Morphometric Analysis using Arc GIS Techniques A Case Study of Dharurvagu, South Eastern Part of Kurnool District, Andhra Pradesh, India

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Abstract: ***Morphometry is the measurement and mathematical analysis of configuration of Earth surface, shape and dimensions of its landforms. The main purpose of the work is to discover holistic stream properties from the measurement of various stream attributes. Dharurvagu located in the south eastern part of Kurnool District is selected for this study. The study area is located in the Survey of India Toposheet nos. 57I/4, and I/8, lies between North latitude 1509'38'' to 1504'53'' and East longitude 7806'37'' to 78016'50''. The catchment area of Dharurvagu is 80.4 Sq. km, partially covered in Owk, Kolimigundla and Sanjamala mandals in Kurnool District, Andhra Pradesh. The quantitative drainage analysis is done aspect wise such as linear aspects and aerial aspects. The linear aspects include stream order, stream number, stream length, and bifurcation ratio, mean length of stream orders, stream length ratio, mean stream length ratio, and form factor. Areal aspects comprise drainage density, stream frequency, and texture ratio, constant of channel length, maintenance length of the overland flow. Morphometric analysis is carried out using Arc GIS (9.2) software, an advanced tool for measuring the drainage basin, the earth surface dimensions of landform and shape with in the short time. The direction of the basin is in NE to SW. The drainage density, 1.90 indicates that the basin has porous nature and very coarse grained texture and the region has highly permeable subsoil materials, homogenous rock type, low runoff zone, loose soil with high infiltration capacity. The entire basin elongation ratio (0.5198) indicates that the basin is elongated shape and less prone to overflowing. The basin bifurcation ratio is 3.66 which indicate dendritic drainage type. Based on the above results, it is inferred that the area is underlined by limestone and ground water prospects are good. Using Arc GIS software exact representation and quantitative measurements with more accurate results is possible in a less time.***

Keywords: Morphometric analysis, Mapping, Arc- GIS, Ground water Prospects, Dharurvagu, Kurnool District.

1. Introduction

Morphometric studies in the field of hydrology were initiated in the 1940s and 1950s. Morphometry is the measurement and mathematical analysis of configuration of the Earth surface and the shape dimensions of its landforms. Structural and geomorphological features control the directions of flow of the tributaries. Drainage morphometric analysis gives overall view of the terrain information like hydrological, lithological, slope, relief, variations in the watershed, ground water recharge, porosity, soil characteristics, flood peak, rock resistant, permeability and runoff intensity and is useful for geological, hydrological, ground water prospects, civil engineering and environmental studies.

A Geographic information system (GIS) integrates hardware, software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information. GIS allows viewing, understanding question, interpreting, and visualizing data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. GIS helps to answer question and solve problems by looking data in a way that is quickly understood and easily shared. GIS technology can be integrated into any enterprise information system framework. More than ever in histories one must manage preserve and restore natural resources and decision makers who must take action need a complete picture of the issues. Arc GIS platform helps to gain a deeper understanding of the problems and bring more accurate information and less guesswork to the table. Arc GIS (9.2) software is powerful tool found a significant role in scientific applications (http://webhelp.esri.com/arcgisdesktop/9.2). The main purpose of the work is to study holistic stream properties from the measurement of various stream attributes and detailed ground water investigation for the purpose of farming. Using Arc GIS (9.2) software techniques for analysis, mapping and quantitative measurements are carried out with accurate results and representations within less time and least cost and developed viable methodology for producing GIS data models for morphometric analysis

1.1 Study Area

Dharurvagu located in the south eastern part of Kurnool District is selected for morphometric analysis. The area is located in the Survey of India Toposheet nos. 57I/4, and I/8, and lies between North latitude 15^0 09'38'' to 15^0 04'53'' and East longitude $78^0$06'37'' to $78^0$16'50''. The catchment area of Dharurvagu drainage basin is 80.4 Sq. km, partially covered in Owk, Kolimigundla and Sanjamala mandals in Kurnool District, Andhra Pradesh (Fig: 1). Dharurvagu drainage basin is a part of the Kurnool group of formations consisting of Narji limestone, Paniam Quartzite and Owk shale (GSI,1999). Major part is covered with Narji limestone and has flat terrain. Agriculture is the main occupation of the people in the study area.

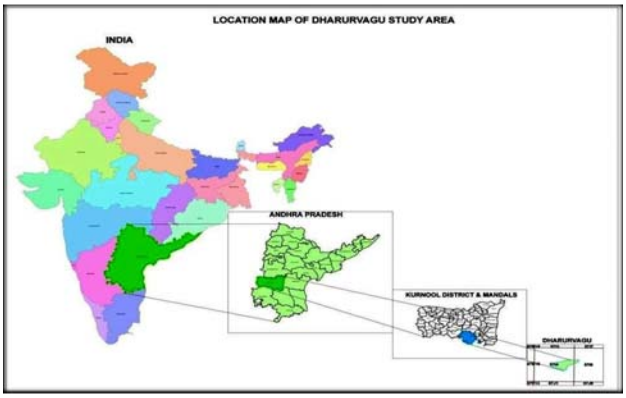

Figure 1: Location Map

2. Methodology

The major goal of the study is to develop a viable methodology for producing GIS data models for drainage morphometric analysis and discover holistic stream properties from the measurement of various stream attributes using Arc GIS (9.2) software. This study has following steps illustrated in Fig: 2.

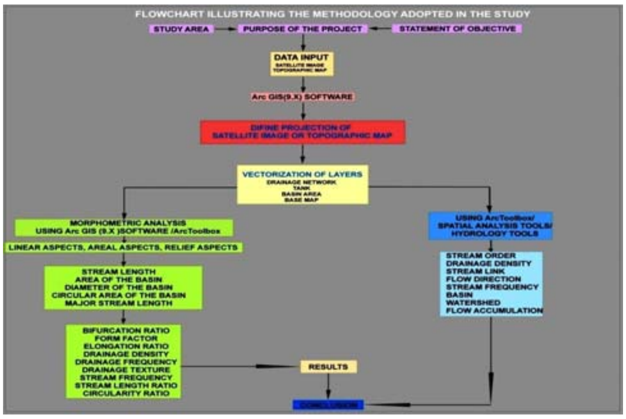

Figure 1: The Drainage Basin Analysis

The drainage basin analysis is carried out quantitatively using Arc GIS 9.2. Using the vectorization of Dharurvagu base map and drainage network map all measurements in the Arc GIS 9.2, like linear aspects such as stream length, main stream length, area of the basin circular area of the basin, and diameter of the basin were calculated. With the help of Conversion tools in the Arc tool box, the data is converted in to raster to vector form. Coverage-tool and personal Geodatabase tools were used in the area to estimate stream length. Topology tool was used to edit line errors like polygon, point and node of overlapping, dangles, and gaps for accuracy. With the help of data management tools projection and transformation was made by registering of raster image with satellite image and topographical map. Hydrology tools were used for creation of drainage basin, delineation of sub-watersheds, flow direction, Stream order and stream intersection points. After this process, Bifurcation ratio, form factor, elongation ration, drainage density, drainage frequency, stream frequency and drainage texture were analyzed. The drainage basin analysis was carried out quantitatively aspect wise such as linear aspects and aerial aspects. In the linear aspects, stream order, stream length, bifurcation ratio, mean length, stream length ratio, and mean length ratio were analyzed. In the basin geometry factors like drainage density, stream frequency, texture ratio, constant of channel maintenance and the length of the overland flow were carried out. The method of calculation and the procedure involved in estimating each parameter is briefly described.

3. Results and Discussion

3.1 Morphometric analysis of the Drainage Basin

3.1.1 Stream order (U)

The first step in the drainage basin analysis is designation of stream orders which is not only the index, the size and scale, but also to afford and approximate index of the amount of stream flow, which can be produced by a particular network, stream order, number which is directly proportional to the size, of the contributing watershed. The stream order is a measure of the degree of stream branching within a watershed. Each length of stream is indicated by its order (Fig. 3).

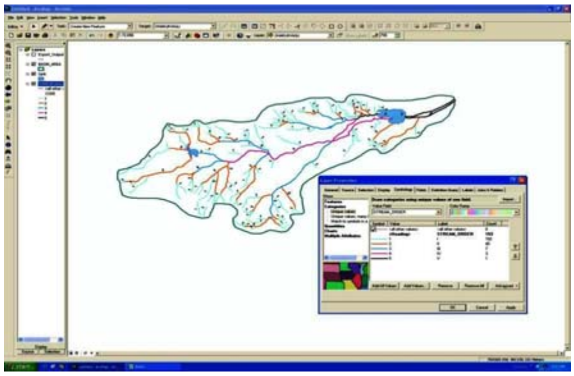

Figure 2: Stream Lengths

3.1.2 Stream Number (Nu)

The count of stream channel in its order is known as stream number. The number of stream segments decreases as the order increases. The higher amount stream order indicates lesser permeability and infiltration. Stream number is directly proportional to size of contributing watershed, to channel dimensions. It is obvious that the number of streams of any given order will be fewer than for the next lower order but more numerous than for the next higher order. The number of streams decreases as the stream order increases. In the present study the order wise stream numbers estimated are given in the Table 1 below.

Table 1: Order wise Stream Numbers

Stream order (U)	Stream number(Nu)
I	102
II	41
III	7
IV	3
V	1

3.1.3 Bifurcation Ratio (Rb)

Bifurcation ratio is defined as number of streams of one order to the next higher order.

R b = Nu / Nu+1 = Average (Rb) = 3.6695
Nu = stream number
Nu +1 = stream number of higher order

The bifurcation ratio, for a given density of drainage lines, is very much controlled by basin shape and shows a very little variation (ranging between 3 and 5) in homogeneous bedrock from one area to another (Chorley, 1984). The bifurcation ratio will not be precisely the same from one order to the next because of the possibility of variations in watershed geometry and the lithology, but tends to be a constant throughout the series. When algorithm of number of streams is plotted against order, most drainage networks show a liner relationship, with small deviation from straight line (Fig 4)

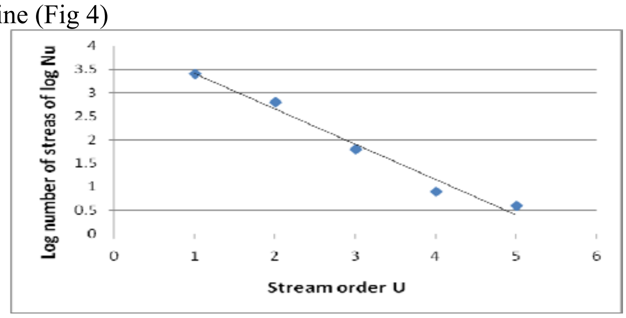

Figure 4: Drainage networks relationship

Bifurcation ratios characteristically range between 3 and 5 for watershed (Gokhale, 2005) in which geologic structures do not distort the drainage pattern. The hypothetical minimum value of 2 is rarely approached under natural conditions. Abnormally higher bifurcation ratios might be expected in regions of steeply dipping rock strata where narrow strike valleys are confirmed between hogback ridges. Elongated basins with higher Bifurcation ratios yield a low but extended peak flow while rounded basins with low ratios procure sharp peak. Bifurcation ratio is mainly controlled by the basin shape and is not only influences the landscape and morphometry but also controls the surface run off. The bifurcation ratio calculated is 3.6695.The direct relationship of bifurcation ratio to stream order is attributed to the semi-arid climate characterized by short- duration flash floods.

3.1.4 Stream Length Ratio (RL)

The length ratio R_L (which is ratio of mean length Lu of segments of order u to mean length of segments of the next lower order **$L_U/(L_U-1)$** tends to be constant through the successive orders of watersheds. It indicates that the stream lengths are decreasing with increasing the order of stream as shown in Fig: 5.

$$R_L = Lu/(Lu-1) = 0.612345$$

Lu = Stream length
Lu-1 = Stream length 0f next lower order

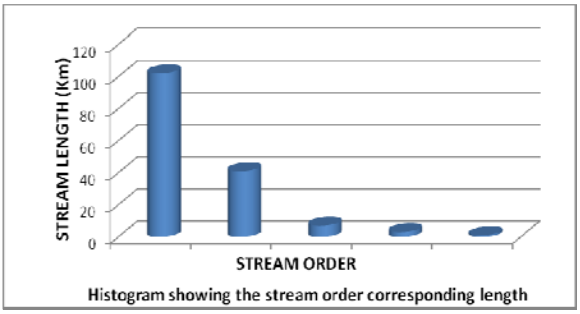

Figure 5: Stream Length Vs Stream Order

3.1.5 Stream length of overland flow (Lf)

Surface run off flows a system of down slope flow forms the drainage divide (basin perimeter) to the nearest channel. This flow net, comprising a family of orthogonal curves with respect to the topographic contours, locally

Converges or diverges from parallelism depending upon position in the basin. The length of overland flow L_f as the length of flow, projected to the horizontal, of non-channel flow from a point on the drainage divide to a point on the adjacent stream channel. Length of over land flow is one of the most important independent variables affecting both hydrologic and physiographic development of drainage basins.

3.1.6 Basin area (Au)

The drainage basin area is one of the important parameters like that of the length of draining - the basin. The area of a given order is defined as the total area projected on a horizontal plane contribution overland flow to the channel segments of the given order, which includes all tributaries of the lower order.

The Dharurvagu drainage basin area = 80.357967 sq. Km.

3.1.7 Stream Frequency (FU)

Stream frequency is the number of streams segment per unit area and relates to the importance to ground water recharge characteristics in a river basin. It is obtained by dividing the total number of stream to the total drainage basin area. The stream frequency for the study area is 1.93.

$$Fu = Nu/A$$

Where A = Area of the basin (80.357 sq. km)
Nu = Stream number (154 sq.km)

3.1.8 Form factor (Rf)

The ratio of the basin area to the square of basin length is called the form factor. It is a less property and is used as a quantitative expression of the shape of basin form.

$$R_f = A/L^2$$

Where A = Area of the basin (80.357 sq. km)
L^2 = Basin length $(18.93)^2$

<5 low values- have flattered and flow for longer durations
>5 high values – have high peaks and flows shorter duration

3.1.9 Circulatory ratios (RC)

Circulatory ratio (**R_C**) is the ratio of basin area Au, the area of circle Ac having the same perimeter as the basin. The circulatory ratio of the study area is 0.2794

$$\mathbf{R_C = Au / Ac}$$

Where Au = Total basin area (80.357 sq. km)
Ac = Circle area with the same perimeter (287.5)

As the basin circulatory ratio reaches unity (one), the basin attains a fan shape and is prone for high floods.

3.1.10 Elongation Ratio (Re)

Elongation ratio is the ratio of diameter of the circle of the same area in the basin to the maximum basin length.

$$\mathbf{R_e = D / L\ (max)}$$

Where D = Diameter of the same area circle (9.843)
L (max) = Max basin length (18.9345)

Higher the ratio lesser will be flood peak. This ratio varies between1.0 to 6.0 over wide variety of climatic and geological formations. Values in range of 0.6 to 0.8 are generally associated with strong relief and steep ground slope, whereas values nearing 1.0 are typical of very low relief. The high values circularity ratio and the elongated ratio suggest that the basins are more elongated. Low form factor and high circulatory ratio suggest that the basin is prone for high floods.

3.1.11 Basin configuration

For determining the shape of the drainage basin, a quantitative study was made using form factor, Circularity Ratio and elongation ratios. In any drainage basin excess run off and sediment production are influenced by relief. The spatial aspects of the basin are further studied through parameters like relief ratio and gradient ratio.

3.1.12 Drainage density (Dd)

It is measured as a sum of the channel lengths per unit area and obtained by dividing the total stream length by total area of the basin. Drainage density is controlled by the type of formations in the basin areas with impervious formations will have higher drainage density than those with pervious formations (Gokhale, 2005). In the Study area drainage density is 1.9006.

$$\boldsymbol{D_d = \sum Lu / Au}$$

Where $\sum$ LU = Mean channel length
Au = Unit area 80.757 Sq.km

In general low drainage density is favored in regions of high resistant or highly permeable sub soil materials, under dense vegetation cover and where relief is low. High drainage density is favored in regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief. The drainage density is governed by the factors like rock type, run off intensity, soil type, infiltration capacity and percentage of rocky area.

3.1.13 Drainage frequency

It is a measure of number of stream segments per unit area and is therefore depend on the stream order, whereas drainage density is independent of stream order.

3.1.14 Drainage pattern

It refers to the orderly spatial arrangement of geologic, topographic or vegetation features. Drainage pattern is an important element in geologic interpretation of aerial photographs. The study area has dendritic drainage type pattern. It is characterized by a tree like branching system in which tributaries join the gently curving main stream at acute angles. The occurrence of this drainage system indicates homogeneous, uniform soil and rock material (GSI, 2002).

3.1.15 Drainage Texture

Drainage texture is also classified on the basis of density of dissection or texture (GSI, 2002). Drainage texture is the product of drainage density and stream frequency. It is expressed the same as the drainage and classification is given below. High relief ratio brings high discharge of surface water in a short duration. Small relief ratio indicates the erosional development of the drainage basin (Table 2). The study area shows a very coarse grain texture (1.90).

Table 2: The Erosional development of the drainage basin

S.NO	Drainage density	Texture
1	< 2	Very coarse
2	2 - 4	Coarse
3	4 - 6	Moderate
4	6 - 8	Fine
5	> 8	Very fine

3.1.16 Arc GIS (9.x)

Above all the results in the Morphometric analysis quantitatively done in the Arc GIS (9.2) software, is a powerful tool and advanced very easily measuring basin length, basin area, automatic creating of drainage network, stream order, stream link, circular area of the basin etc.. Figures (8,9,10,11,12,13) show how to use in the creation of basin, delineation of drainage network, stream link, flow direction and stream order and figures (14,15,16,17,18,19) show how to carry out Dharurvagu drainage Morphometric analysis quantitatively using with Arc toolbox. Using Arc GIS techniques within the short time the work of mapping, statistics, analysis, displaying the data and output is done. In the process of Morphometric analysis Arc GIS tools like Analysis Tools, Conversion Tools, Data management Tools, Geostatistical Tools and Spatial analysis Tools etc. are used. Using all these tools, Morphometric analysis of Dharurvagu drainage basin is carried out quantitatively using Arc GIS (9.2) software. Vectorization of the study area base map layers like tank, settlement, drainage network, road network basin shape etc. using (Arc GIS 9.2) with editor tool bar and preparing layout for all layers (Fig. 7).

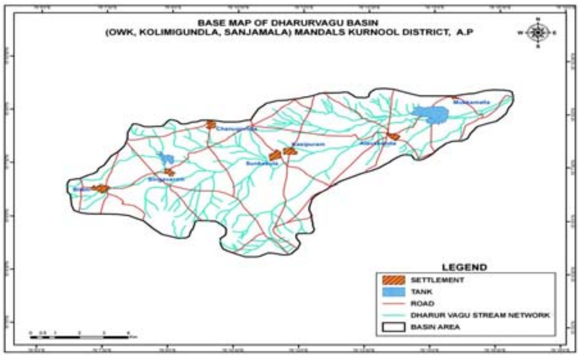

Figure 7: Base map of Dharurvagu Basin

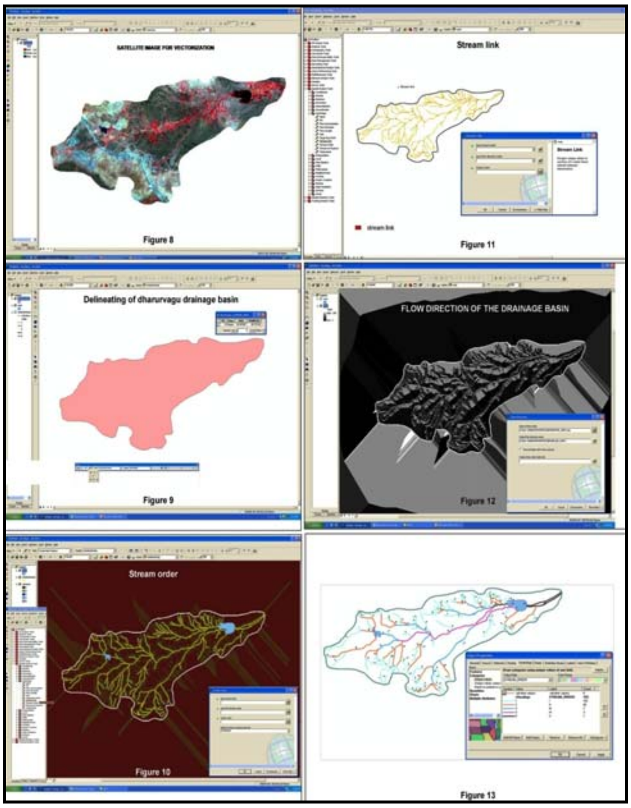

Figure 8: Dharur Vagu, Morphometric Quantitative Analysis in Arc-GIS

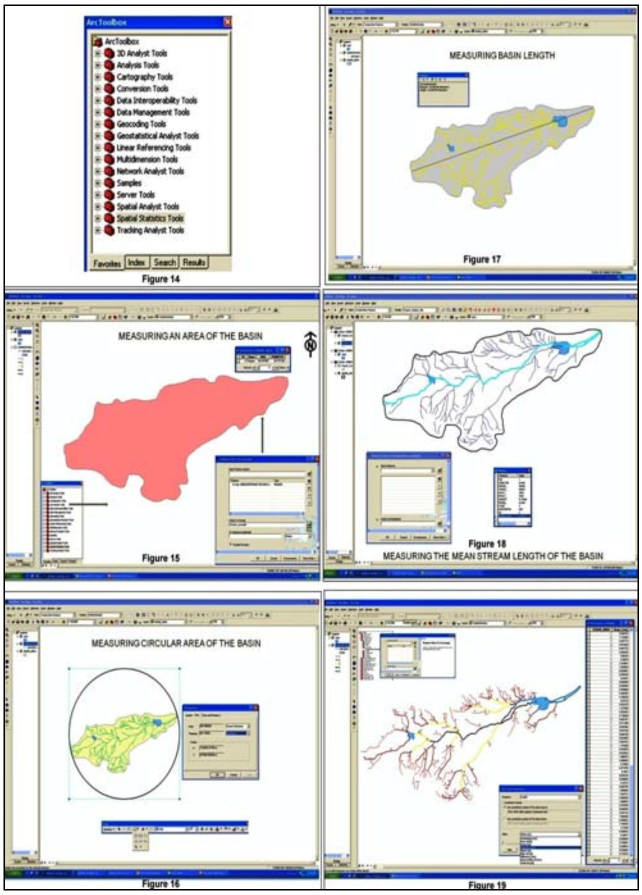

Figure 9: Dharur Vagu, Morphometric Quantitative Analysis in Arc-GIS

Table 3: Morphometry of Dharur Vagu drainage basin

Stream Order (U)	*Stream number (Nu)*	*Stream length (Lu) km*	*Bifurcation ratio (Rb) = Nu/Nu+1*	*Stream length ratio Rl = Lu/Lu-1*
I	102	72.644	2.4878	---------
II	41	36.30	5.8714	0.4997
III	7	19.667	2.3337	0.5417
IV	3	14.378	3	0.7310
V	1	9.713	-------	0.6769

Form factor: $(R_f) = A / L^2$ $80.357 / (18.93)^2 = 0.02244$

Bifurcation ratio: Average $(R_b) = 3.6695$

Circulatory ratio: $(R_c) = Au / Ac$ $80.357/287.5 = 0.2794$.

Elongation ratio: (Re)=D/L(max)9.843/18.9345=0.5198

Drainage density :(Dd)=$\sum$ LU /AU 152.7267/80.757 = 1.9006

Texture: Coarse grain texture 1.90

4. Conclusions

The direction of the Dharurvagu drainage basin is NE to SW. The study area is underlined by a part of the Kurnool group of rocks consisting of Narji limestone, Paniyam

Quartzites and Owk shale. The drainage density, 1.90 indicates that the basin has porous nature and very coarse grained texture and the region has highly permeable subsoil materials, homogenous rock type, low runoff zone, loose soil with high infiltration capacity. The entire basin elongation ratio (0.5198) indicates that the basin is elongated shape and less prone to overflowing. The basin Bifurcation ratio is 3.66 which indicate dendritic drainage type. Based on the above results, it is inferred that the area is underlined by limestone. Dharurvagu drainage basin is having good ground water prospects. Arc GIS 9.2 software tools like Hydrology, Data management, Geo statistical, Analysis tools etc. are very useful for mapping, analysis and representation for fast and accurate results in less time. Drainage morphometric analysis gives overall view of the terrain information, like hydrological, lithological, slope, relief, variations in the watershed, ground water recharge, porosity, soil characteristics, flood peak, rock resistant, permeability and runoff intensity. This information is useful for all geological, hydrological, ground water studies

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