THE GEO PROJECT
GEOSPATIAL EDUCATION & OUTREACH

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GEO TUTORIAL

GEOREFERENCING A RASTER DATASET USING QGIS

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The Geospatial Education and Outreach Project (GEO Project) is a collaborative effort among the Geosystems Research Institute (GRI), the Northern Gulf Institute (a NOAA Cooperative Institute), and the Mississippi State University Extension Service. The purpose of the project is to serve as the primary source for geospatial education and technical information for Mississippi.

The GEO Project provides training and technical assistance in the use, application, and implementation of geographic information systems (GIS), remote sensing, and global positioning systems for the geospatial community of Mississippi. The purpose of the GEO Tutorial series is to support educational project activities and enhance geospatial workshops offered by the GEO Project. Each tutorial provides practical solutions and instructions to solve a particular GIS challenge.

GEOREFERENCING A RASTER DATASET USING QGIS

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REQUIRED RESOURCES
- QGIS (3.16.9-Hannover)

FEATURED DATA SOURCES
- Sanborn Fire Insurance Map from Biloxi, Mississippi, May 1914. Map. Retrieved from the Library of Congress, <www.loc.gov/item/sanborn04432_005/>.

OVERVIEW

This tutorial focuses on georeferencing a raster dataset using QGIS. The fundamental idea behind georeferencing is to locate points on the non-georeferenced dataset to the same locations on a georeferenced dataset. The collection of X,Y pairs of points is called a ground control points (GCPs) table. After compiling a minimum of three GCPs, a first-order polynomial equation is created to spatially register the non-georeferenced dataset. The accurate and precise placement of GCPs, and spatially dispersed sampling of GCPs, has a significant impact on the final georeferenced product.

To perform the steps listed below, you will use a historic fire insurance map from Biloxi, Mississippi as a non-georeferenced dataset, and an OpenStreetMap (OSM) standard basemap as a georeferenced dataset to locate your GCPs. Scanned historic maps are textbook examples of raster datasets that very often do not have a spatial reference defined. This means that they will not overlap with other spatial datasets unless they are georeferenced. The steps presented in this tutorial will illustrate how to define the spatial reference for a raster dataset based on the freely available web basemap.

STEP 1. DOWNLOAD THE SANBORN FIRE INSURANCE MAP

A. Visit the Library of Congress Sanborn Maps collection and access Image 1 of Sanborn Fire Insurance Map from Biloxi, Mississippi, May 1914 using the following link: http://www.loc.gov/resource/g3984bm.g3984bm_g044321914/?sp=1

B. Familiarize yourself with the map. Simply, pan around the image, zoom in and out to see map details such as street names, parcel numbers, and legend.

C. Scroll down to the download menu available in the lower-left corner and from the drop-down list select the JEPG2000 format. Click *Go* to download the file.
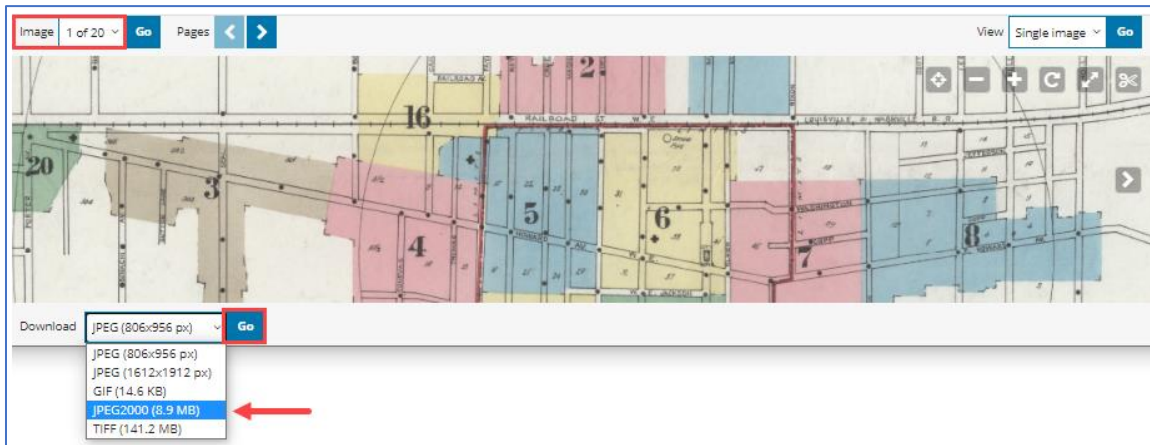

D. Save the image to your local drive, preferably to a folder where you will store all files created in this tutorial. Rename the image to give it a shorter file name, for example: historic_map.jp2.

## STEP 2. START QGIS, CREATE A NEW PROJECT AND ADD A WEB BASEMAP

A. Open QGIS and create a new project (*Project > Save As*) in the same folder where you saved your historic map image. Call the project Georeferencing.qgz.

B. Before adding layers to a project window, it is a good practice to start by setting the appropriate projection (*Project > Properties > CRS*). Type in the following EPSG code into the *Filter* text box: 3857. This will allow you to select WGS 84 / Pseudo-Mercator projection from the automatically displayed list of the predefined *Coordinate Reference Systems* (CRS). The EPSG: 3857 is a commonly used global projection suitable for the display of the OSM basemap.

C. Click on the *WGS 84 / Pseudo-Mercator* and then click *Apply.* Note that the pink projection window shown in the lower-right corner will automatically expand to a global extent. Click *OK* to set the project CRS properties to EPSG: 3857 and close the CRS window.
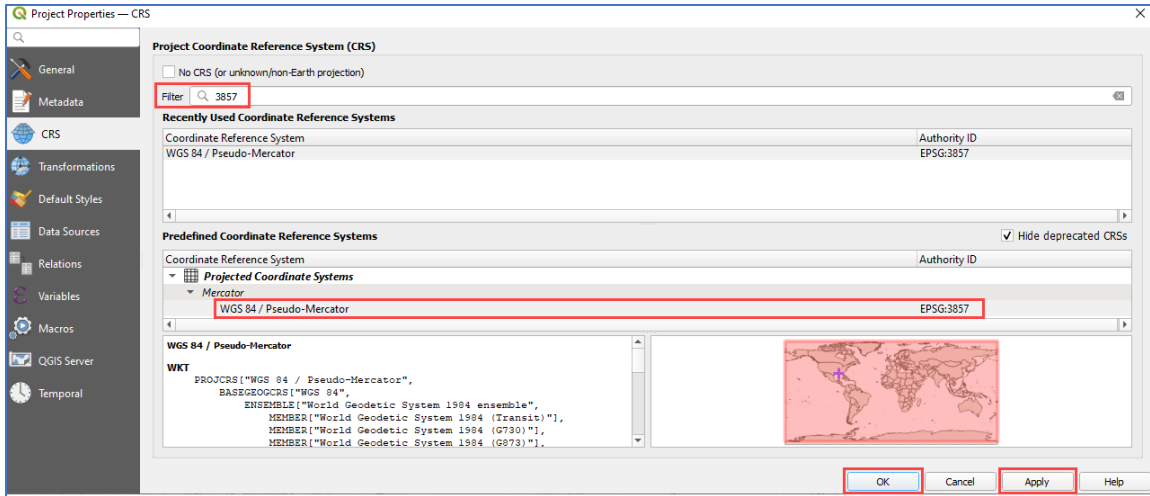
D. You can easily verify that the projection properties have been correctly updated. As shown in the figure below, the EPSG: 3857 is listed in the lower-right corner of the project window. That means that all geospatial layers added to this project will be transformed on-the-fly to match this global projection. More specifically, all layers will be displayed in the EPSG: 3857 coordinate system for the duration of the project.
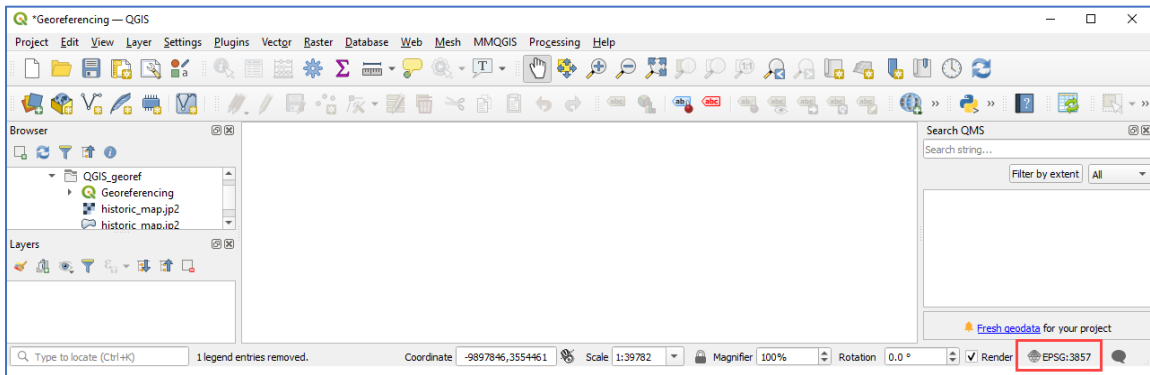

E. Add a standard web basemap to your project (*Browser panel> XYZ tiles > OpenStreetMap > Add Layer to Project*). OSM is a free-to-use map of the entire world created by volunteers and available under the open-content license. You will use this basemap as a source dataset to collect your GCPs.
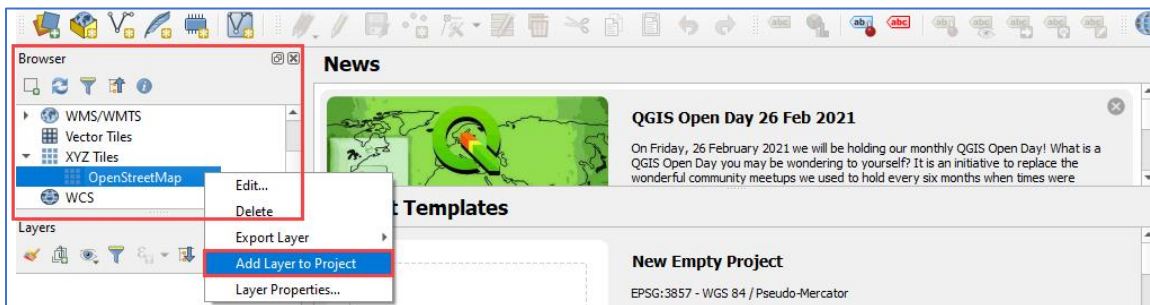
F. Before starting the georeferencing process, it is a good practice to locate the same area on the source dataset (in this case, the OSM basemap) and the destination dataset (in this case, the historic fire insurance map). Zoom in to the area marked with a red square as shown in the figure below.

G. More specifically, zoom in to the downtown area of Biloxi, Mississippi. Visually locate the following three intersections on the OSM basemap: Main Street and Bayview Avenue (point 1), Oak Street and Howard Avenue (point 2), and Seal Avenue and West Howard (point 3).
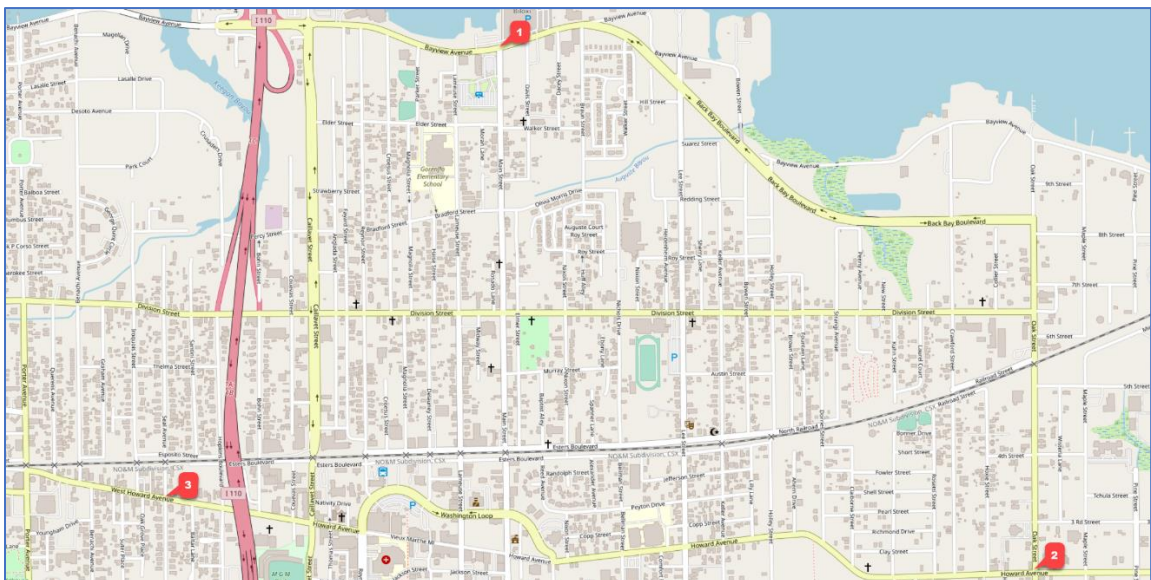

H. Once you locate these intersections, it might be helpful to add a map bookmark for Downtown Biloxi. Georeferencing requires multiple, back-and-forth panning around the map. A bookmark will allow you to return to the exact same location on the OSM basemap. To create a bookmark, select *View > New Spatial Bookmark*. Name it *Downtown_Biloxi*, save it in *Project Bookmarks*, and click *Save* to create it.
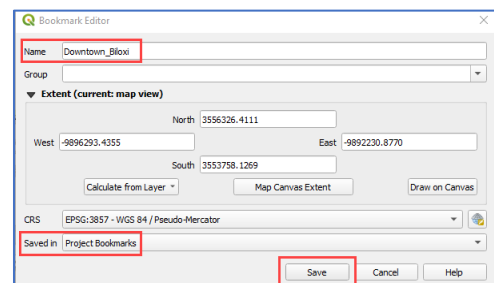
I. At this point, it might be helpful to print the historic fire insurance map and mark the same intersections on the hard-copy map. This may be useful because some of the historic street names have changed over time. Note that the points are uniformly spread out on the historic map (destination dataset) and placed at intersections easily distinguishable on both maps.

## STEP 3. ADD THE HISTORIC MAP TO YOUR PROJECT

A. Add the JEPG2000 file, downloaded in Step 1, to the project window (*Layer > Add Layer >Add Raster Layer*). Browse to the historic_map.jp2 raster dataset. Click *Add* to insert it to the project window.
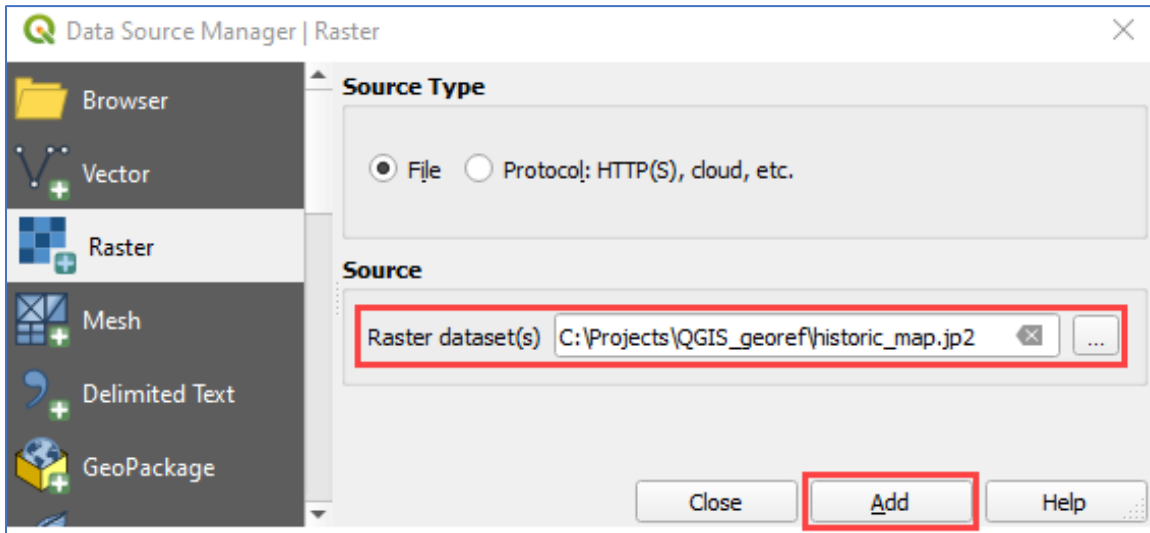

B. When attempting this step, you will see a yellow warning indicating that the *CRS was undefined*. At this time, disregard this warning and add the historic map layer to the project window anyway.
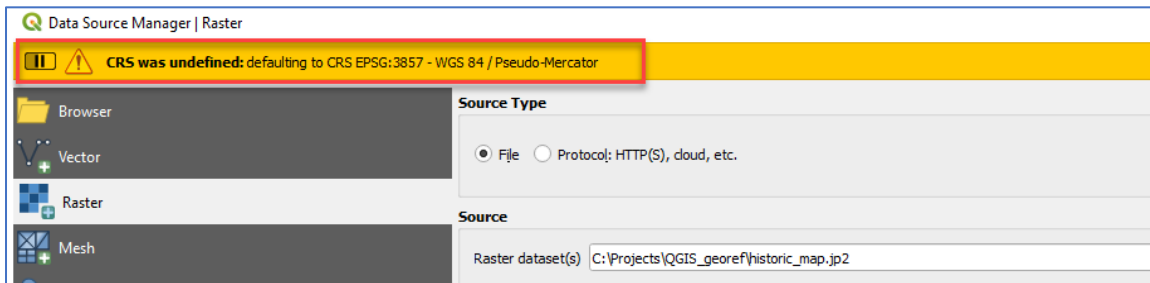

C. Right-click on the recently added layer and click on the *Zoom to Layer* option. As you can see, the historic map layer does not overlap at all with the basemap.
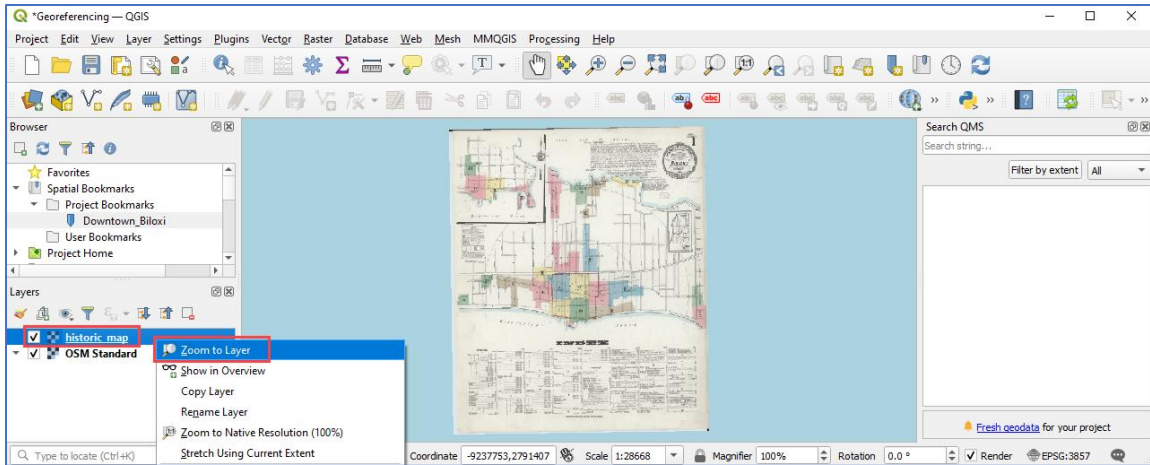
D. This incorrect map placement should not be surprising as this layer does not have any geospatial information that can be used to position this image correctly. Right-click on the historic map layer and select *Remove Layer*.
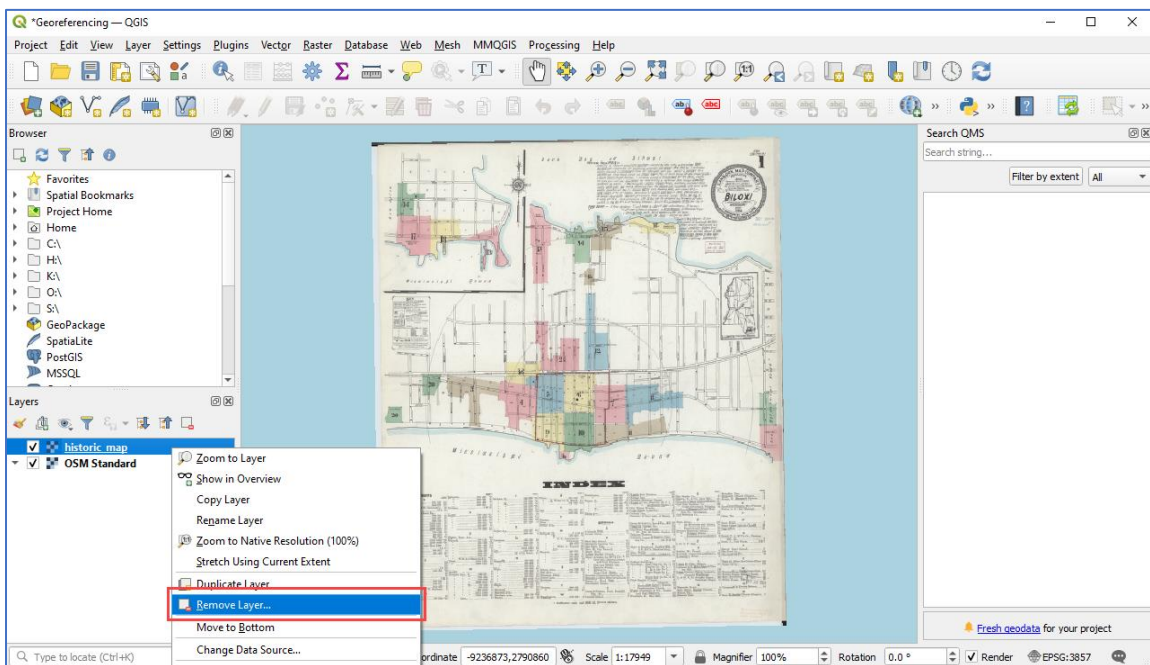

E. In the *Browser* window, find *Spatial Bookmarks > Project Bookmarks*. Click on the *Downtown_Biloxi* bookmark. This will return the map view to the previously defined extent.
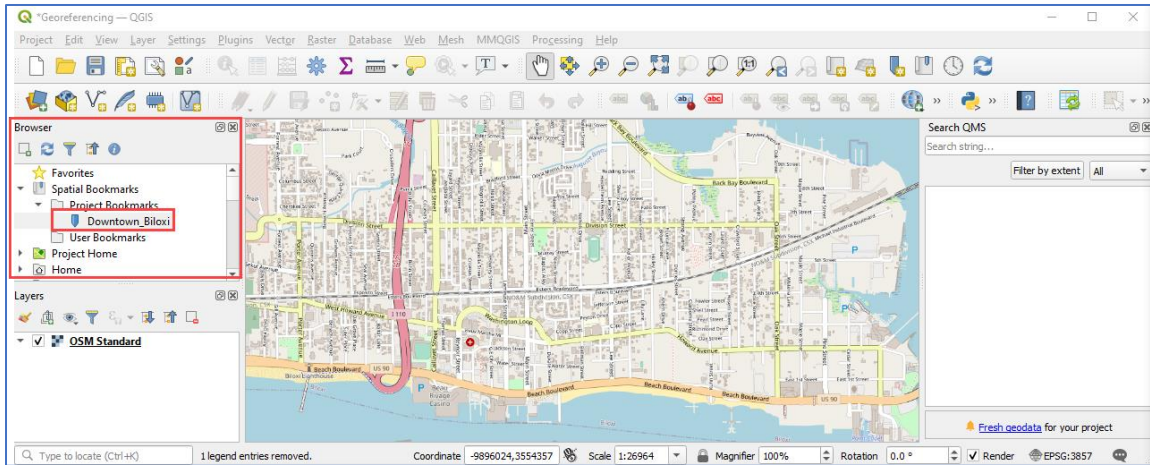
STEP 4. COLLECT GROUND CONTROL POINTS

A. To be able to georeference the historic map layer, you need to use the *Georeferencer* window. Open it by selecting it from the *Raster* menu (*Raster > Georeferencer).*
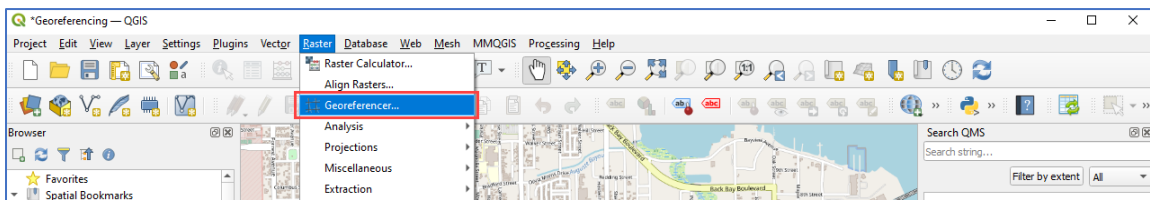
B. The *Georeferencer* window will appear automatically on top of your project window. Since this window is separate from the project window, you can move it around your screen and resize it as needed. Once properly positioned, select *Open Raster* from the *File* menu on the *Georeferencer* window.
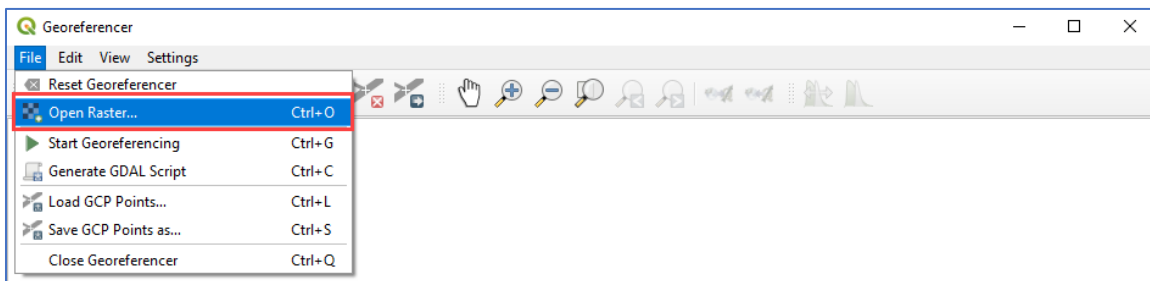

C. Browse to the historic_map.jp2. The image will open to display the full map extent. Use the *Zoom In, Zoom Out,* and *Pan* tools to view details on the map.
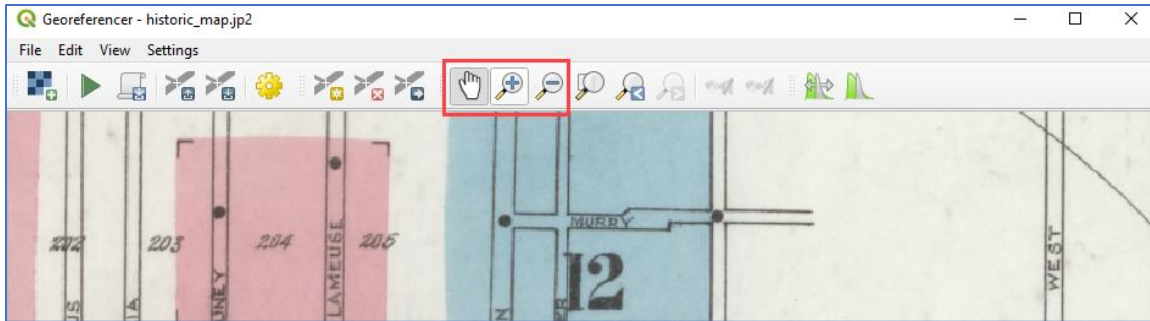
D. Before collecting actual GCPs it is a good idea to make sure the table showing each recorded point is visible (*View > Panels > GCP table*).
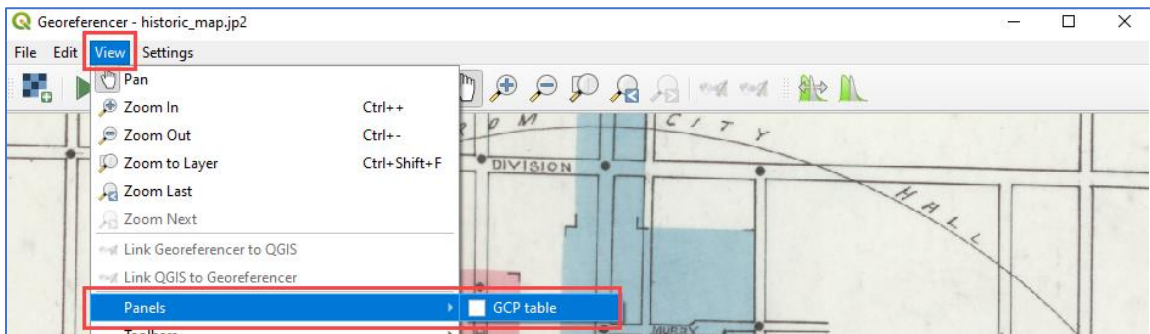

E. An empty GCP table panel will be added at the bottom of the *Georeferencer* window. Once you start adding your GCPs, this panel will gradually fill with pairs of coordinates for the source and destination datasets, as well as residual errors, calculated for each pair of coordinates.
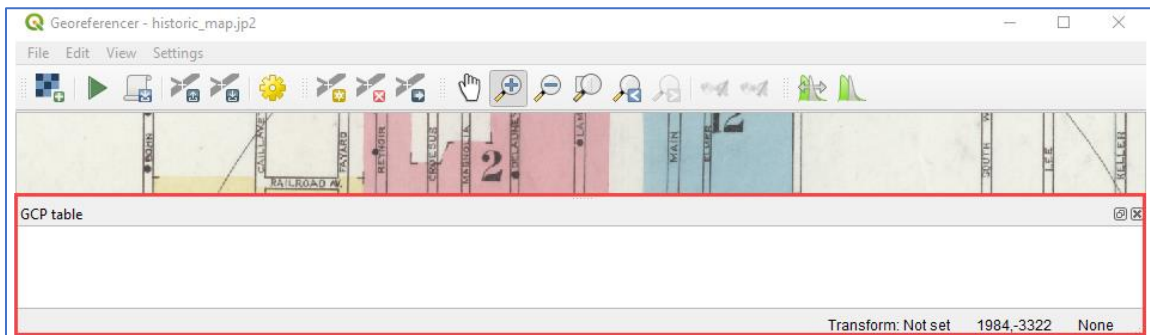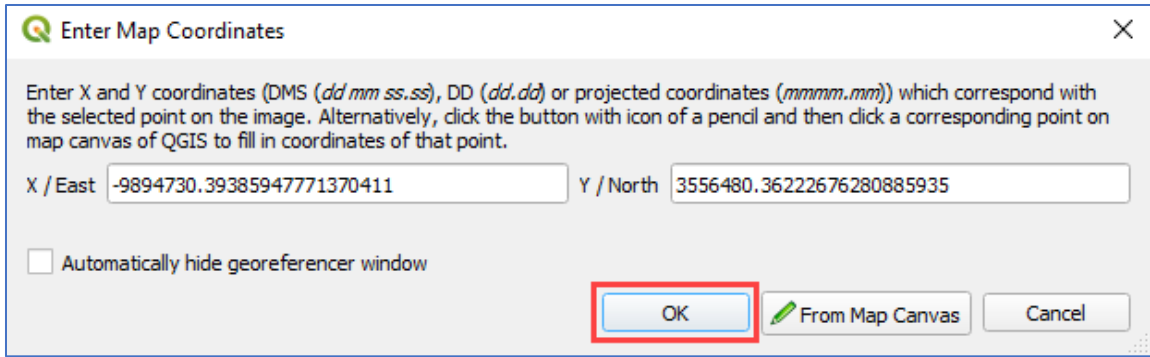
F. Also, it is critically important to update available georeferencing settings (*Settings > Transformation Settings*). In the *Transformation Settings* dialog box, select *Polynomial 1* as the *Transformation type*. This is a simple transformation involving only shifting, rotating, and/or resizing. Under the *Output raster,* create a new raster dataset called **hist_map_gr.tif** and save it in the same folder as your historic_map.jp2 file. Make sure that the box to *Load in QGIS when done* is checked. This way, the newly georeferenced raster dataset will be automatically added to your project window. You can keep the default options for the remaining parameters.

G. Now, you are ready to collect your first GCP. Select the *Add Points* tool from the toolbar in the *Georeferencer* window.
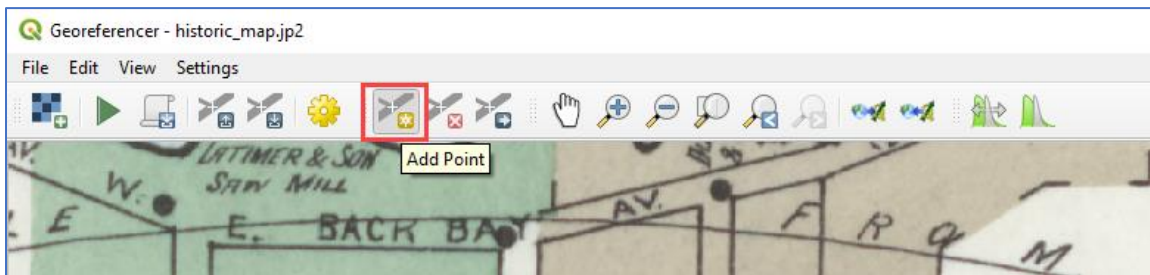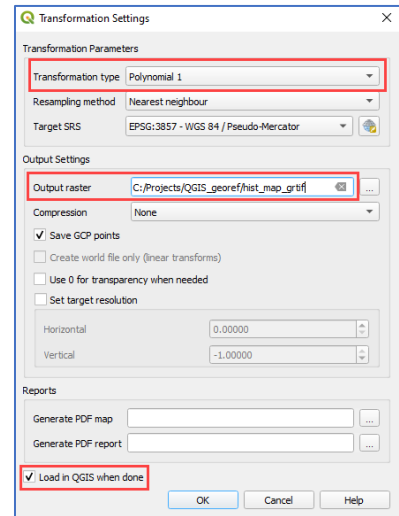
H. On the historic map, move the cursor over the corner of Main Street and Bayview Avenue (note that the old street name is Back Bay Avenue). This will be your first GCP. When you click the left mouse button on that location (be accurate), the following window will appear:
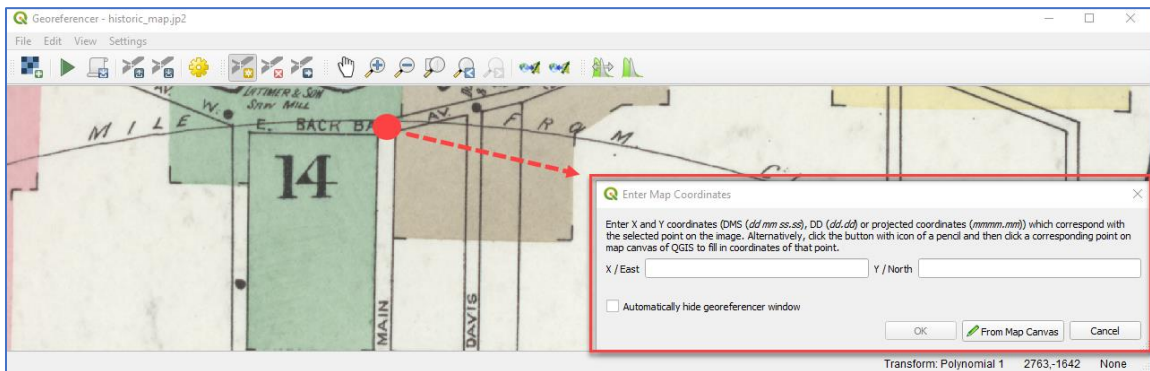
I. On the *Enter Map Coordinates* window, click the *From Map Canvas* option, and select the same street corner on the OSM basemap.

J. Once the GCP is collected the coordinates from the georeferenced dataset will automatically appear in the *Enter Map Coordinates* window.

Enter Map Coordinates

Enter X and Y coordinates (DMS (*dd mm ss.ss*), DD (*dd.dd*) or projected coordinates (*mmmm.mm*)) which correspond with the selected point on the image. Alternatively, click the button with icon of a pencil and then click a corresponding point on map canvas of QGIS to fill in coordinates of that point.

X / East: -9894730.39385947771370411   Y / North: 3556480.36222676280885935

☐ Automatically hide georeferencer window

[OK]   [✏ From Map Canvas]   [Cancel]

K. When you click OK the GCP will be created and displayed in the GCP table. The X,Y coordinates for the source and destination datasets will be listed.

GCP table

| Visible	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)	Residual (pixels)
✔	0	3414.11	-1517.04	-9.89473e+06	3.55648e+06	0	0	0

L. In addition to listing the source and destination coordinates in the GCP table, the control point is marked on the source map with a small red marker. Verify that you can see this point on your basemap and that it is in a proper location.
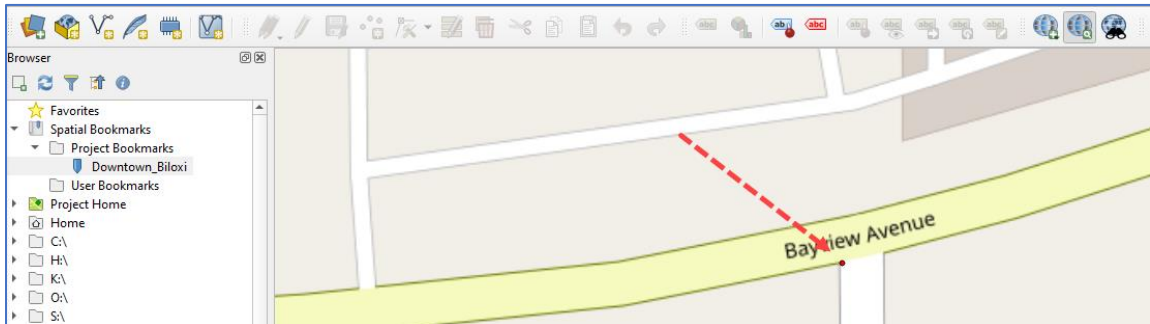

M. Repeat this process for the other two locations, as indicated in Step 2G. Start with the corner of Oak Street and Howard Avenue, and next move on to Seal Avenue and West Howard. Remember, you can always use the project bookmark to return to the original downtown Biloxi extent on the OSM basemap. At first, it may be counterintuitive to work in two separate windows on the same task, but after you collect the first few points the process should become easier.

N. After you successfully collect three points, your table should look similar to the one shown below. Note that your coordinates and residual errors might be slightly different.

GCP table

Visible	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)	Residual (pixels)
✔	0	3414.11	-1517.04	-9.89473e+06	3.55648e+06	0	4.54747e-13	4.54747e-13
✔	1	6150.36	-4247.89	-9.89271e+06	3.5545e+06	0	0	0
✔	2	1552.84	-3828.64	-9.89599e+06	3.55478e+06	-2.27374e-13	1.36424e-12	1.38306e-12

O. For practice purposes, you are welcome to collect a few additional points. In fact, typically more than three points are collected to ensure good image registration quality. However, for the purpose of this tutorial you can successfully georeference a raster dataset using just three points.

P. If you make a mistake, you can easily delete erroneous GCPs. To delete a pair of GCPs, select the *Delete GCP* tool and click on the point to be deleted. Alternatively, in a *GCP table* click on one of the cells for the GCP you want to delete, and then right-click and select remove.

Q. When you are satisfied with the GCPs placement, select the green arrow on the *Georeferencer* toolbar to *Start Georeferencing*.
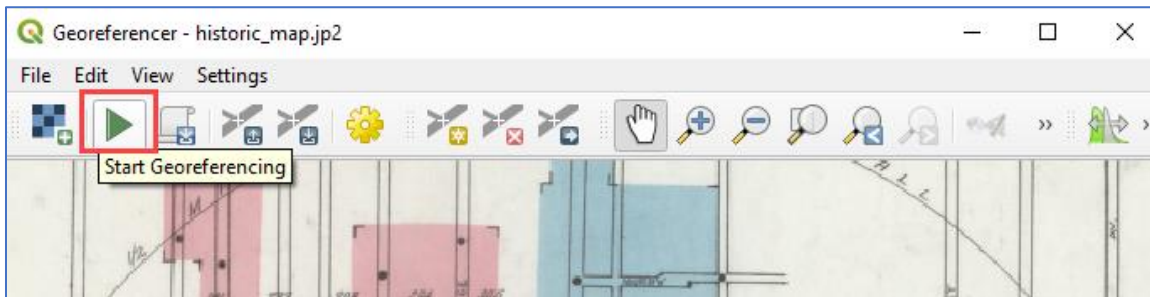
R. If done correctly, this process should not take long to complete. As shown in the figure below, the georeferenced historic map will be automatically added to your project window, and this time will be placed in the correct geographic space.
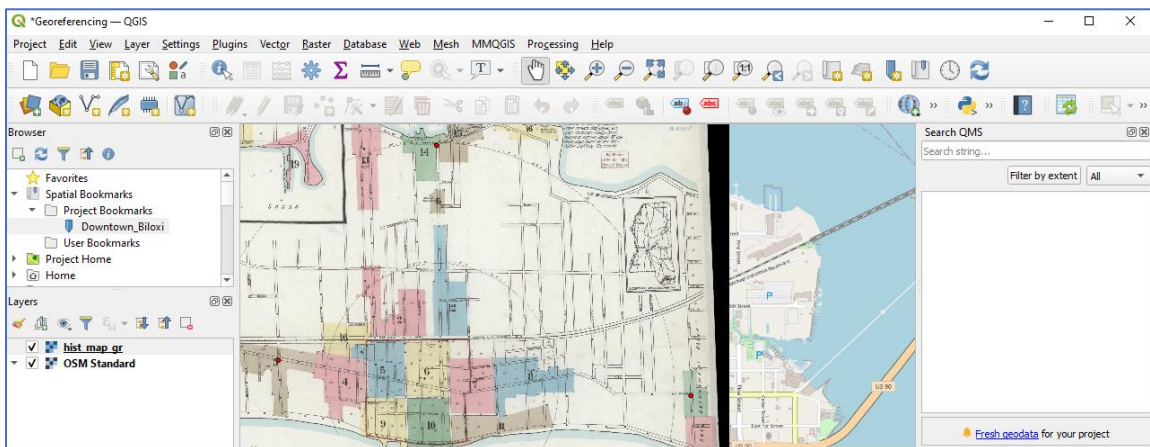
S. You can zoom in and out to examine how well the historic map overlaps with the current OSM basemap. You can also change transparency of the layer to verify how the interior sections of the map are matching or how much the road network has changed over time.

T. If you are satisfied with the georeferencing, close the *Georeferencer* window. When prompted to save the GCP table, click *Yes*. A file with the same name as the scanned historic map will be created, with the word 'points' appended to the file name.

This concludes our GEO Tutorial. The historic fire insurance map of Biloxi has been successfully georeferenced. If you would like to improve the registration accuracy of the destination map, you have an option to generate additional control points. Make sure to distribute your control points

evenly throughout the historic map and avoid concentrating them in a single location. A valid approach is to start by creating four points, one at each map corner, and if the registration is still poor, add several more points, uniformly distributed within the interior portion of the destination map.