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### RESEARCH ARTICLE

#### MORPHOMETRIC ANALYSIS OF BAUR CATCHMENT IN LESSER HIMALAYA: USING GEO-SPATIALTECHNIQUES

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#### Abstract

The current assessment is an undertaking to evaluate and compare various morphometric parameters of the Baur catchment. Morphometric analysis of the river basin provides a quantitative description of the drainage system, which is an important aspect of the categorization of the basin (Strahler, 1964). The Baur catchment is located in the outer part of the Lesser Himalaya in the Kumaun region, which is a major part of Western Himalaya. The geographical area of Baur Catchment is 106.233 Km<sup>2</sup>. Morphometric analysis of Baur Catchment includes linear, areal, and relief aspects. The calculation of the morphometric parameter, along with map preparation, was performed with the help of GIS techniques and ancillary material. Most of the area of Baur Catchment is occupied by Siwalik Group (sandstone and clay intercalation with pseudo-conglomerate) of rocks. The entire Baur Catchment has found 6<sup>th</sup> order drainage, which reveals sub-dendritic to a dendritic type of drainage pattern. It is observed that the drainage density of the Baur Catchment is 3.525 km/halfkm<sup>2</sup>.

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#### Introduction:-

Morphometry can be characterized as the estimation and numerical examination of the configuration of the Earth's surface and of the shape and estimations of its landforms (Bates and Jackson, 1987). Morphometric analysis is referred to as the quantitative evaluation of form characteristics of the Earth's surface and any landform unit. Morphometry represents the topographical expression of land by way of area, slope, shape, length, etc. These parameters affect the catchment streamflow pattern through their influence on concentration-time (Jones, 1999). A catchment is a topographic area from which all runoff finally reaches one single given point, known as the pit. catchments are made up of interrelated systems; draining networks and hill slopes. The morphometric analysis of the river is a very important factor for the purpose of the management and conservation of soil, water, natural resources, and environmental protection (Kanth and Zahoor, 2012 and Reddy et al., 2002). Morphometric analysis requires measurement of a linear feature, areal aspects, and gradient of the channel network of the drainage basin (Nautiyal, 1994). Morphometric analysis of the river basin provides a quantitative description of the drainage system, which is an important aspect of the characterization of the basin (Strahler, 1964). The morphometric parameter has been analyzed for the first time, proposed by Horton (1945). The study is going to deal with various morphometric parameters and understanding the hydrological behaviour of catchment. There are two types of forest found in the area, tropical and temperate. The lower part of the catchment is a tropical and upper part temperate forest. The

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tropical vegetation type is evergreen, mixed, and moist, and the major species of the temperate forest type is Chir-Pine (*Pinus roxburghii*), but it is interspersed with low-level Oak. Plant development can likewise add to actual disintegration in a cycle called bioerosion. Plants separate earthen materials as they flourish and can take breaks and fissure in rocks they experience. They have generated different types of landforms.

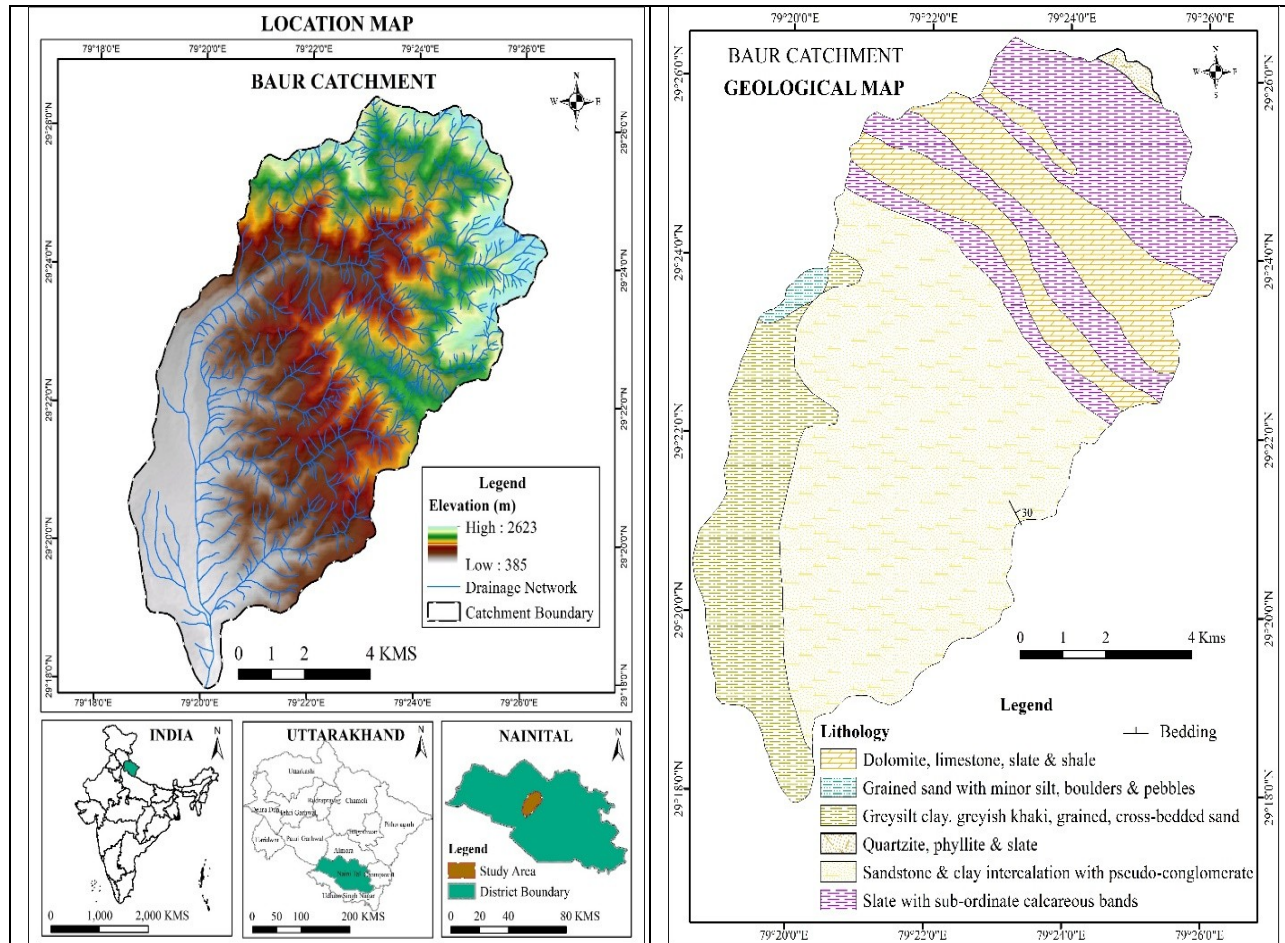
### Study Area

The present study area is an integral part of the Sub-Himalayan region. The Baur river is originated near the Karil Ki Dhar as a spring and its name Sungarkhal Gad. Sungarkhal Gad flows into the south and confluences into the Patharkhani Gad form, which is known as the Baur River. The flow direction of the Baur river is north to south lower Himalayan regions crossing Kotabagh and Bauniyahaldun and finally reaching Gularbhoj Dam (Baur reservoir) near Dalpura reserve forest. It is observed that most of the town developed in this valley near the river bank which connected road network around the city, such as Pandegaon, Bajauniyahaldun, Musabangar. It gives a water supply to the entire season for irrigation. The main tributaries of the Baur river are Sakar Sot, which is a confluence on the right bank, while Luta Gad, Bajun Gad, Ghugwa Gad, and Garuni Gadhera is left bank tributaries. Thala Gad and Titaur Gad is the major tributary of Ghugwa Gad. The Baur river is situated in the north-western furthest point of the Krol belt, shaping an external piece of Lesser Himalaya in the Kumaun region. The study area geographically extends between latitude 29°17'52" N to 29°26'26" N and longitude 79°18'38" E to 79°26'8" E and occupies an area of 106.233 Km<sup>2</sup>. The elevation ranges of the Baur catchment between 385m to 2623m above the mean sea level (Fig. 1). The catchment lies in zone iv of the seismic hazard zone map of India, implying that the area may be subjected to a major earthquake with disastrous consequences. It is the perennial river of the Sub-Himalayan region. The area received good rainfall; the major portion of the area is covered with forests, which have found rich biodiversity. The region can be drawn closer to Nainital by the Nainital-Kunjakhara road flanking the eastern and northern furthest point of the catchment. The area can also be negotiated from Kotabagh by Kaladhungi-Ramnagar road.

### Geology

The Baur catchment is located in the northeastern extremity of the Krol belt, forming the outer part of Lesser Himalaya in Kumaun (Auden, 1935; Valdiya, 1988; Pant and Goswami, 1998; Pant and Goswami, 2003). The catchment encloses rocks of the Ramnagar-Siwalik-Krol-Nagthat succession, which are thrust over the autochthonous Siwalik Group along the Main Boundary Thrust (MBT). The area comprises two major active faults – the Kotabagh Fault (KF) and the Himalayan Frontal Thrust (HFT). The rocks of the area are divisible into five groups: Newer Alluvium Group, Siwalik Group, Jaunsar Group, Baliana Group, and Krol Groups.

The Baur Catchment is the most covered area sandstone and clay intercalation with pseudo-conglomerate, which is the middle part of the catchment, southern part grey silt clay, greyish khaki, grained, cross-bedded, western part grained sand with minor Silt, boulders & pebbles, and northeastern part dolomite, limestone, slate & shale: quartzite, phyllite & slate: slate with sub-ordinate calcareous bands succession of the catchment.



**Fig. 1:-** Location Map and Geological Map of Baur Catchment.

### Objectives:-

1. To delineate the catchment of the study area and extract the drainage system
2. To analyze the various morphometric parameters of the Baur catchment.
3. To analyze the hydrological behaviour and they are controlled of the landform features.

### Materials and Methods:-

Morphometric analysis of the Baur Catchment was carried out using a Survey of India (SOI) topographical map 530/7, with a scale of 1:50,000. The study is outfitted with various spatial and non-spatial datasets arranged by Remote Sensing and GIS methods. The drainage network of the catchment was generated using ASTER-DEM with 30m spatial resolution with ground verification of topographical map and digitization using Arc-GIS 10.4.1 software. The derived parameter was categorized into four groups, such as geometry, linear, areal, and relief aspects of the catchment were found to be six orders. The whole catchment area is divided into 0.5 Km<sup>2</sup> grids.

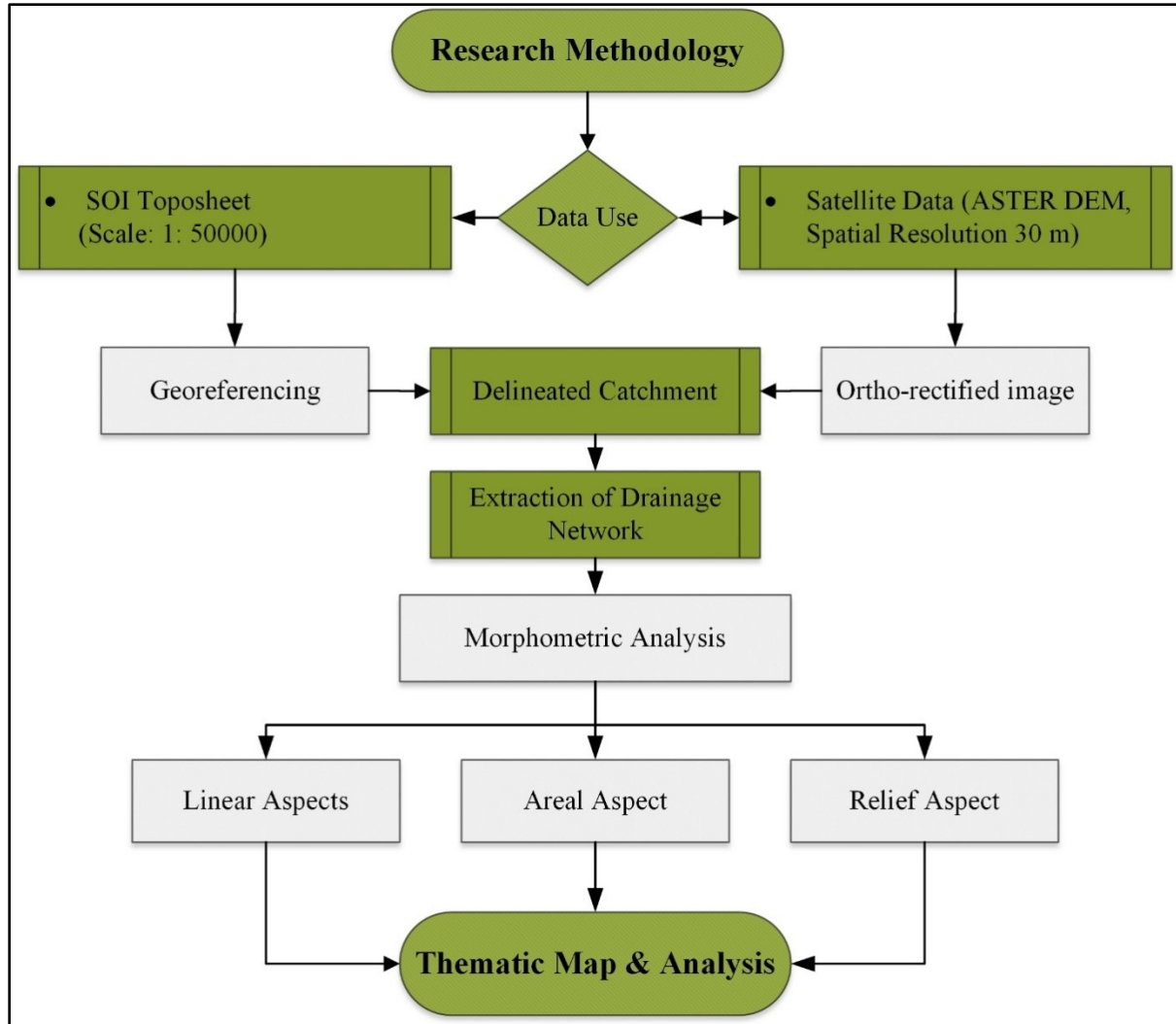


Fig. 2:- Flow Chart of Baur Catchment.

### Results and Discussion:-

In the present work, discuss the morphometric parameters like basin geometry, linear, areal, and relief aspects and given the following tables and descriptions.

#### A - Linear Aspects

Linear aspects of the basins are identified with the channel patterns of the drainage network, wherein the topological attributes of the stream segments regarding open connections of the network system are examined. The morphometric examination of the linear parameter of the basins incorporates stream order ( $u$ ), bifurcation ratio ( $R_b$ ), stream length ( $L_u$ ), mean stream length ( $L_{sm}$ ), stream length proportion ( $R_L$ ), length of overland stream ( $L_g$ ), basin perimeter ( $P$ ), basin length ( $L_b$ ), fitness proportion ( $R_f$ ), etc. and so on. A portion of the significant linear aspects has been processed, as appeared in Table 1.

#### Stream Order ( $u$ )

The essential favourable position of the ordering of streams is that the stream order is dimensionless in number, and henceforth, it very well may be utilized for the examination of the geometry of the drainage network of different linear scales.

The initial phase in the drainage-basin analysis is assigning stream orders. Quantitative investigation of the stream order was firstly proposed by Horton (1945), but Strahler (1952) has represented with certain

changes. Strahler's (1952) method is received for the present examination, and the number of segments of each order is tabulated in Table 1. As indicated by Strahler (1952), where the littlest, unbranched fingertip streams are assigned as the first order, the confluence of two first order channels gives a channel section of second order, two second order streams join to form a section of third order, and so on. Whenever two channels of various orders join then, the higher order is maintained. The trunk stream is the stream fragment of the highest order. The Baur catchment is a sixth-order basin with 624, 134, 29, 7, 2, and 1 fragment in first, second, third, fourth, fifth, and 6th order, respectively. It implies these stream fragments change with expanding order. There is a decline in stream portions with increment in stream orders, which has been obvious from Fig. 3.

### Stream Number (Nu)

The completion of order-wise stream segments is known as stream number. Horton's (1945) law of stream number states that the number of segments of each order from an inverse geometric sequence plotted against the order, which portrays that the proportion of surges of different demands in a given drainage basin tends to eagerly review an opposite geometric degree. This reverse geometric relationship is shown graphically as a straight line (Fig. 4). Most drainage network shows a linear relationship with a little deviation from a straight line. This implies the number of streams, for the most part, diminishes in mathematical movement as the stream order increments. Baur Catchment has identified 797 number streams in a different order that reveals structural and tectonic controlled topography Table 1.

### Law of Stream Numbers

The law of stream numbers has been propounded by Horton (1945), which shows the negative relationship between the stream order and stream number. The law of stream orders that expresses the number of streams usually decreases in geometric progression as the stream order increases. Its relationship is displayed in the semi-log plot diagram Fig. 4, which explained the form of the 'negative exponential function model'. In this diagram, the regression line shows an almost straight line which the actual value and the estimated value of stream order and stream numbers and that express a close relationship between these two parameters. The catchment has found a strong correlation factor that shows perennial type streams and their flow follow the slope and lithological structure.

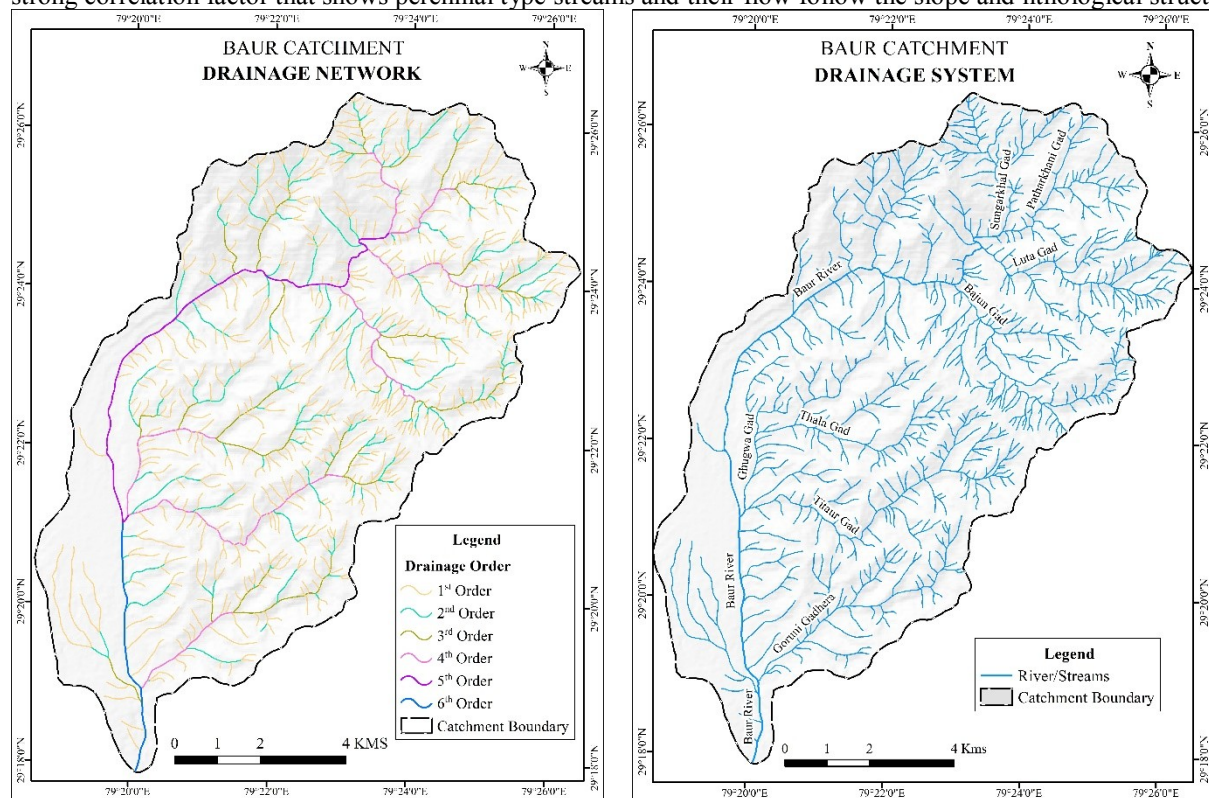
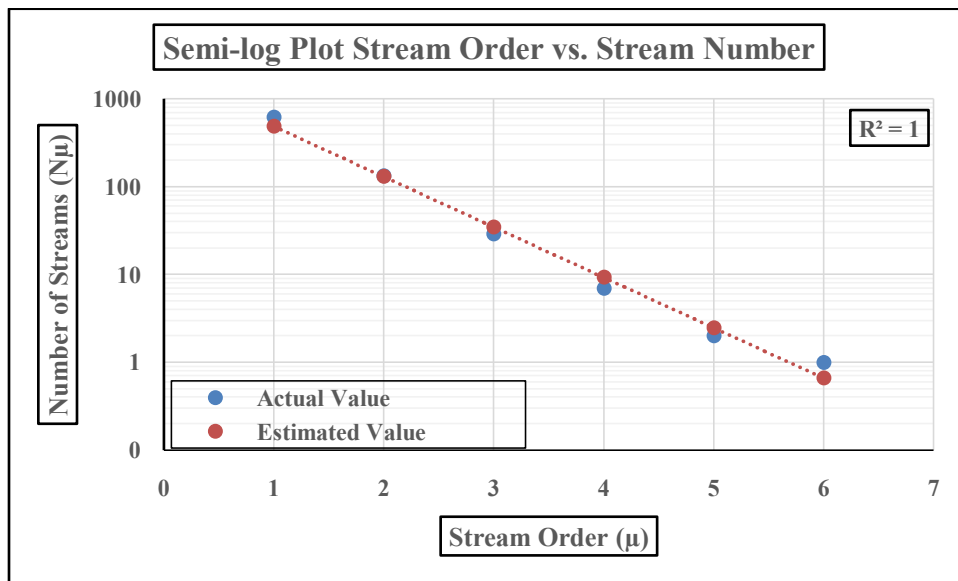


Fig. 3:- Drainage Network and Drainage System of Baur Catchment

**Table 1:-** Results of Morphometric Analysis in Baur Catchment.

Stream Order ( $\mu$ )	Number of streams (Nu)	Bifurcation ratio	Mean bifurcation ratio	Stream Length (Lu) (in km.)	Mean stream length (in km)	Stream Length Ratio ( $R_L$ )	Length of overland flow (Lg)
1	624	4.66		227.459	0.36	0.00	
2	134	4.62		69.463	0.52	1.42	
3	29	4.14	3.15	34.252	1.18	2.28	0.142
4	7	3.50		24.954	3.56	3.02	
5	2	2.00		12.404	6.20	1.74	
6	1	0.00		5.988	5.99	0.97	
<b>Total</b>	<b>797</b>	<b>18.92</b>		<b>374.52</b>	<b>17.82</b>	<b>9.42</b>	

**Fig. 4:-** Relationship between Stream Order v/s Stream Number of Baur Catchment.**Bifurcation Ratio (Rb)**

The term bifurcation ratio is utilized for communicating the proportion of the number of streams of some random order to the numbers of streams in the next higher order (Schumm, 1956). The bifurcation ratio characteristically ranges between 3.0 to 5.0 for the basin in which the geologic structures don't distort the drainage pattern (Strahler, 1957, 1964). The lower value of the bifurcation ratio is the characteristics of the watersheds, which have suffered less structural disturbances (Strahler, 1964). The drainage pattern has not been misshaped as a result of the structured disturbances (Nag, 1998). In the present work, the bifurcation ratio of Baur Catchment ranges from 3.50 to 4.66 (Table 1).

**Mean Bifurcation Ratio (Rbm)**

The mean bifurcation ratio can be defined as the average bifurcation ratio of all orders. The Baur catchment mean bifurcation ratio is 3.15 (Table 1), which has found the ideal condition of the drainage system in the whole catchment that depicts geological controlled landform features.

**Stream Length (Lu)**

Stream length is one of the most noteworthy features of the basin as it reveals surface runoff characteristics of the area with large slopes and fine textures. The longer length of streams is commonly demonstrative of compliment slopes. For the most part, the complete length of stream segments is greatest in first-order streams and decreases as

the stream order increases (Fig. 4). The number of streams of various orders in the basin has been calculated by ArcGIS 10.4.1. The stream lengths are computed in accordance with Horton's (1945) law in the study area. The total stream length of the Baur Catchment has calculated at 374.52 km, which includes different orders. (Table 1). Stream length is the most significant hydrological characteristics, which expresses the surface of runoff that depicts the nature of topography such as altitude, lithological structure, slope characteristics, etc.

### Law of Stream Length

Generally, the number of stream lengths has found a perennial and non-perennial stream in the catchment. Most of the length has calculated the first-order streams, which includes perennial and non-perennial streams. Stream order and stream length is the function of the negative exponential function model, which expresses the relationship between stream order and stream length as successive order. Figure 5 shown the semi-log plot of stream order and stream length. The correlation factor has been found 97 percentage, which indicates the positive relationship between these two parameters. It shows the various landform features in this catchment that controlled all geomorphic factors and their impact on it.

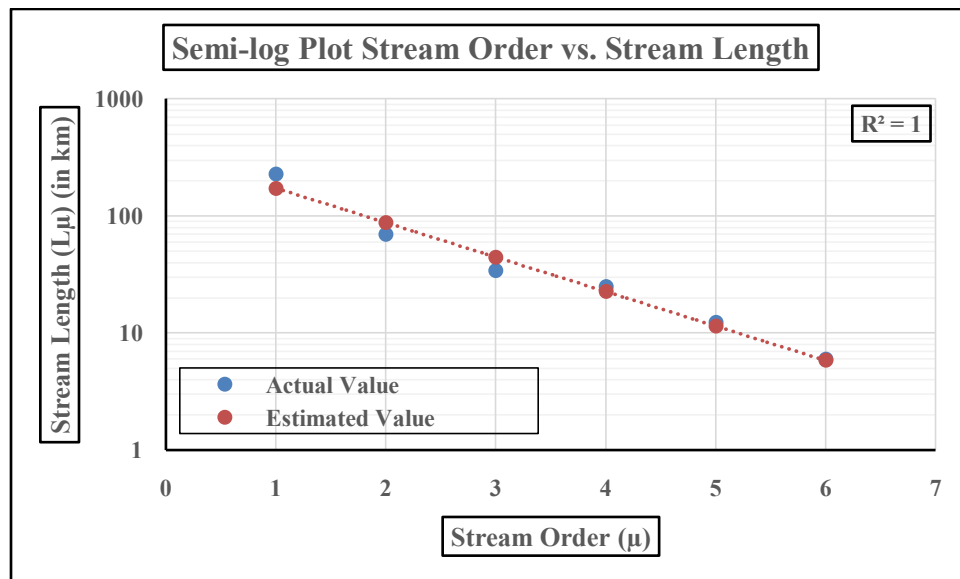


Fig.5:- Relationship between Stream Order vs. Stream Length of Baur Catchment.

### Mean Stream Length (Lsm)

Mean stream length of a stream channel fragment of order 'u' is a dimensional property uncovering the characteristics size of components of a drainage network and its contributing basin surface (Strahler, 1964). It is achieved by separating the complete length of the stream of the order by an all outnumber of fragments in the order (Table 1). The deviation of the computed values from the study area may obviously be attributed to the variation in slope and topography. The mean stream length of the Baur Catchment ranges 0.36 km. to 6.20 km, which describes drainage characteristics and various landform features.

### Stream Length Ratio ( $R_L$ )

The stream length ratio is characterized as the ratio of the mean stream of a given order to the mean stream length of the next lower order (Horton, 1945) and has an important relationship with the surface flow and discharge. The Baur Catchment indicates variation (Table 1) in such a ratio from order to order, thus indicating their youth to mature stage of geomorphic development (Singh and Singh, 1997).

### Length of Overland Flow ( $L_g$ )

Length of overland flow refers to the length of the runoff of the rain on the ground surface before it gets concentrated into definite stream channels, and it approximately equal to the half of reciprocal drainage density (Horton, 1945). The length of the overland flow of the study area is 0.142 indicating a low surface runoff in the basin, and it further confirms the less susceptibility of the basin for both soil erosion and flooding (Table 1).

**Table 2:-** Formulae Adopted for Computation of Morphometric Parameters.

Morphometric parameters	Methods/Formulæ	Results	References
<b>A - Linear Aspect</b>			
Stream Order ( $\mu$ )	Hierarchical Order	6th Order	Strahler, 1964
Stream Number ( $N_\mu$ )	No. of Stream segments of a given order	see table 1	Horton, 1945
Bifurcation Ratio (Rb)	$Rb = N_\mu / N_{\mu+1}$ Where, Rb = Bifurcation ratio, $N_\mu$ = No. of stream segments of a given order $N_{\mu+1}$ = No. of stream segments of next higher order.	see table 1	Schumm, 1956
Mean Bifurcation Ratio (Rbm)	Rbm = Average of bifurcation ratio of all orders	3.15	Strahler, 1964
Stream Length ( $L_\mu$ )	$L_\mu$ = Total Stream Length of order ' $\mu$ ' (in km)	see table 1	Horton, 1945
Mean Stream Length (Lsm)	$L_{sm}$ or $\bar{L}_\mu = \Sigma L_\mu / N_\mu$ where, Lsm = Mean Stream Length $\Sigma L_\mu$ = Total stream length of order ' $\mu$ ' $N_\mu$ = Total no. of stream segments of order ' $\mu$ '	see table 1	Strahler, 1964
Stream Length Ratio (RL)	$RL = \bar{L}_\mu / \bar{L}_{\mu-1}$ Where, RL = Stream Length Ratio $\bar{L}_\mu$ = Mean stream length of a given order $\bar{L}_{\mu-1}$ = Mean stream length of next lower order	see table 1	Horton, 1945
Length of Overland Flow (Lg)	$Lg = 1/2Dd$ where, Lg = Length of overland flow Dd = Drainage Density	0.142	Horton, 1945
<b>B - Areal Aspect</b>			
Stream Frequency (Fs)	$Fs = N_\mu / A$ Where, Fs = Drainage frequency. $N_\mu$ = Total no. of streams of all orders A = Area of the basin (Km <sup>2</sup> )	7.50	Horton, 1932
Drainage Density (Dd)	$Dd = L_\mu / A$ where, Dd = Drainage Density $L_\mu$ = Total stream length of all orders A = Area of the basin (km <sup>2</sup> )	3.525	Strahler, 1964
Drainage Texture (Dt)	$Dt = Nu / P$ Nu = Total number of stream segments of all orders P = Perimeter of the Basin	see figure 7	Horton, 1945
<b>C - Basin Geometry</b>			
Basin Area (A)	GIS Software Analysis	106.233 km <sup>2</sup>	
Basin Perimeter (P)	GIS Software Analysis	48.4762 km	
Basin Length (Lb)	GIS Software Analysis	17.289 km	
Main Channel Length	GIS Software Analysis	21.979 km	
Form Factor (F)	$F = A / Lb^2$ Where, A = Area of the basin L = Basin length	0.355	Horton, 1932
Circularity Index (C)	$C = 4\pi A / P^2$ Where, C = Circularity Index	0.442	Miller, 1953

	A = Area of the Basin P = Perimeter of the Basin		
Elongation Ratio (Re)	$Re = \sqrt{4 \cdot A / \pi} / Lb$ Where, Re = Elongation ratio A = Area of the basin Lb = Basin length	0.67	Schumm, 1956
Lemniscate Ratio (K)	$K = Lb^2 / A$	0.70	Chorley, 1957
Basin Shape (Index) (Bs)	$Bs = Lb^2 / A$ Where, Bs = Basin shape or Shape index Lb = Basin length A = Area of the basin	2.814	Horton, 1945
<b>D - Relief Aspect</b>			
Relative Relief (R)	$R = H - h$ Where, R = Relative relief H = Maximum elevation of the basin (m) h = Minimum elevation of the basin (m) * GIS software analysis using DEM	see figure 9	Strahler, 1952
Absolute Relief (in meter)	GIS Software Analysis	see figure 9	
Slope	GIS Software Analysis	see figure 10	
Slope Aspect	GIS Software Analysis	see figure 10	
Hypsometric Integral	$HI = \text{Mean Elevation} - \text{Min. Elevation} / \text{Max. Elevation} - \text{Min. Elevation}$	0.50	Strahler, 1952

### B - Areal Aspects

The areal aspect is the two-dimensional properties of a basin. It is possible to delineate the area of the basin, which contributes water to each stream segment. Areal aspects introduced in the study area like stream frequency, drainage density, etc.

#### Stream Frequency (Fs)

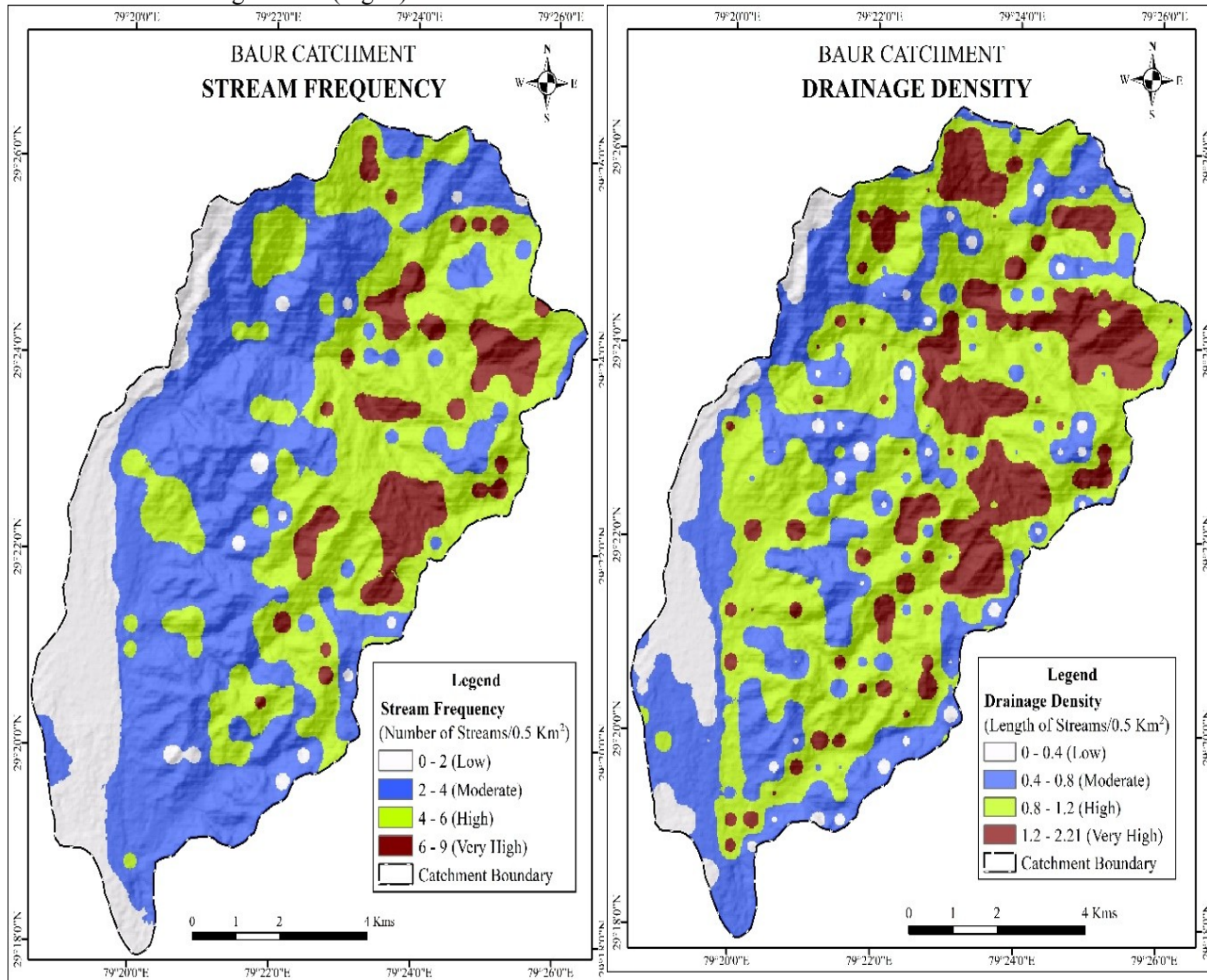
Stream Frequency (Fs) represents the ratio of the total number of streams (Nu) in a basin to the basin area (A) and is defined as the number of streams per unit of area (Horton, 1932). The stream frequency value depends mainly on the lithology of the basin and reflects the texture of the drainage network. Statistically, the stream frequency value is positively correlated with the drainage density value of the catchment, which implies that the expansion in-stream populace is associated with that of drainage density. The value of drainage density and stream frequency for little and enormous drainage basins are not straightforwardly tantamount in light of the fact that they generally change with the size of the drainage area. High stream frequency implies more permeation concerning drainage density and henceforth more surface runoff—the value of stream frequency 7.50 no./half km<sup>2</sup> which indicates high stream frequency (Fig. 6). Baur Catchment can be credited to high relief and low infiltration capacity, bringing about an expansion of the in-stream populace.

#### Drainage Density (Dd)

Drainage density is a measure of the complete stream length in a given basin to the total area of the basin (Strahler, 1964). The drainage density is influenced by the variables that control the characteristic length of the catchment. Drainage density is identified with different features of landscape dissection such as channel head source area, valley density, relief, climate, and vegetation (Moglen et al. 1998), soil and rock properties (Kelson and Wells 1989), and landscape evolution measures. The drainage density of the Baur Catchment is 3.525 km/half km<sup>2</sup>, which demonstrates that the catchment area has a moderate permeable subsurface material with intermediate drainage and low to moderate relief. Higher drainage density is related to the basin of feeble and impermeable subsurface material, sparse vegetation, and high relief. Low drainage density prompts coarse drainage texture, while high drainage density prompts fine drainage texture, high runoff, and erosion potential of the basin area. (Strahler, 1964). The drainage density of the Baur Catchment is given in Fig. 6.

**Drainage Texture (Dt)**

Horton (1945) described the total number of stream segments of all orders per perimeter of that area. It is essential to geomorphology, which implies that the relative spacing of drainage lines. Drainage texture is on the underlying lithology, infiltration capacity, and relief aspect of the terrain. Savindra Singh (1976-78) has classified drainage texture into five different texture, i.e., very coarse (>0.8), coarse (0.8 to 0.6), moderate (0.6 to 0.4), fine (0.4 to 0.2), and very fine (0.2 to 0.001). In the present work, the drainage texture of the Baur Catchment is 7.502, which indicates coarse drainage texture (Fig. 7).



**Fig. 6:- Stream Frequency and Drainage Density of Baur Catchment.**

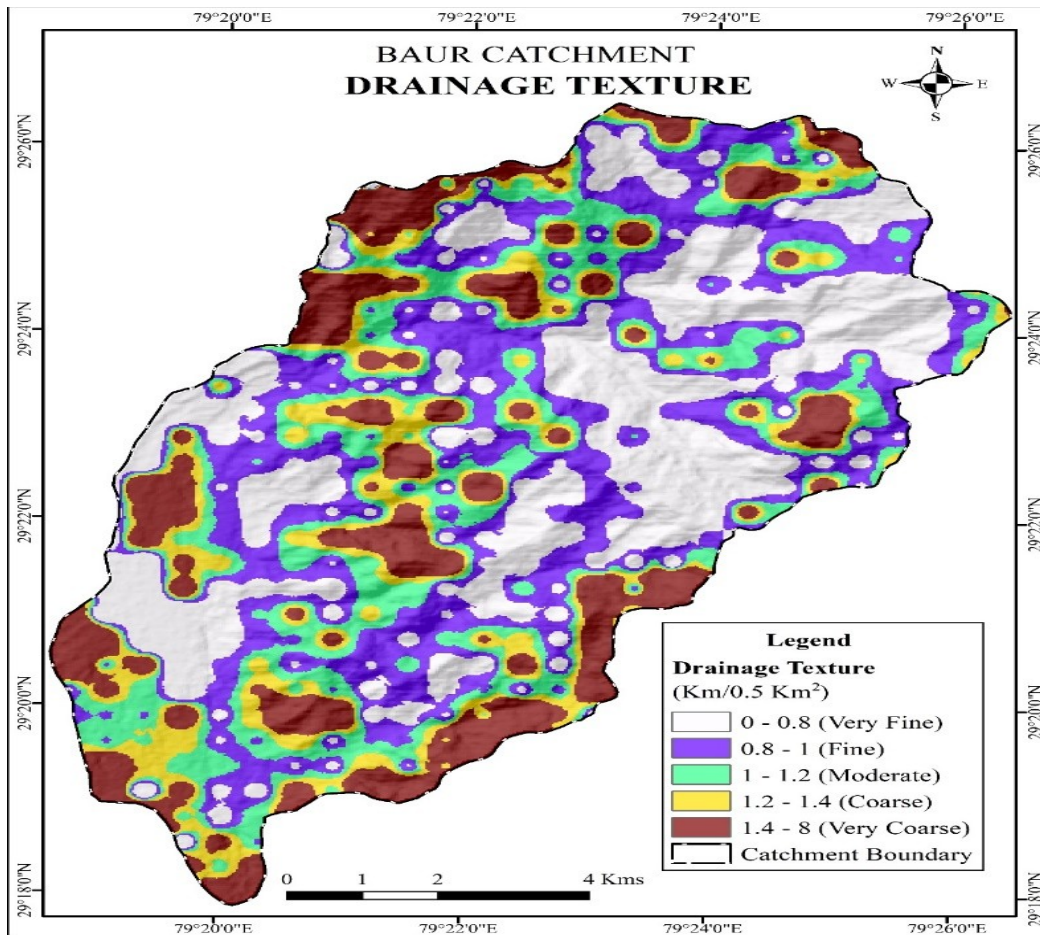


Fig. 7:- Drainage Texture of Baur Catchment.

### C - Basin Geometry

The geometry of basin shape is the most significant parameter with the help of the description of basin shape characteristics controlled by the drainage system. It is related to the function of drainage and its genesis in the catchment. The ideal drainage basin has usually created a shape that depends on basin size and stream length parameters. Shape geometry is depicted wide variables characteristics such as absolute relief, slope, geological structure, soil characteristics, etc. The shape geometry calculated various parameters and output the result in different shapes like circular, elongated, indented, etc.

#### Form Factor (F)

The form factor is the numerical index (Horton, 1932) commonly used to represent different basin shapes. The estimation of the form factor is between zero to one. Little, the estimation of form factor, progressively elongated, will be the basin. The basin with high form factors 1 has high peak flows of a shorter span, while the elongated drainage basin with low form factors has lower peak progression of longer-term. The Baur Catchment shows low values of form factor (0.355) is an elongated circular shape. The value demonstrates the drainage of the Baur Catchment shows a low value of the form factor. The drainage development in this part is low, and the area has a structural disturbance.

#### Circularity Ratio (Rc)

The circularity ratio (Rc) has been utilized as a quantitative measure for envisioning the shape of the basin and is communicated as the ratio of the basin area (A) to the area of a circle (Ac) having the same circumference as the perimeter of the basin (Miller 1953; Strahler 1964). It is constrained by the length and recurrence of the streams, geographical structures, land use, land cover, atmosphere, relief, and slope steepness of the catchment. A drainage basin with an range of circularity ratios of 0.4 to 0.5 was depicted by Miller, demonstrating they are unequivocally

lengthened, exceptionally porous, with homogeneous topographical materials. Low, Medium, and High estimations of circularity ratio show the youthful, mature, and old phases of the geomorphic cycle of the catchment. The circularity ratio estimation of the Baur Catchment is 0.442, which indicates that the catchment is an elongated shape, mature topography, and dendritic pattern of a drainage network.

#### **Elongation Ratio (Re)**

Schumm's 1956 utilized an elongation ratio (Re) defined as the ratio of the diameter of a circle of a similar area as the basin to the maximum basin length. Analysis of elongation ratio indicates that the area with higher elongation ratio values has high infiltration capacity and runoff. The values of elongation ratio generally vary between 0.6 to 1.0 over a wide range of climate and geological conditions (Strahler, 1964). The varying slopes of the watershed may be classified with the help of the index of elongation ratio, i.e., more elongated (<5), elongated (0.5-0.7), less elongated (0.7-0.8), oval (0.8-0.9), and circular (0.9-1.0). The value of the elongation ratio of the Baur catchment is 0.67, which indicates the catchment is elongated.

#### **Lemniscate Ratio (K)**

Chorley et al. (1957) have utilized the term lemniscate or pear shape, which defines precisely the shape of the basin; it is more steady with experimental reality than an ideal circular shape for a basin. Chorley proposed that if the K value is below 0.6, then the basin has circular shape if between 0.6 to 0.9, then oval, and when greater than 0.9, elongated in shape. The Baur Catchment obtained the K value is 0.70 (Table 2), likewise adjusts to the oval shape of the catchment.

#### **Shape Index**

Horton (1945) defined shape index as the ratio of the square of basin length and area of the basin. That is express the shape irregularity of the basin. There is an impact on the rate of water and deposition of sediment in the basin. The value of the shape index of the Baur Catchment is 2.814, which means moderate erosion of the basin.

#### **D - Relief Aspects**

The linear and areal landscapes have been considered as the two-dimensional perspective lie on a plan. The third dimension represents the concept of relief. Present work, introduce to relative relief, absolute relief, slope, slope aspect, etc.

#### **Hypsometric Analysis**

Hypsometry refers to the overall extent of a region at various elevations inside a region, and the hypsometric curve is an area-elevation relationship curve that delineates the dissemination of the zone as for rising (Strahler, 1952). The hypsometric curve and hypsometric integral (Hi) are pivotal pointers of watershed conditions (Ritter et al., 2002). The hypsometry of a drainage basin is illustrated either graphically as a "hypsometric curve" (HC), or quantitatively as an essential called "hypsometric integral" (HI). The hypsometric curve communicates the volume of rock mass in the watershed and the measure of disintegration that has occurred in the watershed against the remaining mass (Hurtrez et al., 1999). The hypsometric integral is determined from the region under a hypsometric curve and is communicated as a rate.

Strahler (1952) looked at and assessed different shapes of hypsometric curves relating to different drainage basins and grouped the basins concurring to their stages of geomorphological evolution as youth stage (convex upward curves, where  $HI \geq 0.60$ ), mature stage (S-shaped hypsometric curve, which is concave upward at high elevations and convex downwards at low elevations, where  $0.30 \leq HI \leq 0.60$ ), and old stage (concave upward curve, where  $HI \leq 0.30$ ). The hypsometric integral (HI) estimation of the Baur Catchment is 0.50 (Fig.7), which shows the mature stage of the catchment. Where the catchment is profoundly vulnerable to disintegration and land sliding, catchment is of high helplessness to surface spillover, soil disintegration misfortune, and land sliding.

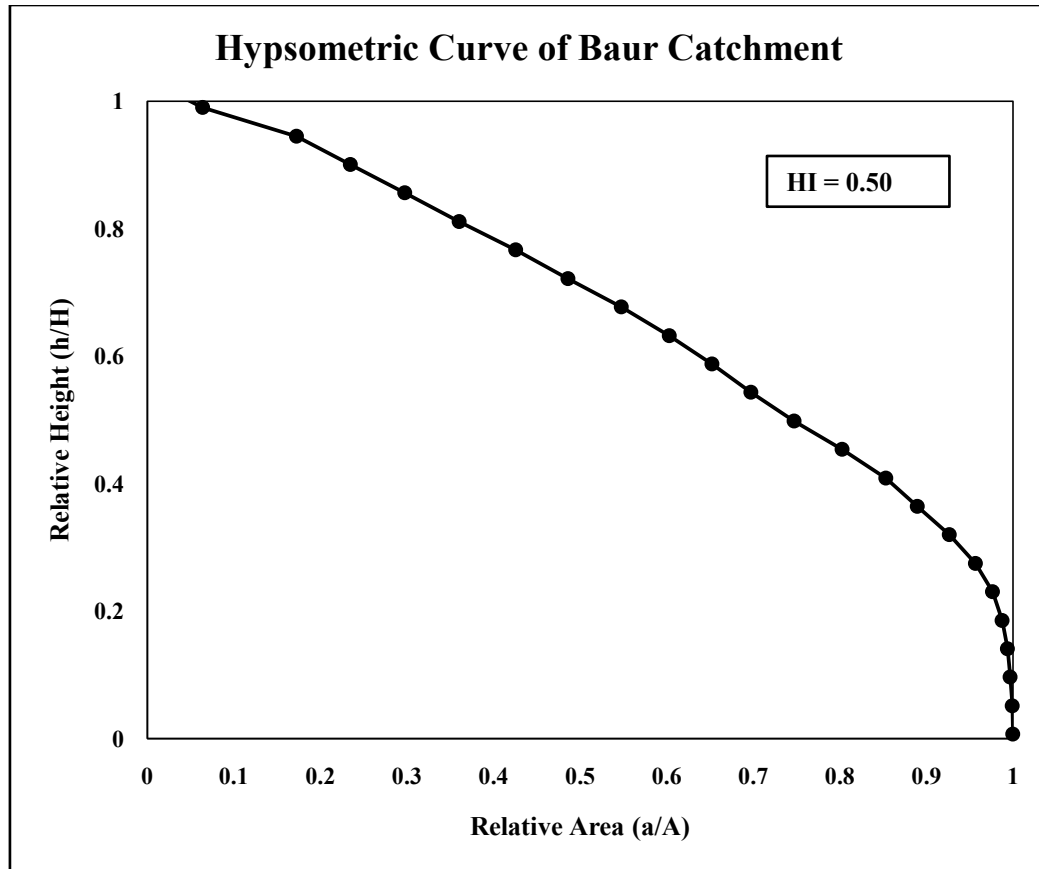


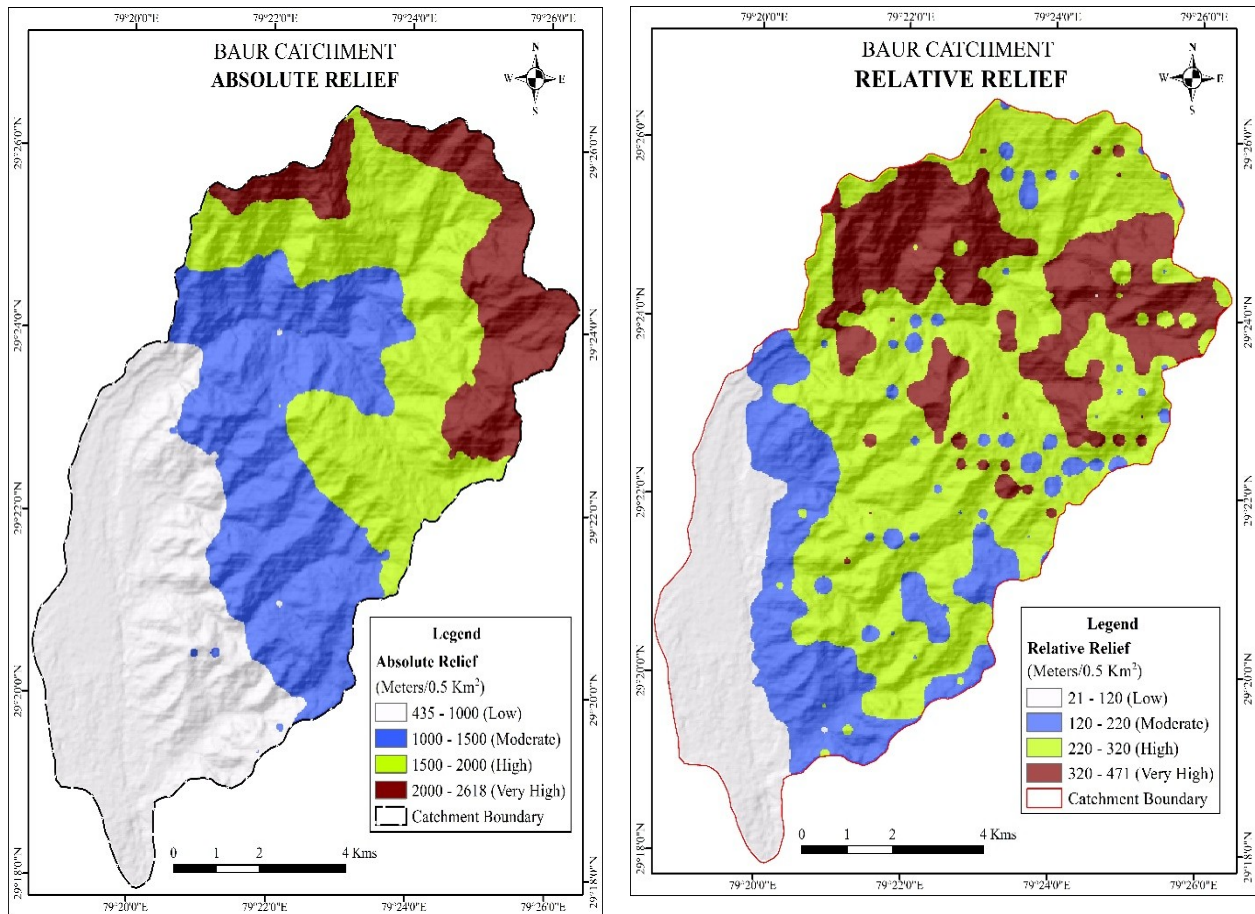
Fig. 8:- Hypsometric Curve of Baur Catchment.

#### Absolute Relief (Ra)

Absolute relief is the measurement of the actual height of a particular area above sea level. The geology of this area differed from 435 – 2618m (Fig. 9). The maximum elevation zone was found in the northern part of the catchment, while the minimum elevation was observed in the southern part of the catchment area. A diagram was plotted to portray the height against the percentage of the region (Fig. 9). In any case, the greatest zone of this catchment was secured by 435 - 1000 meters.

#### Relative Relief (Rr)

Relative relief is defined as the differences in height between the highest and the lowest points in a unit area (Strahler, 1952). It is an important morphometric parameter that is used for the overall assessment of morphological characteristics of terrain. The relative relief of the Baur Catchment ranges between 320–471m (Fig. 9). Because of its close association with slope, the relative relief is more expressive and useful in different fields, including relief dissection and surface ruggedness. When the amplitude of regional relief is greater, the surface roughness will be seen to vary significantly from unit to unit under the over thrusting natural set of geomorphic conditions. Thus the more is local relative relief, the more is the roughness, and their manifold decrease is the effective value of terrain for arable farming (Singh & Dhillon, 1984).



**Fig. 9:-** Absolute Relief and Relative Relief of Baur Catchment.

### Slope Analysis(Sa)

The slope is an area of land that makes a definite angle to the horizontal landscape. In geomorphology, the landscape is made up of slope units. The slope may be defined as the vertical inclination between the hilltop and valley bottom, which stands with the horizontal line and is expressed generally in degrees. Strahler (1964) expressed “the inclination or gradients of the surface of a basin in terms of maximum valley side slope, measured at interval along the valley walls in the steepest part of the contour orthogonal running from divides to adjacent stream channel”. The slope of the Baur Catchment is categorized into five groups, i.e. moderate slope (0-10 degree), moderately steep slope (10-20 degree), steep slope (20-30 degree), very steep slope (30-45 degree), and precipitous slope (45-63 degree) covering an area of 17.52%, 20.41%, 27.35%, 23.70%, and 11.02% respectively which describes into 0.5km by 0.5km grids and describe the catchment is moderately dissected and large area a steep slope covered (Fig. 10).

### Slope Aspect

The slope aspects map shows the relative position of slope facets with respect to the direction of the sun angle. Generally, it refers (Direction of Slope) to the horizontal direction to which a slope face. Baur river flows from north to south direction. Baur Catchment is divided into nine slope aspects. As slope aspect suggests that which area impact is a denudational procedure. The settlement location depends upon the slope aspect condition. The slope aspect of the Baur Catchment has covered the entire direction of the area, and the settlement is situated northern, southwest, and west aspect of the catchment. The dense forest of the study area is located northeast, southwest, and northwest aspect, and the eastern aspect area is open forest and shrub type vegetation of catchment (Fig. 10). The vegetation and forest growth depend upon slope aspects condition.

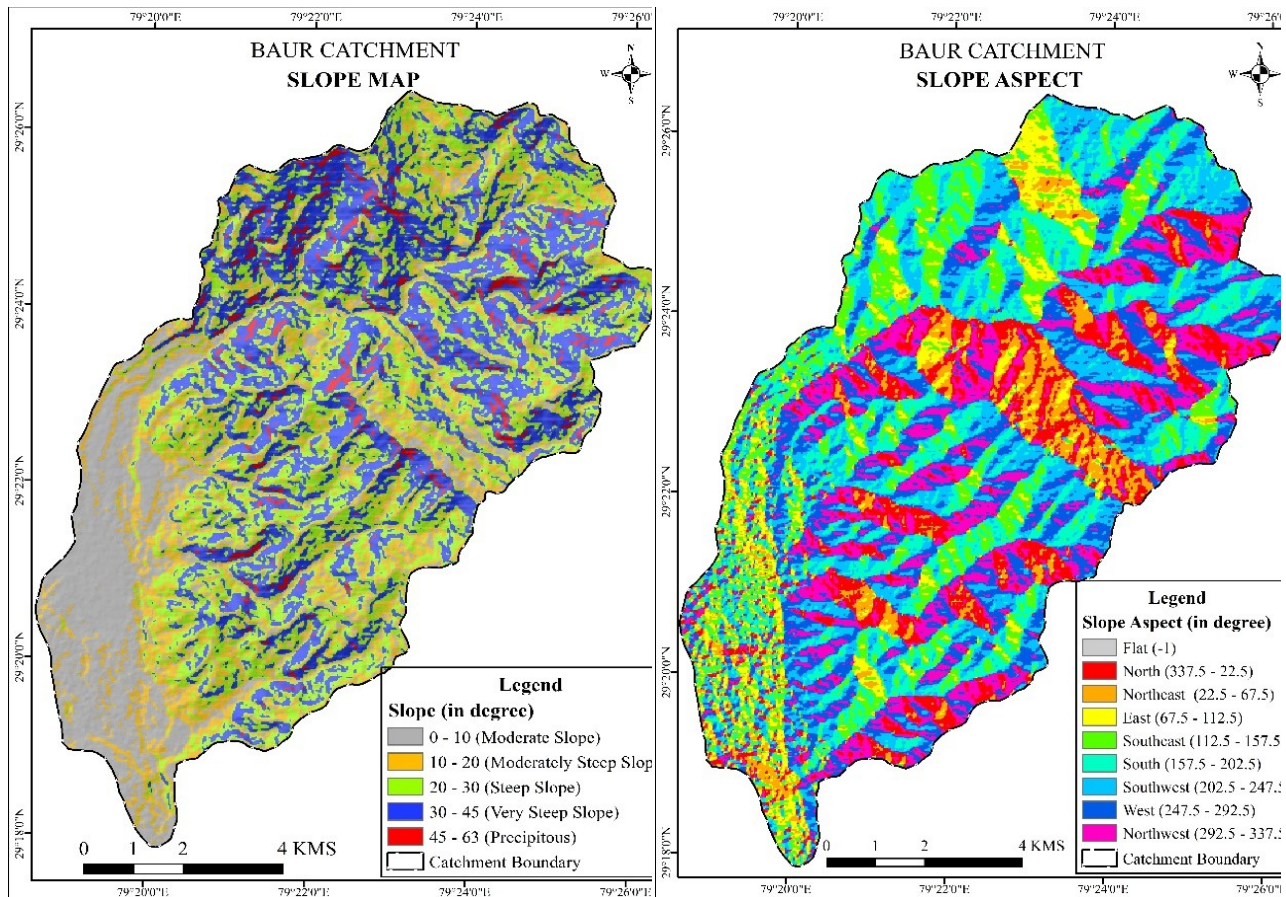


Fig. 10:- Slope and slope aspect of Baur Catchment.

**Dissection Index (Di)**

Dissection index is a parameter referring to the degree of dissection or vertical erosion and the stage of landforms development in any given watershed (Singh, S. and Dubey, A., 1994).The dissection index gives a clue to the development of landforms under the purview of the fluvial geomorphic cycle of erosion (Prasad, 1985).It is the assessment of the vertical erosion of landforms. Dissection index is the ratio relative relief and absolute relief of the basin, which illustrates ‘0’ is the absence of dissection and ‘1’ is an extreme dissection of the landforms.In the present work, the dissection index is shown in Fig.11.

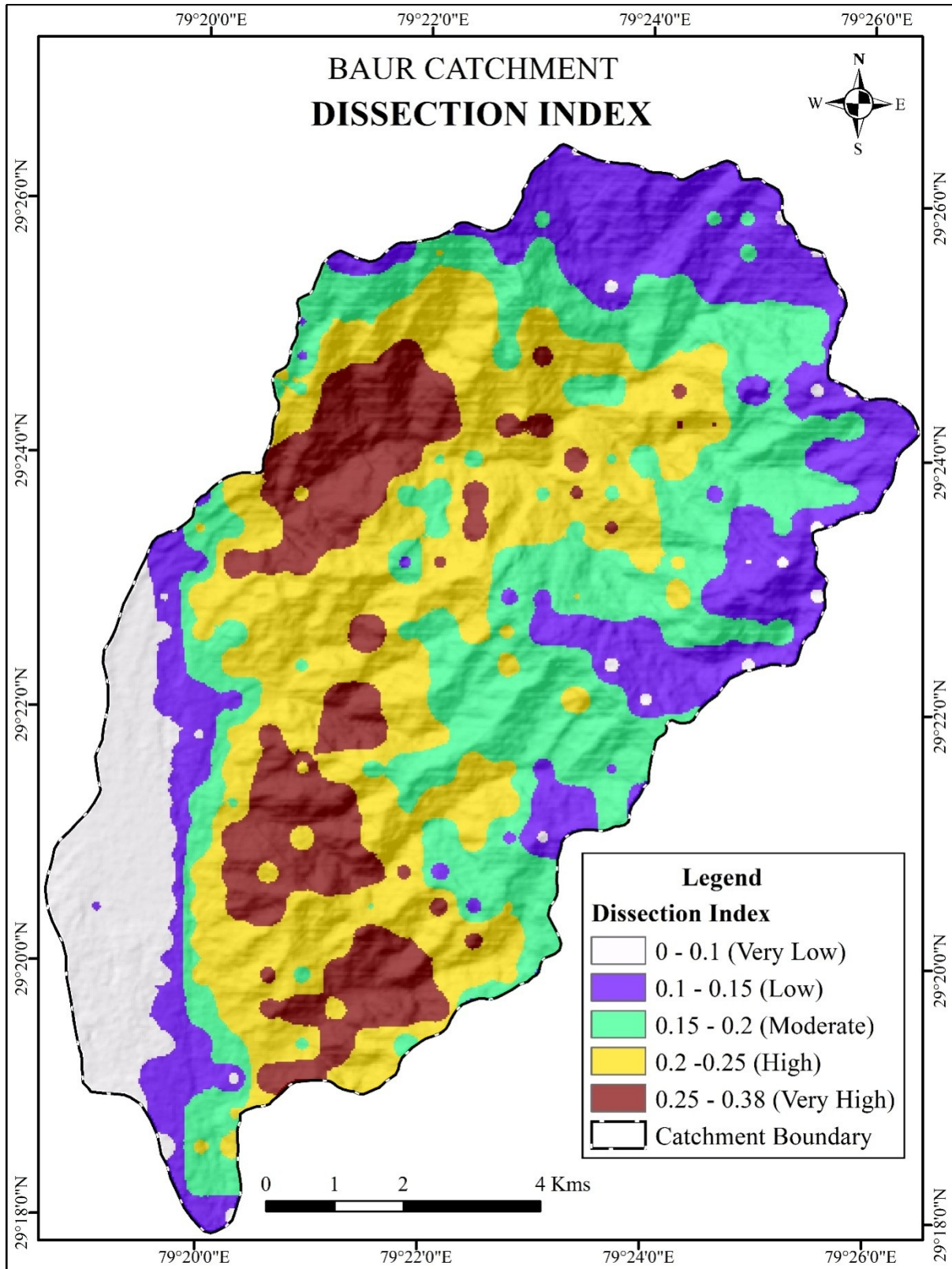


Fig. 11:-Dissection Index of Baur Catchment

### Conclusion:-

Morphometric evaluation of the drainage system is a prerequisite to any hydrological observation. Thus, the deduction of stream networks behaviour and their interrelation with every difference is of excellent importance in many water assets research. Remote sensing data and Arc-GIS techniques have been proved to be an effectual tool in drainage delineation. Their updation at the side of previous datasets brings various pictures enabling geomorphologists to infer a concrete conclusion about the drainage basin. In the existing paper, a morphometric analysis of the Baur River Catchment, based on numerous drainage parameters using satellite data and GIS tools for drainage examination, has been described.

The morphometric examination is carried by using the dimension of linear, aerial, and relief aspects of catchment. It has been found 6<sup>th</sup> order drainage network of Baur Catchment. The bifurcation ratio is 2.0 to 4.66 of the 5<sup>th</sup> and 1<sup>st</sup> order drainage network, which indicates the geological structure is the prominent function of the drainage system in the catchment. In this way, it is seen that there is a decrease in stream frequency as the stream order increases and vice versa. The variation of stream length ratio is probably because of differences in slope/gradients and topographic situations of the place. The mean stream length values 0.36 to 6.20, which indicates the altitudinal variation of the slope position and topographical change of the catchment. This area is high altitudinal zoning of the Lesser Himalaya region, which reveals high relative relief and steep slope characteristics of the catchment. The elongation ratio is 0.67, which indicates the main part of the catchment is moderate relief. The length of overland flow is 0.142, early mature topography of the catchment. There are two types of forests, tropical and temperate while generating the different types of landforms. Generally, the results show that catchment is highly vulnerable to hazards and rich water properties.

Thus, the whole catchment has found the variation of climatic characteristics, i.e., the lower part of the catchment was identified as tropical climatic, and the upper part was identified as temperate climatic. Due to climatic variation, it is found rainfall and snowfall (winter season). The hydrological behaviour of catchment observed different rates of erosion in different topography. Because of this, different types of landforms have been developed in this catchment, such as scarp, v-shaped, spur, river terraces, raffle, etc..

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