International Research Journal of Geology and Mining (IRJGM) (2276-6618) Vol. 3(3) pp. 136-146, April 2013
Available online http://www.interesjournals.org/ IRJGM
Copyright©2013 International Research Journals

Full Length Research Paper

Morphometric analysis of vishav drainage basin using geo-spatial technology (GST)

[1]Rafiq Ahmad Hajam, [2]*Aadil Hamid, [2]Naseer Ahmad Dar and [2]Sami Ullah Bhat

[1]Department of Geography and Regional Development, University of Kashmir-190006, Jammu and Kashmir
[2]Department of Environmental Science, University of Kashmir-190006, Jammu and Kashmir

Abstract

Morphometric analysis revealed that the Vishav drainage basin is characterized by dendritic to sub-dendritic drainage pattern. The development of stream segments in the basin area is more or less affected by rainfall and snow melt off. The analysis has revealed that the total number as well as total length of stream segments is maximum in first order streams and decreases as the stream order increases. The bifurcation ratio (R_b) between different successive orders is almost constant revealing the partial structural control. The stream frequency (F_s) value of 2.44 exhibits positive correlation with the drainage density value of 2.03. The drainage density (D_d) indicates clearly that the region has permeable subsoil and relatively dense vegetation cover. Calculated Circularity Ratio (R_c) value of 0.52 and Elongation Ratio (R_e) value of 0.15 indicates that the drainage basin is elongated in shape, has low discharge of runoff and relatively permeable subsoil condition. The value of Form Factor (R_f), 0.22, represents a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. Hence from the study it is clear that the morphometric analysis based on GIS technique is very useful to understand the prevailing geo-hydrological characteristics and for watershed planning and management.

Keywords: Morphometry, linear parameters, areal parameters, drainage basin, GIS, vishav stream.

INTRODUCTION

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). Morphometric studies in the field of hydrology were first initiated by (Horton, 1940; Strahler, 1950). The morphometric analysis of the drainage basin and channel network play a vital role for understanding the geo-hydrological behavior of drainage basin and expresses the prevailing climate, geology, geomorphology, structural, etc. antecedents of the catchment. The relationship between various drainage parameters and the aforesaid factors are well recognized by many workers (Horton, 1945; Strahler, 1957; Melton, 1958; Pakhmode et al., 2003; Gangalakunta et al., 2004). The drainage basin analysis is important in any hydrological investigation like assessment of groundwater potential, groundwater management, pedology and environmental assessment. Hydrologists and geomorphologists have recognized that certain relations are most important between runoff characteristics, and geographic and geomorphic characteristics of drainage basin systems. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density, size and length of the contributories etc. (Rastogi et al., 1976). Geology, relief and climate are the primary determinants of running water ecosystems functioning at the basin scale (Mesa, 2006). Detailed morphometric analysis of a basin is a great help in understanding the influence of drainage morphometric network on landforms and their characteristics.

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management. The influence of drainage morphometric system is very significant in understanding the landform processes, soil physical

*Corresponding Author Email: aadilenvsc@rediffmail.com

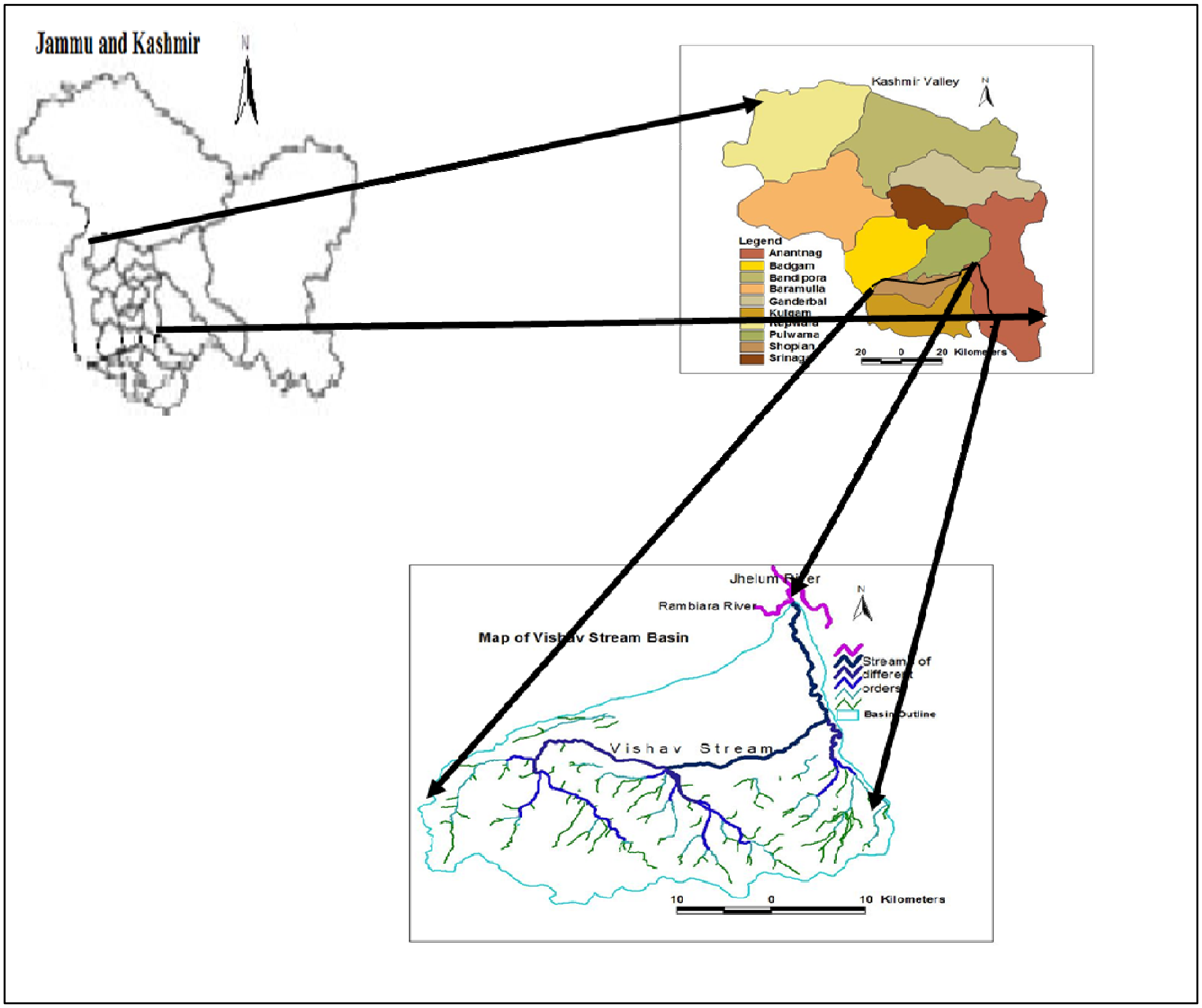

Figure 1. Location map of Vishav drainage basin

properties and erosion characteristics. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996). Geographical Information System (GIS) techniques are now a day used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. The main objective of the present study is to analyze the linear and areal morphometric characteristics of Vishav drainage basin in south-eastern part of Kashmir valley by using Geographical Information System (GIS), as so far no exhaustive work on the morphometric investigation of the region has been carried out. This study gives an insight into the different geo-hydrological characteristics of the drainage basin which in turn help in the management of the water and other natural resources of the area.

Study area

The Vishav drainage basin covering an area of 1083.48 km^2 occupies the south-eastern part of the Kashmir valley (Figure 1) and is situated between 33^0 39′ to 33^0 65′ N latitude and 74^0 35′ to 75^0 11′ E longitudes. The Vishav stream is the important left bank perennial tributary of the Jhelum stream. Having its birth Kounsarnag at an altitude of about 3,840 meters (m.a.s.l.) on the gentler northern face of the Pir Panjal range of Kashmir Himalayas, it follows a zigzag pattern, first moves in northerly direction, then takes a south-easterly course and finally flows laminarly in north-westerly direction till it merges with Jhelum at Niayun. Visually, it seems that Vishav stream stems from a glacier fed stream near the base of Kounsarnag called Teri, which later joins the underground stream believed to originate from Kounsarnag 2 km downstream at Mahinag, dropping steeply north-northeast to reach the main strike valley (Raza et al., 1978).

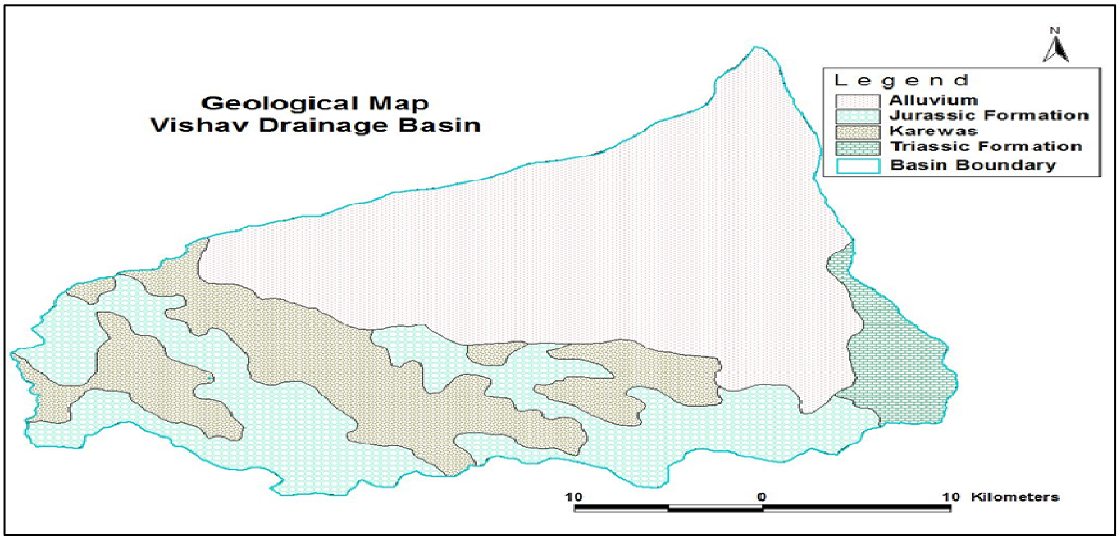

Figure 2. Geological map of the study area

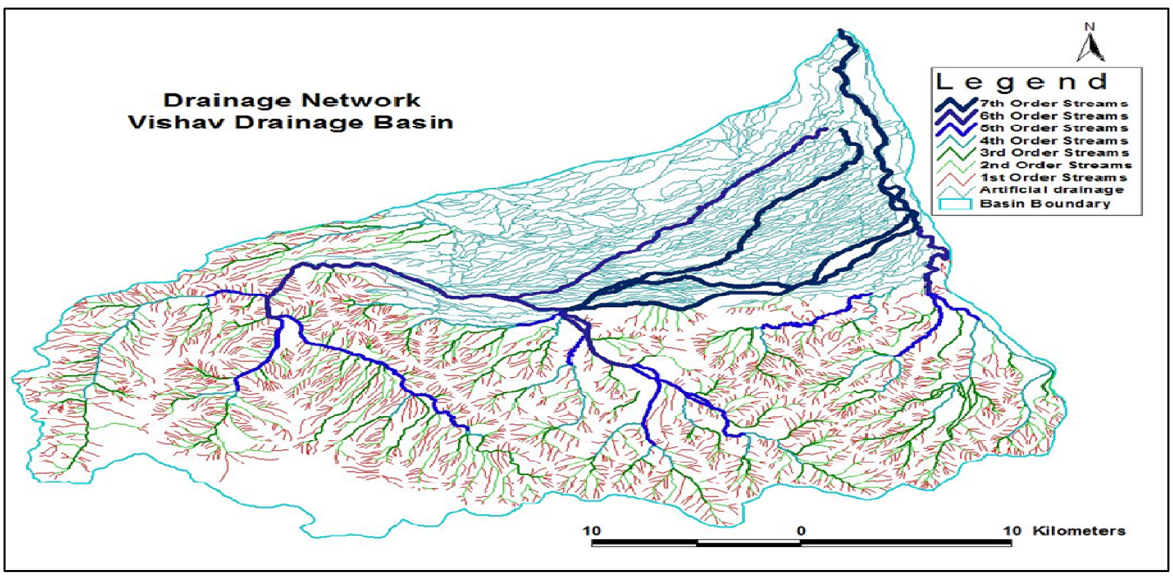

Figure 3. Drainage network map of Vishav drainage basin

The study area is elongated in shape and has varied topography. The soils of the Vishav catchment belong to the groups of the brown forest and mountain soils (> 3,000 m.a.s.l.), and lacustrine or Karewa soils (1,800-3000 m.a.s.l.) and alluvial soils (< 1,800 m.a.s.l.). Lithologically the alluvium consists of blue/grey silts and clay shales and sands of different texture and structure. The size of the grains varies from fine, medium to coarse. The valley possesses distinctive climatic characteristics because of its high altitude location and its geophysical setting, being enclosed on all sides by high mountain ranges. The valley is characterized by sub-Mediterranean type of climate with nearly 70 per cent of its annual precipitation concentrated in winter and spring months (Meher, 1971).

Geology of the area

Kashmir Valley is characterized by a diverse geological record ranging in age from Pre-Cambrian to Recent (Middlemiss, 1911; Wadia, 1975). The geology of the study area is dominated by the Alluvium, followed by Karewas, Jurassic formations and Triassic formations as shown in (Figure 2). The Triassic rocks are surrounded by Palaeozoics (Agglomeratic Slates and Panjal Traps) and the later are overlain by Pleistocene and Recent sediments. The some of the Palaeozoic rocks are overlain by Triassic Limestone (~1000 m thick) occurring in the form of dissected ridges. The limestone is mostly thin bedded, with common shale and sandstone horizons. The fluvio-glacial and fluvio-lacustrine deposits of Pleistocene locally known as Karewas consist of fine lacustrine sandstones, beds of loess and conglomerates. Small valleys between Triassic Limestone ridges and Karewas are filled with Recent Alluvium composed of fine muddy and silty sediments (Wadia, 1975). Alluvium covers half of the area mostly in the plain areas hiding the primary geological set up of the area. However, along the streams the boulders and gravels predominate. Triassic Limestone is the most significant and main aquifer of the area which supplies water to most of the people for domestic and agriculture purposes. The underlying Palaeozoic rocks are mostly impermeable. The overlying Karewas are not productive aquifers but act as efficient filters owing to their high porosity (Jeelani, 2007). Due to the low hydraulic conductivity, alluvium blocks the water flowing through the Triassic Limestone and the water emerges out in the form of springs at the contact between the alluvium and Triassic Limestone mostly in the foothill areas (around 2000 m altitude) and moderately sloping plains (Jeelani, 2008).

MATERIALS AND METHOD

Entire study area is delineated from rectified, mosaiced SOI topographic maps of 1961 with no. 43 K/10, 43 K/12, 43 K/14, 43 K/15, 43 O/1, 43 O/2 and 43 O/3 on the scale 1:50,000 with the help of Arc-View 3.2a software assigning UTM, WGS 1984, 43N zone projection system. Morphometric analysis of a drainage system requires the delineation of all the existing streams. Digitization of the drainage basin was carried out for morphometric analysis in GIS environment using Arc View 3.2a software. The attributes were assigned to create the digital data base for drainage layer of the river basin. Various morphometric parameters such as linear aspects and aerial aspects of the drainage basin were computed. Digitization work was carried out for entire analysis of drainage morphometric network. The different morphometric parameters have been determined as per the standard methodology as shown (Table1).

RESULTS AND DISCUSSION

The study of basin morphometry relates basin and stream network geometries to the transmission of water and sediment through the basin. Systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear aspects of the drainage network, areal aspects of the drainage basin, and relief (gradient) aspects of the channel network and contributing ground slopes (Strahler, 1964). In the present study, the morphometric analysis is carried out with respect to parameters like stream order, stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circularity ratio, form factor, etc. using mathematical formulae as given in (Table 1) and the results are summarized in (Table 2, 3 and 4). The properties of the stream networks are very important to study the landform making process (Strahler, and Strahler, 2002). Morphometric parameters such as relief, shape and length also influence basin discharge pattern strongly through their varying effects on lag time (Gregory and Walling, 1973).

The natural run-off is one of the most potent geomorphic agencies in shaping the landscape of an area. The land area that contributes water to the main stream through smaller ones forms its catchment area or the drainage basin. The arrangement of streams in a drainage system constitutes the drainage pattern, which in turn reflects mainly structural/ or lithologic controls of the underlying rocks (Eesterbrooks, 1969).

The drainage pattern of Vishav stream basin is dendritic in nature. The details of stream characteristics confirm to Horton's (1932) "laws of stream numbers" which state that the number of streams of different orders in a given drainage basin tends closely to approximate an inverse geometric ratio. It also confirms to Horton's (1932) the "laws of stream length" which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio.

Linear morphometric parameters

Linear aspects of the basins are related to the channel patterns of the drainage network wherein the topological characteristics of the stream segments in terms of open links of the network system are analyzed. The morphometric investigation of the linear parameters of the basins includes stream order (Sμ), bifurcation ratio (R_b), stream length (Lμ), mean stream length (L_{sm}), stream length ratio (R_L), length of overland flow (L_g), basin perimeter (P), basin length (L_b), fitness ratio (R_f), wandering ratio (R_w), sinuosity indices, etc. Some of the important linear aspects have been computed as shown in (Table 2 and3).

Stream Order (Sμ)

The designation of stream order is the first step in the drainage basin analysis. It is defined as a measure of the position of a stream in the hierarchy of tributaries (Leopold et al., 1964). There are 2,643 streams linked

Table 1. Morphometric parameters with formulae

S. No.	Parameters	Formula	Reference
1		Linear Morphometric parameters	
1.1	Stream Order (Sμ)	Hierarchical rank	Strahler (1964)
1.2	Bifurcation Ratio (R_b)	$R_b = N\mu / N\mu +1$ Where, Rb = Bifurcation ratio, Nμ = No. of stream segments of a given order and Nμ +1= No. of stream segments of next higher order.	Schumn (1956)
1.3	Mean Bifurcation Ratio (R_{bm})	R_{bm} = Average of bifurcation ratios of all orders	Strahler (1964)
1.4	Stream Length (Lμ)	Length of the stream (kilometers)	Horton (1945)
1.5	Mean Stream Length (L_{sm})	$L_{sm} = L\mu/N\mu$ Where, Lμ = Total stream length of order 'μ' Nμ = Total no. of stream segments of order 'μ'	Strahler (1964)
1.6	Stream Length Ratio (R_L)	$R_L= L_{sm} / L_{sm}\text{-}1$ Where, L_{sm}=Mean stream length of a given order and L_{sm}-1= Mean stream length of next lower order	Horton (1945)
1.7	Length of Overland Flow (L_g)	L_g=1/2D Km Where, D=Drainage density (Km/Km^2)	Horton (1945)
1.8	Basin Perimeter (P)	P=Outer boundary of drainage basin measured in kilometers.	Schumm (1956)
1.9	Basin Length (L_b)	$L_b=1.312*A^{0.568}$	Gregory and Walling (1973)
1.10	Fitness Ratio (R_f)	$R_f = C_L/P$ Where, C_L= Main channel length (Kms) and P= Basin perimeter (Kms)	Melton (1957)
1.11	Wandering Ratio (R_w)	$R_w = C_L/L_v$ Where, C_L = Main channel length (Kms) and L_v = Valley length (Kms)	Smart and Surkan (1967)
1.12	Standard Sinuosity Index (SSI)	$SSI = C_L/L_v$ Where, C_L = Channel length (Kms) and L_v = Valley length (Kms)	Muller (1968)
2		Areal Morphometric parameters	
2.1	Basin Area (A)	Area from which water drains to a common stream and boundary determined by opposite ridges.	Strahler (1969)
2.2	Drainage Density (D_d)	$D_d = L\mu/A$ Where, Dd = Drainage density (Km/Km^2) Lμ = Total stream length of all orders and A = Area of the basin (Km^2).	Horton (1932)
2.3	Drainage Frequency (F_s)	$F_s = N\mu/A$ Where, F_s = Drainage frequency. Nμ = Total no. of streams of all orders and A = Area of the basin (Km^2).	Horton (1932)
2.4	Drainage Texture (D_t)	$D_t = N\mu /P$ Where, Nμ = No. of streams in a given order and P = Perimeter (Kms)	Smith (1950) & Horton (1945)
2.5	Form Factor Ratio (R_f)	$R_f = A/L_b^2$ Where, A = Area of the basin and L_b = (Maximum) basin length	Horton (1932)
2.6	Elongation Ratio (R_e)	$R_e= \sqrt{A /\pi} / L_b$ Where, A= Area of the Basin (Km^2) L_b=Maximum Basin length (Km)	Schumm (1956)
2.7	Circularity Ratio (R_c)	$R_c = 4\pi A/ P^2$ Where, A = Basin Area (Km^2) and P= Perimeter of the basin (Km) Or $R_c = A/ A_c$ Where, A = Basin Area (Km^2) and A_c = area of a circle having the same perimeter as the basin	Miller (1953)

Table 2. Linear morphometric parameters of the drainage network of Vishaw Drainage Basin

Stream order ($S\mu$)	Stream number ($N\mu$)	Bifurcation ratio (R_b)	Stream length ($L\mu$) (kms)	Mean stream length (L_{sm}) (kms)	Cumulative Mean stream length (L_{sm})	Stream length ratio (R_L)	Mean bifurcation ratio (R_{bm})
1st	2005 (75.86)		1301.16 (59.01)	0.65	0.65		
		4.16				1.47	
2nd	482 (18.24)		465.30 (21.09)	0.96	1.61		
		4.26				1.88	
3rd	113 (4.27)		204.15 (9.26)	1.81	3.42		
		4.03				1.95	3.09
4th	28 (1.06)		98.83 (4.48)	3.53	6.95		
		2.54				1.66	
5th	11 (0.42)		64.64 (2.93)	5.87	12.82		
		3.66				1.86	
6th	3 (0.11)		32.75 (1.48)	10.92	23.74		
		3.0				3.53	
7th	1 (0.04)		38.52 (1.75)	38.52	62.26		
Total	2, 643		2205.35				

Note: Figures in parenthesis show Percentage stream length contributed by different stream orders

Table 3. Other linear parameters of Vishav drainage basin

S. No.	Parameter	Calculated value
1	Length of Overland Flow (L_g)	0.25 km
2	Basin Perimeter (P)	161.24 km
3	Basin Length (L_b)	69.46 km
4	Fitness Ratio (R_f)	0.44
5	Wandering Ratio (R_w)	1.02
6	Standard Sinuosity Index (SSI)	1.02

with 7 orders of streams (Figure 1) sprawled over an area of 1,043.48 km^2. A perusal of data indicates that the Vishav stream which is the trunk stream in Vishav drainage basin is of the seventh order (Table 2). According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed and where two of order 2 joins, a segment of order 3 is formed, so on and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. The study area is a 7th order drainage basin. It is observed that there is a decrease in stream frequency as the stream order increases. First order streams constitute 75.86 (maximum proportion) per cent of the total number of streams and the proportion contributed decreases with the increase in stream order. Thus the law of lower the order higher the number of streams is implied throughout the catchment.

Bifurcation ratio (R_b)

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total numbers of stream segments of one order to that of the next higher order in a drainage basin (Schumn, 1956). It is a dimensionless property and shows only a small variation for different regions with different environments except where powerful geological control dominates (Strahler, 1964).Values of R_b typically range from the theoretical minimum of 3 to 5 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). The lower values of R_b are characteristics of the watersheds or drainage basins, which have suffered less structural disturbances and the drainage pattern has not been distorted because of the structural disturbances (Strahler, 1964; Nag, 1998). From the Table 2, it is clear that the bifurcation ratio values for the Vishav drainage basin vary from 2.54 to 4.26 with the mean bifurcation ratio of 3.09. The highest R_b (4.26) is found between 2nd and 3rd order which indicates corresponding highest overland flow and discharge due to hilly less permeable rock formation associated with high slope configuration. The mean bifurcation ratio, which is the average of bifurcation ratios of all orders, is 3.09. This relatively lower value of mean bifurcation ratio suggests the geological heterogeneity, higher permeability and lesser structural control in the area.

Stream length (Lµ)

Stream length is indicative of chronological developments of the stream segments including interlude tectonic disturbances. The stream lengths of various orders in the basin were measured with the help of GIS software i.e., the Arc View 3.2a. In the present work, it was found that the stream segment lengths decreased with the increase in the stream order with the exception of the 7th order stream whose length is greater than the total length of the 6th order stream segments. From table 2 it is evident that the length of first order streams constitute 59.01 per cent of the total stream length with second order 21.09 per cent, third order 9.26 per cent, fourth order 4.48 per cent, fifth order 2.93 per cent, the sixth order 1.48 per cent and the seventh order 1.75 per cent. Generally higher the order, longer the length of streams is noticed in nature and off course it conforms to the Vishav drainage basin as well. These variations from general observation may be due to flowing of streams from high altitude, change in rock type and variation in slope and topography (Singh and Singh, 1997; Vittala et al., 2004). When the logarithm of the number of streams is plotted against order, most drainage networks show a linear relationship, with a small deviation from a straight line (Strahler, 1964). According to Horton's principle the number of streams is negatively correlated with the order (Horton, 1932). Vishav river basin shows a near perfect correlation with the plots falling very near the regression line.

Mean stream length (L_{sm})

Mean stream length reveals the characteristic size of components of a drainage network and its contributing surfaces (Strahler, 1964). The mean stream length is calculated by dividing the total stream length of given order by number of stream of that order. In the study area, it is noted that L_{sm} varies from 0.65 to 38.52 km and its value for any given order is greater than that of the lower order and less than that of its next higher order in the whole drainage basin.

Stream Length Ratio (R_L)

The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and having important relationship with surface flow and discharge and erosion stage of the basin (Horton, 1945). It is noticed that the R_L between successive stream orders of the basin vary due to differences in slope and topographic conditions (Sreedevi 1999). The values of R_L vary haphazardly from 1.47 to 3.53. Since the Vishav stream basin shows changes in R_L from one order to another, it is deduced that it is characterized by the late youth to early mature stage of geomorphic development (Singh and Singh, 1997).

Length of overland flow (L_g)

Length of overland flow is defined as the length of flow path, projected to the horizontal, non channel flow from point on the drainage divide to a point on the adjacent stream channel (Horton, 1945). Horton, for the sake of convenience, had taken it to be roughly equal to half the reciprocal of the drainage density. Overland flow is significantly affected by infiltration (exfiltration) and percolation through the soil, both varying in time and space (Schmid, 1997). In this study, the length of overland flow of the Vishav drainage basin is 0.25 kilometers, which shows low surface runoff in the study area.

Basin perimeter (P)

Basin perimeter is the outer boundary of the drainage basin that encloses its area. It is measured along the divides between basins and may be used as an indicator of basin size and shape Schumm (1956). The author has computed the basin perimeter by using Arc View 3.2a software, which is 161.24 kilometers (NIH, 1998).

Basin length (L_b) or valley length (L_v)

Basin length (L_b) has been given different meanings by different workers (Schumm 1956; Gregory and Walling 1973; Gardiner 1975 and Cannon 1976). The L_b is the

Table 4. Areal morphometric parameters of the Vishav drainage Basin

S .No.	Parameter	Calculated Value
1	Drainage Area (A)	1,083.48 km^2
2	Drainage Density (D_d)	2.03 km/km^2
3	Drainage Frequency (F_s)	2.44 / km^2
4	Drainage Texture (D_t)	12.43-0.01
5	Form Factor Ratio (R_f)	0.22
6	Elongation Ratio (R_e)	0.15
7	Circularity Ratio (R_c)	0.52

longest length of the basin, from the catchment to the point of confluence (Gregory and Walling, 1973). The Vishav stream meets the Jhelum at the point of confluence in the north-western part of the study area. The length of the Vishav river basin is 69.46 kilometers.

Fitness ratio (R_f)

Fitness ratio is the ratio of main channel length to the length of the basin perimeter is fitness ratio, which is a measure of topographic fitness (Melton, 1957). The fitness ratio for Vishav drainage basin or watershed is 0.44.

Wandering ratio (R_w)

Wandering ratio is defined as the ratio of the mainstream length to the valley length or basin length (Smart and Surkan, 1967). Valley length is the straight-line distance between outlet of the basin and the farthest point on the ridge. In the present study, the wandering ratio of the drainage basin is 1.02.

Standard sinuosity index (SSI)

Sinuosity is the property of a stream that shows the deviation of the course of a drainage line from the straight path. It is highly significant in studying the effect of terrain characteristics on the river course and vice versa. Muller (1968) gave the methodology to calculate the sinuosity index as shown in (Table 1). The value of unity (1.0) of SSI shows straight river course, values between 1.0 to 1.5 indicate the sinuous shape of the stream and the values above 1.5 put the streams in meandering course. The calculated value of the Vishav basin is 1.02 that shows the stream has sinuous course.

Areal morphometric parameters

Area of a basin (A) and perimeter (P) are the important parameters in quantitative morphology. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all orders of a basin. Perimeter is the length of the boundary of the basin which can be drawn with the help of GIS software. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size (Chorley et al., 1957). The aerial aspects of the drainage basin such as basin area (A) drainage density (D_d), stream frequency (F_s), texture ratio (R_t), elongation ratio (R_e), circularity ratio (R_c) and form factor ratio (R_f) were calculated and results have been given in (Table 4).

Drainage area (A)

The drainage area is defined as a collecting area from which water would go to a stream or river. The boundary of the area is determined by the ridge separating water flowing in opposite directions. The area of the basin was computed by converting the merged geo-referenced and rectified SOI toposheets of 1971 on scale 1:50,000 of the basin into polygon form. The total area of the basin is found to be 1,083.48 km^2.

Drainage density (D_d)

The drainage density is an expression of the closeness or spacing of channels (Horton, 1932). The significance of drainage density is recognized as a factor determining the time travel by water (Schumm, 1956). The measurement of D_d is a useful numerical measure of landscape dissection and runoff potential (Chorley, 1969). On the one hand, the D_d is a result of interacting factors controlling the surface runoff; on the other hand, it is itself influencing the output of water and sediment from the drainage basin (Ozdemir and Bird, 2009). D_d is known to vary with climate and vegetation, soil, rock properties, relief and landscape evolution processes (Kelson and Wells, 1989; Oguchi, 1997; Moglen et al., 1998). The D_d of the Vishav drainage basin is moderate i.e., 2.03

km/km^2. The drainage density in the study area being relatively low indicates clearly that the region has permeable subsoil, relatively dense vegetation cover and medium relief (Nag, 1998).

Drainage frequency (F_s)

The stream frequency (F_s) or channel frequency or drainage frequency of a basin may be defined as the total number of stream segments within the basin per unit area (Horton, 1945). The F_s of the whole basin is 2.44 / km^2, shown in Table 4. It mainly depends on the lithology of the basin and reflects the texture of the drainage network. It is an index of the various stages of landscape evolution. The occurrence of stream segments depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability. The stream frequency for of the study area shows positive correlation with the drainage density which indicates that the stream population increases with the increase of drainage density**.** Greater the drainage density and stream frequency in a basin, the runoff is faster, and therefore, flooding is more likely in basins with a high drainage and stream frequency **(**Kale and Gupta, 2001).

Drainage texture (D_t)

The drainage texture is considered as one of the important concept of geomorphology which shows the relative spacing of the drainage lines (Chorley et al., 1957). The drainage density less than 2 indicates very coarse, between 2 and 4 as coarse, between 4 and 6 as moderate, between 6 and 8 as fine and greater than 8 as very fine drainage texture (Smith, 1939). In the present study, it was found that the drainage density values (Table 4) are variable and suggests that the study area falls into very coarse to coarse texture category and indicates good permeability of sub-surface material in the study area except the first order streams. The drainage texture values are 12.43 (1st order streams), 1.67 (2nd order streams), 0.70 (3rd order streams), 0.17 (4th order streams), 0.07 (5th order streams), 0.02 (6th order stream) and 0.01 (7th order streams). Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture that in turn depends on the infiltration capacity of the mantle rock or bed rock (Smith, 1939; Thornbury, 1969).

Form factor ratio (R_f)

Quantitative expression of drainage basin outline form through a form factor ratio (R_f), which is the dimensionless ratio of basin area to the square of basin length (Horton, 1932). Basin shape may be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998). The form factor value of the basin is low, 0.22 which represents elongated shape. The elongated basin with low form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. (Christopher et al., 2010).

Elongation ratio (R_e)

Elongation ratio (R_e) is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). 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. Values near to 1.0 are typical of regions of low relief (Strahler, 1964). The value R_e in the study area was found to be 0.15 indicating relatively moderate relief of the terrain and elongated shape of the drainage basin.

Circularity ratio (R_c)

The circularity ratio (R_c) has been used as a quantitative measure for visualizing the shape of the basin and is expressed as the ratio of basin area (A) to the area of a circle (A_c) having the same perimeter as the basin (Miller 1953; Strahler 1964). It is affected by the lithological character of the basin. The ratio is more influenced by length, frequency (F_s), and gradient of streams of various orders rather than slope conditions and drainage pattern of the basin. It is a significant ratio, which indicates the dendritic stage of a basin. Its low, medium and high values are indicative of the youth, mature and old stages of the life cycle of the tributary basins. The calculated R_c value for the study area is 0.52 which indicate that the drainage basin is more or less elongated and is characterized by medium to low relief. Such drainage systems are partially controlled by the structural disturbances (Zavoiance, 1985).

CONCLUSION

The drainage basin is being frequently selected as a unit of morphometric analysis because of its topographic and hydrological unity. GIS softwares have resulted to be of immense utility in the analysis of the Linear and Areal morphometric aspects of the drainage basins. The study reveals that GIS based approach in evaluation of drainage morphometric parameters at river basin level is more appropriate than the conventional methods. GIS based approach facilitates analysis of different morphometric parameters and to explore the relationship between the drainage morphometry and properties of landforms, soils and eroded lands. Based on the drainage orders the Vishav basin has been classified as seventh order basin. The mean R_b indicates that the drainage pattern is not much influenced by geological structures. Drainage density (D_d) and stream frequency (F_s) are the most useful criterion for the morphometric classification of drainage basins which certainly control the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. The D_d of the basin reveals that the nature of subsurface strata is permeable. This is a characteristic feature of coarse drainage as the density values are less than 5.0. The study reveals that the drainage areas of the basin are passing through an early mature stage of the fluvial geomorphic cycle. Lower order streams mostly dominate the basin. The development of stream segments in the basin area is more or less affected by rainfall. R_c, R_f and R_e show the elongated shape of the basin have low discharge of runoff and medium relief of the terrain. It is noticed that stream segments up to 3rd order traverse parts of the high altitudinal zones, which are characterized by steep slopes, while the 4th, 5th and 6th order stream segments occur in comparatively flat lands wherein maximum infiltration of runoff occurs; these are important locations for constructing check dams. Hence from the study it is clear that GIS technique is a competent tool in morphometric analysis (for geo-hydrological studies). These studies are very useful for planning and drainage basin management.

ACKNOWLEDGEMENTS

We appreciate helpful suggestions and ideas stimulated by discussion in respect of exploring various dimensions of geology of the valley of Kashmir with Prof. G. A. Bhat and Dr. Arshid Jehangir. This work was supported and funded by grants from the department of Environmental Science and Geography and Regional Development, University of Kashmir. Authors are highly thankful to Prof. Azra Nahaid Kamili (HoD, Environmental Science) and Prof. Sultan Ahmad (HoD, Geography and Regional Development) is highly acknowledged.

REFERENCES

Abrahams AD (1984). Channel networks: a geomorphological perspective. Water Resour Res, 20: 161–168.

Agarwal CS (1998). Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P. Jour. Indian Soc. Rem. Sen, 26**:** 169-175.

Chorley RJ (1969). Introduction to physical hydrology. *Methuen and Co. Ltd., Suffolk.* 211.

Chorley RJ, Donald EG, Malm, Pogorzelski HA (1957). A new standard for estimating drainage basin shape. Am. J. Sci.; 255:138-141.

Christopher O, Idown AO, Olugbenga AS (2010). Hydrological Analysis of Onitsha North East Drainage Basin using Geoinformatic Techniques. World Applied Science Jour, 11(10):1297- 1302 (2010).

Eesterbrooks D (1969). Principles of geomorphology. *McGraw-Hill Inc. New York.*

Gangalakunta P, Amal K, Kothiram S (2004). Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India – a remote sensing and GIS approach. Int. J. Appl. Earth and Geoinform.; 6:1-16.

Horton RE (1932). Drainage basin characteristics. Am. Geophys. Union, Trans.; 13:348–352.

Horton RE (1940). An approach toward a physical interpretation of infiltration capacity. Proc. Soil Sci. Am.; 5: 399-417.

Horton RE (1945). Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull, 56:275-370.

Jeelani G (2007). Hydrogeology of hard rock aquifer in Kashmir valley: complexities and uncertainties. In: *Ahmed S, Jayakumar R, Abdin S* (ED.) *Groundwater dynamics in hard rock aquifers-including sustainable management and optimal monitoring network design. Springer Verlag, Netherland.* 265pp.

Jeelani G (2008). Aquifer response to regional climate variability in a part of Kashmir Himalaya in India. Hydrogeol. J.;, 16**(**8):1625–1633.

Kale VS, Gupta A (2001). Introduction to Geomorphology. *Orient Blackswan Private Limited.* 84-86.

Kelson KI, Wells SG (1989). Geologic influences on fluvial hydrology and bed load transport in small mountainous watersheds, northern New Mexico, USA. Earth Surface Processes Landforms, 14**:**671–690.

Krishnamurthy J, Srinivas G, Jayaram V, Chandrasekhar MG (1996). Influence of rock type and structure in the development of drainage networks in typical hard rock terrain. ITC J, 3(4): 252-259.

Leopold LB, Wolman MG, Miller JP (1964). Fluvial processes in geomorphology. *W. H. Freeman and Company, San Francisco and London.*

Meher VM (1971). The climate of Srinagar and its variability. Geographical Review of India, 33(1):1-14.

Melton MA (1958). Correlation structure of morphometric properties of drainage system and their controlling agents. J. Geol.; 66: 442-460.

Mesa LM (2006). Morphometric analysis of a subtropical Andean basin (Tucumam, Argentina). Environ. Geol.; 50(8): 1235-1242 .

Middlemiss CS (1911). Sections in the Pir Panjal range and Sindh Valley, Kashmir. Record Geological Survey of India, 41(2):115–144.

Moglen GE, Eltahir EA, Bras RL (1998). On the sensitivity of drainage density to climate change. Water Res. Res.; 34:855–862.

Nag SK (1998). Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. J. Ind. Soc. Remote Sensing, 26(1): 69-76.

National Institute of Hydrology (NIH) (1998). Representative Basin Studies: Morphometric Analysis of Suddagedda Basin, Andhra Pradesh, Roorkee. CS (AR) 24: 97-98.

Obi Reddy GE, Maji AK, Gajbhiye KS (2002). GIS for morphometric analysis of drainage basins. GIS India, 11(4):9-14.

Oguchi T (1997). Drainage density and relative relief in humid steep mountains with frequent slope failure. Earth Surf. Processes Landforms*,* 22:107–120.

Ozdemir H, Bird D (2009). Evaluation of morphometric parameters of drainage networks derived from topographic maps and DEM in point of floods. Environ Geol, 56:1405–1415.

Pakhmode V, Kulkarni H, Deolankar SB (2003). Hydrological drainage analysis in watershed programme planning: A case study from the Deccan basalt, India. Hydrogeol. J.; 11:595–604**.**

Raza M, Ahmed A, Mohammad A (1978). The valley of Kashmir-a Geographical Interpretation, of the Land. *Vikas Publishing House, New Delhi.*

Schmid BH (1997).Critical rainfall duration for overland flow an infiltrating plane surface. J. Hydrol.; 193: 45-60.

Schumn SA (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geol. Soc. Am. Bull, 67:597-646.

Singh S (1998). Geomorphology. *Prayag Pustak Bhawan, Allahabad.*

Singh S, Singh MC (1997). Morphometric analysis of Kanhar river basin. National Geographical J. of India, 1(43):31-43.

Smith GH (1939).The Morphometry of Ohio: The Average Slope of the Land," Annals of the Association of American Geographers*,* 29: 94.

Strahler AN (1957). Quantitative analysis of watershed geomorphology. Trans. Am. Geophys. Union, 38:913-920.

Strahler AN (1964). Quantitative geomorphology of drainage basins and channel networks. In: *Handbook of applied hydrology*. Chow VT, (ED) *McGraw Hill Book Company, New York.* 4-11.
Strahler AN, Strahler AH (2002). A Textbook of Physical Geography. *John Wiley and Sons, New York.*
Thornbury WD (1969). Principles of Geomorphology. *New Age International Publishers, New Delhi.* 124.
Vittala S, Govindaiah S, Honne GH (Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur district, South India using remote sensing and GIS techniques," Jour. Indian Soc. Remote Sen., 4(32):351-362.
Wadia DN (1975).Geology of India. *Tata McGraw Hill*, *New Delhi*.
Zavoiance I (1985). Morphometry of Drainage Basins. Developments in Wat. Sci.; 20:104-105.