

Introduction

The Edwards Aquifer is a karst aquifer in Central Texas whose hydrogeological properties are not fully understood. This is due to exaggerated heterogeneity of properties, high anisotropy due to faulting, and further dissolution of carbonate rocks complicating the system. Additionally, urban expansion, agricultural uses, and dams stand in the way of observing the system fully. Focus for this research lies within the Barton Springs Segment of the Edwards Aquifer, many studies have been done in this particular segment in regards to mapping, measurements of recharge, groundwater traces, and proposed models. Processes such as deposition, dissolution, and fracturing associated with the Balcones Fault System have proved to play important roles in the development and preferred flow path of the Edwards Aquifer. A large issue involving any aquifer in Texas is how the aquifer responds under drought conditions. This response will then be assessed and taken into account when decisions need to be made for values of sustainable yield (groundwater laws for Texas).

Purpose

In regards to this project, I wanted to try and see how the Edwards Aquifer had responded to droughts in the past, and to illustrate how the changes in water levels become distributed spatially. Although the aquifer is variable and hard to predict, I wanted to formulate a model of how it had behaved in the past and maybe new responses to droughts could be compared in the future to pinpoint, in spatial terms, what might have changed to cause different gradients in water level declines. Also the maximum value of change in water levels could be used as a basis for what levels of sustainable yield should be set as.

Problem Formulation

The goal of this project was to map data from water levels in the Barton Creek Segment of the Edwards Aquifer. This segment is contained within Travis and Hays County. This will be done

in ArcMap, using CAPCOG shapefiles and data from the Texas Water Development Board. Notable droughts were felt across Texas in 1970-1971 and 1982-1983. I decided to pick the year at the end of the drought (1971) as the year to find well data from, under the reasoning that it would carry effects from 2 years of drought. I then picked a year that was both 1971 post-drought and pre-1982 drought. I picked the year of 1978, because in both counties sufficiently more data was presented in this year in comparison to many others. Using this well data, we can formulate raster surfaces of well water levels in both years and subtract them from each other to get the change in water levels.

Data Collection

The websites CAPCOG.org and the Texas Water Development Board proved to be extremely useful for this project. The links are provided here, <http://www.capcog.org/data-maps-and-reports/geospatial-data/> and <http://www.twdb.state.tx.us/groundwater/data/gwdb rpt.asp>, respectively. Layers (shapefiles) that I chose to download were the counties shapefile from CAPCOG and the GWDB well locations shapefile available on the Texas Groundwater site. Also, a shapefile from Dr. Helper's Lab 1 was available in the Lab 1 Data folder under "faults" as a shapefile containing the Balcones Fault Zone (with respect to Austin). I ended up starting out with the counties shapefile and using that as the backdrop for my well data.

I then needed to find data for the wells in Travis and Hays County. On the link provided above, I downloaded the text file named **Water Level Table** for each county. However, these textfiles contained ID numbers and measurements for specific years, but lacked latitude and longitude coordinates. In response, I found, at the top of the website page, a shapefile containing all the wells in Texas' with their ID numbers, aquifer, rock types, and spatial coordinates.



Figure 1. Location of text file data needed labeled “Water Level Table.”

Data PreProcessing

Take the well data text files and saved them to the project file. Then, open Microsoft Excel and click Data>FromText. Select your saved table (for Hays and Travis Counties) and use the comma symbol as the delimiting separator. Once you get your table, save this new table in your project folder as “Hays_waterlevel” respectively for both Hays and Travis counties. In ArcMap use the Search tool to search “create table.” In the Table Location column browse to your Hays_waterlevel table that you had converted to Excel and name it appropriately. Click Ok.

For these purposes, we need to find years with drought conditions and years with regular conditions. To see how much data is available for the years in question, Press Control+A and then Data>Sort and pick to Sort with respect to year.

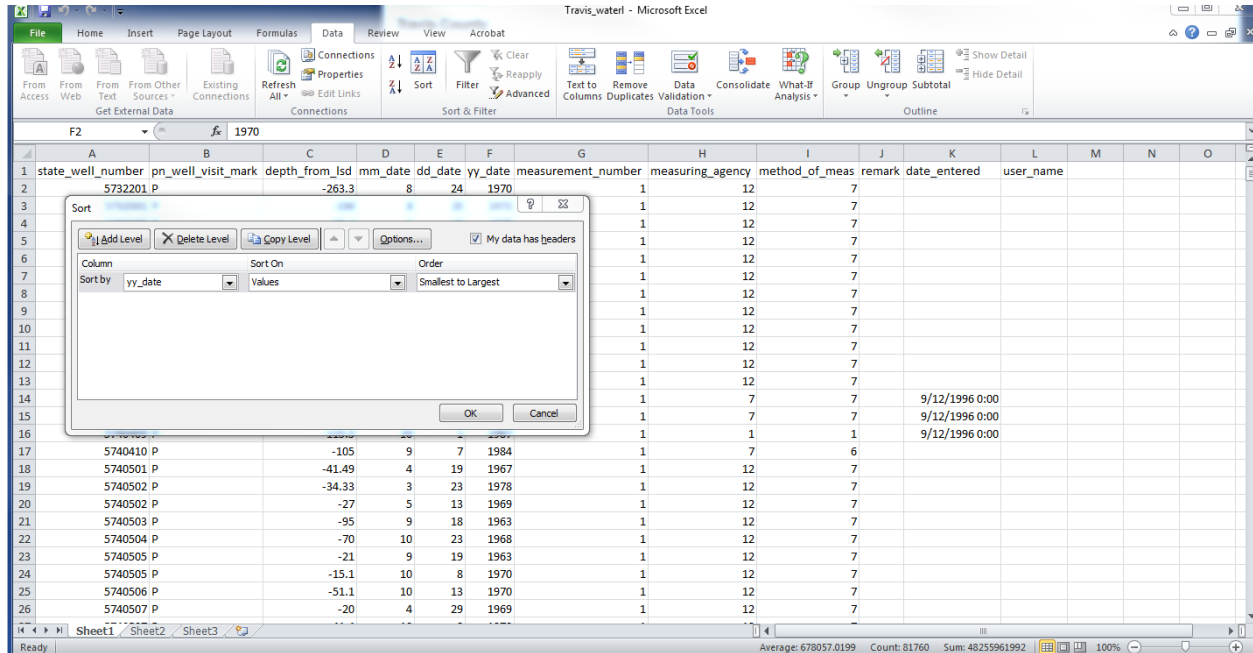


Figure 2: Sorting well data with respect to years

To make the tables less messy, I selected only the years that I was looking into (1971 and 1978 respectively) and I deleted the rest (for both Travis and Hays counties). A problem arised when it was made obvious that these counties had more aquifers then just the Edwards Aquifer. Since I was originally specifying this Aquifer, I also had to delineate the information by only selecting the Edwards Aquifer wells data. In order to do this, on the groundwater data link, one must save the Lookup Table: Aquifer Codes as one did before with the Water Levels in Travis and Hays County (open in Excel as a text file). Then find the Aquifer Codes which are associated with the Edwards Aquifer:

264	218EBFZA	EDWARDS AND ASSOCIATED LIMESTONES - (BALCONES FAULT ZONE AQUIFER)
265	218EDAD	EDWARDS AND ASSOCIATED LIMESTONES, ANTLERS SAND, AND DOCKUM FORMATION
266	218EDAS	EDWARDS AND ASSOCIATED LIMESTONES AND ANTLERS SAND
267	218EDDT	EDWARDS AND ASSOCIATED LIMESTONES, AND TRINITY GROUP
268	218EDGR	EDWARDS AND ASSOCIATED LIMESTONES, AND GLEN ROSE LIMESTONE
269	218EDGRU	EDWARDS AND ASSOCIATED LIMESTONES, AND UPPER MEMBER OF GLEN ROSE LMST
270	218EDPM	EDWARDS AND ASSOCIATED LIMESTONES, AND PERMIAN SYSTEM
271	218EDRD	EDWARDS LIMESTONE
272	218EDRDA	EDWARDS AND ASSOCIATED LIMESTONES

Figure 3: Textfile with ID codes of the Edwards Aquifer

To simplify this process, we can join these tables in ArcGIS in order to join the wells with their respective aquifers. However, we need to add yet another table to do this, because the well data for the counties did not have information about their aquifers. You must join the well_data tables to the well_water level tables that you downloaded as a large shapefile for all the wells in Texas.

ArcGIS Data Load

Load counties shapefile, and download GWDB well locations (shapefile) from the Texas Water Development Board site. Right click the data link, drag it into your project folder. Right click the folder and Extract the Zipped Folder. Erase the old folder and now you have your needed shapefile. Add this shapefile to the counties shapefile. The counties shapefile has a different coordinate system than the county_wells.

Project the counties shapefile from its original coordinate system to the coordinate system that the counties has <NAD1983>. Open ArcToolbox, search for the project tool, Input from the drop-down menu the counties shapefile and for output create a file which is easy for you to find (in my case, placed in the R database within my 'project' folder), then Select a Coordinate System GCS<North America < NAD 1983. Now both layers have the same coordinate system.

In this case, we are only interested in the counties containing the Barton Springs Segment of the Edwards Aquifer. Since the well data contains hundreds of thousands of wells in Texas we need to clip this data to Travis and Hays Counties. Right-click the projected_counties layer and open

the attribute table. Select only Travis and Hays Counties (this is important as then you will not have to specify to which counties you want the wells layer to be clipped to, as long as you use the drop-down menu NOT the folder option). In ArcToolbox, search for the Clip tool (Analysis Tools> Extract>Clip). In the Input Features select counties from the drop-down menu. In clip features select your wells layer, and then create an output feature class that you can find. Hit Okay and this will automatically be added to your map. Erase the old wells layer. Right click your new wells layer and Zoom to the layer. The map now looks like the one below.

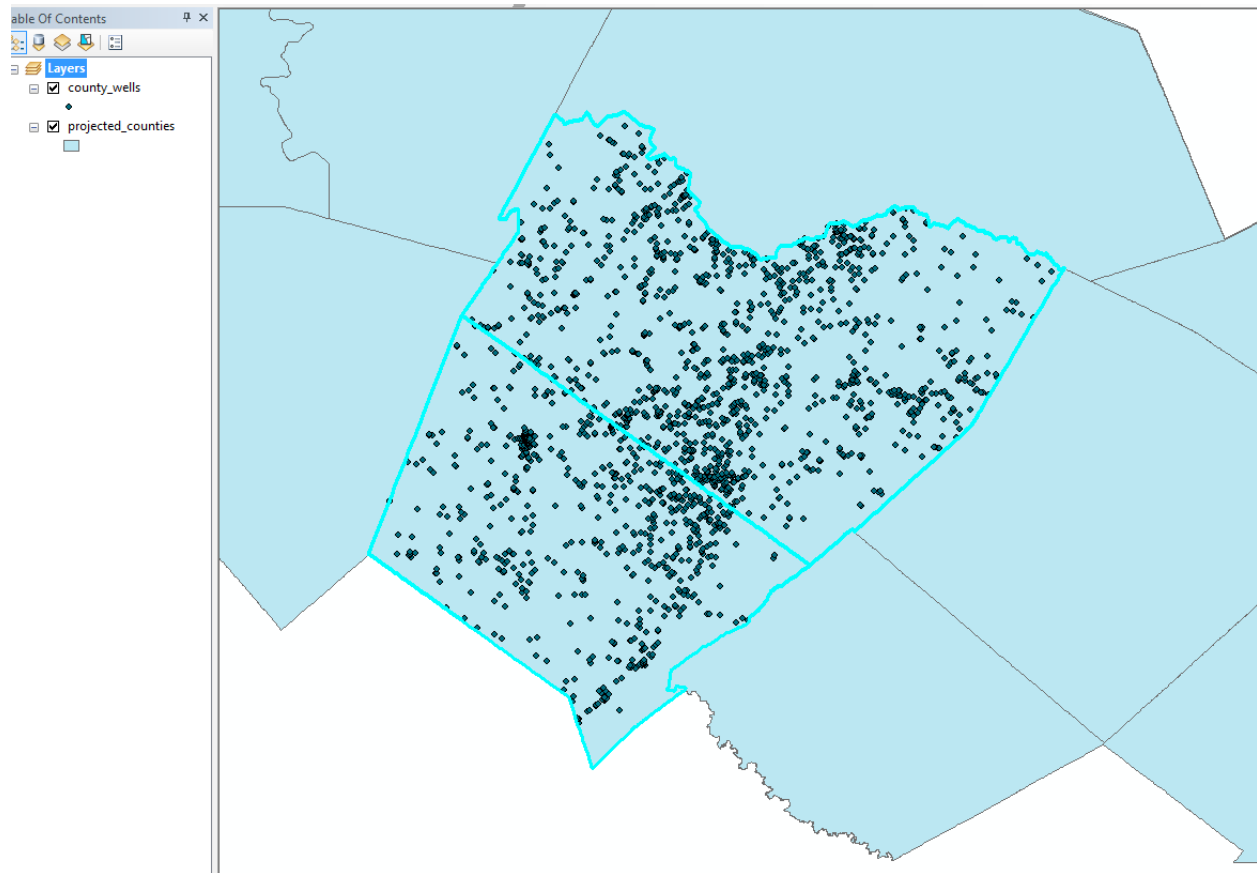


Figure 4: GWDB Well Locations (shp) clipped to Travis and Hays Counties (shp) in ARCMAP.

Relate Tables

In order to only select wells within the Edwards Aquifer, I joined the well_data table and the Travis and Hays Counties water level tables. In order to do this, the Travis and Hays counties tables need to be joined to the layer of county_wells that was already uploaded to the map. I did this twice, once for each county (a problem arised because there were multiple sheets for the Excel Workbook, I then found I needed to pick the sheet that has your saved title attached to it as all the information needed is actually only on one sheet). There are a lot of wells now that have no information for them. We will deal with this problem later.

Clipping extraneous data

Now we must deal with the fact that multiple aquifers are present in this area. We are concentrating on the “Edwards (BFZ)” but there are information for unnamed aquifers, ‘Other,’ ‘Edwards-Trinity’, and ‘Trinity.’ Open your newly joined attribute table. Put the field ‘aquifer_id’ in ascending order (it turns out we didn’t have to find the lookup table for aquifer ID’s as it was located in the huge shapefile of Texas, but at least now we have an idea as to what the abbreviated rock units mean). Once you get to the beginning of “Edwards” click the arrow to the right of the column. Hold down the shift key and then click on the space next to the column which marks the end of the “Edwards” attribute into the “Other.” This will select all the attributes that are important for this concentrated study. See Figure below.

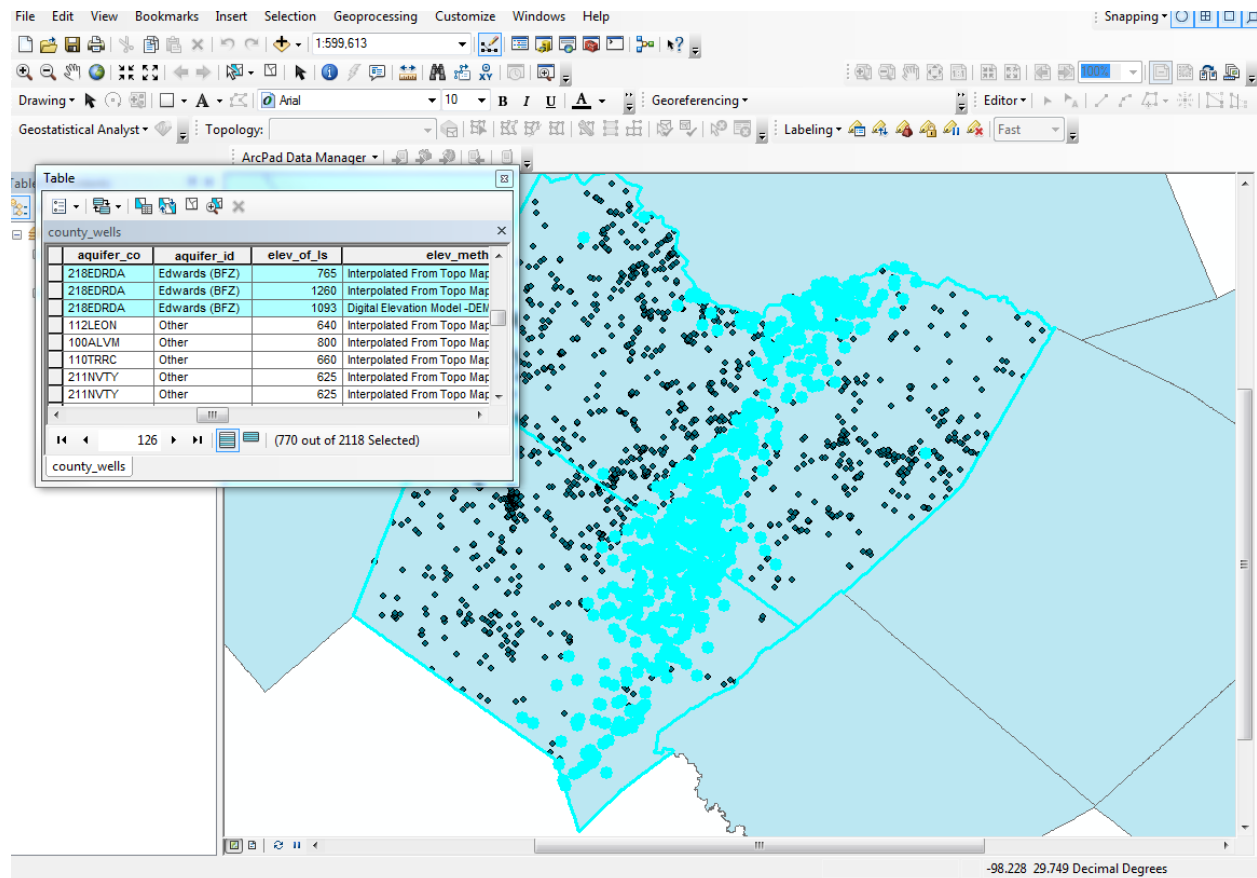


Figure 5: Selecting only data taken from the Edwards Aquifer to clip

Now we need to cut out all extraneous data. We can do this by right-clicking the layer “county_wells” and Data>Export Data and making sure to save the new file as a shapefile. This shapefile “Edwards_wells.shp” was then added to my map and the old county_wells was removed.

Complications arose with respect to the Balcones Fault Zone. The Balcones Fault Zone makes the picture complicated as the Edwards Aquifer is a karst aquifer, and the flow in the aquifer is dominated by the irregular Balcones Fault System and its consequential secondary porosity. Therefore, it should be added if only with respect to see where it effects the aquifer to the greatest degree. To see this fault zone, a shapefile was available in Dr. Helper’s class data for Lab 1.

To eliminate unnecessary data, I had to delete all wells collected that did not have values for the years needed. So I then went to the attribute for year and sorted it in descending order. Then, I selected the ones with available years (since I only added data that had those 2 particular years). Problems arose when only Travis or Hays county would come up although I had joined both counties. Then, I realized that it had joined the tables and there was an extra 'year' attribute table. Therefore, I exported data for Travis county and then for Hays county and had them loaded as two separate layers. Moreover, I decided to split the information up by counties and make four raster sets. Two for the two years in Travis county and two for Hays county. After looking at the map, I realized that most of the fault system was concentrated in Travis County, so I thought it may be interesting to look at each county separately and see how much the fault may have affected my analysis.

First, I again selected data from 1978 for Travis county and exported it as a shapefile saving it as "1978_Travis.shp," I then repeated this step for Hays county and for the 1971 year.

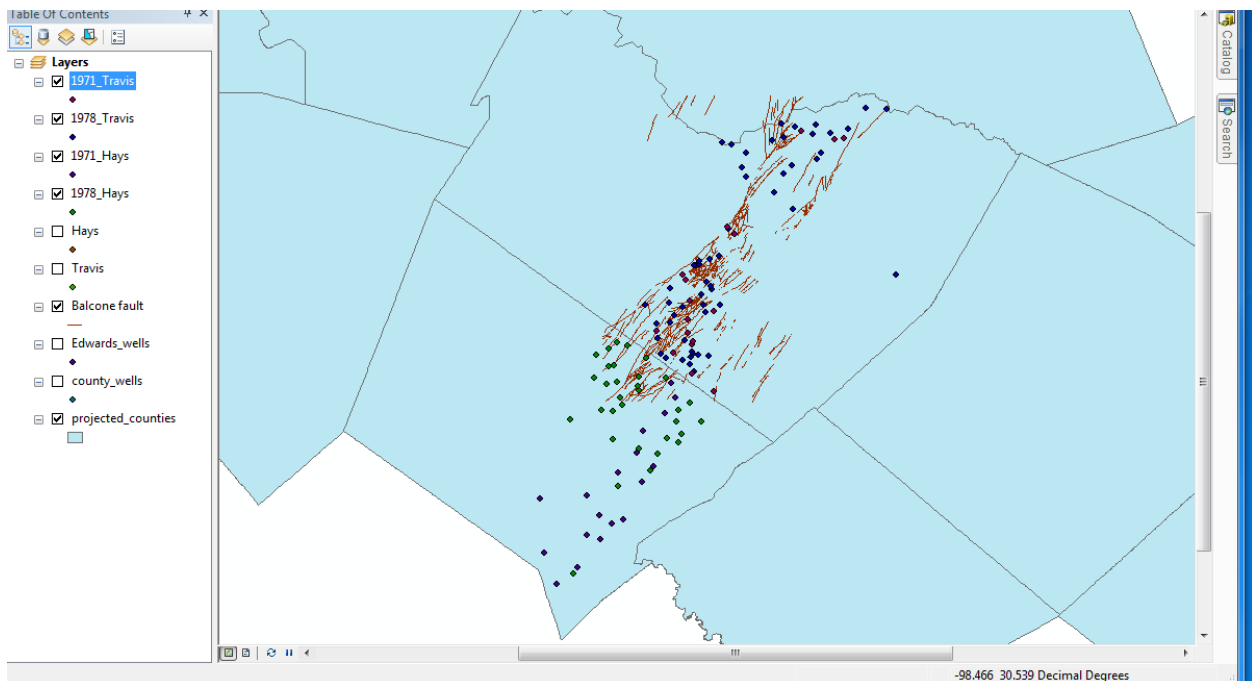


Figure 6: Map of only the well locations containing data collected from the two desired years

Converting Well Points to Raster Surfaces

I searched for the “Point to Raster” Tool in the Search window, and used this conversion tool to convert each of my four layers to rasters. In the beginning, I forgot to format it as a .tif because I did not have a geodatabase to connect it to. If you do not label it as .tif ArcMap will crash. Also, the preferred cell size was hard to choose. At first, I went with the default which was around .0004, and the raster’s were created, but you could hardly see them and they were more like the previous points than what I wanted for a raster surface. I tried a multitude of different cell sizes, and ended up with .05. This cell size is large and so it looks silly. However, if I had gone with a smaller size the surface would not have interpolated and I would not have been able to do any calculations or delete the two surfaces from each other.

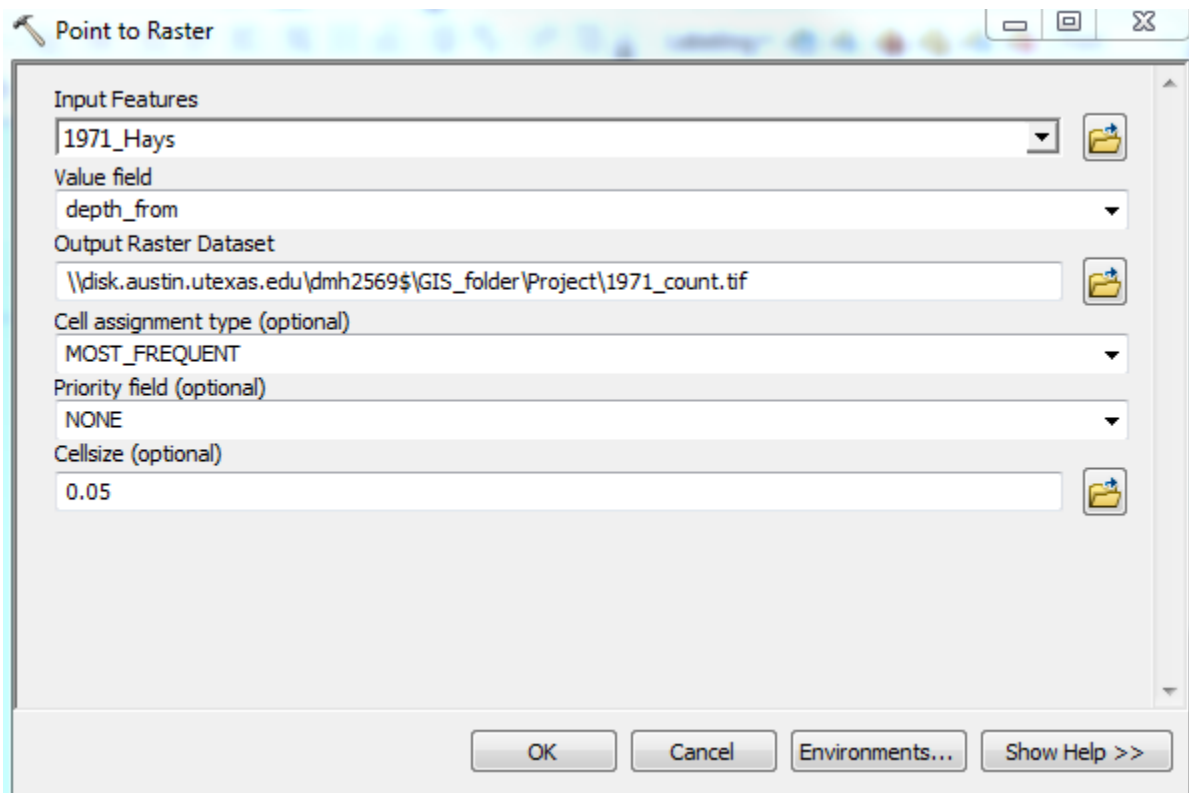


Figure 7: Creating a raster from points using the tool ‘Point to Raster’ with an output cell size of 0.05.

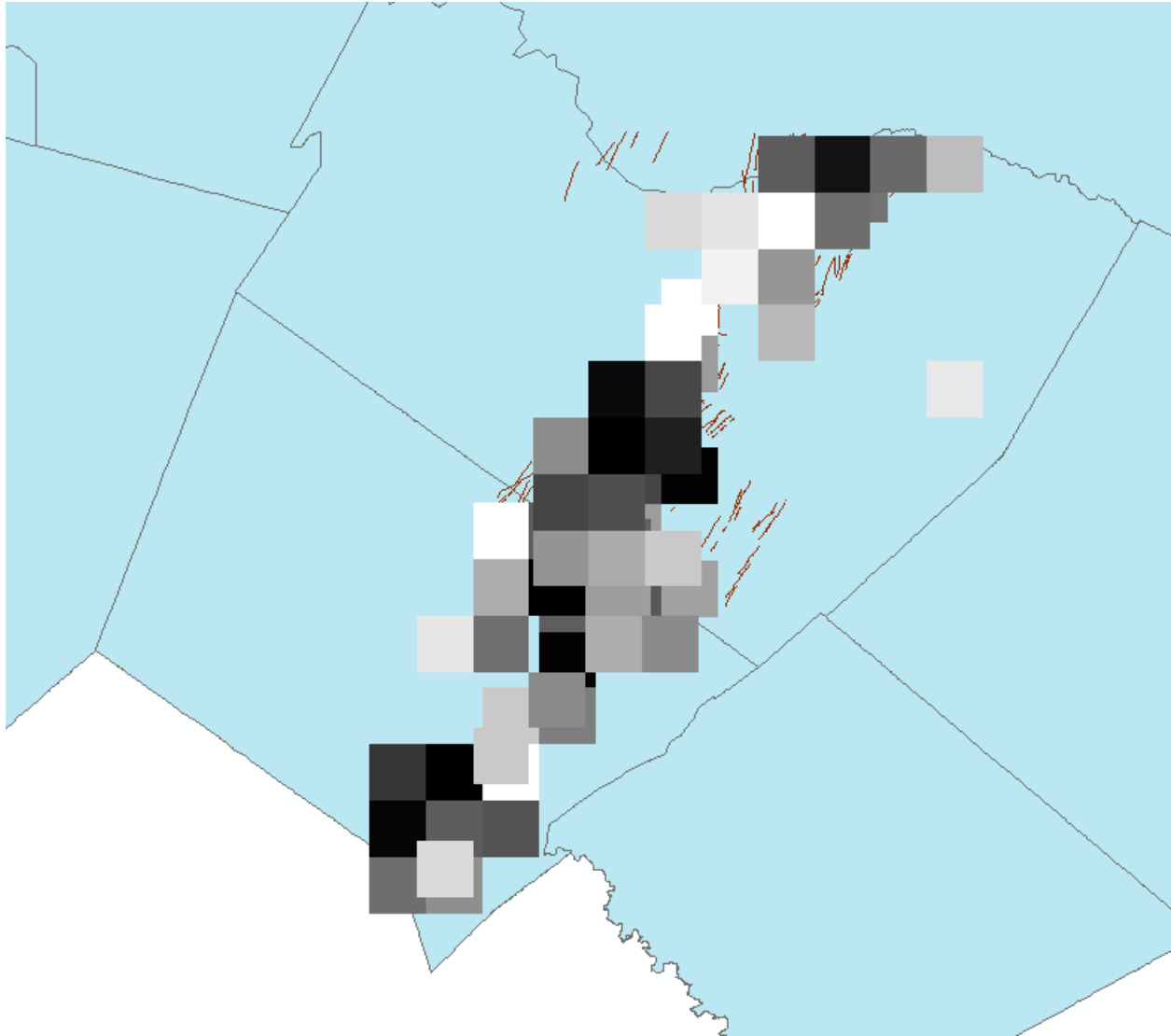


Figure 8: All four raster surfaces reflecting water level measurements from wells.

Also this did not look very aesthetically appealing; I decided to at least try to see what the raster calculator came up with. I opened the tool “Raster Calculator” and used the MapAlgebra Expression to subtract my 1971 raster from my 1978 raster, for both counties. See Figure below.

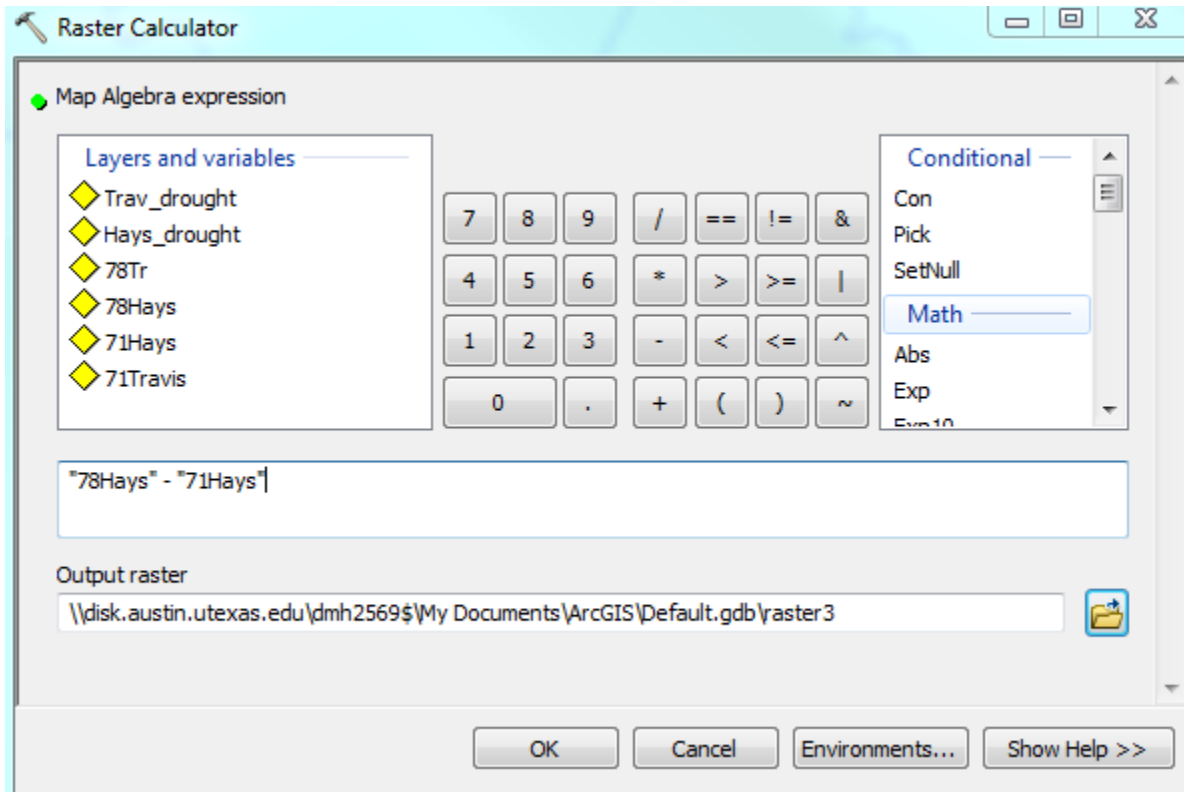


Figure 9: Map Algebra Tool subtracting drought year water levels from normal water level conditions.

This, however, once again left me with poor results. It may have been a better idea to do a spline surface to interpolate between well data but I wasn't sure as to how one would subtract them from each other without the needed 'Raster Calculator' shown in Figure 9. My data ended up looking like this—since many of the cells didn't contain both years in question, the change in those cells could not be calculated and were erased.

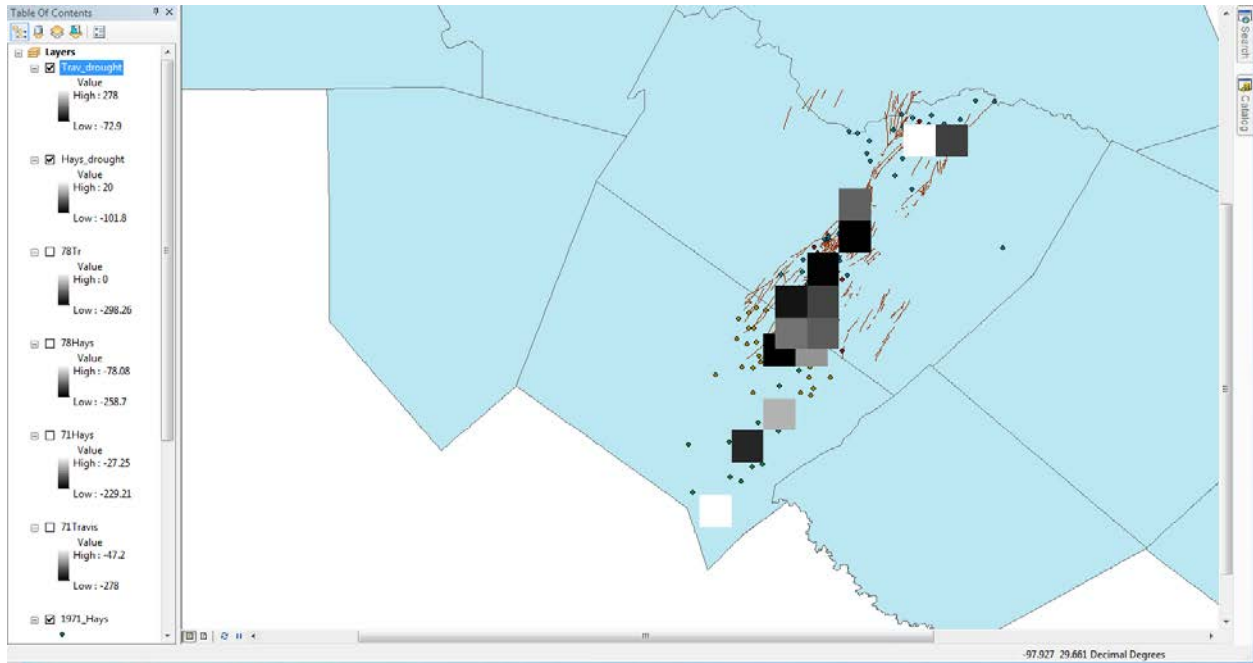


Figure 10: Map with raster surfaces of change in water levels from a drought disturbance.

I had initially planned on having a raster surface for each county, because I was going to show Travis County with respect to the Balcones Fault System, while leaving Hays County without the messy fault system. Therefore, since both rasters contained different minimum and maximum values, I represented each surface with different shades, elevation #1 and elevation #2 color schemes. The final map is provide below as Figure 11. Raster values are shown in feet and positive values reflect places where the water level dropped with response to the 1971 drought disturbance, whereas negative values reflect places where the water level rose during drought conditions.

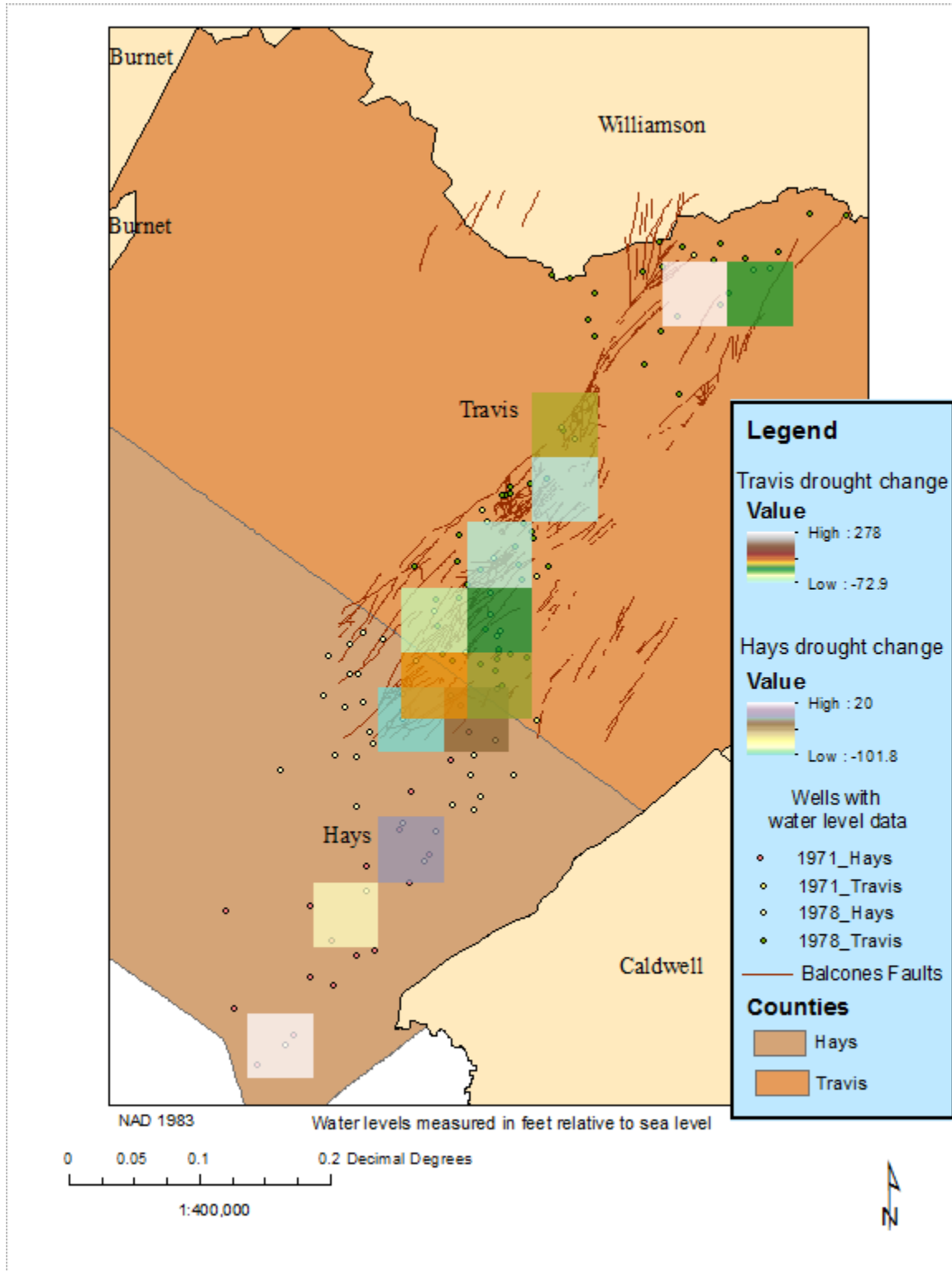


Figure 11: Map of changes in water levels due to drought conditions for the Barton Creek Segment of the Edwards Aquifer.

Conclusions

This project was highly flawed due to lack of excessive data. Wells that contained values for a year such as 1971, didn't have values available for 1978. Also, if there had been a larger number of well data from each year, the raster surface would have been more accurate, complete, and more aesthetically pleasing. Had I known that the data would have ended up so limiting, I may have tried to expand my area of interest to the entire Edwards Aquifer, in order to acquire more data. Also, creating a spline would be a better alternative when one needs to interpolate data in between areas of known values. This would have been utilized, however, Kriging does not have a Math Algebra 'Calculator' Function as the Raster models do. This project was also flawed because it is questionable to ignore the Balcones Fault System's presence—as it controls flowpaths of water at depth. However, karst aquifers are unpredictable and it is very difficult to assess these preferential flow paths anyways due to the high degrees of heterogeneity and anisotropy in the limestone aquifer. Also, as long as things such as topographic gradient, fractures, and rock type change very little with short term periods (with respect to geologic time), such as 7 years in this case, then the change in water levels may provide acceptable data (Note: the water levels alone are unimportant <1971 and 1978 data by itself> without other variables being taken into account).

Although the data is too limited to really make any real conclusion, based off this data water levels in Hays County changed to a smaller degree than in Travis County. Actually, water levels in Hays County actually rose in one area near the boundary between counties. Areas near the county line in Travis County rose to a small degree as well. Otherwise, spatial relationships in changes of water levels can be seen in the final figure of this project.