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Morphometric Analysis using Geospatial techniques in Musi River Catchment areaofRamannapet Mandal, Nalgonda District, Telangana,India.

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Abstract: The study area falls in Ramannapet Mandal, Nalgonda district in Telangana state covering an area of 228.28 Sq.km.The entire area is falling under Musi river basin drainage system. Morphometric analysis is carried out using IRS P6-LISS IV Satellite imagery (2013) and thematic layer preparedby using GIS software. Morphometric analysis is important in any hydrological investigation and it is inevitable in development and management of drainage basin. The development of morphometric techniques was a major advance in the qualitative and quantitative description of the geometry of the drainage basins and its network which helps in characterizing the drainage network. The geomorphological properties which are important from the hydrological studies point of view include the linear, aerial and relief aspect of the watersheds. In the present study a morphometric analysis of Ramannapet drainage area has been carried out using remote sensing and geospatial techniques in GIS. This technique is found relevant for the extraction of river basin and its drainage network. The extracted drainage network was classified according to Strahler's system of classification and it reveals that the terrain exhibits dendritic to sub-dendritic drainage pattern. Morphometric analysis shows that the river is of fifth-order and the basin contains 246 total number of streams. The various linear parameters (Stream order, Stream number, Stream length, stream length ratio, Bifurcation ratio, Drainage density, Texture ratio, Stream frequency) and shape factors (Compactness coefficient, Circularity ratio, Elongation ratio, Form factor) of the drainage area were computed. Hence, it is concluded that GIS techniques proved to be a competent tool in morphometric analysis.

Key words- Morphometric, Remote sensing &Gis, Drainage, Stream Order and Ramannapet.

1. Introduction

The development of a drainage system over space and time is influenced by several variables such as geology, structural components, geomorphology, soil and vegetation of an area through which it flows. Geomorphometry is the measurement and mathematical analysis of earth's surface and its dimensions of the landforms Clarke (1996).

Morphometric analysis of a river basin provides a quantitative description of the drainage system, which is an important aspect of the characterization of basins Strahler (1964). It is important in any hydrological investigation like assessment of groundwater potential, groundwater management, basin management and environmental assessment. Various hydrological phenomena can be correlated with the physiographic characteristics of a drainage basin such as size, shape, slope of the drainage area, drainage density, size and length of the contributories, etc. Rastogi and Sharma (1976). The morphometric analysis can be performed through measurement of linear, aerial, relief, gradient of channel network and contributing ground slope of the basin Nautiyal (1994), Nag and Chakraborty (2003). The dynamic nature of runoff is controlled by the geomorphologic structure of the catchment area and the induced runoff isvery sensitive towards the morphometric characteristics of the contributing area Rudraiah et al. (2008). In India The surface runoff and flow intensity of the drainage system can be estimated using the geomorphic features associated with morphometric parameters Ozdemir and Bird (2009). Pioneer work on basin morphometry has been carried out by Horton (1932), Horton (1945) and Miller (1953). The present study depicts the process to evaluate the various morphometric parameters of RamannapetMandal in using geospatial tectonics.

The study area under part of the Musi River is one of the tributary of river Krishna which is flowing in the Nalgonda district. The length of the flow of the river is 24 km. The study area covers 21 villages and 36 mini micro watersheds. The average annual rainfall in the study area is 649 mm. The South West Monsoon sets in by middle of June and withdraws by the middle of October. About 85% of annual rainfall is received during the Monsoon months, of which more than 75% occurs during July, August and September.

2. Study Area

2.1 Location and Extent

The study area lies in between 78°59'17"- 79°15'12" of East Long and 17°14'42"-17°22'22" of North Lat; study area is located in Northern part of the district of Nalgonda, T.S. State, India. The Ramannapet is around 30 km from Nalgonda in North direction. The location of the study area is as shown in Fig. 2.1

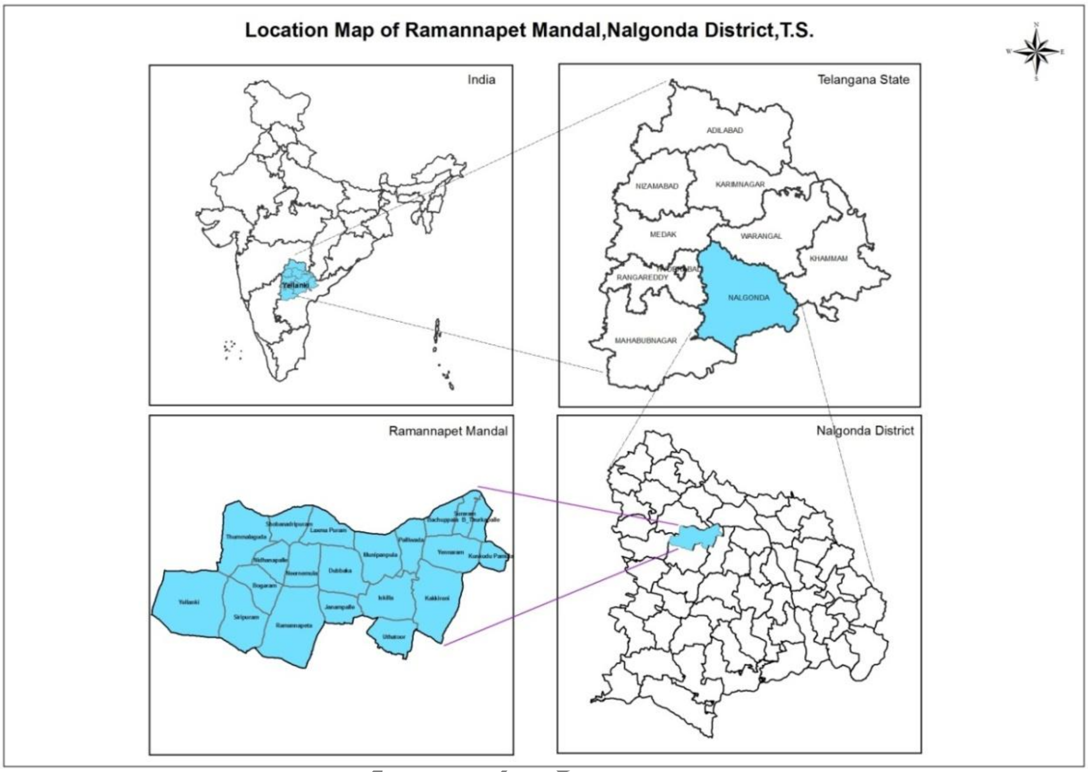

Fig. 2.1 location map of the study area

2.2. Morphometric analysis

The study area was delineated using the Survey of India topographic maps to a scale of 1: 25,000. The ridgelines inthe Toposheets were identified, which act as dividing lines for the runoff. Keeping in mind the functional arearequirement of the study area, the stream network was digitized in GIS software.

2.3 Methodology

The present study is based on Survey of India (SOI) topographic maps of 1971 with no. 56 O/3 the scale 1, 50,000.The satellite data has been used for updating of drainage and surface water bodies. The IRS P6 LISS-IV is a multi-spectral high resolution camera with a spatial resolution of 5.8m at nadir. precision geocoded cloud free data was used to meet the requirement of area under study. Satellite image of the Ramannapet Mandal is shown in map.The first step in the quantitative analysis of drainage basin is designation of stream order. The term "stream order" is a measure of the position of a stream in the hierarchy of tributaries. In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. According to Strahler (1964), the 1storder streams are those, which have no tributaries. The 2nd order streams are those, which have tributaries only of 1storder streams, where two 2nd order channels join, a segment of 3rd order is formed. When two 3rd order segments join, a 4th order channel is formed and so on. Morphometric analysis was carried out for the Ramannapet mandal drainage area. The parameters computed in the present study using RS and GIS technique includes stream order, stream length, bifurcation ratio, drainage density, stream frequency, form factor, circulatory ratio, elongation ratio, relief ratio and ruggedness number. The input parameters for the present study such as area, perimeter, elevation, stream length etc. were obtained from digitized coverage of drainage network map in GIS environment. The morphometric parameters were computed using In general the entire fifth order sub basins are selectedfor the morphometric analysis in following heads:

1.Linear Aspects : one dimension;2.Areal Aspects : two dimensions;3.Relief Aspects : three dimensions.

Table2.1: Methods of Calculating Morphometric Parameters

	Morphometric Parameters	Methods
	Stream order (U)	Hierarchical rank
Linear Parameters	Stream length (Lu)	Length of the stream
	Mean stream length (Lsm)	Lsm = Lu/Nu where, Lu=Stream length of order 'U' Nu=Total
	Stream length ratio (Rl)	Rl=Lu/Lu-1; where Lu=Total stream length of order 'U',
	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream
Relief Parameters	Basin relief (Bh)	Vertical distance between the lowest and highest points of
	Relief ratio (Rh)	Rh=Bh/Lb; Where, Bh=Basin relief; Lb=Basin length
	Ruggedness number (Rn)	Rn = Bh × Dd Where, Bh =Basin relief; Dd=Drainage

	Morphometric Parameters	Methods
Aerial Parameters	Drainage density (Dd)	Dd = L/A where, L=Total length of streams; A=Area of
	Stream frequency (Fs)	Fs = N/A where, N=Total number of streams; A=Area of
	Texture ratio (T)	T = N1/P where,N1=Total number of first
	Form factor (Rf)	Rf=A/(Lb) 2 ;where, A=Area of watershed,
	Circulatory ratio (Rc)	Rc=4πA/P2 ;where, A=Area of watershed, π=3.14,
	Elongation ratio (Re)	Re=2√(A/π)/Lb ;where, A=Area of watershed, π=3.14,
	Length of overland flow (Lof)	Lof = 1/2Dd where, Dd=Drainage density
	Constant channel maintenance (C)	Lof = 1/Dd where, Dd=Drainage density

2.4. Physiography

Ramannapet mandal is located in the Central Part of the District. The study area is bounded on the North by Mothkur and Valigonda, East by Narketpalli, South by Chityala mandal, and West by Choutuppal Mandal.study area elevation varies from 255 to 370m MSL. A major part of the mandal is covered by Musi River Basin which rises in Dubbakaand Nidanpalle Hills, flows from South to north, and passes through Valigonda ,Ramannapet towards Nakrekal and SuryapetMandal within the limits of which it joins the Krishna River near Wadapalli (Wazirabad). The major landforms in granitoid rocks are Pediplains (Shallow and Moderately weathered - 5 to 20m) covering 60% of total area as observed by the satellite imagery with limited field checks; about 8% area is covered with pediment and inselberg zone. Valley zones are covered by 4% of the area. The remaining area is covered by highly dissected hills and water bodies.

2.5.Drainage & Rainfall

The study area drainage pattern is mainly Dendritic drainage. all streams are flow from SW to NE direction The District has an average actual rainfall of 649 mm during 2004-2015 years. the bulk of which is received through the South West Monsoon during the period from June to September.

2.6. Geology &Structures

The area is underlain by older hard rock's like different varieties of granite and gneisses which are intruded by dolerite dykes / quartz veins. Stratigraphically the area predominantly exposes, rocks of Peninsular Gneissic Complex (PGC) along with basic dykes (Proterozoic). The PGC comprises two varieties of granitoid rocks viz., older granite gneiss varieties and younger granite - alkali feldsparGranite is widely distributed throughout the area. It is grey to pink, medium to coarse granited, porphyritic or non-porphyritic and massive. Basic intrusive which include dolerite, Gabbro and pyroxenes, cut across all the rocks in the area.

The majority of the lineaments / faults identified are aligned in the direction of NE-SW and NNE-SSW. Generally dolerite dykes appear to be very hard and compact and poorly devoid of fractures, whereas the Pegmatite veins / Quartz reefs are highly fractured.

2.7. Hydrogeology

In the district granite/gneisses, dolerite dykes at various places. However majority of the area is occupied by hard rock formations like gneissic complex. Only less amount of the area is occupied by other formations. In hard rock formations there is lack of primary porosity. However the aquifer system is developed because of secondary porosity due to various tectonic disturbances and weathering activity. The deeper aquifer system is developed due to major faults, joints, fractures, crevices, shear zones etc. It is observed that the ground water prospects in Moderately weathered Granite gneiss / granitoid rocks and valleys is in the order of 100-200 lpm, whereas it is 50-100 lpm in Shallow weathered Granite gneiss rocks and valleys. In the pediment zones of granitic rocks, the expected yield of the wells is in the order of 10-50 lpm. In highly dissected hills, the prospects are low to poor (0 to 10 lpm).

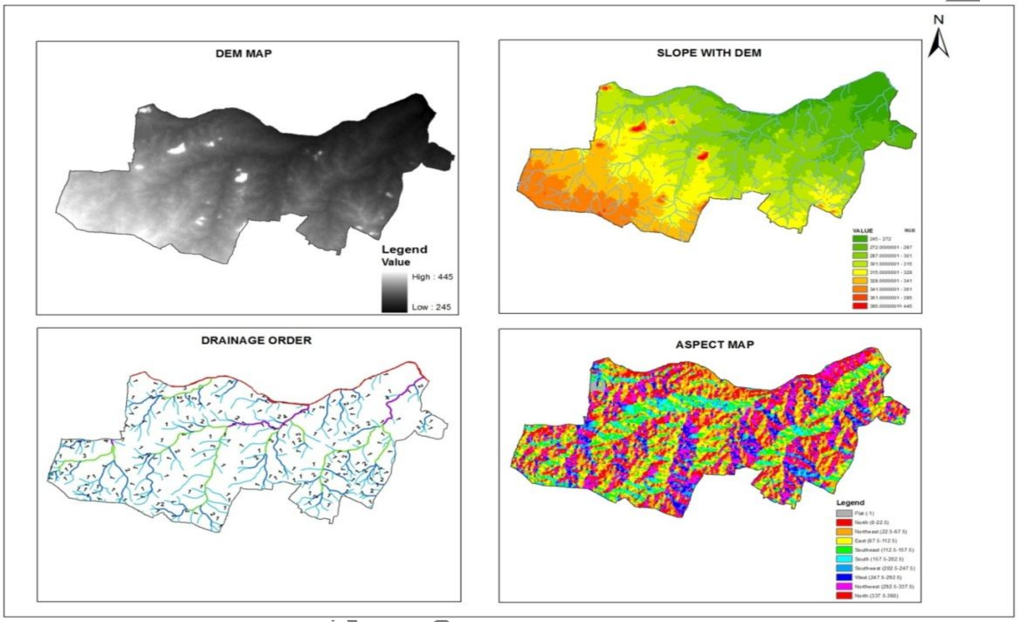

Fig. 2.1 Analysis of the study area

3. Results

The study carried out has been divided into three sections, the first section deals with applicability of Horton's laws of stream numbers and stream lengths in the study area. The second section deals with the various linear and shape morphometric parameters. The total study area drainage is 1,510 km2. The drainage pattern is dendritic to sub-dendritic nature and it is influenced by the general topography of the area. The stream orders of Ramannapet Mandal drainage area varies from 1 to 4 and the total number of stream segments of all orders recorded was 142. Orders of stream network indicated 108 of 1st orders, 27 of 2nd order, 6 of 3rd order and 1 of 4th order. The drainage map of the study area is shown in Fig. 3.1.
The values of different geomorphological parameters were calculated by using the methodology as discussed inmaterials and methods.
3.1. Stream order (u) -The concept of stream order was introduced by Horton in 1932. Stream ordering is a widely appliedmethod for stream classification in a river basin. Stream ordering is defined as a measure of the position of a stream inthe hierarchy of tributaries Leopold et al. (1964) and the streams of RamannapetMusi drainage area have been demarcatedaccording to the Strahler's system of stream ordering. The stream order and the total number of stream segments ineach order for the area are shown in the Table 2.The area has beendesignated as a fourth-order drainage area.
First order streams - Single stream
Second order streams - Joining of two first order streams will form second order
Third order streams - Joining of two second order streams will form Third order
Fourth order streams - Joining of two Third order streams will form Fourth order
Fifth order streams - Joining of two Fourth order streams will form Fifth order

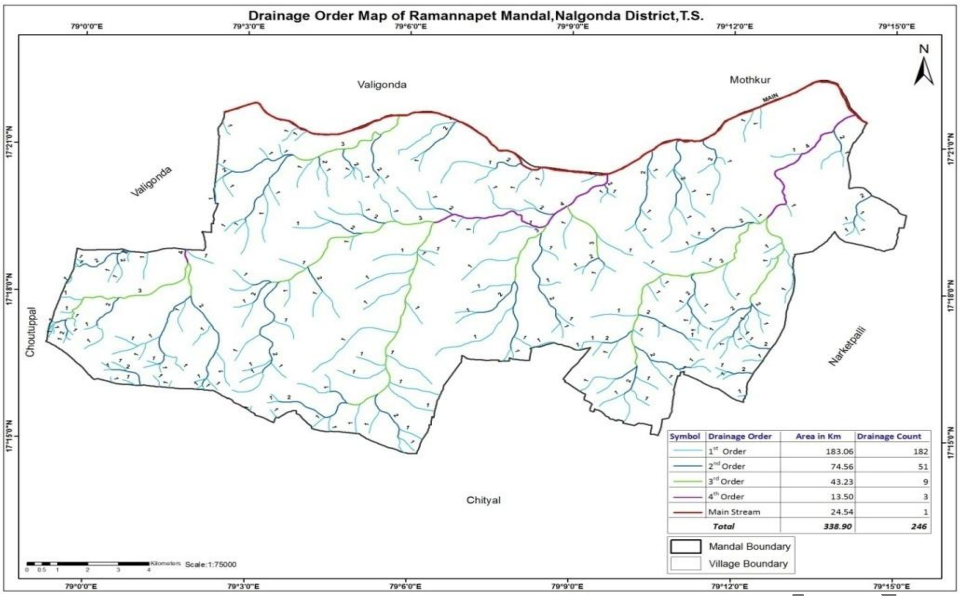

Fig. 3.1 Drainage Order Map of the study Area

3.2. Stream number (Nu)

The number of streams of different orders and the total number of streamsin the basin are counted independently. Generally, the number of streams gradually decreases as the stream orderincreases; the variation in order and size of tributary basins is largely depends on physiographic and structural conditionof the region. The total stream segments in the study area are 246.

3.3. Stream length (Lu)

Stream length is indicative of chronological developments of the stream segments includinginterlude tectonic disturbances. The stream length is measured from mouth of the river to the drainage divide near thesource. 'Lu' has been computed on the basis of Horton's law of stream length, which states that geometrical similarityis maintained in the basins of increasing orders. The stream length of various orders is presented in the Table 2.Generally, the total length of stream segments is the maximum in first-order streams and decreases with an increase inthe stream order. The law holds true in the present case study. The results reveal that the first-order streams are short inlength and are found in the upstream area. Streams with relatively short lengths are representative of areas with steepslopes and finer texture, whereas longer lengths of stream are generally indicative of low gradients Strahler (1964).

Total length of streams (Lu) =183 + 74.5 + 43 +13.5; (Lu)= 314 km.

3.4. Mean stream length (Lsm)

Mean stream length (Lsm) reveals the characteristic size of components of a drainagenetwork and its contributing surfaces. It has been computed by dividing the total stream length of order 'u' by thenumber of stream segments in the order. The Lsm values for the Ramannapet Mandal drainage area differ from 1.01 to 24.54 km with ameanLsm value of 11.18 km. It is noted that Lsm of any given order is greater than that of the lower order and lessthan that of its next higher order in the basin. The Lsm values differ with respect to different basins, as it is directlyproportional to the size and topography of the basin. Strahler (1964) indicated that the Lsm is a characteristic propertyrelated to the size of drainage network and its associated surfaces.

Table 3.1 Stream Parameters of the study Area

Symbol	Drainage Order	Stream lenth(Lu)	No. stream (Nu)	Mean stream lenth(Lsm)	Stream length ratio(Rl)	Bifurcation ratio(Rb)
	1st Order	183.06	182	1.01	2.46	3.57
	2nd Order	74.56	51	1.46	1.72	5.67
	3rd Order	43.23	9	4.80	3.20	3.00
	4th Order	13.50	3	4.50		
	Main Stream	24.54	1	24.54	0.55	3.00

3.5. Stream length ratio (Rl)

It is the ratio between the lengths of streams in a given order to the total length of streams inthe next order.is then calculated for each pair of the orders. Length ratio is for 1st-2nd and 2nd -3rd order of the alluvial plain basin are higher than the basin of other two zones. The Rl values for the Ramannapet Mandal drainage area vary widely from 0.55 to 3.20 and are strongly dependant onthe physiographic and the slope.

3.6. Bifurcation ratio (Rb)

The term ‘bifurcation ratio is indicating (Rb) was introduced by Horton in 1932. Rb is related to thebranching pattern of a drainage network and is defined as the ratio of the number of streams of any given order to thenumber of streams in the next higher order in a drainage basin. It is a dimensionless property and shows the degree ofintegration prevailing between streams of various orders in a drainage basin. Rb shows a small range of variation fordifferent areas or for different environments except those where the powerful geological control dominates. The Rbfor the Ramannapet mandal drainage area varies from 3.00 to 5.67 with a mean Rb of 3.80.

3.7. Mean Bifurcation ratio (Rbm)

The mean bifurcation ratio (Rbm)characteristically ranges between 2.6 and 4.8 for a basin when the influence of geological structures on the drainagenetwork is negligible Verstappen (1983). The analysis showed that the Rb is not same for all orders. Geological andlithological development of the drainage basin may be the reason for these variations. Low Rb value indicates poorstructural disturbance and the drainage patterns have not been distorted whereas the high Rb value indicates highstructural complexity and low permeability of the terrain. This shows that the geologic structures within the drainagearea do not distort the drainage pattern. It also indicates that the basin has mature topography due to the result of theprocess of drainage integration.

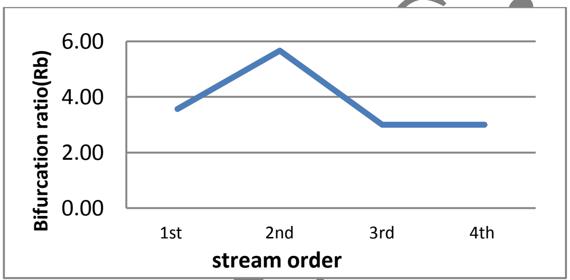

Fig. 3.2 Mean Bifurcation ratio

3.8. Basin length (Lb)

The length (L) is the longest length of the basin from the headwaters to the point ofconfluence Gregory and Walling (1973). The basin length determines the shape of the basin. High basin lengthindicates elongated basin. The L of the basin is 27 km.

3.9. Basin Relief (R)

The relief (R) is defined as the differences in elevation between the highest and the lowest points on thevalley floor of a study area. Basin relief is an important factor in understanding the Denudational characteristics of the basinand plays a important role in landforms, drainage development, surface and sub-surface water flow,permeability and erosion properties of the terrain. From the morphometric study, it should be noted that the maximumrelief value of Ramannapet Mandal drainage area is 12.70.

3.10. Relief ratio (Rh)

The relief ratio has been widely accepted as a effective measure of gradient aspect of the basin,despite uncertainties surrounding definition of its component measurements and may be unduly influence by oneisolated peak within the basin Sharma (1981). Schumm (1956) defined relief ratio as the ratio of maximum relief tohorizontal distance along the longest dimension of a basin parallel to the main drainage line and it measures the overallsteepness of the river basin. The value of relief ratio in the Ramannapet Mandal drainage area is 0.47. This is a dimensionless height-length ratio and allows comparison of the relative relief of any basin regardless of difference in scale or topography. Relief ratio is equal to the right angled triangle and is identical with the tangent of the angle of slope of the hypotenuse with respect to horizontal (Strahler, 1964). Thus is measure the overall steepness of a drainage basin is an indicator of intensity of erosion processes operating on the slope of the basin. Relief ratio normally increases with decreasing drainage area and size of a given drainage basin (Gottschalk, 1964).

3.11. Ruggedness number (Rn)

It is the product of the basin relief and drainage density. The ruggedness number of the basin is 18.79. The low value of ruggedness number indicates low erosion intensity in the basin**.**high values of ruggedness number occur when slopes of the basin are not only steeper but long.

3.12. Drainage density (Dd)

Drainage density (Dd) is one of the important indicators of the landform element and providesa numerical measurement of landscape dissection and runoff potential (Chorley 1969). Dd is defined as the total stream length in a given basin to the total area of the basin (Strahler 1964). Dd is related to various features of landscape dissection such as valley density, channel head source area, relief, climate and vegetation, soil and rock properties andlandscape evolution processes. A low drainage density indicates permeable sub-surface strata and has a characteristicfeature of coarse drainage, which generally shows values less than 5.0. Strahler (1964) noted that low drainage densityis favoured where basin relief is low and vice versa. The Dd of the Ramannapet Mandaldrainage area is 1.48, which indicates that thestudy area has a weak or permeable subsurface material with intermediate drainage and low relief.

Drainage density (D) = L/A
Drainage density (D) =338.90/228.28
Drainage density (D) = 1.48

3.13. Stream frequency (Fs)

Stream frequency is defined as the ratio of the total number ofstream segments of all the orders in the basin to the total area of the basin. 'Fs' is an index of the various stages oflandscape 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 the Ramannapet Mandal drainage area is 1.07. Thestream frequency is dependant more or less on the rainfall and the physiography of the region.

3.14. Texture ratio (T)

It is total number of stream segment of all order per perimeter of the Mandal area. The texture ratio of the study area is 2.10the value of drainage texture is the greater than 8 indicate very fine texture including higher runoff potential of the study area. While medium value is moderate in nature and lower value is coarser in nature indicating less runoff potential.

Texture ratio (T) = N/P
Texture ratio (T) = 182/86.40
Texture ratio (T) = 2.10

3.15. Form factor (Ff)

Form factor is the numerical index. Horton (1932) defined form factor (Ff) as the ratio of the basin area and square root of the basinlength. Form factor is the numerical index (Horton, 1932) commonly used to represent different basin shapes. The value of form factor is in between 0.1-0.8. Smaller the value of form factor, more elongated will be the basin. The basins with high form factors 0.8, have high peak flows of shorter duration, whereas, elongated drainage basin with low form factors have lower peak flow of longer duration. Long-narrow basins have larger lengths and hence smaller form factors. Ramannapet Mandal drainage area Ff value is 0.31.

3.16. Circulatory ratio (Rc)

Miller (1953) defined circularity ratio (Rc) as the ratio of the area of a basin to the area of acircle having the same circumference as the perimeter of the basin. The 'Rc' is influenced more by the lithologicalcharacteristics of the basin rather than anything else. The low, medium and high values of the circulatory ratio areindications of the youth mature and old stages of the life cycle of the tributary basins. Ramannapet Mandal drainage area is in theyouth stage of its development with a circulatory ratio of 0.55.

Basin circularity Ratio (Rc) =$4\pi A / P^2$
Where;
A = Area of the river basin in km^2

P = Perimeter of the river basin in km.
Basin circularity Ratio (Rc) =4*л*228.28/(86.40)^2
Basin circularity Ratio (Rc) = 0.38

3.17. Elongation ratio (Re)

Elongation ratio (Re) is defined as the ratio of diameter of a circle having the same area as ofthe basin and maximum basin length (Schumm 1956). It is a measure of the shape of the river basin and it depends onthe climatic and geologic types. Generally, the Re values vary from 0.6 to 1.0 for most of the basins. The value rangesfrom 0.6 to 0.8 for regions of high relief and the values close to 1.0 have very low relief with circular shape. Thesebasins are efficient in the discharge of runoff than the elongated basin because concentration time is less in circularbasins. The Re value of Ramannapet Mandal drainage area is 0.39, which indicates low relief with steep slope and elongated inshape.

Elongation Ratio (E) = 2√ A/л
Where; A = Area of the river basin in km^2
l = Total length of mainstream in km
Elongation Ratio (E) =2√228.28/л/24.12
Elongation Ratio (E) = 0.39

3.18. Length of overland flow (Lg)

Length of the overland flow (Lg) is the length of water over the ground before it getsconcentrated into definite stream channels. 'Lg' can be defined as the mean horizontal length of flow path from thedivide to the stream in a first-order basin and is a measure of stream spacing and degree of dissection and isapproximately one-half the reciprocal of the drainage density (Chorley 1969). From the morphometric analysis, the LgValue for Ramannapet Mandal drainage area is 0.74The low Lg value indicates that the rainwater had to travel relatively mediumdistance before getting concentrated into stream channels.

3.19. Constant of channel maintenance(C)

Constant of channel maintenance(C) is the 1 divide by the drainage density.
Constant of channel maintenance(C) = 1/Dd
Where; D=Drainage density
Constant of channel maintenance(C) = 1/2.05
Constant of channel maintenance(C) = 0.67

Table 3.2 Morphometric Parameters of the Study Area

Sl No	Morphometric Parameters	Values
1	Study Area of the drainage area in km	338.9
2	Perimeter in km 185.64	86.4
3	Stream order up to	4th
4	Stream number	246
5	Stream length	314
6	Mean stream length	11.18
7	Stream length ratio	0.55 to 3.20
8	Bifurcation ratio	3.00 to 5.67
9	Basin length km	27
10	Basin Relief	12.7

Sl No	Morphometric Parameters	Values
11	Relief ratio	0.47
12	Drainage density	1.48
13	Constant channel maintenance	0.67
14	Stream Frequency	1.07.
15	Length of overland flow in Km	0.74
16	Texture ratio	2.1
17	Circularity ratio	0.38
18	Elongation ratio	0.39
19	Ruggedness number	18.79
20	Form factor	8.45.

Conclusions

The present study has proved that the geoprocessing technique used in GIS is an effective tool for computation andanalysis of various morphometric parameters of the basin and helps to understand various terrain parameters such asnature of the bedrock, infiltration capacity, surface runoff, etc.one of the purposes of fluvial morphometry is to derive information in quantitative from about the geometry of the fluvial system that can be correlated with hydrologic information. The Ramannapet drainage area is well drained in nature withthe stream order varying from 1 to 4. The basin is dominated by lower order streams and the total length of streamsegments is maximum in first order streams. Ramannapet mandal drainage area is an elongated basin with moderate relief and steep slope due to the lower elongation ratio 0.39. Stream frequency and drainage density are the prime criterion for themorphometric classification of drainage basins, which certainly control the runoff pattern, sediment yield, and otherhydrological parameters of the drainage basin. The Dd appears significantly medium in Ramannapet Mandal drainage area, which is anindicative of existence of impermeable rocks and moderate relief, causing more infiltration and high groundwaterprospects. The quantitative analysis of linear, relief and aerial parameters using GIS is found to be of immense utility inriver basin evaluation, basin prioritization for soil and water conservation and natural resource management. Thegeoprocessing techniques employed in this study will assist the planner and decision makers in basin development andmanagement studies. The complete morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect.

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