

GEO 327G Semester Project

***ArcGIS Analysis of the effect of Rain Gardens in Reducing Storm Runoff in the West Bouldin
Watershed, Austin, Texas***

Fall 2013

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I. Introduction

A type of storm water management structure employing green-design that exists in Austin, Texas are rain gardens. Rain gardens are low-lying gardens that absorb and filter rain water that originally falls on roofs, sidewalks or driveways. They are engineered to reduce storm runoff by increasing the infiltration of rain water into the soil and also intend to reduce the amount of pollutants carried to rivers and streams via storm drains. A rain garden is also intended to retain water better than a less intentionally engineered garden, to reduce time spent watering the rain garden (Austin Watershed, 2013).

II. Problem

Austin is a growing city, and with an increase in urbanization, there is an increase in impervious cover (i.e. non-soil surfaces like roofs, sidewalks, and pavement). The need for effective storm water management structures will only increase as the urbanization of Austin increases and more areas become paved. Runoff increases when there is an increase in the amount of impervious surfaces. Therefore, development reduces the ability of the landscape to retain water locally within Austin (Passarello et al, 2012). The runoff instead gets redirected to storm drains that lead to local creeks and streams. This makes the local streams more prone to flooding, which erodes the banks of the streams and can cause damage to properties located by the streams and rivers.

To prevent such damage to public and private property from occurring, much time and money in Austin and other urban areas is being invested into improving storm water management structures that are aesthetically appealing such as rain gardens. If a certain number of rain gardens were installed in a certain watershed, theoretically there would a reduction in water discharge at local creeks during a flood. Using ArcGIS, it can be modeled how the creeks in a small watershed would have responded to an intense rain event if there were different amounts of rain gardens installed in the watershed. The watershed being modeled in this project is the West Bouldin Creek that drains into Town Lake. It was chosen because I have available precipitation data from a tipping bucket rain gage I installed in the watershed since the summer of 2013.

III. Data Collection/Data Processing:

From the City of Austin GIS Data Sets, I downloaded all the creeks, roads, contours and watersheds of Austin as shapefiles from the City of Austin Data Sets. The creeks file includes drainage infrastructure such as storm drains that lead to the creeks. These lines typically run along the roads. The contours downloaded have 2 foot intervals. All the data I collected from the site are in the NAD 1983 State Plane Central Texas (ft) coordinate system.

Orthoimagery data was downloaded from the Central Texas Regional Data website to show an aerial map of the West Bouldin watershed. The orthoimagery data was from 2009, and has 6 inch resolution in MrSID format. I unzipped the files once they were downloaded into my flash drive. The quadrangle boundaries were also downloaded from the same site, so that I could identify what orthoimagery segments to download. An example of a name of the segment is AUSTIN_WEST_SED3. I downloaded six in total so that the particular watershed I am analyzing, the West Bouldin watershed, is completely covered by orthoimagery. The rasters are also in the NAD 1983 State Plane Central Texas (feet) coordinate system.

To collect the discharge amount and gage height of the West Bouldin watershed during a flood event, I went to the National Water Information System website run by the USGS. It contains gage stations all over the country. There is one gage station located in West Bouldin creek that contains

historical data. The gage station ID is 08155541. I wanted to use a large flood event for my GIS analysis, so the rain event I chose was the one around October 31st of 2013. Therefore, I selected the gage height and discharge data from the last 40 days from November 28th (the day I collected the data). This data can be exported as an excel file by selecting the Tab-separated output format (Figure 1). There was also important general information about the gaging station such as GPS coordinates, reference datum, and contributing drainage area (Table 1).

Figure 1: Snapshot of the data collection of from gage station 08155541 from the National Water Information System website

Available Parameters	Available Period	Output format	Days (40)
<input type="checkbox"/> All 2 Available Parameters for this site <input checked="" type="checkbox"/> 00065 Gage height <input checked="" type="checkbox"/> 00060 Discharge	2007-10-01 2013-12-05 2007-10-01 2013-12-05	<input type="radio"/> Graph <input type="radio"/> Graph w/ stats <input type="radio"/> Graph w/o stats <input type="radio"/> Graph w/ (up to 3) parms NEW <input type="radio"/> Table <input checked="" type="radio"/> Tab-separated	<input type="text" value="40"/> -- or -- Begin date <input type="text" value="2013-10-26"/> End date <input type="text" value="2013-12-05"/>

Table 1: Description of West Bouldin watershed gaging station

Item	Description
Gage Station Code	08155541
GPS Coordinates	Latitude 30°14'48" Longitude 97°46'09" NAD83
Location	Travis County, Texas by Oltorf Rd.
Hydrologic Unit	12090205
Drainage area	1.77 square miles (to Town Lake)
Contributing drainage area	1.77 square miles (to Town Lake)
Datum of gage	537.6 feet above NAVD88
Total Length of all creeks (feet)	56987.9417

There was no precipitation data collected at the gage station in West Bouldin Creek, so I used the precipitation data from a tipping bucket rain gage I installed at the Green Classroom, an extension of Becker Elementary School, which is located in the West Bouldin watershed. This data is used to quantify how much water would fall into a rain gardens and how much roof runoff would fall into a rain garden during the storm event. This rainfall data was collected in centimeters per hour.

IV. Excel Processing

Important assumptions that I am made in the analysis of this data is that the rain gardens are only receiving water input from the roof runoff and direct rainfall into the rain garden. There is also no water leaving the rain gardens as runoff. The rain gardens will all be the same size, as well as the same roof size that it is receiving runoff from. I will be following the roof and rain garden dimensions as recommended in Figure 2, which is provided by the Austin Watershed Protection Department that describes how to make a rain garden. A rain garden should be about one-sixth of the area of the roof contributing water to the rain garden. I will assume that all of the water that falls on the roof of a house with the dimensions in Figure 2 gets caught in gutters and directed to rain gardens. Therefore, the roof area assumed for this analysis is 1,800 square feet and the total area of the rain garden on each property is 300 square feet.

To assume the same amount of runoff is going into each garden, this means I also have to assume the precipitation data from the tipping bucket installed in the watershed is the same amount of precipitation happening at the same intensity all over the watershed. The total contributing area of the West Bouldin watershed is only 1.77 square miles, but it is still possible for the rain intensities to be different at different locations in the watershed.

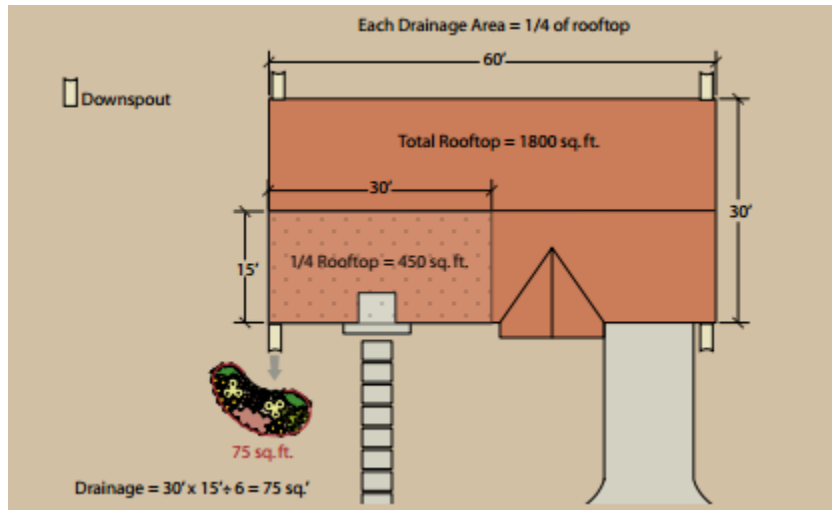


Figure 2: Parameters used to estimate total roof runoff and area of the rain gardens

Another assumption I made to estimate the volume of water in the creeks during a flood event is that the depth and width of all creek beds are the same. Looking at site photographs of West Bouldin Creek watershed (Figures 3 and 4), this is certainly not the case. To be able to properly quantify how different the creeks would look if some runoff was taken in by the rain gardens instead of inputted into the creeks, then the creeks need to have the same creek bank slope and width. I assumed that all creeks were 15 feet wide and began to slope upwards by 10° at the normal height of the creek. This normal height of the river was taken from the gage height during a period of no rain. Using this gage station data, I also had to assume that all the measurements taken at the gaging station would be the same information one would get if gaging stations were installed all over the watershed. Again, looking at the site photographs, not all the creeks have water running through them.



Figures 3 and 4: Site photographs of the West Bouldin watershed along different parts of the creek. Figure 3 shows a creek flowing with water and Figure 4 shows a creek with no flowing water.

To calculate the change in the volume of water after a flood event, I found the max gage height during the most recent flood event on October 30 to 31st (Table 2). I calculated the volume of water by assuming all the banks of the creeks increased at the same slope of 10°. I knew the gage height, so this allowed me to calculate the volume of water expected during this particular flood event.

I calculated how much water would be taken in by a certain number of rain gardens (Table 2) using the parameters discussed earlier (Figure 2) and the precipitation data from my rain gage. Table 2 shows a part of the excel sheet that I used to convert the rainfall rate to a volume of water that is taken in by the rain gardens. I concluded that during that rainfall there was an estimated 5,565 ft³ of water that fell into the rain garden from the roof runoff and direct precipitation onto the gardens. As shown in Table 3, I calculated the volume of water that is taken in by the rain gardens depending on how many of them are installed. The total amount of water taken in by each rain garden was subtracted from the total amount of water in the creek during the peak flood time, which is about 6,795,950 ft³ of water (gage height at 5.04 feet). The average gage height I calculated was 1.59 ft.

Table 2: Shows the process of how to get a volume of water from a rainfall rate

Date	Rainfall rate(in/15min)	Rainfall rate (ft/hr)	Roof Area (ft sq)	Rain garden Area (ft sq)	Volume of water on Roof (ft ³ /hr)	Volume of water on Garden (ft ³ /hr)
10/31/13 2:15	0.36	0.12	1800	300	216	36
10/31/13 2:30	0.56	0.1866667	1800	300	336	56
10/31/13 2:45	0.53	0.1766667	1800	300	318	53

Table 3: Shows how much water is taken up by rain gardens compared to having no rain gardens

Number of rain gardens	Estimated volume of water taken in (ft cubed)	Percent Reduction of Volume of water
100	556,500	8%
250	1,391,250	20%
500	2,782,500	40%

V. ArcGIS Processing

I uploaded my creek_lines shapefile to my Table of Contents. I needed to only show the West Bouldin Watershed, so I used the Select by Attribute and selected only the creeks under the watershed titled WBO (Figure 5).

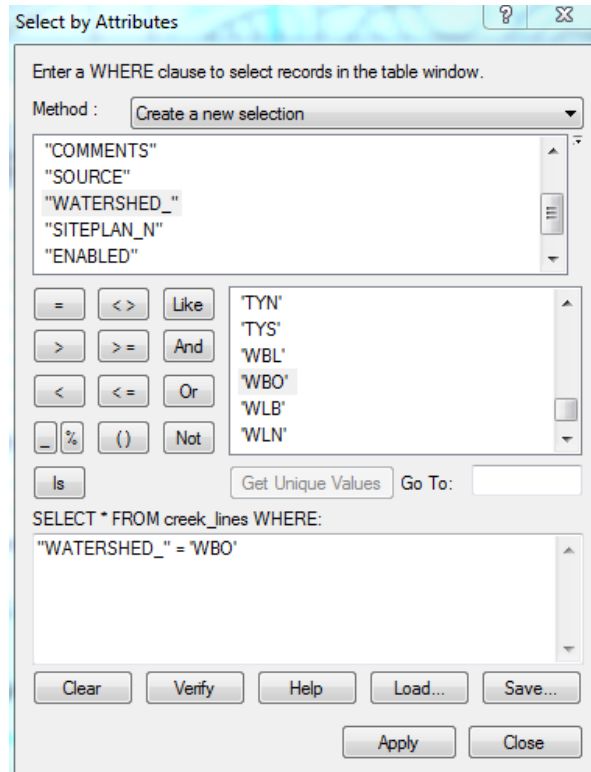


Figure 5: Select by Attributes to get streams only a part of West Bouldin Watershed

I then have to right click the creek_lines shapefile in the TOC, go to Data, then Export Data. On the Export Data box, I have to make sure I export the selected features to the feature class I want it to go to (Figure 6). It is very important to export the new file as a shapefile.

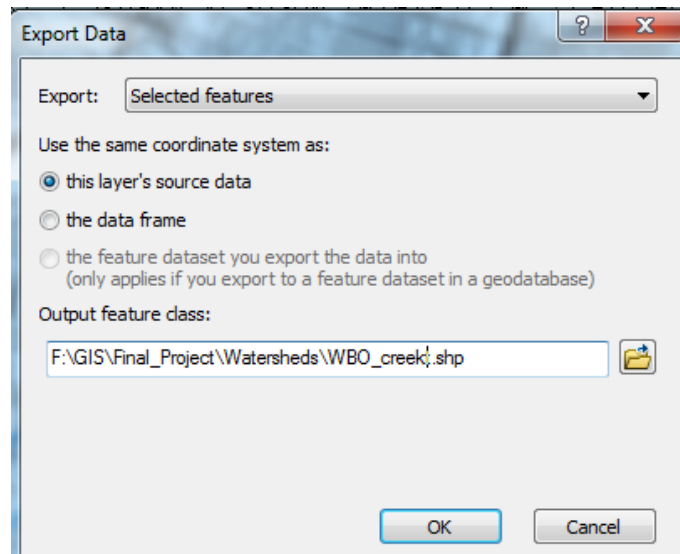


Figure 6: Exporting the West Bouldin creeks to a separate shapefile

I also needed the outline of the West Bouldin creek watershed. After uploading the “watershed” shapefile, I used the Select by Attribute table and selected only the “WBO” watershed (Figure 7). I exported the selected watershed outline the same way I exported the West Bouldin creeks.

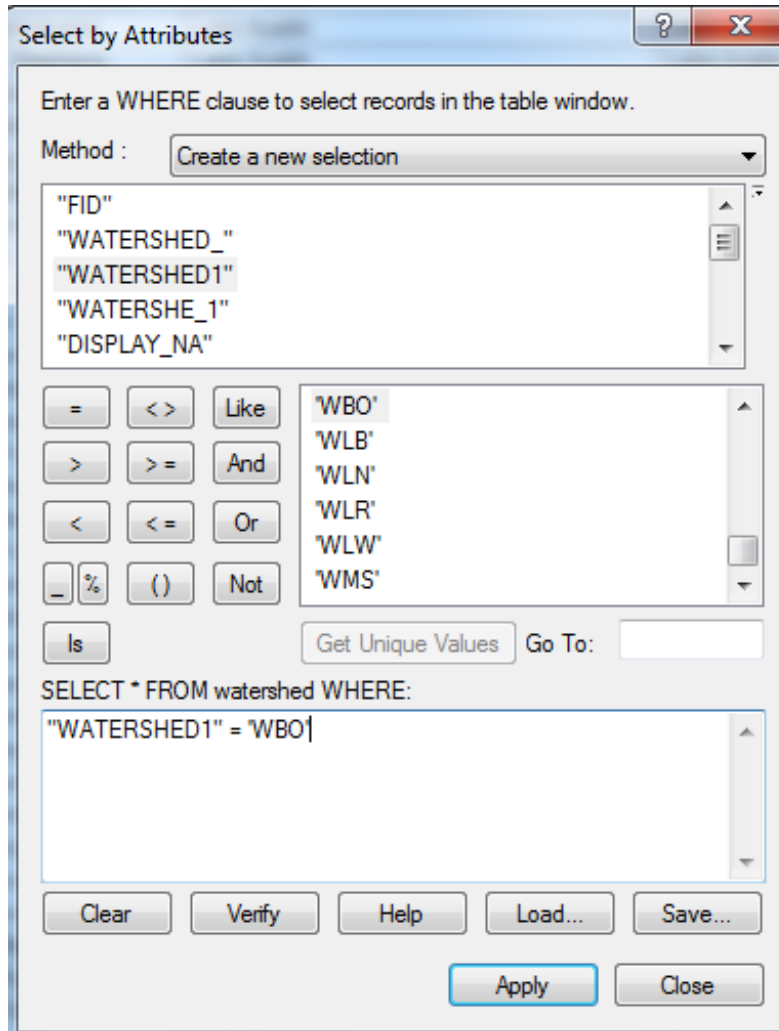


Figure 7: Select by Attributes the outline of the West Bouldin watershed

I uploaded the regional_roads and the two contour shapefiles to the TOC. Using the outline of the West Bouldin watershed, I clipped the contours to the watershed (Figure 8). My input features were what I wanted clipped (contour shapefiles) and the clip features is what I wanted it clipped to (West Bouldin watershed). I needed two separate contour files, so I clipped them both.

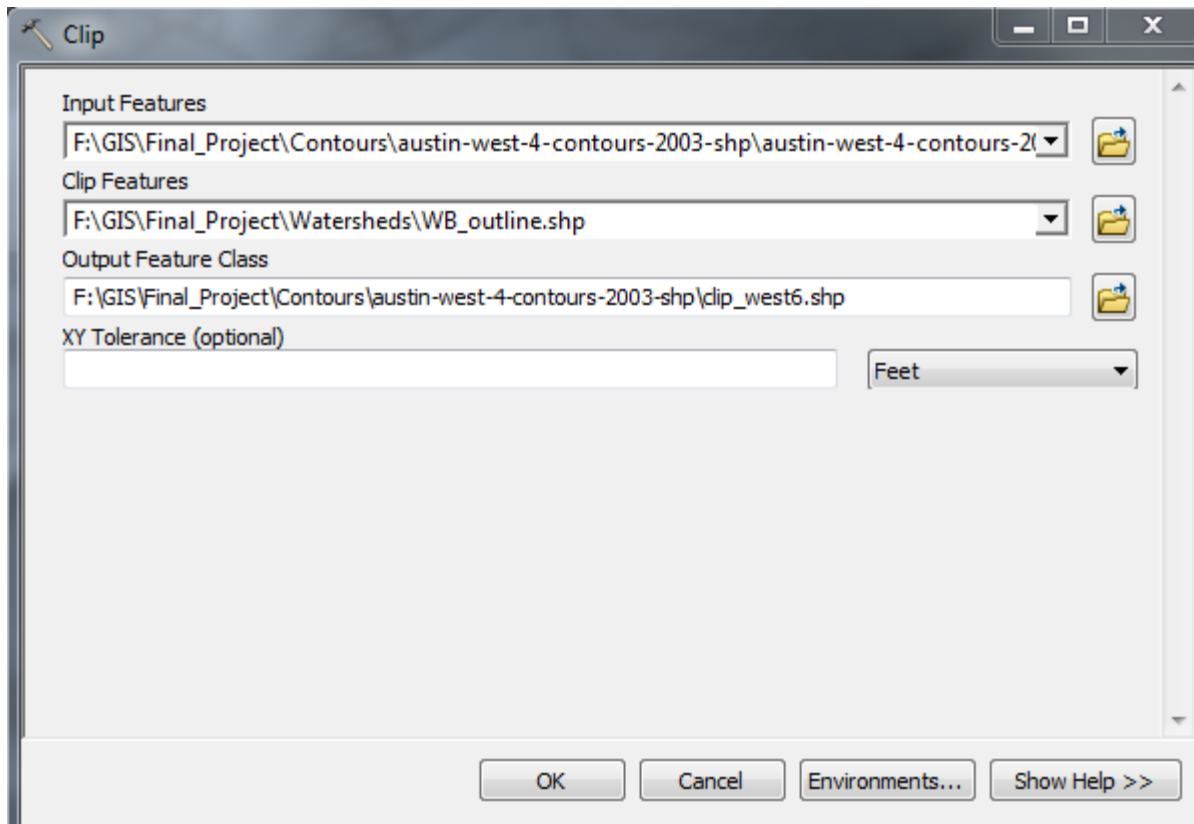


Figure 8: Clip tool used to cut the contour lines to the West Bouldin watershed outline.

I uploaded all the orthoimagery photos that I had unzipped to the TOC in ArcMap. The orthoimagery photos are all projected in the NAD 1983 Central Texas State Plane coordinate system.

To add the GPS location of the gaging station, I first converted the longitude and latitudinal coordinates to UTM coordinates. I then made an excel file with the two coordinates making sure that all the necessary decimal points were showing (Figure 9). To add data points, I go to File > Add Data > Add XY Data which opens up a new window (Figure 10). I find the excel file with the UTM coordinates, choose the appropriate x and y fields, verifying the projected coordinate system is being used, then I press okay. I did this process to add the location of the rain gage and the USGS gaging station in the West Bouldin watershed. The gaging station coordinates I used are shown in Table 1 and I used Google Earth to find the coordinates for the rain gage.

	A	B
1	x	y
2	619321.6200	3347133.3200

Figure 9: Snapshot of the saved Excel file for the rain gage location used to load UTM coordinates to ArcGIS

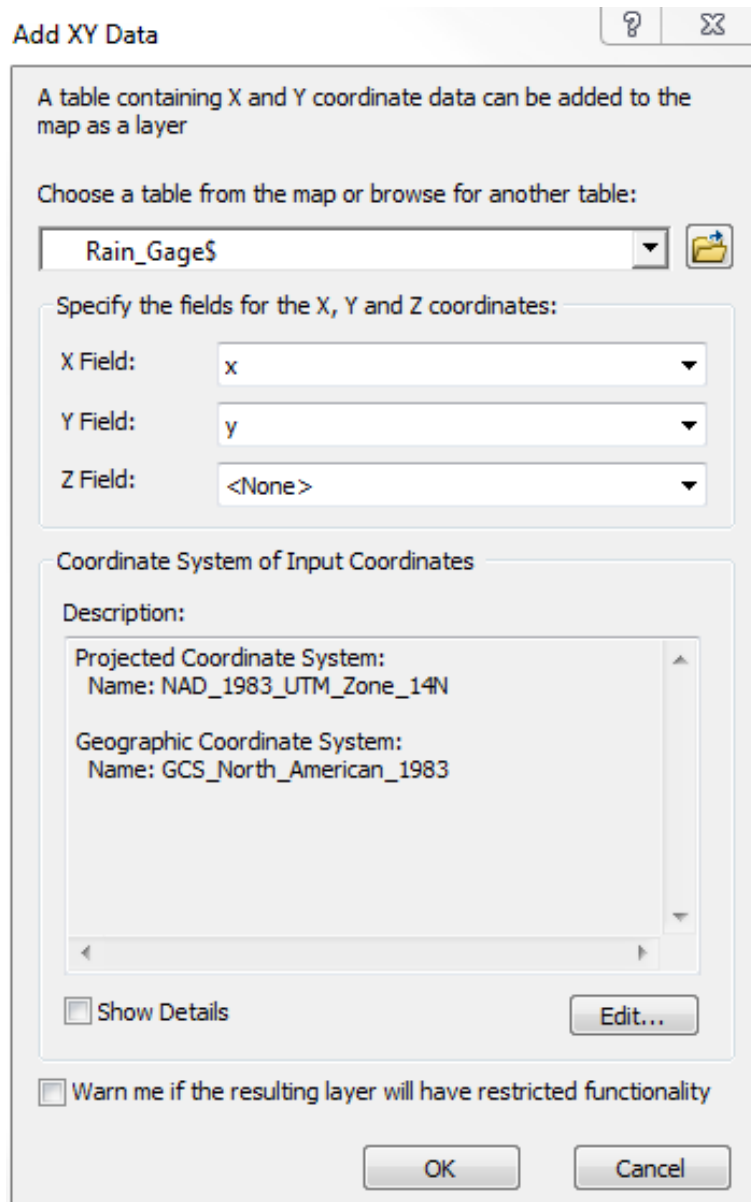


Figure 10: Adding rain gage coordinates into ArcMap

Using my calculations from the excel processing, I now have an estimation of the width of the creeks during flooding events and if there were different amounts of rain gardens installed throughout the watershed. To show this on a map, I used the buffer tool to buffer the streams to a certain width to represent when the water is at an average height, when it's flooded, and when there are 100, 250, and or 500 rain gardens installed in the watershed. I opened the buffer tool, and put the West Bouldin creeks shapefile into the Input Features (Figure 11). I appropriately named each Output Feature Class. The linear distance in feet is half of the total width of the creek (Table 4). I selected the dissolve type as ALL and pressed OK. I did this procedure for all 5 of the different buffers. I made sure the flooded buffer was the lowest layer and the average creek buffer was the topmost layer in the TOC.

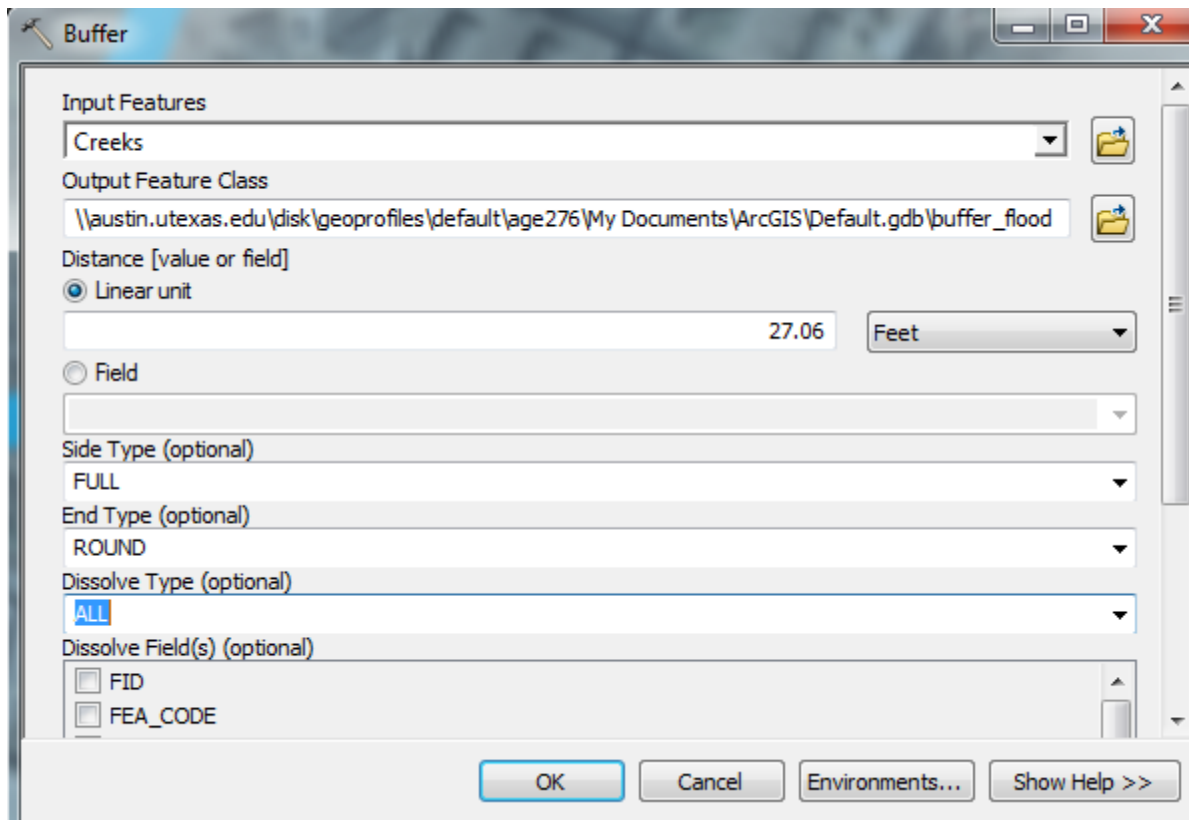


Figure 11: Buffer tool screenshot used to create the width of flooding from each creek

Table 4: Values used in the buffer tool to get a flood hazard

Buffer Type	Total Width of creek (ft)	Length used in buffer tool (ft)
Flooded	54.12	27.06
100 Rain Gardens	52.04	26.02
250 Rain Gardens	48.74	24.37
500 Rain Gardens	42.68	21.34
Average water flow	15	7.5

VI. Data Presentation

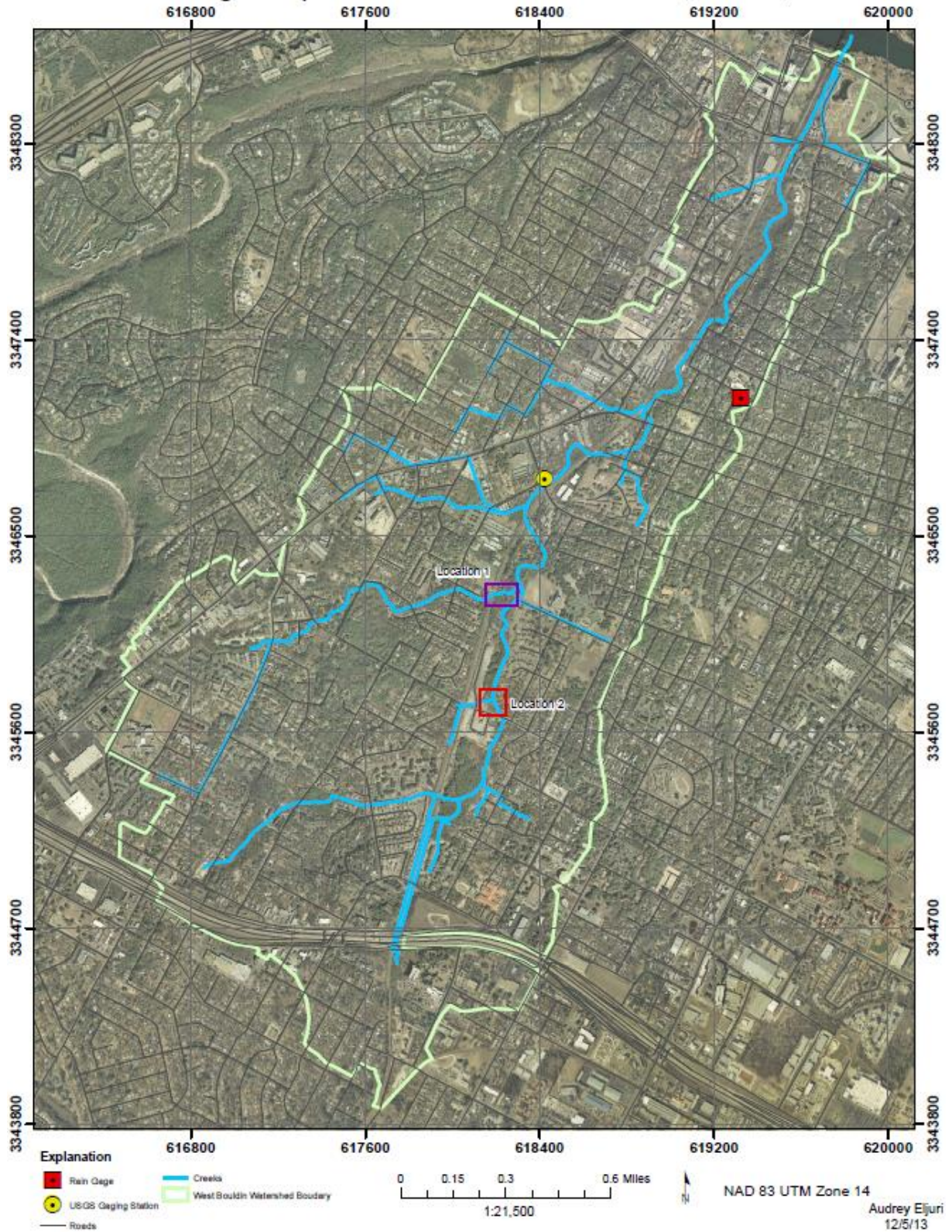
Map 1 is an orthoimage of the West Bouldin Watershed. It shows where the rain gage and USGS gaging station are located, along with where Map 2 and 3 are located in the watershed. The water flows northeast towards Lady Bird Lake.

Map 2 is of Location 1 from Map 1. It estimates how far the water would reach outside of the creek banks during the flooding event in late October. With more rain gardens added into the watershed, the reach of the water during the flood event decreases. With the installation of more rain gardens, it would be expected to see less flooding.

Map 3 is of Location 2 from Map 1. This map is an example of how extreme flooding still is, but doesn't destroy houses. It can still cause damage to properties by eroding away the soil. All maps were projected in NAD 83 UTM Zone 14.

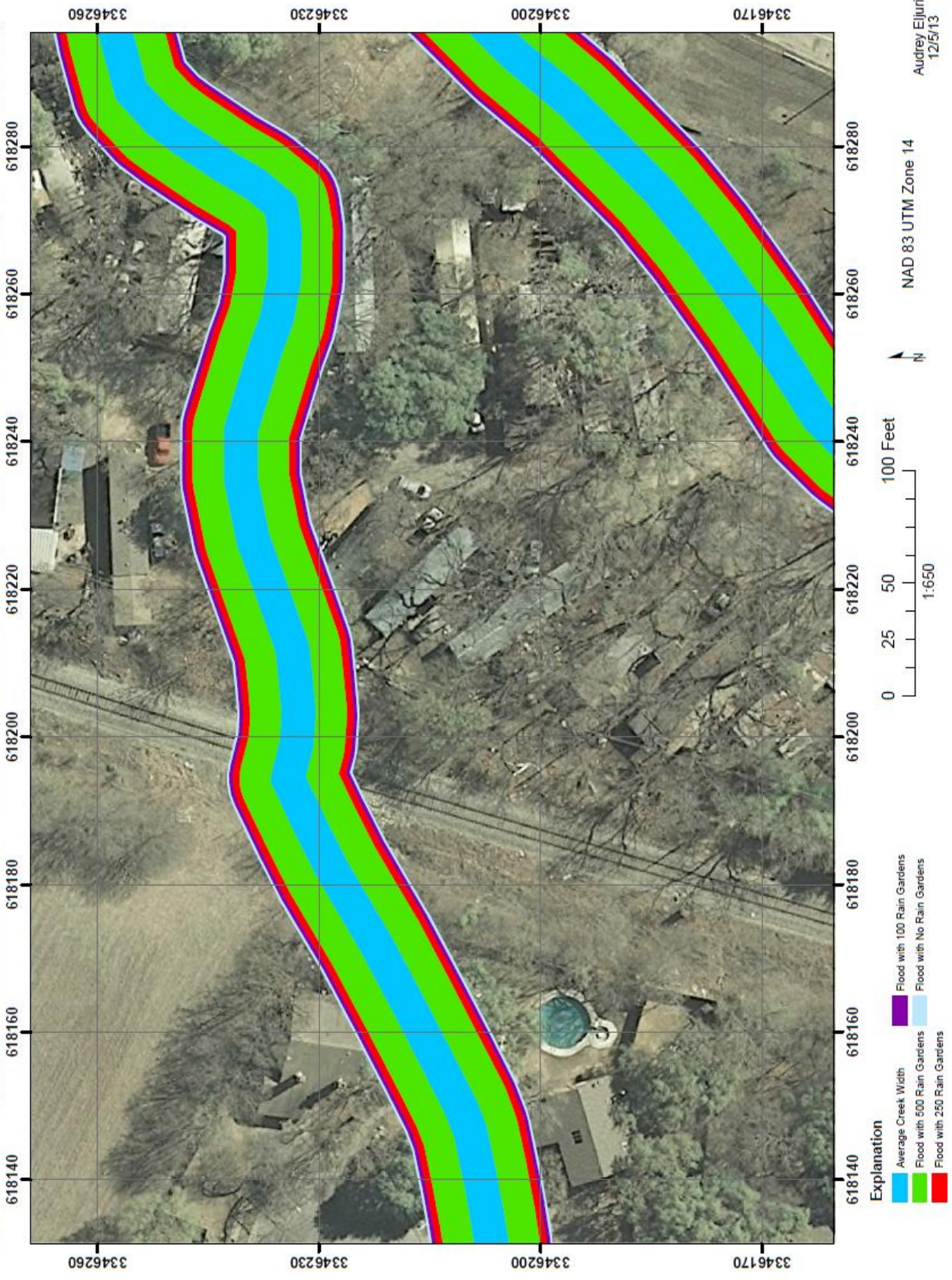
Map 1:

Orthoimage Map of West Bouldin Watershed, Austin, Tx.



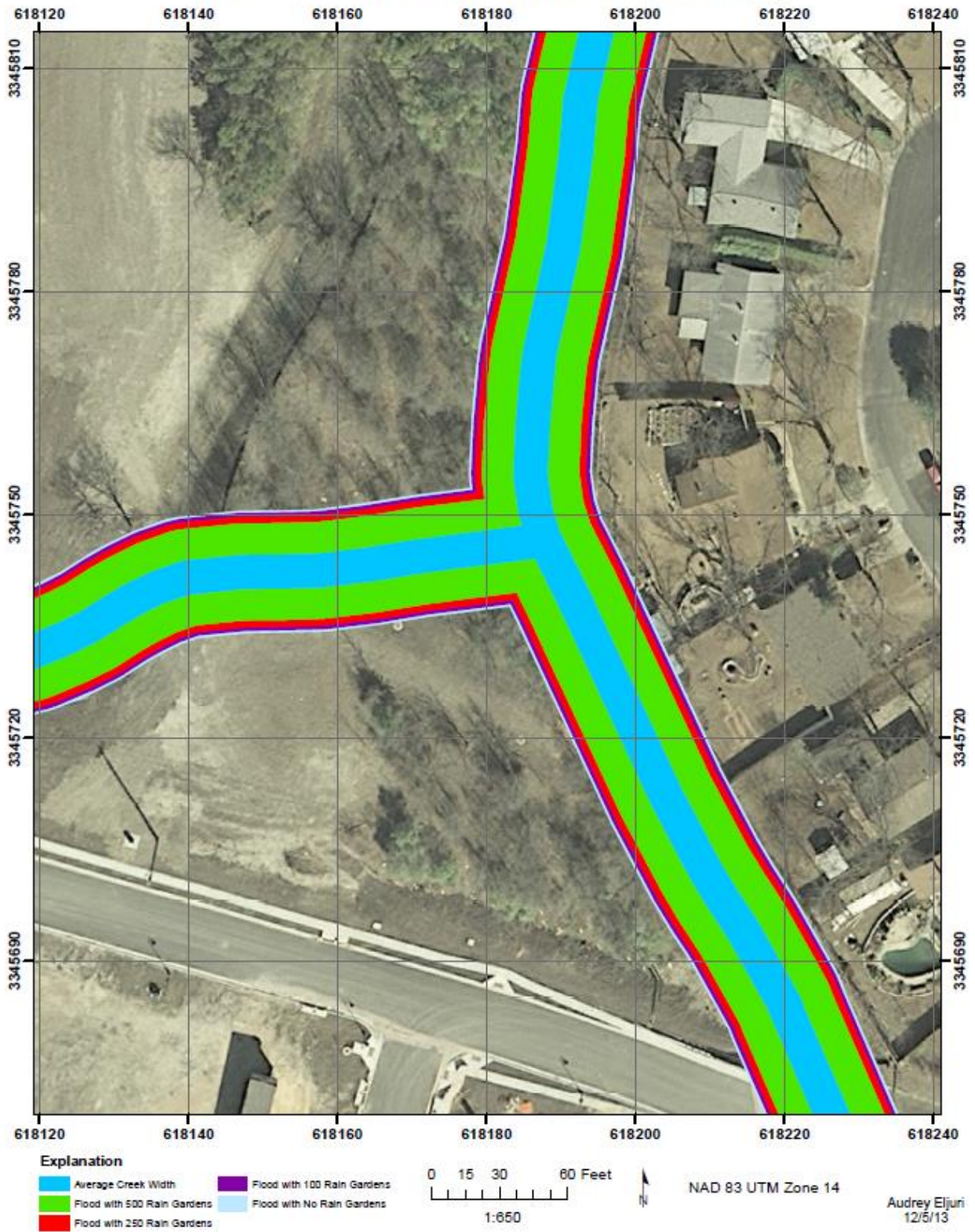
Map 2:

Flood Hazard Map with Installation of Rain Gardens in West Bouldin Watershed, Austin, Tx. (Location 1)



Map 3:

Flood Hazard Map with Installation of Rain Gardens in West Bouldin Watershed, Austin, Tx. (Location 2)



VII. Conclusion/Future Work

Through my excel calculations, I concluded that rain gardens do reduce the amount of runoff that would lead to the local creeks in the West Bouldin watershed. Though I was able to create buffers of where the flood probably reached and how the flood would have looked with rain gardens installed in the watershed, there were a number of limitations to this representation of the data.

Limitations included that the buffer shows a flood width assuming all the creeks were the same width and the banks were the same slope. In actuality, the streams may have actually flooded further than shown or less than shown. I assumed uniform contours along all the creeks, but the contours are different along the creek. Therefore, some areas might have actually been more damaged by this flood amount because they had even less gradual slopes, which is not properly shown in Maps 2 and 3. A way to make the visual representation of the data better would be to elevate the gage height of the stream with respect to the contour lines. This particular limitation was further explored in the Further Analysis part of the paper.

Other future work would be to do this analysis for larger watersheds that have more gaging stations. A limitation of this project was the fact that I only had one gaging station and it was in the middle of the watershed instead of more towards the discharging end of the watershed. In this analysis, I had to assume that the data from the one gaging station was true for all along the creeks. If I had more gaging stations along the creeks, it would reduce the amount of assumptions I have to make.

By next spring, I hope that I will be able to make a GIS model with a reduction in assumptions that displays the flood hazards of the watershed and how installing rain gardens or other storm water management structures will reduce the amount of flood waters.

VIII. Further Analysis (Work in Progress)

The next step in my analysis was to make a buffer that actually would follow the elevation of the streams. To do this, the new data I would need is a DEM of the West Bouldin Creek watershed. I got the DEM data from the National Elevation Dataset at 30 meter resolution. I boxed the area of DEM I wanted, downloaded the file, and unzipped it in my flash drive. To extract the elevations from the DEM, I first needed to convert the lines of my creek to points. I used the Feature Vertices to Points tool to do this (Figure 12).

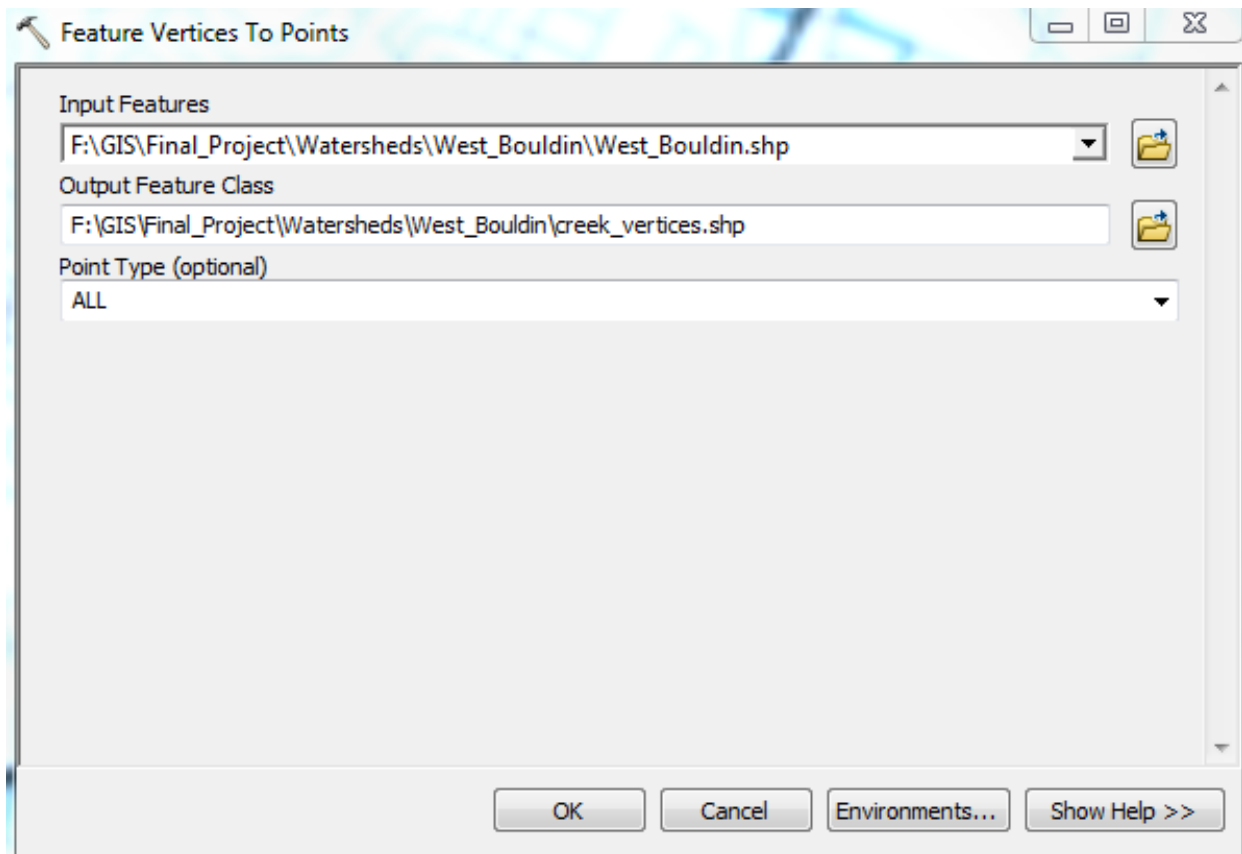


Figure 12: Feature Vertices to points tool to convert the creek line to points

Some of the creek points are the points that are actually drains, so I first made the creek_vertices the only selectable layer then started editing the shapefile to get rid of the vertices that were part of the storm drain path. Figure 13 shows the points of the creeks before I deleted the storm drain points. Figure 14 is a screen shot of the creeks after I was done editing. I did this because drains wouldn't flood the same way a creek floods. There would be flooding where the storm drain entrances are located, and not necessarily throughout the whole piping system.

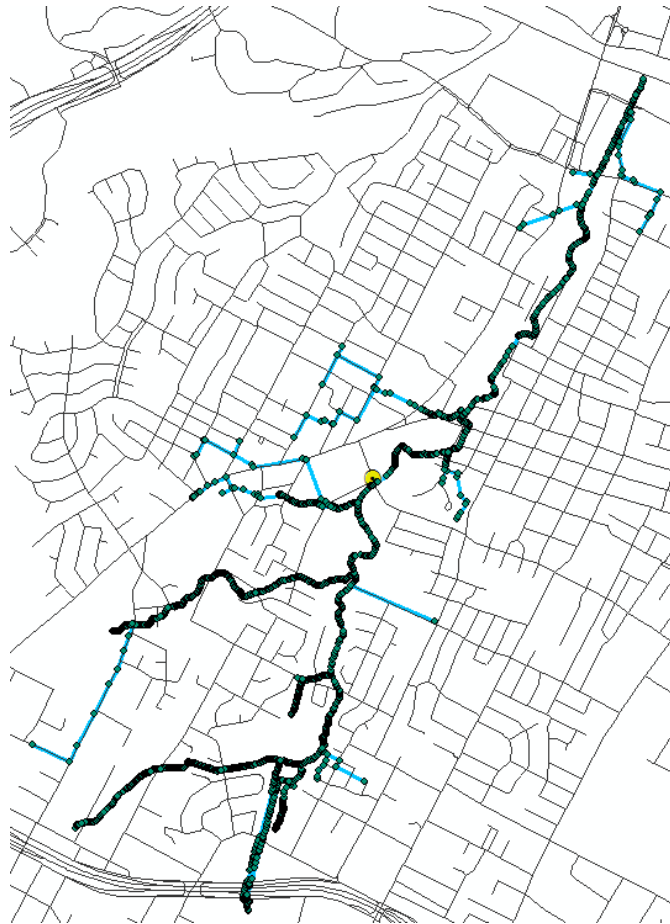


Figure 13: Screenshot of creeks and storm drain paths before editing creek_vertices shapfile

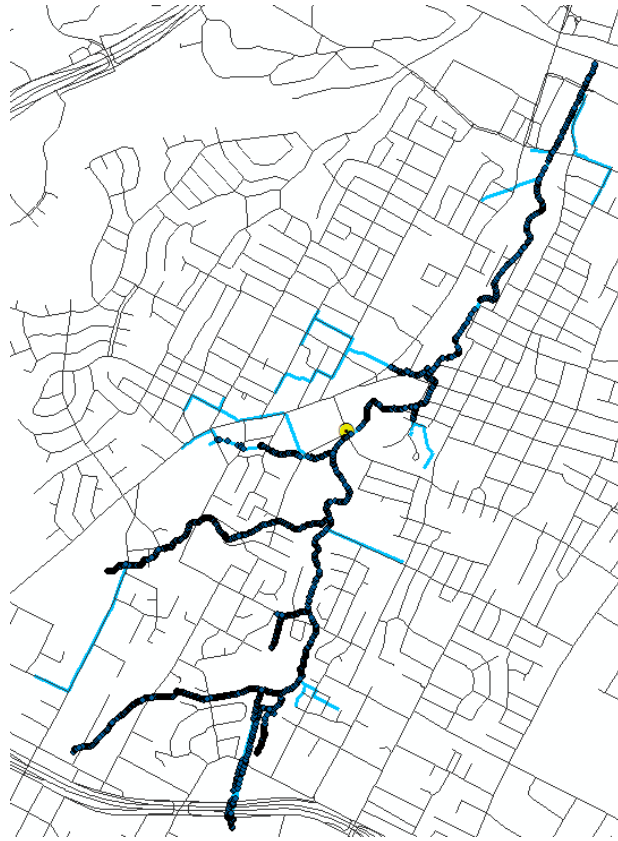


Figure 15: Screenshot of only the creeks after editing creek_vertices shapefile

The DEM I downloaded was in meters, so I needed to convert the values to feet. I used the raster calculator to convert the DEM data in meters to feet. Figure 16 shows the inputs into the Raster Calculator tool. The output file was labeled dem_spcsft. I can then convert the points along the creeks to elevation points using the DEM. To do this, I used the Add Surface Information Tool to get elevation points (Figure 17). The input shapefile was the creek_vertices and the input surface was dem_spcsft. I chose a bilinear method because it takes a weighted distance average of surrounding cells.

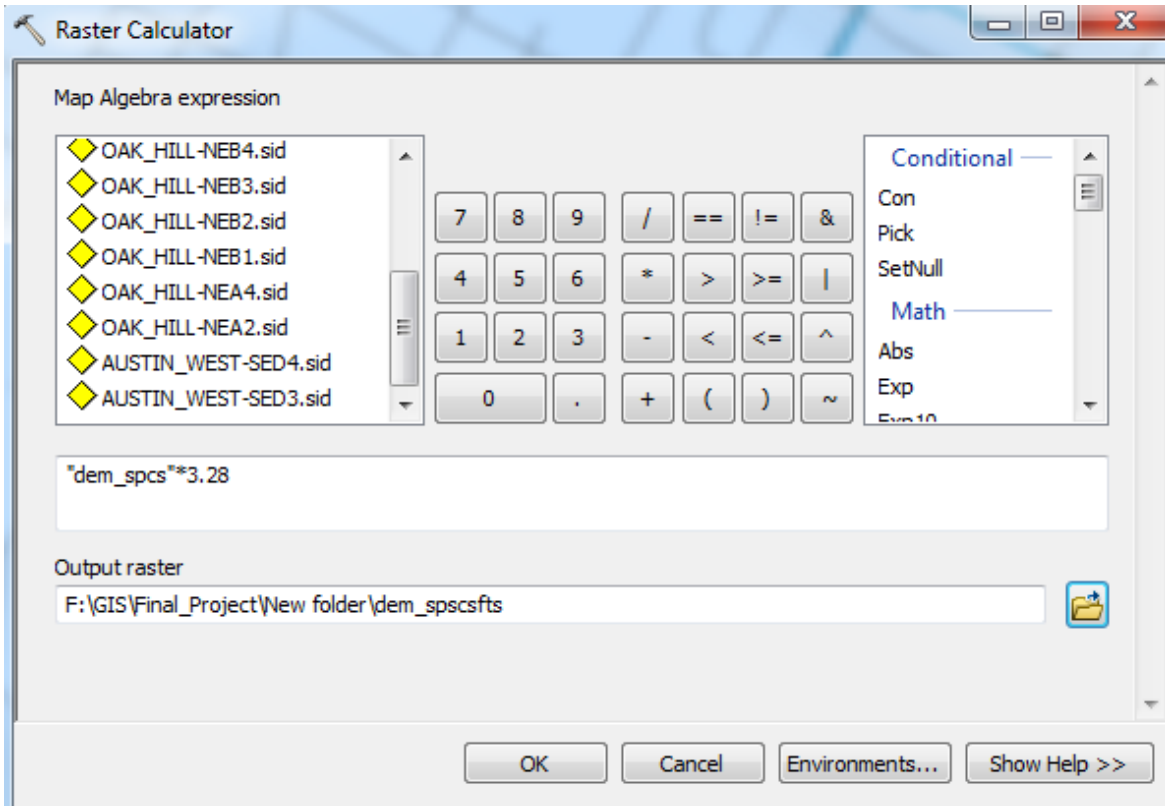


Figure 16: Raster Calculator was used to convert the DEM data in meters to feet.

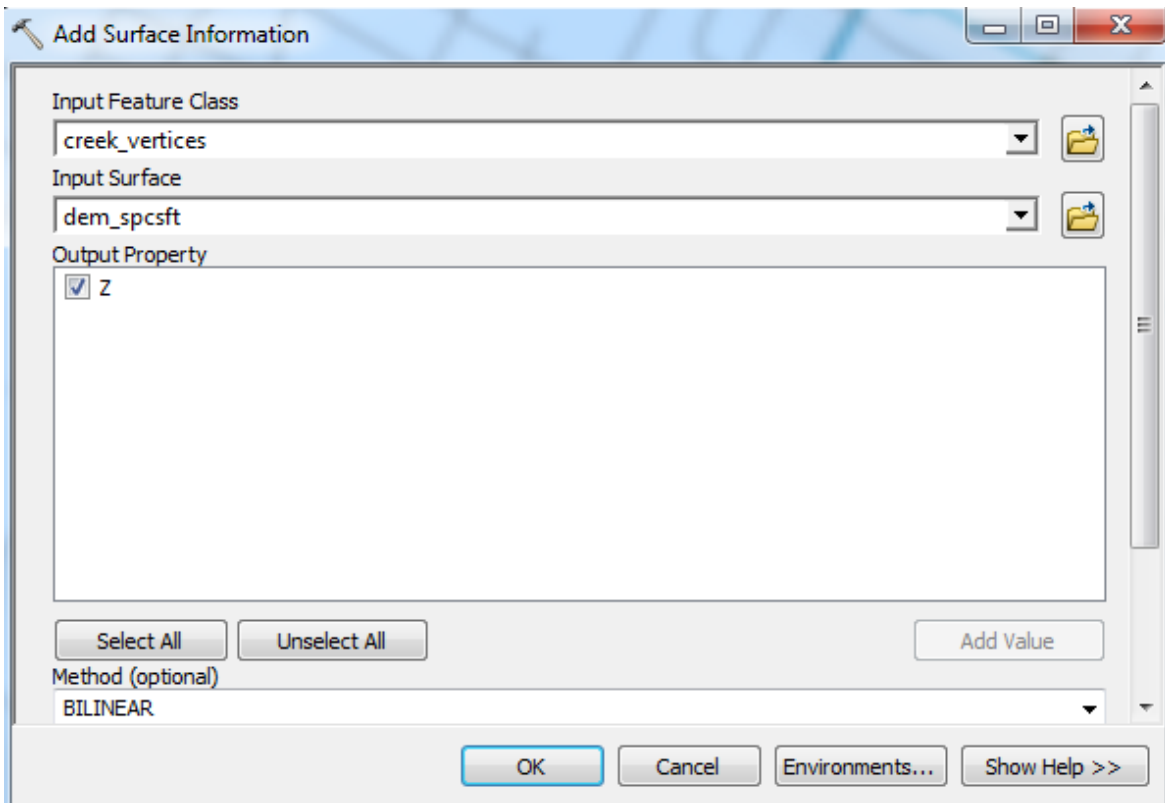


Figure 17: Add Surface Information tool was used to convert the points to elevation values.

I then created a TIN (Triangular Irregular Networks) from the creek elevations. I did this by going to the Create TIN tool (Figure 18). The output file is the name of my new TIN (stream_elev), and my input feature class is creek_elev. To define a spatial reference, I imported a file with a spatial reference that I want the TIN to have (Figure 19). Figure 20 is the image of the TIN after the Create TIN tool was used.

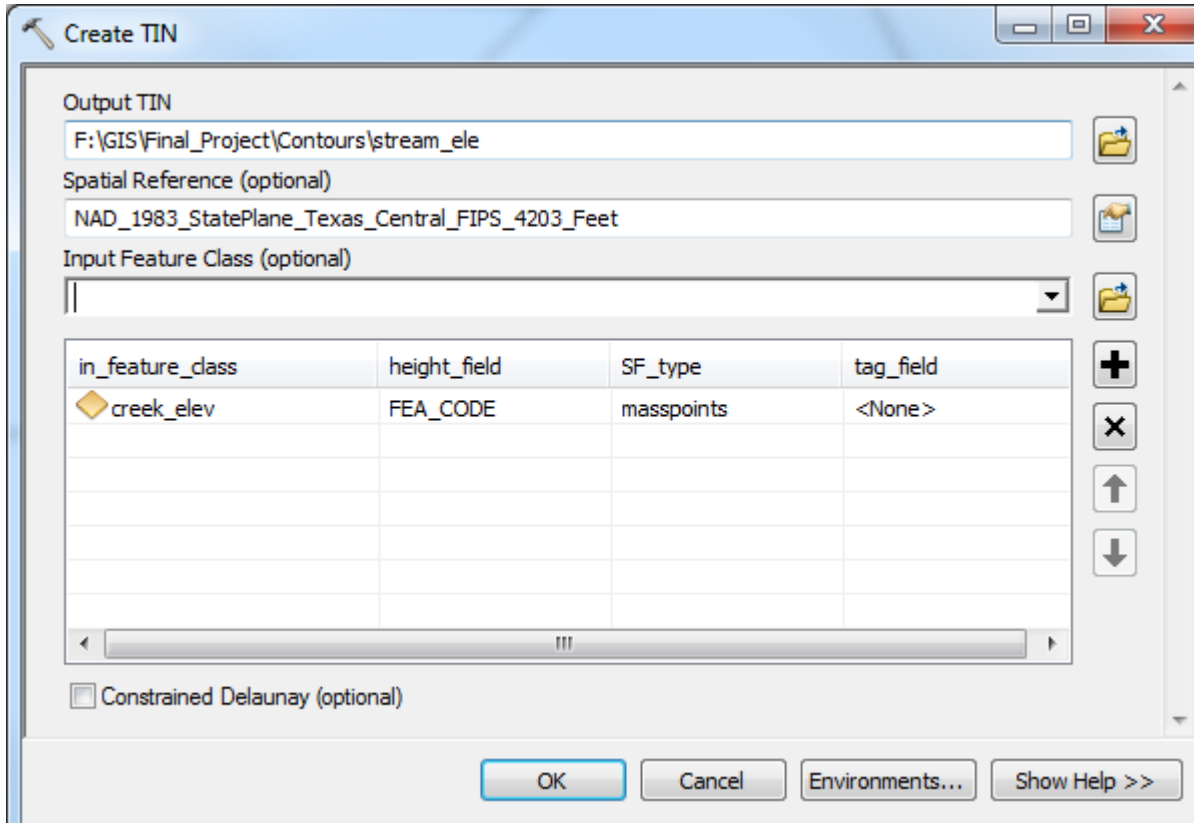


Figure 18: Create TIN tool used to create a TIN from the elevation data

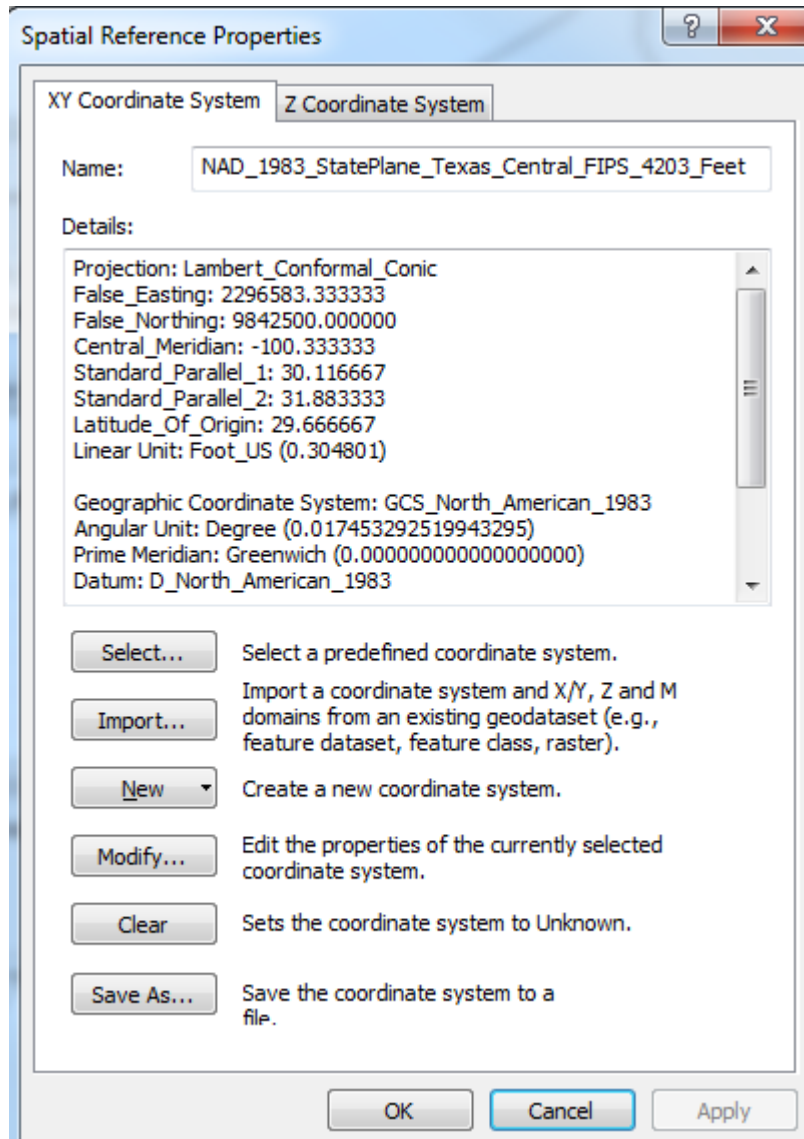


Figure 19: Pressed the Import button to select a shapefile with the spatial reference I want the new TIN to have too

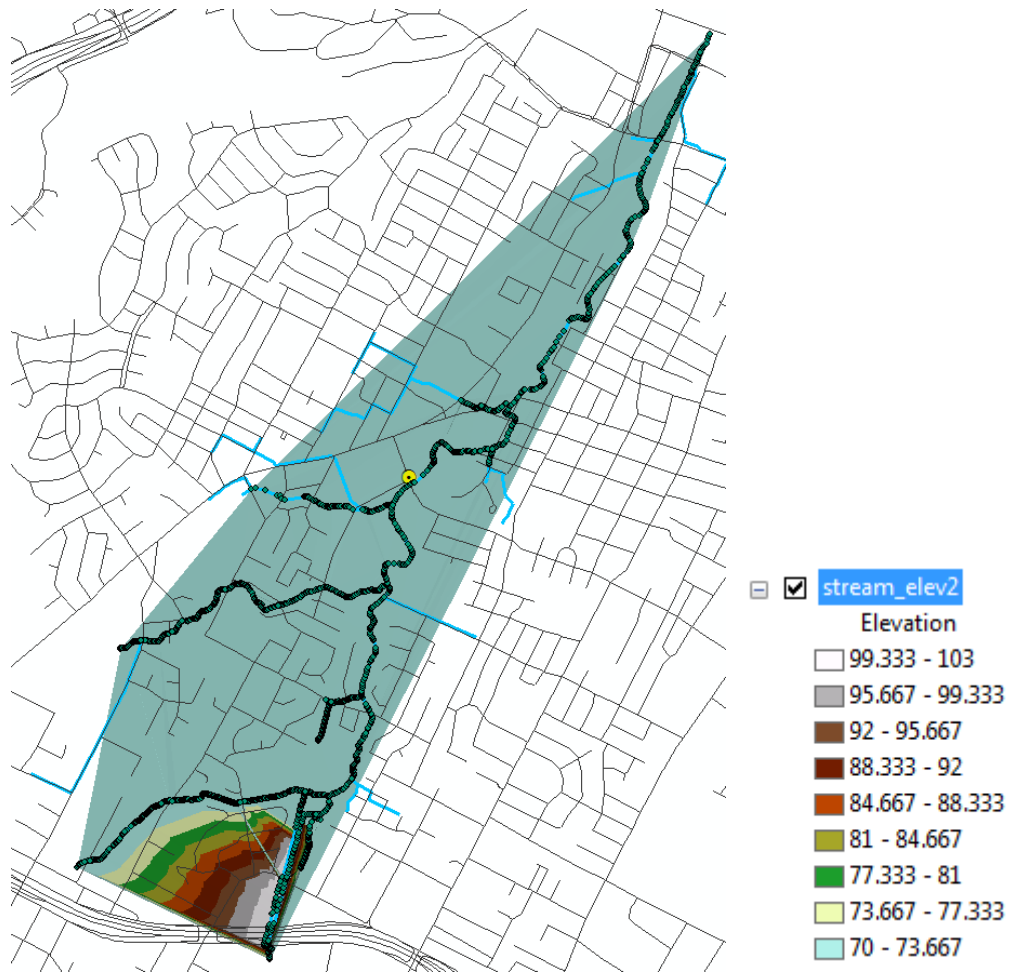


Figure 20: Image of TIN of the West Bouldin Creek Watershed (elevation in feet)

The next step I did was convert the TIN to a raster. The tool used was the TIN to Raster tool. Figure 21 shows the inputs I made into each part. The Output Data Type was chosen as FLOAT because my cell size is a decimal point. I also specified the cell size as 32.8 ft. Figure 22 shows how I made a mask of the raster so that the raster I get back is only contained to the watershed. To get to the Mask, I clicked on the Environments button, went to raster analysis and chose the watershed as my mask. After the raster was made, only a thin black line appeared on the left side of the watershed (Figure 23). Unfortunately, just looking at the TIN image I know that the elevation is not quite right. Looking at the contours lines I downloaded, the watershed decreases in slope the whole way down the watershed, not just in the southernmost part of the watershed. I decided to keep making the raster to see what the net gains raster image would look like.

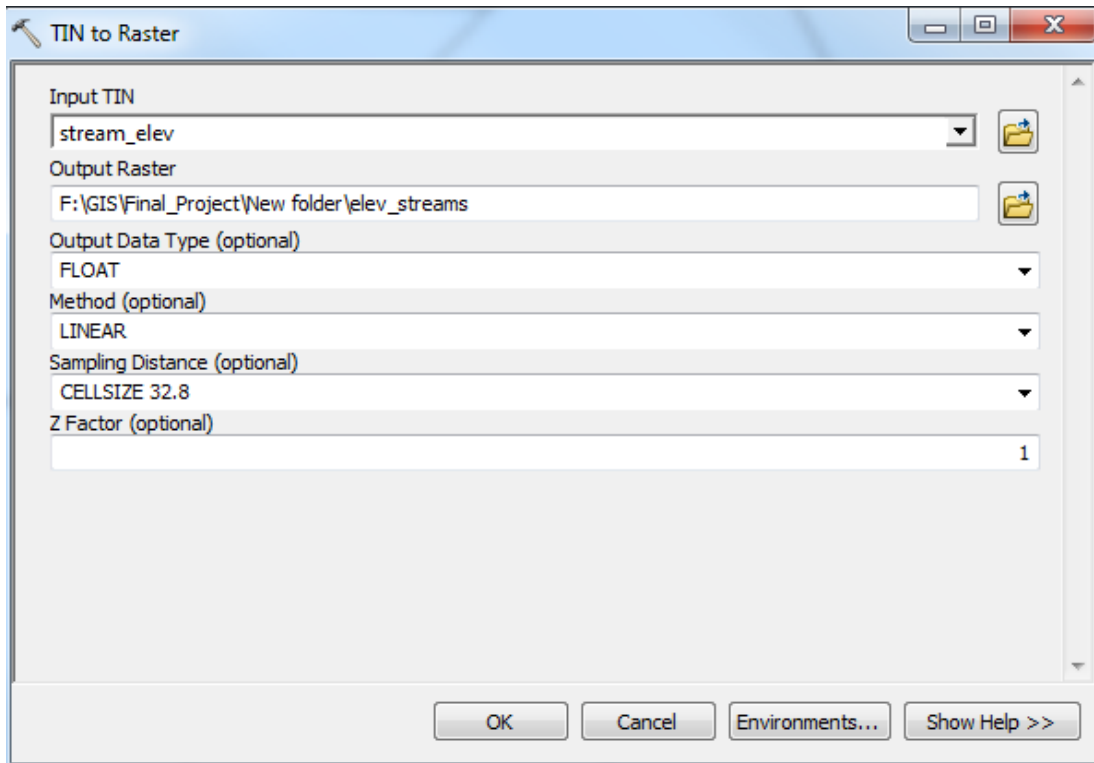


Figure 21: TIN to Raster tool used to make a raster of the stream elevations in the watershed.

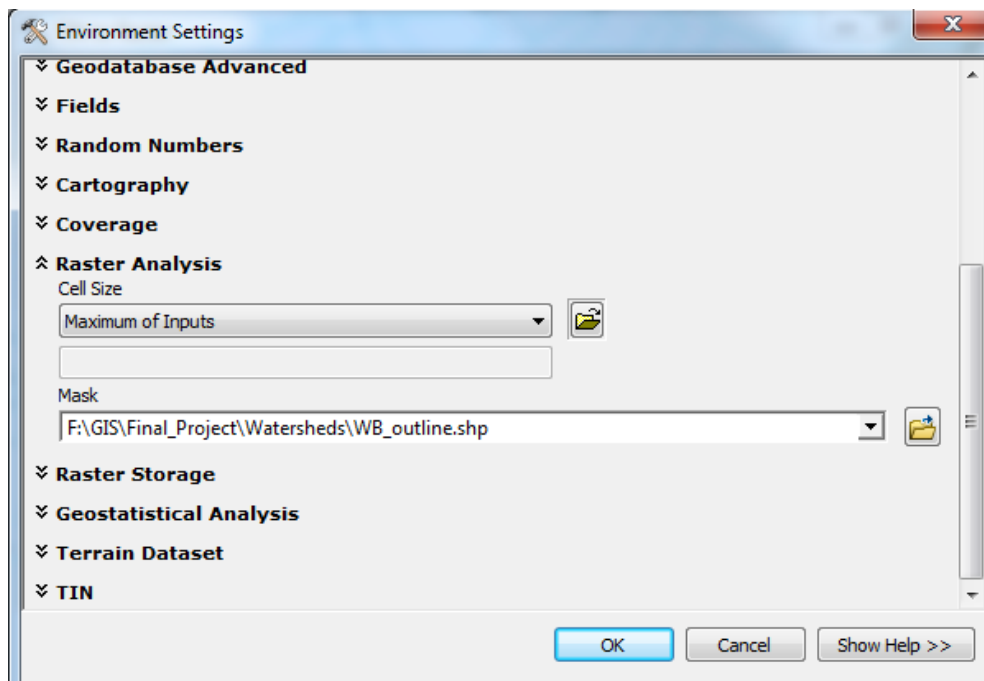


Figure 22: I used a mask to restrict the size of the new raster from the TIN.

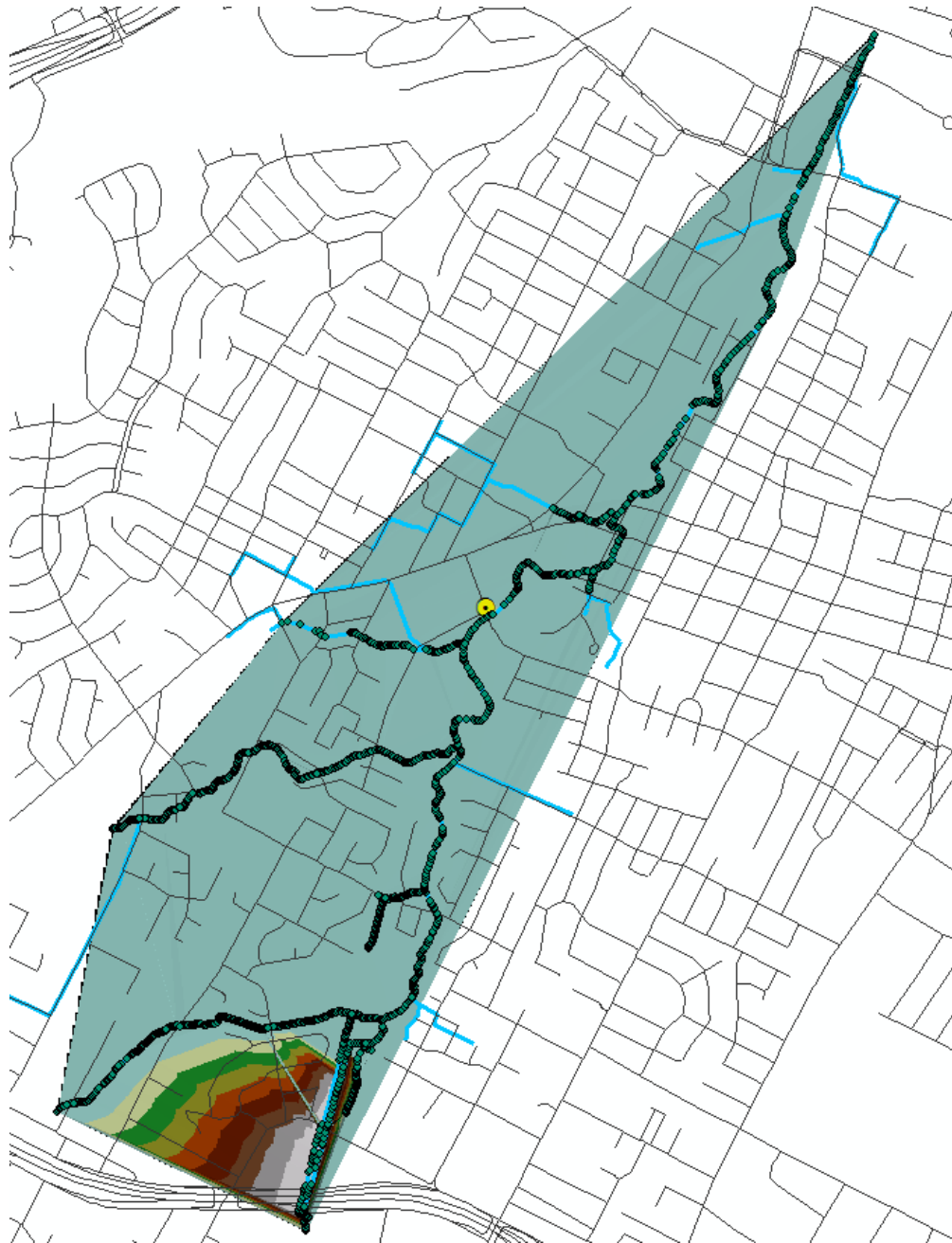


Figure 23: Image after adding the raster from the TIN.

Now I can add how high the river gage got during the peak flood time I chose in October. The peak gage height was again 5.04 feet, so assuming the gage height is referencing the bottom of the creek bed, then I can add 5.04 feet to the elev_stream shapefile to get a flood_elev shapefile. I did this using the Raster Calculator. I then used the Cut Fill tool to display on the map how much of the watershed flooded during the flood event in October (Figure 24). The resulting Figure 25 is the elevation changes during the flood. The red color is the net gain and the blue color is the net loss. Looking at the figure, it shows that almost all of the watershed would have increased in elevation because of the October flood event. Figure 26 shows the raster model of elevation changes from the flooding event when the storm drains were still part of the vector and elevation shapefile. Even though there would not have been that much

flooding as well (this time represented by the blue color), it still is a better representation of how the watershed would react to a flooding event. To show that there should have been a greater elevation change among the watershed, I made a TIN of the contour data (Map 3). I followed the same procedure as making a TIN from elevation raster data.

Moving forward, I need to figure out a way to accurately show the height of the creeks during flood events taking into account the contours of the creek. This may show that some areas are more susceptible to flooding and therefore better water management structures need to be built.

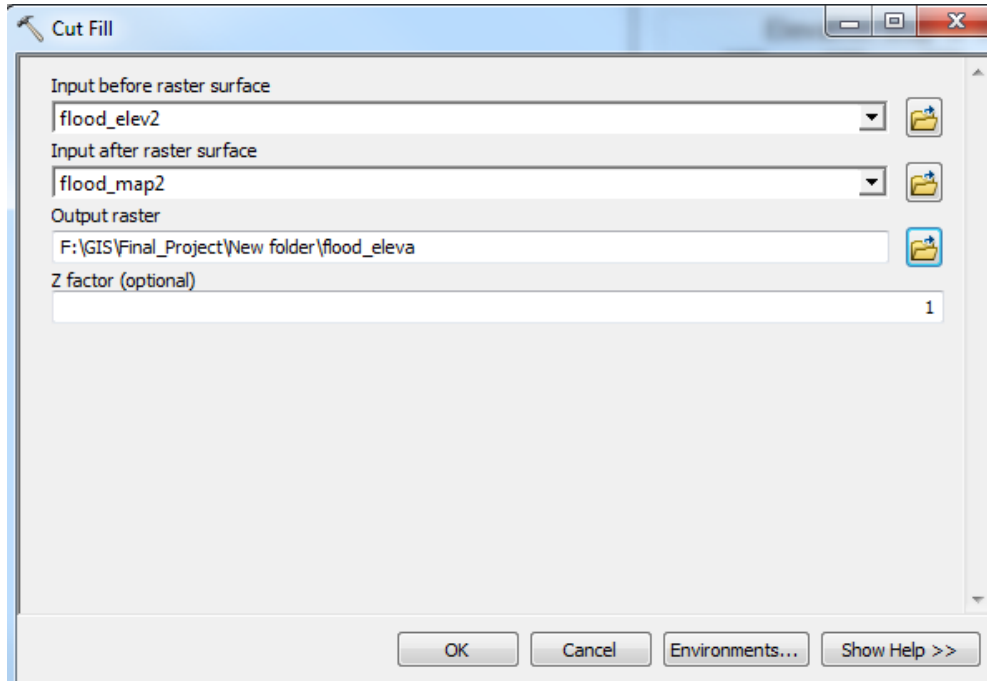


Figure 24: Cut Fill tool used to raise the elevation around the creeks to get the height when it's flooded.



Figure 25: West Bouldin watershed after the Cut Fill tool was used to represent are that was flooded during the October flooding event taking not taking into account the storm drains.

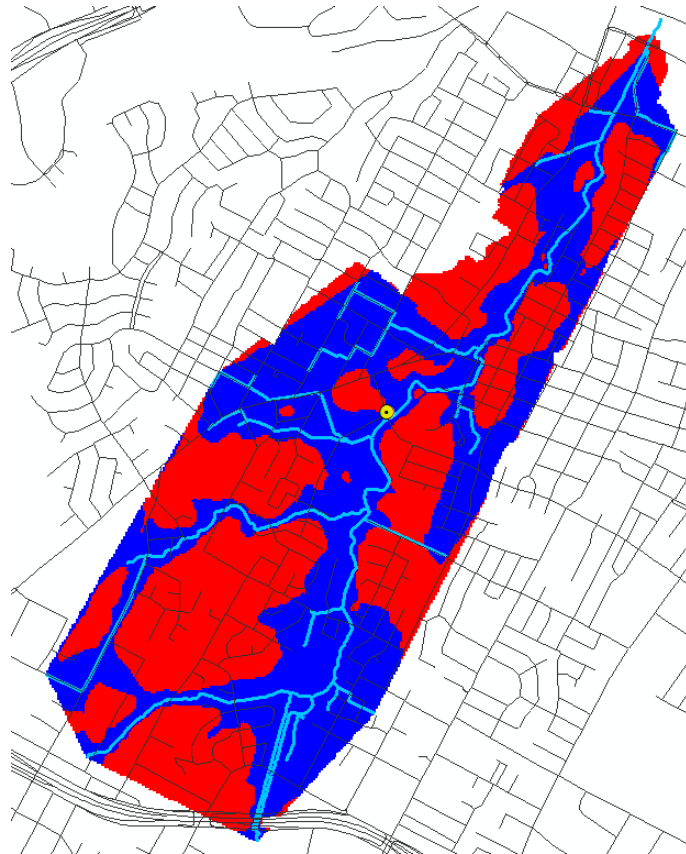
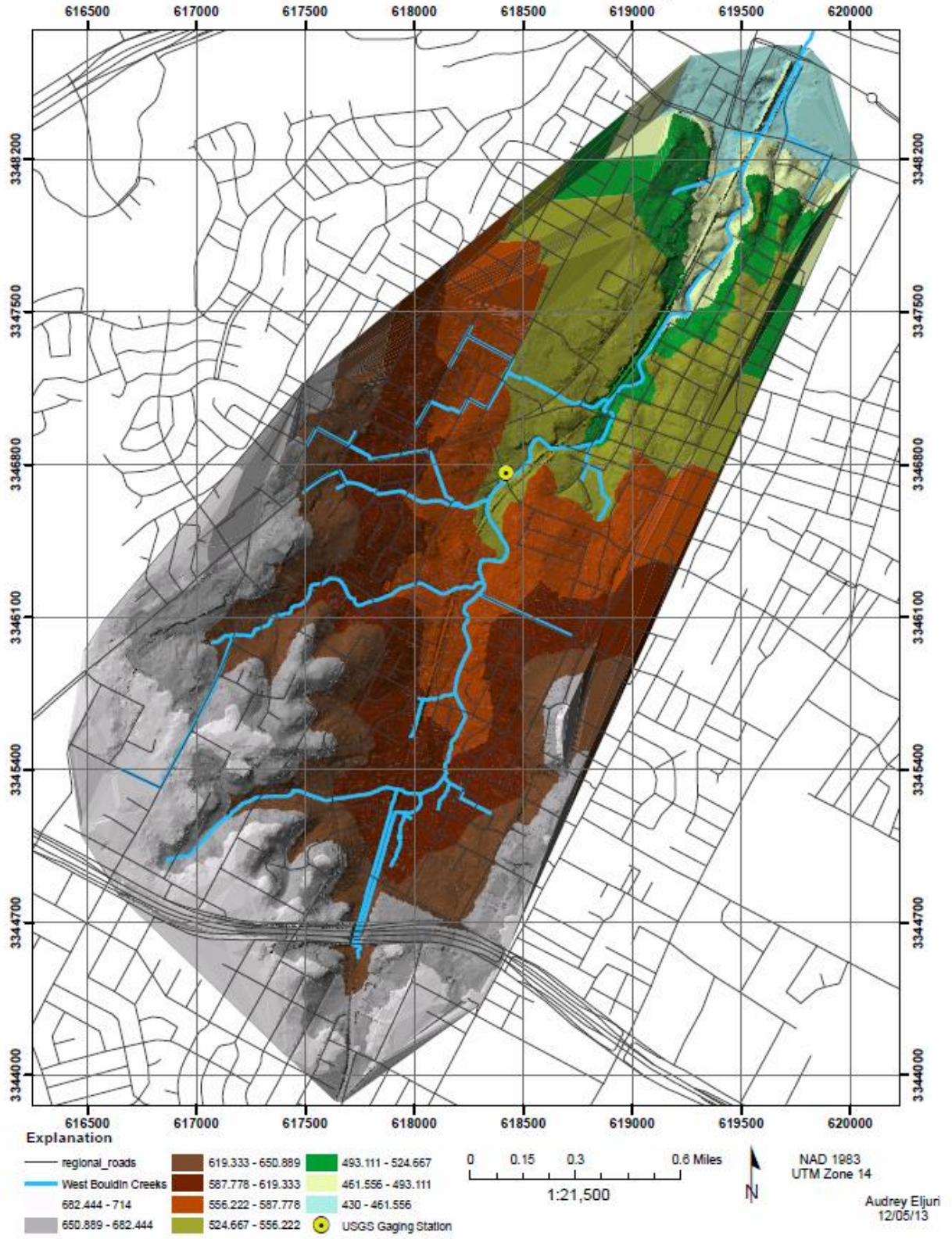


Figure 26: West Bouldin watershed after the Cut Fill tool was used to represent are that was flooded during the October flooding event taking into account the storm drains as well.

Map 3:

Elevation Map of West Bouldin Watershed, Austin, Tx.



IX. References

- Austin** Watershed Management Department, Austin's small-scale green infrastructure: <http://austintexas.gov/department/austins-small-scale-green-infrastructure> (accessed April 2013).
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- Passarello**, M.C., Sharp, J.M. Jr., Pierce, S.A., 2012, Estimating urban-induced artificial recharge: a case study for Austin, Tx.: Environmental & Engineering Geoscience, v. 18, 27p.
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- Texas** Water Development Board, "Rainwater volumes from roof runoff": <http://www.twdb.state.tx.us/innovativewater/rainwater/roofrunoff.asp> (accessed September 2013)
- West** Bouldin Creek Rain Gage Data, USGS Water Data for the Nation, <http://waterdata.usgs.gov/nwis> (accessed November 2013).