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Assessment of Changes to the Salton Sea Since 1985

I.   Introduction:

The Salton Sea is a shallow, endorheic lake located in the Imperial and Coachella valleys of Southern California (Figure 1). It was formed in 1905 when flooding caused the Colorado River to breach its canal gates and flow directly into the basin. This flow was controlled by engineers in 1907 and there is now no sources of natural inflow to the basin. About 75% of the inflow that does occur is by agricultural drainage[2]. In addition to this, its only outflow is by evaporation, which has caused significant water quality issues. Due to its location in a very arid region, lake levels have been receding due to high amounts of evaporation.When the lake level recedes, it exposes a lakebed that has high concentrations of toxic metals such as Selenium[4].This could prove potentially harmful to humans if dust from the lakebed were to become airborne[3]. The Salton Sea used to be a weekend destination for families and a haven for migratory birds and marine life, but today is rapidly changing character.

The aim of this study is to analyse and quantify past changes in surface area and lake volume, related to decreasing lake levels. These trends will be used to make first-order projections of future surface areas and volumes as the lake levels continue to fall.These future projections are important in understanding the potential amounts of exposed lakebed that will be susceptible to erosion, which has important implications for human health in the nearby regions.

Figure 1:Map of California, showing the rivers and counties. Location of the Salton Sea shown by red bounding box. Source: Geology.com

II.   Data Collection

Lake Outlines:

Aerial imagery of the Salton Sea was obtained using the historical Imagery tool in Google Earth Pro. This tool was useful to track the extent of the lake through time. The first available year that was well resolved and had clear outlines visible from the aerial imagery was 1985. This was chosen as the starting year, and baseline year for the study. Starting in 1985, lake size was analyzed at 10 year increments through the year 2015 (1985, 1995, 2005, 2015). The Salton Sea is located at 33°19'54.87"N, 115°49'53.99"W.

Bathymetric Data: https://map.dfg.ca.gov/bios/?al=ds426

One foot contoured bathymetric data was obtained from the California Department of Fish and Wildlife[6]. This data was necessary for the calculations that will be made later. This data was published in 2007.

Basemap: https://www.arcgis.com/home/item.html?id=4a8fac16cdc140c9bde0c08a1eb60d9b

The basemap used in the final map product was obtained from ESRI as a compilation of data from many other sources. It includes many layers such as cities, administrative districts, physiographic features, water features and more. A complete list of features and contributors can be found at the above link.

III.   Data Preprocessing:

The Geographic Coordinate System chosen for this project was NAD_1983_UTM_Zone_10N.

To begin, Google Earth Pro was used to obtain aerial imagery from the years 1985, 1995, 2005, and 2015. The basis upon which these years were chosen is mentioned in the data collection section of this paper. On each image four corner pins were marked and their locations in decimal degrees were noted. Google earth Pro uses WGS 1984, therefore during this portion of the project, the data frame was defined with that geographic coordinate System. The four pin locations were then used to georeference each photo in ArcMap. To do this, I hovered over each pin in the photos and manually entered the latitude and longitude values in decimal degrees into the Y and X locations of the point.

The aerial imagery was used to digitize the lake outline for each year. To do so, I first created a geodatabase in ArcCatalog called Salton_Sea. Within the geodatabase, a feature dataset and a line feature class named "Shoreline" were also created. Once I had digitized the shoreline for one of the years, I created a text field in the attribute table of the "Shoreline" layer called "year". This was used to classify which year a line was associated with. This was to prevent confusion since the lines overlapped in many instances. Next, the feature to polygon tool was used to create a polygon of the lake for the lines of a selected year. This was done for each of the four years. It is important to note that the digitization of the shoreline is a source of systematic, observational

error as I chose to make a delineation between what I believed to be the water versus what I believed to be land.
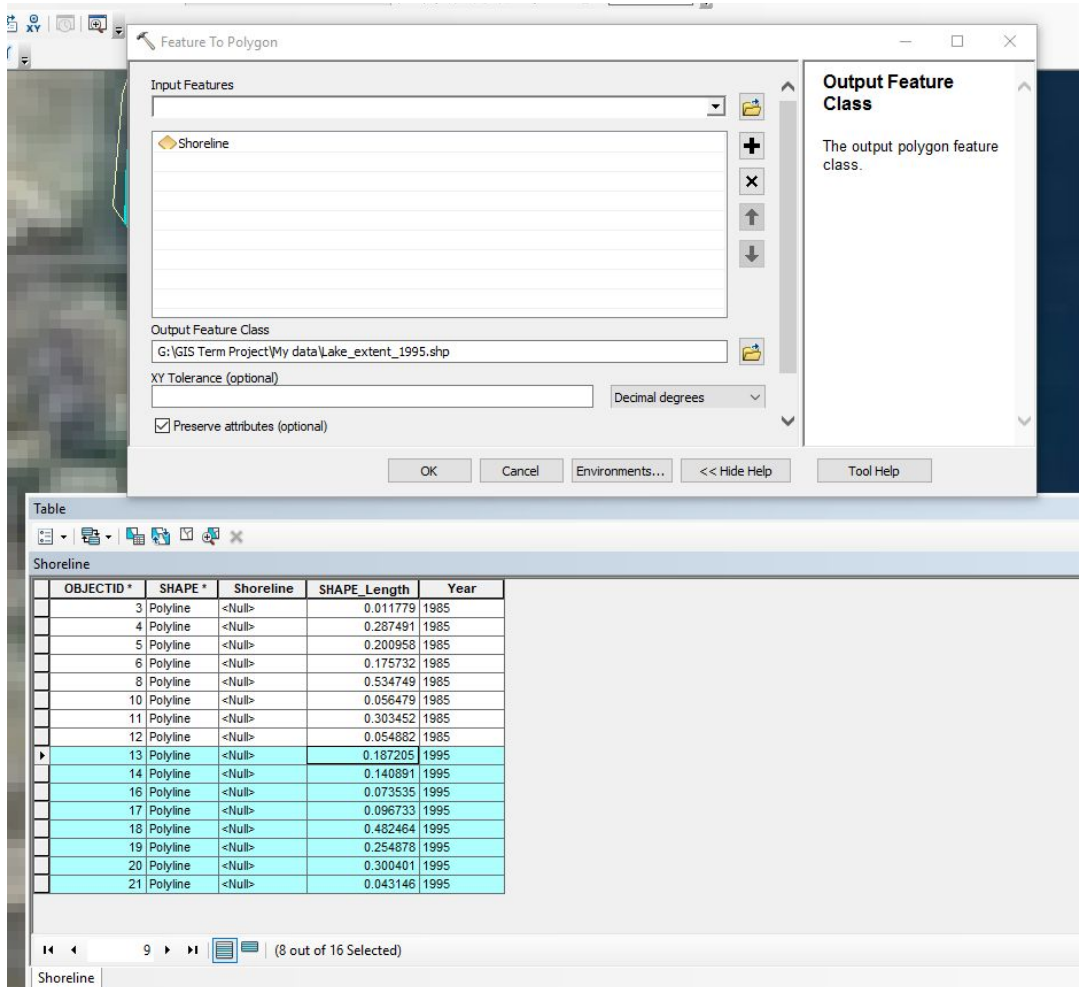

Figure 2: The Feature to Polygon tool Dialogue box. Input Features were the digitized lines in the line Feature class, "Shoreline". The Attribute table for the Shoreline Feature class shown below with only selected records being used by the tool.

From this point, I projected all shapefiles to NAD_1983_UTM_Zone_10N. This was done using the project tool. Each lake extent shapefile was saved as Lake_extent_Year_projected.

The bathymetric contours shapefile was also projected using the project tool to NAD_1983_UTM_Zone_10N. Additionally, the bathymetry shapefile has the elevations in feet of the lake, so I added a field (called Contour_m) for the elevations in meters to its attribute table. In this field I used the field calculator to convert all the contour values into meters. To do this, the following expression was used:

Contour_m = [CONTOUR]*0.3048.

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This shapefile was then used to create a TIN using the create TIN tool found in the 3D Analyst toolbox.
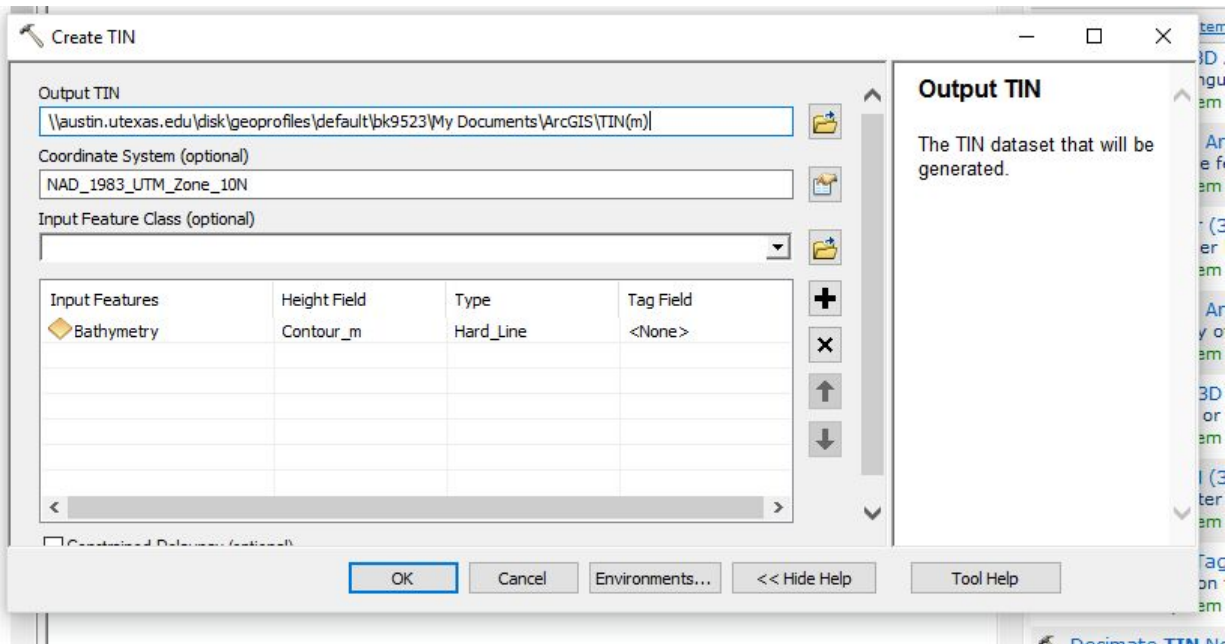
Figure 3: Create TIN tool. The Output TIN was saved in my data file as "TIN". It was created with the UTM Zone 10N as the defined coordinate system and the Input feature was the bathymetry shapefile with the height field specified as the contours in meters.

The ArcMap document now contained the 4 lake extent polygon layers, the bathymetry and the TIN layer in the NAD_1983_UTM_Zone_10N Coordinate System. The coordinate system of the data frame was also set to NAD_1983_UTM_Zone_10N.

IV.   Data Analyses

In order to quantify the change in the surface area and volume of the lake over the four chosen time slices, it was necessary to determine a lake level for each year. I did this by determining which contour line of the bathymetry shapefile matched best for the outline of the lake for each time. It is important to note that the lake outline did not match any one contour line perfectly, however the best fit was chosen and the process of determination of the best fit was consistent between each of the years. A new short integer field was added to the attribute table for each year, and the lake level height was entered into this field. Additionally, to stay consistent with units, a height field in meters was created, and entered as well.

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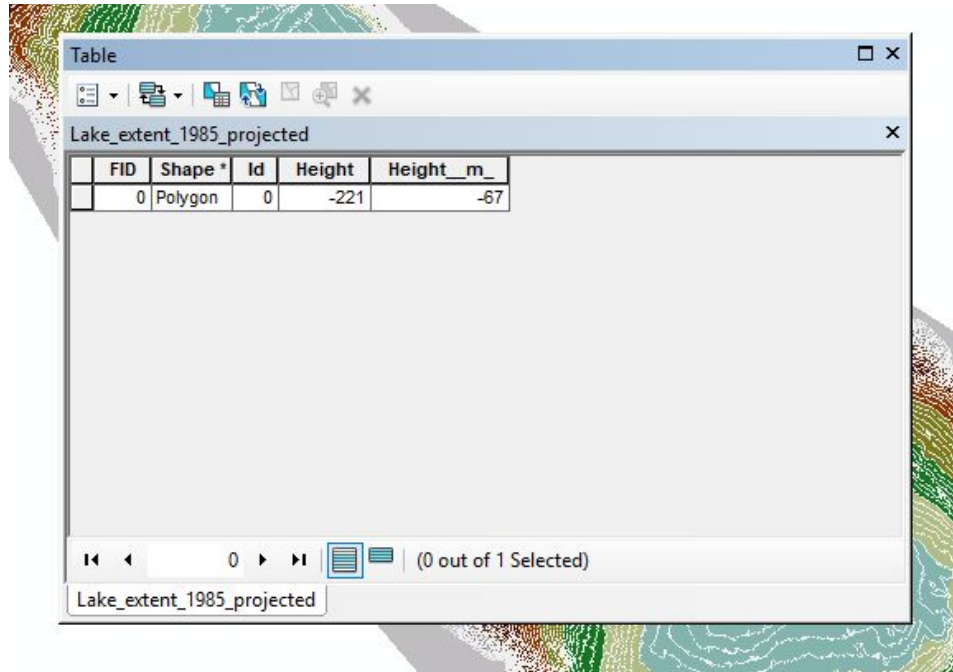
Figure 4: The attribute table for the 1985 lake extent with the added Height field and corresponding lake level (ft below MSL).

Year	Lake Level Height (m)	Lake Level Height (ft)
1985	-67	-221
1995	-69	-227
2005	-70	-229
2015	-72	-235

Table 1: Determined lake Shoreline level for each year in meters and in feet.

Now the information needed to determine the surface area and volume for each year was prepared. In the 3D Analyst toolbox, the Polygon Volume tool was used to do this calculation. The input surface was the TIN created earlier (Figure 3), the input feature class was the lake extent shapefile for the year being analyzed, and the height field was the lake level that was assigned (Figure 4). This was done four times, once for each year.
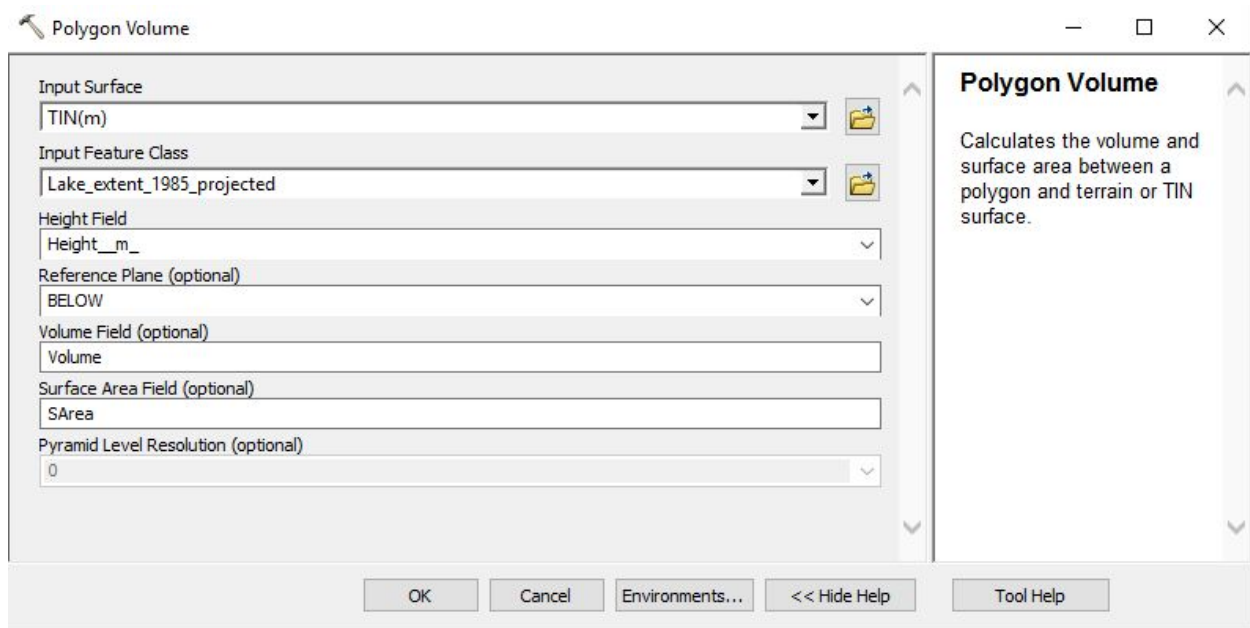
Figure 5: Polygon Volume tool with inputs describe above figure.

This tool populated a new field in the attribute table for each year for surface area called SArea and a new field for the volume called Volume. The data given in the attribute table was in meters, in order to stay consistent with the units of the projection coordinate system. However, since the bathymetry was originally given in units of feet, I decided to analyse the data in that unit. All values were then converted to feet for the remainder of the project.

Volume Analysis:

As the shoreline level of the Salton Sea falls, the volume of the lake shrinks. This is important as it affects the salinity and concentration of contaminants (specifically Selenium) in the water. While the relationship between the salinity and contaminant concentrations and lake volume is not quantified in this analysis, it was found that due the nature of the contaminants and the sediment, the concentrations of contaminants increases as evaporation increases[5]. If the water has higher concentrations of contaminants in the water, the concentrations of Selenium and other toxic metals in the lakebed that is left exposed will also increase.
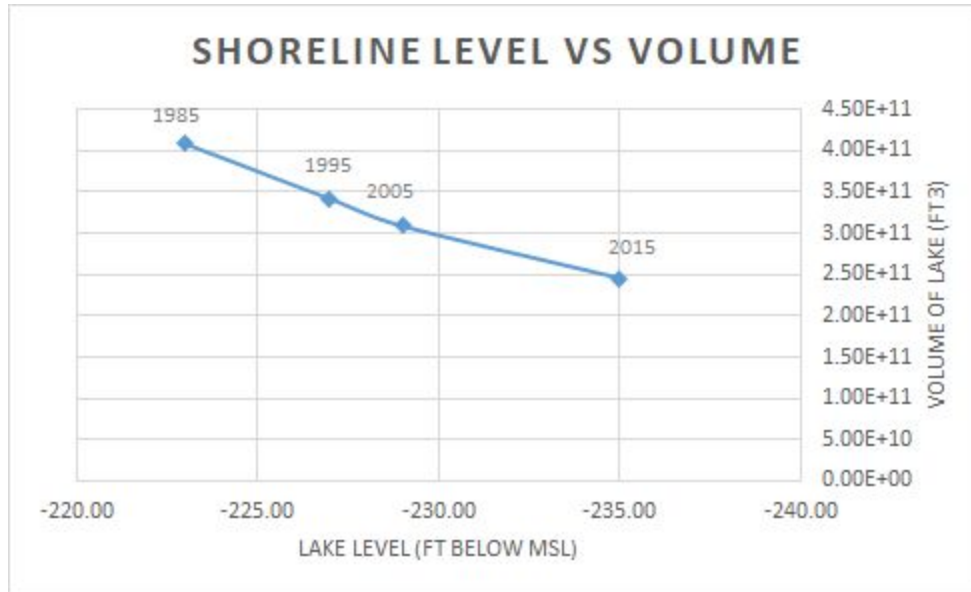
Figure 6: Lake volume changes as shoreline level drops. Data points representing each year that was analyzed.

A calculation of the percent change in the volume of the Salton Sea since 1985 was done by a percent decrease formula using the volume of the 1985 lake and the volume of the lake for the targeted year. By the year 2015, there was a 40.1% reduction in the volume of the Salton Sea. This is a very dramatic reduction in the volume for a lake level drop of only 14 feet. Highlighted by this data is the conclusion that the volume of the sea has the potential to decrease by very large amounts in a very short amount of time.

This percent reduction in volume relative to the volume in 1985 was calculated for each year.

Year	Percent Reduction in Volume since 1985 (%)
1995	16.5
2005	24.5
2015	40.1

Table 2: Percent reduction in the volume of the Salton Sea relative to the volume in 1985.

Area Analysis:

As the lake level decreases, the surface area of the lake decreases greatly (Figure 7). This has important implications for the surface area of the underlying lakebed that is exposed. As the surface area of the exposed lakebed increases, the potential for wind erosion and pollution of the air becomes a more pressing issue for those who live in the surrounding regions.
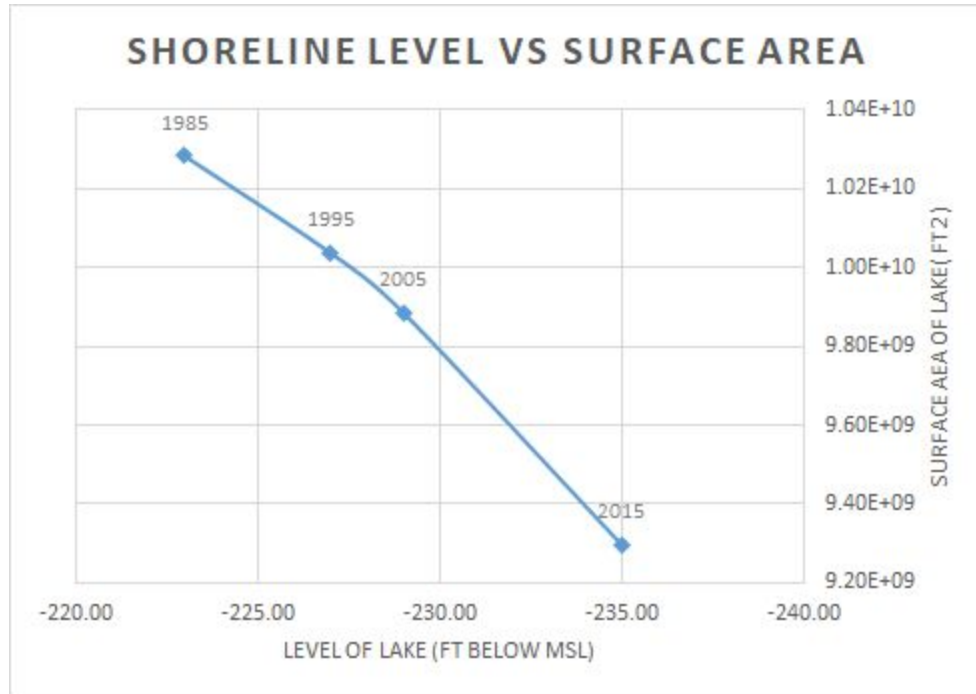
Figure 7: Surface area change as shoreline level changes. Data points representing each year that was analyzed.

By the year 2015, the surface area of the lake experiences a 9.6% reduction relative to 1985. While this figure may seem small, it is equivalent to a total potential exposed lakebed area of 9.86E+08 ft^2 (22,635 acres). Additionally, the largest decrease in surface area and lake level took place between the years of 2005 and 2015. The potential total surface area exposed during this time period was 5.88E+08 ft^2 (13,498 acres) of lakebed, which is over half of the total exposed area since 1985. If the lake were to continue to shrink at a rate comparable to that between 2005 and 2015, potential amount of lakebed exposure could increase rapidly.

Year	Percent reduction in SA since 1985 (%)	Potential Lakebed Exposed Since 1985 (ft^2)
1995	2.4	2.46E+08
2005	3.9	3.97E+08
2015	9.6	9.86E+08

Table 3: Tabulated values for the percent reduction in the Surface area of the lake compared to the lake in 1985, and the potential amount of total exposed lakebed since 1985.

Furthermore, a trendline was applied to this dataset in excel and was used to make estimations of future values of exposed lakebed if the shoreline continues to recede. The values were compared to this study's baseline year of 1985 to determine possible surface area exposure if the lake levels

fell by an additional 1ft, 5 ft,10 ft, and 15 ft from the already reduced 2015 lake level. This was done by finding the difference in the surface area of the lake in 1985 and the surface area of the lake that resulted from the respective amount of shoreline level fall. The values are listed in the table below.

Amount of Additional Lake Level Decrease From 2015 (ft)	Absolute Lake Level (ft)	Potential Lakebed Exposed Since 1985 (ft^2)
1	-236	1.03E+09
5	-240	1.36E+09
10	-245	1.78E+09
15	-250	2.19E+09

Table 4: Surface area of lake with additional shoreline level fall and subsequent potential exposed lakebed compared to 1985.

Based on the past trends, it is plausible that lake level drops of this magnitude could occur within the next 20-30 years if no intervention measures are taken. Even a conservative estimate of an additional 5 feet of lake level drop could result in 1.36E+09 sq feet or 31,221 acres of exposed lakebed.

V.   Conclusion

If no action is taken in the management and restoration of the Salton Sea, lake levels will likely continue to fall. Continued recession of the shoreline will expose thousands of acres of lakebed that contain dangerous concentrations of metals. Exposure of the lakebed will have detrimental effects on the air quality and human health of this region.
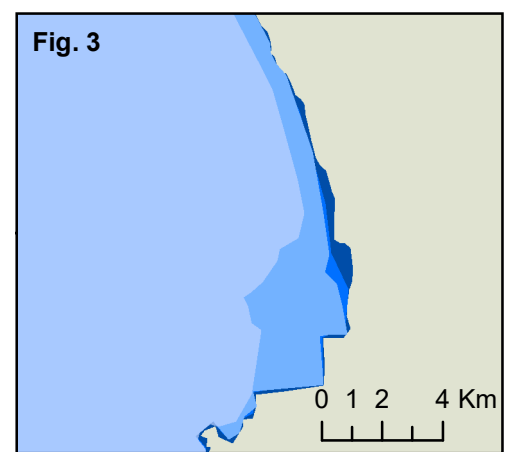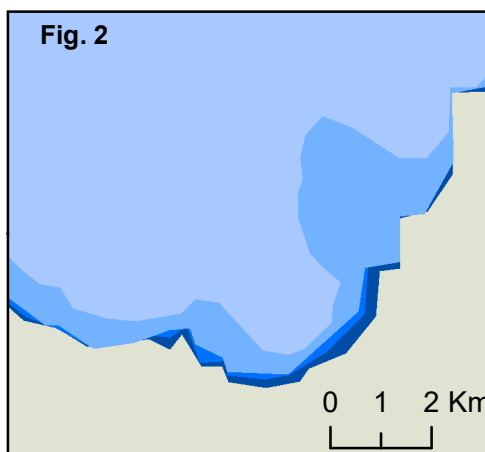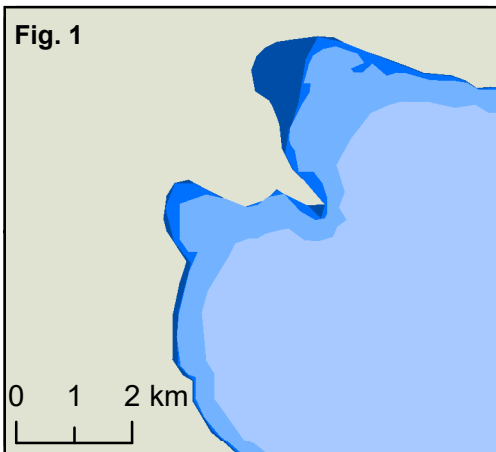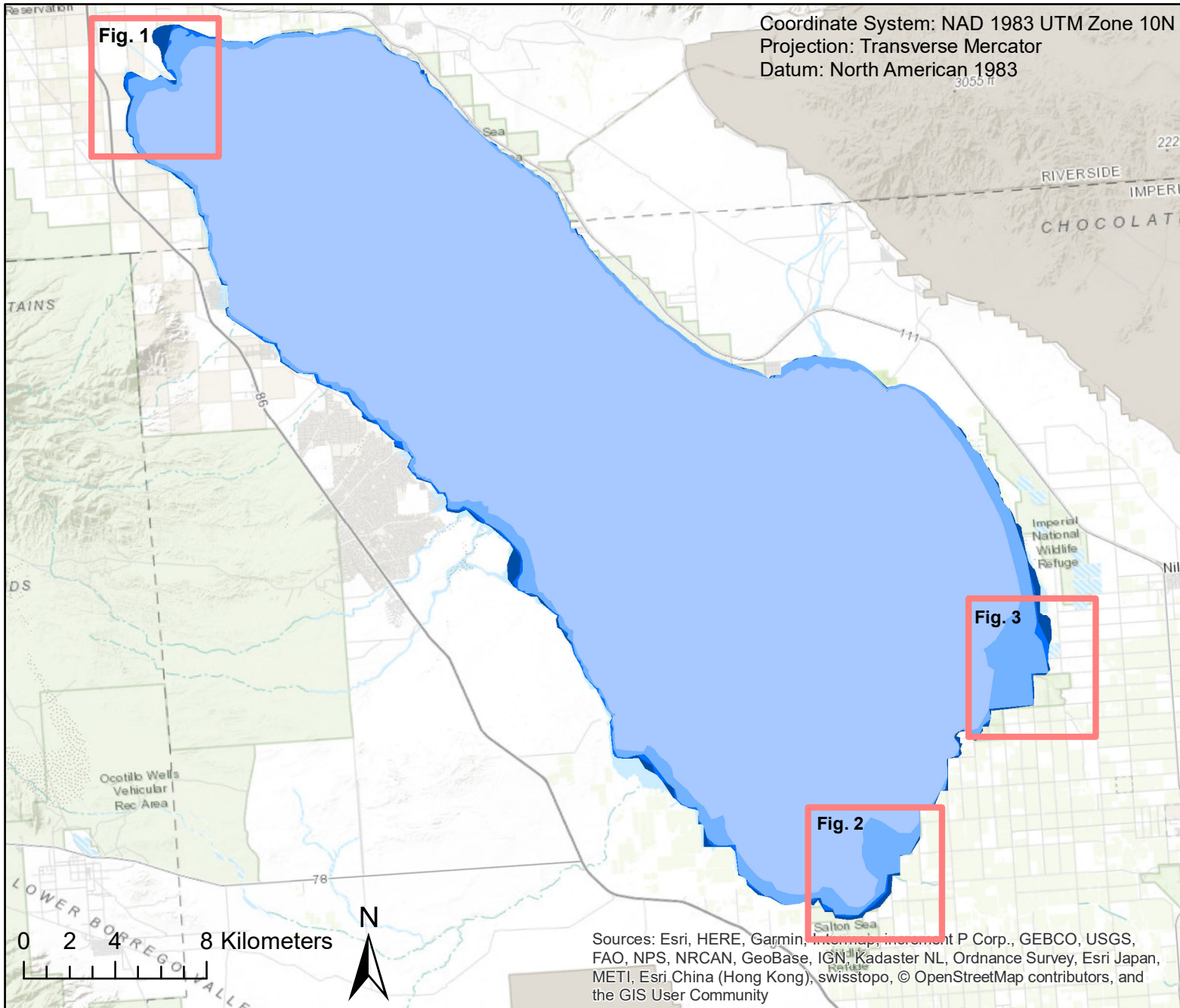
VI.   Future Work

Additional research has been done and is currently occurring to understand the many complexities of the Salton Sea. One of these complexities is variable emissive potential due to the nonuniform character of the surface and mineralogy of the lakebed across the sea[1]. An incorporation of the spatial classification of the types of lakebed that are being exposed could be a valuable analysis as a follow up to this study.

References

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2. Cohen, M. J., Morrison, J. I., & Glenn, E. P. (1999). *Haven or hazard: The ecology and future of the Salton Sea*.

3. Frie, A. L., Dingle, J. H., Ying, S. C., & Bahreini, R. (2017). The Effect of a Receding Saline Lake (The Salton Sea) on Airborne Particulate Matter Composition. *Environmental Science & Technology,* 51(15), 8283-8292.

4. Parajuli, S. P., & Zender, C. S. (2018). Projected changes in dust emissions and regional air quality due to the shrinking Salton Sea. *Aeolian Research*, 33, 82-92.

5. Setmire, J. G. (1993). *Detailed study of water quality, bottom sediment, and biota associated with irrigation drainage in the Salton Sea area*, California, 1988-90. Sacramento, CA: US Geological Survey.

6. White, K. "Bathymetric One Foot Contours- Salton Sea," 01 May 2007.

Decrease in the Surface Area of the Salton Sea from 1985-2015
## Salton Sea, California

Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator
Datum: North American 1983

0 2 4   8 Kilometers

N

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Fig. 1
0 1 2 km

Fig. 2
0 1 2 Km

Fig. 3
0 1 2   4 Km

Explanation

■ Lake Surface Area 1985
■ Lake Surface Area 1995
■ Lake Surface Area 2005
■ Lake Surface Area 2015

Fig. 1, Fig. 2, Fig. 3 representing regions that have been most visibly altered by the reduction in Surface area.