# Generating Map Shapefiles with Open-Source GIS Software

07/21/2026

## Contents

# Introduction

Pacific Northwest National Laboratory (PNNL) supports the U.S. Department of Energy's (DOE) Office of State and Community Energy Programs (SCEP) Home Energy Rebates Program.

PNNL developed this guidance document to assist users in preparing map files for use with the PNNL Address Service. Because map identification and eligibility criteria are unique to each grantee and jurisdiction, each grantee is responsible for creating and maintaining its own map of areas that qualify for location-based contractor incentives. The PNNL Address Service converts address information to latitude and longitude values that are then referenced with US Census Bureau shapefiles and location-based contractor incentive maps to determine area median income values and applicability of location-based contractor incentives. Grantee-specific location-based contractor incentive maps are required to be submitted to the PNNL Home Energy Rebates team in a standardized ESRI shapefile format for consistent map handling and utilization across all grantees utilizing the PNNL Address Service.

## Developing Baselines and Thresholds for Location-Based Contractor Incentives

Program grantees are responsible for the establishment of thresholds, identification data sources, and maps of areas that qualify for location-based contractor incentives. The Low-Income Energy Affordability Data (LEAD) Tool is an interactive data visualization tool created by the DOE State Energy Programs (SEP) office to assist states and communities in making data-driven decisions on energy goals and program planning. This tool offers the ability to visualize income levels, energy costs, and household characteristics across jurisdiction resolutions (state-level, county-level, city-level, and census tract-level). The data within this tool can be utilized by grantees in conjunction with grantee-specified thresholds to identify areas that qualify for location-based contractor incentives. The data available within this tool can be exported at the jurisdiction resolution of interest and can be leveraged by grantees and implementers to identify those jurisdictions where location-based contractor incentives are applicable.

The LEAD Tool is that it cannot currently output the map shapefiles required for the PNNL Address Service's location-based contractor incentive qualification component. The LEAD Tool is a useful resource for benchmarking and establishing location-based contractor incentive thresholds, but PNNL Address Service requires map shapefiles that identify those areas where a location-based contractor incentive is available within the grantee's jurisdiction.

## What is a Shapefile?

The PNNL Address Service utilizes shapefiles for the determination of county subdivisions for area median income lookups and for the determination of areas where location-based contractor incentives are available. A shapefile, also called an ESRI shapefile, is a file storage format that contains geographic information, polygon, line, or point data, and attributes of geographic features. Shapefiles are useful for representing bounded areas and data associated with those areas on a map for querying. While they are colloquially referred to as a singular shapefile, a shapefile is actually a collection of files that, at a minimum, include the following file types:

- .shp: Encodes geometry such as lines, bounded polygons, or points.
- .shx: Indexes the positioning of geometry on a map.
- .dbf: The database of attributes encoded within lines, polygons, or points in the .shp file.
- .prj: Stores the projected coordinate system info for the shapefile.

At this time, the PNNL Address Service supports maps provided in a shapefile format. These files can be created using Geographic Information System (GIS) software such as ArcGIS or QGIS. When a map shapefile is shared with PNNL, .shp, .shx, .dbf, and .prj files are needed as a minimum for use in the PNNL Address Service. These files are utilized by the PNNL Address Service to identify those areas that qualify for a location-based contractor incentive within a grantee's jurisdiction.

# Generating Shapefiles

To illustrate the process for a state or implementer to generate shapefiles for location-based incentive maps, a representative example will be outlined within this section.

## PNNL Locations Overview

As a modern national lab, PNNL maintains multiple office locations and dedicated laboratories for power grid operations, marine sciences, data analytics, and atmospheric sciences, equipping researchers to take on some of the most challenging questions and expand the frontiers of scientific understanding and technological possibility nationwide. Because of these diverse capabilities, PNNL has a presence in multiple cities and states.

## Generating A Representative Shapefile

For the purposes of this exercise, a map shapefile displaying the ZIP-code tabulated areas that contain PNNL campuses within the boundaries of Washington state will be generated utilizing QGIS, which is an open-source GIS software available on Windows, macOS, Linux, Android and iOS. For this example, QGIS will be utilized on a macOS computer; however, these instructions are broadly applicable for Windows and Linux users.

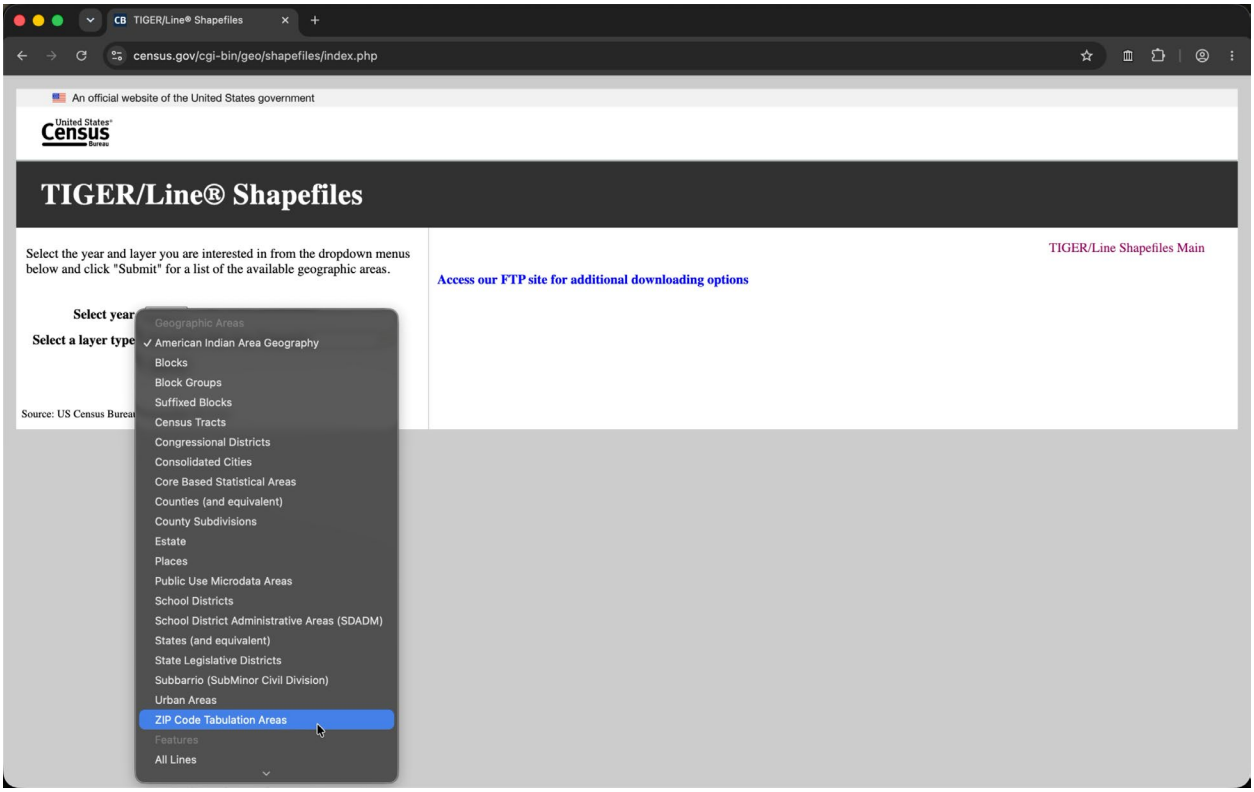
## Step 1: Download and Open QGIS

QGIS can be downloaded for free at https://www.qgis.org/download/.

## Step 2: Download and Import a Starting Shapefile

To begin, it is necessary to start with an existing shapefile that contains polygons representing the specificity of jurisdiction-level of interest. The Census Bureau provides shape and line files for many different types of geographic areas. For this example, ZIP-code tabulated areas (ZCTA) are used as the jurisdiction resolution of interest; however, a similar process could be followed for census tracts, census blocks, counties, county subdivisions, and similar[1].

Shape file for ZCTAs and state footprints can be downloaded from the Census Bureau's webpage here: https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.



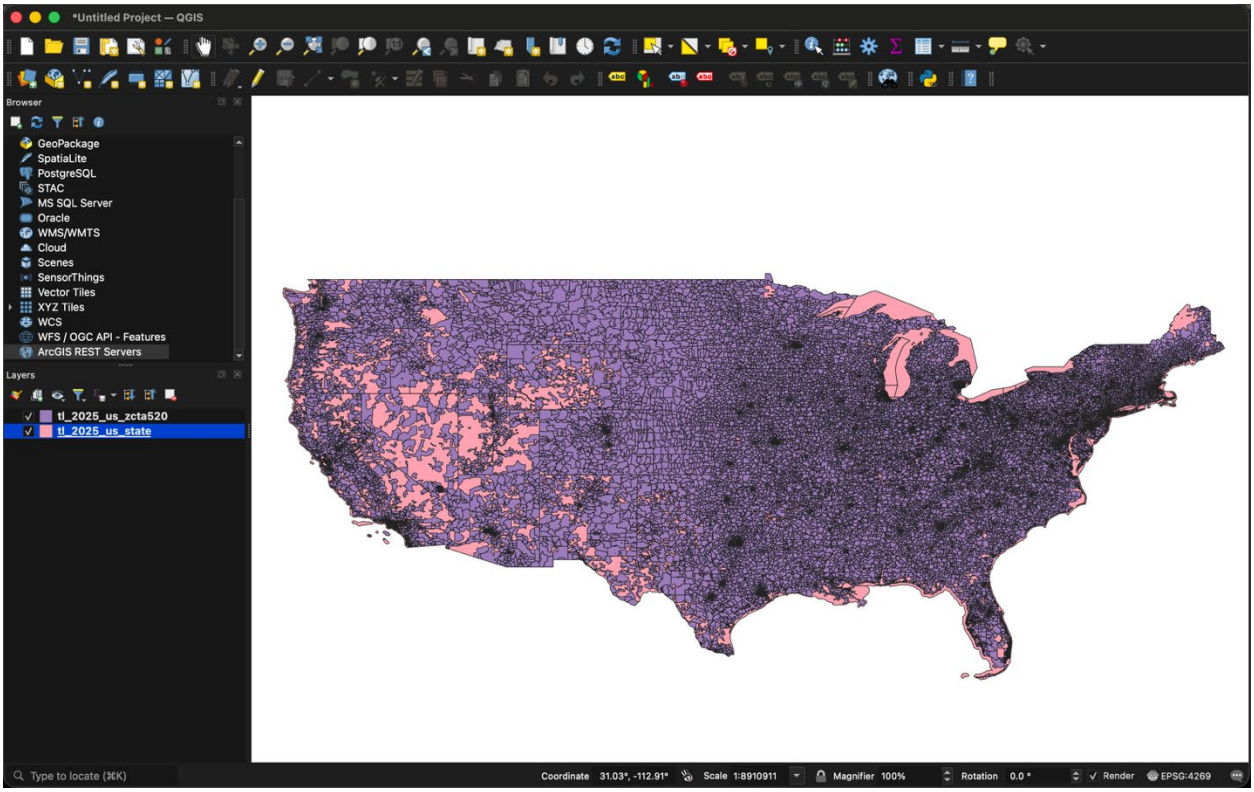

## Step 3: Importing and Manipulating Shapefile Geometry

Source shapefiles can be imported into QGIS by unzipping the respective shapefile folder and importing them as a vector layer. Within QGIS, this can be accomplished by navigating

[1] Note that the US Census Bureau's TIGER shapefiles for census blocks, census block groups, census tracts, county subdivision, and places are available for download at the state or territory-level, so Step 4 of this guide can be disregarded.

through the following toolbars: Layer > Add Layer > Add Vector Layer, then selecting a "Directory" source type and importing the unzipped shapefile folder. Alternatively, unzipped shapefile folders can be imported by dragging the unzipped folder from the computer's file storage into the open QGIS program.

For this representative exercise, both the ZCTA and state footprint shapefiles were imported as vector layers into QGIS.

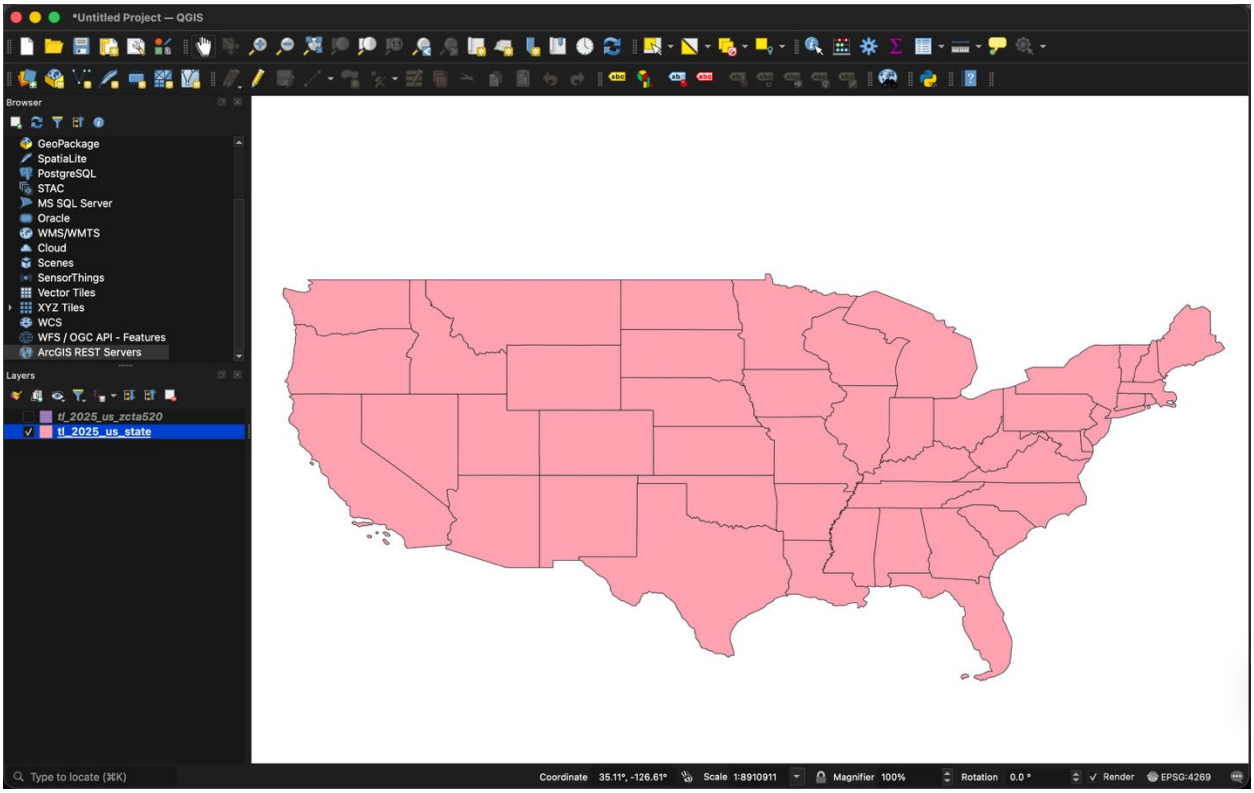



## Step 4: Bounding Shapefiles to the Jurisdiction Footprint of Interest

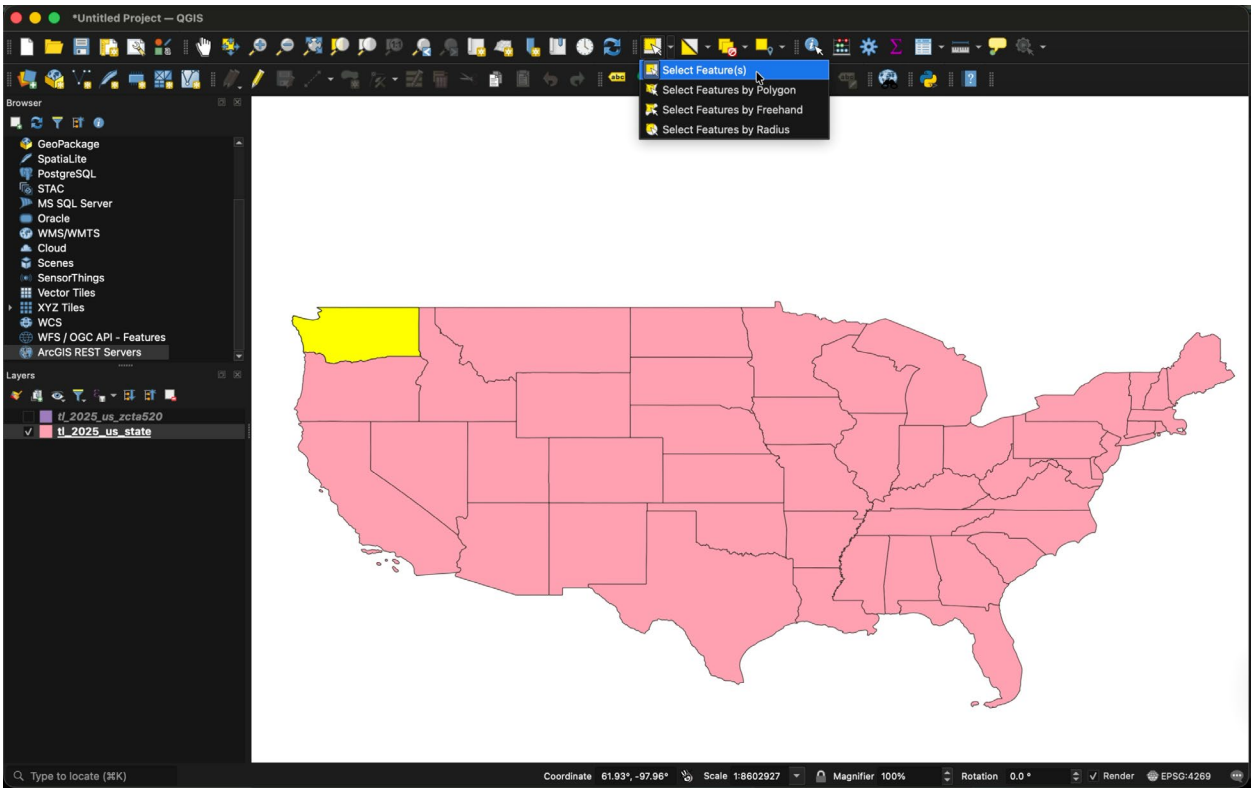
For this exercise, we are tasked with highlighting the ZCTAs that contain PNNL campuses within the boundaries of Washington state. It is worth noting that PNNL also has offices outside of Washington state in Portland, Oregon; College Park, Maryland; and Washington DC, however, these offices are outside of the desired footprint of Washington state.

As follows are the steps to bound the two representative shapefiles to the jurisdiction footprint of interest:

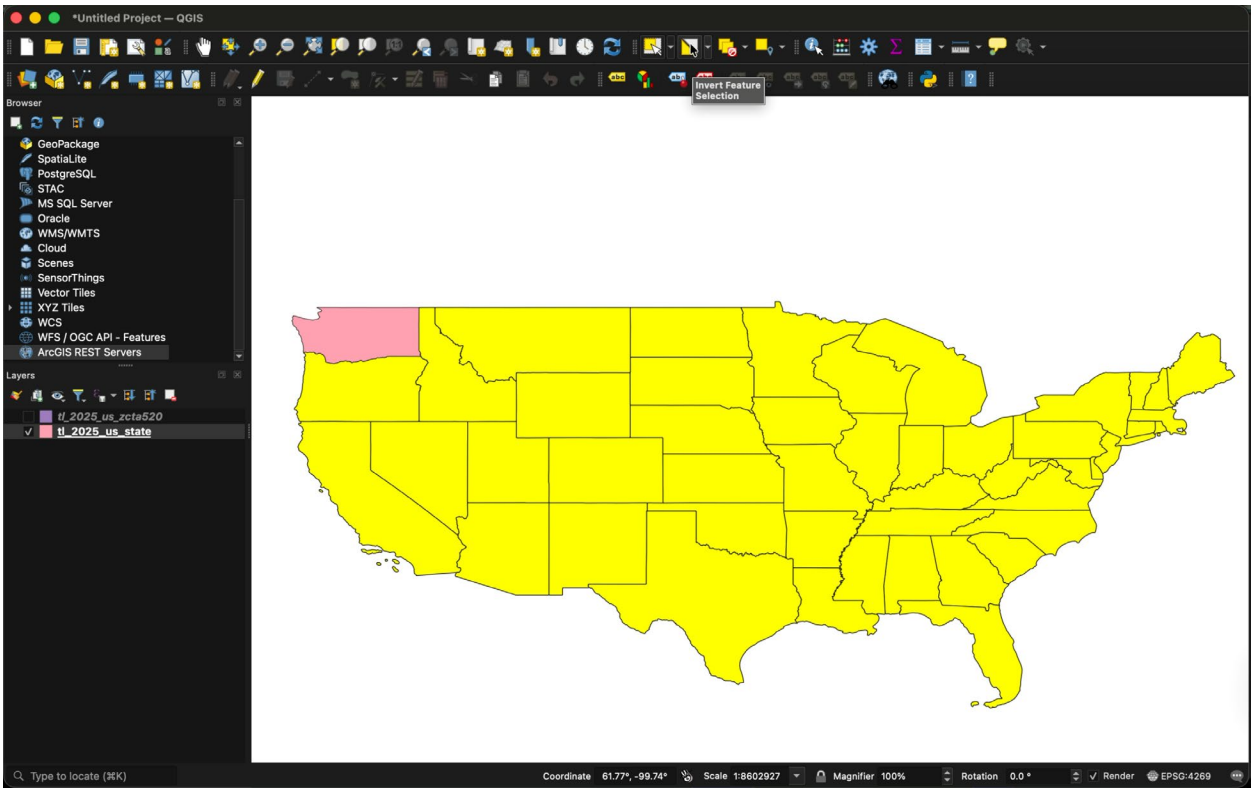
A. To begin, start by deselecting the ZCTA layer to view only the state footprints.


*Untitled Project — QGIS
Browser
GeoPackage
SpatiaLite
PostgreSQL
STAC
MS SQL Server
Oracle
WMS/WMTS
Cloud
Scenes
SensorThings
Vector Tiles
XYZ Tiles
WCS
WFS / OGC API - Features
ArcGIS REST Servers
Layers
tl_2025_us_zcta520
tl_2025_us_state
Type to locate (⌘K)
Coordinate 35.11°, -126.61°
Scale 1:8910911
Magnifier 100%
Rotation 0.0 °
Render
EPSG:4269

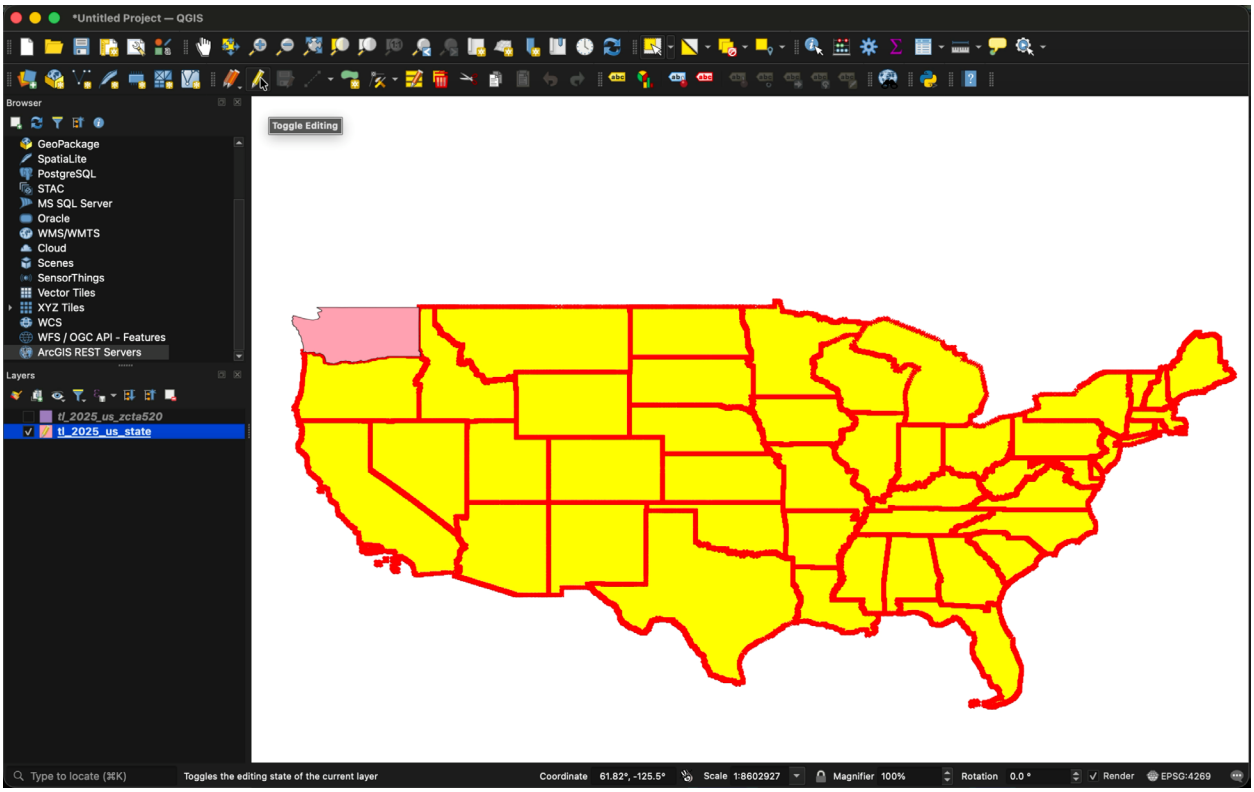
B. Navigate to the selection menu and select “Select Feature(s)”, then select the jurisdiction footprint of interest on the map by clicking on it. A feature will be highlighted when it is displayed as “selected”.



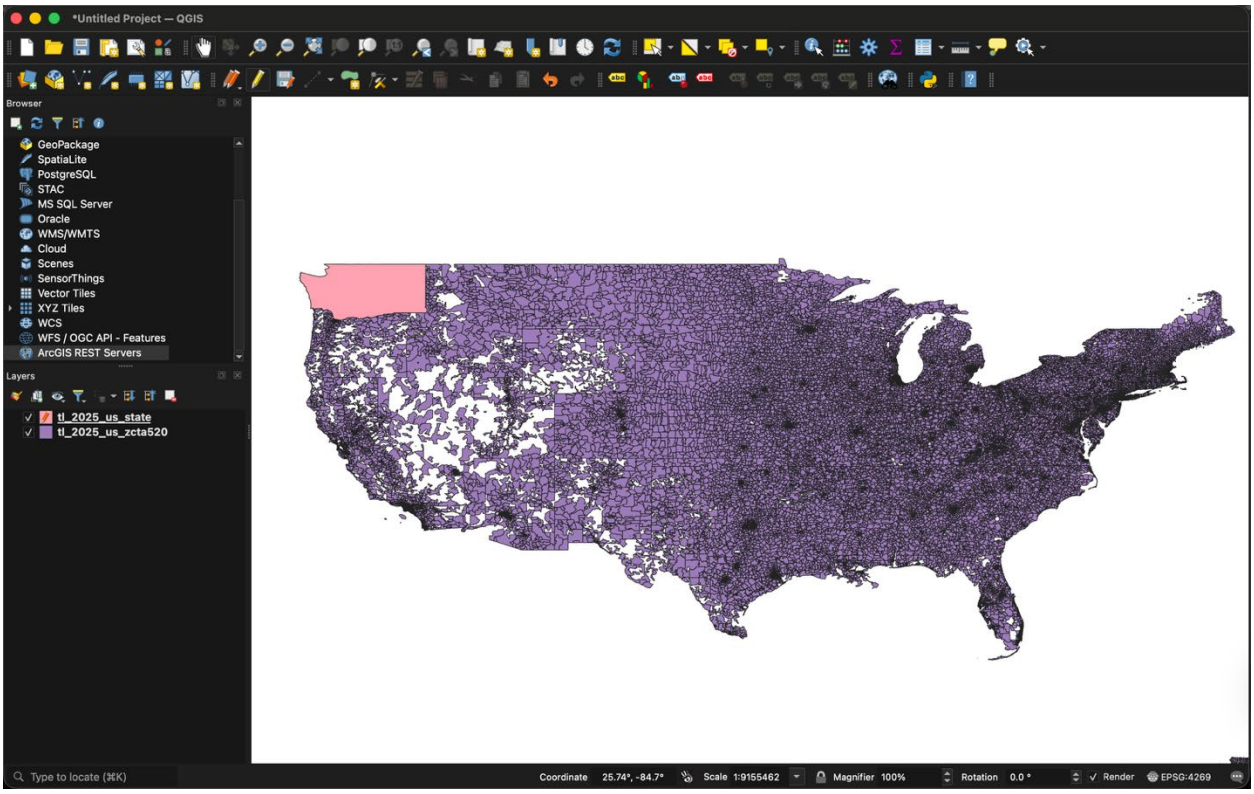
C. With the jurisdiction of interest selected, navigate to the “Invert Feature Selection” button to select all jurisdiction footprints except the jurisdiction of interest.



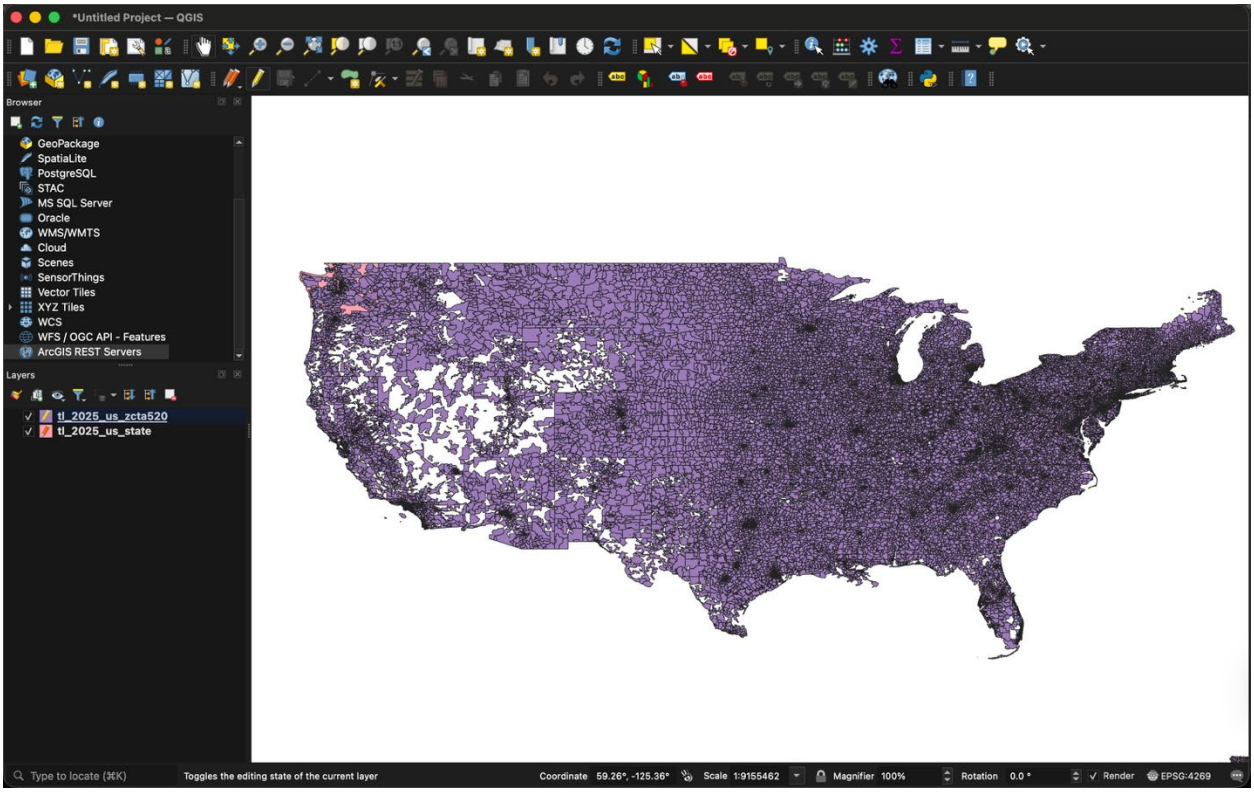
D. Navigate to the “Toggle Editing” button and enable editing for the state footprint layer.



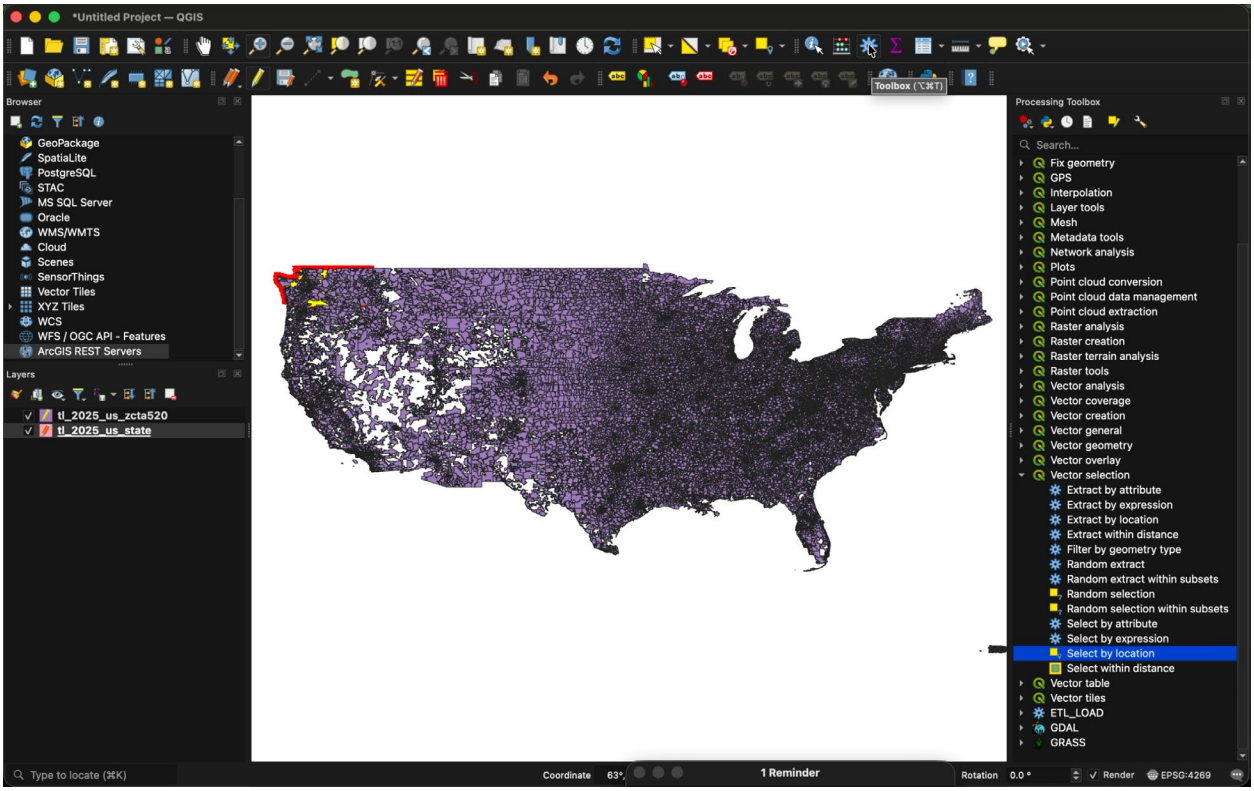
E. Delete all footprints outside of the jurisdiction of interest by clicking the “Delete Selected” button.



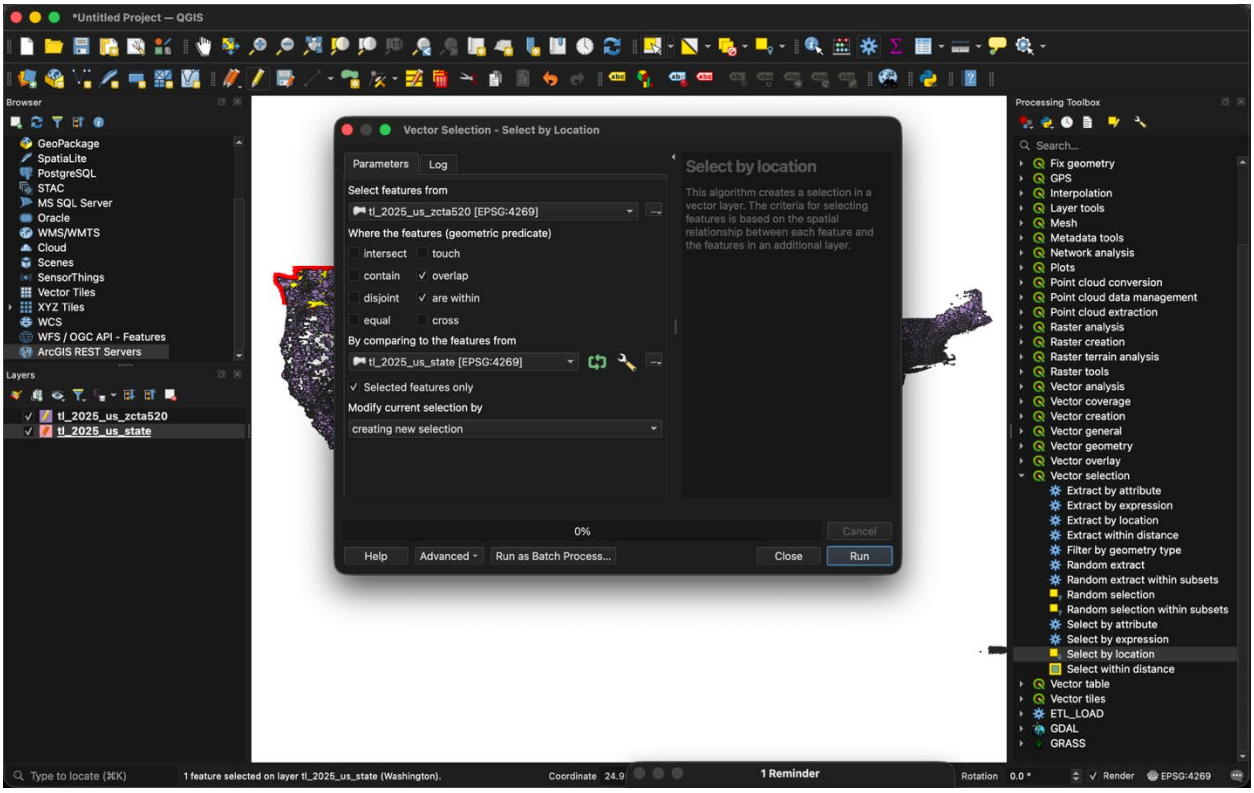
F. Unhide the ZCTA layer and click the “Enable Editing” button for that layer.



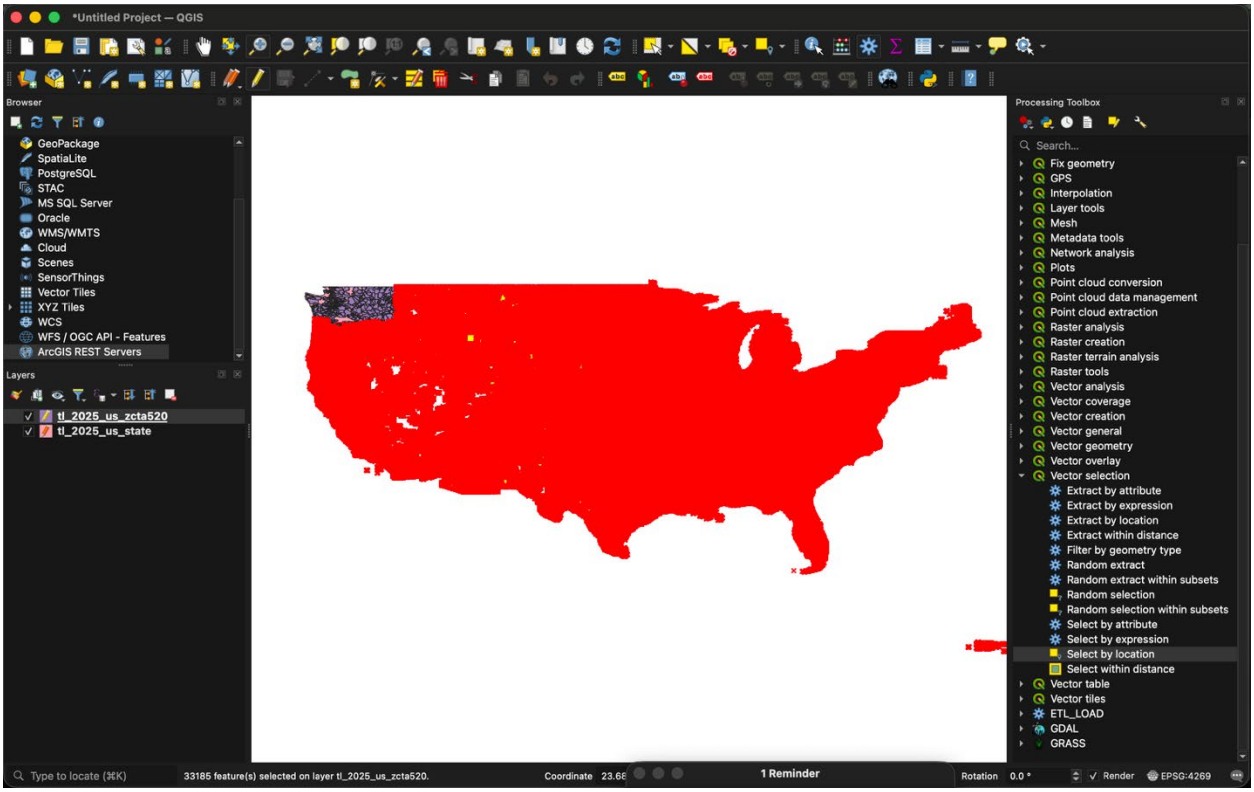
G. Select the state footprint on the map, then navigate to the “Toolbars” menu button and open the “Select by location” tool under Vector selection > Select by Location in the Processing Toolbox.



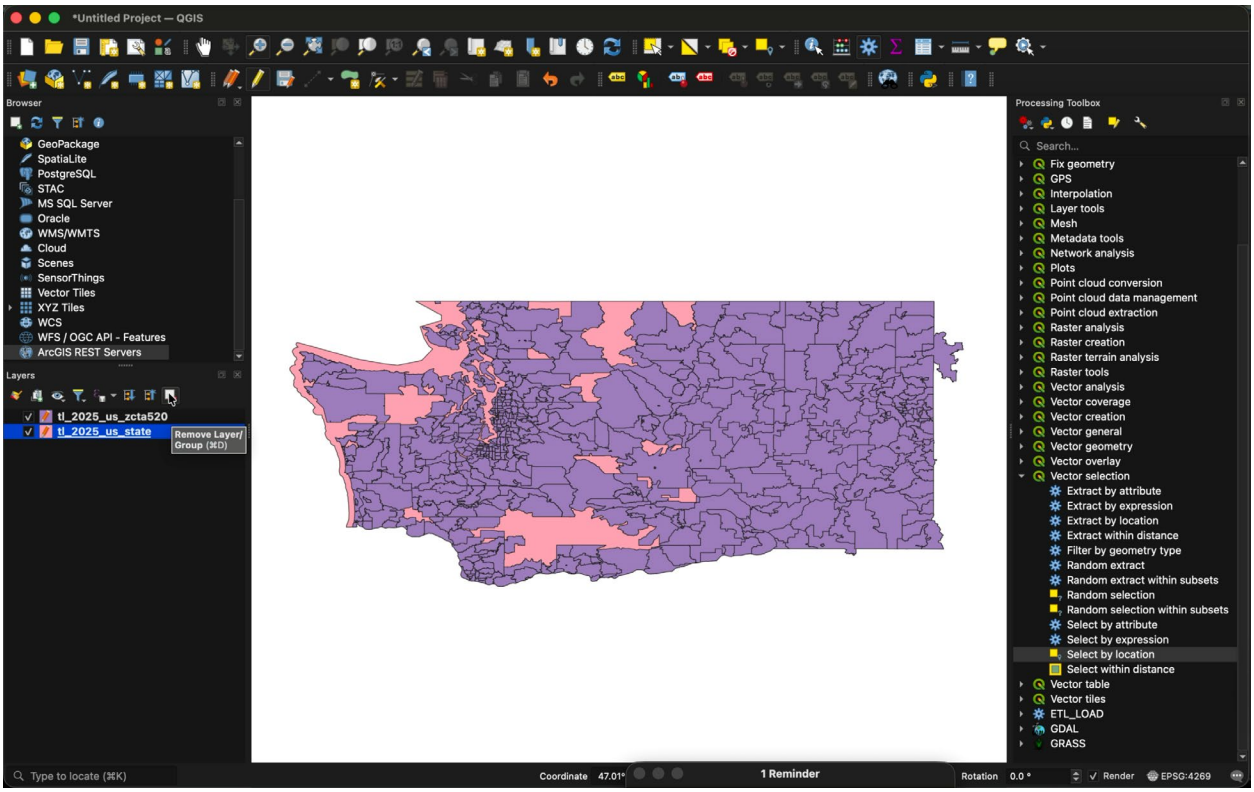
H. Select the state footprint features from the ZCTA layer by comparing with features from the state footprint layer. For this exercise, select features that “overlap” and “are within” the state footprint layer. It is important to select ZCTAs that overlap and are within the state footprint, as ZCTAs can cross state lines and may serve part of a state while not being fully within a state’s footprint. This is less important for areas which are typically fully encompassed by a state’s footprint (e.g., counties, county subdivisions, census tracts, etc.). Also, be sure to bound the selection tool to the “Selected features only” (the selected state footprint). Once tool options are selected, the selection tool can be run.



I. Select the ZCTA layer and invert the selected ZCTAs to select all ZCTAs outside of the state's footprint. Delete all ZCTA features outside of the state of interest's footprint.

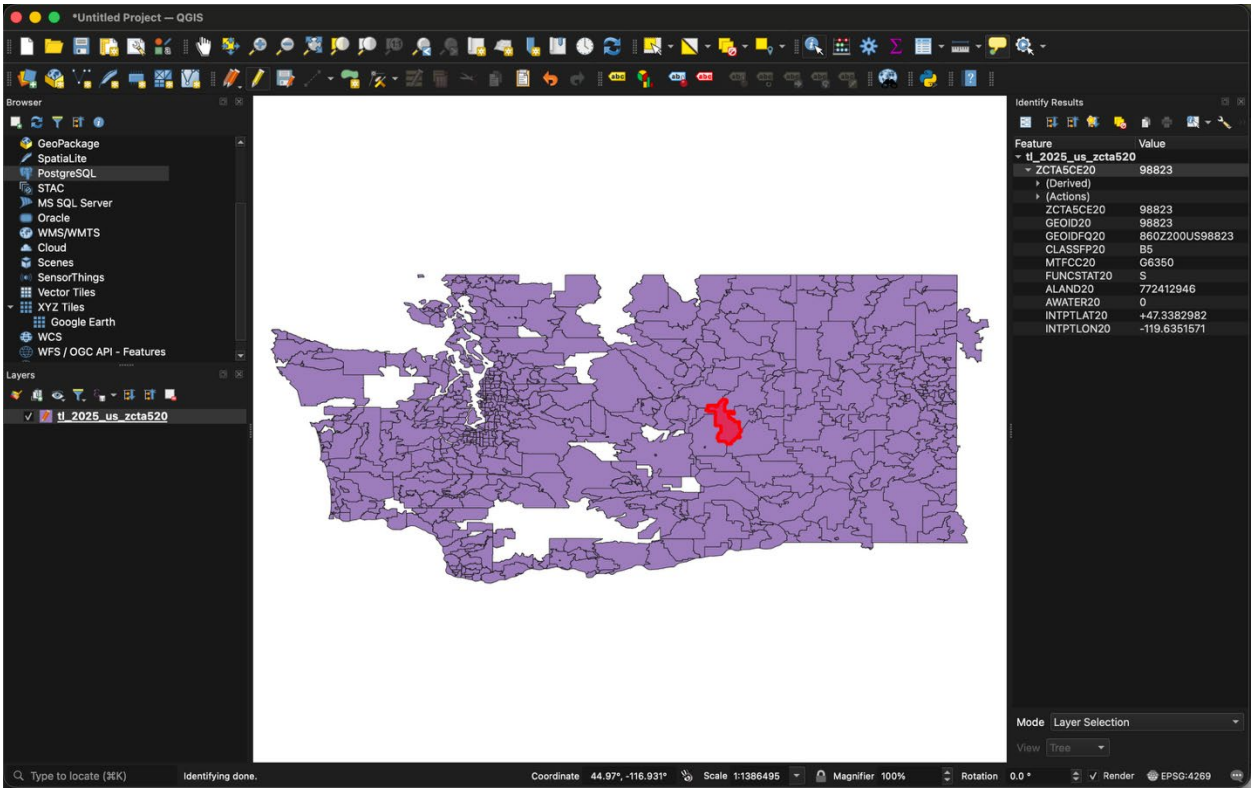


J. With all ZCTA layer now bounded to the state footprint of interest, select the state layer and remove the state layer.



## Step 5: Viewing, Adding, and Editing Shapefile Attributes

Alongside the geometries encoded within a shapefile, attributes can also be associated with every bounded shape represented within a shapefile layer. Attributes are key-value pairs, with a key that describes the data object contained by each bounded shape and the value of that data.




Attributes can be utilized to describe information about the jurisdictions represented within a shapefile, such as jurisdiction names, short names, regional designation, or other information. For this exercise, attributes will be added to the ZCTA map that was previously bound to the footprint of Washington State. These attributes will identify those ZCTAs that contain a PNNL office. A table showing the PNNL offices and their associated ZIP codes can be seen in Table 1.

*Table 1. All PNNL offices and their associated state and local ZIP codes.*

| PNNL Office Name | State Code | ZIP Code |
|---|---|---|
| PNNL Main Campus | WA | 99354 |
| PNNL Seattle Office | WA | 98109 |
| PNNL Sequim Office | WA | 98382 |
| PNNL Portland Office | OR | 97204 |
| PNNL Washington DC Office | DC | 20024 |
| PNNL College Park Office | MA | 20740 |

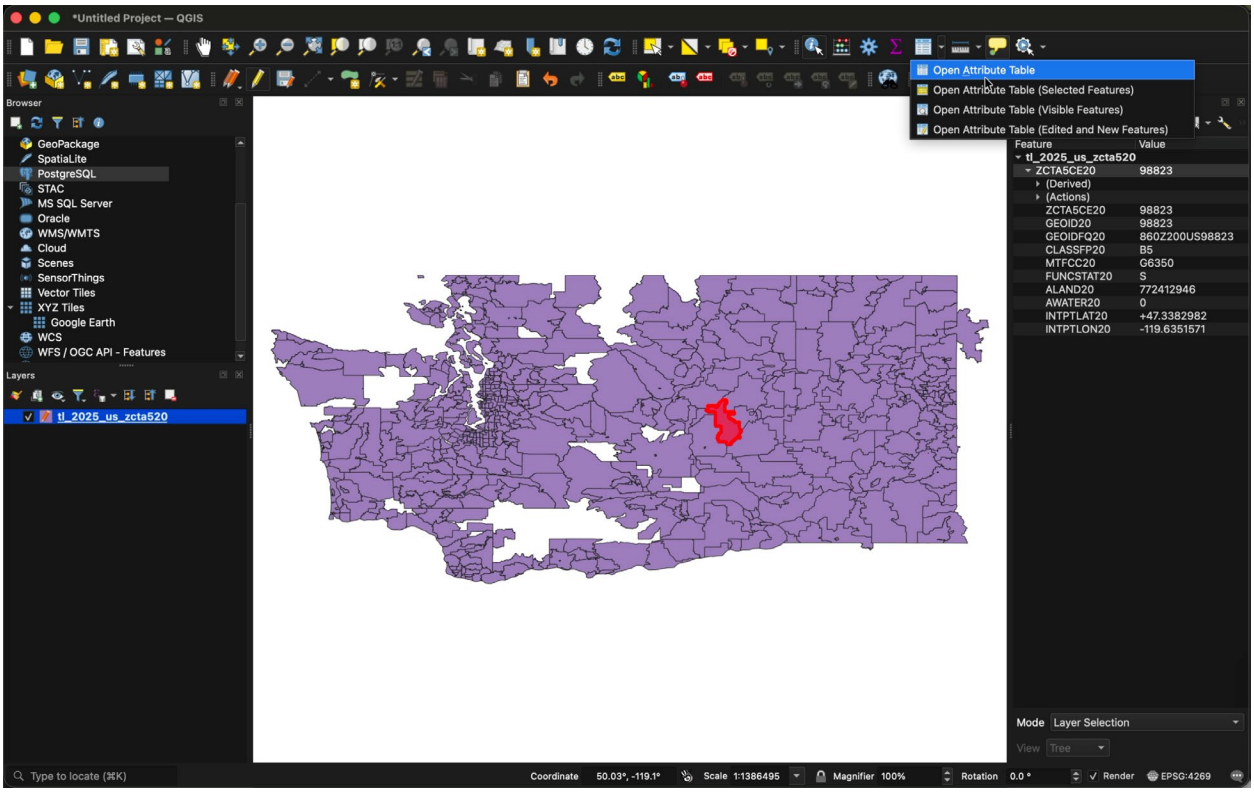
| | | |
|---|---|---|
| PNNL Corvallis Office | OR | 97330 |

## Adding Shapefile Attributes

Utilizing the information in Table 1, attributes will be added to the manipulated shapefile layer to identify those ZCTAs in Washington state that contain a PNNL office. This can be accomplished via the following steps:

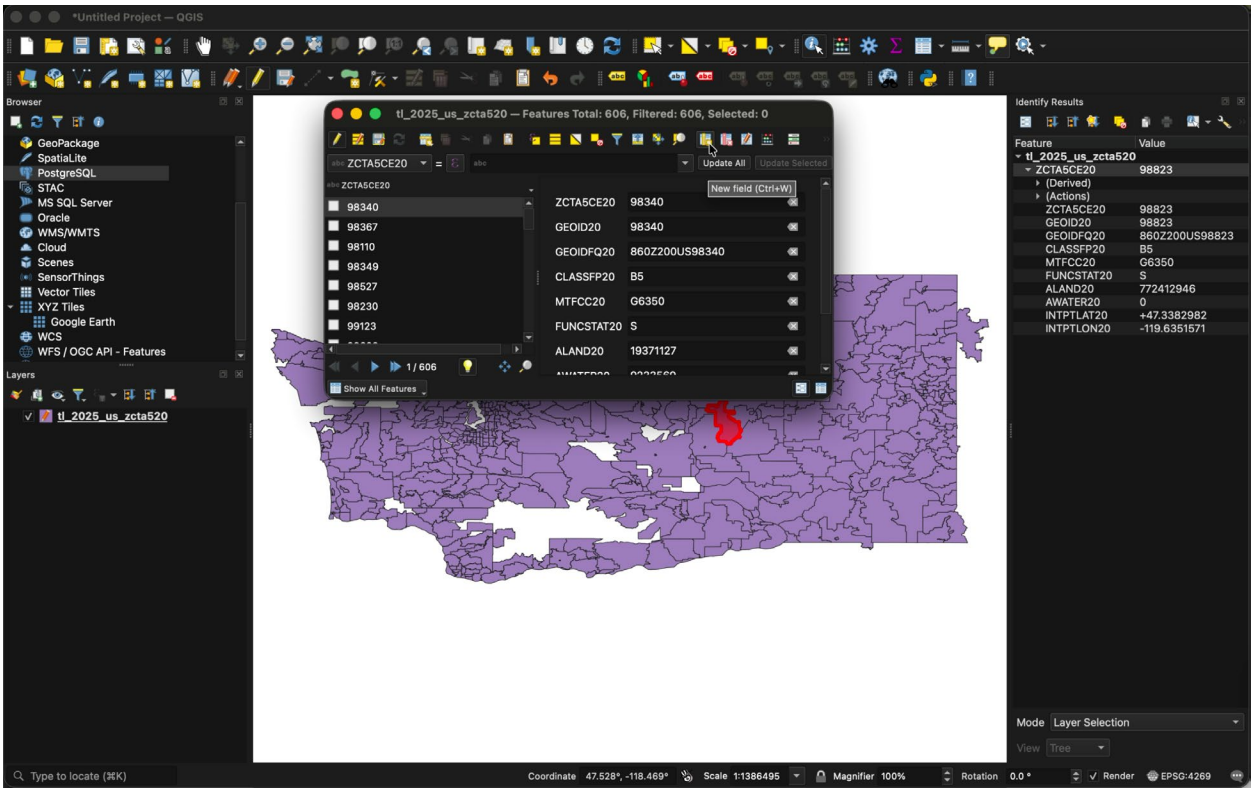
### *Step 1: Open the Shapefile Attributes Table*

While shapefile attributes can be manually viewed by selecting a bounded jurisdiction on the map using the “Identify Features” selector, the entire list of attributes can be viewed by right clicking the shapefile layer and selecting “Open Attribute Table” or by clicking on the “Open Attribute Table” button on the top menu.




### *Step 2: Adding New Fields to the Shapefile Attributes*

While inside the attribute table, click the “New field” button to add a new field to the attributes table for all jurisdictions within the shapefile. For this exercise, a Boolean field called “PNNLCAMPUS” was added to the attributes table. When this field is created, it will be populated with NULL values until a value is specified.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PostgreSQL
STAC
MS SQL Server
Oracle
WMS/WMTS
Cloud
Scenes
SensorThings
Vector Tiles
XYZ Tiles
Google Earth
WCS
WFS / OGC API - Features
Layers
tl_2025_us_zcta520
tl_2025_us_zcta520 — Features Total: 606, Filtered: 606, Selected: 0
ZCTA5CE20
Update All
Update Selected
New field (Ctrl+W)
98340
98367
98110
98349
98527
98230
99123
ZCTA5CE20 98340
GEOID20 98340
GEOIDFQ20 860Z200US98340
CLASSFP20 B5
MTFCC20 G6350
FUNCSTAT20 S
ALAND20 19371127
1 / 606
Show All Features
Identify Results
Feature
Value
tl_2025_us_zcta520
ZCTA5CE20 98823
(Derived)
(Actions)
ZCTA5CE20 98823
GEOID20 98823
GEOIDFQ20 860Z200US98823
CLASSFP20 B5
MTFCC20 G6350
FUNCSTAT20 S
ALAND20 772412946
AWATER20 0
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INTPTLON20 -119.6351571
Mode Layer Selection
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Type to locate (⌘K)
Coordinate 47.528°, -118.469°
Scale 1:1386495
Magnifier 100%
Rotation 0.0 °
Render
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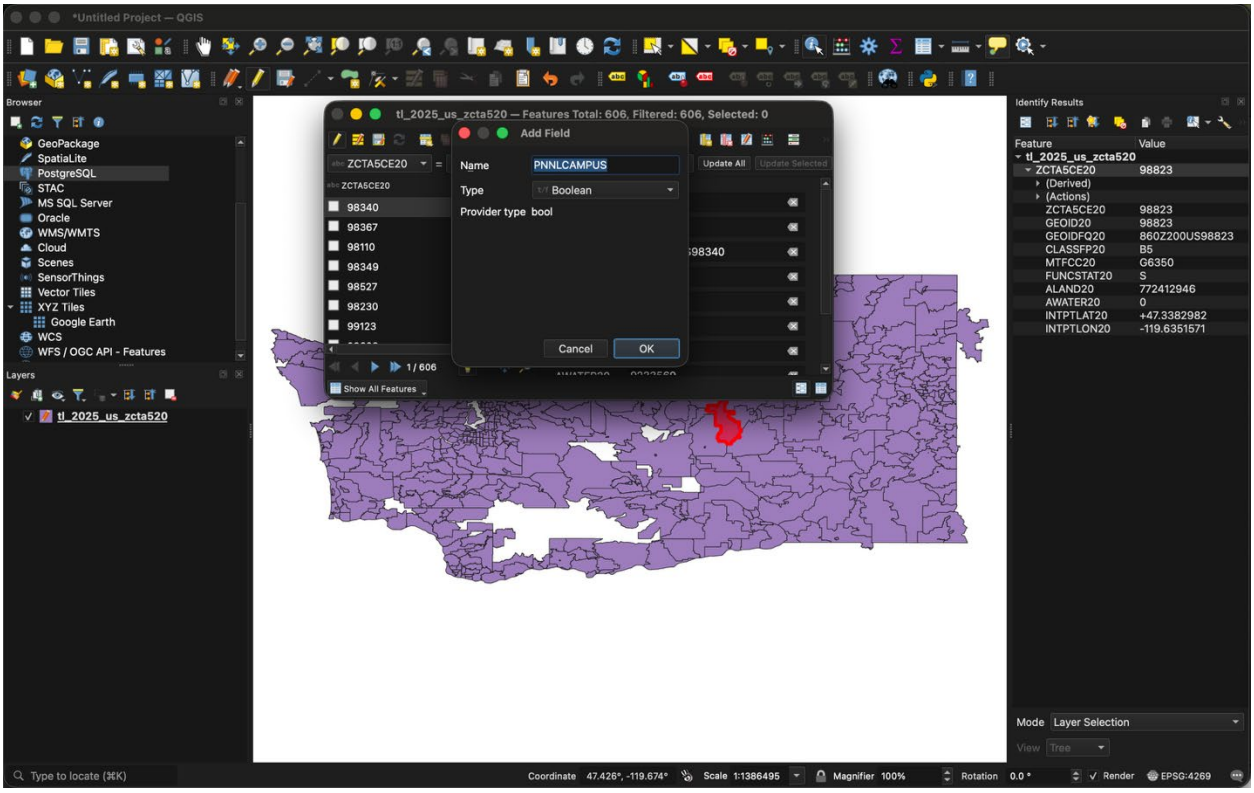
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PostgreSQL
STAC
MS SQL Server
Oracle
WMS/WMTS
Cloud
Scenes
SensorThings
Vector Tiles
XYZ Tiles
Google Earth
WCS
WFS / OGC API - Features
Layers
tl_2025_us_zcta520
tl_2025_us_zcta520 — Features Total: 606, Filtered: 606, Selected: 0
Add Field
Name PNNLCAMPUS
Type Boolean
Provider type bool
Cancel
OK
ZCTA5CE20
Update All
Update Selected
98340
98367
98110
98349
98527
98230
99123
1 / 606
Show All Features
Identify Results
Feature
Value
tl_2025_us_zcta520
ZCTA5CE20 98823
(Derived)
(Actions)
ZCTA5CE20 98823
GEOID20 98823
GEOIDFQ20 860Z200US98823
CLASSFP20 B5
MTFCC20 G6350
FUNCSTAT20 S
ALAND20 772412946
AWATER20 0
INTPTLAT20 +47.3382982
INTPTLON20 -119.6351571
Mode Layer Selection
View Tree
Type to locate (⌘K)
Coordinate 47.426°, -119.674°
Scale 1:1386495
Magnifier 100%
Rotation 0.0 °
Render
EPSG:4269

*Step 3: Populating the Newly Added Attribute Field*

To populate the newly added attribute field, attribute values can be specified either by (1) manually navigating through the attribute table and populating data, or (2) by utilizing the field calculator accessible through the "Open Field Calculator" button with an abacus present both within the attributes table or on the main attributes toolbar.

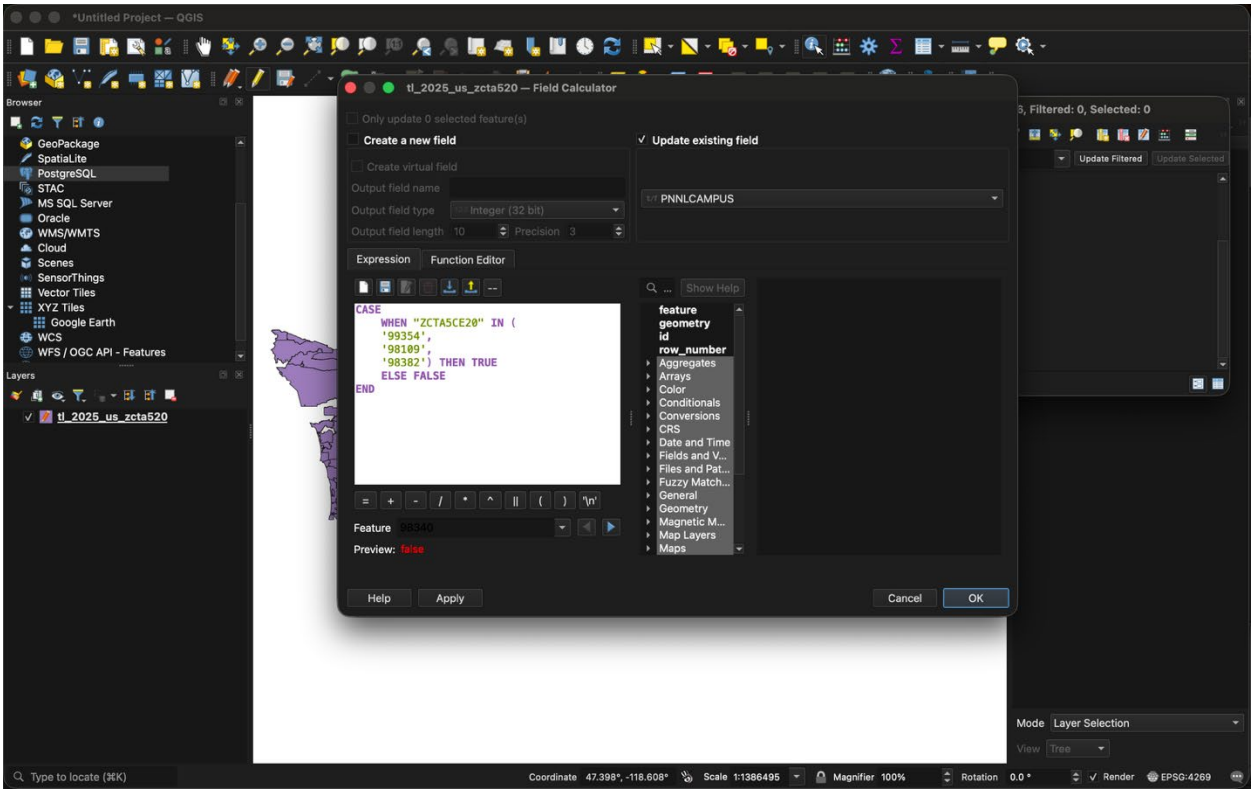
For this exercise, the field calculator was used, as it is the most scalable solution for situations where hundreds or thousands of attributes may need to be specified across many different delimited sub-jurisdictions. The following code can be utilized with the field calculator to populate the newly added attribute field:

```
CASE
     WHEN "ZCTA5CE20" IN (
     '99354',
     '98109',
     '98382') THEN TRUE
     ELSE FALSE
END
```

The above code block is a SQL command that contains the following specifications:

1. **Bolded in Red Text**: The sub-jurisdiction delimiter field of interest. For this specific example, ZIP-code tabulated areas are the sub-jurisdiction delimiter field of interest; however, a different attribute field may need to be specified if a different sub-jurisdiction delimiter of interest is being utilized, e.g., census tracts, counties, county subdivisions, etc. This field is specified as a string.
2. **Bolded in Green Text**: The sub-jurisdictions of interest. For this example, Table 1 specifies that PNNL campuses exist within the ZIP codes of 99354, 98109, and 98382 within the footprint of Washington State. While this example only utilizes three ZIP codes, practical mapping applications may contain hundreds or thousands of sub-jurisdictions of interest. This field is specified as a list of strings delimited by commas.
3. **Bolded in Blue Text**: The attribute values. Per the structure of this command, the attribute sub-jurisdictions of interest specified above are given a value of **TRUE** if they are contained within the list specified above. For sub-jurisdictions of interest not within the specified list, they will be given a value of **FALSE**. This section of the code is written to declare Boolean values as the field generated in *Step 2: Adding New Fields to the Shapefile Attributes* was specified to have a Boolean typing.

With the structure of the command specified, above command can be utilized in the field calculator as follows. Note that the "Update existing field" checkbox should be selected, and the field generated in *Step 2: Adding New Fields to the Shapefile Attributes* should be selected as the field to be updated:

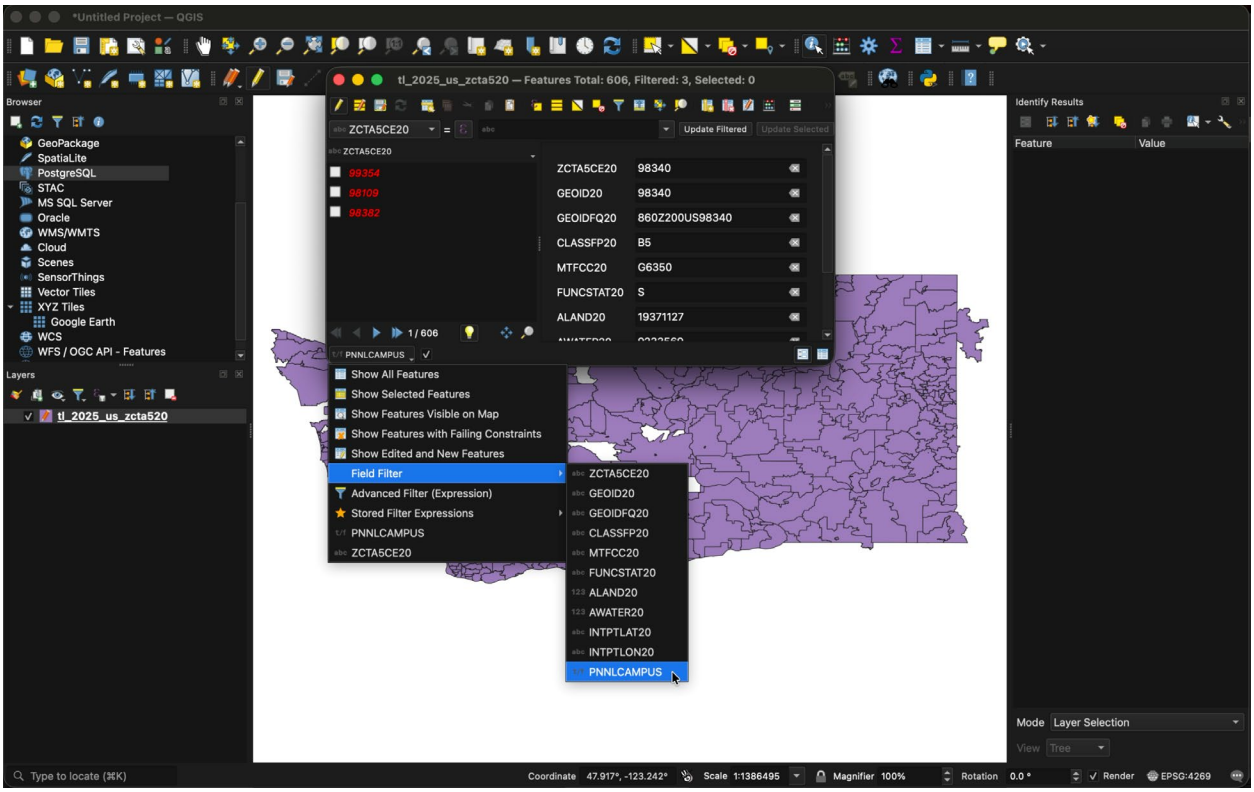



*Step 4: Viewing the Populated Attribute Field*

Within QGIS, attribute values can be viewed either through (1) the attributes table, (2) querying the attributes of sub-jurisdictions via the “Identify Features” function on the map, or (3) creating a false color plot to visually highlight attribute values on the map. Steps on how to view attributes through the available QGIS features are as follows:

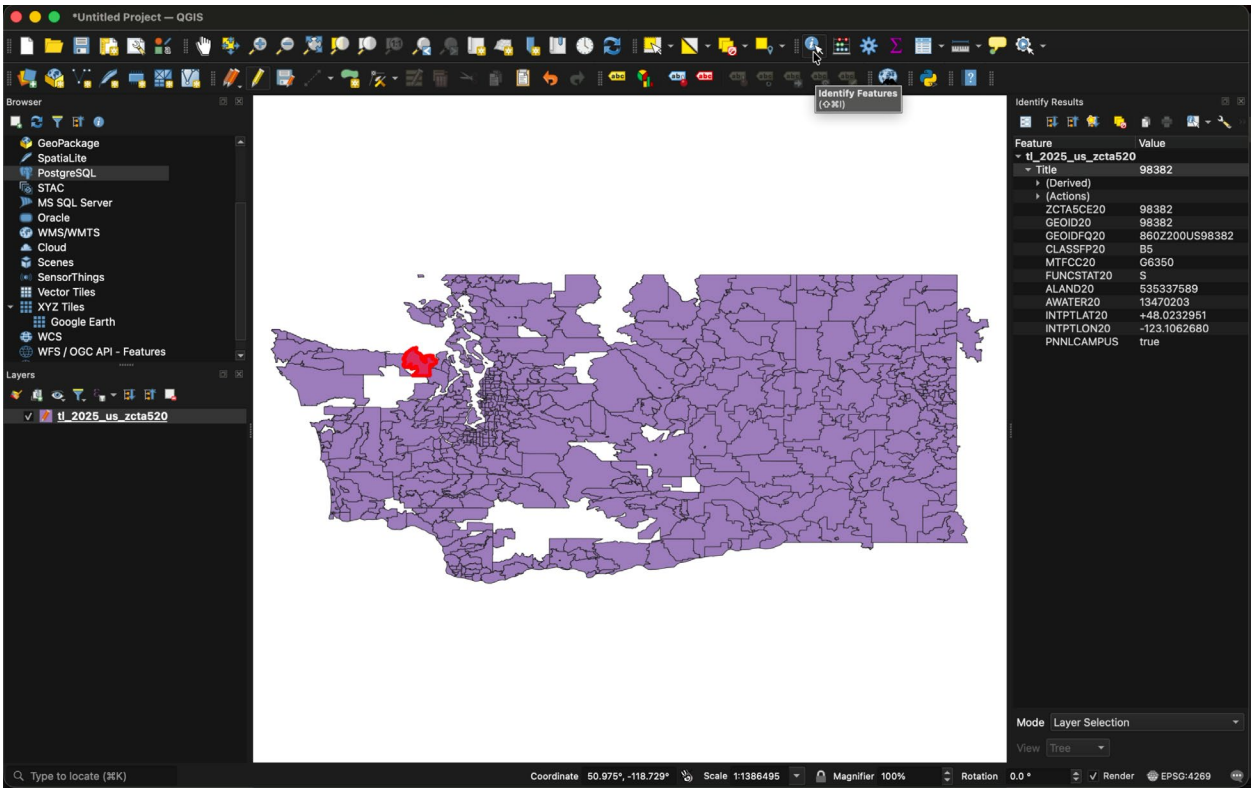
*(1) Utilizing the Attributes Table*

The attributes table can be filtered by selecting a filter field and selecting the check box to only display sub-jurisdictions with TRUE values for the selected field to filter on.



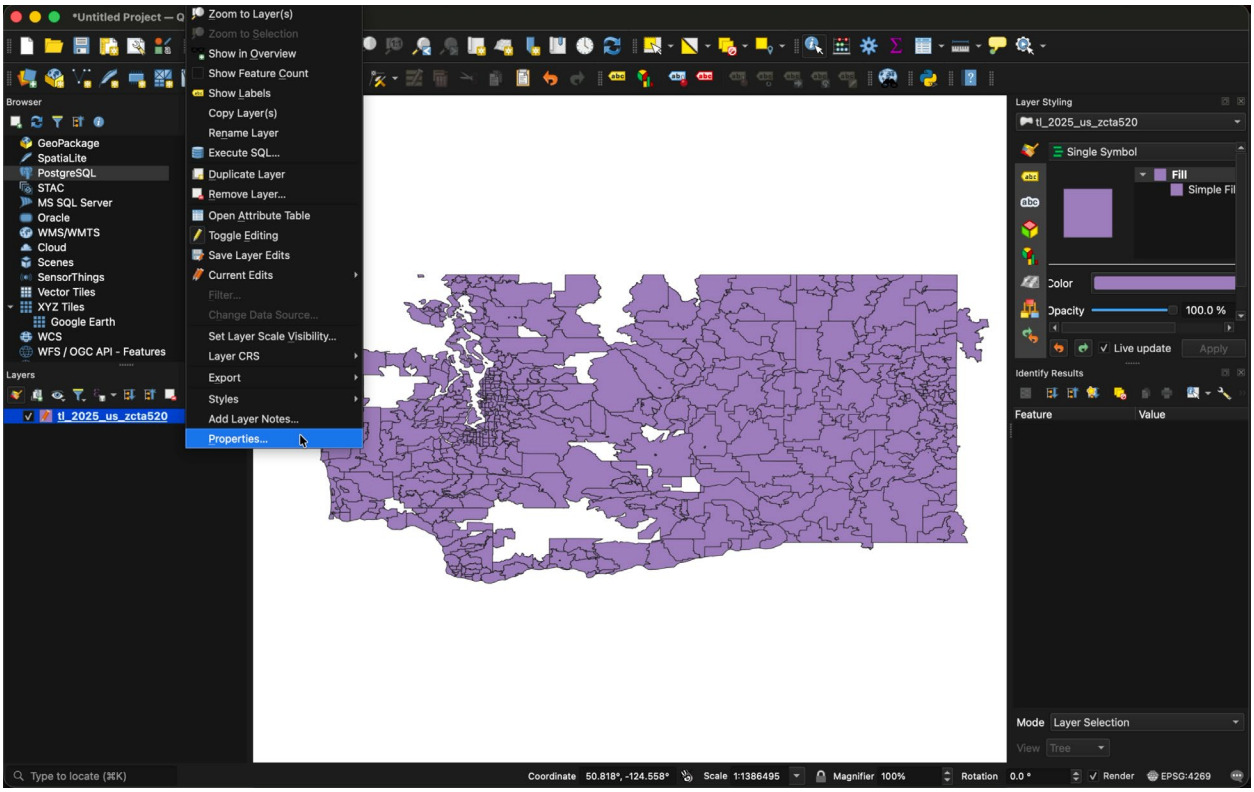

*(2) Utilizing the Map Attribute Viewer*

Sub-jurisdiction attributes can also be manually reviewed by utilizing the “Attribute Viewer” tool and manually selecting sub-jurisdictions on the map.

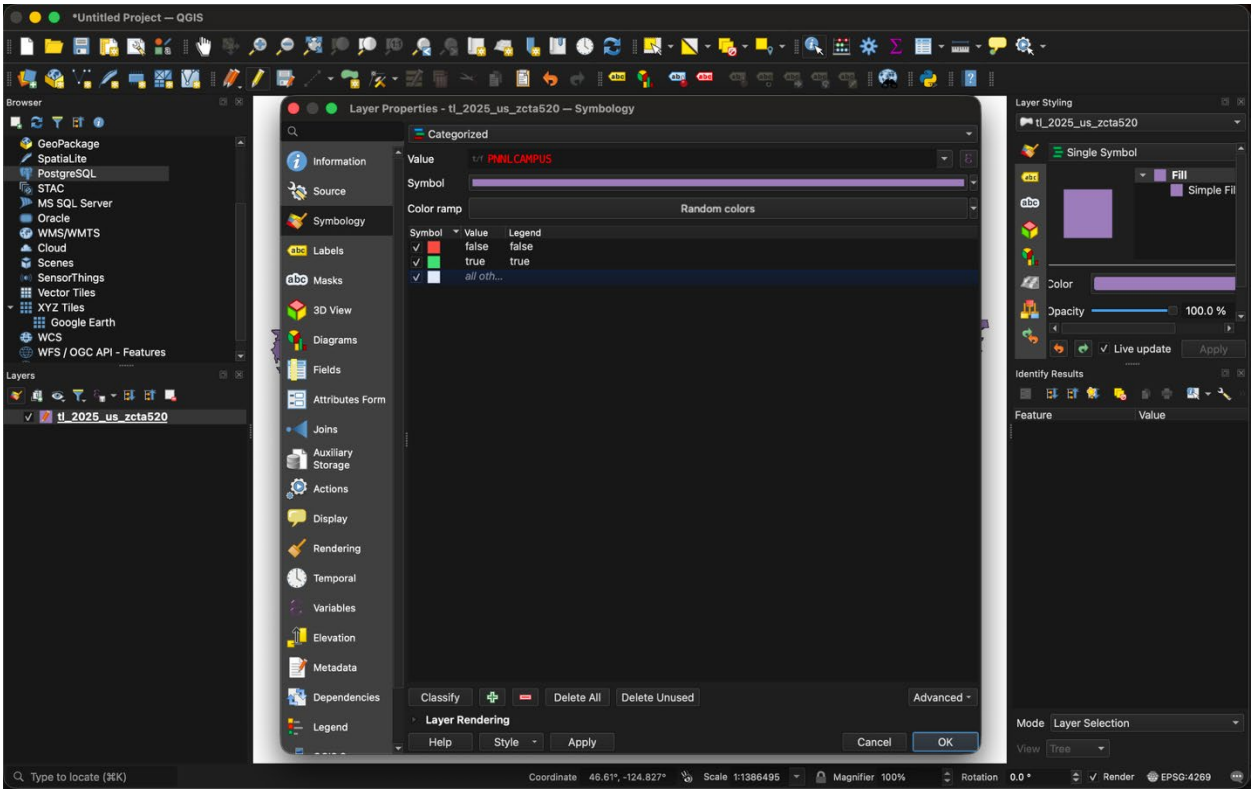



*(3) Utilizing A False Color Map*

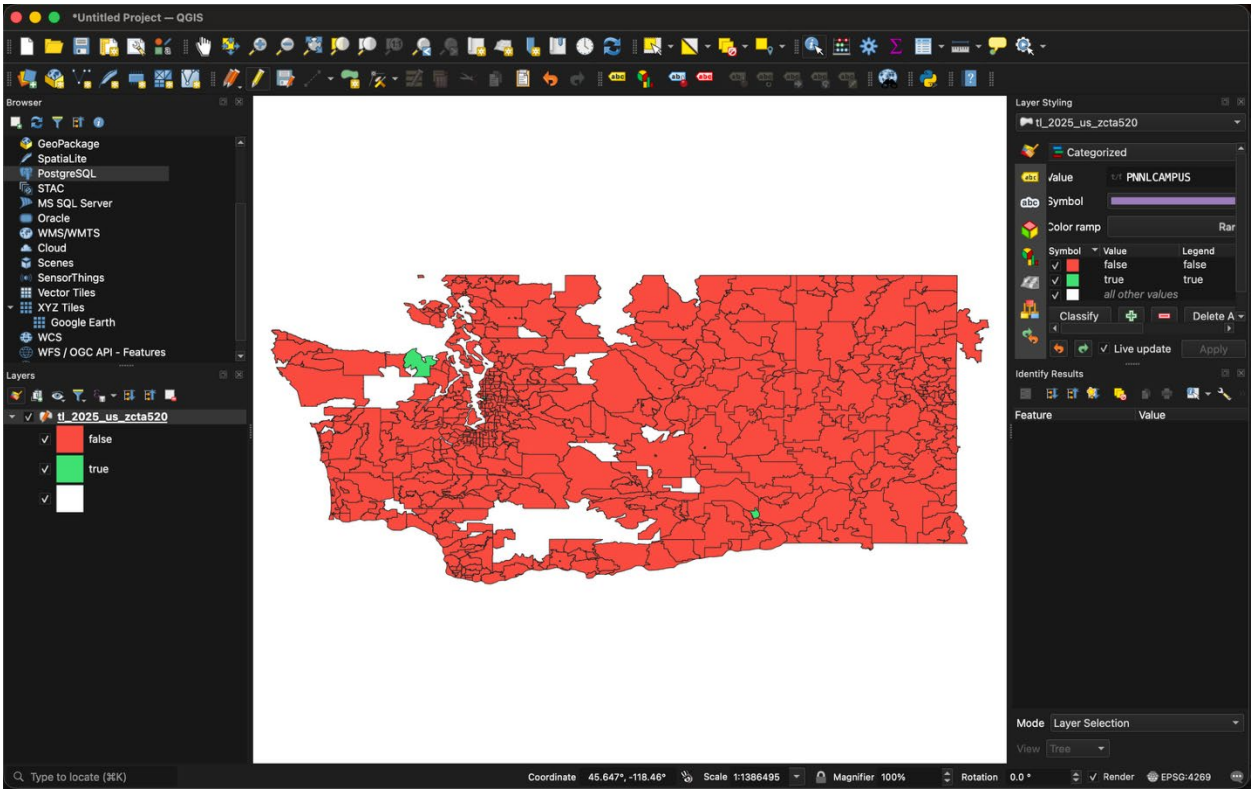
To color a map based upon attribute values, a “categorized” color fill must be selected under Layer>Properties>Symbology. The layer properties menu can also be accessed by right clicking the layer of interest.




Once in the symbology menu, a categorized color map should be selected, and the attribute field of interest can be specified. For this example, “PNNLCAMPUS” was selected. Once the attribute field of interest is selected, color categories can be either manually specified or automatically populated via the “Classify” button.



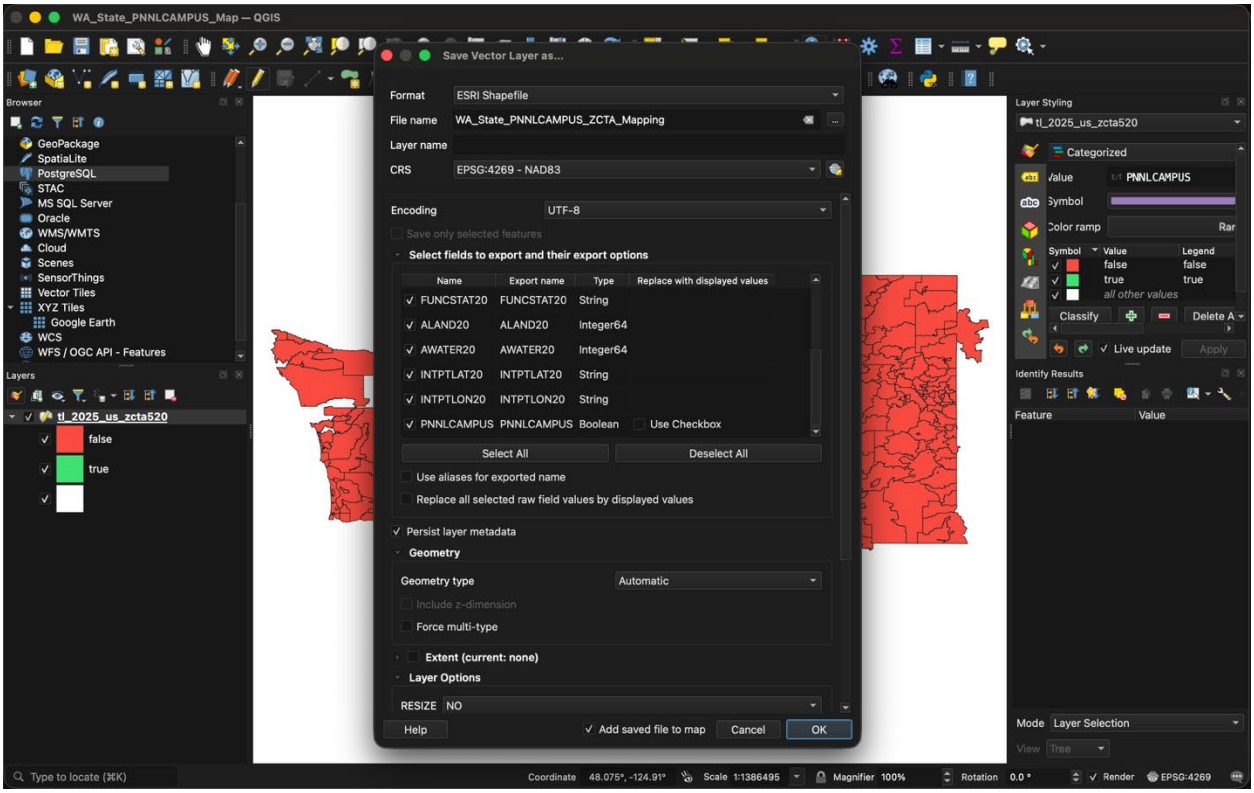

Applying this categorical false color mapping results in a color map where sub-jurisdictions with the attribute of interest declared as TRUE are colored green and those with a value of FALSE are colored red. Any sub-jurisdictions with attribute of interest values that are neither TRUE nor FALSE will be white.




## Exporting Manipulated Map Layers as Shapefiles

With the map geometry manipulated and the attribute values specified, this map layer can now be exported as a shapefile. While not explicitly specified throughout, it is recommended to save the working file often and be sure to save all changes before exporting the map layer. The map layer can be exported by (1) navigating to Layer > Save As in the Layer menu, or (2) right-clicking the layer and navigating to Export > Save Features As…

Exported map layers should be exported as an “ESRI Shapefile” format. For mapping files utilized in the PNNL Rebates API, an “ESPG:4269 – NAD83” coordinate reference system (CRS) should be utilized, as the PNNL Address Service is built upon US Census Bureau TIGER county subdivision shapefiles that also use NAD83 as a CRS. Exported shapefiles should be UTF-8 encoded, export all attribute fields, and persist layer metadata.


WA_State_PNNLCAMPUS_Map — QGIS
Save Vector Layer as...
Format
ESRI Shapefile
File name
WA_State_PNNLCAMPUS_ZCTA_Mapping
Layer name
CRS
EPSG:4269 - NAD83
Encoding
UTF-8
Save only selected features
Select fields to export and their export options
Name
Export name
Type
Replace with displayed values
FUNCSTAT20 FUNCSTAT20 String
ALAND20 ALAND20 Integer64
AWATER20 AWATER20 Integer64
INTPTLAT20 INTPTLAT20 String
INTPTLON20 INTPTLON20 String
PNNLCAMPUS PNNLCAMPUS Boolean
Use Checkbox
Select All
Deselect All
Use aliases for exported name
Replace all selected raw field values by displayed values
Persist layer metadata
Geometry
Geometry type
Automatic
Include z-dimension
Force multi-type
Extent (current: none)
Layer Options
RESIZE NO
Help
Add saved file to map
Cancel
OK
Browser
GeoPackage
SpatiaLite
PostgreSQL
STAC
MS SQL Server
Oracle
WMS/WMTS
Cloud
Scenes
SensorThings
Vector Tiles
XYZ Tiles
Google Earth
WCS
WFS / OGC API - Features
Layers
tl_2025_us_zcta520
false
true
Layer Styling
tl_2025_us_zcta520
Categorized
PNNLCAMPUS
Symbol
Color ramp
Value
Legend
false
true
all other values
Classify
Live update
Apply
Identify Results
Feature
Value
Mode
Layer Selection
View
Tree
Type to locate (⌘K)
Coordinate
48.075°, -124.91°
Scale
1:1386495
Magnifier
100%
Rotation
0.0 °
Render
EPSG:4269