Morphometric Analysis of Khalri Drainage Basin Using Remote Sensing (RS) and Geographical Information System (GIS)

S. D. Payal[1], D. N. Gokhale[2], B. M. Bhuibhar[3]

[1]Assistant Professor, Department of Soil and Water Conservation Engineering CAET, VNMKV, Parbhani (MS), India

[2]Director of Instruction and Dean, VNMKV, Parbhani (MS), India

[3]Associate Professor, Department of Soil and Water Conservation Engineering CAET, VNMKV, Parbhani (MS), India

Abstract: ***Remote Sensing (RS) and Geographical Information System (GIS) has an efficient tool in delineation of drainage pattern and ground water potential and its planning.GIS and image processing technique can be employed for the identification of morphological features and analyzing properties of basin. The morphometric parameters of basin can address linear, areal and relief aspects. The present study deals morphometric parameters such as stream order (NU), Stream length (LU)Bifurcation Ratio (Rb) drainage density (Dd) stream frequency (Fs), Elongation ratio (Re), Circulatory ratio (Rc) and farm factor (Rf) etc. The GIS based morphometric analysis of this drainage basin revealed that the Tanda is 4^{th} order drainage basin and drainage pattern mainly in sub-dendritic to dendritic type indicates homogeneity in texture and lack of structural control. Total number streams is 183, in which 144are first order, 52 are second order, 5 are third order and 12 are fourth order streams. The length of stream segment is maximum for first order stream and decrease as the stream order increases. The drainage density (Dd) of the study area is 1.37 km/km^2. This study will help the local people to utilize the resources for sustainable development of the basin area.***

1. Introduction

Morphometry is the measurement and mathematical evaluation of earth's surface, form and the dimension of the landforms. The morphometric analysis of the drainage basin and channel network plays a significant role in comprehension of the geo- hydrological nature of drainage basin and expresses the prevailing climate, geological setting, geomorphology and structural antecedents of the catchment area. A quantitative evaluation of drainage system is significant aspect of drainage basin.

The morphological and climatic characteristics of a basin govern its hydrological response to a considerable extent. The morphological characteristics of a basin represent its attributes, which may be employed in synthesizing its hydrological response. The importance of morphological factors cannot be overlooked in accurate prediction of runoff. Basin characteristics when measured and expressed in quantified morphometric parameters can be studied for their influences on runoff. Hence linking of the morphometric parameters with the hydrological characteristics of the basin can lead to a simple and useful procedure to simulate the hydrologic behavior of the various basins, particularly the ungauged ones. Interpretation and quantitative analysis of Various drainage parameters enable quantative evaluation of surface runoff, infiltration and susceptibility to erosion within the basin. Maidment (1993), Chalam et al (1996) etc have established some of the relations between hydrologic and geomorphologic variables using statistical methods. Remote sensing has emerged as a powerful tool in recent past for natural resources assessment with the ability of obtaining systematic, synoptic rapid and respective coverage. GIS has made remote sensing a unique technology and widen the spectrum of remote sensing applications in natural resources management. Considering all these aspects an attempt has been made to study the geomorphology of Khalri watershed in Godavari Purna basin (GP-49) in Jintur watershed of Parbhani district of Maharashtra with the help of remote sensing and GIS technology.

2. Study Area

The present study area is located in the Parbhani district of Maharashtra. Jintur sub watershed is part of Godawari-Purna sub basin; the location of the study area is shown in fig 1. The khalri watershed sub-basin lies between76^0 26'36 to76^0 56'13 East longitude and19^0 17'43 to19^{0}44' 17 North latitude in Parbhani district of Maharashtra. The river in watershed is fourth order stream having low gradient. It rise from an elevation of 428 m to 536 m with elevation difference of 108 m. The watershed encompasses an area of 91.75km^2.The rainfall records shows that it is a region of moderate rainfall, where average annual rainfall stands at 647mm and temperature goes up to 42^{0}C summer and comes down to 11^{0}C in winter season. The climate of the district is Semi arid, humid and Subtropical. In the Survey of India Toposheet, it forms part of 56 A/6 on 1:50000 scale. (Fig.1)

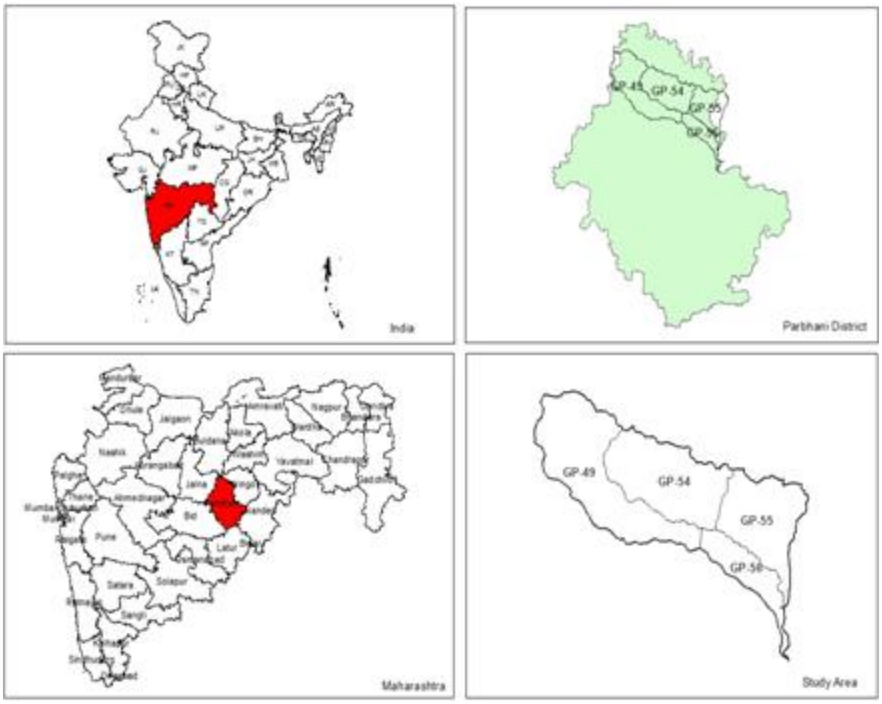

Figure 1: Location map of the study area

3. Material and Methods

Base map of the study area was prepared using the survey of India (SOI) Toposheet no 56A/6 .Remote sensing data of the study area acquired on 01 Jan 2014 procured. The satellite data was first geo referenced with the help of base map prepared using SOI Toposheet. Digital image processing techniques were applied on the images. Making use of spatial and radiometric enhancement techniques in order to remove shadow and for proper tone and texture of the image. The watershed boundary of the study area was delineated using the SOI Toposheet on 1:50000 scale and rempte sensing data. The drainage network was also delineated from SOI toposheet and remote sensing data. Field visit was made in order to collect the training sets for preparation of land use map of the study area. During the field visit actual ground conditions were verified and training sets for different latitudes were marked. The delineated watershed was further divided in to sub watershed and then sub watershed along the boundary were selected for morphometric analysis. The morphometric parameters for selected sub watersheds were calculated in GIS Environment. The input parameters for morphological studies such as perimeters, area, elevation, stream length etc. were obtained directly in Arc GIS 10.60Software using quary based algorithms. Other morphological parameters were calculated using formulae based on input values.

Figure 2: Drainage map of basin Khalri watershed basin

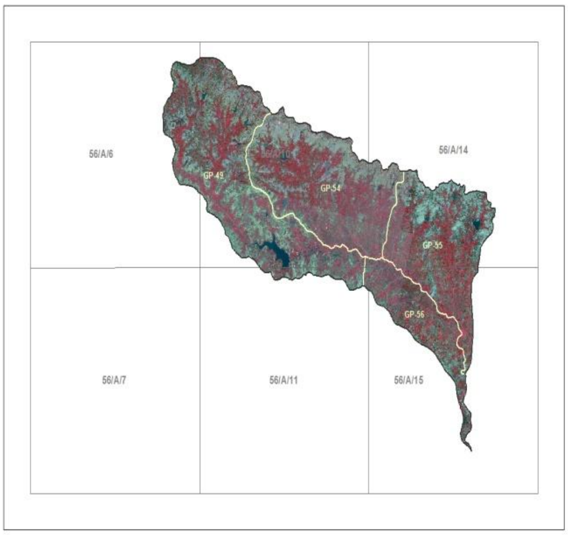

Figure 3: Location map of Khalri watershed basin

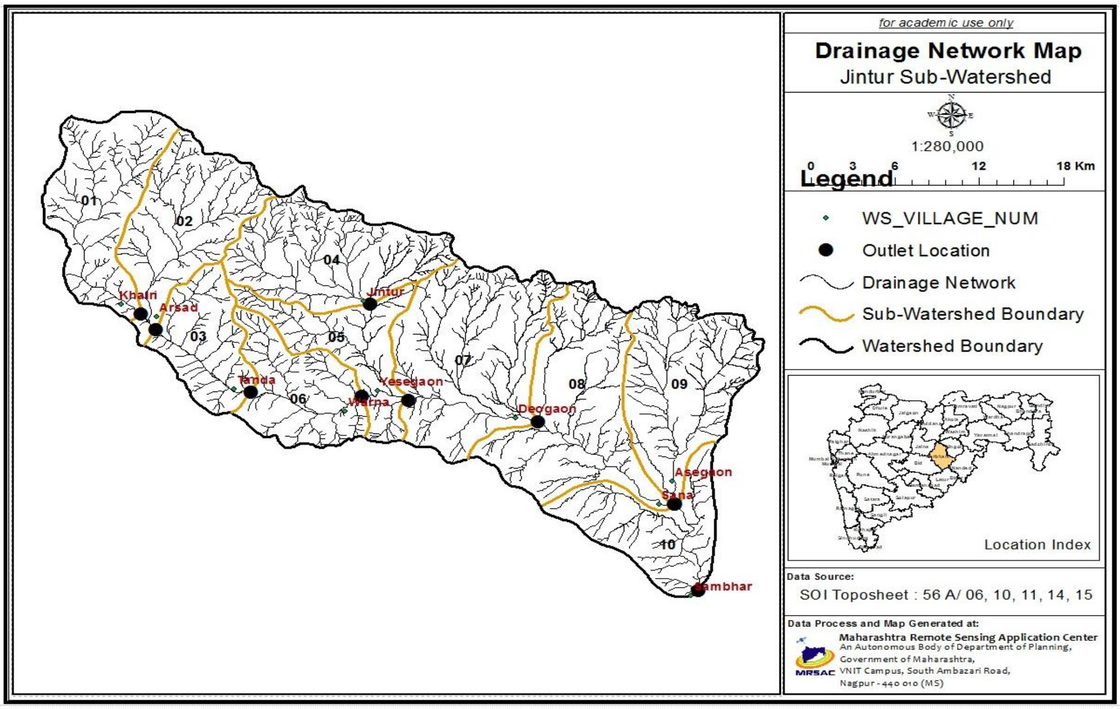

Figure 2: Drainage order Khalri watershed basin

Morphometric parameters	Formula	Reference
	Linear parameters	
Stream order (U)	Herarchical	Strahler (1964)
Srteam length (Lu)	Length of stream	Horton (1945)
Mean stream length (Lsm)	Lsm=Lu/Nu Where, Lsm=Mean stram length Lu= Total stream length of order u Nu=Total No. of stream segment of order u	Strahler (1964)
Stream length Ratio (RL)	RL=Lu/Lu-1 Where, RL= Stream length Ratio LU= Total stream length of order u Lu-1= Total stream length of its next lower order	Horton (1945)
Bifurcation Ratio (Rb)	Rb= Nu/Nu+1 Where, Rb= Bifurcation Ratio Nu= Total No. of stream segments of order u Nu+1= Number of segments of next higher order	Schumm (1656)
Mean Bifurcation Ratio (Rbm)	Average of bifurcation ratios of all orders	Strahler (1957)
	Aerial Parameters	
Drainage density (Dd)	Dd=Lu/A Where, Dd= Drainage density Lu= Total stream length of all orders (km) A= Area of the basin km^2	Horton (1945)
Drainage Texture (Dt)	T=Nu/P Where, Dt= Drainage Texture Nu= Total No. of stream segments of order u P= Perimeter (Km)	Horton (1945)
Stream Frequency (Fs)	Fs=∑ Nu/A Where, Fs= Stream Frequency ∑Nu= Total No. of streams of all order A= Area of the basin km^2	Horton (1932, 1945)
Form Factor (Ff)	Ff=A/L^2 Where, Ff= Form Factor A= Area of the basin km^2 L= basin length (km)	Horton (1932, 1945)
Elongation Ratio (Re)	Re=2√ (A/π)÷L	

Circularity Ratio (Rc)	Where, Re= Elongation Ratio, Π=3.14, A= Area of the basin km^2, L=Basin Length (km Rc=4 πA/P^2 Where, Rc= Circularity Ratio A= Area of the basin km^2 Π =3.14 P= Perimeter (Km)	Schumm (1656) Miller (1953) Strahler (1957
Constant of channel maintenance (C)	C=1/Dd Where, C= Constant of channel maintenance (C) Dd= Drainage density	Schumm (1656)
Length of overland flow (Lg)	Lg=1/2Dd Where, Lg= Length of overland flow Dd= Drainage density	Horton (1945)
Relief Parameters		
Basin Relief (R)	R=H-h Where, R= Basin Relief H= Maximum elevation in meter h= Minimum elevation in meter	Hadley and Schumm (1961)
Relief ratio (Rr)	Rr=R/L Where, Rr= Relief ratio R= Basin relief L= Basin length in Km	Schumm (1956)
Ruggedness number (Rn)	Rn=R*Dd Where, Rn= Ruggedness number R= Basin relief Dd== Drainage density	Schumm (1956)

4. Results and Discussion

4.1 Linear Aspects

The linear aspects of morphometric analysis of basin include stream order, stream lengt, mean stream length, stream length ratio and bifurcation ratio.

4.1.1Stream order (U)

The smallest un branched fingertip streams are designated as 1st order, the confluence of two 1st order channels gives a channel segment of 2nd order, two second order streams joins to form a segment of 3rd order and so on. When two channel of different order join then higher order is mentioned. The trunk stream is the segment of higher order. It is found that in Khalri watershed basin river is of 4th order. In all 183 streams were identified of which 144 are first order, 52 are second order, 5 are third order and 12 are fourth order. Drainage pattern of stream network from the basin have been observed as mainly of dendritict type which indicates the homogeneity in texture and lack of structural control.

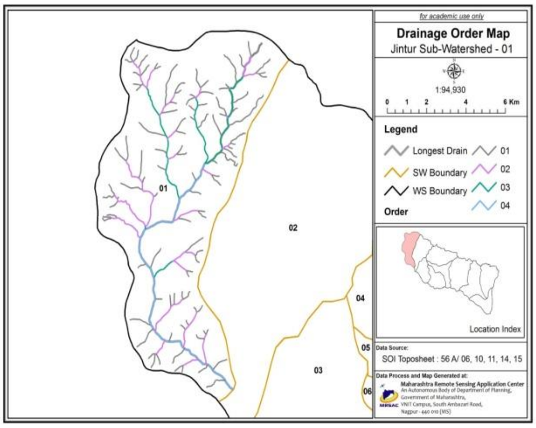

Figure 5: Drainage map of basin Khalri watershed basin

Table 1: Basic morphometric characteristics of Khalri watershed

WS Name	Drain Order	Total Drain Length (km)	Drain count	Bifur cation Ratio	Mean Stream Length (km)	Stream Length ratio	RH Co-Eff.
Khalri	1	67524.5	144		592.3		
	2	27506.9	52	2.2	529.0	0.4	0.2
	3	15624.7	5	10.4	3121.9	0.6	0.1
	4	15053.8	12	0.4	1254.5	1.0	2.3
	Total	**125709.8**	**183**	**4.4**	**1375.2**	**0.6**	**0.9**

4.1.2Stream length (LU)

The stream length (Lu) has been computed based on the law proposed by Horton. Stream length is one of the most significant hydrological features of the basin as it reveals surface run off characteristics. The stream of relatively smaller length is characteristics of areas with larger

Table2: Morphometric Parameters of study area

Table 2: Morphometric Parameters of Khalri Watershed basin

Sr No	Morphometric Parameters	Unit	Count
1	WATERSHED NAME	KHALRI	
2	Watershed Periphery	m	47668.06
3	Watershed periphery	Km^2	47.67
4	Watershed area	M^2	91748674.33
5	Watershed area	Ha	9174.87
6	Watershed area	Km^2	91.75
7	LONG_DRAIN	m	22137.0
8	Elevation High	m	536.0
9	Elevation Low	m	428.0
10	Elevation Difference	m	108.0
11	Slope	%	0.49
12	Total drain length	m	125709.82
13	Drain Count	Numbers	183
14	Average_Drain_Length	km	686.94
15	Drainage Density	Km/km^2	1.37
16	Drainage Frequency	Km^{-2}	1.99
17	Form Factor	-	0.19
18	Basin Shape	-	5.34
19	Circulatory Ration	-	0.51
20	Dimter of Circle	km	10.81
21	Elongation Ratio	-	0.49
22	Channel Maintenance	-	0.73
23	Length of Overland Flow	m	0.36
24	Max Basin Relief	m	108.00
25	Relative Relief	m	226.57
26	Relative Ratio	-	4.88
27	Ruggedness Number (RN)	-	147.98
28	Total Drain Length	Km	125.7
29	Long Drain	km	22.137
30	Bifurcation Ratio	-	4.34
31	Mean Stream Length	m	1375.18
32	Stream Length Ratio	-	0.65
33	Ruggedness Number	-	0.85
34	RHO Coefficient	-	0.9

slopes and finer textures. Longer length of streams is generally indicative of flatter gradient. Generally, the total length of stream segments is maximum in first order stream and decreases as stream order increases. The numbers of streams are of various orders in a watershed are counted and their lengths from mouth to drainage divid are measured with the help of GIS software. The length of 1st order is67.524km, 2nd order is 27.506km, 3rd order 15.624km, And 4th order is 15.053km respectively

4.1.3 Mean stream length (LSM)

The mean stream length is a characteristics property related to the drainage network and its associated surfaces (Strahler, 1964). The mean stream length (Lsm) has been calculated by dividing the total stream length of order by number of streams. The mean stream length of study area is 0.592km for 1st order, 0.529km for 2nd order 3.121km for 3rd order and 1.254km for 4th order. The mean stream length of stream increases with increase of the order.

4.1.4 Stream length ratio (RL)

The stream length ratio can be defined as the ratio of mean stream length of a given order to the mean stream length of next lower order and has an important relationship with surface flow and discharge (Horton, 1945).The RL values between streams of different order in the basin reveal that there are variations in slope and topography.

4.1.5 Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) may be defined as the ratio of the number of streams segment of given order to the number of segment of the higher order (Schumn 1956).It is observed that Rb is not the same from one order to its next order. In the study area mean Rb entire basin is 4.4.Usually these values are common in the areas where geologic structures do not exercise a dominant influence on the drainage pattern.

4.2 Aerial Aspects

It deals with the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and includes all tributaries of lower order. It comprises of drainage density, drainage texture, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow.

4.2.1Drainage density (Dd)

Horton (1932), introduced the drainage density (Dd) is an important indicator of the linear scale of land form elements in stream eroded topography. It is the ratio of total channel segment length cumulated for all order within a basin to the basin area, which is expressed in terms of Km/Km^2.The drainage density, indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964).The drainage density (Dd) of study area is $1.37 Km/Km^2$ indicating moderate drainage densities. The Moderate drainage density indicates the basin is highly permeable subsoil and vegetative cover (Nag, 1998).

4.2.2 Drainage Frequency (Fs)

Stream frequency (Fs), is expressed as the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. The Fs for the basin is 1.99 (Horton, 1932)

4.2.3 Form Factor (Ef)

It is defined as the ratio of the basin area to the square of the basin length. This factor indicates the flow intensity of a basin of a defined area (Horton, 1945). The form factor value should be always less than 0.7854 (circular basin). The smaller the value of the form factor, the more elongated will be the basin. Basins with high form actors experience larger peak flows of shorter duration, whereas elongated watersheds with low form factors experience lower peak flows of longer duration. The Ff value for study area is 0.19, indicating elongated basin with lower peak flows of longer duration than the average.

4.2.4 Circularity Ratio (Rc)

It is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate and slope of the basin. The Rc value of basin is 0.51 and it indicating the basin is characterized by moderate to low relief and drainage system seems to be less influenced by structural disturbances. The high value of circularity ratio shows the late maturity stage of topography.

4.2.5 Elongation Ratio (Re)

Schumm (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin. Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler 1964). These values can be grouped into three categories namely (a) circular (>0.9), (b) oval (0.9-0.8), (c) less elongated (<0.7).The Re values in the study area is 0.49 indicating moderate to slightly steep ground slope and area when collaborated with Strahler's range seem to suggest an elongated shape.

4.2.6 Length of overland flow (Lg)

It is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton, 1945.The length of overland flow is approximately equal to the half of the reciprocal of drainage density. This factor is related inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow to a large degree. The Lg value of study area is 0.36.

4.2.7 Constant channel maintenance (C)

Schumm (1956) used the inverse of drainage density as a property termed constant of stream maintenance C. This constant, in units of square feet per foot, has the dimension of length and therefore increases in magnitude as the scale of the land-form unit increases. The constant C provides information of the number of square feet of watershed surface required to sustain one linear foot of stream. The value C of basin is 0.70.It means that on an average 0.73sq.ft surface is needed in basin for creation of one linear foot of the stream channel.

4.3 Relief Aspects

The relief aspects determined include relief ratio, relative relief and ruggedness number.

4.3.1Relief Ratio (Rh)

The relief ratio (Rh) is ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (shumm, 1956).The Rh normally increases with decreasing drainage area and size of watersheds of a given drainage basin. (Gottschalk, 1964). Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1956). The value of Rh in basin is 4.88indicating moderate relief and moderate slope

4.3.2Relative Relief (Rbh)

This term was given by Melton (1957). In the present study area it is obtained by visual analysis of the digital elevation model prepared from SRTM data. The elevation varies from 403 m to 226.57m which represent the land has gentle to moderate slope.

4.3.3Ruggedness number (Rn)

It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is steep (Strahler, 1956). The value of ruggedness number in present basin is 0147.98

5. Conclusion

GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation and their updation. Bifurcation ratio, length ratio and stream order of basin indicates that the basin is fourth order basin with dendritic type of drainage pattern with homogeneous nature and there is no structural or tectonic control. Relief ratio, Ruggedness number and interpretation of DEM of study area indicate moderate and high relief, low run off and high infiltrations with early mature stage of erosion development. Drainage density, texture ratio, circulatory ratio and elongation ratio shows that texture of basin is moderate and shape of basin almost elongated. The complete morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect.

References

[1] Agarwal, C. S., 1998, Study of Drainage attern through aerial data in Navgarh area of Varanasi district, U.P., Jour. Indian Society of Remote Sensing, pp.169- 175.
[2] Amee K. Thakkar And S.D. Dhiman, 2007, Morphometric Analysis And Prioritization Of Miniwatersheds In Mohr Watershed, Gujarat Using Remote Sensing And GIS Techniques, Journal of the Indian Society of Remote Sensing, Vol. 35, No. 4.
[3] Akram Javed, Mohd Yousuf Khanday, Rizwan Ahmed, 2009, Prioritization of Sub-watersheds based on Morphometric and Land Use Analysis using Remote Sensing and GIS Techniques, J. Indian Soc. Remote Sensing, 37:261–274.
[4] A.M.Esper "Morphometric Analysis of colanguil river basin and flash flood hazard, San juan Argentina, Environmental Geology vol 55 pp 107-111, 2008
[5] Chorley, R.J, 1972, Spatial Analysis in Geomorphology, Mathuen and Co. Ltd., London.
[6] Chorley, R.L, 1967, Models in eomorphology, in R.J. Chorley and P. Haggett (eds.), Models in Geography, London, pp 59-96.
[7] Deepak Khare, Arun Mondal, Prabhash Kumar Mishra, Sananda Kundu and Pramod Kumar Meena, 2014, Morphometric Analysis for Prioritization using

Remote Sensing and GIS Techniques in a Hilly Catchment in the State of Uttarakhand, India, Indian Journal of Science and Technology, Vol 7 (10), 1650–1662.

[8] Faniran, A, 1968, The Index of Drainage Intensity - A Provisional New Drainage Factor, Australian Journal of Science, 31, pp 328-330.

[9] Gottschalk, L.C., 1964, Reservoir sedimentation in handbook of applied hydrology, McGraw Hill Book Company, New York (Section 7-1).

[10] H. Chandrashekhar, K.V. Lokesh, M. Sameena, Jyothi Roopa, G. Ranganna, 2015, GIS –Based Morphometric Analysis of Two Reservoir Catchments of Arkavati River, Ramanagaram District, Karnataka, international conference on water resources, coastal and ocean engineering (ICWRCOE 2015), AquaticProcedia 4, 1345 – 1353.

[11] Horton (1932) Drainage Basin Characteristics Trans AM Geology Union 13:350-361

[12] Horton, R.E., 1945, Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology, Geological Society of America, 56:275– 370.

[13] J.Krishnamurty, G .Srinivas, V.Jayaraman and M. G. Chandrasekhar" Influence of rock type and structures in development of drainage network in typical hard rock ITC Journal no.3-4pp 252-259, 1996.

[14] Miller A quantative Geomorphologic study of drainage basin chatrcteristic in the clinch mountain area, Virginia and Tennessee colubbia university, dept of Geology Tech Report no 3 contact no ONR271-300

[15] Nag, S.K., Chakraborty, S., 2003, Influence of rock types and structures in the development of drainage network in hard rock area, Journ. Of Indian Soc.

[16] S.A.Bhat and S. A. Ramshoo " Degital Elevation Model Based Watershed Characteristics of Upper Watershed on Jhelum Basin, Journal of Applied Hydrology vol no 21 no.2 pp 23-24, 2009

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

[18] Schumm, S.A., 1956, Evolution of drainage systems and slopes in badlands at Perth Amboy, NewJersey" Geological Society of America, 6767:597–646.

[19] Strahler A.N. (1964) Quantative Geomorphology of Drainage Basin and Channel Network in Chow VT (ed) Hardbook of Applied Hydrology, Mc Graw Hill Book Company New york