How would San Francisco be affected if sea level continues to rise?

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GEO 327 G

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PROBLEM:

The California coastline is home to millions of people, tourism attractions and economic businesses. If sea level continues to rise at the present average of 1.94 millimeters per year, then the San Francisco shoreline will be affected with only a 2-meter sea level rise. Therefore, if models are not created to show where land is first interrupted during a gradual sea level rise process or abrupt storm, then it becomes harder to warn people at risk and save valuables. It is important to visually show what areas are most at risk and how long it will take for damage to occur due to sea level rise for future city planning and for the sake of the most populated state in the country.

GOAL:

My goal is to produce a map of the California coastline highlighting the San Francisco area by utilizing GIS and spatial analysis techniques to show what the land will look like in the future when sea level rises. This map will demonstrate what parts of the state and bay will be affected first and how sea level rise will affect the city and surrounding areas. The map will be created using raster data to produce an elevation model and shape files to show accurate location.

DATA ACQUISITION:

- Mean Sea Level Trend Data of San Francisco
  - https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9414290

- US Urban Area Data
  - https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2016&layergroup=Urban+Areas

- San Francisco Raster Elevation Data
  - http://www.ngdc.noaa.gov/docucomp/page?xml=NOAA/NESDIS/NGDC/MGG/DEM/iso/xml/741.xml&view=getDataView&header=none

- California County ShapeFile Data
  - http://www.scec.usc.edu/internships/useit/content/california-counties-shapefiles

- San Francisco Offshore Bathymetry
  - http://pubs.usgs.gov/ds/781/OffshoreSanFrancisco/data_catalog_OffshoreSanFrancisco.html

METHODS:

Step 1

First, I opened a blank ArcMAP file and set the coordinate system to San Francisco's UTM zone, NAD 1983 UTM Zone 10N (Figure 1) by right clicking Layers>Properties>Coordinated Systems>Projected Coordinate Systems>UTM>NAD 1983>NAD 1983 UTM Zone 10N.

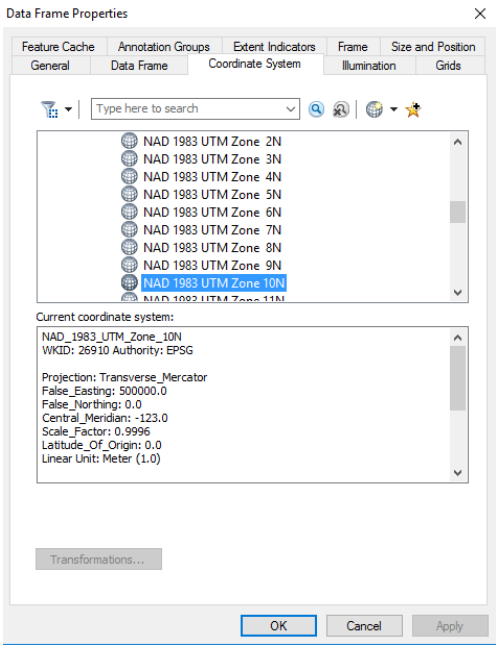

Figure 1: Coordinate system set to NAD 1983 UTM Zone 10N

Step 2

Then, I added the California County shapefile (figure 2) downloaded from the following website,

www.scec.usc.edu/internships/useit/content/california-counties-shapefiles, to outline the state of California and its counties. Before adding it to ArcMap, I set the file's coordinated system by right clicking the file in ArcCatalog>Properties>XY Coordinate System>Geographic Coordinate Systems>North America>NAD 1983.

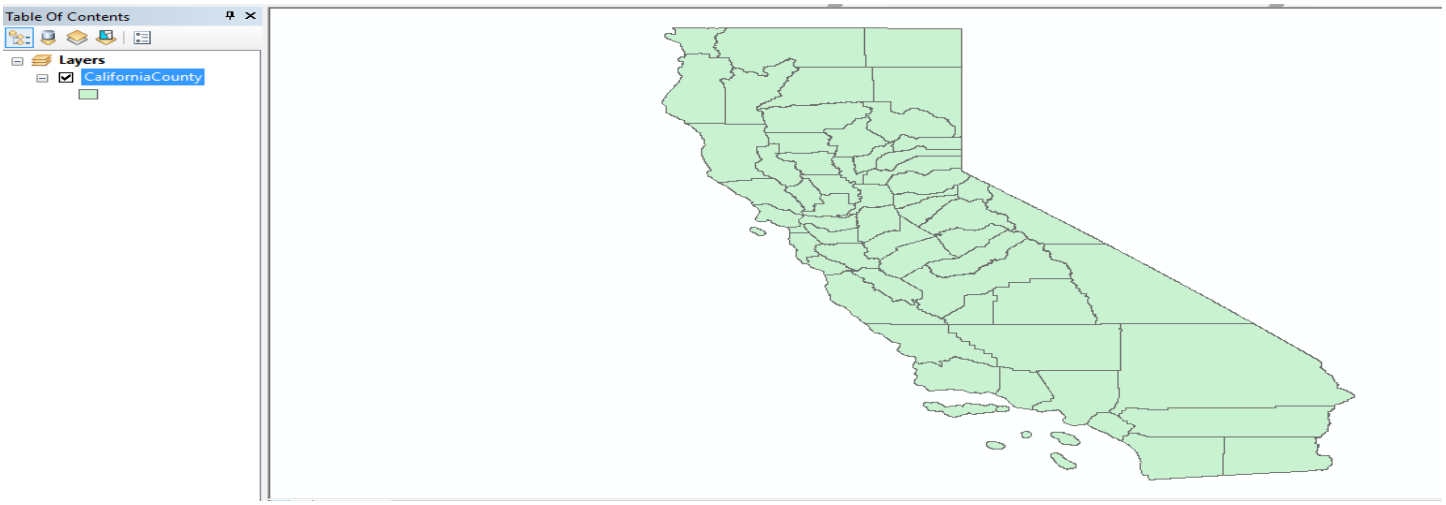

Figure 2: California County shapefile added to ArcMAP

Step 3

In order for the map to depict sea level rise accurately, I had to use a Digital Elevation Model (DEM) of the area of interest with a 10-meter resolution. I added the San Francisco Bay Raster Elevation file (figure 3) downloaded from,www.ngdc.noaa.gov/docucomp/page?xml=NOAA/NESDIS/NGDC/MGG/DEM/iso/xml/741.xml&view=getDataView&header=none, to show the targeted area's elevation and topography. I also made sure its coordinate system was NAD 1983 before adding it to the map.

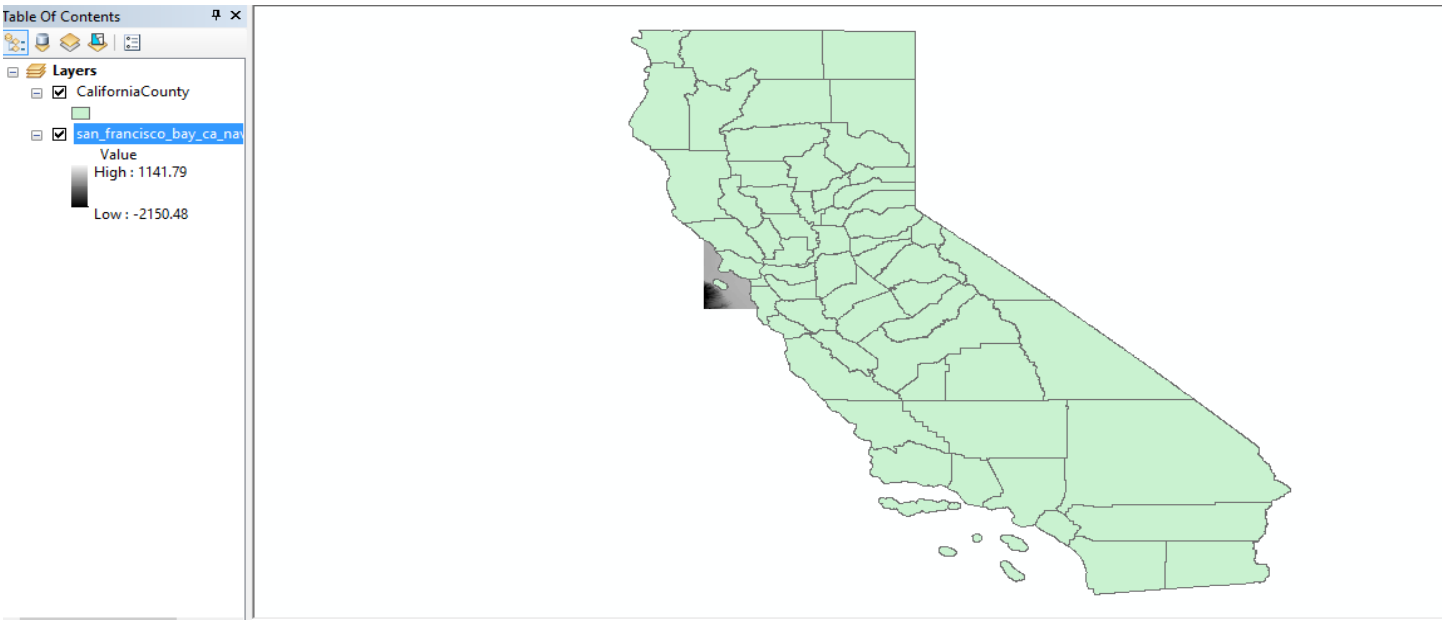

Figure 3: San Francisco Bay Raster Elevation file added to ArcMAP

Step 4

The US Urban Area shapefile was then added to the map (figure 4) downloaded from, www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2016&layergroup=Urban+Areas, to show the most populated areas in the California. As always, I changed the coordinate system to NAD 1983. But then I clipped the file to only show California urban data (figure 5&5b) by using the clip tool.

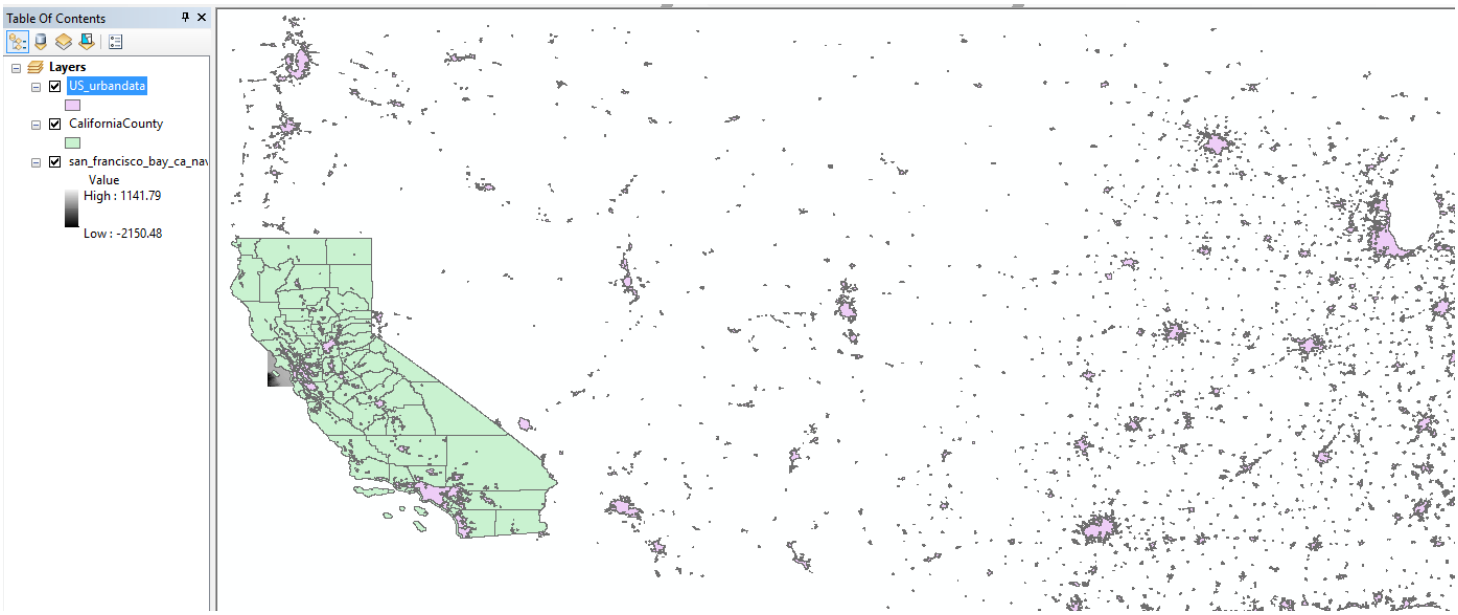

Figure 4: US Urban Area shapefile added to ArcMAP

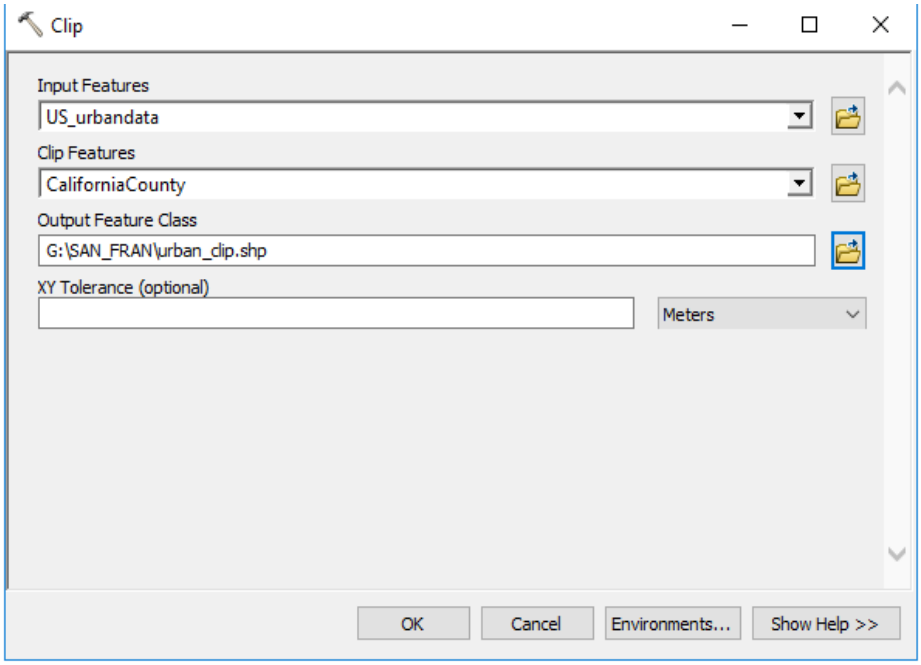

Figure 5: Clipping US Urban Area shapefile

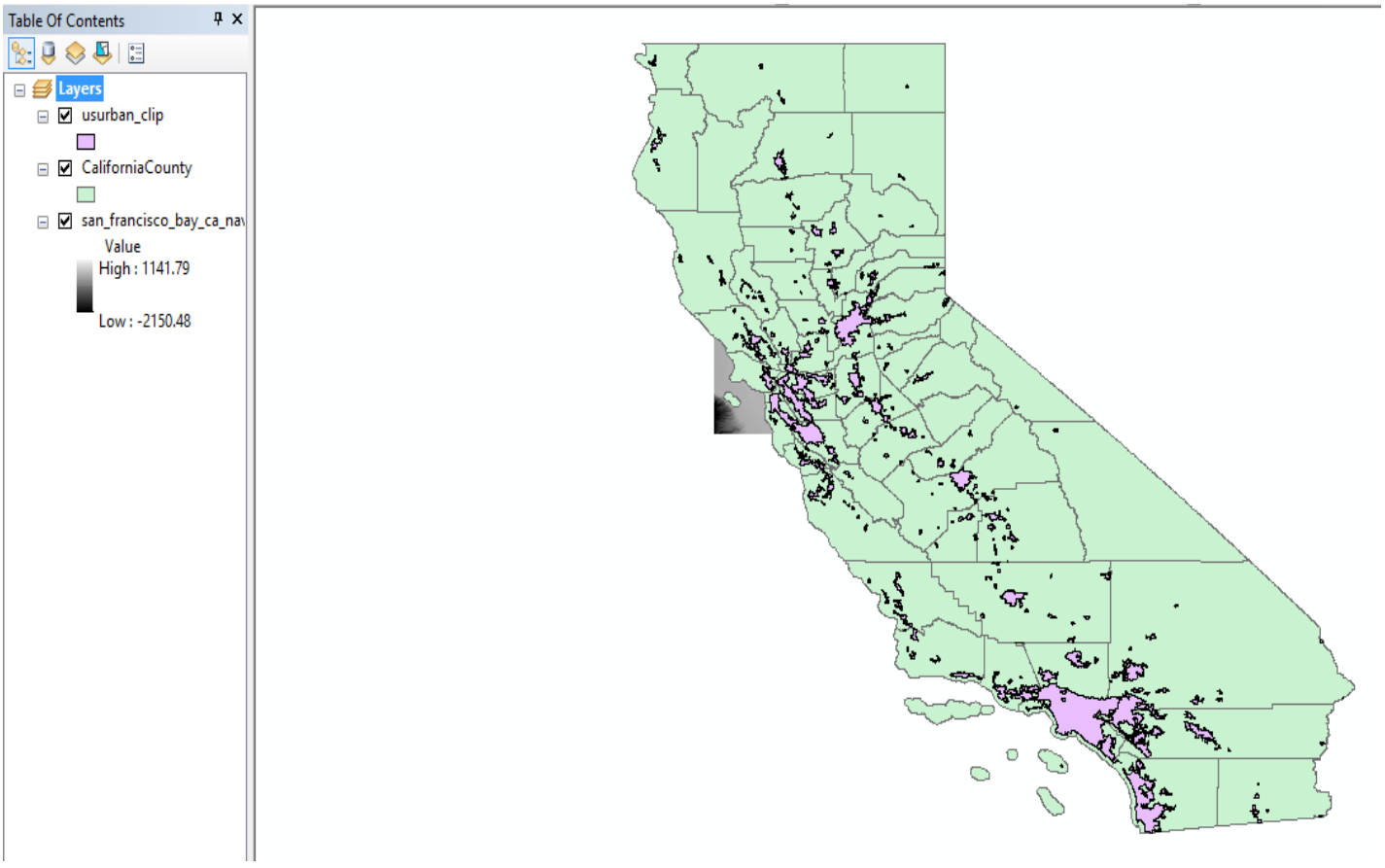

Figure 5b: Clipped US Urban Area file

Step 5

To clearly identify the San Francisco area in the map (figure 6), I first labeled the counties by right clicking the county shapefile in the TOC>Label Features, then I zoomed into San Francisco. But in order to clearly see San Francisco's elevation I had to change the transparency of the urban data shapefile by right clicking the file in the TOC>Properties>Display>Transparent:40% and changing the counties symbology to hollow with green outlines by right clicking the county's file in the TOC>Symbology>Symbol>No Fill Color and Outline Color: Green.

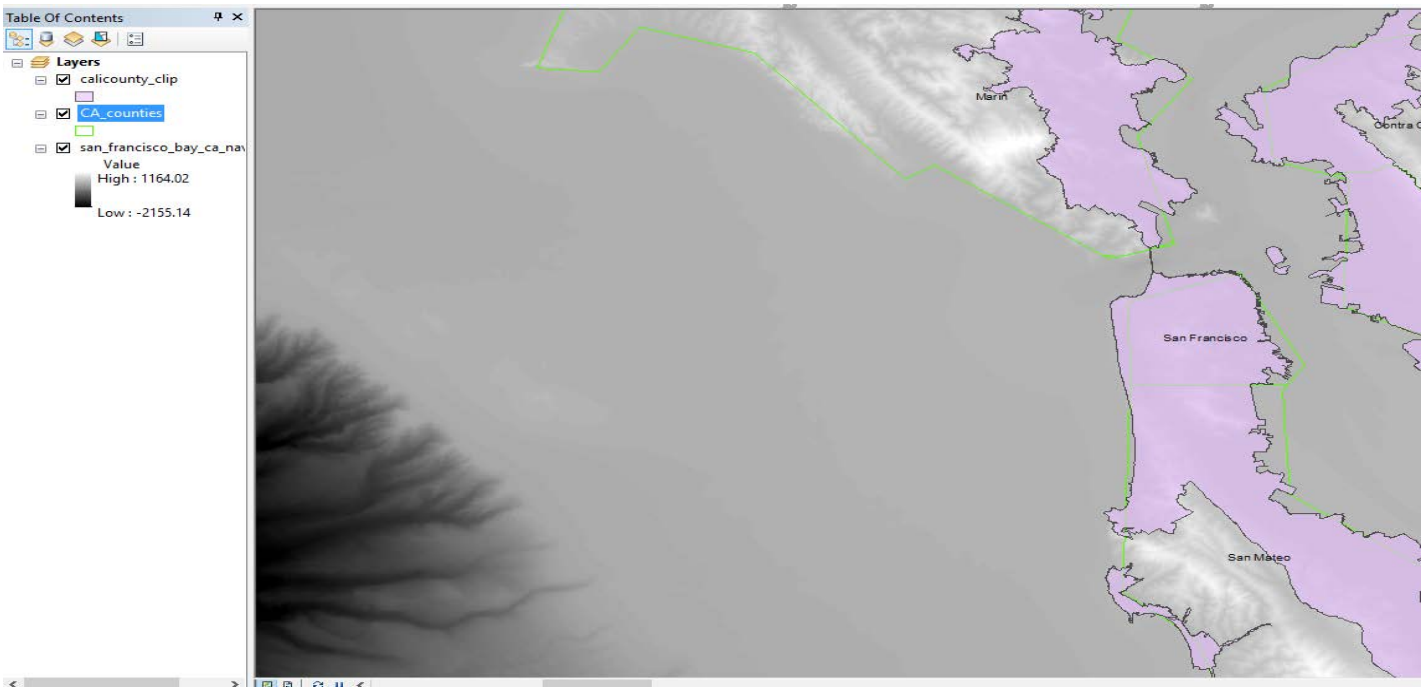

Figure 6: Edited map to clearly identify San Francisco area.

Step 6

To clearly see the break in slope of the coast, I created a hillshade of my DEM using the Spatial Analyst Hillshade tool. First I turned on the Spatial Analyst and 3D Analyst extensions by clicking Customize>Extensions. Then I created the hillshade by clicking ArcToolbox> Spatial Analyst Tools>Hillshade (figure 7). Lastly, I placed the hillshade layer under all layers and changed the DEM transparency to 40% (figure 8) to better see the hillshade layer.

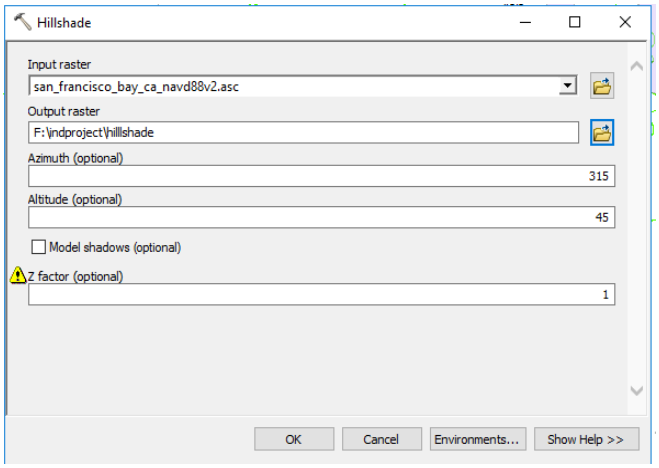

Figure 7: Hillshade (Spatial Analyst) tool

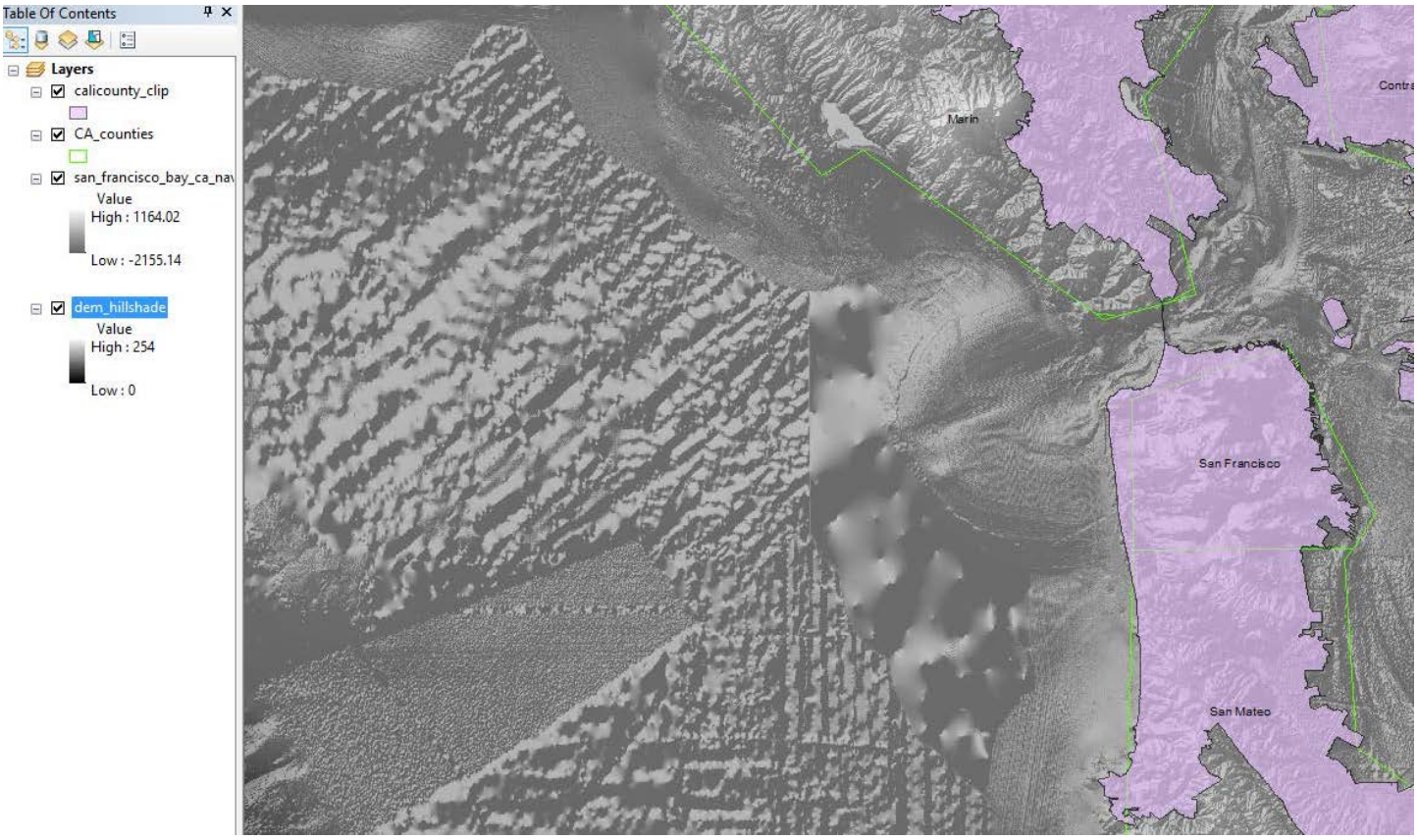

Figure 8: Hillshade added to ArcMAP

Step 7

I then edited the DEM layer to better show topography (figure 10) by changing its color scheme to more a realistic topography color by right-clicking the layer in the TOC>Properties>Symbology>Stretched>Color Ramp>Spectrum-Full Bright and Invert Checked>OK (figure 9).

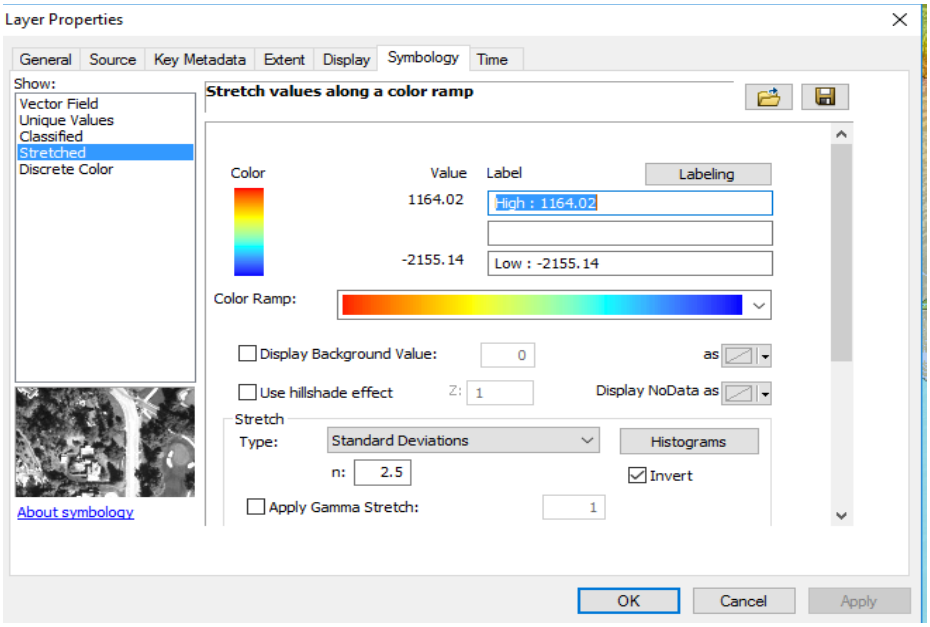

Figure 9: Edited DEM layer

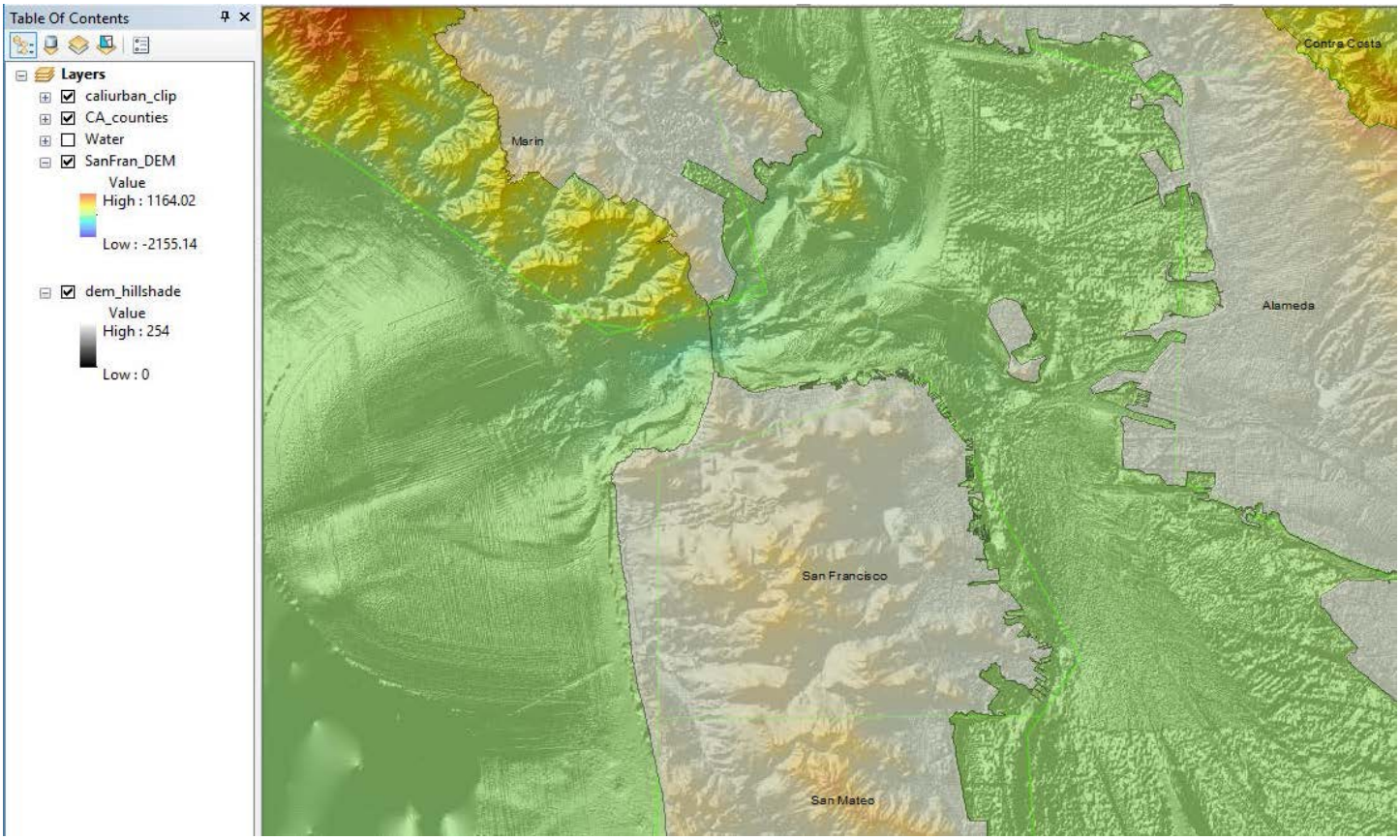

Figure 10: DEM layer with a more realistic color added to ArcMap.

Step 8

I then created a Binary Raster to show the parts of the map that are currently below sea level by clicking ArcToolbox>Spatial Analyst Tools>Map Algebra>Raster Calculator and typed in the conditional statement Con("SanFran_DEM" <= 0,1) (figure 10). Figure 11 shows the calculated layer as water on the map.

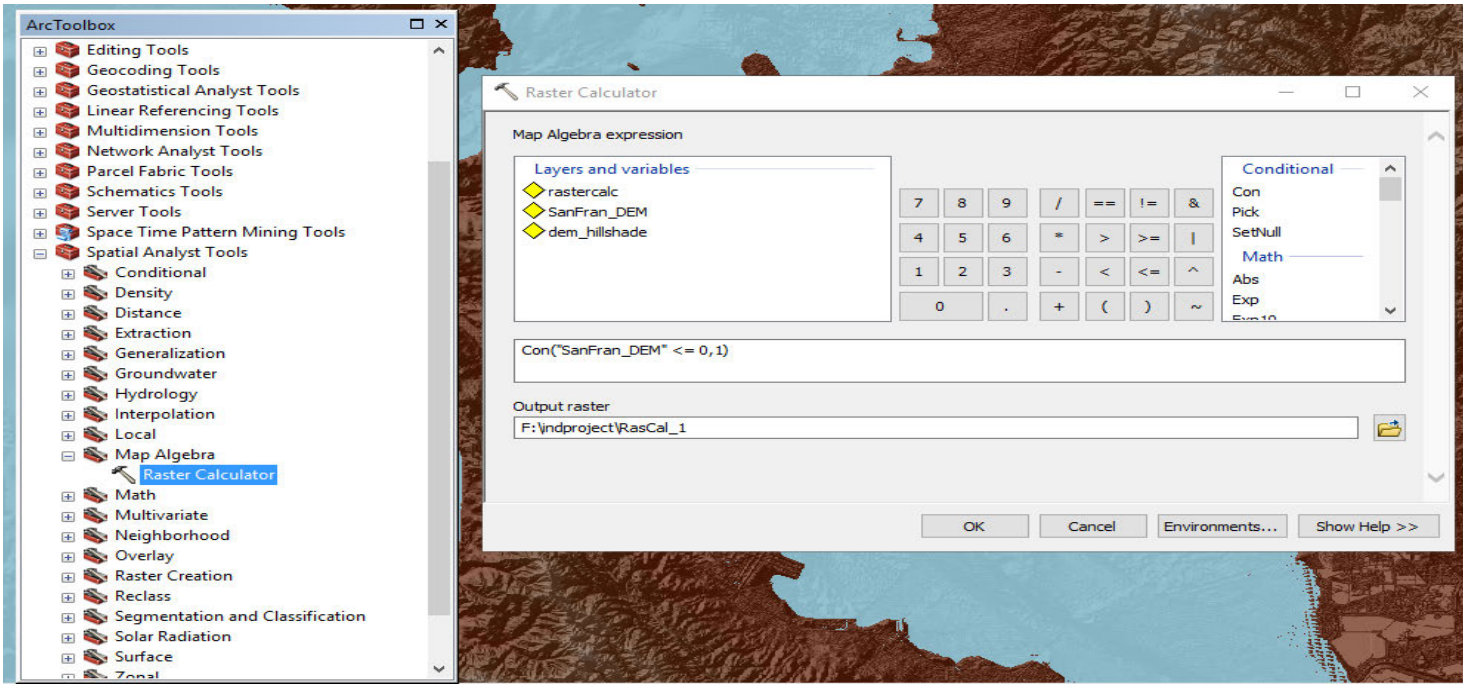

Figure 10: Raster Calculator

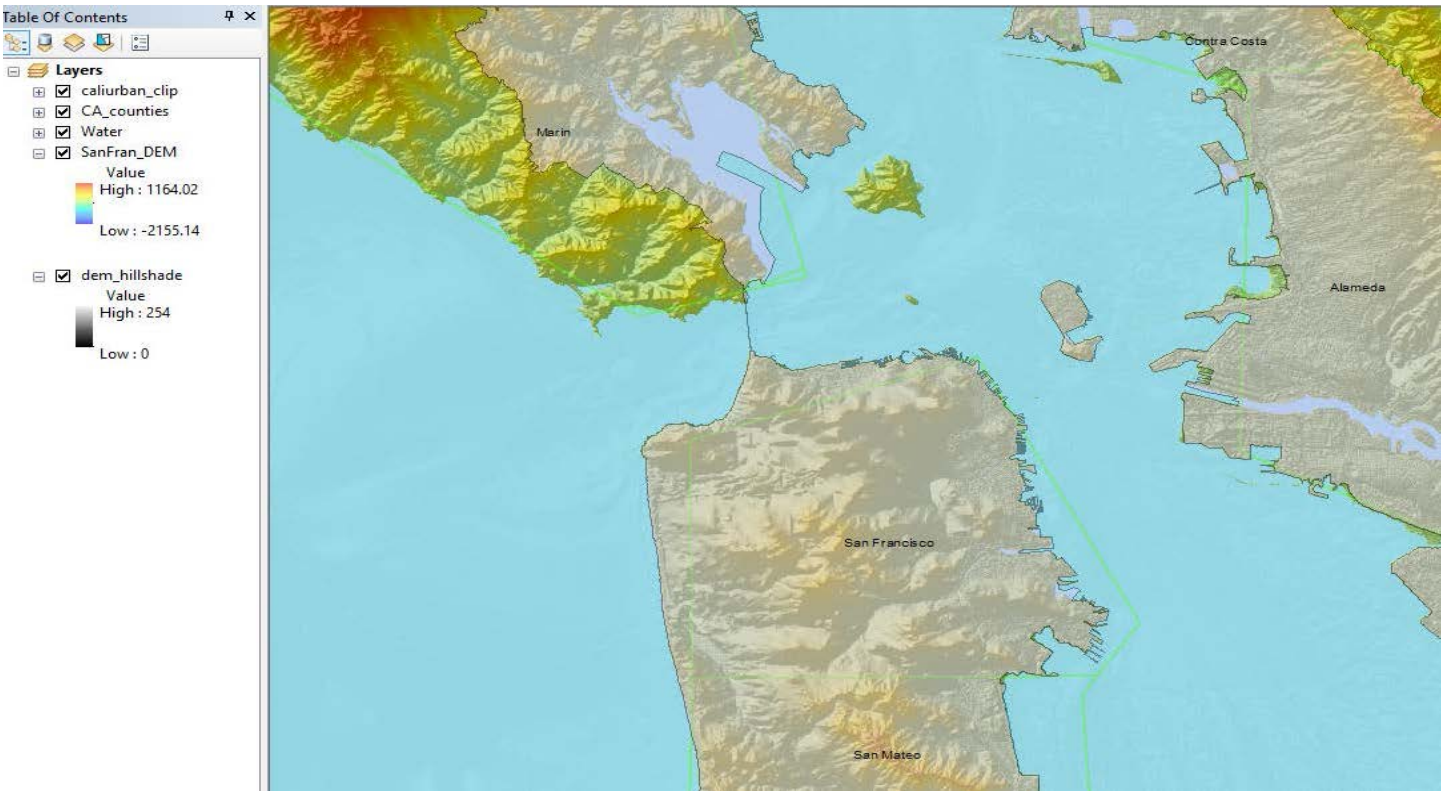

Figure 11: Raster Calculation 1 (current water) added to ArcMAP

Step 9

In order to show the percentage of San Francisco's population that will be affected due to sea level rise, I only displayed San Francisco in the California counties layer by right-clicking the layer> Properties> Symbology> Categories>Unique Values>Value Field>NAME then Add Values>San Francisco. Lastly I edited San Francisco's symbology to No Color and Outline: Purple.

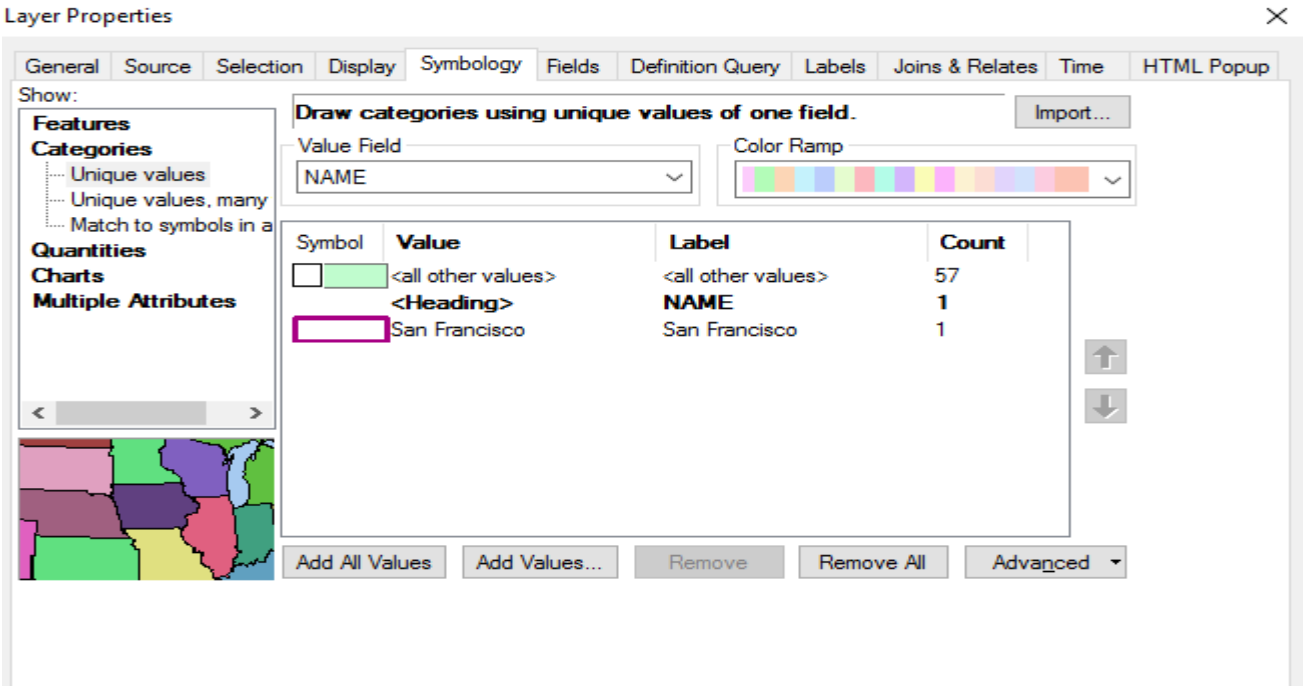

Figure 12: California counties layer edited

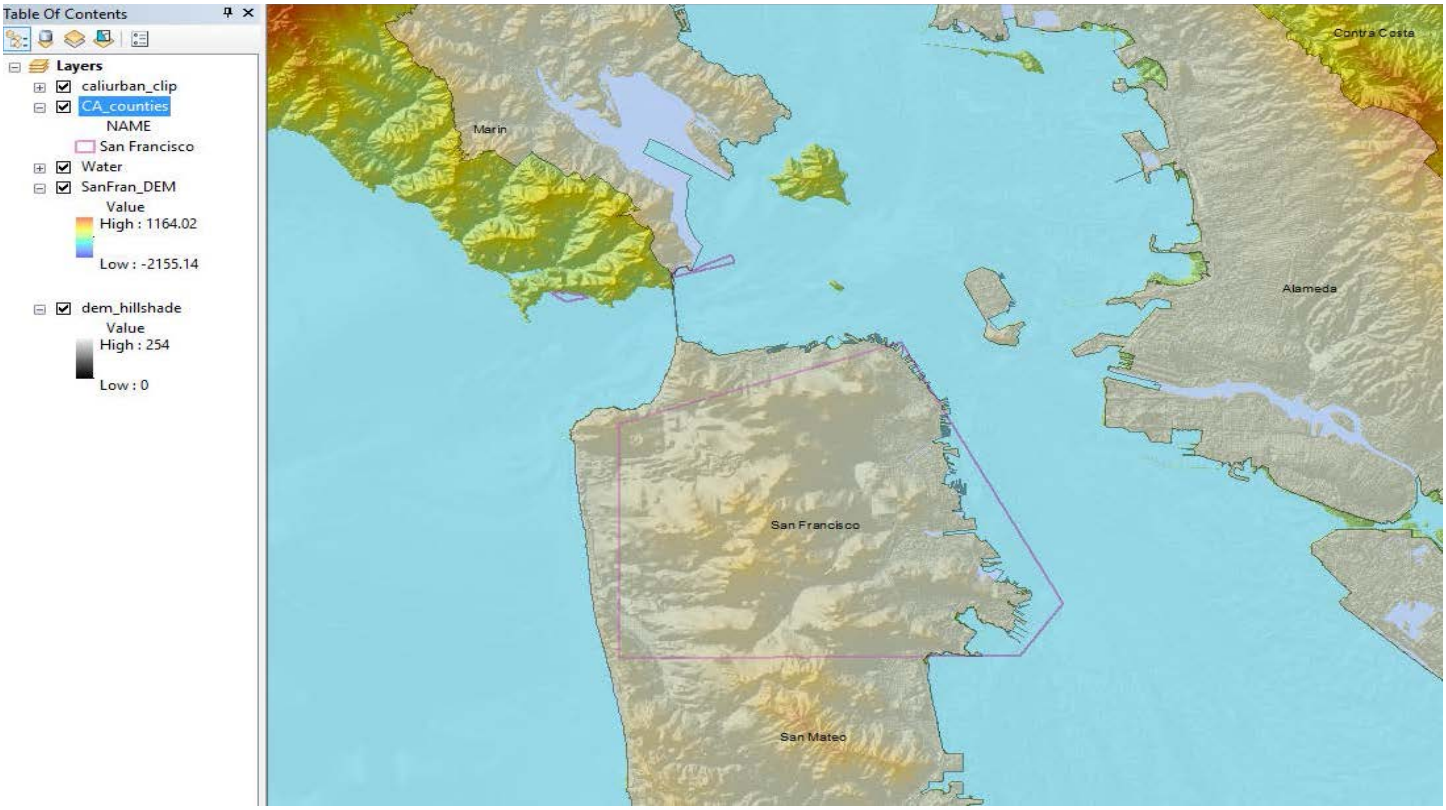

Figure 13: San Francisco county is the only one outlined.

Step 10

To roughly calculate how San Francisco will be affected due to sea level rise, I first found the Mean Sea Level Trend of San Francisco from the following website, www.tidesandcurrents.noaa.gov/ sltrends/ sltrends_station.shtml? stnid=9414290. This national website claims that the sea level in San Francisco is rising at about 1.94 mm/yr. Therefore, if this trend continues, sea level would rise about 2 meters every 1000 years. In order to show changes in sea level, I used the raster calculator to subtract the amount of meters I wanted the sea level to rise from the DEM (figure 14), using the equation "SanFran_DEM" <= # (in this case # =2).

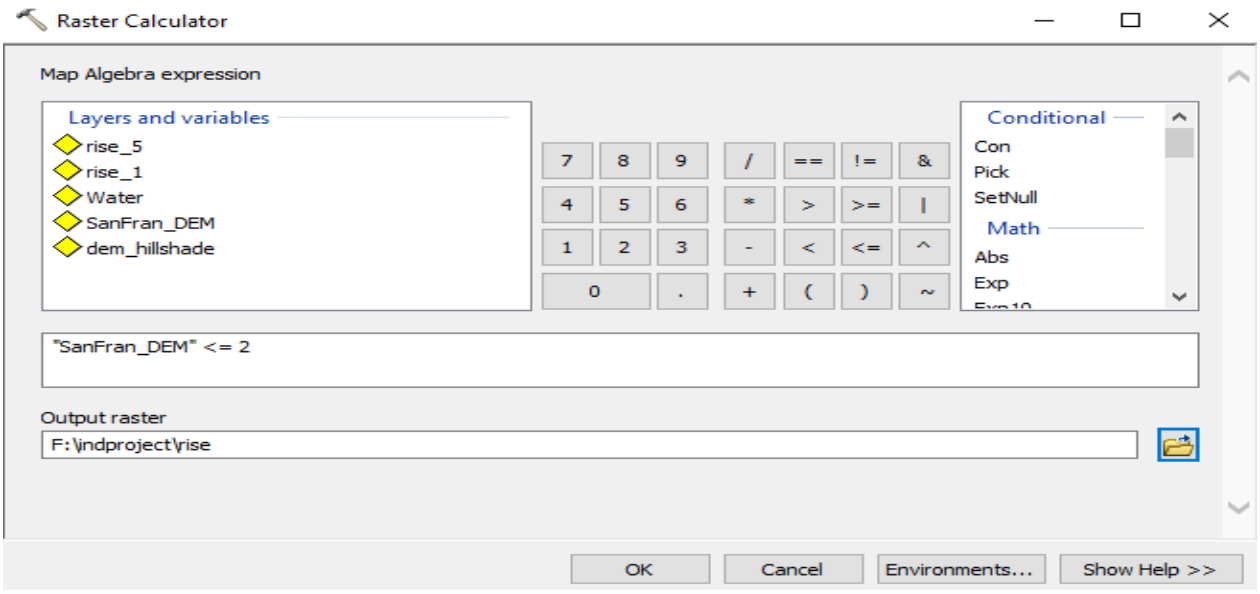

Figure 14: Raster Calculation for 2 m rise in sea level.

Step 11

The result of the raster calculation depicting a sea level rise of 2 meters (figure 15) is shown below covering the maps' topography and elevation. This representation makes it hard to read and understand the map since the topography and elevation is covered.

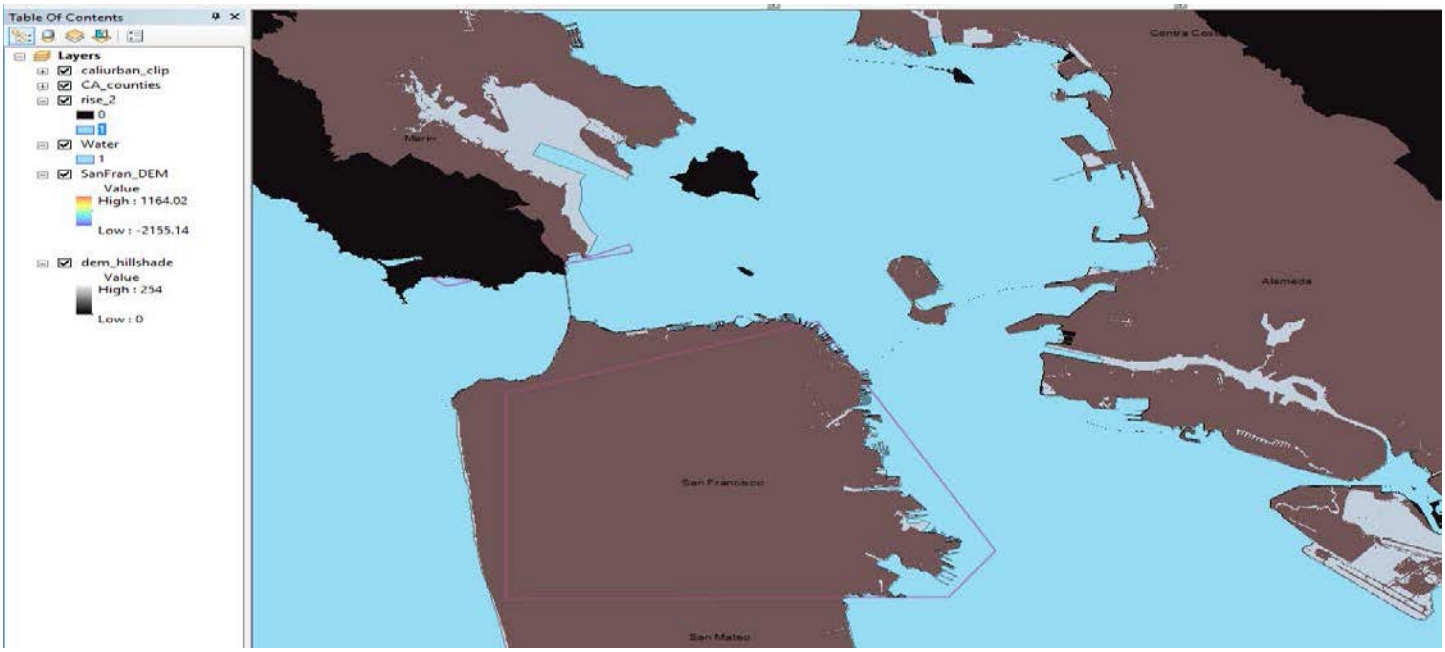

Figure 15: Raster calculation added to ArcMAP representing a sea level rise of 2 meters.

Step 12

In order to improve the map's appearance and legibility I decided to change the new raster's symbology (figure 16) by right clicking the layer>Properties>Symbology. First I edited the "0" meter sublayer (that represents sea level/land) to No Color because I didn't want it to cover the elevation and topography of the map. Then I changed the color of the "1" sublayer to blue since it represents a sea level rise of 2 meters (water). Lastly I got rid of the San Francisco county line since it did not match the real shape of the land and changed the symbology of the urban layer to No Color with a black, 1.5 wide outline to show the current sea level border of the area.

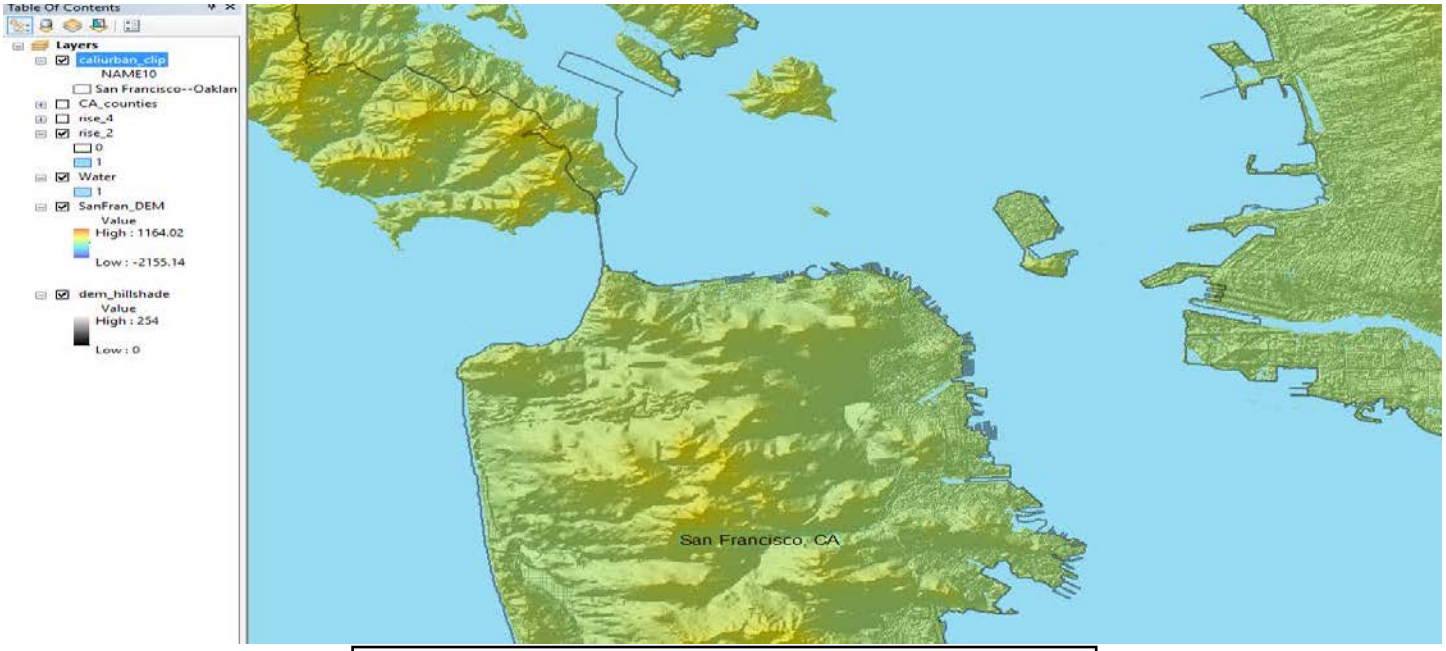

Figure 16: Edited Raster layer to improve map's legibility.

Step 13

To better represent the map's location, I added names of the significant geographic features near my area of interest (figure 19). I did this by using the text tool (figure 17) from the drawing tool bar by clicking the "A" text. But in order for the names to be legible on the map I added a halo around them (figure 18) using the "Change Symbol…" option shown in the picture below.

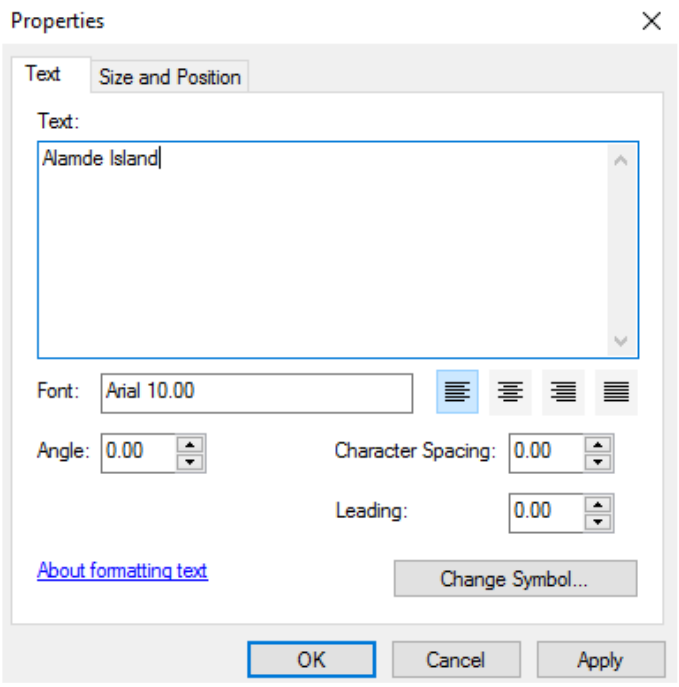

Figure 17: Text Tool from the drawing toolbar

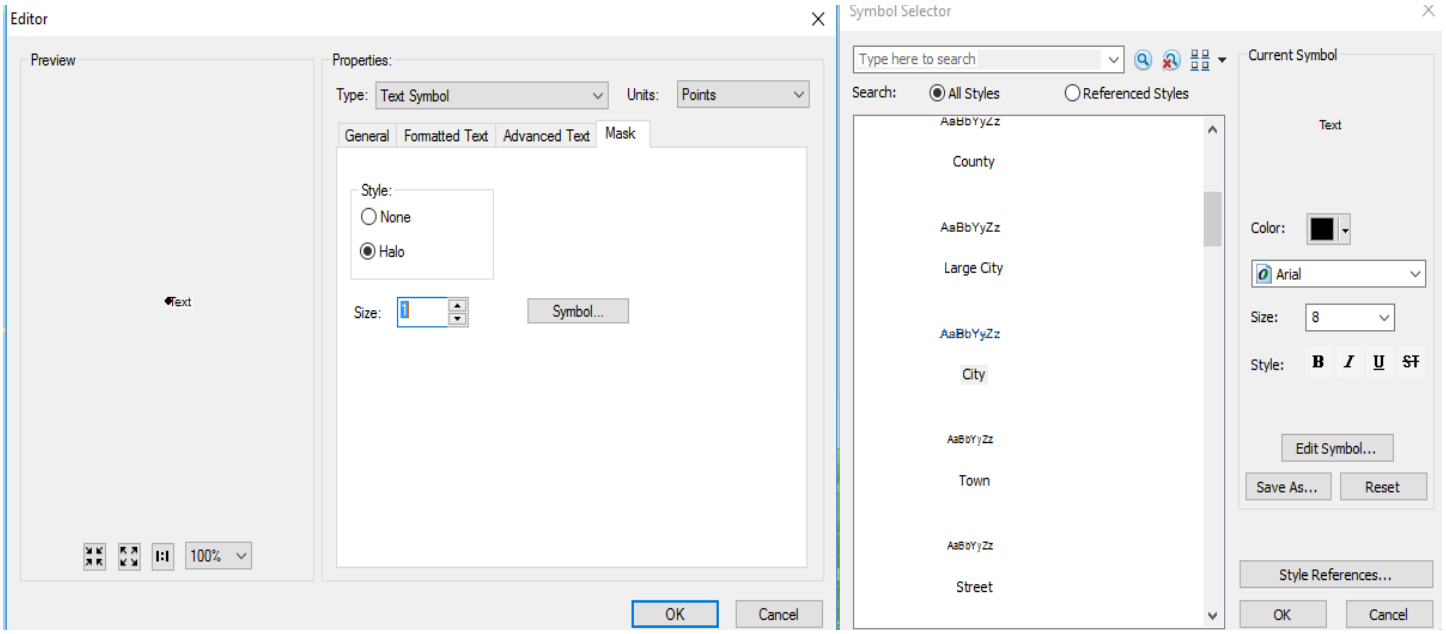

Figure 18: Editing text using the Change/Edit Symbol option

Figure 19: Names of nearby geographic features added to the map.

Step 14

I repeated steps 10-12 to show a rise in sea level by 4, 6, 8 and 10 meters which represents a process of 10,000 years if the mean sea level trend of San Francisco remains constant.

Step 15

Lastly, I set the reference scale of my map to 1: 100,000 since at this scale my area of interest looks best in Layout View. I also did this to better compare the various maps that show different rises in sea level. This was done by right clicking Layers in the TOC>Properties>General>Refrence Scale: 1: 100,000.

Step 16

Finally, I edited the maps in Layout View to look more presentable by adding a legend, scale, north arrow, title, name, date and lastly a zoomed out edition of my map to better show my map's location.

April Treviño
12/04/16

Present Day Sea Level of the San Francisco, CA area

Legend

Present Day Shoreline

Water

Elevation (m)

High : 1164.02

Low : -2155.14

0 1 2 4 6 8 Kilometers

NAD 1983 UTM Zone 10N

1:150,000

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12/04/16

Sea Level Rise of 2 meters for the San Francisco, CA area

Legend

Present Day Shoreline

Water

Elevation (m)

High : 1164.02

Low : -2155.14

0 1 2 4 6 8 Kilometers

NAD 1983 UTM Zone 10N

1:150,000

April Treviño
12/04/16

Sea Level Rise of 4 meters for the San Francisco, CA area

Legend

Present Day Shoreline

Water

Elevation (m)

High : 1164.02

Low : -2155.14

0 1 2 4 6 8 Kilometers

NAD 1983 UTM Zone 10N

1:150,000

April Treviño
12/04/16

Sea Level Rise of 6 meters for the San Francisco, CA area

Legend

Present Day Shoreline

Water

Elevation (m)

High : 1164.02

Low : -2155.14

0 1 2 4 6 8 Kilometers

NAD 1983 UTM Zone 10N

1:150,000

April Treviño
12/04/16

Sea Level Rise of 8 meters for the San Francisco, CA area

Legend

Present Day Shoreline

Water

Elevation (m)

High : 1164.02

Low : -2155.14

0 1 2 4 6 8 Kilometers

NAD 1983 UTM Zone 10N

1:150,000

April Treviño
12/04/16

Sea Level Rise of 10 meters for the San Francisco, CA area

Legend

Present Day Shoreline

Water

Elevation (m)

High : 1164.02

Low : -2155.14

0 1 2 4 6 8 Kilometers

NAD 1983 UTM Zone 10N

1:150,000

CONCLUSION:

With the tools and experiences that I learned in GIS, I was able to create 5 maps that show how sea level rise will affect the San Francisco, CA area. The final maps represent sea level rise in 2-meter intervals. If the mean sea level continues to rise at the present rate of 1.94 millimeters per year, then my maps created using a Digital Elevation Model and other shape files would represent creditable models of the San Francisco area.

As shown in the maps above, the eastern side of San Francisco will flood faster and farther inland compared to the western side. In fact, most of the shoreline that circles around the San Francisco Bay will begin to flood after a 2-meter rise in sea level, which means that people living in that area are the first to be affected by this change. In addition, most of Treasure Island, NW of San Francisco, would be under water after a 10-meter rise in sea level, while Angel Island, north of San Francisco, would look practically the same. Although 10 meters of sea level were calculated to rise in over 10,000 years, a relatively slow process, my maps could still be used as hazard models for storm surges or for future city planning purposes for especially the shorelines around the San Francisco Bay.