Galveston, Texas in the year 2100

Effects of Sea Level Rise on Costal Waterways and Barrier Islands around Galveston Bay

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GEO 327G

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I. Introduction

A) Purpose: The main purpose of this project is to predict the effects sea-level rise will have over the next 90 years along the Texas coast, mainly focusing on Galveston Bay.

B) Problem Formulation:
   a. What will Galveston look like in 2100?
   b. Given the low and high predictions of sea level rise for 2100, what will the effects be on coastal waterways and barrier islands around Galveston Bay?
      i. To Find the answer to these questions one must calculate the initial/present surface area of the “Zero” elevation and then compute the rise in sea level of 0.38m. Take the initial surface area and subtract the new “zero” elevation surface area and you have the amount of land affected by the rise in sea level.
      ii. Do this same process for the rise of 1.4m.
      iii. Compare how the infrastructure is impacted.
      iv. Only the calculated results of the affected area will be reported.
   c. State the results of the project.

II. Data Collection

- Digital Elevation Model (DEM) of Galveston
  - http://seamless.usgs.gov/
      - ned_88244742
- LandSat Image
  - https://zulu.ssc.nasa.gov/mrsid/mrsid.pl
      - N-15-25-2000.sid
- Base Map Data
  - http://www.glo.state.tx.us/gisdata/gisdata.html
    - Texas Roads and Highways
      - usdotroads.shp
    - Waters under Tidal Influence
      - tidalwtr.shp
    - Washover Areas
      - washovers.shp
  - http://www.tnris.state.tx.us/datadownload/county.jsp
    - Galveston Roads
      - 085urban.dgn
    - Harris County Roads
      - 102urban.dgn
    - Chambers County Roads
      - 036urban.dgn

III) Data Processing

1) First, in order to download the DEM from the Seamless Server, one needs to highlight the region to be downloaded. As shown in **Figure 1.**

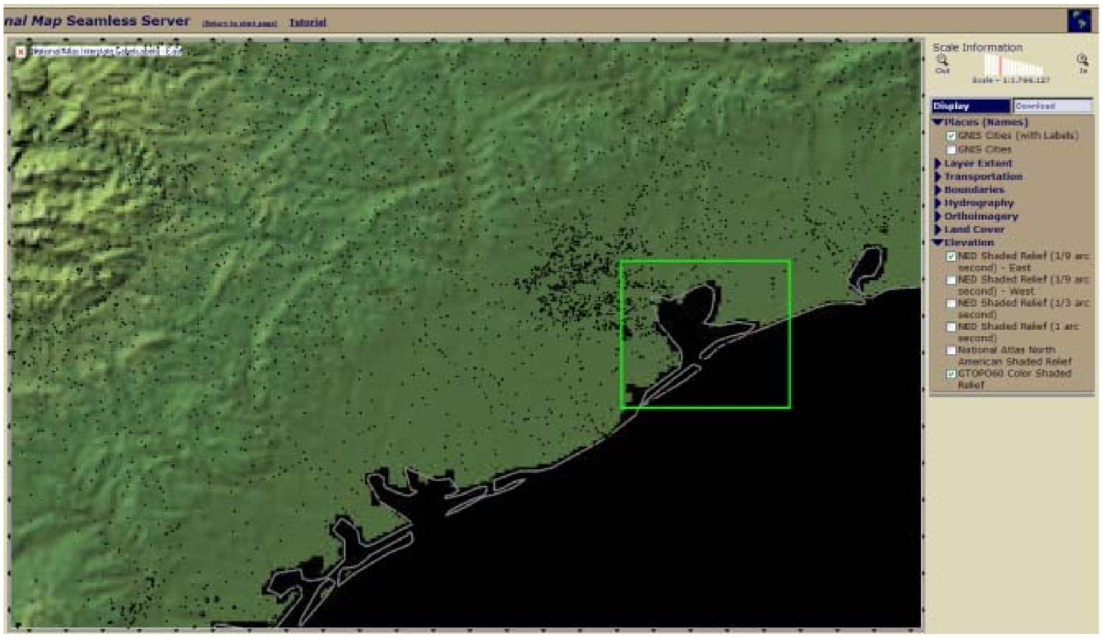


Figure 1: Highlighting the downloaded area of interest, Galveston bay. Downloaded from Seamless Server of the USGS the Digital Elevation Model NED_88244742

2) After downloading the LandSat file from Zulu, and pulling it up in ArcCatalog it was found to have no Spatial Reference.
   a. In order to remedy this problem, one simply clicks on the Edit button and selects a reference datum of their choice. The one chosen for this projection was GCS_North_American_1983 as shown in **Figure 2**.
   b. This is all done before adding it to ArcMap

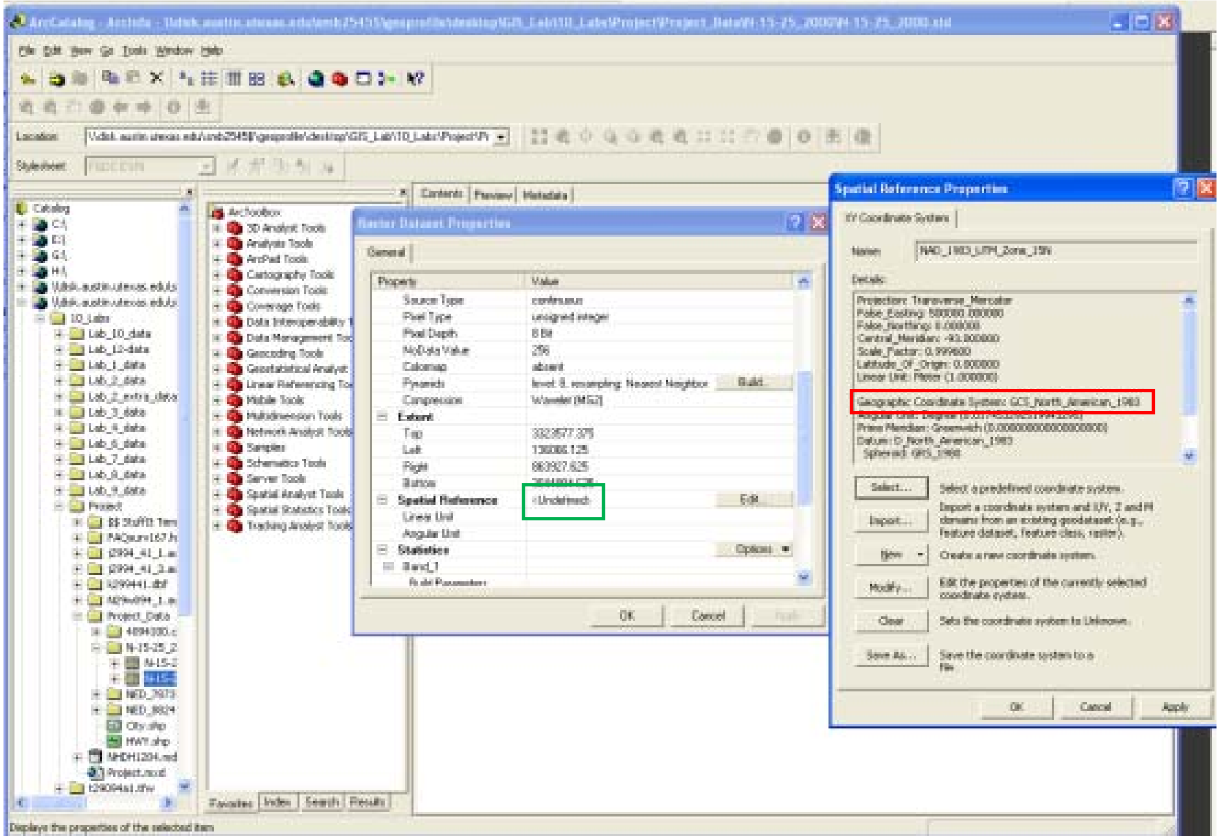


Figure 2: Depiction of the steps involved in editing/adding spatial references to projections. Shown above in the green box is the Raster Dataset Properties box with an <undefined > Spatial Reference. In the Red box, is the Spatial Reference Properties box, which displays the new spatial reference/ Geographic Coordinate System: GCS_North_American_1983.

3) After adding the Galveston Roads, Harris County Roads and Chambers County Roads, all of which had a spatial reference of GCS_North_American_1927, a transformation must be made to calculate the correct position of this data in relation to all the other data.
   a. Figures 3 and 4 show the transformation process from GCS_North_American_1927 to GCS_North_America_1983

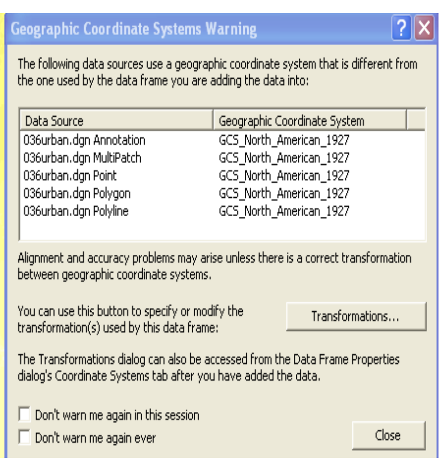
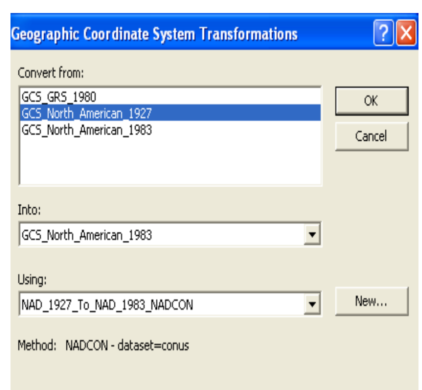


Figure 3: (Left) shows the warning that pops up letting you know that the spatial references of the data that you are adding is different than the Spatial references of the data already loaded.

Figure 4: (Right) the Transformations pop up showing the Datum that will be converted from and the datum it will be converted into. In this case, from GCS_North_American_1927 to GCS_North_American_1983.



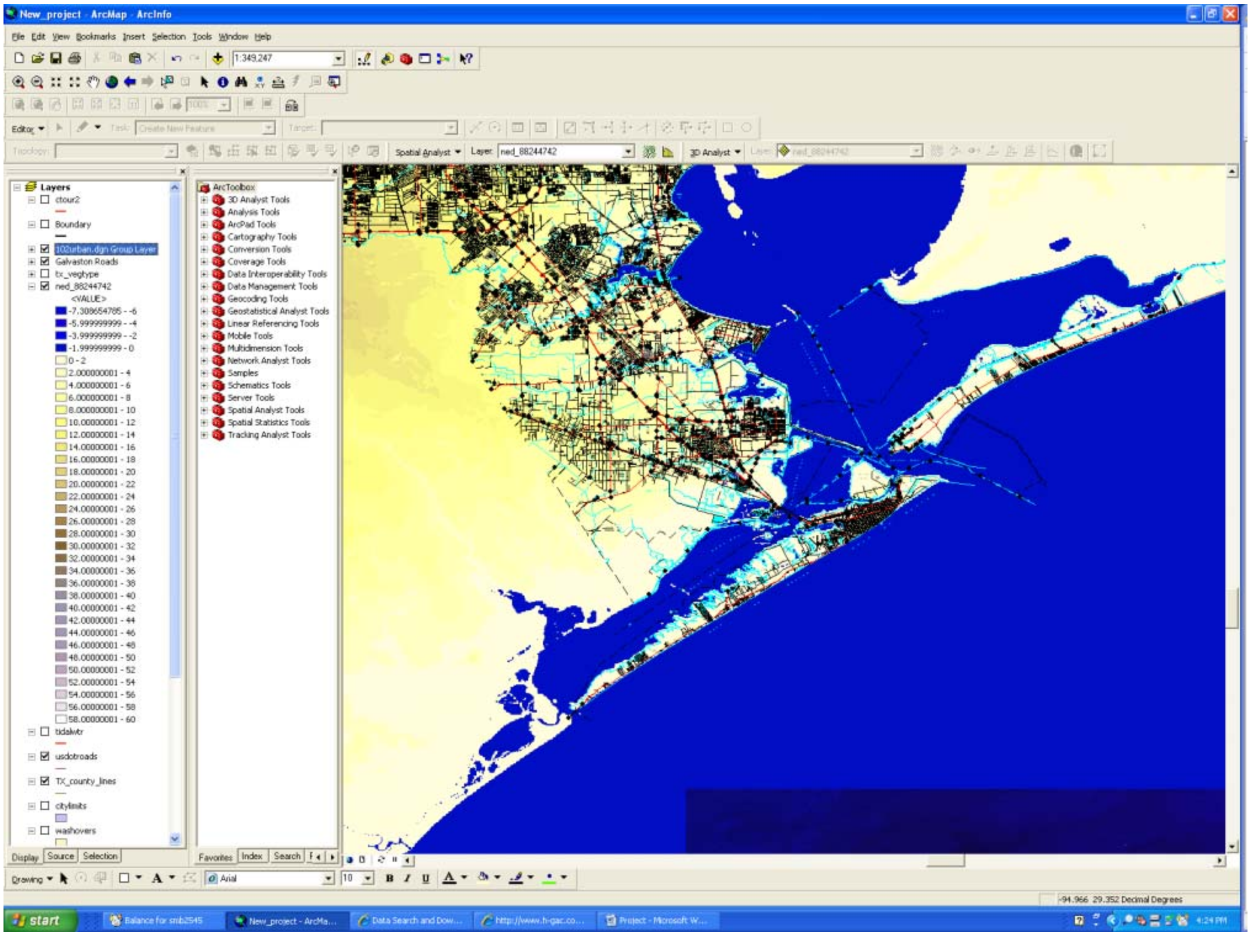


Figure 5: Depiction of the newly added vector data along with reclassification of the DEM into 2m classes. Everything at or below sea level is symbolized blue.

4) In order to really understand the digital elevation model in a fast and visually pleasing way, one must reclassified the interval size of the DEM to 2 meters. Choosing such a small scale helps with identifying the very gentle slope of the coast line. As seen in **Figure 5** everything at or below sea level is symbolized blue.
   a. To reclassify the DEM, one must open the Layer Properties of the DEM, and select the Symbology Tab. Then the Classified scheme must also be selected, which will open up a window much like the one in **Figure 6**.
   b. Click on the Classify… button which will open up the Classification window (**Figure 7**).
   c. From the Classification window select the Method: Defined Interval and set the interval size to 2m.
   d. The Color Ramps can be adjusted and in this project it is imperative to know where the shoreline is located. So to ease in the recognition of the shoreline, the symbology was changed for everything below sea level to dark blue as seen in **Figure 6 and 8**.

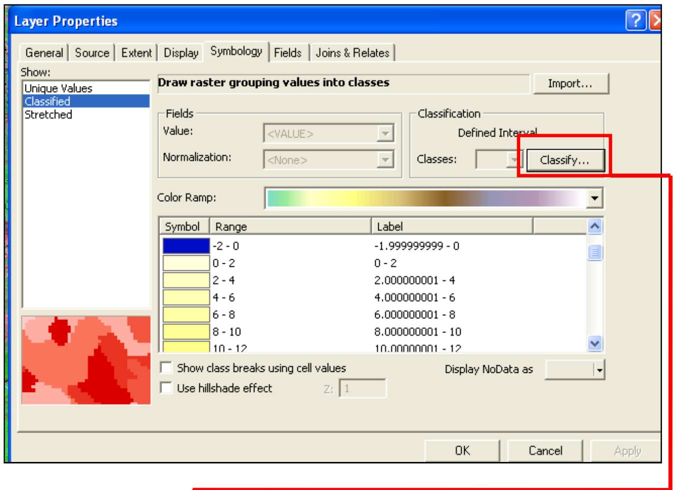


Figure 6: (Top Left) Layer Properties window showing the Symboloby Tab with Classified Field highlighted. Also shows the new classification scheme of 2m intervals and the new color ramp with everything below sea level in blue.

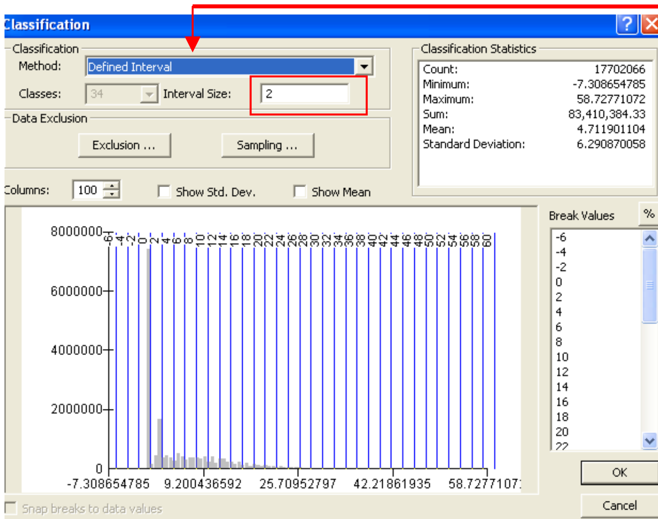


Figure 7: (Middle Left) The Classification Window showing the Defined Interval Method with an interval size of 2m (Red box).

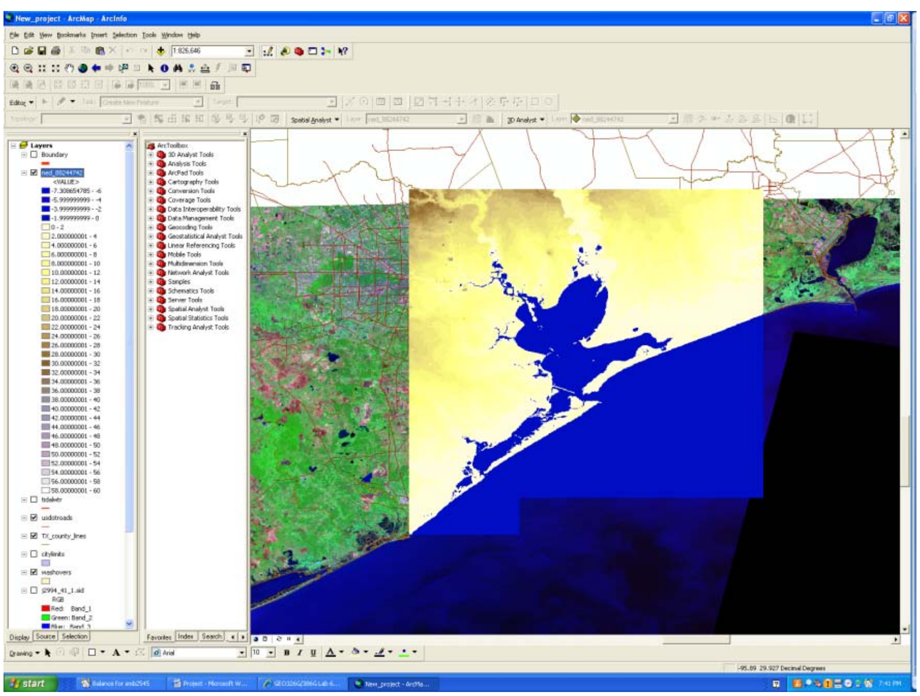


Figure 8: (Bottom Left) Data View in ArcMap showing the newly Classified DEM.

5) Created a Zero elevation (Sea Level) Contour line:
   a. This contour line will denote the present day shoreline. It will be used to visually compare future sea level models.
      i. First one must make sure the Spatial Analyst Extension is on by going to Tools and then Extensions.
      ii. Then under the Spatial Analyst Drop down Menu, select Surface Analysis and Contour…
      iii. This will open the Contour Window as seen in **Figure 9**. In the Input Surface: ned_88244742 (the DEM) and make the base contour: 0 for sea level and the contour Interval: 200 (or anything above the largest elevation on the DEM).
      iv. This will give you a shore line like that in **Figure 10**.

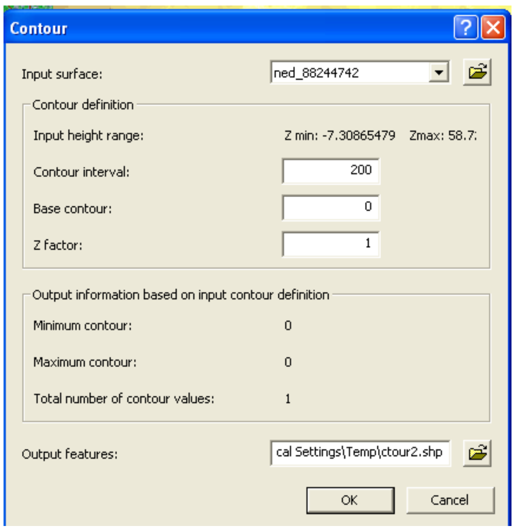
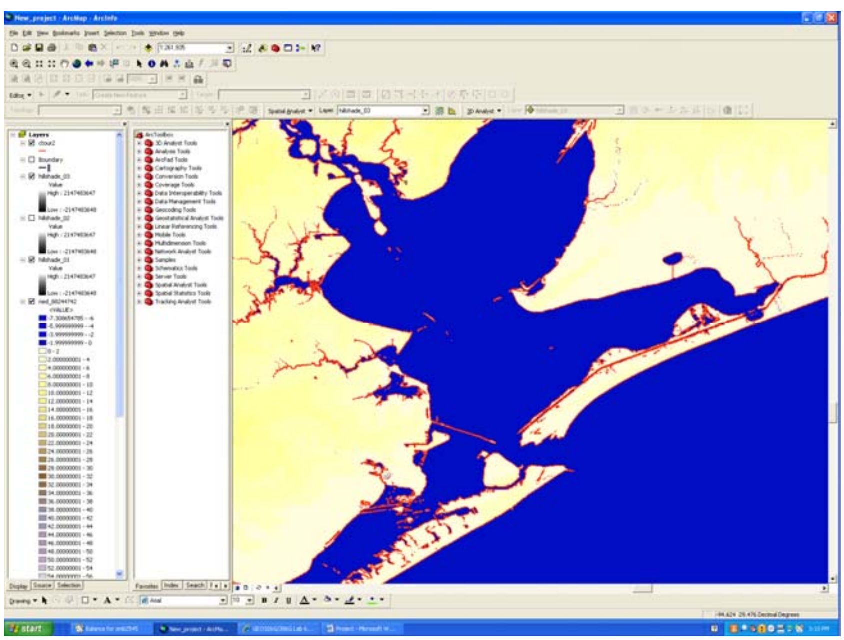
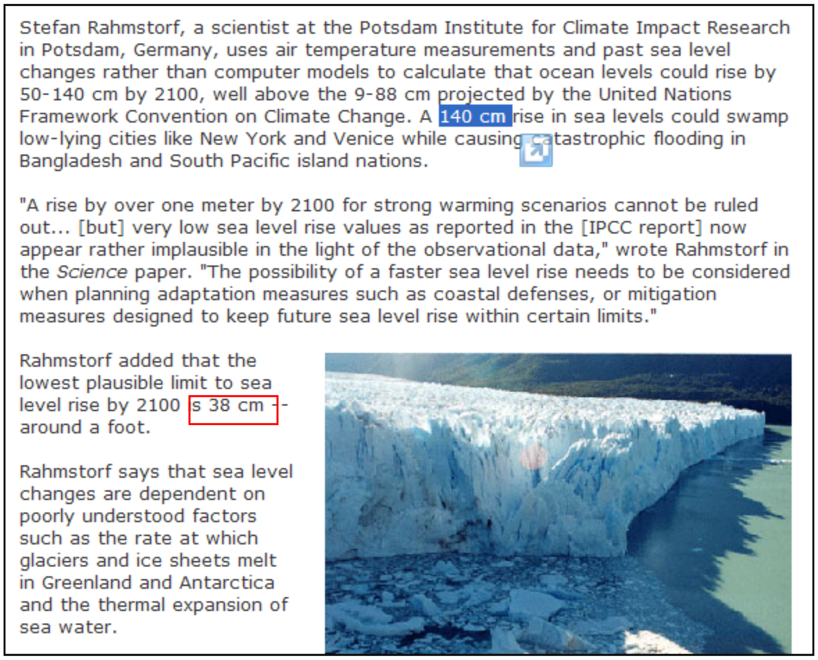


Figure 9: (Left) Shows the Contour Window used to define a single contour (in this case) of the shoreline.

Figure 10: (Below) Screenshot of the DEM with the new shoreline contour line (Zero elevation).



6) In order to find some reasonable estimates of Sea level rise in 2100, some research was needed.
   a. Research found the following website:
      i. http://news.mongabay.com/2006/1214-sea_level.html



Stefan Rahmstorf, a scientist at the Potsdam Institute for Climate Impact Research in Potsdam, Germany, uses air temperature measurements and past sea level changes rather than computer models to calculate that ocean levels could rise by 50-140 cm by 2100, well above the 9-88 cm projected by the United Nations Framework Convention on Climate Change. A 140 cm rise in sea levels could swamp low-lying cities like New York and Venice while causing catastrophic flooding in Bangladesh and South Pacific island nations.

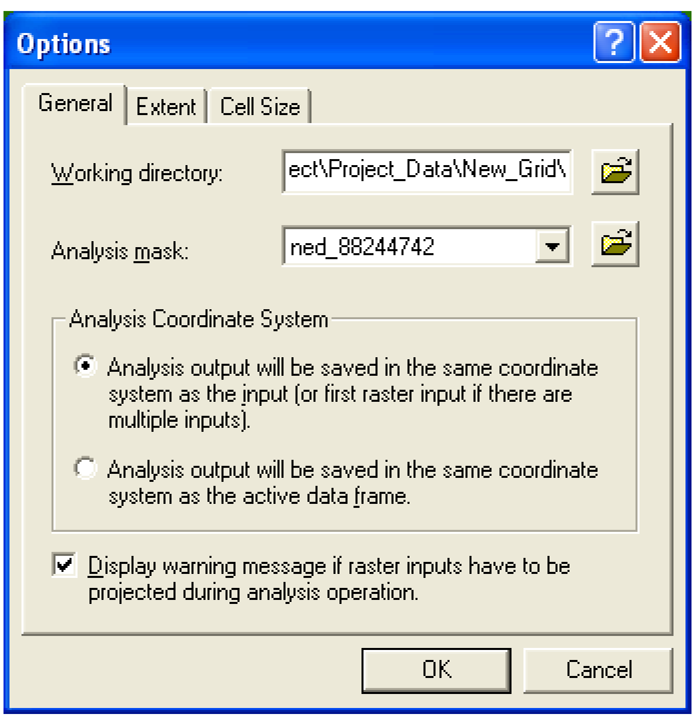
"A rise by over one meter by 2100 for strong warming scenarios cannot be ruled out... [but] very low sea level rise values as reported in the [IPCC report] now appear rather implausible in the light of the observational data," wrote Rahmstorf in the *Science* paper. "The possibility of a faster sea level rise needs to be considered when planning adaptation measures such as coastal defenses, or mitigation measures designed to keep future sea level rise within certain limits."

Rahmstorf added that the lowest plausible limit to sea level rise by 2100 is 38 cm -- around a foot.

Rahmstorf says that sea level changes are dependent on poorly understood factors such as the rate at which glaciers and ice sheets melt in Greenland and Antarctica and the thermal expansion of sea water.

Figure 11: A reliable article, estimating sea level to rise higher than predicted from 0.38m to 1.4m.

7) Create a new DEM with a predicted sea level rise of 0.38m
   a. First, more advanced Spatial Analyst functions require one to create an Analysis Mask as shown in **Figure 12**.



"Before beginning any Spatial Analyst procedures always set the Options. Most functions within this extension create new grids (rasters) by performing operations on old grids. **It is imperative that you set a Working directory**, so that these new grids are saved in a place where you can retrieve them."

-Dr. Helper, Lab 6-

Figure 12: (Left) Showing the Spatial Analyst Options window with the Analysis Mask Set to the DEM we are working with.

b. Use the Raster Calculator to raise the water level/ lower the land level by 0.38m as seen in **Figure 13**.

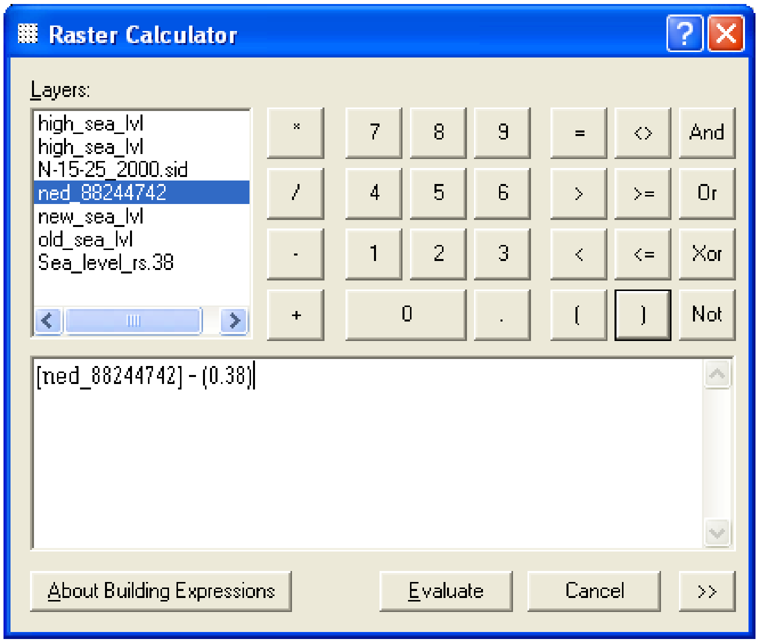
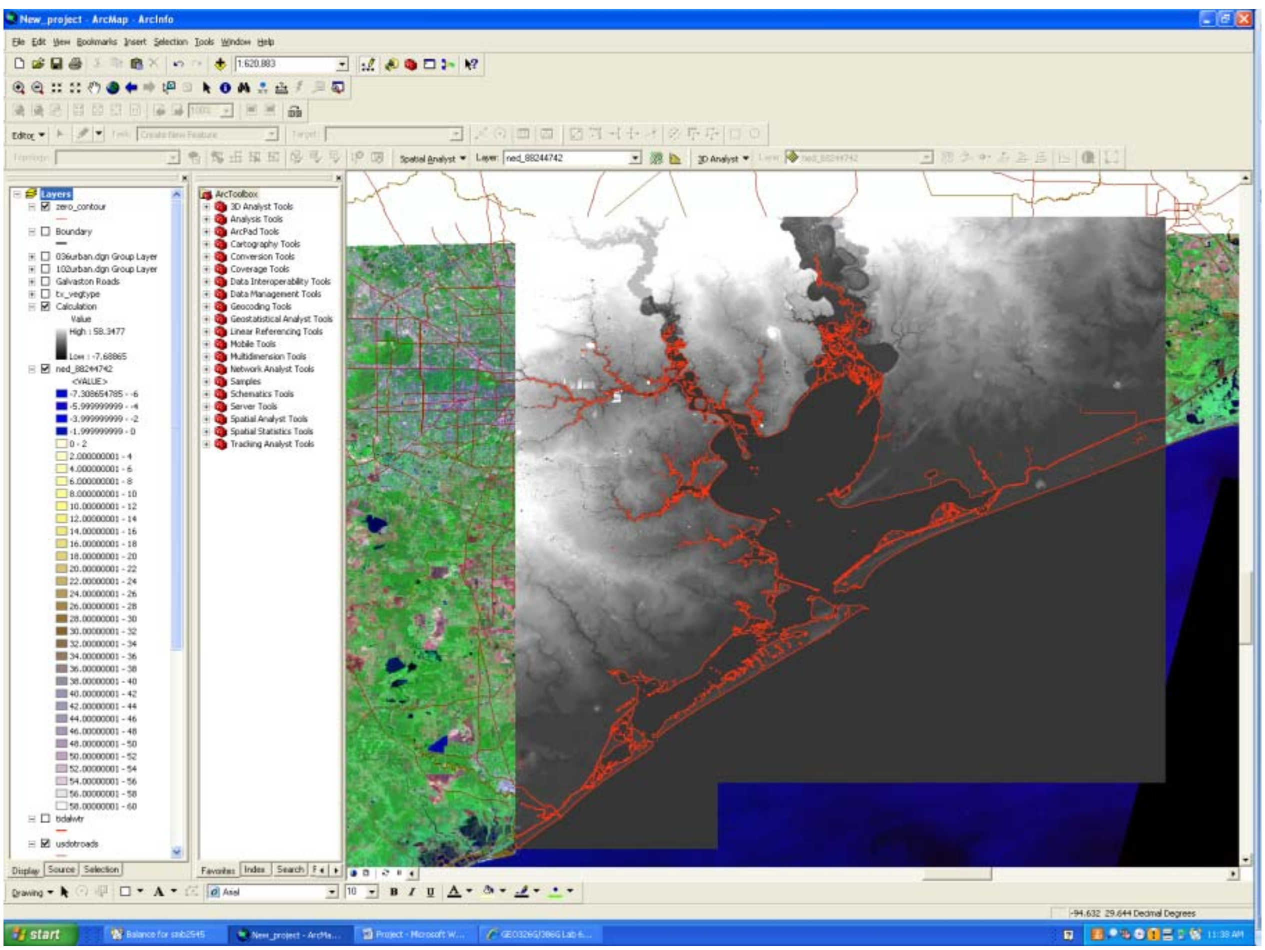


Figure 13: (Left) shows the equation used to lower the land by 0.38m hence raising the water level by 0.38m.

Figure 14: (Below) Shows the new DEM created (black and white) and the shoreline that corresponds to the new rise in sea level. Shown in Red.



8) Create a "Zero elevation" Contour for the new rise in sea level.
   a. Use the same steps as before
      i. First one must make sure the Spatial Analyst Extension is on by going to Tools and then Extensions.
      ii. Then under the Spatial Analyst Drop down Menu, select Surface Analysis and Contour…
      iii. This will open the Contour Window as seen in **Figure 15**. In the Input Surface: HS_Rise.38 (the DEM) and make the base contour: 0 for sea level and the contour Interval: 60m (or anything above the largest elevation on the DEM).
      iv. This will give you a shore line like that in **Figure 14**.

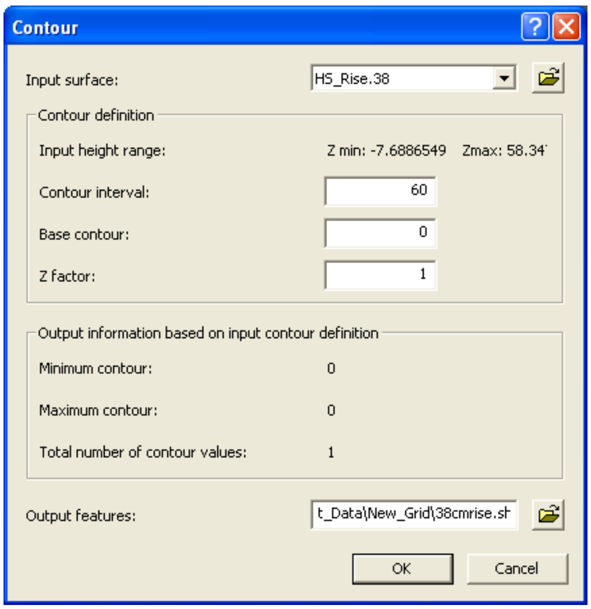


Figure 15: (Left) Shows the Contour Window used to define a single contour (in this case) of the new shoreline.

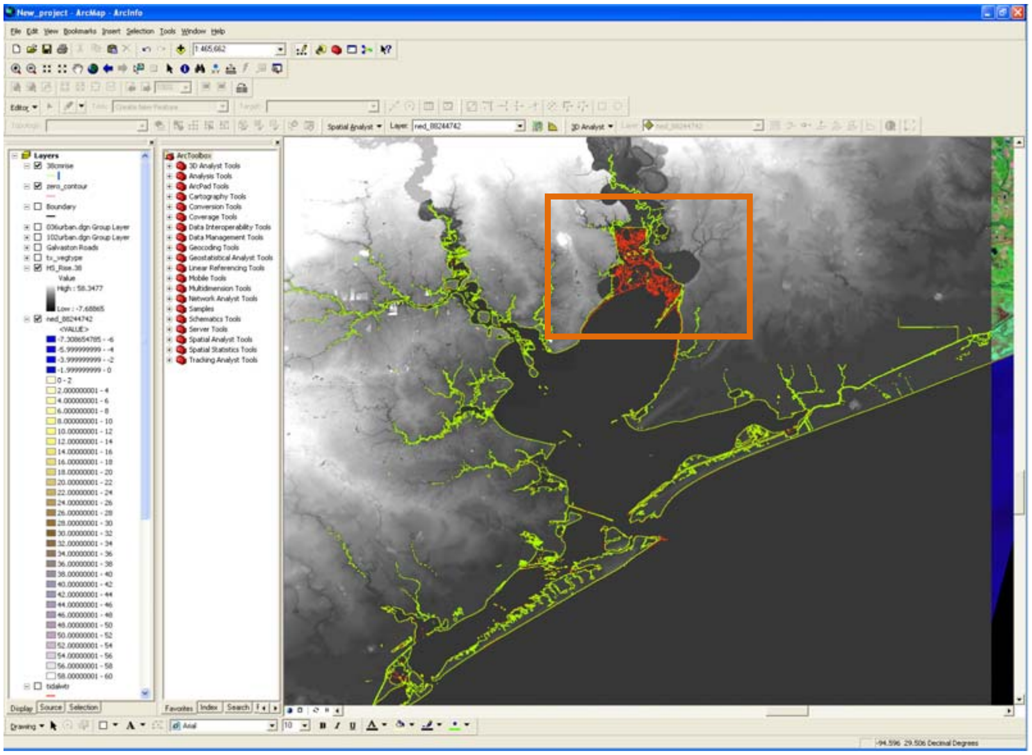
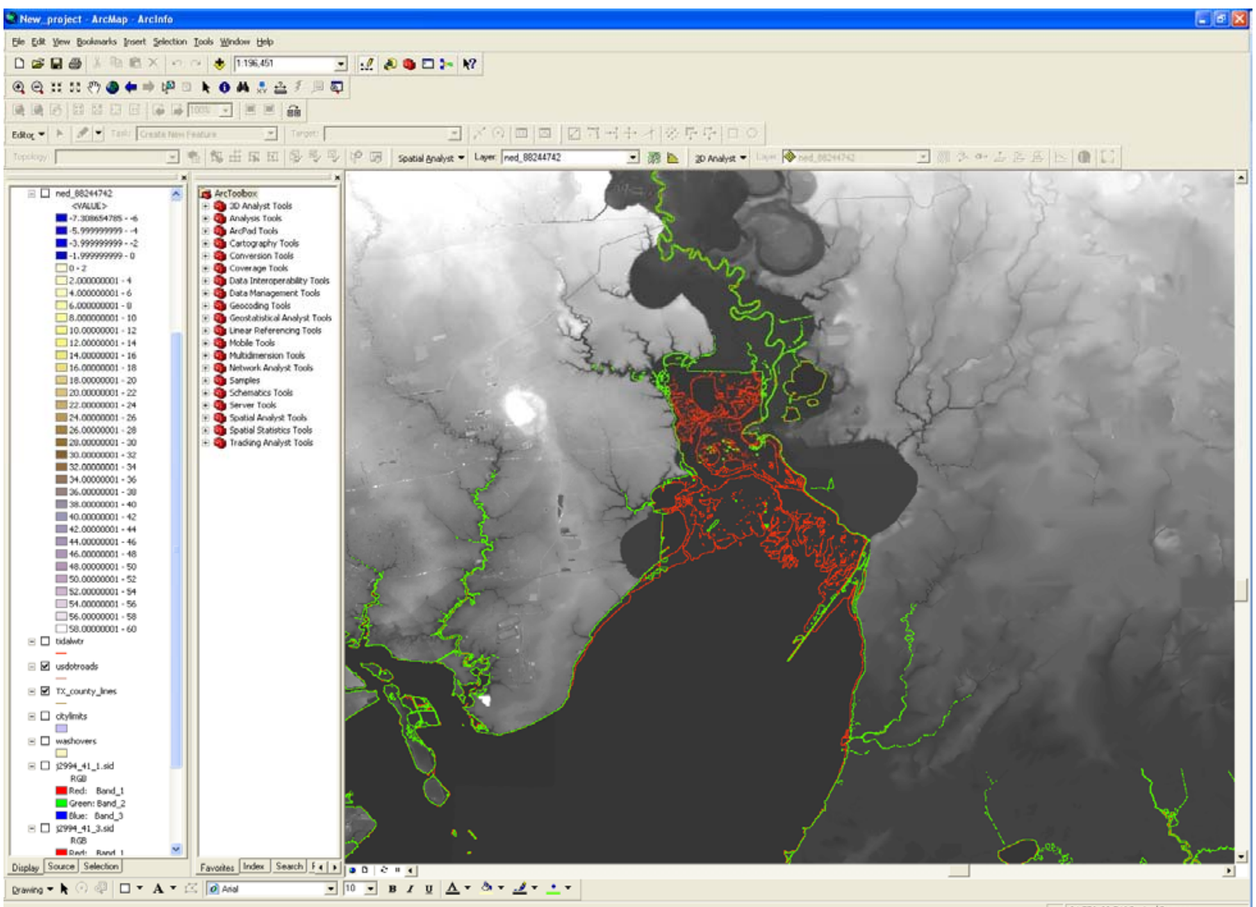


Figure 16: (Left) shows the addition of the new high level of 0.38m in Green with the Red (original Sea level) underneath.

Figure 17: (Below) shows a zoom in on a major area that is affected.



9) Create a new DEM with a predicted sea level rise of 1.40m

   a. Use the same processes as before and use the Raster Calculator as shown in **Figure 18**.

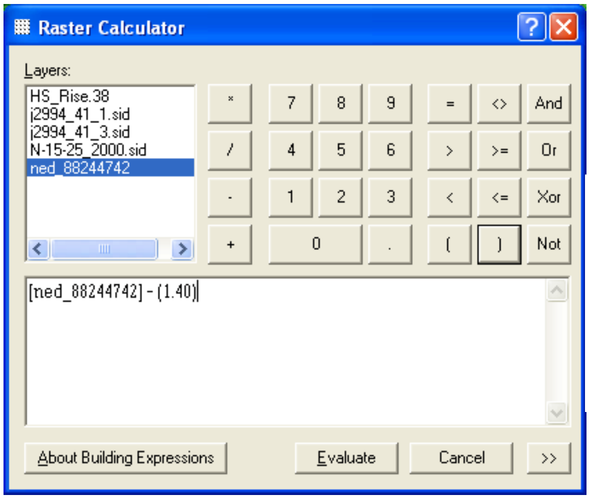


Figure 18: (Left) shows the equation used to lower the land by 1.40m hence raising the water level by 1.40m.

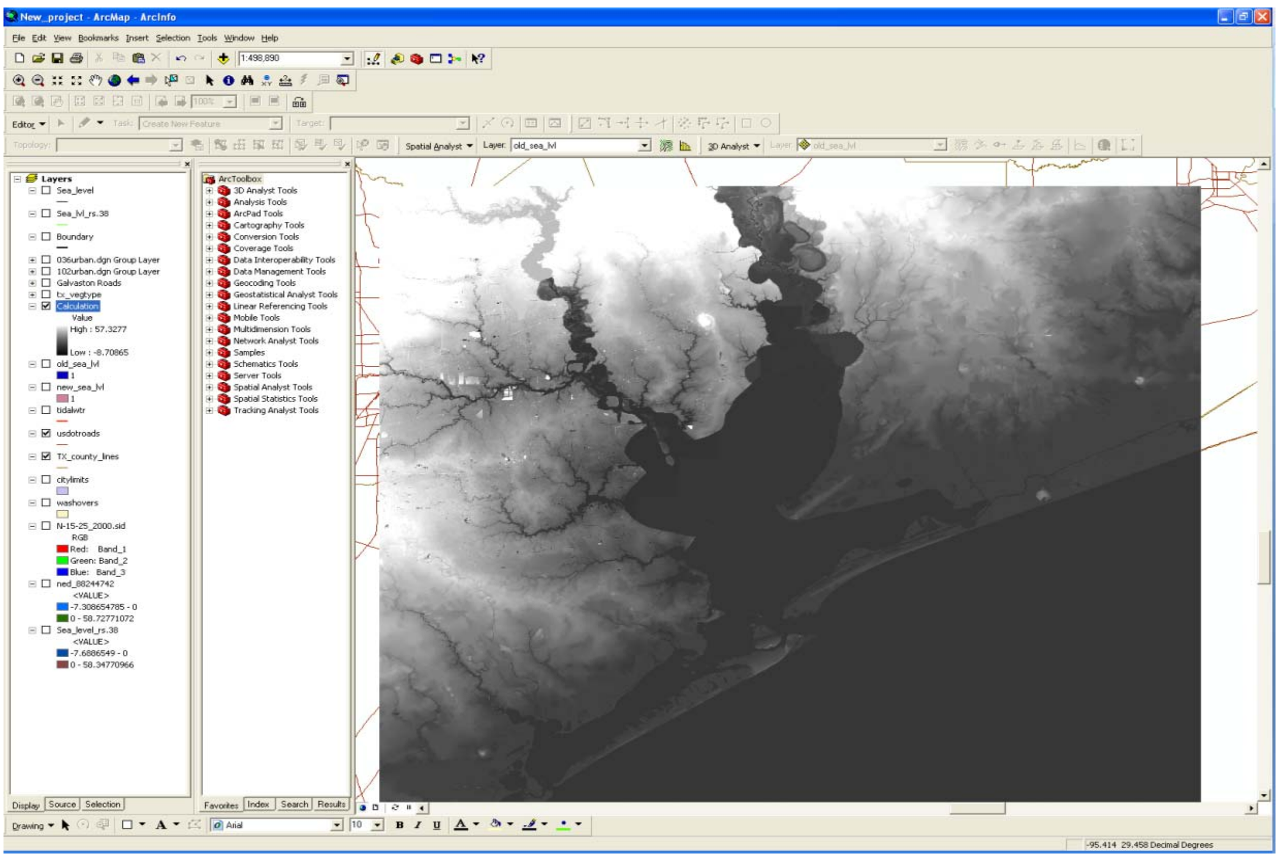


Figure 19: (Above) The created DEM for a rise of 1.40m of sea level.

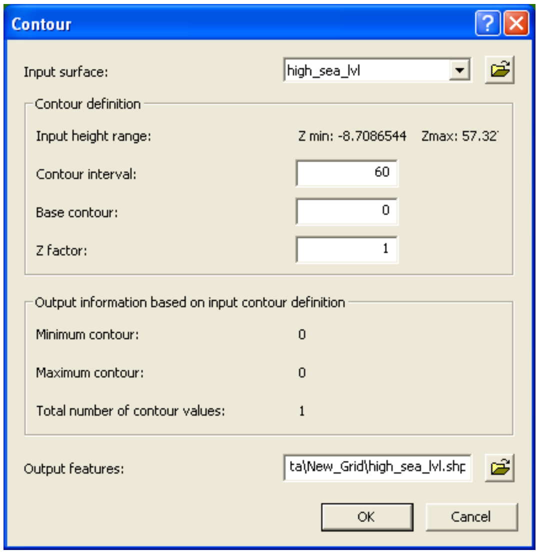


Figure 20: (Left) Shows the Contour Window used to define a single contour (in this case) of the new shoreline of 1.40m.

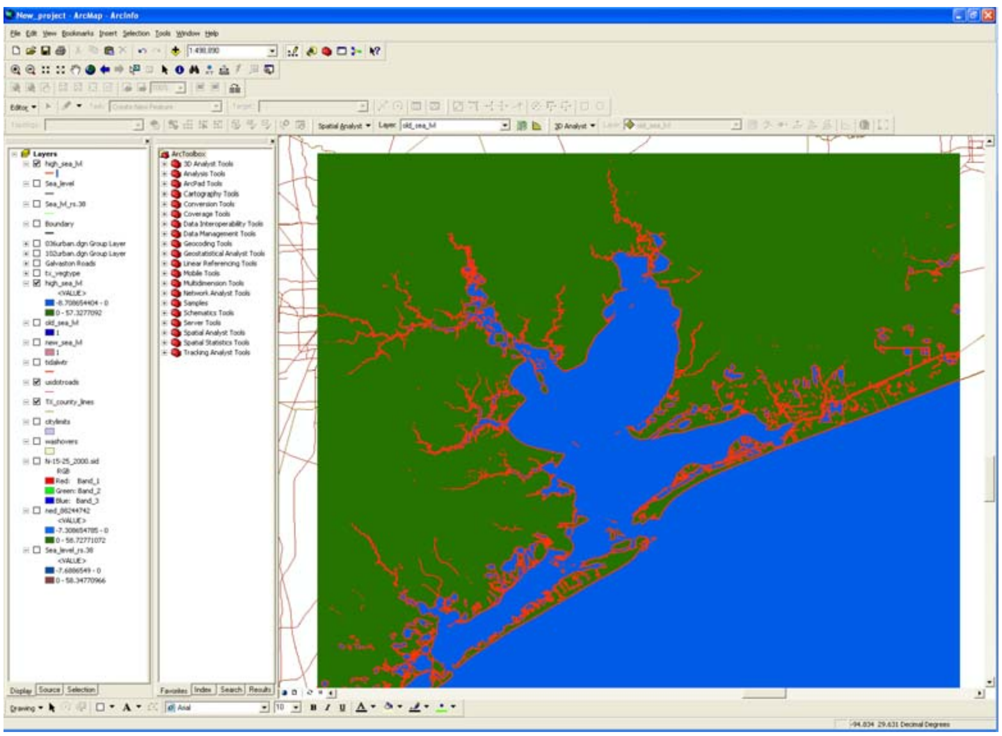


Figure 21: Shows the Sea Level at the highest projected increase of 1.40m, Shoreline in red.

10) Classified the two new rasters into defined intervals of 2m
    a. 0.38m increase raster

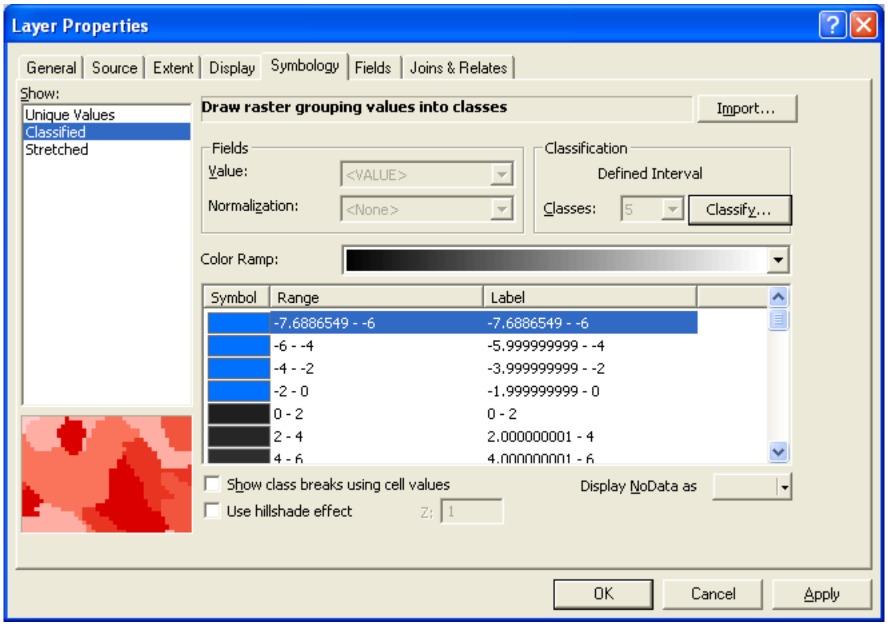


Figure 21: (Top Left) Layer Properties window showing the Symbology Tab with Classified Field highlighted. Also shows the new classification scheme of 2m intervals and the new color ramp with everything below sea level in blue.

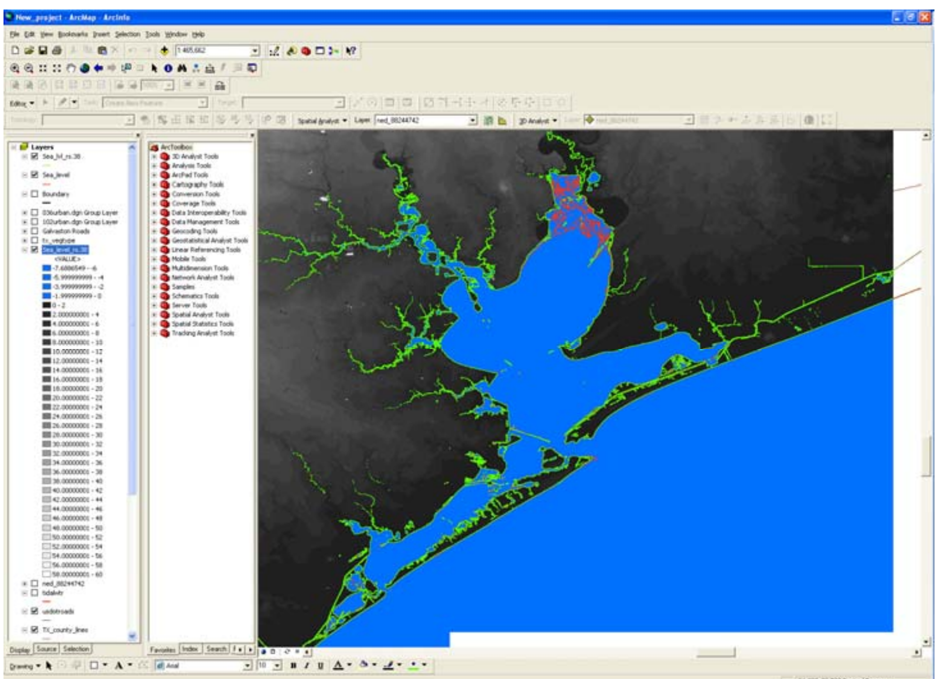


Figure 22: (Left) Shows the rise of 0.38m with the water blue and the shoreline in green.

11) Create a Binary Raster from the old sea level and the new sea levels.
    a. First one must classify the Raster to only have 2 classes

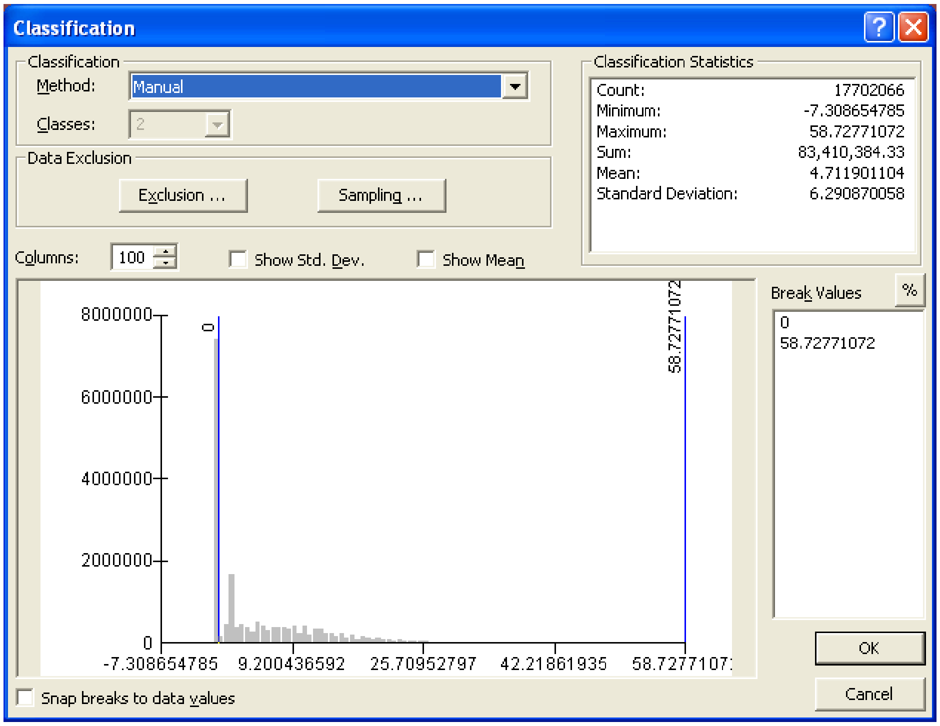


Figure 23: (Left) Classifying the original DEM into 2 classes

Symbolize them accordingly as shown below:

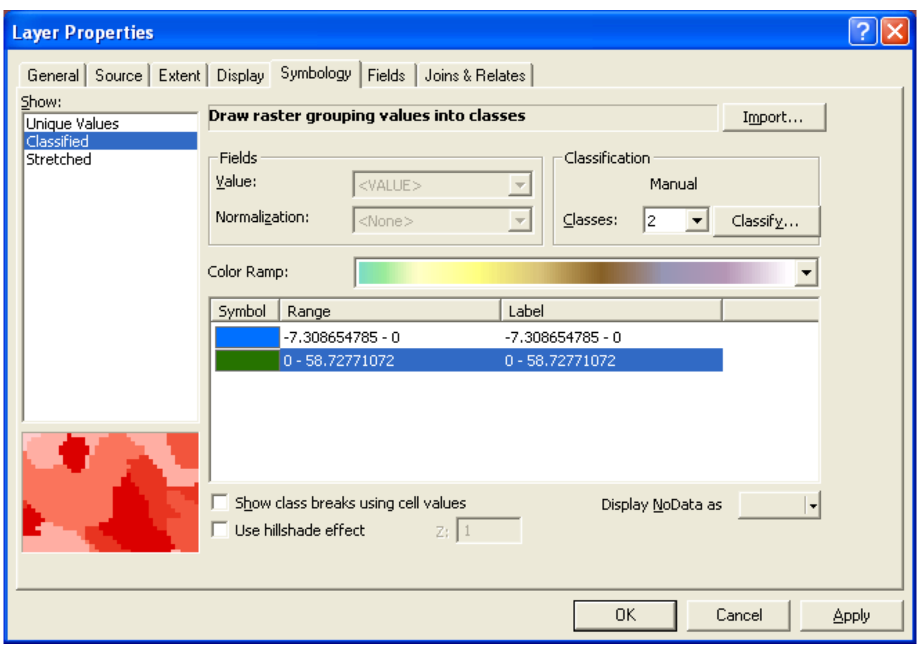


Figure 24: (Left) Water symbolized as blue and land symbolized as green.

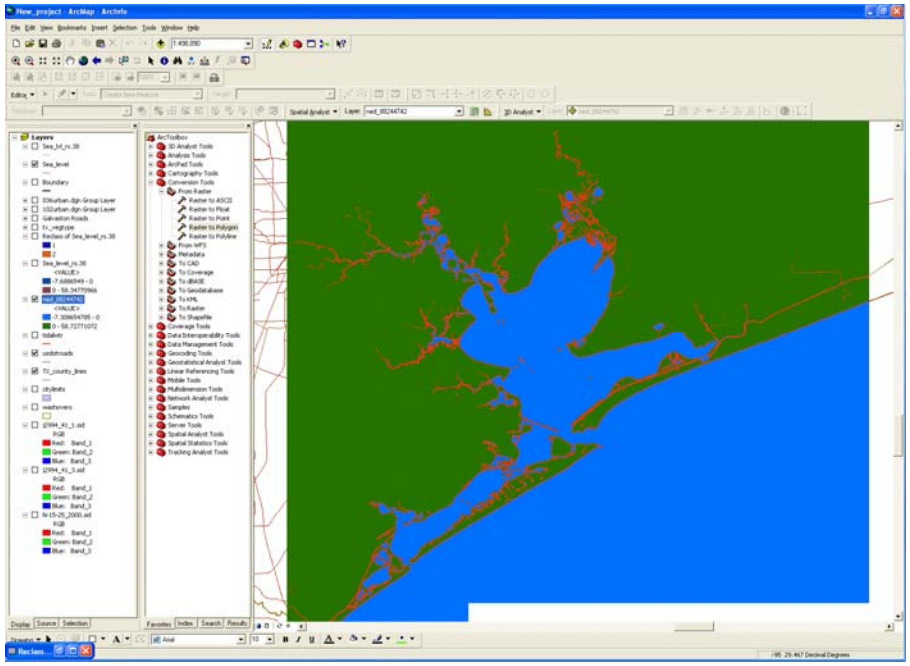


Figure 25: (Above) shows the original DEM with the new 2 class raster with shoreline in red.

12) Then you must Reclassify the two Classes into a binary raster

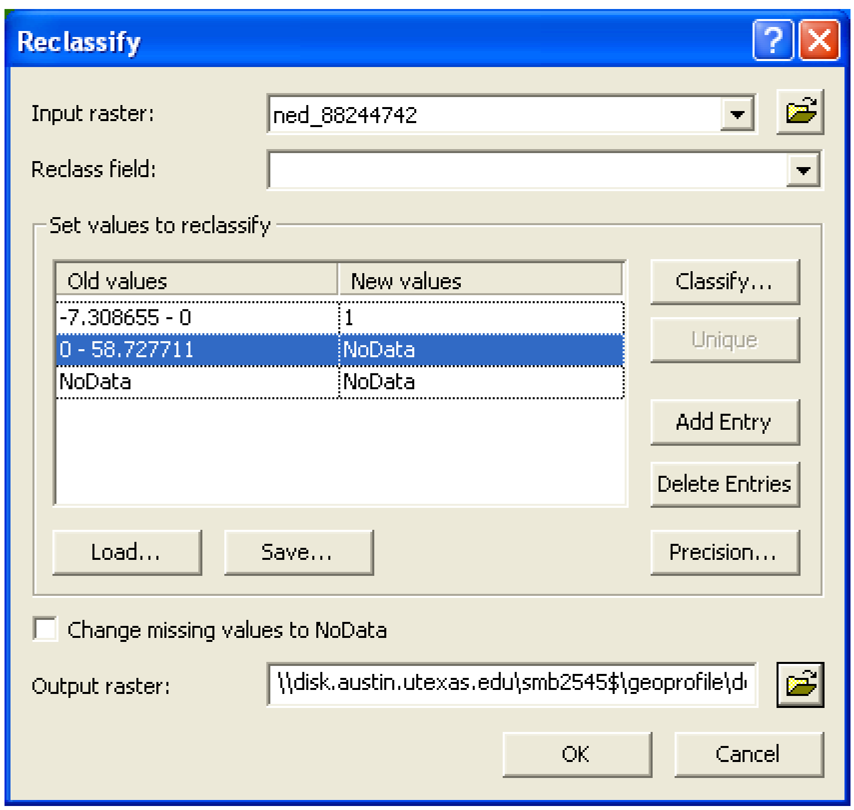


Figure 26: (Left) Shows the Reclassify window with giving values only to the cells at or below sea level.

a. With the following results:

i. A raster with only the values of the area that is below or at sea level as in **Figure 27.**

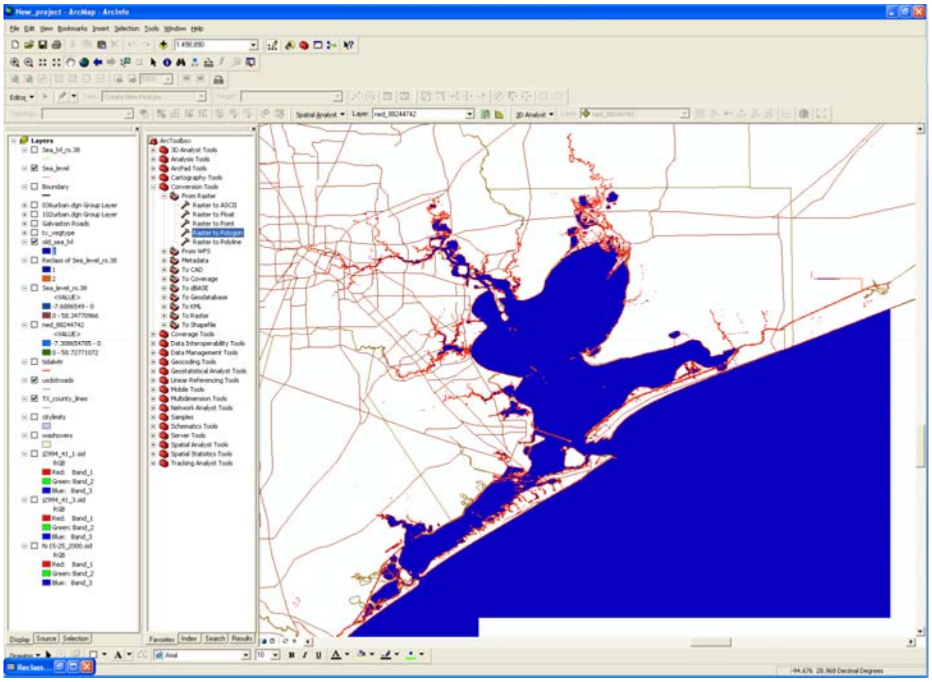


Figure 27: (Left) A raster with only the values of the area that is below or at sea level

13) Do the same procedure with the new sea level of a rise of.38m and 1.40m

a. With the same results

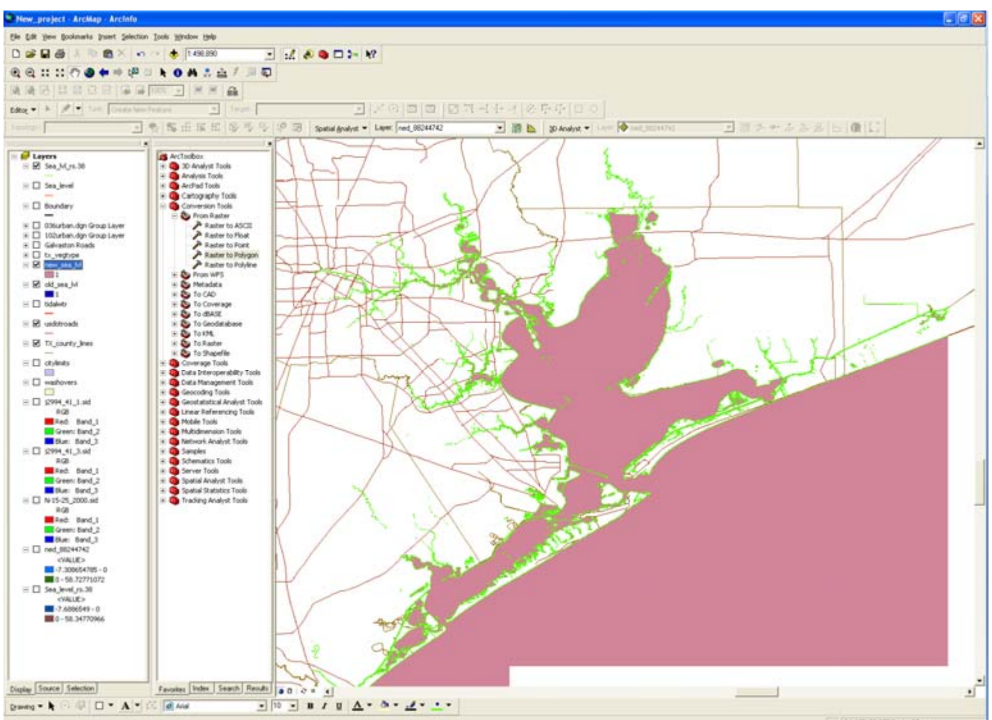


Figure 28: (Left) A raster with only the values of the new rise in sea level that are below or at the new sea level, shown in pink with the shoreline in green.

14) Layering the old and new layers on top of each other, the following results are reached.

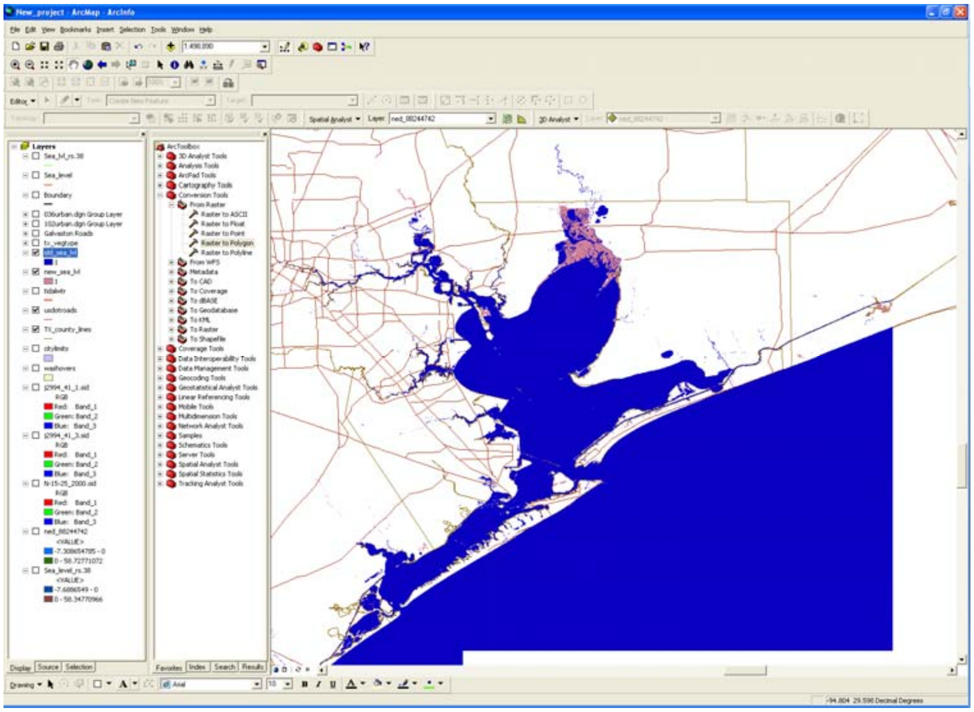


Figure 29: (left) Layering the data on top of one another gives the affected area. Original sea level in Blue and the rise of 0.38m in pink.

15) To calculate the area of the effected land, the following steps must be taken:

   a. Find the Cell Size of the Rasters

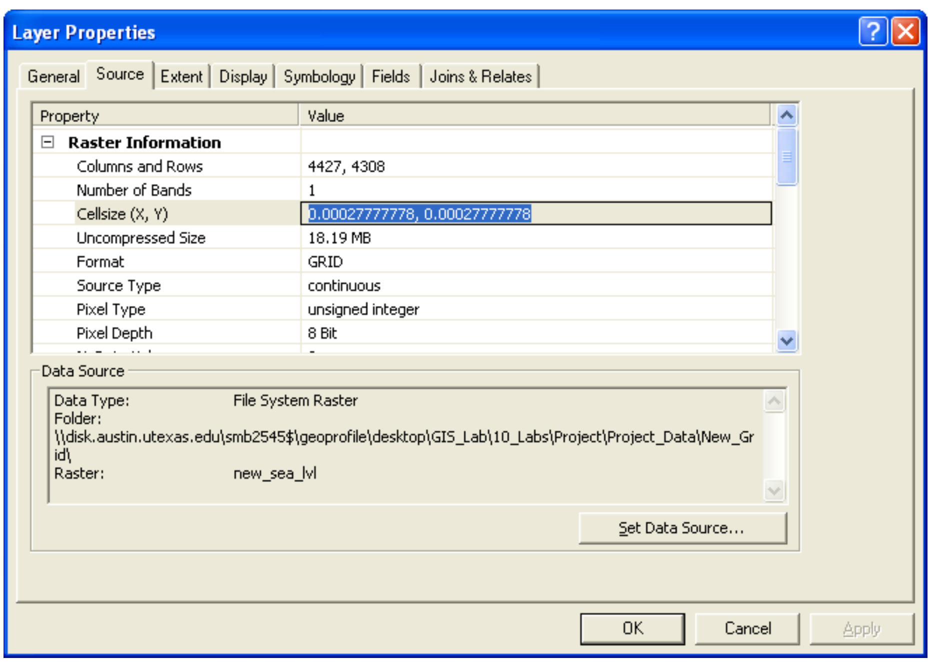


Figure 30: (Left) shows the Layer Properties window with the Cell size highlighted.

b. Find the total Cells of each of the Rasters:
   i. New_sea_lvl_0.38 : 7503956 cells
   ii. Old_sea_lvl : 7379845 cells

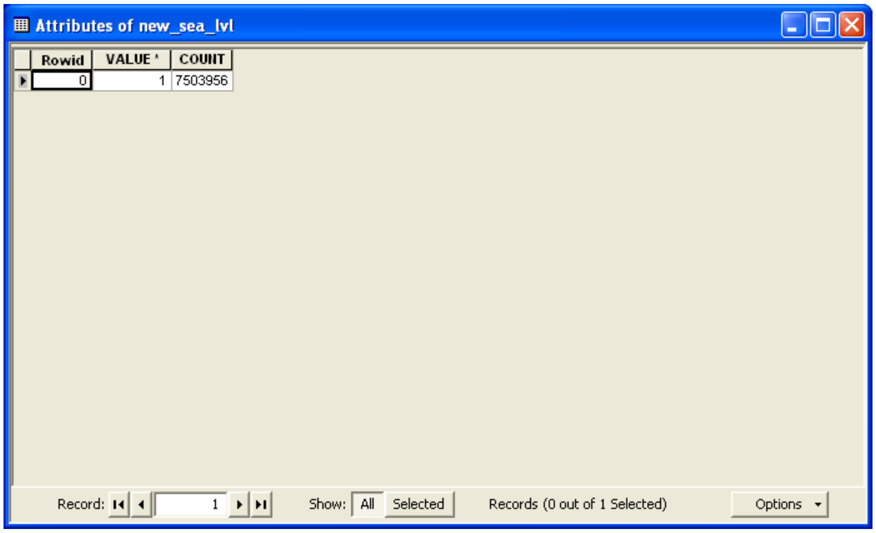


Figure 31: (left) shows the number of cells within the New raster created for the rise in sea level of 0.38m.

b. Since the Cell Size units are in degrees I had to multiply the cell size by 1/120 to get it into kilometers.
   i. 0.00027777778 = 1 arc sec = 30.72222222222m
   ii. $30.72222222222^2 = 943.8549383m^2$ per cell

c. Multiply the total number of cells of each Raster by the cell size:
   i. New_sea_lvl Area: 943.8549383 * 7503956 = 7,082,645,927 m^2 =
   ii. Old_sea_lvl Area: 943.8549383 * 7379845 = 6,965,503,147 m^2 =

d. Then Subtract the old from the new

7,082,645,927 m^2 - 6,965,503,147 m^2 = 117,142,780.1 m^2

16) Calculate the area affected by the rise in sea level to 1.4m
   a. Since the Cell Size units are in seconds of a degree, and 1” = 33.333333meters
      i. 0.00027777778 = 1 sec = 30.72222222222 m
      ii. $30.72222222222^2 = 943.8549383\ m^2$ per cell

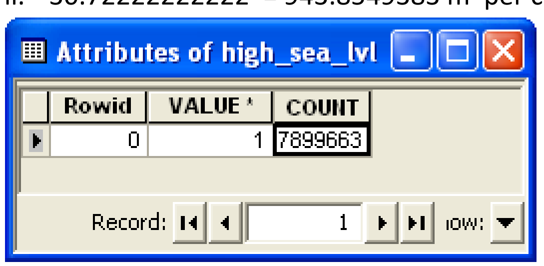


Figure 32: shows the number of cells within the New raster created for the rise in sea level of 1.4m

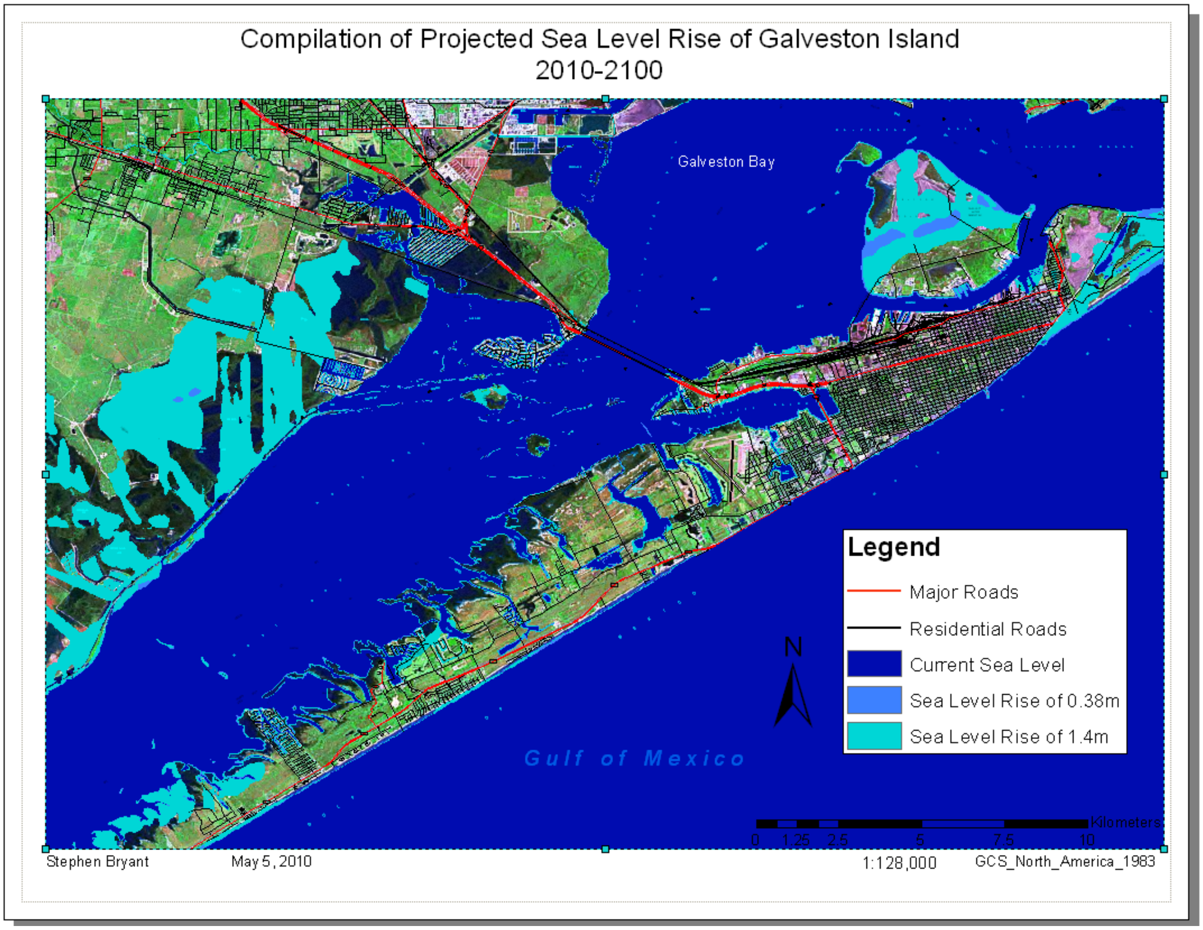
b. Multiply the total number of cells of each Raster by the cell size:
   i. high_sea_lvl 1.40 Area: 943.8549383 * 7899663 = 7,456,135,933 m^2 =
   ii. Old_sea_lvl Area: 943.8549383 * 7379845 = 6,965,503,147 m^2 =

c. Then Subtract the old from the new

7,456,135,933 m^2 – 6,965,503,147 m^2 = 490,632,785.9 m^2

IV) Results

What will Galveston look like in 2100?



Given the low and high predictions of sea level rise for 2100, what will the effects be on coastal waterways and barrier islands around Galveston Bay?

If the sea level rises 0.38m an estimated 117,142,780.1 m^2 of land will be covered with water. If the sea level rises 1.4m an estimated 490,632,785.9 m^2 of land will be covered with water. Luckily, the affected areas are mostly already marshland and are not developed. Some of the low lying Islands will be affected.