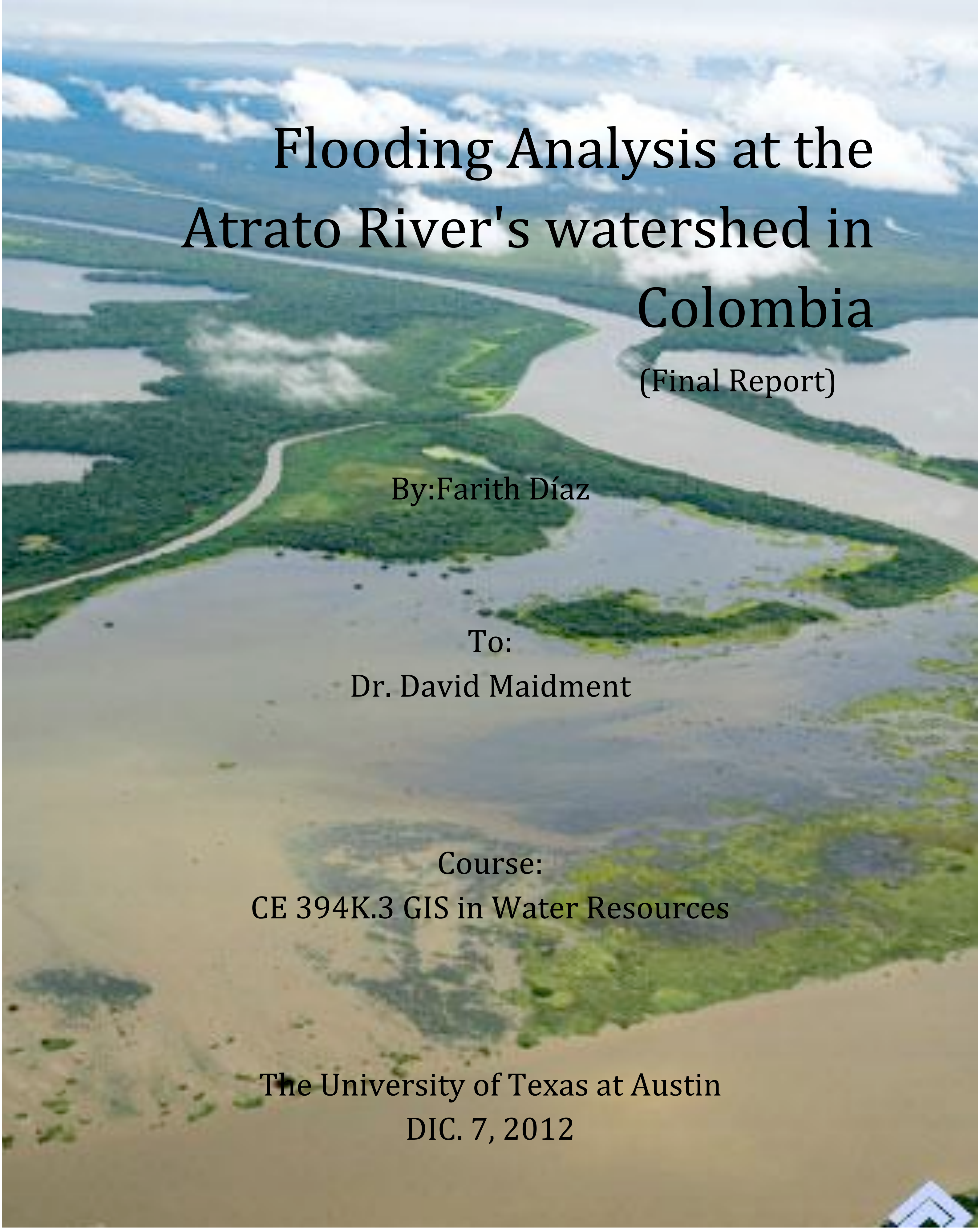

Flooding Analysis at the Atrato River's watershed in Colombia

(Final Report)

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Course:
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1. Introduction

The state of Chocó is located in the northwestern region of Colombia, it shares the southeast border of Panama, and is a well known region in Colombia, essentially what was called 'Chocó Biogeográfico'. El Chocó biogeográfico is a subregion with an approximate area of 100,000 km^2 that includes a variety of different kind of habitats. This area starts in Panamá, then crosses the whole Colombian pacific coast, and finishes in Cabo Pasado, in the Manabí Province in Ecuador. This subregion constitutes a mixture of plants, animals and natural resources, which can provide beneficial uses to human beings.

One of the most important rivers of the Colombian pacific coast is the Río Atrato, which rises in the slopes of the Cerro de Caramanta, in the Western Cordillera and flows to the north to reach the Gulf of Urabá of the Caribbean Sea, where it forms a large swampy delta.

2. Some Facts About The Río Atrato

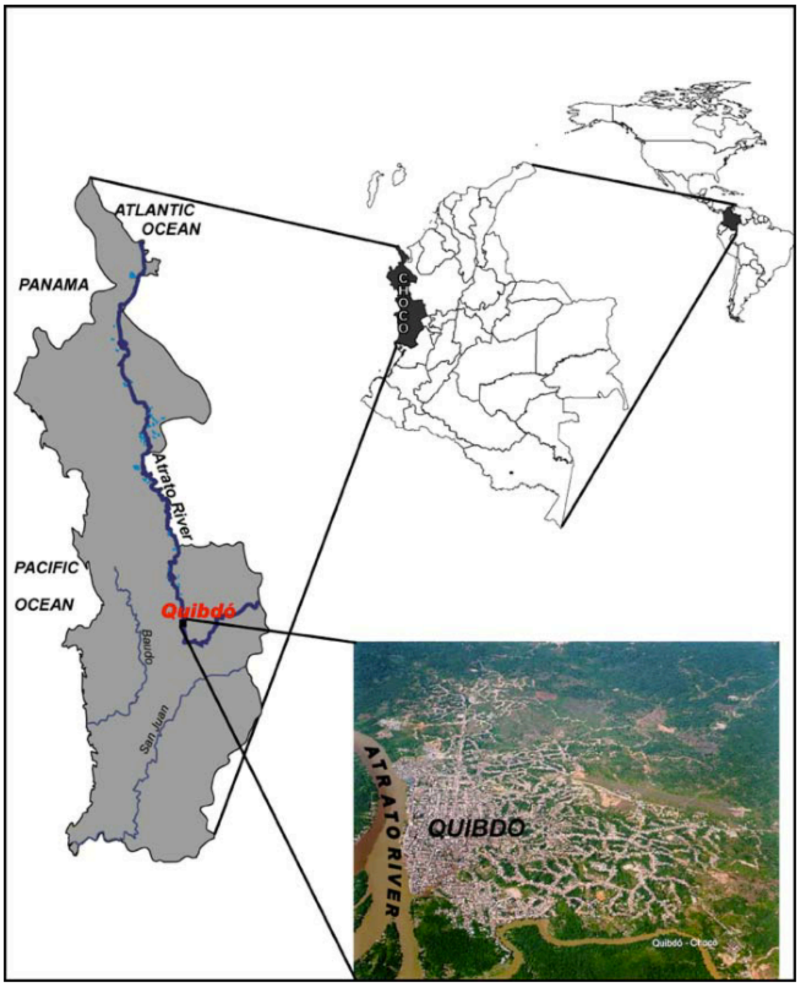
- Length: 750 km (466 miles)
- Basin: 38,500 km^2 (14,865 sq. mi)
- Average Discharge: 4,900 m^3/s
- Source elevation: 3.700 m (12,136 ft)
- Mouth elevation: 0 m (Caribbean Sea)

The lower Atrato has been considered a feasible route for a transisthmian canal. At one time this river attracted considerable attention as a feasible route for a big canal; however, plans were abandoned in favor of the Panama Canal.

The state of Chocó is considered one of the wettest places on earth. Cherrapunji, in India, which is considered to be the place with the largest average annual rainfall receives approximately 11,400 mm (450 in.). However, the municipality of Lloró (Chocó) is probably the place with the largest measured rainfall in the world, averaging 13,300 mm (523.6 in.) per year.

Nevertheless, the municipality of Tutunendo, also located in Chocó, is also considered one of the wettest places on earth, averaging 11,394 mm (448 in.) of rainfall per year. As a matter of fact, in **1974** this town received 26,303 mm (86 ft-3½ in.) of rainfall, the largest annual rainfall measured in Colombia. Tutunendo receives rain almost uniformly distributed throughout the year.[1]

Figure 1. Geographic location of the study area



Author: Mosquera and Sajjad (2007)

3. Background Information

A geographic information system (GIS) is a tool that integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. This tool is really useful to understand and estimate events and situations related to the use of natural resources, and climate change activities in a given area. *The Geographic Approach, provided by using GIS* — allows us to create geographic knowledge by measuring the earth, organizing this data, and analyzing and modeling various processes and their relationships. The Geographic Approach also allows us to apply this knowledge to the way in which we design, plan, and change our world[1].

The high precipitation occurring at the state of Chocó and El Niño and La Niña climatologic events, caused a series of flooding events in the Río Atrato's watershed. These flooding events affected the communities located in the area, the infrastructure and the agricultural production. This type of situations occur randomly, however, in the last decade the intensity of this type of phenomenon has increased significantly thus causing devastating effects on the population.

In the last two years, the flooding events at the Río Atrato's watershed left near 4,903 houses destroyed and more than 17,000 people affected, according to the IDEAM – Hydrology and Meteorology Colombian Institute – in its Sep. 2011 Report.

Therefore, it is important to understand the flooding patron through the elaboration of accurate maps that show the effects and the extent of the flooding, in order to take further actions intended to minimize the damage of this type of event and improve the government response in a faster way when flooding occurs.

[1] http://www.esri.com/what-is-gis/overview#geographic_panel

4. Hydrologic and Hydrographic Information

The state of Chocó is a rainforest region with a unimodal rainfall season. The precipitation is distributed among all months of the year. There are twenty-three hydro-metrological stations in Chocó, 11 are in the Río Atrato and the remaining 12 are located on its tributaries. The hydrological stations measure the water level, from which the river discharge is computed (Mosquera, 2006). The meteorological stations measure precipitation, temperature, wind velocity and solar radiation.

5. Objectives

The original goal of this project was to elaborate a flooding map for the Río Atrato's watershed using the raster obtained from the USGS website, applying the tools learned in the GIS class, and using the HEC-RAS hydraulic model. However, due to the poor quality of the Aster Global DEM and the specific conditions of the Río Atrato's delta it was not possible to achieve this objective, therefore, this work was focused on:

5.1. Applying the Hydrology tools in the ArcGIS Geoprocessing toolbox to the raster smdem.

5.2. Analyzing the flow accumulation resulting from the Río Atrato's delta.

5.3. Explaining the use of the HEC-RAS hydraulic model to get the floodplain mapping.

6. Data and Methodology

Starting from the raw digital elevation data, a geoprocessing analysis was performed to recondition the digital elevation model and generate data on flow direction, flow accumulation, stream segments, and watershed delineation. This project was developed based on the use of statistical techniques of Gumbel, hydraulic modeling (HEC-RAS) and the Geographic Information System (GIS).

7. DEM Reconditioning

7.1 Raw Elevation Data

The raw data used in this project was obtained from the U.S. Geological Service website, using the characteristics shown in Figure 2.

Figure 2. Aster Global DEM characteristics

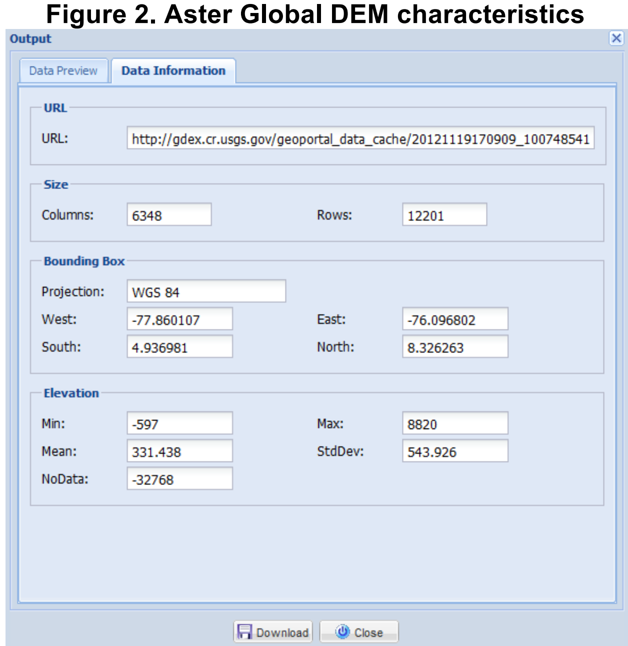
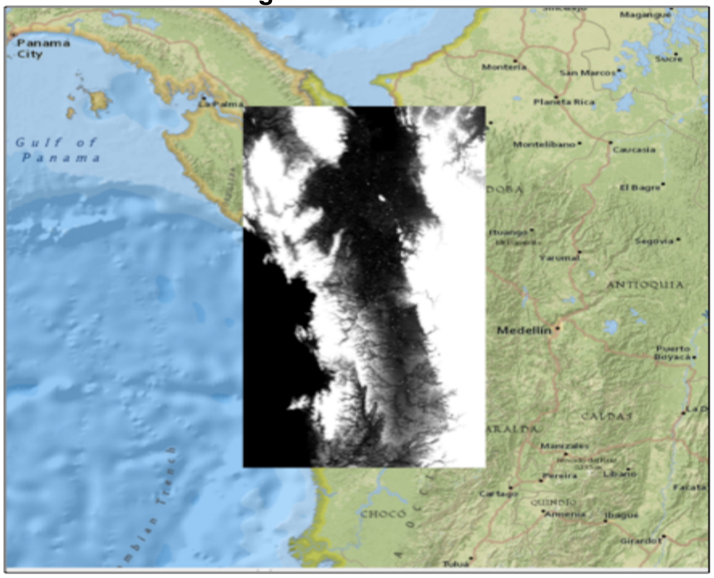


Figure 3 shows the aster global DEM used during the development of this project.

Figure 3. Raw DEM

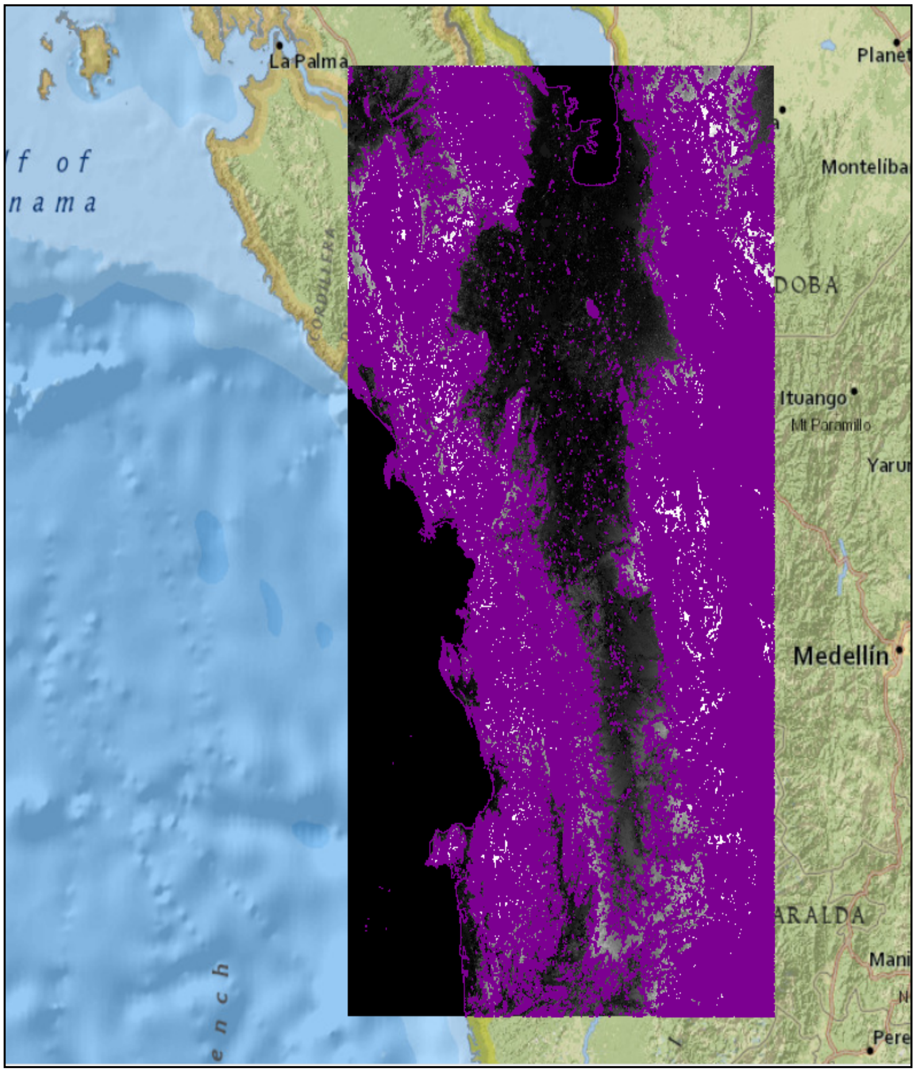


7.2 Fill contours

By following the line of a particular contour, it is possible to identify which locations have the same elevation value. By looking at the spacing of adjacent contours, it is easy to have a general impression of the elevation gradation.

The areas where the contours are closer together indicate the steeper locations, which correspond to areas of higher elevation (See Figure 4).

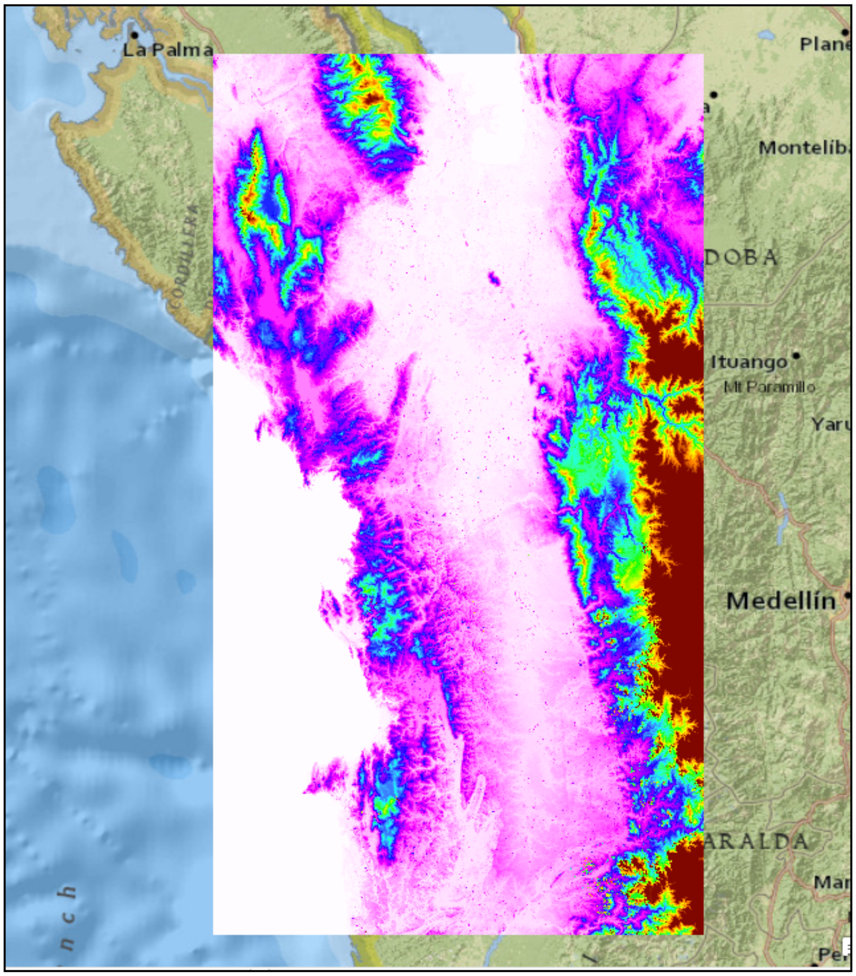
Figure 4. Resulting Fill Contours



7.3 Fill pits

This tool raises the elevation of the pit until a "pour point" occurs. This function fills the sinks in the grid. Figure 5 shows that the river basin is located in a flat region and the highest elevation is located at the Western Cordillera.

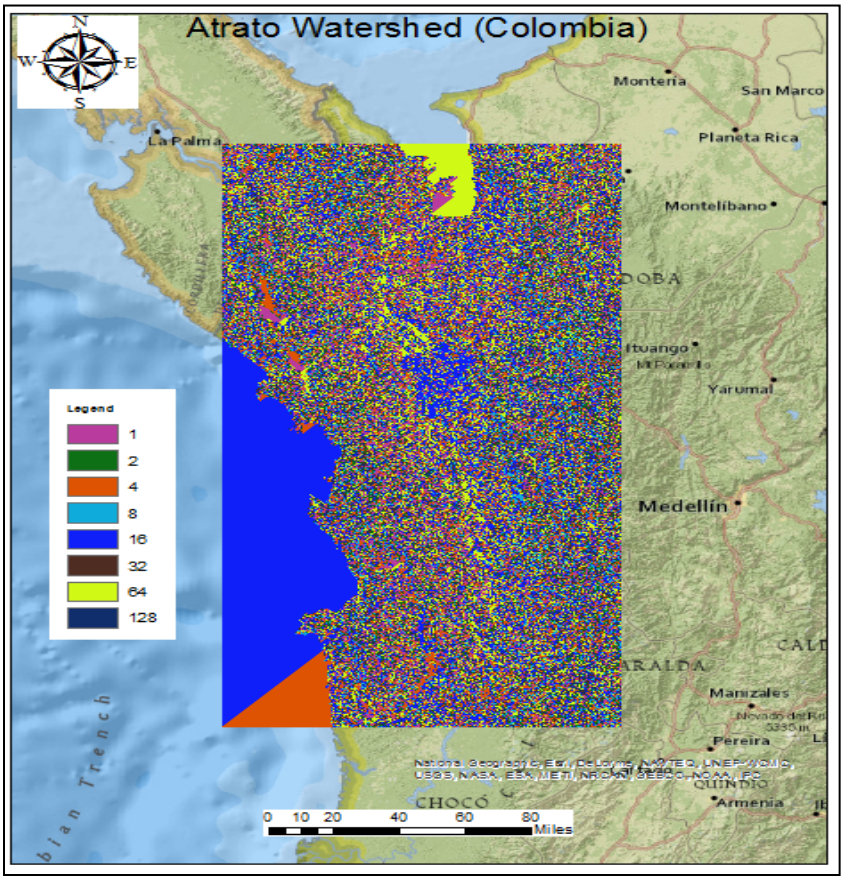
Figure 5. Resulting Fill Pits



7.4 Flow direction

This function computes the flow direction for a given grid. Figure 6 shows that due the geomorphology of the area there is not a clear indication of the direction of the flow, however, near the Río Atrato the flow is conducted to cell 64 in the eight direction (D8) flow model.

Figure 6. Resulting Flow Direction



7.5 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. Figure 7 shows the resulting flow accumulation, which matches the river since its origin but deviates right before reaching the delta.

Figure 7. Resulting Flow Accumulation

7.6 Analysis of the resulting flow Accumulation

The deviation from the river bed occurs mainly because the Río Atrato forms a large, swampy delta before reaching the Gulf. This area has plenty of water bodies, however, due to the low quality of the raster, the resulting flow accumulation choosed a different path that empties into the Caribbean Sea.

Figure 8 shows the different path taken by the resulting flow accumulation, and a picture of the delta.

Figure 8. Resulting Flow Accumulation vs Real River Bed

8. Floodplain Mapping Explanation

HEC-RAS is a Hydraulic model developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. An improved visualization and analysis of floodplain data results from the use of this model along with ArcView GIS.

Two tools are necessary when applying the HEC-RAS model (Tate, 1999):

i) A **planimetric floodplain view**, which is developed using digital orthophotography as a base map.

ii). A **digital terrain model**, which is synthesized from HEC-RAS using cross-sectional coordinate data and a digital elevation model of the study area.

Even though it was not possible to apply the HEC-RAS model due to the poor quality and the lack of the data from the studied area, the application of this model can be summarized in the following five steps (Tate, 1999):

8.1 Data import from HEC-RAS: The HEC-RAS output data is extracted in order to be used in the GIS environment.

8.2 Stream centerline definition: After importing the HEC-RAS output data into ArcView, it is necessary to link the HEC-RAS stream representation to the digital representation of the stream in ArcView.

8.3 Cross-section georeferencing: The first step in geographically referencing the cross-sections is to compare the definitions of the RAS stream and their digital counterpart.

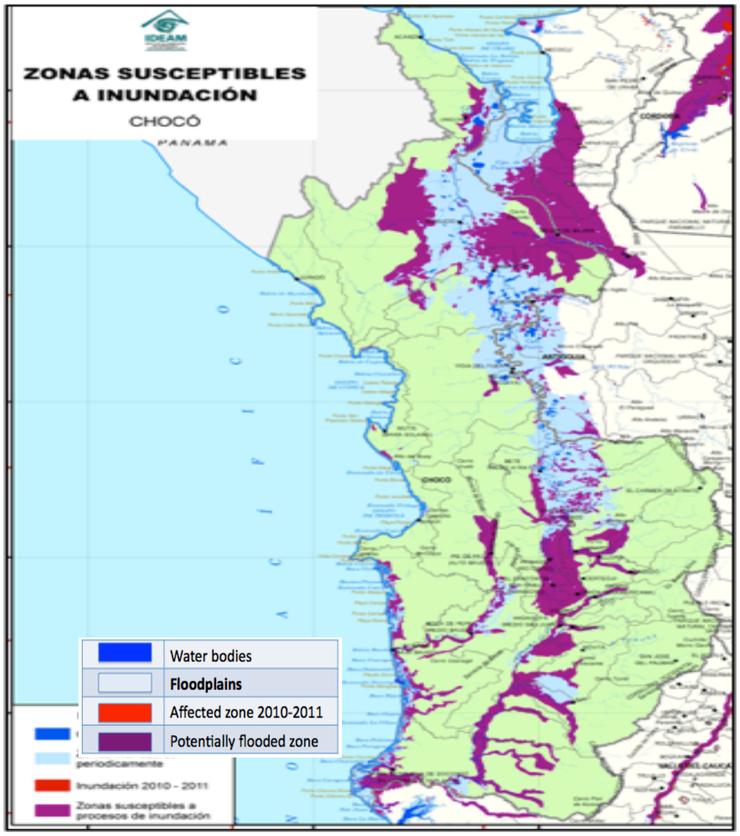
8.4 Terrain modeling: In order to produce a floodplain map, accurate topographic information is required. In GIS, the TIN model is the best data model for large-scale terrain representation.

8.5 Floodplain mapping: With the terrain model complete, the final step is to delineate the floodplain. HEC-RAS represents stream floodplains as a computed water surface elevation at each cross-section.

9. Floodplain Map

Figure 9 shows the resulting floodplain map developed by the IDEAM – Hydrology and Meteorology Colombian Institute. This map includes zones affected by the flooding events caused by La Niña phenomenon and the extreme rainfall during the winter emergency in the last two years.

Figure 9. Floodplain Map



Source: https://www.siac.gov.co/documentos/DOC_Portal/DOC_Agua/20120508_Reporte%20Consoli_2010-2011.pdf

10. Observations

In order to develop the flooding map, it is necessary to have a high-resolution raster and use of LIDAR (light detection and ranging) floodplains.

LIDAR is an optical remote-sensing technique that uses laser light to densely sample the surface of the earth, producing highly accurate x,y,z measurements. It is necessary o use this tool since it allows to detect subtle topographic features such as river terraces and river channel banks.

11. Acknowledgements

Special thanks to Dr. David Maidment for making this class enjoyable to students with different backgrounds and for teaching us the many possibilities for using ArcGIS to solve problems from very distinct topics. I would also like thanks to Gonzalo Espinoza for all his patience and support and for being an excellent Teacher Assistant.

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