Morphometric Analysis of Warana Basin using GIS and Remote Sensing Techniques

Rushikesh S. Patil[1], Omkar V. Vanjari[2]

Dr. D.Y.Patil College of Agricultural Engineering and Technology Talsande, Kolhapur

---***---

Abstract: *In the current era of climate change most of the natural resources are deteriorating with very fast rate, which is the alarming situation in front of all the researchers and policy makers at global, national as well as regional scale. Soil and water resources are most important resources for all the living being. Therefore its conservation is the big challenge in front of world. Conservation of natural resources starts from its proper and precise site specific planning. Watershed is the natural entity in which both soil and water resources are conserved to maintain the natural and economical balance of the region. In earlier days, hand delineation method was commonly used for water delineation may have chances of manual errors at planning stage it may multiply in the lateral stage. But Recently, Geographical Information system (GIS) and Remote Sensing (RS) techniques are mainly used for watershed delineation. Warana river basin, of Maharashtra, India is selected for the present study. The catchment area of the Warana basin is about 2081 km^2. The Data used for study is SRTM 1 ARC 2nd DEM (Digital Elevation Model) with 30 m * 30 m resolution. Morphometric analysis of basin was calculated under linear, areal and relief aspects by using the geospatial technique. Survey of India (SOI) toposheet number E43N11, E43N12, E43N15, E43N16, E43O4, E43U1, E43T13, E43U5 and E43U9 having 1: 50,000 scale is used for the study. Watershed is the big geographical area which can is very difficult to manage conservation practices within a season or year therefore a watershed prioritization is one of the most important tool to prioritise Subwatersheds as per the erosion rate of the natural resources. The results were reveals that, the trunk order stream of the Warana basin was 8th with mean stream length ratio was 2.53 and mean bifurcation ratio of Warana basin was 4.22. Watershed prioritise was done by calculating 74 parameters and its intensity. Sub-watershed 1, Sub-watershed 8, Sub-watershed 10, Sub-watershed 12, and Sub-watershed 13 were most affected and need urgent conservation. On the contrary Sub-watershed 6, Sub-watershed 7, Sub-watershed 11, Sub-watershed 14, Sub-watershed 15 and Sub-watershed 16 are least affected.*

INTRODUCTION

Water plays a vital role in satisfying basic human needs. Water also plays important role in socio-economic development. Water covers about 71% of the earth surface. World has 2.5% fresh water from that India has just 4% of the world's fresh water. As the main source of water in Maharashtra is rainfall, so it becomes necessary for us to conserve the water. Morphometry refers to the study of configuration, evolution and characteristics of land forms.

The morphometric analysis of a watershed plays an important role in deciding the hydrological behaviour such as runoff and soil erosion. Morphometric analysis is also vital to find groundwater potential and management, environmental assessment. Morphometric analysis is helpful in knowing terrain features, hydrological characteristics and also its flow patterns. quantitative analysis of the watershed involves different components such as stream segments, stream order, basin perimeter & area, elevation difference, slope and profile of land has highly responsible for the natural development of basin (Horton, 1945). Horton (1932, 1945) carried out first and highly important work on morphometric analysis of basin. After that some Geomorphologist and Geohydrologist, like Strahler (1953), Schumm (1956), Melton (1957), Morisawa (1957), Strahler (1957), Gregory and Walling (1973), Chorley et al. (1984) modified and developed the Horton's study. Morphometric analysis is helpful to know hydrological system of watershed which is useful for carrying out management strategies. In this study an attempt has made to prioritization of watersheds on the basis of morphometric characteristics of Warana river basin which helps to understand management of natural resources and to identify regions which have high erosion rate. Stream order found for Warana river watershed is 8 and stream length is 377.88 km. The regions which have high erosion rate are sub watershed number 1,8,10,12 and 13 and The regions which have low erosion rate are sub watershed number 6,7,11,14,15 and 16.

STUDY AREA

Warana rivers watershed is spread across the Sangli and Kolhapur district. It is an important tributary of Krishna River. Outlet of this study area is considered as confluence. Confluence occurs where two rivers join to form single channel. The Warana Watershed covers an area of 2,081 square Kilometers and is spread over eight talukas namely Shirala, Valva, Miraj, Shahuwadi, Panhala, Hatkanangale and Shirol. The Warana Valley extends between Sangli and Kolhapur districts and its latitudinal and linear extent extends between N'16^0 47' to N'17^0 47' and E'73^0 30'15" to E'74^0 30' respectively. The study area has as the annual average rainfall range in between 650-2500 mm.

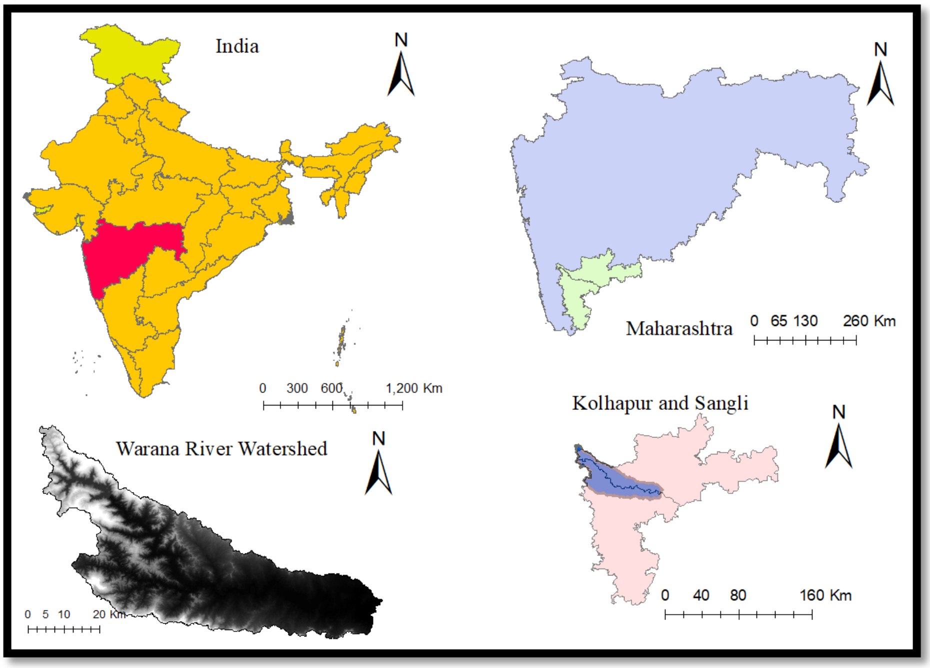

Fig No 1 Study area map

Data Used and Methodology

Remote sensing and GIS (Geographic Information System) technique was used in this study of morphometric analysis of Warana river basin. By using the Survey of India (SOI) topographical maps of about 1: 50,000 remotely sensed data is rectified and Data is analysed by using ArcGIS 10.3 Software by using toposheet and DEM (Digital Elevation Model). Topographical map: SOI (Scale 1: 50,000) Number E43I13; SRTM (DEM) with 30 m x 30 m spatial resolution. By using WGS-1984 datum, Universal Transverse Mercator (UTM) zone 43N projection SOI topographic map is georeferenced in ArcGIS 10.3. In this study the stream order is calculated by using Strahler order. According to Strahler (1957), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed, where two of order 2 join, a segment of order 3 is formed and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order (Vinoth M.).

RESULT AND DISCUSSION

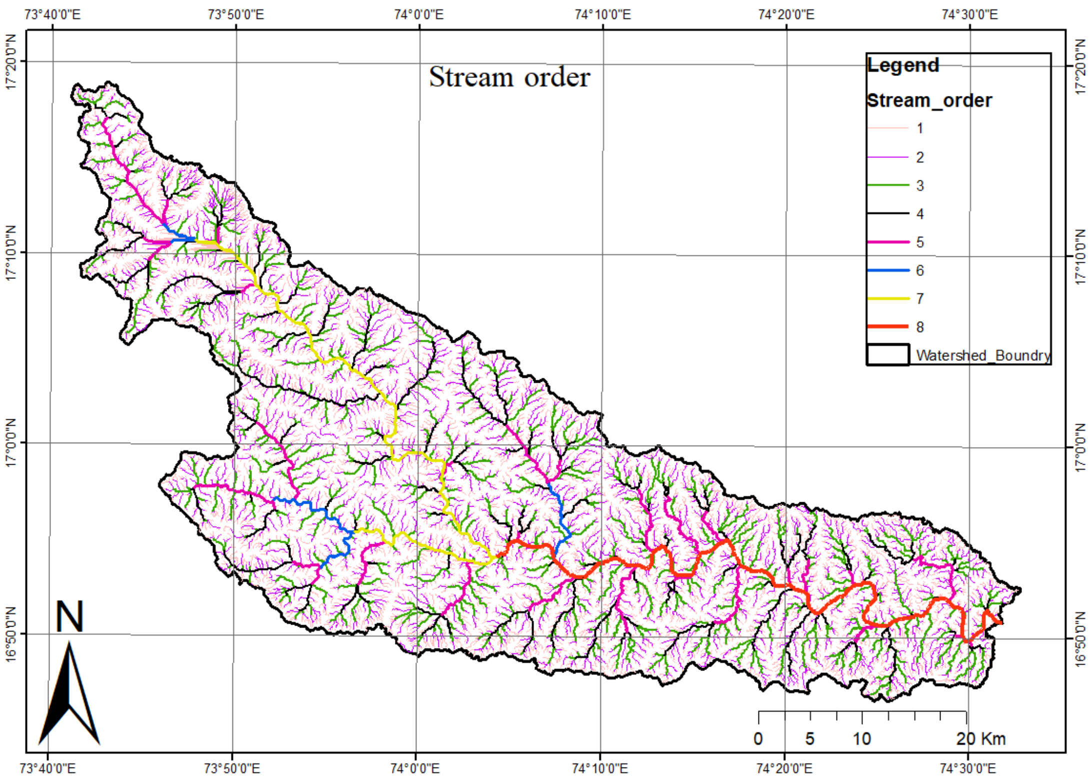

Fig No 2 Stream order map

Stream order (Su)

According to Strahler (1957), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed, where two of order 2 join, a segment of order 3 is formed and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order (Vinoth M.). It was found that the Warana river basin is a 8th order trunk stream.

Stream Number (Nu)

Stream number is defined as the order wise addition of stream segments. Stream number is an inverse of stream order. Stream numbers of 1st, 2nd, 3rd, 4th, 5th, 6th streams are 5001, 1098, 204, 42, 10 and 1 respectively. High value of first order streams Shows that there is possibility of sudden flash flood after heavy rainfall (Horton 1945).

Stream length (Lu)

Stream length is the addition of length all the streams having order u. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. The extent of stream length in a watershed information about the characteristics size of various components of drainage network and its contributing surface area. Total stream length of Warana River is 377.88 km. (Strahler, 1964).

Mean stream length (Lum)

Mean stream length is a characteristic property which relates to the size of drainage network components and its contributing basin surfaces (Strahler, 1964). It is computed by dividing the total stream length of order "u" by the number of streams of segments in the order. There are variations in mean stream length values 0.31 to 0.42.

Stream length ratio (Lurm)

The ratio of the mean length of the one order to the next lower order of the stream segments is known as Stream length ratio (Lurm). (Horton 1945). The amount of stream length ratio varies from 0.81 to 1.057 due to the change in mean stream length of Radhanagari Watershed.

Bifurcation ratio (Rb)

Bifurcation ratio is defined as the ratio of the number of streams of any given order to the number of streams in the next higher order. It is observed that the bifurcation ratio is different from one order to its next order. A bifurcation ratio value greater than 5 is considered as higher value and it indicates that strong structural control on the drainage pattern and the bifurcation ratio value less than 5 is considered as lower values indicates that watershed is not affected by structural disturbance (Nag 1998).

Weighted mean Bifurcation ratio (Rbwm)

Weighted mean bifurcation ratio is calculated by multiplying the bifurcation ratio of each successive pair of orders by total number of streams in this ratio and then calculated the mean of sum of these values Strahler (1953). The value found for Rbwm is 4.71.

Length of main channel (Cl)

The length along the longest watercourse from outflow point of watershed to the uppermost watershed boundary is known as Length of main channel (Cl). The ArcGIS 10.3 software is used to compute the length of main channel (Cl).The value found for (Cl) is 77.9 km.

Channel Index (Ci) & Valley Index (Vi)

Channel Index (Ci) is calculated by dividing Main Channel Length (Cl) with Adm i.e. Ci = Cl / Adm. and Valley Index (Vi) is calculated by dividing Valley Length (Vl) with Adm i.e. Vi = Vl / Adm. The calculated Channel Index (Ci) & Valley Index (Vi) is found to be 1.42 and 1.35 respectively.

RHO coefficient

The Ratio of stream length ratio to the bifurcation ratio is known as RHO coefficient. RHO coefficient determines the relation between the drainage density and physiographic development of basin (Horton, 1945). The factors like biologic, climatic, anthropogenic and geomorphologic factors affects the RHO coefficient. The calculated value of RHO coefficient for this study area is 0.58

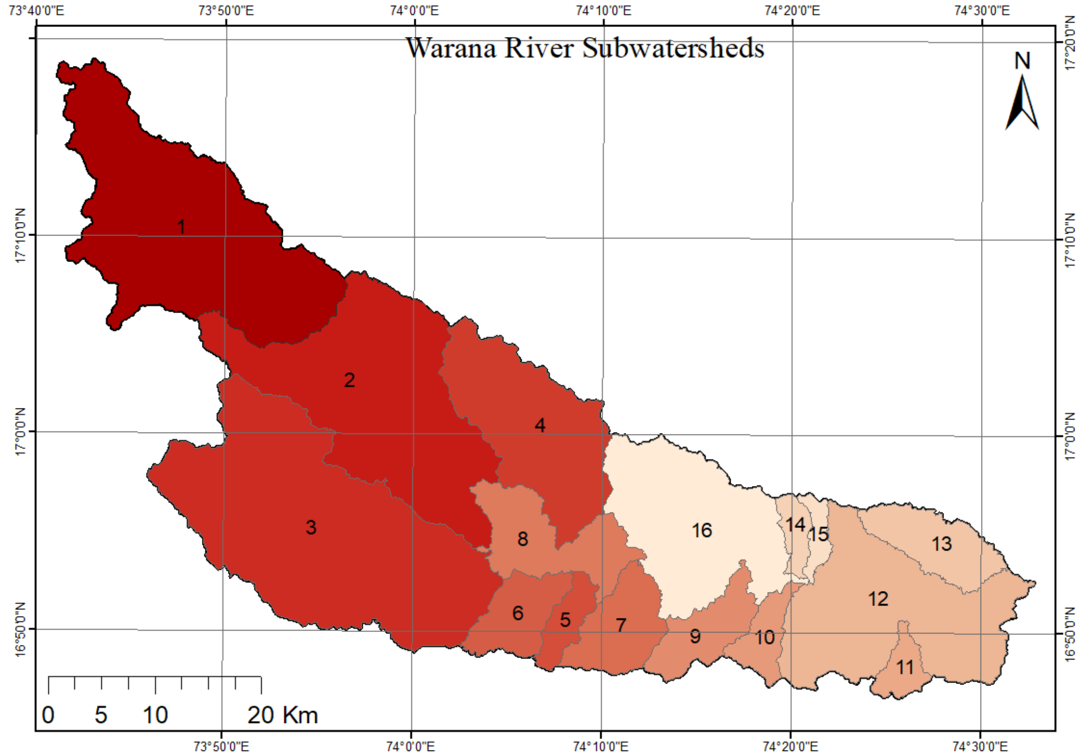

Fig No 3 Subwatersheds map

Linear aspects

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	Whole Basin
STREAM NUMBER (Nu)	1889	2253	2766	1188	104	401	412	615	374	252	159	1824	481	149	93	1501	14461
	393	299	342	162	31	57	72	105	54	30	23	267	65	23	18	173	2114
	86	62	107	38	8	16	17	27	15	7	9	68	19	3	5	58	535
	25	11	21	9	1	2	5	8	2	1	1	20	4	2	2	14	128
	6	1	7	2		1	1	3	1	0		3	1	1	1	6	26
	2	0	2	1				1				0				0	5
	1	1	1					2									2
								1				1				1	1
TOTAL	2399	2626	3243	1399	144	477	507	758	446	290	192	2182	570	178	119	1752	17272
STREAM LENGTH (Lu)	560.9	468	623	254	7.42	88	100.	137.38	77.58	46.8	36.1	100	94.1	32	23.4	307.3	2959
	289.8	278	328	149	19.7	40	48	74.54	42.18	22.4	17.1	48.5	64.4	14.4	12.4	181.6	1633
	113.4	98.4	167	67.0	11.7	17	28	3.43	23.1	14.6	11.5	28.6	24.4	6.48	4.2	93.56	714.0
	72.96	58.3	57.9	33.5	9.36	10	14	13	8.86	9.17	6.76	14.5	11.8	8.66	4.7	24.98	360.0
	26.78	1.88	40.0	11.0		6.3	8.7	2.18	8.52	0		8.76	9.12	1.85	3.72	24.56	153.4
	5.21	0	17.8	9.1				0.43									32.58
	19.51	36.61	17.3					1.11									57.23
								18.7				36.0				24.65	79.51

Total	1088.704	943.17	1253.082	524.25	48.267	163.2	200.88	250.85	160.24	93.15	71.66	236.96	204.06	63.41	48.46	656.8	5989.702
Mean Stream Length	0.29	0.20	0.22	0.21	0.07	0.2	0.2	0.22	0.20	0.18	0.22	0.05	0.19	0.21	0.25	0.204	0.204
	0.737	0.93	0.96	0.92	0.63	0.7	0.6	0.70	0.78	0.74	0.74	0.18	0.99	0.62	0.69	1.050	0.772
	1.318	1.58	1.56	1.76	1.46	1.0	1.6	0.12	1.54	2.09	1.28	0.42	1.28	2.16	0.84	1.613	1.334
	2.918	5.30	2.75	3.72	9.36	5.4	2.9	1.62	4.43	9.17	6.76	0.72	2.96	4.33	2.35	1.784	2.813
	4.463	1.88	5.72	5.51		6.3	8.7	0.72	8.52								5.902
	2.605		8.92					0.43									6.516
								0.55									28.61
stream length ratio (Lur)	2.483	4.48	4.26	4.31	8.93	3.2	2.7	3.17	3.76	4.01	3.27	3.29	5.06	2.91	2.73	5.128	3.774
	1.788	1.70	1.62	1.91	2.29	1.5	2.5	0.17	1.97	2.79	1.72	2.31	1.30	3.44	1.21	1.535	1.727
	2.213	3.34	1.76	2.11	6.39	5.1	1.7	12.7	2.87	4.38	5.24	1.72	2.30	2.00	2.79	1.106	2.107
	1.529377	0.35417	2.073537	1.478974		1.163004	3.02069	0.447179	1.923251	0	0	0	0	0	0	0	2.098132
	0.583645	0	1.559441	0				0.591743									1.103975
	0	0	0	0		0	0	1.290698	0								4.391498

Mean Stream Length Ratio	2.003484	2.470255	2.431666	2.453714	5.875455	2.748999	2.501627	4.148914	2.634257	2.799867	3.41717	2.446349	2.887321	2.789704	2.251659	2.5903	2.533956
Bifuegation Ratio (Rb)	4.806616	7.535117	8.087719	7.333333	3.354839	7.035088	5.722222	5.857143	6.925926	8.4	6.913043	6.831461	7.4	6.478261	5.166667	8.676301	6.840587
	4.569767	4.822581	3.196262	4.263158	3.875	3.5625	4.235294	3.888889	3.6	4.285714	2.555556	3.926471	3.421053	7.666667	3.6	2.982759	3.951402
	3.44	5.636364	5.095238	4.222222	8	8	3.4	3.375	7.5	7	9	3.4	4.75	1.5	2.5	4.142857	4.179688
	4.166667	11	3	4.5		2	5	2.666667	2								4.923077
	3		3.5					3									5.2
	2							0.5									2.5
								2									2
mean bifurgation ratio	4.245	7.24	4.84	5.07	5.07	5.1	4.5	3.94	5.00	6.56	6.15	4.71	5.19	5.21	3.75	5.267	4.227822
Lur-r	850.8	747	952	403	27.1	128	14	211	119	69.3	53.3	148	158	46.4	35.8	489.0	4592.82
	403.2	377.33	496.2	216.46	31.48	57.4	77.17	77.97	65.28	37.09	28.72	77.17	88.9	20.9	16.62	275.25	2347.212
	186.3	156.82	225.46	100.58	21.087	27.98	43.16	16.43	31.96	23.82	18.35	43.16	36.35	15.14	8.9	118.54	1074.102

	99.74	60.27	97.97	44.55	9.367	17.27	23.26	15.18	17.38	9.17	6.76	23.26	20.98	10.51	8.42	49.54	513.54
	26.78	1.88	40.04	11.02	0	6.35	8.76	20.96	8.52	0	0	44.84	9.12	1.85	3.72	49.21	232.97
total	1566	1344	1812	776	89.1	237	301.3	342.46	242.9	139.41	107.14	337.39	313.94	94.82	73.5	981.59	8760.644
Lur*Lur-r																	
	2112.993	3351.375	4059.278	1739.824	242.831	413.111	411.6382	673.4783	450.9687	278.7039	174.4885	491.4333	802.6055	135.5123	98.2038	2508.254	17336.92
	721.0564	642.2141	808.3933	414.1219	72.35143	86.47885	193.0976	13.95269	128.7028	103.7755	49.65876	179.0176	115.637	72.0499	20.2304	422.7705	4054.884
	412.4439	524.3381	397.2326	212.3672	134.8273	143.2786	74.24243	210.1651	91.93688	104.369	96.32563	74.24243	83.61687	30.35009	24.89881	131.1194	2264.002
	152.54	21.34584	203.1444	65.88829	0	20.08507	70.26124	6.788185	33.42609	0	0	0	0	0	0	0	1077.475
																	1023.087
total	3399.033	4539.273	5468.048	2432.202	450.0097	662.9535	749.2396	904.3843	705.0345	486.8484	320.4729	744.6933	1001.859	237.8674	143.3322	3062.144	25756.37
Luwm	2.16917	3.377033	3.017533	3.1336	5.04982	2.787	2.486	2.64084	2.90257	3.49220	2.99116	2.20721	3.19124	2.50862	1.95009	3.119575	2.940009

				35		041	607	7	1	6		8	5	1	8		
Nu-r	2282	2552	3108	1350	135	458	484	720	428	282	182	2091	546	172	111	1674	16575
	479	361	449	200	39	73	89	132	69	37	32	335	84	26	23	231	2649
	111	73	128	47	9	18	22	35	17	8	10	88	23	5	7	72	663
	31	12	28	11	1	3	6	11	3	1	1	23	5	3	3	20	154
	8																
	3																
																	27
TOTAL	2903	2998	3713	1608	184	552	601	898	517	328	225	2537	658	206	144	1997	20068
Rb*Nu-r	10968.7	19229.62	25136.63	9900	452.9032	3222.07	2769.556	4217.143	2964.296	2368.8	1258.174	14284.58	4040.4	1114.261	573.5	14524.13	113382.7
	2188.919	1740.952	1435.121	852.6316	151.125	260.0625	376.9412	513.3333	248.4	158.5714	81.7778	1315.368	287.3684	199.3333	82.8	689.0172	10467.26
	381.84	411.4545	652.1905	198.4444	72	144	74.8	118.125	127.5	56	90	299.2	109.25	7.5	17.5	298.2857	2771.133
	129.1667	132	84	49.5	0	6	30	29.33333	6	0	0	0	0	0	0	0	758.1538
																	54

TOTAL	13668.62	21514.02	27307.94	11000.58	676.0282	3632.133	3251.297	4877.935	3346.196	2583.371	1429.952	15899.15	4437.018	1321.094	673.8	15511.43	127433.3
Rbwm	4.708	7.17	7.35	6.84	3.67	6.57	5.4	5.4	6.47	7.87	6.35	6.26	6.74	6.41	4.67	7.767	6.350
Rho Coefficient (Lur/Rb)	0.516	0.59	0.52	0.58	2.66	0.45	0.4	0.5	0.54	0.47	0.47	0.48	0.68	0.45	0.53	0.591	0.551
	0.391	0.35	0.50	0.44	0.59	0.42	0.5	0.04	0.54	0.65	0.67	0.59	0.38	0.44	0.33	0.514	0.437
	0.643	0.59	0.34	0.50	0.79	0.64	0.5	3.7	0.38	0.62	0.58	0.50	0.48	1.33	1.11	0.26	0.504
	0.367	0.03	0.69	0.32		0.58	0.6	0.1	0.96								0.426
																	2.195
mean rho	0.479	0.39	0.51	0.46	1.35	0.52	0.5	1.1	0.60	0.58	0.57	0.52	0.51	0.74	0.66	0.457	0.823
Main Channel Length (Cl) km	39.53	45.45	38.58	27.4	11.1	13.9	12	22	17.3	12.7	10.0	39.3	6.15	9.55	11.3	33.8	149.2
Vally Length (Vl) Km	38.71	44.2	37.1	25.8	10.0	12.3	12	21	16.8	11.1	9.16	38.2	4.66	8.81	9.63	32.5	146.7
Maximum Areial Distance(Adm)	34.56	34.7	33.8	22.3	9.66	12	11	16	12.7	10.1	7.2	19.1	13.9	7.9	7.66	21.5	105.6
Channel index(Ci)	1.143	1.30	1.14	1.22	1.15	1.1	1.0	1.3	1.35	1.24	1.4	2.05	0.44	1.20	1.47	1.572	1.412
Valley index (Vi)	1.120	1.27	1.09	1.15	1.03	0.9	1.0	1.2	1.31	1.09	1.27	1.99	0.33	1.11	1.25	1.511	1.388

Areal aspect

The areal aspect of the drainage basin (watershed) such as Drainage density (Dd), Stream frequency (Fs), Drainage Texture (Rt), Form Factor (RF), Constant of channel maintenance (C), Lemniscate (k), Infiltration Number (If), Basin perimeter (P),Elongation ratio (Re), Circularity ratio (Rc), Length of overland flow (Lg) Were calculated and result shown in Table 4.

Length of basin (Lb)

Basin length is computed by measuring the longest dimension of basin parallel to principal drainage line (Schumm, 1956). It is calculated according to Schumm (1956) as it is found to be 62.8 km.

Basin area (A)

The ArcGIS 10.3 software is used to calculate the Basin area (A), the value found for (A) is 2081 km2.

Basin Perimeter (P)

The area enclosed by the outermost boundary of basin that area is known as the basin perimeter. The factors like size and shape of watershed is indicated by basin perimeter. The ArcGIS 10.3 software is used to calculate the Basin Perimeter (P), the value found for (P) 222m.

Length area relation (Lar)

Length area relation (Lar) is calculated by formula Lar = 1.4* A0.6 Hack (1957) gives the relation between the stream length and basin area.

Lemniscate's (k)

Lemniscate's value gives the slope of basin Chorely (1967). the formula for Lemniscate's value k= Lb2/4*A where Lb is basin length in km and A is the area of basin in km2. the value found for k is 2.66.

Form factor (Ff)

Different basin shapes are represented by the Form factor (Horton, 1932). By the Horton, form factor is defined as the ratio of the basin area and square of the basin length. The values for Form factor Varies between 0.1 to 0.8. Circular type basin shape is indicated by higher value of form factor while the enlongated basin is indicated by smaller value. The value found for (Ff) is 0.184 which indicates basin is Fern shaped.

Elongation ratio (Re)

As given by Schum, elongation ratio is defined as the ratio of diameter of a circle having same area as of the basin and maximum basin length. According to Strahler The value 0.6 to 1.0 is the actual range of elongation ratio values. Shapes of basin are based on elongation ratio; smaller than 0.7 it is elongated, 0.8 to 0.7 it is less elongated, 0.9 to 0.8 it is oval shaped and greater than 0.9 it is circular shape. (Singh and Singh in 1997) The value found for (Re) is 0.48, which represents that the basin is elongated.

Texture ratio (Rt)

Ratio between the first order streams and perimeter of basin i.e. (Rt= NI/P) is Texture ratio. Texture ratio depends on factors like relief aspects of terrain, lithology and infiltration capacity. The value found for (Rt) is 42.59.

Circulatory ratio (Rc)

As per law of Miller, circulatory ratio is defined as the ratio of the area of a basin to the area of a circle possessing the same circumference as the perimeter of the basin. According to Miller (1953) range for the circulatory ratio of basin varies from 0.4 to 0.6 which shows that the basin is elongated and highly permeable geological materials. The value found for (Rc) is 0.22 which indicates that the basin is elongated type.

Drainage texture (Dt)

The ratio of stream segments of all orders to the perimeter of that area is known as Drainage texture (Horton, 1945). Smith created the five drainage texture classification Smith (1950) i.e., very fine (>8), fine (6 to 8), moderate (4 to 6), coarse (2 to 4), very coarse (<2). The value found for (Dt) is 50.87 which indicates that texture is very fine.

Compactness coefficient (Cc)

According to Gravelius Compactness coefficient (Cc) is the ratio of perimeter of watershed to circumference of circular area, which is equal to the area of watershed (Gravelius 1994). Compactness coefficient depends not on the size of watershed but on the slope. The value found for (Cc) is 2.11.

Fitness ratio (Rf)

Fitness ratio is defined as ratio of the main channel length to the length of watershed perimeter. Topographic fitness is measured by Fitness ratio (Melton 1957). The value found for (Rf) is 0.0041.

Wandering ratio (Rw)

Wandering ratio (Rw) is defined as the ratio of main stream length to the valley length (Smart & Surkan 1967). The straight line distance measured between outlet of basin and remost point on the ridge is called the valley length. The value found for (Rw) is 1.40.

Watershed Eccentricity (τ)

The watershed eccentricity formula is, $\tau = [(|Lcm2 - Wcm2|)]\ 0.5 / Wcm$ Where τ = Watershed eccentricity, Wcm = Width of the watershed at the centre of mass and perpendicular to Lcm and Lcm = Straight length from the watershed mouth to the centre of mass of the watershed. The value found for (τ) is 1.54.

AREAL ASPECTS																	
	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	Whole Basin
Length from W's Center to Mouth of W's (Lcm) Kms	15.36	17.2	15.87	12.41	4.8	3.85	6.4	10.81	7.51	6.03	3.18	11.57	5.23	4.37	4.55	11.89	51.03
Width of W's at the Center of Mass (Wcm) Kms	14.81	12.5	14.39	8.97	2.86	2.84	7.19	5.12	4.27	3.14	3.21	11.7	4.88	2.3	1.88	23.38	27.74
Basin Length (Lb) Kms	36.36	34.3	40.64	24.41	8.228	12.03	13.55	16.43	12.12	8.84	7.20	28.38	13.3	6.62	5.75	25.9	100.62
Lb in Meters	3635 9.72	3437	4064 2.16	2441 4.99	8228. 032	1203 7.03	1355 8.24	1643 3.23	1212 9.29	8848.4 82	7201.3 14	28384. 67	13389. 67	6628.7 1	5753.9 15	25956. 39	10062 6.5
Mean Basin Width (Wb)	9.54	9.14	10.37 765	7.043 213	3.079 716	4.113 14	4.502 797	5.212	4.137 094	3.2547 96	2.7828 26	7.8982 77	4.4601 55	2.6128 76	2.3462 29	7.3789 14	20.680 44
AREA	346.6 9	314	421.7 7	171.9 6	25.34	49.51	61.05	85.65	50.18	28.8	20.04	224.19	59.72	17.32	13.5	191.53	2081
PERIMETER	115.1 4	113.9 1	116.8 3	71.34	28.61	37.92	38.36	68.06	43.14	32.62	24.27	100.62	46	23.78	24.73	85.47	339.48
Relative Perimeter (Pr)	3.01	2.76	3.610 117	2.410 429	0.885 704	1.305 643	1.591 502	1.258 448	1.163 19	0.8828 94	0.8257 11	2.2280 86	1.2982 61	0.7283 43	0.5458 96	2.2409 03	6.1299 63

Length Area Relation (Lar)	46.78	44.08	52.62274	30.7174	9.736705	14.55271	16.50211	20.21922	14.67055	10.51389	8.45798	36.01619	16.28546	7.749198	6.67311	32.76952	137.117
Lemniscate's (k)	3.81	3.76	3.916318	3.466457	2.671686	2.926482	3.01107	3.152961	2.931837	2.718598	2.587771	3.59378	3.002064	2.53694	2.45241	3.517644	4.865782
Form Factor Ratio (Rf)	0.26	0.27	0.255342	0.288479	0.374296	0.341707	0.332108	0.317162	0.341083	0.367837	0.386433	0.278259	0.333104	0.394176	0.407762	0.284281	0.205517
Shape Factor Ratio (Rs)	3.81	3.76	3.916318	3.466457	2.671686	2.926482	3.01107	3.152961	2.931837	2.718598	2.587771	3.59378	3.002064	2.53694	2.45241	3.517644	4.865782
Elongation Ratio (Re)	0.58	0.58	0.57033	0.606209	0.690514	0.659769	0.650436	0.635632	0.659167	0.68453	0.701621	0.595373	0.651411	0.708615	0.720723	0.601782	0.511669
Elipticity Index (Ie)	3.39	4.88	2.565	3.038	3.122	2.414	1.863	4.049	4.420	3.3704	3.2867	5.1148	0.2854	3.5178	5.3924	4.3291	8.1181
Texture Ratio (Rt)	16.41	19.7	23.67	16.65	3.635	10.57	10.74	9.036	8.669	7.725	6.5512	18.127	10.456	6.265	3.7606	17.561	42.59
Circularity Ratio (Rc)	0.33	0.30	0.388	0.424	0.389	0.432	0.521	0.232	0.338	0.340	0.427	0.278	0.354	0.384	0.277	0.329	0.226

Circularity Ration (Rcn)	3.01	2.76	3.610	2.410	0.88	1.30	1.59	1.25	1.16	0.882	0.825	2.2280	1.2982	0.7283	0.5458	2.2409	6.1299
Drainage Texture (Dt)	20.84	23.05	27.75828	19.61032	5.033205	12.57911	13.21689	11.13723	10.33843	8.890251	7.911001	21.68555	12.3913	7.485282	4.811969	20.49842	50.87781
Compactness Coefficient (Cc)	0.00	0.00	0.000187	0.000685	0.012658	0.004395	0.002924	0.002636	0.004867	0.011173	0.017169	0.000569	0.003664	0.022521	0.03855	0.000662	2.23E-05
Fitness Ratio (Rf)	0.34	0.40	0.330223	0.384076	0.390772	0.366825	0.336809	0.32486	0.401715	0.389945	0.415328	0.391175	0.133696	0.401598	0.458148	0.39546	0.439555
Wandering Ratio (Rw)	1.09	1.32	0.94926	1.122261	1.35877	1.1556	0.952926	1.345444	1.428773	1.437535	1.399745	1.386664	0.459309	1.440703	1.969094	1.302184	1.48291
Watershed Eccentricity (τ)	0.28	0.95	0.465055	0.956072	1.347874	0.915283	#NUM!	1.859491	#NUM!	1.639472	0.137684	0.150327	#NUM!	#NUM!	#NUM!	1.693093	1.544041

Centre of Gravity OF the Watershed (Gc)	73.51 E & 18.47 N	73.53 E & 18.43 N	73.51 E & 18.45 N	73.43 E & 18.50 N	73.47 E & 18.51 N	73.45 E & 18.51 N	73.43 E & 18.52 N	73.41 E & 18.54 N	73.37 E & 18.55 N	73.33E & 18.57N	73.34E & 18.58N	73.34E & 18.58N	73.34E & 18.58N	73.34E & 18.58N	73.34E & 18.58N	73.34E & 18.58N	73.34E & 18.58N
Hydraulic Sinuosity Index (Hsi) %	2.13	2.81	3.858 435	6.060 606	11.19 843	12.16 112	7.382 55	5.163 43	3.184 323	13.651 88	10.132 16	2.9718 46	28.932 04	8.6549 71	16.456 92	3.9634 15	1.7001 75
Topographic Sinuosity Index (Tsi) %	97.87	97.19	96.14 156	93.93 939	88.80 157	87.83 888	92.61 745	94.83 657	96.81 568	86.348 12	89.867 84	97.028 15	71.067 96	91.345 03	83.543 08	96.036 59	98.299 82
Standard Sinuosity Index (Ssi)	1.02	1.03	1.039 052	1.062 016	1.113 546	1.127 229	1.073 09	1.051 855	1.030 934	1.1438 85	1.1004 37	1.0298 27	1.3197 42	1.0839 95	1.1765 32	1.04	1.0171 78
Longest Dimension Parallel to the Principal Drainage Line (Clp) Kms	38.71	44.20	37.13	25.8	10.04	12.34	12.04	21.02	16.81	11.12	9.16	38.22	4.66	8.81	9.63	32.5	146.7
Stream Frequency (Fs)	6.92	8.36	7.689 025	8.135 613	5.682 715	9.634 417	8.304 668	8.849 971	8.888 003	10.069 44	9.5808 38	9.7328 16	9.5445 41	10.277 14	8.8148 15	9.1473 92	8.2998 56
Drainage Density (Dd) Km / Kms2	3.14	3.00	2.971 008	3.048 674	1.904 775	3.296 304	3.290 418	2.928 78	3.193 304	3.2343 75	3.5758 48	1.0569 61	3.4169 46	3.6610 85	3.5896 3	3.4292 28	2.8782 81
Constant of Channel Maintenance (Kms2 / Km)	0.32	0.33	0.336 586	0.328 011	0.524 996	0.303 37	0.303 913	0.341 439	0.313 155	0.3091 79	0.2796 54	0.9461 09	0.2926 59	0.2731 43	0.2785 8	0.2916 11	0.3474 3

Drainage Intensity (Di)	2.20	2.78	2.588019	2.668574	2.983405	2.922794	2.523895	3.021726	2.783325	3.113258	2.679319	9.208305	2.793296	2.807128	2.455634	2.667479	2.883616
Infiltration Number (If)	21.73	25.12	22.84415	24.80283	10.82429	31.75797	27.32583	25.91962	28.3821	32.56836	34.25962	10.2872	32.61318	37.62547	31.64192	31.36849	23.88931
Length of Overland Flow (Lg) Kms	0.16	0.17	0.168293	0.164006	0.262498	0.151685	0.151956	0.17072	0.156578	0.154589	0.139827	0.473055	0.14633	0.136572	0.13929	0.145805	0.173715

Relief aspect

Relief aspects provides information related with elevation. Relief aspects are Maximum basin relief (H), Relief ratio (Rhl), Relative relief (Rhp), Absolute relief (Ra), Channel gradient (Cg), Ruggedness Number (Rn), Melton Ruggedness number (MRn), Gradient ratio (Rg).

Maximum basin relief (H)

The difference between the elevation of highest Point in the catchment and the catchment outlet is known as Maximum basin relief (H). The value found for (H) is 568 m and it reveals that basin has undulating terrain having high kinetic energy of water results in severe soil erosion.

Relief ratio (Rhl)

Relief ratio (Rhl) is defined as the ratio between the total relief of basin (H) and the longest dimension of basin parallel (Lb) to main drainage line (Schumm, 1956) i.e. Rhl = H / Lb. The value found for (Rhl) is 5.33.

Relative relief (Rhp)

The formula used to calculate Relative relief (Rhp) is Rhp= H*100/P which is given by the Melton (1957), where P is perimeter in meter & H is total basin relief. The value found for (Rhp) is 0.167.

Absolute relief (Ra)

The elevation difference between the given location and the sea level. ArcGIS-10.3 software is used to calculate the absolute relief and the value found for (Ra) is 1109 m.

Channel gradient (Cg)

Channel Gradient (Cg) is calculated by formula Cg = H / {(π/2) * Clp} which is given by the Broscoe (1959) where Clp is the longest dimension parallel to the Principal drainage line (Clp) Kms and 'H' is total basin relief. . The value found for (Cg) is 2.4661.

Ruggedness Number (Rn)

Ruggedness number is calculated by the multiplication of basin relief and drainage density (Strahler, 1968). Ruggedness number (Rn) measures the surface unevenness or roughness. Ruggedness number is combination of the slope steepness along with the length. For this study area value for Ruggedness Number (Rn) found is 1.63.

Melton Ruggedness number (MRn)

Melton Ruggedness number (MRn) is defined as the slope index that gives special representation of the relief ruggedness within the watershed. For this study area value for Melton Ruggedness number (MRn) found is 12.45.

RELIEF ASPECTS	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	Whole Basin
Height of Basin Mouth (z) m	559.00	566.00	576	599	603	624	642	650	647	682	681	681	681	681	681	681	559
Maximum Height of the Basin (Z) m	777.00	680.00	711	1110	819	967	1164	1226	1272	1097	1134	1134	1134	1134	1134	1134	1272
Total Basin Relief (H) m	218.00	114.00	135	511	216	343	522	576	625	415	453	453	453	453	453	453	713
H in kilometer	0.22	0.11	0.135	0.511	0.216	0.343	0.522	0.576	0.625	0.415	0.453	0.453	0.453	0.453	0.453	0.453	0.713
Relief Ratio (Rhl)	0.01	0.00	0.003636	0.019806	0.021514	0.027796	0.043355	0.027402	0.03718	0.03732	0.049454	0.011852	0.09721	0.051419	0.04704	0.013938	0.00486
Absolute Relief (Ra) m	777.00	680.00	711	1110	819	967	1164	1226	1272	1097	1134	1134	1134	1134	1134	1134	1272

Relative Relief Ratio (Rhp)		0.19	0.10	0.115553	0.716288	0.754981	0.904536	1.360792	0.846312	1.448771	1.272226	1.866502	0.450209	0.984783	1.904962	1.831783	0.530011	0.210027
Dissection Index (Dis)		0.28	0.17	0.189873	0.46036	0.263736	0.354705	0.448454	0.469821	0.491352	0.378304	0.399471	0.399471	0.399471	0.399471	0.399471	0.399471	0.560535
Channel Gradient (Cg) m / Kms		3.59	1.64	2.315843	12.61542	13.70315	17.70432	27.61496	17.4538	23.68169	23.77079	31.49946	7.549321	61.91739	32.75085	29.9621	8.878001	3.095706
Gradient Ratio (Rg)		0.01	0.00	0.003322	0.02093	0.026252	0.028495	0.038501	0.035051	0.051528	0.046901	0.062905	0.015959	0.033832	0.068339	0.078729	0.017452	0.007086
Watershed Slope (Sw)		0.01	0.00	0.003322	0.02093	0.026252	0.028495	0.038501	0.035051	0.051528	0.046901	0.062905	0.015959	0.033832	0.068339	0.078729	0.017452	0.007086
Ruggedness Number (Rn)		0.68	0.34	0.401086	1.557872	0.411431	1.130632	1.717598	1.686977	1.995815	1.342266	1.619859	0.478803	1.547876	1.658472	1.626102	1.55344	2.052214
Melton Ruggedness Number (MRn)		11.71	6.43	6.573489	38.96792	42.9092	48.74697	66.80788	62.23845	88.22968	77.33068	101.1927	30.25451	58.61899	108.849	123.291	32.73255	15.6298
Total Contour Length (Ctl) Kms		688.41	187.46	90.82	1184.77	110.52	145.37	187.96	332.3	1264.11	499.46	331.37	332.37	333.37	334.37	335.37	336.37	
Contour Interval (Cin) m		10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	10M	

Slope Analysis (Sa)		0.01	0.00	0.001134	0.014966	0.016537	0.008278	0.006865	0.008258	0.05127	0.045842	0.041393	0.003711	0.013974	0.048327	0.062188	0.004396	0
Average Slope (S) %		0.71	0.36	0.113407	1.49661	1.653729	0.827779	0.686534	0.825793	5.126976	4.584234	4.139333	0.371125	1.397403	4.832749	6.218781	0.439638	0
Mean Slope of Overall Basin (Θs)		0.20	0.06	0.021533	0.68898	0.436148	0.293617	0.307879	0.387974	2.519151	1.734236	1.653543	0.148254	0.558222	1.930543	2.484222	0.175623	0
Relative Height (h/H)		IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table
Relative Area (a/A)		IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table	IN Hypsometric table
Surface Area of Relief (Rsa) Sq Kms		346.69	314.00	421.77	171.96	25.34	49.51	61.05	85.65	50.18	28.8	20.04	224.19	59.72	17.32	13.5	191.53	2081
Composite Profile area (Acp) sq.km.		346.69	314.00	421.77	171.96	25.34	49.51	61.05	85.65	50.18	28.8	20.04	224.19	59.72	17.32	13.5	191.53	2081

Sr No	Parameters	SW 1		SW 2		SW 3		SW 4		SW 5		SW 6		SW 7		SW 8		SW 9		SW 10		SW 11		SW 12		SW 13		SW 14		SW 15		SW 16	
		V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P	V	P
1	Bifurgation Ratio (Rb)	3.9	7	5.8	2	4.6	5	6.8	1	3.1	13	3.72	10	2.67	15	3.04	14	4.01	6	3.94	8	3.70	11	4.76	4	3.91	9	3.53	12	2.65	16	4.83	3
2	stream fequency (Fs)	6.92	15	8.37	12	7.69	14	8.14	13	5.68	16	9.63	4	8.30	11	8.90	8	8.89	9	10.07	2	9.58	5	9.74	3	9.54	6	10.28	1	8.81	11	9.15	7
3	Drainage Texture (Dt)	20.86	4	23.06	2	27.78	1	19.46	6	5.03	15	12.58	8	13.22	7	11.20	10	10.33	11	8.89	12	7.91	13	21.70	3	12.39	9	7.49	14	4.81	16	20.51	5
4	Form Factor (Rf)	0.26	4	0.24	2	0.40	13	0.30	7	2.69	16	0.32	9	0.41	14	0.25	3	0.28	6	0.35	10	0.35	12	0.59	15	0.31	8	0.27	5	0.18	1	0.35	11
5	Circularotory Ratio (Rc)	0.32	6	0.30	5	0.38	11	0.41	13	0.39	12	0.43	15	0.52	16	0.23	1	0.34	8	0.34	9	0.43	14	0.28	3	0.35	10	0.38	13	0.28	2	0.33	7
6	Elongation Ratio (Re)	0.57	6	0.56	2	0.71	14	0.62	8	0.58	4	0.64	10	0.72	15	0.56	3	0.60	7	0.67	11	0.67	13	0.86	16	0.62	9	0.59	5	0.48	1	0.67	12
7	Compactness Coefficient (Cc)	1.75	11	1.83	13	1.61	5	1.15	1	1.61	6	1.53	3	1.39	2	2.81	16	1.73	10	1.73	9	1.54	4	1.91	14	1.69	8	1.62	7	1.91	15	1.75	12
8	Length Of Overland Flow (Lg)	0.15	11	0.17	4	0.16	6	0.16	5	0.26	2	0.15	10	0.15	9	0.17	3	0.16	7	0.15	8	0.14	1	0.47	13	0.15	12	0.14	16	0.14	15	0.15	13
9	Drainage Density (Dd)	3.14	11	3.00	13	2.97	14	3.05	12	1.90	16	3.30	6	3.29	7	2.93	15	3.19	9	3.23	8	3.57	4	4.74	1	3.14	10	3.66	2	3.59	3	3.43	5
10	Stream Length Ratio (Lur)	1.71	15	2.47	10	2.25	12	3.29	5	3.53	3	3.28	6	2.33	11	7.47	1	2.63	9	3.73	2	3.42	4	1.06	16	2.93	8	2.20	13	2.08	14	3.22	7
11	Drainage Intensity (Di)	2.20	16	2.79	2	2.59	13	2.67	11	2.98	4	2.92	5	2.52	14	3.04	3	2.78	9	3.11	11	2.68	10	9.21	4	2.79	7	2.81	6	2.46	15	2.67	12
12	Infiltration No (If)	21.75	14	25.13	11	22.86	13	24.81	12	10.82	15	31.76	5	27.33	9	26.06	10	28.38	8	32.57	4	34.22	2	10.29	16	32.61	3	37.63	1	31.64	6	31.39	7

13	Rugdness No (Rl)	1.71	3	1.50	4	1.41	5	1.04	8	0.79	13	1.41	6	1.34	7	9.44	1	1.01	9	0.41	14	0.90	12	0.32	15	0.19	16	0.96	10	6.94	2	0.94	11
14	Relief Ratio (Rhl)	15.01	9	13.90	12	14.80	10	14.32	11	42.95	1	34.49	2	33.25	4	0.26	16	23.56	7	13.86	13	33.42	3	15.38	8	3.93	15	32.83	5	30.24	6	11.76	14
15	Relative Relief Ratio (Rhp)	0.47	9	0.44	10	0.40	12	0.47	8	1.46	1	1.13	2	1.06	4	0.44	11	0.73	7	0.39	13	1.04	6	0.30	15	0.12	16	1.10	3	1.06	5	0.32	14
16	RHO Coefficient	0.43	15	0.43	16	0.49	14	0.51	13	1.16	2	0.88	6	0.87	7	2.46	1	0.66	11	0.95	4	0.93	5	1.00	3	0.75	9	0.62	12	0.79	8	0.67	10
17	Lamniscate (K)	3.81	13	4.10	15	2.46	2	3.29	9	3.72	12	3.10	7	2.47	3	4.01	14	3.56	10	2.87	6	2.84	4	1.71	1	3.27	8	3.68	11	5.52	16	2.85	5
18	Compound value	5.00		5.53		5.50		5.33		5.21		6.55		5.99		4.90		5.46		5.13		6.31		4.96		4.63		6.46		6.09		5.59	
19	Ranking	4		10		9		7		6		16		12		2		8		5		14		3		1		15		13		11	
20	Priority	High		Medium		Medium		Medium		Medium		Low		Low		high		Medium		high		Low		high		high		Low		Low		Low	

Prioritization Table

Conclusion

Satellite data was also used for better understating of landform and their processes. Both processes are helpful for water management planning, natural resource management, plantation and understanding physiography of basin.

Prioritization of watershed is done on basis of the linear aspect (La), Areal aspect (Aa), Relief aspect (Ra). Higher first order stream results in easily disposal of water hence groundwater recharge is less. Length ratio, bifurcation ratio and stream order of basin indicates that the basin is eight order basin with dendritic type of drainage pattern Form factor, Elongation ratio and Circulatory ratio shows the basin type is elongated. Drainage texture shows that the basin texture is very fine that implies it has more risk of soil erosion and infiltration ratio indicates basin has lower infiltration capacity and higher runoff. From the maximum basin relief the terrain is undulating type having kinetic energy of water is high results higher runoff.

Acknowledgement

I thankful to Dr.V.P.Mandale Training Co-ordinator, JD INFOTECH, Aurangabad, Maharashtra for providing Technical Assistance during INPLANT Training program.

REFERENCES

Alexander, P.O (1979), "Age and Duration of Deccan Volcanism: K. Ar. Evidence", Deccan Volcanism Geological Society of India, Memoir No. 3, Bangalore, pp 244-257

Bhagwat, T. N., Shetty, A., and Hegde, V. S., 2011. Spatial variation in drainage characteristics and geomorphic instantaneous unit hydrograph (GIUH); implications for watershed management-A case study of the Varada River basin, Northern Karnataka. Catena, 87(1), 52-59. DOI: 10.1016/j.catena.2011.05.007

Broscoe, A.J (1959), "Quantitative Analysis of Longitudinal Stream Profiles of Small Watersheds", Project N. 389-042, Tech. Bep. 18, Geology Department, Columbian University, ONR, Geography Branch, New York

Calef, W. C (1950), "Form and Process, Cambridge University Press", London, pp 473. Catchment", International Association of Scientific Hydrology - Bulletin, 13, pp 61-68.

Chorley, R. J., Schumm, S. A. and Sugden, D. E., 1984. Geomorphology: London. Methuen and Co. London. Chorley, R.J (1972), "Spatial Analysis in Geomorphology", Mathuen and Co. Ltd., London

Chorley, R.L (1967), "Models in Geomorphology", in R.J. Chorley and P. Haggett (eds.), Models in Geography, London, pp 59-96.

Dury, G.H (1952), "Methods of Cartographical Analysis in Geomorphological Research", Silver Jubilee Volume, Indian Geographical Society, Madras, pp 136-139.

Esper Angillieri, M. Y., 2008. Morphometric analysis of Colangüil river basin and flash flood hazard, San Juan, Argentina. Environmental Geology, 55(1), 107-111. DOI: 10.1007/s00254-007-0969- 2

Faniran, A (1968), "The Index of Drainage Intensity - A Provisional New Drainage Factor", Australian Journal of Science, 31, pp 328-330.

Gaikwad, R. and Bhagat, V., 2017. Multi-Criteria Watershed Prioritization of Kas Basin in Maharashtra India: AHP and Influence Approaches. Hydrospatial Analysis, 1(1), 41-61. DOI: 10.21523/gcj3.17010105

Gold, D. P (1980), "Structural Geology", Chapter 14 in Remote Sensing in Geology, edit by Siegal, B. S. and Gillespie, A. R., John Wiley, New York, pp 410-483.

Gregory, K. J., and Walling, D. E., 1976. Drainage basin form and process: A geomorphological approach. Edward Arnold, London

Gregory, K.J. & Walling, D.E (1968), "The Variation of Drainage Density within a Horton, R.E (1932), "Drainage Basin Characteristics", Transactions, American Geophysical Union, 13, pp 350-61.

Horton, R.E (1945), "Erosional Development of Streams and their Drainage Basins",Bulletin of the Geological Society of America, 56, pp-275-370.

King, C.A.M (1966), "Techniques in Geomorphology", Edward Arnold, (Publishers)Ltd. London, pp 319-321.

Magesh, N. S., Chandrasekar, N., and Soundranayagam, J. P., 2011. Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, TamilNadu, India: a GIS approach. Environmental Earth Sciences, 64(2), 373-381. DOI: 10.1007/s12665-010-0860-4

Melton, M.A., An analysis of the relations among elements of climate, Surface properties and geomorphology, Project NR 389042, Tech. Rep. 11, Columbia University,1957.

Pareta, K (2003), "Morphometric Analysis of Dhasan River Basin, India", UttarBharat Bhoogol Patrika, Gorakhpur, 39, pp 15-35.

Pareta, K (2004), "Hydro-Geomorphology of Sagar District (M.P.): A Study through Remote Sensing Technique", Proceeding in XIX M. P. Young Scientist Congress, Madhya Pradesh Council of Science & Technology (MAPCOST), Bhopal.

Pareta, K (2005), "Rainfall-Runoff Modelling, Soil Erosion Modelling, Water Balance Calculation, and Morphometric Analysis of Molali Watershed, Sagar, Madhya Pradesh using GIS and Remote Sensing Techniques", proceeding in 25th International Cartographic Congress, INCA.

Pareta, K. and Koshta, Upasana (2009), "Soil Erosion Modeling using Remote Sensing and GIS: A Case Study of Mohand Watershed, Haridwar", Madhya Bharti Journal, Dr. Hari Singh Gour University, Sagar (M.P.), 55, pp 23-33.

Rai, P. K., Mohan, K., Mishra, S., Ahmad, A. and Mishra, V. N., 2017. A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. Applied Water Science, 7(1), 217-232. DOI: 10.1007/s13201-014-0238-y

Richards, K.S. Arnett, R.R. and Ellis, J (1985), "Geomorphology and Soils", George Allen and Unwin, London, pp 441.

Scheidegger, A.E (1965), "The Algebra of Stream Order Number", U.S. GeologicalSurvey Professional Paper, 525B, B1, pp 87-89.

Schumm, S.A (1954), "The relation of Drainage Basin Relief to Sediment Loss",International Association of Scientific Hydrology, 36, pp 216-219.

Schumm, S.A (1956), "Evolution of Drainage Systems & Slopes in Badlands at PerthAnboy, New Jersey", Bulletin of the Geological Society of America, 67, pp 597-646.

Schumm, S.A (1963), "Sinuosity of Alluvial Rivers on the Great Plains", Bulletin of the Geological Society of America, 74, pp 1089-1100.

Shreve, R.L (1966), "Statistical Law of Stream Numbers", Journal of Geology, 74, pp 17-37

Singh, P., Gupta, A., and Singh, M., 2014. Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques. The Egyptian Journal of Remote Sensing and Space Science, 17(2), 111-121. DOI: 10.1016/j.ejrs.2014.09.003

Smith, G.H (1939), "The Morphometry of Ohio: The Average Slope of the Land (abstract)", Annals of the Association of American Geographers, 29, pp 94.

Strahler, A. N., 1957. Quantitative analysis of watershed geomorphology. Transactions, American Geophysical Union, 38(6), 913-920. DOI: 10.1029/tr038i006p00913

Strahler, A.N (1952), "Hypsometric Analysis of Erosional Topography", Bulletin of the Geological Society of America, 63, pp 1117-42.

Strahler, A.N (1956), "Quantitative Slope Analysis", Bulletin of the GeologicalSociety of America, 67, pp 571-596.

Strahler, A.N (1964), "Quantitative Geomorphology of Drainage Basin and Channel Network", Handbook of Applied Hydrology, pp 39-76

Sujatha, E. R., Selvakumar, R. and Rajasimman, B., 2014. Watershed prioritization of Palar subwatershed based on the morphometric and land use analysis. Journal of Mountain Science, 11(4), 906-916. DOI: 10.1007/s11629-012-2628-7

Thornbury, W.D (1954), "Principles of Geomorphology", John Wiley and Sons, London.

Vinoth M. 2014 Characteristics of Drainage Morphological Studies Using GIS in Kolli Hills, Central of Tamil Nadu, India. International Journal of Remote Sensing & Geoscience (IJRSG). 2014; 3(3):10-15.