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Morphometric Analysis Based Prioritisation of Belkund Sub-Watershed, Jabalpur District, M.P., India

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Abstract: Land, water and soil are limited natural resources and their wide utilisation with increasing population is a major area of concern. Belkund sub-watershed is a part of Hiran River Basin. Belkund River is a tributary of Hiran River, which in turn is a tributary of Narmada River of central India. In the present study emphasis is given on the morphometric parameters of sub watershed, Geology using GIS Techniques for prioritizations of micro watersheds.

Keywords: Watershed Prioritisation, GIS, Remote Sensing, Drainage Morphometery.

I. INTRODUCTION

Land, water and soil are limited natural resources and their wide utilisation with increasing population is a major area of concern. Conservation of such type of natural resources is important to mitigate the increasing demand of land and water resources. The future of human being is closely associated with proper development and conservation of natural resources like land and water.

Hence sustainable development of natural resources is of prime importance (Panhalkar et al., 2012). The watershed under study receives more than 80% of the rainfall in the monsoon season (June-September).Due to undulating topography much of the naturally incoming water flows out quickly resulting in soil erosion and poor recharge of underground water resources. Keeping above facts in view this study was undertaken to derive different drainage characteristics and thereby to develop geomorphic based prioritisation of sub-watershed.

A watershed is an area from which runoff resulting from precipitation flows past a single point into large streams, lakes or oceans. A watershed is a naturally occurring hydrologic unit characterized by a set of similar topographic, climatic and physical conditions.

Watershed prioritisation is the ranking of different critical sub-watersheds according to the order in which they have to be taken up for the treatment by soil and water conservation measures. A watershed with higher rate of erosion needs to be given higher priority for soil conservation measures to be adopted.
Geomorphological analysis provides quantitative description of the basin geometry to understand initial slopes or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964).

So, in the absence of huge hydrological data, morphometric parameters along with satellite based land-use /land-cover information watershed may be helpful in prioritizing the sub-watersheds.

II. STUDY AREA

Belkund sub-watershed is a part of Hiran River Basin. Belkund River is a tributary of Hiran River, which in turn is a tributary of Narmada River of central India. This area lies in the northern part of the Narmada basin which is in the Jabalpur district between 800 10’-800 30’ E longitudes and 230 25’-230 40’ N latitudes.

III.METHODOLOGY

Topographic sheets (No. 64A/3, 64A/6 and 64A/7) of 1:50000 scale of the area were scanned and imported in ERDAS imagine 8.6 Software. Topographic sheets were georeferenced and mosaiced to have a final map.

In Arc GIS 10.1 software this map was imported and digitised. By digitization of sub-watershed boundary, micro-watershed boundaries and stream network, digital maps were generated, which were used for morphometric analysis.
For the prioritisation, 15 micro-watersheds of 4th order were taken. District Resource map of Jabalpur of Geological Survey of India (GSI) was used for geology.

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IV. RESULTS AND INTERPRETATIONS

1. Qualitative and Descriptive Analysis of the Study Area

Belkund sub-watershed represents a very complex history of development. This river initially runs towards east, then it takes a turn following north-south lineament. Further ahead it moves in the southerly direction till it comes in the contact of the Gondwana rocks and metamorphics, where again it moves south-westward, then gradually turning to west-north-west to finally settle along the westerly direction. The whole course is like a hook. The Belkund River rising from the metamorphic terrain, shows youthful stage. This is a puzzling point in the sense whether this area was the metamorphic platform originally higher in this area or it faced neo-tectonic rejuvenation? In any case intense differential weathering governed by structures and lineaments are quite obvious. In the southern part of this sub-watershed two alluvial fan-like depositions are present. (Figure- 1 & Figure- 2)

2. Quantitative Analysis of the study Area

For the sake of statistical analysis in this work most important parameters have been taken in consideration and are given in the table below.

Table-1: Formulae for computation of morphometric parameters

Please Refer Annexure-I

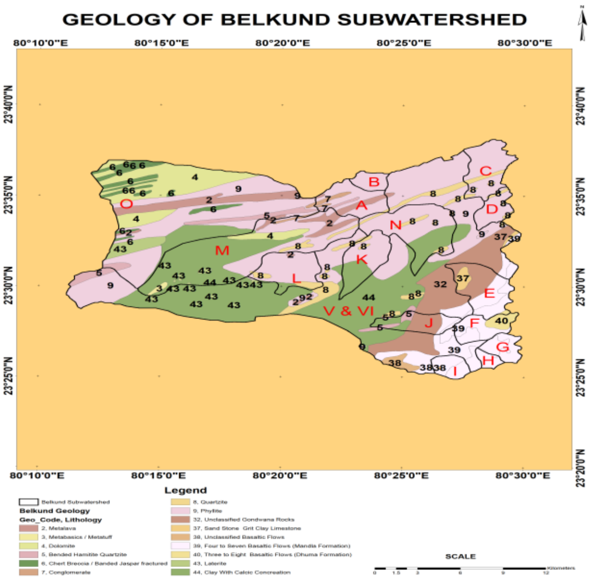

Figure-1. Geological Map of the Area

Values of different morphometric parameters obtained are shown in Table-2. Statistical analysis was done through Pearson correlation matrix. The form parameters have complexly controlled the organisation but these are not correlated with number of 1st and 2nd order streams and length of 1st order streams.

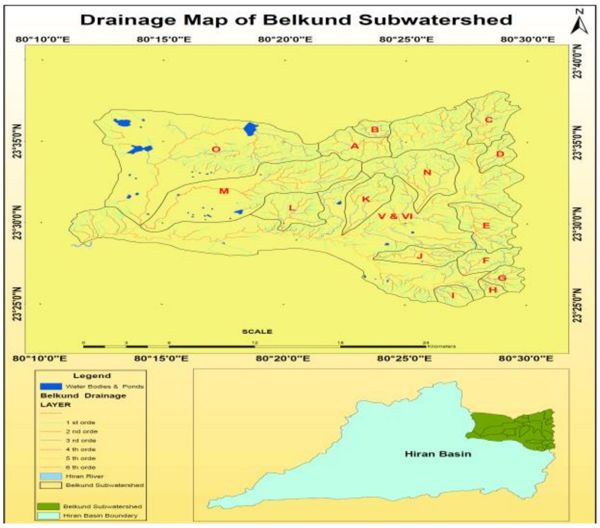

Figure-2. Drainage network of Belkund Sub-watershed

Table-2.Values of morphometric parameters of Belkund Sub-watershed

Please Refer Annexure -II

Therefore, the sub-watershed becomes very deceptive. At initiation stage, the runoff processes dominate and the stream organisation suddenly appears to execute the erosional functions on the basin but here the hydro-dynamics is taking use of the opportunity of available structural features, lithological directions and original form of the terrain. But as soon as the organisation up to second order level completed, it comes down to obstructive nature of the lithology and structures, which then take an upper age in controlling the drainage basin development, that becomes form and ratio dependent. The stream frequency in most of the cases falls around the value of coefficient around 0.50, but the drainage density shows very strong correlations with the form factors and relief parameters. This typical sensitivity is ratio dependent, which is itself a complex operative state of drainage system. The erosive nature in upper reaches is not duly balanced in the lower reaches and at higher order it indicates shift of energy state showing sudden depositional phase towards the lower end.

Prioritisation of Sub-watershed

For the prioritisation of micro-watersheds, on the basis of morphometric parameters, ranking of micro-watersheds were determined. After the ranking of each parameter, compound values were obtained by adding the ranking values for all the parameters of each micro-watershed. Based on average value of these parameters, final priorities were given to all micro-watersheds of a sub-watershed.

The highest values of morphometric parameters i.e. stream frequency, drainage density, texture ratio, relief ratio, drainage texture and length of overland flow of micro-watersheds were given rating 1, the next highest values

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were given a rating of 2, and so on as these morphometric parameters generally show positive correlation with soil erosion (Biswas et al., 2002; Nooka Ratnam et al., 2005; Thakkar and Dhiman, 2007; Sharma, 2010). The lowest values were rated last in the series number.

For the basin shape parameters i.e. form factor, circulatory ratio, elongation ratio and compactness coefficient the lowest values were given a rating of 1, the next lowest values were given a rating of 2, and so on as the basin shape parameters generally show negative correlation with soil erosion (Biswas et al., 2002; Nooka Ratnam et al., 2005; Thakkar and Dhiman, 2007; Sharma, 2010).

The values of compound parameters were taken for priority classification. Minimum value of compound parameter was given the top priority whereas maximum value of compound parameter was given the last priority. The micro-watersheds were classified into four scales of priority i.e. very high priority, high priority, medium priority and low priority.

Table-3 presents the ranking of micro-watersheds of Belkund sub-watershed on the basis of morphometric parameters which were computed earlier and were presented in Table-2.

Table-3. Ranking of micro-watersheds of Belkund Sub-watershed.

Table-4.Final priority of Belkund Sub-watershed Please refer Annexure-IV

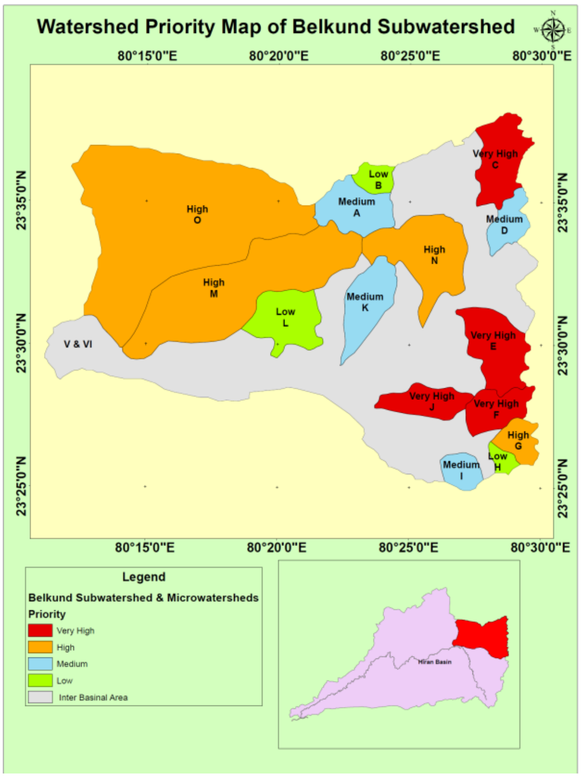

Figure-3 Prioritisation of micro-watersheds of Belkund Sub-watershed.

The micro-watersheds were classified into four scales of priority i.e. very high priority, high priority, medium priority and low priority. Final priority map is presented in Fig.-3. As per table-4, micro-watersheds F, E, J and C are under very high priority, micro-watersheds G, M, O and N are under high priority, micro-watersheds A, D, K and I are under medium priority and micro-watersheds L, H and B are under low priority.

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ANNEXURE –I

Morphometric Parameter	Formula	Reference
Stream Order	Hierarchical rank	Strahler (1964)
Stream length(Lu)	Length of the stream	Horton (1945)
Watershed Perimeter(Pr)	Length of the watershed boundary	
Maximum Length of Watershed (Lb)	Distance between watershed outlet and the farthest point in the watershed	
Mean stream length (Lm)	Lm = Lu / Nu where Lu=Total stream length of order 'u' Nu=Total number of stream segments of order 'u'	Strahler (1964)
Stream length ratio (SLR)	SLR= Lu / L u-1 where Lu = mean stream length of order 'u' L u-1 = mean stream length of its next lower order	Horton (1945)
Bifurcation ratio (Rb)	Rb = Nu / N u + 1 where Nu = Total no. of stream segments of order 'u' N u + 1 = Number of segments of the next higher order	Schumm (1956)
Drainage density (Dd)	Dd =TLu /A where Dd = drainage density TLu = Total stream length of all orders A = area of the basin (km^2)	Horton (1945)
Stream frequency (Fs)	Fs =TNu/A where F_s = stream frequency TNu = total number of streams of all orders A = area of the basin(km^2)	Horton (1945)
Circulatory ratio (CR)	$CR = 4 * \pi * A/P_r^2$ where CR = circulatory ratio $\pi = \pi$ value i.e., 3.141 A = area of the basin, km^2 Pr^2 = square of the perimeter, km	Miller (1953)
Elongation ratio (ER)	$ER = 2/ Lb.\sqrt{\frac{A}{\pi}}$ where ER = elongation ratio A = area of the basin, km^2 $\pi = \pi$ value i.e., 3.141 Lb = basin length, km	Miller (1953)
Form factor (Ff)	$Ff = A/Lb^2$ where, Ff = form factor A = area of the basin, km^2 Lb = basin length	Schumm (1956)
Drainage texture (DrTx)	DrTx = TNu/P where TNu = total no. of streams of all orders Pr = basin perimeter, km	Horton (1945)

Compactness Coefficient(CC)	$CC=0.2821.Pr/A^{0.5}$ Where A=Area of the basin(km^2) Pr=Perimeter of the basin(km)	Horton (1945)
Texture Ratio(TxR)	$TxR = N_1/Pr$ where, N_1=Total number of first order streams; Pr=Perimeter of watershed	Horton (1945)
Length of overland flow (Lo)	Lo= 1/2Dd where, Dd=Drainage density	Horton (1945)
Constant of channel maintenance (Cm)	Cm= 1/Dd where, Dd=Drainage density	Schumm(1956)
Rho Coefficient (ρ)	Rho Coefficient (ρ)= Stream Length Ratio(SLR)/ Bifurcation Ratio (Rb)	Horton (1945)
Infiltration Number (IN)	Dd. Fs where, Dd = drainage density Fs = stream frequency	Faniran, (1968)
Lemniscate's Ratio (Lmt R) (k)	$k = Lb^2 / 4$ .A. Where, Lb is the basin length (Km) and A is the area of the basin (km^2).	Chorley et.al.(1957)
Maximum Watershed Relief(H)	Maximum vertical distance between the lowest and highest points of a watershed	
Relief Ratio	Total relief of watershed divided by the maximum length of the watershed.	Schumm(1956)
Ruggedness Number (RN)	RN = H.Dd where H= Maximum Watershed Relief Dd=Drainage density	Strahler (1968)
Relative Relief(Rr)	Rr=H/Pr where H=maximum watershed relief Pr=perimeter of the watershed	Melton (1957)

Annexure –II

S. No	Name of Mico-Watershed	Area (A)	Perimeter (Pr)	Basin Length (Lb)	No. Of 1st order streams (N1)	Length of Ist order streams (L1)	No. Of 2nd order streams (N2)	Length of 2nd order streams (L2)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
2	A	13.16	16.24	5.27	39	21.7	9	8.67
3	B	4.10	8.28	2.58	23	9.73	5	1.99
4	C	14.70	19.65	6.49	65	32.43	13	11.47
5	D	6.70	12.50	4.88	25	15.15	5	3.94
6	E	16.47	19.15	6.68	78	31.17	19	13.64
7	F	9.21	13.85	5.15	59	20.6	15	5.13
8	G	5.88	10.79	3.27	33	11.68	10	5.85
9	H	2.98	6.68	2.44	14	3.99	4	2.00
10	I	5.08	8.36	2.91	25	10.08	6	4.76
11	J	9.26	14.82	6.49	44	12.99	16	7.03
12	K	13.50	17.28	7.55	26	17.17	4	10.03
13	L	14.85	17.77	5.01	49	29.93	10	9.52
14	M	56.86	40.46	17.09	84	50.02	22	23.34
15	N	24.64	25.43	7.44	76	42.09	18	12.48
16	O	106.62	50.34	16.44	151	90.54	37	27.42

S.No	Name of Mico-Watershed	No. Of 3rd order streams (N3)	Length of 3rd order streams (L3)	No. Of 4th order streams (N4)	Length of 4th order streams (L4)	Total No of Streams (TNu)	Total Length of Streams (TLu)
1	**2**	**10**	**11**	**12**	**13**	**14**	**15**
2	A	2	2.55	1	4.68	51	37.6
3	B	2	4.49	1	0.37	31	16.58
4	C	4	5.57	1	5.65	83	55.12

5	D	2	5.05	1	0.66	33	24.8
6	E	4	4.50	1	7.72	102	57.03
7	F	3	7.53	1	0.91	78	34.17
8	G	3	3.02	1	1.15	47	21.7
9	H	2	0.97	1	0.70	21	7.66
10	I	3	2.79	1	0.54	35	18.17
11	J	2	3.23	1	6.08	63	29.33
12	K	2	6.75	1	1.91	33	35.86
13	L	3	2.91	1	2.71	63	45.07
14	M	7	7.00	1	20.23	114	100.59
15	N	3	12.81	1	6.07	98	73.45
16	O	6	17.21	1	3.12	195	138.29

S. No	Name of Mico-Watershed	Drainage Texture (DrTx)	Texture Ratio (TxR)	Stream Frequency (Fs)	Drainage Density (Dd)	Stream Length Ratio Between 1st & 2nd Order (SLR 1st&2nd)	Stream Length Ratio Between 2nd & 3rd Order (SLR 2nd&3rd)
1	**2**	**16**	**17**	**18**	**19**	**20**	**21**
2	A	3.14	2.40	3.88	2.86	1.73	1.32
3	B	3.74	2.78	7.56	4.04	0.94	5.64
4	C	4.22	3.31	5.65	3.75	1.77	1.58
5	D	2.64	2.00	4.93	3.70	1.30	3.20
6	E	5.33	4.07	6.19	3.46	1.80	1.57
7	F	5.63	4.26	8.47	3.71	0.98	7.34
8	G	4.36	3.06	7.99	3.69	1.65	1.72
9	H	3.14	2.10	7.05	2.57	1.75	0.97
10	I	4.19	2.99	6.89	3.58	1.97	1.17
11	J	4.25	2.97	6.80	3.17	1.49	3.68
12	K	1.91	1.50	2.44	2.66	3.80	1.35
13	L	3.55	2.76	4.24	3.04	1.56	1.02
14	M	2.82	2.08	2.00	1.77	1.78	0.94
15	N	3.85	2.99	3.98	2.98	1.25	6.16
16	O	3.87	3.00	1.83	1.30	1.24	3.87

S. No	Name of Mico-Watershed	Bifurcation Ratio Between 1st order & 2nd Order (Rb 1st&2nd)	Bifurcation Ratio Between 2nd order & 3rd Order (Rb 2nd&3rd)	Form Factor (Ff)	Circulatory Ratio (CR)	Elongation Ratio (ER)	Compactness Coefficient (CC)	Constant Channel Maintenance (Cm)
1	**2**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
2	A	4.33	4.50	0.47	0.63	0.78	1.26	0.35
3	B	4.60	2.50	0.62	0.75	0.89	1.15	0.25
4	C	5.00	3.25	0.35	0.48	0.67	1.45	0.27
5	D	5.00	2.50	0.28	0.54	0.60	1.36	0.27
6	E	4.11	4.75	0.37	0.56	0.69	1.33	0.29
7	F	3.93	5.00	0.35	0.60	0.67	1.29	0.27
8	G	3.30	3.33	0.55	0.63	0.84	1.25	0.27
9	H	3.50	2.00	0.50	0.84	0.80	1.09	0.39
10	I	4.17	2.00	0.60	0.91	0.87	1.05	0.28
11	J	2.75	8.00	0.22	0.53	0.53	1.37	0.32
12	K	6.50	2.00	0.24	0.57	0.55	1.33	0.38
13	L	4.90	3.33	0.59	0.59	0.87	1.30	0.33
14	M	3.82	3.14	0.19	0.44	0.50	1.51	0.57
15	N	4.22	6.00	0.45	0.48	0.75	1.45	0.34
16	O	4.08	6.17	0.39	0.53	0.71	1.38	0.77

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S. No	Name of Mico-Watershed	Length of Over Land Flow (Lo)	Lemniscate Ratio (Lmt R)	Infiltration Number (IN)	Rho Coefficient (ρ) Between 1st & 2nd Order (ρ 1st&2nd)	Rho Coefficient (ρ) Between 2nd Order & 3rd Order(ρ 2nd&3rd)
1	**2**	**29**	**30**	**31**	**32**	**33**
2	A	0.18	1.32	11.07	1.31	0.96
3	B	0.12	0.65	30.58	0.17	1.84
4	C	0.13	1.62	21.17	1.12	1.54
5	D	0.14	1.22	18.23	0.41	2.00
6	E	0.14	1.67	21.44	1.15	0.86
7	F	0.13	1.29	31.42	0.13	0.79
8	G	0.14	0.82	29.50	0.96	0.99
9	H	0.19	0.61	18.11	1.81	1.75
10	I	0.14	0.73	24.64	1.68	2.08
11	J	0.16	1.62	21.55	0.40	0.34
12	K	0.19	1.89	6.49	2.82	3.25
13	L	0.16	1.25	12.88	1.53	1.47
14	M	0.28	4.27	3.55	1.89	1.21
15	N	0.17	1.86	11.86	0.20	0.70
16	O	0.39	4.11	2.37	0.32	0.66

S. No	Name of Mico-Watershed	Basin Relief	Relief Ratio	Ruggedness Number (RN)
1	**2**	**34**	**35**	**36**
2	A	0.06	0.011	0.03
3	B	0.1	0.039	0.16
4	C	0.14	0.022	0.08
5	D	0.04	0.008	0.03
6	E	0.22	0.033	0.11
7	F	0.14	0.027	0.10
8	G	0.12	0.037	0.14
9	H	0.08	0.033	0.08
10	I	0.12	0.041	0.15
11	J	0.16	0.025	0.08
12	K	0.1	0.013	0.04
13	L	0.14	0.028	0.08
14	M	0.18	0.011	0.02
15	N	0.1	0.013	0.04
16	O	0.18	0.011	0.01

Annexure-III

S. No	Micro-watershed	Drainage Texture	Rank	Texture Ratio	Rank	Stream Frequency	Rank
1	A	3.14	12	2.40	11	3.88	12
2	B	3.74	9	2.78	9	7.56	3
3	C	4.22	5	3.31	3	5.65	8
4	D	2.64	14	2.00	14	4.93	9
5	E	5.33	2	4.07	2	6.19	7
6	F	5.63	1	4.26	1	8.47	1
7	G	4.36	3	3.06	4	7.99	2
8	H	3.14	11	2.10	12	7.05	4
9	I	4.19	6	2.99	6	6.89	5
10	J	4.25	4	2.97	8	6.80	6
11	K	1.91	15	1.50	15	2.44	13
12	L	3.55	10	2.76	10	4.24	10

13	M	2.82	13	2.08	13	2.00	14
14	N	3.85	8	2.99	7	3.98	11
15	O	3.87	7	3.00	5	1.83	15

S. No	Drainage Density	Rank	Length of Over Land Flow	Rank	Relief Ratio	Rank
1	2.86	11	0.18	5	0.011	12
2	4.04	1	0.12	15	0.039	2
3	3.75	2	0.13	14	0.022	9
4	3.70	4	0.14	12	0.008	15
5	3.46	7	0.14	9	0.033	4
6	3.71	3	0.13	13	0.027	7
7	3.69	5	0.14	11	0.037	3
8	2.57	13	0.19	3	0.033	5
9	3.58	6	0.14	10	0.041	1
10	3.17	8	0.16	8	0.025	8
11	2.66	12	0.19	4	0.013	11
12	3.04	9	0.16	7	0.028	6
13	1.77	14	0.28	2	0.011	14
14	2.98	10	0.17	6	0.013	10
15	1.30	15	0.39	1	0.011	13

S. No	Compactness Coefficient	Rank	Form Factor	Rank	Circulatory Ratio	Rank	Elongation Ratio	Rank
1	1.26	5	0.47	10	0.63	11	0.78	10
2	1.15	3	0.62	15	0.75	13	0.89	15
3	1.45	14	0.35	6	0.48	2	0.67	6
4	1.36	10	0.28	4	0.54	6	0.60	4
5	1.33	9	0.37	7	0.56	7	0.69	7
6	1.29	6	0.35	5	0.60	10	0.67	5
7	1.25	4	0.55	12	0.63	12	0.84	12
8	1.09	2	0.50	11	0.84	14	0.80	11
9	1.05	1	0.60	14	0.91	15	0.87	14
10	1.37	11	0.22	2	0.53	5	0.53	2
11	1.33	8	0.24	3	0.57	8	0.55	3
12	1.30	7	0.59	13	0.59	9	0.87	13
13	1.51	15	0.19	1	0.44	1	0.50	1
14	1.45	13	0.45	9	0.48	3	0.75	9
15	1.38	12	0.39	8	0.53	4	0.71	8

Annexure-IV

S. No	Micro-watershed	Drainage Texture	Texture Ratio	Stream Frequency	Drainage Density	Length of Over Land Flow	Compactness Coefficient
1	A	12	11	12	11	5	5
2	B	9	9	3	1	15	3
3	C	5	3	8	2	14	14
4	D	14	14	9	4	12	10
5	E	2	2	7	7	9	9
6	F	1	1	1	3	13	6
7	G	3	4	2	5	11	4
8	H	11	12	4	13	3	2
9	I	6	6	5	6	10	1
10	J	4	8	6	8	8	11
11	K	15	15	13	12	4	8

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12	L	10	10	10	9	7	7
13	M	13	13	14	14	2	15
14	N	8	7	11	10	6	13
15	O	7	5	15	15	1	12

S. No	Relief Ratio	Form Factor	Circulatory Ratio	Elongation Ratio	Compound Parameter	Final Priority	Priority Scales
1	1	10	11	10	8.8	9	Medium
2	14	15	13	15	9.7	15	Low
3	7	6	2	6	6.7	4	Very High
4	11	4	6	4	8.8	10	Medium
5	5	7	7	7	6.2	2	Very High
6	10	5	10	5	5.5	1	Very High
7	12	12	12	12	7.7	5	High
8	15	11	14	11	9.6	14	Low
9	13	14	15	14	9.0	12	Medium
10	9	2	5	2	6.3	3	Very High
11	8	3	8	3	8.9	11	Medium
12	6	13	9	13	9.4	13	Low
13	3	1	1	1	7.7	6	High
14	4	9	3	9	8.0	8	High
15	2	8	4	8	7.7	7	High