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Model Builder and ArcHydro Tools of Geospatial Technology to Extract Drainage Network and Watershed Delineation using Digital Elevation Model

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Abstract – For any hydrological modeling, delineation of watershed details like drainage network and catchment area extraction are very important. It is of great need to delineate the catchment area in the form of sub watershed areas to find out the characteristics easily. It is possible to develop using geospatial technologies due to temporal and spatial variations. Automatic delineation of watershed is time consuming when compare to manual method. With the development of Geospatial technology, automatic extraction of watershed details became very popular. Digital Elevation Model (DEM) data can be considered as input data to delineate catchment area and drainage network using GIS. ArcHydro is an add-on tool in ArcGIS software, which plays a vital role in building any hydrological information system for the support of hydrologic modeling in water resources development. In ArcHydro model, there are many sequential dropdown tools available, which are to be properly followed in order to delineate watershed for the management of water resources. Hence, a comprehensive geospatial model has been developed in Model Builder of ArcGIS software to run the model at a time to complete the process to extract the features like drainage network and catchment area from ArcHydro tool. In the present research, Nandyal area is selected to delineate catchment area and drainage network. 30m DEM data was used for delineation of watershed as input data. The major functions of ArcHydro tool are Flow Direction, Flow Accumulation and determining watershed and extraction of drainage lines.

Key words: *ArcHydro Tool, Geo-spatial Model, Model Builder, DEM, Watershed Delineation.*

I. Introduction

Delineation of drainage network and catchment are prerequisite to establish any hydrological models. The automated extraction of watersheds relies heavily on DEM. For large-scale watersheds with hundreds of catchments to define, the conventional manual catchment delineation approach is time consuming and exhausting. In recent times, the analogue delineation of the catchment methods are being rapidly changing by automated procedures, thanks to the advent of software tools that can analyse data fast and efficiently. Automatic catchment delineation methods provide several advantages, including process dependability and repeatability, time and labour savings, and findings that may be connected to other data sets within a digital domain. For the purposes of GIS, these are replaced with digital data in the form of digital elevation models. Using the ArcHydro and Model Builder capabilities of ArcGIS, a drainage network as well as catchment boundary is generated for the case study region using 1sec (30mx30m grid spacing) DEM data.

ArcHydro is a paradigm for developing hydrologic information systems that combine geographic and temporal water resource data for hydrologic modelling and analysis. The model is designed to work with ArcGIS software as an add-on. It's used to create geometric networks for hydrologic research by extracting topologic variables from a digital elevation model raster (DEM). The hydrologic simulation models are supported by this geographical and temporal model. Water resources aspects such as network, drainage, channel, hydrography, and time series are divided into five groups in the full model. The ArcHydro tools create a number of datasets that collectively represent a catchment's drainage pattern. This facility is used by most watershed managers more than other sophisticated hydrologic analyses for their watershed management needs. A raster analysis is used to create data on flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. These data are then utilised to create a vector representation of catchments and drainage lines, which will aid in the creation of a geometric network.

Model Builder is one of ArcGIS' most powerful but underutilised features. The Model Builder environment provides a brand-new approach to conduct analysis and automate operations. The Model Builder interface is a graphical modelling framework for designing and implementing geoprocessing models using ArcGIS library tools and scripts, as well as geographic data that is compatible with ArcGIS software. Model Builder provides a rich environment that tightly combines GIS and process models, allowing users to make the most of their time and efforts. One of the nicest things about developing geographic models using Model Builder is that it doesn't require any programming knowledge.

II. Study Area and Objectives

Present study area is a part of Nandyal mandal of Kurnool District. Which is belongs to sub basin of Kuderu River basin. Generating a rainfall runoff model for the present study area is required to assess the water quantity for irrigation purposes. To generate the model boundary of the study area catchment delineation and drawing drainage network is essential. The main objective of the present research is to develop a comprehensive geospatial model in Model Builder of ArcGIS, in line of ArcHydro and to delineate drainage network and catchment area of the selected case study. The study area are its geographical location is shown in Figure 01.

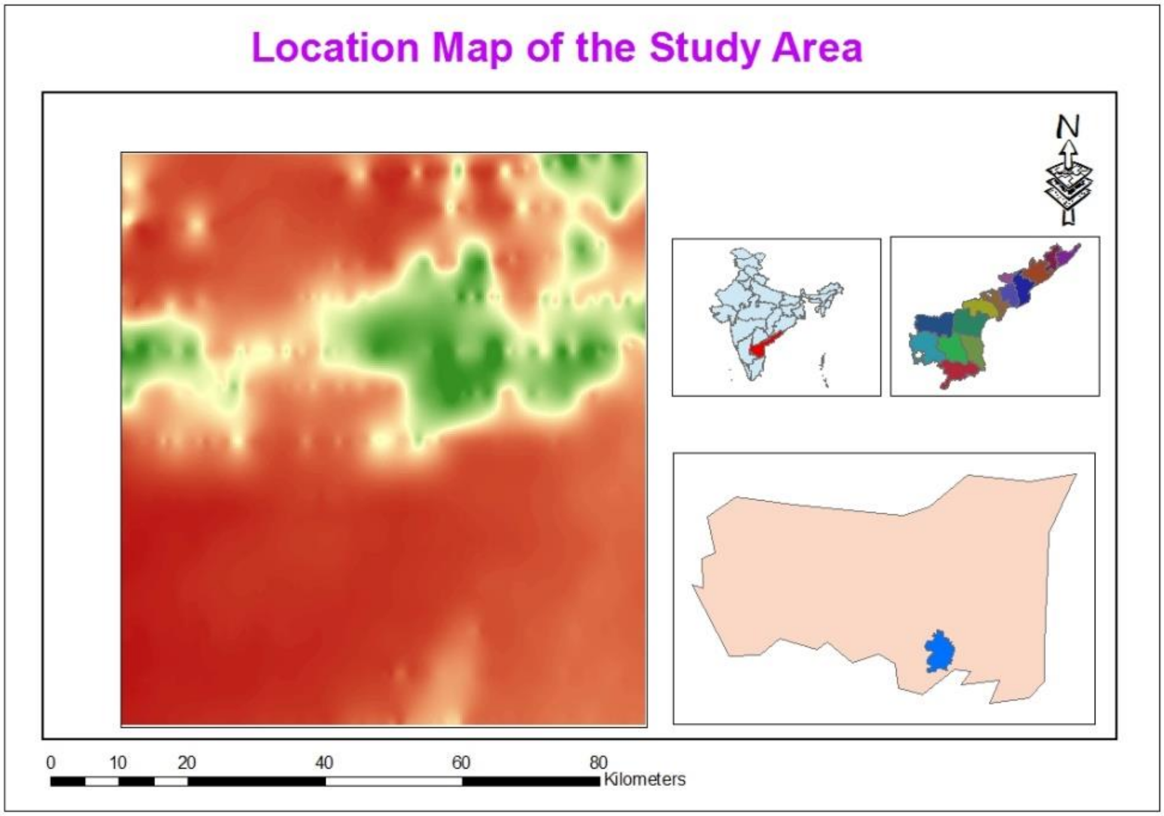

Figure01. Location Map of the Study Area.

A. Digital Elevation Model (DEM)

The term "digital elevation model" refers to a quantitative or digital representation of field elevation as a function of geographic location. For a geographically distributed hydrological model, DEM is the essential data for the automated catchment delineation and drainage network. These topographic frames are used to split the watershed into a series of components, each of which produces runoff and drains into a single channel. DEMs from the United States Geological Survey are now more widely available across the world, thanks to the advent of excellent spatial data collection technologies (USGS). In the present study, the 1sec DEM (30m x 30m) data of USGS was utilised for deriving catchment and drainage flow direction.

III. METHODOLOGY

A. Delineation of Drainage Networks and Catchments using ArcHydro

The sequential orders followed in this study for delineation of stream network and catchment area using DEM data are as below:

1. Fill Sinks:

It's the initial stage in the DEM preprocessing process. The goal of this phase is to create a model with less depression. The Sink tool was used to identify sinks in the original DEM. A sink is often an erroneous value that is lower than its surroundings. Any water that enters into these depressions points cannot flow out, posing an issue. These depressions were filled using the Fill tool and a fill DEM was found to guarantee correct drainage mapping. Increased elevations of depression points to their lowest outflow point fill depressions.

2. *Flow Direction:*

The direction of flow of water from each cell is decided in this step. The fill DEM from the previous stage is utilised as input in this step, and the tool - Flow Direction is employed. The flow model assigned flow from each grid cell to one of its eight neighbouring cells in the direction with the greatest downward slope.

3. *Flow Accumulation:*

It is the primary stage of defining the stream network system. Using the tool - Flow Accumulation, the number of upslope cells flowing to a location is calculated here. The flow direction raster created in the previous step is the input for generating Flow Accumulation.

4. *Stream Network:*

Specifying a crucial support area that determines the minimal drainage area necessary to begin a channel using a threshold value is the most frequent technique of extracting channel networks from DEM. In practise, the visual resemblance between the extracted network and the lines displayed on topographic maps is frequently used to determine this threshold value. On the raster of flow accumulation obtained from the previous phase, the threshold value has been defined. As a consequence, all cells having more than one 'threshold value' cell flowing into them were added to the stream network.

5. *Stream Segmentation:*

Following the derivation of the stream network, each part of the stream raster line was allocated a unique value associated with a flow direction. The stream Link tool was used to two raster files that were retrieved from the previous steps 2 and 3.

6. *Catchment Grid Delineation:*

The catchments are generated in the study area using the ArcHydro. As inputs, the flow direction raster and the flow accumulation raster based on fill DEM data were determined from the outputs of steps 2 and 5 respectively.

7. *Catchment Polygon Processing:*

Eventually, catchment polygons were discovered. The catchment of interest is the polygon on which the research area is located. Figure 02 is a detailed flow chart that depicts the whole process of watershed delineation in ArcGIS utilising the ArcHydro extension toolbar.

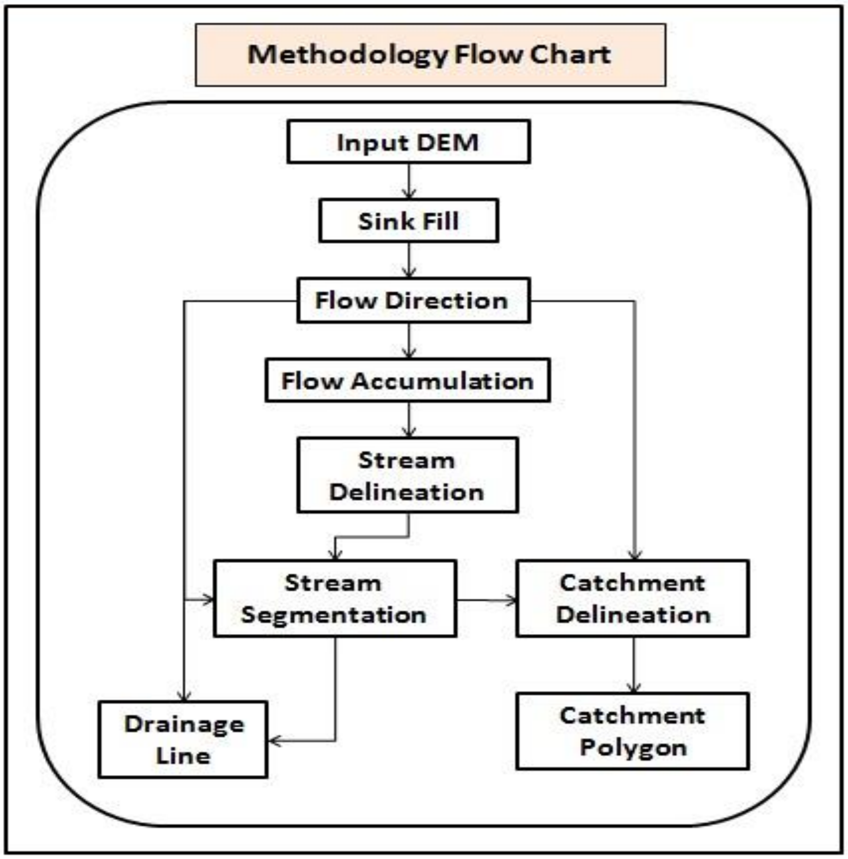

Figure 02. Methodology comprehensive flow chart

B. Geospatial model development with ArcGIS Model Builder

Then, utilising the capabilities offered in the Arc Hydro Tools toolbox's Terrain Processing toolset, a full ArcHydro watershed delineation process geospatial model was created on the Model Builder platform. This geospatial model has the benefit of allowing a newbie with minimal GIS expertise to run the model with a single click to receive his or her defined watershed. Another significant benefit of this paradigm is that the user does not need to worry about a specific folder in which to save the output. By double-clicking on the output oval and adjusting the file path, the user may save the output to any of the output folders of his or her choice. As a result, there would be less opportunities for the user to make mistakes. The model would not crash as frequently as it did when utilising the ArcHydro Add-on/extension toolbar tools to execute the procedure. The user would not have to worry about remembering the order in which to complete the watershed delineation procedure. The result may be obtained with a single click of the Run button. The offered figure depicts a detailed model (Figure 03).

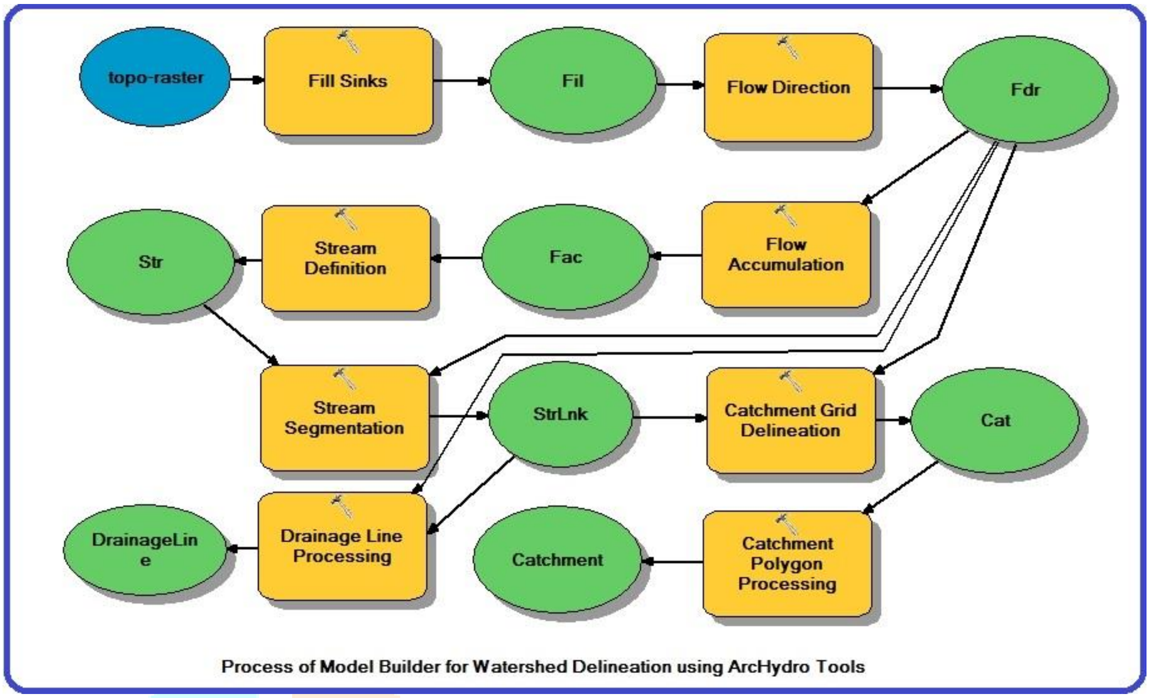

Figure 03. Comprehensive Geospatial model for watershed delineation using Model Builder

IV. Results and Discussions

Using DEM data and ArcHydro tools and Model Builder of ArcGIS, catchment areas and drainage networks for the research region were defined using the aforementioned technique. The defined catchment is seen in the diagram below (Figure 04). The most difficult task during catchment delineation was determining the threshold value, often known as the flow accumulation threshold region. After many trials with various threshold values, this study revealed that the catchment produced for the study region did not vary in shape for the threshold value ranges of 50 to 300. For the final catchment delineation, a threshold value of '292' was used. Within the research region, 115 sub catchments were discovered. The catchment area is approximately 1284.82 km2 and the drainage lines are 466.09 km long.

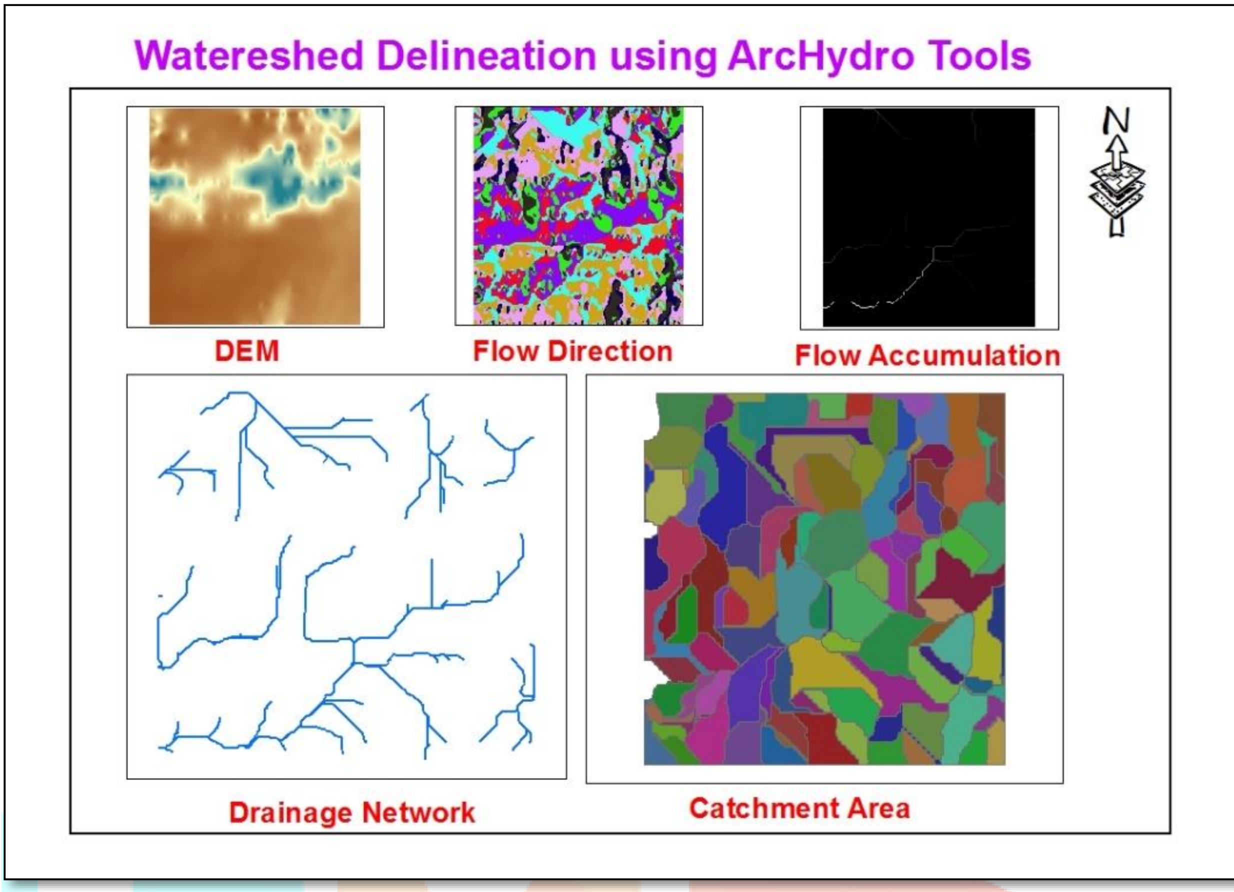

Figure 04. Delineated watershed using Model Builder with ArcHydro Tools

V. Conclusions

The size and accessibility of data sources, the kind and distinctive features of the modelled region, and the correctness and competency of the GIS database all play a role in a successful GIS-based automated catchment delineation. For the current study region, the catchment area and drainage network were defined extremely precisely using DEM with the aid of ArcHydro tools and ArcGIS Model Builder. The hydrological modelling relied heavily on the accuracy of catchment delineations. This work took a straightforward method to automated demarcation. The study found that grid spacing of DEM data plays a vital role in automatic delineation and also it observed that selected tools like ArcHydro with help of Model Builder are time consuming to use for large areas to run the model in short time, hence, time is saved. The fixing of a "flow accumulation threshold area value" was discovered to be particularly essential during the delineation of the catchment and drainage network. The automated delineation of catchment and drainage networks presented in this study will allow new researchers who are new to this subject to significantly speed up the process of generating first catchment delineations.

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