Sudan University of Science and Technology

College of Graduated Studies

Avoidance of Severe Flood Damages In Sudan Using GIS

تجنب الأضرار الحادة للفيضانات في السودان بإستخدام ال GIS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE MASTER’S DEGREE IN COMPUTER SCIENCE

(GIS Geographical Information System)

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الآية

﴿اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ (5) ﴾

(سورة العلق.)

DEDICATION

To my dear beloved mother.

To my dear father.

To my dear fellow brother and sisters.

To all my friends and all those who have conferred their favors upon me and paved my way to success, all words and expressions of gratitude and thankfulness will be a drop in your sincere wide… wide sea of help and support.

ABSTRACT

In last year's rainfall affected many parts of Sudan including people by losing their beloved and healthy environment, in which they lived basically their whole life. So we need to find a suitable solution to solve this problem and to avoid severe damages. All previous studies we reviewed presented mathematical theory solutions and did not support or prove any practical solution.

The idea of this research is to processing and prepare data of water gauge stations to allow for the calculation of the amount of water and the area which might become affected by floods. We will show that after the right pre-processing of the data of gauge stations we are ready to calculate the amount of flood water.

In detail we found out that it is important to know the highest point in the river and the lowest level, in order to use this information for a detailed flood water analysis presenting the areas which are affected.

المستخلص

الفيضانات في السنوات الأخيرة أثرت على العديد من المناطق في السودان كذلك أثرت على الممتلكات الداعمة لعيش الناس . لذلك نحن في حوجة للتخلص من هذه المشكلة .كانت هنالك العديد من الدراسات السابقة لنفس المشكلة إلا أنها اقتصرت على المعاملات الرياضية النظرية غير مدعومة بأي تطبيق عملي .

فكرة المشروع هي معالجة و تهيئة البيانات المأخوذة من موقع الدراسة المحدده لتصبح صالحه لحساب كمية المياه والمناطق التي قد تتأثر بالفيضان. تم اتمام تلك الخطوة لمعالجة و تهيئة البيانات الماخوذة من منطقه الدراسة و أصبحت جاهزة لحساب كمية الفيضان .

في هذا البحث بعد معالجة و تهيئة البيانات تم تحديد اعلى منطقة في النهر والمناطق المنخفضة بناءاً على ذلك في حالة ارتفاع المياه عن ارتفاع تلك النقطة سوف يحدث فيضان وتمكنت من معرفه المناطق التي تتأثر من الفيضان.

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1.1 Introduction

Since late June 2014, seasonal rainfall across many parts of Sudan has been above-average, with some local areas experiencing rainfall surpluses in excess of 100mm within 30 days. On 17th June, about 750 people were affected by heavy rain that destroyed 37 houses.

Generally, the number of affected people in 2014 had increased to almost 257,000, and 49 deaths had been reported. Blue Nile was the most affected state, followed by Khartoum, North Darfur and River Nile.

The states affected are Khartoum, Northern, River Nile, Gezira, Red Sea, Sennar, North Kordofan, Gedaref, North Darfur, Blue Nile, White Nile and South Darfur, Kassala, and South Kordofan, according to the Ministry of Health. The Humanitarian Aid Commission further reports affected populations in Abyei and West Kordofan

A Geographic Information System (GIS) is a system designed to collect, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations.

The broad variety of applications using geo-spatial analysis includes crisis management, climate change modeling, weather monitoring, sales analysis, human population forecasting and animal population management.

Geo-spatial analysts filter out relevant from irrelevant data and apply it to conceptualize and visualize the order hidden within the apparent disorder of geographically sorted data.

Geo-spatial analysis is sometimes considered to encompass as much intuition as it is [1]

1.2 Problem Statement

In some years when there are heavy rain falls, the flood water finds its way to the Nile breaking buildings and demolishing houses. Also In Sudan a lot of people build their houses and exploitation in the old water rapids (downhill). Hence the idea of research reduces the damage caused by the floods and minimizes losses in resources and lives

1.3 Objectives

1.3.1 General Objectives

To avoid severe flood damages (for humans, resources, and environment).

1.3.2 Specific Objectives

Benefit from the flood waters for use in manual irrigation, understanding the natural environment, and managing water resources.

1.4 Solution

Analyses of the situation with all geo-spatial data available and model paths for the water, high water and flood water. The output will indicate the area that will be flooded.

Furthermore, we will try to foresee in a simulation study the event of a flood by using weather data in order to respond appropriately.

1.5 Methodology and Further Tools

1.5.1 Methodology

Using Scrum Methodology: Scrum is an iterative and incremental agile software development framework for managing product development.

1.5.2 Further Tools

Software: QGIS, Esri ArcGIS

1.6 Scope of study

The Scope of study include Marabee Al shreef city (DEM Data of study area)

2.1 Introduction

This chapter is divided into two sections, the first section gives a general description of the field of research, and the second section describes the related studies to the research project.

2.2 Introduction to ArcHydro and ArcHydro tool*s*

2.2.1 Arc Hydro

ArcHydro is part of Esri's ArcGIS-based system geared to support water resources applications. It consists of two key components:

- ArcHydro Data Model
- ArcHydro Tools

These two components, together with the generic programming framework, provide a basic database design and a set of tools that facilitate the analyses often performed in the water resources area.

ArcHydro is intended to provide the initial functionality that can then be expanded by adding to its database structures and functions required by a specific task or application.

In this study we are using ArcHydro Tools to solve the problems.

2.2.2 ArcHydro Tools

The ArcHydro tools operate in the ArcGIS environment. Some of the functions require the Spatial Analyst extension. The majority of the tools are accessed through the ArcHydro Tools toolbar, where they are grouped by functionality into six menus and nine tools. Additional tools have been developed in the geo-processing environment and are available in the ArcHydro Tools toolbox that can be used both in ArcMap and in ArcCatalog.

The ArcHydro tools have two key purposes. The first purpose is to manipulate (assign) key attributes in the ArcHydro data model. These attributes form the basis for further analyses. They include the key identifiers (such as Hydroid, Drain ID, NextDownID, etc.) and the measure attributes (such as Length Down).

The second purpose for the tools is to provide some core functionality often used in water resources applications. This includes DEM-based watershed delineation, network generation, and attribute-based tracing.

The functionality of ArcHydro tools is expected to grow over time. They have been implemented in a way that allows easy addition to their functionality, either internally (by adding additional code) or externally, by providing additional functionality through the use of key ArcHydro data structures.

2.2.3 ArcHydro Terrain Preprocessing

ArcHydro is arranged such to perform deranged, combined and dendritic terrain preprocessing using Arc Hydro tools. The processing is organized into workflows based on the key geomorphologic characteristics of the terrain being processed.

In the following some geomorphologic (use case) terminology is explained in more detail:Completely deranged terrain. Contains only sinks. Streams are not represented in ArcHydro.

✓ Completely dendritic terrain. There are no sinks in the system, only streams.

✓ Combined dendritic/deranged terrain. There are streams and sinks in the system.

Any type has four cases depending on the data available:

DEM only (no stream or sink information)

DEM and known sinks

DEM and known streams and sinks

DEM and known streams

In the case using completely dendritic terrain and DEM, then several steps are to perform:

DEM Reconditioning

Fill Sinks.

Flow Direction.

Flow Accumulation.

Stream Definition.

Stream Segmentation.

Drainage Line Processing.

Catchment Grid Delineation.

Catchment Polygon Processing.

Adjoint Catchment Processing.

Append Coastal Catchments. [2]

2.2.4 Modeling Floodplain

Modeling floodplain delineation requires a Digital Elevation Model (DEM) of the area on which we add or create a vector of the river and a point location where the water heights have been measured.

Although the ArcHydro models can accommodate complex drainage basins and multiple gauge stations, we will focus here on a simple 1-river/1-gauge station system.

2.3 Related Studies

2.3.1 Title of Study: A GIS-based model for urban flood inundation [3]

Name of researcher: Jian Chen *, Arleen A. Hill, Lensyl D. Urbano

Study objectives: Evaluate urban flood hazard of an urban university campus with a history of flooding.

The model consists of two components: a storm–runoff model and an inundation model. Cumulative surface runoff, output of the storm–runoff model, serves as input to the inundation model.

The storm runoff model adapts the AGreeAmpt model to compute infiltration based on rainfall characteristics, soil properties, and drainage infrastructure conveyance. The basis of the inundation model is a flat–water model.

This flooding is isolated from riverine influence and has led to both disruption of normal university functioning and significant loss.

Idea of study:

The model uses the total volume of rainfall excess which accumulates in topographic depressions in the study area.

Assumption:

The surface of accumulated water is horizontal (gradient h = 0). R rainfall is neither infiltrated into the soil nor conveyed by sewer System, in cubic meter.

F: is (volume of cumulative infiltration, also in cubic meter), D: is (cumulative volume storm water conveyed by underground sewer system in cubic meter). Then the Equation to calculate Rainfall is: $R = P - F - D$ (1)

Calculate D: $D = Q\ t\ A$ (2)

Q is the permanent con-viable flow rate, in cubic meter per second per hectare (comes/ha), t is the cumulative time, in seconds (s), A is the drainage area for study area, in hectare. Now we need to calculate φ from the percentage of impervious area in the study area

The storm–runoff model simulates surface runoff (rainfall excess) based on AGreeAmpt equation-based infiltration-model was used to quantify the influence of land-use on infiltration by applying an adjust index, φ, Φ: is calculated from the percentage of impervious area in the study area µ: obtained from morphologic analysis of high-resolution satellite image, orthoimagery or GIS analysis of detailed and use map layers)

$$\varphi = 1 - \mu \quad (3)$$

If no such data are available, then estimates from the SCS may be used for different land use types. Adjusted infiltration (q) is then computed

$$q = F - \varphi \quad (4)$$

where F is the cumulative infiltration prior to adjustment; and φ is the adjustment index. R, the Rainfall becomes:

$$R = P - q - D \quad (5)$$

The Scope of study:

It includes the main campus of the University of Memphis. This campus has suffered repeatedly from flash flood events over several years, where frequent heavy rains overwhelm the capacity of the underground sewer systems.

Results:

Flat–water model instead of physically based dynamic model:

This means that physical factors such as gravity and friction were not considered and mass conservation is the governing equation. Surf friction will cause a time lag to reach the maximum inundation depth most of cases comparing to a flat–water model results

Treatment of sewer conveyance as permanent convey able flow rate: actually it is not a constant rate at all for storm events. This simplification can overestimate sewer Unit rainfall in study area: this strategy needs to be adapted to work for a large area. For a small study area like University of Memphis, a unit rainfall hyetograph is appropriate. An alternative strategy for this approach would be to use unit hyetograph for each catchment to account for the spatial variation of rainfall.

Attachment based inundation: unrealistic inundation conditions may exist for the catchment boundary area. Since inundation in each catchment is simulated separately, there is potential for uneven inundation surfaces for adjacent catchments. A mechanism to adjust inundation conditions by comparing.

2.3.2 Title of Study: Flood management and a GIS modelling method to assess flood-hazard areas—a case study [4]

Name of researcher: Nektarios N. Kourgialas & George P. Karatzas

Study objectives: evaluate urban flood hazard of an urban university campus with a history of flooding.

Idea of study:

This paper presents a viable approach for a flood management strategy in a river basin based on the European Floods Directive.

A reliable flood management plan has two components:

a proper flood management strategy

Determination of the flood-hazard areas.

The study area was divided into five regions characterized by different degrees of flood hazard ranging from very low to very high. In this study the flood management strategy includes:

Pre-flood measures.

Technical measures

A flood-preventing protection plan should start from the mountainous regions in order to moderate the phenomenon in its generation. Based on the European Floods Directive and the Water Framework Directive, the elevations of the river basin were divided into three management zones:

Low region (<200 m).

Intermediate region (200–800 m).

High region (>800 m)

Flood warning system (FWS)

It is important to have a satisfactory flood warning system, which are the milestones in the occurrence of a flood event. The first milestone is the determination of the precipitation area, that causes the flood and the last is the exceedance of a water-level threshold, at which property damage, injuries or loss of life occurs.

Actions taken by the public or public servants between these milestones may mitigate the flood damage. The time between the beginning of precipitation and the threshold exceedance is the maximum potential warning time.

The Flood Hazard Research Center (FHRC) in the UK reviewed the flood response and suggested that the avoided actual flood damage, Da can be estimated as:

$$Da = D_p \times R \times P_a \times P_r \times P_e$$

Dp is the maximum potential flood damage avoided with a fully effective system. R is the reliability of the flood warning system, Pa is the proportion of residents available to respond to a flood warning, Pr is the proportion of households which will respond to a flood warning, Pe is the proportion of households which respond effectively.

POST-FLOOD MEASURES. Post-flood measures in the first few hours after a flood must be taken, as demonstrated by a number of actions taken in the Koiliaris River basin.

Scope of study:

The proposed methodology can be applied to any river basin and was applied here to the Koiliaris River basin in Greece.

Results:

Estimate the flood-hazard areas, and create the corresponding map. Among these factors, flow accumulation, slope, elevation and rainfall intensity have numeric values, whereas geology and land use are expressed in descriptive form. The effect of each factor is mapped at five different hazard levels: very high, high, moderate, low and very low. The hazardous areas cannot be estimated by considering the effect of each factor separately. The integration of all factors is necessary in order to obtain the overall map of flood-hazard areas. The rate weight of the elevation factor is significantly higher than the rainfall intensity.

3.1 Introduction

This chapter presents problems in previous studies and operational research methodology.

3.2 Tools and Research Design Procedure

3.2.1 Tools

In this research the ArcHydro Tools are used, which operate in the ArcGIS environment.

The majority of the tools are accessed through the ArcHydro Tools toolbar, where they are grouped by functionality into six menus and nine tools. Additional tools have been developed in the geoprocessing environment and are available in the ArcHydro Tools toolbox, that can be used both in ArcMap and in ArcCatalog.

3.2.2 Research methodology

Six main phases describe the research methodology: Workspace Set Up, Stream Delineation, Localization of Gauge Station, Creation of Time Series Table, Stream WSE from Point Measurements, and Flood from Stream WSE.

3.2.2.1 Workspace Set Up

First the preparation and processing of a digital elevation model (DEM) of the study area has to be executed, which automatically creates the Geodata base and Feature Dataset for further processing.

3.2.2.2 Stream Delineation:

In this step, we determine the limits and trend currents by several operations – quite often the following operation is calculated from the previous operation (see Fig. 3.1)

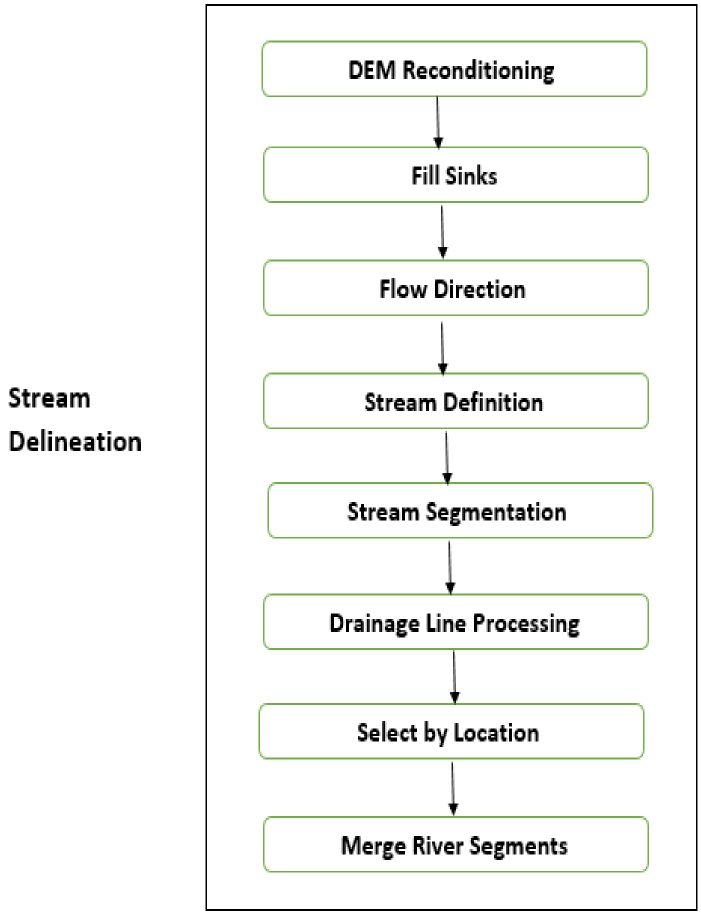

Figure 3-1: Stream Delineation

3.2.2.2.1 DEM Reconditioning

This function modifies Digital Elevation Models (DEMs) by imposing linear features onto them (burning/fencing).

3.2.2.2.2 Fill Sinks

This function fills the sinks in a grid. If a cell is surrounded by cells with higher elevations, the water is trapped in that cell and cannot flow. The Fill Sinks function modifies the elevation value to eliminate these problems.

3.2.2.2.3 Flow Direction

This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

Assign a flow direction to each grid cell based on the neighboring cell with the lowest elevation

3.2.2.2.4 Flow Accumulation

This function computes the flow accumulation grid that contains the Accumulated number of cells upstream of a cell, for each cell in the input grid.

It calculates the number of grid cells drain into an individual grid cell. Cells with higher values are the ones that have low values on the elevation grid.

3.2.2.2.5 Stream Definition

This function generates a Stream Grid for a user-defined threshold. This threshold is defined as a number of cells.

3.2.2.2.6 Stream Segmentation

The Stream Segmentation tool allows assigning the same unique value to stream cells located within the same stream segment. Segments are defined as either head stream segments (the most upstream stream branch) or segments located between two segment junctions. All the cells in a particular segment have the same grid code that is specific to that segment.

The Stream Link is used as input by the Catchment Delineation tool (Link grid) to define the catchments as the sub watersheds draining into each stream segment. Note that the value of the Catchment Grid is the value of the associated Link, and this value is also stored in the Grid ID field for Catchment/Drainage Line and Adjoint Catchment). [5]

Stream Segmentation generates a grid of stream segments from the flow direction grid, whereas the stream grid is depending on the stream definition processing.

3.2.2.2.7 Drainage Line Processing & Drainage Point Processing

This process converts the stream link grid into a drainage line feature class that we are familiar with (we normally represent rivers, streams as line features). It also creates a drainage point at the most downstream point in the catchment

3.2.2.2.8 Catchment Grid Delineation & Catchment Polygon Processing

Catchment area is the region of land whose water drains into a specified drainage line. (Center of a grid cell with the largest value in the flow accumulation grid for that catchment)

Catchment Grid Delineation: 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.

Catchment Polygon Processing: This function converts a catchment grid into a catchment polygon feature.

3.2.2.2.9 Adjoin Catchment Processing.

This function generates the aggregated upstream catchments from the "Catchment" feature class. For each catchment that is not a head catchment a polygon is representing the whole upstream area. Draining to its inlet point is constructed and stored in a feature class that has an Adjoin Catchment

3.2.2.2.10 Append Coastal Catchments (optional)

The function Appends Coastal Catchments is another option to the existing set of catchments. As this is an optional step that should be done for larger DEMs with large portion of coastal areas – areas defined as not draining into the "streams". This function defines coastal catchments and appends them to the catchment feature class.

3.2.2.2.11 Select by Location

Selects features in a layer based on a spatial relationship to features in another layer.

In this case select some of catchment feature class.

3.2.2.2.12 Merge River Segments

Combines multiple input datasets of the same data type into a single, new output dataset, in this case Merge River Segments - it is determined in Select by Location.

3.2.2.3 Localization of Gauge Station

In Fig. 3.2 the localization of gauge stations is on display. Those stations are most important as they deliver the water heights depending on time.

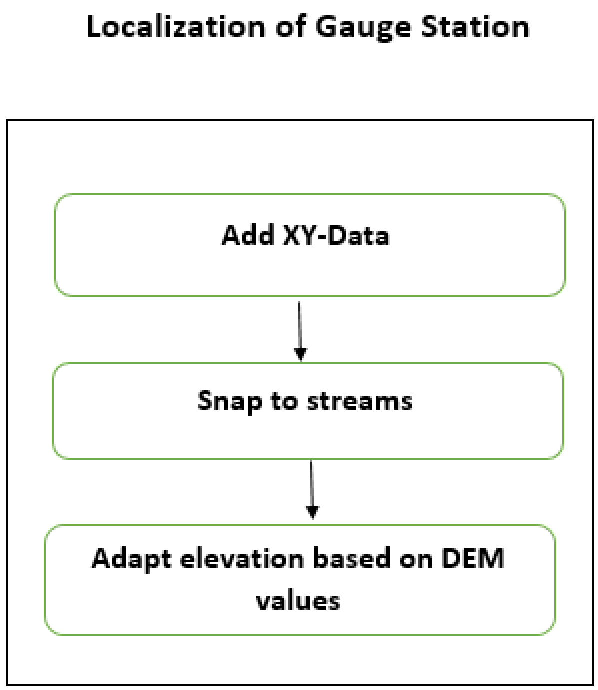

Figure 3-2: Localization of Gauge Station

3.2.2.3.1 Add XY-Data

Add XY Coordinates is most commonly used to get access to point features to perform analysis or to extract points based on their x, y location. If the Input Features are in a geographic coordinate system, POINT_X and POINT_Y represent the longitude and latitude, respectively.

3.2.2.3.2 Snap to streams

The Snap Pour Point tool is used to ensure the selection of points of high accumulated flow when delineating drainage basins using the Watershed tool. Snap Pour Point will search within a snap distance around the specified pour points for the cell of highest accumulated flow and move the pour point to that location.

3.2.2.3.3 Adapt elevation based on DEM values

The concept is as follwos: Start with a raw DEM, "burn in the streams" using polylines for the drainage system or streams. Convert the stream layer to a raster with a big value and subtract that from the DEM.

3.2.2.4 Creation of Time Series Table

The observations of water heights are depending on time. Therefore they have to be converted into a time series format (see Fig. 3.3).

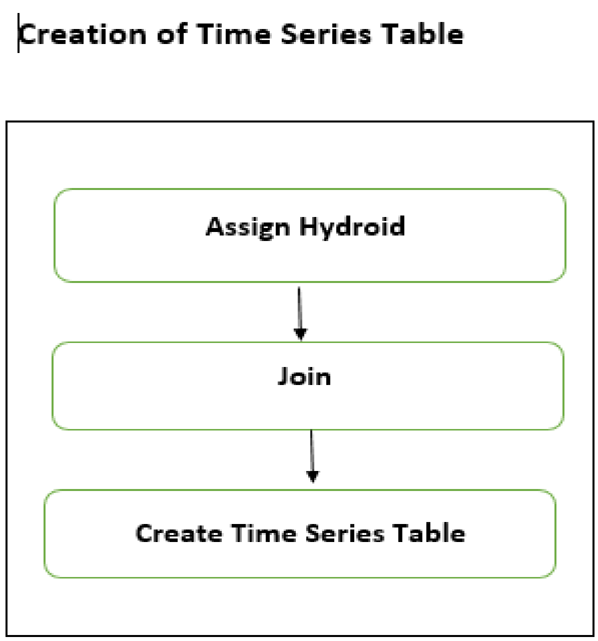

Figure 3-3: Creation of Time Series Table

3.2.2.4.1 Assign Hydroid (unique identifier)

Hydroid is unique across an ArcHydro geodatabase. Its implementation is based on two key premises:

There is the option of a simple implementation for a general user, who does not want to micro-manage the Hydroids between the feature classes. The end user does not have to do anything – every feature in a geodatabase will have a unique number, starting with 1 and incrementing by 1 for every new feature generated in any Arc Hydro compliant feature class.

The complex implementation is meant for a user, who wants to have control over Hydroids in each feature class. The user has the ability to specify a starting point for assignment of Hydroids for each feature class. For example, the user can specify that the Hydroids for a catchment feature class will start at number 100,000, for the drainage line feature class will start at number 200,000, and for the hydro junction and hydro edges feature classes will start at 300,000.

The counter (LASTID) contains the last Hydroid that was assigned to a new feature.

To provide the flexibility, for which each feature class can have an independent counter, this can be implemented through two related tables.

The first table (LAYERKEYTABLE) contains the relationship between the feature class name and the last used Hydroid key

The second table (APUNIQUEID) contains the relationship between the last used Hydroid key. [2]

3.2.2.4.2 Time Series

A time series is a chronological sequence of observations on a particular variable. Usually the observations are taken at regular intervals (days, months, years), but the sampling could be irregular. In this case, the sequence may contain high values of points at different times. In this case, the time series table is empty, but will be filled with data using the Weather Downloader or by history of the study location.

If the data is analyzed, it can be exported as an Excel sheet as well.

The following attributes of Time Series can be assigned:

Feature ID: This is an integer identifier, usually set equal to the Hydroid.

TS Type ID: This is an integer identifier that points to a specific record in the TS Type Info table.

SdateTime: Each element in the Time Series table has a distinct timestamp, or a labeled point in time.

TSDesc: This is a two-character string, which provides information about the nature of a particular Time Series record (optional). [6]

3.2.2.5 Stream WSE from Point Measurements

This model consists of several input files: Point location of the gauge, a table containing water heights, a vector of the stream and a DEM raster of the area. (Already prepared). The model will create two temporary output files: a line raster file included in the folder containing the geodata base and a Line3D file within the geodata base (see Fig.3.4) [7].

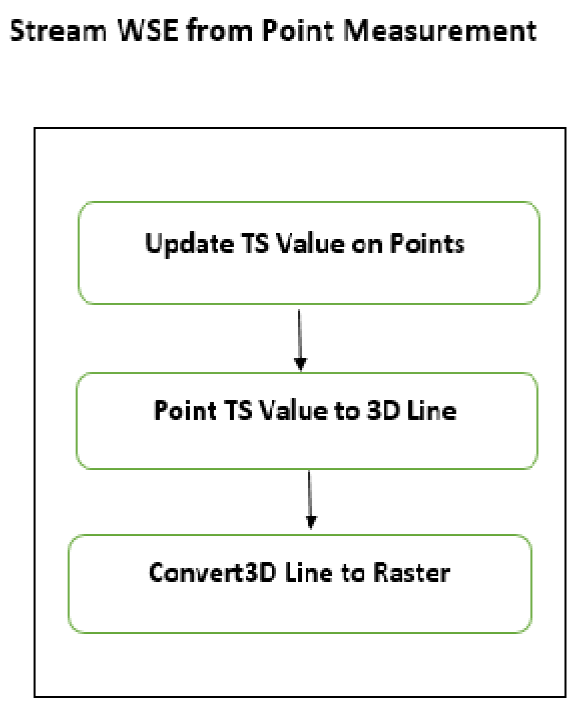

Figure 3-4: Stream WSE from Point Measurements

In this model basically we start with Calculate maximum flooded area based on maximum flood levels along a stream. The following steps are carried out:

First: Update the Time Series with all values .

Second: Compute the geometric intersection of 3D line features and one or more surfaces to return the intersection as segmented line features and points.

Finally: Create the line raster file included in the folder containing the geodata base and a Line3D file within the geodatabase.

3.2.2.6 Flood from Stream WSE

This model is using the output of the first model as input and then produces a raster and a polygon of the flooded area. The target raster location workplace is the folder containing the geodatabase while the target vector location workspace is within the geodata base – it also produces a very precise map of the flooded area, both as a raster of water depth in the floodplain and as a polygon feature of the flooded area (see Fig 3.5) [7].

Flood from Stream WSE

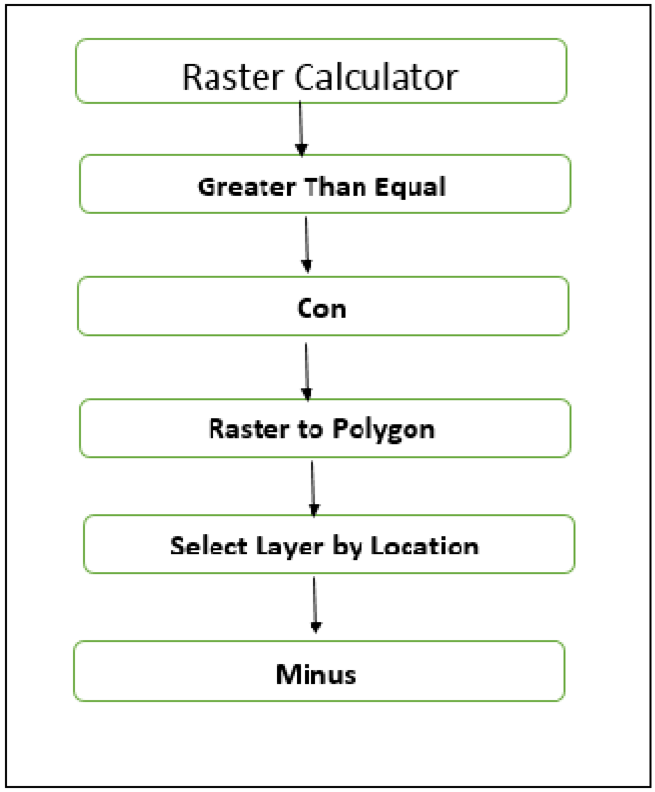

Figure 3-5: Flood from Stream WSE

In the step Raster Calculator we first determine, which values from the input raster are NoData on a cell-by-cell basis(is Null), also an evaluation on each of the input cells of an input raster(con) is done. The multiplication of the values of two rasters on a cell-by-cell basis (Times) has to be carried out. If one raster cell value has 'floating' format it must be converted to an integer (int).

Thereafter it replaces the raster cells corresponding to a mask with the values of the nearest neighbors (Nibble), converts each raster cell value into a floating-point representation (Float).

The function 'Divides' divides the values of two raster's on a cell-by-cell basis.

The ‘relational greater-than-or-equal-to operation’ is working on two inputs on a cell-by-cell basis (Greater Than Equal).

The function ‘Raster-to-Polygon’ converts a raster dataset to polygon features. Using the ‘Select Layer by Location’ selects features in a layer and investigates for a spatial relationship to features in another layer.

The ‘Select’ operator extracts features from an input feature class or input feature layer by SQL statements.

The ‘Minus’ operator subtracts the value of the second input raster from the value of the first input raster on a cell-by-cell basis.

4.1 Function input and output

This section presents inputs and outputs for each listed processing function and displays screen shots of the results.

4.1.1 DEM Reconditioning

Input: Raw DEM and AGREE stream.

Output: AGREE DEM

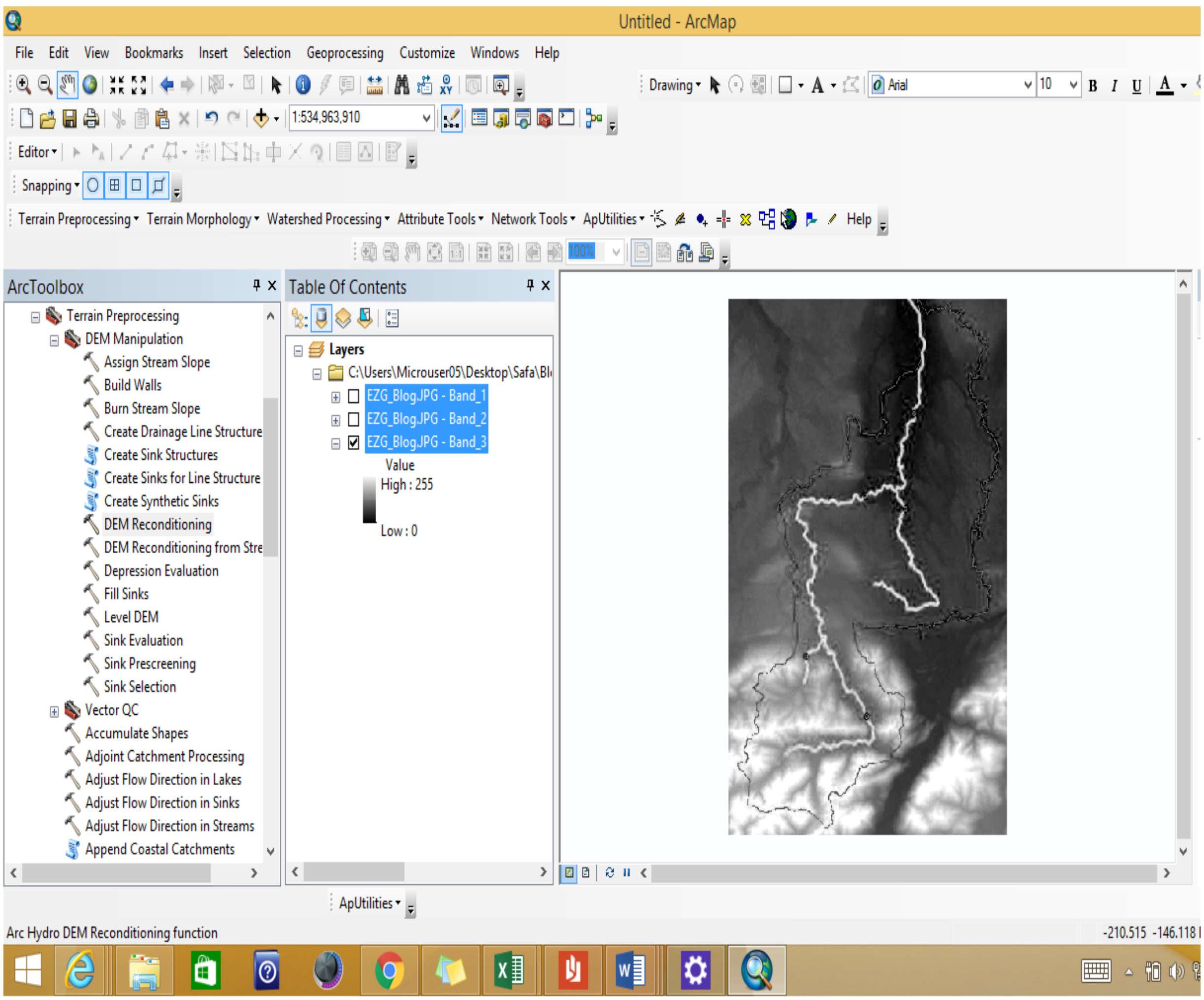

Figure 4-1: DEM reconditioning output

4.1.2 Fill Sinks

Input: Raw DEM

Output: Filled DEM

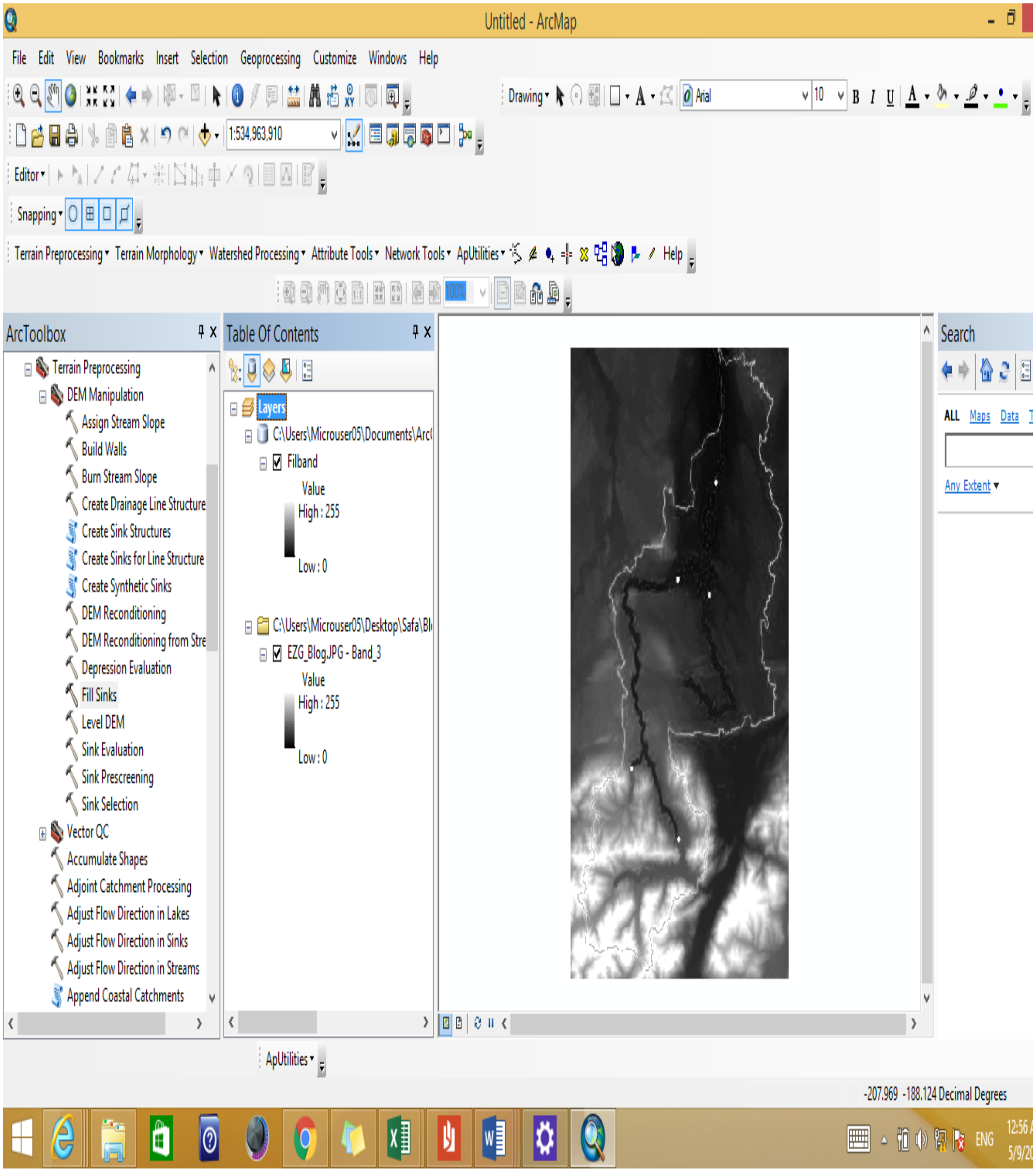

Figure 4-2: Fill Sinks output

4.1.3 Flow Direction

Input: DEM and Outer Wall Polygon (optional)

Output: Flow Direction Grid

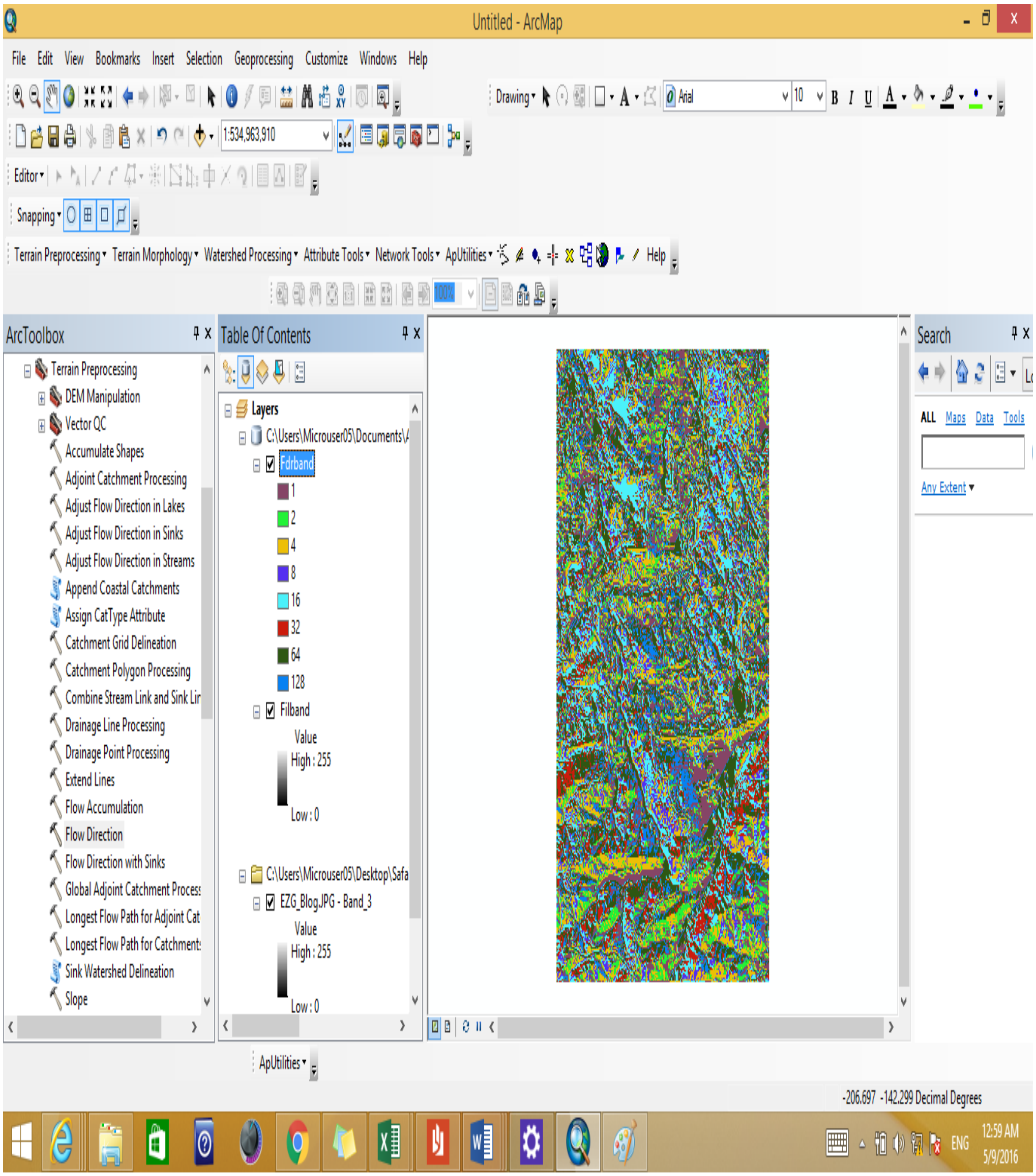

Figure 4-3: Flow Direction output

4.1.4 Flow Accumulation

Input: Flow Direction Grid

Output: Flow Accumulation Grid

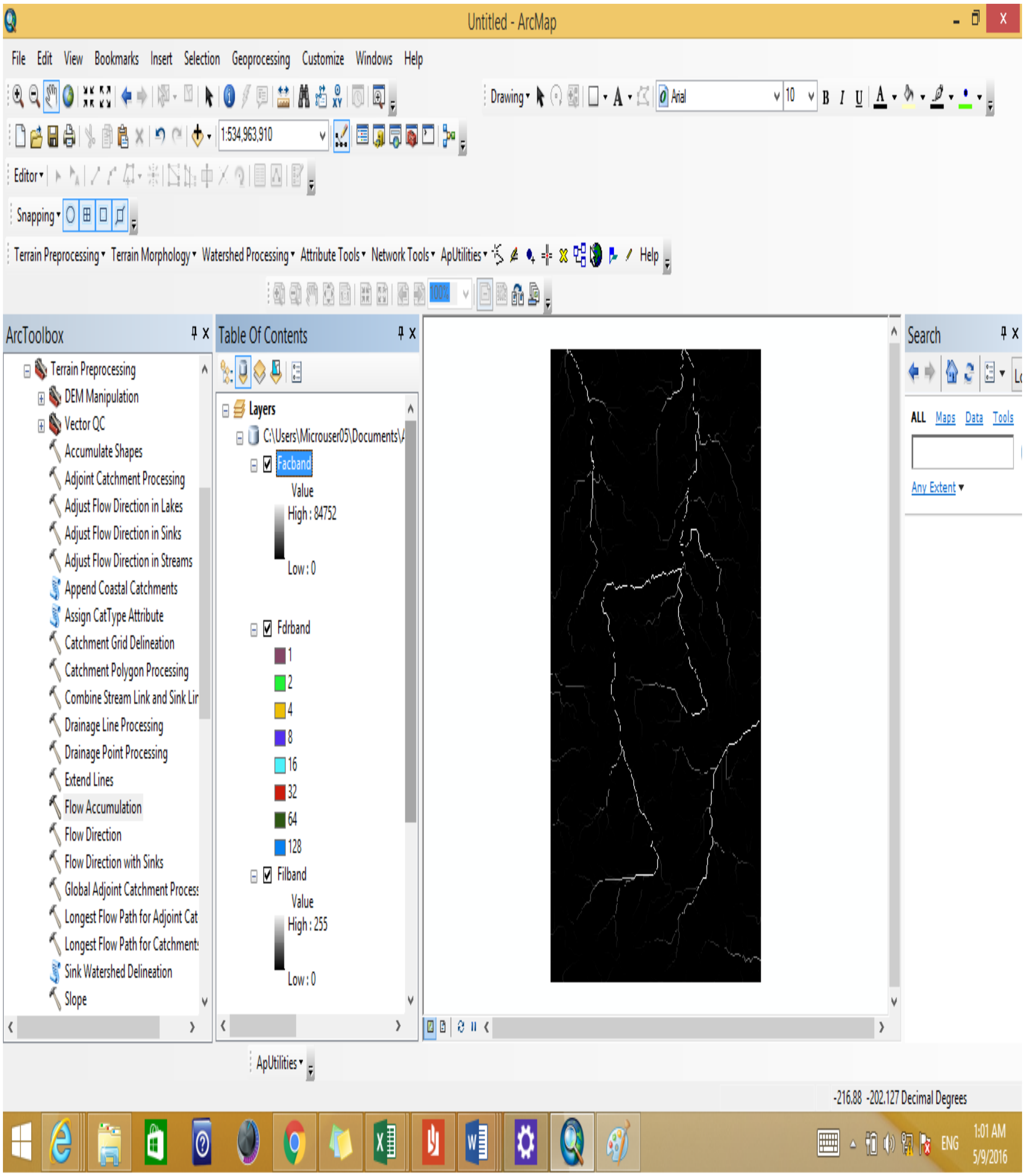

Figure 4-4: Flow Accumulation output

4.1.5 Stream Definition

Input: Flow Accumulation Grid and Number of Cells to Define Stream (or area in km2)

Output: Stream Grid

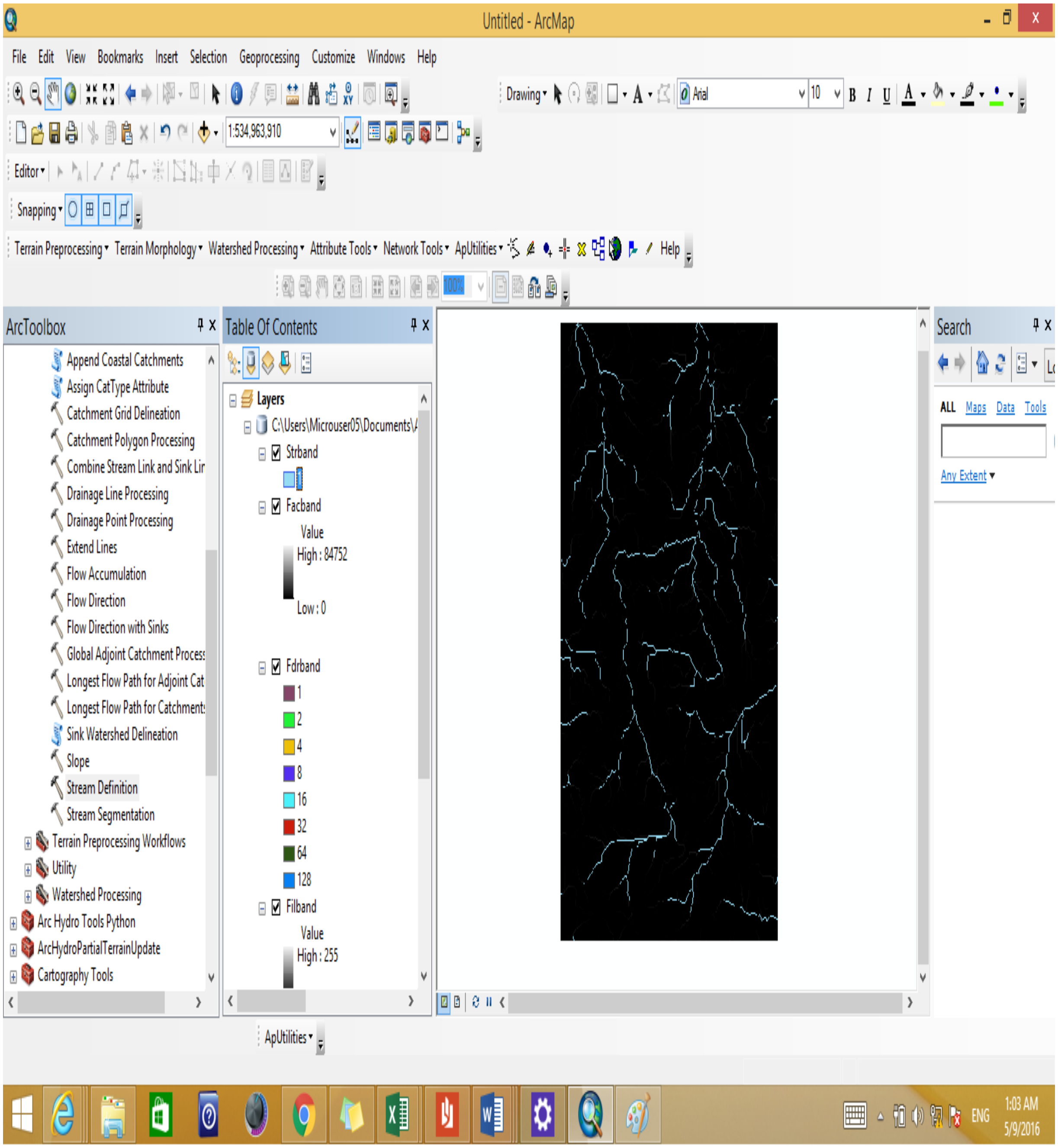

Figure 4-5: Stream Definition output

4.1.6 Stream Segmentation

Input: Stream Grid, Flow Direction Grid and other optional Sink Watershed Grid, Sink Link Grid

Output: Stream Link Grid

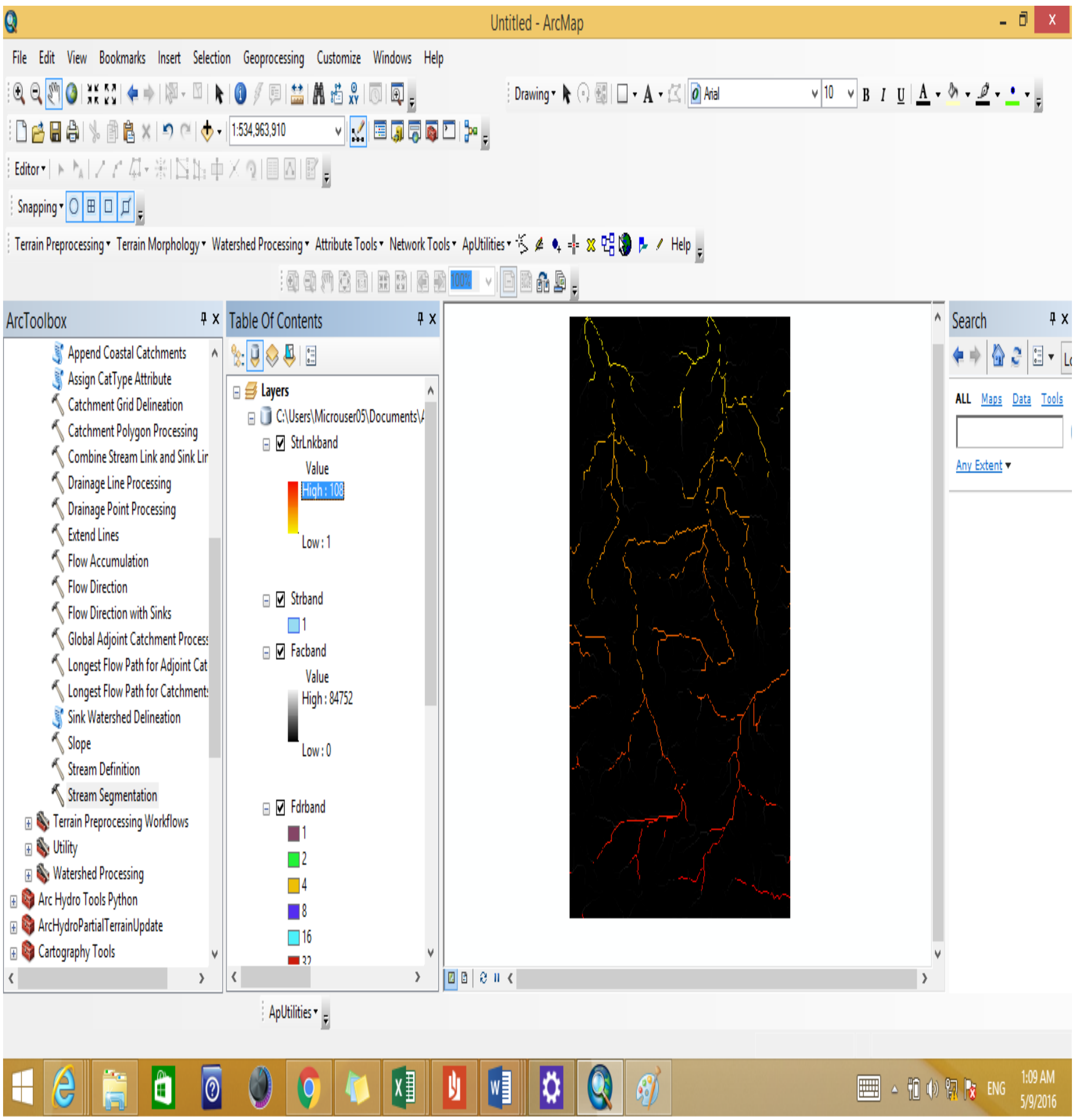

Figure 4-6: Stream Segmentation output

4.1.7 Drainage Line Processing:

Input: Stream Link Grid (in this case link grid with streams and sinks) and Flow Direction Grid

Output: Drainage Line Feature Class

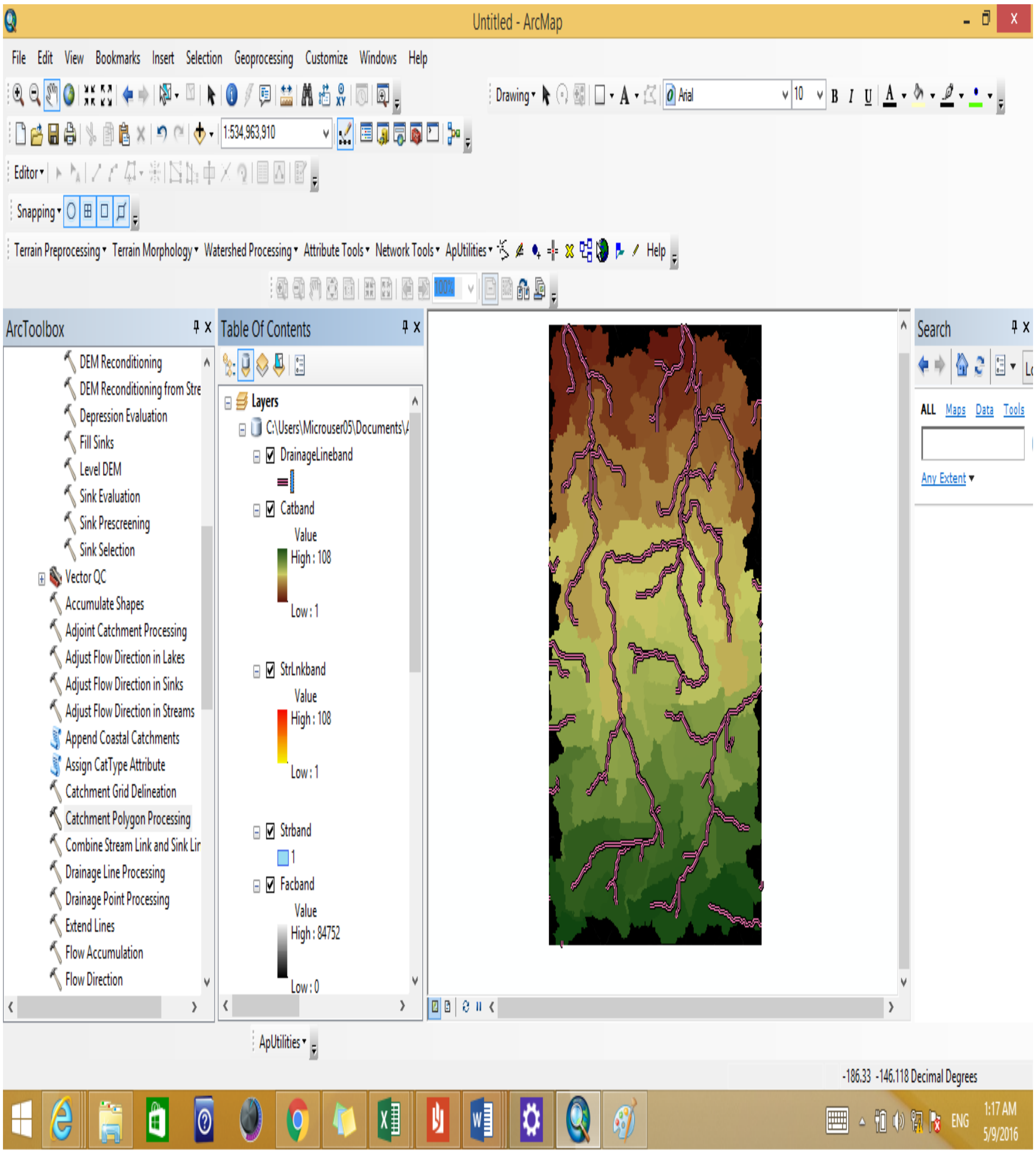

Figure 4-7: Drainage Line Processing output

4.1.8 Catchment Grid Delineation

Input: Flow Direction Grid and Link Grid (in this case Link Grid from previous step)

Output: Catchment Grid

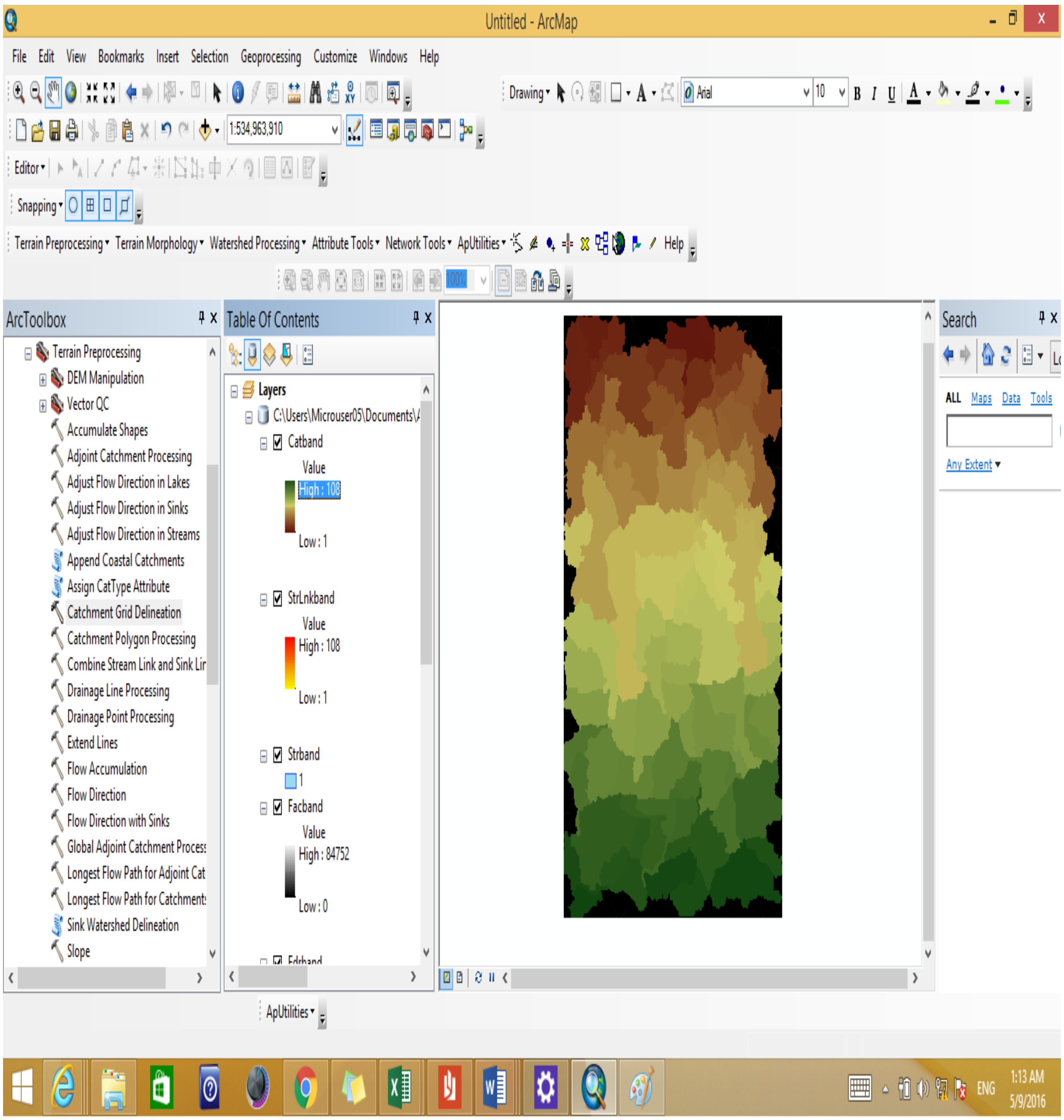

Figure 4-8: Catchment Grid Delineation output

4.1.9 Catchment Polygon Processing

Input: Catchment Grid

Output: Catchment Feature Class

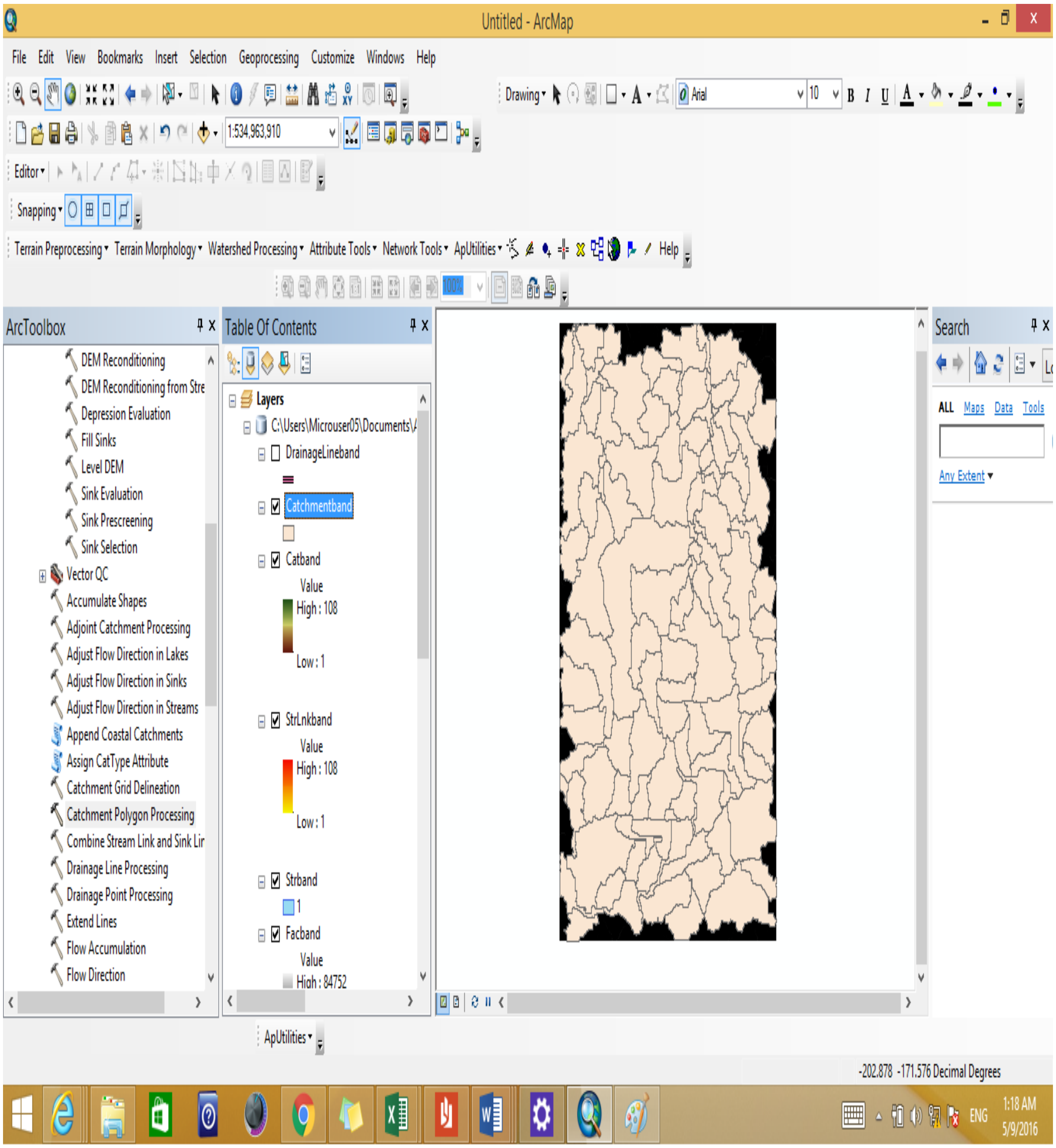

Figure 4-9: Catchment Polygon Processing output

4.2 Drainage point Processing

Input: Catchment Grid, Catchment Feature Class and Flow Direction Grid

Output: Drainage point Feature Class

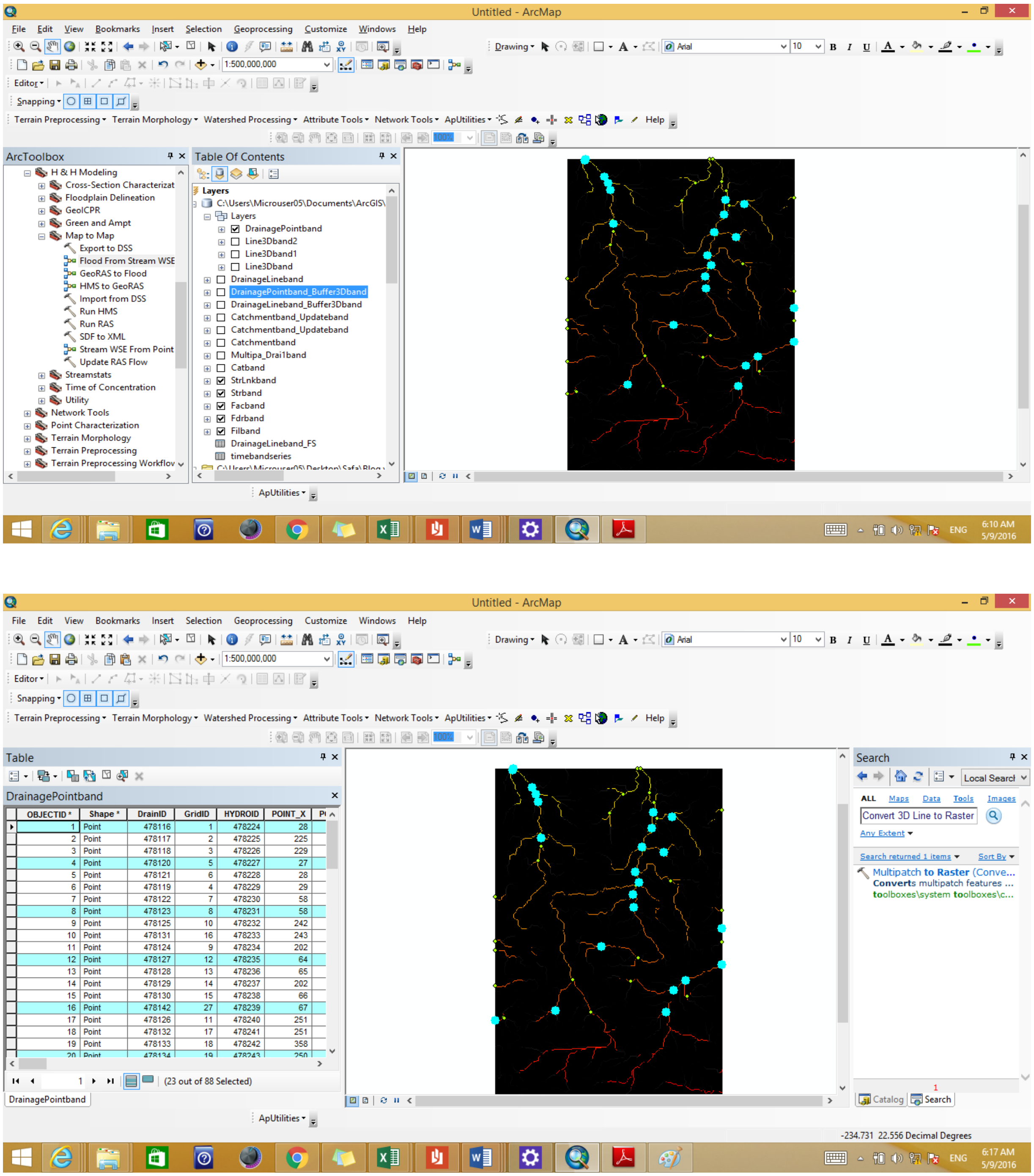

Figure 4-10: Drainage point Processing output

4.2.1 Select by Location

Input: Catchment Feature Class

Output: Catchment Feature Class with Selected Location

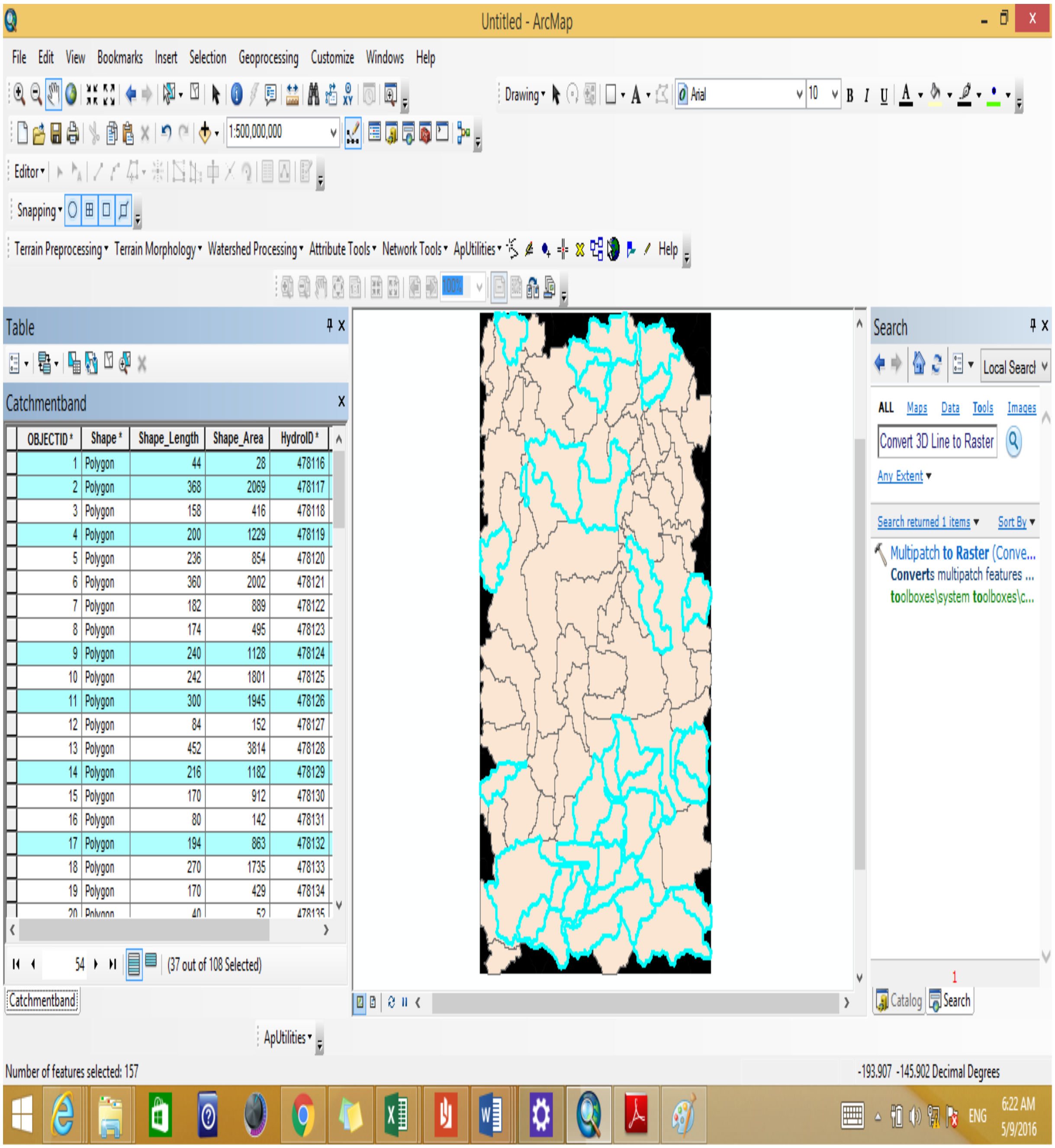

Figure 4-11: Select by Location output

4.2.2 Add XY-Data

Input: Drainage point Feature Class

Output: Grid Point of Area

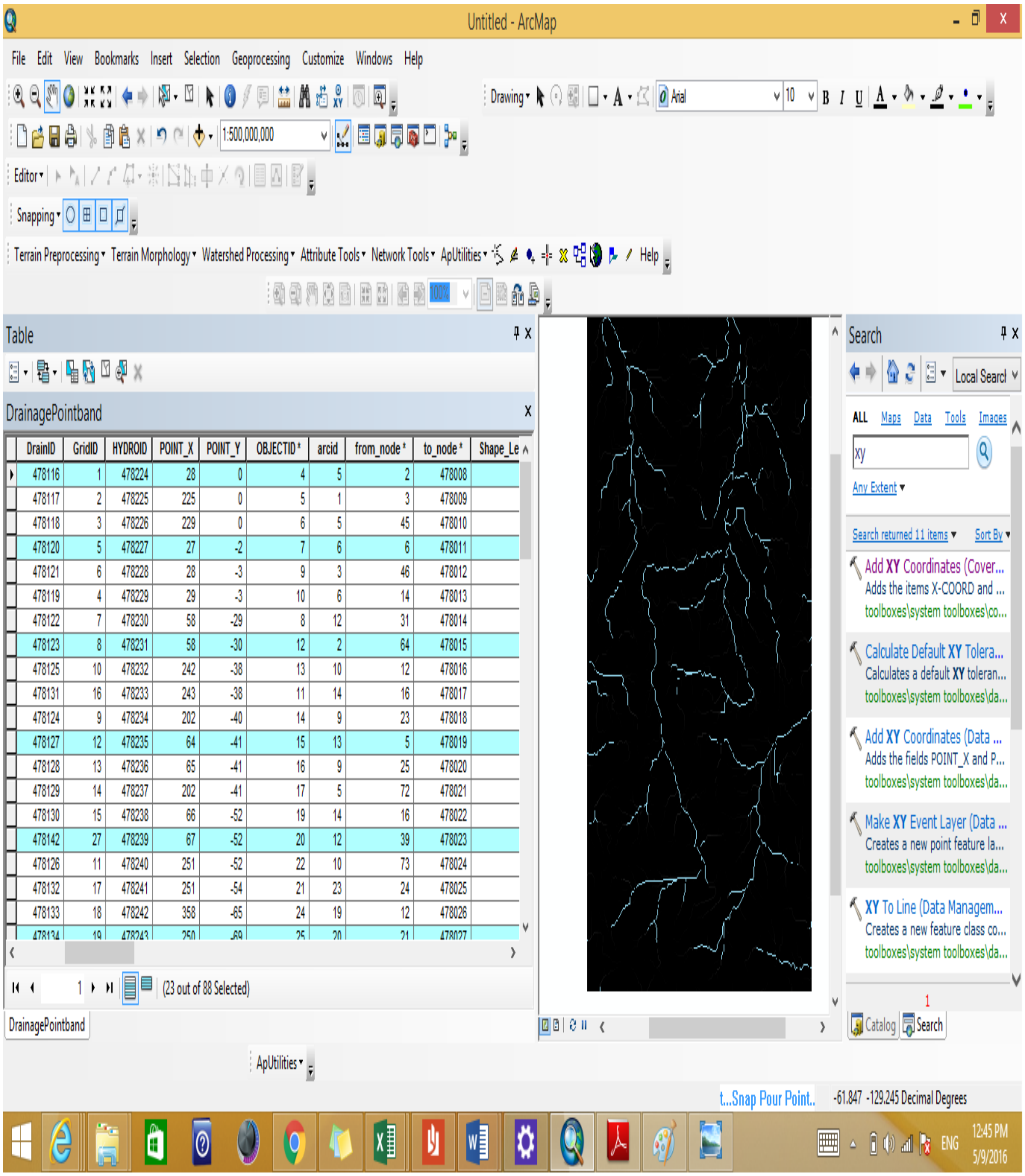

Figure 4-12: Add XY-Data output

4.2.3 Snap to streams

Input: point locations selected, flow accumulation

Output: pour point integer raster

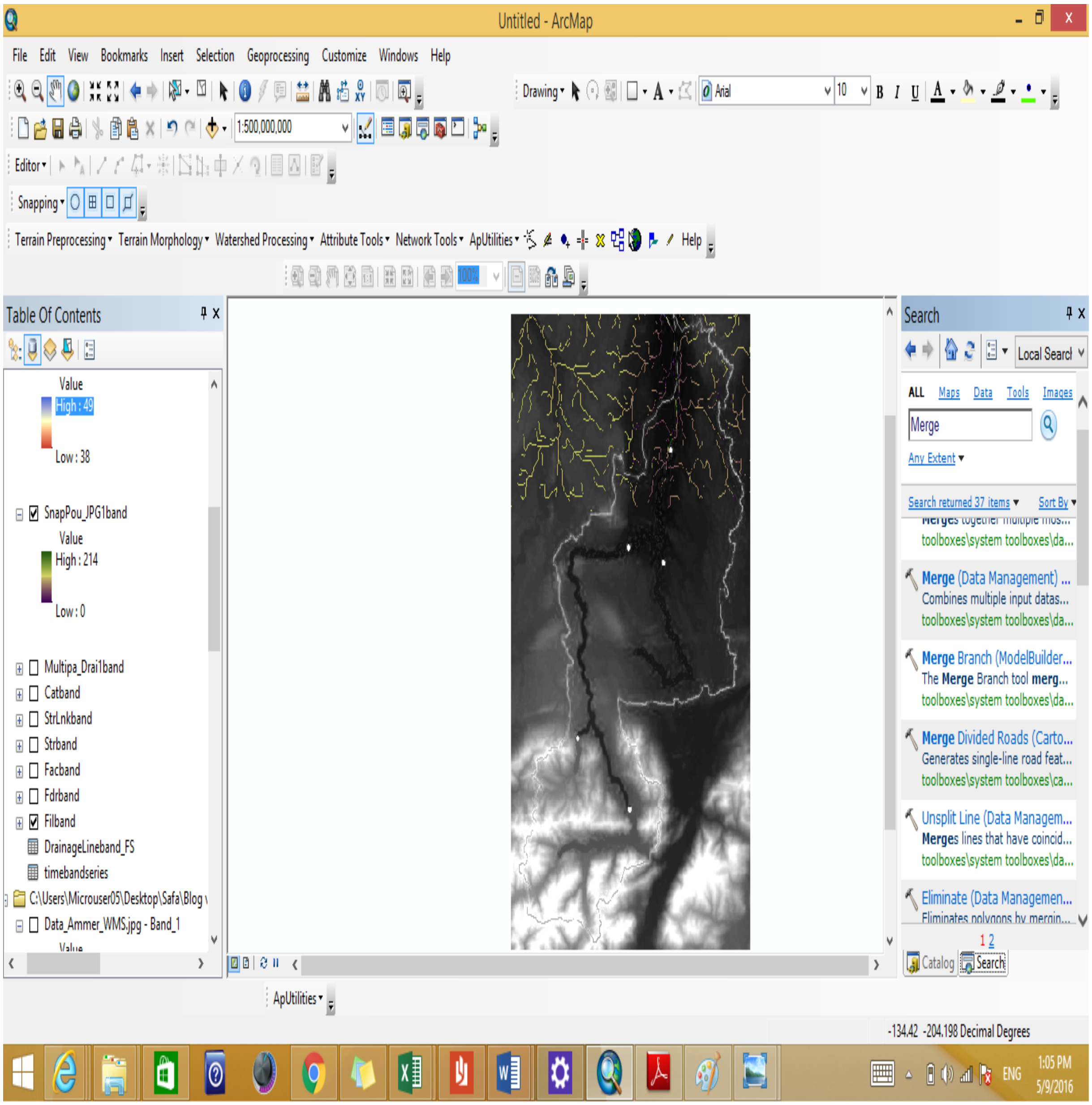

Figure 4-13: Snap to streams output

4.2.4 Stream WSE from Point Measurements

Input: point location of the gauge, water height, stream and DEM

Output: line raster file, folder containing the geodatabase and a Line3D file within the geodatabase.

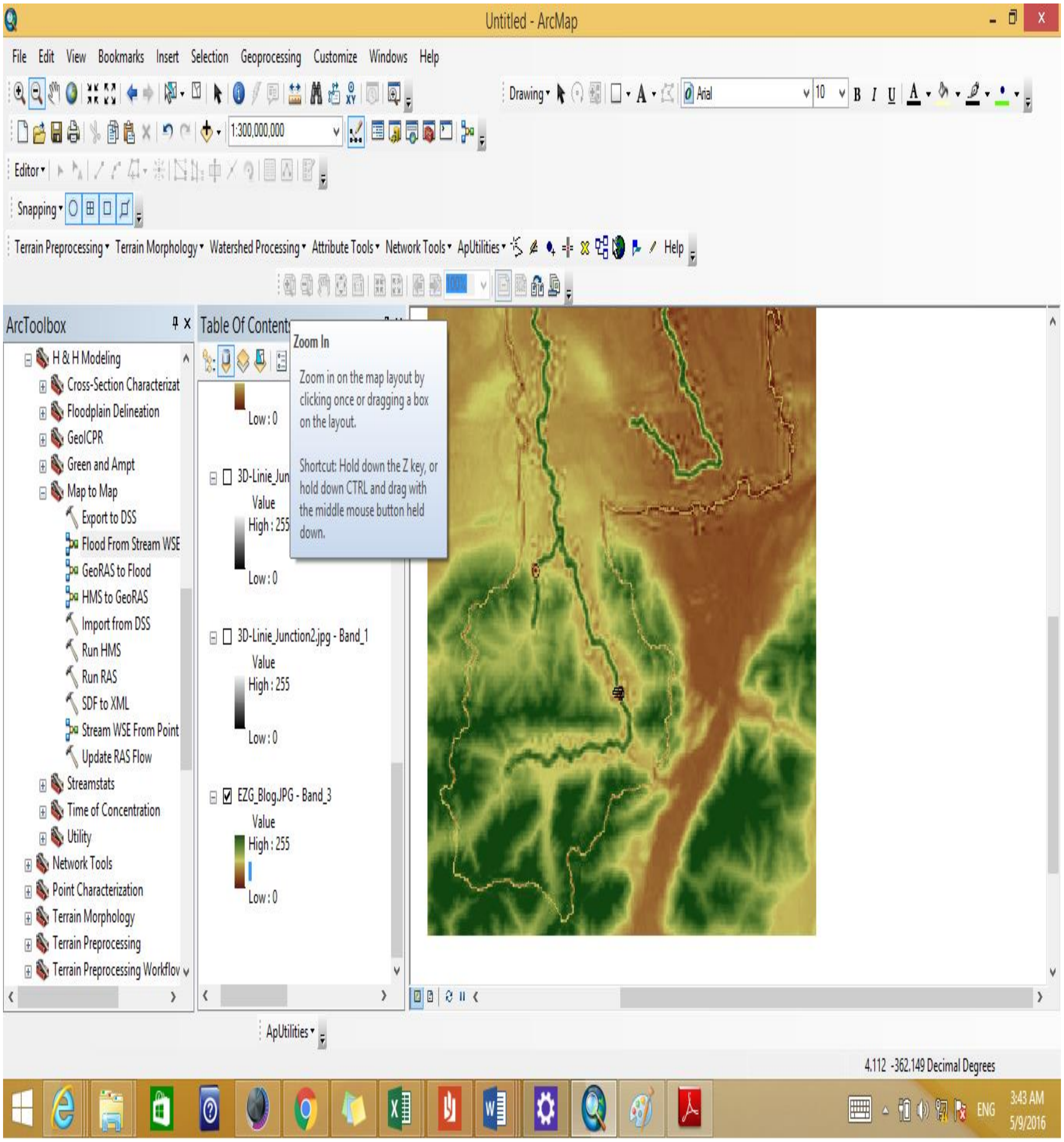

Figure 4-14: Stream WSE from Point Measurements models output

4.2.5 Flood from Stream WSE

Input: all output files from Stream WSE from Point Measurements

Output: raster and a polygon of the flooded area

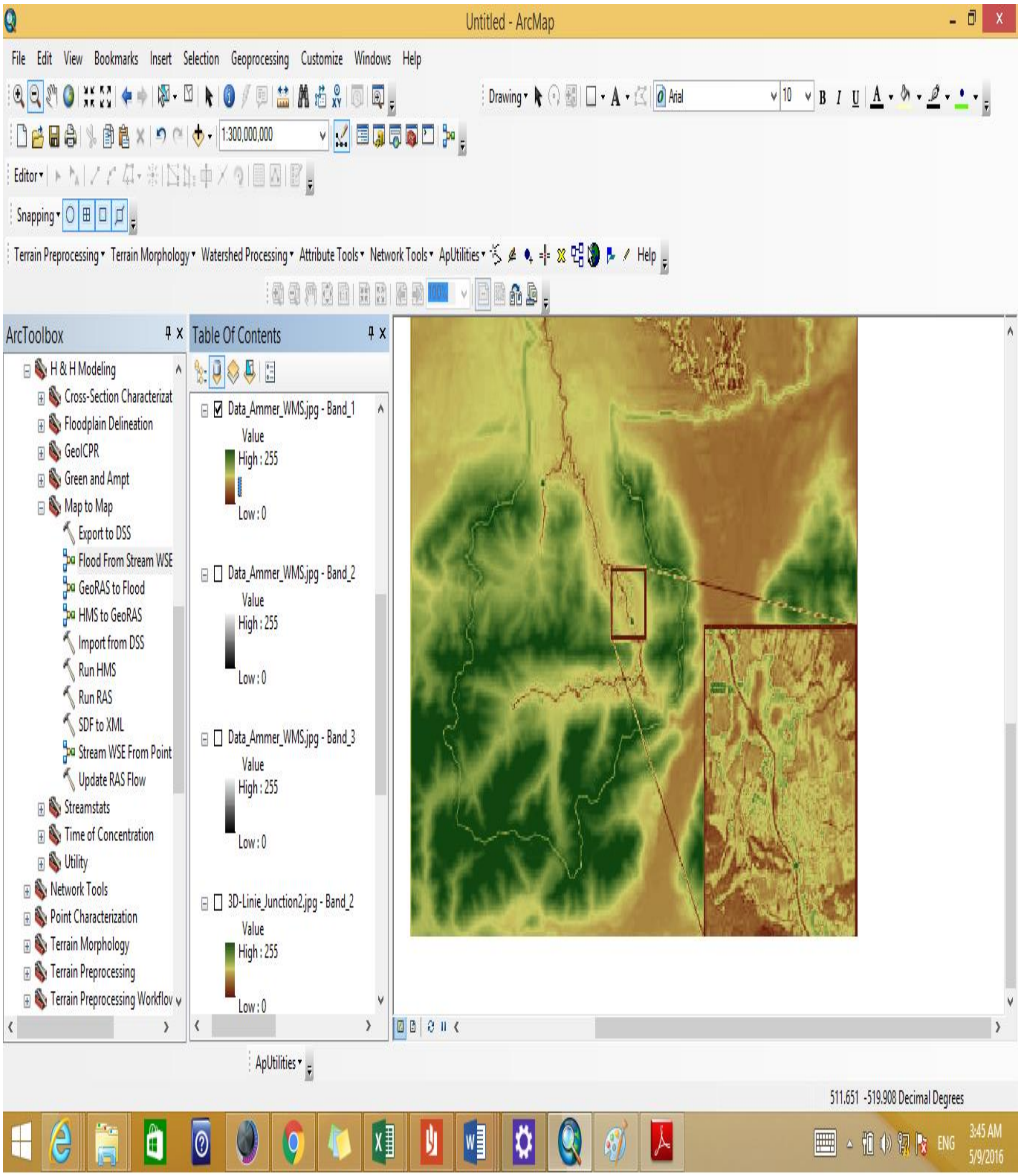

Figure 4-15: Flood from Stream WSE models output

5.1 Conclusion:

This work aims to reduce the impact of flood water using Esri’s ArcHydro tools and models.

The idea was originally proposed by Prof. Dr. Izzelden, SUSTECH. This study did use the ArcHydro tool and models to solve this problem. For the study area we have chosen the river Nile around Khartoum. All available data have been prepared and analyzed by the ArcHydro tool, the results have been modelled and the highest point and the lowest station of river Nile have been determined. Under the assumption that the water swaps over this point, then a flood will occur and all surrounding areas are effected. Based on the experiences of this study we will give some notice to the Authority of Natural Disasters to take the right decisions from their point of view.

5.2 Recommendations:

Join this work with weather data to know the amount of water on a daily basis.

- Using the HEC _GEOHMS, which is another tool in the ArcHydro model.
- We suggest to find easy and good equations to calculate the amount of flood water to help officials to make the right decisions.

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