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Prioritization of Sub-Watersheds Based on Morphometric Analysis of Drainage Basin- A Case Study of Medkhali River Basin in Lower Siwalik Basin, India

Vipin Kumar
Department of Geography, Banasthali University, Banasthali- 304022

ABSTRACT

The study area presented here has undertaken to assess the drainage characteristics of the Medkhali River basin for the prioritization of sub-watersheds using the topographical sheets published by survey of India on a scale of 1:50000. The total area of the basin is 63.25km^2 and for micro analysis the whole basin is divided into 26 sub watersheds. There are total 222 streams in the basin and Medkhali is a 5th order stream. The drainage frequency is 2.74km/km^2. The shape parameters indicate it's elongated to circular shape. The sub watersheds no. 3, 4, 5, 6, 7, 8 and 9 are considered to be highly erosive and are placed in priority for conservation.

Key Words- *Stream order, Drainage density, Bifurcation ratio, Shape parameters, Prioritization*

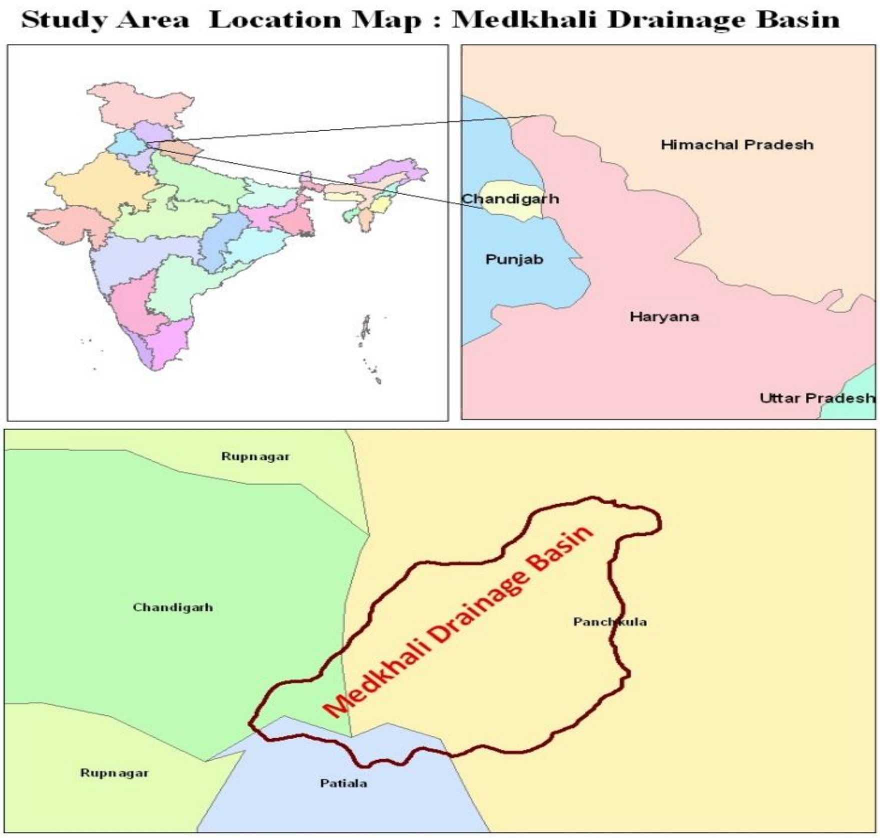
INTRODUCTION

Natural resources mainly soil, water and vegetation are the most vital natural resources for the survival of man and animals. To obtain the maximum and optimum production of agriculture, all these three resources have to be managed efficiently. For their efficient management, one has to look for suitable potential zones for their management, so that these resources are handled and managed collectively, effectively and simultaneously. Hence, there is great need to delineate/ identify such zones to conserve and manage maximum nature resource, particularly for the hilly region like Siwalik. The present study is aimed at delineating the potential zones for the conservation of natural resources in the Medkhali Drainage Basin at lower Siwalik region.

Study Area

The Medkhali River is a tributary of Ghaggar River, arise from the outer slope of the lower part of Siwalik range in the Panchkula district of Haryana and takes a south-western course, which drains in the plain low land of Panchkula district of Haryana. At last it merge into Ghaggar River near Mubarikpur town (Panchkula district, Haryana), after about a course of 17 kms from its origin.

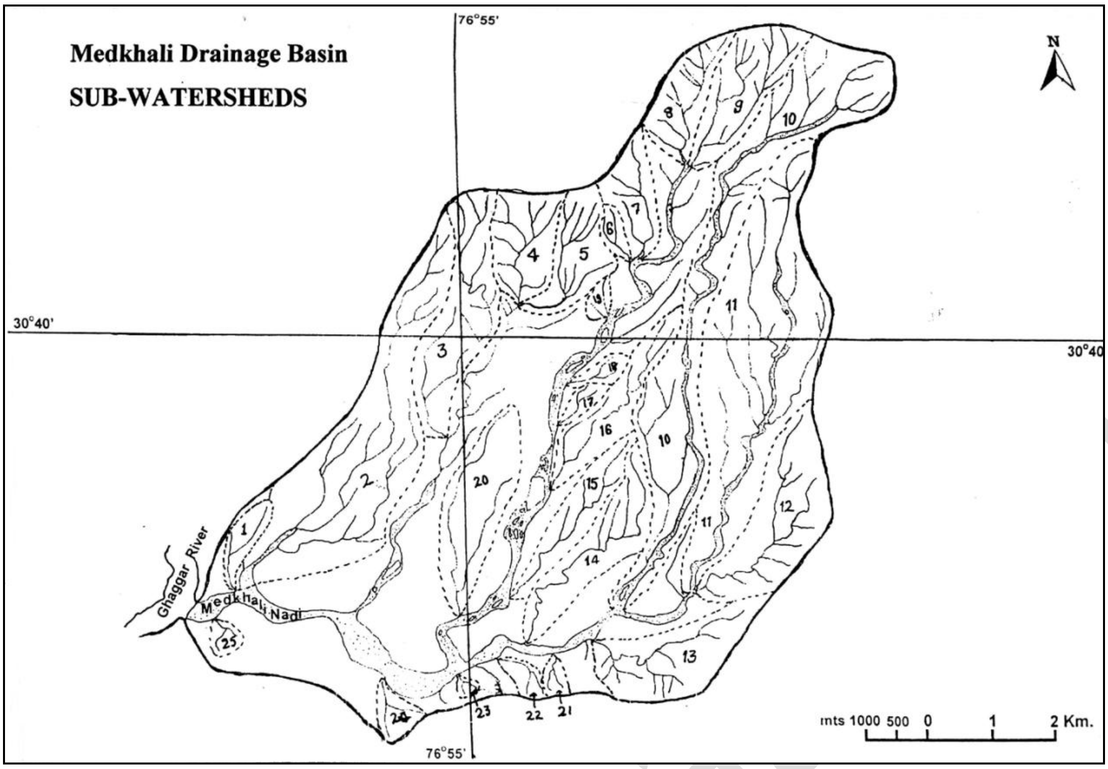
The extension of Medkhali River lies between 77^0 52$^/$E to 77^{0}59$^/$E longitude and 30^0 37$^{//}$N to 30^0 42.5$^/$ N latitude. The total calculated area of Medkhali basin is 63.25 kms^2. Map 1 shows the location of Medkhali drainage basin. For micro analysis the basin is further divided in to 25 sub watersheds (Map-2).



Map-1

Geology- The study area has occupied the outer most range of Siwalik hill. The Siwalik ridges are composed of conglomerates. The gradient on either side of the ridges is controlled by the regional dip. The dip slopes sides of the ridges form a gently sloping ground; whereas steep scarps develop on the opposite side. The entire valley exposing the youngest Siwalik sediments is drained by numerous parallel streams joining it. The geology of watershed is developed in Tertiary to Quarternary period.

Climate- The watershed has a sub-tropical continental monsoon type climate, where we find great variation in climatic elements. Normally the period from November to February is cold, this is followed by the summer season from March to the end of June. The South-west monsoon mostly breaks in the last week of June or first week of July and continues up to about the middle of September. The period from mid September to the mid of November is the post monsoon or transition season. In winters, frost sometimes occurs during December and January. The watershed also gets occasional winter rains from cyclones or western disturbances. The rainfall is mostly restricted to rainy season.



Map-2

OBJECTIVES

1. To study the morphometric analysis of Medkhali River and its sub watersheds
2. Prioritisation of sub-watersheds for natural resource conservation

Data Source and Research Methodology

Survey of India Topographical maps no. 53B/14 on 1:50000 scale is the main source for delimitation the area of Medkhali River and its sub-watershed. The morphometric analysis of the river and its sub-watershed also calculated on the base of this topographical sheet. Village Directory Ambala district, Haryana also consider knowing the social environment of the watershed area. Climatic data like Rainfall, Temperature, Humidity, Wind direction, Frost etc. has been collected from Irrigation Department and Forest Department Ambala District. The variables for the study of morphometric aspects of the basin including stream orders, stream numbers, stream length, bifurcation ratio, basin circularity, drainage texture, relief ratio etc. have been analysed using the standard quantitative techniques (Table-1) followed by several pioneers in the field, (such as Horton, Strahler and Schumm, etc.) and some of them are used for the detail study at sub watershed level. The aerial and liner parameters have been measured by Rotameter, digital Plannimeter and graphic method.

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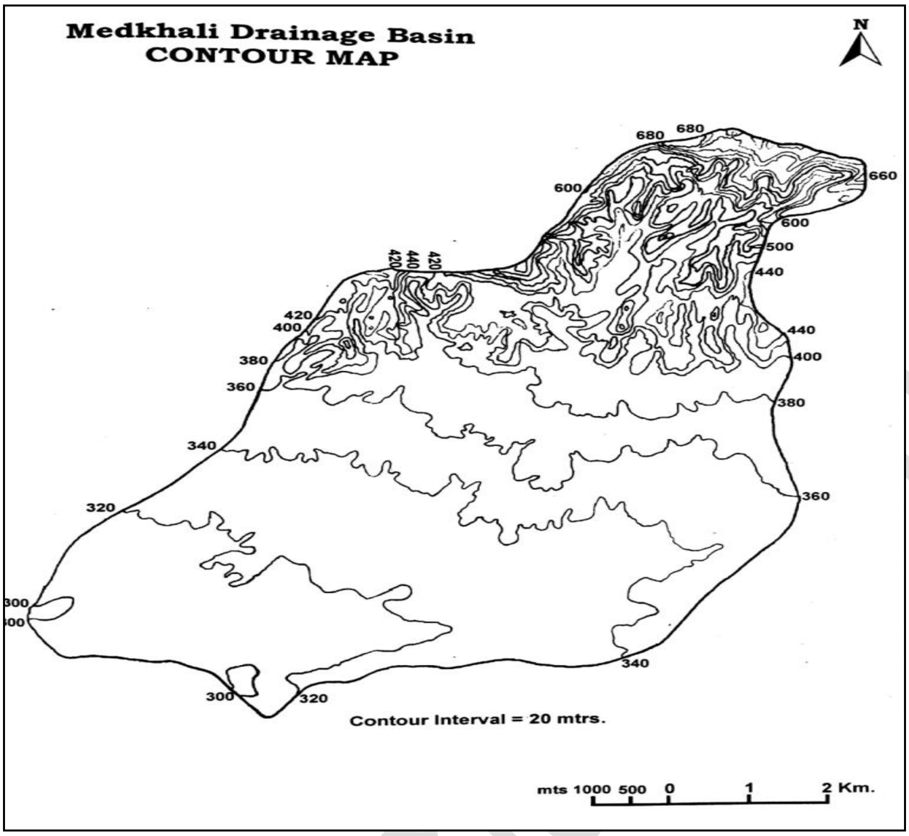

Map-3

RESULTS AND DISCUSSIONS

Watershed and sub-watersheds are studied in terms of various parameters, which are their quantitatively expressed attributes. The formulas that have been used for morphometric analysis are listed in table 1. The Morphometric parameters are divided into two categories viz. linear aspect, and areal aspect-

Linear aspect- Stream order (O), Stream number (Nu), Stream length (L), Stream length ratio (Rl), Mean length of stream segments in km (Lsm), Bifurcation ratio (Rb), Mean bifurcation ratio (Rbm).

Table 1- Formulae Adopted for Computation of Morphometric Parameters

S. no.	Parameters	Formula	Reference
1	Stream Order (O)	Hierarchical Rank	Strahler 1964)
2..	Stream Number (Nu)	Total numbers of streams	Horton (1945)
3.	Stream Length (L)	Length of stream	Horton (1945)
4.	Stream Length Ratio (Rl)	Rl= Lu/ Lu-1 Lu = total stream length of order 'u' Lu-1= Total stream length of its next order.	Horton (1945)
5.	Mean Stream Length (Lsm)	Lsm= L_U/N_U Lu = Total stream length of order 'u' Nu= Total no. of stream segments of order 'u'	Strahler (1964)
6.	Bifurcation Ratio (Rb)	Rb = Nu/ Nu+1 Nu = Total no. of stream segments of order 'U' Nu+1= Total no. of segments of next higher order.	Schumn (1956)
7.	Mean bifurcation Ratio (Rbm)	Rbm= Average of bifurcation ratios of all orders	Strahler (1957)
9.	Drainage Density (Dd)	D=Lu/A Lu= Total Stream Length of all orders, A= Area of the Basin (km^2)	Horton (1932)
10.	Stream Frequency (Df)	Fs= Nu/A Nu=Total no. of streams of all orders, A= Area of the basin (Km^2)	Horton (1932)
11.	Drainage Texture (Dt)	Rt= Fs × D Fs= Stream Frequency, D= Drainage Density	Smith (1950)
12.	Circularity Ratio (Cr)	Cr= 4 x π x A/P^2 π = 'Pi' value i.e. 3.14, A= area of the Basin (Km^2) P= Perimeter (km)	Miller (1953)

13.	Form Factor (Ff)	Ff= A/Lb^2 A= Area of the Basin (Km^2), Lb^2= Square of the basin Length	Horton (1932)
14.	Elongation ratio (Re)	Re= 2√(A/π /Lb) A=Area of the basin (km^2), π = 'Pi' value of i.e. 3.14 Lb= Basin Length	Horton (1945)
15.	Length of Overland Flow (Lg)	Lg= 1/D×2 Lg= Length of overland flow, D=Drainage Density	Schumn (1956)
16.	Constant channel maintenance (C)	Inverse of drainage density 1÷ D	Horton (1932

Areal aspect- Basin area (A), Basin Perimeter (P), Basin length (L), Drainage density (D_D), Drainage (Stream) frequency (D_F), Drainage texture (D_T), Constant of channel maintenance (C_{CM}), Length of over land flow (L_{OF}), Circularity Ratio (C_R), Elongation Ratio (E_R), and Form Factor (F_F).

A brief account of some morhphometric aspects of the Medkhali River is shown in table- 2.

Parameter	Result
Area	63.25 km^2
Perimeter	36 kms
Length of Basin	16 kms
Stream Order	5^{th}
Total No of Streams of all order	222
Total Stream Length of all order	173.8 kms
Total Relief (H)	760-300= 460

Stream Frequency (Fs)	3.51km/km^2
Drainage Density (D)	2.74km/km^2
Drainage Texture (Rt)	9.64
Constant Channel Maintenance (C)	0.36
Relief Ratio(Rh)	28.75
Form Factor (Rf)	0.24
Circularity Ratio (Rc)	0.60
Length of Overland Flow	0.182
Ruggedness Number	2082.4
Dissection Index	0.60
Gradient Ratio	26.1

Table-2

LINEAR ASPECTS

Stream Order, Stream Number and Stream Length

It is obvious that the total number of stream gradually decrease as the stream order increase. From the stream order analysis, Medkhali River is a fifth order basin. The watershed consists of 164 1st order streams, 46 second order, 9 third order, 2 fourth order and 1 fifth order streams (Table-3). Among the 25 sub-watersheds, 9 are 3rd order and 17 are 2nd order sub-basins.

Bifurcation Ratio (Rb)

Bifurcation ratio is the ratio of stream number of a given order to the stream number of the next higher order. It is therefore dependent upon techniques of stream ordering and gives an expression of the rate at which a stream network bifurcates. It has been correlated with hydrograph parameters and sometimes with sediment delivery factors (Goudie et. al., 1985).

Lower value of Rb indicates structurally less disturbed areas without any distortion in drainage pattern (Nag, 1998). According to Harton (1945), the mean bifurcation ratio (Rbm) may be defined as the average of bifurcation ratios all order**.** Mean bifurcation ratios vary from about 2.0 for flat or rolling basins to 3.0 - 4.0 for mountainous and hilly dissected basin.

Table-3

Medkhali Drainage Basin

Number of Streams and Length of streams as per stream order in each sub-watershed

Sub-Watershed	Number of Streams as per order						Length of Stream as per order (kms)					
	1st	2nd	3rd	4th	5th	Total	1st	2nd	3rd	4th	5th	Total
1	2	1				**3**	1.50	0.50				**2.00**
2	12	5	1			**18**	7.50	4.00	5.25			**16.75**
3	8	1				**9**	5.50	4.00				**9.50**
4	9	2	1			**12**	3.75	1.00	1.00			**5.75**
5	8	2	1			**11**	4.00	0.50	1.50			**6.00**
6	2	1				**3**	1.00	0.30				**1.30**
7	4	1				**5**	2.75	1.00				**3.75**
8	10	3	1			**14**	3.50	0.75	1.75			**6.00**
9	13	3	1			**17**	4.75	3.25	0.20			**8.20**
10	17	6	1			**24**	8.00	3.50	9.00			**20.50**
11	14	4	1			**19**	9.50	8.50	4.00			**22.00**
12	10	2	1			**13**	5.25	1.50	1.75			**8.50**
13	11	3	1			**15**	4.00	2.15	1.00			**7.15**
14	4	1				**5**	3.75	2.75				**6.50**
15	4	1				**5**	2.15	2.50				**4.65**
16	4	1				**5**	3.00	4.00				**7.00**
17	2	1				**3**	0.75	0.50				**.80**
18	2	1				**3**	0.80	0.50				**1.30**
19	2	1				**3**	1.00	0.25				**1.25**
20	2	1				**3**	5.25	0.20				**5.45**
21	2	1				**3**	0.40	0.10				**.50**
22	2	1				**3**	0.40	0.60				**1.00**
23	2	1				**3**	0.40	0.20				**0.60**
24	2	1				**3**	1.00	0.50				**1.50**
25	2	1				**3**	0.50	0.30				**0.80**
26*	14			2	1	**17**	8.00			16.4	2.7	**27.10**
Total	164	46	9	2	1	**222**	88.4	43.35	25.45	16.4	2.7	**176.65**

26* Area excluding from sub-watersheds

In present case, the values of Rb of the Medkhali basin lie between 5.1 to 2.15 and the Rbm is 3.73 indicating, that the watershed is not too affected by structural disturbances. Sub-watersheds 2nd, 3rd, 4th, 5th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 15th, and 16th, has high value of Rbm (more then 3.00) indicating mountainous and hilly dissected basins, while in other sub-watersheds have the lower value of Rbm indicating that the sub-watersheds are nearly flat terrain and not affected by structural disturbances. Basically, Rbm values of all sub-watersheds are less than 5.0, which indicate that sub-watersheds are not affected by structural disturbances

Table- 4

Medkhali Drainage Basin

Bifurcation Ratio and Mean Bifurcation Ratio

Sub-watershed	Bifurcation Ratio			Mean
	I/II	II/III	III/IV	
1	2.0			2.0
2	2.4	5.0		3.7
3	8.0			8.0
4	4.5	2.0		3.2
5	4.0	2.0		3.0
6	2.0			2.0
7	4.0			4.0
8	3.3	3.0		3.15
9	4.3	3.0		3.6
10	2.8	6.0		4.4
11	3.5	4.0		3.7
12	5.0	2.0		3.5
13	3.6	3.0		3.3
14	4.0			4.0
15	4.0			4.0
16	4.0			4.0
17	2.0			2.0
18	2.0			2.0
19	2.0			2.0
20	2.0			2.0
21	2.0			2.0
22	2.0			2.0
23	2.0			2.0
24	2.0			2.0
25	2.0			2.0

Areal Aspect

Area and Perimeter

The total drainage area of the Medkhali basin is 63.25 km^2. The perimeter is the total length of the drainage basin boundary, which is 36 km of the Medkhali basin.

Basin Length (L)

The basin length corresponds to the length of the basin and sub-basin is measured to the main drainage line. The basin length of Medkhali drainage basin is 16 km and the value of 'L_B' for the twenty five sub-watersheds is shown in table- 5.

Drainage (Stream) Frequency (D_F)

Drainage frequency is the number of streams in per unit area. It is a dimensional parameter and is used as a supplementary measure of the fineness of the texture of topography. It is associated with lithology, degree of slope, stages of fluvial cycle and amount of surface run-off. Investigations reveal that high frequency of stream is found in areas of non-porous bedrocks, relatively low degree of slope, high rainfall, and thin vegetation cover. High values of drainage frequency are represented by mature watersheds whereas; low range of drainage frequency indicates the youth stage of development. (Sidhu, et. al. 1974).

The drainage frequency of the Medkhali basin is 3.51streams/km^2. The value of stream frequency is very high (more then 10) in five sub-watersheds, indicating denser network of streams in along the hilly regions, where the first order and second order streams are well developed and are larger in number. In some cases, small area of sub-watersheds also affects the drainage network of watershed. There are ten sub-watersheds, where drainage frequency has comparatively low. The stream frequency of Medkhali drainage basin is poor (i.e. 3.51streams/km^2) due to poor stream network of the basin. It is noticed in every case that there is a decrease in stream frequency as the stream order increases. The stream frequency of sub-watersheds is shown in table 5.

Drainage Density (D_D)

Drainage density is the length of stream channels per unit area. Drainage density is a very significant measure of drainage basin character, because the value of Drainage density reflects the climate over the basin and the influence of other basin characteristics including rock type, soil, vegetation land use, and topographic characteristics. Drainage density has also an important influence upon stream-flow because water-flow in channels is faster than water-flow over or through slope. The higher the drainage density the faster the hydrograph rise and the greater the peak discharge (Goudie, et. al.1985).

Langbein (1947) recognised the significance of drainage density as a factor determining the time of travel by water and, he also suggested a drainage density varying between 0.55 and 2.09 km/km^2 in humid region with an average density of 1.03 km/km^2.

Table-5

Aerial aspects of Medkhali Basin and sub-watersheds

SW	A	P	L_B	D_F	D_D	D_T	C_{CM}	L_{OF}
1	0.30	3.75	1.60	6.66	6.66	44.35	0.15	0.07
2	5.75	14.2	6.70	2.26	2.82	6.37	0.35	0.17
3	2.25	8.5	5.70	3.55	4.22	14.98	0.23	0.02
4	1.50	4.8	1.30	6.00	3.83	22.98	0.26	0.13
5	1.00	5.5	1.80	8.00	6.00	48.00	0.16	0.08
6	0.27	2.2	0.60	7.27	4.81	34.96	0.20	0.10
7	1.00	4.2	1.70	4.00	3.75	15.00	0.26	0.13
8	1.25	5.2	1.80	8.00	4.80	38.40	0.21	0.10

9	1.56	6.1	1.90	7.69	5.25	40.37	0.19	0.09
10	6.50	20.5	9.70	2.60	3.15	8.19	0.31	0.15
11	7.25	15.0	6.90	1.93	3.03	5.84	0.33	0.16
12	2.93	7.50	3.30	3.41	2.90	9.88	0.34	0.17
13	2.25	8.00	2.70	4.88	3.17	15.46	0.31	0.15
14	1.31	7.20	3.80	3.05	4.96	15.12	0.20	0.10
15	1.26	5.5	2.80	3.17	3.69	11.69	0.27	0.13
16	1.06	7.20	2.90	3.77	6.60	24.88	0.15	0.07
17	0.12	2.00	0.75	16.00	1.04	16.64	0.96	0.48
18	0.18	2.00	0.80	11.11	7.22	80.21	0.13	0.06
19	0.18	1.50	0.07	11.11	6.94	77.10	0.14	0.07
20	2.07	7.20	3.40	0.96	3.50	3.36	0.28	0.14
21	0.16	1.60	0.50	12.50	3.12	39.00	0.32	0.16
22	0.23	2.10	0.90	8.69	4.34	37.71	0.23	0.11
23	0.09	1.20	0.25	20.61	6.00	123.66	0.16	0.08
24	0.26	2.80	0.85	7.61	5.76	44.29	0.17	0.08
25	0.24	1.30	0.35	8.33	3.33	27.73	0.30	0.15
Medkhali Basin	63.25	36.00	16.00	3.51	2.74	9.61	0.36	0.18

SW- sub watershed, A- Area ((km^2), P- Perimeter (km), L- Length of Basin (km), D_F- Drainage Frequency, D_D- Drainage Density (km/km^2), Drainage Texture (D_T) Constant of Channel Maintance-C_{CM}, Length of Overland flow (L_{OF})

Density factor is related to relief, rocks, climate, surface roughness, and run-off intensity index. The amount and type of precipitation influences directly the quantity and character of surface runoff. Amount of vegetation and rainfall, absorption capacity of soils, which influence the rate of surface run-off, affects the drainage density of an area. Strahler (1957) described drainage density values, less than 5.00 as course, 5.00-13.7 as medium, and 13.7-155.3 as fine and above 155.3 as ultra fine.

In present case, the drainage density of the Medkhali basin 3.51 km/km^2. The drainage density of the eight sub-watersheds is less than 5.00 and varies between 3.49 to 1.90 km/km^2 (Table-5**).** This value indicates the low drainage density that the nature of sub-surface strata is permeable with coarse drainage. The basic factor of high drainage density of some areas is high slope and small area of basin.

Drainage Texture (D_T)

The characters and geometry of the drainage network is generally evaluated in terms of drainage texture, which includes the drainage density and stream frequency. (Kale, et al, 2001).

Climate affects the drainage texture both directly and indirectly, where precipitation comes largely as thundershowers, a large percentage of rainfall is inserted into run-off immediately producing a large number of drainage lines. Infiltration capacity of bedrocks is probably the most important single factor influencing texture ratio. (Sidhu et.al. 1974).

Pal (1972) suggest the scale of drainage texture, is as follow-

Form 4.0 and below	- Coarse
4.0 to 10.0	- Intermediate
10.0 to 50.0	- Fine
Above 50.0	-Ultra fine (e.g. Bad-land topography)

Table-5 shows the drainage texture of sub-watersheds of Medkhali drainage basin. According to Tideman (2003), medium drainage texture is observed in rock formations characterized by fractures and joints. In such areas, the soil are moderately deep, medium in texture and moderately permeable.

In present study, seventeen sub-watersheds have fine drainage texture, four have intermediate texture, three have bad-land topography and one sub-watershed has coarse texture. The fine drainage texture is observed in Medkhali watershed.

According to Tideman (2003), fine drainage texture with dendritic pattern indicates that here rock formations are impervious and the permeability is low. Soil formed in such areas is deep, heavy, and slowly permeable. They are subject to severe erosion hazards forming gullies at several places.

Length of Overland flow (L_{OF})

It is an important morphometric indicator of the spacing of streams in a given basin, which affects the hydrological and topographic development of the basin. Horton (1945) used this term to refer the length of rainwater on the ground surface before it get localised into definite channels. This factor relates inversely to the average slope of the channel, and is quite synonymous with the length of sheet flow to a large degree. The length of overland flow in the hilly terrain is low as compared to gentle sloping and flat terrain. It is an important parameter for the detailed study of runoff process in drainage basin and especially at the concentration time. Overland flow disappears shortly after rainfall, water being absorbed by soil, retained by plant cover or gets evaporated. High value of over land flow is found in the low slope areas where erosion process is not high. It is generally related to the stage of basin development.

It has been observed that, length is decrease with increase stage of development of a river. The L_{OF} data reveals that the value of L_{OF} of Medkhali drainage basin is 0.18. The value of length of over land flow of all sub-watersheds has sown in the table-5. In these sub-basins, less rainfall is sufficient to contribute a significant volume of surface run-off to stream discharge.

Constant of Channel Maintenance (C_{CM})

Schumn (1956) has used the inverse of drainage density as a property termed as constant of channel maintenance. It is the area of basin surface needed to sustain a unit length of stream channel. It depends on the rock type, permeability, climate regime, vegetation cover, as well as duration of erosion. In the areas of close dissection, the value will be very low. In case of Medkhali basin the values of 'C_{CM}' are less than 1.0 in all cases (Table-5). It indicates these sub-watersheds are under the influence of structural disturbance, low permeability; steep to very steep slopes and high surface runoff.

Shape Parameters

Basin Shape Using Circularity ratio (C_R)

The circularity ratio is expressed as the ratio of the basin area (A) and the area of circle with the same perimeter as that of the basin (P) (Miller, 1953 and Strahler, 1964). A 'zero' value indicates a highly elongated shape and the value 'one' a circular shape. The C_R is influenced by length and frequency of stream, geological structures, land use/land cover, climate, relief, and shape of the basin.

Miller (1953) described the basins of the circularity ratios range 0.4 to 0.5, which indicates strongly elongated and highly permeable homogenous geological material. According to Strahler (1964) 'Long narrow basins with high bifurcation ratios would be expected to have attenuated flood discharge periods, while rotund basins of low bifurcation ratio would be expected to have sharply peaked flow discharge'.

In the present study, the value of C_R of Medkhali basin is 0.61, which indicate circular shape of watershed. The C_R of sub-watersheds ranges from 0.89 to 0.25 (Table-6).

Basin Shape Using Elongation Ratio (E_R)

The Elongation ratio (E_R) is an indicative of the shape of the river basin. According to Schumm (1956), elongation ratio is defined as the ratio of the diameter of a circle having the same area as the basin and the maximum basin length.

The values of elongation ratios generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. The values close to 1.0 are typical of the regions of very low relief; whereas values in the range of 0.6 to 0.8 are generally associated with high relief steep ground slope (Strahler, 1964). These values can be grouped into four categories viz.

i.	Above 0.9	- Circular
ii	0.9 to 0.8	- Oval
iii	0.8 to 0.7	- Less Elongated
iv	0.7 and below	- Elongated

It is a very significant index in the analysis of basin shape, which helps to give an idea about the hydrological character of a drainage basin. A circular basin is more efficient in the discharge runoff then an elongated basin. This information is more significant, particularly for flood forecasting (Singh. et.al, 1997).

The elongation ratio of Medkhali basin is 0.56, which shows its elongated shape. Table-6 shows the elongation ratio of selected sub-watersheds. It ranges from 0.1 to 2.59. This shows that among twenty five sub-watersheds are circular shaped, only two have less elongated shape, whereas eighteen sub-watersheds are elongated.

Table-6

Medkhali Drainage Basin

Shape parameters of sub-watersheds

Sub-watershed	Area (km^2)	Perimeter (Km)	Basin Length (Km)	Form Factor (F_F)	Circularity Ratio (C_R)	Elongation Ratio (E_R)
1	0.30	3.75	1.60	0.12	0.26	0.38
2	5.75	14.2	6.70	0.12	0.35	0.40
3	2.25	8.5	5.70	0.06	0.39	0.29
4	1.50	4.8	1.30	0.88	0.81	1.06
5	1.00	5.5	1.80	0.30	0.41	0.62
6	0.27	2.2	0.60	0.75	0.70	0.97
7	1.00	4.2	1.70	0.34	0.71	0.66
8	1.25	5.2	1.80	0.11	0.58	0.70
9	1.56	6.1	1.90	0.43	0.52	0.74
10	6.50	20.5	9.70	0.06	0.19	0.28
11	7.25	15.0	6.90	0.15	0.40	0.44
12	2.93	7.50	3.30	3.71	0.65	0.52
13	2.25	8.00	2.70	0.30	0.44	0.62
14	1.31	7.20	3.80	0.09	0.31	0.33
15	1.26	5.5	2.80	0.16	0.52	0.44
16	1.06	7.20	2.90	0.12	0.25	0.40
17	0.12	2.00	0.75	0.21	0.37	0.52
18	0.18	2.00	0.80	0.28	0.56	0.59
19	0.18	1.60	0.07	18.0	0.88	2.39
20	2.07	7.20	3.40	0.17	0.50	0.23
21	0.16	1.60	0.50	0.64	0.78	0.10
22	0.23	2.10	0.90	0.28	0.65	0.30
23	0.09	1.20	0.25	1.60	0.78	1.35
24	0.26	2.80	0.85	0.36	0.41	0.67
25	0.14	1.4	0.35	2.00	0.89	1.20
Medkhali Basin	63.25	36.00	16.00	0.24	0.61	0.56

Basin Shape Using Form Factor (F_F)

Horton (1945) proposed this parameter to predict the flow intensity of a basin of a defined area. Therefore, Form Factor of a basin is expressed as the ratio between the area of the basin (A) and the squared of the basin length (L^2).The ‘0’ value of F_F indicates a highly elongated shape and, 1.0 value a circular shape. According to Nautiyal (1994), the basin with high form factor values have high peak flow for longer duration. Flood flows of elongated basins are easier to manage than that of circular basins.

The values of F_F of Medkhali basin is 0.24. Table 6 shows the value of form factor of all sub-watersheds.

Prioritization of sub-watersheds using morphometric parameters

The Medkhali river basin is experiencing the severe and rapid environmental degradation due to severe erosion process, generated through physical and anthropogenic factors. The human interference is increasing due to mounting population pressure in the watershed. This rapid growth of population requires more area for settlement, agriculture and other related activities. Thus, the watershed represents the rugged and dissected region in the Siwalik hill region. Therefore, there is a great need to conserve the natural resources of the region.

A number of empirical and conceptual sediment yield models are being used to prioritise the watershed units to address soil and water conservation and management. Generally, such models require soil, slope, land-use/land-cover and drainage as inputs in spatial mode and it is often difficult to generate those maps in short time. In such conditions, the morphometric analysis of a watershed could be the ideal to derive the useful information about the watershed and for the prioritisation of such sub-watersheds. The erosional processes are closely related to the linear and areal parameters of morphometry. The intensity of the erosional processes can be accessed from the detailed study of these variables. The morphometric parameters show high correlation with area, and are considered for prioritization of sub-watersheds.

The sub-watersheds 3, 4 5, 6, 7, 8, and 9 are considered to be of highly erosion intensive and are placed in priority for the conservation of natural resources mainly soil, water and vegetation. Keeping these parameters in view, it is observed that drainage density, drainage frequency, and drainage texture are high in the areas, which are helpful to accelerate soil erosion in soft rocks. Higher is the drainage density, lower is the availability of groundwater. Low value of length of overland flow, Constant of channel maintenance and high value of relative relief, mean bifurcation ratio and ruggedness number indicate the hilly terrain.

Stream frequency of the Medkhali drainage basin is poor (i.e. 3.51) because more than 60 percent of the total area lies in foothills and plain area, where the slope is very low. The large number of locally originating first order streams also result in high stream frequency. It indicates that Medkhali basin have young stage of development. The Drainage density the Medkhali watershed is 2.74 km/km^2 and drainage density of sub-basins of the Medkhali basin is less than varies between 1.04 to 6.64. It has been observed that the Medkhali drainage basin and all sub-watersheds have Fine to Coarse drainage texture. Low drainage density is noticed in regions of high resistance with permeable soil under dense vegetative cover and low relief. Further, high drainage density is observed in regions of high altitude, which are highly impermeable with high relief.

Shape parameters indicate that these watersheds are elongated to circular shape. Long and narrow watersheds are likely to have longer times of concentration, resulting in lower runoff rates than more square shaped watersheds of the same size, which have a number of tributaries discharging into the main channel near one point (Tideman, 2003).

Chiefly dendritic, sub-dendritic and sub-parallel drainage patterns have been evolved out of the dissected hills. Dendritic pattern is one of the dominant patterns in the Himalayas. This pattern accelerates runoff and soil erosion.

CONCLUSION

The study reveals that the analysis of morphometric aspects can play an important role to understand the geological environment and helpful to find out the erosive zones in any area. In present case, The Medkhali have fifth order stream, consists of 164 1st order streams, 46 second order, 9 third order, 2 fourth order streams. The mean bifurcation value indicates that the basin is not too affected by structural disturbances. The drainage density of the eight sub-watersheds lies between 3.49 to 1.90, which indicate the low drainage density that the nature of sub-surface strata is permeable and a characteristic feature of coarse drainage. The value of Constant of Channel Maintenance indicates that sub-watersheds are under the influence of structural disturbance, low permeability; steep to very steep slopes and high surface runoff. The shape parameter shows the oval shape of basin. On the basis of morphometric aspects, the sub-watersheds 3, 4 5, 6, 7, 8, and 9 are considered to be of highly erosion intensive and are placed in priority for natural resource conservation.

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