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A REVIEW ON RUNOFF ESTIMATION OF VRISHABHAVATHI WATERSHED USING GIS

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ABSTRACT

Inthis project we came to know about various aspects of GIS (Geographical Information Systems). Geographic Co-ordinate system- Latitude and Longitude which is measured in degrees, minutes and seconds or decimal degrees. Different types of maps such as Digital Elevation model, contour, layout, continental network, soil and slope map. Toposheets- Coordinates, water bodies, streams, drainage network, road and railway network, settlement or habitation, contours, relative heights of bunds or river banks, legends, administrative boundary, topo index.Scale is the ratio of maps units to ground units. Watershed analysis includes division of water bodies such as region, basin, catchment, sub catchment, watershed, sub watershed, mini watershed, and micro watershed.

Geo referencing of topo sheets is the process of assigning real-world coordinates to each pixel of the raster.Morphometric analysis of the watershed includes quantitative analysis of size and shape. For example drainage networks, stream ordering, stream numbering, etc.

Keywords: Digital Elevation model(DEM), Toposheets, Runoff Estimation, Morphometric Analysis.

CHAPTER 1 INTRODUCTION TO GIS

1.1 **Geographic Information System (GIS)**

A Geographic Information System (GIS) is a system that creates, manages, analyzes and maps all types of data. GIS connects data to a map, integrating location data with all types of descriptive information. This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships and geographic context. The benefits include improved communication and efficiency as well as better management and decision making.

1.2 Important aspects in GIS

Important aspects in Geographic Information System (GIS):

- Mapping
- Measurement
- Monitoring
- Model Making
- Management

1.3 Advantages of GIS

The following are the advantages of GIS:

- **Improved decision making**- decisions can be made easilyas specific and detailed information can be presented about one or more locations.
- **Reduce costs and increase efficiency** – cost reduction particularly with regard to maintaining schedule, fleet movement,schedule timetable as so on.

- **Improves incommunication** between any involved organizations or departments as the visual format is easily understood by all.
- **Easy Record-Keeping**Geographical changecan be easily recorded usingGIS by those who are responsible for recording such changes.
- **Geographical Management**helps to know/ understand what is and/or will be occurring in a geographical space/area,& enable plan any course of action.

1.4 Disadvantages of GIS

The disadvantages of GIS are as follows :

- **High cost**– Geographic Information System is a very expensive software , It requires enormous amount of date inputs to be practical for some tasks , It makes it prone for error , It has relative loss of resolution and it has violation of privacy .

- **Availability in weaker areas**–Geographic Information System signal needs to be found in remote areas , It is too heavily relied on , The geographic error is increased as you get into a larger scale as the earth is round , Funding for GIS is needed because it is more costly , there will be a loss of knowledge of geography .

- **Cause of Mistakes**–GIS layers cause some costly mistakes when the property agents are to interpret the GIS map or the design of the engineer around the utility lines of the GIS , The data availability is a major issue , If the data is not available , then the GIS system is useless .

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- **Accuracy**–Another issue of analyzing the results from a GIS is that the results will only be as accurate as the data that they come from. So, the data may not be able to serve different contexts , particularly if the data is not applicable .

- **Complexity**–GIS systems are so complex , the technology behind GIS technology expands rapidly, causing GIS systems to have a high rate of obsolescence , As GIS is relatively new , integrating GIS data with traditional maps is difficult .

1.5 Functions of GIS

- Data Capturing and Storing
- Data Manipulation
- Querying
- Analysis
- Output
- Display

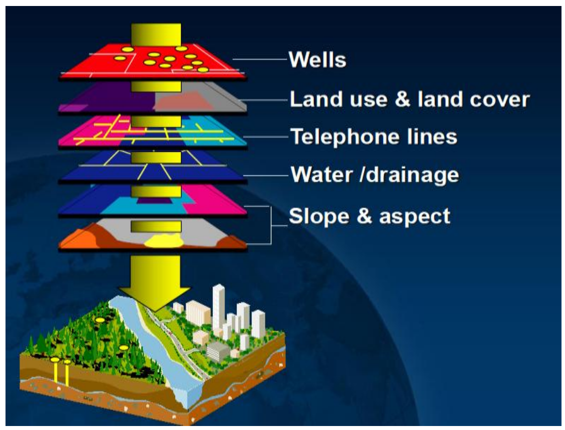

Fig 1: Layers used in GIS

CHAPTER 2 WATERSHED

2.1 Definition

- An area of land that drains or sheds water into a specific waterbody. It is a Hydrological Unit.
- It is a topographical delineated area drained by a stream system, from which Runoff is Resulted from one point to other point when precipitation is occurred.

2.2 Need of Watershed

Biological, physical, and chemical processes occurring within watersheds provide critical ecosystem functions and services that support plants and animals, including humans. Nutrient cycling, carbon storage, erosion control, soil formation, increased biodiversity, wildlife corridors, water storage, water filtration, flood controls, timber, and recreation are just a portion of the services provided by ecosystems within watersheds. For instance, riparian forests (forest habitat adjacent to streams) act as buffers to nonpoint source pollution and as corridors for animal foraging (Clipp& Anderson, 2014). The role of watersheds in nutrient cycling is important for stabilizing the environment at local and global scales (Allan & Castillo, 2007).

Forested headwater streams function to filter sediment and pollutants, which directly benefit humans and other animals in the form of clean water. At a larger scale, naturally vegetated floodplains provide storage and slow release of water. This benefit reduces the risk of flooding for anyone who lives near a river. Stable soils, an absence of pollutants, and a rich biological community are all characteristics of a healthy watershed (USEPA, 2017). When watersheds are degraded and pollution ensues, ecological benefits and services can be reduced or completely lost.

Within watersheds, much of the water transported from high to low elevations is carried through streams and rivers. Because this water carries sediments and pollutants from the land area it drains, impairments in rivers and streams are indicators of unhealthy watersheds caused by upstream land use. The U.S. Environmental Protection Agency reported that 44 percent of the nation's rivers and streams and 64 percent of lakes, ponds, and reservoirs were impaired or not clean enough to support their designated uses (2009).

The National Water Quality Inventory: Report to Congress documented that the leading causes of impairment to rivers, streams, lakes, ponds, and reservoirs are pathogens, habitat alterations, and toxins and pollutants in the water. The main causes for these pollutants include agricultural activities, hydrologic modifications, atmospheric deposition, and other unknown or unspecified sources (USEPA, 2009). If water bodies can no longer support their designated or natural uses, the environment and/or humans will be negatively impacted.

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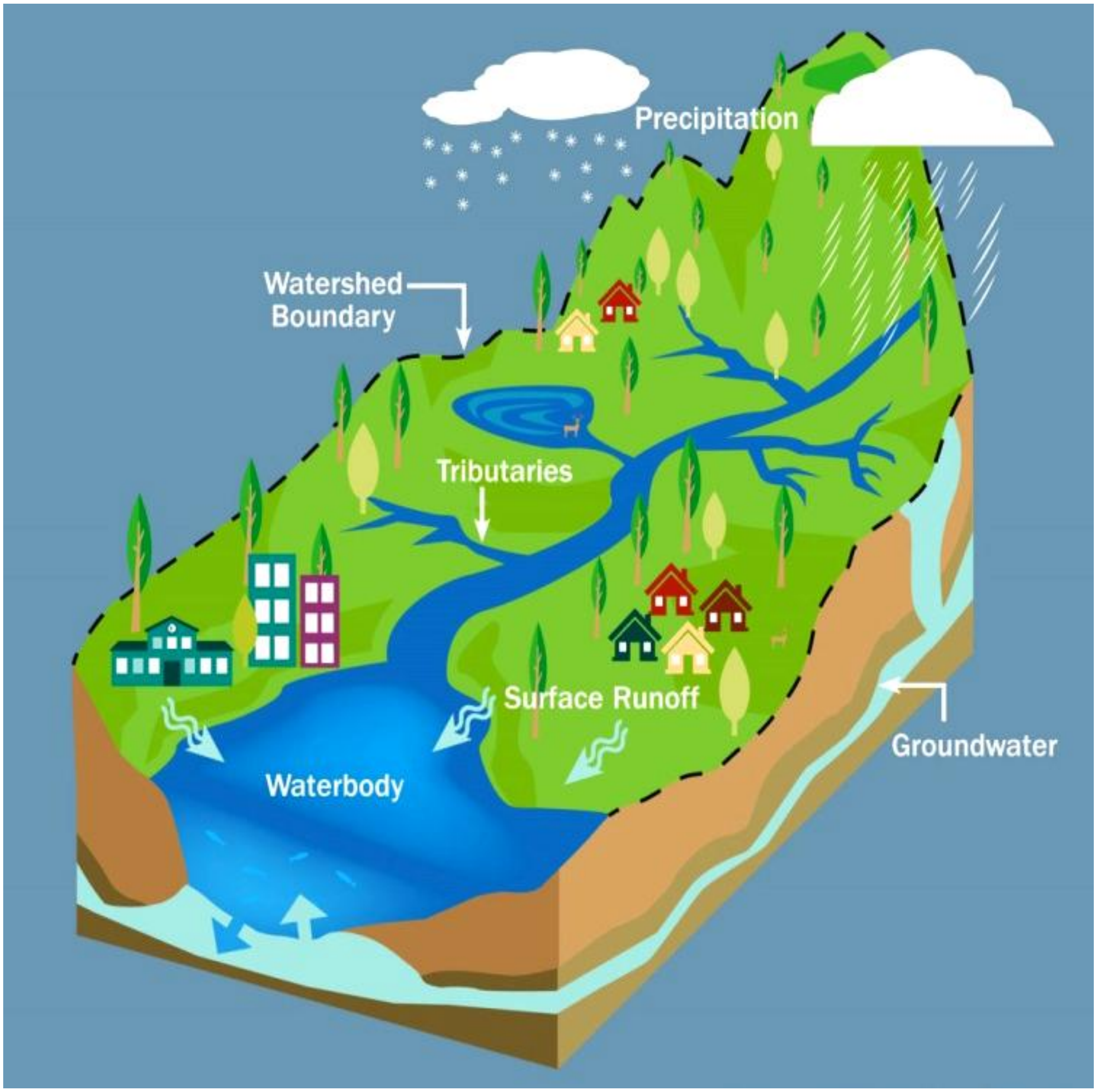

Fig 2: Watershed

2.3 WATERSHED CATEGORIES

- REGION
- BASIN
- CATCHMENT
- SUB CATCHMENT
- WATERSHED
- SUB WATERSHED
- MINI WATERSHED
- MICRO WATERSHED

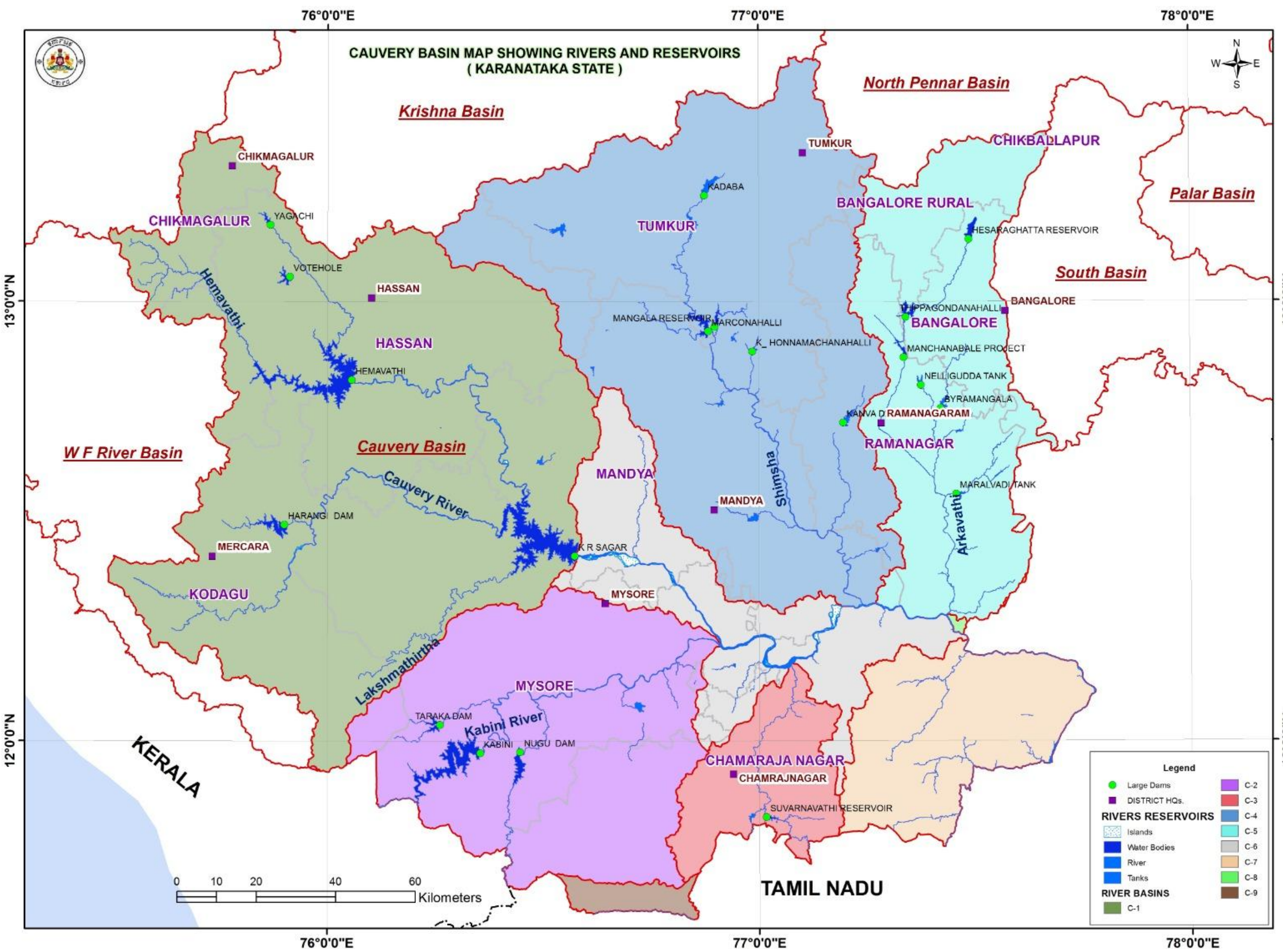

FIG 3:CAUVERY BASIN MAP SHOWING RIVERS & RESERVOIRS

- **REGION**

  It is the natural distribution and movement of water in the entire water management. Example, Bay of Bengal Region.

- **BASIN**

  Area drained by a river and its tributaries. Ex. Krishna Basin, Cauvery Basin.

- **CATCHMENT**

  Area through which runoff joins the stream.

- **SUB CATCHMENT**

  Division of catchment - A region of land where all surface runoff drains into a network of streams.

- **WATERSHED**

  Area containing set of streams and rivers. Area of land that drains or sheds water into a specific water body

- **SUB WATERSHED**

  Area containing set of stream tributaries within the watershed including mini watersheds and micro watersheds.

- **MINI WATERSHED**

  Small hydrological unit consisting least number of water bodies and micro watersheds.

- **MICRO WATERSHED**

  It is a small natural hydrological area which consists of rainfall runoff, small streams and drains joining a major stream.

2.4 Watershed Management

Every body of water (e.g., rivers, lakes, ponds, streams, and estuaries) has a watershed. The watershed is the area of land that drains or sheds water into a specific receiving waterbody, such as a lake or a river. As rainwater or melted snow runs downhill in the watershed, it collects and transports sediment and other materials and deposits them into the receiving waterbody.

Watershed management is a term used to describe the process of implementing land use practices and water management practices to protect and improve the quality of the water and other natural resources within a watershed by managing the use of those land and water resources in a comprehensive manner.

2.5Need of Watershed Management

- For Scientific management of Land and Water Resources.
- To know the balance Between Availability and Needs.
- To Regular monitoring to assess the status of development.

CHAPTER 3 Map Elements

3.1 SCALE

It is the ratio of map units to ground units

- SCALE CONVERSION eg, 1:50,000 scale
- In 0.5 km how many cm are there
- 1 km = 1000 m
- 1 m= 100 cm
- 1 km=100000 cm
- 0.5 km =50,000 cm

1cm on map = 50,000cm on ground

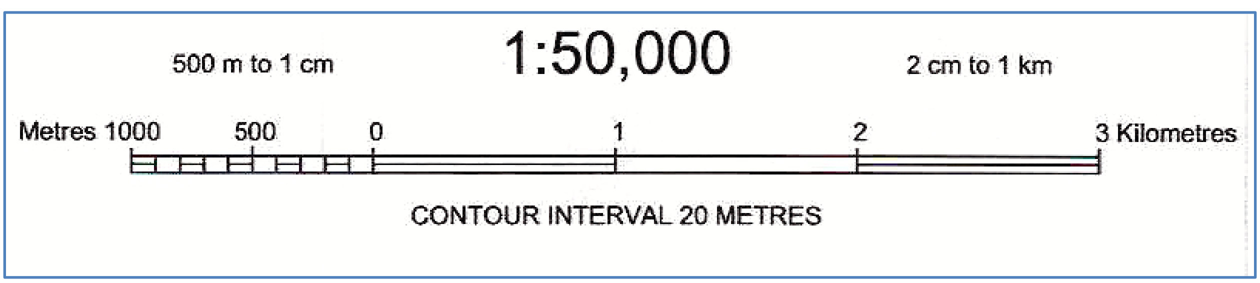

Fig 4: Scale of toposheet

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3.2 TOPOSHEET CONTENTS

- Co-ordinates
- Waterbodies, streams
- Road/railway network
- Settlements/habitations
- Contours
- Major land use
- Spot heights (RL)
- Power grid line
- Relative heights
- Legends (symbols)
- Admin boundaries
- Topo index

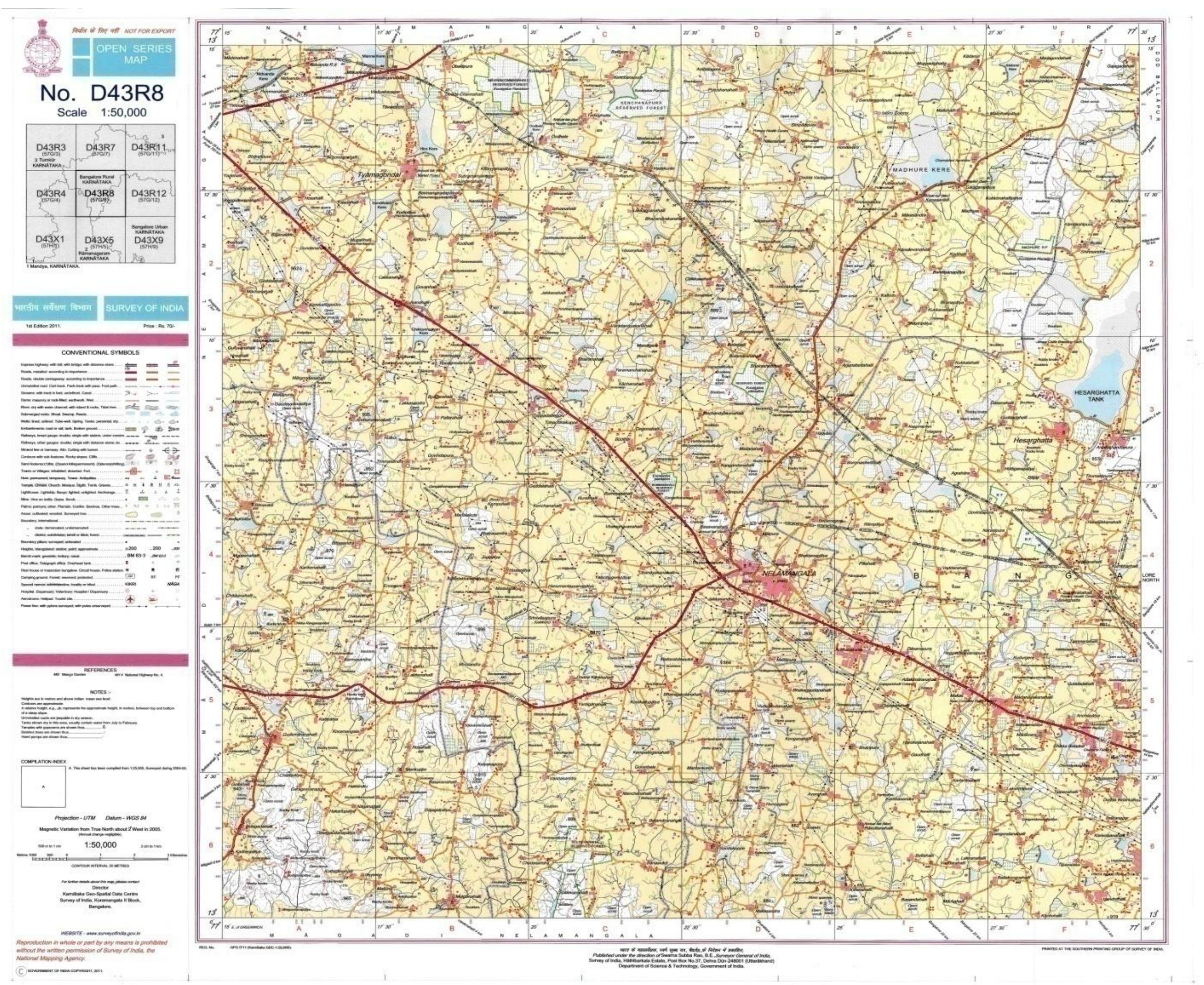

Fig 5: Toposheet

- **Co-ordinates**
  The map's edge contains the coordinate value for each grid line. Easting values can be read along the map's north or south edges, and northing values can be read along its east or west margins.
  Eastings are the vertical lines that cross a topographical map in a topo sheet's grid structure. They are calculated eastward from the grid's starting point. Northings are the horizontal lines that cross a topographical map in a topo sheet's grid structure.

- **Waterbodies, streams**
  The topographical maps use the color blue to show water bodies like perennial rivers, canals, well, tanks and springs.

- **Settlements/habitations**
  Development of town / city

- **Contours**
  Contours are the imaginary lines connecting equal elevations

- **Major land use**
  The landforms like mountains, hills, plateaus , peaks, ridges, agricultural land etc.

- **Spot heights (RL)**
  A spot height is an exact point on a map with an elevation recorded beside it that represents its height above a given datum

- **Power grid line**
  It Includes power transmission lines, towers, etc.

- **Relative heights**
  A feature's relative height is its height in relation to the surrounding land's height, not to mean sea level. It is symbolised by a little 'r' in the height. Benchmark height is the height of a location that is really noted as a permanent reference on a stone pillar, rock or shown on a building.

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- **Legends (symbols)**
  The map's legend provides a list of the symbols used and what they represent. These symbols must be described in detail in the legend and must appear exactly as they do in the map's main body.

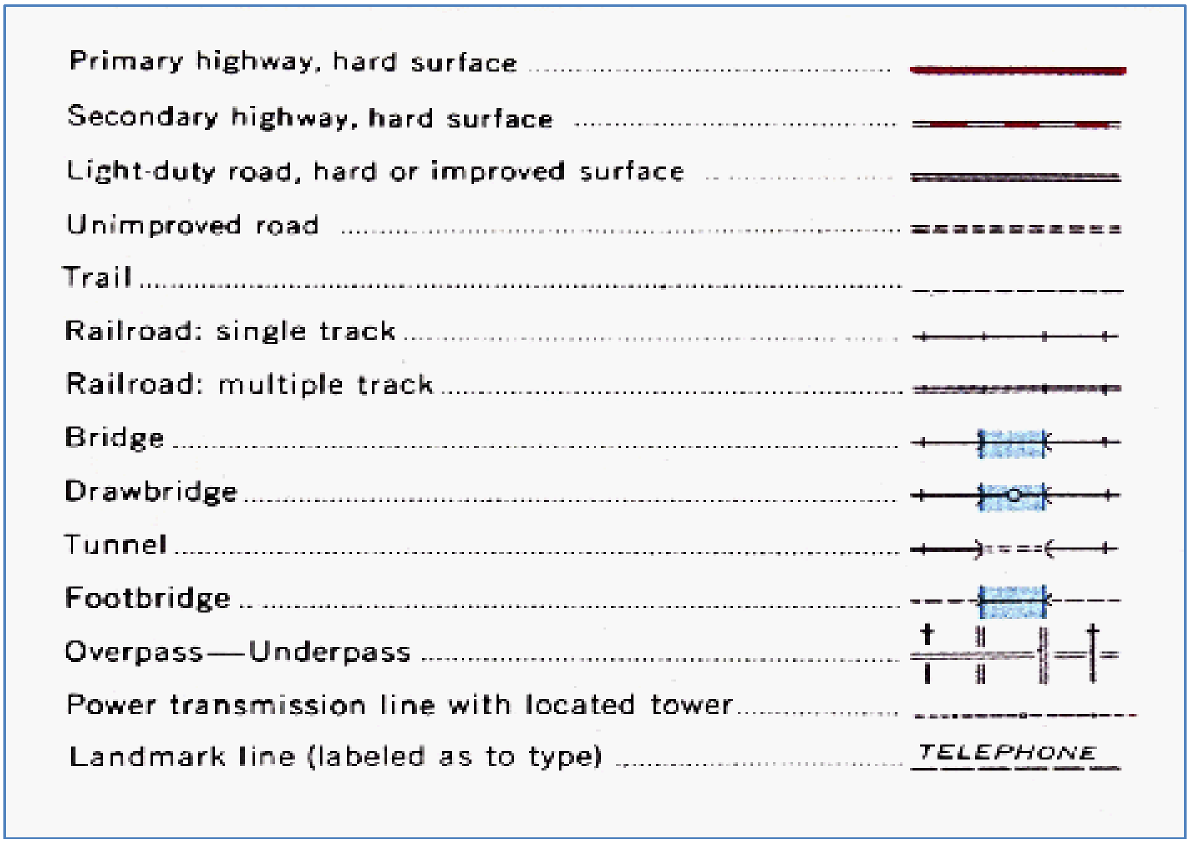

Fig 6: Legend symbols

- **Admin boundaries**
  State boundary & District boundary

- **Topo index**

Different scales are used to make these maps. The Survey of India has devised a numbering system in order to identify a map of a certain location. A base map with a size of 1: 1,000,000 is used for an international series (between 4° N to 40° N Latitude and 44° E to 124° E Longitude).

3.3 TYPES OF MAPS

1. **DEM (Digital Elevation Model)**
   Is the topographical 3D projected map which shows elevations, ground undulations, excluding trees, buildings etc.

2. **Contour Map**
   Is the topographical map consisting of various contours in the particular region with various elevations

3. **Layout Map**
   Is the map showing the divisions or proposed division of land into plots etc.

4. **Continental Map**
   Also called as world map showing all the 7 continents of the globe.

5. **Network Map**
   It may be any network like – road or railway network, stream or water network.

6. **Soil Map**
   It is the geographical representation showing different types of soil in particular area.

7. **Slope Map**
   It is the two dimensional representation of the gradient of a surface.

3.4 DEGREES – CONVERSION TO DISTANCE

Circumference of the equator : 40,075 km

1^{o} = 40075 / 360	=	111.319 km	On ground
1’ = 111.319 / 60	=	1.855 km	
1” = 1.855 / 60	=	30.9 m	

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CHAPTER 4:GEOREFERENCING OF TOPOSHEETS

4.1 Georeferencing :

It is the process of inserting toposheets at the actual latitude and longitude of a certain location in the GIS platform and assigning real world coordinates to each pixel of the raster. A geographic coordinate system can be related to the internal coordinate system of a map or aerial photo image.

4.2 Types :

Geo Referencing

Vector　**Raster**

Vector data – points, lines, polygons

Raster data – matrix of cells, pixels

Geo Referencing can be done using -

- Arc GIS
- Online Geo Referencer
- Quantum GIS softwares

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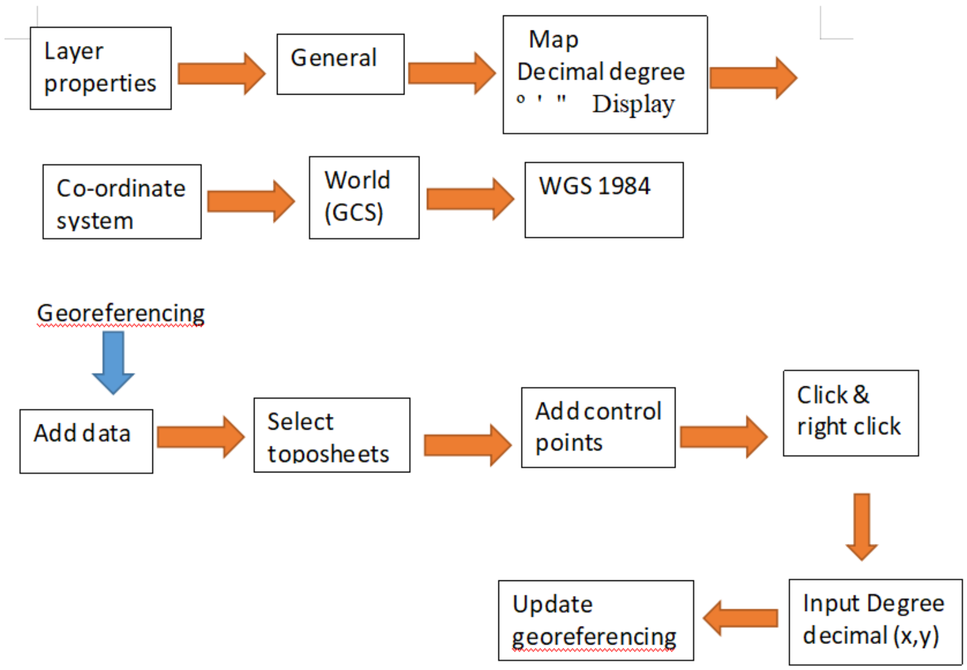
Method



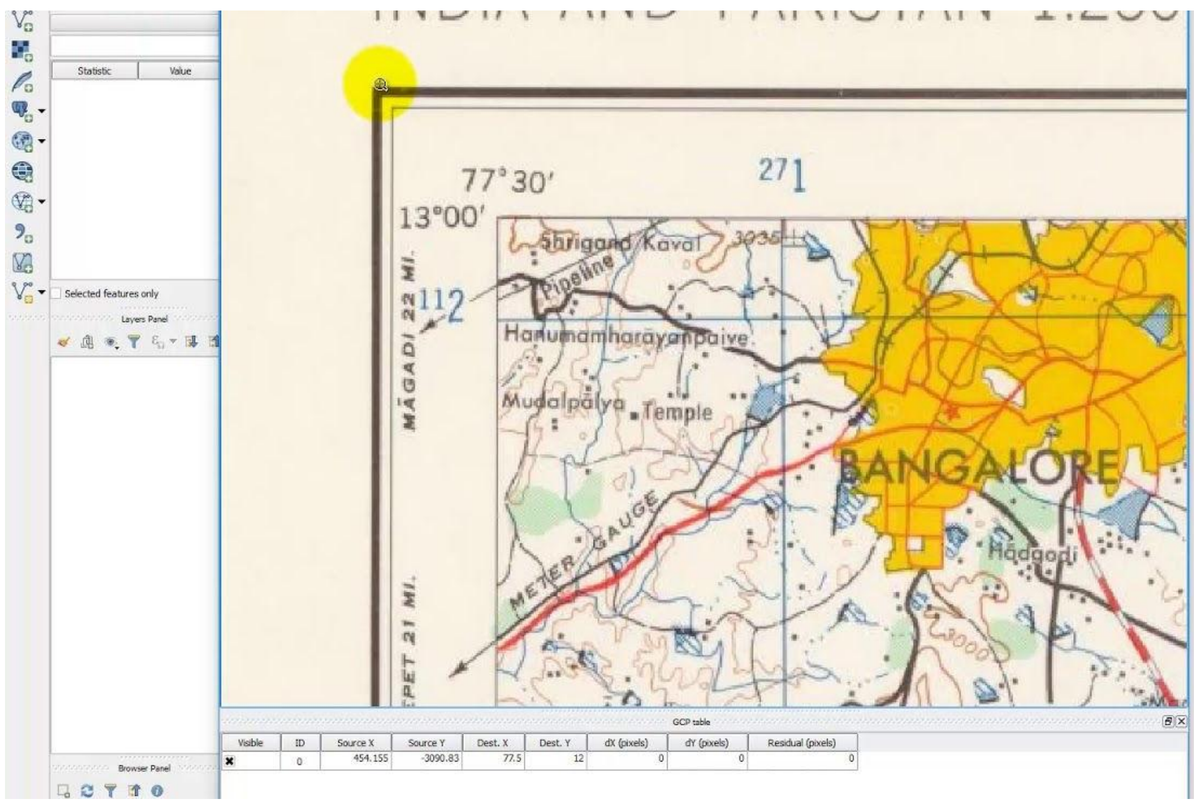


Fig 7: Georeferencing of toposheet

CHAPTER 5 : DIGITIZING THE STREAMS OF WATERSHED

5.1 :Digitizing

In a GIS, digitising is the process of turning geographic data into vector data by tracing the features from a hard copy or scanned image. Features from the traced map or image are recorded as coordinates in point, line, or polygon format throughout the digitising process.Digitization is a crucial technique for data and storage in **GIS Development**. The processof Digitization is expensive and time-consuming.

Digitization is converting hardcopy / scanned copy or satellite/Aerial base maps into vector data. Features are extracted from the existing maps or satellite images.

5.2: Types of Digitization

1. Manual Digitizing

Manual Digitizing is done by digitizing tablet. The digitizer manually traces all the lines from the hardcopy map (eg.Toposheet), and parallelly. The digital maps are created on the computer. It is only less time consuming but also has high accuracy when comparing with other digitizing methods.

2. Heads-up Digitizing

Heads-up Digitizing is similar to manual digitizing. In the manual digitizing process, it digitizes in hardcopy, but in this method, it scans the map directly and displays it on the desktop screen.

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3. Interactive Tracing Method

The interactive tracing method is an advanced technique that has evolved from Heads-up digitizing. When it comes to speed and accuracy, it is fairly good.

4. Automatic Digitizing

Automatic Digitizing is the process of converting raster to vector in an automated method using pattern recognition and image processing techniques. In this technique, the computer traces all the features on the map; it gives high accuracy with low time consumption. It allows customization and improved quality of images. This process is also known as Vectorisation.

5.3 :Accuracy in the Digitization Process

In the digitization World, an important role is the accuracy of the digitized features. A good GIS database is entirely dependent on the Spatial accuracy of the features. But accuracy of the digitized map ultimately depends on errors which occur in the digitization process.

5.4: Types of Errors in Digitization

Errors on digitized maps are classified into the geodetic, machine, cartographic, manuscript, positional and attribute errors.

1. Geodetic Errors

Geodetic errors are due to the odd choice of a projection system. Generally, earth features are in 3 Dimensions. But the features on the map are in 2 Dimensions. So the projection system leads to inaccuracy. Improper projection leads to inaccurate placement of elements on the map. Therefore making the map and the digitized features do not overlap each other appropriately.

2. Machine Error

Machine error occurs due to the digitizing tablet or the software used to digitizing the elements. It is an inherent error that cannot be removed but can only be minimized. Sometimes it may occur when converting the maps from analog to the digital formats.

3. Cartographic Errors

Cartographic errors arise due to existing mistakes that are present in the source map itself, and it can be transferred into the digital map. Incorrect interpretations or drafting of the elements in the maps are also one of the reasons for these errors.

4. Manuscript Errors

Manuscript errors occur based on the quality of the source maps. Hard copy maps shrink with time. Any stretching, warping, wrinkling, or traces of folding of the original map might affect the digitization process. It may lead to irregular shape, area & coordinates of the digitized features. It can't be completely rectified.

5. Positional Errors

Positional Error happens when an element is not captured correctly or carelessness of the digitizer, and it can be completely rectified. Positional Error is categorized as Dangling Nodes, Switchbacks, knots, and loops, Overshoots, and Undershoots, Silvers, and Overlaps.

5.4: Digitization of Vrishabhavathi watershed

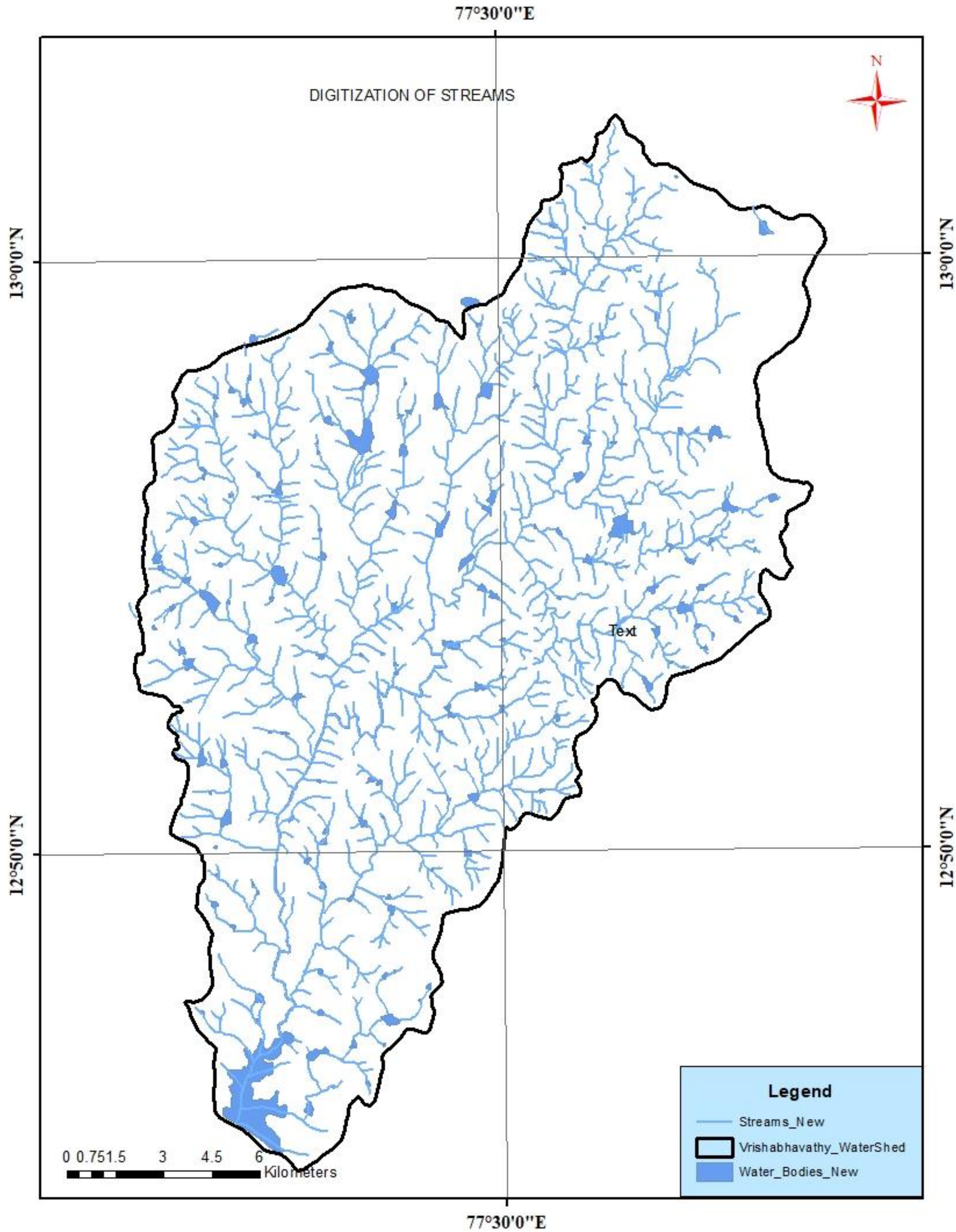

FIG 8: DIGITIZATION OF STREAMS FOR VRISHABHAVATHI

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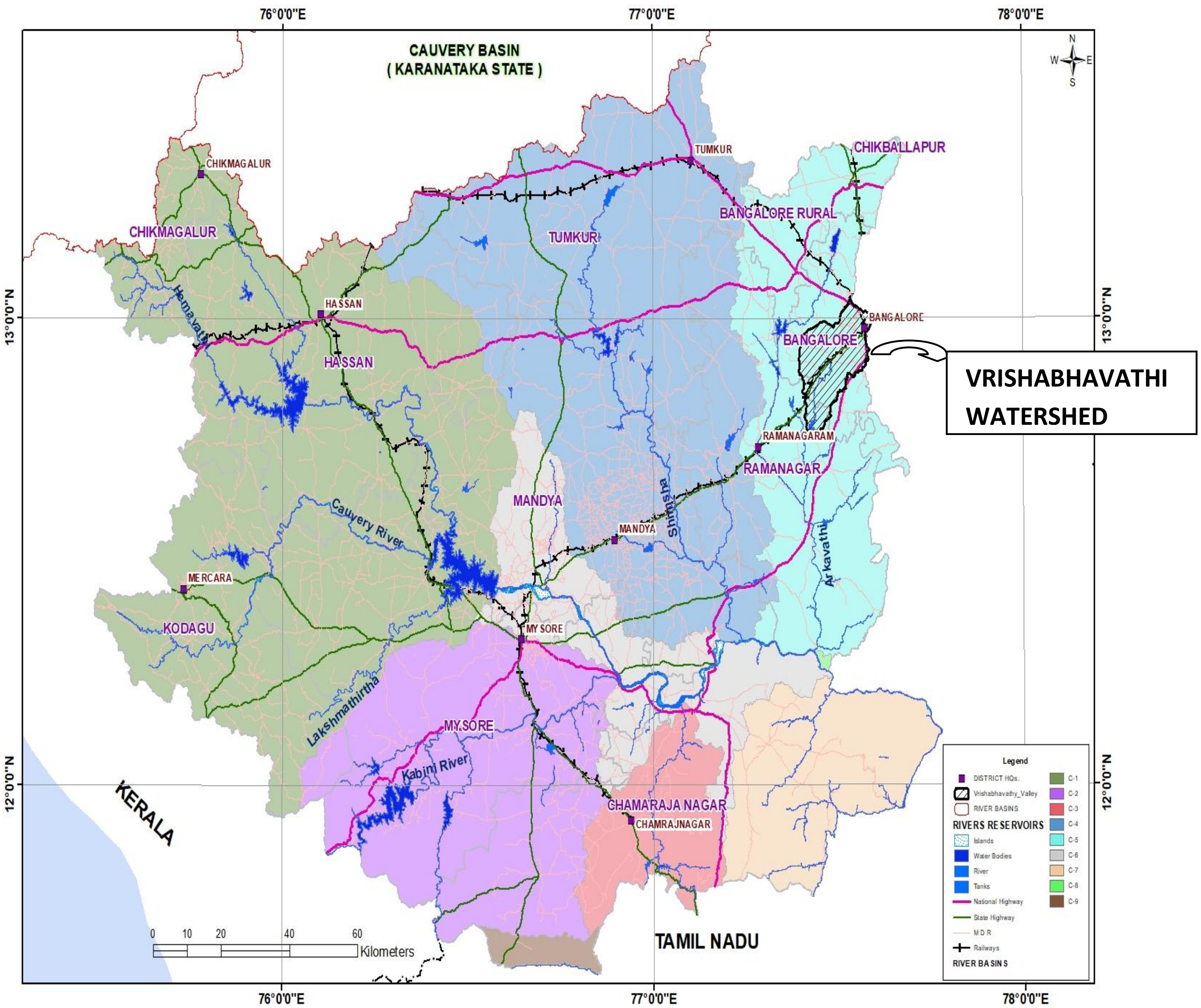

FIG 9:LOCATION OF VRISHABHAVATHI WATERSHED ON CAUVERY BASIN MAP

CHAPTER 6 : MORPHOMETRIC ANALYSIS OF THE WATERSHED

6.1Abstract

Using a geographic information system (GIS), this study seeks to investigate the morphometric aspects of the Vrishabhavathi watershed. This analysis has demonstrated that there is a negative linear relationship between stream order (U) and stream number (Nu), which results in an increase in order with a decrease in the number of stream segments of a specific order. The watershed has a dendritic pattern of drainage, indicating high relief and steep ground slope with less elongated young and mature landforms in which geological structures don't have a dominant influence. Other morphometric parameters, such as stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), form factor ratio (Rf), relief ratio (Rh)

6.2 Introduction to Morphometric Analysis

It is the quantitative analysis of form, shape, a concept of size, etc. Quantitative description, analysis of landforms also called as geomorphology when referred to land.

6.3 DRAINAGE MORPHOMETRY

It is the measurement of any drainage basin's or watershed's linear, aerial, and relief properties. Our area of study is the Vrishabhavathi watershed. It contains information about drainage density, texture, stream frequency, form factor, circulatory ratio, and elongation ratio, among other things.

6.4 STUDY AREA

TheVrishabhavathi Watershed, Bangalore Urban, and Ramanagara District are all parts of theArkavathi River Basin, which has a 379.710km2 area with a tropical, seasonally dry climate. Boundary line is drawn by connecting ridge points and has a radius of 101.241 km. The river is 45.23 kilometres long. The watershed is 20.49 km wide and 33.47 kilometres long. The Big Bull temple in Basavanagudi and Dakshinamukha Nandi Theertha in Malleshwaram are its sources. Significant places include the agriculture research station Hebbal, Uttarahalli, Kengeri,

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Tavarekere, Manchanabele, Bidadi, and Byramangala are included in the Vrishabhavathi watershed. Rainfall occurs from June through October.

Morphometric Parameters	Formula	References
Linear Aspects		
Stream Order (U)	Hierarchical order	Strahler,1952
Stream Length (Lu)	Length of the stream	Horton, 1945
Mean stream length (Lsm)	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order (km), Nu=Number of stream segment.	Horton, 1945
Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu-1= Total Stream Length of its next lower order	Horton, 1945
Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments, present in the given order, Nu+1= Number of segments of the next higher order	Schumm, 1956
Channel Sinuosity (S)	S=SL/Lb Where, SL= longest stream length , Lb= Basin length	Schumm, 1956
Areal Aspects		
Drainage density (Dd)	Dd=L/A Where, L=Total length of stream, A= Area of basin.	Horton, 1945
Stream frequency (Fs)	Fs=N/A Where, L=Total number of streams, A=Area of basin	Horton, 1945
Texture ratio (T)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of basin.	Horton, 1945
Form factor (Rf)	$Rf=A/(Lb)^2$ Where, A=Area of basin, Lb=Basin length	Horton, 1945
Elongation ratio (Re)	$Re=\sqrt{(Au/\pi)}/ Lb$ Where, A=Area of basin, π=3.14, Lb=Basin length	Schumm, 1956
Circulatory ratio (Rc)	$Rc=4\pi A/P^2$Where A= Area of basin, π=3.14, P= Perimeter of basin.	Miller,1953
Length of overland flow (L)	L=1/2Dd Where, Drainage density	Horton, 1945
Constant channel maintenance(C)	C=1/Dd Where, Dd= Drainage density	Horton, 1945
Relief Aspects		
Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.	Schumm, 1956
Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin relief, Lb=Basin length	Schumm, 1956
Ruggedness Number (Rn)	$Rn=Bh\times Dd$ Where, Bh= Basin relief, Dd=Drainage density	Schumm, 1956

Table 1 MORPHOMETRIC PARAMETERS FORMULA

6.5: MORPHMETRIC ANALYSIS

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Sl no.	Morphometric parameter	Notation	Formula	Value	
1	Watershed area (Km^2)	A	-	379.710	
2	Watershed's Perimeter(Km)	P	-	101.241	
3	Highest stream order	N	-	6	
4	Length of watershed (Km)	Lb	-	33.479	
5	Watershed's Max width (Km)	W	-	20.499	
6	Cumulative stream segment	ΣNu	-	798.000	
7	Cumulative stream length (Km)	ΣLu	-	708.449	
8	Longest stream length (Km)	S_L	-	45.239	
9	Ratio of the Stream Length	R_L	Lu/Lu-1		
10	Bifurcation Ratio	R_b	Nu/Nu+1		
11	Drainage Density	D_d	ΣLu/A	1.866	
12	Stream frequency	F	ΣNu/A	2.102	
13	Drainage Texture	T	D_dX F	3.921	
14	Length of Overland flow	L	$1/2D_d$	0.268	
15	Constant of Channel Maintenance	C_m	$1/D_d$	0.536	
16	Elongation ratio	R_e	$(2\sqrt{A/\pi})/L_b$	0.657	
17	Circulatory ratio	R_c	$4\pi A/P^2$	0.465	
18	Form Factor	R_f	A/Lb^2	0.339	
19	Total Watershed relief ratio	H	Highest RL - Lowest RL	0.274	962.4 - 688.306 =274.094
20	Relief ratio	R_h	H / Lb	0.008	
21	Ruggedness Number	R_N	H x Dd	0.511	
22	Relative relief	R_r	H / P	0.003	
23	Compactness constant	C_c	$0.2821\ P/A^{0.5}$	1.466	19.4861
24	Channel sinuosity	S	SL / Lb	1.351	
25	Texture ratio	Tr	N1/P	5.946	

Table 2 MORPHOMETRIC PARAMETERS

6.6 Results and discussion

A basin's properties are described by morphometric analysis, which uses quantitative evaluation of several criteria. The linear, areal, and relief dimensions of the parameters determine how they are distributed. Through their various impacts on lag time, morphometric characteristics like relief, shape, and length also have a significant impact on basin discharge patterns (Gregory and Walling, 1973). The drainage pattern is determined by how the streams are arranged in a drainage system, which in turn reflects the primary structural or lithologic restrictions of the subordinate rocks (Eesterbrooks, 1969). For studies of linear aspects, Horton (1945), Strahler (1952), and Schumm (1956) methods are used; for studies of areal aspects, Horton (1945), Miller (1953), and Schumm (1956) methods are used; and for studies of relief aspects, Schumm (1956) methods are employed. The subsequent computation and

6.7 Linear morphometric parameters

The information on one-dimensional parameters such as Stream Order, Stream Number, Bifurcation Ratio, Stream Length, and Channel Sinuosity is provided through linear aspects. This shows that the drainage network's channel patterns have the topological features of stream segments, and the study is based on the network's open linkages.

6.7.1 Stream order (U) & stream numbering

According to Leopold, Wolman, and Miller (1964), it is a measurement of where a stream falls in the hierarchy of tributaries. Due to its clarity, modified Horton's law (also known as the Strahler law) has been used for the analysis. First order refers to the smallest, unbranched fingertip streams. Second order channels result from the intersection of two first order channels, third order channels from the union of two second order channels, and so on. The higher-order is preserved while defining the stream order between two channels of different orders. The highest order in our project is 6.The stream numbering and ordering approach developed by Strahler and Horton has been used.

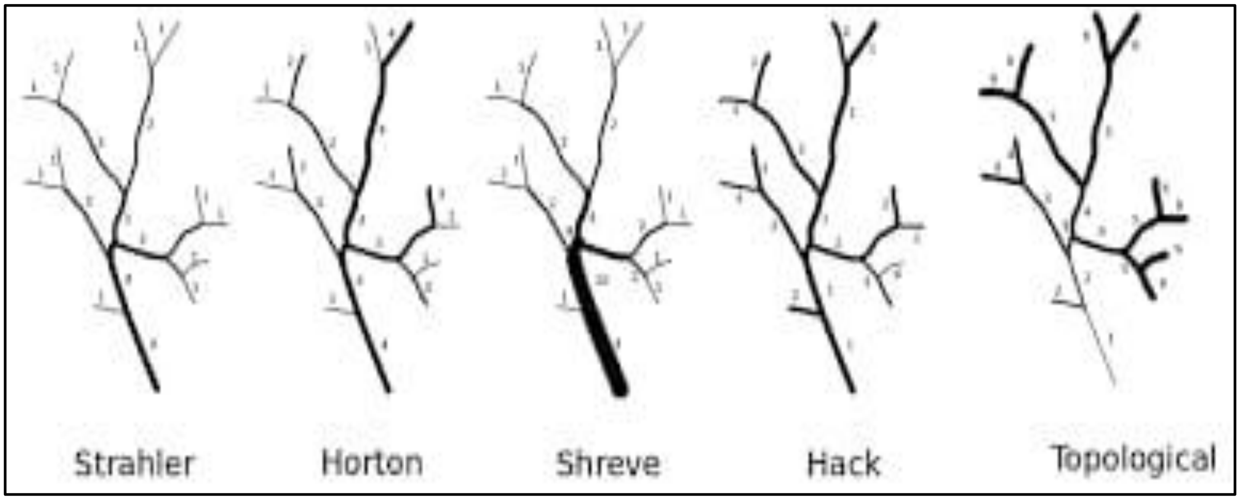
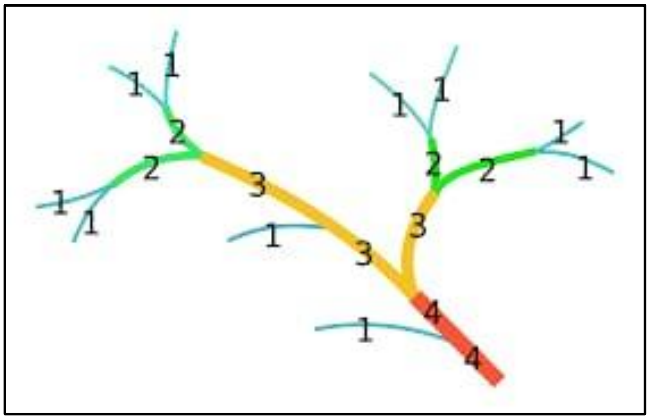


Fig 10 Strahler Horton stream ordering & numbering



When streams of the same order intersect, the stream order rises. As a result, when two first-order links intersect, a second-order link results, when two second-order links intersect, a third-order link results, and so on.

The Horton approach is based on producing runoff when rainfall intensity exceeds the infiltration capacity and illustrates how infiltration capacity falls as the precipitation event progresses. Additionally, the recovery of infiltration capacity during dry times is described by the modified Horton's equation.

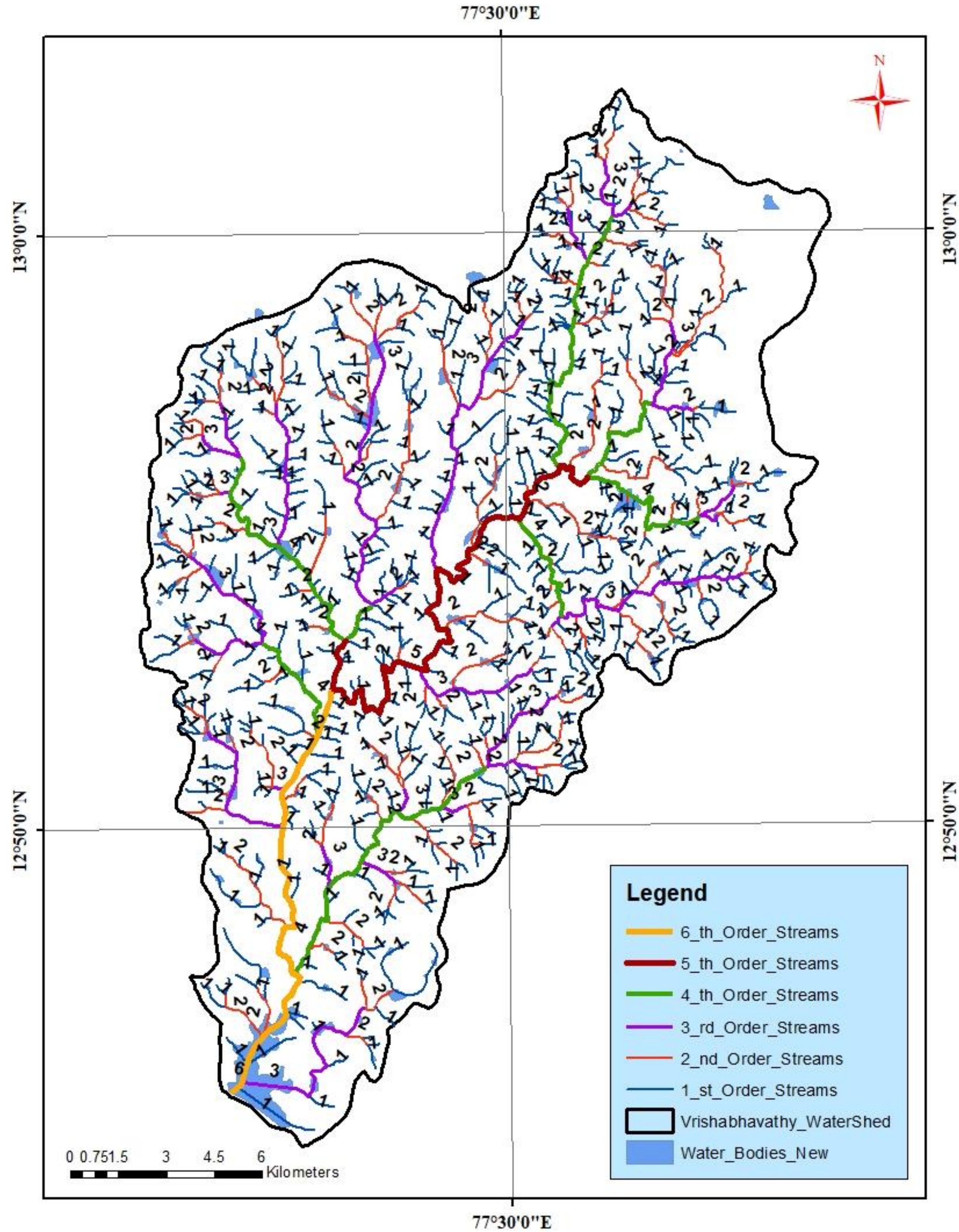


Fig. 11Stream ordering and numbering of vrishabhavathi watershed

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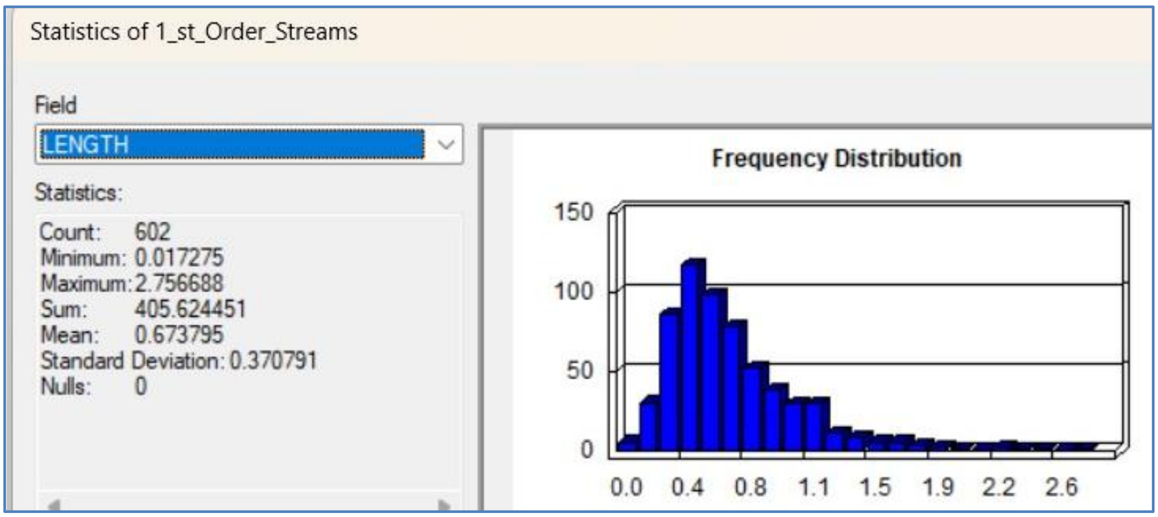
6.7.2 Stream length (Lu) &Mean stream length (Lsm)

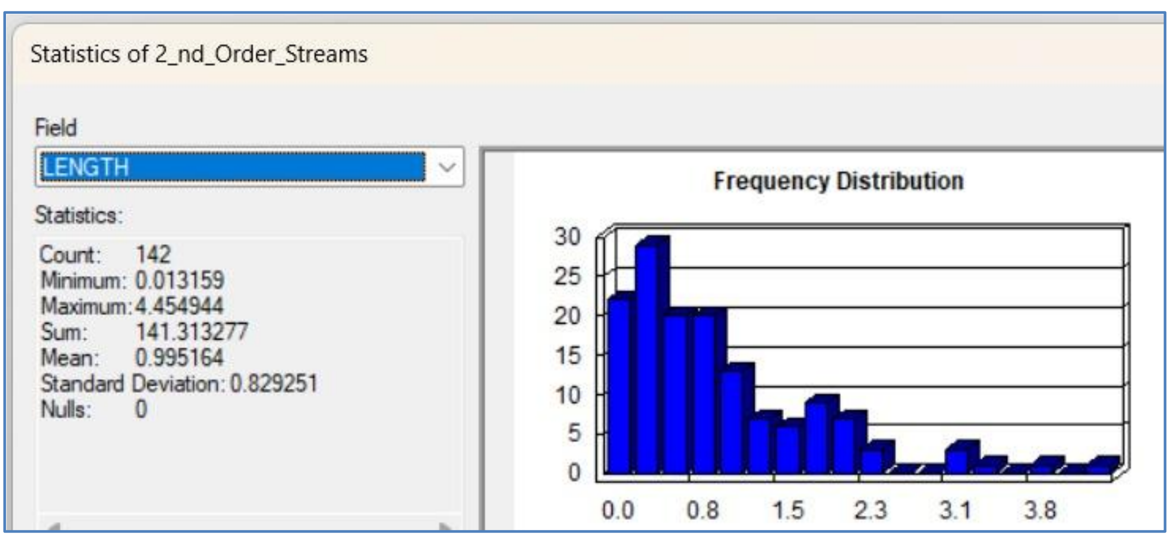
The behaviour of surface runoff on the basin is shown by stream length, which is important to the drainage basin system. Longer streams typically indicate a flatter gradient, whereas smaller streams are more typical in regions with steeper slopes and finer textures. First-order streams have the longest total length of stream segments, which is shorter as stream order rises.

Statistics of each order streamsLength

1st order



2nd order



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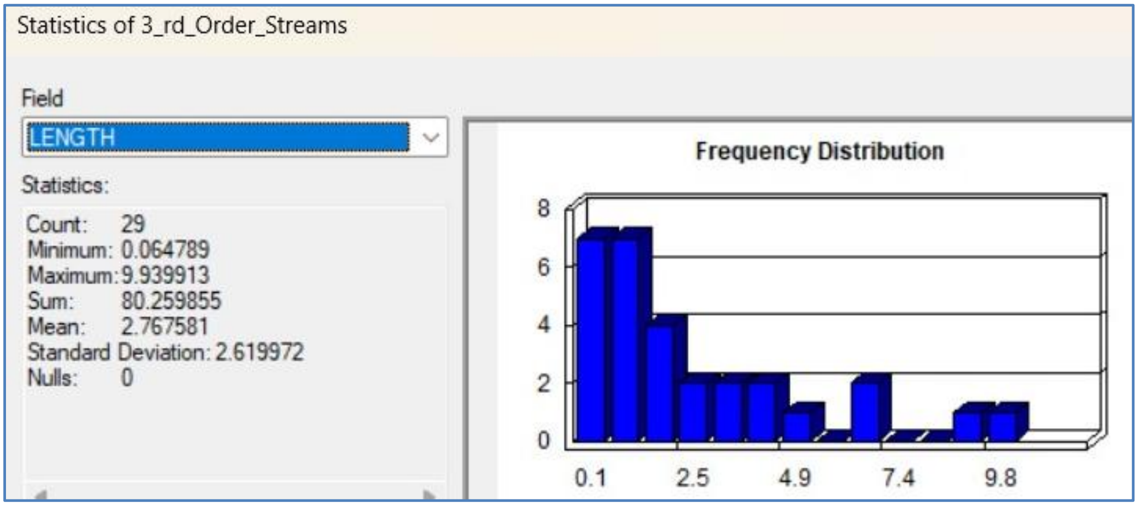
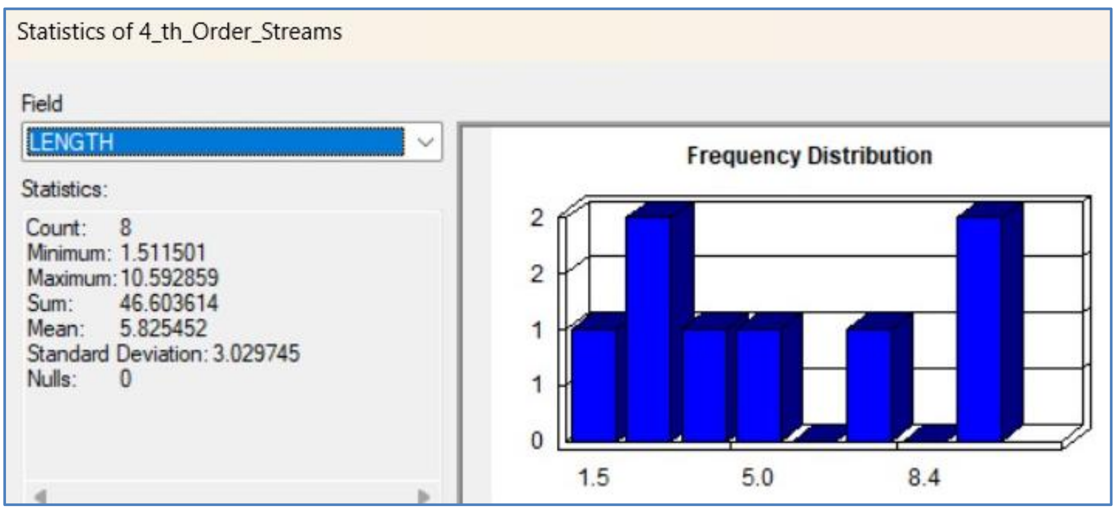
3rd order



4th order



This statistical table displays the total number of streams, the length of each stream in each order, as well as the maximum and minimum stream lengths.

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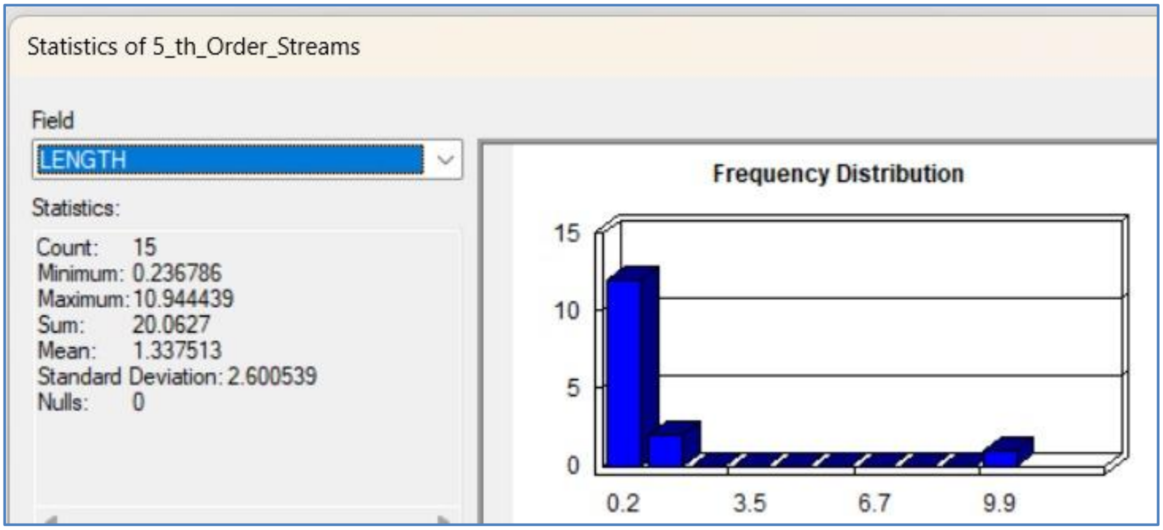
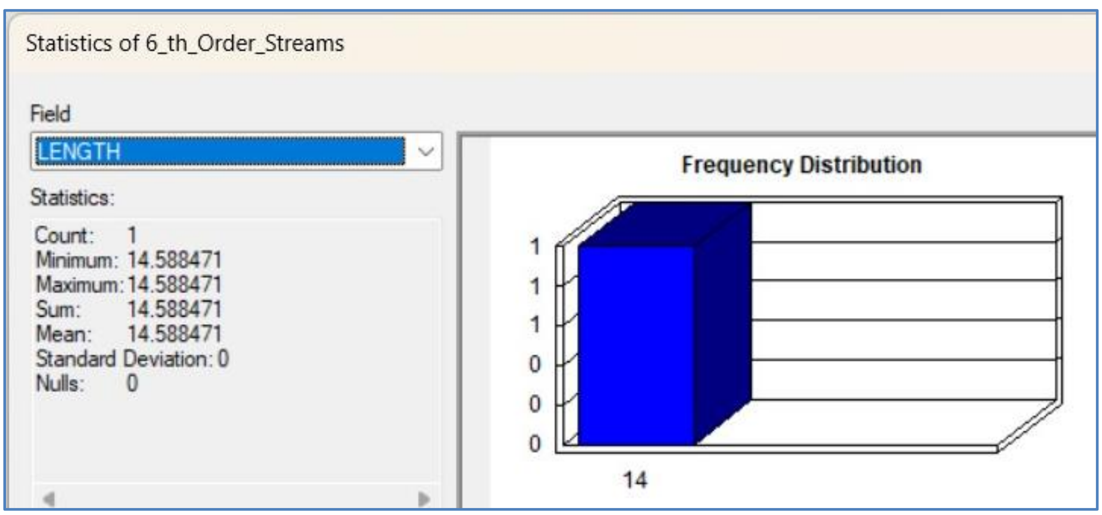
5^{th} order



6^{th} order



6.7.3 Ratio of Stream length (RL)

According to Horton (1945), the stream length ratio is the ratio of the mean stream length of one order to the mean stream length of the next lower order and has a significant impact on the basin's surface flow, discharge, and erosion stage. The result is displayed below:

RATIO OF STREAM LENGTH		
Order of streams	**Lu**	**Lu/Lu-1**
1st order	405.624	-
2nd order	141.313	0.348
3rd order	80.259	0.568
4th order	46.603	0.581
5th order	20.062	0.430
6th order	14.588	0.727
summation (ΣLu)	708.449	

Table 3 STREAM LENGTH RATIO

6.7.4 Ratio of Mean stream length (ΣLu)

It is calculated by adding the total stream length of order (u) and dividing it by the total stream length of the order below it.

6.7.5 Ratio of Bifurcation (R_b)

A drainage network's branching structure and bifurcation ratio are related. According to Schumm (1956), it is the proportion of all stream segments of one order to those of the next higher order in a drainage basin. In contrast to places where geology is dominant, Strahler (1957) showed that the bifurcation ratio has a narrow range of variation for distinct regions or different environmental situations. It has been seen that Rb changes from one order to the next. The basin as a whole has a mean Rb of 3.87. The natural drainage system within a homogeneous rock is indicated by the bifurcation ratio, which ranges between 3 and 5, according to Kale and Gupta (2001).Higher values of the bifurcation ratio show strong structural control over the drainage pattern and have well-dissected drainage basins, whereas lower values of the bifurcation ratio are characteristics of the watershed which have flat or rolling watersheds. Less risk of flooding results from a larger bifurcation ratio (Eze & Efiong, 2010).

The calculation is given below:

`

BIFURCATION RATIO		
Order of streams	**Nu**	**Nu/Nu+1**
1st order	602	4.239
2nd order	142	4.733
3rd order	30	3.750
4th order	8	0.533
5th order	15	15.000
6th order	1	-
summation (ΣNu)	798	

Table 4 BIFURCATION RATIO

6.7.6 Ratio of mean bifurcations (ΣNu)

It is calculated by adding the total number of stream segments in the specified order and dividing it by the total number of segments in the following higher order.

6.7.7 Channel Sinosity(S)

The proportion of the longest stream length (Rl) to the catchment length(Lb).

S = SI/Lb: 1.351

Sinuosity is the relationship between channel length and valley length. Rivers meander to keep the channel slope in balance with flow and sediment load. On a meandering river, sinuosity is the watershed length to channel length ratio. Any tectonic deformation that alters the slope of a river valley, according to Pinter

(2002), results in a conformal change in sinuosity to preserve the equilibrium channel slope.

Muller (1968) defined channel sinuosity (S) as the product of the ratio of the stream length (Sl) to the valley length (Vl), where S = Sl/Vl. The ratio of the channel length to the valley axis length can be used to determine the waviness index (Brice, 1964). According to Brice (1964), if the sinuosity index of a reach is 1.3 or more, the reach is considered meandering, a straight reach has a sinuosity index of 1, and reaches that have sinuosity indices between 1.05 and 1.3 are considered sinusoidal. .

6.8 Surface Aspects

The total area projected onto a horizontal plane that contributes overland flow to a channel segment of the given order is defined as the areal aspects (Au) of a watershed of a particular order u, and this includes all lower-order tributaries. The stream's flow characteristics are significantly influenced by the watershed's structure; for instance, alternating flood flow is typical in an elongated watershed with a high bifurcation ratio. On the other hand, a watershed that is round or circular and has a low bifurcation ratio may experience a sharp peak flood flow.The manner in which runoff and sediment are transported is significantly impacted by the form of the watershed. The rate at which water enters the stream is also influenced by the geometry of the watershed. Shape factor, circularity ratio, and elongation ratio are three metrics that can be used to describe the watershed's quantitative expression.

6.8.1 Form factor (R_f)

Horton defines the shape factor Rf as the dimensionless ratio of the catchment area (A) to the square of the catchment length (L). The shape factor value would always be less than 0.7854 (for a perfect circular basin). A catchment with a higher form

factor is usually circular and has high peak flows for a shorter period of time, while an elongated catchment with lower form factor values has
low peak flows for longer periods of time. For the current study area, the shape factor is 0.339

A/Lb^2 = basin area divided by the square of the basin length

6.8.2 Ratio of Circularity (R_c)

Ratio of circularity is the ratio of the catchment's surface area to the surface area of a circle with the same catchment's circumference (Miller, 1953).The higher the circularity ratio, the lower the value, which varies from 0.2 to 0.8. The ratio is crucial and reveals the degree of dissection in the research field. The region's young, mature, and old stages of the tributary watershed cycle and the acquired value correspond to its low, medium, and high values, respectively.

$(4\times\pi\times379.710)\div101.241^{\wedge}(2)$ =0.46 is our circulation ratio.

$4\,\pi A/P^2$ = where p is the watershed's perimeter and A is the watershed's area

6.8.3 Ratio of Elongation (R_e)

The ratio between a circle's diameter and maximum length that has the same area as the basin is known as the elongation ratio (Schumn, 1956). More pelvic extension is indicated by a smaller form factor. Peak flows will be higher and last for a shorter time in a catchment with a higher form factor. The peak flow will be flatter and last longer in an elongated basin with a low form factor. The elongation ratio's value ranges from 0.4 to 1, with the smaller number indicating a longer watershed. The elongation ratio is calculated to be 0.657 for this study region. $(2\times\sqrt{(379.710\div\pi)})\div33.479$ =0.657

Where Re is the elongation ratio, Lb is the total length of the basin and A is the total area of the basin.

6.8.4 Drainage density (D_d)

Drainage density is a function of climate, lithology, structures, relief history of the region, etc., it can ultimately be used as an indirect indicator to explain those variables, as well as the morphogenesis of landforms. Drainage density is the other component of drainage analysis that provides a better quantitative expression to the dissection and analysis of land forms. One of the key indicators of the linear scale of landform components in stream-eroded topography is drainage density (Dd). It is defined as the sum of all stream lengths divided by the entire watershed area.The drainage density, which is given as km/Sq.km, provides a numerical representation of the watershed's average length of stream channel area. The overland flow's length depends inversely on the drainage density, which gives at least some insight into the basin's drainage effectiveness. Mathematically, drainage density is represented as (Lu/A).

A = Area of watershed (Sq. km), where Lu is the total length of all streams (in km). A geomorphologist or hydrologist can obtain a meaningful numerical measure of runoff potential and landscape dissection from the measurement of drainage density. In areas with little possibility for runoff and high levels of permeability, drainage densities can occasionally be less than 1 kilometre per square kilometre. Densities of above 500 km per square kilometre are frequently observed on severely dissected surfaces. A number of elements interact to affect stream density, according to more thorough research of the processes causing variance in drainage density.Climate, terrain, soil infiltration rate, vegetation, and geology are a few of these variables. The region's wells will have good water potential and better specific capacities because the low value of drainage density impacts more infiltration. Infiltration is lower and surface runoff is higher in locations with greater drainage density. Due to its surface runoff and permeability, an area's drainage density might also hint at its potential for groundwater. Drainage density was measured and was found to be 1.866. This led to the conclusion that the area is a much coarser watershed. The low drainage density found in the research area suggests that the subsoil there is either very resistant or highly permeable.

Stream length cumulatively divided by watershed area 708.449/379.710 =1.866

6.8.5 Channel maintenance constant (Cm)

The constant of channel maintenance (Cm) has an inverse relationship to drainage density. It shows how many square kilometres of watershed are needed to support one linear km of canal.

Cm = 1/Dd 0.536

It is influenced by the permeability of the rock type, the climatic regime, the flora, the relief, as well as the length of erosion and the climate's history. In regions of near dissection, the channel maintenance constant is quite low.

6.8.6 Stream frequency (F)

By comparing the number of stream segments to the area drained, stream frequency can be expressed. In other terms, stream frequency is equal to the size of the watershed divided by the total number of stream segments. Stream frequency, also known as channel frequency, was first defined by Horton (1932) as the number of stream segments per area. The stream frequency for the current investigation is

F = ΣNu/A 2.102

Total Number of stream segments/

A = Total watershed area (in square kilometres).

6.8.7 Texture Ratio (T_r)

According to the underlying lithology, infiltration potential, and relief aspect of the terrain, texture ratio is a significant factor in the drainage morphometric studySchumm, 1956). The ratio between the first-order streams and the basin's edge is used to express the texture ratio. In the research area, the texture ratio is 5.946km^{-1}.

Tr N1/P 5.946

N1 = No. of 1st Order Streams in Total

P = Perimeter of basin (Km)

6.8.8 Drainage texture (T)

Climate, rainfall, vegetation, lithology, soil type, infiltration capacity, and stage of development all have an impact on drainage texture, which is a measure of relative channel spacing in a fluvial-dissected landscape (Smith, 1950). The study area's Dd value of 3.921 km/km2 suggests a hilly landscape with a range of steep to extremely steep slopes and varying vegetation covering. Drainage texture is divided into five separate textures by Smith.

T Dd X F 3.921

Where, D_d = Drainage density

F = Stream frequency

6.8.9 Length of overland flow (L_g)

According to Horton (1945), the Length of Overland Flow (Lg) is the amount of time that water spends over the land before it is concentrated into the main flow, which affects the hydrologic and physiographic evolution of the drainage basin. Infiltration (exfiltration) and percolation through the soil, both of which vary in time and place, have a considerable impact on l_g (Schmid, 1997). According to

Chitra et al. (2011), the high Lg value shows that the rainwater had to travel a comparatively longer distance before becoming concentrated in stream channels. This research's figure for the overland flow length—0.268 km—indicates reduced distance runoff in the study area.

L g   1/2Dd0.268

Where, Dd = Drainage density

6.9 Relief aspects

When determining the amount of the denudational process occurring inside the watershed, relief aspects are crucial since they show the direction of the water's flow.

6.9.1 Watershed relief (H)

The elevation difference between the farthest point along the water divide line and the watershed's discharge point is known as the watershed relief.

H = (Difference in Elevation of Watershed Outlet) - (Difference in Elevation of Watershed Highest Point)

The contour map that is supplied is used to determine the difference in elevation between the discharge point and the farthest point.

At a height of 962.400 m above mean sea level, watershed forms the highest relief. The lowest relief was obtained at the Byramangala Reservoir at an elevation of 688.306 m above msl. 274.094 m was the total relief determined for the watershed.. (0.274 km).

H =Highest RL - Lowest RL

962.4 - 688.306

274.094m

= 0.274 km

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6.9.2 Relief ratio (Rh)

According to Schumm (1956), the relief ratio is the ratio of the total watershed relief to the watershed's maximum length. The watershed's relief ratio was calculated to be 0.008. The drainage basin's overall sharpness is increased by the relief ratio, which also serves as a gauge of the process's intensity and watershed's shape.

R_h	H / Lb	0.008

Where Rh = Relief ratio

H = Total catchment relief

Lb = Length of watershed (km)

6.9.3 Relative relief (R_r)

The ratio of the highest watershed relief to the watershed's perimeter is known as relative relief. It is calculated using the equation

R_r	H / P	0.003 km

Rr = H/P

Where Rr= Relief ratio

Where H = Total catchment relief (km)

P = Perimeter of the watershed (km)

6.9.4 Ruggedness number (Rn)

According to Strahler (1964), The ruggedness number, which typically mixes slope steepness with length, is a result of drainage density and watershed relief. High values of the roughness number are present in the watershed area as a result of increased drainage density and relief. It is calculated using the equation to be 0.511.

R_N	H x Dd	0.511

Where R_n = Ruggedness number,
H = relief of the watershed in kilometers,
D_d is the Drainage density in km/Km²

6.9.5 :Compactness constant (C_c)

The ratio between the basin's area and perimeter is known as the compactness constant. For a perfect circle, the compactness constant is one, and it rises with increasing basin length. As a result, it offers a clear indication of how long the basin is. Compactness constant for our study is 1.466

C_c	0.2821 $P/A^{0.5}$	1.466	19.4861

Where P = Watershed's perimeter
A = Watershed's area

6.10 : Digital Elevation Model (DEM)

DEM is a digital cartographic dataset that represents a continuous topographic elevation surface through a series of cells. Each cell represents the elevation (Z) of a feature at its location (X and Y). Digital Elevation Models are a "bare earth" representation because they only contain information about the elevation of geological (ground) features, such as valleys, mountains, and landslides, to name a few. They do not include any elevation data concerning non-ground features, such as vegetation or buildings.

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Digital Elevation Models could be used to create topographical maps of overland terrain, as well as bathymetric maps, which serve to illustrate underwater terrain.

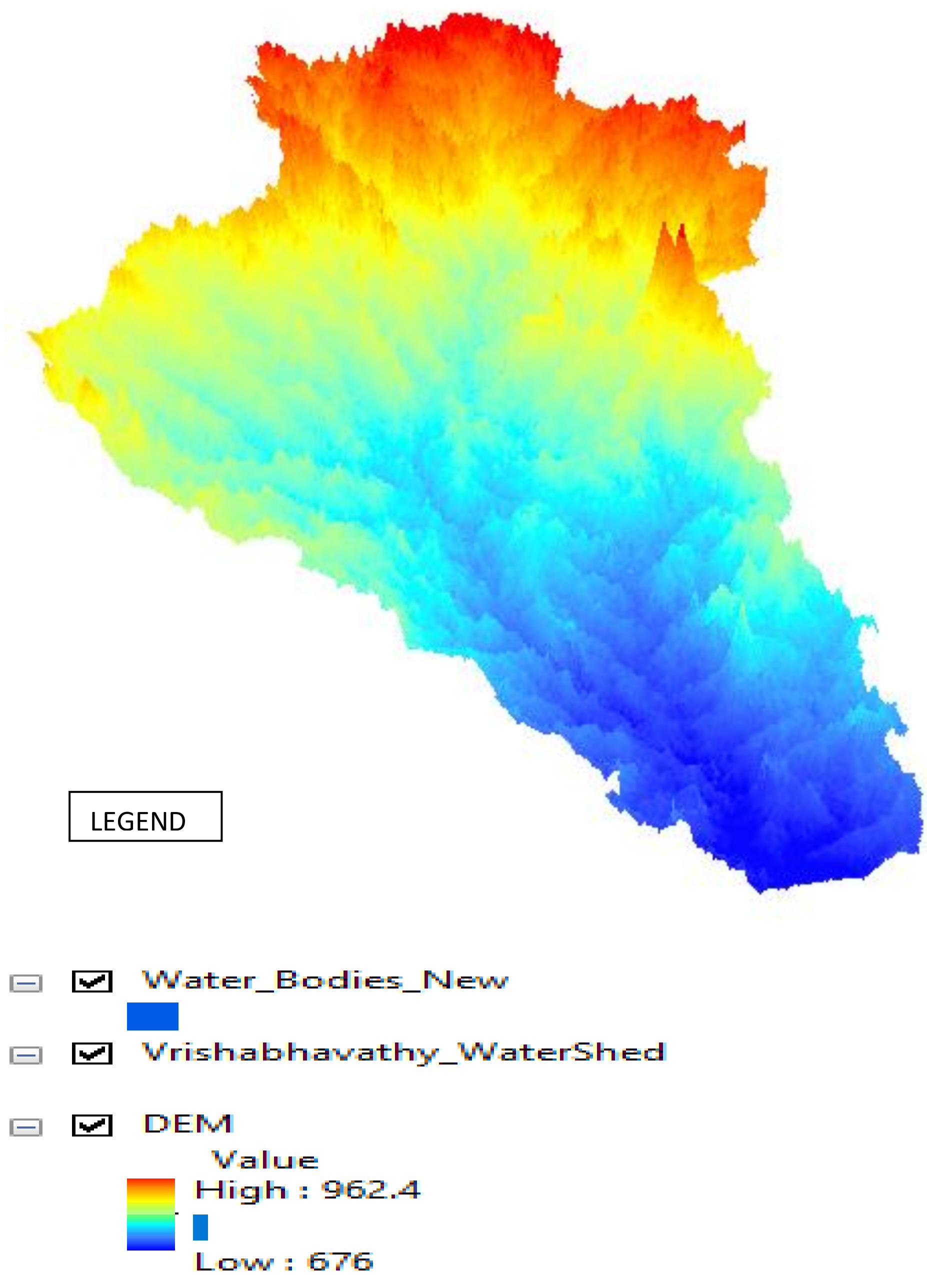

FIG 12: 3D DEM MODEL

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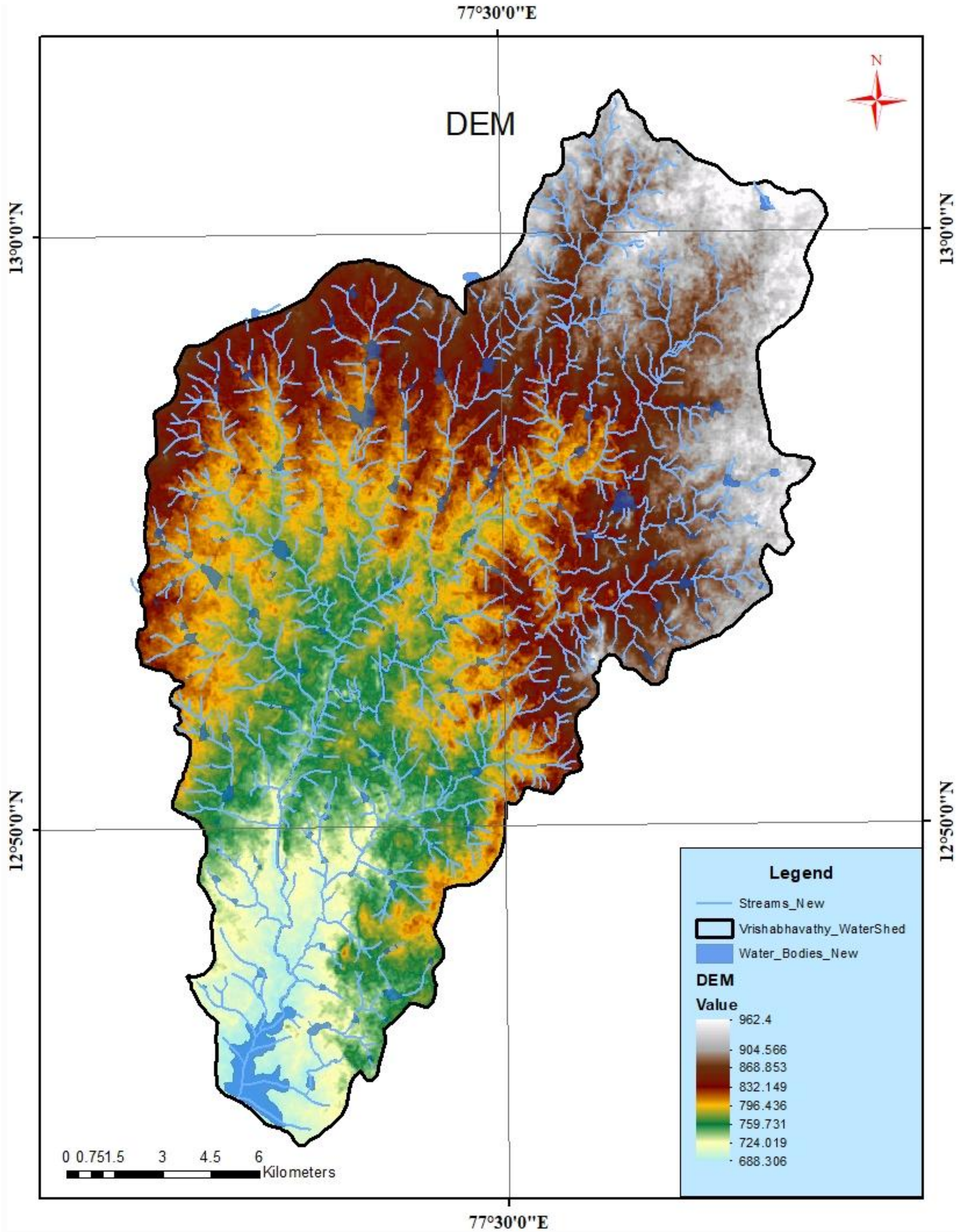

FIG 13: DEM MAP

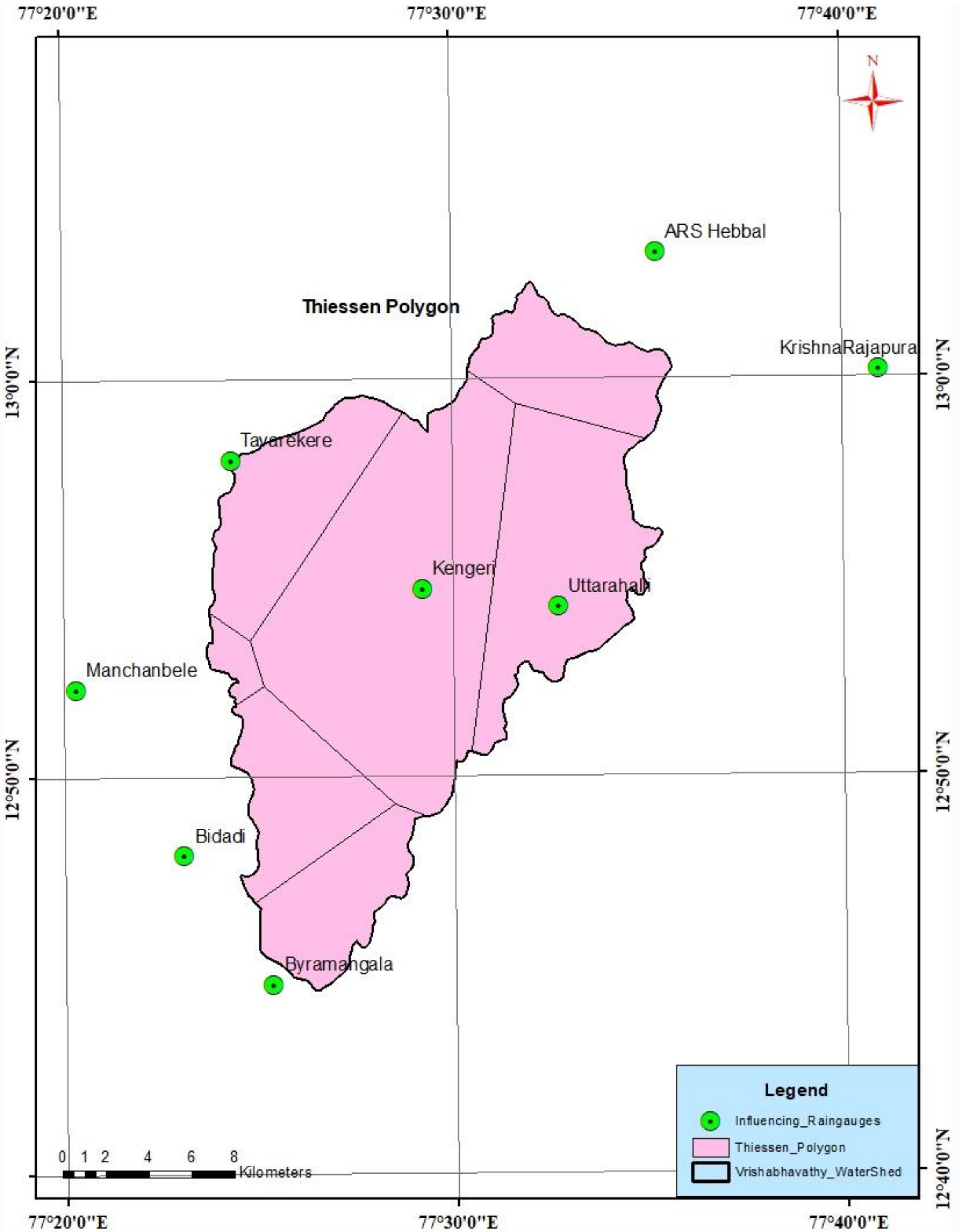

FIG14INFLUENCING RAINGAUGE STATION USING THIESSEN POLYGON

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FID	Id	Input_FID	Station Name	District	Taluk	Basin	Sub_Basin	POINT_X	POINT_Y	Catchment Area	Weightage
0	0	7	Byramangala	Ramanagar	Ramanagaram	Cauvery	C-5	77.4222	12.7464	33.2482855	0.08750878
1	0	6	Bidadi	Ramanagar	Ramanagaram	Cauvery	C-5	77.3842	12.8006	37.1427508	0.09775893
2	0	8	ARS Hebbal			Cauvery	C-5	77.5876	13.0523	36.0669076	0.09492734
3	0	5	Manchanbele	Ramanagar	Magadi	Cauvery	C-5	77.3386	12.8703	5.64108051	0.0148472
4	0	3	Tavarekere	Bangalore Urban	Bangalore south	Cauvery	C-5	77.4058	12.9661	46.6243661	0.12271435
5	0	2	Kengeri	Bangalore Urban	Bangalore south	Cauvery	C-5	77.4872	12.9119	145.802935	0.38375024
6	0	4	Uttarahalli	Bangalore Urban	Bangalore south	Cauvery	C-5	77.545	12.9042	75.4159375	0.19849315
TOTAL CATCHMENT AREA										379.942263	

Table 5: Data imported from arcGis softwarefrom theissen polygon influencing raingauge station

CHAPTER 7 : RUNOFF ESTIMATION USING STRANGE'S TABLE METHOD

7.1 :NEED FOR RUNOFF ESTIMATION

In many activities of water resource development and management, such as a: flood control and its management, irrigation scheduling, design of irrigation and drainage networks, hydropower generation, etc., rainfall-generated runoff is particularly essential.In order to obtain a continuous height record that can be associated to flow, runoff is typically measured in the field using current metres, calibrated or rated channel cross sections, flumes, or standardised weirs, along with readings of the water level, frequently from automatic recorders.

7.2: STRANGE'S TABLES

Strange (1892) studied the available rainfall and runoff in the border areas of present day Maharashtra and Karnataka and has obtained yield ratios as functions of indicators representing catchment characteristics. Catchments are classified as ***good, average and bad*** according to the relative magnitudes of the yield they give. For example, catchments with good forest / vegetal cover and having soils of high permeability would be classified as bad, while catchments of low permeable soils and having little or no vegetal cover is termed good.

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Table 5.3(a) ***Strange's Table of Total Monsoon Rainfall and estimated Runoff***

Total Monsoon rainfall (inches)	Total Monsoon rainfall (mm)	Percentage of Runoff to rainfall			Total Monsoon rainfall (Inches)	Total Monsoon rainfall (mm)	Percentage of Runoff to rainfall		
		Good catchment	Average catchment	Bad catchment			Good catchment	Average catchment	Bad catchment
1.0	25.4	0.1	0.1	0.1	31.0	787.4	27.4	20.5	13.7
2.0	50.8	0.2	0.2	0.1	32.0	812.8	28.5	21.3	14.2
3.0	76.2	0.4	0.3	0.2	33.0	838.2	29.6	22.2	14.8
4.0	101.6	0.7	0.5	0.3	34.0	863.6	30.8	23.1	15.4
5.0	127.0	1.0	0.7	0.5	35.0	889.0	31.9	23.9	15.9
6.0	152.4	1.5	1.1	0.7	36.0	914.4	33.0	24.7	16.5
7.0	177.8	2.1	1.5	1.0	37.0	939.8	34.1	25.5	17.0
8.0	203.2	2.8	2.1	1.4	38.0	965.2	35.3	26.4	17.6
9.0	228.6	3.5	2.6	1.7	39.0	990.6	36.4	27.3	18.2
10.0	254.0	4.3	3.2	2.1	40.0	1016.0	37.5	28.1	18.7
11.0	279.4	5.2	3.9	2.6	41.0	1 041.4	38.6	28.9	19.3
12.0	304.8	6.2	4.6	3.1	42.0	1066.8	39.8	29.8	19.9
13.0	330.2	7.2	5.4	3.6	43.0	1092.2	40.9	30.6	20.4
14.0	355.6	8.3	6.2	4.1	44.0	1117.6	42.0	31.5	21.0
15.0	381.0	9.4	7.0	4.7	45.0	1143.0	43.1	32.3	21.5
16.0	406.4	10.5	7.8	5.2	46.0	1168.4	44.3	33.2	22.1
17.0	431.8	11.6	8.7	5.8	47.0	1193.8	45.4	34.0	22.7
18.0	457.2	12.8	9.6	6.4	48.0	1219.2	46.5	34.8	23.2
19.0	482.6	13.9	10.4	6.9	49.0	1244.6	47.6	35.7	23.8
20.0	508.0	15.0	11.3	7.5	50.0	1270.0	48.8	36.6	24.4
21.0	533.4	16.1	12.0	8.0	51.0	1295.4	49.9	37.4	24.9
22.0	558.8	17.3	12.9	8.6	52.0	1320.8	51.0	38.2	25.5
23.0	584.2	18.4	13.8	9.2	53.0	1346.2	52.1	39.0	26.0
24.0	609.6	19.5	14.6	9.7	54.0	1371.6	53.3	39.9	26.6
25.0	635.0	20.6	15.4	10.3	55.0	1397.0	54.4	40.8	27.2
26.0	660.4	21.8	16.3	10.9	56.0	1422.4	55.5	41.6	27.7
27.0	685.8	22.9	17.1	11.4	57.0	1447.8	56.6	42.4	28.3
28.0	711.2	24.0	18.0	12.0	58.0	1473.2	57.8	43.3	28.9
29.0	736.6	25.1	18.8	12.5	59.0	1498.6	58.9	44.4	29.41
30.0	762.0	26.3	19.7	13.1	60.0	1524.0	60.0	45.0	30.0

Table 5 STRANGE'S TABLE

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	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Total
Year	Bidadi	0.098	Byramangala	0.088	Kengeri	0.384	Manchanbele	0.015	Tavarekere	0.123	Uttarhalli	0.198	ARS Hebbala	0.095	
1980	455.3	44.510	467.1	40.875	453.8	174.146	593.2	8.807	357.2	43.834	322.8	64.074	416	39.490	415.735
1981	655.2	64.052	656	57.406	603.9	231.747	794.8	11.801	563.2	69.113	455.3	90.374	463.2	43.970	568.462
1982	393.9	38.507	440.4	38.539	637	244.449	512.6	7.611	489.3	60.044	402.3	79.854	634.9	60.269	529.273
1983	793.6	77.581	732.2	64.074	965	370.319	745.3	11.066	359.6	44.128	325.6	64.629	541.4	51.394	683.191
1984	676.3	66.114	633.2	55.411	418	160.408	674.5	10.014	369.2	45.306	366.2	72.688	617.8	58.646	468.587
1985	459.8	44.950	409.2	35.809	344	132.010	743.2	11.034	391.5	48.043	697.6	138.469	368.2	34.952	445.266
1986	337.4	32.984	714	62.481	923.8	354.508	606.4	9.003	436.2	53.528	345.6	68.599	618.7	58.732	639.836
1987	310.1	30.315	544.2	47.622	456.2	175.067	569.2	8.451	321.6	39.465	371.2	73.681	322.9	30.652	405.253
1988	914.5	89.401	811.9	71.048	1063.9	408.272	881.7	13.091	365.3	44.828	536.2	106.432	790.4	75.031	808.102
1989	657.2	64.247	624.9	54.684	631.4	242.300	905.8	13.449	206.3	25.316	596.3	118.361	772.7	73.350	591.708
1990	480.4	46.963	324.6	28.405	384.9	147.705	569.3	8.453	382.3	46.914	658.3	130.668	324	30.756	439.865
1991	469.8	45.927	944.2	82.626	888.2	340.847	832.9	12.366	1058.4	129.881	553.6	109.886	1124.5	106.746	828.279
1992	457.2	44.695	661.8	57.913	639.8	245.523	1016.2	15.088	654.5	80.317	490.6	97.381	675.2	64.095	605.012
1993	442.1	43.219	554	48.480	744.2	285.587	784.5	11.648	802.2	98.441	369.2	73.284	948.5	90.039	650.697
1994	497.8	48.664	467.1	40.875	455.3	174.721	840.1	12.473	469.4	57.602	313.5	62.228	659.7	62.624	459.188
1995	580.9	56.788	611.8	53.538	671	257.496	653.2	9.698	456.3	55.995	346.2	68.718	746.8	70.892	573.125
1996	612.7	59.897	693.8	60.714	909.2	348.906	583.3	8.660	478.5	58.719	411.2	81.620	830.4	78.828	697.343
1997	832.1	81.345	742.8	65.002	454	174.223	934.5	13.875	654.3	80.292	546.2	108.417	1052.2	99.883	623.036
1998	852.2	83.310	847.2	74.137	1117	428.649	1089.4	16.175	256.3	31.452	451.2	89.560	762.0	72.335	795.618
1999	749.8	73.300	786	68.782	448.4	172.074	781.8	11.608	501.3	61.517	431.2	85.590	702.9	66.724	539.594
2000	1015.2	99.245	1050.1	91.893	504.1	193.448	866.6	12.867	578.3	70.966	424.8	84.320	785.4	74.556	627.294
2001	437.2	42.740	640.7	56.067	549.7	210.948	892.3	13.248	356.2	43.711	462	91.704	637.2	60.488	518.905
2002	339.4	33.179	320.8	28.073	379.3	145.556	753.1	11.181	319.4	39.195	856.5	170.009	298.7	28.355	455.549
2003	472.8	46.220	520.4	45.540	281.8	108.141	836.2	12.415	401.5	49.270	569.3	113.002	473.6	44.958	419.546
2004	682.6	66.730	649.2	56.811	806.2	309.379	604.8	8.980	459.3	56.363	302.5	60.044	611.3	58.029	616.336
2005	971.9	95.012	968.2	84.726	874.6	335.628	837.2	12.430	354.2	43.465	369.5	73.343	890.4	84.523	729.128
2006	598.9	58.548	526.8	46.100	428.2	164.322	963.2	14.301	356.2	43.711	259.3	51.469	289.1	27.443	405.894
2007	266.7	26.072	494.1	43.238	643.4	246.905	516.1	7.663	496.2	60.891	385.2	76.460	716.2	67.987	529.215
2008	609.6	59.594	704.9	61.685	712.4	273.384	606.9	9.011	420.8	51.638	563.2	111.791	721.1	68.452	635.555
2009	584.5	57.140	685.3	59.970	656.1	251.779	529.3	7.859	475.2	58.314	413.2	82.017	535.9	50.872	567.950
2010	571.3	55.850	584.2	51.123	433.6	166.394	863.2	12.816	426.5	52.338	412.8	81.938	550.5	52.257	472.716
2011	521.6	50.991	682.3	59.707	669.7	256.998	940.8	13.968	566.1	69.469	786	156.016	680.5	64.598	671.746
2012	685.8	67.043	393.8	34.461	184.2	70.687	659.2	9.787	393	48.227	313	62.128	326.7	31.013	323.346
2013	519.5	50.786	711.1	62.227	581.5	223.151	722.3	10.724	517.6	63.517	611	121.279	767.6	72.866	604.551
2014	446.3	43.630	736.8	64.476	733.2	281.366	896.2	13.306	781	95.840	613.5	121.776	779.0	73.948	694.342
2015	509.2	49.779	762.8	66.752	800	307.000	813.6	12.080	781	95.840	511	101.430	433.0	41.104	673.984
2016	426.3	41.675	812.8	71.127	841	322.734	790.2	11.732	273.1	33.513	1048.8	208.180	791.6	75.144	764.105
2017	732.1	71.569	695.3	60.845	959	368.016	794.2	11.792	920.6	112.971	1126.2	223.543	893.2	84.789	933.525
2018	568.9	55.615	721.9	63.173	623.6	239.307	620.5	9.213	502.2	61.627	572.2	113.578	604.2	57.355	599.867
2019	526.9	51.509	843.4	73.805	913.1	350.402	801.9	11.906	642.5	78.844	542	107.583	806.4	76.549	750.599
2020	549.3	53.699	787.4	68.904	1318	505.783	809.1	12.013	839	102.957	784	155.619	1089.2	103.395	1002.370

Table 7 Yearly Rainfall Data of different Raingauge stations

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	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Area	Wt	Total
Year	Bidadi	0.098	Byramangala	0.088	Kengeri	0.384	Manchanbele	0.015	Tavarekere	0.123	Uttarhalli	0.198	ARS Hebbala	0.095	
2020	549.3	53.699	787.4	68.904	1318	505.783	809.1	12.013	839	102.957	784	155.619	1089.2	103.395	1002.370
2017	732.1	71.569	695.3	60.845	959	368.016	794.2	11.792	920.6	112.971	1126.2	223.543	893.2	84.789	933.525
1991	469.8	45.927	944.2	82.626	888.2	340.847	832.9	12.366	1058.4	129.881	553.6	109.886	1124.5	106.746	828.279
1988	914.5	89.401	811.9	71.048	1063.9	408.272	881.7	13.091	365.3	44.828	536.2	106.432	790.4	75.031	808.102
1998	852.2	83.310	847.2	74.137	1117	428.649	1089.4	16.175	256.3	31.452	451.2	89.560	762.0	72.335	795.618
2016	426.3	41.675	812.8	71.127	841	322.734	790.2	11.732	273.1	33.513	1048.8	208.180	791.6	75.144	764.105
2019	526.9	51.509	843.4	73.805	913.1	350.402	801.9	11.906	642.5	78.844	542	107.583	806.4	76.549	750.599
2005	971.9	95.012	968.2	84.726	874.6	335.628	837.2	12.430	354.2	43.465	369.5	73.343	890.4	84.523	729.128
1996	612.7	59.897	693.8	60.714	909.2	348.906	583.3	8.660	478.5	58.719	411.2	81.620	830.4	78.828	697.343
2014	446.3	43.630	736.8	64.476	733.2	281.366	896.2	13.306	781	95.840	613.5	121.776	779.0	73.948	694.342
1983	793.6	77.581	732.2	64.074	965	370.319	745.3	11.066	359.6	44.128	325.6	64.629	541.4	51.394	683.191
2015	509.2	49.779	762.8	66.752	800	307.000	813.6	12.080	781	95.840	511	101.430	433.0	41.104	673.984
2011	521.6	50.991	682.3	59.707	669.7	256.998	940.8	13.968	566.1	69.469	786	156.016	680.5	64.598	671.746
1993	442.1	43.219	554	48.480	744.2	285.587	784.5	11.648	802.2	98.441	369.2	73.284	948.5	90.039	650.697
1986	337.4	32.984	714	62.481	923.8	354.508	606.4	9.003	436.2	53.528	345.6	68.599	618.7	58.732	639.836
2008	609.6	59.594	704.9	61.685	712.4	273.384	606.9	9.011	420.8	51.638	563.2	111.791	721.1	68.452	635.555
2000	1015.2	99.245	1050.1	91.893	504.1	193.448	866.6	12.867	578.3	70.966	424.8	84.320	785.4	74.556	627.294
1997	832.1	81.345	742.8	65.002	454	174.223	934.5	13.875	654.3	80.292	546.2	108.417	1052.2	99.883	623.036
2004	682.6	66.730	649.2	56.811	806.2	309.379	604.8	8.980	459.3	56.363	302.5	60.044	611.3	58.029	616.336
1992	457.2	44.695	661.8	57.913	639.8	245.523	1016.2	15.088	654.5	80.317	490.6	97.381	675.2	64.095	605.012
2013	519.5	50.786	711.1	62.227	581.5	223.151	722.3	10.724	517.6	63.517	611	121.279	767.6	72.866	604.551
2018	568.9	55.615	721.9	63.173	623.6	239.307	620.5	9.213	502.2	61.627	572.2	113.578	604.2	57.355	599.867
1989	657.2	64.247	624.9	54.684	631.4	242.300	905.8	13.449	206.3	25.316	596.3	118.361	772.7	73.350	591.708
1995	580.9	56.788	611.8	53.538	671	257.496	653.2	9.698	456.3	55.995	346.2	68.718	746.8	70.892	573.125
1981	655.2	64.052	656	57.406	603.9	231.747	794.8	11.801	563.2	69.113	455.3	90.374	463.2	43.970	568.462
2009	584.5	57.140	685.3	59.970	656.1	251.779	529.3	7.859	475.2	58.314	413.2	82.017	535.9	50.872	567.950
1999	749.8	73.300	786	68.782	448.4	172.074	781.8	11.608	501.3	61.517	431.2	85.590	702.9	66.724	539.594
1982	393.9	38.507	440.4	38.539	637	244.449	512.6	7.611	489.3	60.044	402.3	79.854	634.9	60.269	529.273
2007	266.7	26.072	494.1	43.238	643.4	246.905	516.1	7.663	496.2	60.891	385.2	76.460	716.2	67.987	529.215
2001	437.2	42.740	640.7	56.067	549.7	210.948	892.3	13.248	356.2	43.711	462	91.704	637.2	60.488	518.905
2010	571.3	55.850	584.2	51.123	433.6	166.394	863.2	12.816	426.5	52.338	412.8	81.938	550.5	52.257	472.716
1984	676.3	66.114	633.2	55.411	418	160.408	674.5	10.014	369.2	45.306	366.2	72.688	617.8	58.646	468.587
1994	497.8	48.664	467.1	40.875	455.3	174.721	840.1	12.473	469.4	57.602	313.5	62.228	659.7	62.624	459.188
2002	339.4	33.179	320.8	28.073	379.3	145.556	753.1	11.181	319.4	39.195	856.5	170.009	298.7	28.355	455.549
1985	459.8	44.950	409.2	35.809	344	132.010	743.2	11.034	391.5	48.043	697.6	138.469	368.2	34.952	445.266
1990	480.4	46.963	324.6	28.405	384.9	147.705	569.3	8.453	382.3	46.914	658.3	130.668	324	30.756	439.865
2003	472.8	46.220	520.4	45.540	281.8	108.141	836.2	12.415	401.5	49.270	569.3	113.002	473.6	44.958	419.546
1980	455.3	44.510	467.1	40.875	453.8	174.146	593.2	8.807	357.2	43.834	322.8	64.074	416	39.490	415.735
2006	598.9	58.548	526.8	46.100	428.2	164.322	963.2	14.301	356.2	43.711	259.3	51.469	289.1	27.443	405.894
1987	310.1	30.315	544.2	47.622	456.2	175.067	569.2	8.451	321.6	39.465	371.2	73.681	322.9	30.652	405.253
2012	685.8	67.043	393.8	34.461	184.2	70.687	659.2	9.787	393	48.227	313	62.128	326.7	31.013	323.346

Table 8 Yearly Rainfall data in descending order for 50% dependable year from different raingauge stations

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From Strange's Tables for good catchment

584.2 – 18.4

604.551 - x

609.6 – 19.5

By interpolation, x = 19.28 %

Year 2013 is 50% dependable area

604.551 x 19.28% = 116.557 / 10^3 = 0.1165

Total catchment area = 379.9423 km^2 (from Theissen polygon)

= 379942300 m^2 x 0.1165

Volume = 44263277.95 m^3

Runoff = 44263277.95 m^3 / 10^6

= 44.263 Mm^3 (million meter cube)

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CHAPTER 8 CONCLUSION

The delineation of watersheds uses automated GIS watershed tools. The application potential of DEM to several hydrologic, hydraulic, and water resources has significantly increased as a result of GIS's technological advancements and the growing availability and quality of DEM. Increased efficiency is offered by GIS ArcHydro; a typical hydrographical analysis was carried out both using GIS and conventional methods. Efficiency in a hydrographical study largely refers to reducing the cost of data acquisition and the amount of time needed to complete the analysis. These findings can be efficiently used to watershed studies, hydrological modelling, land use planning, and reservoir operation and planning.

This study demonstrates the capability of GIS-based spatial interpolation technique for developing sustainable land-use system on watershed basis. There are enough opportunities for diversification of the rainfed upland area with short duration field crops and vegetables for higher land productivity and water productivity.

We have used arcGIS software for georeferencing of toposheets, digitizing streams of watershed for calculating morphometric parameters, for extracting DEM (Digital Elevation Model), influencing rainguage stations and Theissan Polygon.

For 44.263Mm^3 runoff 44262999999.99 litres serves 3278704.074 population

REFERENCES

1. Ajey Kumar V G et al., November 2019, 'Rainfall Analysis of Vrishabhavathi Valley inBengaluruRegion'.InternationalJournalofRecentTechnologyandEngineering(IJRTE),Volume-8Issue-4,PP-9288-9290.

2. AravindaPT, BalakrishnaH B, Morphometric Analysis of Vrishabhavathi watershed using Remote Sensing and GIS, International Journal of Research in Engineering and Technology.Vol 2 PP- 2321-7308

3. Gos K, Rao S et al., (2004) GIS-based technologies for watershed management, volume 87, International Journal of Water Management Modeling PP -948-952

4. Kar G, Patra PK, et al., (2021) Land resources evaluation and drainage network analysis of watershed for site specific crop planning using GIS, Vol 121, International research journal of engineering and technology, PP-1470-1478

5. Kiran Kumar, K.M, Govindaiah, S, Nagabhushan, P, et al., (2018)Morphometric Analysis of the Tumkur-GubbiWatershedofShimsha River Basin, Karnataka, India,by using Remote Sensing and GIS Techniques, International Journal of Creative Research Thoughts (IJCRT), vol 6, PP-1628-1640

6. L John et al., (2016)Integrated watershed management evolution, development and emerging trends, vol 10,International Journal of Water Management Modeling ,vol 27, PP-944-967

7. M.Latha and M.Rajendran, et al.,(2015) An Empirical Approach to Estimate Runoff of an Unguaged Catchment- Strange Table Method, International Journal of Research in Advent Technology, Vol.3 PP-125-128

8. N Mangrule and J Um. Kahalekar, et al., (2013)Watershed Planning and Development Plan by Using Rs and GIS of KhultabadTaluka of Aurangabad District, volume 3.International journal of water resources development. Pp-1094-1100

9. PandeyA, Behra RP. Pandey and Singh RP et al.,(2011), Application of GIS for Watershed Prioritization and Management A Case Study, International Journal of Water Management Modeling ,Vol 2, PP -26-42

10. Setyawan C, Susanto S and Lee SS et al., (2019) Spatial modelling of watershed health assessment by using GIS, International research journal of engineering and technology ,Vol 355, PP- 1038-1315

11. Suthar VK, Bhoite RR, Mane AB, Mandhare AJ, Salvi SS et al., (2022) Watershed Management of PurandarTaluka by Remote Sensing and GIS, International Journal For Research in Applied Science and Engineering Technology. PP 0022-1945

12. Sandeep A et al.,(2020) Morphometric Analysis of a Drainage Basin: A Study of Ghatganga River, Bajhang District, Nepal, The Geographic Base Vol. 7: 127-144