A Study of Lake Mead Water Surface Area Changes from 1996 to 2016

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Introduction

Lake Mead, the largest reservoir by volume in the United States. It is one of the major water sources that supplies water, irrigates crops and generates hydropower to produce electricity for California, Arizona, and Nevada. Lake Mead is an enormous natural habitat for amphibians, fishes, riparian vegetation, and aquatic birds.

Figure 1. *Lake Mead map from Google Map*

The lake is located along the border between southeast Nevada and northwest Arizona and is part of the Colorado River system (Figures 1 and 2). It contains four sub-basins: Boulder Basin, Virgin Basin, Temple Basin and Gregg Basin, and a 30 mile long Overton Arm (USGS 2012).

Figure 2. *A photo of Lake Mead captured on March 30, 2016 by Robert Alexander*

Lake Mead has consistently decreased in volume on an annual basis in this century. This study focuses on the water surface area changes in Lake Mead during the past two decades using remote sensing and geographic information system (GIS) techniques.

This study aims to raise the awareness regarding the changes in the basin. In doing so, it is hoped that awareness of the water shortage crisis will be raised, thus influencing the public to start preserving and protecting water resources, influence individuals to change daily water use habits, and assist governments in water management and policies establishment.

Data and Data Sources

Landsat 4, Landsat 5, and Landsat 8 satellite images were used to study Lake Mead water surface area changes. Twenty Landsat images captured from 1996 to 2016 with a 10 % or less cloud cover rate were collected from the USGS Global Visualization Viewer (GloVis). Digital Elevation Models (DEM) were used for three-dimensional (3D) model generation. Four DEMs were acquired from the USGS Earth Explorer. Lake Mead water level data was used for studying water decrease pattern. Water elevation records were collected from www.water-data.com (Table 1). A study area shapefile and a study area's center point shapefile were digitized for calculating water surface area. All data was stored on a Windows computer and backed up in a 1TB external hard drive.

Dataset	Source
Year 1996 to 2011 Landsat 4 and 5 (Thematic Mapper) Satellite Images	USGS GloVis
Year 2013 to 2016 Landsat 8 (Operational Land Imager) Satellite Images	USGS GloVis
Digital Elevation Models (DEM)	USGS Earth Explorer
Lake Mead Center Point - Point Shapefile	Self Digitized
Lake Mead Study Area - Polygon Shapefile	Self Digitized
Lake Mead Water Level Data table	www.water-data.com

Table 1. List of data and data sources used in the project

Methodology

A tool was created using a Python script to calculate water surface area changes (Figures 3 and 4). The Water Surface Area Changes Calculator tool identifies water bodies in Landsat images, calculates water surface area, combines and export the results as a map layer in shapefile format. Six parameters are created for users to identify their raster or vector dataset's folder, study area and study area's center point, study area name, and research's starting and ending period.

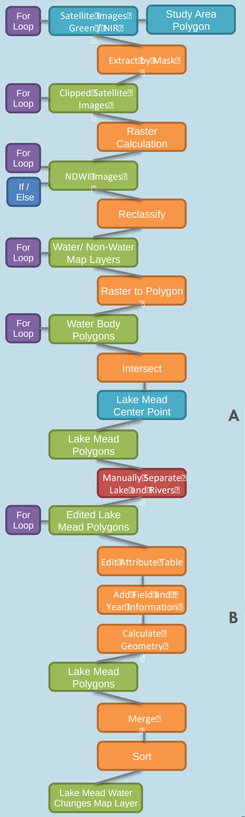

Figure 3. *Spatial model of the Water Surface Area Calculator Tool*

The Normalized Differences Water Index (NDWI) was applied to classify the water and non-water regions.

$$NDWI = \frac{(\text{Green Band} - \text{Near Infrared Band})}{(\text{Green Band} + \text{Near Infrared Band})}$$

(McFeeters 1996)

Lake Mead Polygons were generated from the tool (part 1) and were manually edited to separate all river connections. The edited Lake Mead polygons were input back to the tool (part2) and used to compute the size of the water surface area. All Lake Mead polygons files and water surface area statistics were combined and output as a shapefile.

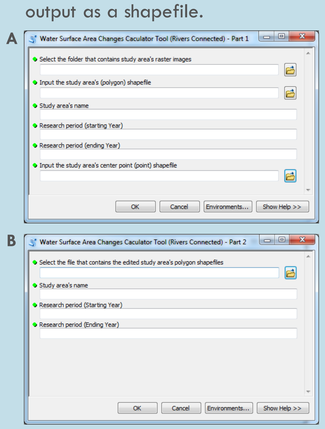

Figure 4A and B. *Water Surface Area Calculator tool (Part 1 and Part 2) for the study of water body which has river connections.*

Timeline

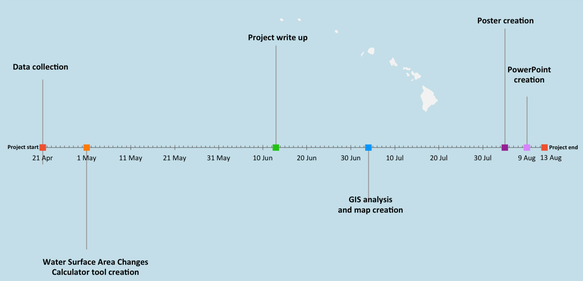

Figure 5. Project Timeline

Results

The water analysis results indicate that Lake Mead's surface size has reduced by approximately 42.5% of its surface size from 1996 to 2016.

Lake Mead water surface area dropped approximately 42.5 % from 544.7 million m^2 to 313.2 million m^2, and Lake Mead water level decreased approximately 10 % from 363.1m to 326.8m over the past two decades. The trend in reduction of Lake Mead surface area and water levels are very similar (Figures 7, 8 and 9).

The largest water reduction was found in the Overton Arm and Gregg Basin areas. One third of the water surface area in the Overton Arm and half of the water surface area in the Gregg Basin disappeared over the past two decades. When comparing the Lake Mead polygons between 1996 to 2006 period and 2006 to 2016 period, the 1996 to 2006 period showed larger water surface area changes (Figure 7).

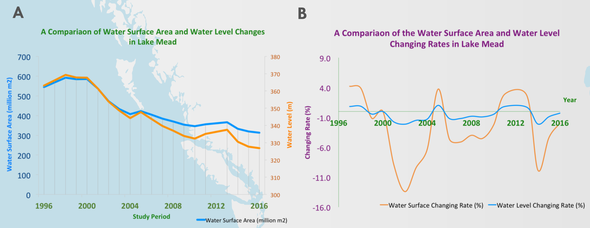

Figure 7A and 7B. *Comparison graphs of the water surface area and water level reduction rates and patterns from 1996 to 2016.*

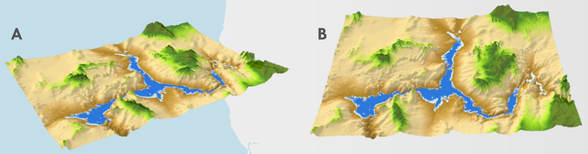

Figure 8A and 8B. *3D Model of Lake Mead from 1996 to 2016 captured in different angles.*

Data indicate that the speed of reduction of Lake Mead's surface area slowed after 2005. However, the water level decreased at a constant speed, which implies that the decline of Lake Mead's water volume was not getting better in the past decade.

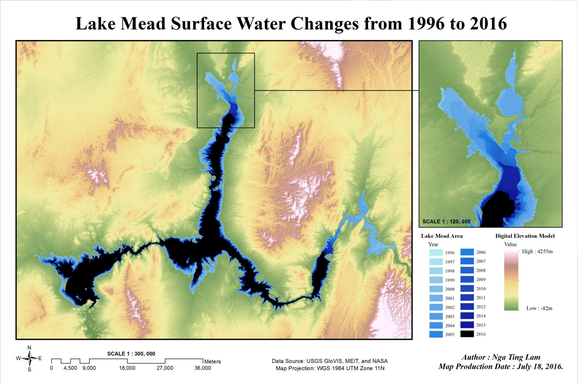

Figure 9. *Lake Mead water surface area changes map from 1996 to 2016*

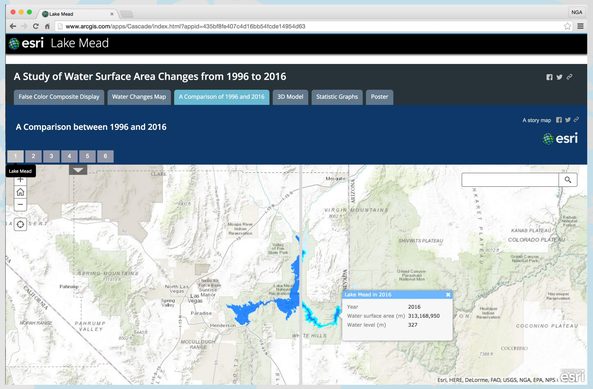

Figure 10. *A Lake Mead web app that contains all the map products delivered in this study.*

Discussion

Results indicate that Lake Mead's surface area and water volume decreased over the past two decades. Given these results, the reduction trend is likely to continue. These findings have the potential to be significant to government agencies on developing water management policies. The study results can bring awareness to the public about the potential impacts of climate changes and the existence of local water sources. It has a high potential to influence the public to maintain efficient water using habits in daily life.

This study has a limitation on data quality, which may contribute potential inaccuracies in the water surface area calculation results. Since the image pixel covers a 30 by 30 meter area, one pixel may cover water and non-water areas, which will cause some uncertainty when calculating lake surface area.

Conclusion

Lake Mead had a sizeable reduction by 42.5% on its surface area from 1996 to 2016. The most serious water loss occurred in the Overton Arm and Gregg Basin. Although the reduction speed of the water surface area decelerated after 2005 but the water level reduced at a constant speed.

Understanding the volume of Lake Mead is the following step to assist government agencies on calculating the actual amount of the available water, evaluating the ways on distributing water, and monitoring individual and local uses of water. The future work of this study may extend the Lake Mead's study period from 20 years to 50 years, modify of the Water Surface Area Calculator tool by allowing users to input different types satellite and select various output file formats, and create a Water Volume Calculator Tool using TIN and polygon volume analysis.

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Reference website:
http://www.arcgis.com/apps/Cascade/index.html?appid=435bf8fe407c4d16bb54fcde14954d63