P.E.S COLLEGE OF ENGINEERING
MANDYA – 571401
(An Autonomous Institute Affiliated to VTU, Belgaum)

A DISSERTATION REPORT ON
"QUANTITATIVE MORPHOMETRIC AND HYPSOMETRIC ANALYSIS USING RS AND GIS TECHNIQUES"

Submitted in partial fulfilment of the requirement for the award of the Bachelor of Engineering Degree

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CERTIFICATE

This is to certify that VINAY K P (4PS17CV123), UMER ABDUR RAHMAN (4PS17CV119), ROHITH R (4PS17CV083) and MANU K (4PS18CV413) have successfully completed the dissertation work entitled "**QUANTITATIVE MORPHOMETRIC AND HYPSOMETRIC ANALYSIS USING RS AND GIS TECHNIQUES"** in partial fulfilment for the award of Bachelor of Engineering in Civil Engineering of P E S College of Engineering, Mandya during the academic year 2020-2021. It is certified that the project has been approved as it satisfies the academic requirement in respect of project works prescribed for the degree in Bachelor of Engineering.

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CANDIDATE'S DECLARATION

We, VINAY K P (4PS17CV123), UMER ABDUR RAHMAN (4PS17CV119), ROHITH R (4PS17CV083) MANU.K (4PS18CV413) the undersigned students of VIII semester of Civil Engineering, PES College of Engineering Mandya, declare that our project work entitled **"QUANTITATIVE MORPHOMETRIC AND HYPSOMETRIC ANALYSIS USING RS AND GIS TECHNIQUES"**, has been prepared by us under the guidance of **Prof. R.K.KUMARASWAMY**. Associate Professor, Department of Civil Engineering, PESCE Mandya. This work has been submitted for the partial fulfillment of the requirement for the award of Bachelor of Engineering degree. We also declare that this project was not entitled for submission to any other university in the past and shall remain the only submission made and will not be submitted by us to any other university in the future.

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ABSTRACT

Morphometric analysis is crucial in any hydrological inquiry and is required for watershed development and management. Measuring the linear, areal, and relief characteristics of basins allowed for a critical examination of morphometric parameters. The Manchanabele reservoir catchment of the Arkavati river system were subjected to a detailed morphometric investigation using ARC- GIS. The Arkavati River is a tributary of the Cauvery River, with a catchment area of 4038 square kilometers. The Arkavati River is crossed by the Manchanabele Reservoir. The Manchanabele Reservoir has a 152.99-square-kilometer catchment area. An attempt has been made in this study to analyze the Command area at the watershed. Geographically, the study region is located between 77˚ 50' 0" E and 77˚ 25' 0" E. With an area of 1594.541sq.km, it is located at 77˚ 50' 0" E and 77˚ 25' 0" E longitude and 12˚ 45' 0" N and 13˚ 0' 0" N latitude. Horton and Strahler method of stream ordering has been applied for the analysis. The analysis reveals that the stream order varies from 1st to 8th order and the total number of stream segments of all orders found to be 40368. The drainage density is 6.2704, indicating that the studied region has a very fine soil and infiltration is less. The circularity ratio value indicates that the geologic material is more circular and very permeable.

The hypsometric analysis carried out and value of hypsometric integral (HI) is found to be 0.5 based on integrating method , which indicates the watershed is at equilibrium or mature stage. The study concludes that morphometric and hypsometric analysis using RS and GIS technique proves to be very helpful to identify the geo-hydrological, geomorphological characteristics of basin for planning, sustainable development, management and conservation of soil for Manchanabele command area.

KEYWORD: Morphometric Analysis, Remote Sensing, Geographical Information System, Hypsometric Integral Value.

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CHAPTER 01

INTRODUCTION

1.1 MORPHOMETRIC ANALYSIS

Land and water resources are scarce in countries like India, where population pressure is always increasing, and their widespread use is essential. Drainage basins, catchments, and sub-catchments are the basic administrative entities for natural resource conservation. The watershed management concept recognizes the interrelationships among the linkages between uplands, low lands, land use, geomorphology, slope and soil. Soil and water conservation are the key issues in watershed management while demarcating watersheds

The measurement and quantitative analysis of the configuration of the earth's surface, shape, and size of its landforms is known as morphology (Agarwal, 1998). In the discipline of hydrology, morphometric analysis was developed to determine comprehensive stream characteristics by quantifying numerous stream properties (Horton, 1940). Horton was the first person to explain the formation of streams, stream ordering technique and basins quantitatively and it is then revised by Strahler (1952).

Morphometric analysis is significant for characterization of watersheds and gives information about quantitative description of the streams network and useful for hydrological investigation. The influence of stream network is significant in understanding the landform process, soil physical properties and land degradation status (Schumm, 1956). Morphometric analysis can be analyzed through measurement of linear, areal and relief aspects of basins by using Remote sensing (RS) and Geographic Information System (GIS) technique.

In comparison to the traditional method, the integration of Remote Sensing (RS) and Geographic Information Systems (GIS) techniques is more convenient for morphometric analysis. RS and ArcGIS tools can be used to create various theme layers required for the morphometric study (Sharma, 2018).

RS and GIS is a proven technique for delineating, updating and analyzing the morphometric parameters of drainage basin. Delineation of drainage network and its parameter analysis generally emphasis the climate, geology, geomorphology and relief aspects of a basin.

Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, geological and geomorphic history of drainage basin (Strahler, 1964). The quantitative morphometric analysis of the drainage basin is considered to be the most satisfactory method because it enables us

i) To understand the relationship between different aspects of the drainage pattern of the same basin.

ii) For comparative evaluation of different drainage basins developed in various geologic and climatic regimes and

iii) To define certain useful parameters of drainage basins in numerical terms.

1.1.1 SCOPE OF PRESENT WORK

- Manchanabele dam is the main source of drinking water for Magadi and some parts of Ramanagar. It also supplies water for irrigation purposes to hundreds of acres of land through its left bank and right bank canals.
- Based on the inferences obtained from morphometric analysis, effective management and conservation of natural resources in the study area can be determined.
- The data utilize the resources for planning rainwater harvesting and watershed management.
- Hypsometric analysis describes the elevation distribution across an area of land surface and its erosion stage in the study area.
- Based on this analysis, importance in estimation of erosion status of watershed and subsequent prioritization for taking up soil and water conservation activities can be made.

1.2 HYPSOMETRIC ANALYSIS

Hypsometric analysis is a useful method to identify the stage reached by a drainage basin in the present cycle of erosion and evaluate the erosional status of a basin and also expresses the denudation processes over a region. Hypsometric curve is the graphical representation of area vs. elevation. Strahler (1952) evaluated different shapes of hypsometric curves through the comparison of different drainage basins and classified as youth stage, where the watershed undergoes erosion and land sliding, equilibrium or mature stage, less erosion and land slide than youth stage and lastly old stage, very less erosion and land slide.

The idea of hypsometry was first introduced by Langbein and Basil in 1947 to express the overall slope and the forms of drainage basin, and was later extended by Strahler (1952) to include the percentage hypsometric curve and the hypsometric integral (HI). Hypsometric analysis is highly popular because of its dimensionless nature that permits comparison of watersheds irrespective of scale issues (Dowling, 1998).

Hypsometric integral is the area under hypsometric curve which shows percentage of landmass eroded from the watershed based and on this the watershed is divided into three stages as old (HI < 0.3), equilibrium or mature stage (HI 0.3 < 0.6) in which watershed is highly susceptible to erosion (Strahler 1952).

The hypsometric integral is expressed as a percentage and is an indicator of the residue of the present volume as compared to the original volume of the basin. The hypsometric integral thus helps in explaining the erosion that had taken place in the watershed during the geological time scale due to hydrologic processes and land degradation factors (Strahler, 1964).

The hypsometric integral value can be an indirect estimator of the erosion from the watershed systems. The shape of hypsometric curve represents the geomorphic stages of landform evolution. Convex shape indicates younger, un-dissected, disequilibrium landscapes stage. Smooth S-shape shows mature or equilibrium stage and concave shape curve is related to an old deeply dissected and pen plain landscapes stage (Magesh, 2013).

Differences in the shape of the curve and the hypsometric integral value are related to the degree of disequilibrium in the balance of erosive and tectonic forces as shown in fig 1.1

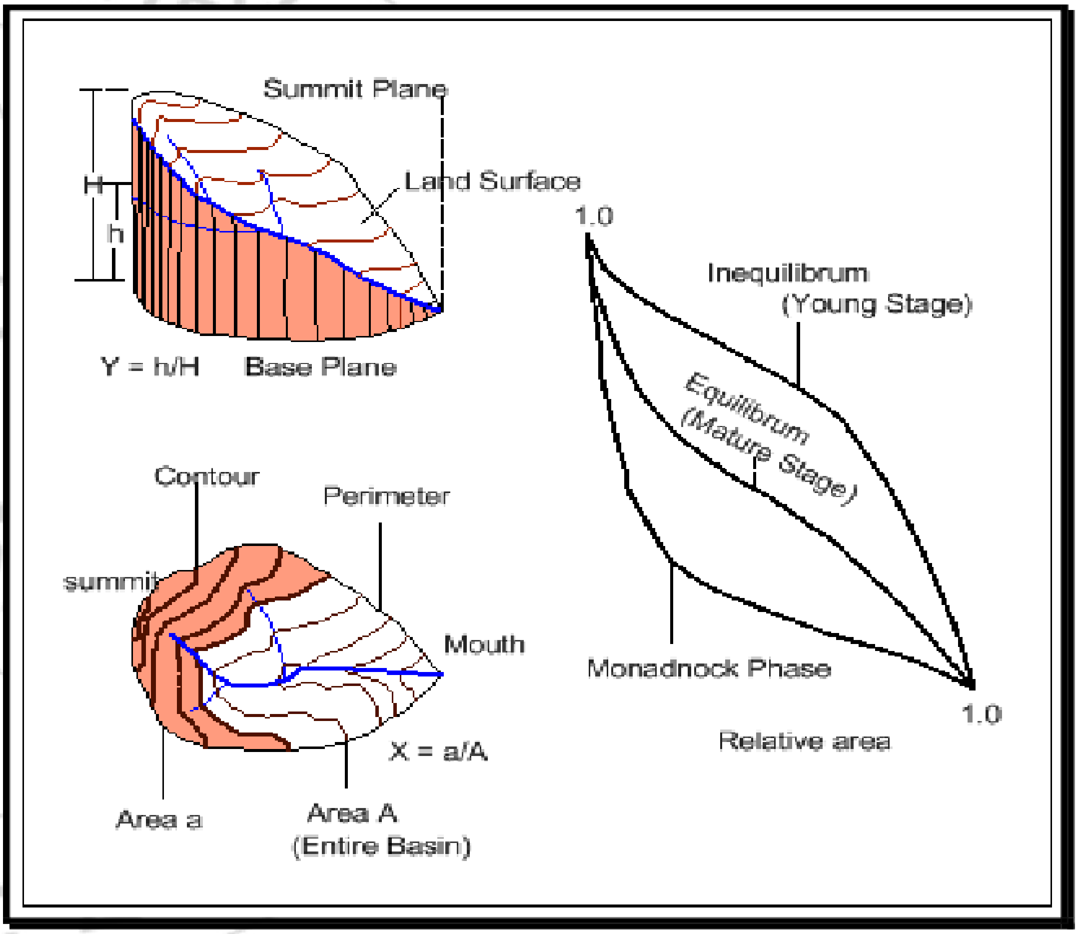


Figure 1: The concept of hypsometric analysis and model hypsometric curves (Ritter, 2002)

Fig 1.1 The hypsometric analysis and model hypsometric curves

1.2.1HYPSOMETRIC CURVE

Hypsometric curve is the graphical representation of area vs. elevation. Strahler (1952) evaluated different shapes of hypsometric curves through the comparison of different drainage basins, and classified as youth stage, where the watershed undergoes erosion and land sliding, equilibrium or mature stage, less erosion and land slide than youth stage and lastly old stage, very less erosion and land slide as shown in fig 1.2.

A hypsometric curve is a histogram or cumulative distribution function of elevations in a geographical area. Differences in hypsometric curves between landscapes arise because the geomorphic processes that shape the landscape may be different.

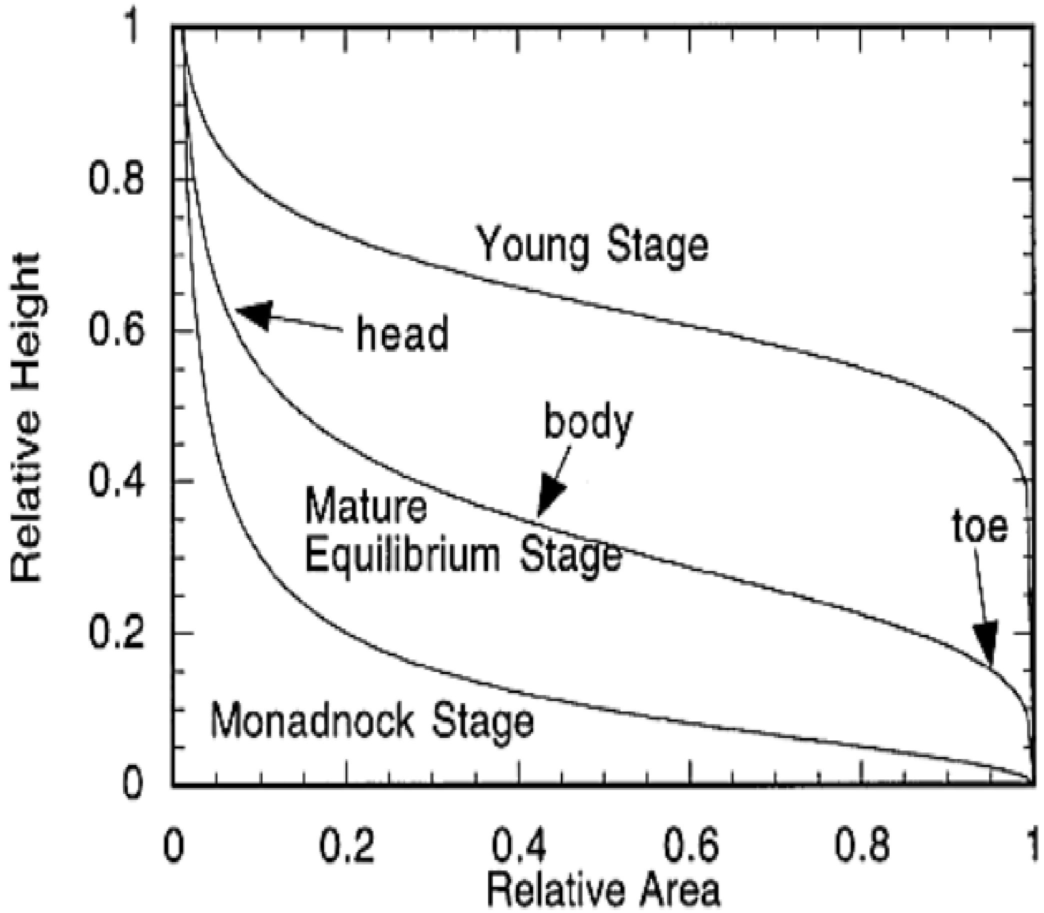


Fig 1.2 standard hypsometric Curve

1.2.2 ABSOLUTE HYPSOMETRIC CURVE

The absolute hypsometric curve has been used in regional geomorphic studies to show the presence of extensive summit flatness or terracing, where the surfaces lies approximately horizontal. Where these surfaces have a pronounced regional slope, they may not appear on the curve. Because a good toposheet, from which the hypsometric curve was prepared, will usually show these features, the justification for an elaborate hypsometric process for interpreting geomorphic history is doubtful.

For analysis of the form quality of erosional topography, use of absolute units is unsatisfactory because areas of different size and relief cannot be compared, and the slope of the curve depends on the arbitrary selection of scales. To overcome these difficulties, it is desirable to use dimensionless parameters independent of absolute scale of topographic features.

1.2.3 PERCENTAGE HYPSOMETRIC CURVE

The percentage hypsometric method used in this investigation relates the area enclosed between a given contour and the upper (headward) segment of the basin perimeter to the height of that contour above the basal plane. The method has been used by Langbein (1947) for hydrologic investigations. Fig 1.3. Shows The Percentage Hypsometric Curve (Strahler, 1964).

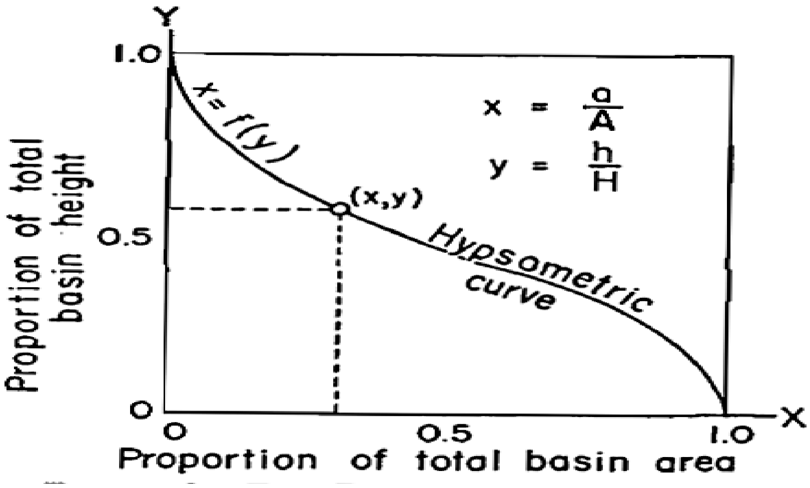


Fig 1.3 percentage Hypsometric curve

1.3 OBJECTIVE

The objectives of study area are,

1. Preparation of the different thematic maps using Survey of India (SOI) Topomaps of 1:50000 scale.
2. To derive the morphometric parameters such as linear, areal and relief aspects of the study area.
3. Morphometric analysis has been carried out by using Remote sensing (RS) and Geographic Information System (GIS) technology to compute basin morphometric

characteristics for various parameters.

4. To understand the knowledge of RS and GIS Techniques.

1.4 REMOTE SENSING

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object, in contrast to in situ or on-site observation. The term is applied especially to acquiring information about the Earth and other planets.

Remote sensing is used in numerous fields, including geography, land surveying and most Earth science disciplines (for example, hydrology, ecology, meteorology, oceanography, glaciology, geology); it also has military, intelligence, commercial, economic, planning, and humanitarian applications, among others.

In current usage, the term "remote sensing" generally refers to the use of satellite or aircraft-based sensor technologies to detect and classify objects on Earth. It includes the surface and the atmosphere and oceans, based on propagated signals (e.g. electromagnetic radiation). It may be split into "active" remote sensing (when a signal is emitted by a satellite or aircraft to the object and its reflection detected by the sensor) and "passive" remote sensing (when the reflection of sunlight is detected by the sensor**).**

CHAPTER 2
LITERATURE REVIEW

a. **Biswas et al., (1999)**

Carried out Prioritization of sub-watersheds based on morphometric analysis of drainage basin, Midnapore district, West Bengal. They pointed out that morphometric analysis of drainage basin and its stream system can be better achieved through measurement of linear, areal and relief aspects of drainage basin. Detailed morphometric analysis of a basin is of great help in understanding the influence of drainage morphometry on landforms and their characteristics.

b. **Deepak K et al., (2014)**

Carried out Morphometric analysis for prioritization using remote sensing and GIS techniques in a hilly catchment in the state of Uttarakhand, India. They concluded that Remote Sensing (RS) and Geographical Information System (GIS) techniques were used to update drainage and surface water bodies and to evaluate linear, relief and aerial morphometric parameters of the sub watersheds.

c. **John Wilson J S et al., (2012)**

Worked for Morphometric analysis of major sub-watersheds in Aiyar and Karai Pottanar Basin, Central Tamil Nadu, India. They suggested that Morphometric analysis with the help of Geographic Information System (GIS) is most effective, time saving and accurate technique for prioritization, planning and management, site specific suitability of various soil and water conservation measures and development and management of ground water on watershed basis.

d. **Kuldeep Pareta et al., (2011)**

Carried out research work on "Quantitative Morphometric Analysis of Watershed of Yamuna Basin, India, using ASTER (DEM) Data and GIS and found out obtaining synoptic view of large area through DEM at one time is very useful in analyzing the drainage morphometry and (GIS) techniques helpful to assess the geo-hydrological characteristics. Also physiography of basin which is helpful for river water management, irrigation and site suitability for reservoirs.

e. **Magesh et al., (2013)**

Carried out study on Geographical information system-based morphometric analysis of Bharathapuzha river basin, Kerala, India and suggested that the development of a drainage system over space and time is influenced by several variables such as geology, structural components, geomorphology, soil and vegetation of an area through which it flows.

f. **Magesh N S et al., (2011)**

Carried out study on Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu, India and concluded that Morphometric analysis of the watershed is considered to be the most satisfactory method because it enables (i) an understanding of the relationship of various aspects within a drainage basin (ii) a comparative evaluation to be made of different drainage basins developed in different geomorphological and topographical regimes and (iii) the definition of certain useful variables of drainage basins in numerical terms.

g. **Nageswara Rao K et al., (2006),**

Carried out study on morphometry of the Mehadrigedda watershed, Visakhapatnam district, Andhra Pradesh, using GIS and RS data and found out that using traditional methods, it is difficult to examine all drainage networks from field observations. GIS technique as emerged as powerful tool for analyzing the drainage morphometry.

h. **Rekha et al.,(2011)**

Carried out study on Morphometric analysis and micro-watershed prioritization of Peruvanthanam sub-watershed, the Manimala River Basin, Kerala, South India and suggested that Integration of Remote Sensing (RS) and Geographical Information Systems (GIS) techniques are more convenient for morphometric analysis as compare to conventional method. It is a proven technique for delineating, updating and analyzing the morphometric parameters of drainage basin and effective planning and management of natural resources is more suitable than other methods.

i. **Srinivas V S et al.,(2008)**

Carried out study on Morphometry using RS and GIS techniques in the sub-basins of Kagna river basin Gulbarga district, Karnataka, India and concluded that RS technique has emerged as a powerful tool in obtaining synoptic view of large area at one time and very useful in analyzing the drainage morphometry.

j. **Sethupathi A S et al., (2011)**

Worked on Prioritization of mini watersheds based on morphometric analysis using RS and GIS in a drought prone Bargur Mathur sub watersheds, Ponnaiyar River basin, India and suggested that Morphometric analysis with the help of GIS is most effective, time saving and accurate technique for prioritization and provides information about specific suitability of various soil and water conservation measures

CHAPTER 3

STUDY AREA

The study area is comprised of catchment area of Manchanabele reservoirs of Arkavathi river sub-basin. The area is bound between E Longitude **77º 50' 0" – 77º 25' 0"** and N Latitude **12º 45 '0" – 13º 0' 0"** covered in Survey of India toposheet **No 57H/5** of 1:50,000 scale. The subject area forms a part of semi-arid tract in the agro climatic environs of East Dry Zone of Karnataka. The land use of the catchment area is agricultural and forest area. The catchment area of the tank is affected by soil erosion. The intensive farming in the catchment and command area with intensive application of Chemical Fertilizers has resulted in ground water and soil contamination. Manchanabele reservoir is constructed across the Arkavati River after having been drained by 'Chiktore' stream near Manchanabele. It is located in Magadi taluk of Ramanagaram district. It is about 10 km south of Chamarajasagar reservoir which is also across the river Arkavathi near Tippagondanahalli that feeds water to certain parts of Bangalore City.

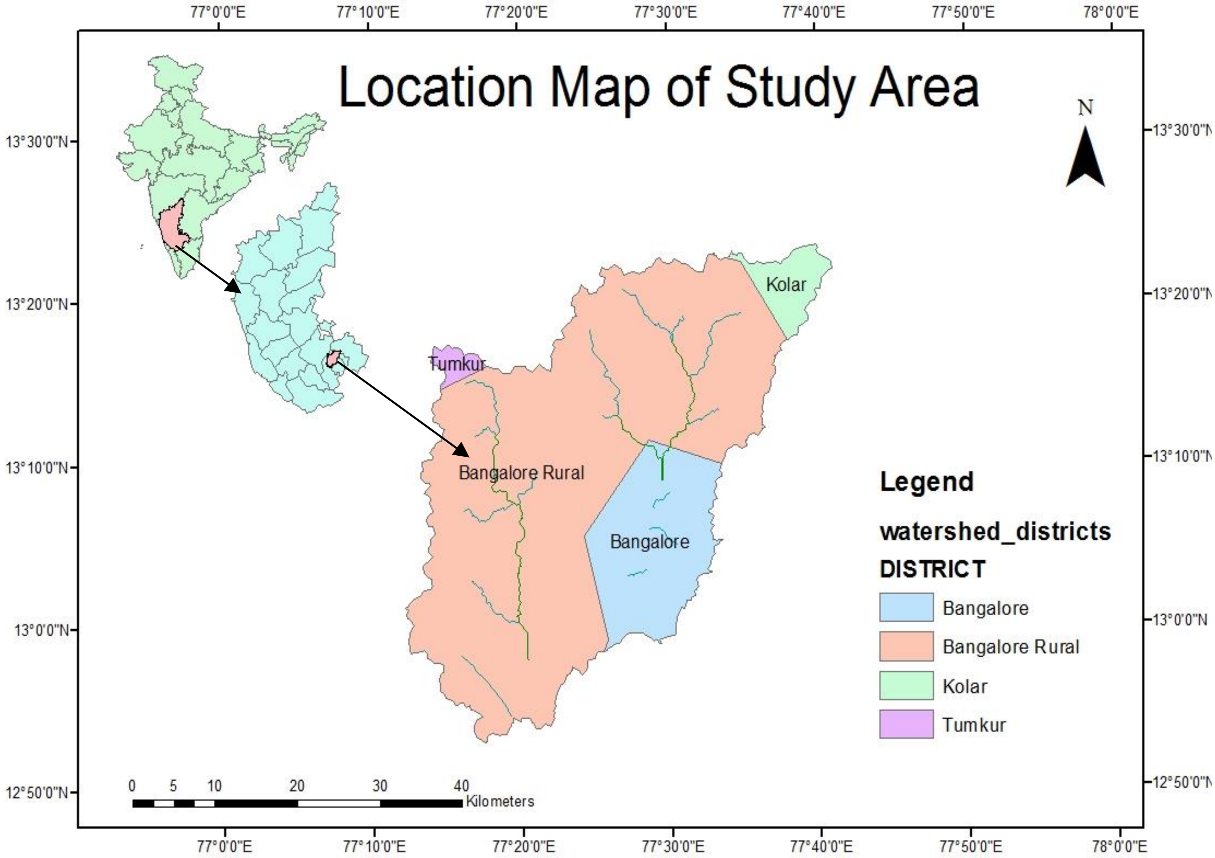


Fig 3.1 Location map of study area

3.1 DATA USED

The most important step in any project is the reliable data. In fact, in almost all project, the most time consuming and resource oriented processes is the data acquisition process. Various data required for this study were taken from various sources and are described under various headings.

3.2 DIGITAL ELEVATION MODEL (DEM)

Digital Elevation Model (DEM) is the digital representation of the land surface elevation with respect to any reference datum. DEM is frequently used to refer to any digital representation of a topographic surface and also to determine terrain attributes such as elevation at any point, slope and aspect. This is popular for calculations, manipulations and further analysis of an area, and more specifically analysis based on the elevation. Hydrological application of DEM include groundwater modelling, estimation of volume of reservoir, flood prone area mapping etc. It can also be used to find features on the terrain, such as drainage basins and watersheds, drainage networks and channels, peaks and pits, outlets of the terrain and other landforms. We used a standard GIS software to generate a DEM based on the principles of Photogrammetry. DEM having spatial resolution of 30 m from LANDSAT 8 satellite was downloaded from NASA’S USGS earth explorer Geo-portal website and mosaicking of DEM to get the required study area was done by utilizing tools within the ArcGIS 10.3 interface. The watershed delineation provided drainage pattern of land surface terrain including the stream network, and outlets of the river basin. Watersheds were defined by the model using a DEM-based automated method. Figure 3.2 shows the elevation map of the study area whose value ranges from 738 to 1446 meter.

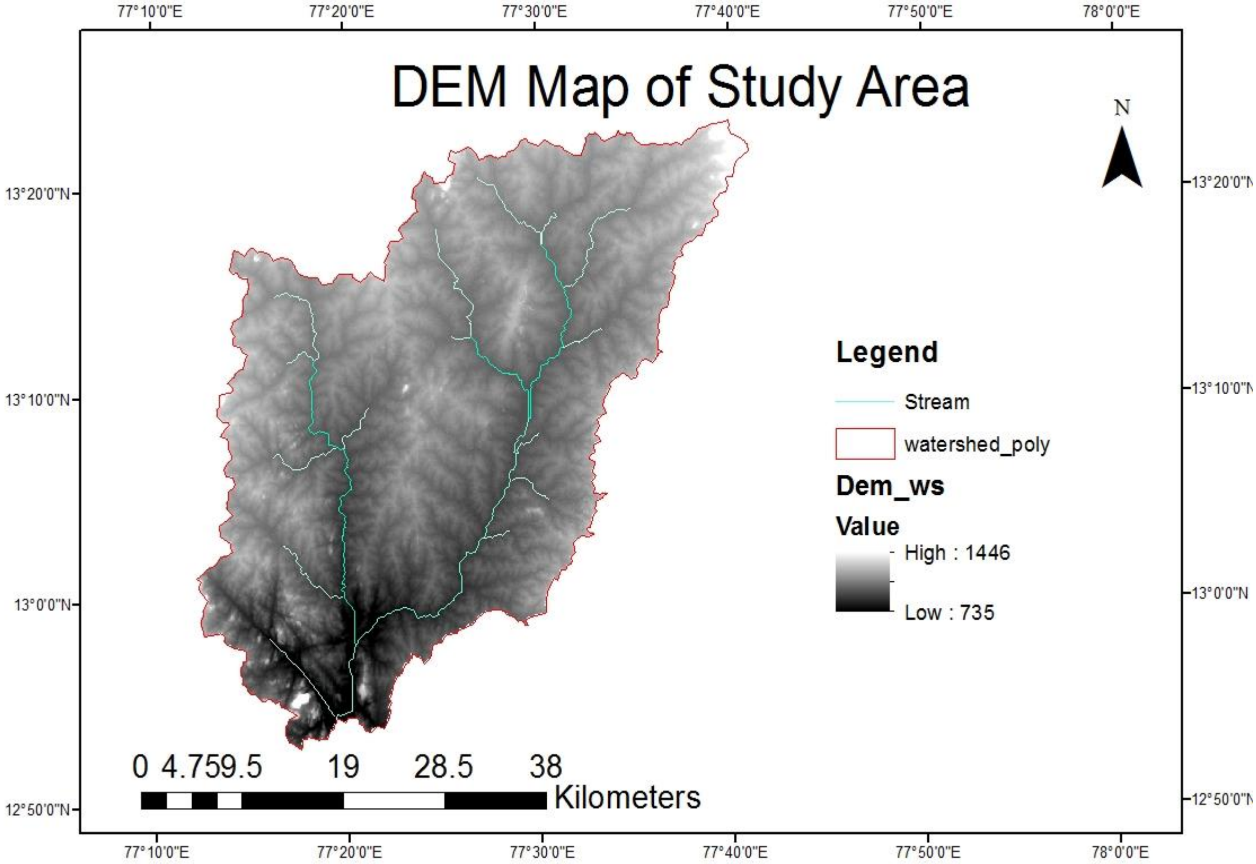


Fig 3.2 Dem map of study area

CHAPTER 4
TOOLS AND METHODOLOGY

4.1 GEOGRAPHIC INFORMATION SYSTEM (GIS)

A geographic information system (GIS) is a conceptualized framework that provides the ability to capture and analyze spatial and geographic data. GIS applications (or GIS apps) are computer-based tools that allow the user to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyze spatial information output, and visually share the results of these operations by presenting them as maps. Geographic information science (or, GIScience)—the scientific study of geographic concepts, applications, and systems—is commonly initialized as GIS, as well.

Geographic information systems are utilized in multiple technologies, processes, techniques and methods. They are attached to various operations and numerous applications that relate to: engineering, planning, management, transport/logistics, insurance, telecommunications, and business. [2] For this reason, GIS and location intelligence applications are at the foundation of location-enabled services that rely on geographic analysis and visualization.

GIS provides the capability to relate previously unrelated information, through the use of location as the "key index variable". Locations and extents that are found in the Earth's space-time, are able to be recorded through the date and time of occurrence, along with x, y, and z coordinates; representing, longitude (x), latitude (y), and elevation (z). All Earth-based, spatial–temporal, location and extent references, should be relatable to one another, and ultimately, to a "real" physical location or extent. This key characteristic of GIS, has begun to open new avenues of scientific inquiry and studies

4.2 ARC – GIS:

ArcGIS is a geographic information system (GIS) application developed and maintained by the American company Esri. ArcGIS consists of the following Windows desktop software ArcReader, which allows one to view and query maps created with the other ArcGIS products.

ArcGIS Desktop (often referred to as "ArcMap" to distinguish it from ArcGIS Pro), made up of four fundamental applications:

1. ArcMap, for viewing and editing spatial data in two dimensions and creating two-dimensional maps;
2. ArcScene, for viewing and editing three-dimensional spatial data in a local projected view.
3. ArcGlobe, for displaying large, global 3D datasets;
4. ArcCatalog, for GIS data management and manipulation tasks.

ArcGIS Pro, a new, integrated GIS application, planned to eventually supersede ArcMap and its companion programs. ArcGIS Pro works in 2D and 3D for cartography and visualization, and includes Artificial Intelligence (AI).

There are also server-based ArcGIS software as part of the ArcGIS Enterprise product, as well as ArcGIS applications for mobile devices like phones and tablets. Extensions can be purchased separately.

4.3 MORPHOMETRIC ANALYSIS

The Survey of India (SOI) topographical maps of 1:50,000 scale were used to prepare (i) Base maps, (ii) Drainage maps of Manchanabele reservoir catchment of Arkavati river basin. The drainage maps are Stream network for the above catchments are traced and scanned. The scanned stream network map was geo referenced and converted into digital format using Arc GIS 10.3 version GIS software. ASTER (Advanced Space born Thermal Emission and Reflection and Radiometer) digital elevation data set (30m resolution) was used for computing relief parameters.

Quantitative morphometric analysis was carried out for different catchments as mentioned above for linear aspects, areal aspects and relief aspects. The analysis was carried out using GIS Arc- Info software. System of stream ranking (Strahler, 1957) has been used for calculating the morphometric parameters of the reservoir and lake catchments of the present study.

In this chapter, morphometric analysis of MANCHANABELE catchment is carried out using GIS which is a suitable tool to derive the morphometric parameters. The analysis was carried out through measurement of linear, aerial and relief aspects of basins. The morphometric parameters were useful in understanding the hydrological processes of the drainage basin.

4.3.1 LINEAR ASPECTS

Linear aspects include the measurements of linear features of drainage such as stream order, stream length, stream length ratio, bifurcation ratio, length of overland flow and drainage pattern.

4.3.1.1 STREAM ORDER

The stream order is a measure of degree of stream branching within a watershed. The designation of stream orders is the first step in the watershed analysis and is based on hierarchic ranking of streams.

In the present study, ranking of streams has been carried out based on the method proposed by Strahler (1964). According to Strahler (1964), channel segments are ordered numerically from a stream's headwaters to a point somewhere down stream. A first order streams are those that do not have any tributary. The smallest recognizable channels (stream) are called first order and these channels normally flow during wet weather (Chow et al., 1988). A second order stream forms when two first order stream join and a third order when two second order streams are joined and so on (Strahler, 1964). The highest order stream is known as trunk or principal stream through which all discharge of the watershed passes through the outlet. Fig 4.1 shows the stream order map.

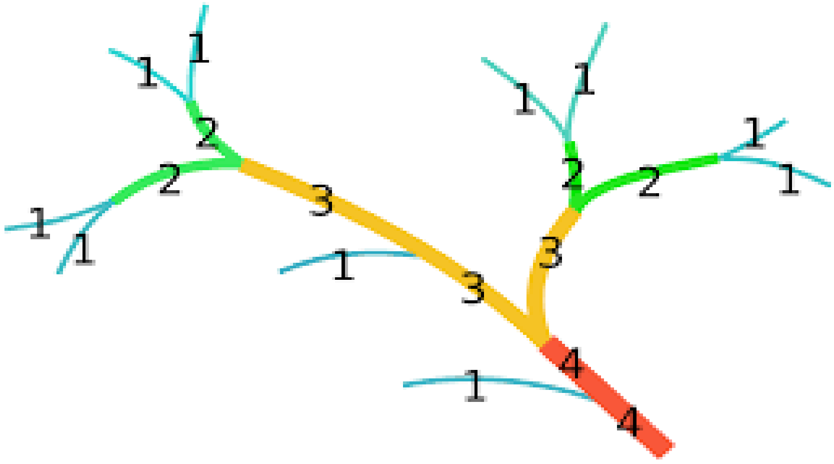


Fig 4.1 stream order

4.3.1.2 STREAM NUMBER

The order wise total number of stream segment is known as the stream number. The drainage watershed is seventh order stream includes as many as 1748, 436, 125, 27, 4, 1 and 1 as first, second, third, fourth, fifth, sixth and seventh order streams respectively. The data reveals that the number of stream segments decreases with increase in stream order. The decrease in the number of stream segments is experienced because when a channel of lower order joins a channel of higher order, the channel downstream retains the higher of the two orders (Chow et al, 1988).

4.3.1.3 STREAM LENGTH

Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. Streams with relatively short lengths are representative of areas with steep slopes and finer textures whereas longer lengths of stream are generally indicative of low gradients. The length of river network has been measured using GIS techniques. Length of the stream is indicative of the contributing area of the basin of that order.

Length of the stream is an indication of the contributing area of the watershed. The length of the stream is an indication of the steepness of the drainage basin as well as the degree of drainage. Steep well drained areas generally have numerous small tributaries; whereas, in plains, where soils are deep and permeable, only relatively long tributaries (generally perennial streams) will be in existence. This factor thus gives the idea of the efficiency of the drainage network (Nag et al., 2011).

4.3.1.4 MEAN STREAM LENGTH

The mean stream length (Lu) of a channel is a dimensional property and reveals the characteristic size of the drainage network components and its contributing basin surfaces (Strahler, 1964). The mean stream length is calculated by dividing the total stream length of order u and number of stream segments of order u and is expressed as,

$$L_{sm} = \frac{\sum_{i=1}^{N} L_u}{N_u}$$

Where,

L_{sm}= Mean stream length of order u (km)

L_u= Total stream length of order u (km)

N_u= Total number of stream segments of order u.

Generally it is observed that the mean stream length of any given order is greater than that of the lower order but less than that of the next higher order.

4.3.1.5 BIFURCATION RATIO

According to Schumn (1956), the term bifurcation ratio may be defined as the ratio of the number of the stream segments of given order to the number of segments of the next higher orders. Bifurcation ratio shows a small range of variation for different regions or for different environments except where the powerful geological control dominates (Strahler, 1957).

It is obvious that the number of stream segments of any given order will be fewer than for the next lower order but more numerous than for the next higher order. The ratio of number of segments of a given order Nu to the number of segments of the higher order N (u+1) is termed the bifurcation ratio R_b expressed as

$$R_b = \frac{N_u}{N_{(u+1)}}$$

Where,R_b

R_b = Bifurcation Ratio

N_u = Number of stream segments of order u

$N_{(u+1)}$=Number of stream segments of order (u+1)

The bifurcation ratio is a dimensional property and it ranges between 3 and 5 for watersheds in which the geologic structures do not distort the drainage pattern. According to Strahler, in a region of uniform climate and stage of development, R_b tends to remain constant from one order to next order. The irregularities of the drainage basin depend upon lithological and geological development, leading to changes in the values from one order to the next. An elongated watershed has higher R_b than the normal watershed and circular watershed. In the present study, the higher values of R_b indicates strong structural control on the drainage pattern while the lower values indicative of sub watersheds that are not affected by structural disturbances.

4.3.1.6 STREAM LENGTH RATIO

Stream length ratio (R_i) is the ratio of mean length of segments of order u to mean length of segments of the next lower order and is expressed as

$$R_i = \frac{L_u}{L_{(u-1)}}$$

Where, $R_i = \ streamlength\ ratio.$

L_u = mean stream length of order u (km)

$L_{(u-1)}$=mean stream length of the next lower order (u-1) (km)

4.3.1.7 LENGTH OF OVER LAND FLOW

Length of overland flow is the flow of water over the surface before it becomes concentrated in definite stream channels. The length of overland flow is a measure of erodibility, and is one of the independent variable affecting both the hydrologic and physiographic development of the drainage basin.

Surface runoff follows a system of downslope flow paths from 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. Horton defined the length of overland flow “L0” as the length of flow path, projected to a horizontal of the rain flow from a point on the drainage divide to point on the adjacent stream channel. “L0” is approximately equal to one half of the reciprocal of the drainage density. The shorter the length of overland flow, the quicker the surface runoff from the streams.

4.3.1.8 DRAINAGE PATTERN

The drainage pattern is an indicator of landforms and bedrock type and also suggests soil characteristics and site drainage condition. The drainage pattern is the plan metric arrangement of stream engraved into the land surface by a drainage system. The aggregate of drainage ways establish a design on the earth's surface, adjusted to topographic, structural a lithological controls.

The drainage pattern may reflect original slope, original structure, or the modification of the Earth surface, including uplift depression, tilting and other structural elements like faulting, folding, warping and jointing. The drainage pattern of the study area is dendritic and shown in the below fig 4.2

Table 4.1 linear aspects results

Stream Order	Bifurcation ratio(R_b)	Mean Stream Length(Km)	Stream length ratio(R_i)	Cumulative Stream Length	Drainage Density(D_d) Km/Km^2
1	-	0.18671429	-	5985.5	6.2704377
2	4.829316059	0.324191021	0.359532203	8137.48	
3	5.024981075	0.716336109	0.439725276	9083.76	
4	4.786231884	1.751376812	0.510821321	9567.14	
5	4.842105263	3.97	0.468141007	9793.43	
6	3.8	6.704	0.444385523	9893.99	
7	5	21.06666667	0.628480509	9957.19	
8	3	41.28	0.653164557	9998.47	

4.3.1.9 DRAINAGE MAP OF MANCHANABELE WATERSHED

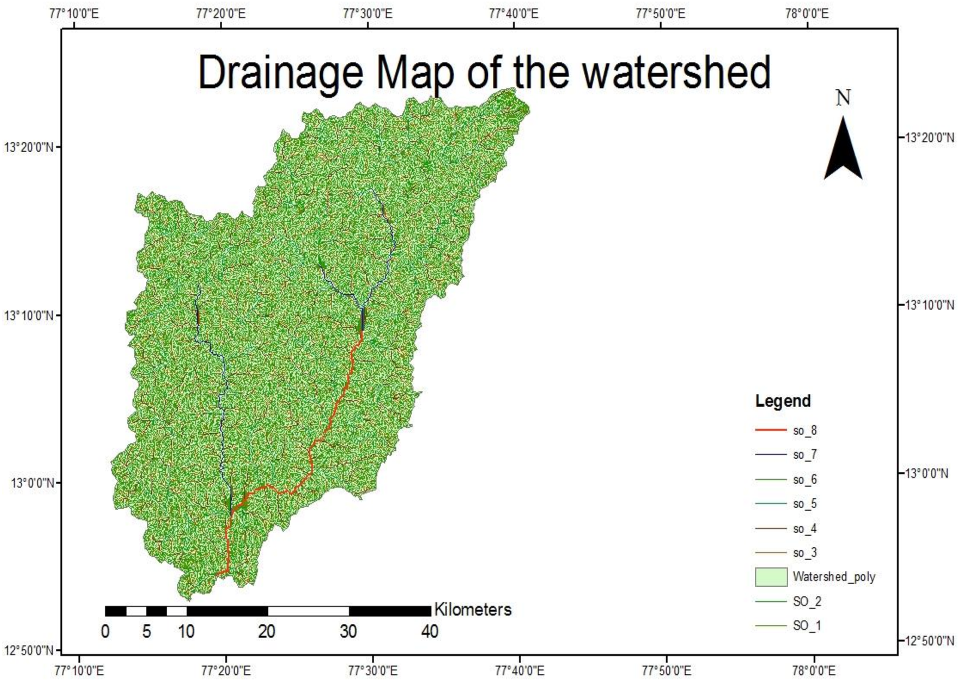


Fig 4.2 Drainage map of the watershed

4.3.2 AREAL ASPECTS

Area and perimeter of a watershed are two important parameters in quantitative morphometry. The area of the watershed is defined as the total area projected upon a horizontal plane contributing to cumulate of all order basins. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps.

4.3.2.1 WATERSHED SHAPE FACTOR

Watershed shape is the shape of projected surface on the horizontal plane of watershed map. The watershed shape has a significant effect on stream discharge characteristic for example; the elongated watershed having a high bifurcation ratio can be expected to have alternated flood discharge. But on the other hand, the round or circular watershed with a low bifurcation ratio may have a sharp flood discharge.

The shape of watershed has a profound influence on the runoff and sediment transport process. The shape of the drainage basin also governs the rate at which water enters the stream. The quantitative expression of watershed can be characterized by form factor, compaction coefficient, circularity ratio, and elongation ratio.

4.3.2.2 FORM FACTOR

Form factor (R_f) may be defined as the ratio of the area of the basin and square of the basin length (Horton, 1932) and is expressed as

$$R_f = \frac{A}{L^2}$$

Where,

R_f = Form factor; A = Area of the watershed (sq. km); L = watershed length (km)

The value of form factor would always be greater than 0.78 for a perfectly circular watershed. Smaller the value of the form factor, more elongated will be the watershed.

4.3.2.3 COMPACTNESS COEFFICIENT

$$\text{compactness coefficient} = \frac{Perimeter\ of\ the\ watershed}{\begin{array}{c} circumference\ of\ a\ circle\ whose\ area\ is \\ equal\ to\ the\ area\ of\ the\ watershed \end{array}}$$

$$compactness\ coefficient = \frac{P}{2\sqrt{\pi A}}$$

Where,

P = Perimeter of the watershed (km)

A = Area of the watershed (km2)

4.3.2.4 SHAPE FACTOR

An index of shape factor defined by Horton (1945) is the reciprocal of the form factor given by,

$$s_f = \frac{L^2}{A}$$

Where

s_f = watershed shape factor.

L = Total length of watershed (km) A = Total area of watershed (km)

4.3.2.5 CIRCULATORY RATIO

A dimensionless circulatory ratio (R_c) as the ratio between the area of the watershed and the area of the circle having the same perimeter as that of the watershed (Miller, 1953).

$$R_c = \frac{4\pi A}{p^2}$$

Where,R_c = Circulatory ratio

A = watershed area (Sq.km)

P = Perimeter of watershed (km)

The value ranges from 0.2 to 0.5, greater the value more is the circularity ratio. It is the significant ratio which indicates the stage of dissection in the study region. Its low, medium and high values are correlated with youth, mature and old stage of the cycle of the tributary watershed of the region.

4.3.2.6 ELONGATION RATIO

It is the ratio of the diameter of a circle of the same area as the watershed to the maximum length of the watershed (Schumm 1956).

$$R_e = \frac{2\sqrt{A/\pi}}{L}$$

Where,

R_e = Elongation ratio.

A = watershed area (Sq.km).

L = Length of the watershed (km).

The value of Re ranges from 0.4 to 1, lesser value more is the elongation of the basin. Strahler states the ratio runs between 0.6-1 over a wide variety of climatic and geologic types. Values of 1 are found in typical regions of low relief, while values from 0.6-0.8 are generally associated with strong relief and steep ground slopes. Catchment shape ratio and its interface.

Table 4.2 watershed shape for elongation ratios

Watershed Shape	**Ratio**
Circular	0.9
Oval	0.8-0.9
Less elongated	0.7-0.8
Elongated	0.5-0.7
More elongated	0.5

(Source: Horton and Strahler 1964)

4.3.2.7 DRAINAGE DENSITY

Drainage density is the other element of drainage analysis which provides a better quantitative expression to the dissection and analysis of land forms, although a function of climate, lithology, structures and relief history of the region and can ultimately be used as an indirect indicator to explain those variables, as well as the morphogenesis of landform.

Drainage density is defined as the total length of streams of all orders to total drainage area. The drainage density, which is expressed as km/Sq.km, indicates a quantitative measure of the average length of the overland flow, and therefore, provides at least some indication of the drainage efficiency of the basin. Drainage density is expressed as

$$D_d = \frac{\sum L_u}{A}$$

Where,

D_d = Drainage density (km/Sq. km)

$\sum L_u$= Total stream length of all orders (km).

A = Area of watershed (Sq. km).

The drainage density indicates the closeness of spacing of channels (Horton, 1932). Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, run-off intensity index. Low drainage density generally results in the areas of highly resistant or permeable sub-soil material, dense vegetation and low relief. High drainage density is the result of weak or impermeable sub-surface material, sparse vegetation and mountainous relief. Low density leads to coarse drainage texture while high drainage density leads to fine drainage texture.

The low value of drainage density influences greater infiltration and hence the wells in this region will have good water potential leading to higher specific capacity of wells. In the areas of higher drainage density the infiltration is less and surface runoff is more. The D_d generally increases with rainfall (R)

Thus $D_d \propto$ R

D_d= K*R

$\frac{D_d}{R}$= K, where, K is a constant and its value is always less than one

The $D_d$and R studies reveal that D_d controls runoff following a particular period of precipitation and the increasingD_d shows increasing size of mean annual flood. The drainage density can also be indirectly indicates the groundwater potential of an area, due to its surface runoff and permeability. Drainage density for different textures is 6.27 Very fine.

Table 4.3 soil textures for drainage density

Drainage density (Km/km^2)	Textures
< 1.24	Very coarse
1.24-2.49	Coarse
2.49-3.73	Moderate
3.73-4.97	Fine
> 4.97	Very fine

(Source: Horton and Strahler 1964)

4.3.2.8 CONSTANT OF CHANNEL MAINTENANCE

The inverse of drainage density is the constant of channel maintenance (Schumn's, 1956). It indicates the number of Sq.km of watershed required to sustain one linear km of channel and expressed as Sq.km/km.

$$C = \frac{1}{D_d}$$

It not only depends on rock type permeability, climatic regime, vegetation, relief but also as the duration of erosion and climatic history. The constant is extremely low in areas of close dissection.

4.3.2.9 STREAM FREQUENCY

Stream frequency or channel frequency (S_f) is the total number of stream segments of all orders per unit area (Horton, 1932).

$$S_f = \frac{N_s}{A}$$

Where,

S_f = Stream frequency,

N_s = Number of streams,

A = Area of the watershed (Sq. km)

Table 4.3 shows the stream frequency for No. of streams/Sq.km and the inference can be drawn for the study area.

Table 4.4 Stream frequency for No. of streams/Sq.km

Stream Frequency	No. streams/Sq.km
Low	0-5
Moderate	5-10
Moderate high	10-15
High	15-20
Very high	20-25

(Source: Horton and Strahler 1964)

Areal Aspects

Table 4.5 Areal Aspects results

Form Factor((R_f)	0.342428878
Shape Factor(S_f)	2.920314448
Compactness Coefficient(C_c)	1.657667369
Circularity Ratio(R_c)	0.363919413
Elongation Ratio(R_e)	0.372485187
Constant of Channel Maintenance(c)	0.1594785
Stream Frequency(S_f)	25.31637631
Drainage density (D_d)	6.270 Km/Km^2

4.3.3 RELIEF ASPECTS

Relief aspects is an indicator of flow direction of water as it is an important factor in understanding the extent of denudation process that have undergone within the watershed. It comprises of watershed relief, relief ratio, relative relief, ruggedness number.

4.3.3.1 WATERSHED RELIEF

Watershed relief is the difference in elevation between the remotest point in the water divide line and the discharge point of the watershed. The difference in elevation between the remotest point and the discharge point is obtained from the available contour map.

$$H = (\,Difference\ in\ elevation\ of\ the\ highest\ point\ of\ watershed) \\ - (\,Difference\ in\ elevation\ of\ the\ watershed\ outlet)$$

The highest relief in the watershed is found to be 900 m above the mean sea level and the lowest relief is 780 m above the mean sea level. The overall relief calculated for the watershed is 0.12 Km.

4.3.3.2 RELIEF RATIO

Relief ratio is the ratio of maximum watershed relief to the horizontal distance along the longest dimension of the watershed parallel to the principal drainage line (Schumn, 1956). It measures the overall steepness of a watershed and is an indicator of the intensity of erosion processes operating on slopes of the watershed.

$$R_{f=\frac{H}{L}}$$

Where,

R_f = relief ratio

H = Total watershed relief (km),

L = Maximum length of the watershed (km)

4.3.3.3 RELATIVE RELIEF

Relative relief is defined as the ratio of the maximum watershed relief to the perimeter of the watershed. It is computed as

$$R_r = \frac{H}{P}$$

Where,

R_r= Relative relief

H= Maximum relief (km)

P = Perimeter of the watershed (km)

4.3.3.4 RUGGEDNESS NUMBER

It is defined as the product of the watershed -relief and drainage density and usually combines slope steepness with its length, Strahler (1958). High values of the Ruggedness number in the catchment are because both the variables like relief and drainage density are enlarged. Extensively high value of ruggedness number occurs for a high relief region with high stream density. It is computed as,

$$R_n = \frac{H\ D_d}{1000}$$

Where,

R_n= Ruggedness number

H = watershed relief (m)

D_d= drainage density (km/Sq km)

Relief Aspects

Table 4.6 relief aspects results

Watershed relief(H)	696 m
Relief	708 m
Relief Ratio(R_f)	10.19944606
Relative Relief(R_r)	3.017066883
Ruggedness No(R_n)	4.364224639

Morphometric Parameters for Manchanabele Watershed

Table 4.7 Morphometric Parameter Results

Sl.No.	Particulars	Unit	Values
1	Area	*Km^2*	1594.54
2	Perimeter	*Km*	243.66
3	Length of watershed	*Km*	68.23
4	Width of watershed	*Km*	42.59
5	Total No. of segments	*No.*	40368.00
6	Total length of stream segments	*Km*	9998.47
7	Mean length ratio		0.42
8	Highest order of streams	*No.*	8.00
9	Bifurcation ratio		3.91
10	Stream length ratio		0.50
11	Form factor		0.34
12	Shape factor		2.92
13	Elongation ratio		0.37
14	Compactness coefficient		1.65
15	Circulatory ratio		0.36
16	Stream frequency	*No./Km*	25.31
17	Drainage density	Km/Km^2	6.27
18	Drainage texture		165.67
19	Constant of channel maintenance	Km^2/Km	0.16
20	Length of overland flow	*Km*	3.13
21	Difference in elevation	*m*	708.00
22	Watershed relief	*M*	696.00
23	Relative relief		3.01
24	Ruggedness number		4.36

Table 4.8 Calculation of stream order, length of stream, mean of stream.

Sl. No	Stream Order	Count	Length(km)	Mean
1	1	32057	5985.5	0.1867
2	2	6638	2151.98	0.3241
3	3	1321	946.28	0.7163
4	4	276	483.38	1.7513
5	5	57	226.29	3.9701
6	6	15	100.56	6.7045
7	7	3	63.2	21.065
8	8	1	41.28	41.286

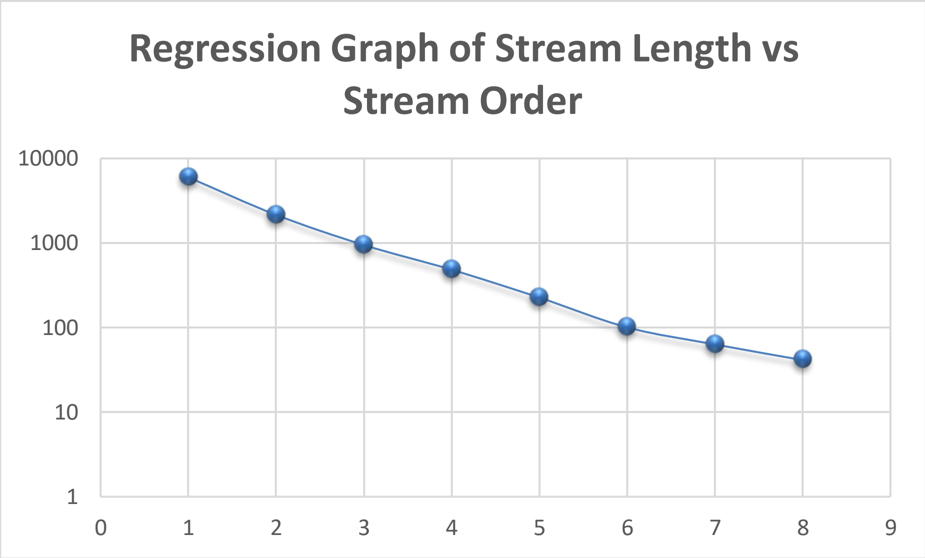


Fig 4.3 Regression Graph of Stream length vs. stream order

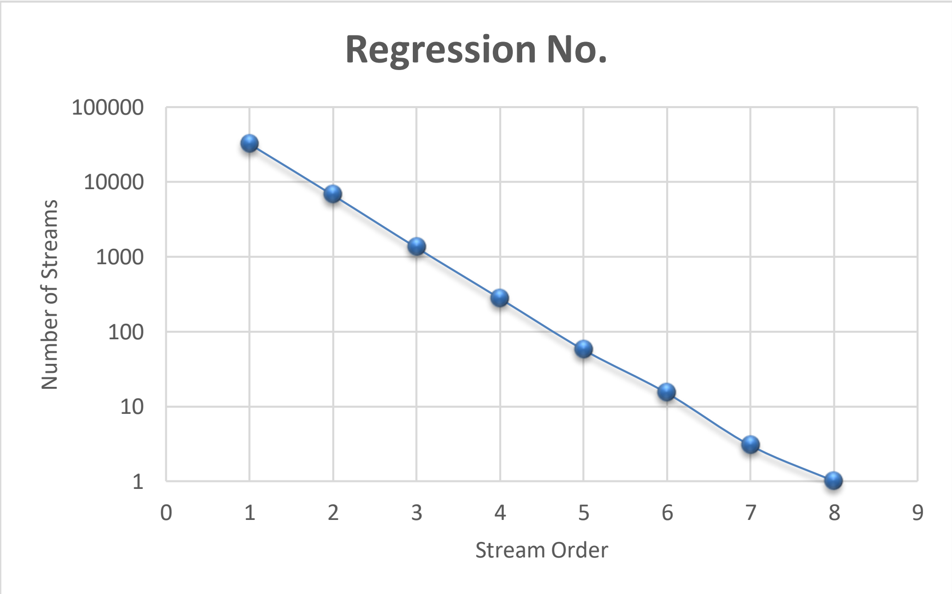
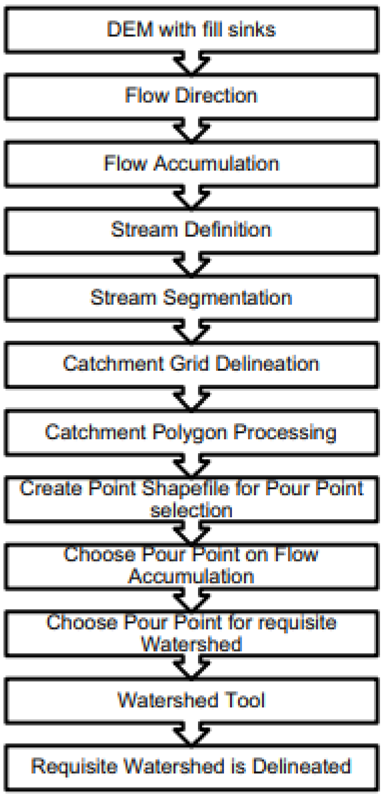


Fig 4.4 Regression graph of number of streams vs. stream order

Fig 4.5 Steps followed for delineation of Manchanabele Watershed



CHAPTER 5

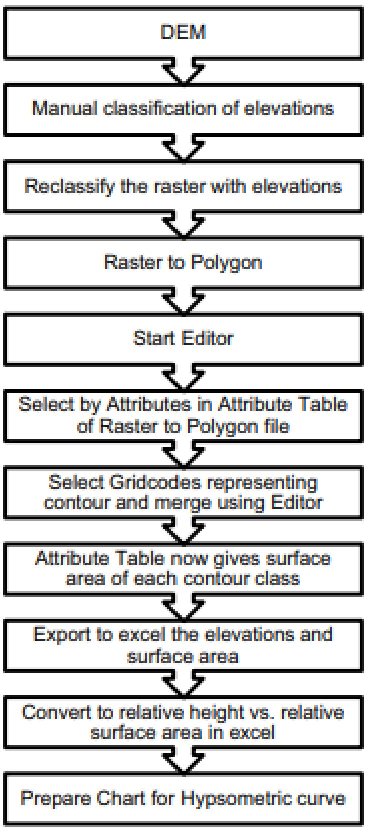
HYPSOMETRIC ANALYSIS

5.1 HYPSOMETRIC METHODOLOGY

Digitization of contours and drainage network to be carried out using Arc GIS, followed by generation of a Digital Elevation Model (DEM). The digital contour map is used to generate the data required for relative area and elevation ranges. Taking the drainage basin to be bounded by vertical sides and a horizontal base plane passing through the mouth, the Relative height 'y' is the ratio of height of the contour above the base level of the stream mouth i.e. 'h' to the total height of basin with reference to the same base level i.e. 'H'. Relative area 'x' is the ratio of which 'a' is the area enclosed between a given contour within the basin to the 'A' which is the total area of the basin. The hypsometric curves for the basin were prepared based on Strahler (1952) method. Hypsometric integrals of the basins have been calculated using empirical formula proposed by Pike and Wilson (1971)

Mathematically expressed as, $\boldsymbol{E} = \frac{[E_{mean} - E_{min.}]}{[E_{max} - E_{min.}]}$ ----------1

Fig 5.1 Steps followed for derivation of hypsometric curve



Steps followed for derivation of Hypsometric Curve

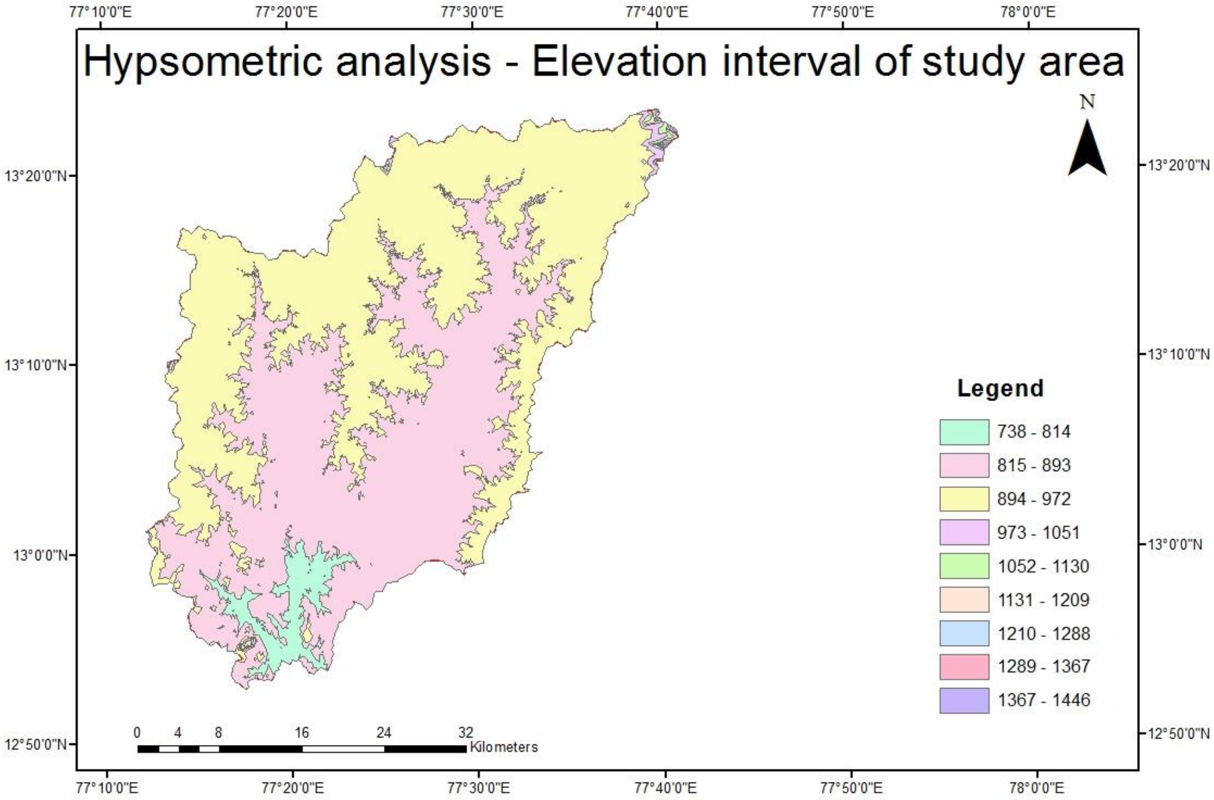


Fig 5.2 Hypsometric analysis – Elevation interval of study Area

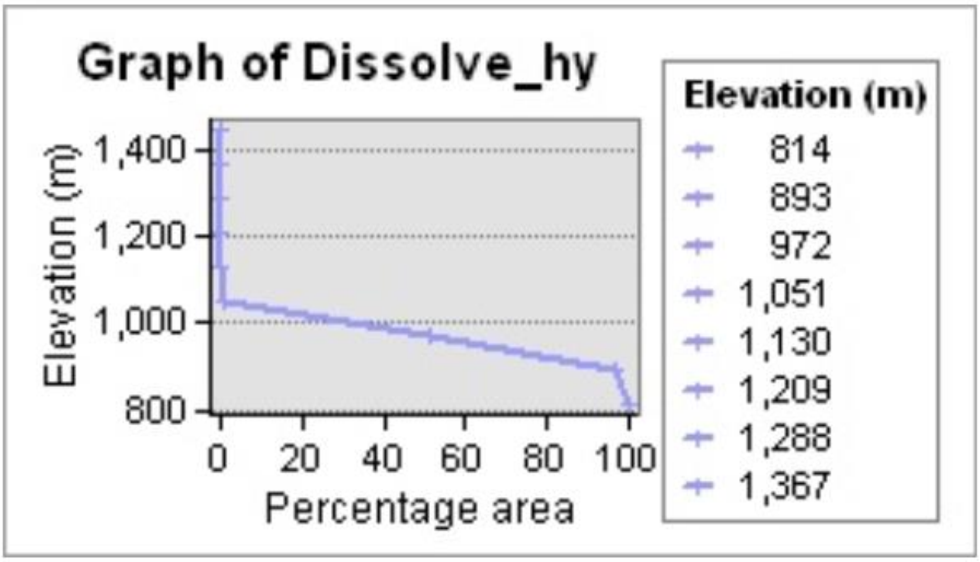


Fig 5.3 hypsometric graph

Table 5.1 Hypsometric integral calculations and defining geological stage

Sl No.	Elevation Classified(m)	Elevation(m)	Area (km^2)	Cumulative Area	E	E/Emax	a/A	Hypometric Integral	Geological Stage
		1446	0.2535	0.2535	711	1	0.000159	0.5	Equilibrium or Mature Stage
1	735-814	1367	0.5537	0.8072	632	0.888889	0.000347		
2	814-893	1288	0.8273	1.6345	553	0.777778	0.000519		
3	893-972	1209	2.0406	3.6751	474	0.666667	0.00128		
4	972-1051	1130	3.213	6.8881	395	0.555556	0.002015		
5	1051-1130	1051	8.2562	15.1443	316	0.444444	0.005178		
6	1130-1209	972	789.629	804.7733	237	0.333333	0.495272		
7	1209-1288	893	734.169	1538.9423	158	0.222222	0.460486		
8	1288-1367	814	55.392	1594.3343	79	0.111111	0.034743		
9	1367-1446	735							

CHAPTER 6

CONCLUSION

From the above discussion following conclusions can be drawn.

1. The length of overland flow in the Manchanabele reservoir catchment in the present study is more than 3.135. Hence, the Reservoir catchments selected for study have longer flow paths associated with less infiltration and more Runoff.
2. Morphometric analysis on watersheds Manchanabele reservoir reveals much valuable information to set up watershed developmental plan for this area.
3. • Analyzed morphometric parameters such as area, length, stream pattern, flow direction, and perimeters all these are reflect the shape and topography of the given watershed.
4. Helps in management of Natural resources used in water conservation, such as primarily watershed evaluation, characterization and drainage development etc.
5. The results of morphometric analysis provide information about catchment development on priority basis and areas vulnerable for land degradation.
6. It is found that drainage density of 6.2704km/km^2 was indicated that the basin is not much affected by structural disturbance and indicates the very fine texture of the watershed.
7. In the areas of higher drainage density the infiltration is less and surface runoff is more.

5. The higher value of stream frequency is observed in Manchanabele catchment and Manchanabele catchment indicates low conducting subsurface material, sparse vegetation and high relief.

7. The higher value of form factor in Manchanabele catchment indicates wider basin and lower value of form factor in Manchanabele catchment indicates narrow basin.

8. Hypsometric Curve from hypsometric analysis clearly shows that the watershed is equilibrium at mature stage.

9. The hypsometric Integral Value works out to be 0.5 from integrating method.

CHAPTER 7

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