Hazardous Areas and Evacuation Plan for Possible Category Four Hurricane in Galveston and Harris Counties

Isaac Jimenez

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Introduction

Objective:

The objective of this study is to identify the zone most susceptible to a Category 4 Hurricane Storm Surge of a maximum of 15 feet flooding in the Galveston and Harris counties focusing on the City of Galveston. As well to be able to create a safe and effective evacuation route that does not cross a rivers flood plain.

Background:

On September 8, 1900 the City of Galveston was demolished by the deadliest natural disaster in United States history. The unnamed hurricane or better known as "The Great Hurricane of 1900" made land fall on the 30 mile-long, 3 mile-wide Texas coastline that was Galveston a city of about 42,000 people with a shipping port and the largest cotton port in the nation. The hurricane created storm surges of 15ft that covered the city whose highest point of elevation was only 8.7 feet above sea level. These giant waves destroyed houses, knocked buildings off their foundations as well as swept thousands of people into sea, the estimated death tolls of 6,000 to 12,000 however most sources believe it to be just over 8,000 deaths with damage to property around $30 million. The storm path is not fully known but through records and studies it seems to have continued on through East Texas up North to the Great Plains and back towards the East United States eventually making its way to Canada.

Assessing the Problem:

The Great Hurricane of 1900 is a horrific story of death and destruction. The Galveston Island will always be vulnerable to hurricanes and tropical storms, that doesn't mean that it can have a safety plan to be able to reduce the death toll should another major hurricane hit the city. I believe creating this study can show the citizens of Galveston the hazardous areas and create a plan when the time of evacuation arrives.

Data

Data Used:

- ■ Texas Natural Resources Information System(TNRIS) http://www.tnris.org/get-data?quicktabs_maps_data=1

1) Texas County Boundaries
2) Texas City Boundaries
3) Center of City Points
4) Texas Roads
5) Texas Rivers

- Texas Parks & Wildlife
  http://www.tpwd.state.tx.us/landwater/land/maps/gis/data_downloads/
  1) Texas Minor Bays

- The National Map http://nationalmap.gov/viewer.html
  1) Elevation of Galveston and Harris County

Data Collection:

The data that was used in this study was collected from three different sources mentioned above. The data from TNRIS was very simple to obtain, once I clicked on the link the file began to download and I saved it to my project folder and were readable for ArcCatalog and ArcMap. The same goes for the data obtained from the TPWD where I downloaded Texas Minor Bays (minorbays.shp). The elevation data from "The National Map" had some extra steps to obtain the data. On the viewer you select what information you want shown on the map. I proceeded to search for Galveston County and zoomed out until I had Harris County on the screen. Then selected the "Overlays" tab on the table of contents, in there I selected the "Elevation Availability" then "Best Available NED Resolution". Once these were all selected I clicked on the download data link at the top of the web page and selected "Download by current map extent" after this the National Map emailed the data order to me and received it as a ZIP file which once unzipped was readable in ArcCatalog and ArcMap.
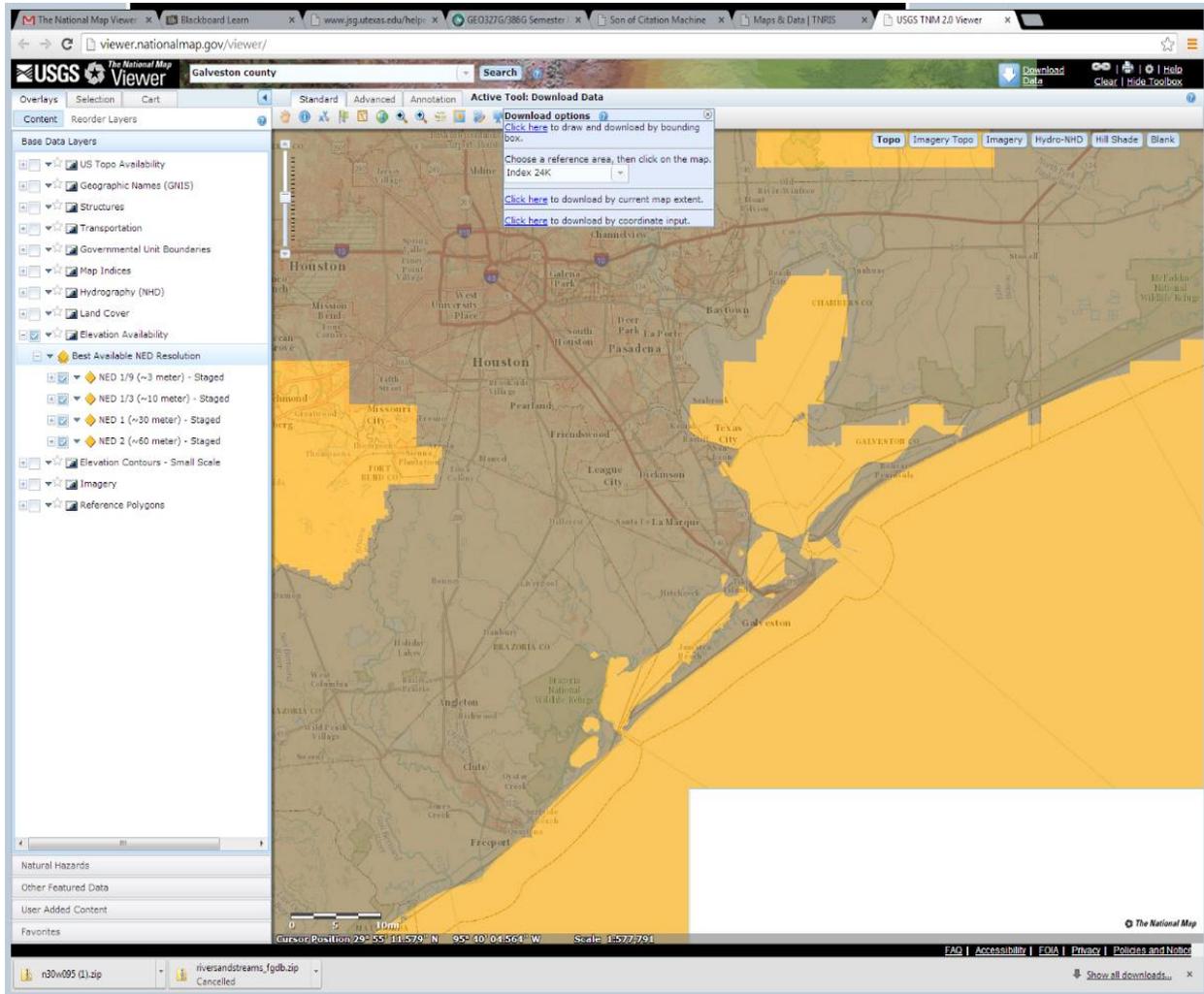
Figure 1: Screen Shot of The National Map viewer with selected items and elevation shown.

Processing

Data Preprocessing:

One of if not the most important item to check before starting your project is the projection that the data is in. Because I downloaded data from three different sources each had a different projection and datum. The data from TNRIS came in the NAD_1983_Texas_Statewide_Mapping_System (Lambert Conformal Conic). The data from TPWD in NAD_1983_Lambert_Conformal_Conic and the elevation data from the National Map was received in the GCS_North_American_1983. In order for all of these too match up on a map with the least amount of distortion I projected them onto the NAD_1983_StatePlane_Texas_South_Central_FIPS_4204 using ArcCatalog, this projection covers the area of interest specifically.

ArcMap Processing:

Procedure:

A.) Create a Map of Galveston and Harris Counties
B.) Create an Area of Interest
C.) Symbolize Data
D.) Calculate a raster of area affected by the 15 foot storm surge
E.) Calculate the Area and how far inland the storm surge would reach
F.) Buffer Rivers
G.) Intersect the Roads and River Flood Plains
H.) Create an evacuation plan with safest roads

A.)Create a Map of Galveston and Harris Counties

1. Open a blank document in ArcMap
2. Connect to your folder where you stored your downloaded data
3. Add the counties.shp
4. Project (data management) the counties.shp to the NAD_1983_StatePlane_Texas_South_Central_FIPS_4204 (open the properties of the data frame and select the "Import" tab and select the counties.shp to set it to the NAD_1983_StatePlane_Texas_South_Central_FIPS_4204).
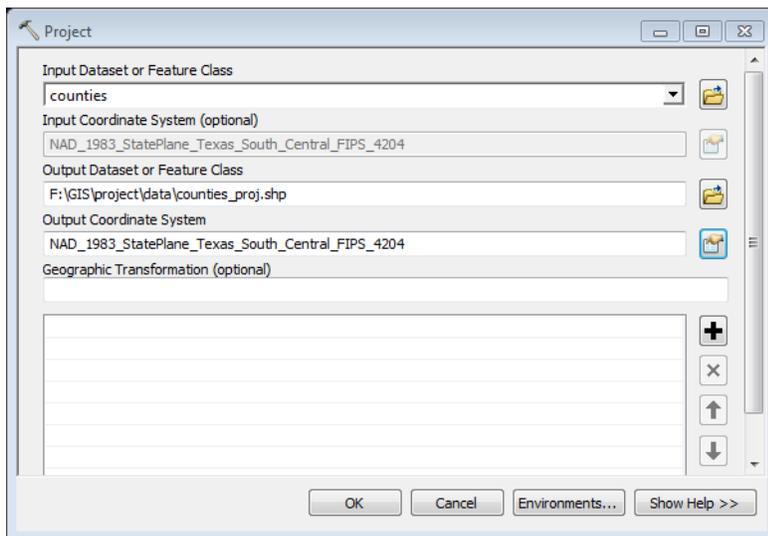
Figure 2: Showing the procedure to project a .shp to the coordinate system of choice

5. Repeat step 3 and 4 for the rest of the data.
6. You will end up with a map of Texas projected in the NAD_1983_StatePlane_Texas_South_Central_FIPS_4204).

7. In order to focus on the area we want and clean up the map we must create an area of interest.

B.) Create an Area of Interest

1. The elevation data came in two rasters that cover an area of Galveston and Harris County, we need to combine these two using
2. Open the Arc toolbox: Data Management-> Raster-> Raster Dataset-> Mosaic
3. Input both of the elevation rasters, and for the Target Raster add a mosaic to your folder. Click Ok (See Figure3)

4. We can now clip all of our data sets to only show the information inside the elevation raster. Open the Arc toolbox: Analysis tools-> Extract-> Clip (analysis)
5. For the Input enter "counties.shp", for the clip feature enter "mosaic", for the output, look for your project folder and save as "county_clp.shp" (see Figure 3)
6. Repeat steps 2-3 for "rivers", "City points", "Texas Roads", "City Boundaries", "Texas Minor Bays"
7. We can now only focus on the area that we have elevation information on .
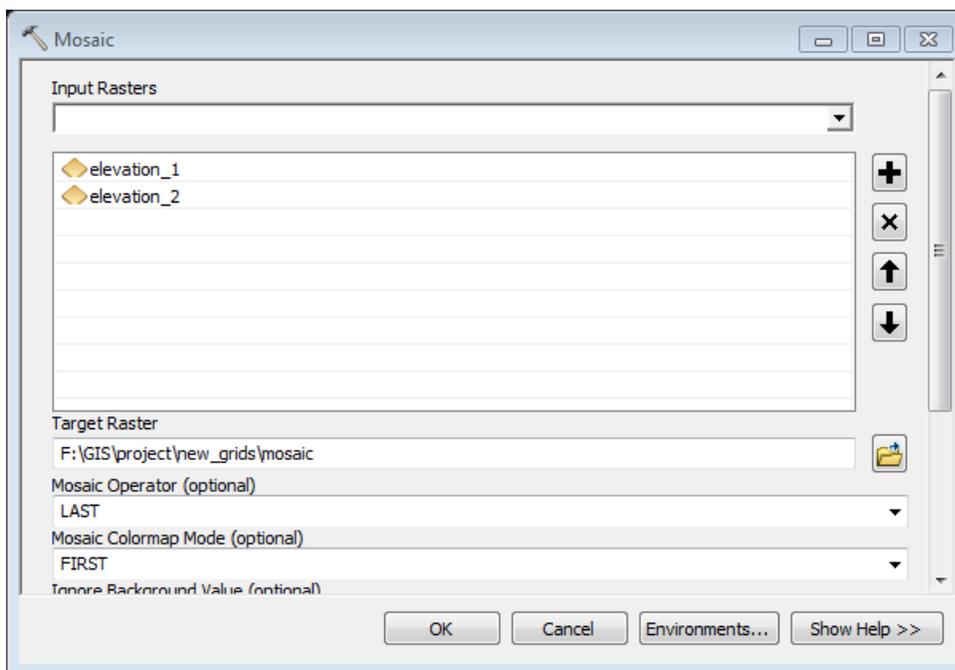
Figure 3: Mosaic Window Example
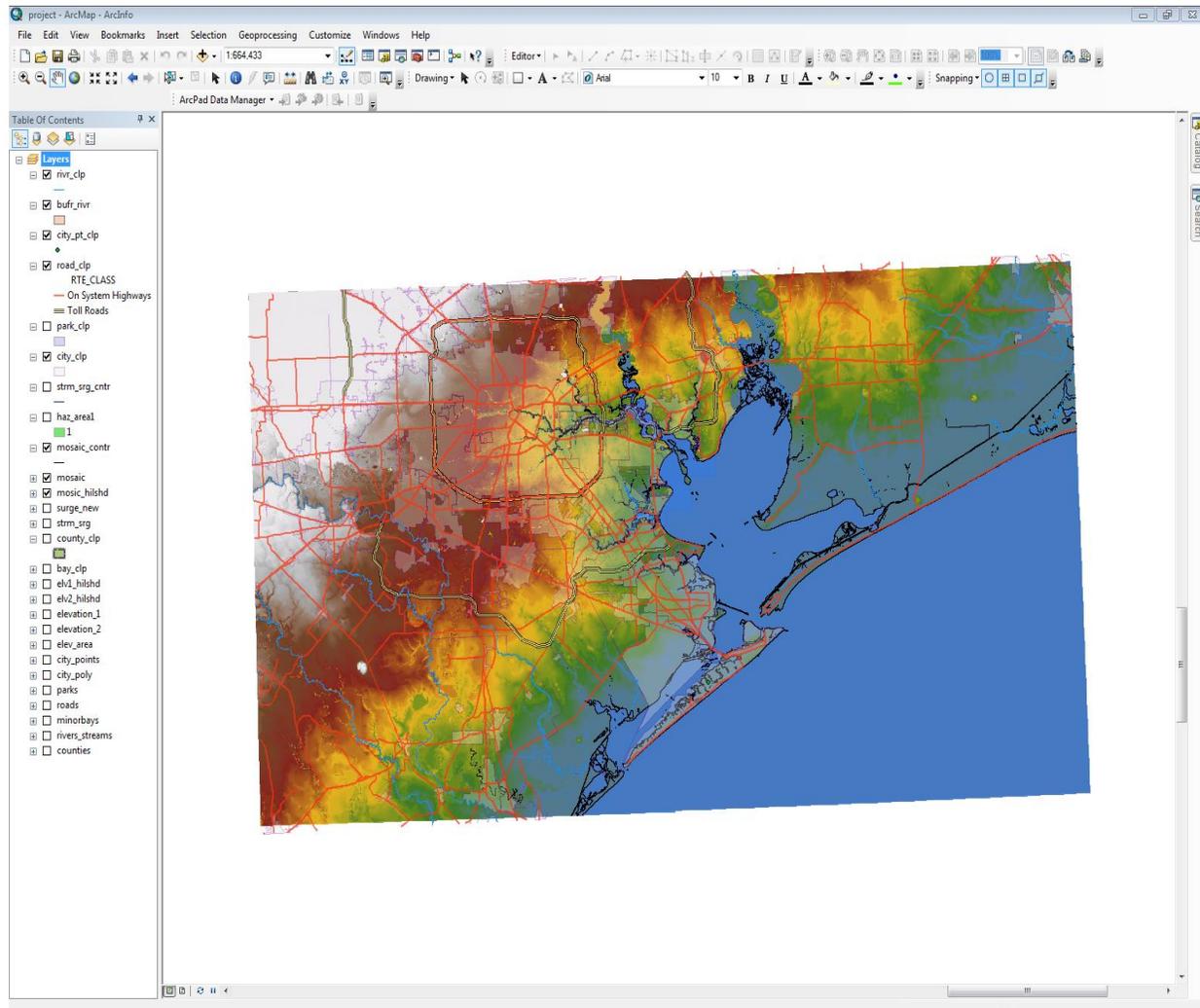
Figure 4: Example of Cliped Data

C. Symbolize Data

1. Double click the "mosaic", select the symbology tab
2. Right click the color ramp bar and make sure that the "Graphic View" is marked off, and select "Elevation 1". Then right click the color ramp bar again and select the "properties" Click on the first color bar and select both "color 1" and "color 2" to "Cretean Blue", click on the next color bar down and change "color 1" to "Cretean Blue" and "color 2" to "Fir Green" Hit ok on all three windows. (See figure 5)
3. Select the roads_clp.shp, the symbology tab and remove from there all but the "On System Highways" and select the predetermined "Highway Ramp" symbol. The "Toll Roads" as the predetermined symbol for "Expressway"
4. Select the river_clp.shp set to the "River" symbol.

5. The City polygons should have an outline of 1.0 thickness, color of "Dark Amethyst" and the polygon color should be "Grey 10%". Change the transparency to 70% in the display tab.

6. The city_pt_clp symbol to a diamond, color leaf green, size 4.

7. Symbolize the bays with the predetermined "Lake" symbol.
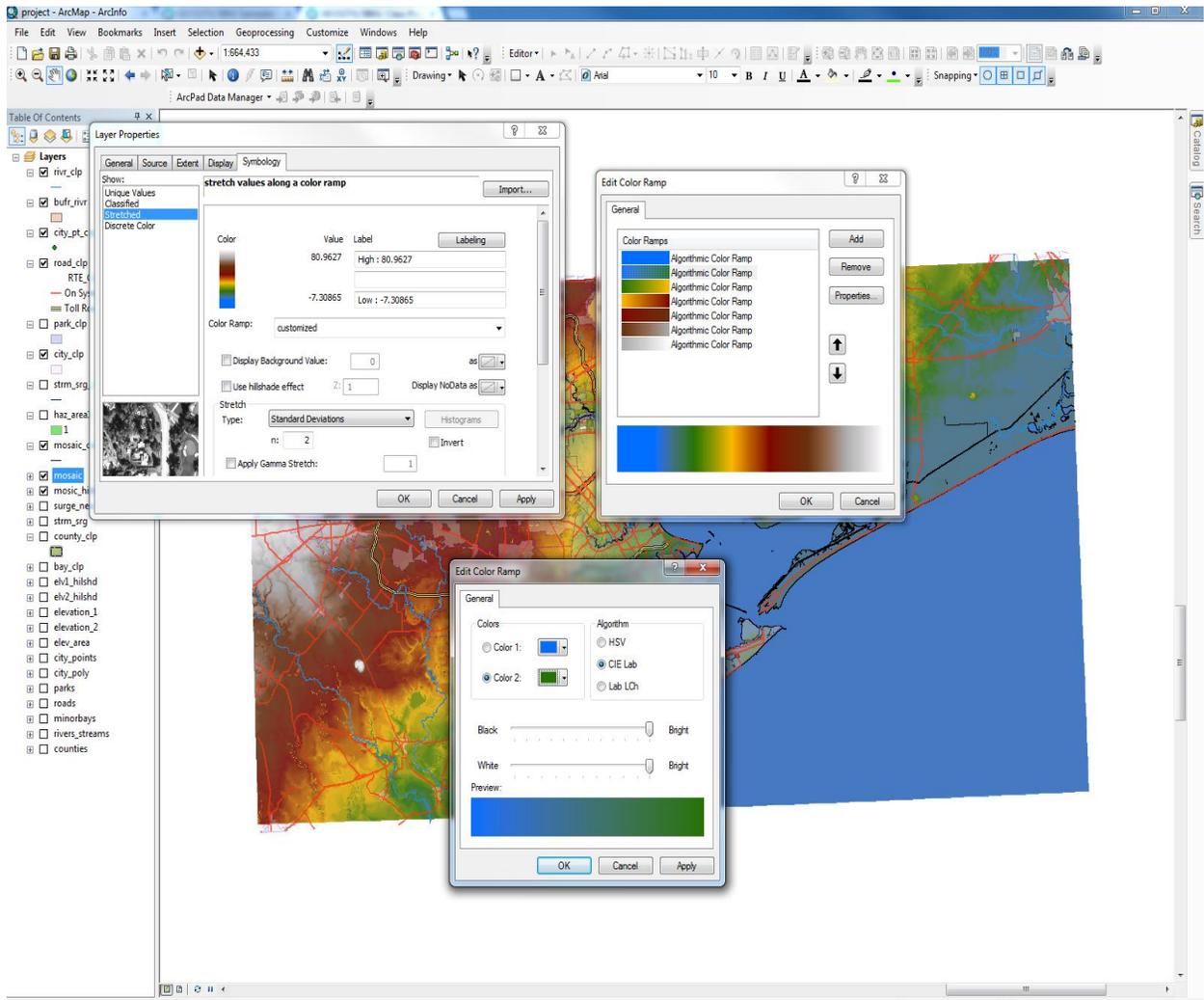
Figure 5: A visual example of the customization of the mosaic color ramp. Showing water as bule and land as an elevation color ramp.
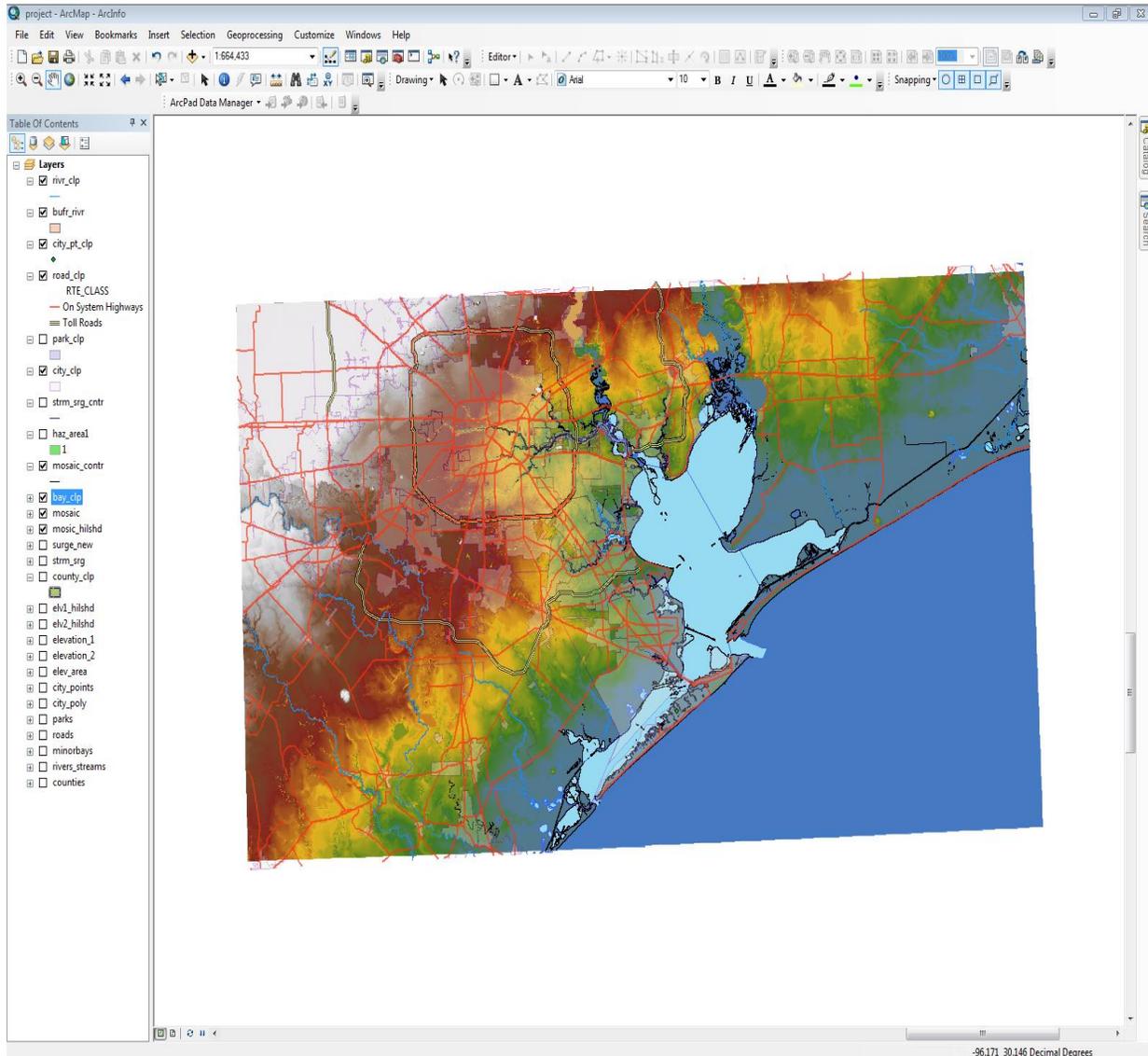
Figure 6: Symbolized data on Clipped Area of Interest. Showing Elevation, Roads, Rivers, Bays and City Area

D. Calculate a raster of area affected by the 15-foot storm surge

1. In order to calculate the area affected by the storm surge we must use the Raster Calculator tool to select and the elevation area between 0 and 15ft of elevation. Note: Because the Elevation data comes in meters we must convert 15 feet to meters (15 ft = 4.5m, I rounded up to 5m)

2. Open toolbox: Spatial Analyst-> Map Algebra-> Raster Calculator (Note: Be sure to turn on the Spatial Analyst box, Customize (tab on main bar)-> Customize-> select the Spatial Analyst box, if this box is not check the raster calculator will not work).

3. Use the Map Algebra expression "("mosaic" <=5) & ("mosaic" > 0)"

4. For the output raster: browse to your folder and label it something as "strm_surge" (see figure 7)
5. Once the Storm Surge raster is created display it as "Fuisha Pink"
6. We must now create a hillshade for the mosaic and the storm surge in order for them to show relief.
7. Open toolbox: Spatial Analyst tools-> surface-> Hillshade
8. For the Input Raster select the "mosaic", for the output raster browse to your folder and label as such "mosaic_hilshd", leave the azimuth and altitude at default and z factor at 1, click ok.
9. Repeat Step 6-7 for the Storm Surge raster, once both are created place the Hillshade beneath each raster respectively on the table of contents. Then go to the properties of the raster's and on the display tab adjust the transparency to 20% each.
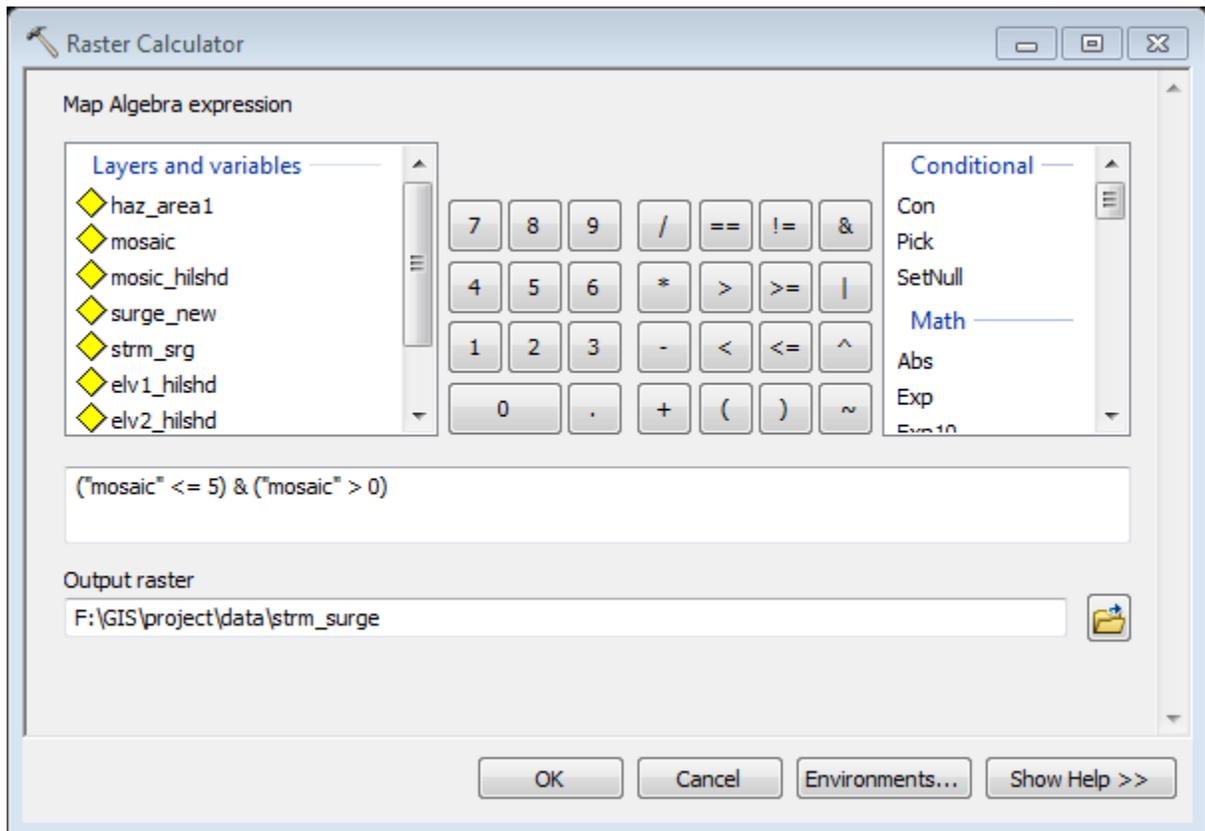
Figure 7: Raster Calculator: Map Algebra Example of the Storm Surge Hazard Area
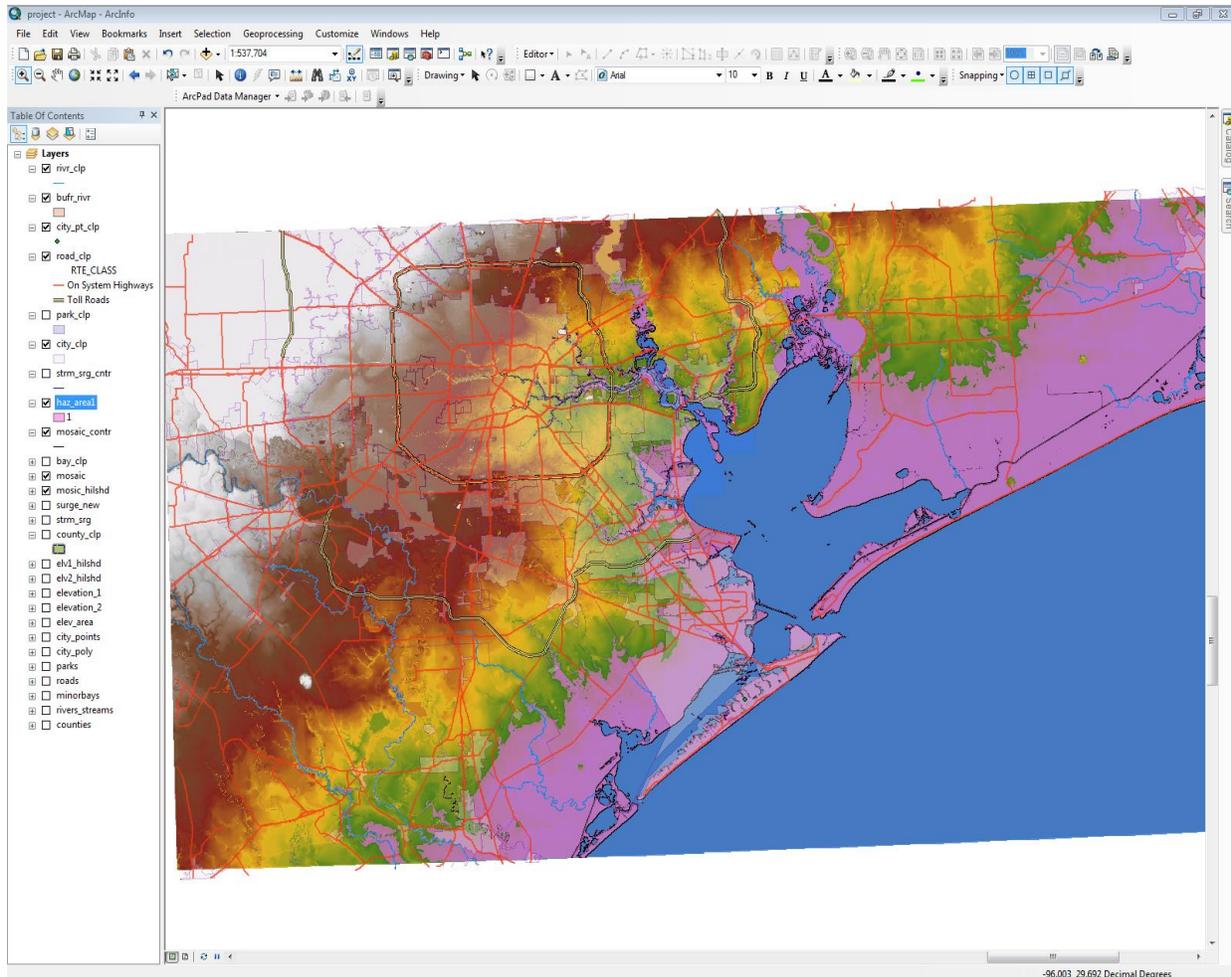
Figure 8: Map of the Area of Interest showing the Storm Surge area being affected in dark pink.

E.) **Calculate the Area and how far inland the storm surge would reach**

1. Turn on the 3D Analyst extension refer to step D2 in order to turn on the extension.
2. Open Arc toolbox: 3D Analyst tools-> functional Surface-> surface volume
3. Input the strm_surg raster, set the output text file to your data folder as stm_srg_stats.
4. Click ok
5. This tool creates a table and places it in the Table of Contents, then right click and select open to be able to see the statistics.
6. Look for the Area_2D (See figure8)
7. The units are in meters^2, we must convert to feet^2.
8. Create 6-10 lines using the Draw tool from the area from where the storm surge ends on the surface to the water where it starts.

9. Right click the line-> properties-> length tab, again the units are in meters so I imported the data from each line into Microsoft Excel where I calculated the Feet, average feet and average miles.
10. We can now create contour lines to show where the elevation is 0 and at 15 ft above sea level.
11. Open Arc toolbox: Spatial analyst-> surface-> contour
12. Input raster will be the "mosaic", output will be labeled sea_lvl_contr, and for contour interval we will put 100 since the highest elevation in our data is 88 in order to get a zero contour. Leave the base contour at 0.
13. Click ok
14. Symbolize it as black and 0.5 thickness.
15. Repeat steps 11-13 except on step 12 instead of leaving the base contour at 0 move it up to 5 (units in meters).
16. Symbolize the surg_lvl_contr as navy blue and at 0.5 thickness.
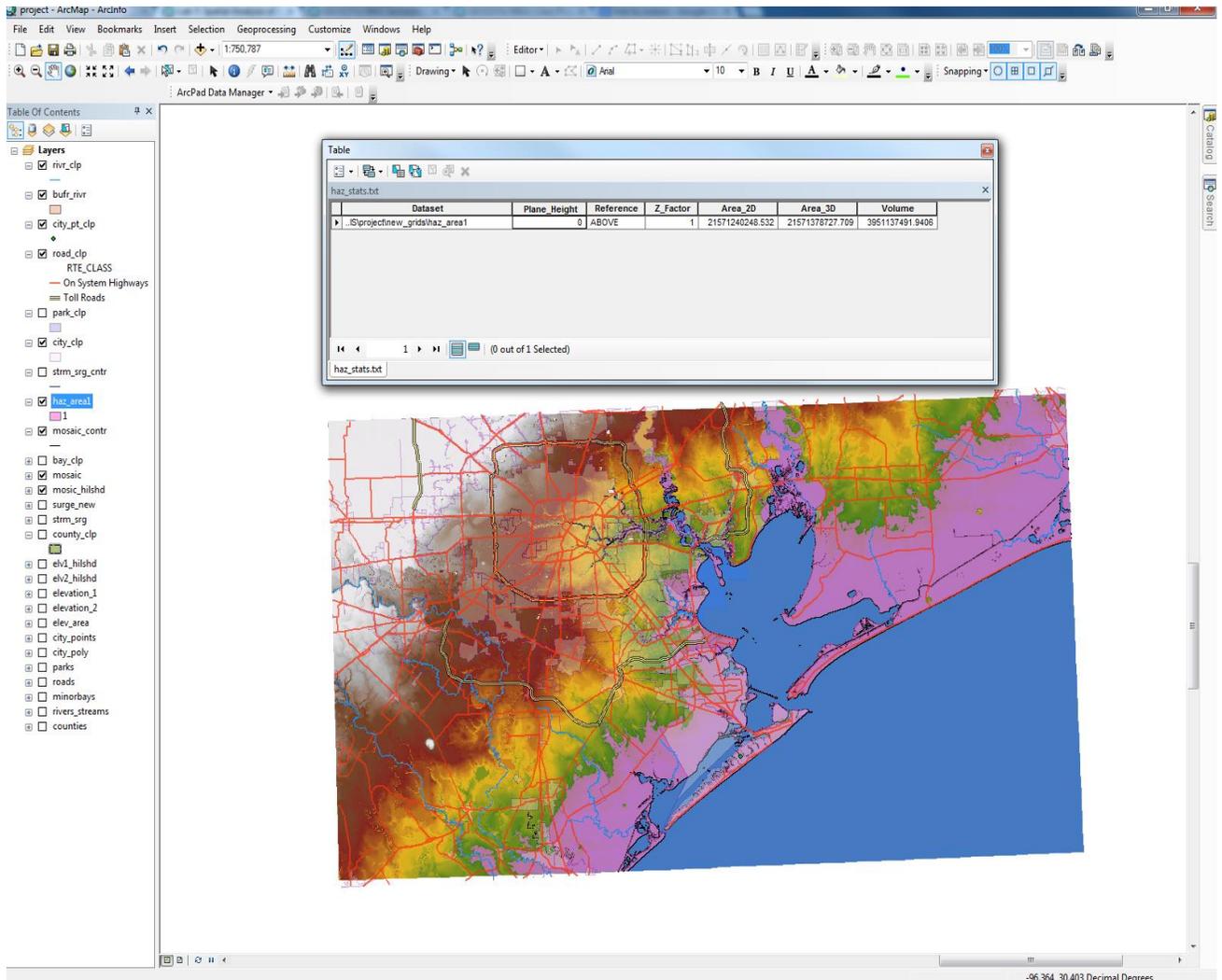
Figure 9: ArcMap ares showing the Storm Surge Statistics. The units are in meters.

F.) Buffer Rivers

1. Open the Arc toolbox: Analysis-> proximity-> buffer
2. Input features select the rivr_clp, output feature browse to your folder to store your rivr_buffr, for the distance select the Linear Distance and input 1320 feet, this is a quarter mile.
3. Click ok and when buffered change the color to "apatite blue" and a 0.40 thickness

G.) Intersect Roads and River Flood Plains

1. Open Arc toolbox: Analysis tools-> Overlay-> Intersect

2. Input the river_clp_buffer and the roac_clp, the output browse to your folder and label it something as "haz_road"
3. Click Ok (see figure 10)
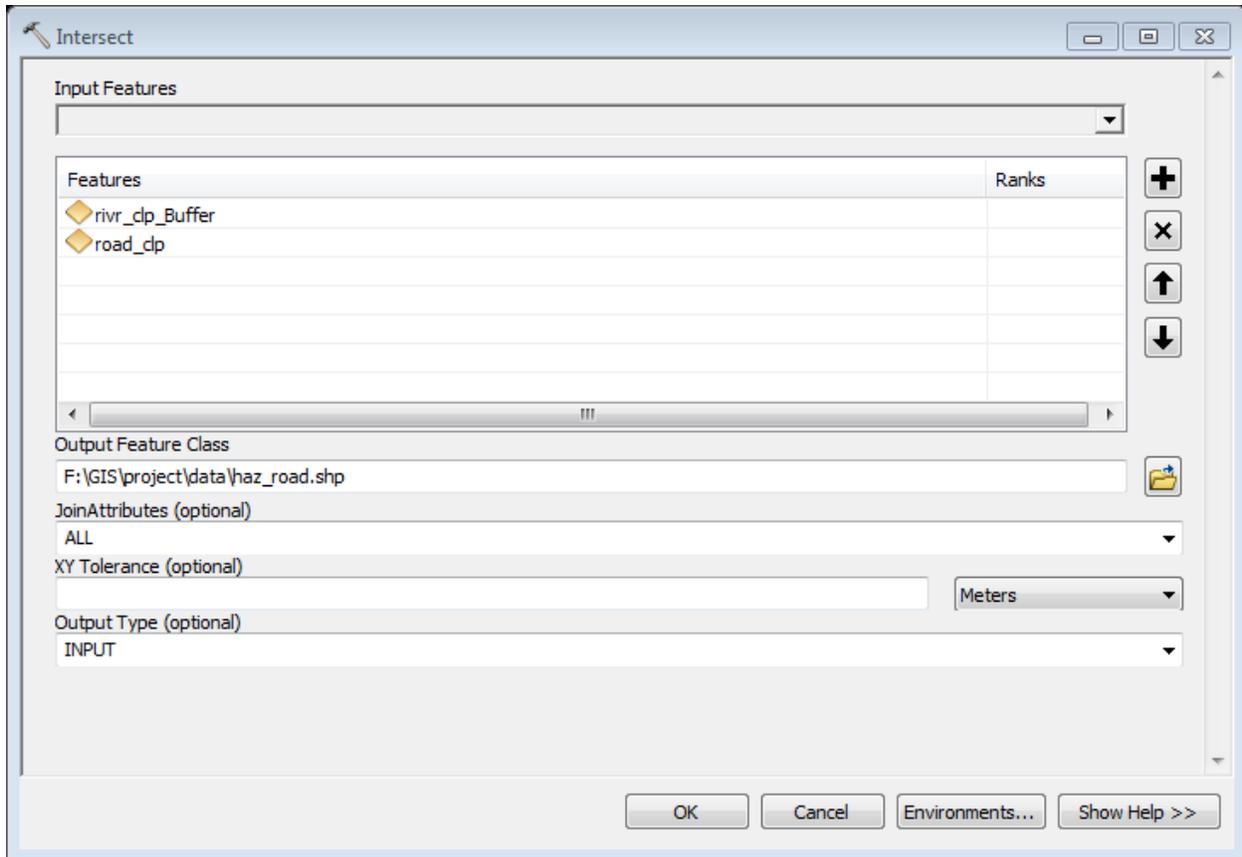
Figure 10: Intersect example to find the roads that are hazardous to drive on during or after the storm.

H.)Create an evacuation plan with safest roads

1. After reviewing the data on the map I was able to isolate three highways coming out of the City of Galveston that will take you to different parts of Houston, TX.
2. I selected the highways by using the identify tool and once I had the names of the Highways, I used select by attribute tool in the Selection Tab.(Note: to make selctions easier, you can use the selectable tab in the Table of Contents and only select the road_clp)
3. In the select by attribute table make sure that under layer you have the road_clp selected. Under method is "Create a New Selection" then look for "ST_NM" double click it and it will appear in the box below, click on the "=" then the "Get Unique Values" tab and type in the "Go to" one of the highways of choice.
4. Click ok, a cyan colord line will appear where the street is located.

5. Go back to selection-> select by attributes, change the "Method" tab to "Add to current selection" and replace the first highway with the second. Continue this until all of the highways of interest are selected.
6. Once all are selected you right click on the road_clp in the table of contents-> selection-> create layer form selected features
7. This will create a separate layer for the highways in which you can customize, I symbolized the highways as Queztel Green and 4.00 thickness.

Conclusion

Results:

The total area of the affected by the storm surge in our area of interest is $2.3219 \times 10^{11} ft^2$ or $8,328.7 mi^2$. This shows that the entire City of Galveston and the bay would be engulfed in water as well as on average 12 miles inland will see some sort of flooding due to the storm surge and/or precipitation flooding. With an effective warning system and evacuation plan the citizens of Galveston can evacuate safety if they take IH-45 out of the bay and over to the main land and from there can either continue on straight or take SH-3 or SH-6 into the City of Houston and not have to worry about flooding from nearby rivers or the storm surge.

Maps:
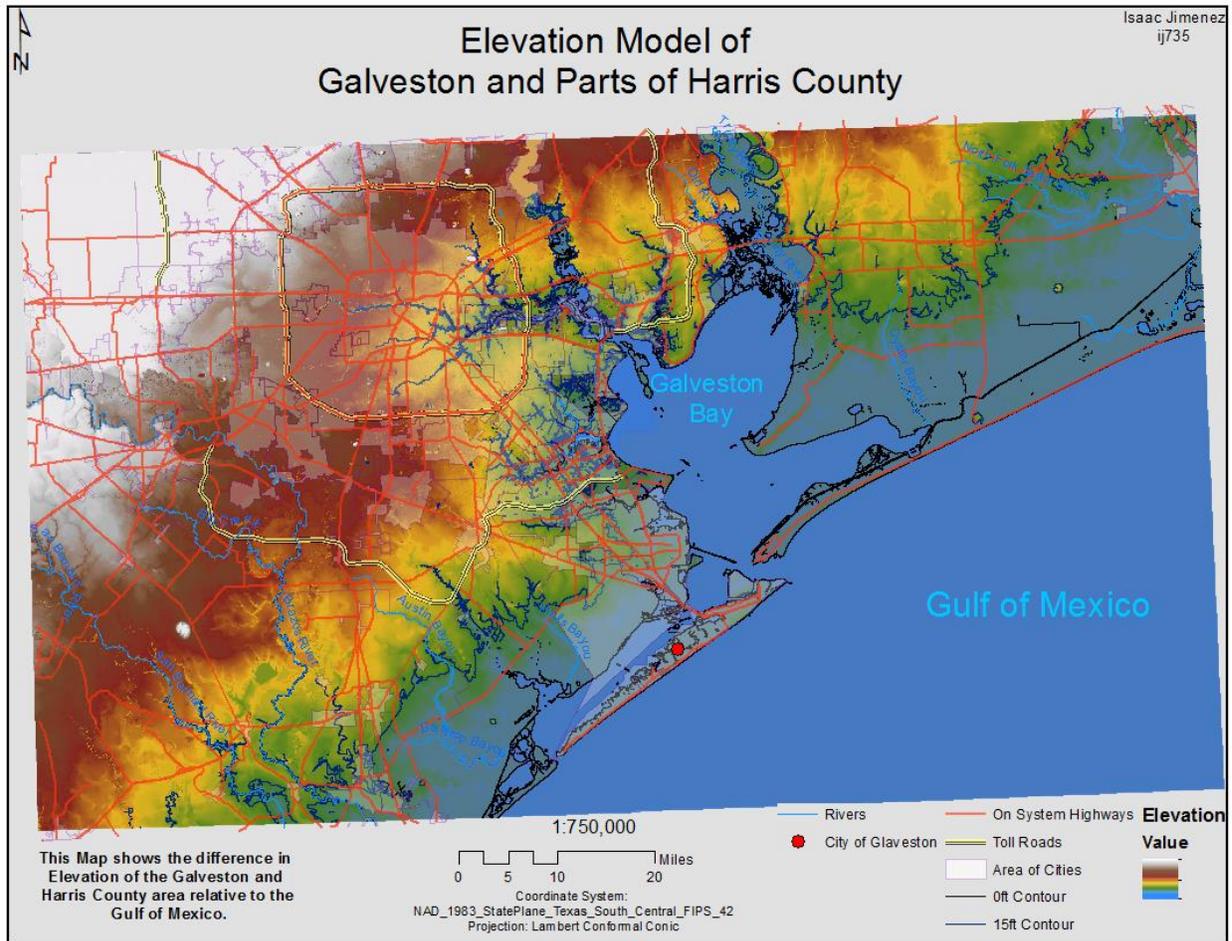
Figure 11: Map 1 shows the elevation of the interested area with roads and rivers.
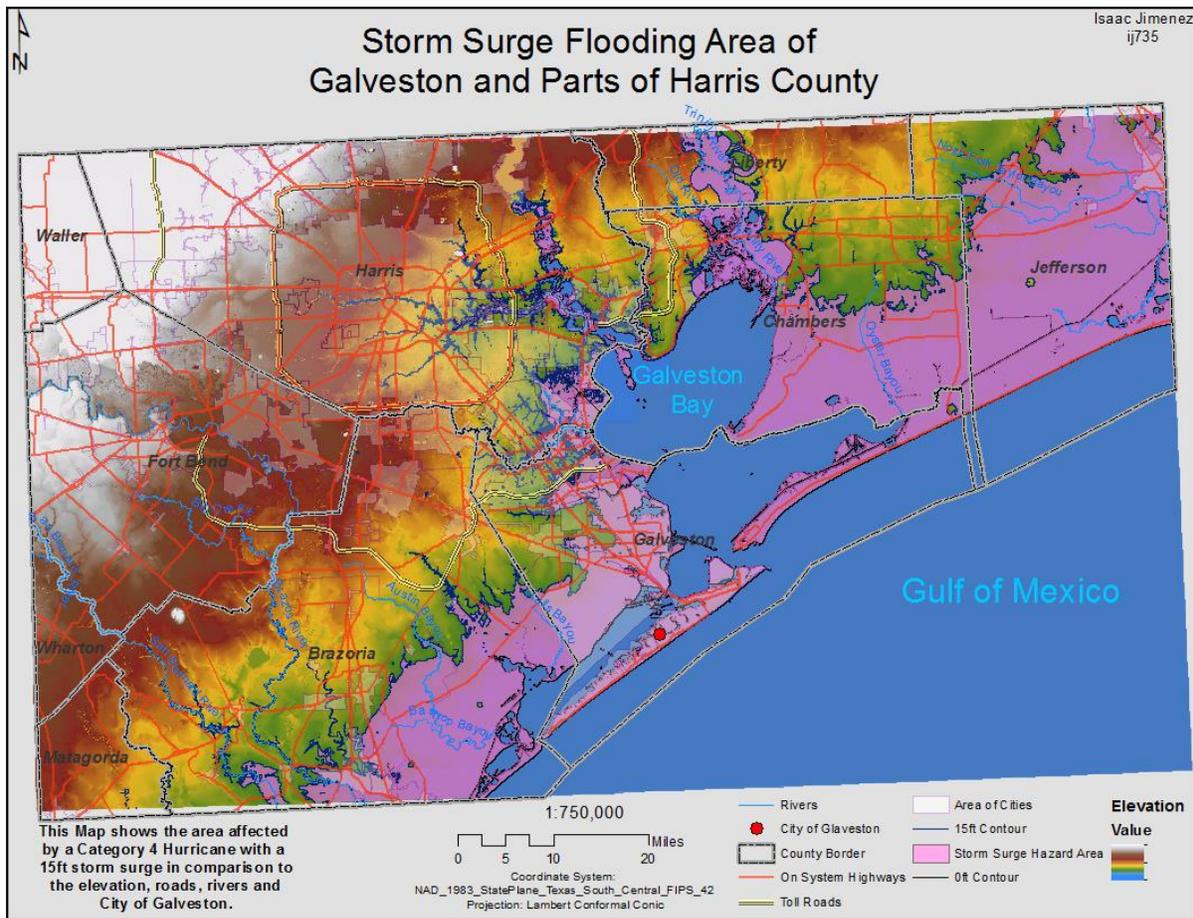
Figure 12: shows the hazardous area that a Category 4 Hurricane Storm Surge can potentially flood. You notice that the entire city of Galveston would be flooded.

Figure 13: An evacuation plan for the City of Galveston in the event of a Category 4 Hurricane with 15ft high storm surge waves. The three safest Highways out of Galveston are highlighted in Green. These highways can take you to different parts of Houston.

Sources

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