SHRINKING LAKE MEAD

Effects of persistent drought on HUC 15010005

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Contents

Objective

The objective of this project was to better understand how drought has affected Lake Mead and potential affects this may have on the Las Vegas Valley. The drought effects on the lake level are obvious to the casual observer by “bathtub rings” along the lake as can be seen in the picture below.

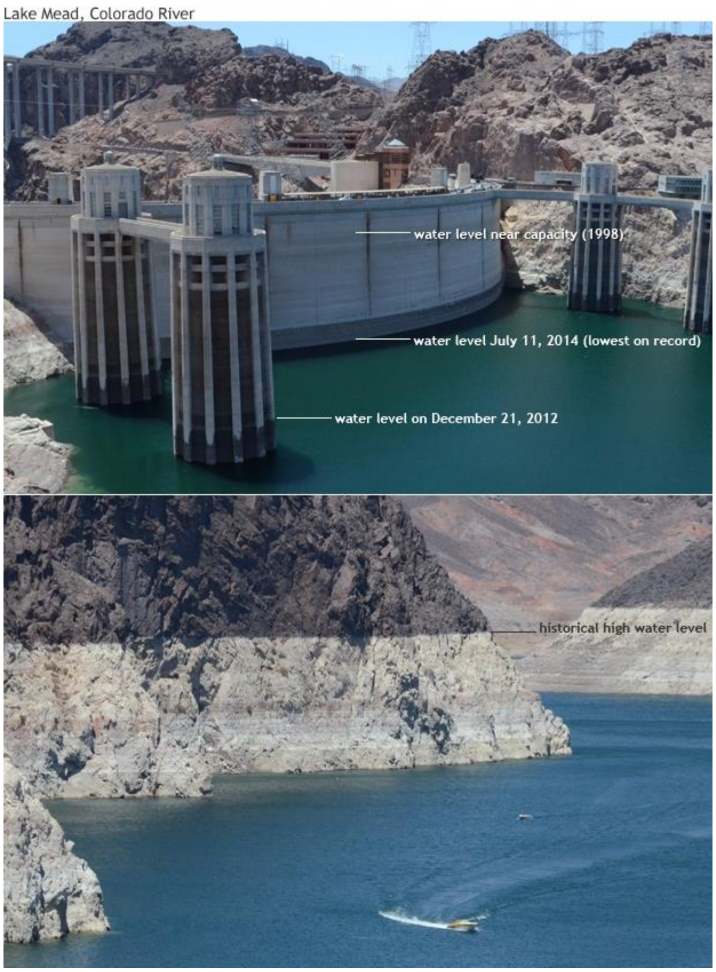


Figure 1: Image of Lake Mead from SNWA

As of November 30, 2016, the water level was 1077 ft above sea level which means the reservoir is only 37% full. Throughout this project, I looked at the lake level and shoreline from a variety of different data sources including a digital elevation model, bathymetry, and flowlines to determine the current volume. Using historical data I compared how the volume has changed over time. With this and weather data I can conclude that drought is affecting the level of Lake Mead.

Background

Lake Mead is the largest reservoir in the United States with a capacity of 27,441,000 acre-ft. The lake was formed by the Hoover Dam which was built in 1935. It provides water for many southwestern states including Nevada, Arizona, and California. Most of Lake Mead's source water is from the Colorado River. This accounts for over 97% of the flow. There are also some other sources such as the Virgin River (1.4%), Muddy River (0.1%), and the Las Vegas Wash (1.5%).

The lake itself is a large recreation area in addition to being a water supply. It has over 22 million users per year. Many of these users are from Las Vegas. The city is heavily dependent on Lake Mead acquiring 90% of its freshwater needs from the lake. The rest is from groundwater sources. Since Las Vegas is so dependent on the lake it is especially important the city to carefully monitor the water level.

Las Vegas has had a drastic increase in users. It had about 130,000 residents when it initially started to use Lake Mead as its water source. This was in 1971. The census estimated over 600,000 residents for 2015 and 2.1 million residents in Clark County where Las Vegas resides (census.gov). Las Vegas is also known for its tourism industry. With around 40 million tourists a year the water usage in the city can be highly attributed to tourists in addition to residents.

There are three ways that water may leave Lake Mead: evaporation, through Hoover Dam, and by pumping out for municipal water treatment at Saddle Island. Evaporation is an important factor. With an increase in temperature it has been hypothesized that evaporation will increase lowering the lake even faster. Hoover Dam is required by agreements to discharge a certain amount each year. Finally pumping out the water for municipal water use requires pumps significantly below the water level. Since the lake level has been decreasing this has become an issue for the water authority.

The Southern Nevada Water Authority constructed a third drinking water intake. This intake draws water from lower depths than the previous two with a minimum depth of 875 ft. The current level is 1077 ft and the third intake has been under use since last September.

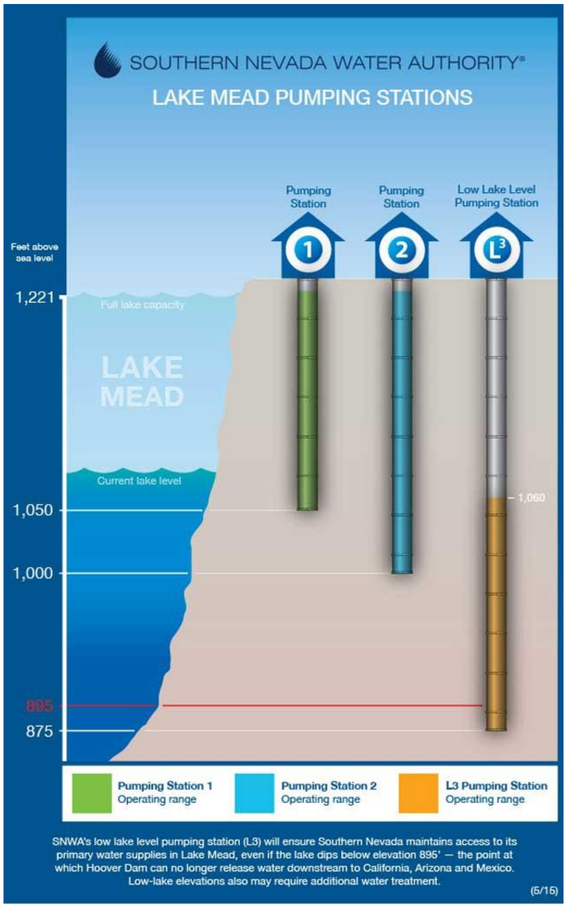


Figure 2: Third intake in Lake Mead (https://www.snwa.com/about/regional_pumping_low.html)

Originally, I wanted to know how this third intake would affect the lake level. If it would lower it and cause more of those bathtub rings shown on the previous slide. However, after further research I found that Las Vegas essentially removes the same amount of water with this third intake so flow does not increase. The level of the lake is just too low for that same amount of water to be taken from intakes 1 and 2. Lake Mead has been under persistent drought conditions for some time now. The lowering of Lake Mead thus seems to be entirely caused by upstream flow decrease and drought. To validate this the following analysis was done.

Method

First the shoreline of lake mead had to be determined. Three different methods were used for this. The first was to use an estimate of the shoreline shapefile. The second was to use bathymetry data. The third was to use a digital elevation model.

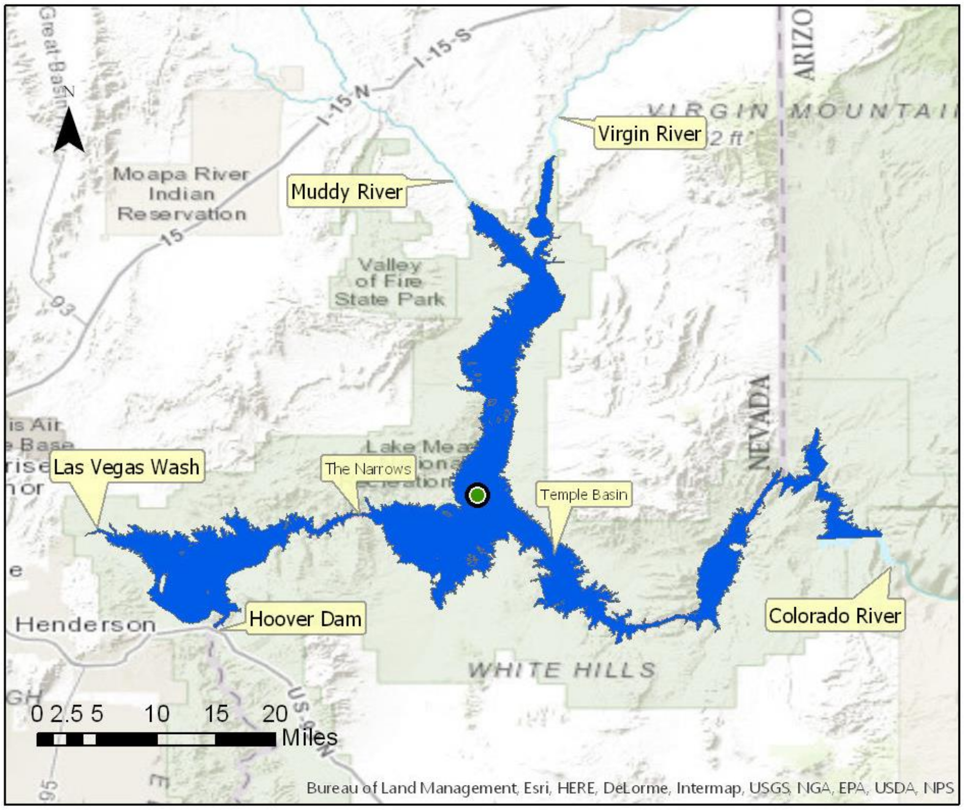


Figure 3: Lake Mead shoreline and landmarks developed in ArcGIS

Next data had to be derived from gages so the gages within HUC 15010005 were taken from USGS. 152 gage points were found within HUC 15010005 (http://waterdata.usgs.gov/nv/nwis). Six of those gages were included in the analysis.

The basin, subwatershed, and flowlines were added. All the gages, waterbodies, and other features had to be clipped to within a basin boundary buffer of 100m. The product is the following map with features that include data that can be used in the analysis

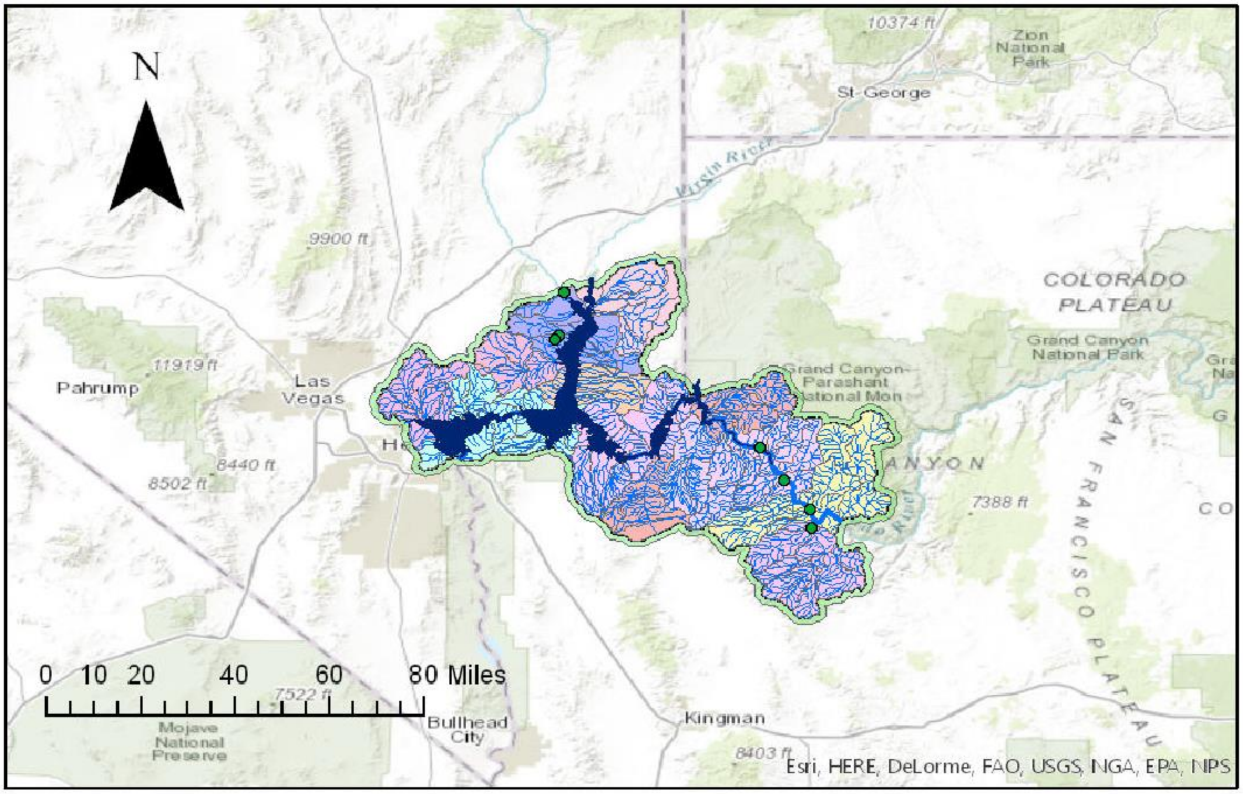


Figure 4: Map of HUC 15010005 including subwatersheds, flowlines, water bodies, and some gages

Bathymetry data was also provided the Lower Colorado Regional Office at the Bureau of Reclamation. The data created the following maps.

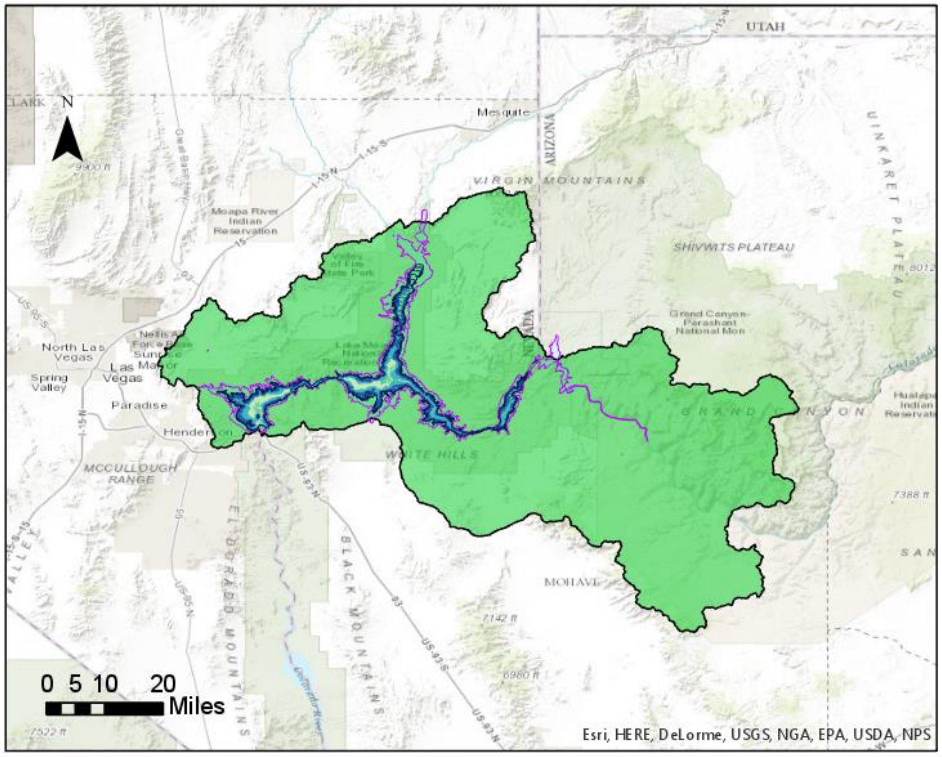
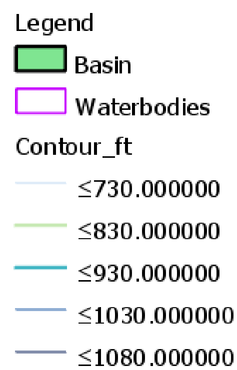


Figure 5: Bathymetry for the entire lake



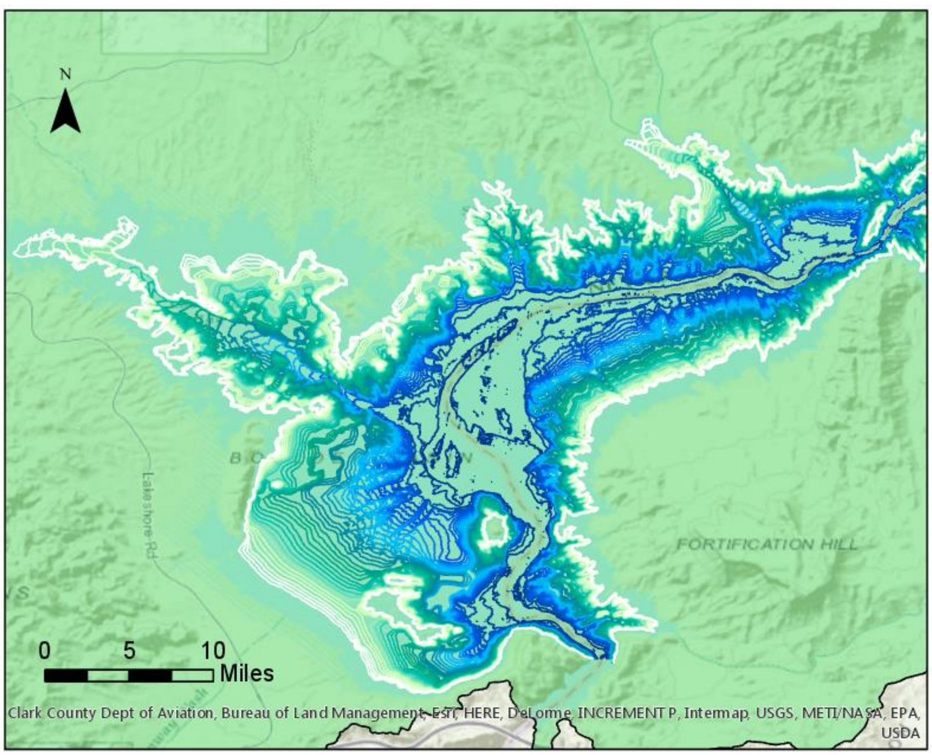


Figure 6: Bathymetry for the Las Vegas Bay and Boulder Basin

Data Analysis

To run some analysis on the lake the bathymetry data was converted into a raster using the polyline to raster tool while filling in pits using the Zonal Fill tool. The missing data from the bathymetry data was filled in with averages.

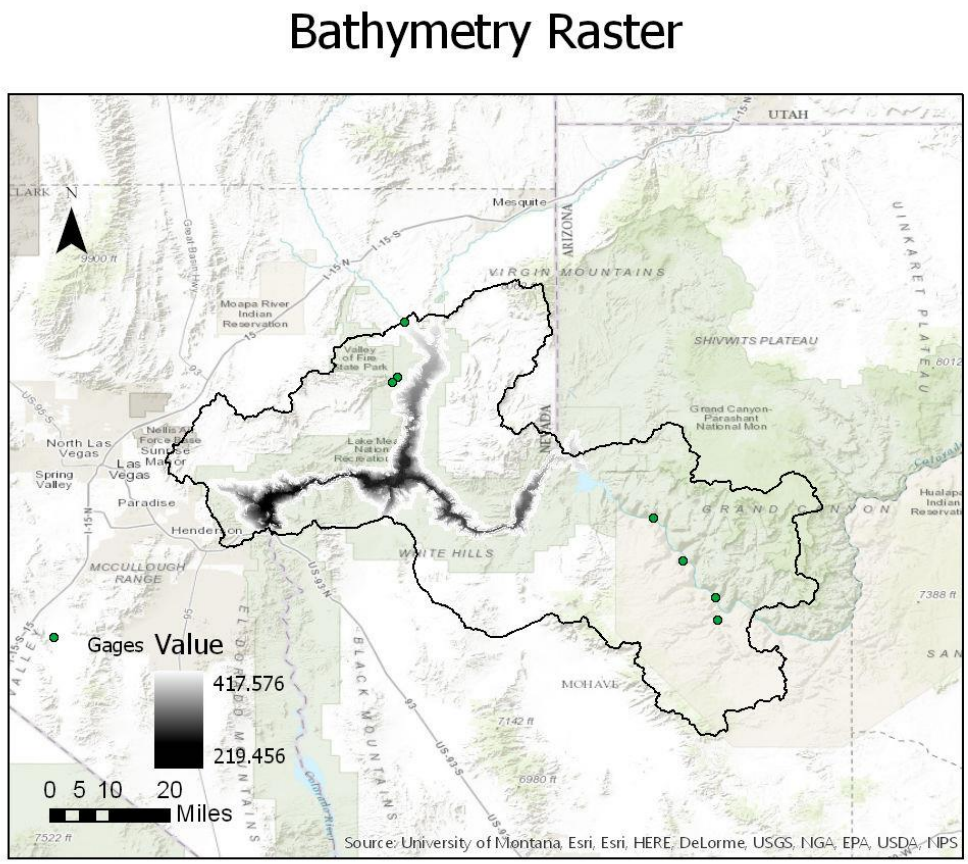


Figure 7: Raster formed from converting bathymetry polylines

By converting the bathymetry polylines into polygons, the surface area can be estimated. By doing this for each contour line an estimate the amount of surface area per the elevation can be derived. The following chart shows the smoothed result. This in general is about 18% less than what was derived from LiDAR data by SNWA. There are a variety of reasons that could cause this. The first is simply that the data is from different years. In addition, although there isn't much vegetation LiDAR is inhibited by that. The highest amount of surface area occurs at the highest elevation of 375 m(1229 ft) and comes to 659 km2 (162,900 acres)

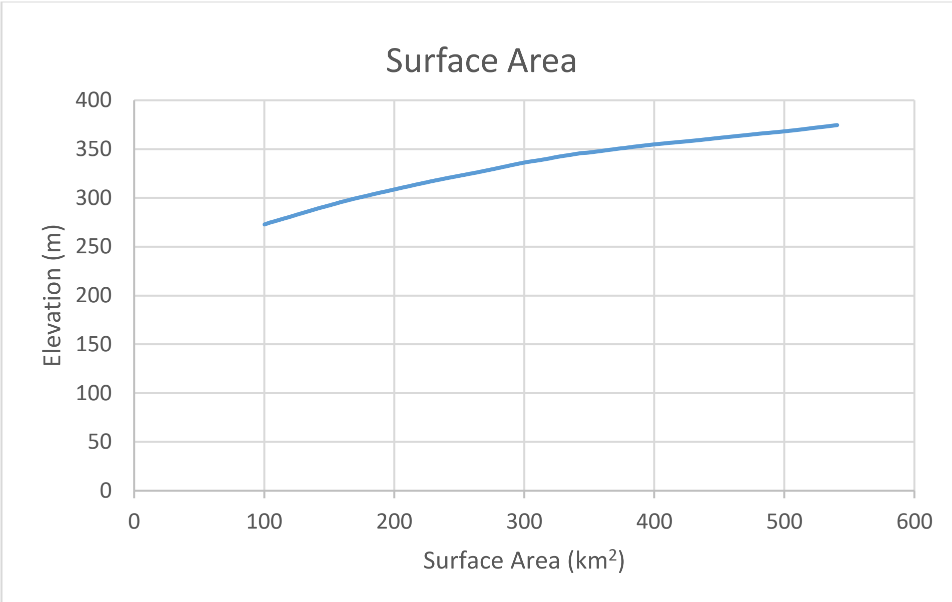


Figure 8: Derived surface area from elevation and DEM data

The next step is to derive the volume by multiplying the change in elevation and the surface area. These layers can then be added up much like integration. The volume derived by this method at 375 m (1229 ft) was 28.0 km^2 (acre-ft) while the literature value is 33.85 km^3(27,441,000 acre-ft) This equates to a -17.2% which makes sense since the estimated surface volume was about 18% less than the literature values.

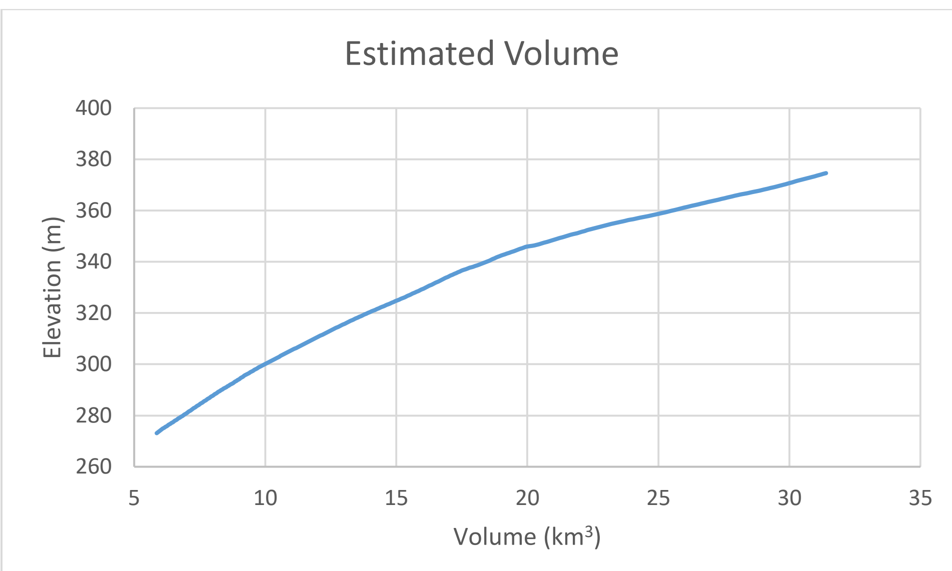


Figure 9: Derived Volume from elevation and DEM data

A digital elevation model was also created for analysis.

DEM with flowlines for HUC 15010005

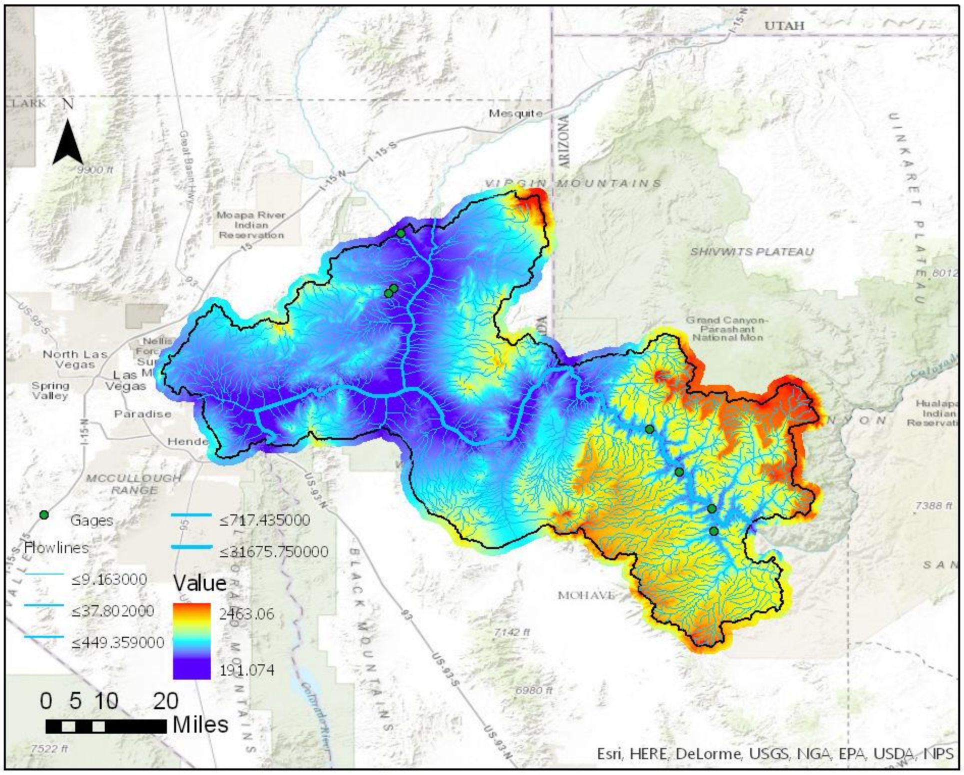


Figure 10: Digital elevation model

Now that the water body of Lake Mead and the entire basin has been characterized I considered some of the factors that can cause lowering of the water level. Land cover can be used to determine what activities are surrounding Lake Mead. Las Vegas is easily seen just outside of the watershed to the west as the large developed area. The rest of the surrounding area is shrub, scrub, and grass. From this graph, it does not look like agriculture is an important factor, but development might be.

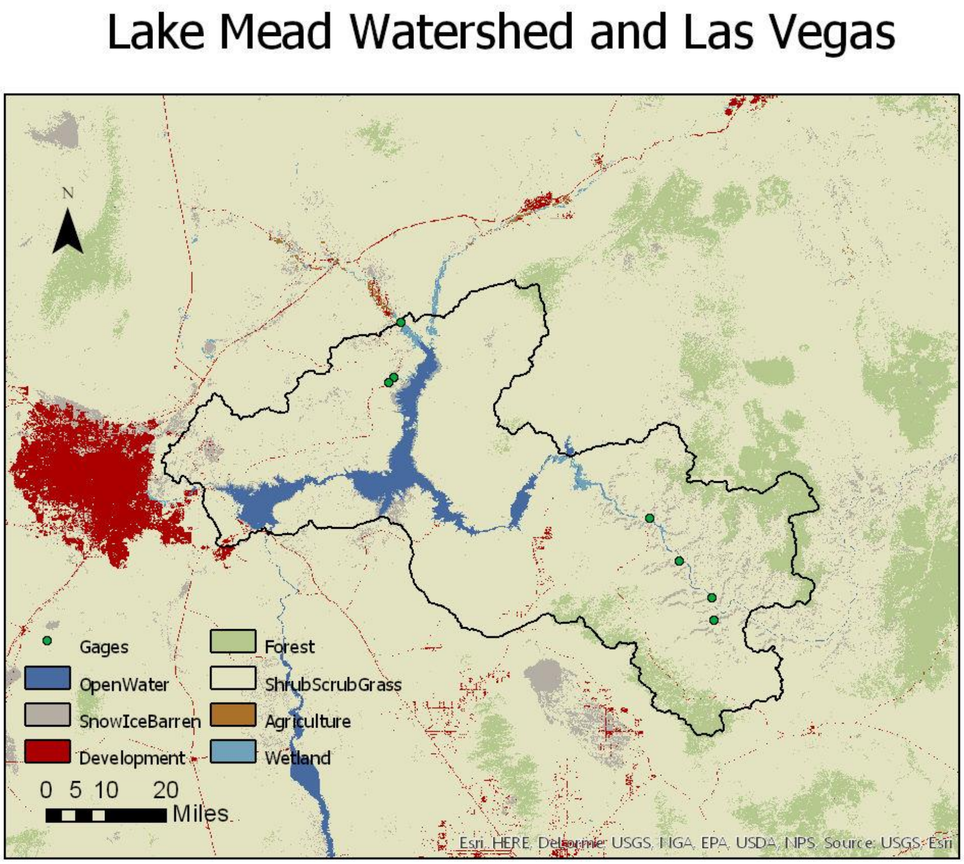


Figure 11: Land Cover

Table 1: Land Cover Classifications

OBJECTID	LC_CLASS	FREQUENCY	SUM_Count	Area (km2)	% of Area
1	Agriculture	1	1444	1.30	0.0
2	Development	4	57667	51.90	0.5
3	Forest	2	978137	880.32	7.7
4	OpenWater	1	739810	665.83	5.8
5	ShrubScrubGrass	2	10344272	9309.84	80.9
6	SnowIceBarren	1	544468	490.02	4.3
7	Wetland	2	117300	105.57	0.9

Beyond the land use the population has changed significantly over time. Below is the map of the population density as of 2015.

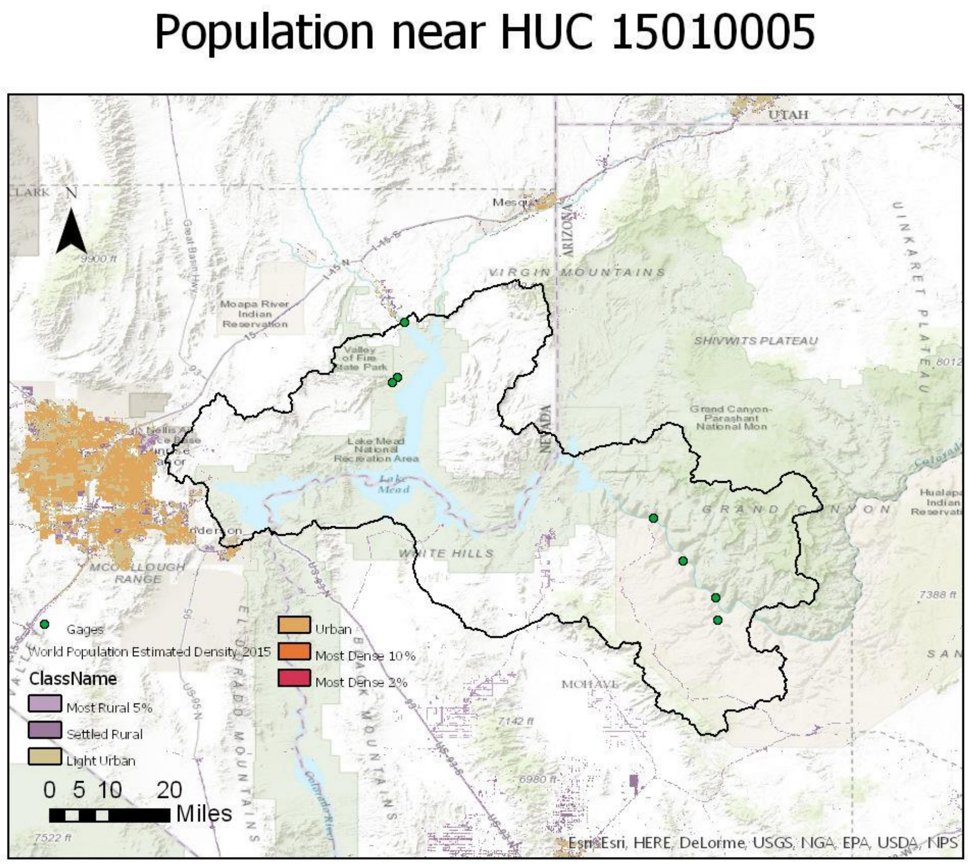


Figure 12: Population density map (Living Atlas)

Most of the population in the whole region resides in Las Vegas to the west. Some other rural areas are scattered around. Once again, the population has quadrupled in the last 45 years in just the Las Vegas metropolitan area. The water usage drastically increased from 1956 to 2008 where it has started a downward trend. During this downward trend in water usage lake mead water levels have continued to decrease.it Thus it can be inferred that the increase in population is not causing the Las Vegas Water

Valley District to pump out more water (at least not without replacing it).

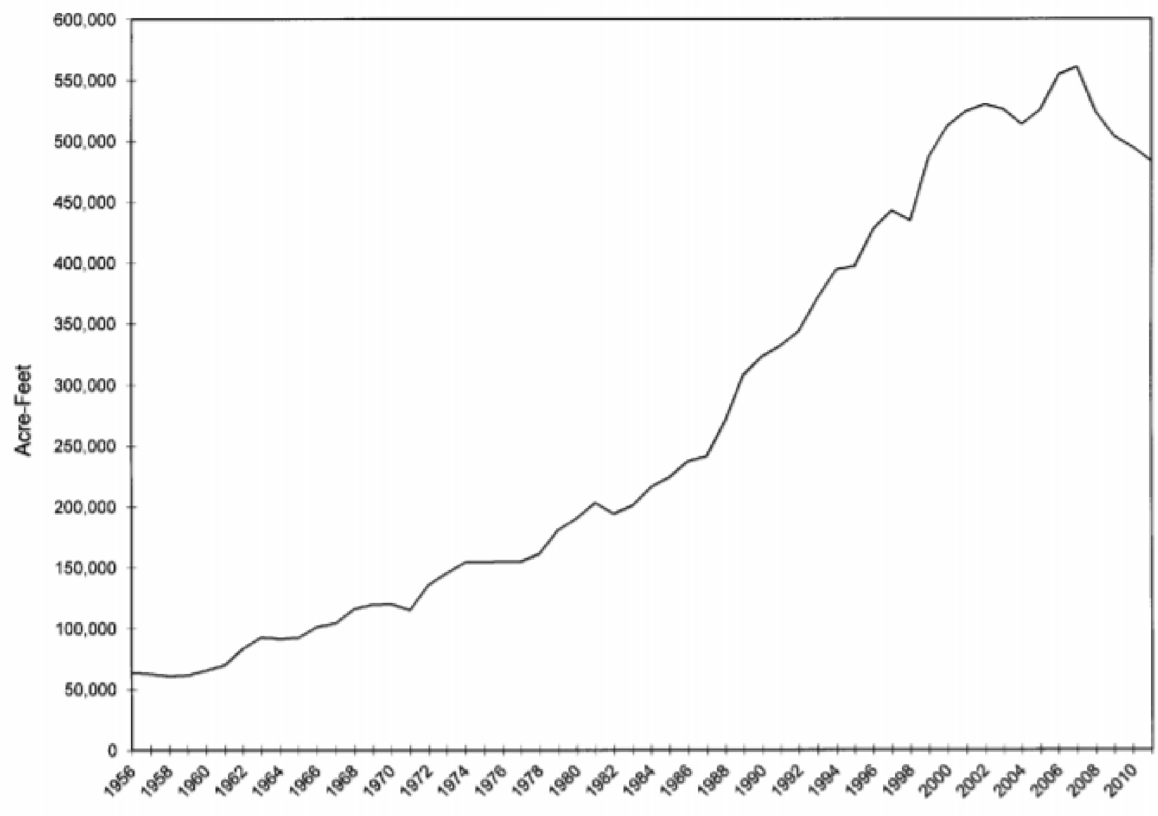


Figure 8. Annual water usage for the Las Vegas Valley, 1956-2011.

Figure 13: Water usage in Las Vegas from 1956-2011 (http://water.nv.gov/data)

The next factor to consider is the environment. The following figure shows data for Clark County. Clark County contains Las Vegas and a large portion of Lake Mead. In 2014 Clark County saw extreme drought conditions. This figure shows how the drought intensity has changed in the last 16 years. There has been mostly drought conditions in 14 of the 16 years.

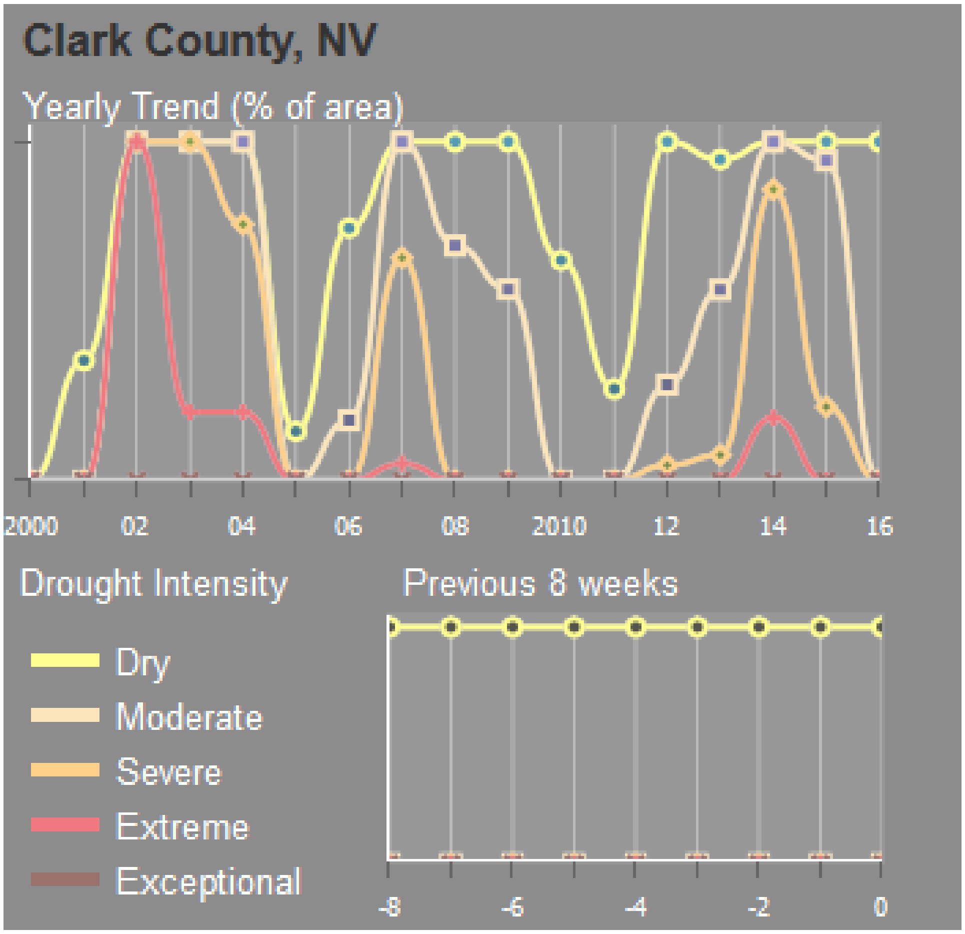


Figure 14: Persistent drought in Clark County

The below evapotranspiration plot shows an average of 200 mm per year throughout the region. Over the lakes surface this is a significant water loss and can be a key factor in the lowering of the lake level.

Evapotranspiration of HUC 15010005

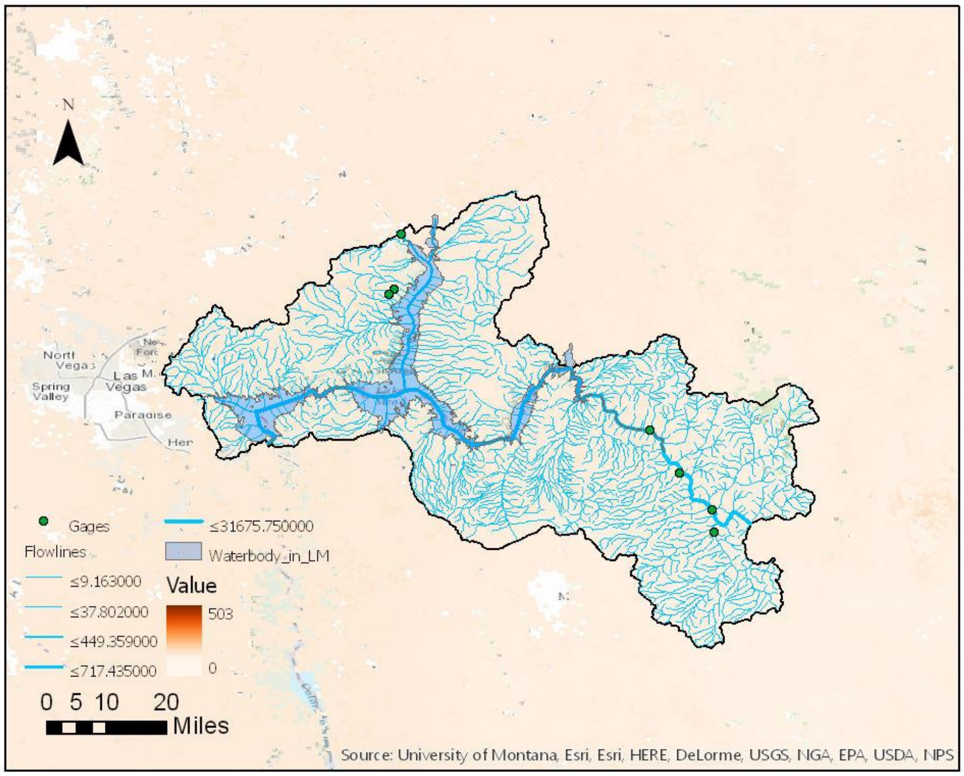


Figure 15: Evapotranspiration map

Conclusion and Further Work

Overall this method of determining the volume and surface area of Lake Mead was not completely consistent with the literature values. It should not replace other methods such as use of LiDAR. From the above maps, we can however, conclude that the water elevation has been decreasing. Population rise has occurred during the same time period, but water use from the Las Vegas metropolitan area has not increased in proportion to the decrease in lake volume. A persistent drought over the last decade except for two years (2005 and 2011) has covered the region. Since most water in Lake Mead is from snowmelt the most likely reason for the decrease in water is less snow and thus less snow melt. In addition, more has been evaporating with increasing temperature. Finally, more water is being used upstream. These three contributing factors (drought, evapotranspiration, and upstream water usage) can be concluded as the main reasons for the decreased volume in Lake Mead.

There are many opportunities for future work in this area. The key area is to correlate how much a decrease in snow melt or an increase in evaporation with lower the lake level by. ArcGIS has proven to be a very useful tool not only in visualization, but in analysis of large data sets.

References

United States Geological Survey http://waterdata.usgs.gov/nv/nwis

Clark County http://www.clarkcountynv.gov/gis/services/Pages/FreeGISData.aspx

Nevada USGS http://nevada.usgs.gov/lmqw/

Bureau of Reclamation -Lower Colorado Regional Office (provided bathymetry data)

United States Bureau of Reclamation http://www.usbr.gov/lc/riverops.html

National Oceanic and Atmospheric Administration
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http://www.emc.ncep.noaa.gov/mmb/nldas/

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