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Study on Drainage Morphometric Characteristics of Suvarnamukhi watershed in Tumkur District, Karnataka using Geospatial technology

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Abstract

The Knowledge of Drainage characteristics are an important pre-requisite to evaluate the basin hydrology of the watershed. The amount of water reaching a stream system depends on the morphology of the basin, precipitation, topography, infiltration, losses due to evapo-transpiration and absorption by soil and vegetation. It also reveals information on lithology and structural control of the basin, relative run-off and recharge, erosional aspects and stage of development of watershed itself. Though Geomorphology is concerned with the study of surface features of the earth, its importance in hydrogeological investigations is immense.

In the present work, an attempt has been made to understand the dynamics of Drainage Morphometric Characteristics of Suvarnamukhi Watershed in Tumkur district in Karnataka state for quantitative geomorphological study of the basin and its relation to hydrogeology. This study forms basis for the surface and subsurface hydro geological investigation. It is widely acknowledged that basin wise approach gives the best result for such studies.

Introduction

Watershed is a geo-hydrological unit or piece of land that drains at a common point. This Natural unit is evolved through the interaction of rain water with land mass and typically comprises of arable lands, non-arable lands and natural drainage lines in rain fed area. The ultimate goal of watershed management is to achieve and maintain a balance between resources development to increase the welfare of population and resources conservation i.e. Soil and Water conservation.

The quantitative geo-morphological investigation has been greatly dealt by Horton[1]. In his opinion, the quantitative geomorphology involves factors like infiltration and slope erosion. Strahler[4] has given a variety of geometrical properties like length, magnitude, dimension or their product and dimensionless properties, which are applied to the systematic description for drainage basin.

Stream order, stream length, Bifurcation ratio and length ratio are analyzed in the case of linear aspects. In the areal aspects, form factors, circulation ratio, elongation ratio, drainage density, stream frequency, constant of channel maintenance, and the length of the overland flow are analyzed. Finally in the case of relief ratio and ruggedness number are evaluated. Morphometry is the measurement and mathematical analysis of configuration of earth surface and the shape and dimensions of its landforms (Clarke, 1966).

Study Area

The watershed boundary lies between Longitude of 76^0 23’ 51’’ to 77^0 10’ 45” East and Latitude of 13^0 16’ 15” to 13^0 57’ 38” North which has an area of 3,22,400 hectares. It lies within the Tunga Bhadra sub basin under Krishna basin under Bay of Bengal region. The map depicting the study area Suvarnamukhi watershed boundary along with its drainages and surface water bodies in Tumkur district jurisdiction been prepared using GIS and coded based on National watershed Atlas prepared by AISLUS, Ministry of Agriculture, Govt. of India.

Data Used

- SOI Topographic maps of 1:50,000 scale bearing toposheet numbers 48N/7, N/8, N/11 and N/12.
- Watershed boundary maps from National Watershed Atlas.
- Slope maps, which were prepared by NRDMS Centre, using contours of SOI Toposheets.
- Revenue village boundary with taluk and district boundaries.

Methodolology

To study the characteristics of Suvarnamukhi watershed to determine its basin hydrology, the survey of India toposheets (scale of 1:50000) are used. Toposheets bearing no.s **57B/12, B/16, 57 C/6,C/7,C/9,C/10,C/11,C/13,C/14,C/15 AND 57 G/2, G/3** are utilized for scanning and digitization. The drainage basin analysis is carried out in two phases viz., qualitative and quantitative. The qualitative drainage analysis is done aspect wise namely linear aspect, areal aspect and relief aspect. In the linear aspect stream order, stream length, bifurcation ratio and length ratio are analyzed. In the area aspect the factor, circularity ratio, elongation ratio, drainage density, stream frequency, constant of channel maintenance and length of over land flow are detailed, whereas in the case of relief aspect channel gradient is evaluated. The basin analysis is integrated for the over all basin hydrologic analysis of the watershed area.

Quantitative geomorphology

The linear and areal measurements were carried out using GIS. The fluvial morphometric parameters of a basin are divided in to three groups viz., (a) Linear (b) Areal and (c) relief features.

1. Linear aspects

The Suvarnamukhi watershed is elongated in the east-west direction as shown in the map 1.1. The maximum length of basin is 72.5 km along North-South and the maximum width is 77.5 km along E-W.

(a) Stream Order

The first step in the analysis of any basin is the determination of the order of streams, the concept of which was introduced by Horton[1] and later modified by Strahler[4]. In the present studies Strahler's (1952) method of numbering is used, assuming that the channel network base map includes all the intermitted and permanent flow lines. In this watershed, the order of mainstream has been designated as **7th** order.

(b) Stream length

After the classification of the streams of the entire drainage network, the channel length of each order is measured with the help of Map measurer of GIS. It has been determined that, the average length of stream channel segments is greater than that of the next lower order, but less than that of the next higher order. To obtain the mean length of the stream channel segment of a order U, the total length is divided by the total number of segments of streams of that order as shown in the table below and is calculated by the equation.

Lu = ∑Iu / Nu **---------(1)**

Where, Lu = mean length of stream channel segment of order U in km.

Lu = Total length of all the stream segments of order U in km.

Nu = Number of Streams of order U.

Table 1.1: Stream order and number of streams of the area.

Stream order (U)	Total number of streams (Nu)
1	5989
2	1334
3	328
4	72
5	26
6	4
7	1

From the data as shown in the Table, it is obvious that the number of stream segments of any given order will be lesser than from the next higher orders. Thus, it follows that the number of streams gradually decreases as the steam order increases. For the Suvarnamukhi watershed, the main stream is found to be of **7th** order. Hence, the watershed can be designated as the **7th** order watershed.

Table 1.2: Stream length and number of streams in the watershed area.

Stream order(U)	**No.of streams of each order Nu**	**Total length of each order in km. ∑ lu**	**Mean length in km Lu=∑Iu / Nu**	**Total length of all streams n km ∑ Lu**
1	5989	3314	0.55	**5867**
2	1334	1244	0.93	
3	328	652	14.18	
4	72	326	4.53	
5	26	188	7.24	
6	4	103	25.75	
7	1	40	40	

Horton's[1] law of stream lengths states that, the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric pattern. Hence, a plot of stream length on ordinate & the function of order on abscissa should yield a set of points lying essentially along a straight line as shown in graph 1.3.

(C) Bifurcation Ratio:

The bifurcation ratio is the ratio of the number of segments of given order (Nu) to the number of segments of the next higher order (Nu+1), which is denoted as:

$$Rb = \frac{Nu}{Nu+1} \qquad \text{--------- (2)}$$

Where, Rb= Bifurcation Ratio

Nu= Number of stream segments of the given order

Nu+1 = Number of stream segments of next higher order.

It characteristically ranges from 3.0 to 5.0 for watersheds where the geological structure does not distort the drainage pattern.

Table 1.3: Bifurcation ratio of Suvarnamukhi watershed.

Stream order(U)	**No. of streams of each orders(N_u)**	**Bifurcation Ratio(R_b)**	**Mean Bifurcation Ratio**
1	5989	4.49	
2	1334	4.06	**4.4**
3	328	4.50	
4	72	2.77	
5	26	6.5	
6	4	4	
7	1	0	

From the data given in table, it can be seen that in the watershed the bifurcation ratio of the entire stream orders ranges between 3 and 5.5. The slope in the graph is equivalent to the Horton's bifurcation ratio (Rb). The average Horton's bifurcation ratio of Suvarnamukhi watershed is 4.40.

(d) Length Ratio:

Horton[1] has observed that the mean length of streams of the 1^{st} order is smaller than that of the higher order. Length ratio (RL) is defined as the ratio of mean length of an order to that of the lower order.

$$Rl = \frac{Lu}{Lu^{1}} \qquad \text{--------- (3)}$$

Where, Rl = Length Ratio

Lu= Mean length of order u (1,2,3,…..6)

Lu^{1} = Mean length of lower order

Table 1.4: Length ratio of the Suvarnamukhi watershed.

Stream order (U)	Mean length of Streams (Lu)	Length ratio of Stream (Rl)
1	0.55	0.93
2	0.93	0.06
3	14.18	3.13
4	4.53	0.63
5	7.24	0.28
6	25.75	0.64
7	40	0

Verification of Horton's law of stream numbers and lengths supports the theory i.e., geometrical similarity is preserved in the basin of increasing order as shown in Table 1.4.

(e) Drainage Density

The drainage density can be defined as the average length of the stream per unit area within the basin or simply the ratio of total channel segment lengths accumulated for all orders within a basin, to the total area of the basin.

Ie Drainage density **$Dd = \sum L/A = 5867/3210 = 1.83\ km/km^2$** **--------- (4)**

Where, L= Total length of all channel segments – 5867 km

A= Total area of the Suvarnamukhi basin - 3210 km^2

For the Suvarnamukhi watershed the drainage density is 1.83, a medium value that indicates the medium infiltration rate and medium runoff. The parameter of drainage density can be best utilized to categorize the drainage pattern of a basin.

The constant of channel maintenance **C** is the inverse of drainage density.

$C=1/D$ = 1/1.83 = 0.55 **--------- (5)**

(f) Length of overland flow of streams

Horton[1] defines the length of overland flow as the length of flow path projected to the horizontal of the non-channel flow from a point on the drainage and divide to a point on the adjacent stream channel. According to Horton[1], the average length of overland flow Lo is taken to be half of the reciprocal of the drainage density i.e. **Lo= 0.5 / Dd =** 0.5 / 1.83 = **0.27 km²/km** **--------- (6)**

2. Areal aspects

The Suvarnamukhi watershed is elongated in the east-west direction as shown in the map 1.1. The area of the watershed is 3210 sq. km and its perimeter is 311 km.

(a) Basin Shape

The shape of the basin is quantitatively measured by various factors such as form factor, circularity ratio, elongation ratio and compactness co-efficient (The long narrow basins have high bifurcation ratios where as round basins will have low bifurcation ratio will have sharp peaked flood discharges).

(i) Form factor

The form factor is defined as the ratio of the basin area to the square of the stream length of the basin.

$\mathbf{Rf = A / Lb^2} = 3210/(78)^2 = \mathbf{0.52}$ **--------- (7)**

Where, A = Area of the basin -3210 km^2 , Lb= Stream length of the basin - 78 km

(ii) Circularity Ratio(Rc)

To know the shape of the basin, Millar[3] has used dimensional circularity ratio (Rc), which is defined as the Ratio of the area of the basin to the area of the circle whose perimeter is equal to the perimeter of the basin, thus

$\mathbf{Rc = 4\pi A / P^2} = 4\pi 3210/311^2 = \mathbf{0.42}$ **--------- (8)**

Where, A= Area pf the basin - 3210 $km^{2,}$ P= Perimeter of watershed - 311 km

(iii) Elongation Ratio(Re)

To determine the Shape of the basin, Schumm (1956) used the elongation ratio (Rc) which is the ratio of the diameter (De) of a circle (Whose area is same as the area of the basin) to the stream length of the Basin

$\mathbf{Re = De/ Lb = 2 A/\pi / Lb} = 2*3210/\pi / 78 = \mathbf{0.26}$ **--------- (9)**

Where, Lb = Length of the basin- 78 km and A= Area of the basin - 3210 km^2

(iv) Compactness coefficient (Ce) :

The compactness coefficient(Ce) is defined (Schumm, 1956) as the ratio of perimeter of the basin to the perimeter of a circle (whose area is equal to the area of the basin)

i.e. $\mathbf{Ce = P / 4\pi A} = 311 / 4\pi*3210 = \mathbf{0.07}$ **--------- (10)**

Where, P = Perimeter of the basin = 311 km, A= Area of the basin =3210 km^2

By determining the above factors and also on the basis of the bifurcation ratio, the Suvarnamukhi watershed is inferred as an oval shaped basin.

(b) Drainage Texture:

One of the geomorphic concepts is the drainage texture which means the relative spacing of drainage lines. Horton (1945) points out that the drainage texture includes both drainage density and stream frequency. Singh (1967) has graded the basins of the five different textures basin on the drainage density. Suvarnamukhi watershed with 1.83 drainage density is regarded a very coarse textured basin.

(c) Stream Frequency :

The stream frequency has been defined as the number of channels or stream segments per unit area i.e.

F= Nu / A = 6420/ 3210 = 2 --------- (11)

Nu = Total No. of Stream segments – 6420, A= Total area of Basin - 3210 km^2

Thus, the frequency in the basin is 2, which indicates that the channels are controlled mainly by fractures.

3. Relief aspects (Gradient aspects)

The relief of the basin is expressed as the ratio of the total relief of the basin to the longest dimension parallel to the principal drainage line (Schumm, 1956). The relief (Rh) indicates the overall slope of the watershed surface, which is a dimensionless number.

(a). Channel Gradient

The total drop in elevation from the source to the mouth is found out, the main stream of the watershed and the horizontal distance is measured along the channel using GIS.

(b). Relief Ratio

When the horizontal distance on which it is measured divides the watershed relief, it results in dimensionless relief ratio and it is an indicator of the intensity of an erosion process.

(c). Ruggedness Ratio

In order to combine the qualities of steepness and length, a dimensionless number is developed which is the product of relief and drainage density.

Results and Conclusion

The results of the study on morphometric characteristics has been computed and listed in the table.

Table 1.5: Morphometric characteristics of the basin.

No	Drainage characteristics	Values
	Area in Sq. km (A)	3210
	Stream order (u)	7
	Total No. of streams (Nu)	6420
	Bifurcation ratio (Rb)	4.4
	Total length of the streams in km (Lu)	5867
	Drainage density	1.83
	Average Length ratio (RL)	0.95
	Perimeter in km^2	311
	Maximum basin length in km (Lb)	78
	Drainage density in km / km^2	1.83
	Stream Frequency (F)	2
	Form factor (Ff)	0.52
	Circularity ratio (Rc)	0.42
	Elongation ratio (Re)	0.26
	Constant of channel maintenance (C)	0.55
	Length of overland flow (Lo)	0.27

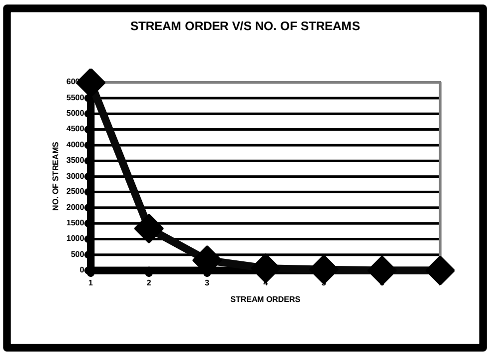


Figure 1: Stream order v/s No. of Streams**.**

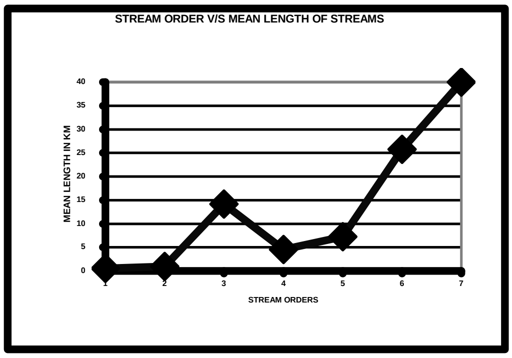
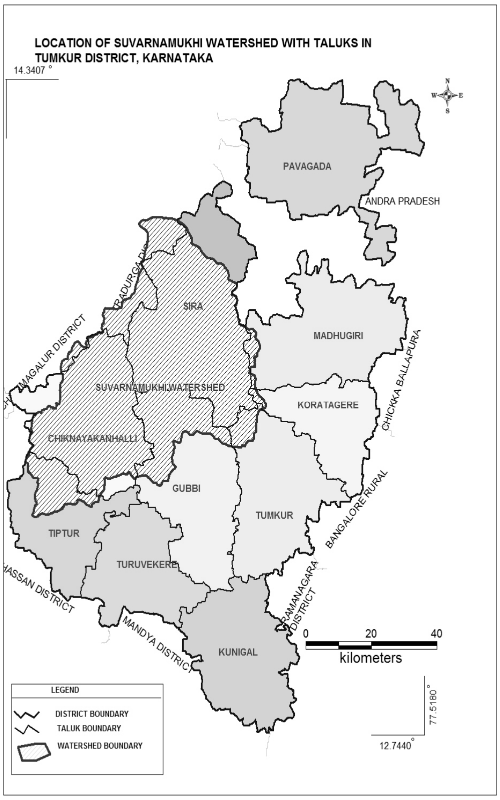
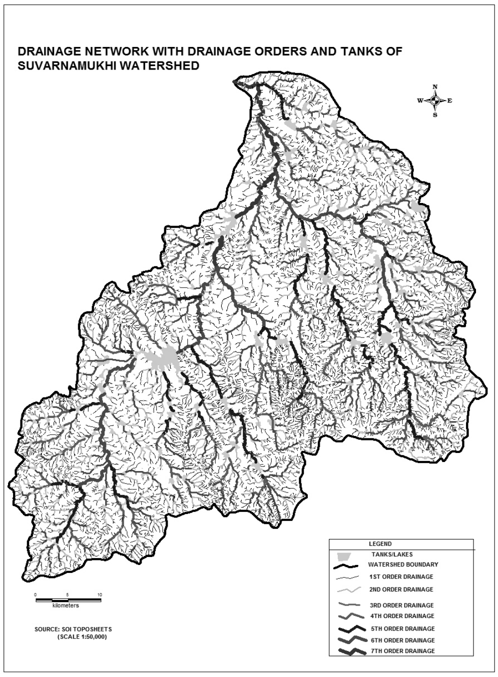


Figure 2: Stream order v/s Mean Length of Streams.



Map 1: Administrative Location**.**



Map 2: Drainage network with tanks.

Conclusions

The morphometric analysis from the above study shows that the stream course is irregular and tributaries flow into the main stream at an acute angle to the direction of flow of the main stream (Suvarnamukhi). So, area is drained by insequent streams. Suvarnamukhi watershed with 1.83 drainage density is regarded a very coarse textured basin. The factors of geology (lithology) , infiltration, vegetation cover and potential evapo-transpiration influence the drainage density (Melton, 1957; Strahler 1971). In Suvarnamukhi watershed, which consists mostly of mixed and sandy soil, allows a medium off which tend to give medium drainage and also represents gentle slop to plane land.

The upper part of the basin exhibits the sub dendritic drainage pattern, the middle part of the basin possess almost trellis-dendritic drainage pattern, this is due to structural control or complexity and end part of the basin is once again follow the dendritic drainage. The straight line plot of the stream order versus stream number satisfied Horton’s first law of stream numbers which states that the number of streams of different orders in a given drainage basin tends to be a reverse geometric series in which the first term is unity and the ratio is bifurcation ratio. The bifurcation ratio of Suvarnamukhi basin shows that there are structural effects or faulting in the basin. Low stream frequency 2 (1 to 3.5) indicates the stream or channel segments being controlled by fractures as per Melton (1958). The longitudinal profile drawn on arithmetic paper shows that the upstream has gentle slope and gradually the gradient is very gentle to plain land towards the mouth of the basin. According to Strahler these relief measures may be indicative of the potential energy of the drainage system because of its elevation above the mean sea level.

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