Intergovernmental Oceanographic Commission

Manual and Guides

82

PREPARING FOR COMMUNITY TSUNAMI EVACUATIONS

From Inundation to Evacuation Maps, Response Plans, and Exercises

SUPPLEMENT 2

February 2023 Draft Revision

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INTRODUCTION AND USE OF QGIS (I)

A. Introduction

This manual and practical tutorial describes the process of creating tsunami inundation maps using a geographic information system (GIS), specifically QGIS. The tsunami inundation model results used in this manual are based on data from the Cedeño, Honduras model, produced by the MOST numerical model (ComMIT interface). The original version of the manual (Spanish and English) was prepared in Spanish by Engineer Carlos Rodriguez as part of TEMPP – Honduras, Central America Pilot (2015 – 2017). In 2017 and 2018 TEMPP training was conducted in the Indian Ocean, organized by the ICG/IOTWMS and the Indian Ocean Tsunami Information Center (IOTIC), and the English manual was updated. In 2018 and 2019, the manual was used as an evacuation mapping learning activity within the ITIC Training Program (ITP) in Chile (2018) and in Hawaii (2019), and further updates were made to account for the new tools from Version 3.8.2 “Zanzibar”. In 2021, the manual was updated by Jenna Kent from the Honolulu, Hawaii International Tsunami Information Center (ITIC) to reflect the QGIS version 3.20.2 “Odense”. In 2023, the manual was updated by Desireé Bayouth García from the Mayaguez, Puerto Rico International Tsunami Information Center Caribbean Office (ITIC-CAR). The 2023 manual update aims to provide an overview of the workflow for preparing tsunami evacuation maps using QGIS regardless of the software version, with included examples prepared using the QGIS version 3.26.0 “Buenos Aires”.

B. Introduction to QGIS

Quantum GIS (QGIS) is a free and open-source cross-platform desktop geographic information system application that supports viewing, editing, and analyzing geospatial data. The project was initially released in July 2002 with the initial objective of providing a GIS data viewer. QGIS has reached a point in its evolution where it is being used by both individuals and corporations to meet their daily needs for viewing, analyzing, and managing GIS data. QGIS provides a growing range of skills through basic and complementary roles. Users can view, manage, edit, analyze data, and design maps that can be printed in different formats. QGIS is written in C++, Python, and Qt. It runs on Microsoft Windows, Linux, MacOS, and Android platforms.

C. System/Hardware requirements and installation

New versions of QGIS are released regularly. If using the software please review the minimum and recommended system requirements for the current version, most stable version, or other version of interest on the page Download QGIS for your platform.

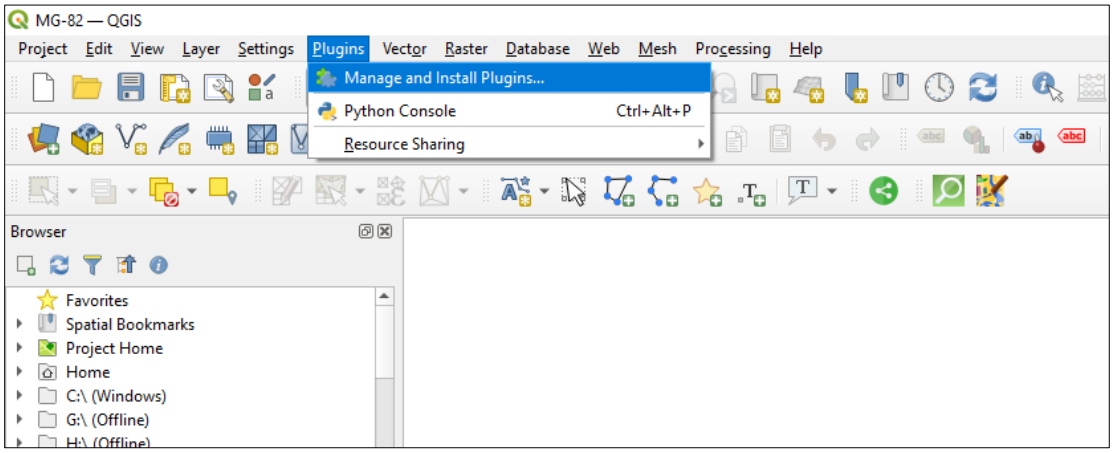
D. Plugin installation

QGIS Plugins recommended to develop Tsunami Evacuation Maps:

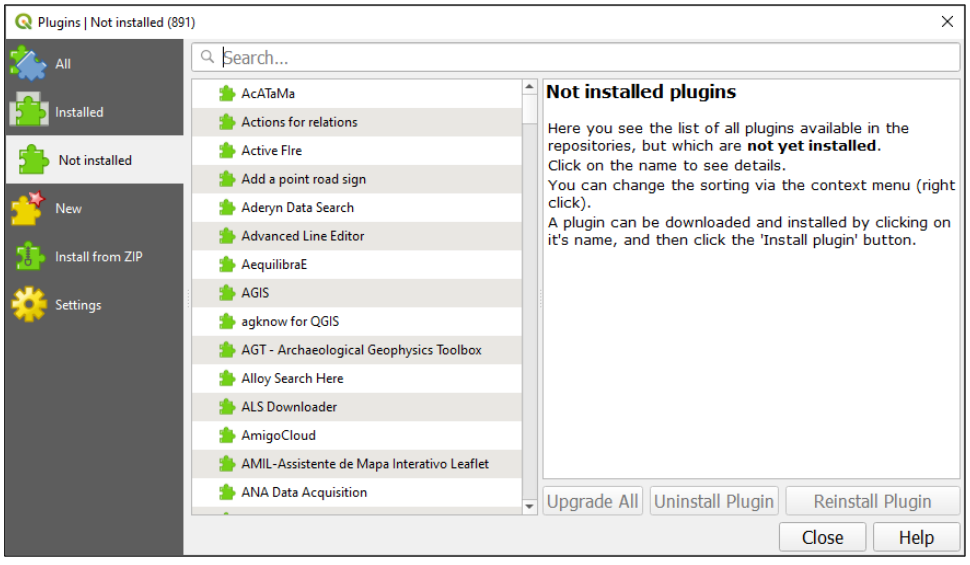
- QuickMapServices: Facilitates users to add the web map services from Google Maps, OSM, NASA, etc.
- QuickOSM: Executes QGIS specific queries for information from Open Street Maps (OSM data).
- QGIS Resource Sharing: Downloads the database for UNOCHA Humanitarian Icons, which can be used to prepare standardized tsunami evacuation maps.
- Heightmap Export: Prepares and exports a 16-bit PNG image from DEM data.

Objective. Install the Plugins required to develop Tsunami Evacuation Maps.

QGIS Step 1. In the QGIS Menu Bar click *Plugins* > *Manage and Install Plugins…*



QGIS Step 2. In the Plugin dialog window select Not installed. Type the name of the plugin of interest, select it and click the lower right button that says Install Plugin. Follow this step for the rest of the required plugins.

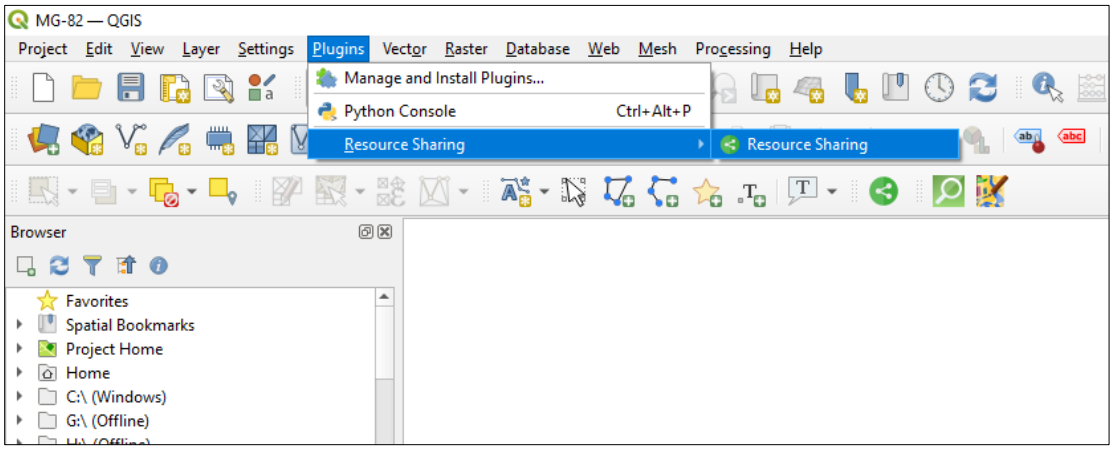


E. OCHA icons and fonts installation

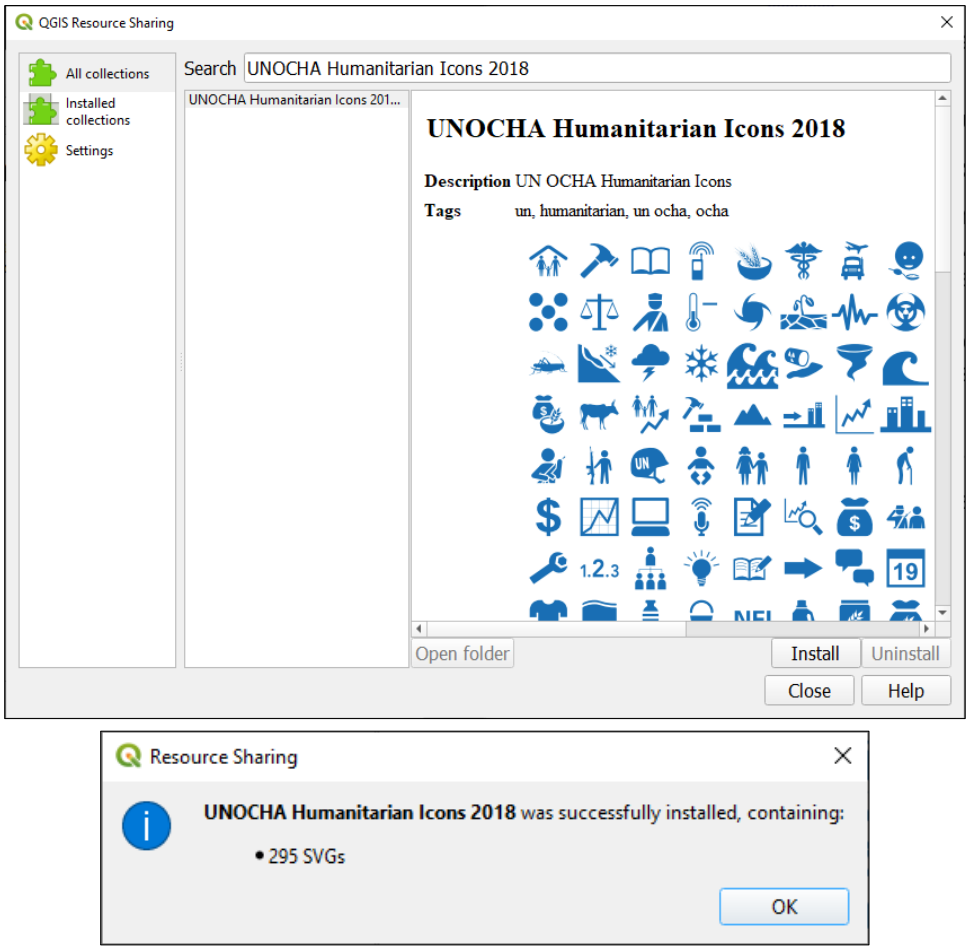
The United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) created standardized icons and fonts in various GIS ready formats for ESRI (ArcMap and ArcGIS Pro) and QGIS. Creating evacuation maps using simple and universally recognized symbols is essential to the maps' success in saving lives and reducing tsunami impacts. For this reason, we recommend using only the UNOCHA icons and fonts for evacuation maps. These can be installed using the QGIS Resource Sharing plugin previously installed.

Objective. Install the OCHA icons and fonts to develop standardized tsunami evacuation maps.

QGIS Step 1. After installing the QGIS Resource Sharing plugin select *Plugins* > *Resource Sharing* > *Resource Sharing* in the QGIS Menu Bar.



QGIS Step 2. Once the QGIS Resource Sharing Window is open search for the collection UNOCHA Humanitarian Icons 2018 and click the lower right button that says install. A window indicating that the installation is complete will be displayed.

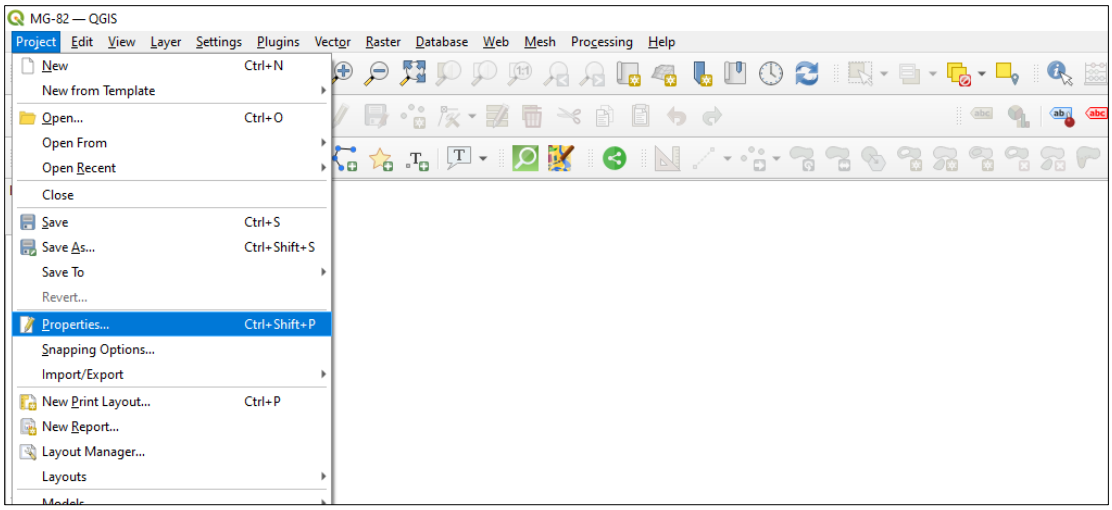


F. Selection of the project's coordinate system

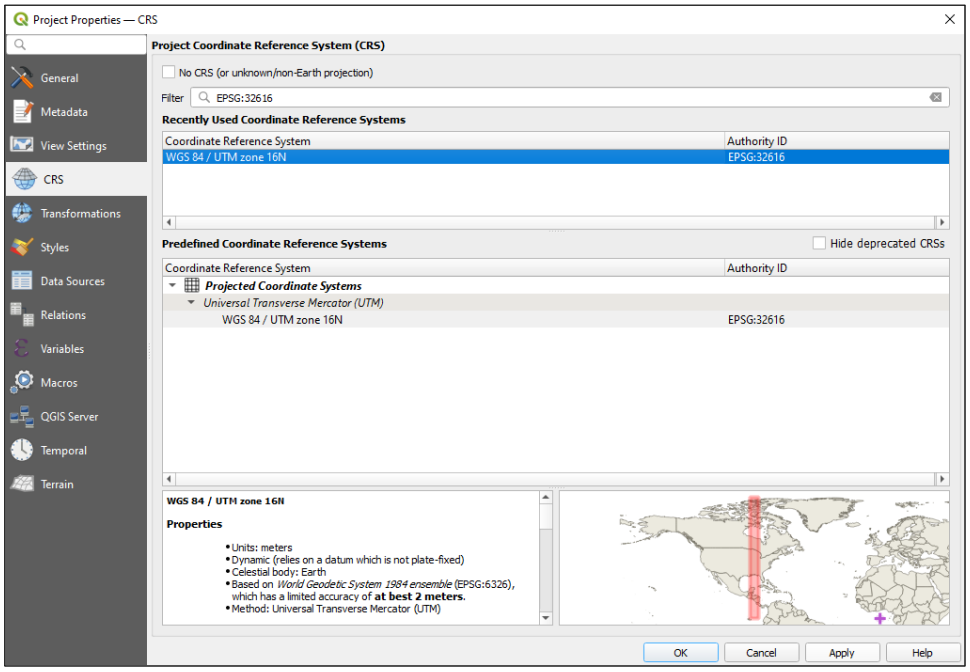
Before importing the data to use for developing tsunami evacuation maps select the area of interest's coordinate system.

Objective. Select the coordinate system of the country or region for which the tsunami evacuation map will be developed.

QGIS Step 1. In the QGIS Menu Bar click *Project* > *Properties…*



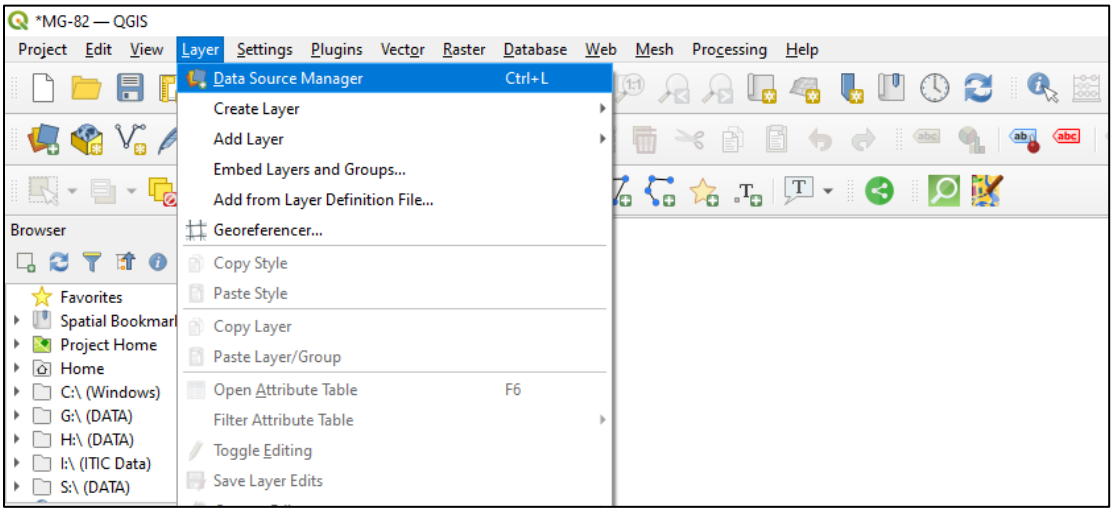
QGIS Step 2. In the Project Properties dialog window select CRS. In the Filter section type the name of the Coordinate Reference System (CRS) corresponding to the country or region of interest, select it, click Apply and OK. For this manual example based on the Cedeño, Honduras model the selected CRS is WGS 84 / UTM zone 16 N and the Authority ID is EPSG:32616.



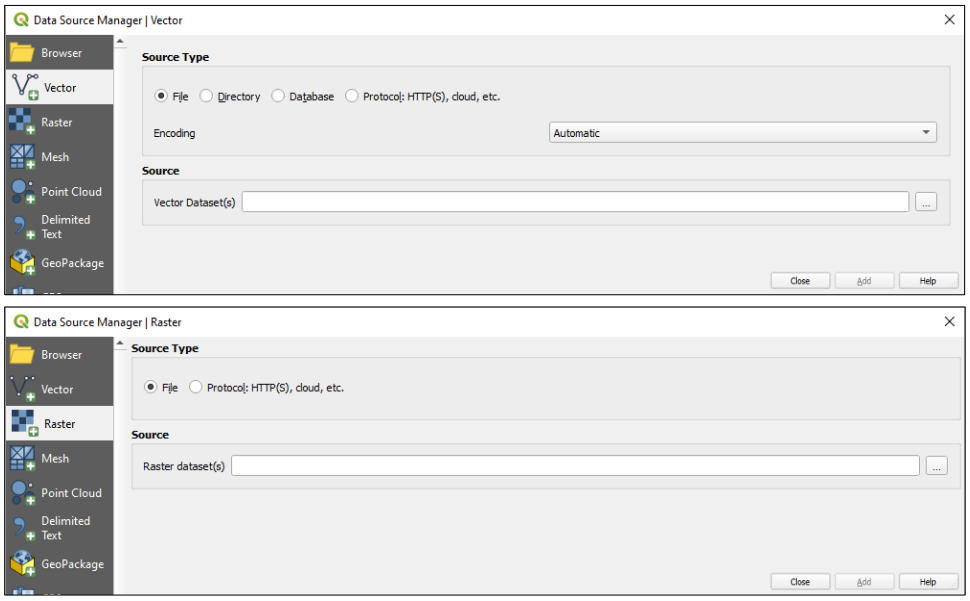
G. Addition of vector and raster data layers (basics to know during the map preparation)
Raster and vector datasets provide information of the area of interest and are used in GIS software for developing tsunami inundation maps.

Objective. Import raster and vector datasets.

QGIS Step 1. In the QGIS Menu Bar click *Layer* > *Data Source Manager*.



QGIS Step 2. In the Data Source Manager dialog window select Vector or Raster. If importing a vector dataset, select Vector and browse for the Vector dataset of interest and click Add. If importing a raster, select Raster and browse for the Raster dataset of interest (*.tif) and click Add.

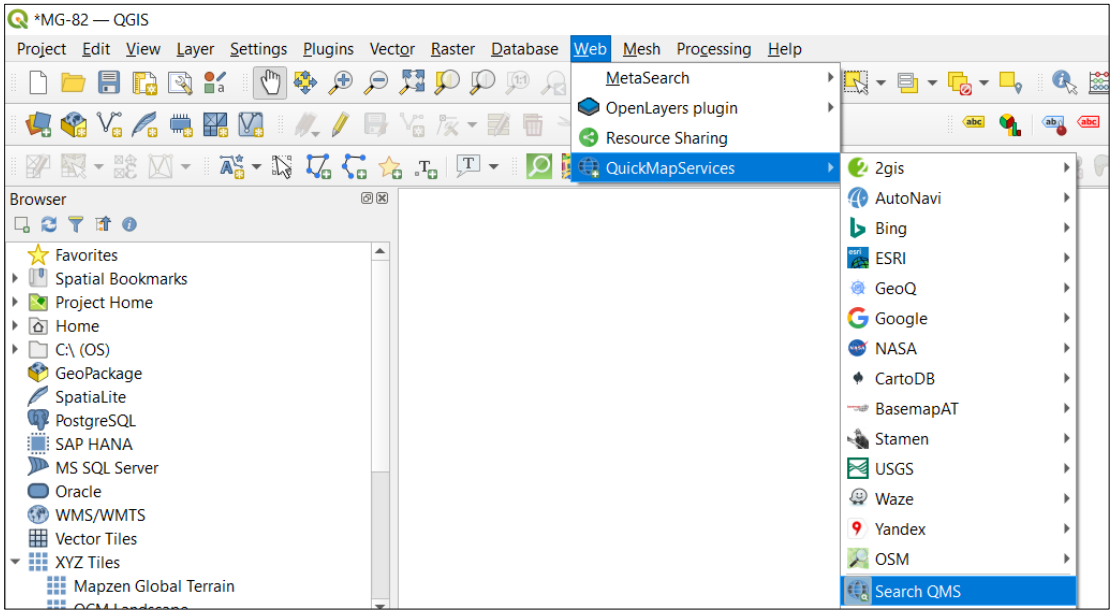


H. Addition of satellite imagery (basemaps) using the QMS plugin.

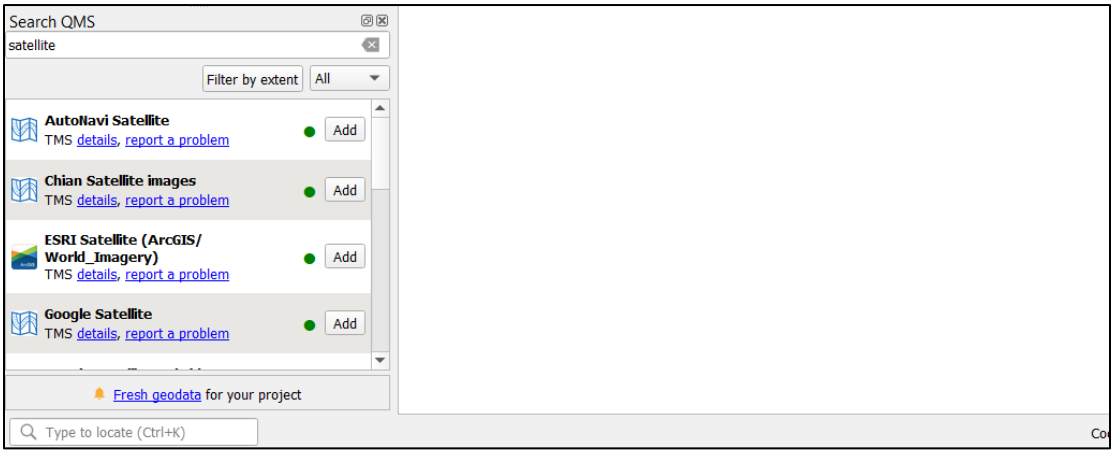
Satellite imagery provides reference of the area of interest and is used in GIS software for developing tsunami inundation maps.

Objective. Import basemaps.

QGIS Step 1. Ensure that the QuickMapServices plugin is installed. In the QGIS Menu Bar click *Web* > *QuickMapServices* > *Search QMS*.



QGIS Step 2. In the Search QMS window added to the project type keywords associated to basemaps of interest and results will list services associated. Click Add and the selection will be included in the Layers panel. For this manual example based on the Cedeño, Honduras model, “satellite” was typed to obtain a list of associated services and ESRI Satellite (ArcGIS/World_Imagery) was selected.



FINALIZING INUNDATION LAYERS USING QGIS (II)

This manual section covers the use of QGIS to finalize the development of a tsunami inundation layer based on a numerical modeling output in GeoTIFF raster file format from Community Model Interface for Tsunami (ComMIT). For information and training on ComMIT and its capability for exporting tsunami model runs in multiple formats visit the NOAA Center for Tsunami Research ComMIT webpage.

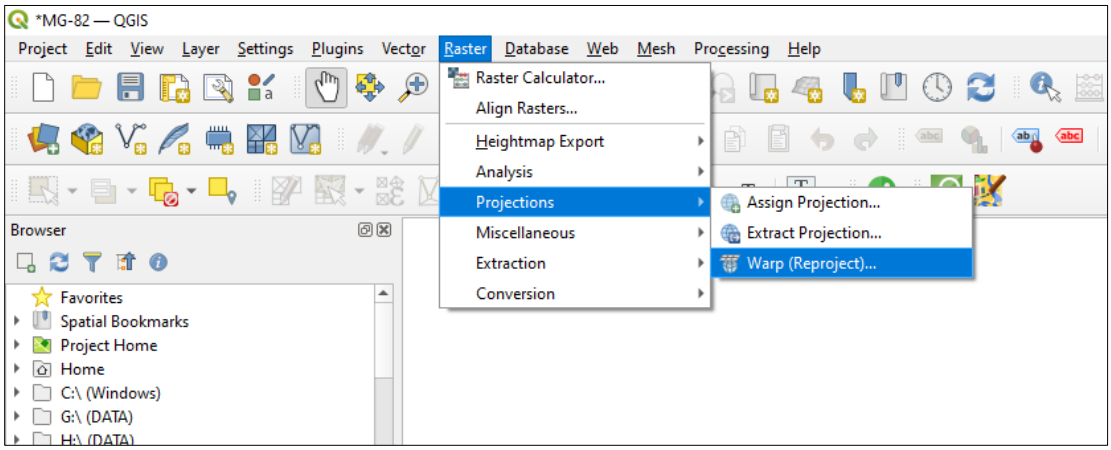
A. Preparation of the final tsunami inundation extent layer

Objective. After selecting a coordinate system projection in the GIS software of interest, import the tsunami inundation modeling results (raster) to your project.

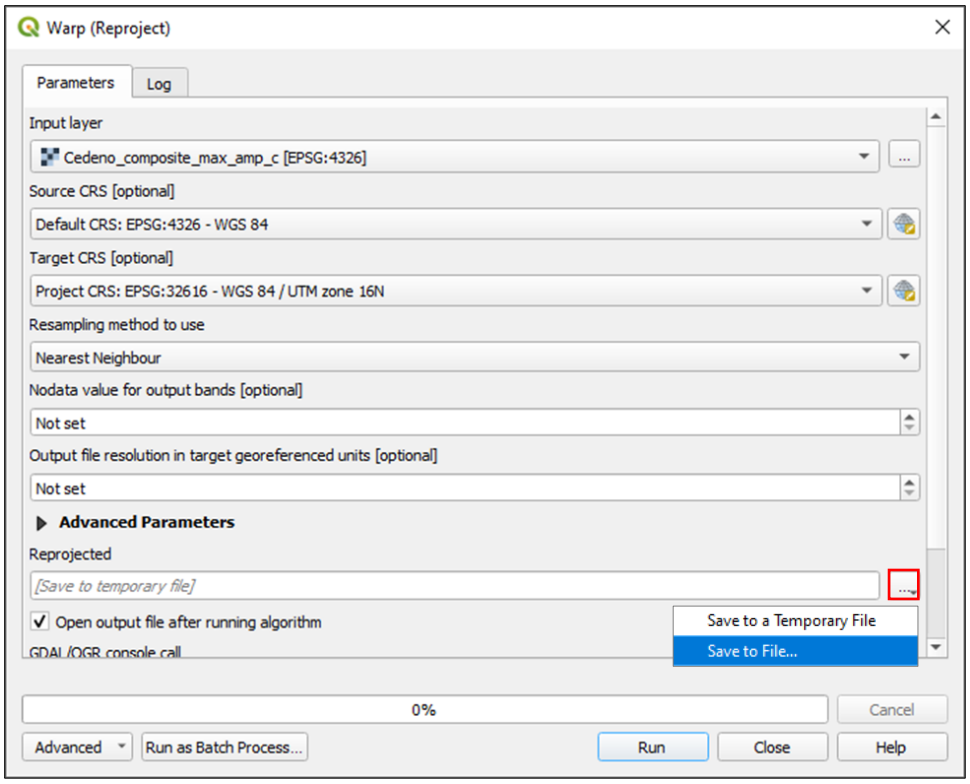
QGIS Step 1. Add the .tif raster layer, exported from ComMIT, to QGIS.

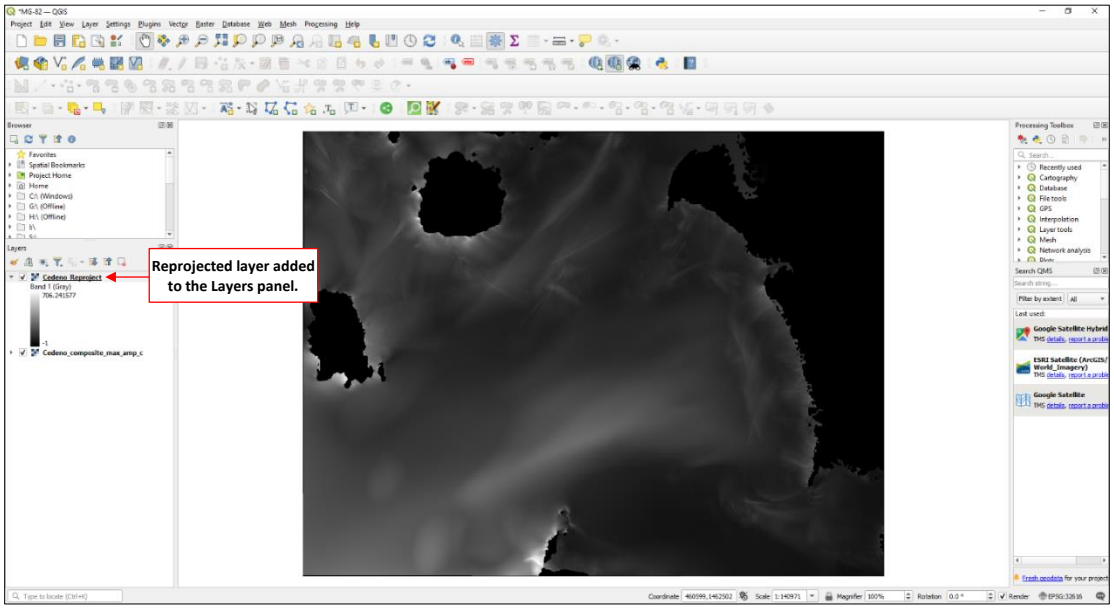
Objective. Reproject the tsunami inundation raster layer to the project's coordinate system.

QGIS Step 1. In the QGIS Menu Bar click *Raster > Projections > Warp (Reproject)…*



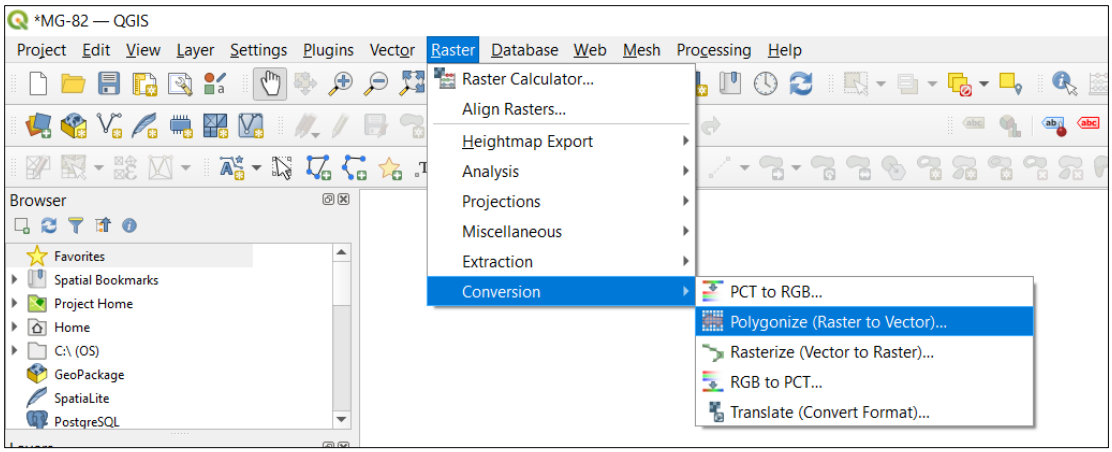
QGIS Step 2. In the Warp (Reproject) dialog window search the Input layer to reproject, specify the Target CRS, and select Save to File… in Reprojected. After specifying the parameters of interest and the location to save the file to be reprojected click Run. The reprojected raster will be added to the Layers panel and Map View.



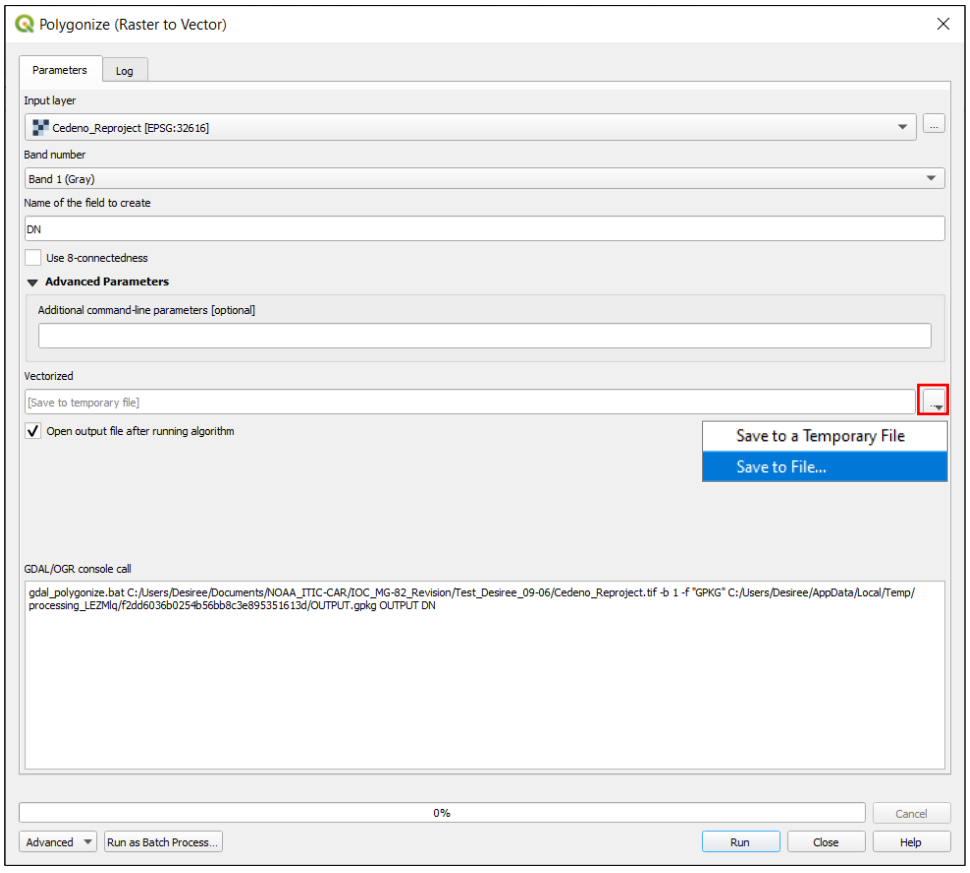


Objective. Convert the reprojected raster to a polygon vector layer. This conversion will allow for the inundation layer to be easily used and manipulated during the layer generation and editing and evacuation map design process.

QGIS Step 1. In the QGIS Menu Bar click *Raster* > *Conversion* > *Polygonize (Raster to Vector)…*



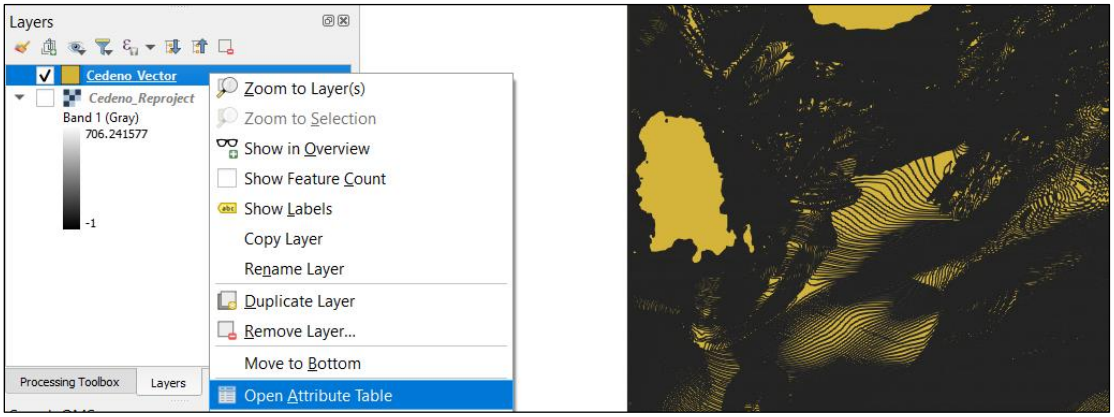
QGIS Step 2. In the Polygonize (Raster to Vector) dialog window search the Input layer to vectorize, and select Save to File… in Vectorized. After specifying the parameters of interest and the location to save the file to be vectorized click Run. The vectorized layer will be added to the Layers panel and Map View.



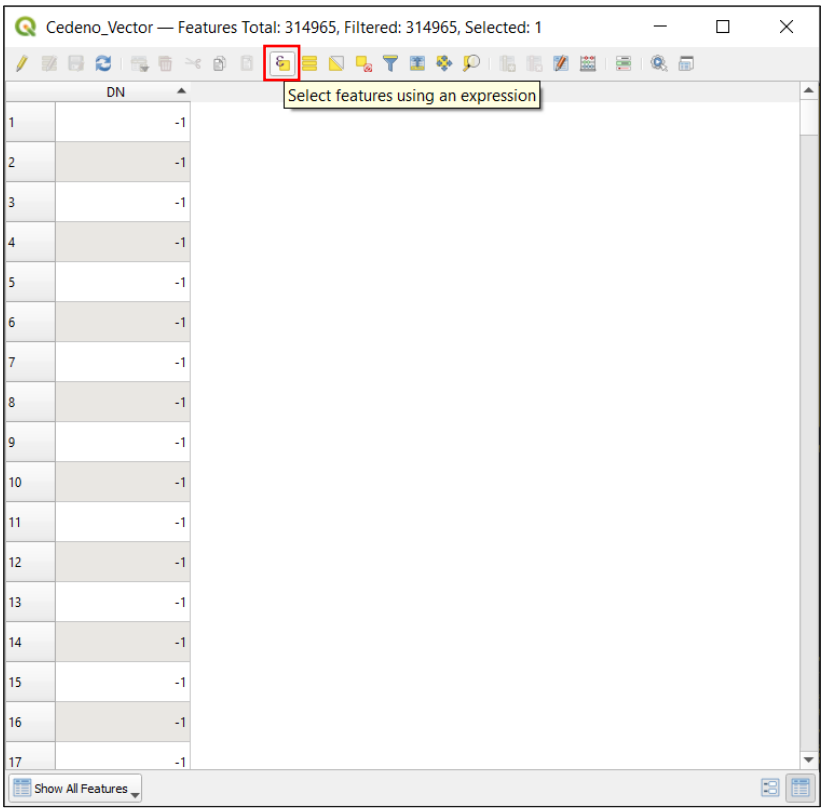
Objective. Use the vectorized layer's attribute table to select the features where the modeling output indicates that a tsunami generated flooding. Once these features are selected, export or save them as a new vector layer. This selection will allow for the final

layers to be used in the evacuation map design process to only display the inundation extent data.

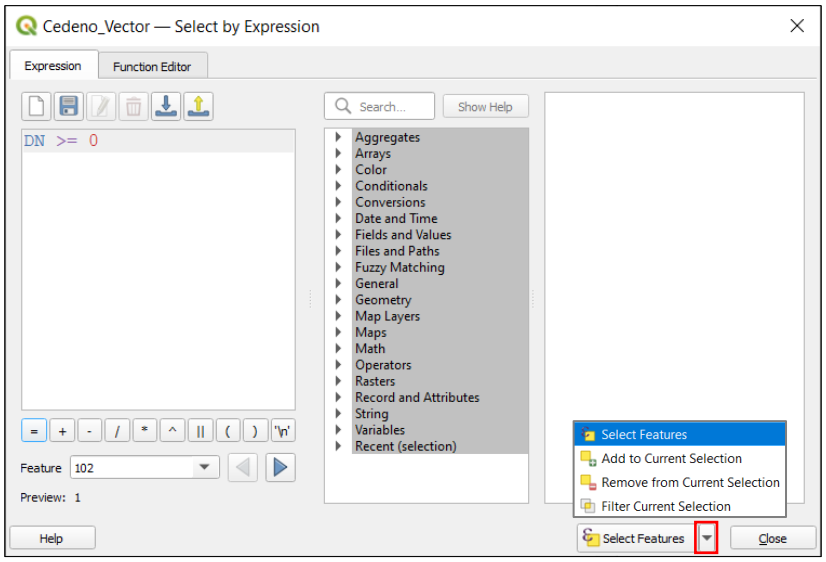
QGIS Step 1. Right click on the polygon (output of QGIS step 3) and click Open Attribute Table.

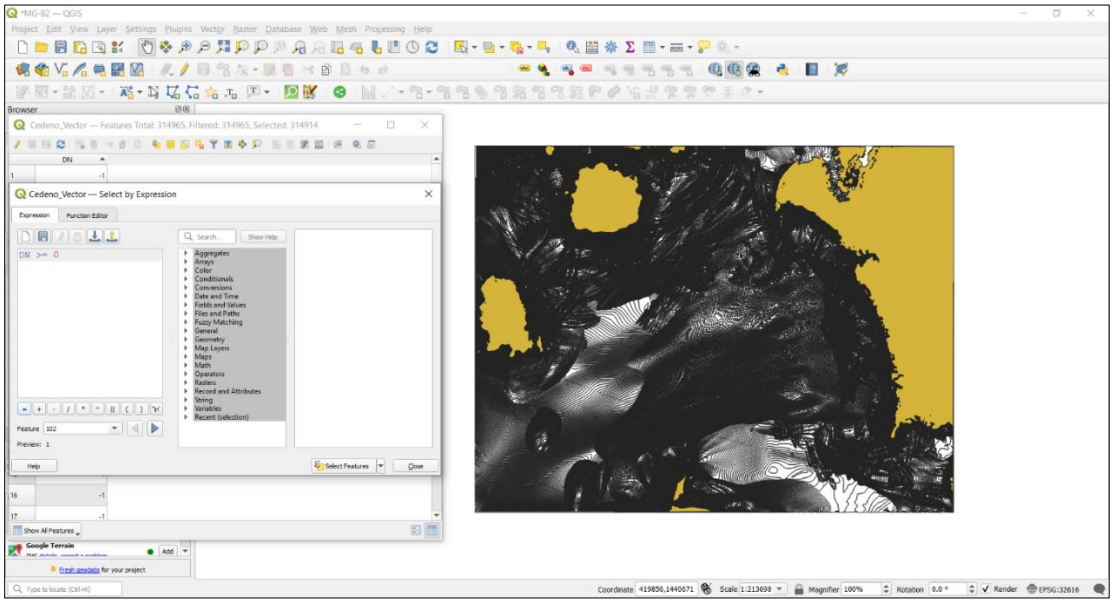


QGIS Step 2. Click Select features using an expression in the Attribute Table.

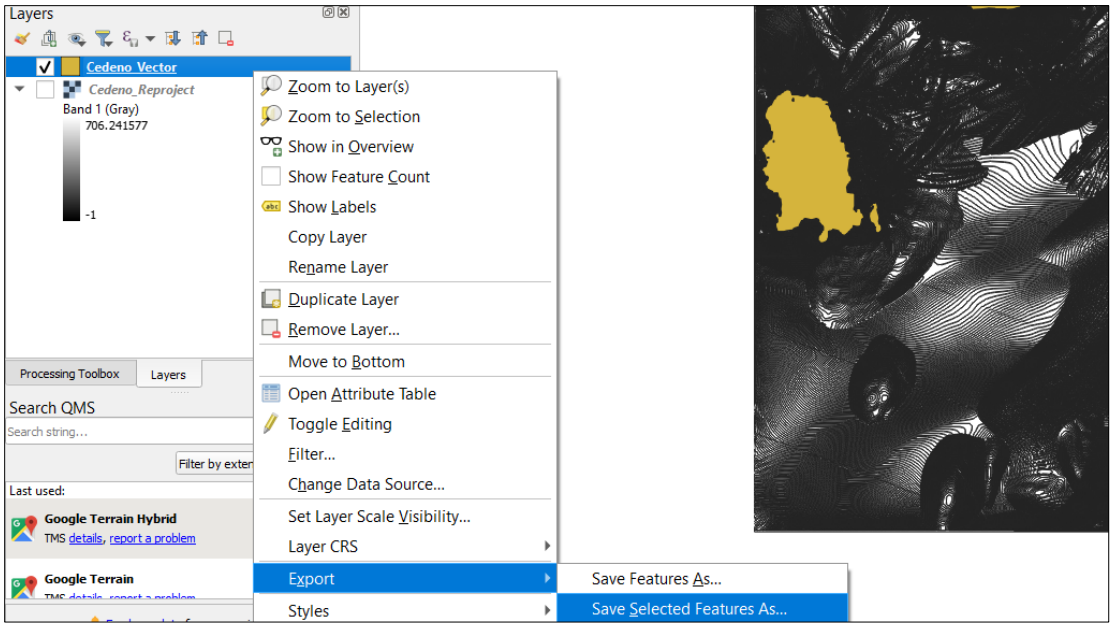


QGIS Step 3. In the blank query space type “DN >= 0” and click Select Features. All the features with a value greater than or equal to zero in the vectorized layer’s DN column will be selected. The total amount of selected features will be indicated in the Attribute Table dialogue window and visible in Map View.

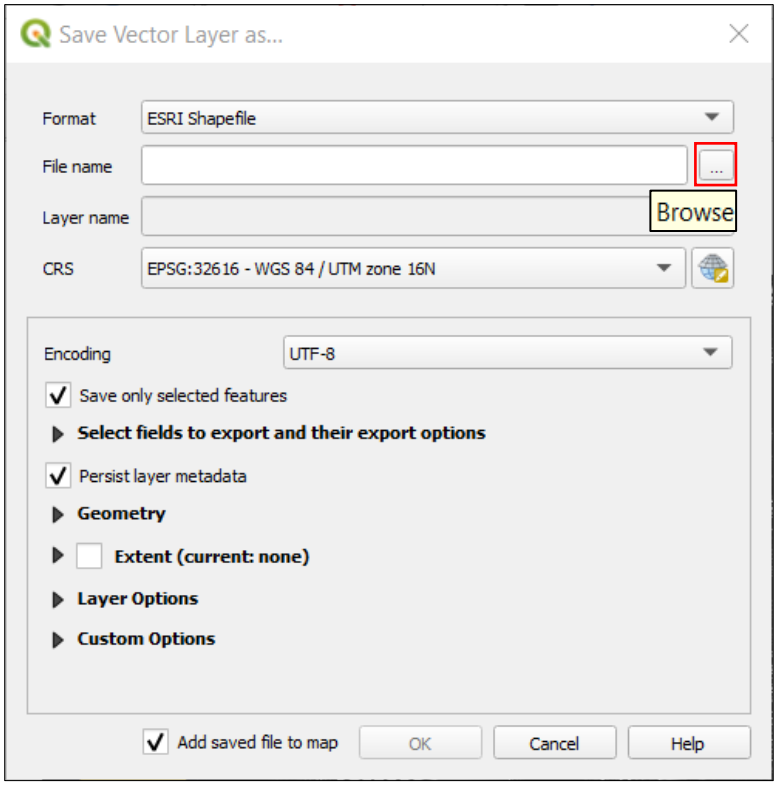




QGIS Step 4. Right click on the polygon (output of QGIS Step 3) and click *Export* > *Save Selected Features As…*

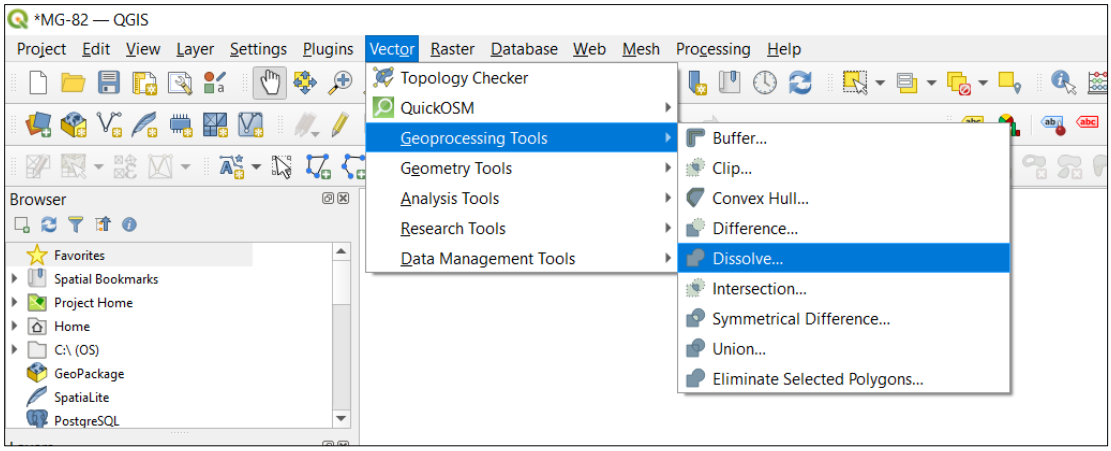


QGIS Step 5. In the Save Vector Layer As… dialogue window click Browse and specify the location to save the file and file name, check the Save only selected features box option, and click OK. The layer containing only the selected features will be added to the Layers panel and Map View.

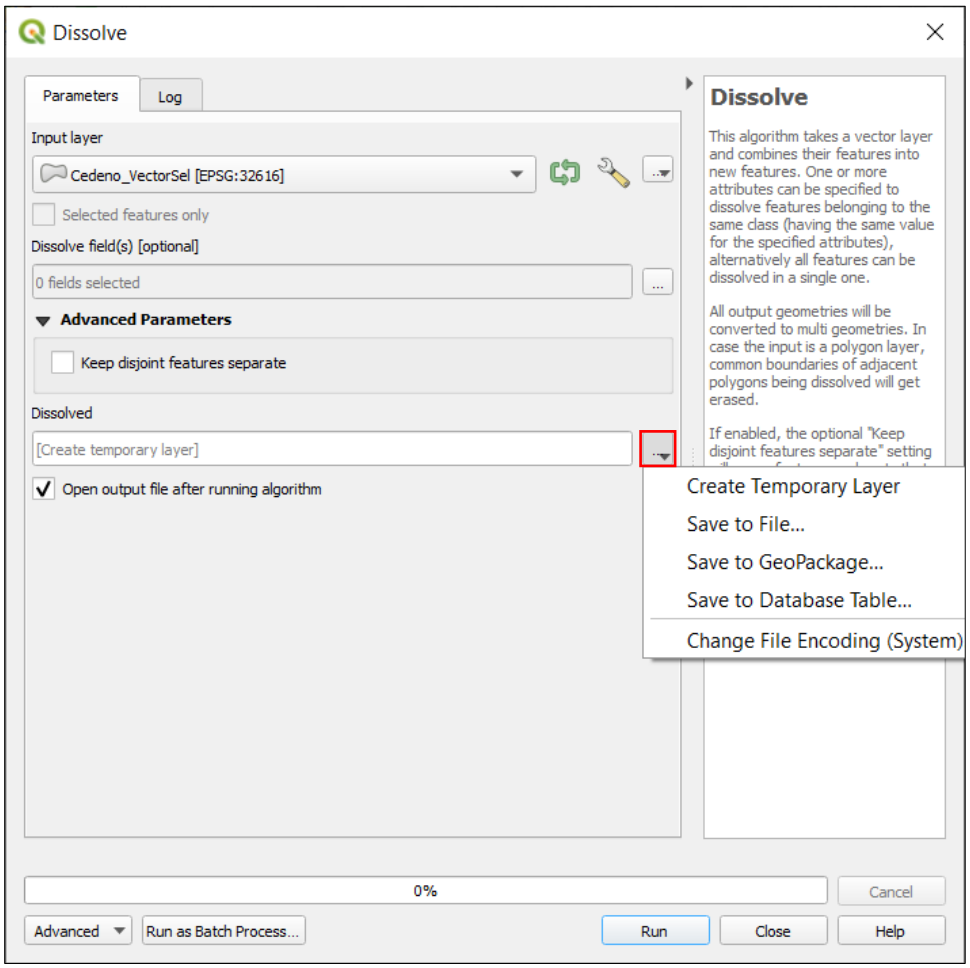


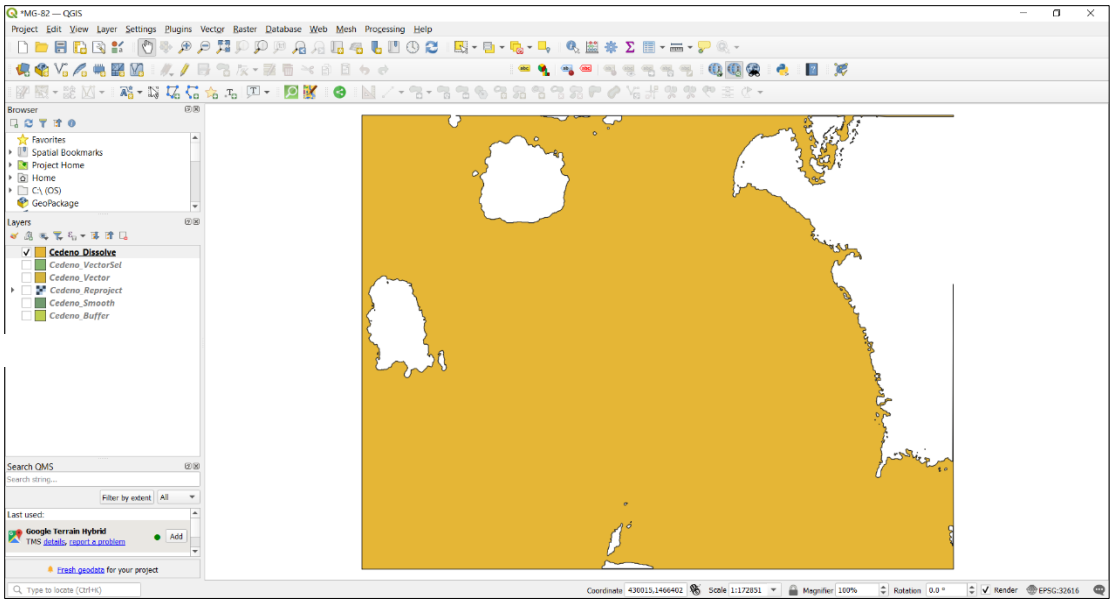
Objective. Merge the multiple polygon features of the previously exported vector layer into a single polygon feature.

QGIS Step 1. In the QGIS Menu Bar click *Vector* > *Geoprocessing Tools* > *Dissolve…*



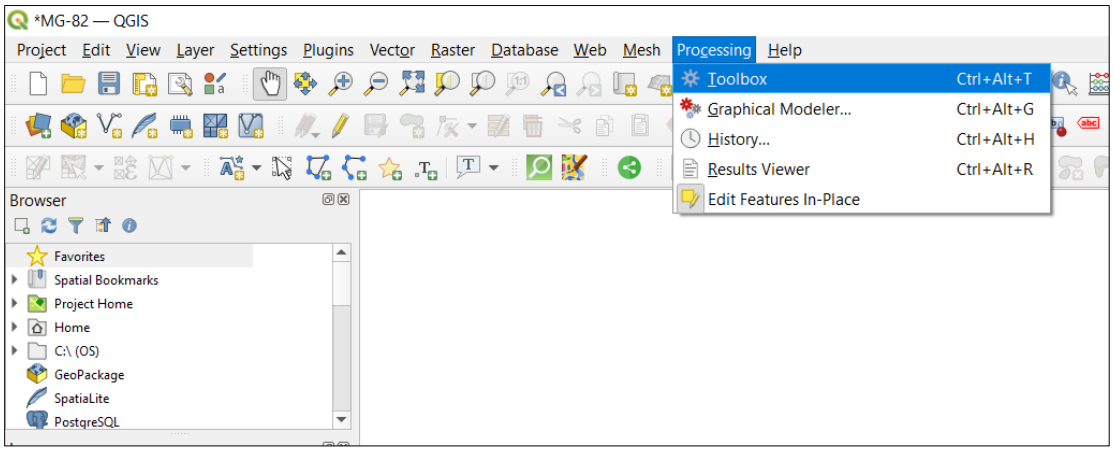
QGIS Step 2. In the Dissolve… dialog window search for the Input layer to dissolve, select Save to File… in Dissolved, and click Run. The dissolved layer will be added to the Layers panel and Map View.

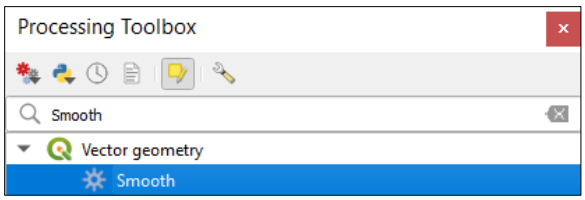




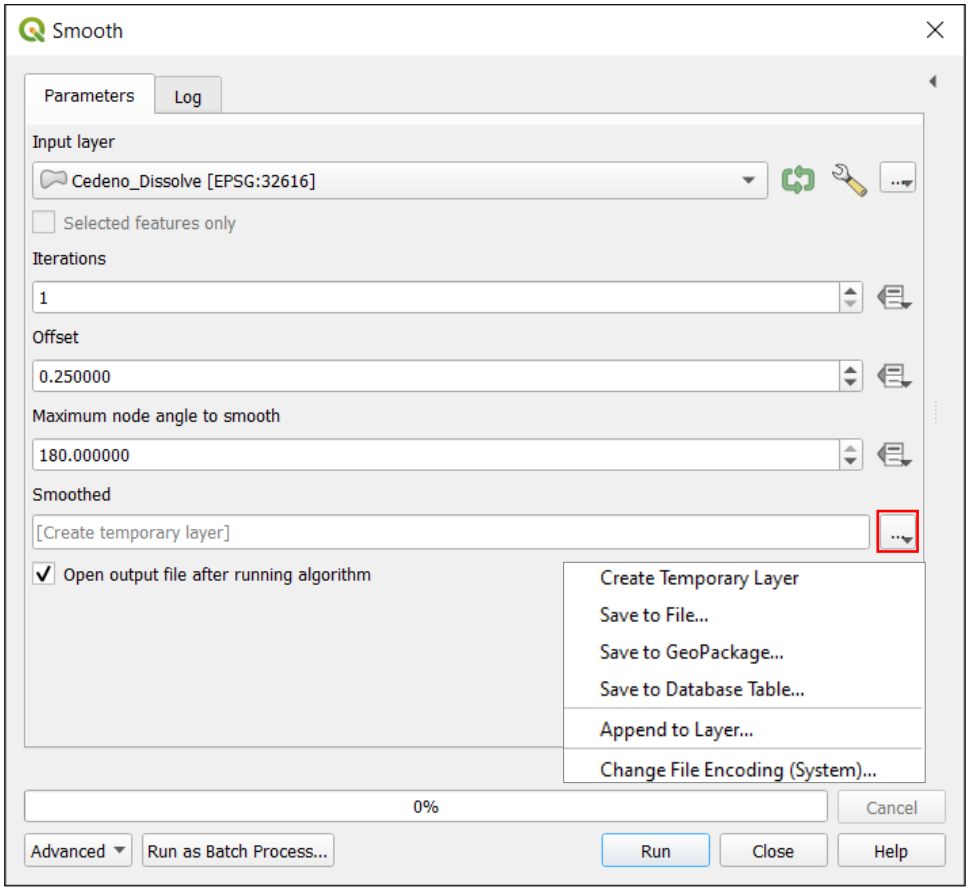
Objective. Modify the dissolved polygon's outline by smoothing the vector to minimize a pixelated or sharp appearance. The automatic vectorization of data can result in a pixelated polygon layer that varies and depends on the resolution of data per region of interest. The output layer from this process will be used for data display/presentation purposes during the evacuation layer generation and evacuation map design process.

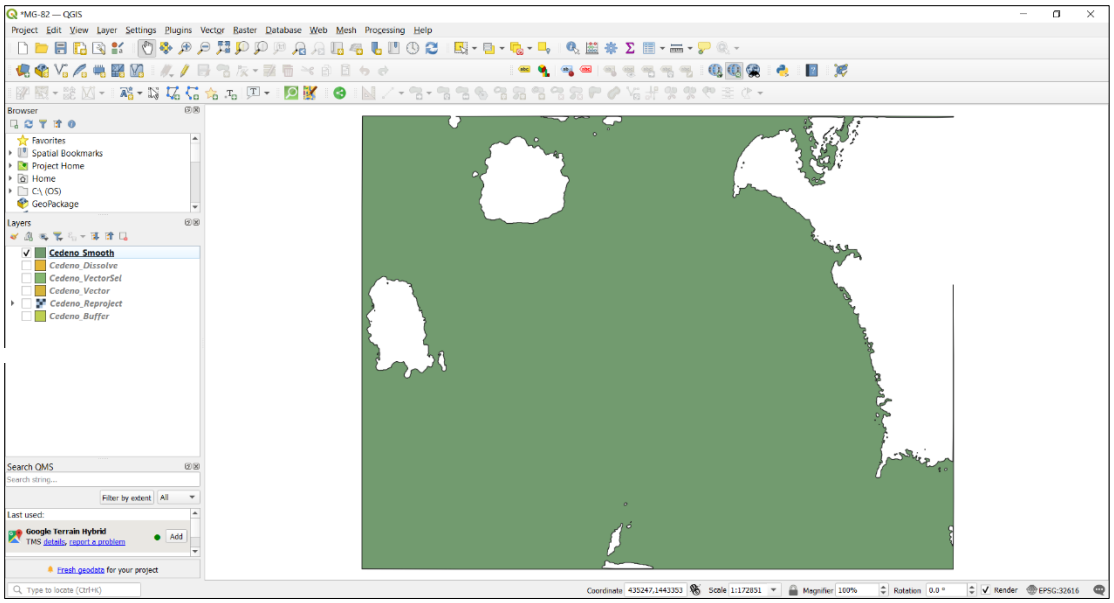
QGIS Step 1. In the QGIS Menu Bar click *Processing* > *Toolbox*, type "Smooth" and select the tool.





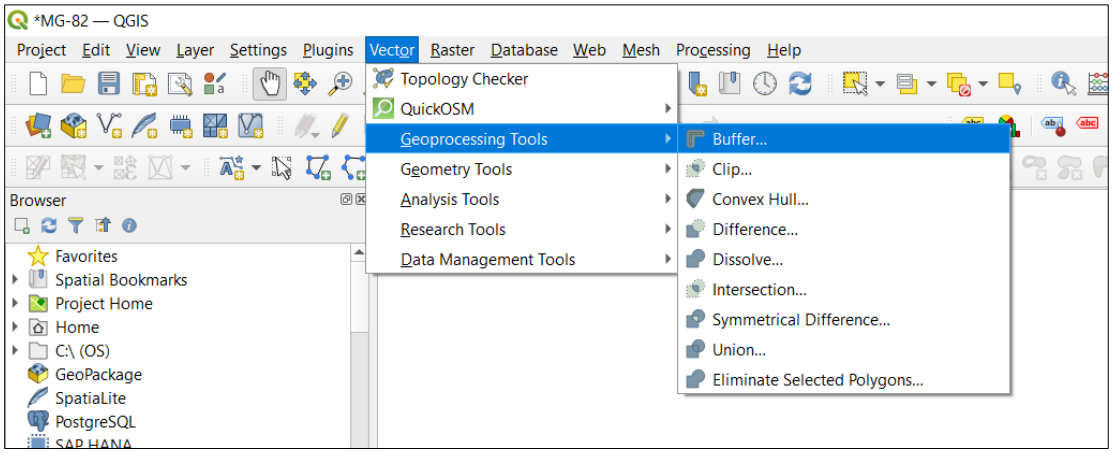
QGIS Step 2. In the Smooth dialog window search for the Input layer to smooth, select Save to File… in Smoothed, and click Run. The smoothed layer will be added to the Layers panel and Map View.



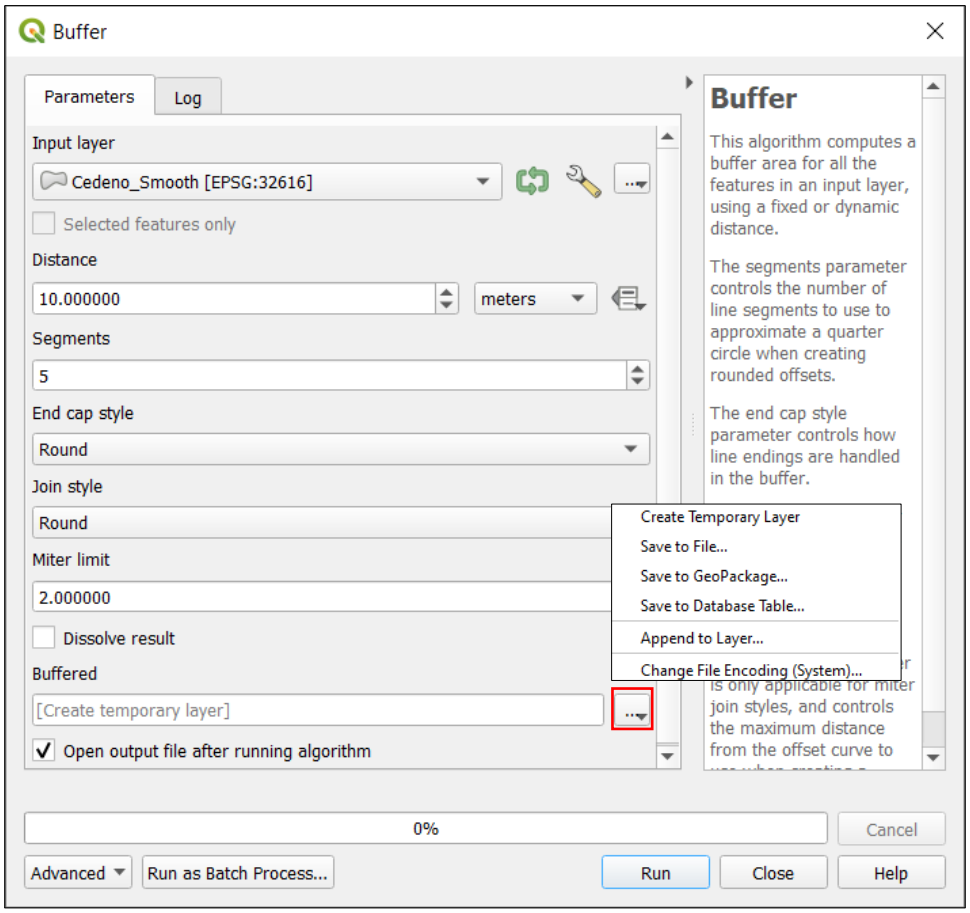


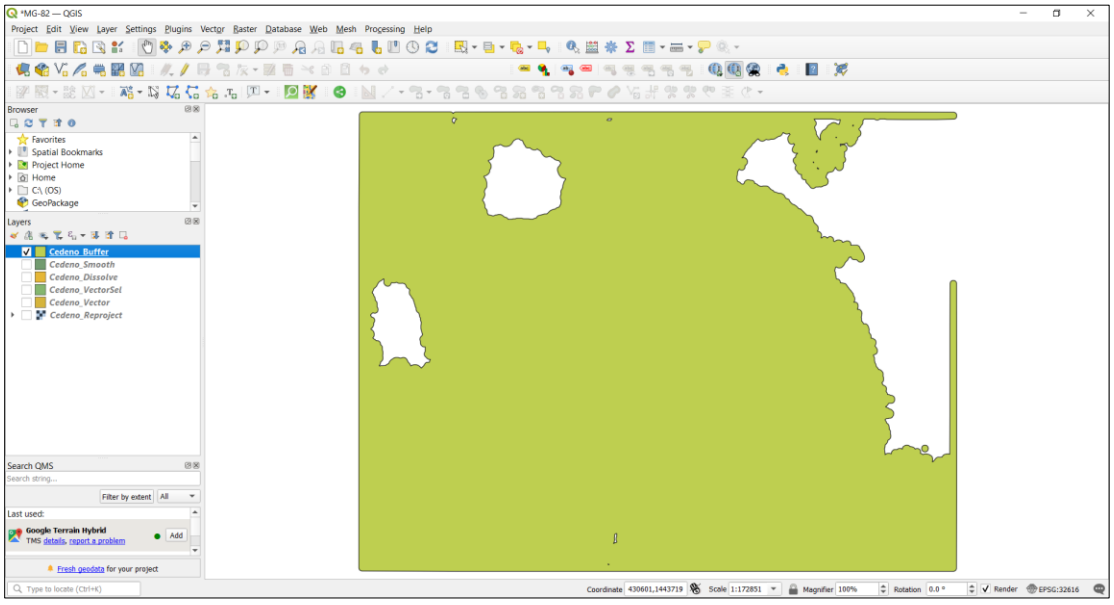
Objective. Add a buffer zone to the smoothed polygon output of the tsunami hazard zone to consider uncertainties of the tsunami modeling. Follow IOC Manuals and Guides 82 Preparing for Community Tsunami Evacuations – From Inundation to Evacuation Maps, Response Plans, and Exercises (MG-82) for details and considerations when selecting buffer zone values. The output layer from this process will be used as the tsunami evacuation layer during the evacuation map design process.

QGIS Step 1. In the QGIS Menu Bar click *Vector* > *Geoprocessing Tools* > *Buffer…*



QGIS Step 2. In the Buffer dialog window search for the Input layer to add a buffer to and select Save to File… in Buffered. After specifying the parameters of interest and the location to save the file to add a buffer to click Run. The buffered layer will be added to the Layers panel and Map View. For this manual example based on the Cedeño, Honduras model, a 10 m buffer zone was added to the tsunami hazard zone.


Buffer
Parameters
Log
Input layer
Cedeno_Smooth [EPSG:32616]
Selected features only
Distance
10.000000
meters
Segments
5
End cap style
Round
Join style
Round
Miter limit
2.000000
Dissolve result
Buffered
[Create temporary layer]
Open output file after running algorithm
Create Temporary Layer
Save to File...
Save to GeoPackage...
Save to Database Table...
Append to Layer...
Change File Encoding (System)...
Buffer
This algorithm computes a buffer area for all the features in an input layer, using a fixed or dynamic distance.
The segments parameter controls the number of line segments to use to approximate a quarter circle when creating rounded offsets.
The end cap style parameter controls how line endings are handled in the buffer.
is only applicable for miter join styles, and controls the maximum distance from the offset curve to
0%
Cancel
Advanced
Run as Batch Process...
Run
Close
Help


Browser
Layers
Cedeno_Buffer
Cedeno_Smooth
Cedeno_Dissolve
Cedeno_VectorSel
Cedeno_Vector
Cedeno_Reproject

DEVELOPING TSUNAMI EVACUATION MAP USING QGIS (III)

This manual section primarily covers the use of QGIS to develop a tsunami evacuation map based on the tsunami inundation layer prepared in section II and datasets of interest. The section also provides a guidance example on the use of UNOCHA symbols in QGIS for the preparation (plugin installed in section I) of maps following standardized symbology.

A. *Datasets required for the development of a tsunami evacuation map*

Objective. Import the datasets required for developing a tsunami evacuation map to your GIS software of interest.

QGIS Step 1. Import the vector and raster datasets.

1. Georeferenced imagery - The imagery is a key element for the development of the map and must be as recent as much of the georeferenced information that is displayed on the map. It also serves a basis for better decision making when making complex editing and identifying highly sensitive or more vulnerable and fragile areas.
2. Digital Terrain Model – Can be a grid text as an image with elevation attributes. This layer allows adding a suitable color ramp along vulnerable coastal areas.
3. Tsunami inundation vector layer – This polygon layer is vital to the development of the evacuation area as it defines the flood zone and gathers topographic elements, road systems, and other natural elements easily recognized by the community to design and refine the tsunami evacuation zone. Typically, the evacuation zone is not wider than +/- 30% of the flood zone limits.
4. Tsunami evacuation vector layer – This polygon layer is the recommended evacuation area and vulnerable area prepared for the community of interest. This zone is designed by the map developer based on the tsunami modeling outputs and vector layer and is openly discussed with the community.
5. Road network vector layer – This polyline layer is vital for determining evacuation routes to be displayed on the evacuation map. Most communities are familiar with the road systems in the area and often can recommend the best options for evacuation routes using public roads or other routes.
6. Water bodies vector layer – Polygon layers that display mangroves, lakes, or ponds, and other low lying areas where water may be present are important to consider when determining evacuation routes. Typically, in water affluent areas there are bridges that should be inspected to determine if they are at risk of collapse or if there is critical structural failure. Water bodies are a critical factor because they contain a large volume of water.
7. Infrastructure vector layer – The specific elements on the map known as landmarks or benchmarks are places easily recognized by the general population. They provide effective location awareness to make critical decisions in a relatively short

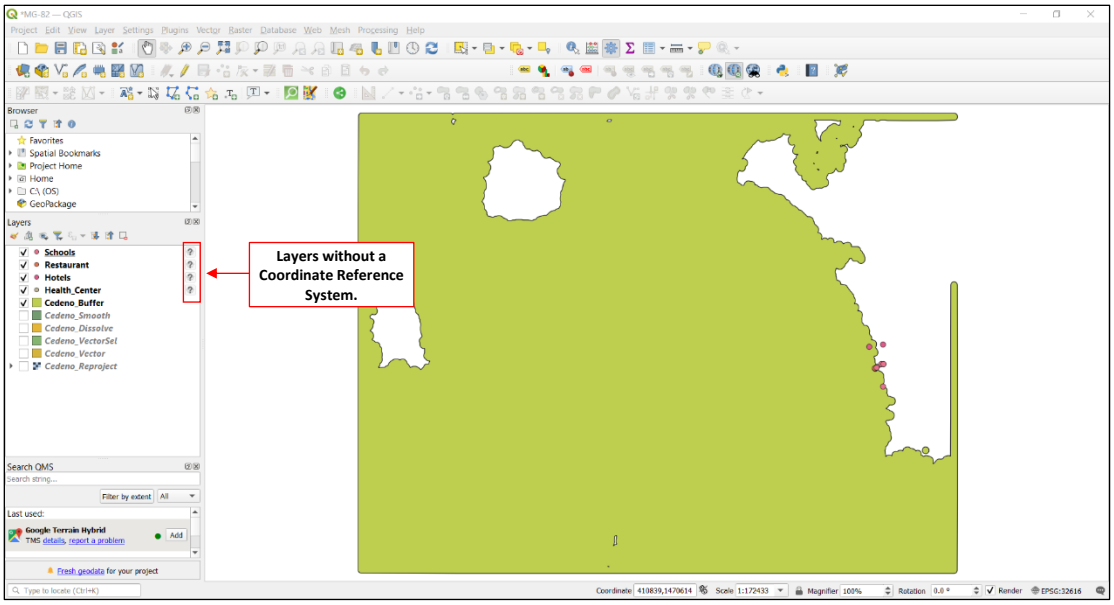
period of time. The infrastructure or benchmark polylines and/or polygons can include, but are not limited to: airports, schools, academic/education centers, hospitals, primary health care centers, springs, seaports, marinas, anchoring areas, beaches and resorts, bridges, police and fire department offices, camping sites, touristic areas of interest, shelters, and assembly points.

8. Assembly points – This point layer provides the coordinate locations of designated assembly points for the evacuation map and can be displayed following the UNOCHA symbols.
9. Evacuation routes – This point or polyline layer will provide the coordinate locations of geometries that will be displayed with an arrow symbology pointing towards the recommended and general direction of the evacuation route to assembly points.

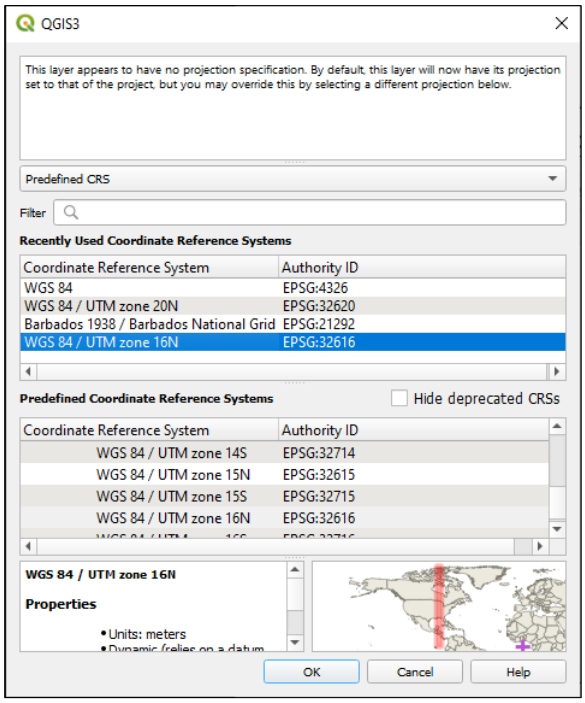
B. *Symbology change – Standardized maps*

Objective. Verify that the added infrastructure layers have the project's coordinate reference system.

QGIS Step 1. After adding to QGIS the infrastructure layers, verify in the Layers panel that the layers have a coordinate reference system. If they do not, a question mark will appear to the right of the layers' name.

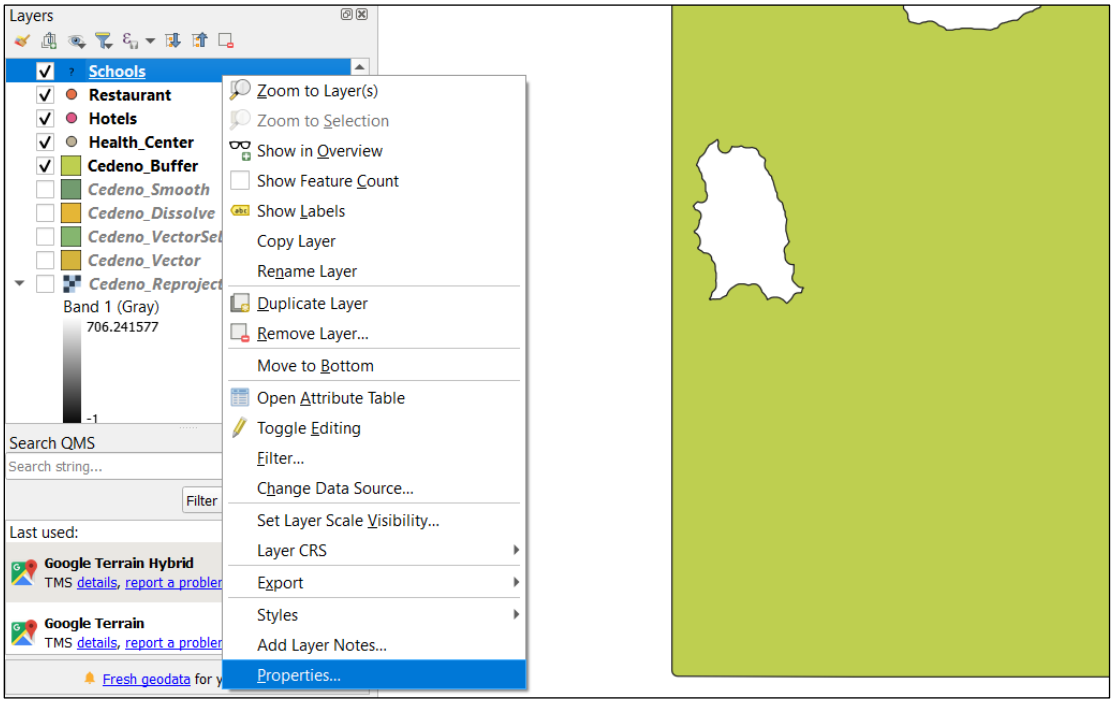


QGIS Step 2. Click on the question mark and when the dialog window opens, search and/or select the projection that corresponds to the ongoing project and click OK. For this manual example based on the Cedeño, Honduras model the selected CRS is WGS 84 / UTM zone 16 N and the Authority ID is EPSG:32616.



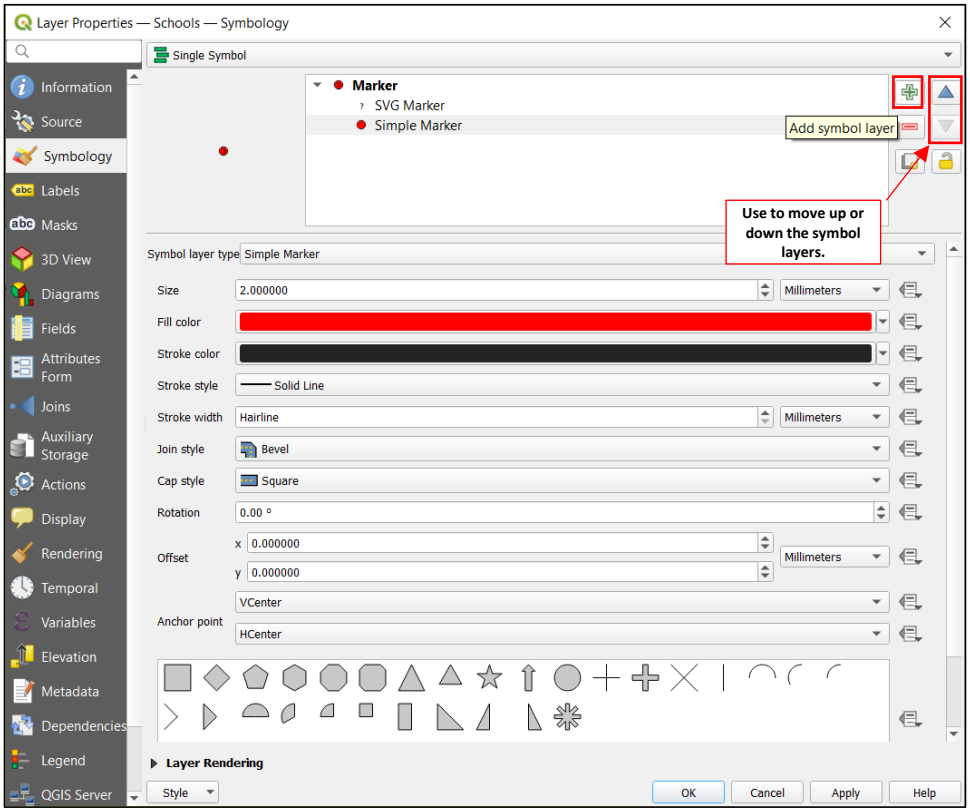
Objective. Use the UNOCHA symbol plugin to standardize the display of infrastructure layers on the map.

QGIS Step 1. Right click on the infrastructure layer of interest and go to Properties…

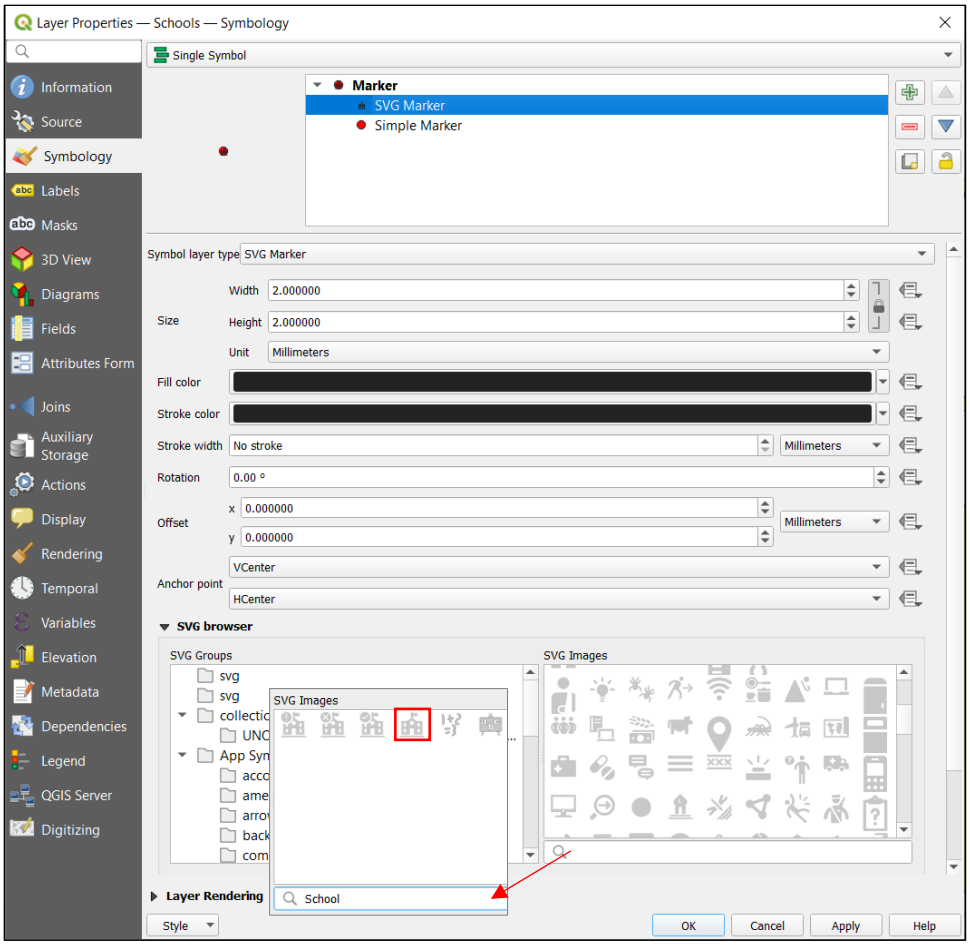


QGIS Step 2. Select the Symbology tab and click on Add symbol layer. This additional symbol layer will be added to prepare a layered symbol that is similar to the ones from

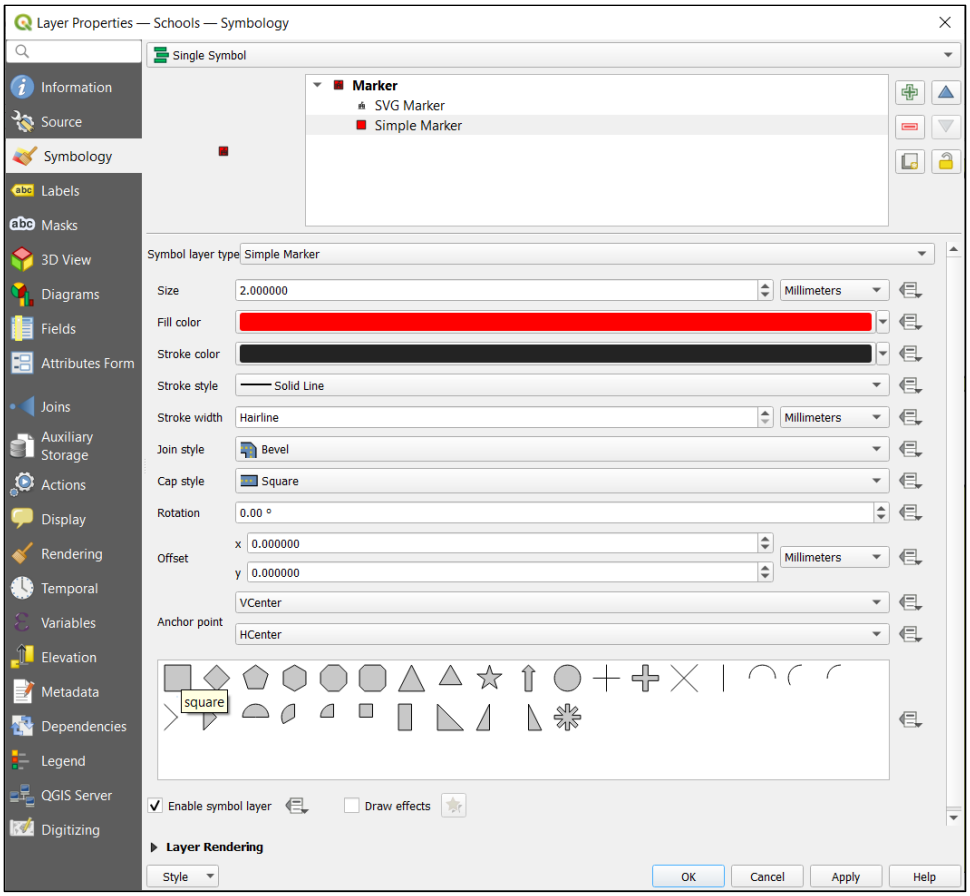
other map examples. The “Simple Marker” layer appears under “Marker” after clicking Add symbol layer. Select the sublayer and use the arrows to the right to move them up or down to overlay them, or change the Symbol layer type. For this type of symbology, keep the SVG Marker layer above the Simple Marker layer.



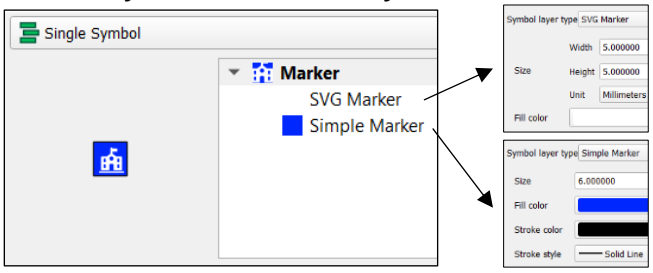
QGIS Step 3. Select the SVG Marker layer. In the SVG browser, in SVG Groups select *collections > UNOCHA Humanitarian Icons 2018*. Next to SVG Groups, type keywords of associated infrastructure of the layer of interest in the SVG Images search area. For this manual example the Schools layer was selected, “school” was typed in the search box and the fourth symbol was selected.



QGIS Step 4. Select the Simple Marker layer. For this manual example the square symbol shape was selected.

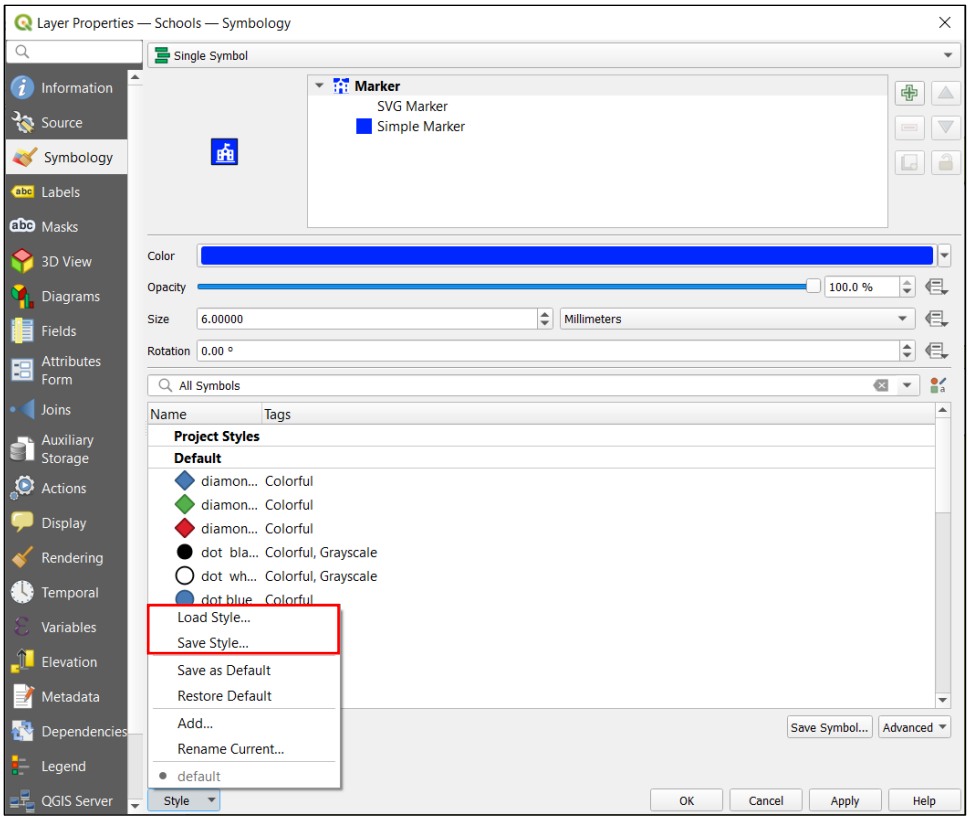


QGIS Step 5. Modify the color and sizes of the added symbol layers and markers for each. The sizes will vary as they depend on the extent and scale of the area of interest as well as the symbol color and style used for the map.



For this example the SVG Marker color was changed to white and the square to blue with a black border. The SVG Marker size is smaller than the Simple Marker for design purposes. The colors, shapes, and design will vary per map or country.

Note (optional step). If determining a standard symbology to use for future maps, save these styles instead of manually setting them up per layer. In the bottom of the Layer Properties – Symbology dialog window click on *Style* > *Save Style*… to save the symbol layer preset and click on *Style* > *Load Style*… to import a previously saved symbol layer preset to use in another layer.



QGIS Step 6. Repeat the previous steps per infrastructure layer.

Note. Regarding the evacuation routes dataset, it is also recommended to use an editing software to add arrows that indicate evacuation direction during the tsunami evacuation map development as these could be constantly changed during revision processes. Once the final evacuation arrows are determined, a shapefile including them can be prepared.

C. *Determining the optimal evacuation route*

Refer to MG-82 for considerations on determining the tsunami evacuation route. In addition to these considerations, GIS techniques such as network analysis support the selection of evacuation routes based on providing the shortest distance between specified locations, for example road networks and assembly points. In ArcGIS the Network Analyst extension is available and in QGIS the tool Network Analysis is available. Road networks and slope datasets (extracted from the DEM) are often used to employ this technique. If road network layers are unavailable or incomplete use the OpenStreetMap plugin in QGIS or go directly to their website to extract, download, and save as a shapefile the road network of the area of interest. For network analysis purposes all road segments in a single shapefile layer must be connected, use snapping tools to achieve this before employing the technique.

FINALIZING TSUNAMI EVACUATION MAPS FOR PRINTING (IV)

This manual section primarily covers the use of QGIS to develop the printable version of the tsunami evacuation map prepared in section III.

A. *Required elements for the evacuation map design.*

The evacuation map design process involves arranging map elements in an effective way that clearly and easily communicates spatial information to all users. Important considerations for the map review process:

- Datasets in the Table of Contents ordered in such a manner that one layer's symbology does not cover the symbology of another (e.g. infrastructure layers should be above a road network so that the road network does not cover the depicted symbology).
- Labels in the final map should be added to infrastructure and areas that are commonly recognized by residents and tourists for easy identification and understanding. Consider the selected background basemap and colors used for the datasets symbology to select a legible symbology for labels.

The following elements should be included in the final evacuation map:

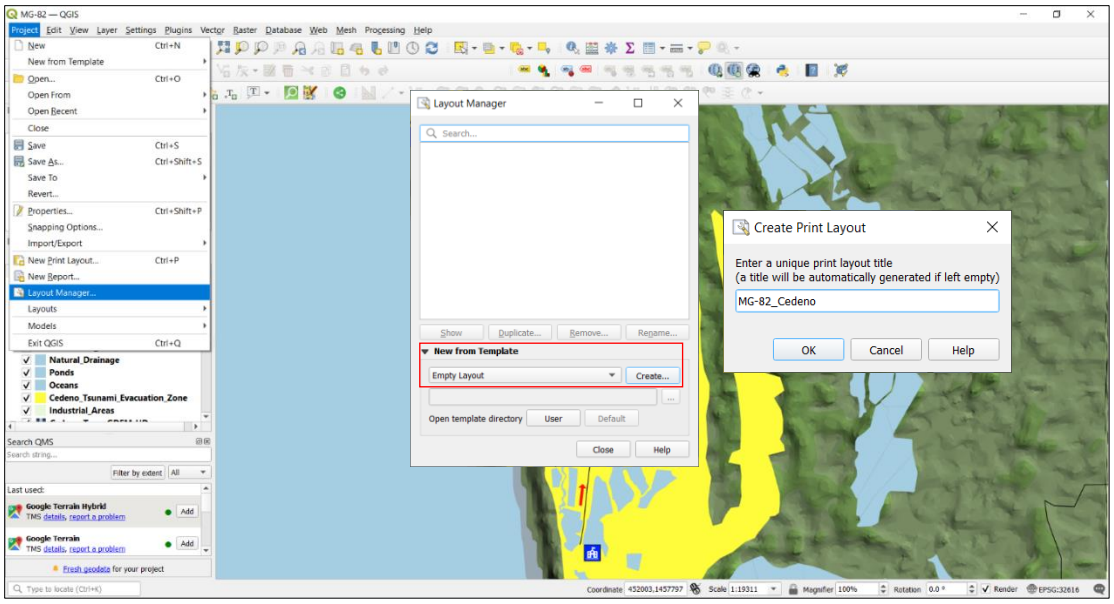
1. Title
2. Legend
3. North arrow
4. Map scale
5. Inset Map
6. Entity logos
7. Grids
8. Date of production
9. Agency contact information
10. Disclaimer/Notes (if applicable)
11. Project funding the tsunami modeling and/or relevant details
12. Acknowledgements
13. Labeled key infrastructure
14. Labeled or listed assembly points (location name list also)

B. *Print Layout Guide*

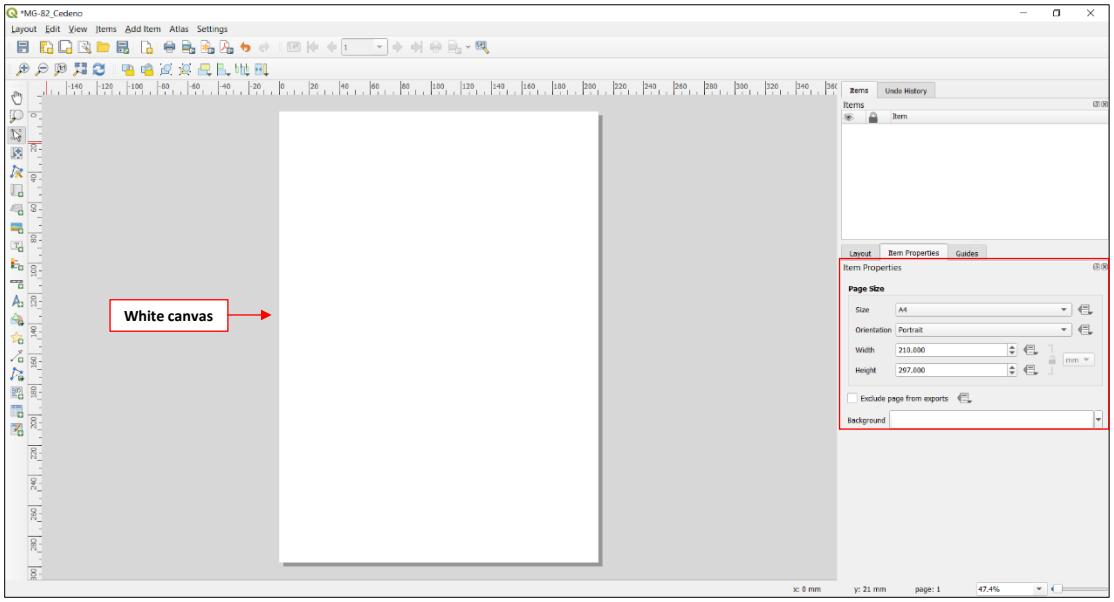
After all the layers required for the tsunami evacuation map are added and organized its design can be developed.

Objective. Prepare the final map for export after importing the required layers and setting up the symbology.

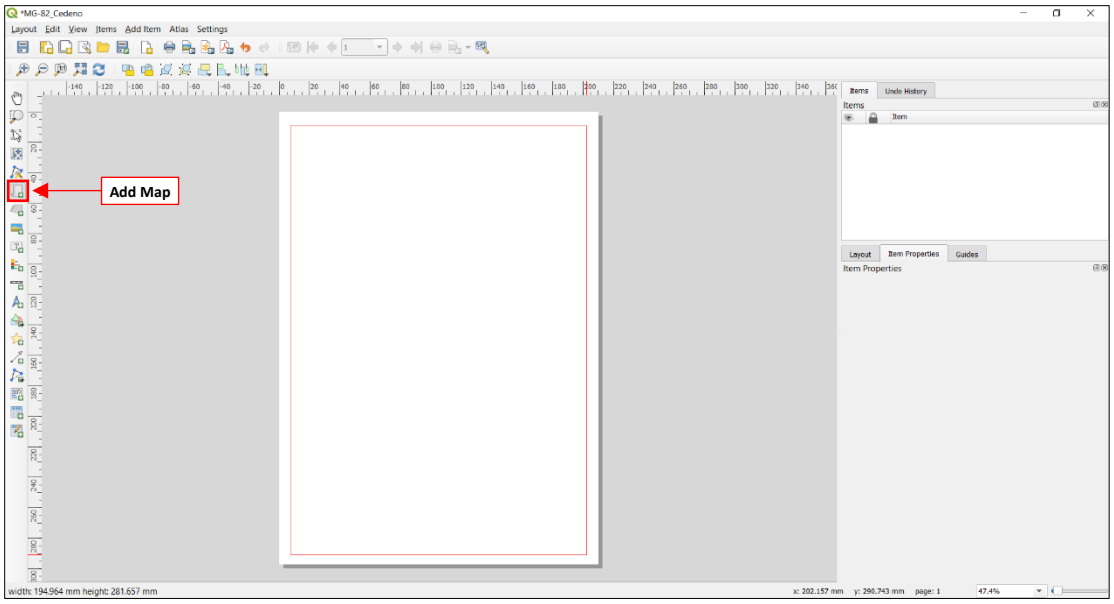
QGIS Step 1. In the QGIS Menu Bar click *Project* > *Layout Manager…* In the dialog window select *Empty Layout* > *Create…* and when the Create Print Layout window opens type a name for the layout and click OK. After clicking OK a new window will open.



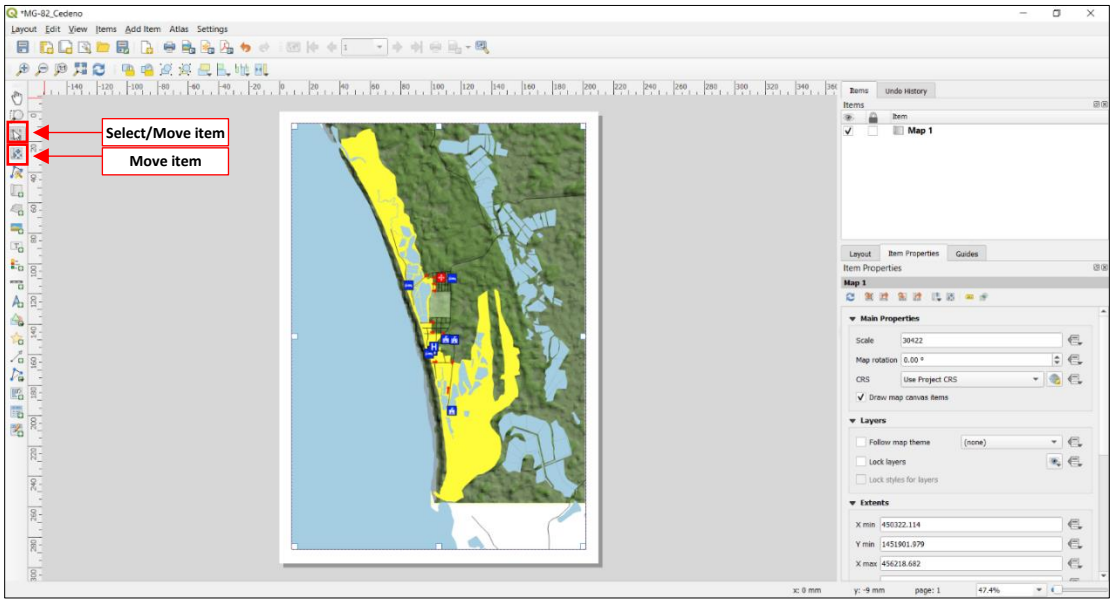
QGIS Step 2. Click on the white canvas and the Item Properties tab on the right side panel will show information. Select the page size of interest for your project and map background. For this manual example based on the Cedeño, Honduras model the A4 portrait template and white background was selected.



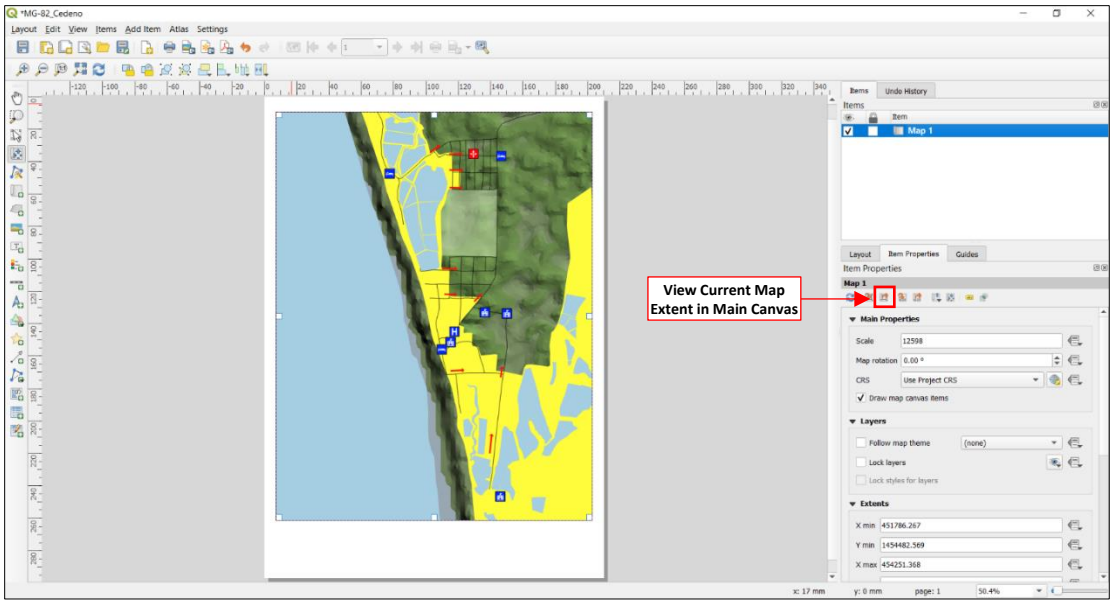
QGIS Step 3. Select the Add Map toolbar button and drag the mouse over the canvas to draw the extent of interest.

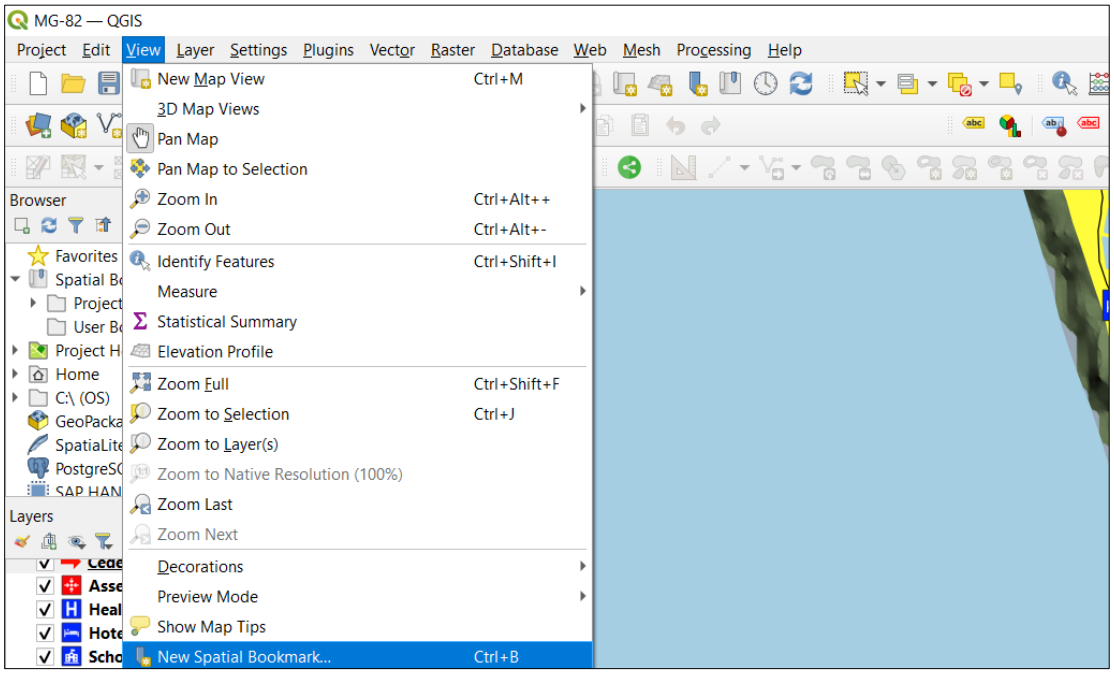


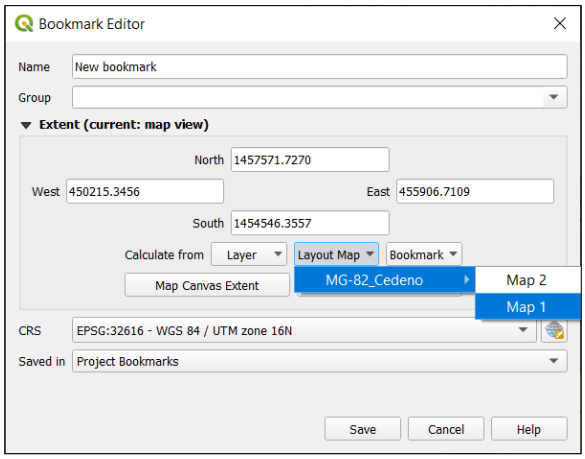
QGIS Step 4. The map will load from the active map canvas in QGIS. To adjust the map extent click on the Select/Move toolbar button. To zoom in and out of the map extent click the Move item content toolbar button, then click ctrl + scroll the mouse wheel.



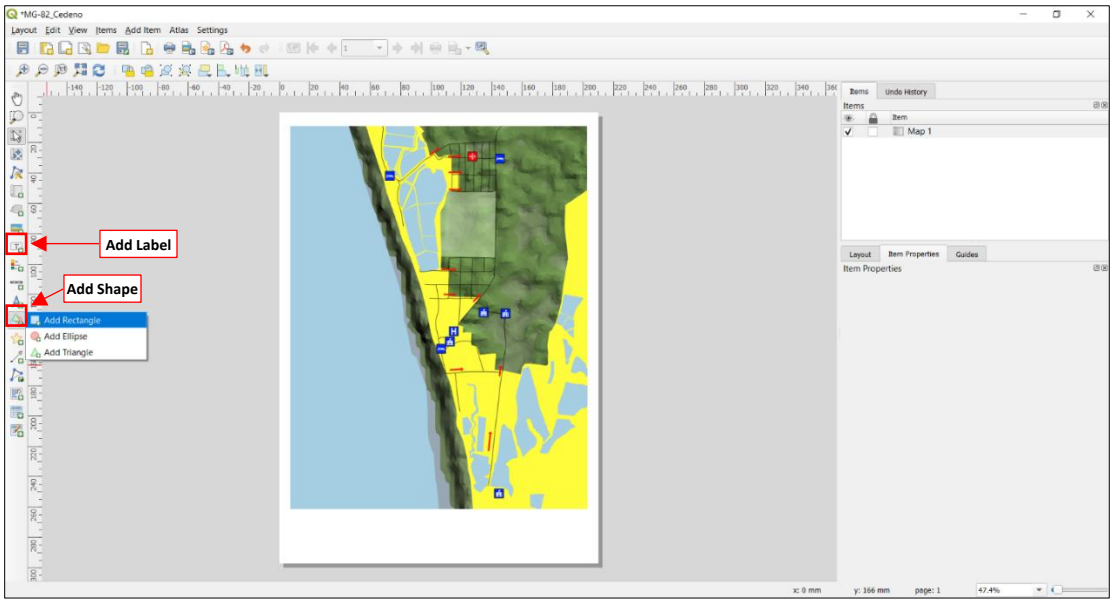
QGIS Step 5. Prepare a Spatial Bookmark to save the final map extent. Click View Current Map Extent in Main Canvas and the QGIS project window will be updated. In the QGIS Menu Bar click *View* > *New Spatial Bookmark…* In the Bookmark Editor window click on *Calculate from* > *Layout Map* > *Map 1* (Map 1 contains the Evacuation Map elements). Click Save.


View Current Map
Extent in Main Canvas


MG-82 — QGIS
Project
Edit
View
Layer
Settings
Plugins
Vector
Raster
Database
Web
Mesh
Processing
Help
New Map View Ctrl+M
3D Map Views
Pan Map
Pan Map to Selection
Zoom In Ctrl+Alt++
Zoom Out Ctrl+Alt+-
Identify Features Ctrl+Shift+I
Measure
Statistical Summary
Elevation Profile
Zoom Full Ctrl+Shift+F
Zoom to Selection Ctrl+J
Zoom to Layer(s)
Zoom to Native Resolution (100%)
Zoom Last
Zoom Next
Decorations
Preview Mode
Show Map Tips
New Spatial Bookmark... Ctrl+B
Browser
Layers

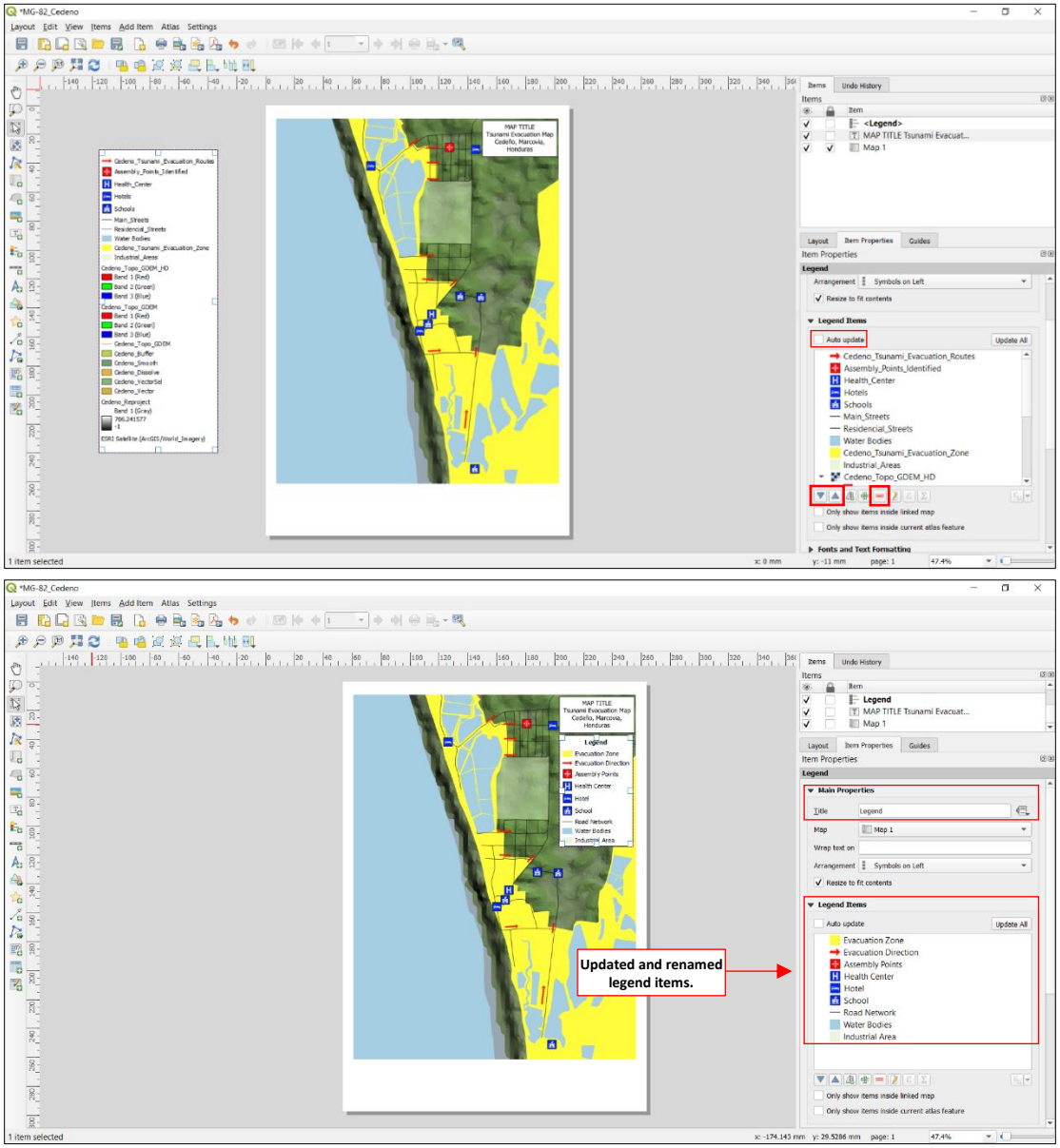


QGIS Step 6. Select the toolbar buttons such as Add Labels and Add Shape to add text such as the map title, date of production, agency contact information, disclaimer/notes, project funding information, acknowledgements, amongst others.

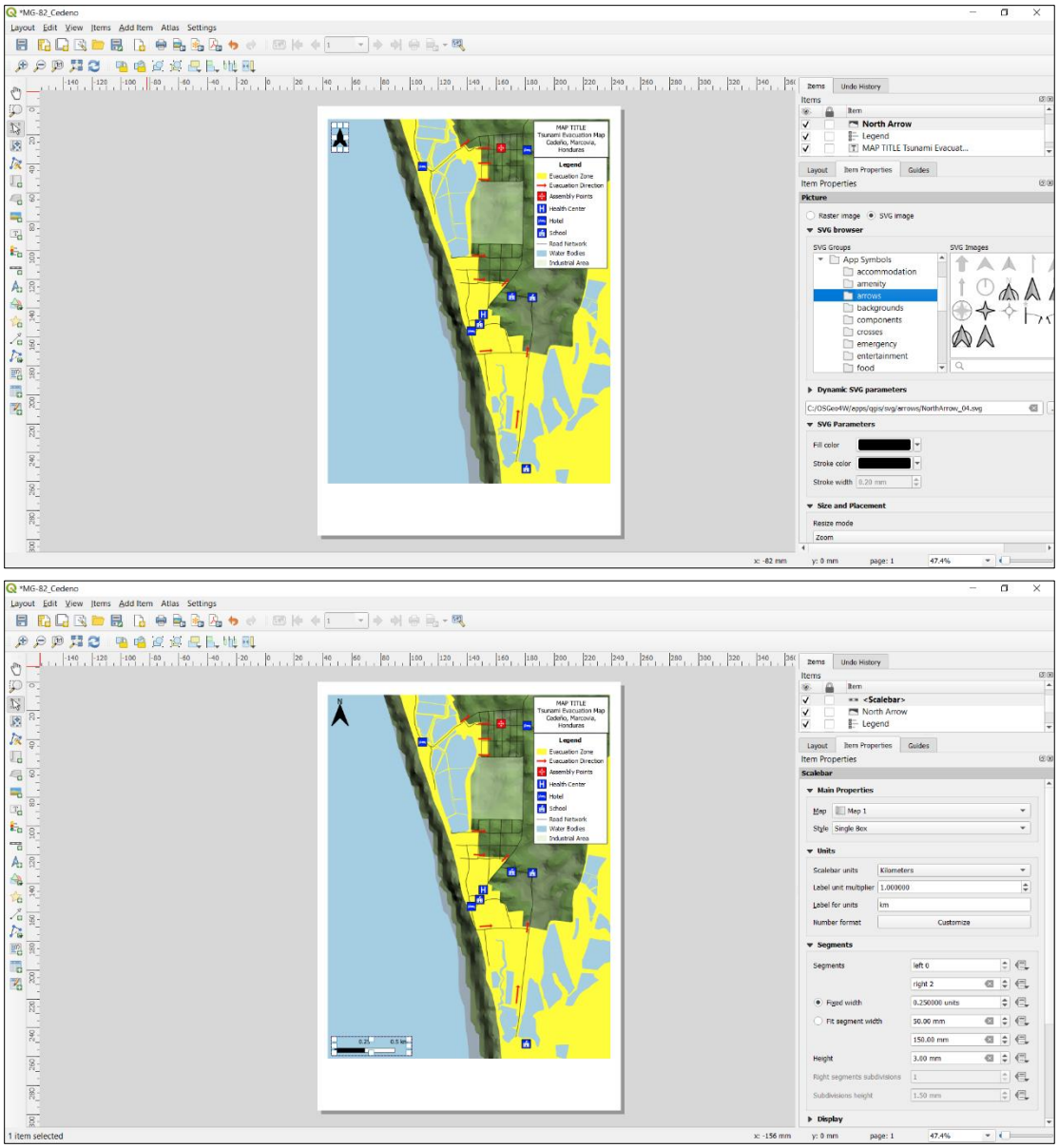


QGIS Step 7. Select the Add Legend toolbar button and drag the mouse over the canvas to draw the extent of interest. A legend with all layers, and their names, that are currently on the Map Canvas will be generated. To remove the layers that are not of interest for the tsunami evacuation map click on the legend and in the Item Properties Tab on the right side panel deselect Auto update under Legend Items. Select legend items to remove and click on “Remove selected item(s) from legend”. Another alternative to remove the layers from the legend is to select “Only show items inside linked map”. To modify the label name of a layer double click it on the Legend Items section and change the text. To

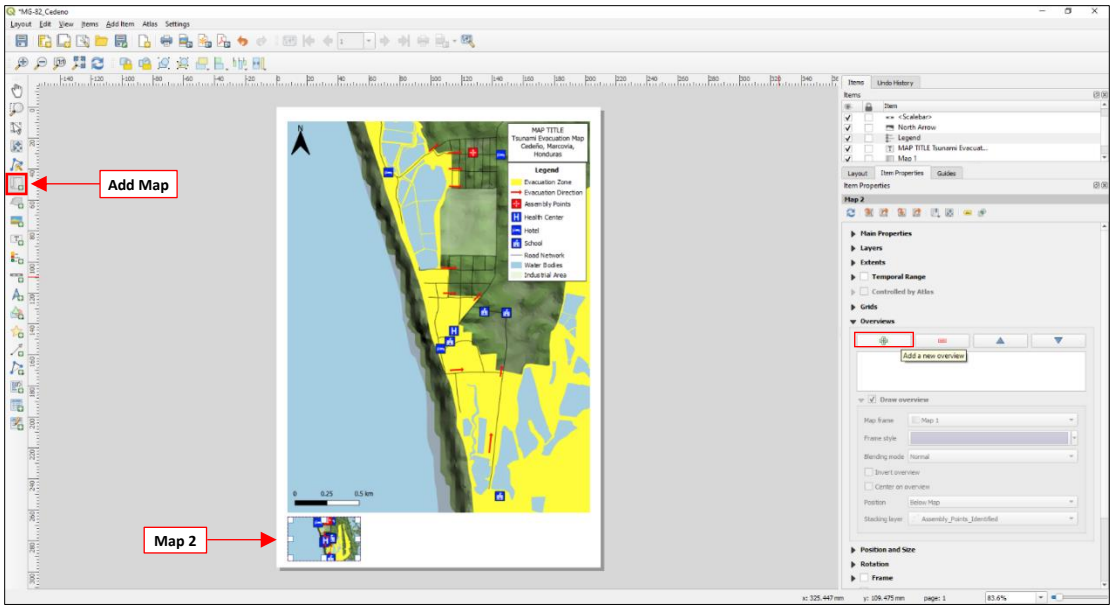
rearrange the layers order use the arrows on the Legend Items section. Add a title to the legend on the Main Properties section.

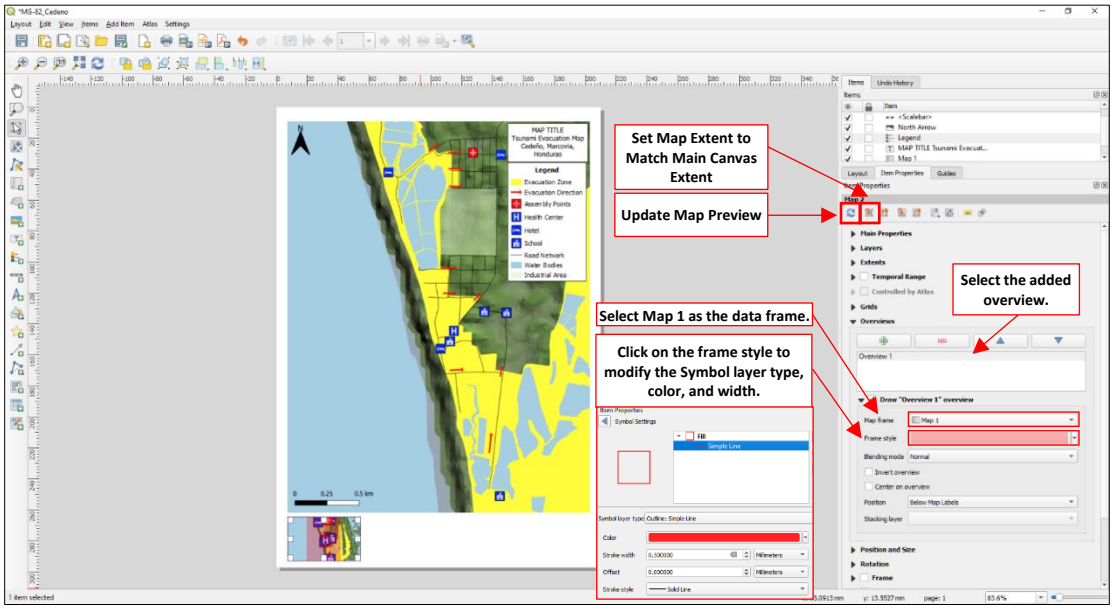


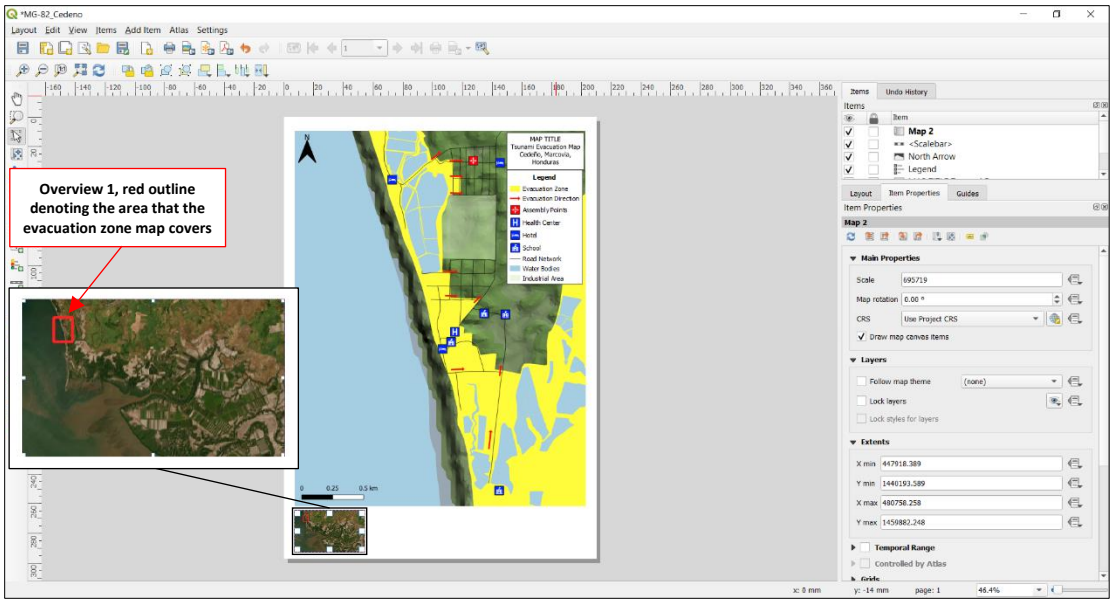
QGIS Step 8. Select the toolbar buttons North Arrow and Scale Bar and drag the mouse over the canvas to draw the extent of interest for each element. To change the North Arrow symbol click on the element, in the Item Properties Tab on the right side panel under Picture go to the SVG browser, in the App Symbols folder go to Arrows and select the preferred one. To modify the scale bar click on the element, in the Item Properties Tab on the right side panel under Scalebar modify the display units and segments.



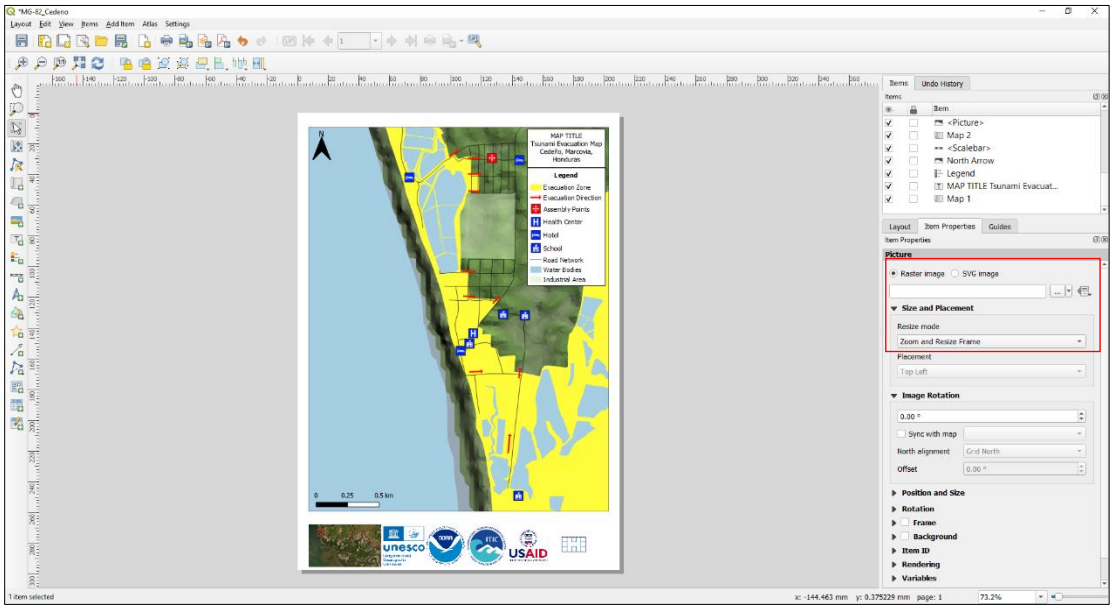
QGIS Step 9. Select the toolbar button Add Map to add an inset. Drag the box to the size of interest and place where desired. Select the box and go to *Item Properties* > *Overviews* > *Add a new overview*. In the subsection Draw “Overview 1” overview select under Map frame “Map 1” which covers the extent of the evacuation map. If the name was modified select the corresponding one. The style of the inset, the extent it covers, and the basemap to display will depend per country or community. For this particular example the inset zooms out of the main extent, but does not include the whole country, and the imagery basemap was used. To update the extent under Map 2, in Item Properties click “Update Map Preview” and “Set Map Extent to Match Main Canvas Extent”. Then modify the Frame style.


Add Map
Map 2

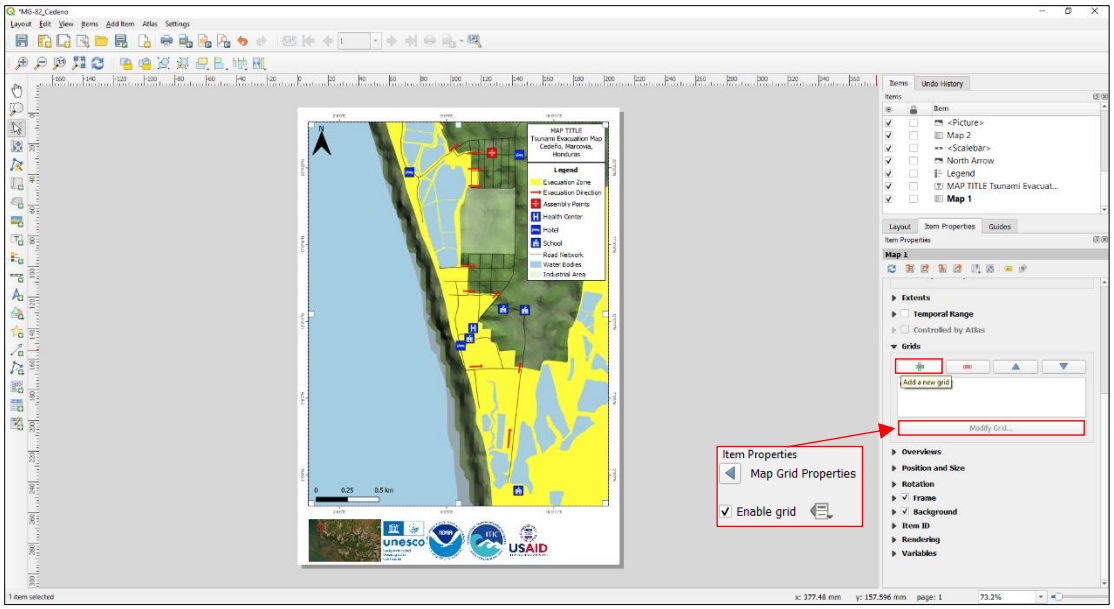

Set Map Extent to Match Main Canvas Extent
Update Map Preview
Select the added overview.
Select Map 1 as the data frame.
Click on the frame style to modify the Symbol layer type, color, and width.



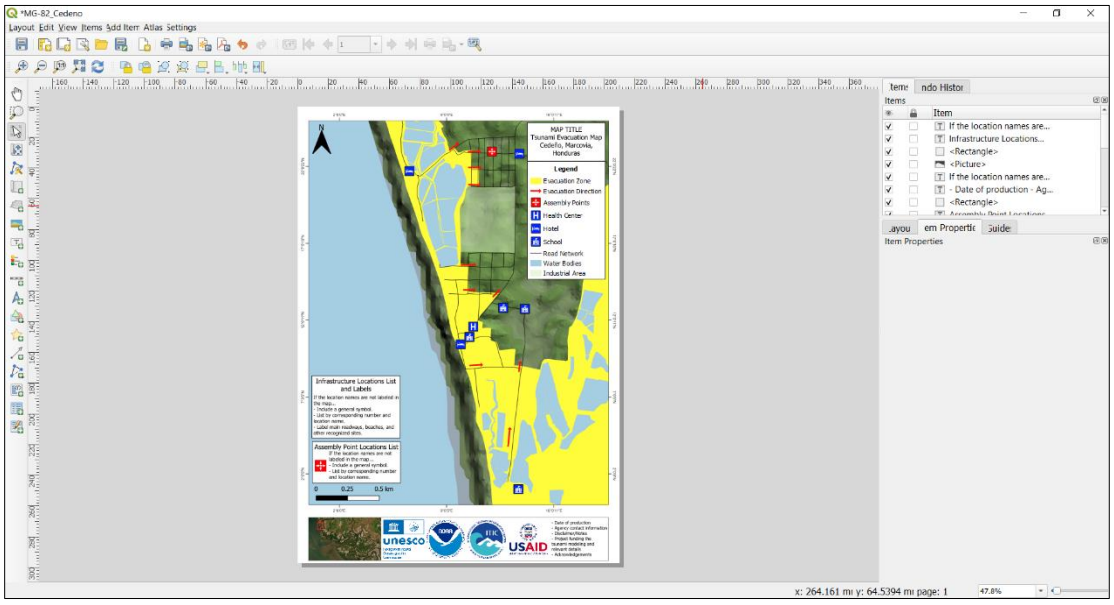
QGIS Step 10. Select the toolbar button Add Picture to add entity logos. Go to *Item Properties* > *Picture*, select Raster image and browse for the file. To display the pictures with higher quality click Resize mode and change to Resize Frame to Image Size.



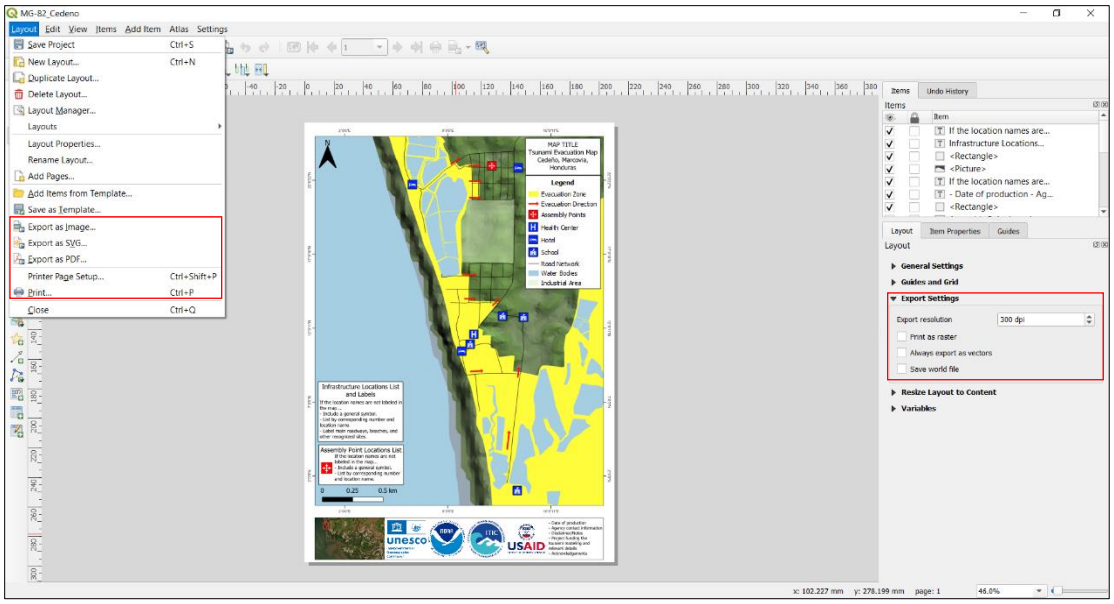
QGIS Step 11. Go to *Item Properties* > *Grids* > *Add a new grid* > *Modify Grid…* > *Enable grid* and modify the appearance and coordinates according to the country and community.



QGIS Step 12. Select the toolbar buttons such as Add Labels and Add Shape to add the remaining text for the map such as the date of production, agency contact information, disclaimer/notes, project funding information, acknowledgements, amongst others.



QGIS Step 13. After completing the map, select the Export Settings and select the export format in Layout.


MG-82_Cedeno
Layout
Edit
View
Items
Add Item
Atlas
Settings
Save Project Ctrl+S
New Layout... Ctrl+N
Duplicate Layout...
Delete Layout...
Layout Manager...
Layouts
Layout Properties...
Rename Layout...
Add Pages...
Add Items from Template...
Save as Template...
Export as Image...
Export as SVG...
Export as PDF...
Printer Page Setup... Ctrl+Shift+P
Print... Ctrl+P
Close Ctrl+Q
MAP TITLE
Tsunami Evacuation Map
Cedeño, Marcovia,
Honduras
Legend
Evacuation Zone
Evacuation Direction
Assembly Points
Health Center
Hotel
School
Road Network
Water Bodies
Industrial Area
Infrastructure Locations List and Labels
Assembly Point Locations List
0 0.25 0.5 km
Items
Undo History
Item
If the location names are...
Infrastructure Locations...
<Rectangle>
<Picture>
If the location names are...
- Date of production - Ag...
<Rectangle>
Layout
Item Properties
Guides
Layout
General Settings
Guides and Grid
Export Settings
Export resolution
300 dpi
Print as raster
Always export as vectors
Save world file
Resize Layout to Content
Variables
x: 102.227 mm
y: 278.199 mm
page: 1
46.0%