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Comparing Data:
Lake Travis Total Water Volume Change from 2004-2014:

Introduction

Over the last decade Texas has experienced a succession of droughts ending with the current drought that began in the fall of 2010. As a result, Lake Travis (Fig. 1), the second reservoir lake of the Highland Lakes chain, has experienced large fluctuations in water level. Average water level heights provided from the LCRA, show that the water level has dropped approximately 50 ft. from 2004 to 2014. This project's goal was to determine how a 50 ft. decrease in water level translates to volume of water lost.

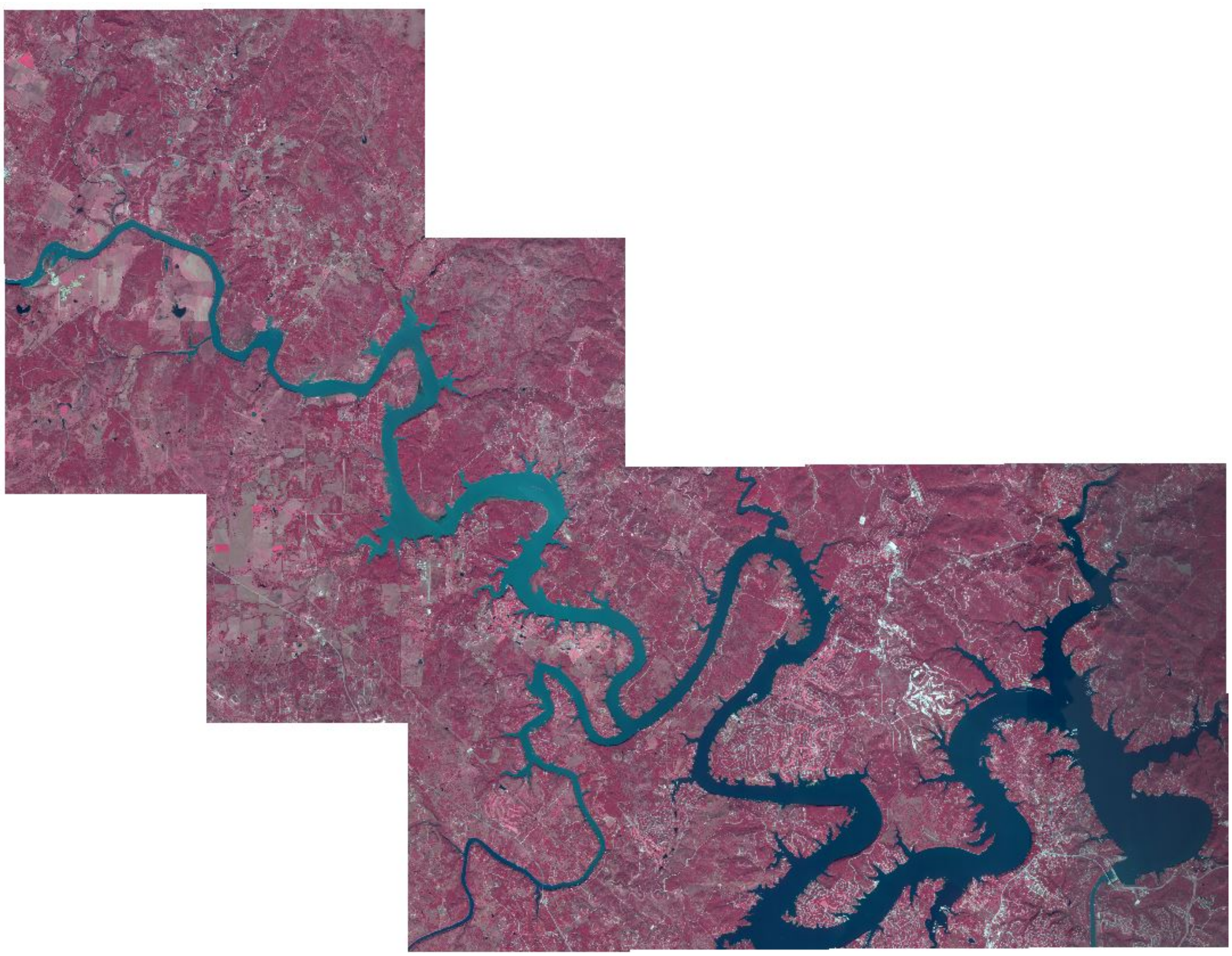


Fig. 1 2004 NAIP 1M CIR of Lake Travis

Data Acquisition

The average minimum water level was calculated through Microsoft Excel spreadsheets provided by the LCRA (Fig. 2).

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2	2004	669.18	670.45	671.24	677.34	680.42	681.08	680.73	679.64	679.7	677.78	685.29	682.79
3	2005	681.65	681.63	682.75	680.98	680.25	679.23	673.38	672.58	671.52	667.39	665.37	664.25
4	2006	663.92	663.58	663.67	662.49	664.23	659.97	655.86	651.12	646.83	645.01	644.58	643.86
5	2007	645.75	647.22	651.81	668.63	674.18	683.29	689.89	683.47	681.86	680.54	680.23	680.48
6	2008	682.30	682.01	680.85	678.93	677.81	672.29	665.99	662.28	659.53	657.52	656.80	656.12
7	2009	655.36	654.42	654.08	653.27	653.28	647.77	639.87	634.34	630.57	635.22	649.12	654.33
8	2010	657.24	672.43	679.50	681.34	680.20	677.05	673.64	669.76	670.38	670.11	668.72	667.33
9	2011	667.58	666.71	664.99	660.81	653.41	648.20	643.39	636.92	631.58	628.19	626.52	626.60
10	2012	626.40	628.32	634.65	639.94	641.26	641.69	639.85	637.36	634.89	634.34	632.92	631.58
11	2013	631.52	631.34	630.60	630.49	628.42	628.17	625.25	622.71	620.18	622.43	625.85	628.19
12	2014	628.36	627.86	627.68	626.86	625.68	629.85	628.72	626.12	623.8915			
13													
14	2004 AVG	677.97				2004-2014				Depth is in feet above Mean Sea Level			
15	2005 AVG	675.08				50.75							
16	2006 AVG	655.43											
17	2007 AVG	672.28											
18	2008 AVG	669.37											
19	2009 AVG	646.80											
20	2010 AVG	672.31											
21	2011 AVG	646.24											
22	2012 AVG	635.27											
23	2013 AVG	627.10											
24	2014 AVG	627.22											

Fig. 2 Edited Historical Water Level spreadsheet showing average heights over last decade. Note the difference in water level height based on annual averages.

(*Historical Lake Levels)*

In addition to the water level heights, Lake Travis's bathymetry data was also needed. The Capital Area Council of Governments (CAPCOG) website provides bathymetry data for all of the major lakes and rivers in Texas (published 2009). This data uses multiple datasets from the Texas Water Development Board (TWDB) and illustrates elevation changes along the lake bottom with 2 to 10 ft contours. The data uses the *NAD 1983 StatePlane Texas Central FIPS 4203 Feet* projected coordinate system and the *GCS North American 1983* geographic coordinate system.

*Note that all data was run off of my flash drive as the large datasets would have taken much too long on my personal system network.

**Figure 1 shows the average lake levels of 2004 and 2014 (circled). As the contours in the Lake Travis area are in 10 ft. intervals, the 2004 and 2014 average heights were rounded to 680 ft. and 630 ft. respectively.

Data Preprocessing

As the CAPCOG data includes the bathymetry of all major lakes and rivers in Texas, I first had to create a shapefile excluding all information other than that of Lake Travis. I began by creating a new map in ArcMap called ‘Project’. I first imported the CAPCOG bathymetric data using the ‘Add Data’ button. I used the ‘Select by Polygon’ (Fig. 3) tool to create a polygon that enclosed the Lake Travis contours from the Max Starcke Dam to the Mansfield Dam. I then right-clicked the layer and selected ‘Export Data’ (Fig. 4).

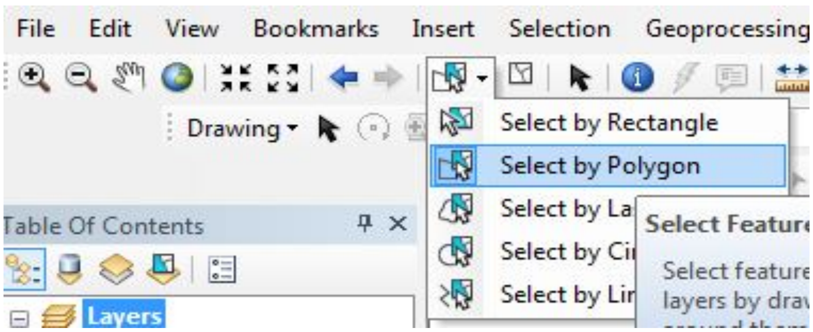


Fig. 3 Select by Polygon Tool found in ‘Standard’ Toolbar

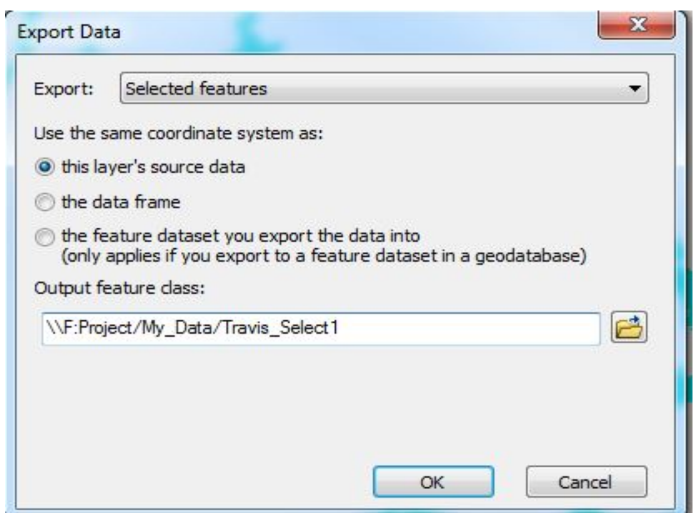


Fig. 4 Export Data window showing creation of the base shapefile ‘Travis_Select1’

The resulting shapefile ‘Travis_Select1’ would become the base shapefile for all future processing (Fig. 5). I removed the original ‘CAPCOG’ layer and imported the newly created shapefile into the Dataframe.

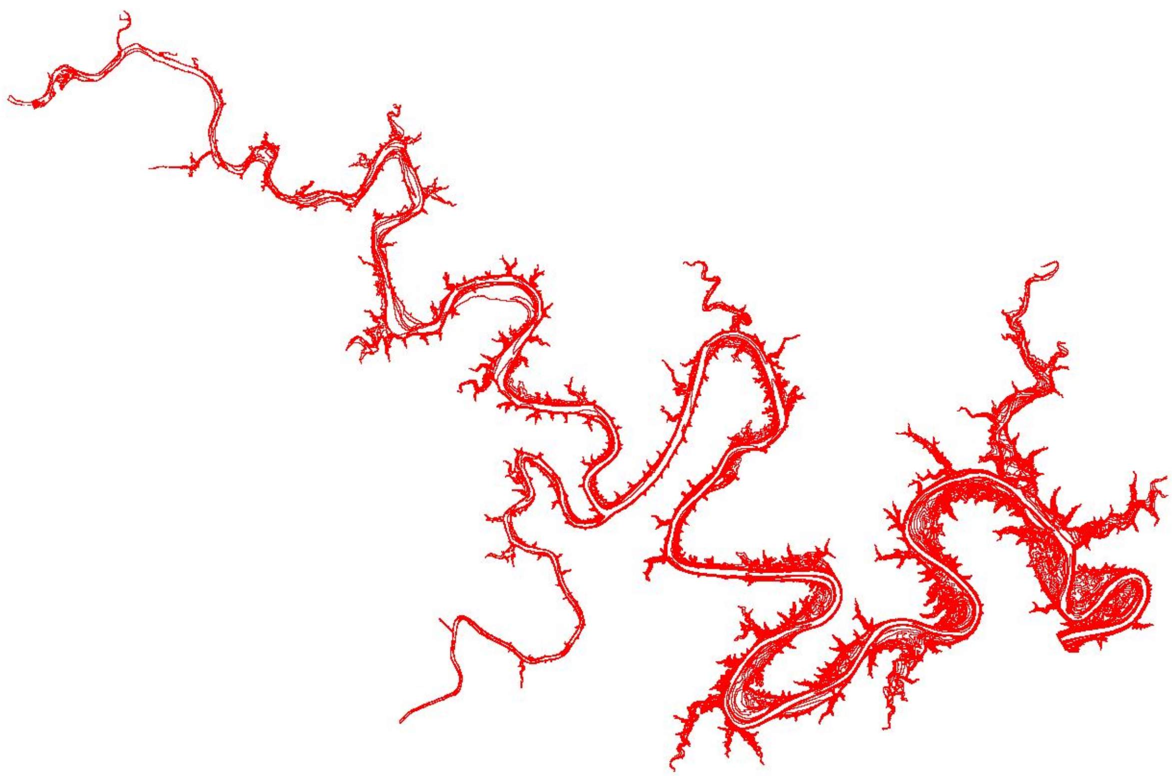


Fig. 5 Base shapefile ‘Travis_Select1’

Data Processing (Step 1)

Now that I had removed all extraneous data, I began to create the 3-D surface that I would use to calculate the 2004 water volume at a water level height of 680ft (see Fig. 2). I used the ‘Select by Attributes’ tool found on the ‘Standard’ toolbar and proceeded to select all contours less than or equal to 680 (Fig. 6).

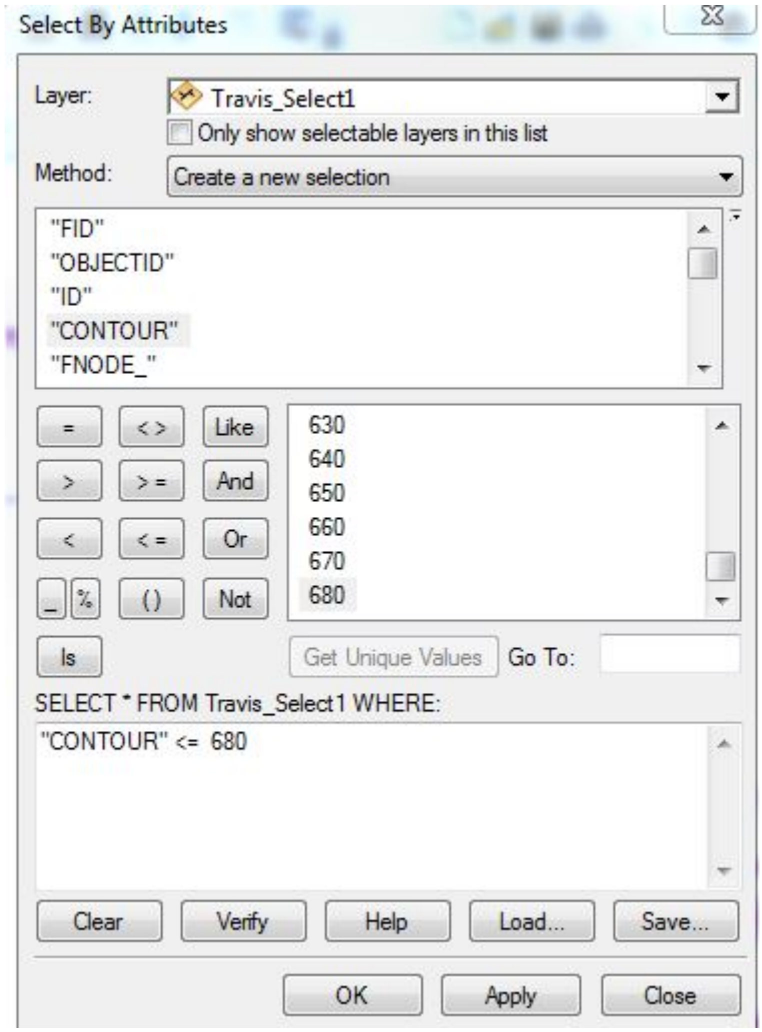


Fig. 6 Select By Attributes tool

I then used the 'Create TIN' tool in ArcToolbox under '3-D Analyst Tools' (Fig. 7). I chose to use a TIN as it creates a three dimensional surface and requires no change in resolution. It also allows for the selection of a 'Soft Line' Surface Feature type. 'Soft Line' creates breaklines that enforce a height value, but at a more gradual change in slope than those created by 'Hard Line'. This selection accounts for the soft sediments that are assumed to have been accumulating on the lake bottom since the lake's formation.

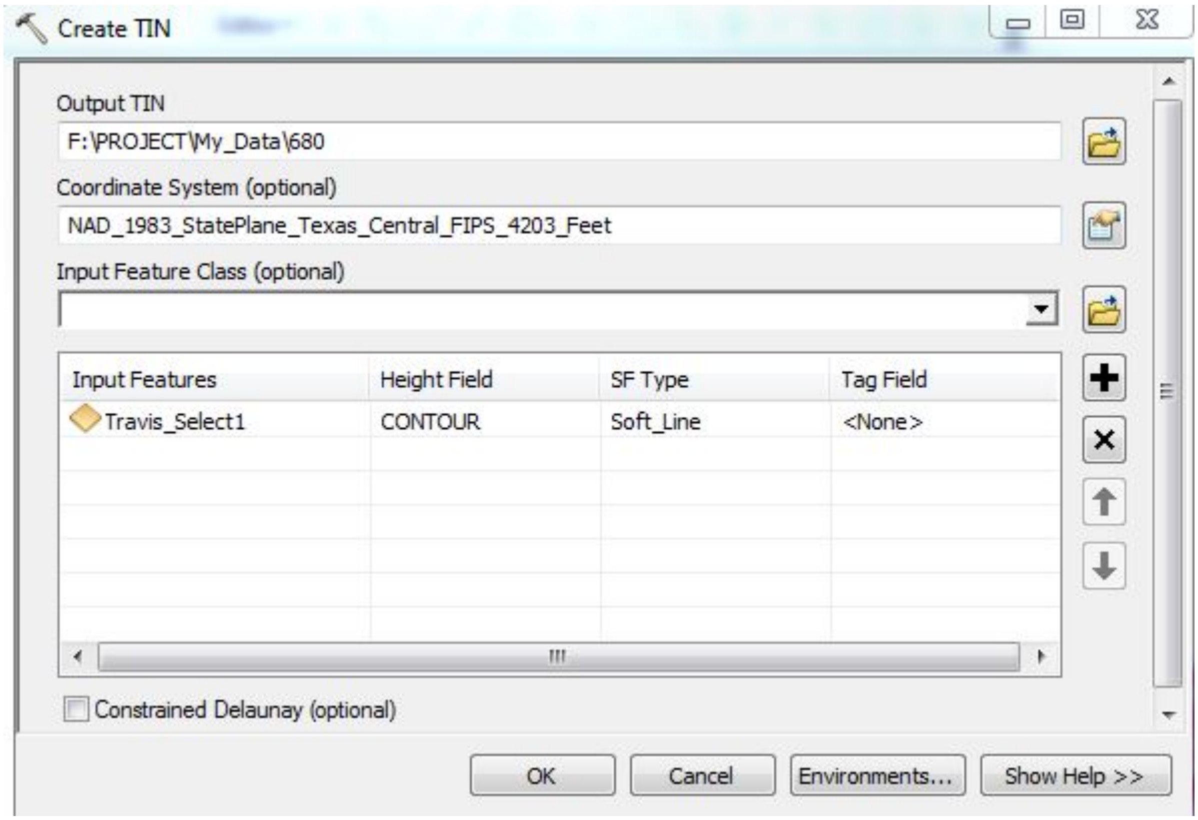


Fig. 7 Input and tool used to create the '680_TIN'

Though constraining Delaunay triangulation would create fewer triangles, it would create longer, skinnier triangles that would hinder accurate surface analysis. Thus, I left it unchecked.

The resulting TIN (Fig. 8) now gave me a three dimensional surface which I could perform surface analysis on.

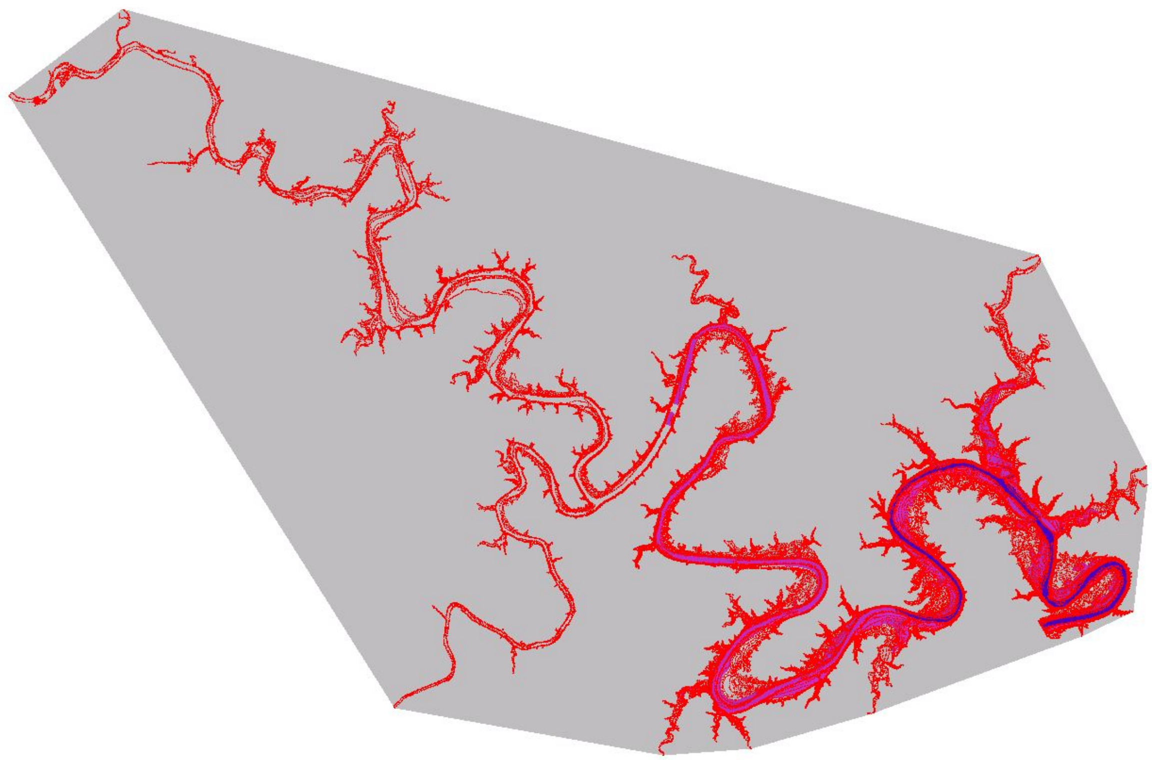


Fig. 8 ‘680_TIN’ with contours up to 680 ft.

Fortunately, ArcToolbox contains a ‘Surface Volume’ tool under ‘3D Analyst Tools’. This tool allows for the calculation of the volume above or below a set plane height. I chose to calculate the volume below the plane height of 680 and kept the ‘Z Factor’ at 1 so as to keep the resulting units in cubic feet (Fig. 9).

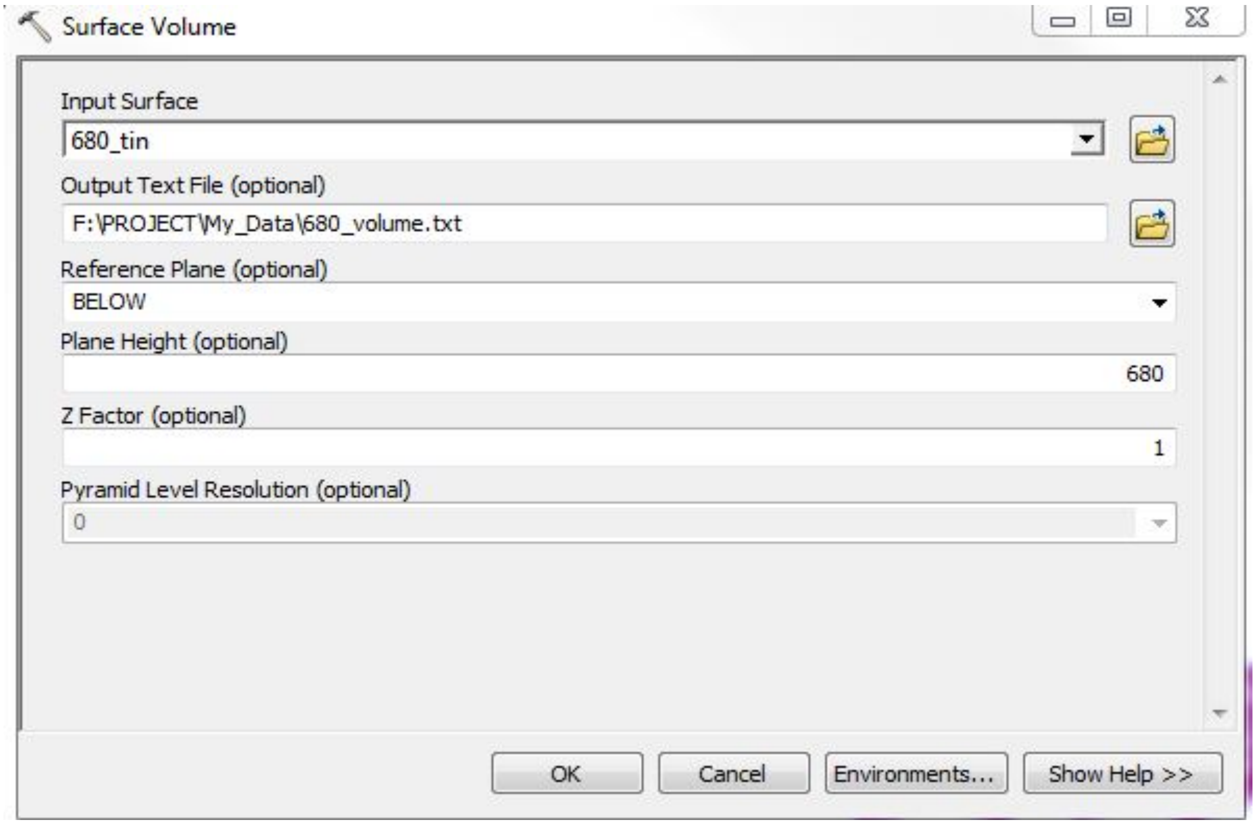
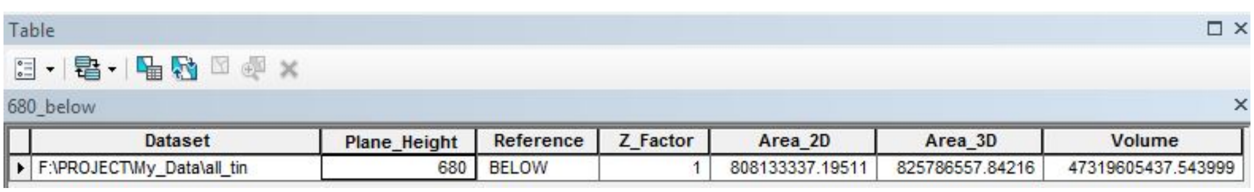


Fig. 9 'Surface Volume' tool with Input

The tool then created a table that displayed the resulting volume (Fig. 10).



Table

680_below

Dataset	Plane_Height	Reference	Z_Factor	Area_2D	Area_3D	Volume
F:\PROJECT\My_Data\all_tin	680	BELOW	1	808133337.19511	825786557.84216	47319605437.543999

Fig. 10 Table created from 'Surface Volume' tool and '680_TIN'

Using google unit converter, I converted the volume from cubic feet to acre-feet (Fig. 11).

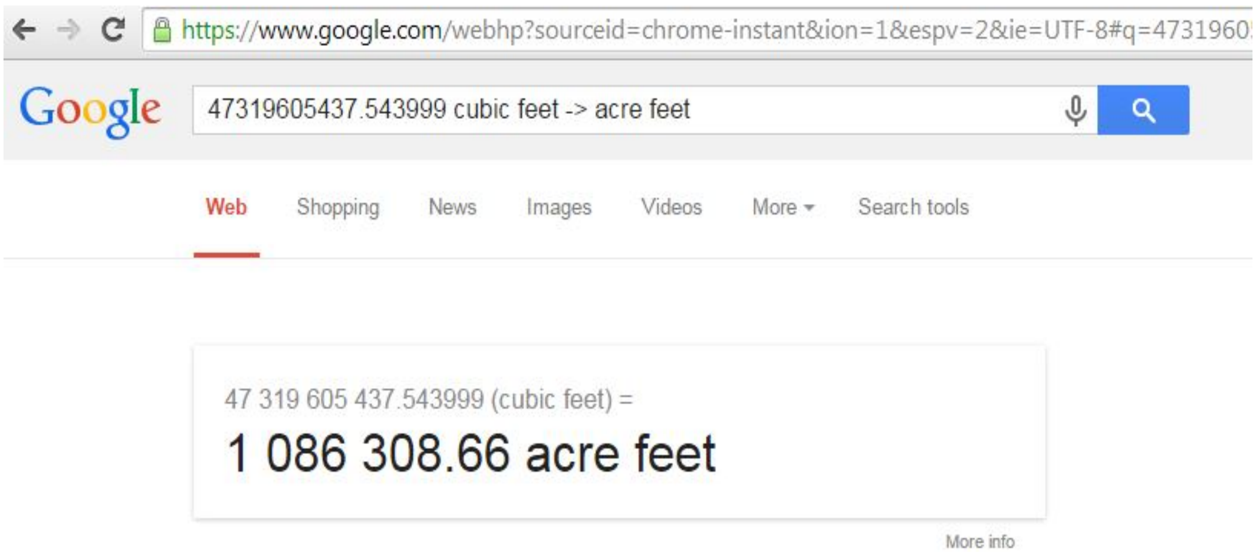


Fig. 11 Resulting volume conversion

Data Processing (Step 2)

Now that I had the volume of Lake Travis from 2004, I used the same steps to calculate the volume of the lake in 2014 (630 ft.). I first created a new map, 'Project 2'. I imported the base shapefile 'Travis_Select1' (Fig. 5), and using the 'Select By Attributes' tool again, I selected for all contours less than or equal to 630 ft. I then exported the selected data as a shapefile and imported it back into the map as '630_export' (Fig.12).

Fig. 12 ‘630_Export’ shapefile

I then used the ‘Create TIN’ tool (Fig. 7) to create a new ‘630_TIN’ (Fig. 13). I kept all of the input the same except for the input feature, which was the ‘630_Export’.

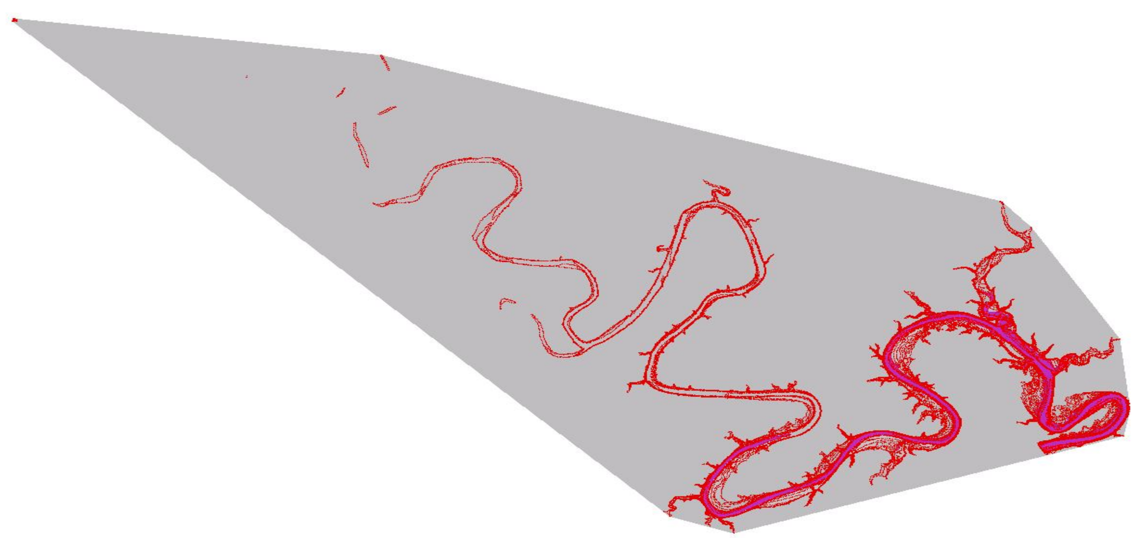


Fig. 13 ‘630_TIN’ created from ‘630_Export’

Once again, I used the ‘Surface Volume’ tool (Fig. 9) with all of the same input, except for the input surface, ‘630_TIN’, and the plane height, 630. The tool then created a table with the resulting volume in cubic feet (Fig. 14).

Table

630_Volume

Dataset	Plane_Height	Reference	Z_Factor	Area_2D	Area_3D	Volume
F:\PROJECT\My_Data\630_tin	630	BELOW	1	386185462.60855	392988142.07371	18354264235.046001

Fig. 14 Volume in cubic feet of at water level 630 ft.

I then used the google unit converter to convert the volume to acre-feet (Fig. 15).

Fig. 15 Resulting volume in acre-feet

Results

Now that both volumes had been acquired, I simply subtracted the 2014 (680 ft.) volume from the 2004 (680 ft.) volume:

1,086,308.66 acre feet – 421,355.928 acre feet = **664,952.732 acre feet**

To put that into perspective, that means the lake has lost**61.21%** of its volume in the last decade.

In order to check the accuracy of my results, I compared both the 2004 and 2014 volumes to the LCRA's volume calculator (Figs. 16 & 17).

*Note that the calculator combines the volume of Buchanan and Travis, both which were calculated using the National Geodetic Vertical Datum of 1929. Buchanan was zeroed out by setting the level at empty and the accuracy of the results was likely effected by the difference in vertical datum.

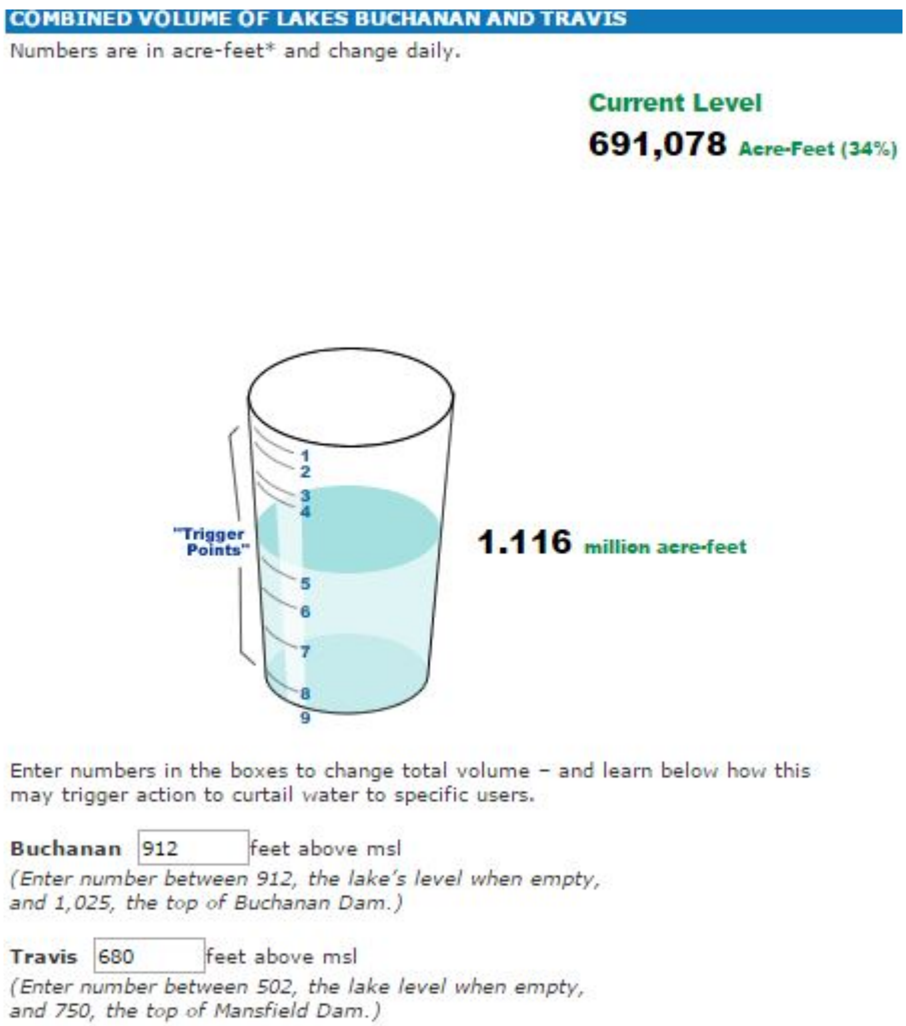


Fig. 16 LCRA Volume calculation for water level at 680 ft.

1,086,308.66 acre feet ÷ 1,160,000 acre feet x 100 = **93.65%** accurate

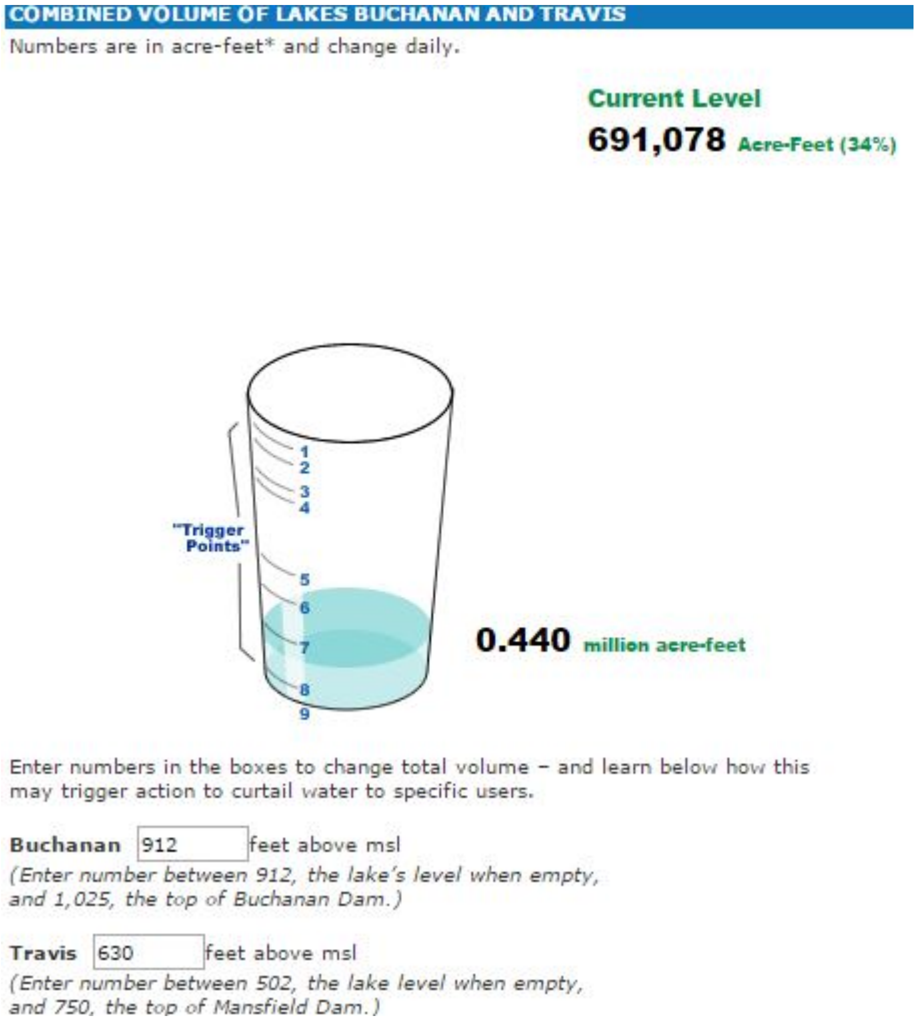


Fig. 17 LCRA Volume calculation for water level at 630 ft.

421,355.928 acre feet ÷ 440,000 x 100 = **95.72%** accurate

Conclusion

ArcGIS is a powerful tool that allows for the visualization and calculation of information that would otherwise be nearly impossible to reproduce. Although I encountered many difficulties throughout the project, I really enjoyed the process of creating a method to answer a difficult question. I believe that the method I used is fairly accurate considering the gaps in data (i.e. contour lines that do not connect) seen in the original CAPCOG shapefile. I believe that this method, or one close to it, can be used to answer other questions, e.g. how does the rate of volume loss change over decreasing depth?

References

2004 NAIP 1M CIR of Lake Travis. TNRIS. (Accessed 11/23/2014).

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Bathymetry Data. CAPCOG. Published May 2009. (Accessed 11/23/2014).

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URL: http://hydromet.lcra.org/lakevolume/