

Delineate Catchment Areas of Vindhyachal Region Using Geospatial Techniques

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Abstract

In this paper we used an integrated suite of raster and vector geospatial datasets to delineate and characterize watersheds. The geospatial datasets used to delineate and characterize watersheds with the help of Arc Hydro tools of Arc GIS software. We have performed drainage analysis on a terrain model for Vindhyachal Region. With the availability of digital elevation models (DEM) and geographic information system (GIS) tools, watershed properties can be extracted by using automated procedures. The processing of DEM to delineate watersheds is referred to as terrain pre-processing. The Arc Hydro tools are used to derive several data sets that collectively describe a drainage pattern of the catchments. The input to this tool is Raster data and Raster analysis is performed to generate output in flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. With these data, a vector representation of catchments and drainage lines from selected points is being developed. Thus, this Arc Hydro tool helps in generating such attribute data that can be useful in the hydrologic modeling. This paper represents the use of Arc Hydro tools to process a DEM to delineate watershed, sub-watersheds, stream network and some other watershed characteristics that collectively describe the drainage patterns of a basin.

Keywords: Delineate, catchment areas, GIS, DEM, raster analysis

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BACKGROUND

In water resources projects, DEMs are used to identify drainage features such as ridges, valley-bottoms, channel networks, surface drainage patterns and to quantify sub-catchment and channel properties such as size, length, and slope. The accuracy of this topographic information is a function both of the quality and resolution of the DEM^[1]. Geographic information system (GIS) and digital elevation models (DEM) can be used to perform watershed delineation to a point, a reach, or an area of interest, which is usually one of the first steps in such studies^[2]. In hydrologic analysis, delineation of watershed is one of the most

commonly performed activities. And DEMs are derived automatically using GIS technology, which provides good terrain representation from which watersheds can be extracted. The techniques for automated watershed delineation have been implemented in various GIS systems and custom applications^[3].

This paper represents a methodology for watershed delineation using DEM pre-processing which provides the basis for quick and consistent watershed delineation on DEMs of any resolution and size, using GIS technology.

LOCATION OF STUDY AREA

The present area of study covers Vidhyanchal region of Mirzapur district in Uttar Pradesh, which lies within the 25°08' 51" N to 25°10' 03" N latitude and 82°26' 30" E to 82° 29' 11" E longitude. It covers approximately 5.74 sq.km of area. The climate is sub-tropical and average rainfall is about 11 cm/year.

METHODS

Delineation of the watershed is very crucial part of the water resource projects. To generate delineation, it involves a number of processes to be in co-relation with the results to achieve desired output. These processes are done under Arc Hydro tools of Arc GIS environment. Arc Hydro tools acts as a starting point for water resources database and application development^[4].

Watershed Delineation

From the smallest organisms to biggest trees, a life support system relies on the kind of environment within the watershed^[5]. Watershed is a hydrological unit which has its impact on socio-political as well as ecological entity and plays a decisive role in determining food, social and economical security while supplying life support activities to rural people^[6]. The following steps are to be executed to achieve the delineated watershed, which can be developed under

GIS environment using Terrain processing tool of Arc Hydro tools under Arc GIS software. Terrain Pre-processing uses DEM to identify the surface drainage pattern^[7]. Once pre-processed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation. All the steps followed in Terrain Processing menu should be performed in a progressive order i.e., from top to bottom. Before using watershed processing functions, all the pre-processing steps must be accomplished. DEM reconditioning and filling sink steps depend on the initial quality of the DEM and may not be required, if DEM is of good quality. DEM reconditioning also acts as a modifying elevation data which are more consistent with the input vector stream.

DEM Reconditioning

This function modifies a DEM by imposing linear features onto it. The function needs a raw DEM and a linear feature class (like the drainage network) as input, both of which have to be present in the map document.

From the Arc Hydro toolbar select Terrain Preprocessing further select DEM Reconditioning.

Then select the appropriate DEM (Extract DEM) and linear feature (drainage line).

The resultant output is a reconditioning Agree DEM.

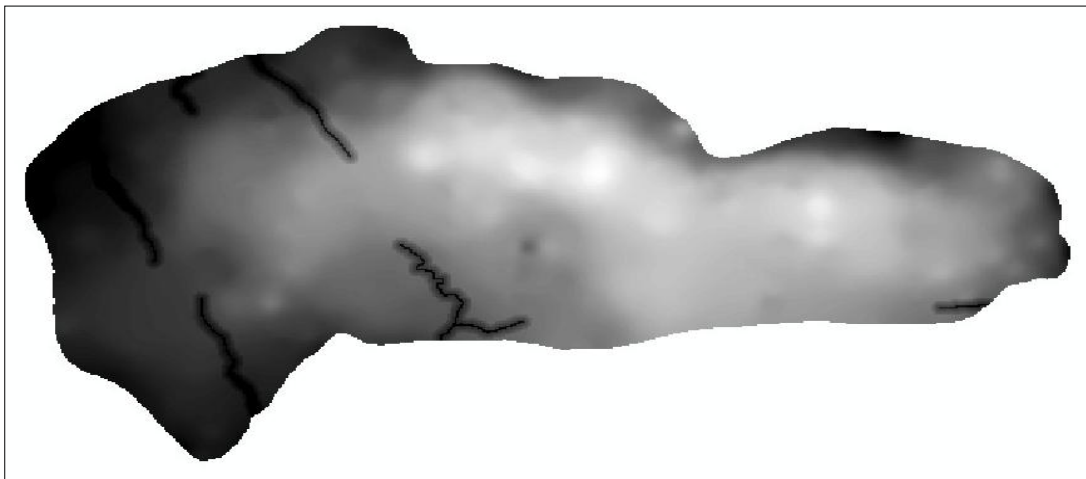


Fig. 1: Results of DEM Reconditioning.

Now, we have to examine the folder where we are working. A new folder named Layers was created, where Arc Hydro grid outputs will be stored. A personal geo-database with the same name as the Arc Map document was also created, where vector feature class data of Arc Hydro gets stored.

Fill Sinks

This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot

flow. The fill sinks function modifies the elevation value to eliminate these problems^[8]. Select Terrain Pre-processing and further select Fill Sinks from Arc Hydro Toolbar. Be confirmed that the input for DEM is "Agree DEM" generated in previous process.

The output was the Hydro-DEM layer, with the name "Fil" as default. With the successful completion of the process, the "Fil" layer is displayed in Figure 2.

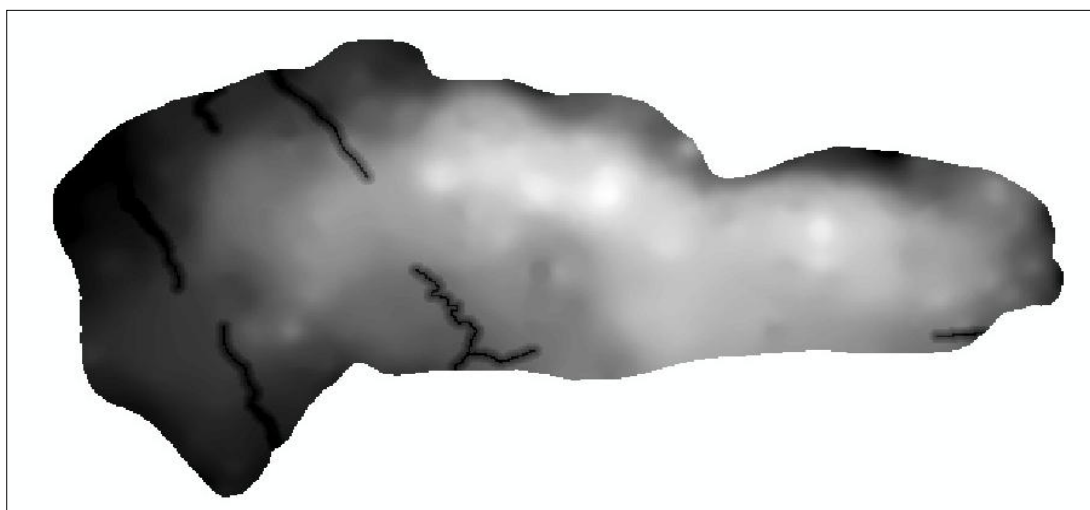


Fig. 2: Result of Fill Sink "Fil".

Flow Direction

This function computes the flow direction for a given grid. The value in the cells of the flow direction grid indicates the direction of the steepest descent from that cell^[8].

Select Terrain Preprocessing further Select Flow Direction from Arc Hydro Toolbar. The result of Fill Sink acts as input for Hydro DEM named as "Fil".

The resultant is the flow Direction Grid, which is saved by default named "Fdr".

Flow Accumulation

The Flow Accumulation tool identifies how much surface flow accumulates in

each cell. Cells with high accumulation values are usually stream or river channels. It also identifies the local topographic highs (areas of zero flow accumulation) such as mountain peaks and ridgelines^[9].

From Arc Hydro Toolbar, select terrain preprocessing, then select flow accumulation. The input of the flow direction grid is "Fdr".

The output is the flow accumulation grid which is saved by default name "Fac" is generated and plotted in map. With successful completion of this process, the flow direction grid "Fdr" is displayed in Figure 3.

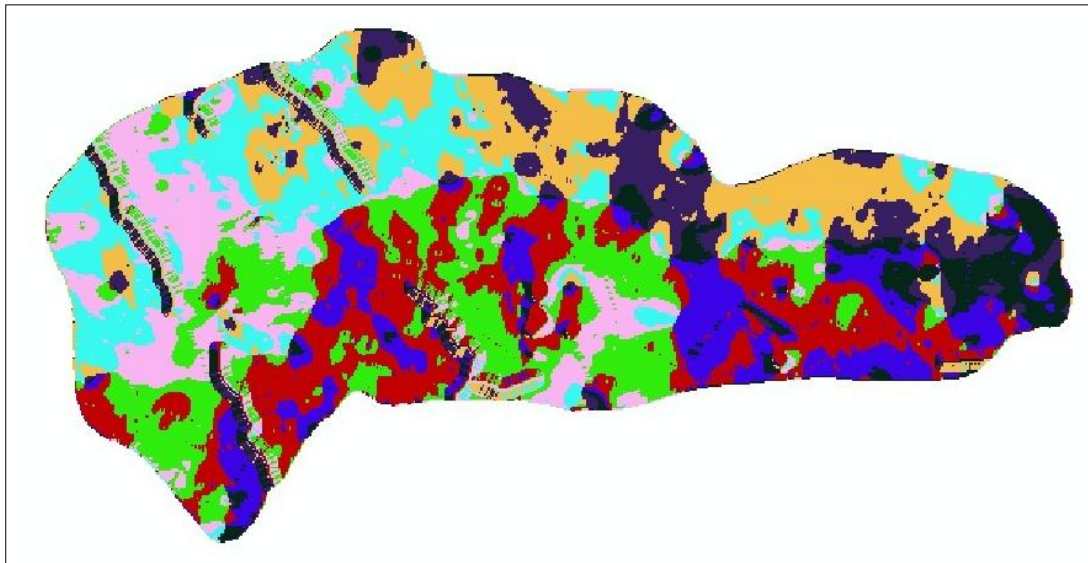


Fig. 3: Result of Flow Direction "Fdr".

Stream Definition

This function computes a stream grid, which contain a value of "1" for all the cells in the input flow accumulation grid that have a value greater than the given threshold. All other cells in the stream grid contain no data^[8].

From Arc Hydro Toolbar, Select terrain Pre-processing, then select stream

Definition. A smaller threshold will result in denser stream network and usually in a greater number of delineated catchment. For the present study, the threshold value was 570 for Stream Definition. With this threshold value, the resultant stream grid was saved as default as "str". The result for the stream definition is represented in Figure 4.

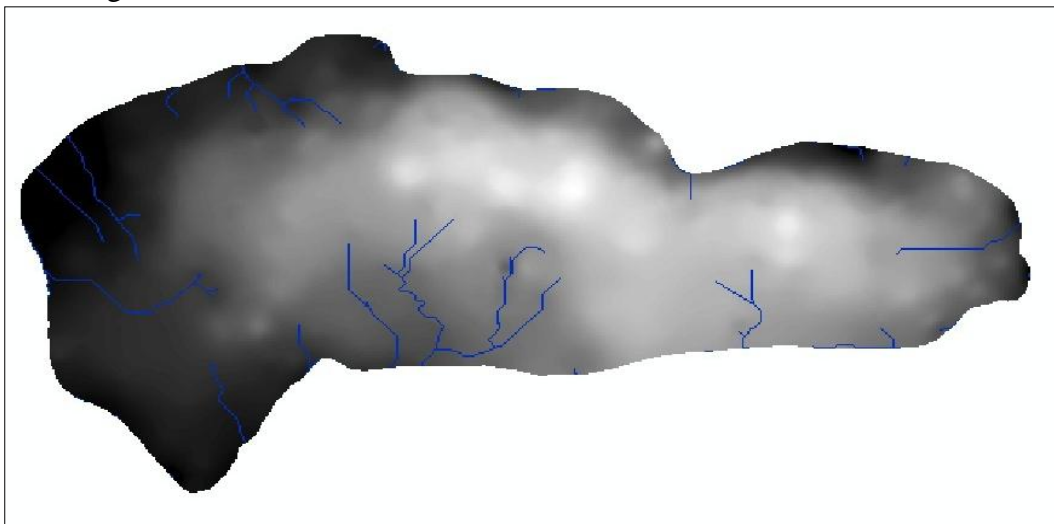


Fig. 4: Results of Stream Definition.

Stream Segmentation

This function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two junctions. All the cells in a particular

segment have the same grid code that is specific to that segment^[10].

From Arc Hydro Tool bar, Select terrain preprocessing, then select stream segmentation.

The input for stream segmentation should be "fdr" and "str" which are results of flow direction grid and stream grid respectively.

The output is the link grid, named as "lnk" by default. Here in link grid, each link has its own value.

Figure 5 below depicts the results for the Stream Segmentation.

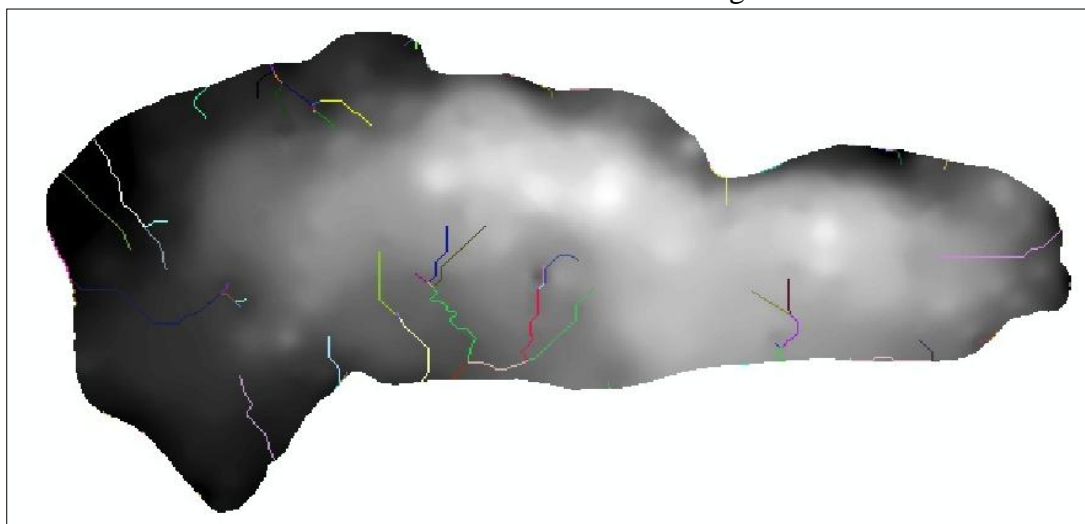


Fig. 5: Results of Stream Segmentation.

Catchment Grid Definition

This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by

the stream segment that drains that area, defined in the stream segment link grid^[10]. Select Terrain Preprocessing, and then select Catchment Grid Delineation, from Arc Hydro Tool bar.



Fig. 6: Results of Catchment Grid Definition.

The inputs will be the Flow Direction Grid and link Grid i.e., "Fdr" and "Lnk" respectively. The resultant is the Catchment Grid layer saved by default

name "Cat", which is represented in Figure 6.

Catchment Polygon Processing

This function converts a catchment grid into a catchment polygon feature^[6]. From Arc Hydro Tool bar, select Terrain Pre-processing, followed by Catchment Polygon Processing. The input "Cat" is for catchment grid. The output is the Catchment Polygon feature class which is by default saved as "Catchment". This vector data is stored in a feature data set also named Layers within the geodatabase linked with the Arc map document.

There are total 82 sub-catchments within the present area of study.

Drainage Line Processing

This function converts the input stream link grid into a Drainage line feature class. Each line in the feature class carries the identifier of the catchment in which it resides^[10].

From Arc Hydro Tool bar, select Terrain pre-processing, followed by selecting Drainage Line Processing.

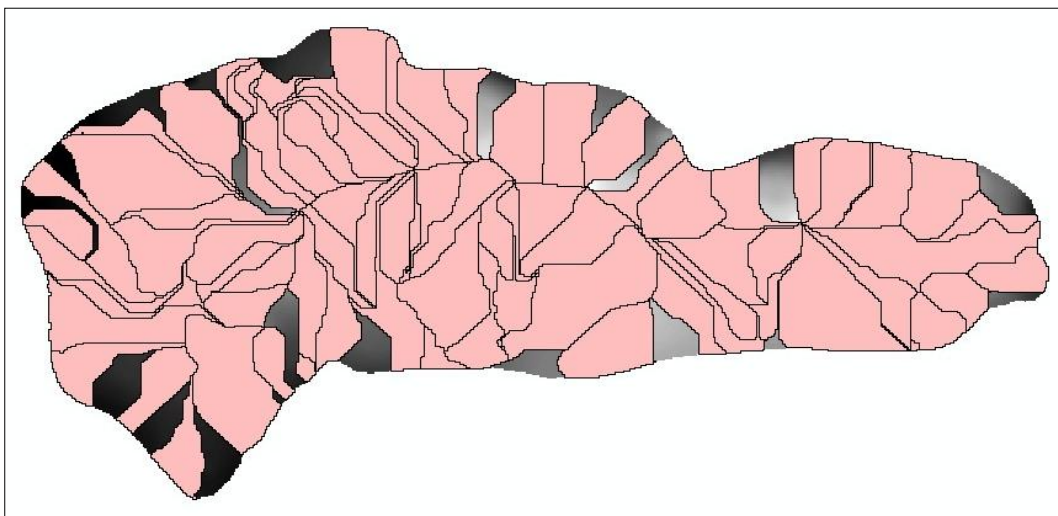


Fig. 7: Results of Catchment Polygon Processing.

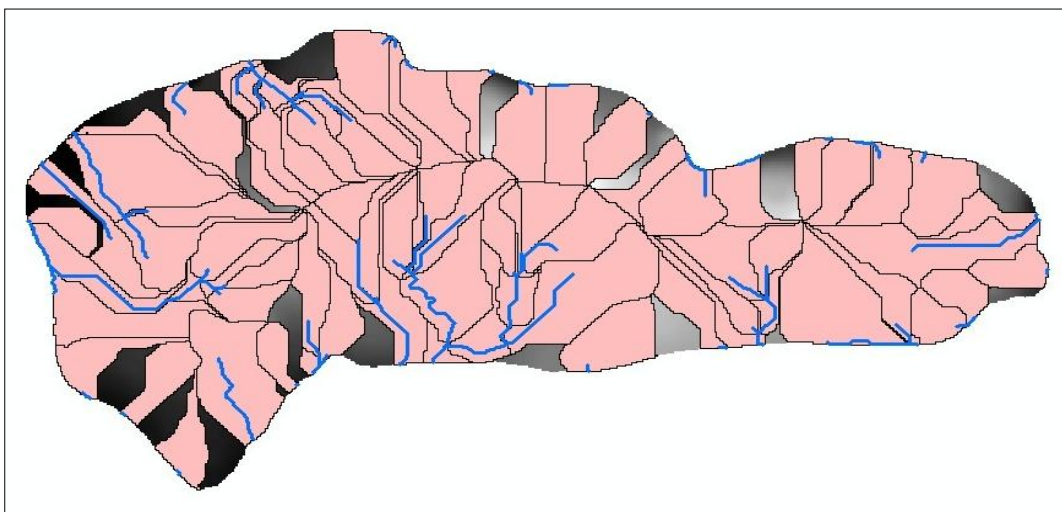


Fig. 8: Results of Drainage Line Processing.

The input is Link Grid and Flow Direction Grid "lnk" and "Fdr" respectively. The output is Drainage Line with its default name "Drainage Line".

The result for the drainage line processing is displayed in the Figure 8.

Adjoin Catchment Process

This function generates the aggregated upstream catchments from the “Catchment” feature class. For each catchment that is not a head catchment, a polygon representing the whole upstream area draining to its inlet point is constructed and stored in a feature class that has an “Adjoin Catchment” tag^[8]. From Arc Hydro Toolbar, select Terrain

Pre-processing from this select Adjoin Catchment Processing.

The input is Drainage Line and Catchment “Drainage Line” and “Catchment” respectively. The output is saved as default “Adjoin Catchment”. A polygon feature class named “Adjoin catchment” is represented above in Figure 9. There are 35 such catchments in the present area of study.

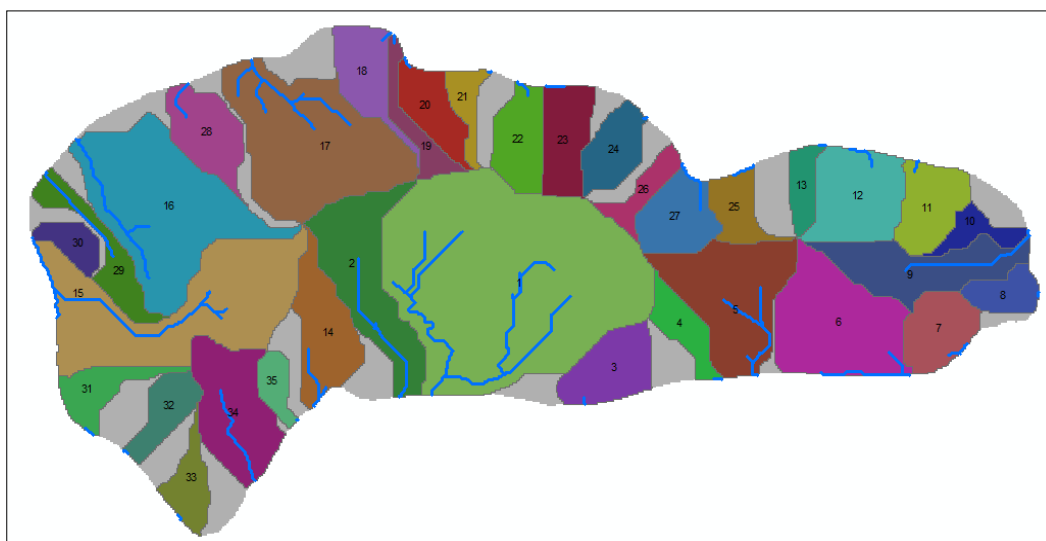


Fig. 9: Results of Adjoin Catchment Processing.

Drainage Point Processing

This function allows generating the drainage points associated to the catchments^[6]. From Arc Hydro Tool bar, select Terrain Pre-processing, then selecting Drainage Point Processing.

The inputs for Flow Accumulation Grid, Catchment Grid as well as Catchment feature class are “fac”, “cat” and “catchment” respectively which results in Drainage Point feature class. The output is Drainage Point having default name as “Drainage Point”.

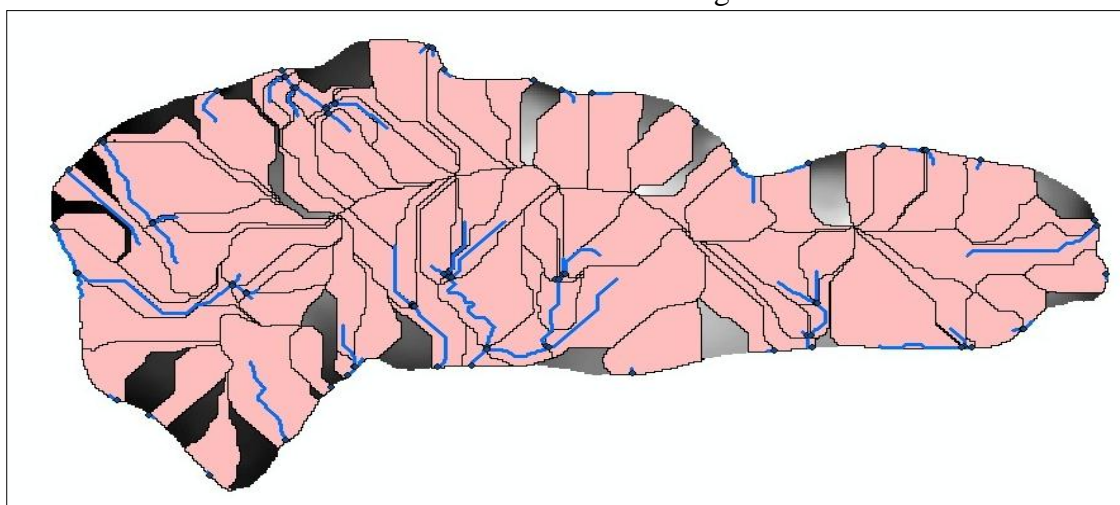


Fig. 10: Results of Drainage Point Processing.

RESULTS

The Terrain processing tool of the Arc GIS, Arc Hydro tool helps to generate catchments of the study area. This tool has the characteristics feature to generate the results even of small area.

Table 1: Resultant Catchments with Area.

Catchment No.	Catchment area (per sq km)
1	0.878
2	0.218
3	0.106
4	0.060
5	0.238
6	0.253
7	0.095
8	0.052
9	0.163
10	0.042
11	0.100
12	0.159
13	0.044
14	0.134
15	0.407
16	0.388
17	0.376
18	0.094
19	0.052
20	0.082
21	0.041
22	0.093
23	0.098
24	0.079
25	0.063
26	0.047
27	0.101
28	0.107
29	0.088
30	0.042
31	0.067
32	0.067
33	0.058
34	0.176
35	0.038

Here, in the present area of the study, which covers approximately 5.74 sq km, a total no. of 35 catchment areas of different sizes was achieved. The list of these catchment areas is mentioned in Table 1. These catchments are separated by ridge, situated in the middle of the study area. The utility of this catchment area is to help in water resource planning, rainwater

harvesting, sustainable development of the area as well as hydrological modeling.

CONCLUSION

Hydro-logically, catchment is an area from which the run-off flows to a common point on the drainage system. Here, the natural boundary of the watershed was accurately delineated with the help of Arc Hydro tools. These Arc Hydro tools are used to derive several data sets that collectively describe the drainage patterns of the catchments. The basic function of this Arc Hydro tool is to perform Raster analysis to generate output data on flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. These output data then acts as input data to develop a vector representation of catchment and drainage lines. The utility of Arc Hydro tools is used to develop attributes that can be useful in hydrologic modeling which further helps in water resource management, rain water harvesting, and sustainable development, supporting social and economic development of the concerned area.

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