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Original Research Article

Delineation of Wadi Haseeb Watershed from Digital Elevation Model Using HEC-Geo-HMS in ArcGIS, East Nile, Sudan

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Abstract: Traditionally, topographic maps are usually employed for drainage analysis. However, channel network extraction and watershed delineation from topographic maps require time and expertise in cartography. The application of Geometrics (Remote Sensing (RS) and Geographic Information Systems (GIS) and land topographic information) is necessary for drainage network delineation. In the present study, the main objective is to delineate the drainage network and basin area of the wadi Haseeb watershed from the Digital Elevation Model (DEM) using the HEC-GeoHMS tool. The DEM of 10 m resolution is processed to define the primary natural flow routes and catchment. The hydrological analysis is performed for fill, flow direction, flow accumulation, stream definition, and finally, catchment delineation using the HEC-GeoHMS tool. Results show that the watershed was divided into four sub-basins (W240 - W270 - W410 - W420), the length of the catchment is 40 km, the watershed area was approximately 170 ha and the watershed slope was 0.9.

Keywords: Drainage network, GIS, HEC-GeoHMS, DEM.

1. INTRODUCTION

The land that drains all streams and rainfall to a common outlet is called a watershed. Basically, a watershed is all the land and water area which pool runoff to an outlet in the main flow channel. A watershed is a topographically delineated area that is drained by a stream pattern. A watershed is also a hydrological reply unit, a biophysical unit, and a holistic environment in terms of the resources, energy, and data that flow through it. Therefore, as long as being a valuable unit for physical analyses, it will also be the appropriate socioeconomic-political unit for management planning and execution. Watershed size differs from thousands of square kilometers to a small area(Gupta *et al.*,1997*)* (Alvarez *et al.*,2008) *(* Bo *et al.*,2011) (Wang *et al.*, 2016). Drainage patterns in the watershed differ broadly. An intricate pattern of a watershed is a pointer to high drainage density. The drainage patterns, which are familiar in aerial photographs, reflect geologic, soil, and vegetation effects and are frequently related to hydrologic features, such as runoff response, annual water yield, or sediment yield (Singh, 2003)(Krois *et al.*,2014). River basin analysis needs the delineation of the sub- basins, including not only sub-basin boundaries, but also their morphometric factors such as centroid, longest flow path, and others. These will be used to define e.g. precipitation time series, water balance, and hydrograph. For the delineation, a digital elevation model (DEM) is required basically. It is also advantageous to have a rough idea of the basin boundaries, so as to clip the DEM to a manageable size before beginning the delineation process (Kumar, 2010) (Roehrig, 2016) (Shahid, 2017).

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Study Area

This study concentrates on Wadi Haseeb watershed, which is located on east Nile, Khartoum State. It is surrounded by latitudes [15° 20' - 15° 50' N], and longitudes [32° 03-33° 26'E].

2.1.2 Data Required

- Digital Elevation Model (DEM) 10m.
- ArcGIS 10.1.
- HEC-GeoHMS extension.
- HEC-HMS software.

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2.2 METHODOLOGY

GIS approach toward hydrological analysis needs a terrain model such as the digital elevation model (DEM), which is used as an input in the HEC-GeoHMS to derive eight additional datasets that jointly describe the drainage pattern of the watershed and allows for stream and sub-basin delineation. The first six datasets are grid layers that represent the fill sinks, flow direction, flow accumulation, stream network, stream segmentation and watershed delineation. The next two datasets are vector layers of the watershed and streams. After the terrain processing is completed, another two tools namely project point and project area are to be processed under the HEC-HMS project setup. The project area layer is used to show the upstream drainage area for the outlet point and the project point layer shows the location of the outlet point. The methodology flow chart shows in Figure (1).

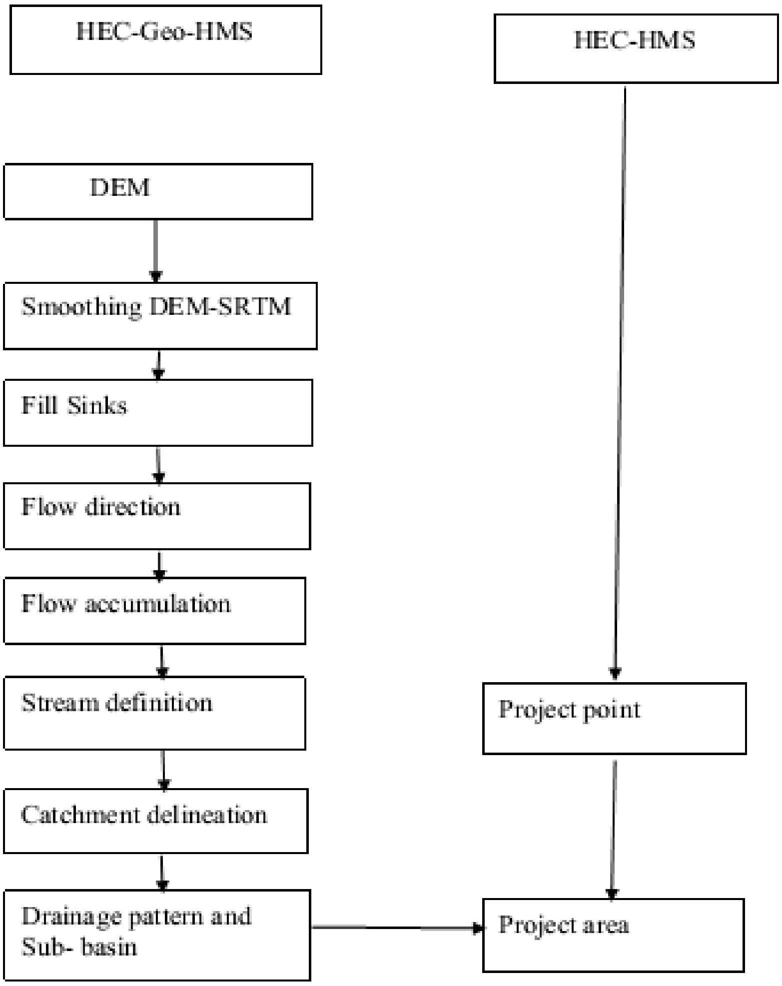

Figure 1: Methodology Flow Chart

3. RESULTS AND DISCUSSION

Eight datasets have been derived to form the watershed drainage pattern including and sub-basins areas:

3.1 Fill Sinks

Fill sinks is resulted to a cell surrounded by high elevation cells causes taped water leads to undrain water, this needed a reconditioning the DEM to raise the base level of the its values to prevent negative values in the DEM and to ensure that flow was not altered by artificial depressions. Therefor the fill sink needed to smooth the artificial 0depressions and to ensure proper delineation of basins and streams as shown in Figure 2.

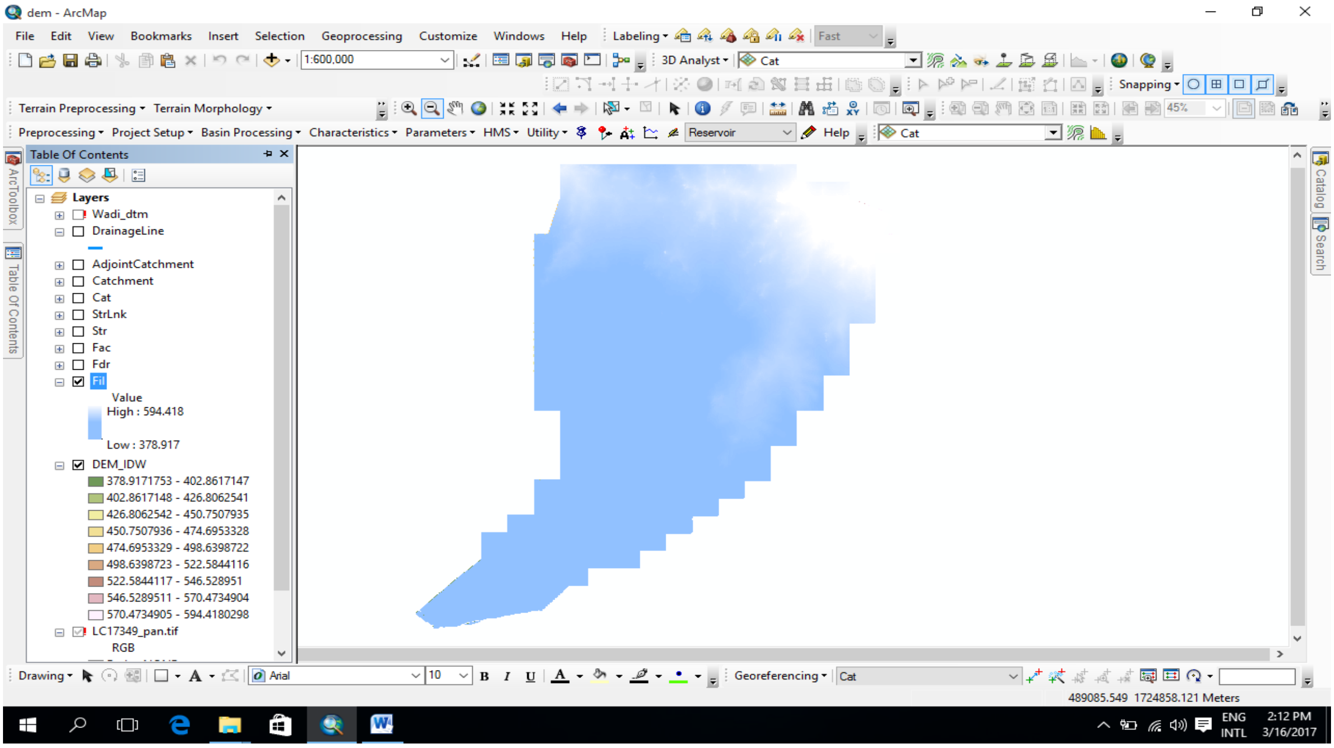

Figure 3: Fill Sinks

3.2 Flow Direction

The flow direction algorithm was used to produce the flow direction map. An output raster is created representing the ratio of the maximum altitude change from each cell in the direction of flow over the distance of the path between the centers of the cells, expressed as a percentage. The values of 1, 2, 4, 8, 16, 32, 64, and 128 represents eight possible direction of the flow in each cell which is connected to one of its eight neighboring cells according to the direction of steepest descent, given an elevation grid, and thus a grid of flow direction is constructed as shown in Figure 4.

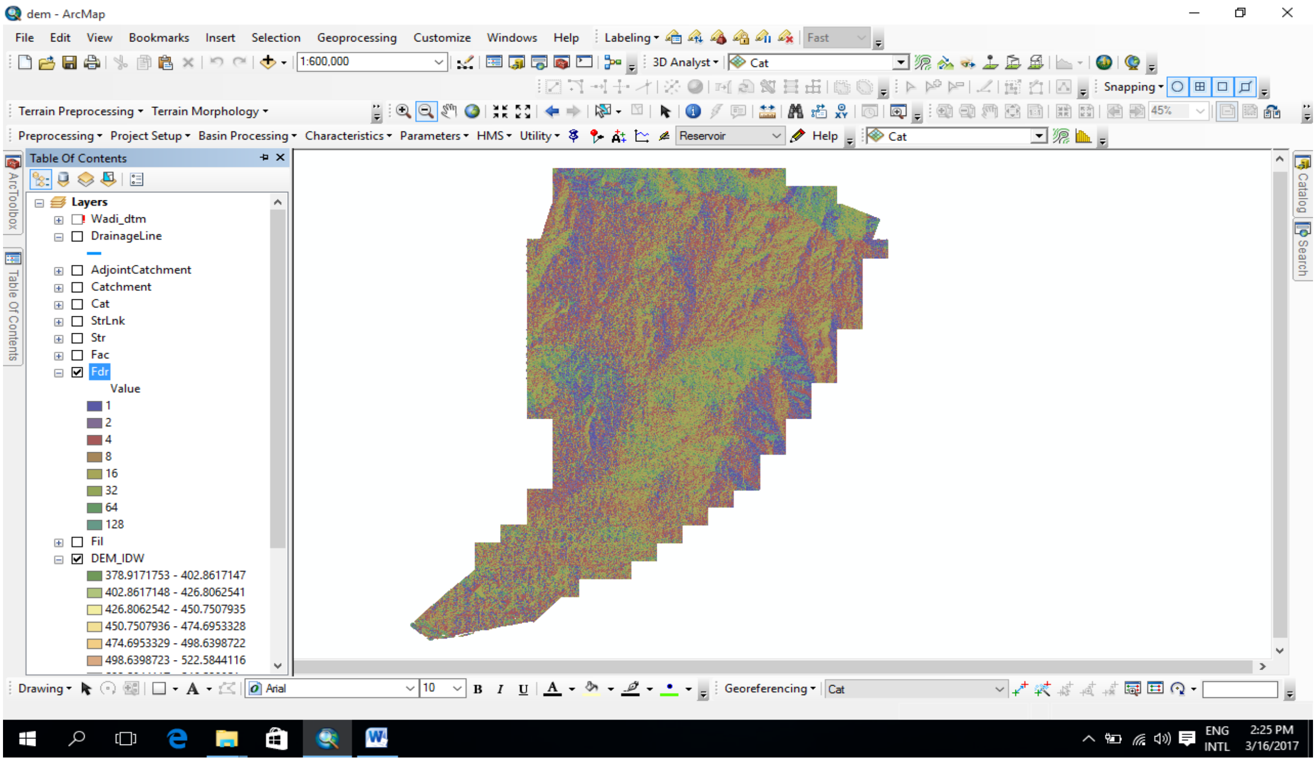

Figure 4: Flow Direction

3.3 Flow Accumulation

A grid of Flow accumulation is derived, which is counting the number of cells upstream of a given cell. This calculation is important to specify the threshold by which watercourses are defined in the next step. The raster image thus created shows the drainage pattern in classes of diverse colors show in Figure 5.

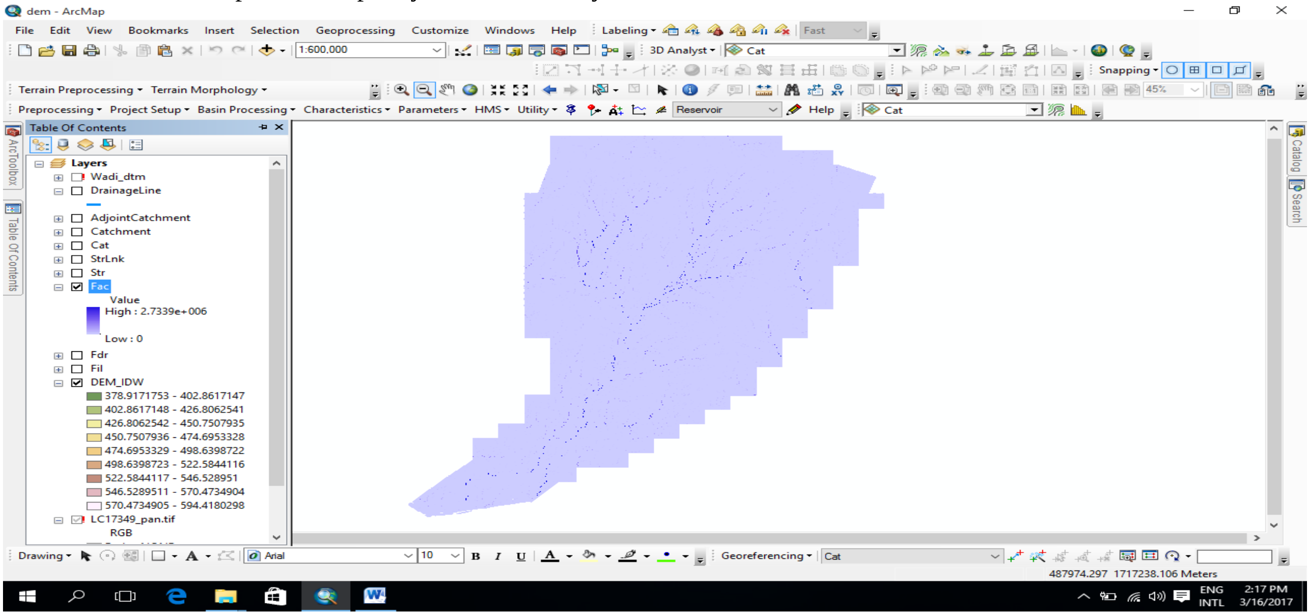

Figure 5: Flow accumulation

3.4 Stream Definition

Stream definition mean that Streams are identified as lines of cells whose flow accumulation exceeds a specified number of cells and thus a specified upstream drainage area. The stream definition layer output map shows Figure 6 is in binary raster format with cells happening within stream features gave a value of 1.

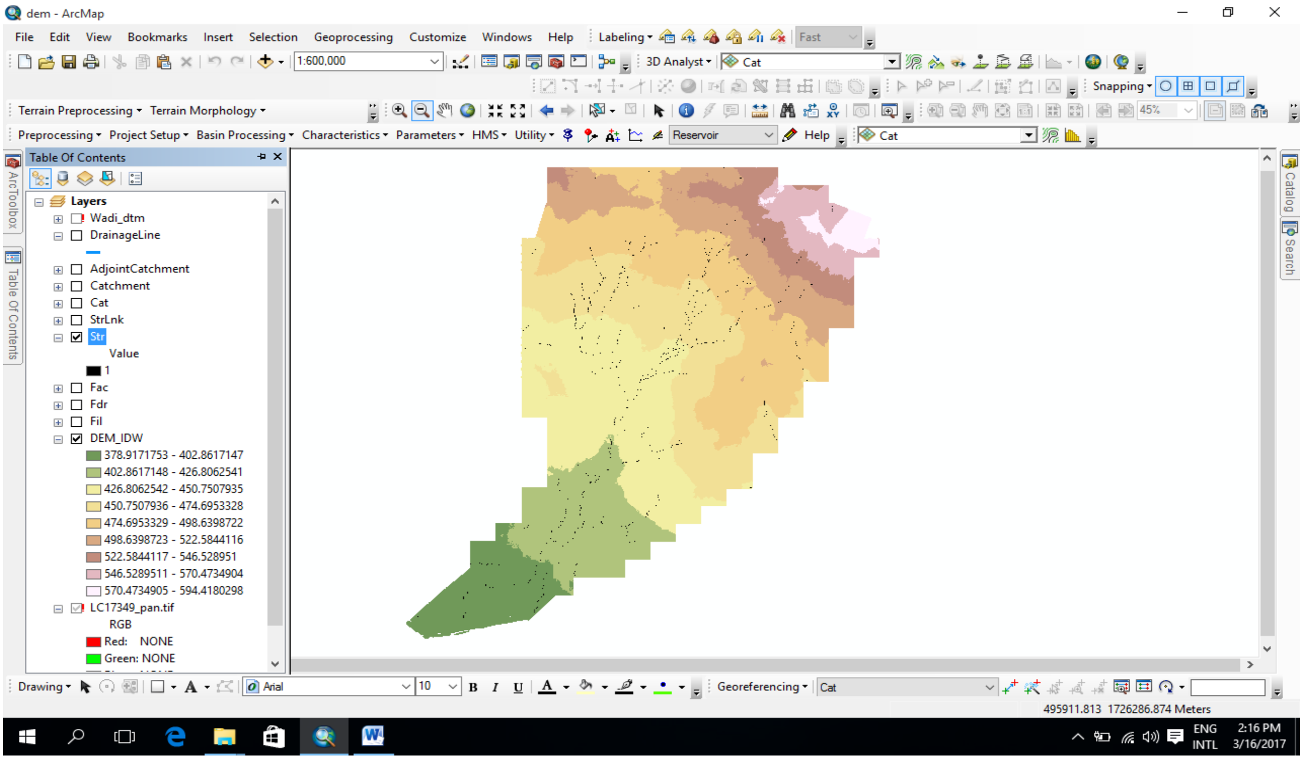

Figure 6: Stream Definition

3.5 Stream Segmentation

All cells in a given link segment have the same value that exclusively recognizes the segment. Stream segmentation map shows Figure 7 represents headwater tributaries or segments between confluences were generated with junctions and branches.

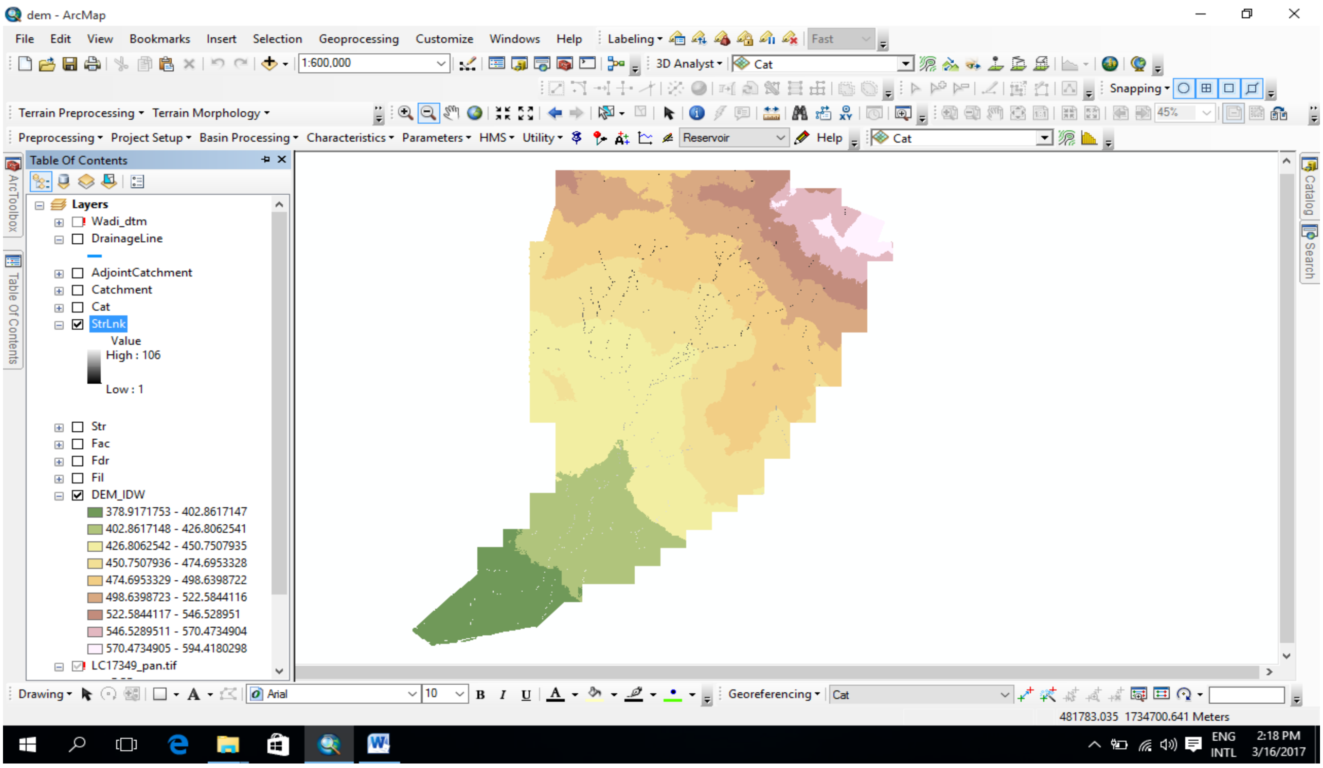

Figure 7: Stream Segmentation

3.6 Catchment Grid

Catchment grid delineation map shows Figure 8 was produced explained catchments delineation in some places and empty patches in other places. Cell carries a value (grid code) indicative of which catchment the cell belongs, and value matches to the value carried by the stream segment that drains that area, cleared in the input Link grid.

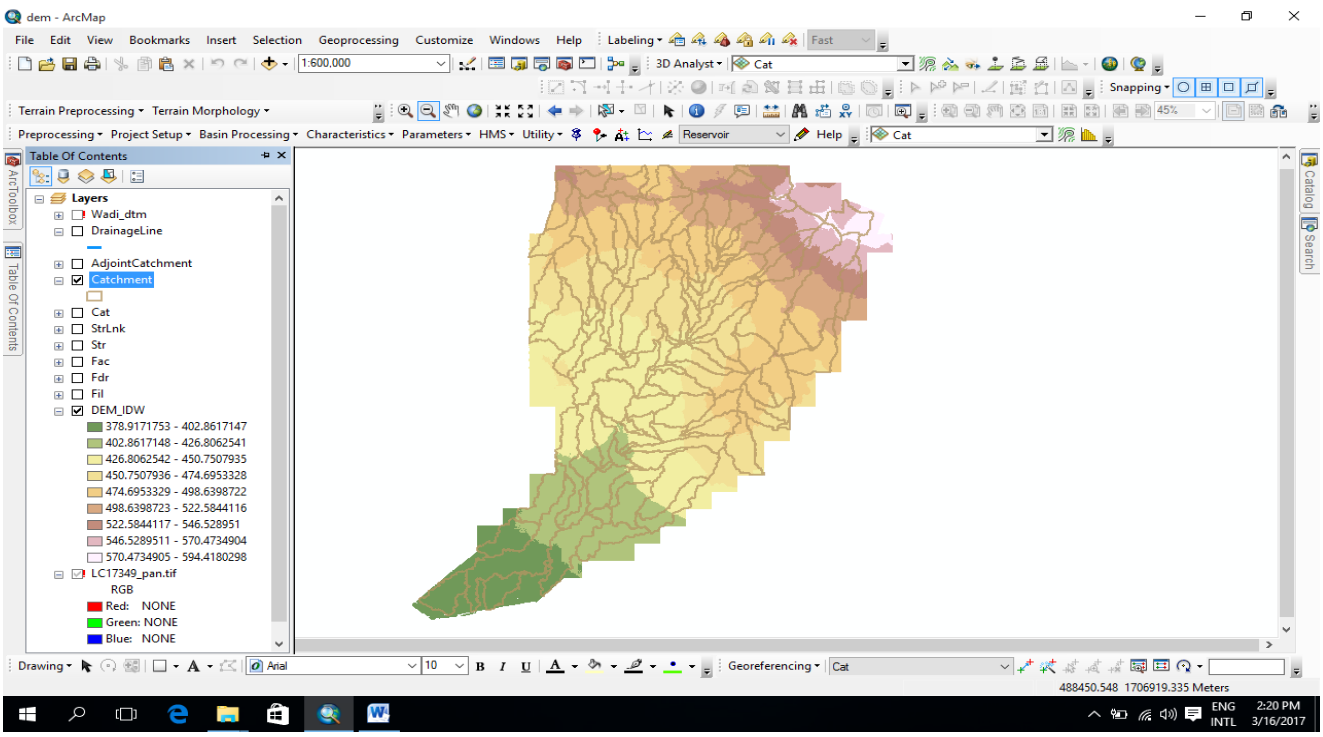

Figure 8: Catchment Grid Delineation

3.7 Catchment polygon

Catchment polygon processing convert catchment grid into a catchment polygon victor features map shows in Figure 9.

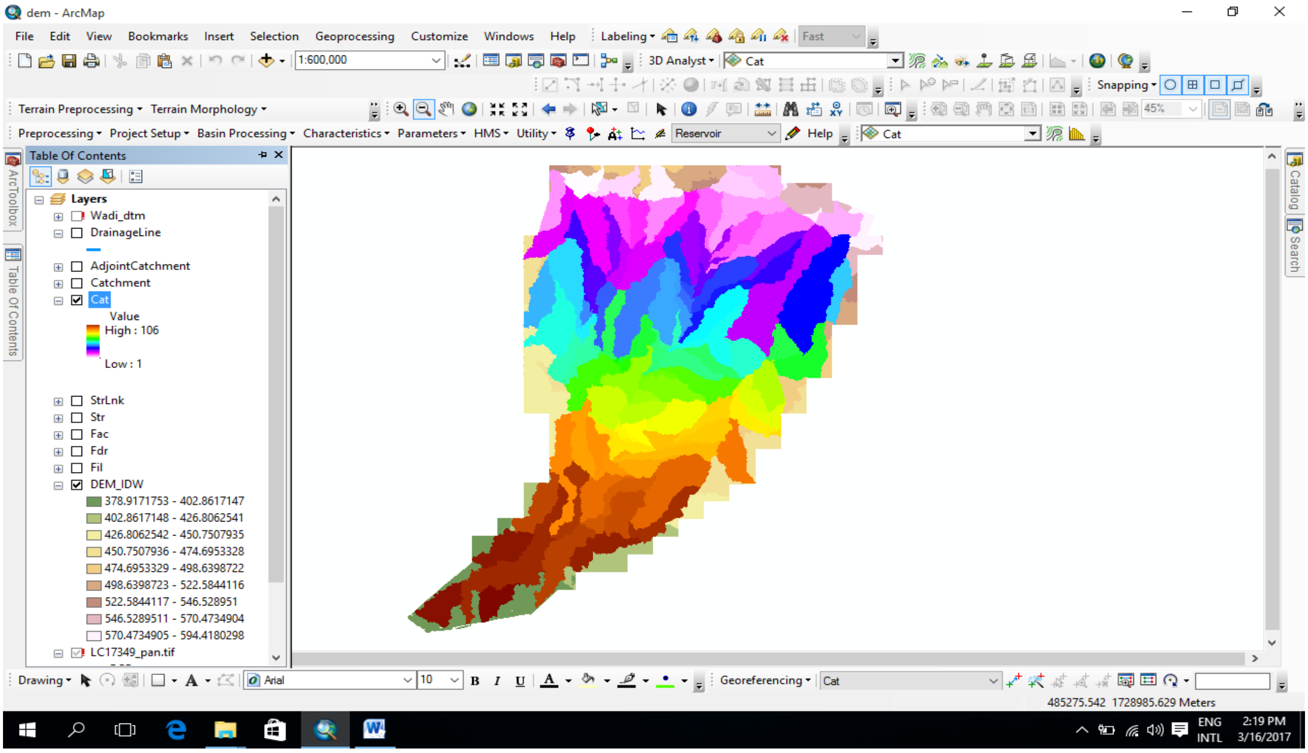

Figure 9: Catchment Polygon Processing

3.8 Drainage Pattern Delineation

Finally the Drainage lines map has been generated as shown in Figure 10. That collectively describes the drainage pattern of the Wadi Haseeb and allows for stream and sub-basin delineation for run-off estimation. Most of the drainage types in the study area were shallow, dendrites, narrow, and intensively distributed and represent good supplies of water. All streams in the study area flow towards the main watercourse and then to the Blue Nile. These results agree with (Mustafa *et al*, 2005 Singh, 2003; Eljack, Elhag and Elsheikh, 2015), while noted that the watershed with gentile slope always gives a shallow and broad streams in hydrology analysis.

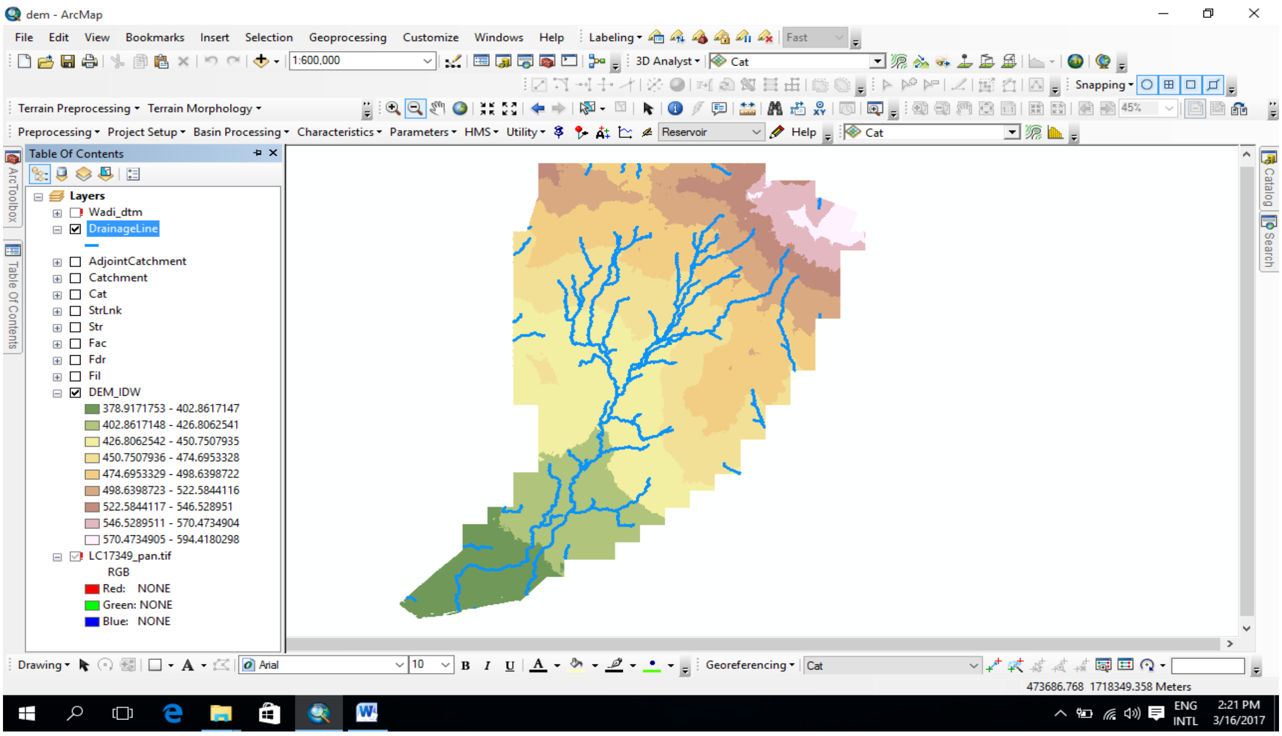

Figure 10: Drainage Pattern

3.9 Sub-Basins Delineation

Sub-basins have delineated and was consisting from four sub-basins named as: W240 and W270 in length of 10 and 9 km and catchment areas are 601 and 485 Km^2 respectively, and sub-basins W410 and W420 in catchment areas of 1086 and 1708 Km^2 respectively as shown in Figure 11. Finally, the morphological characteristics of the watershed presented in Table 1 were produced such as watershed area which was estimated at 170,000 ha considering a large area and contain a lot of seasonal streams, a considerable agricultural area and many villages form rich natural resources for integration management. The wadi extend in a long distance approximately 40 km passed by a fertile agriculture land this lead to increase cultivated area and livestock in the study area . And the slope of the catchment was found to be 0.93 which is very gentle and makes the main stream shallow and board and flood in low mode supporting the water utilization in cultivated area. These results disagree with (Ganawa *et al.*, 2011), as they noted that the topography was high and low land with steep slope, and agreed with (Eljack, *et al.*, 2015), whereas stated that the topography is flat with slope ranged from 1 to 0.9.

Table 1: Characteristics of the watershed

Parameter	Value	Unit
Watershed Area	170,000	Ha
Catchment Length	40	Km
Catchment Slope	0.93	-

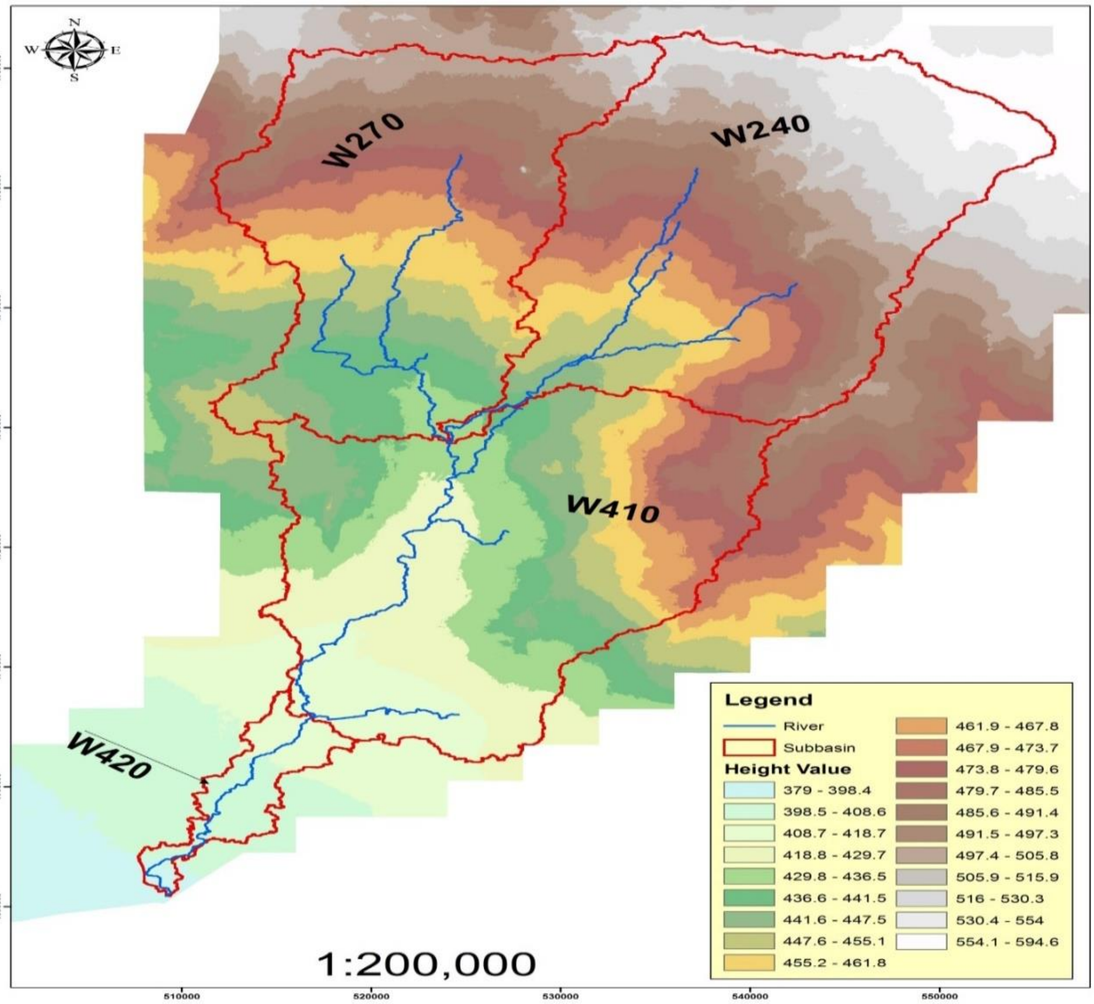

Figure 11: Topography and sub-basins

4. CONCLUSION

Digital Elevation Models (DEMs) have been a focus of increasing attention and utilization in the last few decades because of the relation facilitate in delineation, extraction and calculation of various drainage and terrain morphometric parameters from them. For delineating the watershed DEM is efficient when using with HEC- GeoHMs in ArcGIS interface. It allowed us to perform terrain analysis in 3D form. The hydrological analysis enhanced the visibility of natural drainage pattern in readable map.

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