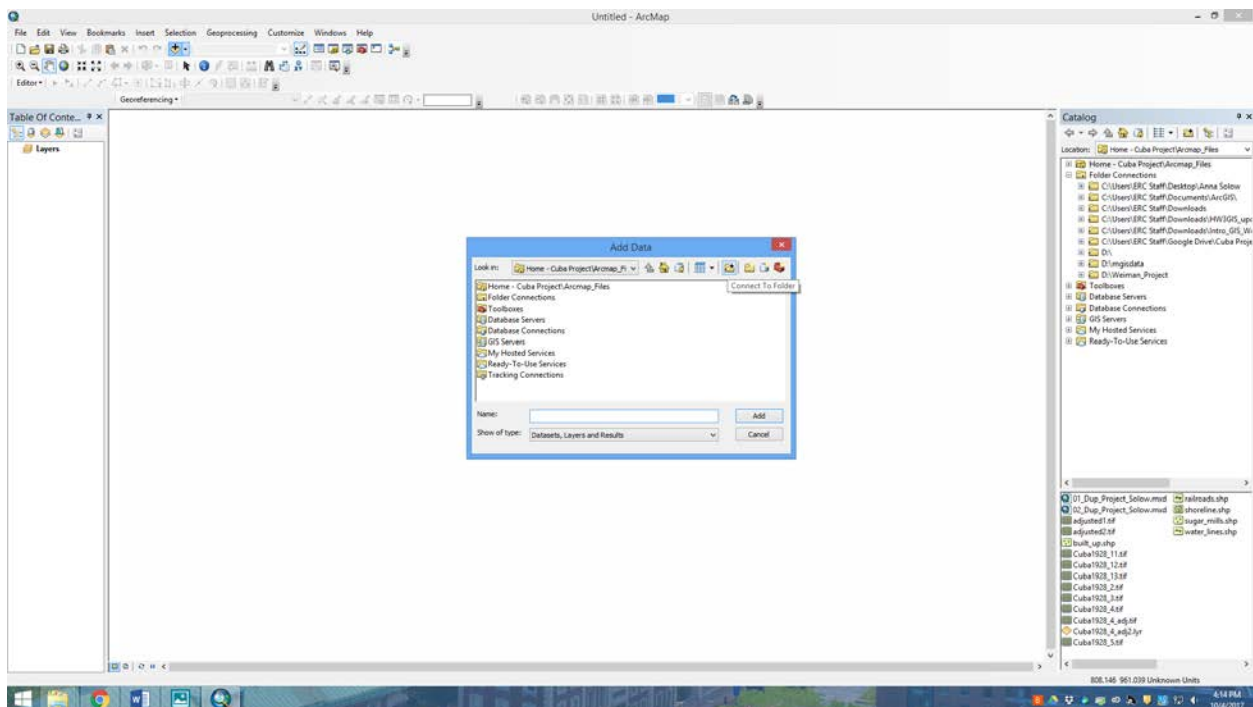## Georeferencing

Today, we will align a historical map image layer to the right spot on our map. Georeferencing is necessary when you are working with maps that you have scanned from images or historical sources and that you want to include as a GIS later. In simple terms, you must tell the GIS software how to line up your map image with the other GIS layers which are in a projected coordinate system.

1. Download the zip folder from the Dropbox link provided and extract it to your working folder.
2. Open ArcMap. Navigate to the Customize tab > Toolbars > Georeferencing. This will ensure you have the Georeferencing toolbar which looks like this:
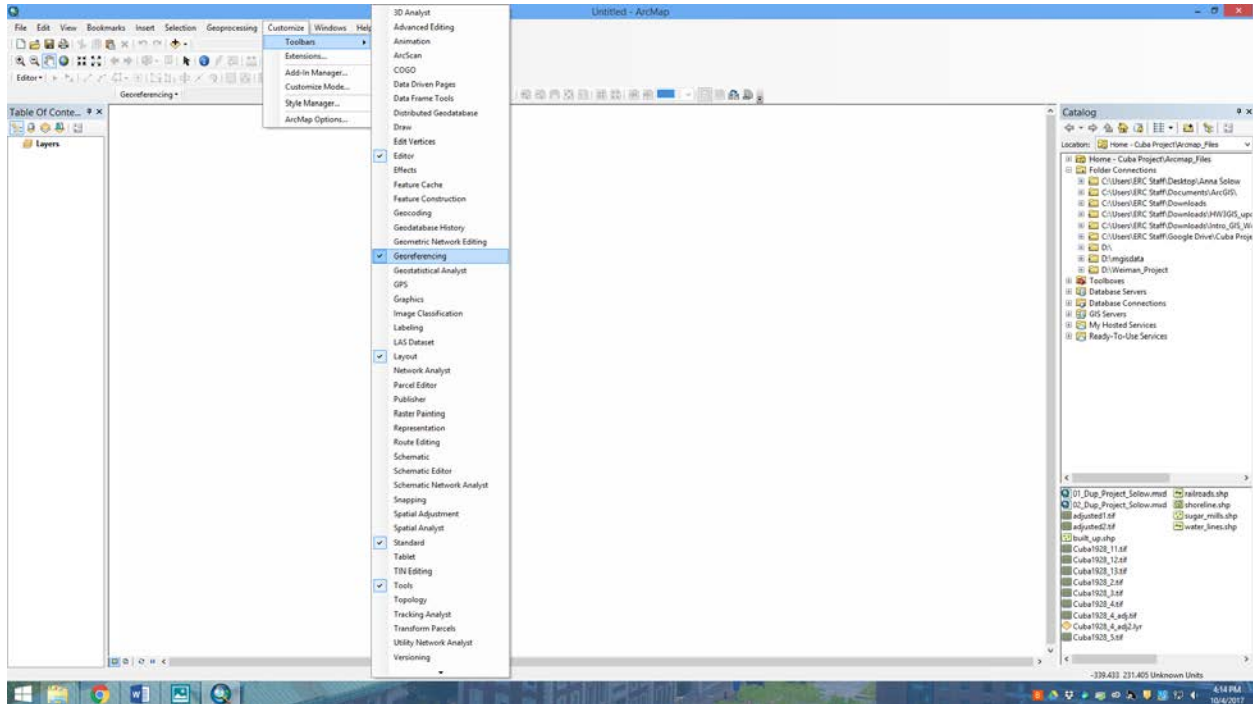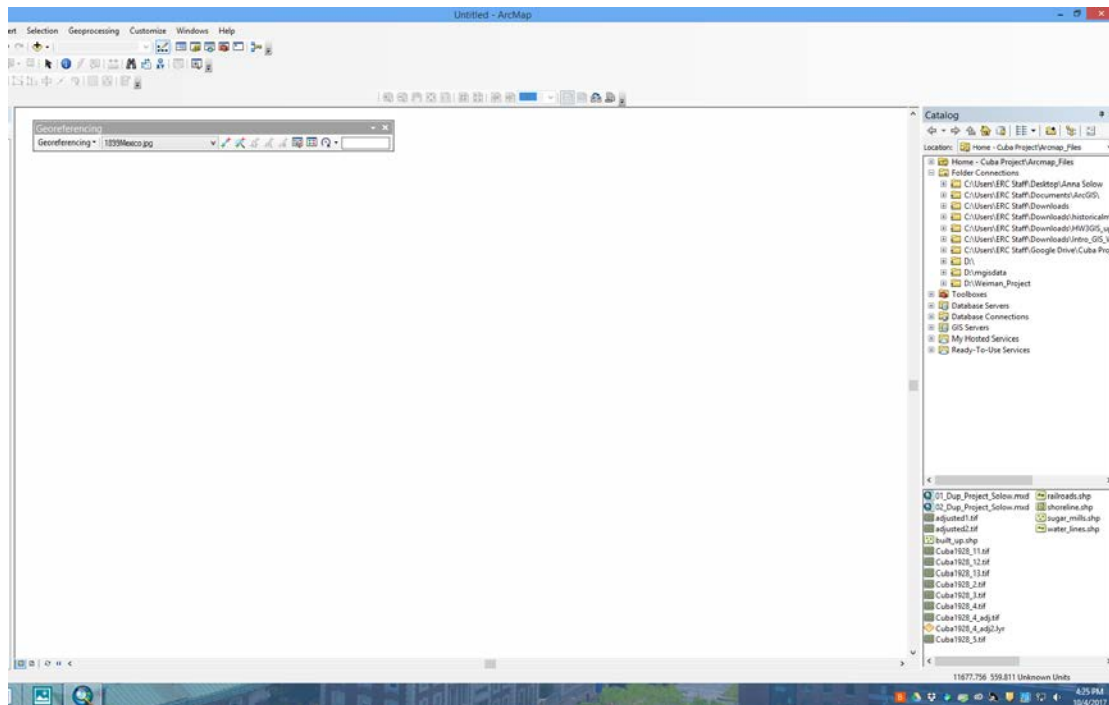
3. Click on the Add Data icon and choose Add Data. Click on the Connect to Folder icon to connect to your working directory. Add that folder. Once you do that, find it in Folder Connections and navigate to the 1899 Mexico image.



You will likely have a popup box indicating that the image has no spatial reference. This is because the image has no geographical data attached to it. Just click OK.

4. Now we'll add a basemap to georeference the historical map to. Click on the arrow next to the Add Data icon and click Add Basemap. Choose Open Street Map.
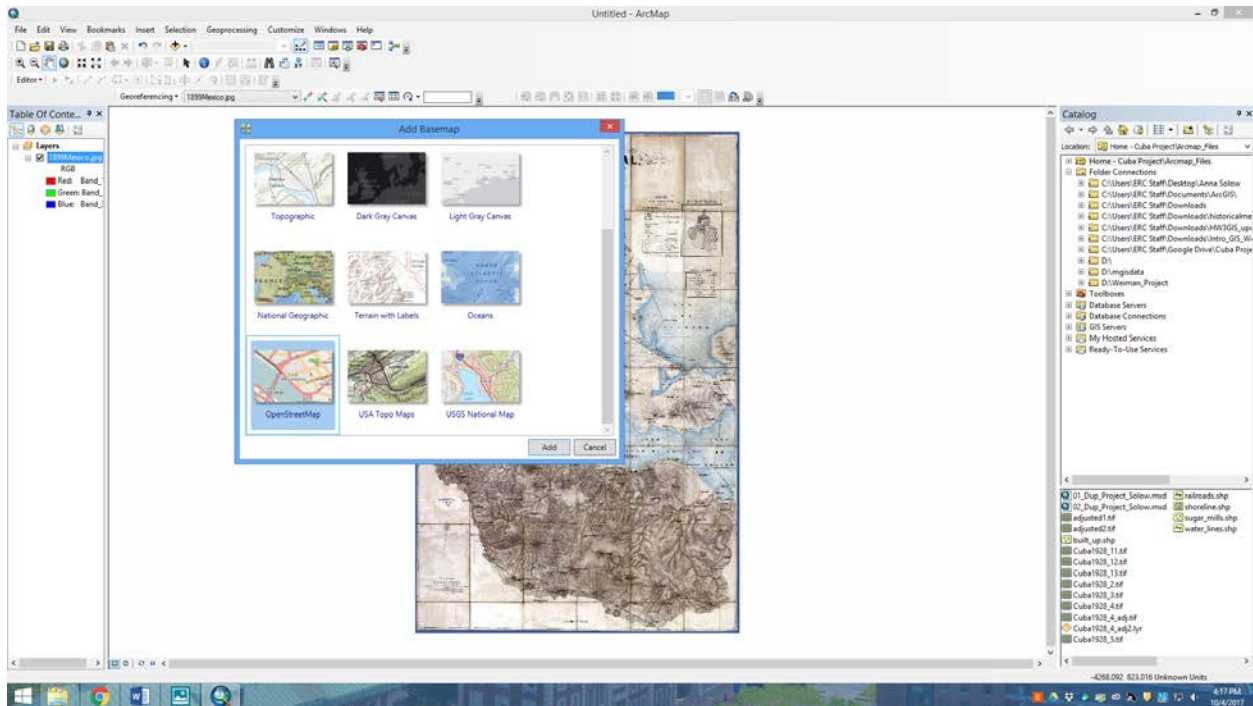


You may see a small cross next to the Open Street Maps layer on the left side of your screen. If that's the case, right click on the layer and click "Ungroup":
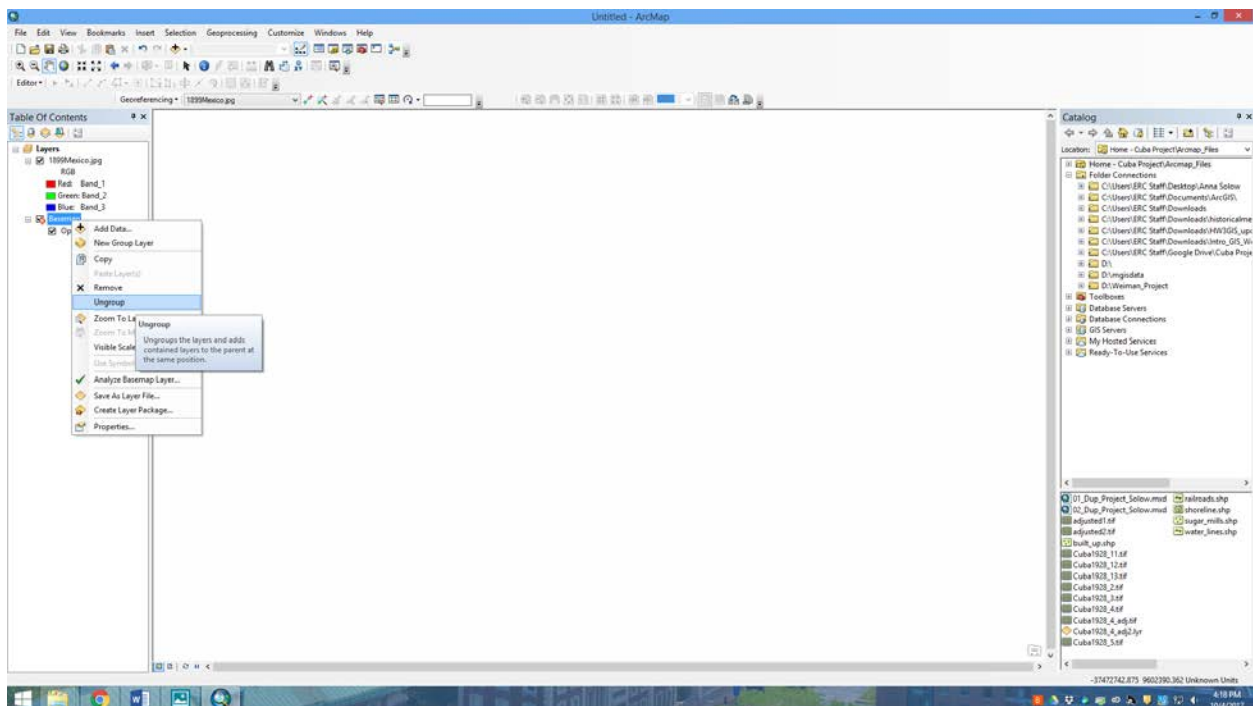
5. Your screen should now display a full world map. Whenever you need to zoom to either layer, right click on the layer on the left side of the screen and click "Zoom to Layer". We will first do this with the 1899 Mexico map, which is currently in the incorrect place and scale on the open street map:
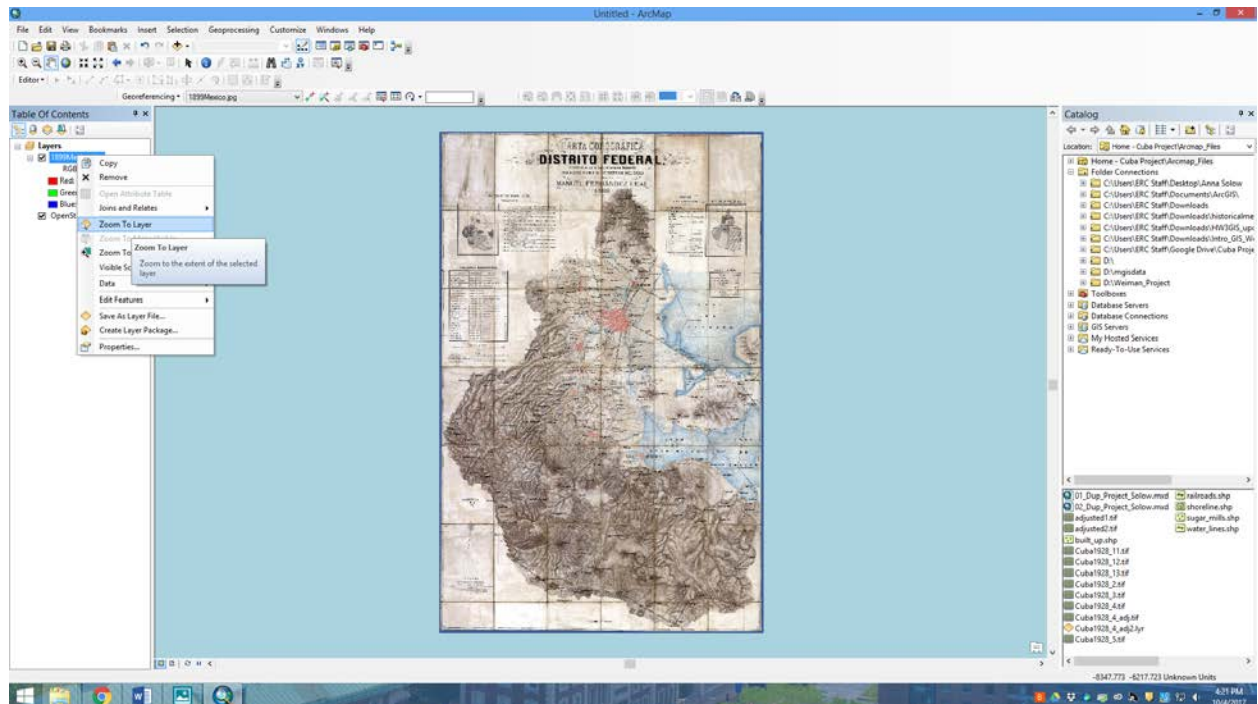


6. From here, we begin selecting points on the 1899 map to georeference to the open street map. Let's begin by zooming in to the northwest quarter of the Mexico map and identifying the following river intersection. You can switch been the zoom in tool (magnifying glass with the + sign, or simply scroll on your mouse) and the pan tool (white hand, click and drag) to comfortably navigate to this point:
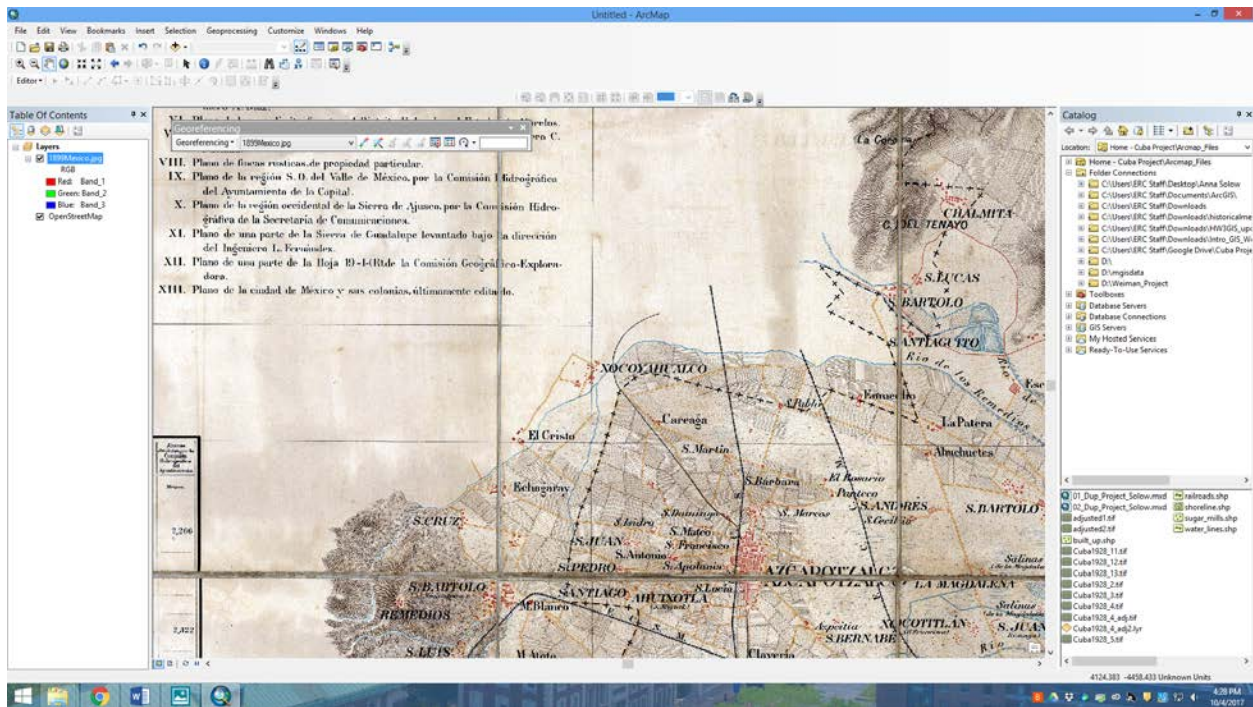
Click on the "Georeferencing" drop-down in the georeferencing toolbar and check off "Auto adjust":
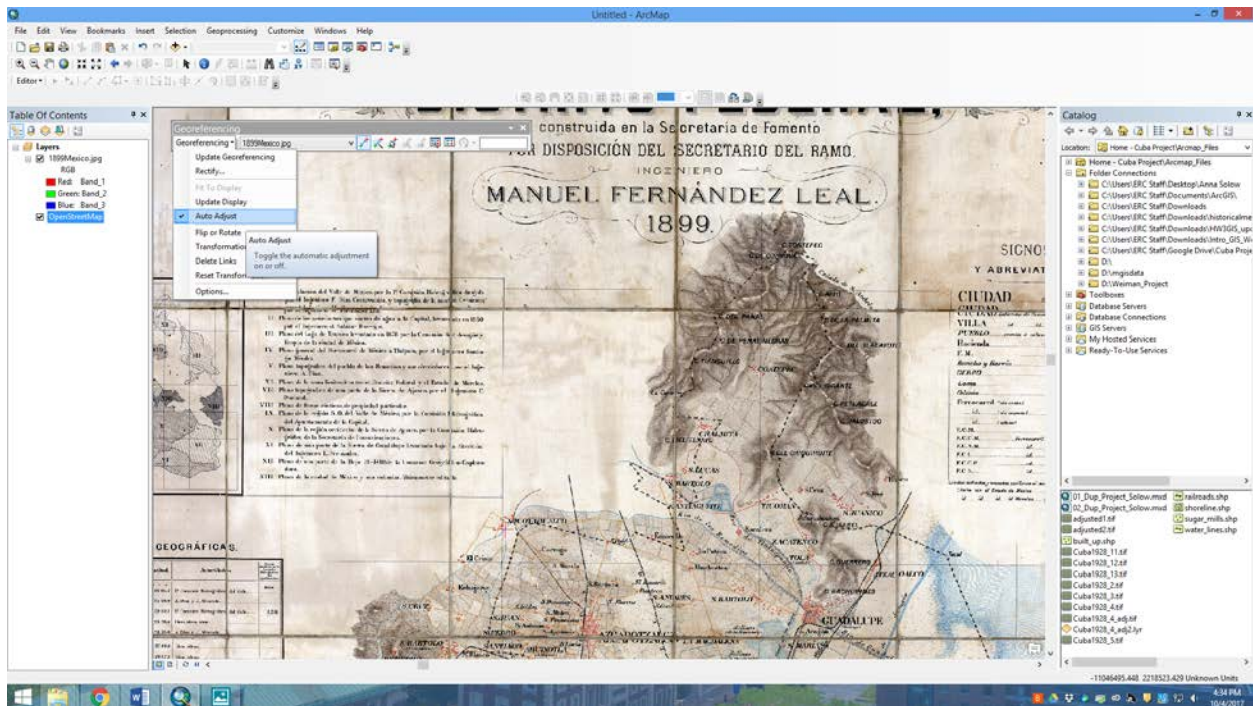


7. Using the "Add control points" tool on the geoereferencing toolbar, click on this river intersection to plot the first georeferencing point (look for the small green + to the left of Nocoyahualco):
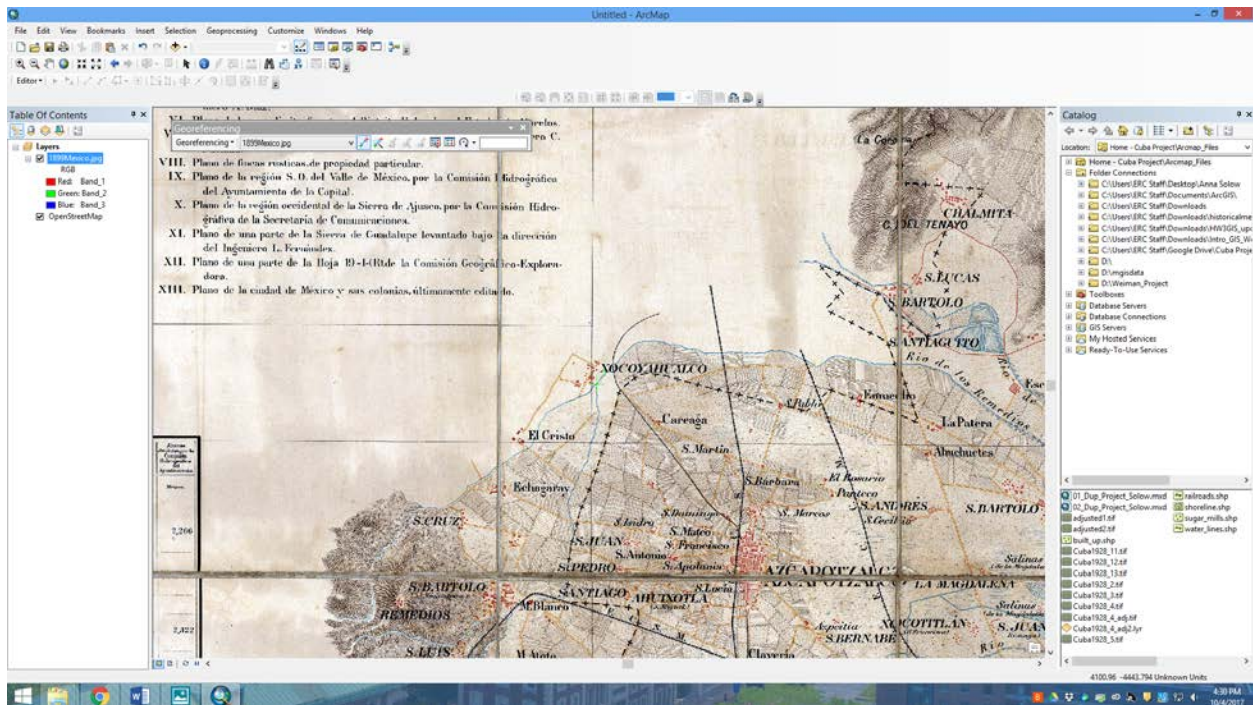
8.  Without clicking anywhere else, navigate to the "OpenStreetMap" layer on the left side of the screen, and zoom to this layer. Now zoom in to Mexico city on the world map:
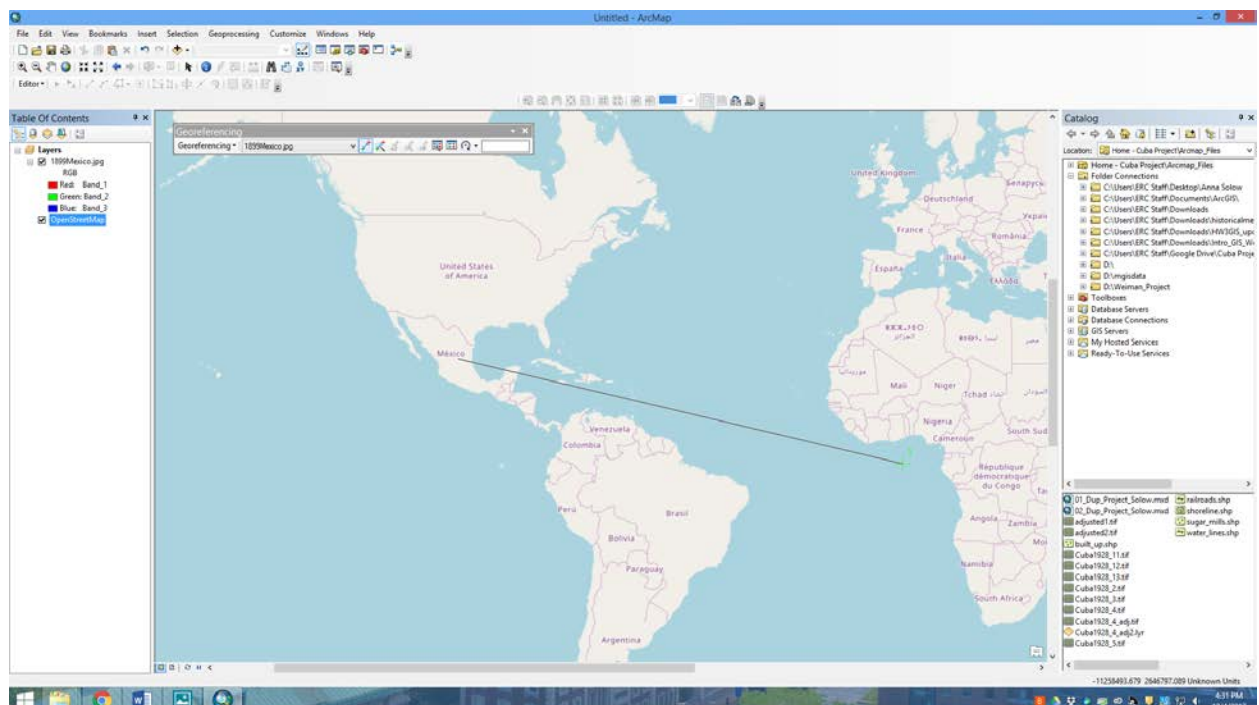


Use the zoom in and pan tools to navigate to the northwest corner of "Ciudad de Mexico", looking for Tlalnepatla as an approximate reference to zoom in to:
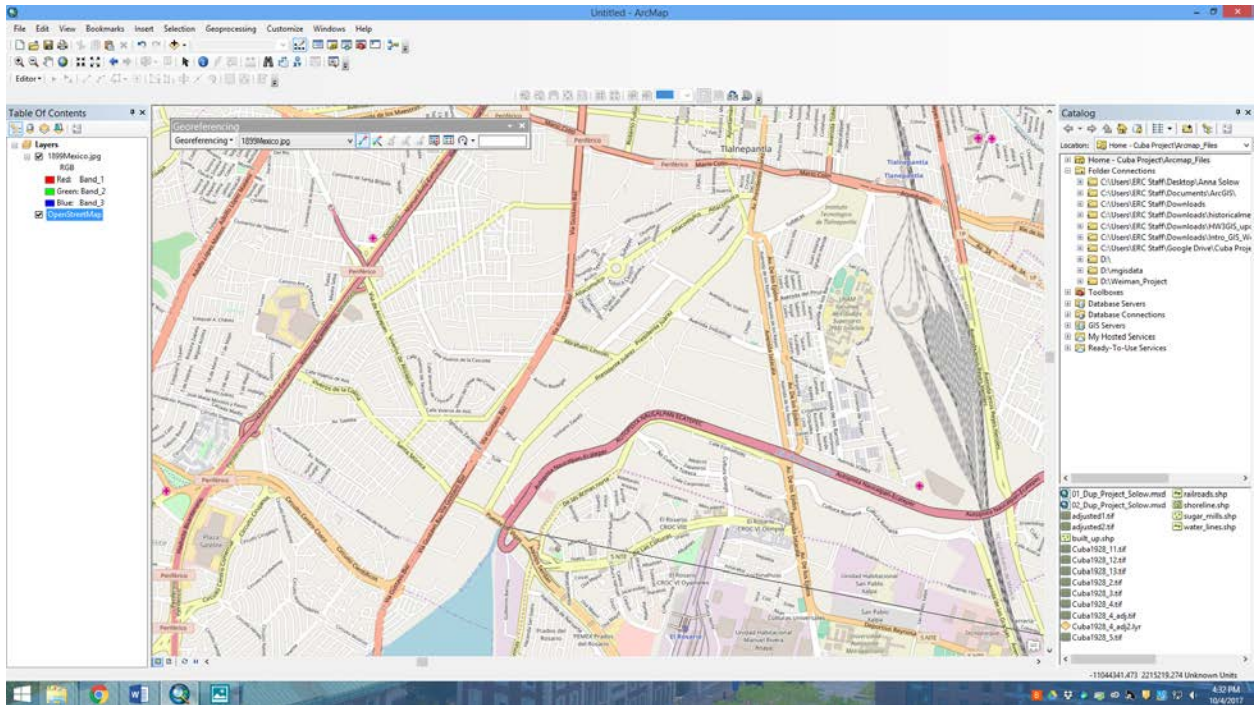
Clicking on the river intersection point (right above the blue triangle in this map) should adjust the historical Mexico map to this. Be sure to have "auto adjust" checked off in the georeferencing toolbar, as discussed above:
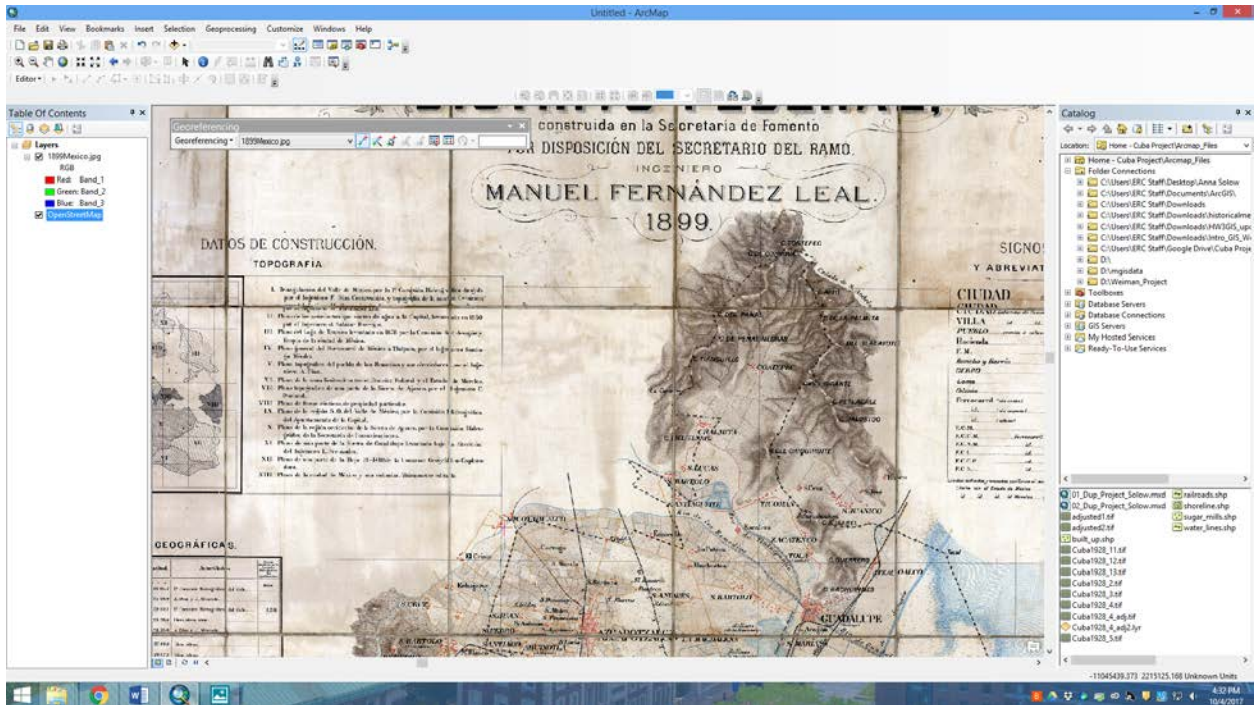


9. **IF** you accidentally clicked in the wrong place and want to delete this point reference, click the "View Link Table" option on the georeferencing toolbar:
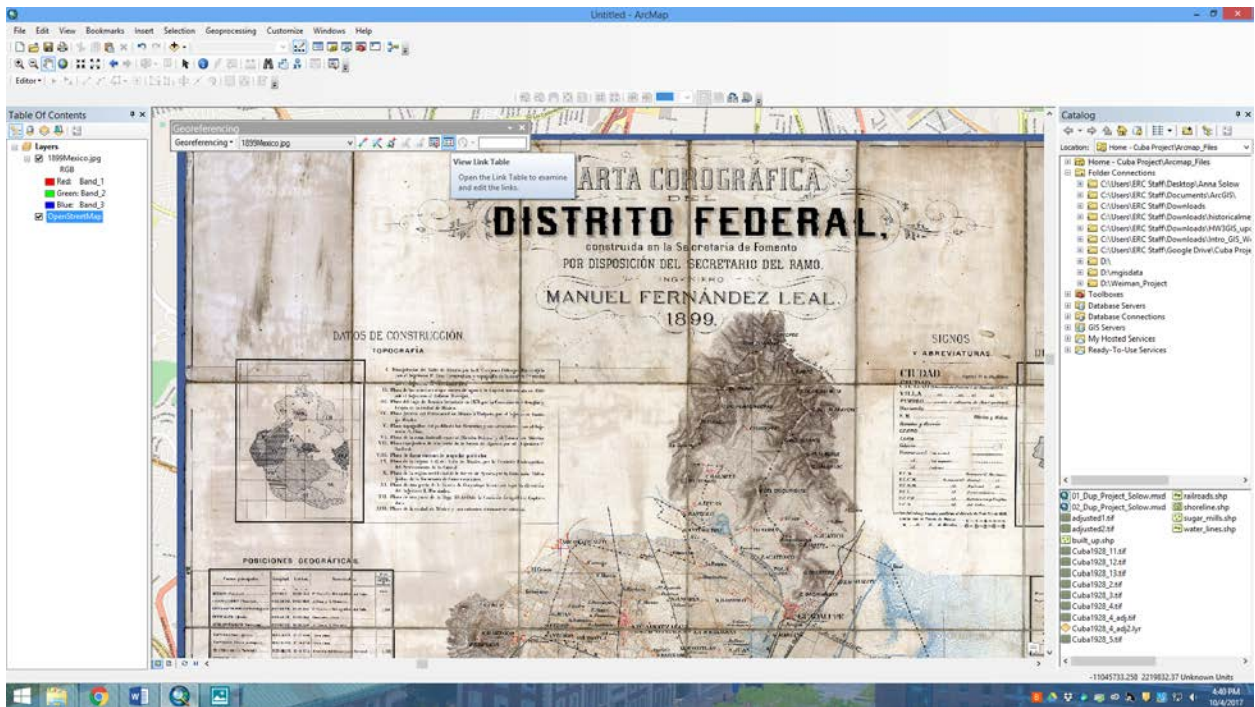
Select the first link and click "Delete Link":
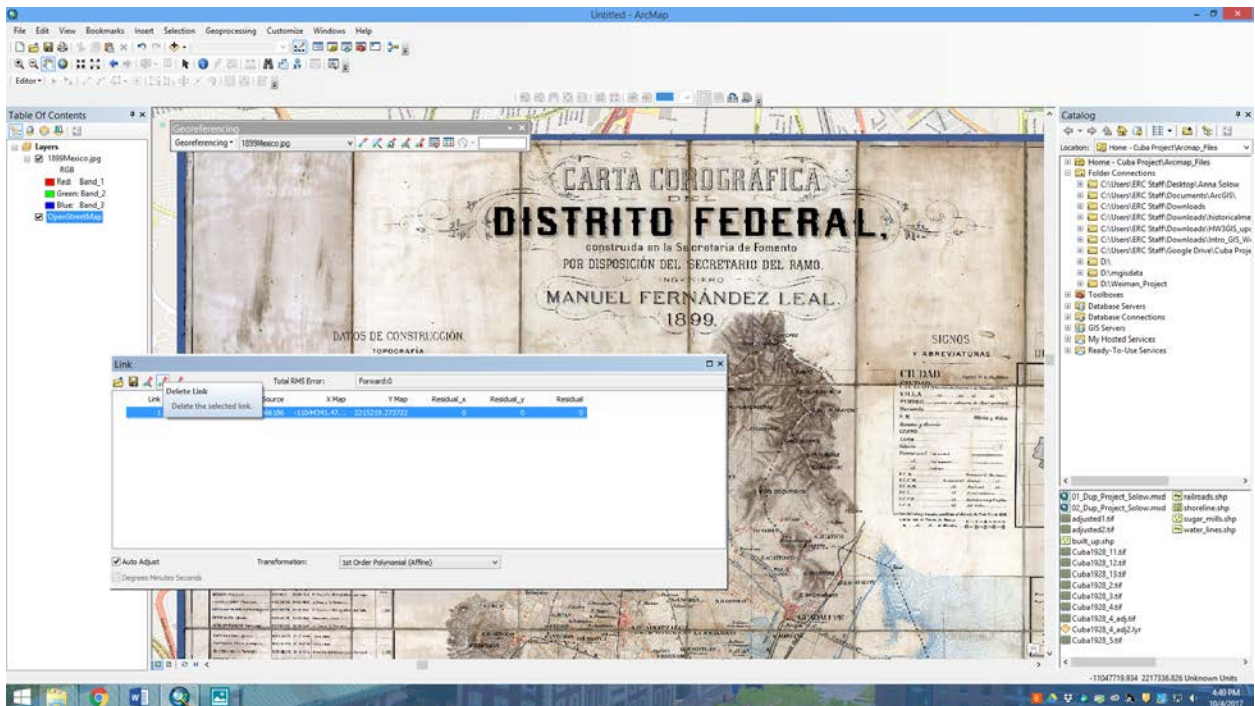


Repeat steps through 6-8 to replot this point.

10. You've georeferenced your first point! The process for georeferencing all other points is the same. It may become easier to toggle the layers on and off when you have to find points that

are hidden under a layer. The second point for this tutorial is found on this point in the historical basemap (the light green +):
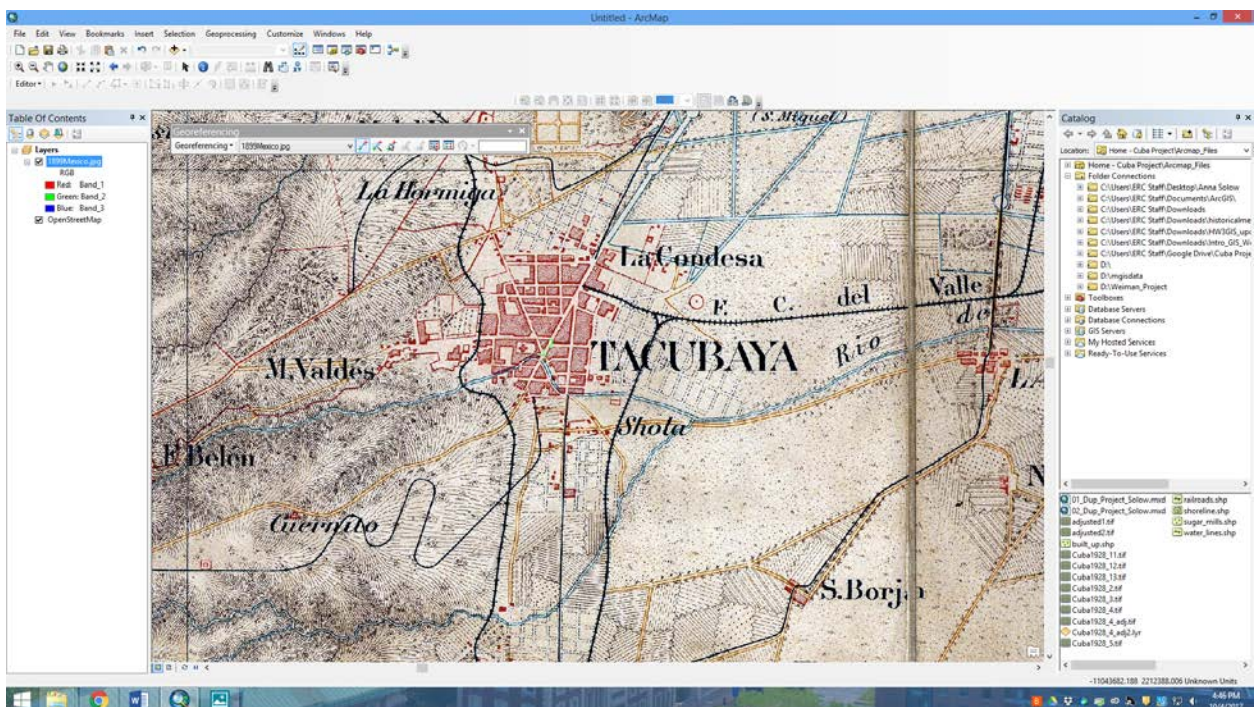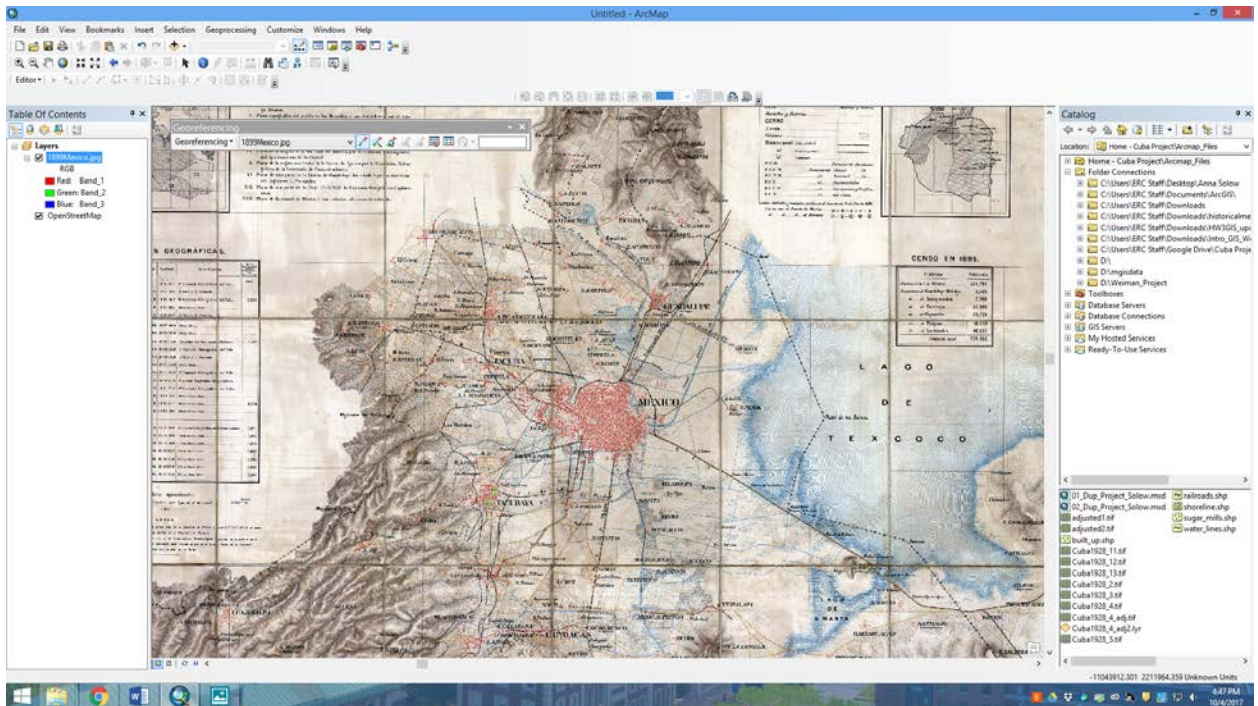




11. The associated point on the basemap is right below where the historical Mexico map is currently placed. Look for the X-shaped intersection:
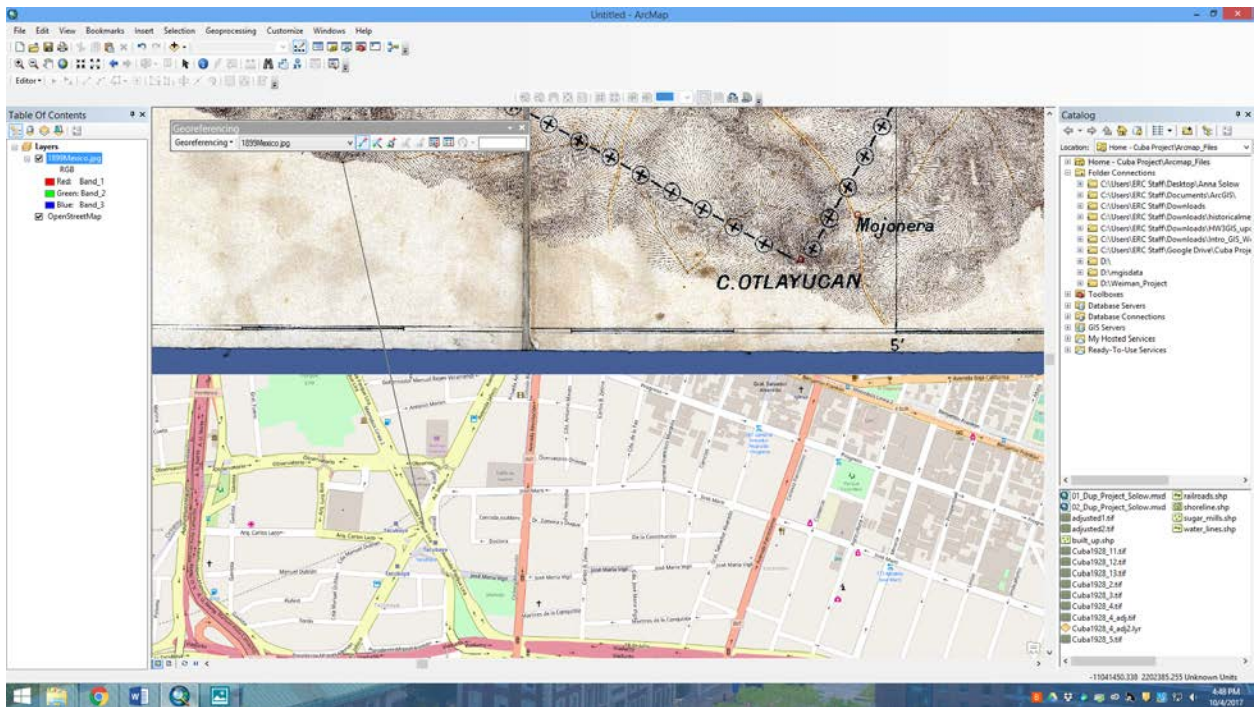
12. After you've clicked the point, your map should automatically adjust to the following, seen in this view when zoomed out:
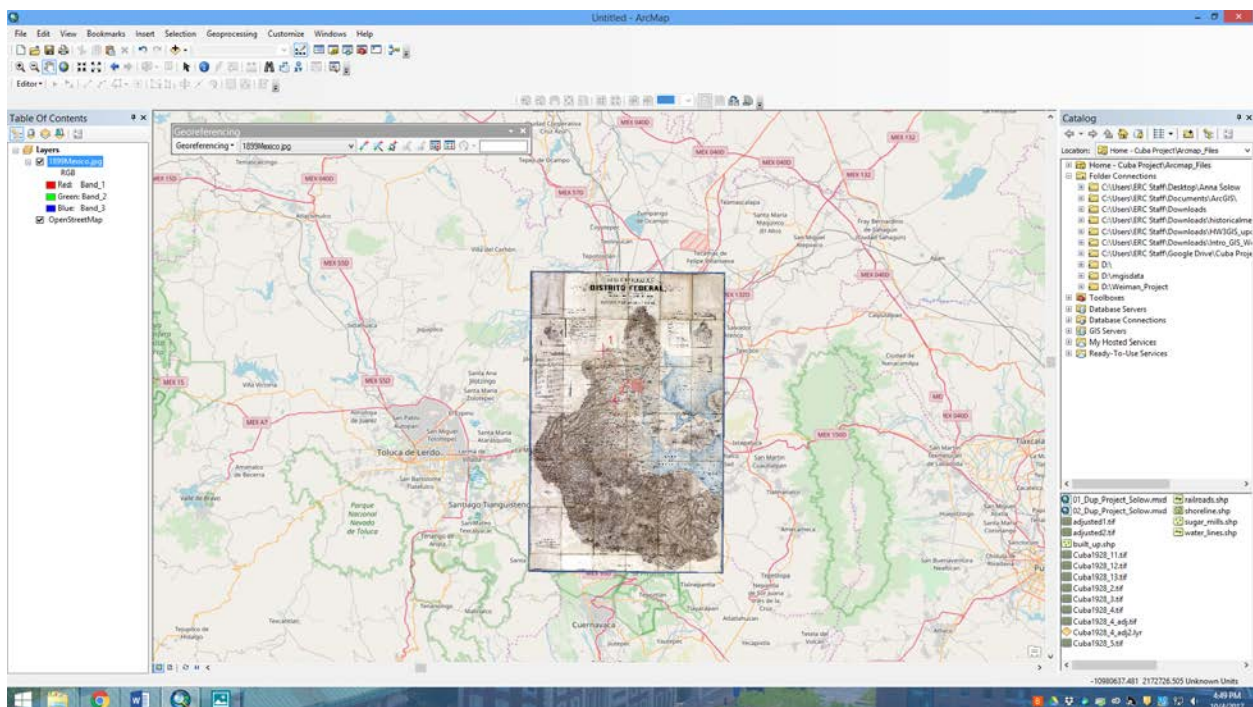


13. The third point will be the intersection of roads where Milpa Alta is. The first image
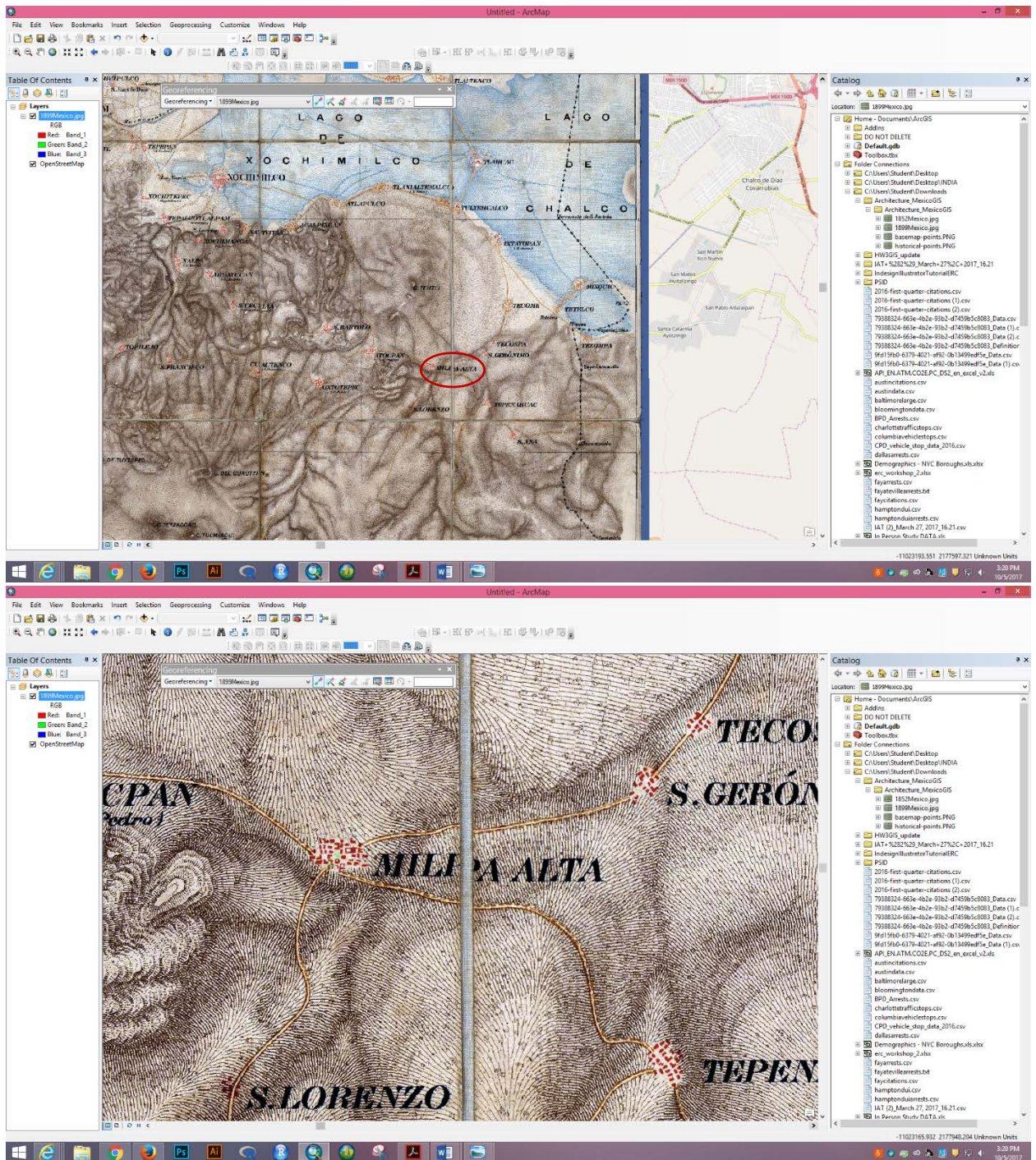
14. If you zoom out after adding the point, you will find that the map is covering the same area on the Basemap where we would want to put our point. In the Layers panel, uncheck the 1899Map.

15. You can now find the point on this map:
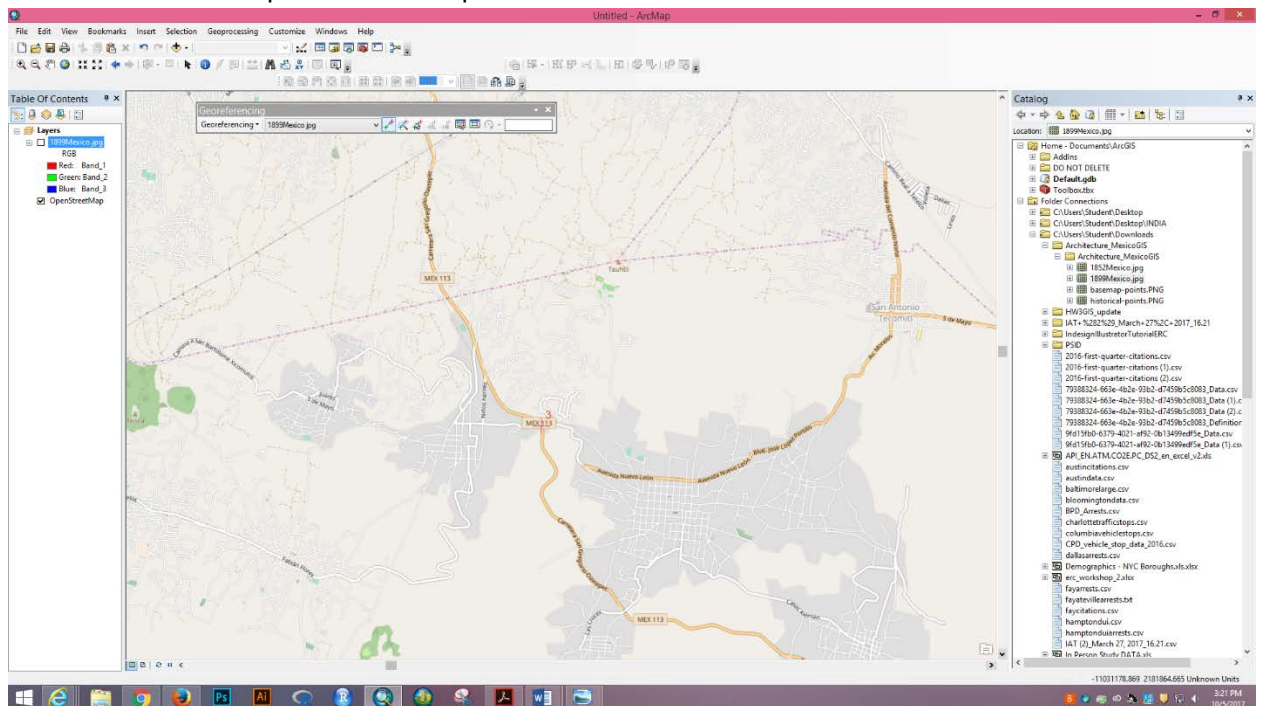


16. Your historical map is now georeferenced over the basemap, i.e. OpenStreetMap. For other maps, you may need more of such points to accurately georeferenc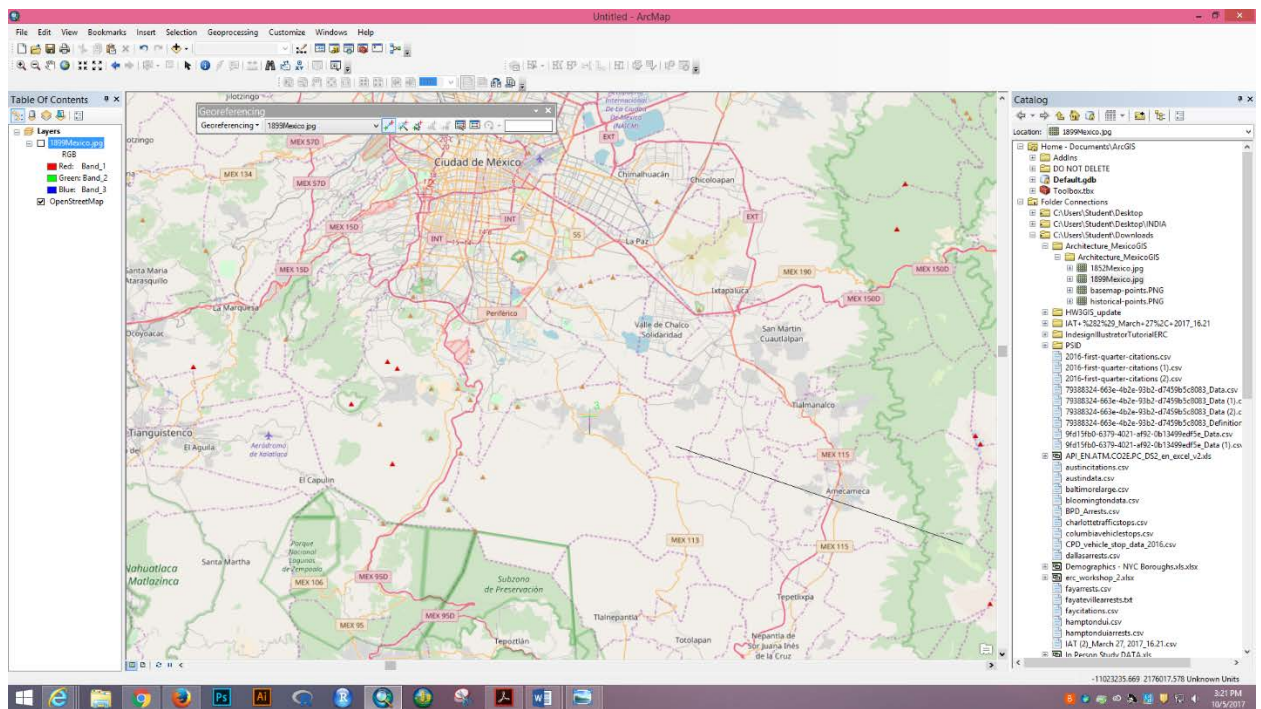ed the image. You can turn the historical map layer on and off to see how well it fits. You can also change the transparency of the map layer. Before we do that, always keep in mind that ArcMap uses data from local connections, i.e. data on the computer you're working on. If you are transferring your project from one computer to another, always be sure to export the working map with the associated

data you connected (in this case, the 1899 Mexico map). You will need to re-establish the folder connection on the new computer.

17. To also save the image as a new file, click on Georeferencer > Rectify.
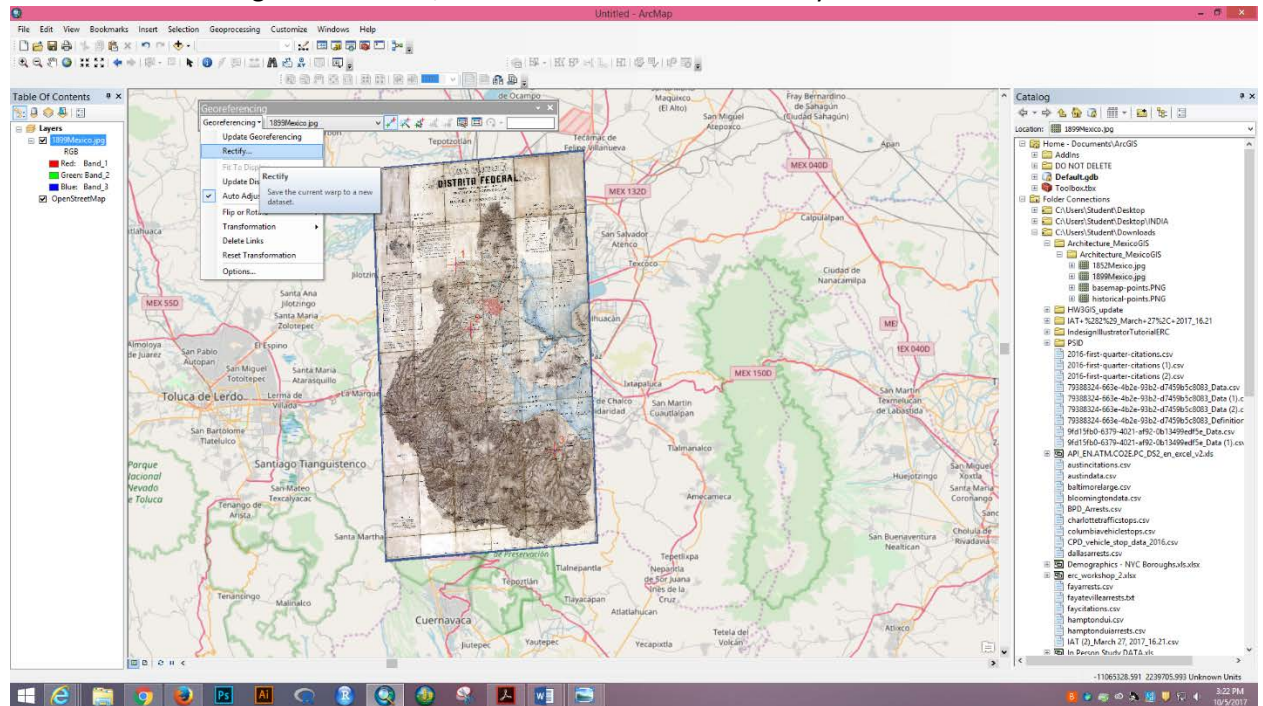


18. Leave the settings as is, and simply change the output folder to your working directory. Change the name of the file if you would like so that you know this is a georeferenced image. Notice that the file is now saving as a tiff. Click Save. This might take a minute or two.
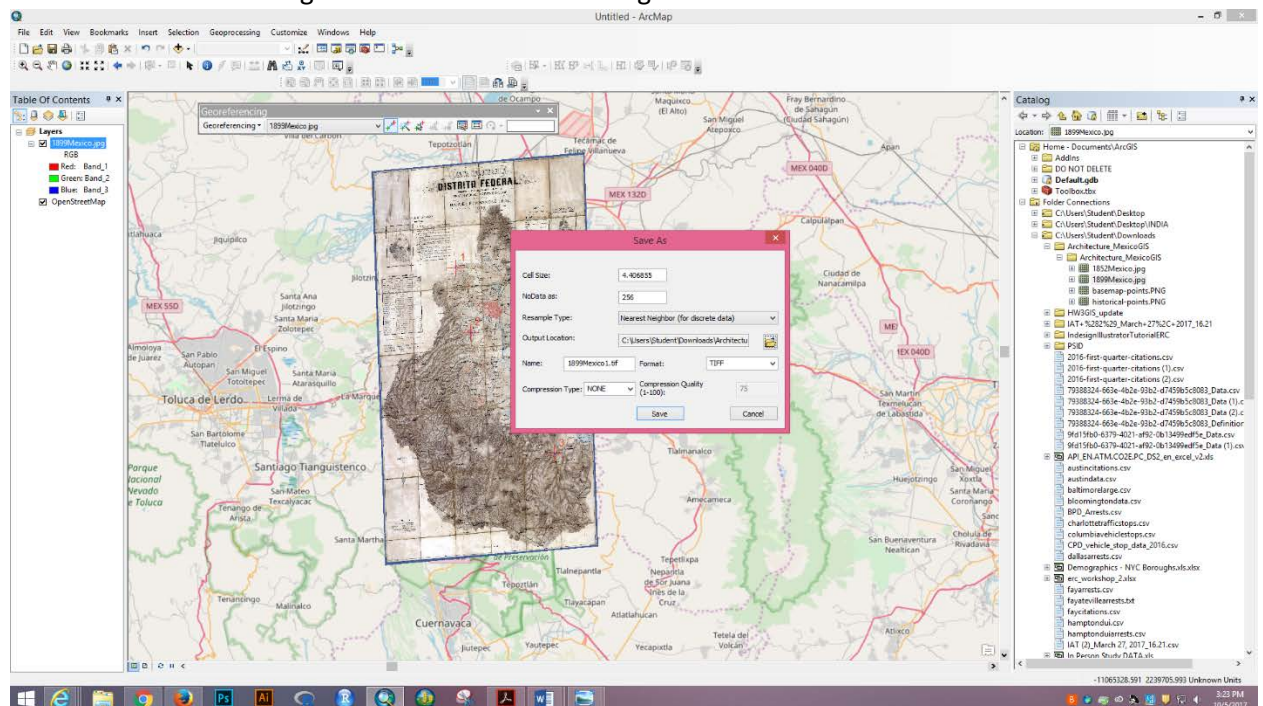


19. Once it is saved, click on Georeferencer > Update Display. Then, right click the map layer in the layers panel, and click on Properties.
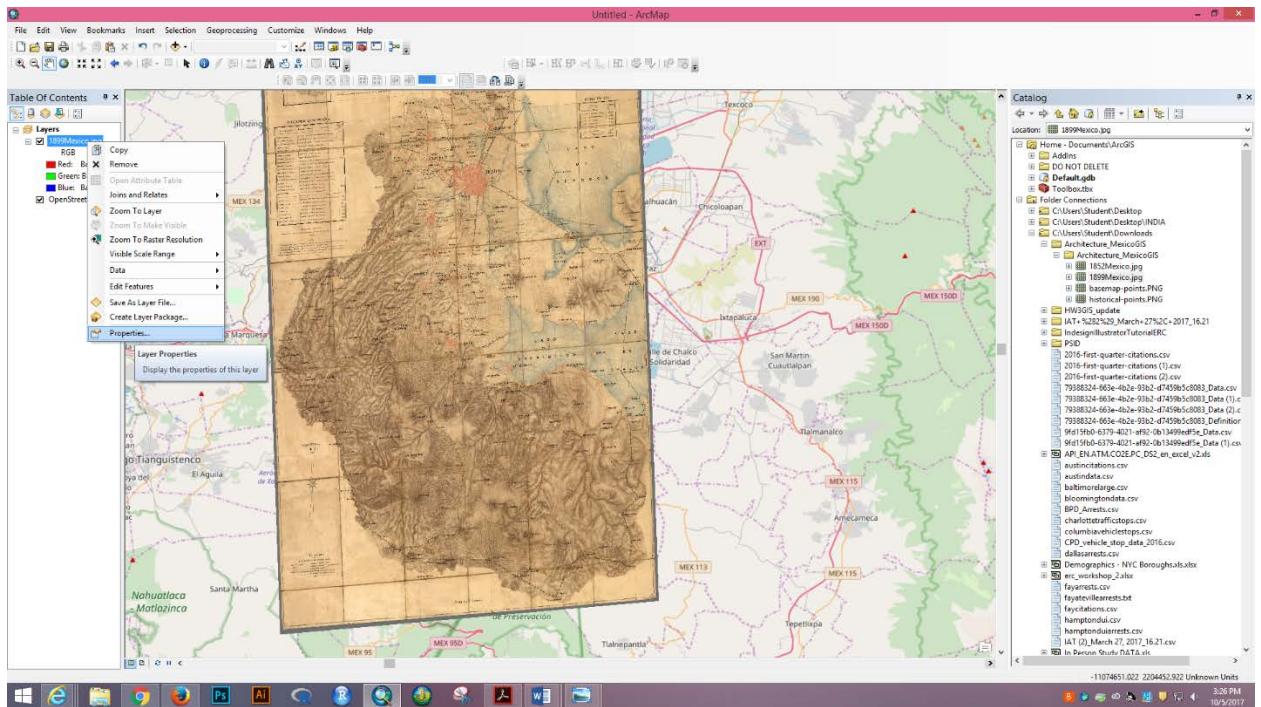
20. Go to the Display tab, and change the transparency:
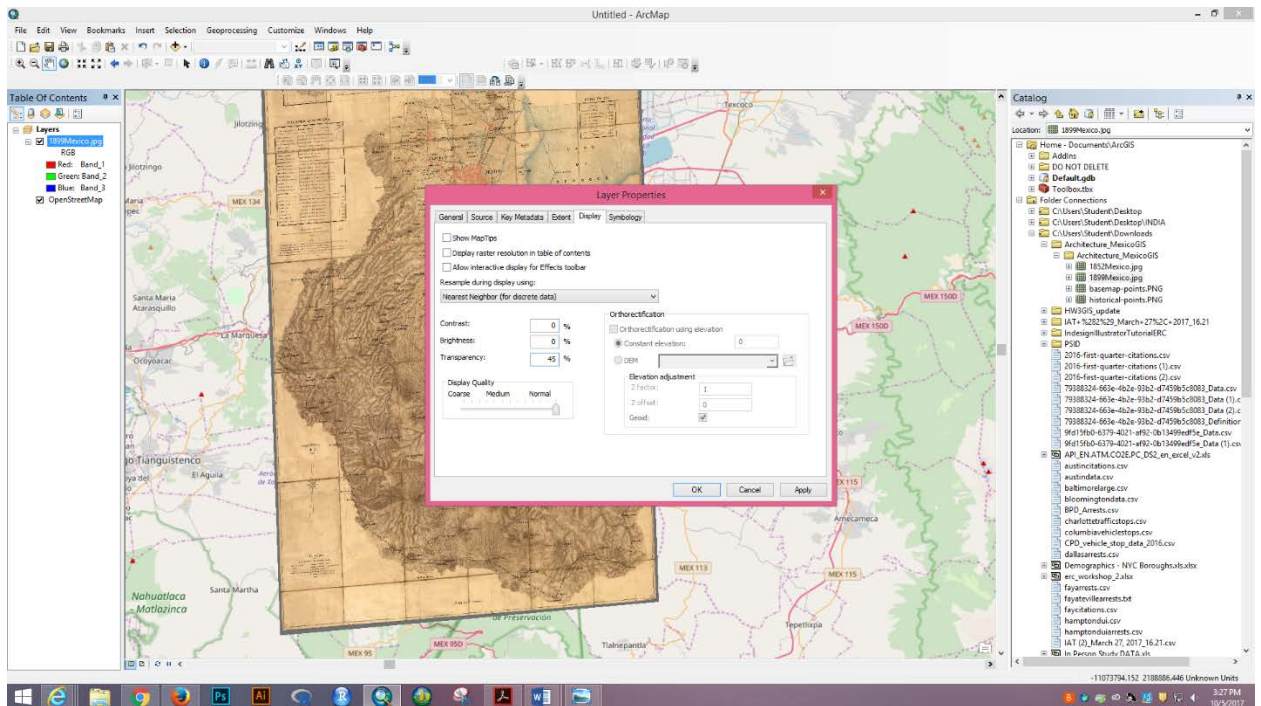


21. Click ok and see whether the map is georeferenced accurately. Our map is not perfectly matching up. To make it match better, you can edit the links we created by clicking View Links in the Georeferencer toolbar or you can add new links.

Now, we will move on to the Digitizing Portion of the workshop. This is useful for when you want to map certain points of interest, routes, or polygons, but cannot find a shapefile that reflects the information you want.

Creating your Shapefile:

22. First, we will uncheck the OpenStreetMap layer since we are only going to be working with the 1899 Map. Then, choose the 1899Mexico map on the Layers panel, and go into Properties, changing the transparency back to 0.
23. Right click on your working directory. From the menu, choose New > Shapefile.
24. Give your shapefile a name and select a geometry based on what type of features you are trying to draw. Right now, we will name our file BodiesWater and choose Polygon.
25. Use the Edit button to select the coordinate system that you are using in your ArcMap project. Type 3857 into the search bar and choose the WGS 1984 Coordinate System that pops up as a result. Click ok to close the Coordinate System window and then click ok again to create your shapefile.

Editing Your Shapefile:

26. You will now see your new shapefile in the Layers Panel. Open its Attribute table, by right clicking on the BodiesWater shapefile, and choosing Open Attribute Table.
27. Using the Table Options button, use the Add Field button to add fields that you may want to keep track of. In this case, we may want to have names for our bodies of water. Give the attribute a name, in this case we will name our attribute Name. And we will choose the type of this field to be Text. We will keep the length at its default of 50.
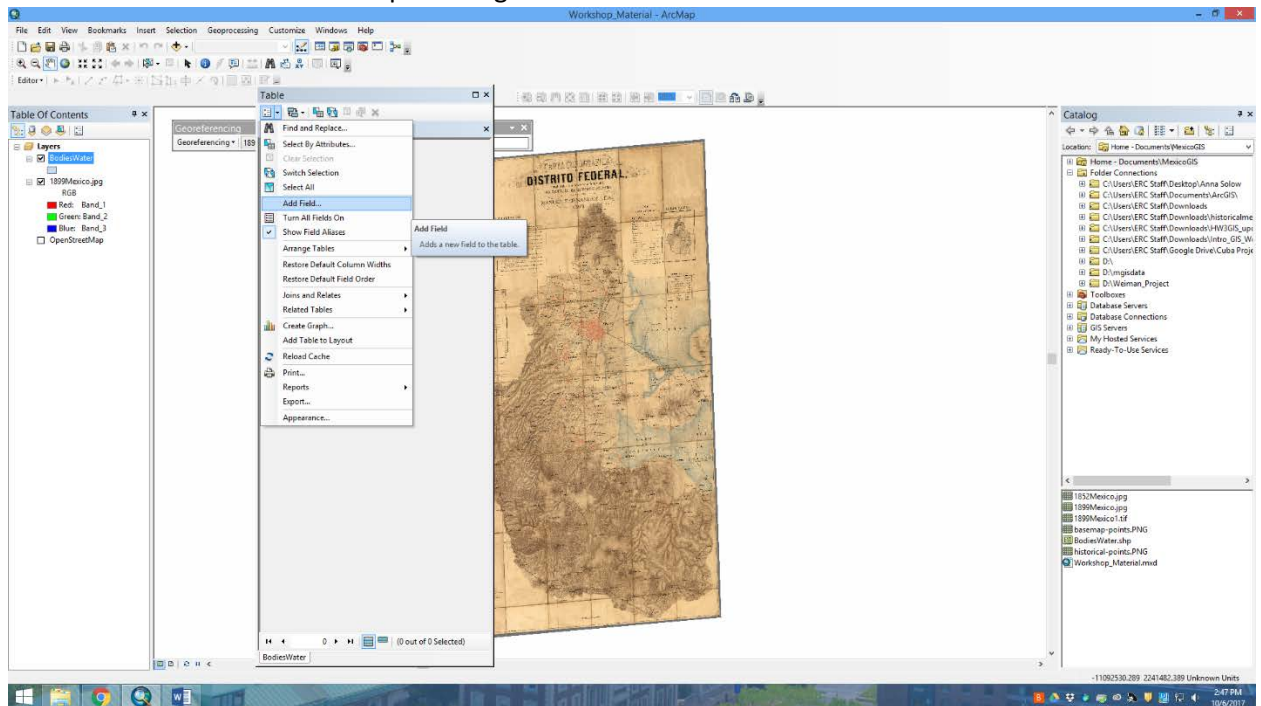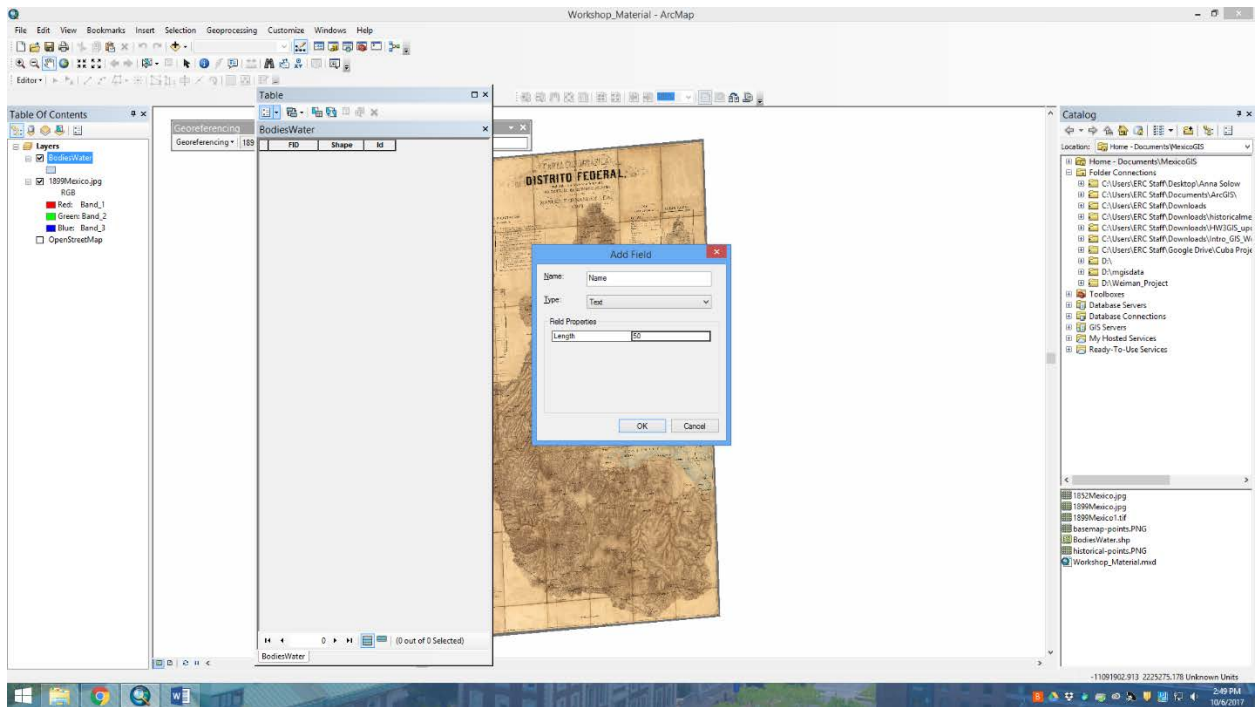
28. Once added, the attribute should show up in your table:
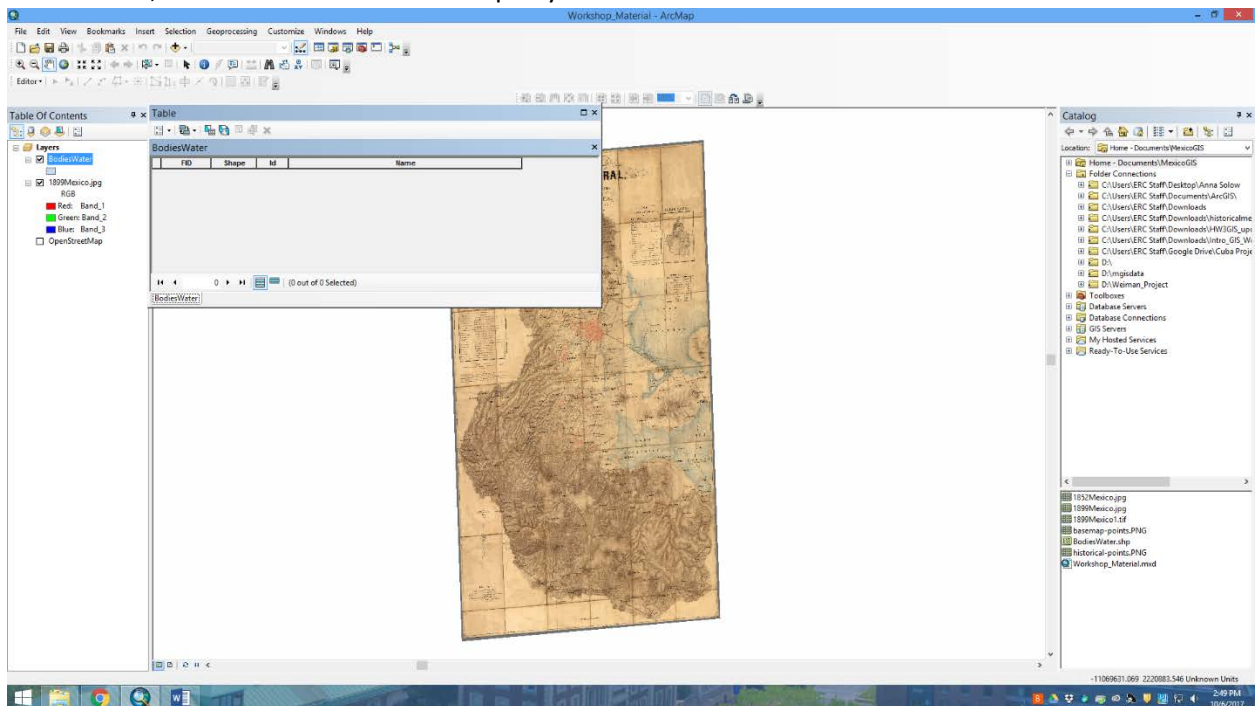


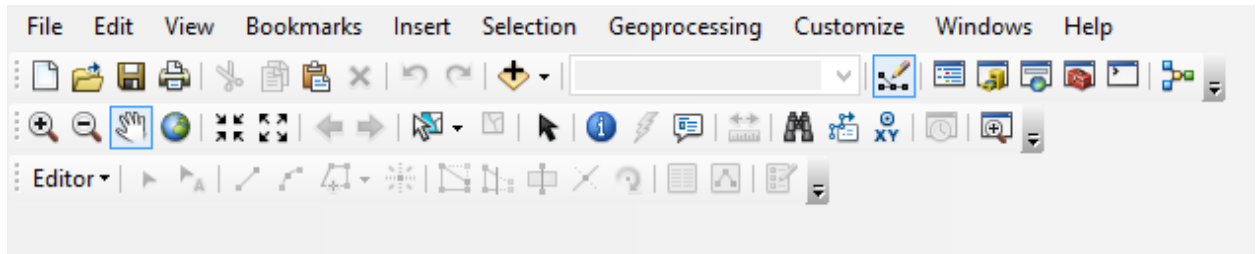29. You can close your attribute table. Now, turn on the editor toolbar, by going to Customize > Toolbars >Editor. The toolbar should appear under the magnifying glasses, and we will click on the Editor button on the toolbar and choose the Start Editing option.

30. You may get an error that says our Spatial Reference for the layer does not match the Data Frame. This is because we specified the coordinate system for our shapefile, but the DataFrame may not automatically have that coordinate system. Click Stop Editing. Then, in the Layers Panel, right click on the word Layers, and choose Properties. In Properties, head to the Coordinate System tab and search up ESPG:3857 and choose it.

31. Go back to the Editor toolbar and choose Start Editing. Click on the rightmost icon in the Editor Toolbar, which should say Create Feature when you scroll over it. A window on the right should pop up. To give yourself more room to work with, close the catalog. Then, select the Shapefile you want to work on, in our case: BodiesWater. In the bottom panel, we will see the option to choose different types of Polygons. Since our lakes are irregularly shaped, we will choose polygon.
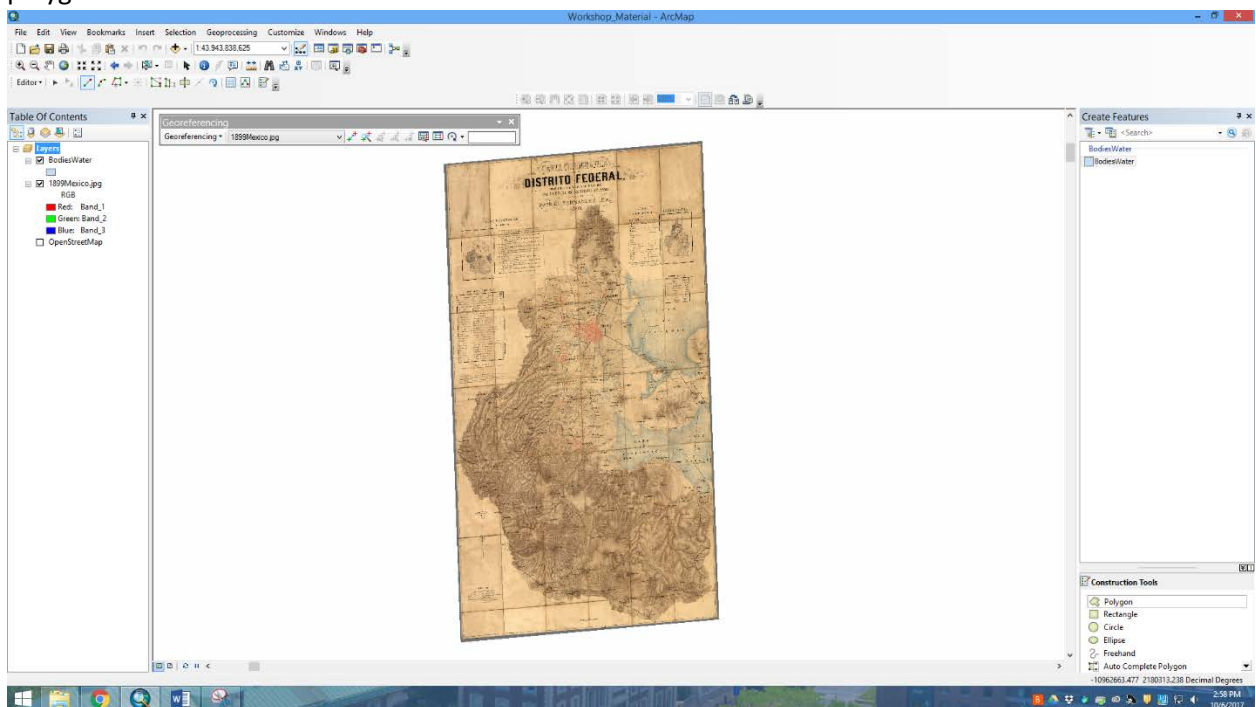


32. Your mouse should look like a plus sign. We can now start clicking around the border of the lake to create our polygon. Make multiple points along the border so that the shape we create most closely resembles the feature. The polygon should start forming as you go. Once you are done, double click on your last point to finish. You should now have your polygon!
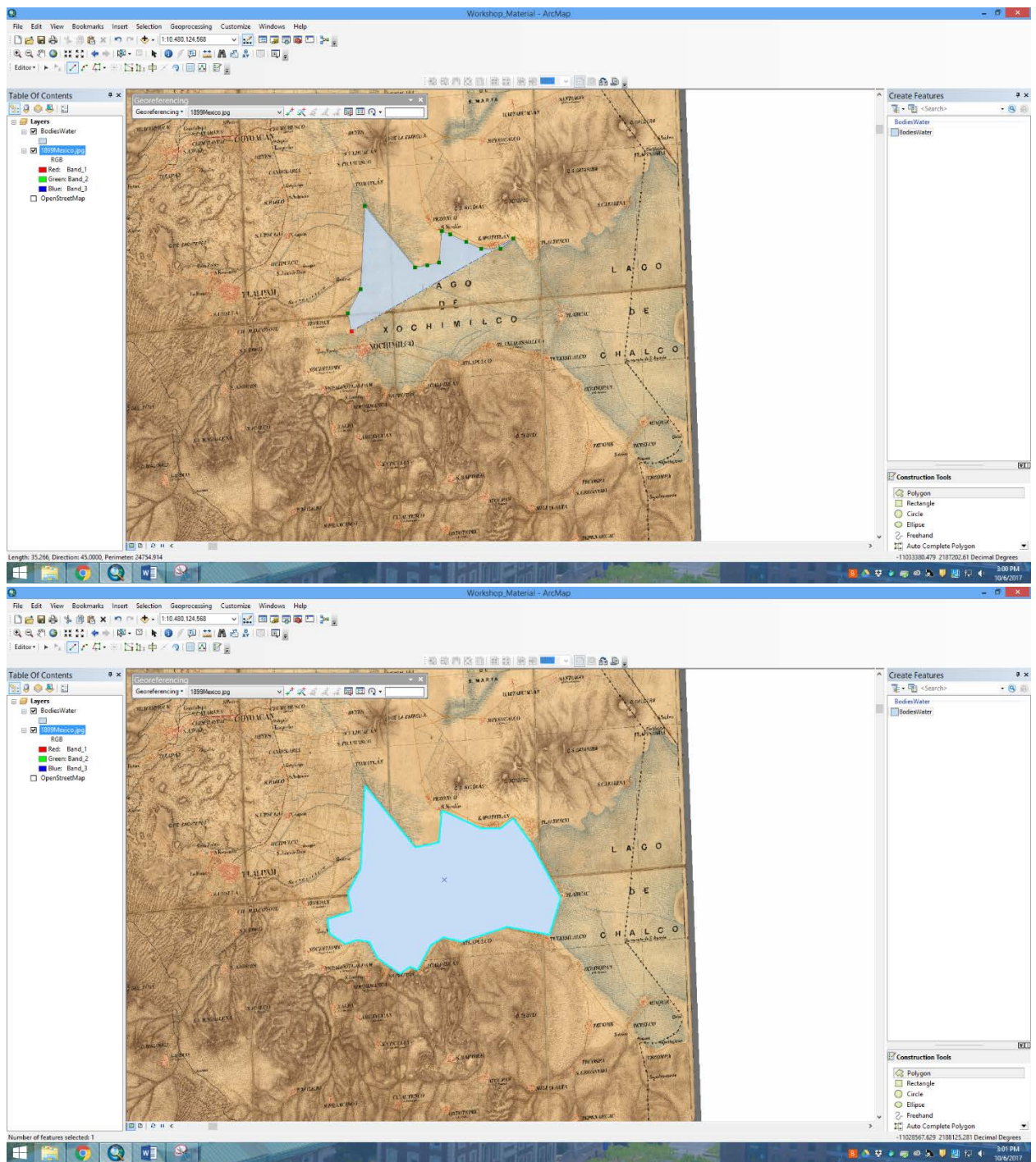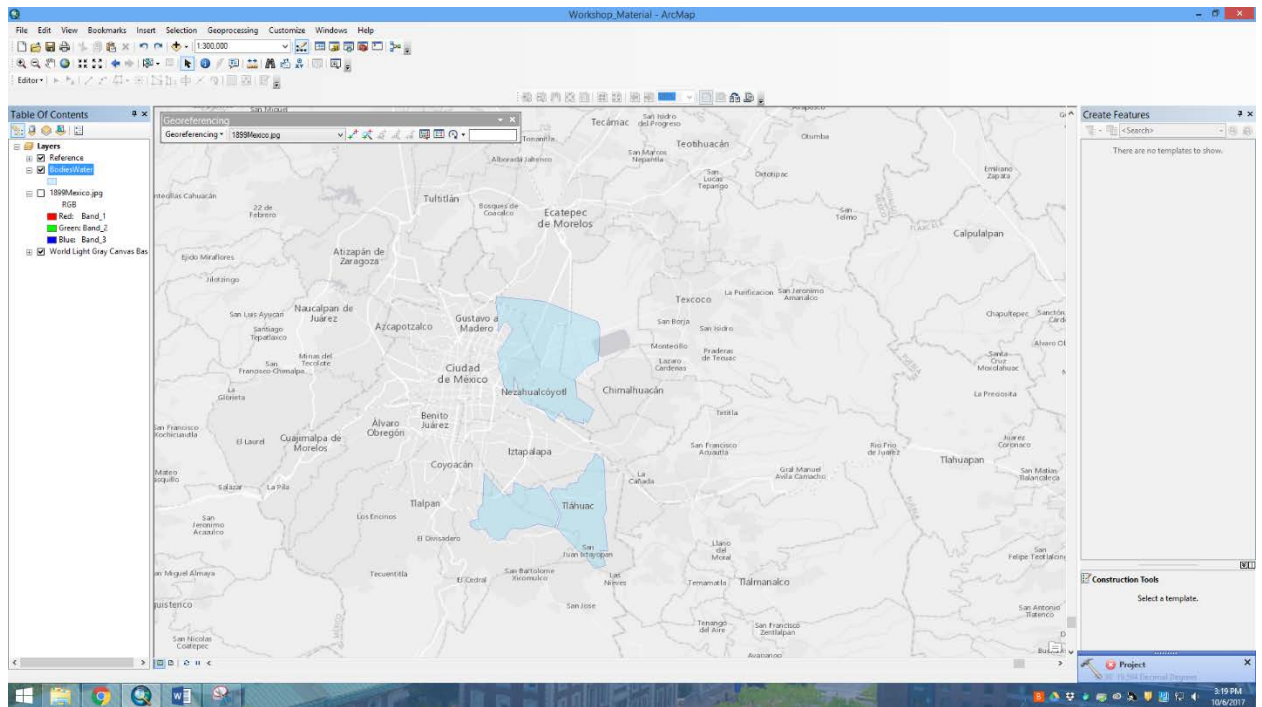
33. To edit the attribute table for the feature you just created, click on the Attributes icon on the Editor toolbar.  All the editable fields for the feature you just created will appear. The other two

attributes should automatically populate, but fill in the Name attribute of the polygon:
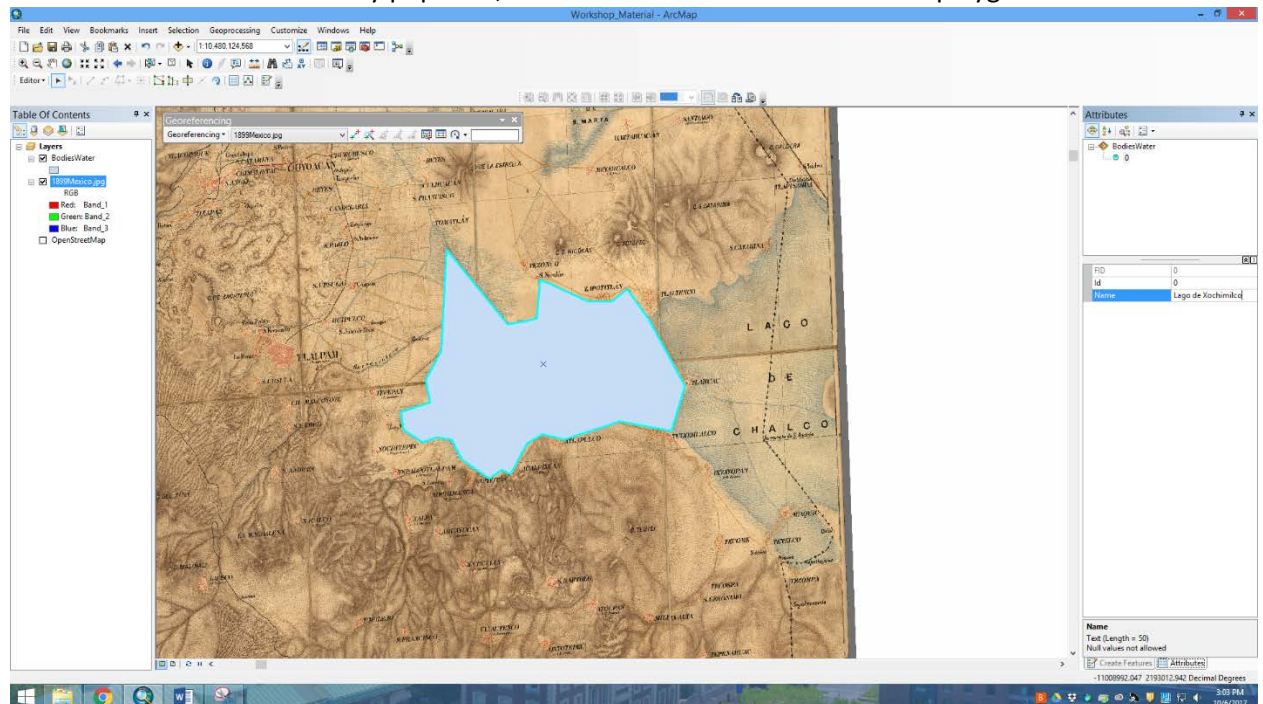


34. Continue repeating this process until you have all the features you want. When you're done creating features click on the Editor button on the Editor toolbar and select Save Edits, and then Stop Editing
35. Things to keep note of:
    a. You can only edit the values in the Attribute Table of your shapefile while in Editing is turned on.
    b. However, you cannot create new fields in the Attribute Table while Editing is turned on. Create fields before starting an editing session.
36. You can repeat this process to also create a Line shapefile for the rivers or a Point file for cities and towns, depending on what features you are interested in. Just make sure when you create your Shapefile to choose the appropriate Feature type.
37. If your only use for the image file was to digitize points off of it and now you would like to compare the bodies of water to Mexico City currently, you can uncheck the map layer and check off the basemap. You can play around with it then as you'd like depending on what you want to show.
38. Here is an example of what you could do by changing the basemap and editing the transparency and color of the bodies of water. This could perhaps help you show change of water over time if you continued to georeferenced other maps over the 20th century and used all the water features to see how they've changed over time.

Have fun making your own maps!