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GIS BASED MORPHOMETRIC ANALYSIS OF GANESHWADI STREAM, YERLA RIVER BASIN, MAHARASHTRA FOR WATER RESOURCE MANAGEMENT

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Abstract: Morphometric analysis is significant for investigation and management of the watershed. This study depicts the morphometric analysis of Ganeshwadi tributary of the Yerla River basin, Satara district, Maharashtra, Central India using Geographic Information System (GIS) techniques. The study has been carried out through measurement of various aspects like linear, aerial and relief aspects of tributary. The drainage network of the study area is generated from SOI toposheet No. 47 K/7 using ESRI Software, ArcGIS. The analysis reveals that drainage pattern is dendritic and the stream order in the watershed varies from 1 to 2. The total number of stream segments of all orders counted as 6, out of which the majority of orders (78.33 %) was covered by 1st order streams and 2th order stream segments covers only 16.66 %. The bifurcation ratio reflects the geological and tectonic characteristics of the watershed and estimated as 1.41. Drainage density and stream frequency values of the study area are 2.18 km/km^2 and 1.53 streams/km^2 respectively indicates coarse texture due to highly resistant sub-soil material and low relief. The systematic analysis of various parameters in GIS has a vast utility for a comprehensive water resource management.

Keywords: Drainage basin morphometry, GIS, Ganeshwadi, Yerla River Basin

Introduction:

In geomorphology the development of a landscape can be known by measuring morphometry of drainage and relief properties. Morphometric analysis is widely used to assess the drainage characteristics of the river basins for watershed management plans. Morphometry is the measurement and mathematical analysis of the configuration of the Earth's surface, shape and dimensions of its landforms (Clarke, 1966). It is the precise measurement of landforms (Strahler, 1969). Horton (1945) is the pioneer worker who introduced the natural composition of drainages which was further modified and developed by Strahler (1950), Schumm (1956), Chorley (1957) and others. The quantitative description of the geometry of the drainage basin and its network is helpful in charactering the drainage network, comparing the characteristics of several drainage networks and examining the effects of variables such as lithology, rock structure, rainfall etc. on the drainage network (Kale and Gupta, 2010).

Geomorphic analysis of various basins has been studied by many scientists using conventional (Horton, 1945; Strahler, 1957) and remote sensing and GIS methods (Agarwal et al., 2012). The basin characteristics is used in many of the successful implementation of watershed management programs (Chadha and Neupane, 2011; Unde and Telore, 2013). Geoinformatics techniques are essential for geomorphic analysis of basins for

watershed management (Saptarshi and Raghavendra, 2009; Telore, 2015; Sahu et al., 2017). Morphometric analysis of a drainage system requires delineation of all existing streams. The stream delineation of the study area has done digitally in GIS system using ArcGIS 9.3 software. All tributaries of different extents and pattern were digitized from Survey of India topographical sheets of 1:50,000 scale. Digitization work is carried out for an entire analysis of drainage morphometry. In the present chapter, the morphometric analysis of the Yerla River basin for the linear, relief and areal has been carried out using the mathematical formulae given in Table 1 and the results are summarized in Table 2.

Objectives

- To derive the different drainage aspects of the study area.
- To evaluate linear aspects of morphometric characteristics of the study area.
- To evaluate areal aspects of morphometric characteristics of the study area.

Research Methodology

Topographical maps prepared by Survey of India on 1:50,000 scale are used to generate the base map of the study area. Morphometric analysis of a drainage system requires delineation of all existing streams. The study area is delineated with the help of ArcGIS 9.3 software. All tributaries of different extents and pattern were digitized from topographical sheets of 1:50,000 scale. Digitization work is carried out for an entire analysis of drainage morphometry. Various thematic maps such as drainage map, stream ordering map, contour map, elevation map, slope map, aspect map and DEM are prepared. Shuttle Radar Topographic Mission (SRTM) DEM data of 90 m spatial resolution is used to create digital elevation model (DEM) of the study area in ArcGIS 9.3, ERDAS IMAGINE 9.2 software. Ground realities are checked with the help of handheld GPS during field visits. These parameters are measured from the toposheets. The various linear, relief and areal morphometric parameters such as area, perimeter, stream order, stream length, stream number, bifurcation ratio, drainage density, stream frequency, drainage texture, length of basin, form factor, circulatory ratio and elongation ratio are computed based on the formula suggested by (Horton 1945; Miller 1953; Schumm 1956; Strahler 1964) given in Table 1 and the results are summarized in Table 2.

Study Area:

Total geographical area of the study area is 3.90 km^2. It is located on the right bank tributary of Nani River, in the mid-western plateau region of the Yerla River basin (Figure 1). The study area covers an area of 3.90 km^2 of Aundh Hill of Mahadev Hill range of the Western Ghat. The area represents semi-arid condition. The study area lies between latitudes of 17°29'56" and 17°31'34" North and longitudes of 74°18'57" to 74°20'28" East and receives 543.07 mm average annual orographic type of rainfall. The study area lies 16 km south west of Vaduj town. Administratively area lies in Khatav Taluka of Satara District. The micro watershed rises on southern side of the Yamai Hill, Aundh (Plate 1A). The area receives 552.72 mm average annual rainfall. The drainage network is sub

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dendritic pattern (Figure 3B). Stony field is found in the source region (Plate 1A). The soils of the study area are residual, derived from the underlying basalts. Ganeshwadi village is located in the middle reaches while Vadgaon (Jayaram Swami) village is located in the lower reaches of study area. Area is facing acute drinking water shortage almost throughout a year (Plate 1E, F). Groundwater level is declined in the area due to scanty rainfall and heavy pumping (Plate 1E, F). Plate 1C shows onion expholiation and calcareous content in the upper reaches. Details of the morphometric parameters are given in Table 1.2, various maps are shown in Figure 3 A to E and photographs are shown in Plate 1 A to F.

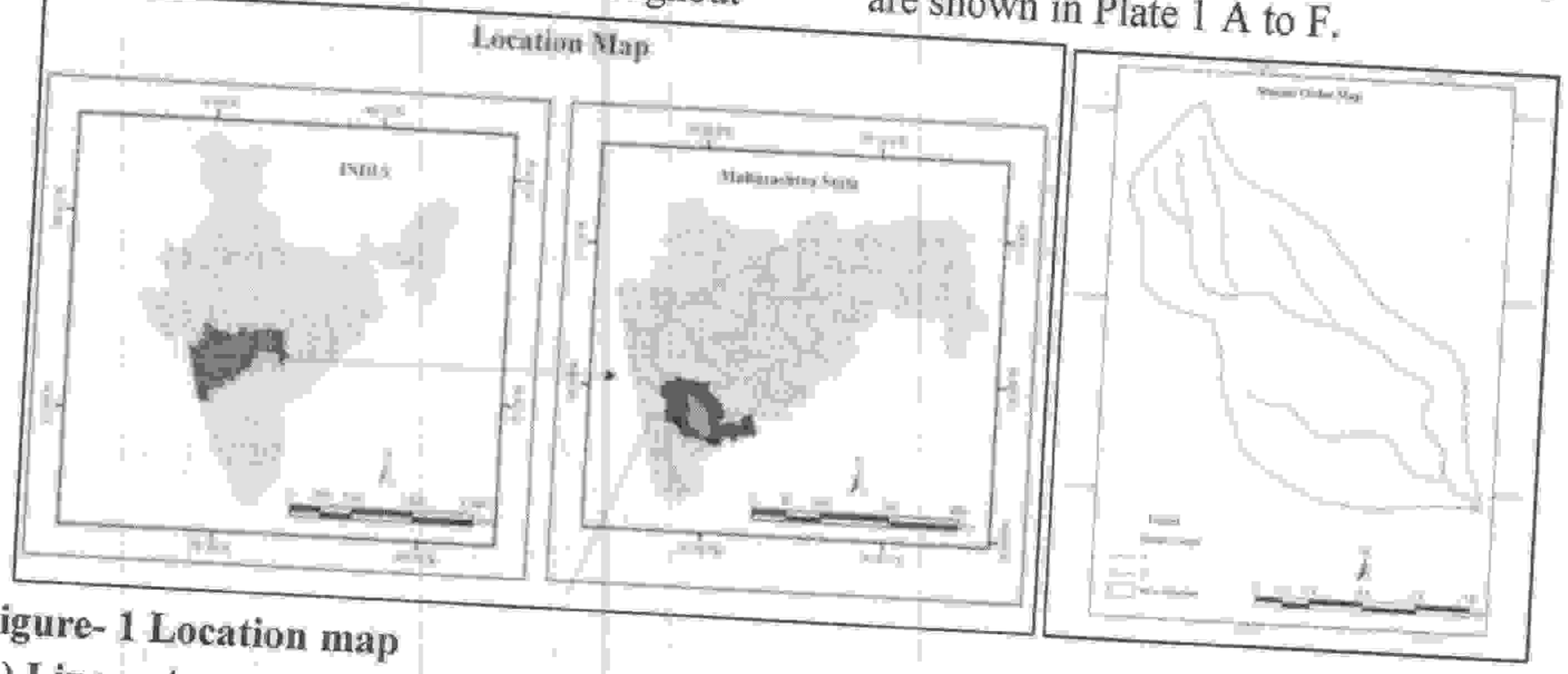

Figure- 1 Location map

A) Linear Aspects

Linear aspects that includes stream order, stream length, mean stream length, stream length ratio and bifurcation ratio were determined and results have been given in Table 2.

Stream Order (Nu)

To determine the stream ordering system of the study area Strahler's (1952) stream ordering system has been used. The stream ordering map (Figure 1.2) shows that the study area is a second order stream. The number of streams (N) of each order (U) of the Yerla basin is shown in Table 2.

Stream Number

The total order wise stream segments are known as stream number. Horton (1945) stated that the number of stream segments of each order form an inverse geometric sequence with stream order number. The negative correlation observed between stream order and number of streams in the study area (Table 2).

Stream Length (L)

The total stream length of the study area is 8.5 km (Table 2). It reveals that the total stream length 58.58 per cent is consist of the first order streams. Longer lengths of streams are generally indicative of flatter gradient and coarse texture. Smaller lengths of streams are generally indicative of larger slopes and finer texture in the study area (Plate 1 E).

Morphometric Parameters	Formula	Reference
Stream Order (U)	Hierarchical order	Strahler (1964)

Stream Length (Lu)	Length of the stream	Horton (1945)
Mean Stream Length (Lsm)	Lsm = Lu/Nu Where, Lu = Stream length of order 'U', Nu=Total number of stream segments of order 'U'	Horton (1945)
Stream Length Ratio (RL)	RL = Lu/Lu-1 Where, Lu = Total stream length of order 'U' Lu-1 = The total stream length of its next lower order	Horton (1945)
Bifurcation Ratio (Rb)	Rb = Nu/Nu+1 Where, Nu = Total number of stream segment of order 'U'; Nu+1 = Number of segment of next higher order	Schumn (1956)
Drainage Density (Dd)	Dd = L/A Where, L = Total length of streams of all orders A = Area of the basin (km^2)	Horton (1945)
Stream Frequency (Fs)	Fs = N/A Where, N = Total number of stream A = Areas of the basin (km^2)	Horton (1945)
Drainage Texture (Rt)	Rt = Nu/P Where, Nu = Total number of streams of all orders, P=Perimeter of basin km	Horton (1945)
Circulatory Ratio (Rc)	$Rc = 4\pi A/Lp^2$ Where, A=Area of the basin Lp=Perimeter of the basin	Miller (1953)
Elongation Ratio (Re)	$Re=(2 \times (A / \pi)^{0.5}) / Lb$ Where, A=Area of watershed, π=3.14, Lb=Basin length	Schumn (1956)
Compactness Coefficients (Cc)	$Cc = 0.2821 P/A^{0.5}$ A = areas of basin (km^2), P = basin perimeter (km)	Horton (1945)
Basin Relief (Bh)	Vertical distance between the lowest and highest points of watershed	Schumn (1956)
Relief Ratio (Rh)	Rh = H/Lb Where, H = Total relief (relative relief) of the basin in km; Lb = Basin length	Schumn (1956)
Length of Over-land flow (Lg)	Lg = 1/Dd*2 Where, Dd = Drainage density	Horton (1945)
Chanel Sinuosity	Channel sinuosity = O_L / E_L Where, O_L = observed path of a stream; E_L = expected straight path of a stream	Schumm (1963)

Table- 1 Formulae for computation of morphometric parameters

Slope (%)	Height (m)	Form Factor (Ff)	Circularity Ratio (Rc)	Elongation Ratio (Re)
0-43.38	749-940	0.29	0.61	0.61

Drainage Density (Dd)	Stream Frequency (km/km^2)	Compactness Coefficient (Cc)	Length of Overland flow (Lg)
2.18	1.53	0.99	0.23

Area (km^2)	Basin Length (km)	Perimeter (P) (km)	Number of Streams		Stream Length (km) (Lu)		Mean Stream Length (km)	Bifurcation Ratio (Rb)	
			I	II	I	II		I	II
3.90	3.68	8.99	5	1	4.98	3.52	4.25	1.41	

Table- 2 Linear and areal aspects of the study area

Mean Stream Length

The orderwise mean stream length varies from 4.98 km to 3.52 km. The positive correlation coefficient between stream order and mean stream length is observed (Table 2).

Bifurcation Ratio (Rb)

Horton (1945) defined the bifurcation ratio as the ratio between the number of streams of any given order to the number in the next lower order. Bifurcation ratio of the area is low i.e. 1.41 indicates the study area lies in the flatter surface.

B) Relief Aspects

Absolute relief of the Yerla River basin is 940 m. Relative relief is the difference between the highest (940 m) and lowest (749 m) points in the basin. Relative relief of the Yerla River basin is 191 m indicates moderately high relative relief, which is well illustrated in DEM (Figure 3). DEM is a digital representation of surface topography. Slope map (Figure 3) illustrated that all the margins of plateau have greater slope between 0 and 43.38 degrees. Slope is decreasing from source to outlet region of the study area. Steep slope is observed in the source region of Ganeshwadi stream (Photo 1 A, D). The direction of the slope on the entire relief of the study area is illustrated in aspect map (Figure 3). The stream flows south to south east direction. Middle portion is covered by flat plateau surface. The relief measurements are tabulated in Table 2.

Relief Ratio

The relief ratio (Rh) of mainstream relief to horizontal distance along the largest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumm, 1956) (Table 1). The relief ratio normally increases with decreasing drainage area and size of basin of a given drainage basin. The value of the relief ratio of the study area is value of 191 m.

C) Areal Aspects

Drainage Area (A)

The drainage area of a study area is the surface area located within the watershed basin boundary. Drainage area of the study area is 3.90 sq. km (Table 2). It is observed that mean areal extent of the drainage basin increases as the order of stream increases.

Basin Perimeter

Basin perimeter of the study area has been measured from the topographic sheets. The basin perimeter of the drainage basin is 8.99 km (Table 2). Generally, both drainage parameters, stream order and basin perimeter has strong positively correlated. Perimeter of the Yerla River increases as the order of the basin increases.

Basin Length

The basin length was measured of the study area from the toposheets. Table 2 shows basin length of the study area is 3.68 km. It is observed that basin length increases as stream order increases.

Drainage Density (Dd)

Drainage density is the sum of stream lengths per unit area (Horton, 1945). The drainage density of the stream is low i.e. 2.18 km / km^2 (Table 2) indicating coarse drainage texture. Low drainage density of study area indicates highly resistant or permeable sub-soil material and low relief.

Stream Frequency (Fs)

Stream or channel frequency is the total number of streams per unit area (Horton, 1945). The drainage density of the study

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area is 1.53 streams/km^2 indicating poor stream frequency (Table 2).

Drainage Texture (T)

According to Smith (1950) five different types of drainage textures have been classified based on the drainage density. The drainage density values of the study area is 2.18 indicating coarse drainage texture (Table 2).

Circularity Ratio (Rc)

The circularity ratio (Rc) has been used as an areal aspect and is expressed as the ratio of basin area of a circle having the same perimeter as the basin (Strahler, 1964). The circularity ratio of the study area is 0.61 indicates elongated shape.

Form Factor (Ff)

Form factor is defined as the ratio of basin area to the square of the basin length (Horton, 1945). The values of form factor would always be less than 0.78 Smaller the value of Ff means more elongated will be the basin. The form factor ratio of the study area is 0.29 indicates that the area has a elongated shape (Table 2).

Compactness Coefficient (Cc)

Compactness coefficient is used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. In the study area value of Cc is 0.99 indicates less hazardous basin (Table 2).

Elongation Ratio (Re)

Schumm (1956) defined elongation ratio as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. Elongation ratio of the study area is 0.61 indicates that the basin falls in the less elongated category and showing high relief and steep ground slope (Table 2).

Length of Overland Flow (Lo)

It is the length of water over the ground before it gets concentrated into define stream channels (Horton, 1945) (Table 1). The length of overland flow approximately is equal to half of the reciprocal of drainage density (Horton, 1945). The length of the overland flow of the study area is 2.23 km.

Cross Sections

First cross section is taken on the upper reaches on mainstream from 1.21 km from its source. The left bank is having steep slope than the right bank. Silts and clay contents are more on both banks occupied by agricultural lands. The channel width and depth of the area is 44.6 and 1.61 m respectively with 74.03 m^2 cross sectional area (Figure 2, CS1). Second cross section is taken on first order east stream located from 0.55 km from the source of mainstream. Here, channel width and depth is 5.4 and 1.15 m, cross sectional area is 6.25 m^2 (Figure 2, CS2). Both banks has gentle slopes and occupied by agricultural land.

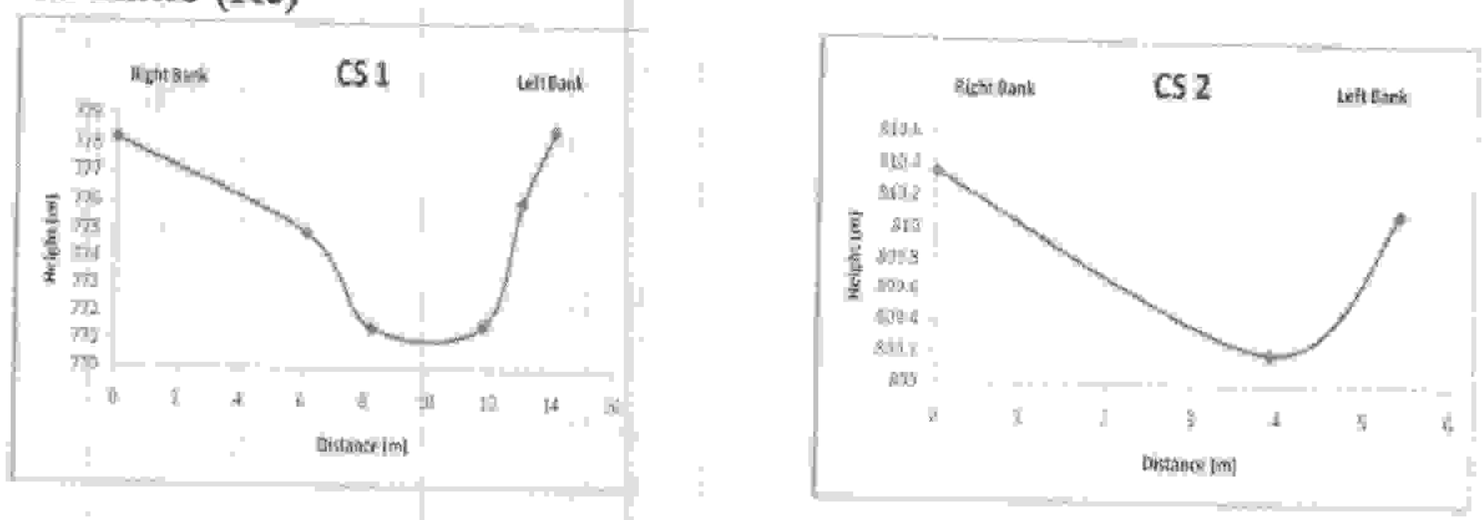
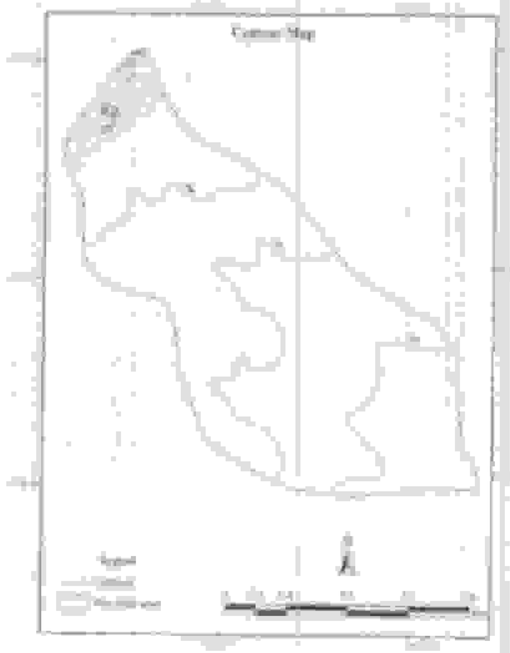
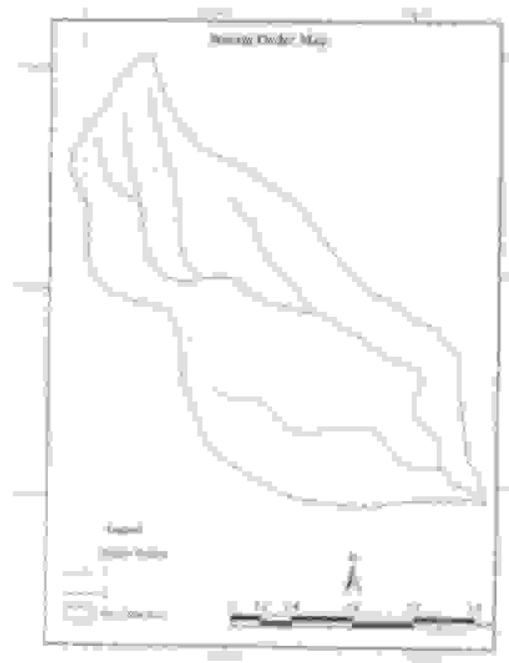


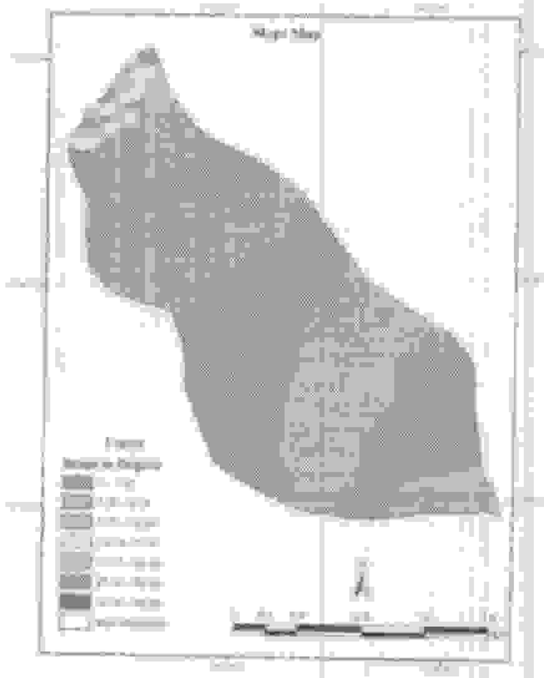
Figure 2 Cross section locations at Ganeshwadi Stream



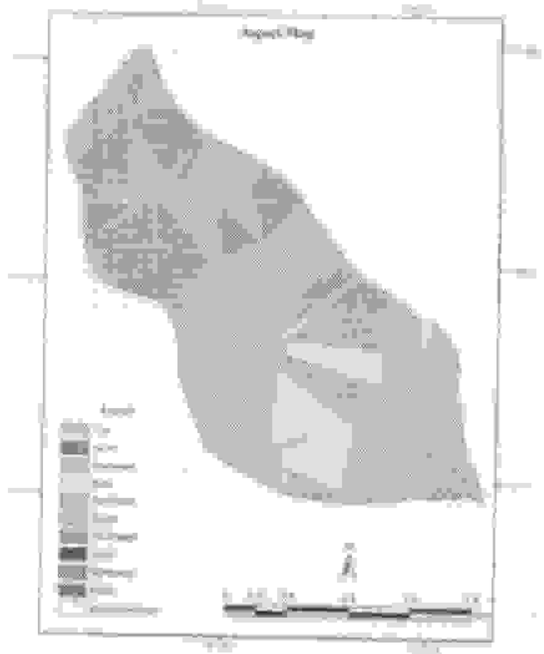
A. Contour map



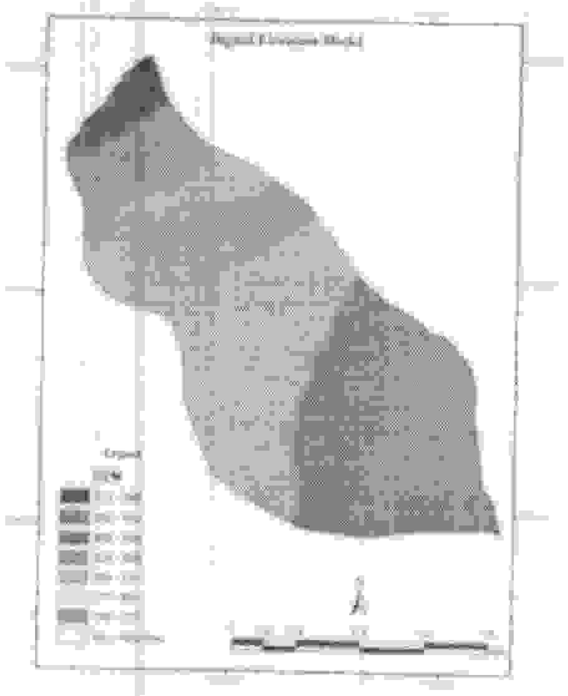
B. Stream Order map



C. Slope map

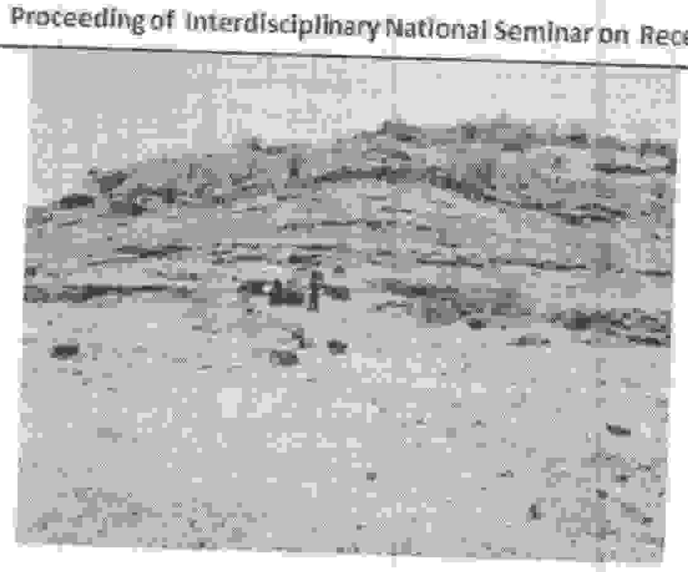


D. Aspect map



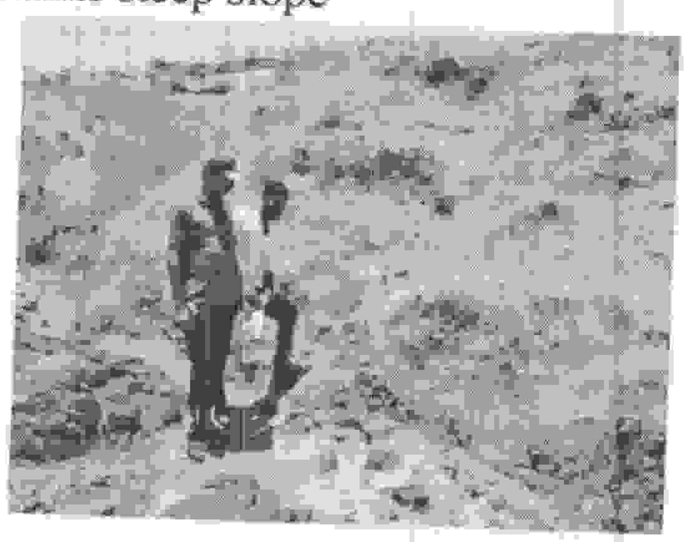
E. Digital Elevation Modal

Figure- 3 Various maps of the study area



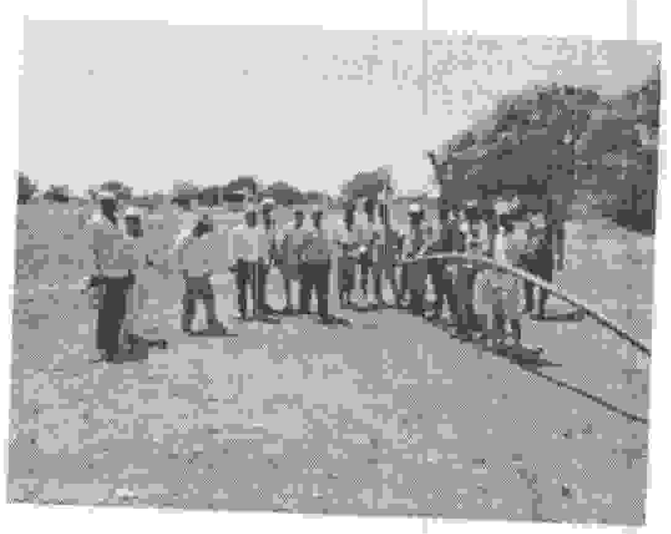
A. Stony field in the upper reaches, area exhibits steep slope

B. Block disintegration is common phenomenon



C. Calcareous content

D. Deep gorges in the source region



E. Interaction with villagers

F. 45 ft deep well exhibits no water in April 2018

Plate 1 Photographs of the study area

Result and Conclusion

Ganeshwadi stream is developed on third order tributary of the Yerla River in the Deccan Trap region. Drainage density and stream frequency values of the study area are 2.18 km/km^2 and 1.53 streams/km^2 respectively indicates coarse texture due to highly resistant sub-soil material and low relief. The calculated Millers form factor ratio(0.29), circularity ratio (0.61), elongation value (0.61) indicates less elongated shape of the area. Compactness coefficient value of the study area is 0.99 indicates less hazardous micro watershed. Length of overland flow is 0.23 km. The area has 191m of moderately high relative relief. Absolute relief of the area is 940 m. The mean bifurcation ratio of the area is 1.41 is low indicates that structure does

not exercise a dominant influence of the drainage pattern. The area is characterised by an undulating topography with an average slope of about 5.22 percent. Slope of the area ranges between 0 to 43.38 degrees of which 90 percent area lies below 12.24 degrees. Aspect map shows slope is towards east and south east. These results will be of vast utility for a comprehensive water resource management at watershed level.

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