# SITE SUITABILITY ANALYSIS FOR PROPOSED IMPOUNDMENTS ALONG THE LOWER-MIDDLE BRAZOS RIVER, TEXAS

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## INTRODUCTION

Texas currently faces many environmental challenges that strain water resources, including droughts, flooding, water contamination, and rising population growth. Impoundments along major rivers provide water for human consumption, recreational use, and flood protection. The Brazos River is the largest river in Texas, and many cities rely on its reservoirs, including Lake Somerville and Lake Whitney, for the aforementioned demands. There is currently a proposed impoundment, namely Allens Creek Reservoir that is set to impound over 200,000 acre-feet of water after its 2020 impoundment date. This analysis intends to determine if a GIS can reaffirm this chosen location for an impoundment, as well as locate other areas that may be suitable.

This site suitability analysis aims to delineate suitable locations for a proposed impound along the Lower-Middle Brazos River based on geologic features, specifically topographic slope, as well as economic considerations, including large cities and existing reservoirs. These parameters assess the river's capacity to hold viable quantities of water while also determining areas that are in need of water. The area of interest is the Lower-Middle Brazos River; reservoirs are needed towards downstream segments of the river for flood protection measures. This area was also chosen as the study site because it is relatively devoid of reservoirs. Determining sites for a new, proposed impoundment is critical in order to meet future demands.

## FILES

Vector and raster data are combined to provide a thorough analysis of suitable areas for a new impoundment along the Brazos River.

Digital Elevation Models – National Elevation Dataset 2013
- http://tnris.org/data-download/#!/statewide
  - Clay Quadrangle
    - File name: ned13_3096.zip
  - Burleigh Quadrangle
    - File name: ned13_2996.zip
  - Thompsons Quadrangle
    - File name: ned13_2995.zip
  - Montgomery Quadrange
    - File name: ned13_3095.zip

Rivers
- http://www.twdb.texas.gov/mapping/gisdata.asp
  - File name: Major_Rivers_dd83.zip
  - Original coordinate system: GCS_North_American_1983

Cities
- TX Cities: http://mrdata.usgs.gov/geology/state/state.php?state=TX

- File name: TXgeol_dd.zip
- Original coordinate system: GCS_North_American_1983

Reservoirs
- TX Existing Reservoirs: http://www.twdb.texas.gov/mapping/gisdata.asp
  - File name: Existing_Reservoirs.zip
  - Original coordinate system: GCS_North_American_1983

TCEQ Guidelines for Proposed Impoundments
- http://www.tceq.texas.gov/publications/rg/rg-473.html/at_download/file


## METHODS

The four mosaics downloaded from TNRIS, each with 10m x 10m resolution, are first combined using the **Mosaic to New Raster** function to create a one raster, namely **Mosaic_2** (Fig. 1). Pixel type of 32_BIT_FLOAT and Number of Bands = 1 are necessary to carry out this function.
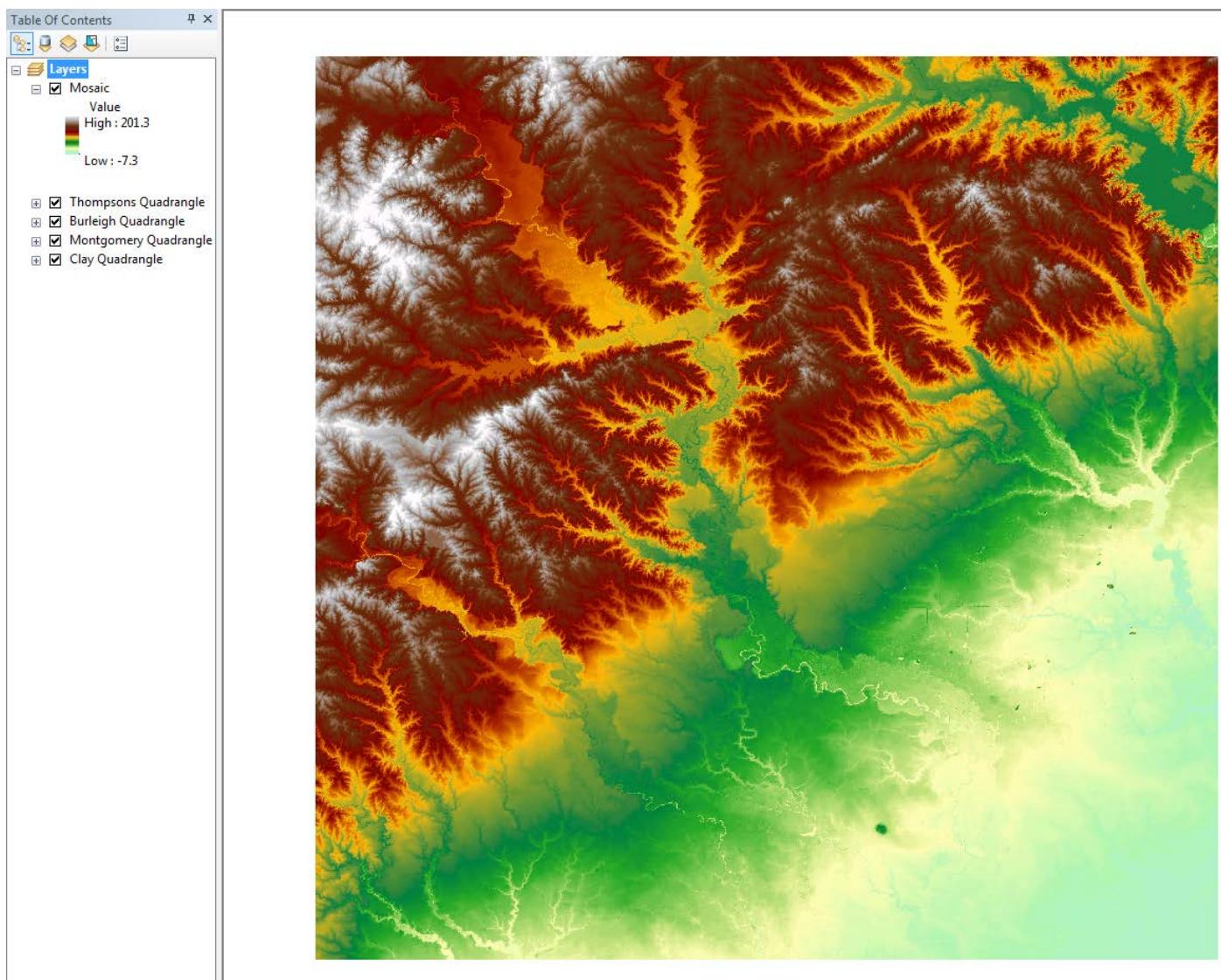


Figure 1: Raster (**Mosaic**) created by merging the four DEMs of the Lower-Brazos River basin.

The Brazos River also spans multiple State Plane zones, so a state-wide projection is chosen to encompass the Brazos River basin. **Mosaic** is projected using the Project Raster tool to NAD 1983 Texas Centric Mapping System (Albers) using a nearest neighbor resampling technique to **Mosaic_proj** (Fig. 2). All other files, including the Brazos River, Texas Reservoirs, and Cities shapefiles are also projected.
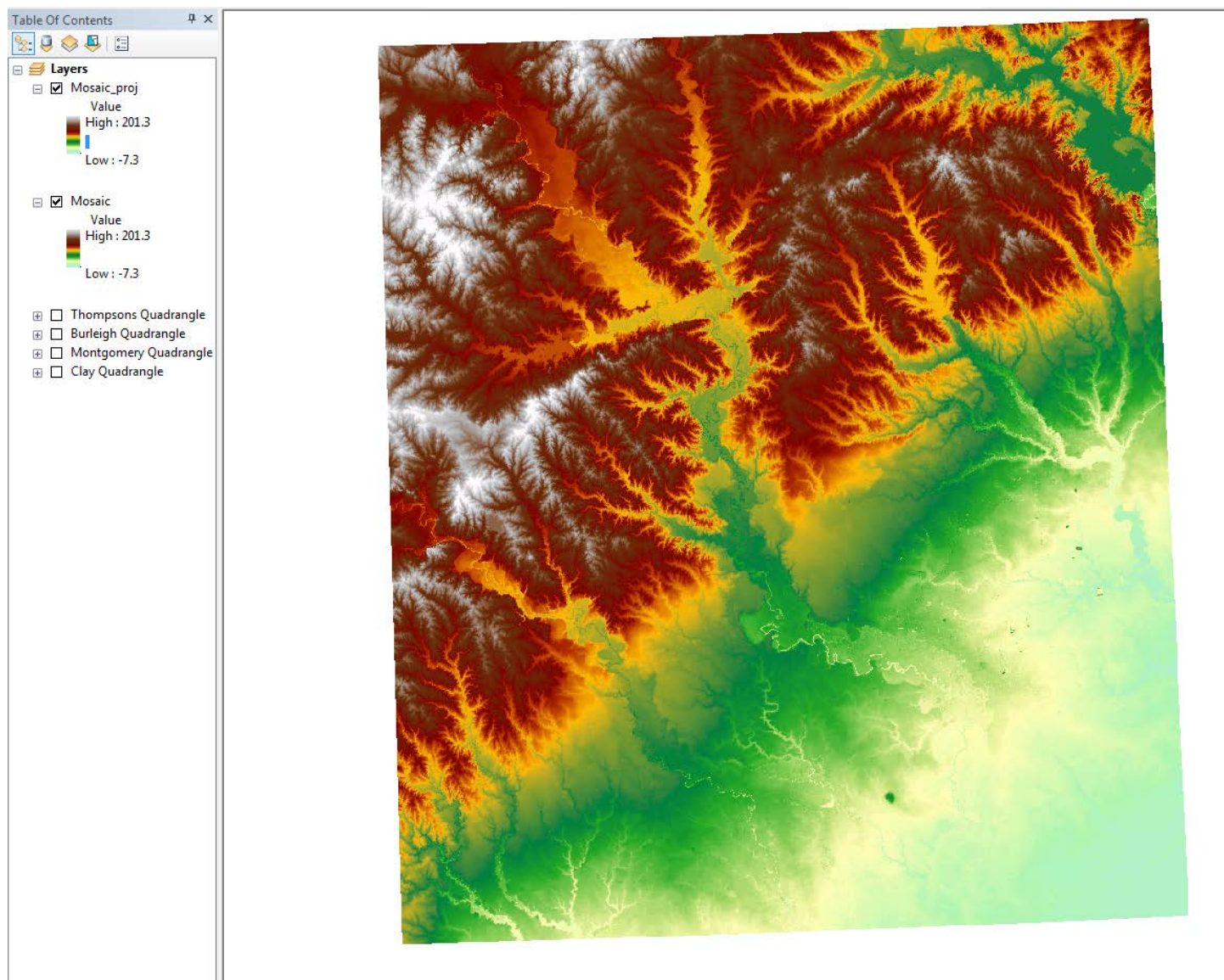


Figure 2: **Mosaic_proj** projected in NAD 1983 Texas Centric Mapping System (Albers).

The Texas Commission on Environmental Quality (TCEQ) has provided certain guidelines that are useful in determining potential locations for a new dam. For example, slope should be approximately 3H:1V (H=horizontal, V=vertical), or equivalently 18 degrees. In order to assess quantitatively assess slope, the following steps are taken:

Spatial Analyst → Surface → Slope

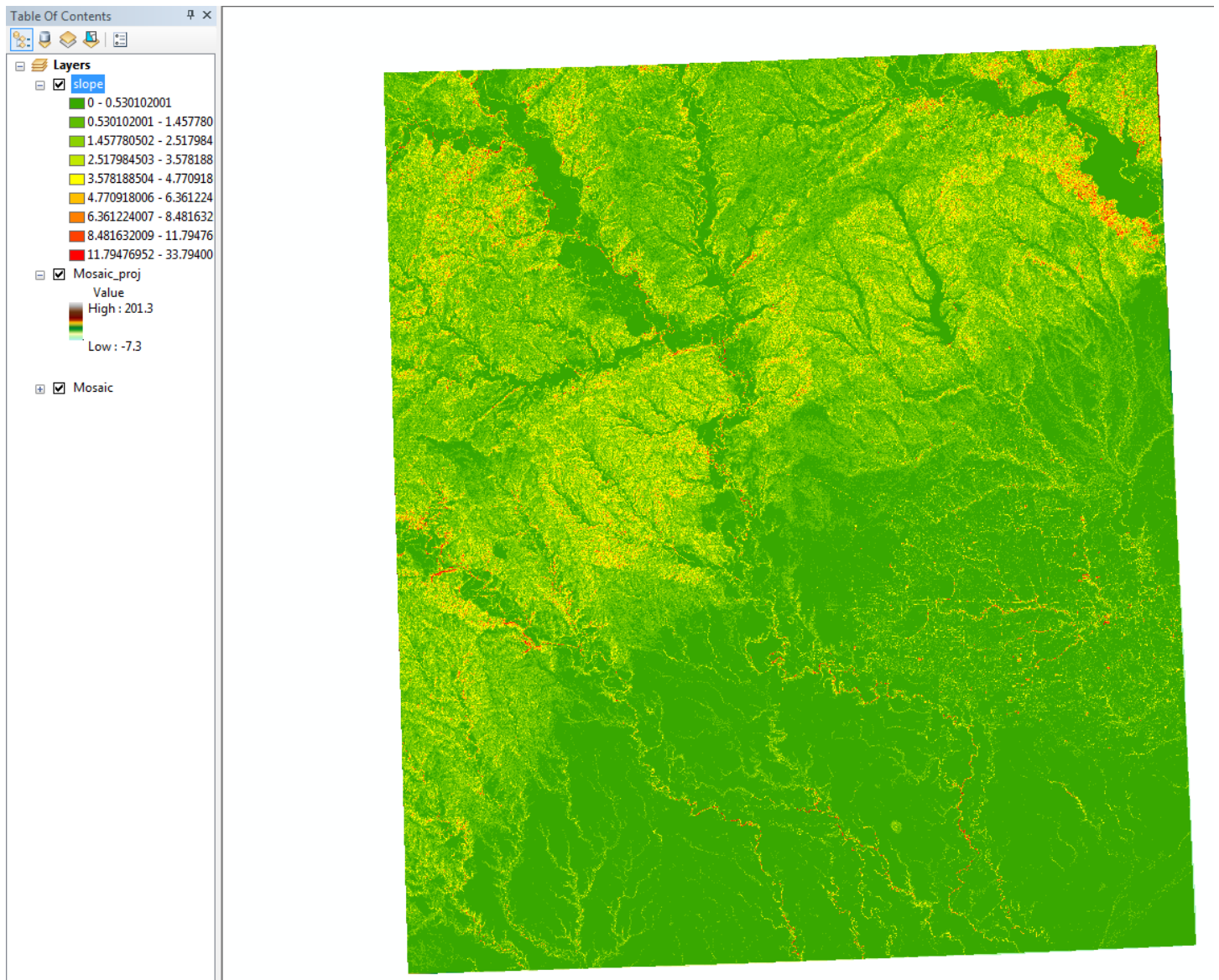In doing so, the new raster, **slope**, calculates slope using a degree output measurement (Fig. 3).



Figure 3: Slope measured in degrees of **slope**.

The classification scheme in Fig. 3 is not helpful in analyzing the best areas for a new impoundment from a visual perspective. The Reclassify (Spatial Analyst) tool is first used to create four ranges of slope (in degrees) designated by 3 ranks of suitability (Fig. 4). Slope that ranges from 0-5 (too shallow) and greater than 18 degrees (too steep) are considered unsuitable, as denoted by their rank of 1. Moderately suitable areas in terms of slope (5-10 degrees) receive a rank of 2. Lastly, rank 3 is assigned to the ideal slope needed for a new impoundment, and ranges from 15-18 degrees. The output of the reclassification tool is named **mos_reclass2**.
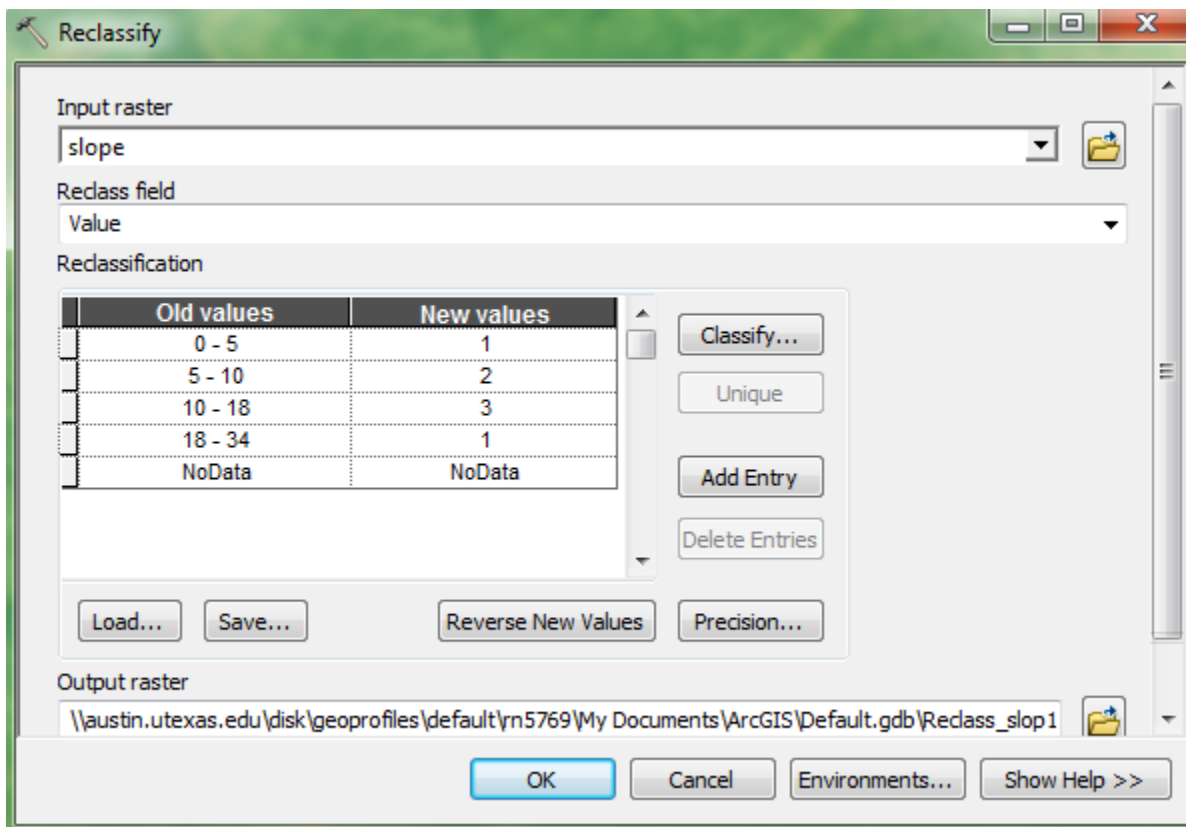


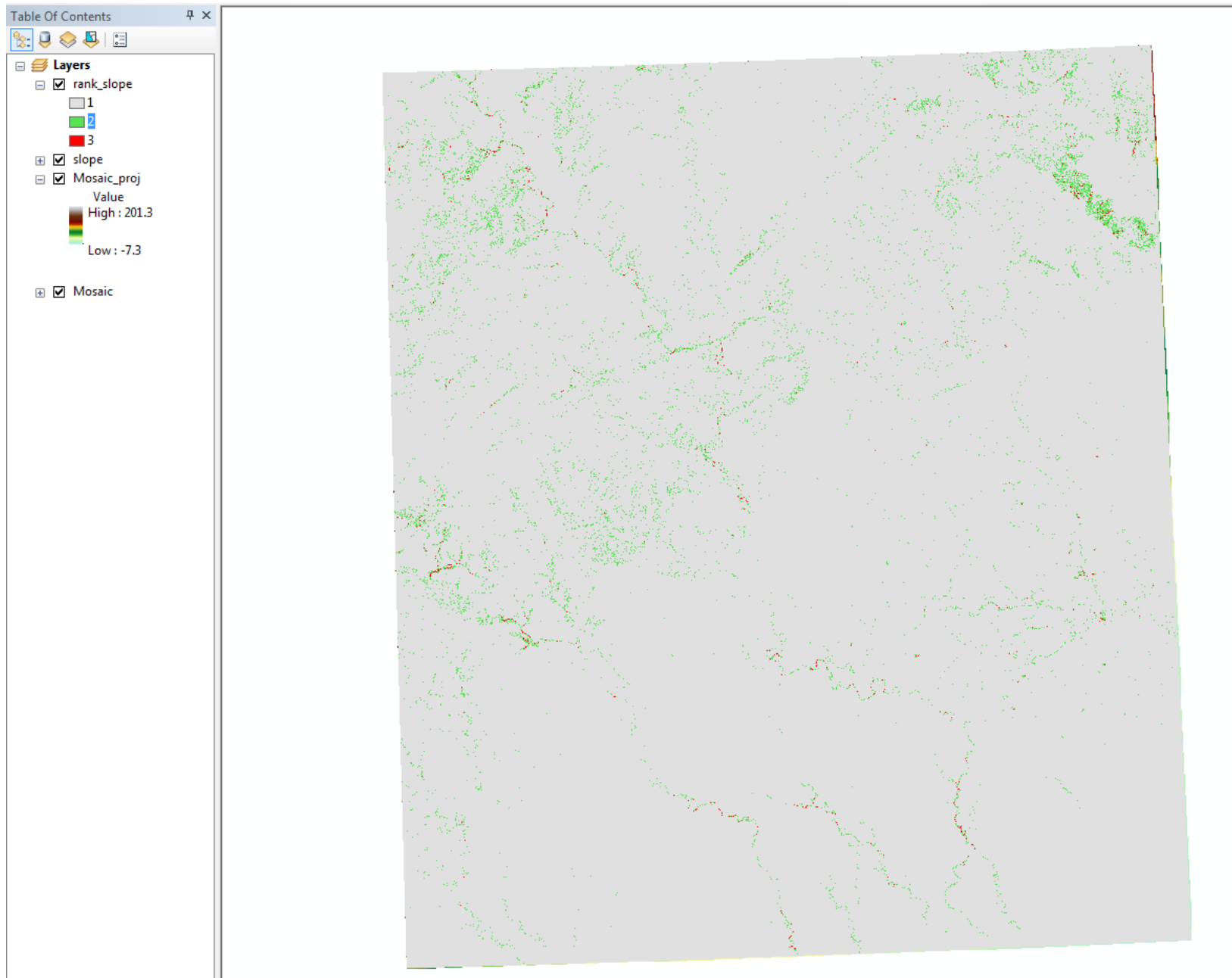Figure 4: Reclassification scheme applied to **slope**.

Figure 5: Output (**rank_slope**) of the reclassify tool. 1 is gray, or slopes that are too steep or too shallow. 2 is green, representing areas that are moderately suitable. 3 is red, and delineates the most suitable areas for an impoundment in terms of slope.

The first step in assessing economic considerations requires the "Selection by Location" of reservoirs and cities within the raster extent. A new polygon that encompasses the raster extent is created (**raster_extent**). Existing reservoirs and cities within **raster_extent** that are "completely within the source layer" are exported to new layers (Fig. 6). The new reservoirs shapefile is named **brazos_reserv**. Because only cities with populations greater than 5,000 people are considered for this analysis, the "select by attribute" feature must also be applied before exporting the cities shapefile to a new layer (**cities_5000**).
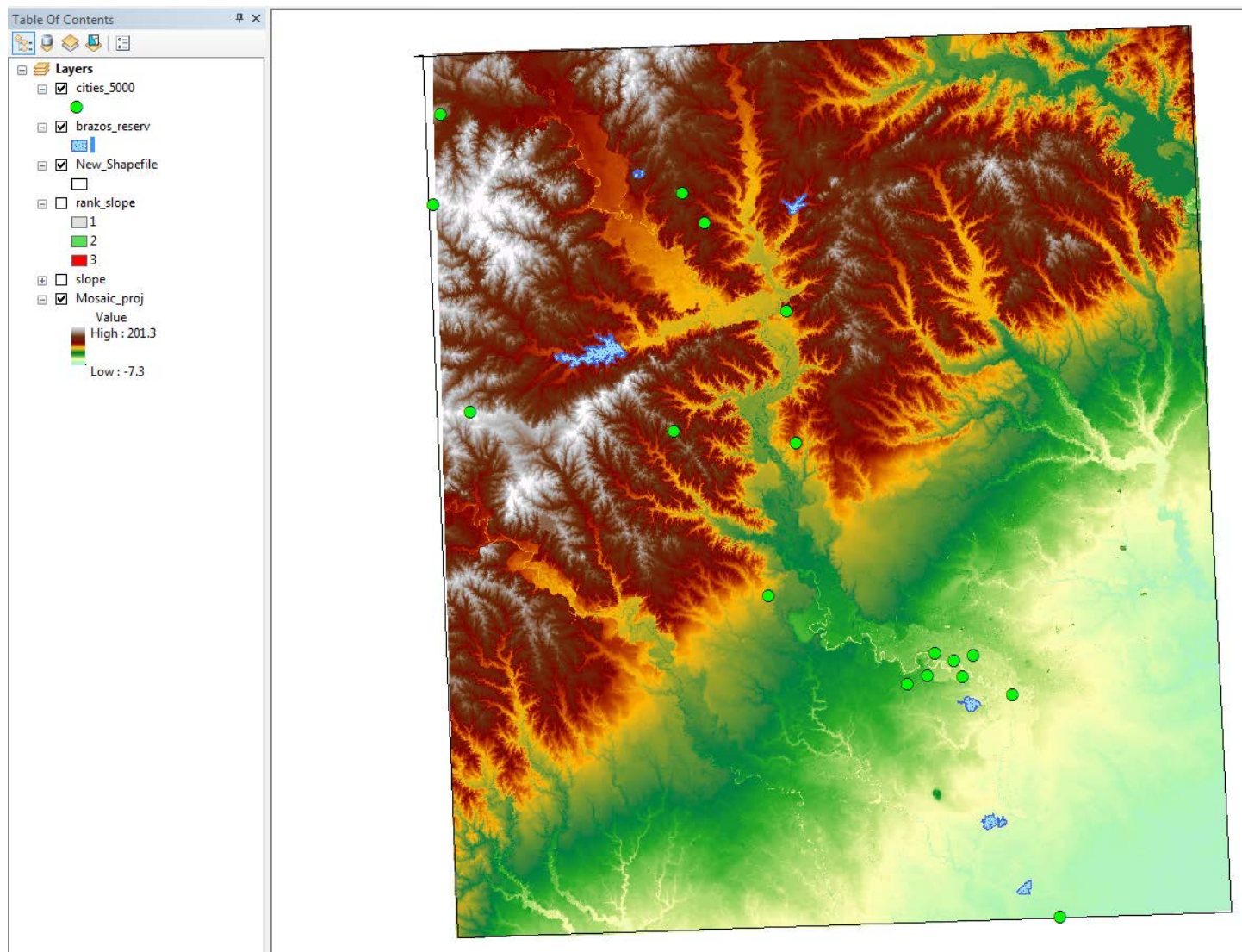


Figure 6: Existing reservoirs (**brazos_reserv**) and cities with populations greater than 5,000 people (**cities_5000**) within the Lower-Middle Brazos River basin.

"Buffer" and "Erase" are useful tools for vector analysis. For the purposes of this project, buffers are used to determine the radial extent in which a certain condition must be met. For example, the existing reservoirs are buffered 10 miles (**reserv_buff**; Fig. 7) because certain flows are necessary for nutrients and sediments to be carried downstream for ecosystems to thrive. Reservoirs should also be spread throughout the river in order to cater to different cities that may rely on it. Further, the clip tool is used to remove areas of **reserve_buff** shapefile that are not within **raster_extent**. This new file is named **reserve_buff**.
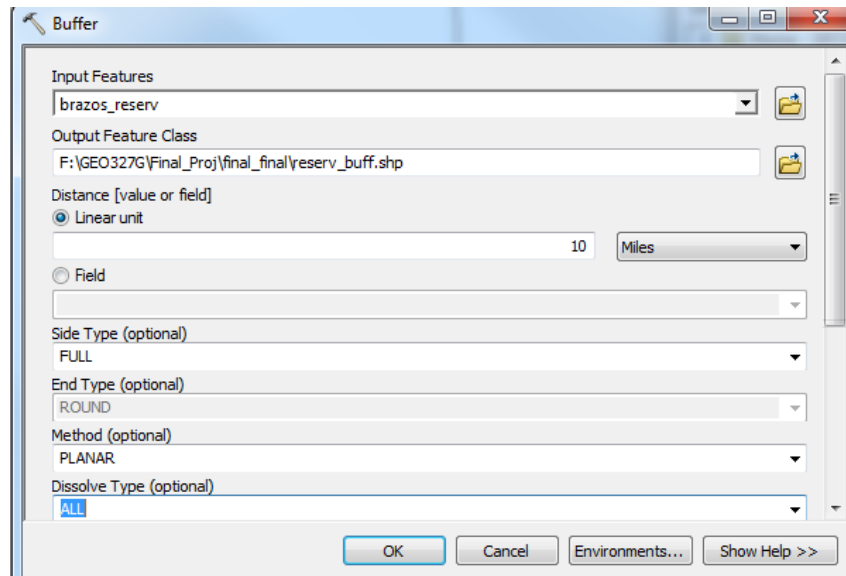


Figure 7: 10 mile buffer for existing reservoirs (**reserve_buff**).

Additionally, a 10 mile buffer within cities of populations greater than 5,000 is also necessary to provide water for human consumption. Impoundments are expensive endeavors and should be built in areas where their benefits are maximized. The clip tool was also used to remove areas from the city buffer not within the area of interest. This new file is named **city_buff**. Figure 9 exhibits the results of these tools.
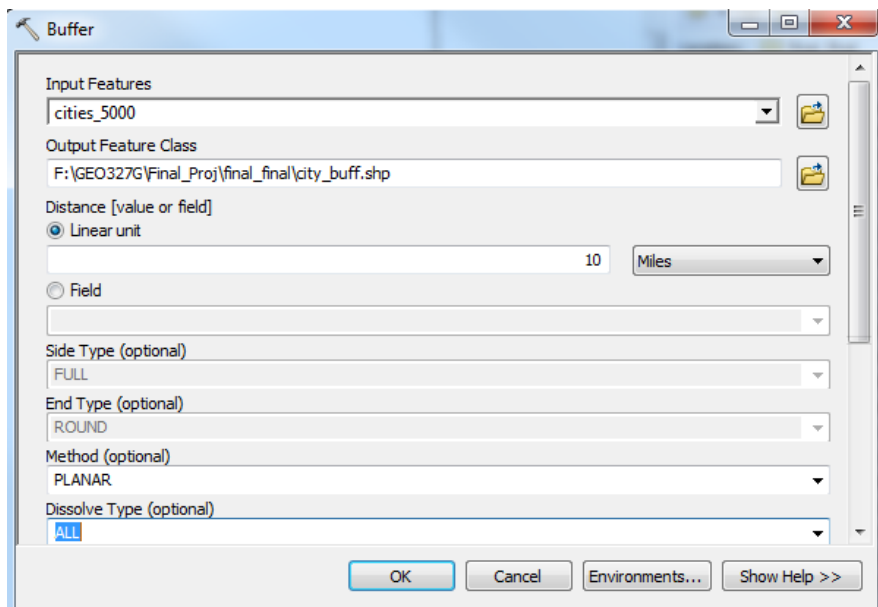
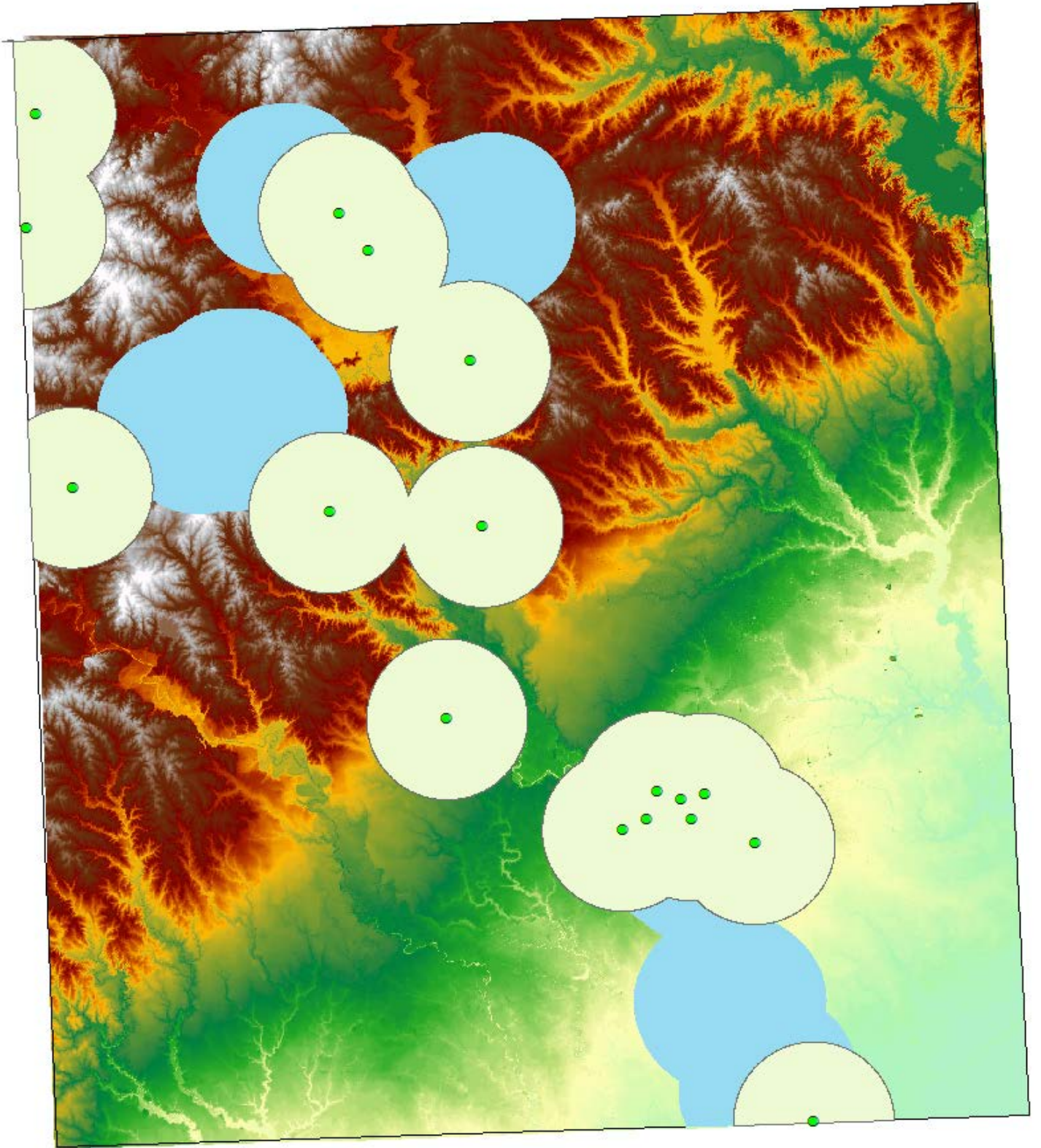Figure 8: 10 mile buffer for cities with populations greater than 5,000.



Figure 9: Buffers for existing reservoirs (blue) and cities with populations greater than 5,000 (yellow).

The "Erase" tool is useful for this spatial analysis because the new reservoir cannot be within the **reserve_buff** shapefile, but it must be within the **city_buff** shapefile. Erasing the areas of the city buffer that intersect the reservoir buffer will yield suitable areas based on these criteria (Fig. 10), namely **cities_erase** (Fig. 11).
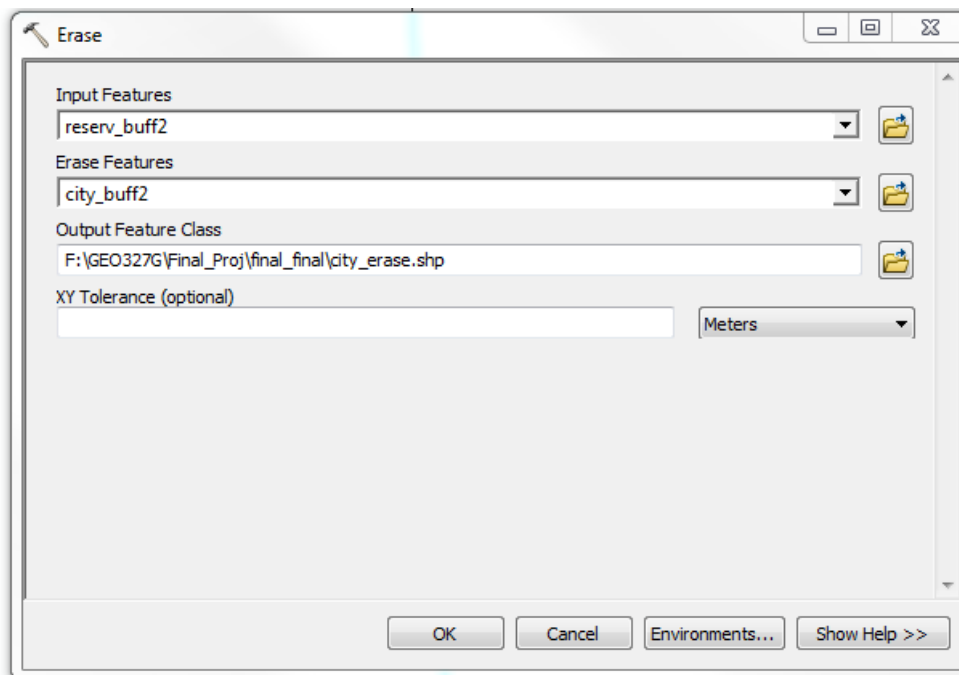


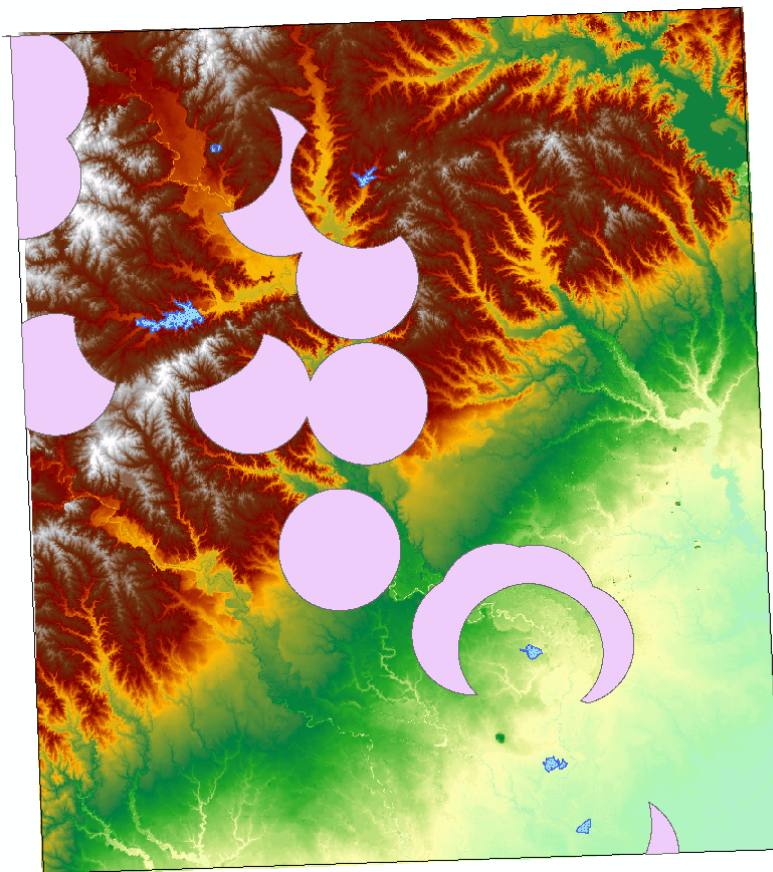Figure 10: Erase tool used to determine areas of intersection before **reserve_buff2** and **city_buff_2**.



Figure 11: cities_erase shapefile from erase tool.

The **cities_erase** shapefile must be converted to a raster layer in order to be useful for the spatial analysis (Fig. 12). In order to do so, the "Features to Raster" (Spatial Analyst) tool is utilized to transform the shapefiles to raster layers, namely **buff_raster** (Fig. 13). The new raster does
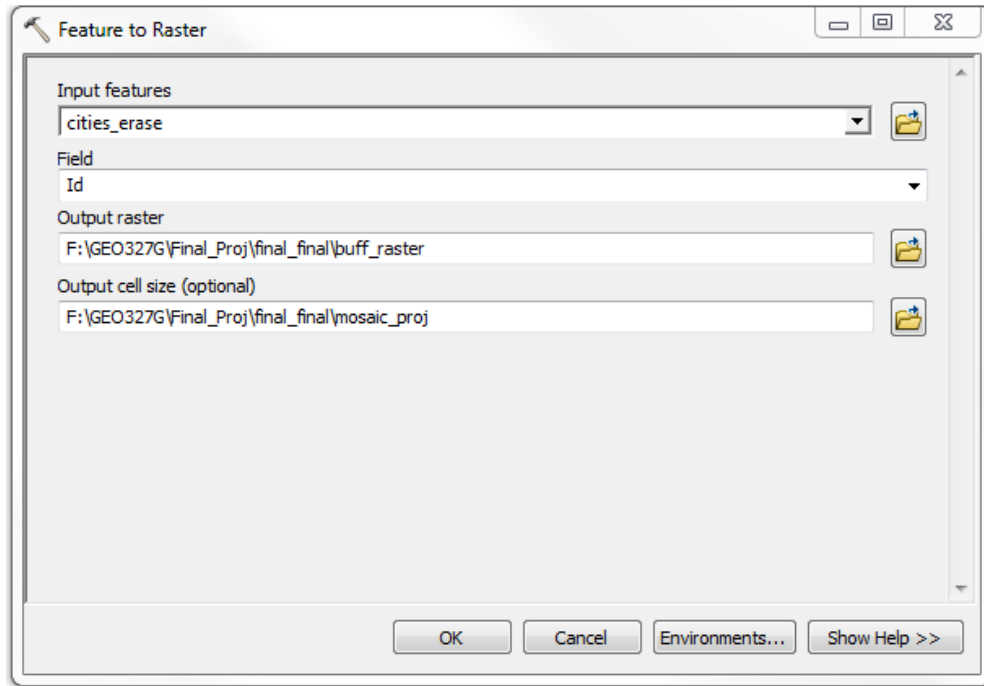


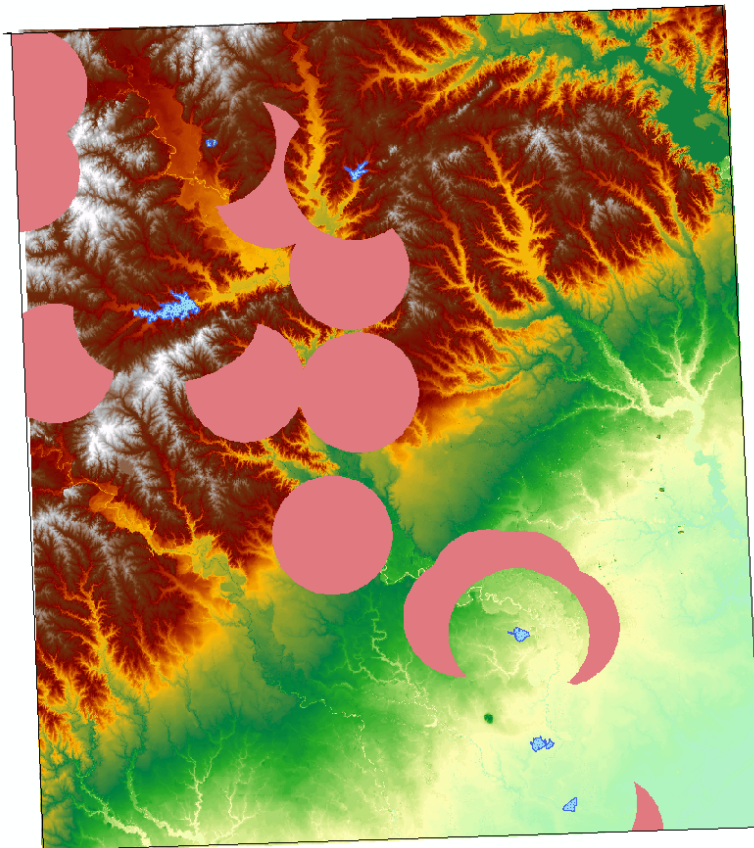Figure 12: Feature to Raster tool to create **buff_raster** layer.



Figure 13: **buff_raster** layer.

The reclassify tool is also used to assign new values to **buff_raster**. The areas shaded in pink are automatically assigned a value of "0" and all other values are assigned "NoData." The "0" and "NoData" old values are reclassified as "2" and "1", respectively, in order to carry other further raster analyses (Fig. 14).
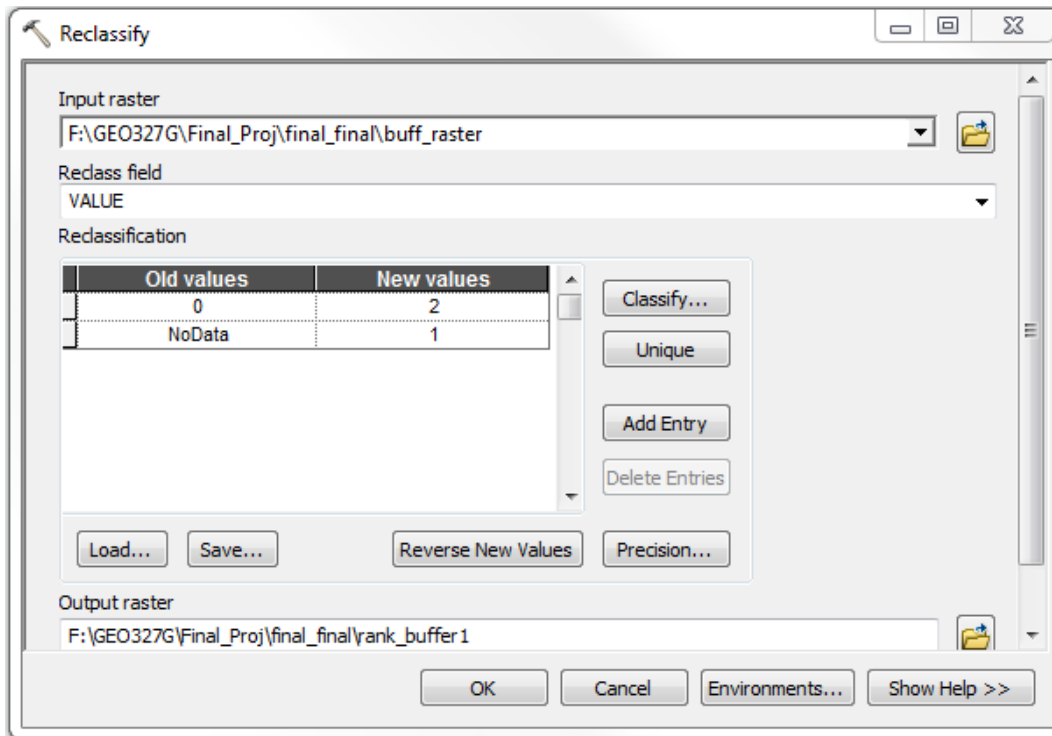


Figure 14: Reclassify tool used to create a new layer, **rank_buffer1**, with new values.

The two reclassified layers are used to do map algebra. Raster Calculator adds the ranks of both raster layers to yield a final rank based on the parameters considered (Fig. 15).
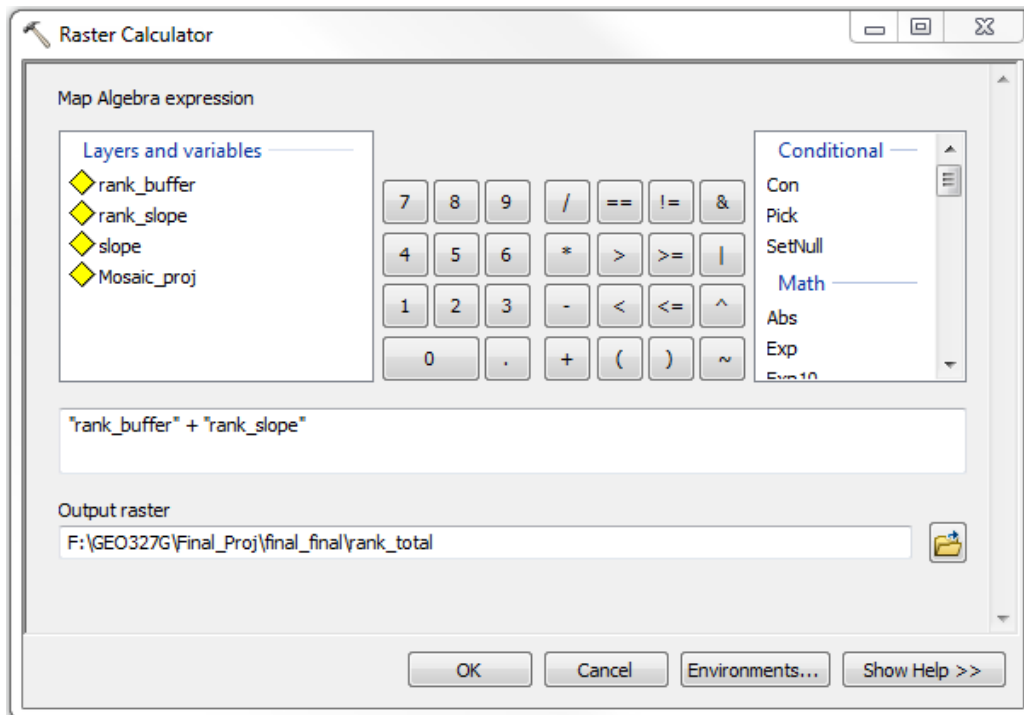


Fig. 15: Raster Calculator function, which adds the ranks assigned to **rank_buffer1** and **rank_slope**, yielding **rank_total**.

**Rank_total** provides a simple way of determining the most suitable locations for a new impoundment. Table 1 describes the significance of each rank. Figures 16-18 showcase the most suitable areas from upstream to downstream of the river, in black, as a result of the raster calculations.

Table 1: Ranks assigned to determine site suitability for a proposed impoundment.

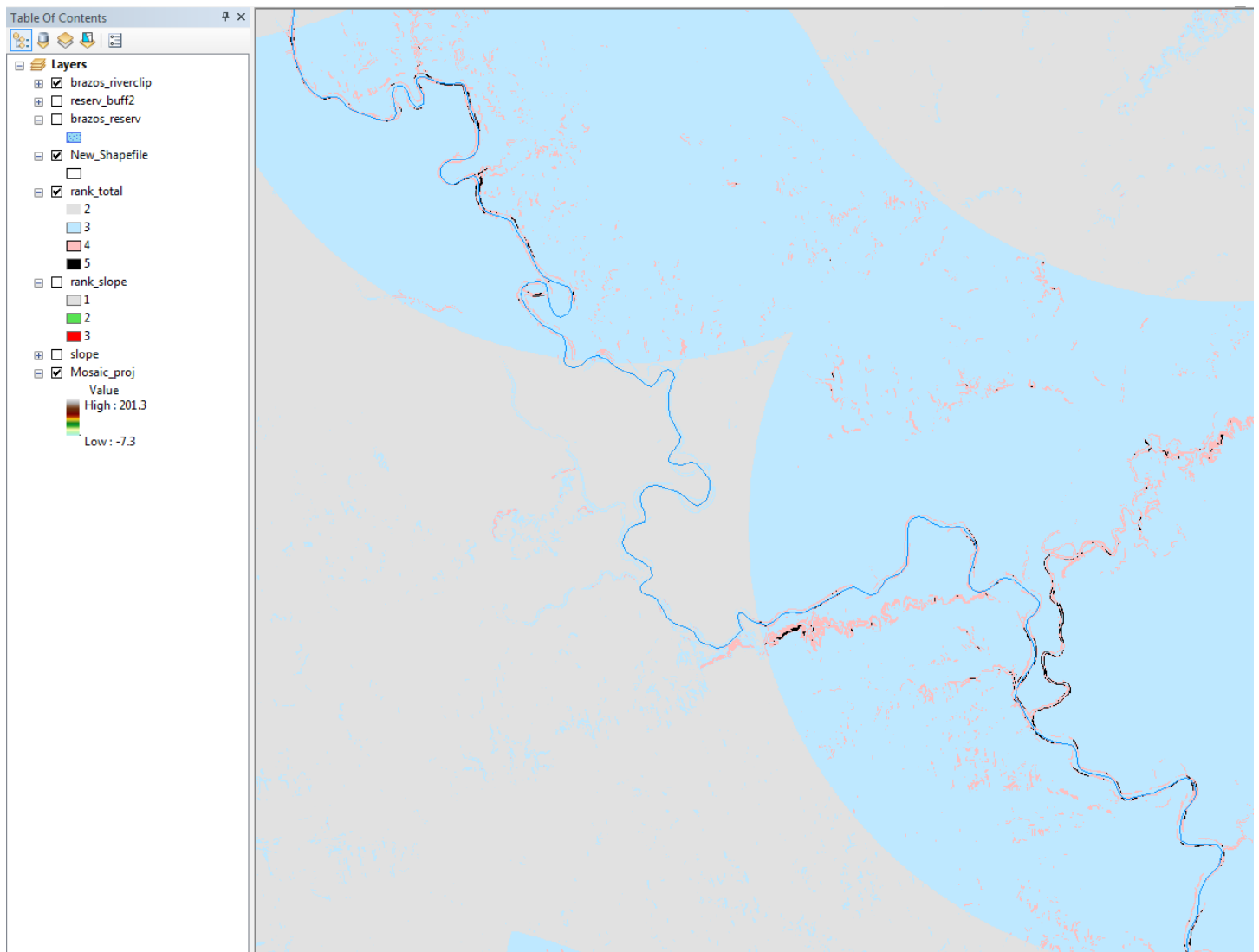| Rank | Suitability | Color |
|------|-------------|-------|
| 2 | Not suitable | Gray |
| 3 | Slightly suitable | Blue |
| 4 | Moderately suitable | Pink |
| 5 | Most suitable | Black |



Figure 16: Northern segment of the Brazos River within the area of interest, showcasing suitability ranks (**rank_total**).
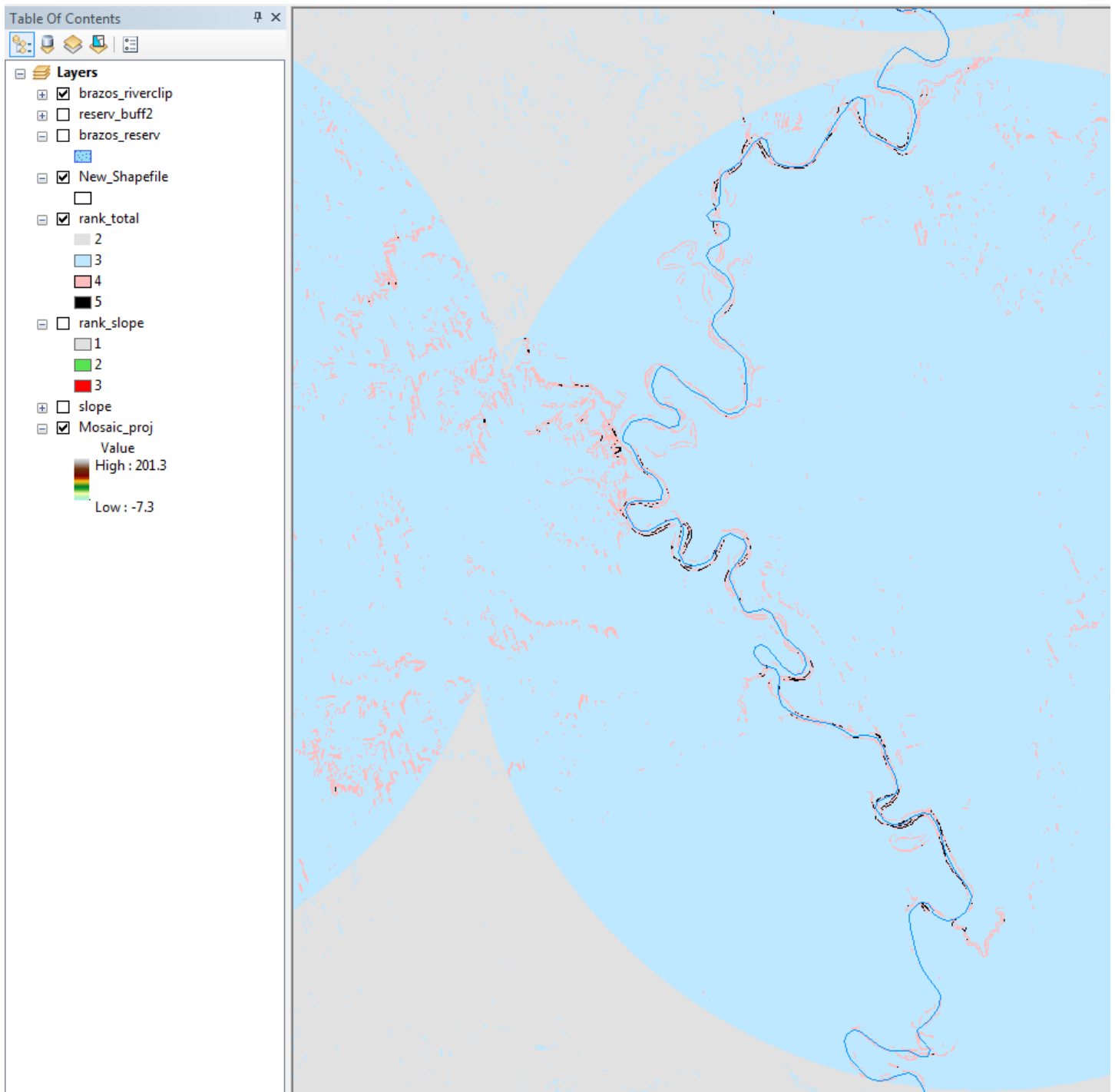
Figure 17: Middle segment of the Brazos River within the area of interest, showcasing suitability ranks (**rank_total**).
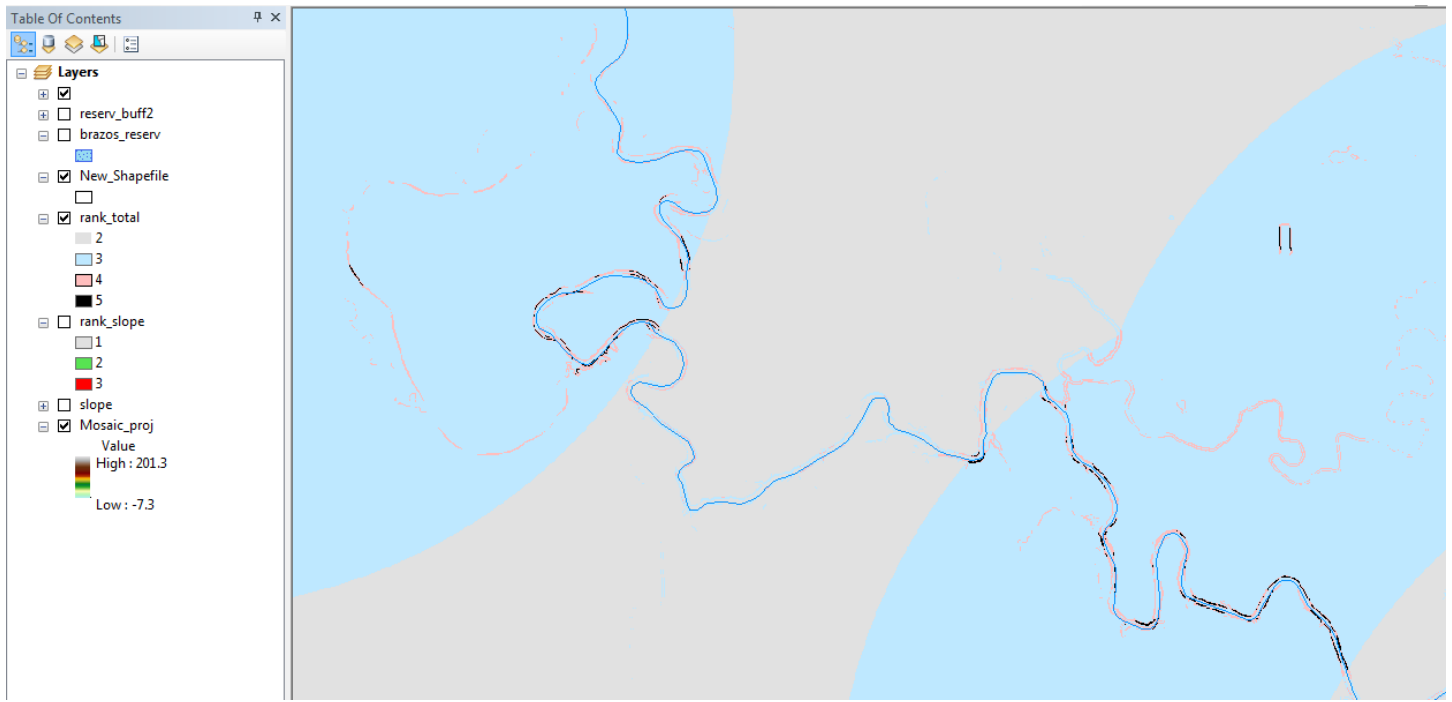
Figure 18: Lowest segment of the Brazos River within the area of interest, showcasing suitability ranks (**rank_total**).

Lastly, a hillshade is created for the DEM layer to show the pronounced changes in bank height and their relationship to slope and suitability for an impoundment (Fig. 19).
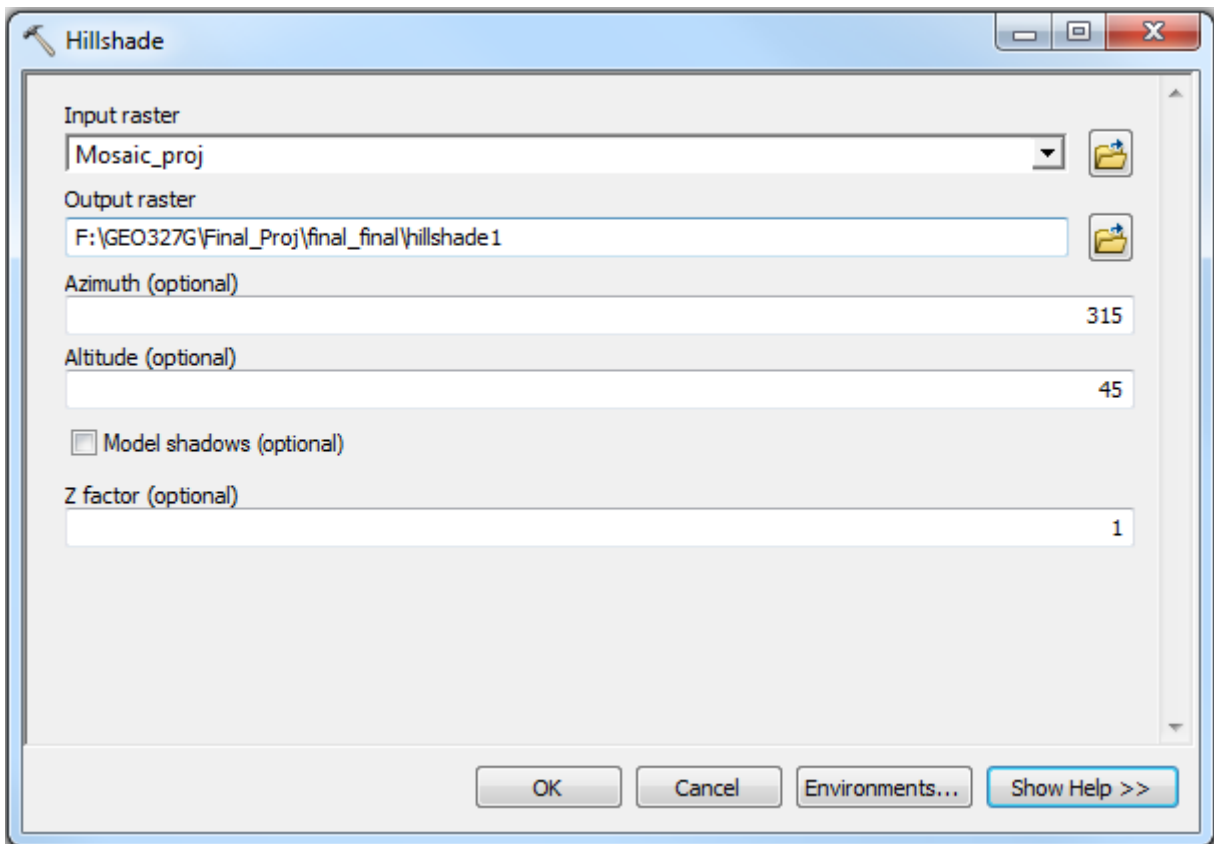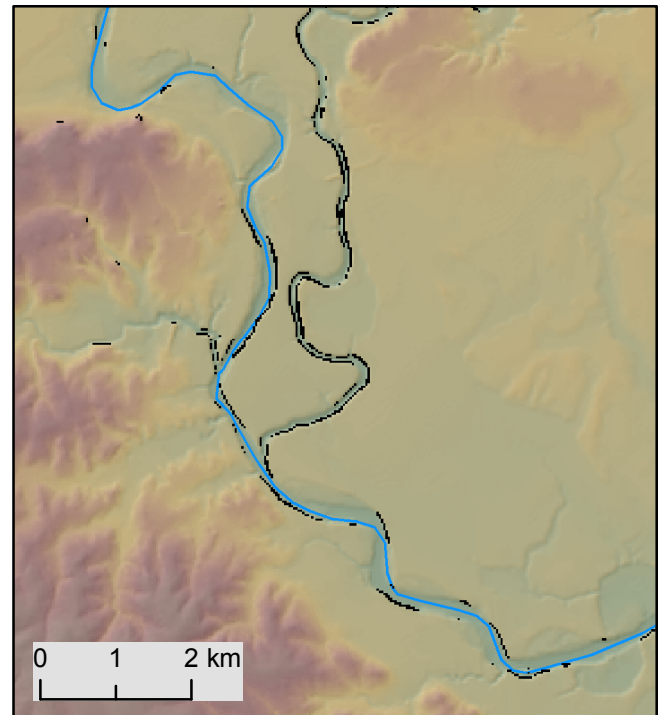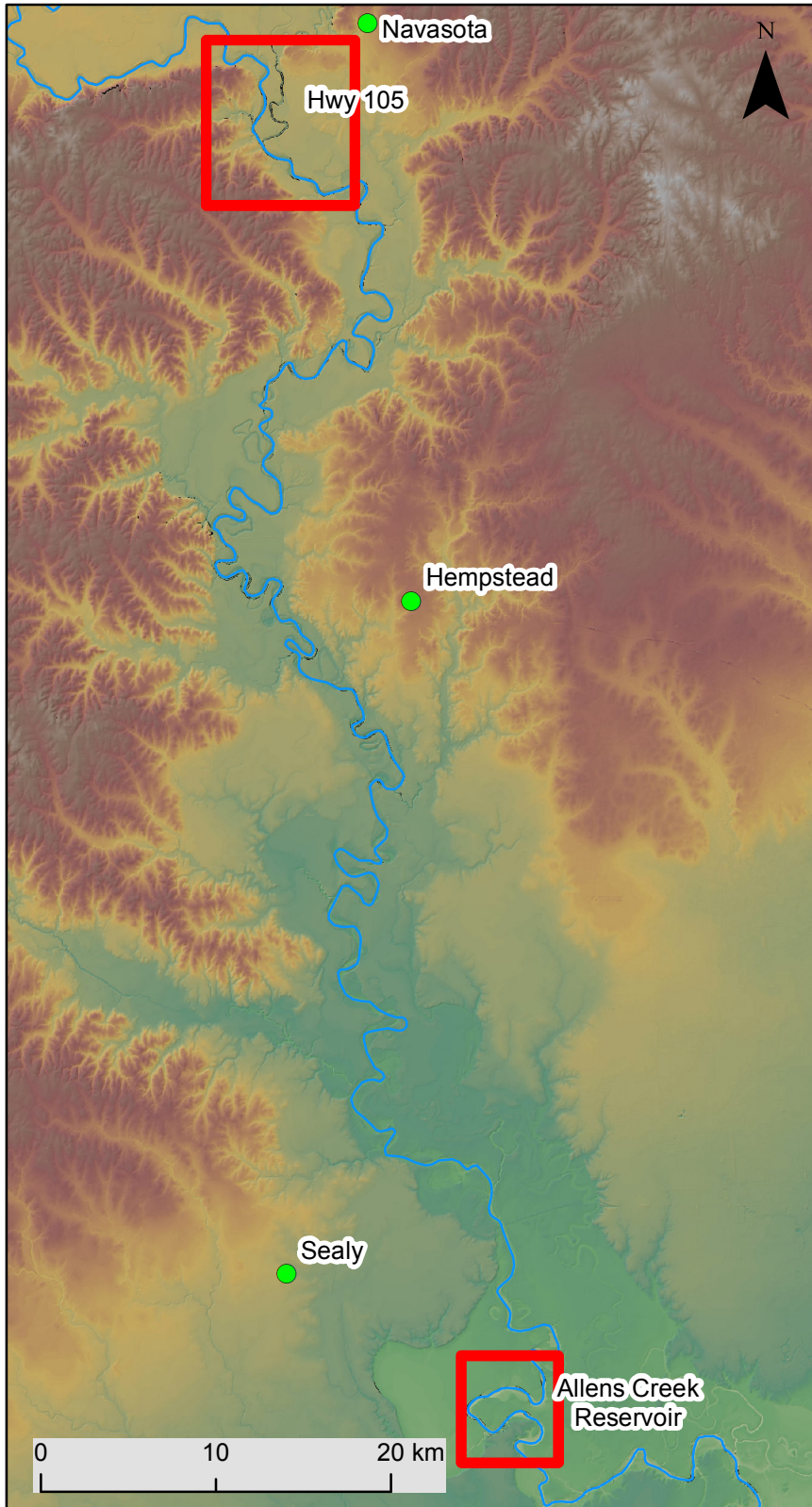


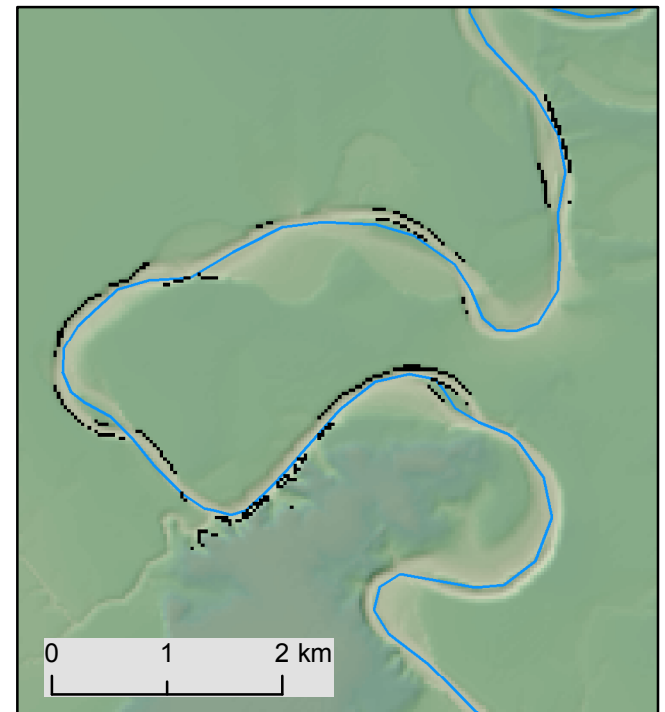Figure 19: Inputs in hillshade tool to create **hillshade_1**.

## RESULTS AND CONCLUSION

Suitable areas for proposed impoundments throughout the Lower-Middle Brazos River are fragmented in the highest, middle, and lowest stream segments of the Lower-Middle Brazos River, as shown in Figures 16-18. Slope was the most limiting factor because the range of suitable slopes, 15-18 degrees, was so narrow. This suitability analysis encompassed Allens Creek Reservoir, the proposed impoundment that will be constructed in 2020. This highlights the merit of these parameters considered for impoundment suitability. Although this analysis simplifies a highly complex problem, the parameters that it does take into account, topography and economic considerations, are fundamental parameters to consider when determining a new site for an impoundment.

# Site Suitability Analysis for Proposed Impoundments Along the Brazos River



Navasota

Hwy 105

Hempstead

Sealy

Allens Creek Reservoir

N

0    10    20 km

NAD 1983 Texas Centric Mapping System Albers          Units: Meter



0    1    2 km

Suitability along the upper extent of Lower-Middle Brazos River near Highway 105



0    1    2 km

Suitable area along Lower-Middle Brazos River near proposed Allens Creek Reservoir

## Legend

— Brazos River

■ Most Suitable for Impoundment

● Cities

**Elevation (m)**

- High : 202

- Low : -8

This map shows the areas along the Lower-Middle Brazos River that are suitable for a new impoundment. Factors taken into consideration include topographic slope between 15 and 18 degrees, greater than 10 miles away from reservoirs, and within a 10 mile radius of cities with popualtions greater than 5,000.