Follow-Up on the Nueces River Groundwater Problem
Uvalde Co. TX

Analysis by Ryan Kraft

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Problem Formulation

A reduction in discharge was detected at a gauging station along a portion of the Nueces River in Uvalde county Texas. Two possible solutions formulate as a result, either the groundwater is being lost to fractures in the underlying Glen Rose limestone or the water is being diverted around the gauging station by means of highly permeable gravel terraces that make up a part of the topography in the field site. By using airborne LIDAR data and spatial analysis tools in ArcGIS, it may be possible to extrapolate a groundwater surface that can be examined for trends. Analyzing the surface of the groundwater may answer why a loss of discharge was observed.

Data Collection

Because this question is building off previous work most of the data I required was already provided in lab 7.

Data Preprocessing

After investigating the properties of LIDAR data I came to the conclusion that the digital terrain model (DTM) created in lab 7 did not record static water heights. This is because I checked an area known to have standing water and when I queried a point in the center of the water body with the identify tool, the elevation was lower than the elevation given at the boundary. I assumed that the LIDAR data gathered was topographic LIDAR which would not detect water surfaces (especially still bodies of water). Therefore when I recorded water body heights I used the edges since the edges of the water bodies intersect the ground at known elevations.

From here it was a question of which water bodies in the water body feature class (provided in lab 7 data folder) were actually present in the field. This is because I recall discovering at least one area where streams or water bodies were thought to be present but were actually dry. This is a hard question to answer since not every place on the map was visited. Therefore I will only exclude bodies of water that I know are not present because I was at the location and observed there to be no water. In addition I do not think recording the height of all water bodies present on the map will be accurate either. This is because some of the bodies of water are located on the Glen Rose formation and are not connected to the Nueces river tributaries. If I assume that the Glen Rose is not permeable (which is needed to satisfy one of the hypotheses) then disconnected bodies of water on the Glen Rose should not contribute to the discharge seen in the Nueces River. A few water bodies on the Glen Rose are affected by this and are displayed in Figure 1. Also it is worth mentioning that two of the water bodies on the Glen Rose formation were suspiciously close to large plots of irrigated farm land which suggests they may have an anthropogenic origin. Figures 2 and 3 are pictures of terraces taken in the field and show their composition. Besides identifying what features to exclude, the rest of the data was already processed and included in the lab 7 folder.

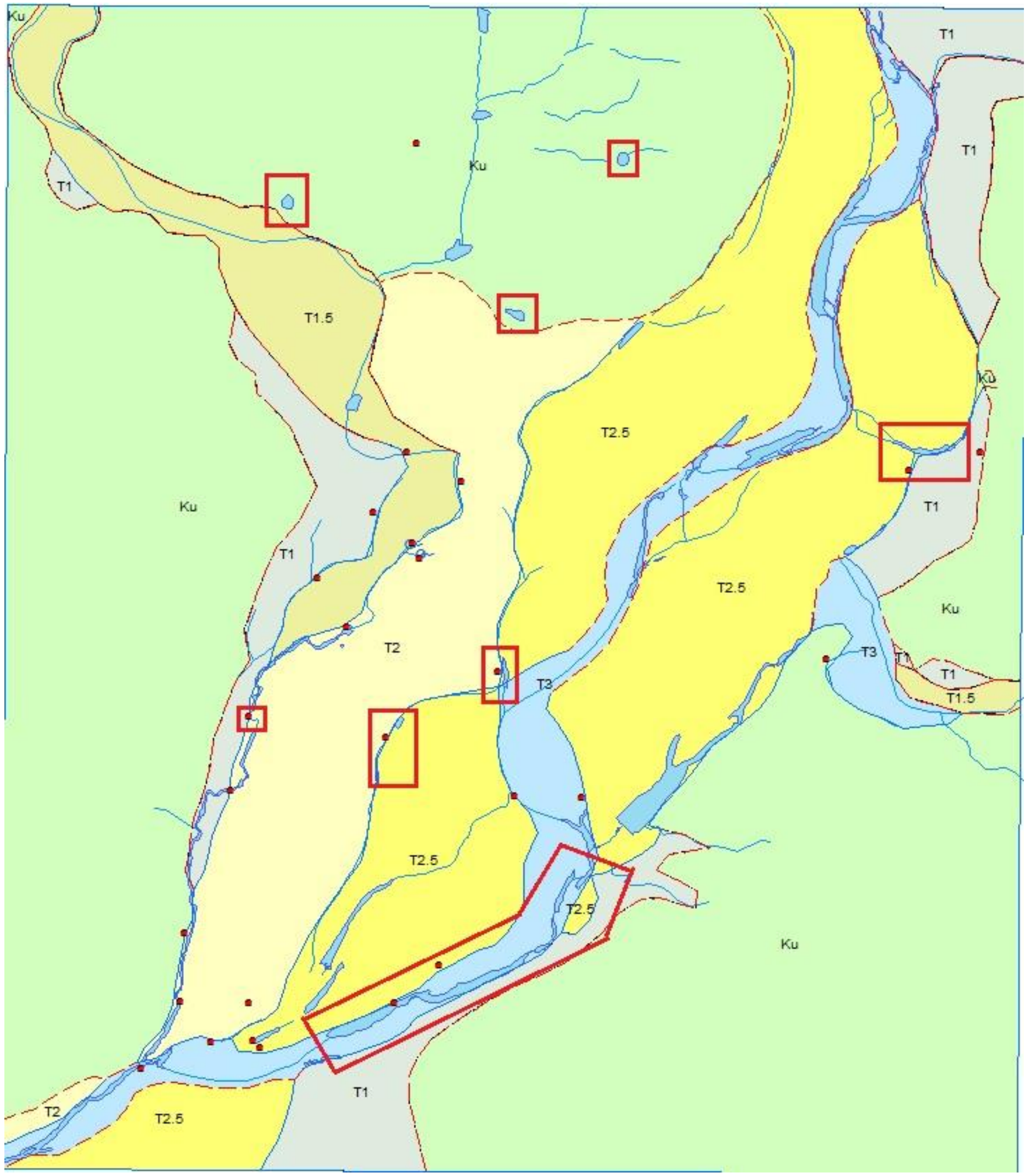

Figure 1. Map of the study area. Locations visited in person area indicated with red dots. Red boxes indicate water bodies that are omitted from the groundwater surface extrapolation. Ku and T1-T3 are the Glen Rose and Terraces 1-3 respectively.

Figure 2. An example of the composition of the terrace labeled T2 (picture taken in field). It contains a fine matrix but still has the capacity for fluid flow.

Figure 3. Image of the third terrace (T3) taken in the study area. The unconsolidated gravel likely has a high hydraulic conductivity making it ideal for flow deviation.

<u>ArcGIS Processing</u>

After mentally omitting certain water bodies I created a new point feature class labeled "Water table heights". This was done by going to the Nueces River 2014 geodatabase --> Right-clicking the Geologic Units feature dataset --> New --> feature class.

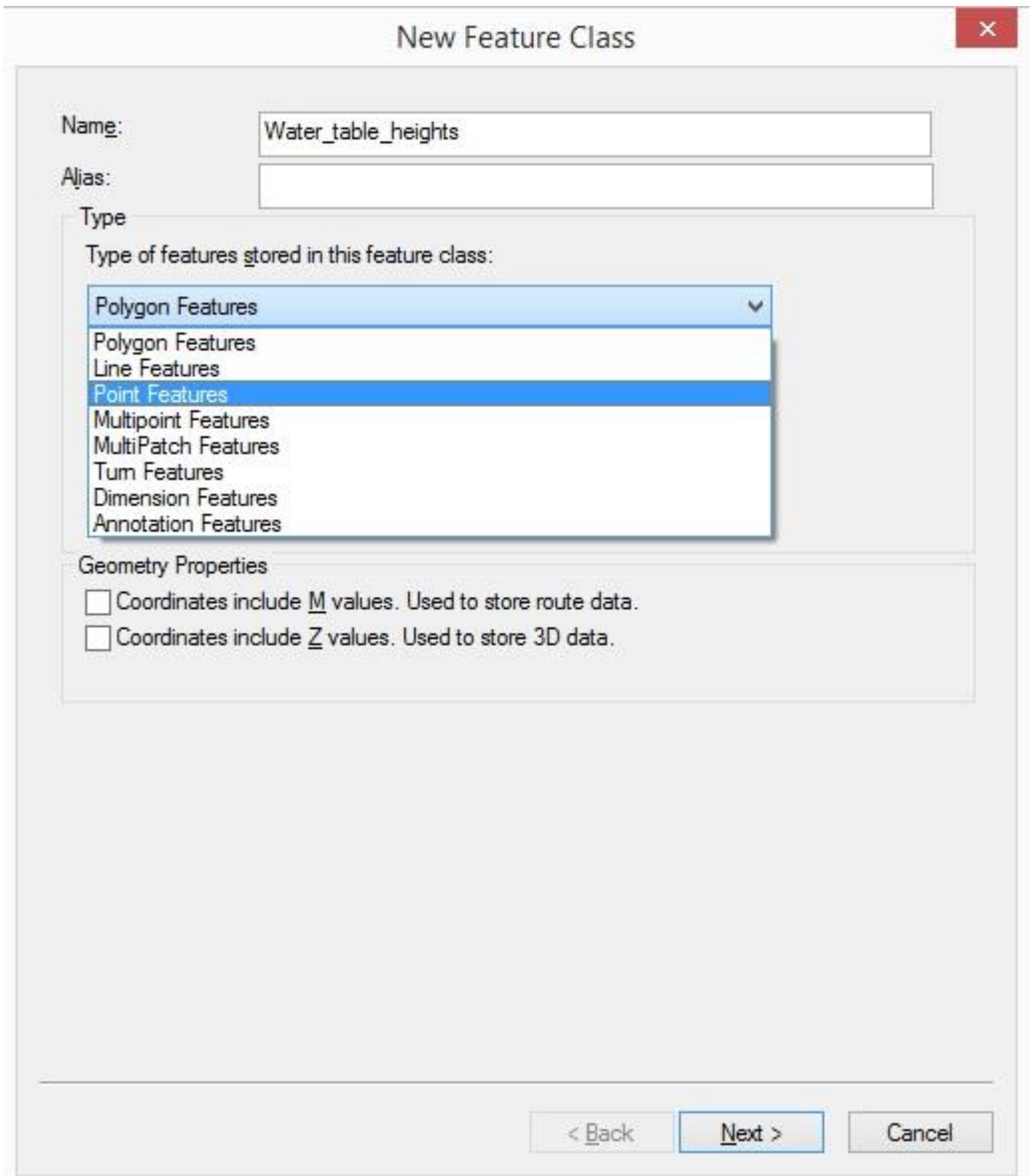

Figure 4. Creation of a new point feature class

I did not annotate any of the fields for the new point feature class. Instead I used the “Extract Multi Values to Points tool” in the “Spatial Analyst toolbox” to extract elevation from the DTM onto the points.

Before that however I had to create the points within the point feature class. This was done by turning on the editor tool bar (Editor --> start editing), selecting water table heights as the feature to edit and then plotting points on the boundaries of the water body polygons (snapping made the process easier). I did not create points at the water bodies I decided to omit as stated previously so they are the naked water bodies in Figure 5. The points were arbitrarily placed on the boundaries and I limited the number of points for each water body.

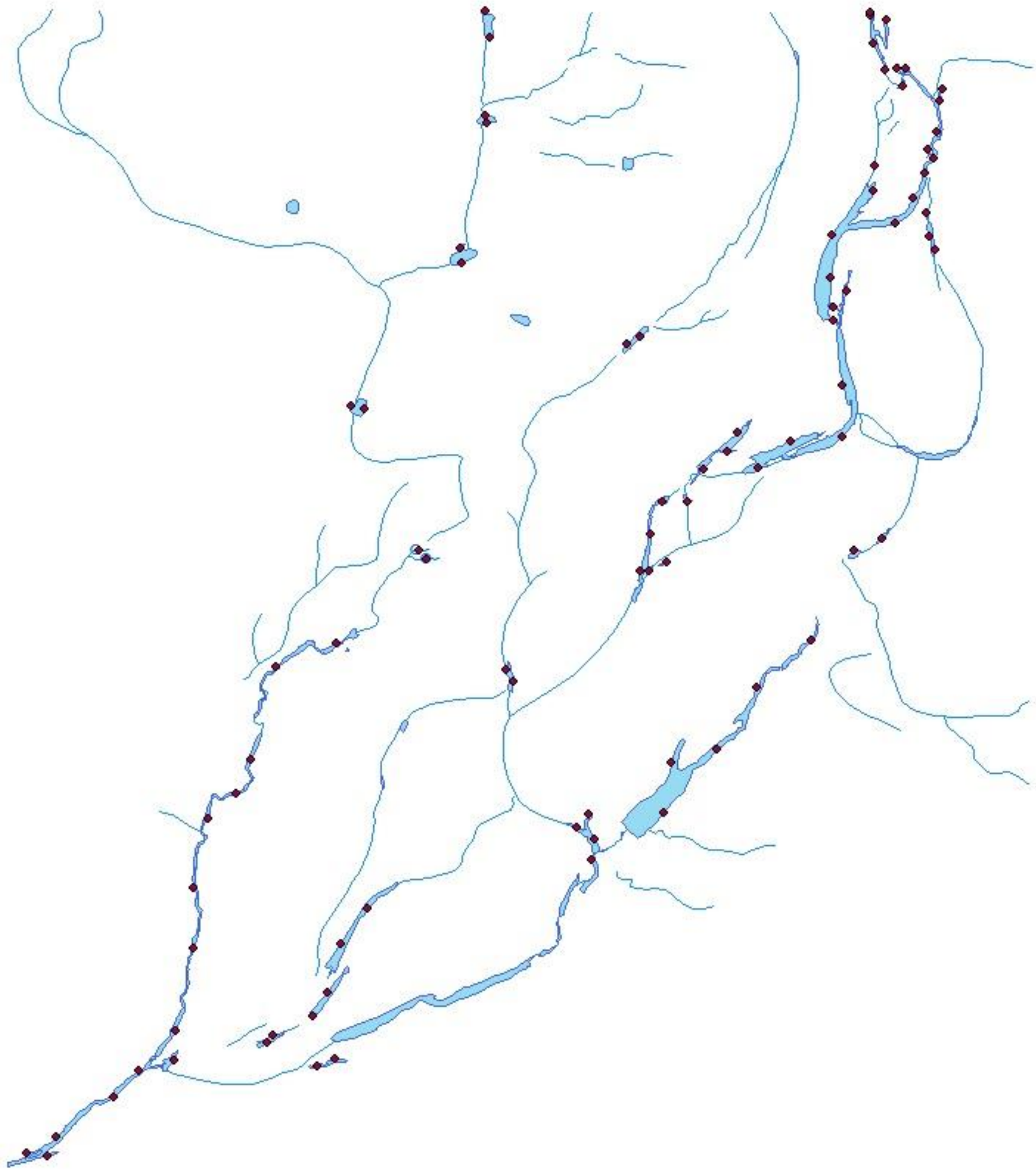

Figure 5. The surface water elevation points (purple dots) created to allow for 3D interpolation

Once the points were created I used the "Extract Multi Values to Points tool", as stated before, to assign Z-values to each point (Figure 6). After that step I was then able to use the Spline tool (Figure 7) within the 3D Analyst toolbox to create a surface that estimates the surface of the water table in the study area. I used spline because it produces smooth curves which are how groundwater surfaces are shaped. The result is shown in Figure 8.

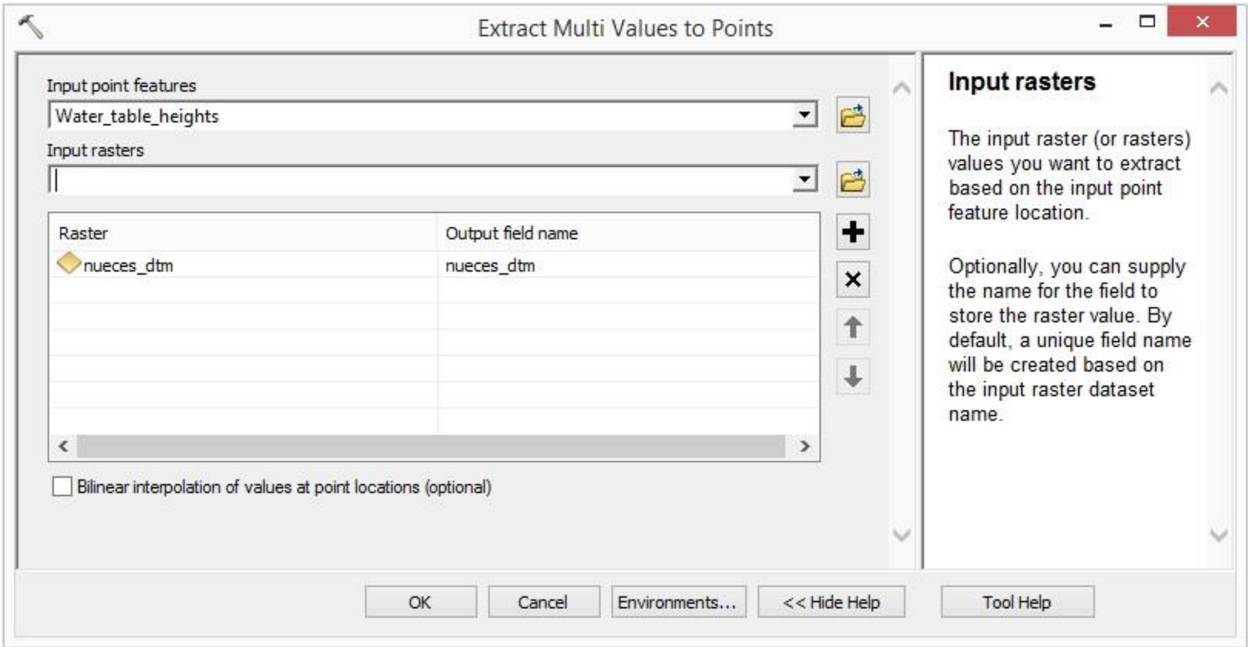

Figure 6. The Nueces DTM values were the inputs for the water table heights feature class

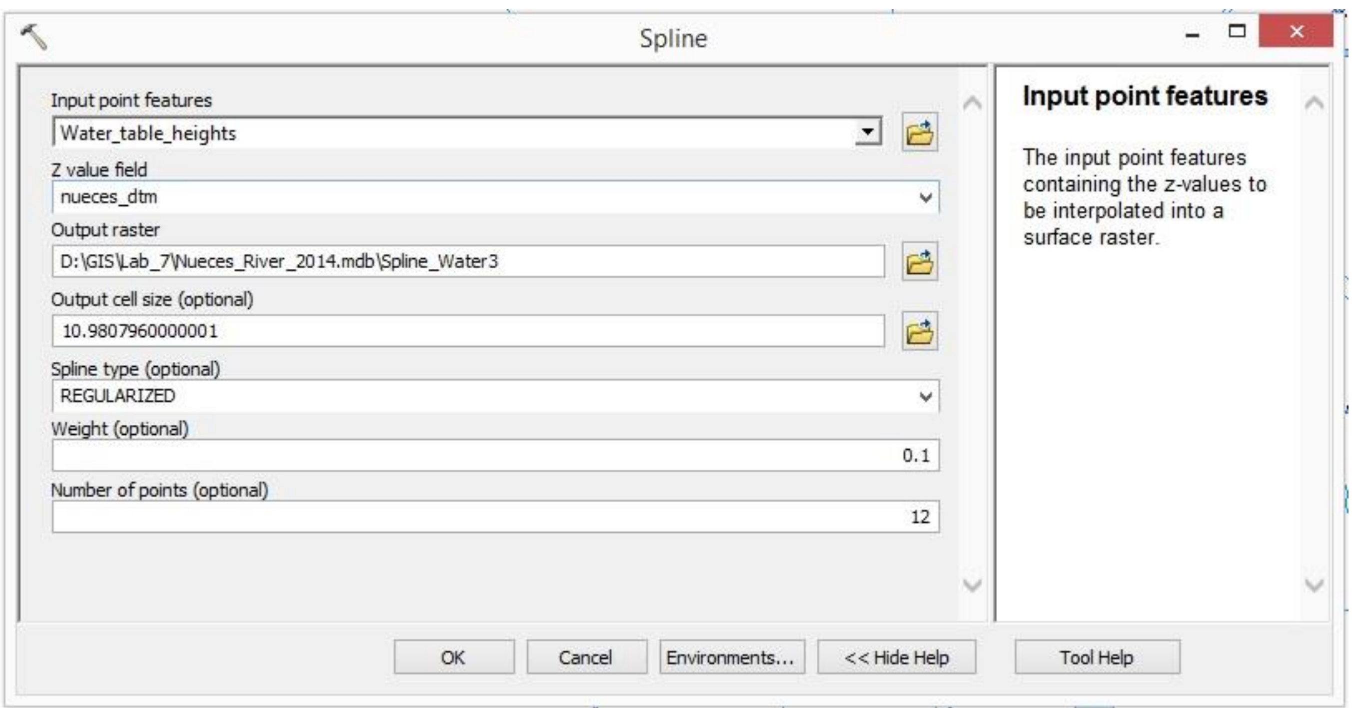

Figure 7. Spline tool used to create a new raster surface that estimates the water table surface in the study area

Figure 8. New raster that serves as an estimate for the groundwater elevation

Ideally this new raster represents the relative changes in elevation of the groundwater surface by using all of the points shown in Figure 5. A volume calculation was also done using the “Surface Volume tool” within the 3D analyst toolbox. Table 1 shows the estimated volume. It was determined from the lowest point on the raster. However it is likely an over estimate because it includes the area over the Glen Rose as well.

Plane Height	Reference	Z Factor	Area_2D	Area_3D	Volume
378	ABOVE	1	9344786	9345435	117444462

Table 1. Calculation of Volume from Surface Volume tool

If it was assumed that the Glen Rose is not very fractured and thus not containing water, I would guess that a better estimate of the volume of groundwater would be constrained to the terraces. So to see the difference, I clipped the raster surface to the terrace boundaries. I first had to create a new polygon and delineated its boundaries by tracing the outside boundaries of the terrace region. The product is displayed in Figure 9.

Plane Height	Reference	Z Factor	Area_2D	Area_3D	Volume
377	ABOVE	1	4639355	4639582	57683683

Table 2. Calculation of Volume from Surface Volume tool for the clipped groundwater surface

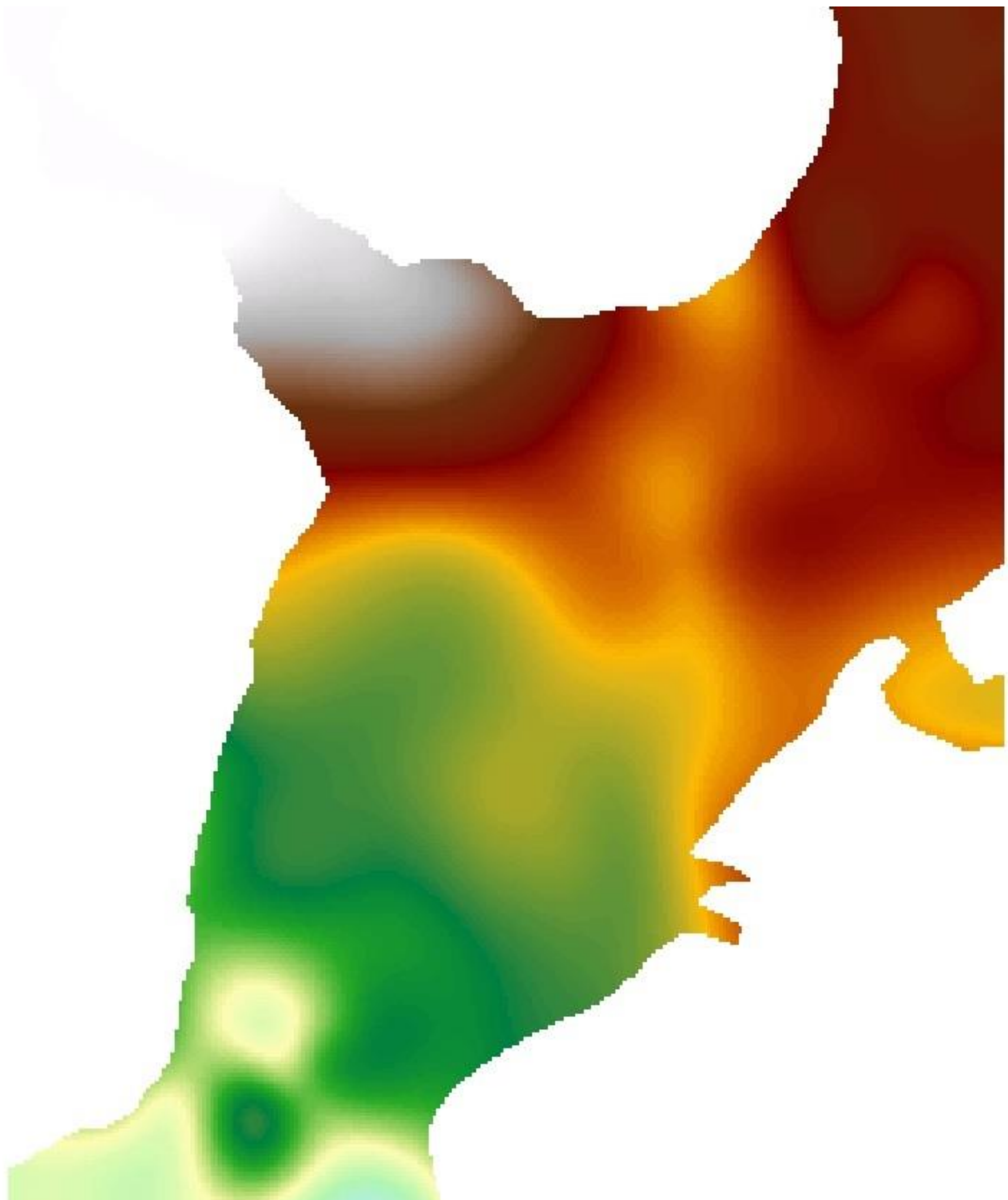

Figure 9. Clipped version of Figure 8. This assumes the Glen Rose is impermeable

I decreased the plane height in table two to account for approximately one extra meter of terrace below the surface which is assuming that the bottom most gravel layer is laterally extensive over the region. Finally a perspective view was created in ArcScene to get a better look at the groundwater surface. It appears the groundwater follows the contours to some extent.

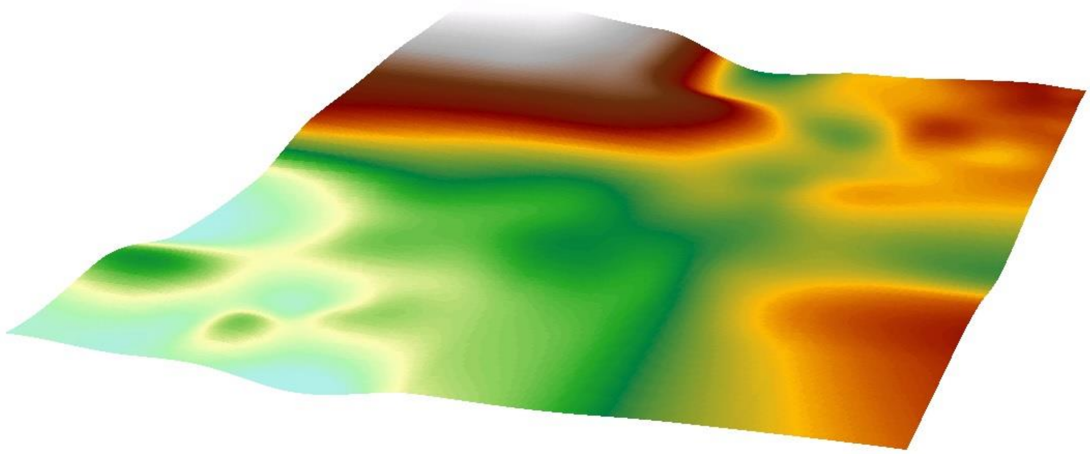

Figure 10. Perspective view of the groundwater surface in ArcScene

Conclusions

By taking elevations of water bodies and using the ArcGIS Spatial Analysis tools I was able to create what might be the surface of the groundwater within the study area in Uvalde county Texas. Though it does not completely solve the problem I think it sheds some light on what the answer may be. I believe the answer leans towards the Glen Rose hypothesis. If the T3 terrace was diverting the water one would expect to see the groundwater elevation have a low spot near the gauging station but increase in elevation downstream to its original thickness. The results of this analysis however show that this is not the case. The groundwater is losing volume down gradient. Further analysis needs to be done but this can serve as a preliminary look into the groundwater properties.

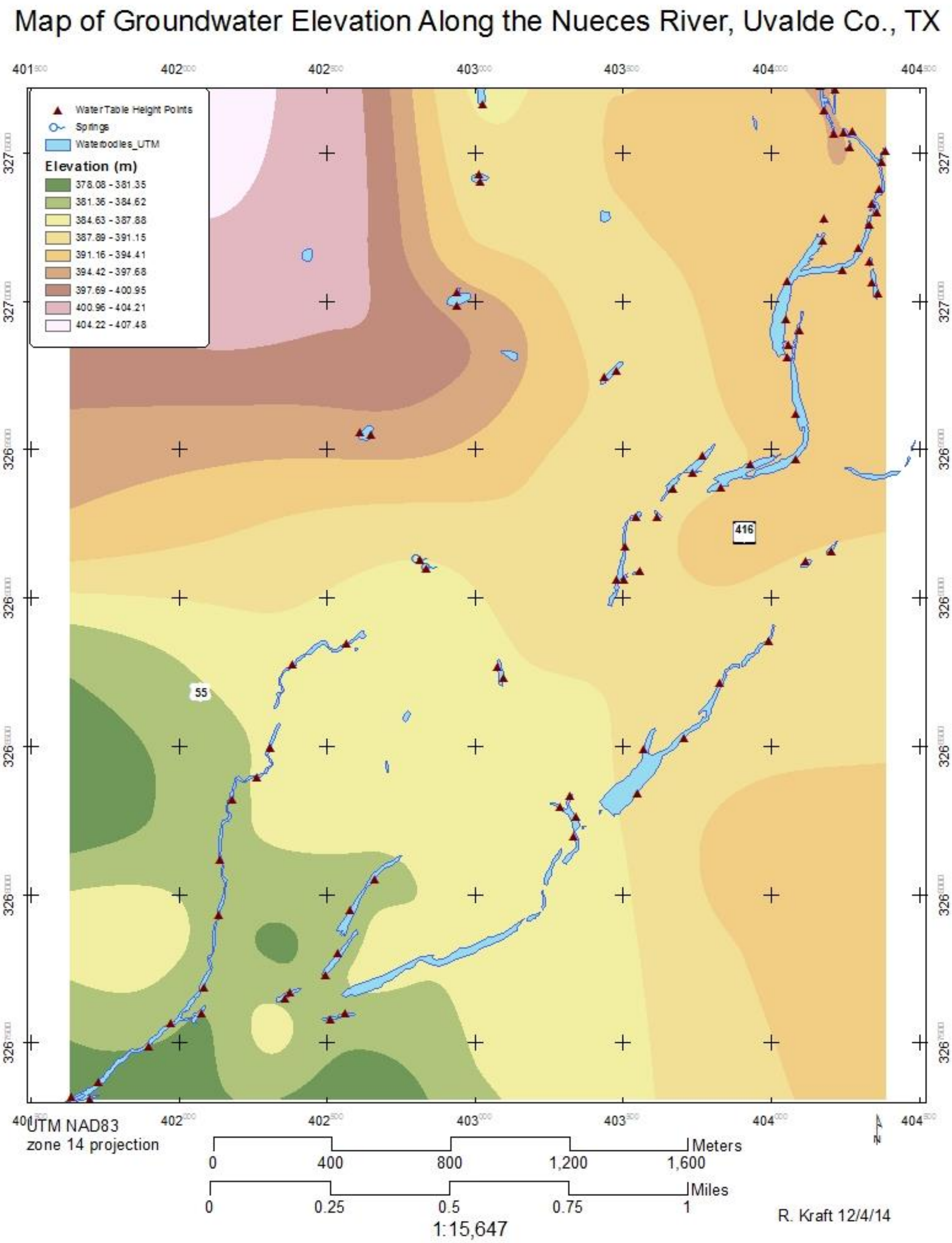

Figure 11. Groundwater Surface Map.