Bhumika D. Mistry, 2022, 10:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Lower Tapi River Basin Delineation using Geographical Information System (GIS)

Asst. Prof. Bhumika D. Mistry
Department of Civil Engineering,
Pacific School of Engineering,
V: Sanki, Ta. Palsana, Surat-394305, Gujarat, India.

Abstract- Watersheds are natural hydrological feature that cover a specific aerial expanse of land surface from which the rainfall - runoff flows to a defined channel, drain, channel or river at any specify point. Catchment area and watershed delineation is common task in Water resources engineering and hydrology. DEM is spatial grids which are used to automatic delineation of watershed boundary determination. DEM based Arc-Hydro model was run on the dataset of the Lower Tapi river basin. Several intermediate results were produced while model run and basic parameter of the Tapi River, its catchment area has been defined at the end of model. The result of this study area can be useful in Rainfall-Runoff analysis and other advance research technology on the catchment area or river basin. Adding to this, it would have support for decision making on ground as well as surface water resource, distribution and management. This study of delineated watershed is further used to calculate hydrologic features by SCS-CN technique for developing a Rainfall-Runoff model in MATLAB. It is observed that the study area i.e., Lower Tapi basin is well drained and the drainage is in a well-integrated pattern. Current Study demonstrated that GIS is found to be flexible technology and is relatively easy to apply on large scale areas enabling gathering of data with information in a common data base for watershed delineation analysis and stream network process.

Keywords- Watershed delineation, GIS (Geographic Information System), Digital Elevation Model (DEM), Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS).

I. INTRODUCTION

Watershed has emerged as the very basic planning unit of all hydrologic analyses and designs. Every watershed shows different characteristics which are much variable that not even two watersheds are identical. Watersheds are natural hydrological entities that cover a specific aerial expanse of land surface from which the rainfall runoff flows to a defined drain, channel, stream or river at any particular point [1]. The terms region, basin, catchment, watershed are widely used to denote hydrological units. Even though these terms have similar meanings in popular sense, technically they are different.

Size of a watershed is governed by the size of the stream occupied by it [1]. Size of the watershed is of practical importance in development programs (CGWB). Watersheds have been classified into different categories based on area viz Micro Watershed (0 to 10 ha), Small Watershed (10 - 40 ha), Mini Watershed (40 - 200 ha), Sub Watershed (200 - 400 ha), Watershed (400 - 1000 ha) and Sub basin (above 1000 ha).

Watersheds can be delineated by several methods. One used extensively is hand delineation based on the contour information depicted on topographic maps. Even with the advent of GIS technology. This method is often still used prior to creating a digital watershed dataset while compare to manual method can result in accurate delineations. It is a time consuming and expensive task. The availability of digital topographic maps has made heads-up digitizing methods possible, but this method can also be slow and costly. Because the watershed delineation process is a subjective one that depends not only on the hydrological characteristics of a study area but also on the requirements of the delineator, a fully automatic system is not practical for many purposes [1].

GIS with its ability to gather spatial data from distinct sources into an integrated environment emerged as an important tool for delineation of watersheds. Particularly, GIS provided a consistent method for watershed delineation using digital elevation models (DEM) and based on the contour information depicted on topo sheets.

The underlying functionality of the tools and commands for watershed delineation is built on the reach catchment areas created. A catchment is subsequently produced from the digital elevation model for each one of these reaches.

II. STUDY AREA

The Tapi River is the second largest westward river of the Peninsula. This river originates start from Multai reserve forest in Betul district of Madhya Pradesh at an elevation of 752 m. Length of the tapi river from origin to downstream into the Arabian Sea is 724 km for the first 282 km. River flows from Madhya Pradesh, out of which 54 km from the Common boundary with Maharashtra State. It flows for 228 km in Maharashtra before entering Gujarat State. On the other hand remaining length of 214 km in Gujarat. It joins Arabian Sea in the Gulf of Cambay after flowing pass the Surat city [6].

The Tapi basin consists of 3 sub river basins namely- Upper Tapi, Middle Tapi and the Lower Tapi sub river basin. The upper Tapi sub basin extends over an area of 28,047.34 sq.km. It consists main Tapi stream from its origin up to the hathnur weir excluding Purna river sub basin. The middle Tapi sub basin covers maximum Geographic area of the basin and extends over an area of 31,766.67 sq.km. This consists of main Tapi stream from hathnur Weir up to Ukai Dam.Lower Basin consists the main Tapi stream from Ukai Reservoir to its mouth in the Gulf of Cambay. (River Basin atlas of India, 2012, Integrated Hydrological Data Book CWC, March -2012). The Lower Tapi Basin extends over an area of 4108.90 sq.km. Sub Basin wise distribution of drainage area is shown in Table1.

Table 1. Catchment area of Tapi river basin.

Sub Basin	Drainage Area (km^2)	Percentage of Total Area
Tapi Lower Sub Basin	4109	6.43%
Tapi Middle Sub Basin	31767	49.70%
Tapi Upper Sub Basin	28047	43.88%
Total	65145	100%

Source: India Water Resources Information System: www.india-wris.nrsc.gov.in

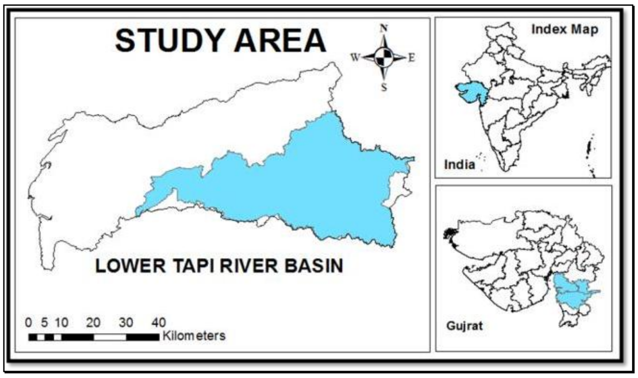

Fig 1. Lower Tapi Basin Index Map.

III. DATA COLLECTION

DEM taken from Bhvan-ISRO web portal (www.bhvan3.nrsc.gov.in) of spatial resolution of 90mhave been used for this study shown in figure 2. Spatial reference of WGS_1984_World_Mercator with datum of D_WGS_1984 is used.

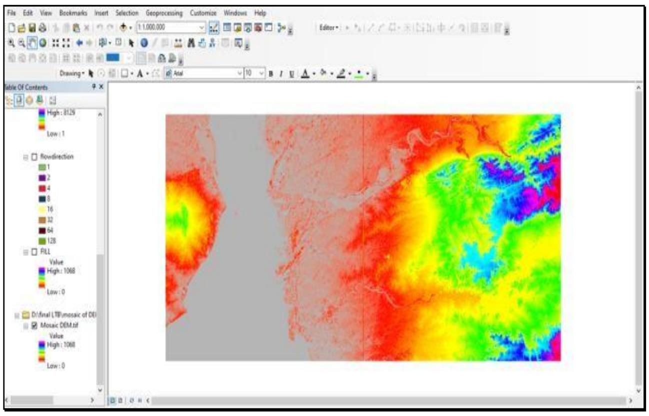

Fig 2. Digital Elevation Model for Tapi Basin.

IV. METHODOLOGY

1. Hydrology Tool:

The Hydrology tools are used to model the flow of water across a surface. All information about the feature of the earth's surface is useful for various fields such as regional planning, agriculture and forestry. These fields require an understanding of how water flows across an area and how changes in that area may affect that flow when modeling the flow of water; you must want to know where the water came from and where it is going.

Table 2. Hydrology tools and its description.

Tool	Description
Basin	Creates a raster delineating all drainage basins.
Fill	Fills sinks in a surface raster to remove small imperfections in the data.
Flow Accumulation	Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied.
Flow Direction	Creates a raster of flow direction from each cell to its steepest down slope neighbor.
Flow Length	Calculates the upstream or downstream distance, or weighted distance, along
Sink	Creates a raster identifying all sinks or areas of internal drainage.
Snap Pour Point	Snaps pour points to the cell of highest flow accumulation within a specified distance.
Stream Link	Assigns unique values to sections of a raster linear network between intersections.
Stream Order	Assigns a numeric order to segments of a raster representing branches of a linear network.
Stream to Feature	Converts a raster representing a linear network to features representing the linear network.
Watershed	Determines the contributing area above a set of cells in a raster.

This is the initial step in which DEM is used to derive additional datasets that describes the drainage pattern of the watershed and for delineation of the stream and sub-basin. These datasets are flow direction, flow accumulation, stream network, stream segmentation and watershed delineation.

2. Fill:

It fills the sink to the top raster to remove minor data imperfections. A sink is a cell with an unspecified drainage system; there are no surrounding cells on the ground. The outlet is a boundary cell with a very low base of the contributing area of the sink. If the sink was full of water, this would be the point where the water would come out. Fill command can also be used to remove peaks.

Elevation is a cell where there are no nearby top cells. To remove the tops, the installation raster must be adjusted. This can be done with a removal tool. Specify the maximum amount of top raster as the first input minus and surface raster as the second input Fill in.

Modify the results to get an area with real raster values removed from the tops. The z limit can also be used in this process. If nothing is specified in the z-limit, it will mean that all peaks will be removed. If specified, when the difference of z value between the highest value and its closest neighbor is greater than the z limit, that sum cannot be deducted.

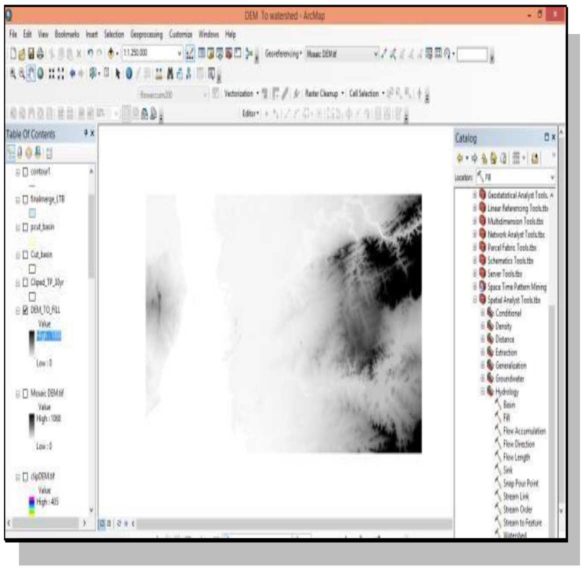

Fig 3. Fill sink map of Lower Tapi River Basin.

3. Flow direction:

This step defines the direction of the highest concentration of each cell in an area. The output of the Flow Direction command is a raster whose number ranges from 1 to 255. The fill sink is used as an input and as an exit we get a flow direction map as shown in figure 4.

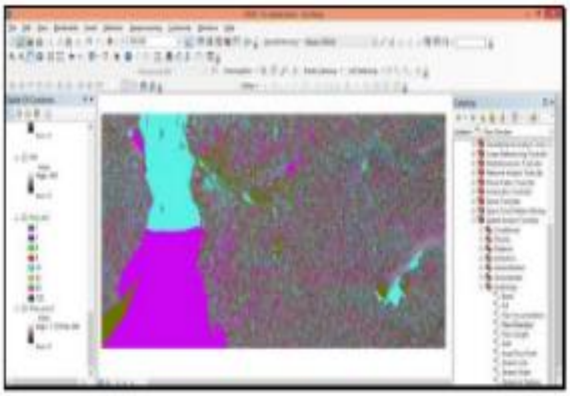

Fig 4. Flow Direction map of Lower Tapi RiverBasin.

4. Flow Accumulation:

The result of Flow Accumulation tool is a raster of all merged accumulated flow to each cell, as determined by accumulating the weight for all the cells that flow into each down slope cell. Cells which have undefined flow direction will only receive flow. It will not contribute to any downstream flow. The cell is considered to have an undefined if its value in the flow direction raster is other than 1, 2, 4, 8, 16, 32, 64, or 128. This type of accumulated flow is based on the number of cells flowing into all cell in the output raster. The current processing cell is not considered in this accumulation.

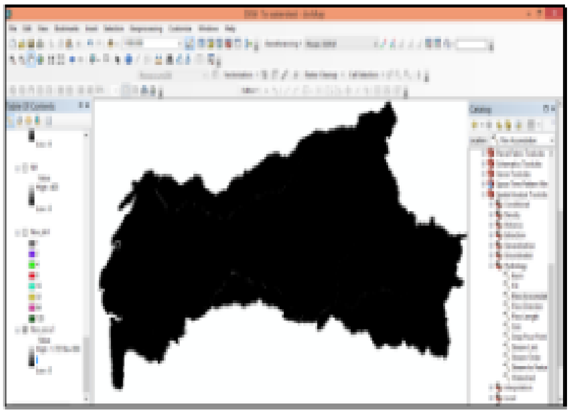

Fig 5. Flow Accumulation Map for Lower TapiRiver Basin.

Output cells with a high flow accumulation are areas of concentrated flow and can be used to identify stream channels. Output cells with a flow accumulation of zero are local topographic highs and can be used to identify ridges. This step determines how many numbers of upstream cells draining to a given cell. Upstream drainage area at a given cell can be calculated by multiplying the flow accumulation value by the grid cell area. Above calculated flow direction grid is used as the input for this tool and the result of flow accumulation is generated as shown in figure 5.

5. Basin:

This tool is used for creating a raster delineating all drainage basins. Drainage basins are delineated within the analysis window by identifies ridge lines between the two basins. The input flow direction raster is analyzed to find all sets of connected cells that belong to the same drainage basin. The drainage basins are created by locating the pour points at the edges of the analysis window as well as sinks, then identifying the contributing area above each pour type point. This results in a raster of drainage basins is shown in figure 6.

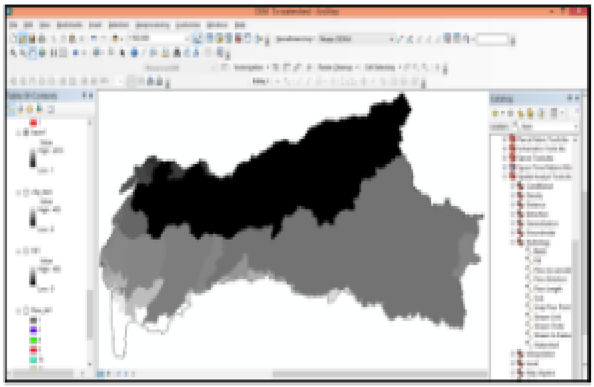

Fig 6. Delineate River Basin map for Lower TapiBasin.

6. Watershed:

Watershed Tool determines the contributing area above a set of cells in a raster. The value of each watershed will be taken from the value of the source in the input raster or feature pour point data. When the pour point is a raster dataset, the cell values will be used. When the pour point is a point feature dataset, the values will come from the specified field.

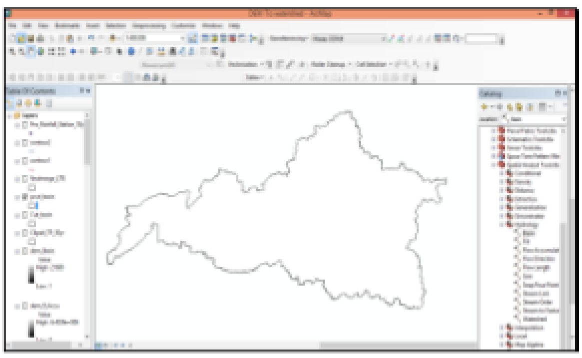

Fig 7. Delineate Watershed Map for Lower TapiRiver Basin.

7. Drainage line processing:

This step creates a vector stream layer. Flow accumulation and flow direction grid is used as input for this tool and output of drainage line/stream line is generated by Raster Calculator tool as shown in figure 8.

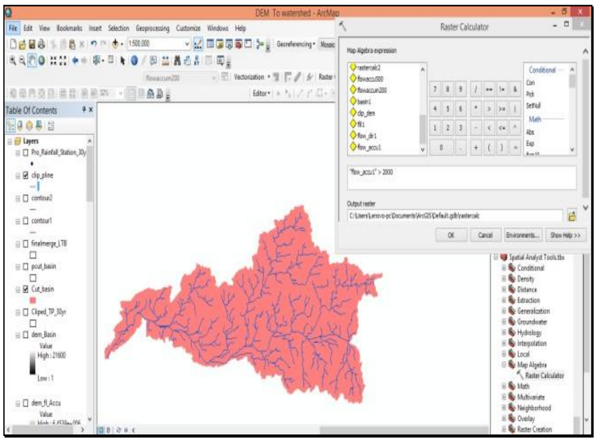

Fig 8. Drainage Map for Lower Tapi River Basin.

V. CONCLUSION AND DISCUSSION

Calculated Lower Tapi river basin area from DEM is 4200 km^2 which is 92.90 km^2 (2.23%) more than the basin area information provided by Water Resource Information System of India. It may happen because of the difference between manually delineation method and delineation from satellite data. For different satellite data, this result may vary according to the spatial resolutions of data.

This delineated watershed shape file of lower Tapi basin can be further used to divide sub basin into watershed and calculate their hydrologic and topographic features by HEC-geo HMS for developing a Rainfall-Runoff model in HEC-HMS or MATLAB Software.

ACKNOWLEDGMENT

I would like to thank M.S. University for providing me the required support and platform for this research.

REFERENCES

[1] A. S. Chandra Bose, P. Sridhar (2012). Watershed Delineation and Stream Network Analysis Using GIS, International Journal of Watershed Engineering, Vol. 1, Issue 1.

[2] M.A.E. Bastawesy, R. R. Ali and A. H. Nasr (2008). The use of remote sensing and GIS for catchments delineation in northwestern coast of Egypt: An assessment of water resource and soil potential, The Egyptian Journal of Remote Sensing and Space Science, Vol. 11, 3-16

[3] N. Donia (2009). Application of Remotely Sensed Imagery to Watershed Analysis; A case Study of Lake Karoun Catchment, Egypt, Thirteen International Water Technology Conference, IWTC, Hurghada, 1035- 1049.

[4] Ochir Altansukh (2012). Tapi River and Its Catchment Area Delineation from Satellite Image, Computational Water, Energy and Environmental Engineering, 1, 9-23.

[5] HEC-GeoHMS, Geospatial Hydrologic Modelling Extension, User's manual: Version 10.1, U.S. Army Corps of Engineers, Hydrologic Engineering Centre.

[6] http://www.india-wris.nrsc.gov.in

[7] https://guj-nwrws.gujarat.gov.in

[8] https://www.epa.gov/sites/production/files/2015 - 07/documents/lecture-3-watershed-deline atio n.pdf

[9] http://nptel.ac.in/courses/105101010/downloads /L ecture13.pdf

[10] http://bhuvan3.nrsc.gov.in/map