainage basin (Horton, 1945). The values ranges from 0.03 to 5.9, both values indicate structural control parameter which is inTE-77 watershed in higher order stream respectively (Table 7). The rho coefficient values doesn't shows any pattern, means as per Horton (1945) said about lithology of bed rock is main control over an area i.e. hydrological inhomogeneous and heterogeneity properties of Deccan Trap or Deccan Volcanic Province.

Table 7: Rho (ρ) factor or coefficient of study area

Sr. No.	Watershed / Basin	Rho (ρ) factor or coefficient				
		Rl/rb of I	Rl/rb of II	Rl/rb of III	Rl/rb of IV	Rl/rb of V
1	TE_56	0.11	0.16	0.10	0.11	0.22
2	TE_65	0.10	0.11	0.36	0.15	0.48
3	TE_66	0.10	0.15	0.15	0.13	0.23
4	TE_77	0.09	0.15	0.10	0.04	5.90
5	TE_78	0.08	0.13	0.26	0.03	3.68
6	TE_89	0.09	0.21	0.17	0.29	0.29
7	TE_90A	0.08	0.22	0.09	0.28	0.20
	Panjhara	0.10	0.15	0.15	0.13	0.26

Areal Aspect:

Geometry of areal extent of a study area is describing the features depend on area basis.

Area of watershed or sub-basin (Aw):

Area is two dimension properties which can be measured in planer area. Planer area of hydrologic unit as watershed or sub-basin polygon is measured in ArcGIS tool with reference to WGS 1984 projection and UTM 43N zone as datum. The Panjhara sub-basins area is about 1288.43 km^2. (65.36% out of Taluka is 1971.28 sq.km of Dhule Taluka. The Panjhara sub-basins include 7 watersheds, having area varies from maximum 280.48 km^{2}to minimum 75.12km^2 viz. TE-56 and TE-89 respectively. The sub-basin are also have right and left banks tributaries area viz. Panjhara river sub-basin has left bank area about 38.09 km^2 and right bank has an area about 61.96 km^2 as shown in Table 8.

Length of basin (Lb):

Schumm (1956) described length of basin is an lengthiest measurement of a hydrologic unit or watershed or sub-basin parallel to principle drainage line. It is calculated by GIS software ArcGIS 10.1 (Musy, 2001). The lengthiest basin is TE-56 having 95.88 km length, while shortest is TE-89 having length of about 45.75 km (Table 8).

Perimeter (P)

Perimeter is length of perimeter of a drainage basin or total length of watershed divide. It is measured by geometric calculation by the ArcGIS 10.1 software tool. Schumm (1956) indicated that, relation between area and stream length of a hydrologic unit as watershed or river basin, which contributing to support an area. Out of 7 watersheds, maximum 93.19 km perimeter is of TE-56 watershed and minimum 45.84 km is of TE-89 watershed. Perimeter of Panjhara sub-basins is 207.93 km (Table 8).

Length Area relation (L_{ar}):

Hack (1957) identified that for a large number of basins, the stream length and basin area is associated by a simple power function as shown in Fig. 6. The L_{ar} of the 7 watersheds of Panjhara sub-basin shown Fig. 6, length area relation has less correlation due to regression constant value is less viz. R^2= 0.7894 and equation is as below.

$$Lar = 6.2087 \times A^{0.4654}$$

As per Hack's power equation, values of length vs area relation are calculated as Panjhara basin varies from 18.69 to 41.20 of TE-89 and TE-56 watersheds.

Table 8: Length Vs Area relation in Watersheds

Sr. No.	Sub-Basin	Watershed	Basin Perimeter	Basin length	Basin area	Length area Relation	Length area Relation equation
			Schumm (1956)	*Schumm (1956)*	*Schumm (1956)*	*Hack (1957)*	*As per graph*
			(P)	(Lb)km	(A) sq km	(Lar)Lar=1.4*A^0.6	(Lar)
1	Panjhara	TE-56	93.1940	95.88	280.48	41.20	Lar=6.2087*$A^{0.4654}$ R^2 = 0.7894
2	Panjhara	TE-66	85.7110	83.71	254.00	38.82	
3	Panjhara	TE-65	74.1940	74.15	241.78	37.69	
4	Panjhara	TE-77	73.1280	62.52	173.59	30.89	
5	Panjhara	TE-90A	55.7280	55.21	147.64	28.03	
6	Panjhara	TE-78	61.9580	67.86	115.81	24.23	
7	Panjhara	TE-89	45.8420	45.75	75.12	18.69	

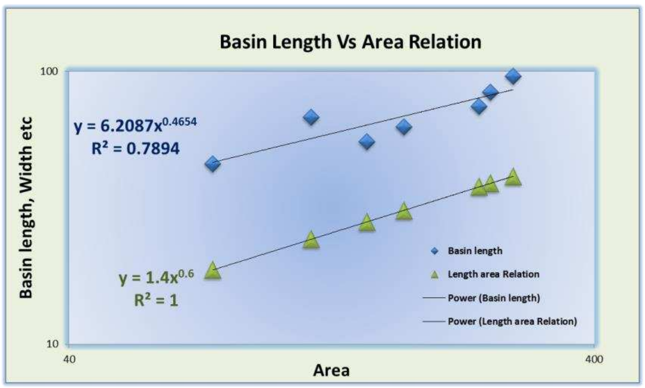

Figure 6: Graph of Length Vs Area relation

Form Factor (F_f):

Form factor (F_f) is the ratio of the basin area to the square of the basin length and used to predict the intensity of a basin of defined range (Horton, 1945; Sreedevi et al., 2013). F_f value is lower indicate basin is more elongated and has lower peaks of flow, while more value indicate higher peak flows of smaller period (Rai et al., 2018). If the form factor values are < 0.78 means elongated basin and > 0.78 means circular basin, (Rai et al., 2017; Vinutha and Janardhana, 2014). Elongated watershed means it has low peak flows for longer duration while a circular watershed has high peak flows for a shorter duration (Sukrishtiyanti, 2017). In study area form factor values are ranges from 0.19 to 0.782 of 7 watersheds, Mostly 6 watershed values indicate slightly elongated in nature and flatted peak flows with longer duration. Only TE-65 watershed value indicate circular in shape and high peak flow for short duration (Table 9).

Table 9: Significant of form factor

F_f	Shape	Nature of Flow	Watershed
0	Highly elongated	Low peak flow and longer duration	-
0 - 0.6	Slightly elongated	Flatted peak flow and longer duration	TE-90A, TE-89, TE-56, TE-66, TE-78, TE-77
0.6 - 0.78	Perfectly circular	Moderate to high peak flow for short duration	-
0.78 – 1.0	Circular	High peak flow for short duration	TE-65

Elongation Ratio (R_e):

It is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). The value varies from 0 (in highly elongated shape) to unity i.e. 1.0 (in the circular shape).Thus higher the value of elongation ratio more circular shape of the basin and vice-versa. Values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964).These values can be grouped as shown in Table 10. In study area values of elongation ratio are ranges from 0.49 to 1. Out of 7 watersheds mostly the 4 watersheds indicate elongated shape, while Panjhara basin shows less elongated in shape. Only TE-65, TE-90A and TE-77 shows circular, oval and more elongated shape respectively.

Table 10: Categories of Elongation ratio (Re)

Elongation ratio (Re)	Shape of basin	Watershed
<0.5	More Elongated	TE-77
0.7 - 0.5	Elongated	TE-56, TE-66, TE-78, TE-89
0.8-0.7	Less elongated	Panjhara
0.9-0.8	Oval	TE-90A,
>0.9	Circular	TE-65

Circularity Ratio (Rc)

It is a similar as elongation ratio, originally defined by Miller (1953), as the ratio of the area of the basin to the area of the circle having same circumference as the basin perimeter. The value of circularity ratio varies from 0 (in line) to 1 (in a circle). The higher the value represents more circularity in the shape of the basin and vice-versa (Miller, 1953). This ratio is more concern with length, frequency of stream, geological structures, land use land cover, climate, relief and slope of the basin (Bera et al., 2018). It is significant ratio that indicates the stage of dendritic pattern of watershed. Circularity ratio of study area is varies from 0.38 to 0.60 of 7 watersheds, while 0.37 of Panjhara sub-basin. Mostly the watershed shows less elongated viz. TE-56, TE-66, TE-77, TE-78, TE-89 and Panjhara River basin. Only TE-65 and TE-99 shows less circular in nature (Table 1 and 11).

Table 11: Circularity ratio and Shape of basin

Circular ratio (Rc)	Shape of basin	Results in Watershed
0.0 – 0.3	More Elongated	-
0.3– 0.5	Less Elongated	TE-56, TE-66, TE-77, TE-78, TE-89, Panjhara
0.5 – 0.7	Les Circular	TE-65, TE-90A,
0.7 – 0.8	Oval	-
0.8 – 1.00	Circular	-

Compactness Coefficient (C_c)

C_c is depend on size and slopes in the basin and useful to understand risk of erosion with their hydrologic relationship (Ali et al., 2014; Iqbal et al., 2014; Patel et al., 2013, Zende et al 2013). The C_c values are classified into three category viz. low (1.60-1.67), moderate (1.67-1.90) and high (1.90-2.48). Lower values indicate more elongation and higher erosion in the basin (Farhan and Al-Shaikh, 2017). In study area C_c value 1.30 to 1.64, i.e. most of watershed shows the low value, while in Panjhara Basin shows that 1.65 value of compactness ratio (Table 12).

Table 12: Category of Compactness Coefficient

Compactness Coefficient (Cc)	Category	Results in Watershed
		TE-56, TE-66, TE-65, TE-77, TE-90A, TE-89
1.60 – 1.67	Low	TE-78, Panjhara
1.67 – 1.90	Moderate	
1.90 – 2.48	High	

Texture aspect

Drainage Texture (Dt)

Drainage texture analysis is inferred the sub-basin frequency, density and intensity of the drainage characteristics. Horton (1945) defined drainage texture is the total number of stream segments of all order in a basin per perimeter of the basin. It is important to geomorphology which means that the relative spacing of drainage lines. Drainage texture is on the underlying lithology, infiltration capacity and relief aspect of the terrain. Drainage texture (Dt) is total number of stream segments of all orders per perimeter of that area (Horton, 1945). It is a measure of closeness of the channel spacing, depending on climate, rainfall, vegetation, lithology, infiltration capacity and relief aspect of the terrain (Smith, 1950). Smith (1950) has classified drainage texture into five different classes (Table 11). Drainage lines are numerous over impermeable areas than permeable areas and it is measure of the total number of segments of all order per perimeter of that area. It gives an idea of the infiltration rate of the area. Drainage texture values show lithology (Rao and Yusuf, 2013) and depend rock, soil, infiltration capacity, relief, climate, vegetation, etc. (Kulkarni, 2015; Vandana, 2013; Iqbal et al., 2013; Chatterjee and Tantubay, 2000). In the study area the drainage texture of the watershed varies from 5.02 to 11.9, and Panjhara basin has 20.05. If the Dt value is greater than 8 indicates that the category is very fine drainage texture and impermeable lithology (Table 13).

Table 13: Categorization of Study area as drainage texture by Smith (1950)

Category	Texture	Watersheds			
Very coarse	<2				
Coarse	2-4				
Moderate	4-6	TE-78	TE-89		
Fine	6-8	TE-77	TE-90A		
Very fine	>8	TE-65	TE-66	TE-56	Panjhara

Stream Frequency (Fs)

The drainage frequency introduced by Horton (1932) means stream frequency or channel frequency as the number of stream segments (Nu) per unit area (A). In the present study area, the stream frequency of the Most of sub-watershed is indicates low Fs i.e. mean 2.69 to 3.98 streams/km^2 (as shown in Table 14). The lower value indicates the non-permeable lithology with heterogeneous anisotropic nature of Basalt terrain. The stream frequency depends on lithology, relief, subsurface permeability, infiltration capacity, drainage network, rainfall, vegetation cover, etc. (Wilson et al., 2012; Kulkarni,2015; Raja and Karibasappa, 2016) therefore, useful to understand physiography, infiltration rate, permeability, number of streams and vegetative cover (Chatterjee and Tantubay, 2000; Pareta and Pareta, 2011; Singh and Singh, 2011; Romshoo et al., 2012; Vandana, 2013; Patel et al., 2013; Iqbal and Sajjad, 2014; Rai et al., 2014; Farhan and Al-Shaikh, 2017). Dense forest shows less frequency of streams whereas agricultural lands show higher frequency (Zende et al., 2013).

Table 14: Category of Stream frequency (No. of stream/km²)

Stream frequency (Fs)	No. of Streams/km²	Watershed
Low	0-5	TE-65, TE-56, TE-66, TE-78, TE-77, TE-89, TE-90A, Panjhara
Moderate	5-10	-
Moderate high	10-15	-
High	15-20	-
Very high	20-25	-

Drainage Density (Dd)

Drainage density is the measure of the texture of the drainage basin. Drainage density is the ratio of the total stream length (Lu) cumulated to all order in the basin to the total basin area (A).High drainage density is favored in region of weak rock or impermeable subsurface material. Low density shows highly permeable or highly resistant subsoil material under dense vegetation and low relief. The drainage density is an important indicator of the linear scale of landform element in stream eroded topography and defines as the total length of stream of all orders/drainage area and may be an expression of the closeness of spacing of channels (Horton, 1932). Drainage Density has indeed been widely accepted as an index of stream drainage characteristics and has been one of the most commonly used parameters in studies relating hydrologic and geomorphologic characteristics of region (Langbein, 1947; Schumm, 1956; Molton, 1957, Carlston; 1963, Cotton; 1964; Strahler, 1964; Orsborn, 1970, 1976; Gregory and Walling, 1973; Patton and Baker, 1976; Murphey et al. 1977, Digman S. L. 1978). The significance of drainage density is recognized as a factor determining the time travel by water (Langbein, 1947). Drainage density is a better quantitative expression to the dissection and analysis of landform, although a function of climate, lithology, runoff, infiltration, structures and relief history of the region can finally use as an indirect indicator to explain, those variables as well as the morphogenesis of landform (Verstappen, 1983; Patton, 1988; Reddy et al 2004). The computed drainage density in study area indicates high to very high drainage density viz. varies from 2.43 to 2.84 (Table 1 and 15). It is useful to understand the terrain, rocks, relief, soils, groundwater, erodibility and discharge of water and sediment (Pareta and Pareta, 2011; Engelhardt et al., 2011; Gebre et al., 2015). Higher values of indicates gentle slopes (Vandana, 2013) with semi-permeable hard rock, coarse textures, favorable conditions for groundwater conservation (Khare et al., 2014; Gebre et al., 2015).

Table 15: Distribution of drainage density and category

Range of Drainage Density (Km/Km²)	Explanation	Watershed
Up to 1.00	Less	-
1.01 -2.00	Moderate	-
2.01 – 3.00	High	TE-65, TE-56, TE-66, TE-78, TE-77, TE-89, TE-90A, and Panjhara basin
Above 3.00	Very High	-

Constant of Channel Maintenance (km²/km) (C):

Schumm (1956) used the inverse of drainage density or the constant (C) of channel maintenance as a property of landforms. The constant indicates the number of km²of basin surface required to develop and sustain a channel 1 km long. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1952). Channel maintenance constant of the study area is varies from 035 to 0.41, and 0.38 is of Panjhara river as shown in (Table 1 and 14) and it indicates most of the study area is moderately low erodible to low erodible of TE-65 and TE-78 watersheds only (Table 16).

Table 16: Constant channel maintenance (after Schumm, 1956)

Cc (km^2/km)	Significant	Watershed
<0.2	More erodible	
0.2-0.3	Moderate erodible	
0.3-0.4	Moderately low erodible	TE-56, TE-66, TE-77, TE-90A, TE-89 and Panjhara
0.4-0.5	Low erodible	TE-65 and TE-78
>0.5	Least erodible	

Drainage Pattern (Dp)

In the sub-basin, the drainage pattern reflects the influence of slope, lithology and structure. The study of drainage pattern helps in identifying the stage in the cycle of erosion. Drainage pattern presents some characteristics of drainage basins. It is possible to deduce the geology of the basin, the strike and dip of depositional rocks, existence of faults and other information about geological structure from drainage patterns. Drainage texture reflects climate, permeability of rocks, vegetation, and relief ratio, etc. (Howard, 1967) related drainage patterns to geological information. In the study area the drainage pattern is dendritic to sub-dendritic (Fig. 5). Dendritic pattern is most common pattern is formed in a drainage basin composed of fairly homogeneous rock without control by the underlying geologic structure. The longer the time of formation of a drainage basin is, the more easily the dendritic pattern is formed.

Length of Overland Flow (Lg)

The length of overland flow is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton, 1945). The computed "Lg" value of the watersheds varies from 0.18 to 0.21 and Study area i.e. Panjhara watersheds has the value 0.19 (Table 1), It indicates that the more channel erosion than sheet erosion.

Relief Aspect

Linear and areal features have been considered as the two dimensional aspect lie on a plan. The third dimension introduces the concept of relief.

Absolute Relief (Ra)

The main objectives of absolute relief are to determine how much erosion has taken place in relation to the present summits of the area (Prasad, 1985). Absolute relief refers to the maximum elevation of any area's morphology which also provides clues to estimate the type and intensity of denudational forces at work (Thakur, 2008). Analysis of absolute relief has been made by calculating the elevation above mean sea level for delineating the heights. Considering the range of elevations, five categories of absolute relief have been identified in the present study (Fig 7). The minimum elevation is 127 m above mean sea level (amsl) in TE-65 watershed in Panjhara river basin while highest elevation Near Laling viz. 585 m (as shown in Table18). Most part of the study area (91 %) having 150 to 350 m height i.e. 1120.03 km^2 which showed that the moderate to low absolute relief category and indicate low to moderate runoff and high infiltration in the study area. Remaining 9% area under high relief category and low infiltration in study area (as show in Table 17 and Fig. 7)

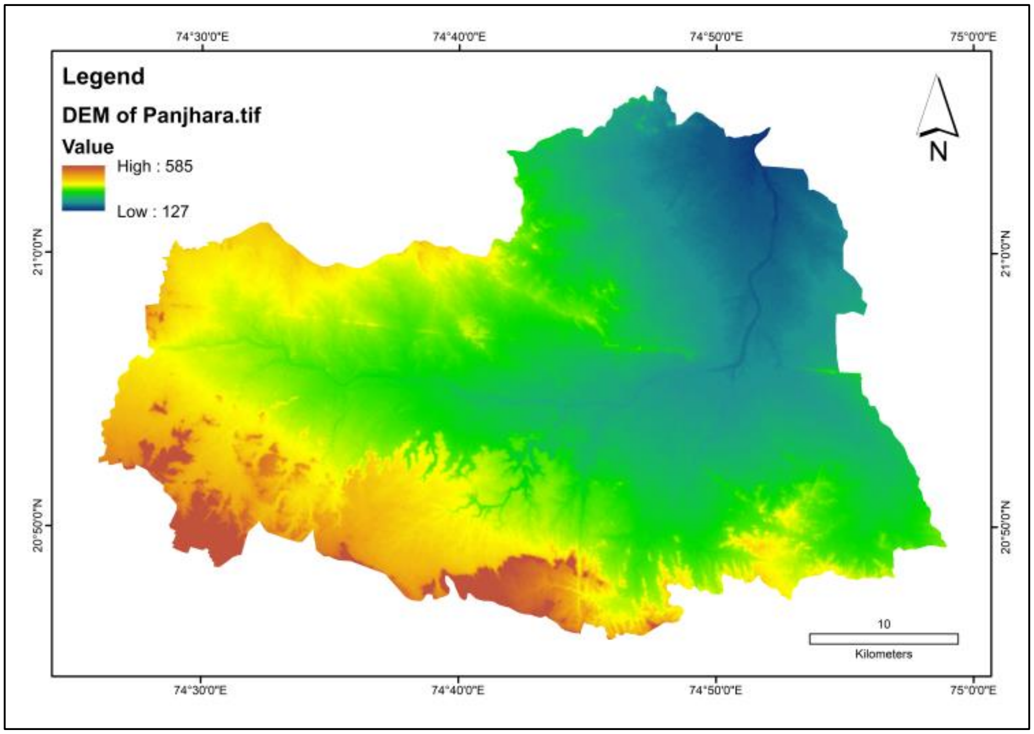

Figure 7: Relief map of Study area

Table 17: Distribution of Absolute Relief

Elevation (m)	**Area km²**	**% of Area**
127-150	26.64	2.17
150-200	271.23	22.04
200-250	353.41	28.72
250-300	326.71	26.55
300-350	168.68	13.71
350-400	54.64	4.44
400-450	25.39	2.06
450-500	3.23	0.26
500-550	0.48	0.04
550-584	0.02	0
Total	1230.43	100

Slope

Slope is a measure of change in elevation (z) with respect to horizontal (x or y) direction distance. The slope is expressed as a percentage and angle. To calculate percent slope, divide the difference between the elevations of two points by the distance between them, and then multiply the quotient by 100. The difference in elevation (z) between two horizontal points is called the rise. The distance between the points is called the run (along X or Y direction).

$$Slope\ (\%) = (rise/run) \times 100$$

An understanding of slope distribution is essential for planning, settlement, mechanization of agriculture, deforestation, planning of engineering structures and conservation practices etc. (Sreedevi et al 2005). The slope analysis is helpful to identify the potential sites for watershed management (Zolekar and Bhagat, 2015). It affects mostly the drainage characteristics in region (Patel et al., 2016). It also play an important role of amount of runoff, rate of infiltration, drainage density (Wilson et al., 2012), Land with moderate slope is more suitable for conservation of resources and key criterion in watershed management (Gaikwad and Bhagat, 2017 and 2018). Mostly the 82% area is gently sloping and 5 % area is Moderate steep to steep sloping, viz. situated to south of study area (Table 18 and Fig. 8).

Table 18: Slope % in study area

Slope Category	Slope %	Area in sq.km	% of area
Nearly Level	0 - 1 %	3.63	0.28
Very gently sloping	1 - 3 %	516.89	40.12
Gently sloping	3 - 5 %	547.45	42.49
Moderately sloping	5 - 10 %	59.31	4.60
Strongly sloping	10 - 15 %	3.61	0.28
Moderately Steep to Steep Sloping	15 - 35 %	60.45	4.69
Very Steep Sloping	35 - 50 %	7.25	0.56
Other	Habitation Mask	45.92	3.56
Other	Water bodies Mask	43.92	3.41
Grand Total	-	1288.43	100

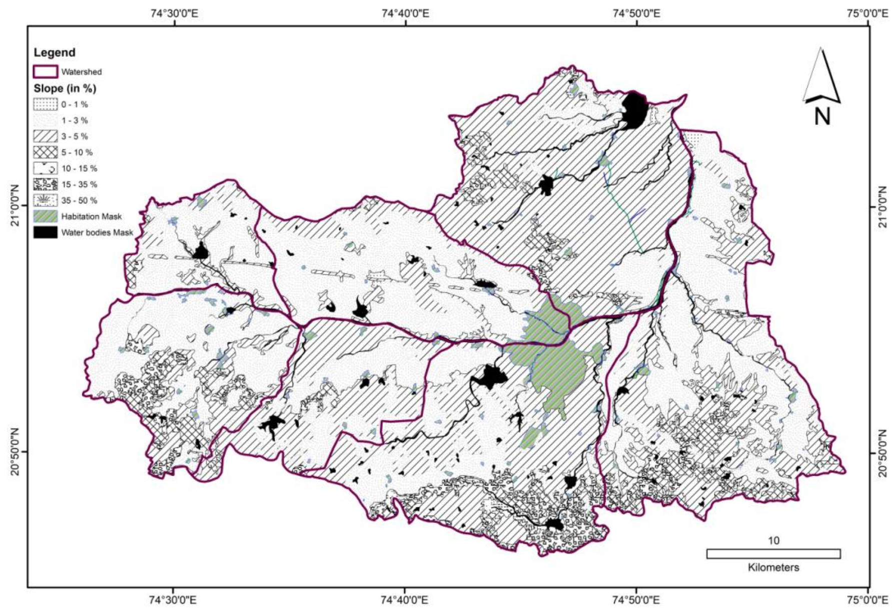

Figure 8: Slope map of Study area

CONCLUSION

Drainage density of the study area indicates that gentle slopes with presence of semi-permeable hard rock, coarse textures, and favorable conditions for groundwater conservation. The computed "Length of Overland Flow" value of the watersheds indicates that the more channel erosion than sheet erosion. Major part of the study area has gently sloping and except to south of study area have moderate steep to steep sloping. Therefore water conservation structure should be built in the central part of the study area to recharge maximum rainwater in to groundwater through various rainwater harvesting structures.

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