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MORPHOMETRIC ANALYSIS OF VINCHARNA RIVER WATERSHED: A COMPARATIVE STUDY OF THE TWO DIFFERENT SPATIAL DATASETS.

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Abstract:

In this paper, an attempt has been made to study the detailed morphometric characteristics of Vincharna watershed, tributary of the Sina river basin in Ahmednagar district, Maharashtra. The drainage patterns are dendritic and parallel, covering 390 sq. km. Morphometric analysis was done to determine the drainage characteristics of Vincharna watershed using topographic maps, ASTER and SRTM DEM (30 m Resolution).

For detailed study, ASTER and SRTM data was used for preparing Digital Elevation Model (DEM). The relief data was derived from SOI toposheets and GIS - RS techniques were used to evaluate Linear, Areal and Relief aspects of morphometric parameters. Watershed boundary, flow accumulation, flow direction, flow length, stream ordering were prepared using Hydrology Tool; and contour, Slope, Aspect, Hillshade have been prepared using Surface Tool in ArcGIS-10 software. Different thematic maps like Stream Network, Slope, Relief, Aspect and Hillshade were prepared by using ArcGIS software. Based on all morphometric parameters achieved, it can be concluded that the development in erosive processes of the area by the river has been progressed beyond the maturity which indicates the lithology had an influence on the drainage development. These studies are very useful for planning rainwater harvesting and watershed management.

Keywords: Morphometric Analysis, ASTER and SRTM (DEM), GIS, Watershed management.

Abbreviations: GIS (Geographical Information System), RS(Remote Sensing), DEM (Digital Elevation Model),ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer),SRTM(Shuttle Radar Topography Mission), ArcGIS(Aeronautical Reconnaissance Coverage Geographic Information System) software.

1. Introduction:

Morphometric analysis of a drainage basin demonstrates the dynamic equilibrium that has been achieved due to interaction between matter and energy. It helps to understand the prevailing geo-hydrological characteristics of the drainage basins (Rao Liaqat A. K. Et.al. 2011).The basin morphometry shows the connection between basinand stream network geometries to the water and sediment discharge through the basin. The size of adrainage basin is proportionate to the amount of water, thelength, shape and relief; affect the rate at which wateris discharged from the basin and total yield ofsediments. The analysis clearly indicates difference amongst the various datasets used viz. Toposheets, ASTER and SRTM DEM. The spatial resolutions of these data sets are sufficient enough to achieve the analysis. Efficient explanation of the geometry of adrainage basin and its stream channel requiresmeasurement of linear aspects of the drainage network,areal aspects of the drainage basin, and relief aspects of the channel network and contributing ground slopes. Thus, the present study will help to determine a comparative study for further studies in the field of geomorphology.

2. Study area:

The study area compriseswatershed of Vincharna River and its main tributary Bhor River. Vincharna River is the tributary of Sina River. Administratively study area is divided into three different tahsils of two different districts. The Vincharna river basin falls under Jamkhed Tahsil of Ahmednagar district of Maharashtra. While the Basin of Bhor River, falls under Ashti Tahsil of Beed district of Maharashtra. The upper reaches of Vincharna River basin is fall under Patoda Tahsil.

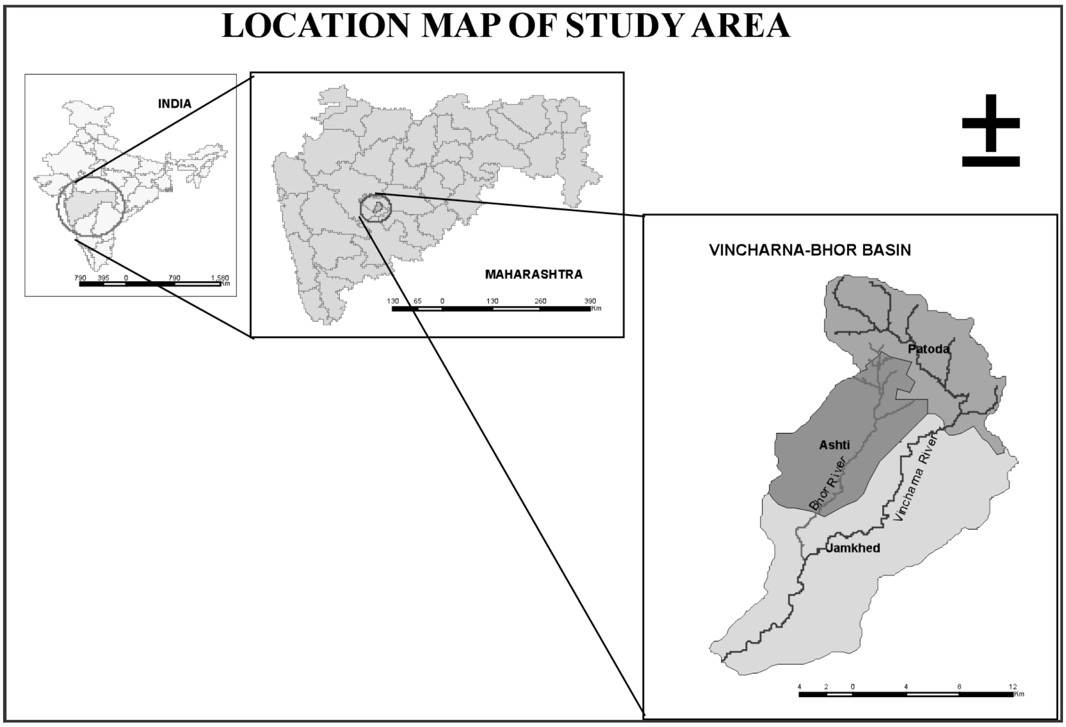
The extent of study area is Latitude 18°61' N to 18°9' N and Longitude75°18' E to75°4' E. The total area of study area is 389.29 km2.Table 1. Major tahsils and their geographical area covered in Vincharna-Bhor Watershed

Table 1. Major tahsils and their geographical area covered in Vincharna Bhor Watershed

Name of Tahsils	District	Area (km^2) (Under Vincharna Basin)
Jamkhed	Ahmednagar	206.25
Patoda	Beed	95.88
Ashti	Beed	86.78
	Total=	**389.29**

Jamkhed is the main town within the study area, located at the elevation of 590 m. This is the part of southern plain region of Ahmednagar District. The whole area is characterized by black cotton soil. According to Dry Farming Research Station, this soil is suitable mostly for crops like Bajra, Groundnut, Sunflower, Grasses and Plantation. Jamkhed is located in a semi-arid, very drought-prone area, with fairly flat land and poor, rocky soil. Annual average rainfall is 14 inches, mostly in the monsoon months of July to September from south west monsoon. Due to uneven distribution of rainfall there is a long dry spell of about 9 months. The weather patterns in this area are drastically different than those of Mumbai or Pune.

Fig. 1: Location map of the study area



The usual pattern (although exceptions have been known to occur): Rainy season begins early June and lasts through October. The peak of the rainy season tends to occur during the months of July (late) though August to mid-September. The months of October-February tend to be very pleasant and dry. During the winter months, the temperature can drop to 4°C at night and rise up to 29°C during the day due to the intense sun. The months of March-June are treacherous due to the intense heat and lack of cloud cover. Temperatures can peak at 45°C during the day, although it's dry heat. These are also the driest months of the year.

As of 2011 Census, Jamkhed had a population of 34,017. Males constitutes 52.7% and females 47.3%of the population. The average literacy rate of Jamkhed is 69%which is higher than the national average of 59.5%. Male literacy is 76%, and female literacy is 63%. In Jamkhed, 14% of the population is under 6 years of age.

3. Aim and objectives:

The study aims to understand the morphometric characteristics of river and to analyse it using various datasets. Following are the objectives of the respective study.

i) To determine the drainage characteristics of Vincharna watershed using topographic maps, and ASTER and SRTM DEM.

ii) To assess the difference amongst various geomorphic parameters and analysed datasets.

4. Data and Methodology:

Following data and methods has been used in this study.

1) Data for preparation of various thematic maps and DEM:

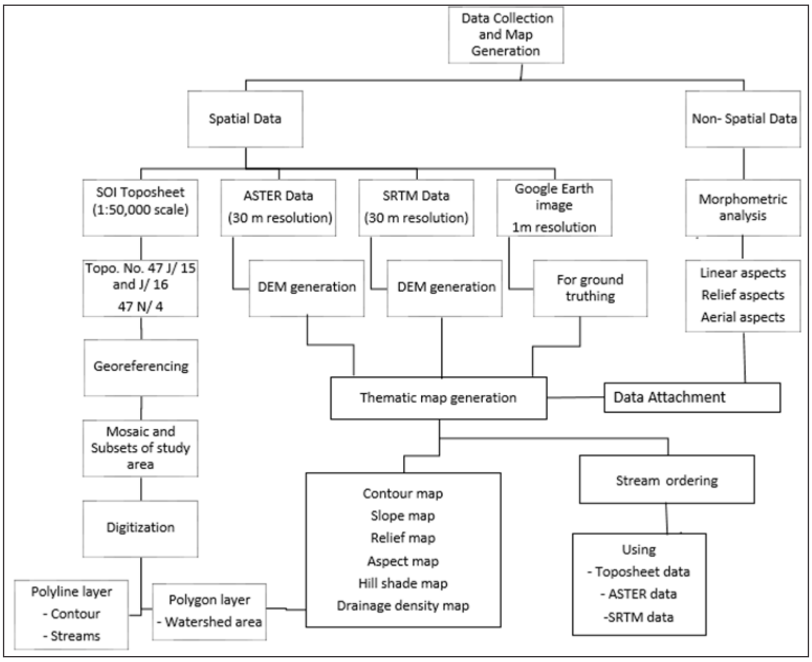
i) SOI Toposheet: 47 J/15,47 J/16, 47 N/4 with scale= 1:50000

ii) ASTER (DEM) (30m resolution)

iii) SRTM (DEM) (30 m resolution)

iv) Google earth (1 meter resolution)

Fig. 2: Flowchart of methodology



1) **Preprocessing:** The raw satellite images will be processed for generation of final maps. Following procedure will be followed.
   i) *Georeferencing:* Toposheets were georeferenced using their coordinates in ArcGIS software.
   ii) *Mosaic and subset study area* : Different DEM's and To posheets were mosaic and extraction of study area has been done.
   iii) *Digitization* : Contours and Streams were digitized from Toposheets.
   iv) *Morphometric analysis* : Morphometric analysis has been carried out for a watershed using three different data sets viz, Topo sheets, ASTER and SRTM.

Fig. 3 *(a and b)* : Contour map and Hillshade map of the study area.

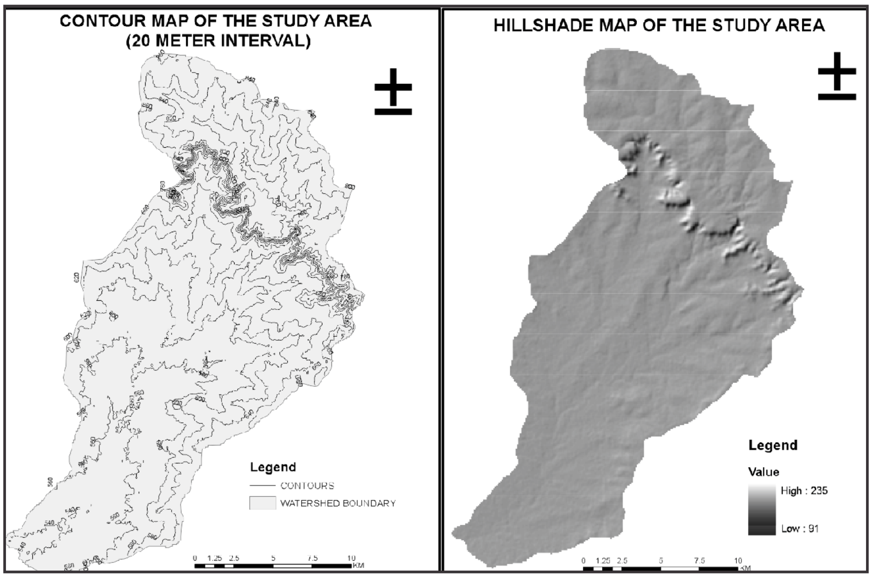
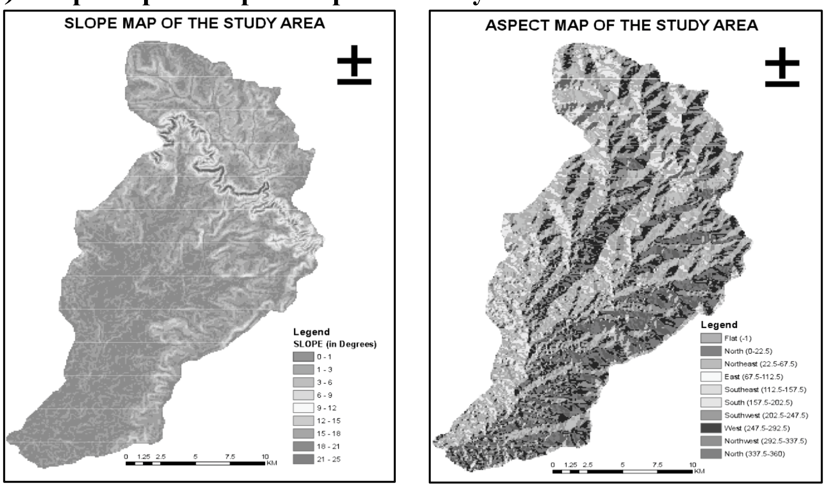


Fig. 4 *(a and b)* : Slope map and Aspect map of the study area.



a) DEM and then compare using software algorithm. (Fig. 3a)
b) Hillshade map: This map shows overall relief and structure of landforms in the basin.. (Fig. 3b)
c) Slope map: This is combined map for all three datasets. With the help of Spatial Analyst Tool from Arc Toolbox, raster data of DEM was used to derive slope map. This shows slope in degrees.. (Fig. 4 a)
d) Aspect map: The Aspect identifies the downslope direction of the maximum rate of change in stream flow. It can be thought of as the slope direction. This is also a combined map for all three data sets. . (Fig. 4 b)
e) Drainage density map: Here in this map all streams were digitized and calculated drainage density has been shown using Toposheets. For other two datasets viz, ASTER and SRTM, all streams automatically extracted using Digital Elevation Models of both the datasets.

.Fig. 5 (a and b): Stream Ordering derived from ASTER and SRTM DEM.

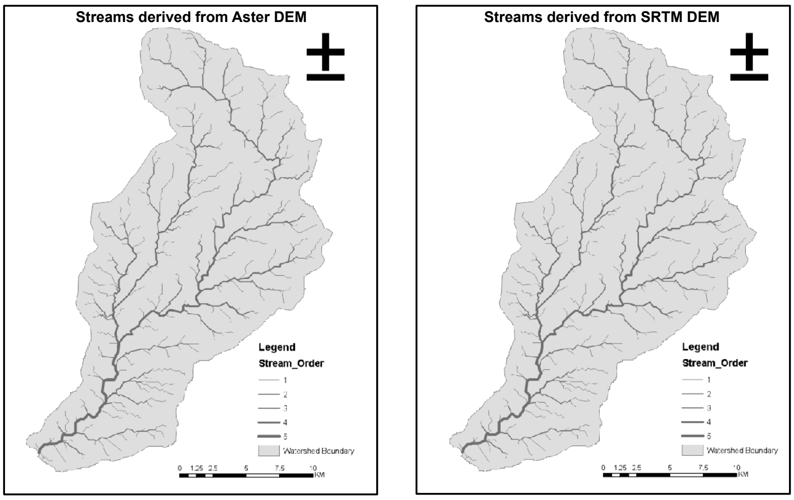
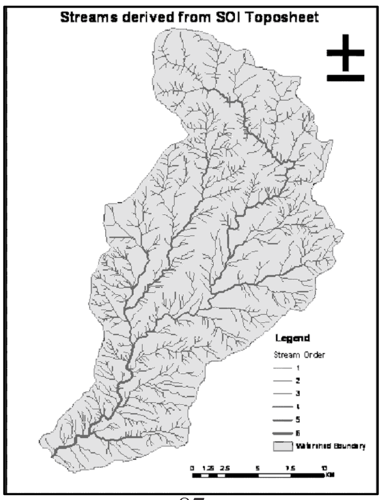


Fig. 6: Stream Ordering derived from SOI Toposheets.



5. Results and discussion:

In the present study, themorphometric analysis is studied with respect toparameters like stream order, stream length,bifurcation ratio, stream length ratio, basin length,drainage density, stream frequency, elongation ratio,circularity ratio, form factor, relief ratio, etc. The properties ofthe stream networks are very important to study the landform making process. Morphometricparameters such as relief, shape and length alsoinfluence basin discharge pattern strongly through theirvarying effects on lag time

5. 1. Linear aspects:

5. 1. 1. Stream order(u):

The major step in any morphometric analysis is stream ordering, stream orders and is basedon a hierarchic ranking of streams. Ranking of streams has been carried out based on the methodproposed by Strahler (1964). It is observed that the maximum frequency is in the caseof first order streams.According to this study, SRTM and ASTER data shows 5th higher order of stream network, whereas Toposheets shows 6th higher order of stream network. That clearly shows the difference amongst various datasets.

5. 1. 2. Stream length(lu):

Stream length is one of the most important hydrological feature of the basin as it reveals that the surface run-off behaviors. The number of streams of various orders in a watershed is counted and their lengths from mouth to drainage divide are measured.

5. 1. 3. Mean stream length (lsm):

The mean stream length is a dimensionless property, characterizing the size aspects of drainage network and its associated surface (Strahler, 1964). It is obtained by dividing the total length of stream of order by total number of segments in the order (Table II). In the study area the mean stream length varies from 0.99 to 12.01 and mean stream length of any given order is greater than that of the lower order and less than of its next higher order in the entire sub–watersheds except which might be due to variation in slope and topography.

5. 1. 4. Stream length ratio (rl):

it is the ratio between the mean lengths of streams of any two consecutive orders. Horton's law (1945) of stream length states that the mean length of stream segments of each of the successive orders of a basin tends to approximate a direct geometric series, with stream lengths increasing towards higher stream order. All the sub-watersheds in the study area show variation in stream length ratio between streams of different order indicating their late youth stage of geomorphic development (Liaqat A. K. et. al., 2011)(Table II).

5. 1. 5. Bifurcation ratio(rb):

The bifurcation ratio (Rb) is the ratio of the number of the stream segments of given order 'Nu' to the number of streams in the next higher order (Nu+1) Horton (1945) considered the bifurcation ratio as index of relief and dissertation. Strahler (1957) demonstrated that bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. In the present study, the higher values of Rb indicates strong structural control on the drainage pattern, while the lower values indicative of sub-watersheds that are not affect by structural disturbances. The mean bifurcation ratio (Rbm) may be defined as the average of bifurcation ratios of all order.(Table II).

Table-II Linear Aspects of Vincharna Basin

Stream Order	No. of Streams (Nu)	Stream Length (Km)	Bifurcation Ratio	Mean Bifurcation Ratio	Log Nu	Log Lu	Mean Stream length (Lsm)	Stream Length Ratio
Linear aspects derived from Toposheet								
1	797	493.14	4.63	3.98	2.90	2.69	0.62	2.90
2	172	169.91	4.91		2.24	2.23	0.99	2.04
3	35	83.34	4.38		1.54	1.92	2.38	1.45
4	8	57.36	4		0.90	1.76	7.17	3.21
5	2	17.86	2		0.30	1.25	8.93	1.32
6	1	13.5	-		0.00	1.13	13.50	-
Linear aspects derived from ASTER DEM								
1	240	201.14	4.36	4.23	2.38	2.94	3.61	0.23
2	55	97.34	6.88		1.74	3.58	68.77	0.16
3	8	66.56	2.67		0.90	4.36	2870.24	1.73
4	3	15.78	3		0.48	4.12	4427.09	1.00
5	1	13.25	-		0	4.12	13247.48	-
Linear aspects derived from SRTM DEM								
1	229	201.14	4.58	4.31	2.36	2.94	3.78	0.23
2	50	97.34	7.14		1.70	3.58	75.65	0.16
3	7	66.56	3.5		0.85	4.36	3280.28	1.73
4	2	15.78	2		0.30	4.12	6640.63	1.00
5	1	13.25	-		0	4.12	13247.48	-

5. 2. Relief Aspects:

5.2.1Basin Area (A): Volume of water is directly proportional to the basin area. The Vincharna Basin has maximum area of 389.66 km2. This aspect was generated from the GIS software.(Table1)

5.2.2Basin Length (Lb): It is defined as the longest dimension of basin parallel to the principal drainage channel (Schuman, 1956). It represents the main channel in watershed through which greatest volume of water travels. The basin length of Vincharna watershed is 33.80km derived with the help of spatial data processed in Arc-GIS 10. (Table 1)

5.2.3 Basin Perimeter(P): It is length of the boundary of basin by which basin is delineated. Perimeter represents watershed size. The basin perimeter of Vincharna watershed is 102.62 km derived with the help of spatial data processed in Arc-GIS 10. .

5.2.4 Relief Ratio(Rh): Difference in the elevation between the highest point of a basin (on the main divide) and the lowest point on the valley floor is known as the total relief of the river basin. The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line.The valueof Rh in the given watershed is 9.91 which indicates low relief and moderate to gentle slope.

5.2.5 Ruggedness Number(Rn): It is the product of maximum basin relief (H) anddrainage density (D), where both parameters are in thesame unit. An extreme high value of ruggednessnumber occurs when both variables are large and slopeis not only steep but long as well. In the presentstudy, the value of ruggedness number is low i.e. 0.5029 which indicates gentle slope.

Table III. Result of morphometric parameters using different subsets

Sr. no.		**Parameters**	**Formulae**	**References**	**Results (Data derived from)**		
					Toposheet	**ASTER DEM**	**SRTM DEM**
1.		Stream order(U)	Hierarchical rank	Strahler (1964)	6	5	5
2.		Stream length(Lu) km	Length of the stream	Horton (1945)	835.11	394.07	394.07
3.	**Linear**	Mean stream length(Lsm) km	Lsm= Lu/Nu Where Nu is no. of streams	Strahler (1964)	139.185	78.814	78.814
4.		Stream length ratio(Rl)	Rl=Lu/(Lu-1)	Horton (1945)	1.82	0.624	0.624
5.		Bifurcation ratio(Rbm)	Rbm= Average of all bifurcation ratios	Strahler (1957)	3.98	4.23	4.31
6.		Basin Area (A)	GIS Software Analysis	Schumm (1956)	389.66 km^2		
7.		Basin Length (Lb)	GIS Software Analysis	Schumm (1956)	33.80km^2		
8.		Basin width (Lw)	GIS Software Analysis	Horton (1932)	16.44 km		
9.	**Relief**	Basin Perimeter (P)	GIS Software Analysis	Schumm (1956)	102.62 km		
10.		Basin Relief (Bh)	Bh =H-L	Schumm (1956)	132 m		
11.		Relief Ratio (Rh)	Rh=Bh/Lb	Schumm (1956)	9.91		
12.		Ruggedness Number (Rn)	Rn = Bh × Dd	Schumm (1956)	0.5029		
13.		Drainage density(Dd)	Dd=Lu/A	Horton (1932)	2.14		
14.		Texture ratio(T)	Rt=N1/P	Schumm(1965)	7.77		
15.		Stream frequency(Fs)	Fs=Nu/A	Horton (1932)	2.60		
16.	**Aerial**	Elongation ratio(Re)	Re = (2 / Lb) * (A /π)0.5	Schumm (1956)	0.81		
17.		Circularity ratio(Rc)	Rc=4pA/ P2	Miller (1953)	0.46		
18.		Form factor(Ff)	Ff=A/Lb2	Horton (1932)	0.34		
19.		Length of overland flow(Lg)	Lg = A/(2*Lu)	Horton, 1945	1.07		
20.		Constant of Channel	1/Dd	Schumm (1956)	0.47		

5. 3. Areal Aspects:

5. 3. 1. Drainage Density(Dd): It isdefines as the total length of stream of all orders/drainage area.. The drainage density in the study area is low i.e. 2.14 km/km2, indicates clearly that the region has highly permeable subsoil, dense vegetation cover and low relief. The drainage density factor is also related with the climate, surface roughness and runoff in the area of interest.

5. 3. 2. Texture Ratio(T): It is defined as the ratio of total number of first order streams to basin perimeter. T = N1 / P, where N1 is the number of first order streams, P is basin perimeter (km). It indicates relative spacing of streams. Smith (1950) categorized the drainage texture in five classes as very course (<2), course (2-4), moderate (4-6), fine (6-8) and very fine (>8). Here, texture ratio in Vincharna basin is 7.77 that indicates fine texture of subsoil and gentle relief of the basin.

5. 3. 3. Stream Frequency(Fs): It is expressed as the total number of streams per unit area of the basin. Fs = N / A, where N is total number of stream segments, A is basin area (km2) (Horton, 1945). Here, the lower values of stream frequency i.e. 2.60 indicate lower volume of surface runoff, dense vegetation, gentle relief and moderate infiltration capacity.

5. 3. 4. Elongation Ratio(Re): Elongation ratio is the ratio of diameter of a circle ofthe same area as the drainage basin and the maximumlength of the basin. The Re values generally rangesbetween 0.6 and 1.0 over a wide variety of climate andgeologic types. Thesevalues are further categorized as circular (>0.9), oval(0.9-0.8) and less elongated (<0.7). The Re values inthe study area is 0.81 (Table-III),which indicateselongated shape of the basin with moderate to gentle ground slope.

5. 3. 5. Circulatory Ratio(Rc): It is defined as the ratio of the area of the basin (A) to the area of a circle having the same circumference as the perimeter (P) of the basin. The Rc of Vincharna river basin is 0.46(Table III). This value is an indicative of the lack of cir- cularity of the basin.

5. 3. 6. Form Factor (Ff): The form factor is the ratio of basin area to square of the basin length and is a quantitative expression of drainage basin outline. The Ff values (Table III) in the study area is 0.34, thus indicate that the basinis elongated ones.

5. 3. 7. Length of Overland Flow(Lg): It is the maximum length of surface flow generated by rain water before it gets into definite stream channels. (Horton 1945) Here, the overland flow length is observed nearly 1.07. (Table III)

5. 3. 8. Constant of Channel Maintenance(C): It has dimensions of length and therefore increases in magnitude as the scale of the landform units increases. The Constant of Channel Maintenance of the basin is 0.47 (Table III). This low value indicates geomorphic stability, high permeability, moderate to gentle slopes and moderate surface run off.

6. Conclusion:

The relevant use of GIS and RS techniques can be accepted as immensely powerful tool in the field of fluvial geomorphology, watershed management and hydraulic studies. The datasets used in this study gives accurate perception of the morphometry of Vincharna watershed. The higher number of stream orders i.e. 5th order indicate that the river is in uniform stage and achieving equilibrium. The lower under control of geomorphic processes. The lower bifurcation ratio i.e. 3.98 to 4.31 indicates the lithological stability, systematic bifurcation of the stream orders and controlled conditions of geomorphology. Vincharna watershed basin haslow drainage density i.e. 2.14 km/km2, indicates that the region has highly permeable subsoil, dense vegetation cover and low relief. Circularity and elongation ratio shows that the basin has elongated shaped.

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