QGIS

Introduction

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Additional tools:

QGIS User Guide: https://docs.qgis.org/3.22/en/docs/user_manual/

> *Provides detailed guidance for using QGIS*

QGIS Training Manual: https://docs.qgis.org/3.22/en/docs/training_manual/

> *Provides tutorials and more general guidance in QGIS*

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1. Download QGIS

To download and install QGIS, go here: https://www.qgis.org/en/site/forusers/download.html

For those new to QGIS, they recommend the standalone installers. The most stable option is the long term release. This guide is based on QGIS version 3.22 long term release.

2. Starting a Project

When you open QGIS, you can start a new project or open a recent one from the Project tab along the top menu. To create a new one, go to Project => New and a blank map will open with default map properties and settings.

Save the project by going to Project => Save or with the save button just below the Project tab.

2.1. Map properties

Project (along top menu) => Properties

- *General:* Define map units for distance/area measurements and coordinate display
- *Metadata:* Project description; useful when sharing project
- *CRS:* Define **map** coordinate system (CRS); automatically assumes the CRS of the 1st layer added to the map, whether or not it was manually set before adding the 1st layer
- *Default Styles:* Define default symbology
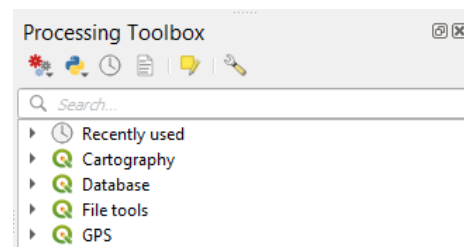
2.2. Toolbars and panels

View (along top menu) => Toolbars

- Allows easier access to tools above map

Project Toolbar

Map Navigation Toolbar

Selection Toolbar

Attributes Toolbar

Digitizing Toolbar

View (along top menu) => Panels

- Allows easier access to other tools
- Recommend having the Processing Toolbox Panel available to easily access and search for tools (shown to right; not all tools shown)

Processing Toolbox

Q Search...
▸ Recently used
▸ Q Cartography
▸ Q Database
▸ Q File tools
▸ Q GPS

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2.3. Plugins

Some tools may not be automatically available/visible. For example, if the Processing tools are initially unavailable, the Processing plugin needs to be added. To add plugins, go to Plugins (along the top menu) and select Manage and Install Plugins. This takes you to the following menu to select and install or uninstall plugins:
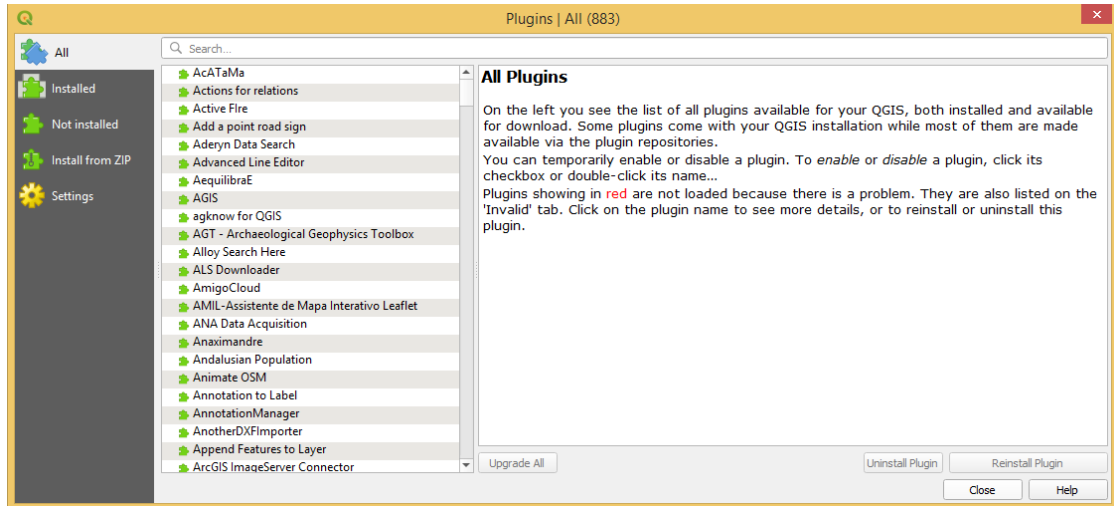
3. Adding Data

To add a data layer, go to Layer (along the top menu) and select Add Layer. From there, you can select what type of data you are adding (e.g., vector, raster).

3.1. Layer properties

Information: Layer name, data type, coordinate system, fields

Source: Includes Assigned Coordinate System **Note: changing this does not reproject the data; see 3.2 below for how to change the projection for a layer*

Symbology: Settings for layer symbol design

Labels: Settings for layer labeling

Auxiliary Storage: Stores information that only belongs to the project; information is not saved in the data sources itself (e.g., label information such as position, rotation, size)

Rendering: Define how the layer appears on the map (not symbology); allows scale dependent visibility (changes what layers are visible based on the map scale)

Metadata: Details about the layer; useful if sharing layer

3.2. Reproject vector data

Vector (along top menu) => Data Management Tools => Reproject Layer

- *Input Layer:* the layer to be reprojected
- *Target CRS:* the coordinate system you want the layer to be
- *Reprojected:* the original layer and new reprojected layer will be saved as two separate layers; this is where you name and save the new reprojected layer; the small box to the right of this allows you to choose how this layer is saved
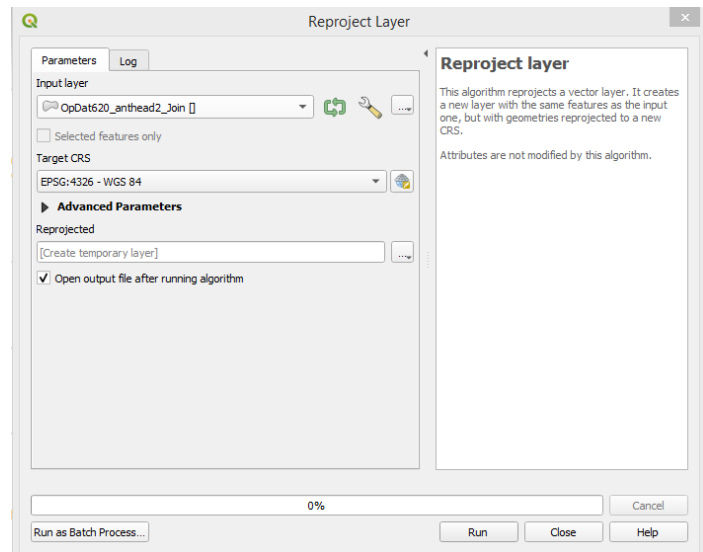
3.3. Other vector and raster tools

All other vector and raster tools are located under their respective tabs along the top menu. Tools can also be searched for in the Processing Toolbox Panel. Upon opening any tool, there should be a description of how the tool works and what data is required or optional. See the full QGIS manuals (linked at top) for a more detailed discussion of additional tools.

4. Attribute Table

Open the attribute table by right clicking the chosen layer and selecting Open Attribute Table.

4.1. Organization

This button opens a table similar to the one shown to the right.

Checked fields are shown in the attribute table. Fields can also be re-ordered by clicking and dragging any field above or below the others.
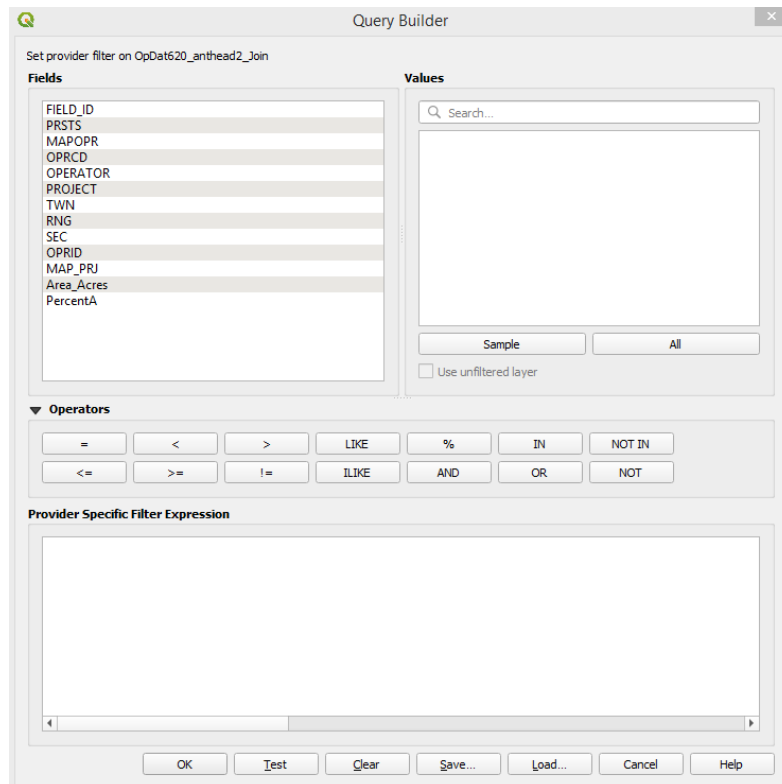
4.2. Filtering data

Data can be filtered from the attribute table menu or the map layers menu.

*From the attribute table*, a form is used to filter the data based on entered values:

From the map layers menu, right click the layer to be filtered and select Filter. This will open the following form, which requires an expression to filter data:

4.3. Field Calculator

The field calculator creates and updates fields in the attribute table based on the expression entered. Expressions follow a programming language-like syntax. Functions, variables, and other values are provided in the center drop down menu. Clicking on any function brings up a description, including input parameters. Double-clicking adds the function to the expression. A preview of the output is also given in the bottom left corner.
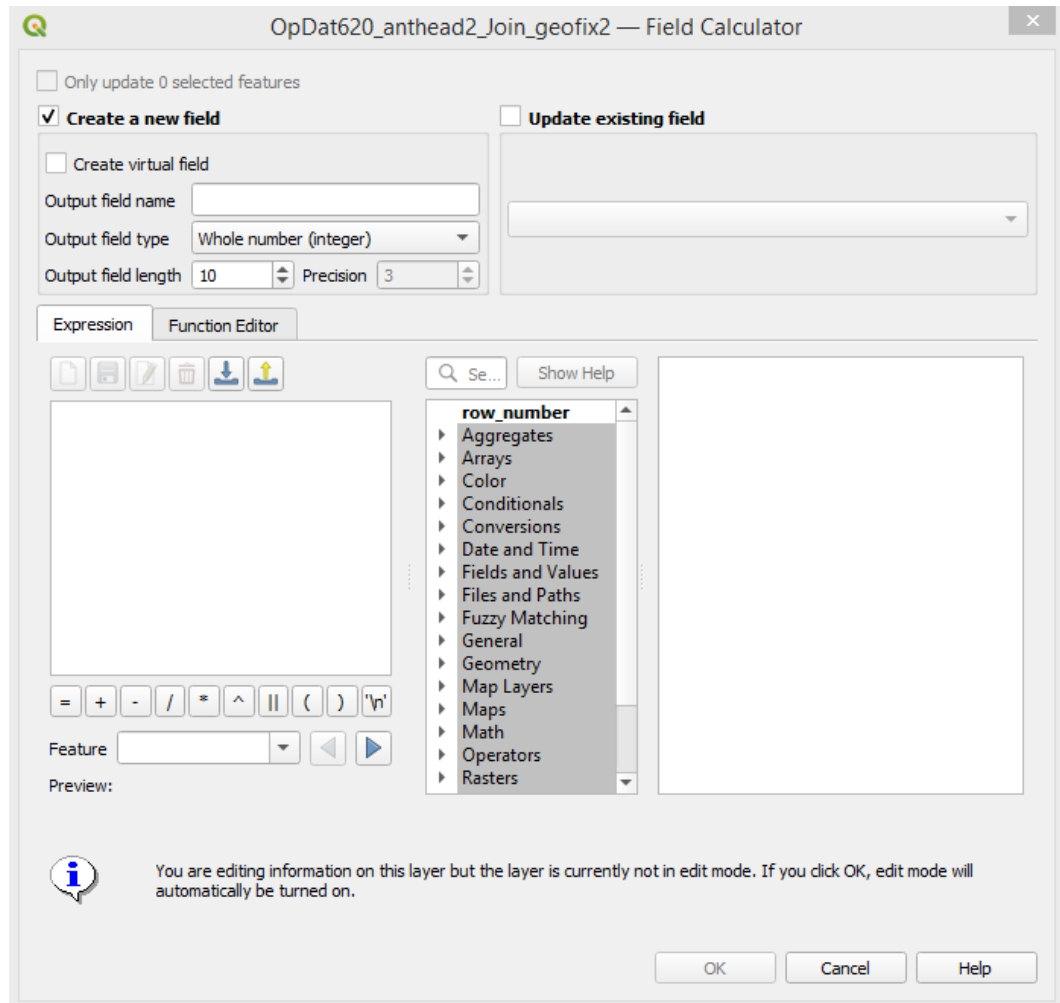
Fields can be created without an expression to update values by

(1) entering edit mode by clicking the pencil icon in the top left corner of the attribute table and

(2) selecting the New Field icon:
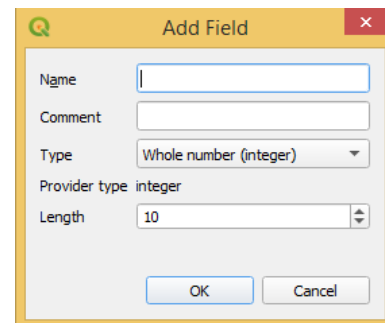
Fields may also be deleted in edit mode by selecting the Delete Field icon:

5. Creating and Editing Shapefile Layers

5.1. Creating a new shapefile layer

To create a new layer, go to Layer (top menu) => Create Layer => New Shapefile Layer.

A form is brought up, which allows you to name the layer, choose the type of features (points, lines, or polygons), and add any new fields to the attribute table (these can be edited later according to section 4 above).

5.2. Snapping options

Before editing features, check the snapping options. Snapping allows you to add or connect features to existing features (e.g., connect lines at a line endpoint or at vertices). This is especially useful for ensuring that spatial relationships between features are maintained (topology).

Snapping settings are found by going to Project (along the top menu) and selecting Snapping Options. This brings up a form similar to the one shown below, which allows you to choose which layers have active snapping settings and the type of snapping allowed.
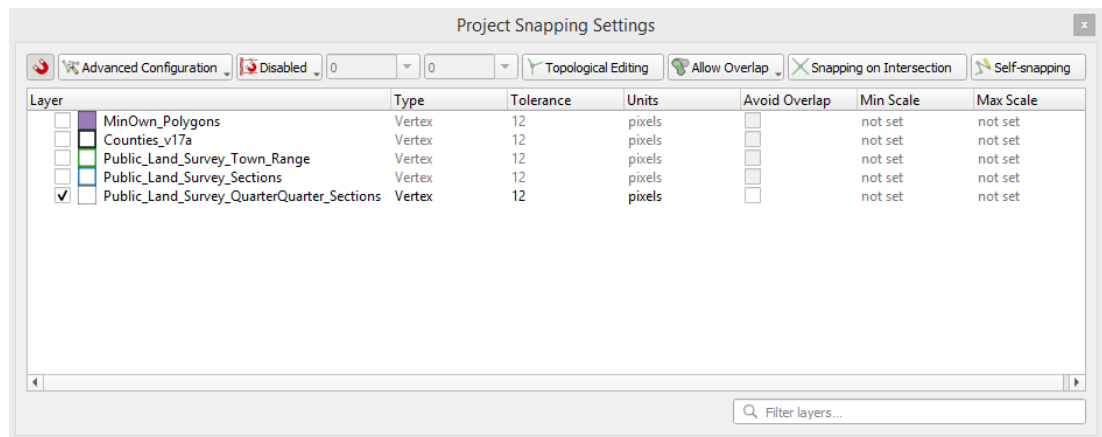
For a more detailed discussion on the types of snapping available, see the QGIS User Manual page on snapping.

5.3. Digitization tools

Once you have created a shapefile layer, or if you have a pre-existing one, you can edit the layer points, lines, or polygons using the Digitizing Toolbar:

All icons in this toolbar will likely start grayed out, unable to be used. To enable the tools on the digitizing toolbar, click the single pencil icon to allow editing. Other icons will vary depending on the type of layer features (points, lines, or polygons; the toolbar above is for polygons). One tool allows feature creation, another allows editing of vertices.

IMPORTANT! The normal project save button ***does not save layer edits!*** To save layer edits, you ***must use the save button in the digitizing toolbar***, next to the pencil editing icon.

6. Symbology

6.1. Single symbol editing

Layer symbology can be edited by double clicking a layer to open the Properties panel, then selecting Symbology. QGIS will automatically set a default symbology, but it typically needs to be changed. A sample symbology tab is shown below:
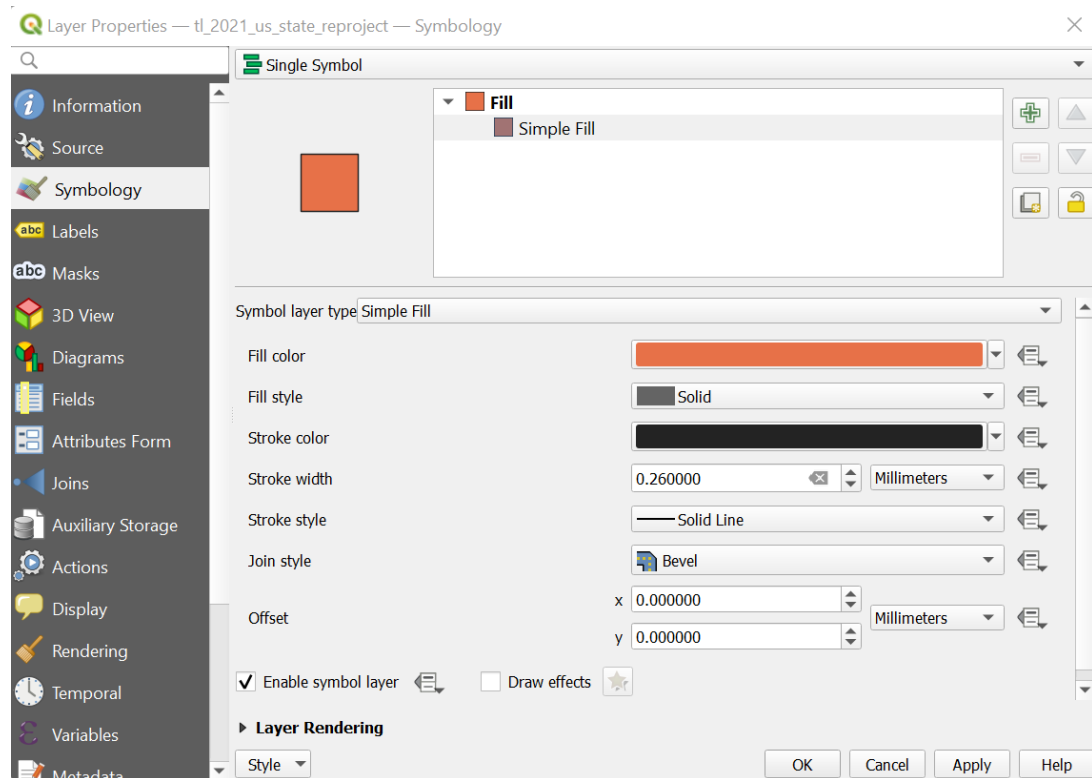
The default symbology is a Simple Fill. By selecting this within the symbology tab, you can change the symbol fill and border (called "stroke").

For both symbol fill and stroke, the color can be changed by going to the drop down next to the current color. You may either move the color around the color wheel given or enter more specific RGB/html values by selecting Choose Color. Another option, Pick Color, allows you to choose a color from your current screen (similar to the eyedropper option found in PowerPoint).
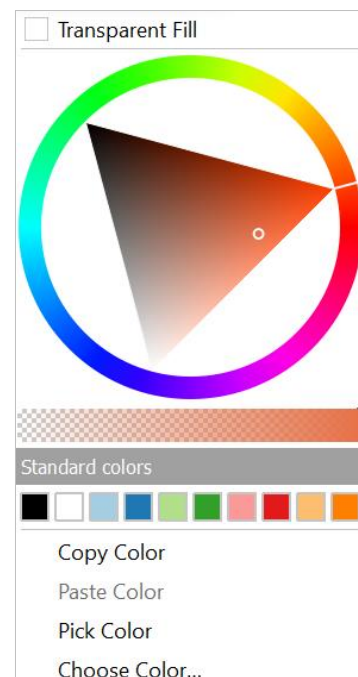
6.2. Categorized and other symbols

Other symbology options are found in the drop down next to Single Symbol at the top of the form. A few of these are Categorized, Graduated, and Rule-based:

- *Categorized* symbols allow you to have different symbols based on a chosen attribute.

- *Graduated* symbols allow a different symbol size (and color) based on a chosen attribute.

- *Rule-based* symbols allow more control over symbols for different features. This option allows you to enter an expression to define what features are grouped for symbols.

6.3. Layer rendering

Below the symbol fill options is a dropdown labeled Layer Rendering. In this dropdown is an option to change the layer opacity. This is most useful when you have multiple symbols for a single layer (i.e., when you choose any option other than Single Symbol). Instead of changing the opacity for each individual symbol, the setting under Layer Rendering allows you to change it for all symbols at once.

6.4. Creating your own symbol

Under the symbology tab in layer properties, you can change the symbol type by selecting the drop down for Symbol Layer Type.

Using Simple Marker, you can layer simple marker symbols by adding symbols with the green plus sign in the upper right corner.
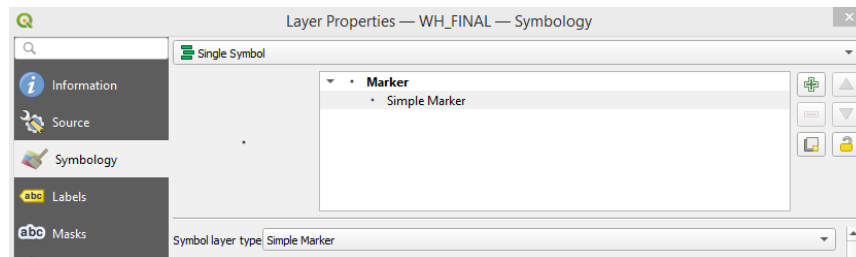
6.5. Saving and copying layer symbology

Symbology may be copied from one layer to another within a single project and saved to use in different projects.

Copying a color from one layer to another is the simplest. First, open the symbology tab for the layer you want to copy a color from, then open the color dropdown menu (as described and pictured in section 6.1). You will see an option to Copy Color. Select this to copy the color. Next, go to the layer you want to copy the color to. When you open the color dropdown, there should now be an option to Paste Color. Select this to paste the color you copied.

If you want to copy more than just the color, you can copy a symbol by right clicking on the layer, going to Styles, and selecting Copy Symbol. Similarly, you can paste this symbol into a new layer by right clicking, going to Styles, and selecting Paste Symbol.

You can also save an entire symbol. For example, you have a point layer symbolized by red triangles and a second point layer with the default symbology.
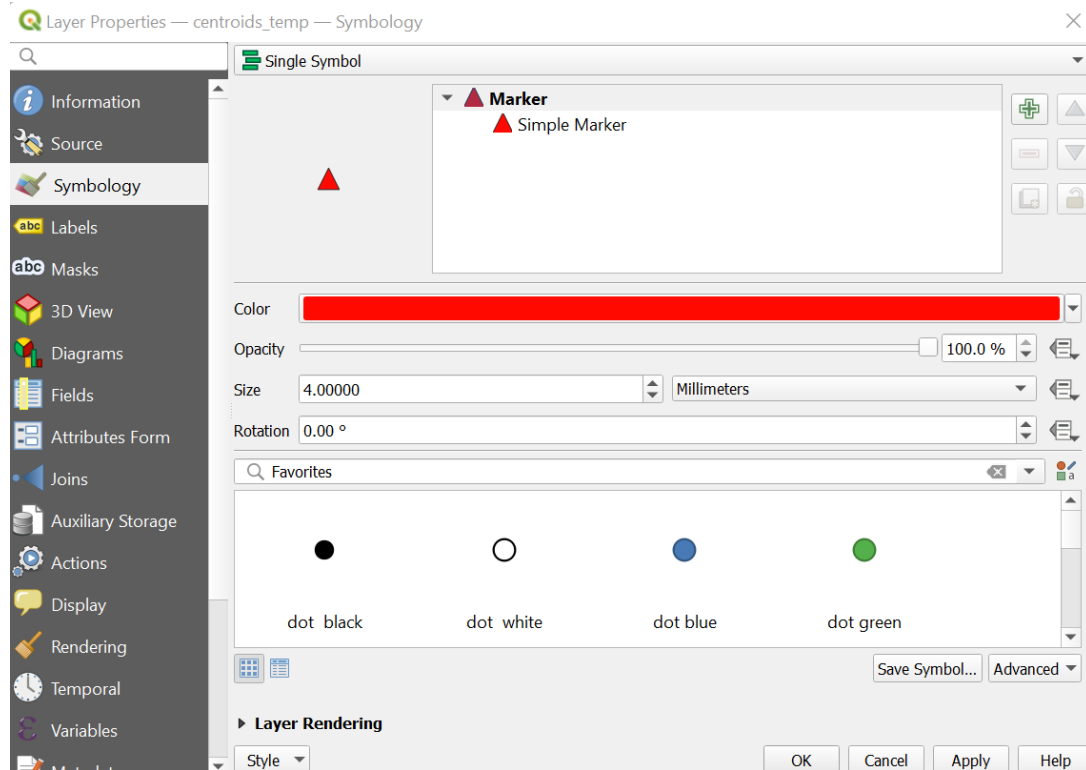
To save the red triangle symbol, go to the symbology tab for that layer. In the bottom right corner, select the Save Symbol button. This brings up a dialogue box to give your symbol a name (shown at right). Adding a tag or checking Add to favorites makes the symbol easier to find and use later (I recommend at least adding it to favorites).
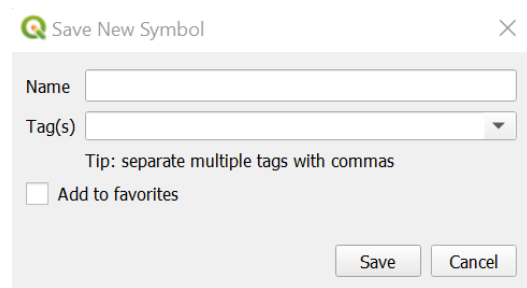
Now that the symbol is saved, you can close this layer's symbology and go to the layer that still has the default symbology. Open its symbology tab. In the middle of this tab is a search bar that says Favorites. This shows symbols that have been saved.
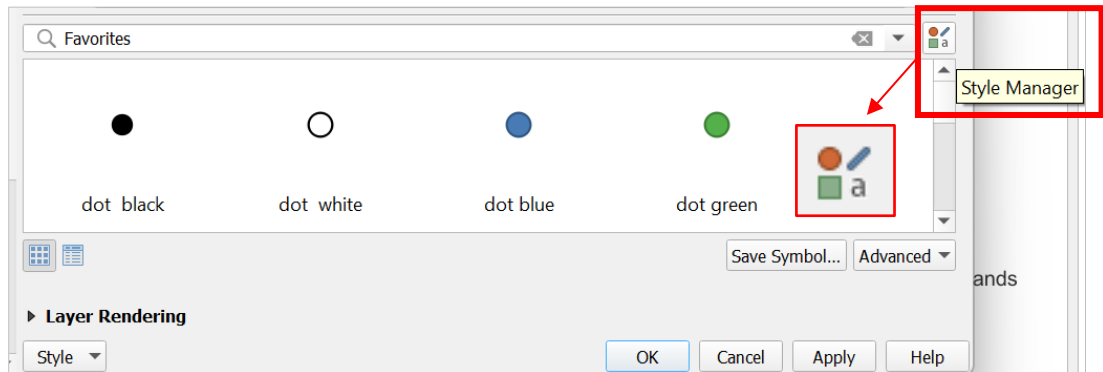
You can also find the red triangle by opening the full Style Manager:

Within the style manager, you can browse symbols by their group (Favorites and Tags) and by symbol type (marker, line, fill).

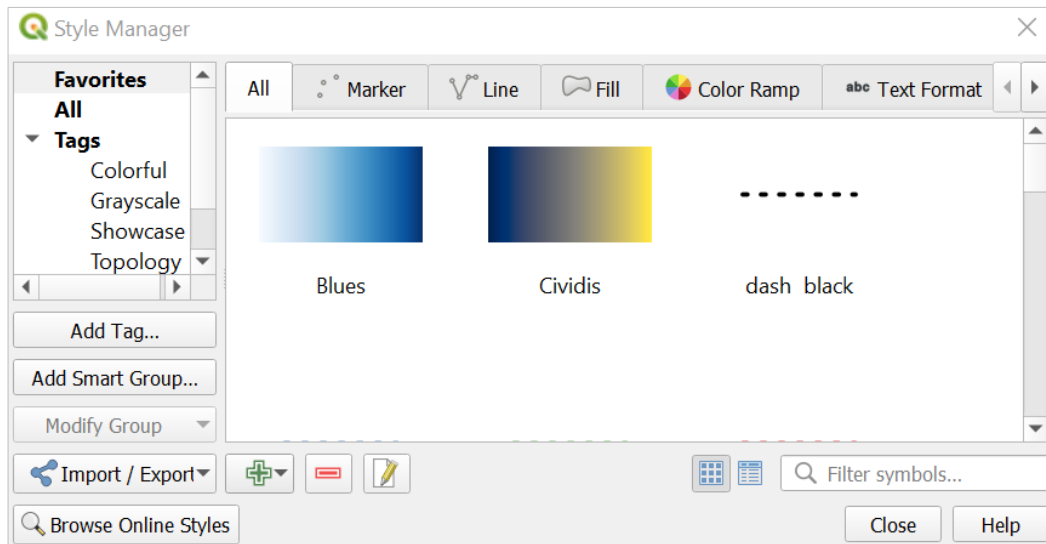Finally, within Style Manager, there is an option to Import/Export symbols in XML (not available for all style items), PNG, and SVG formats. This provides a method of sharing symbology with other people. Another method, using a GeoPackage file format, allows sharing of layer data as well as symbology. This is discussed below in section 10.
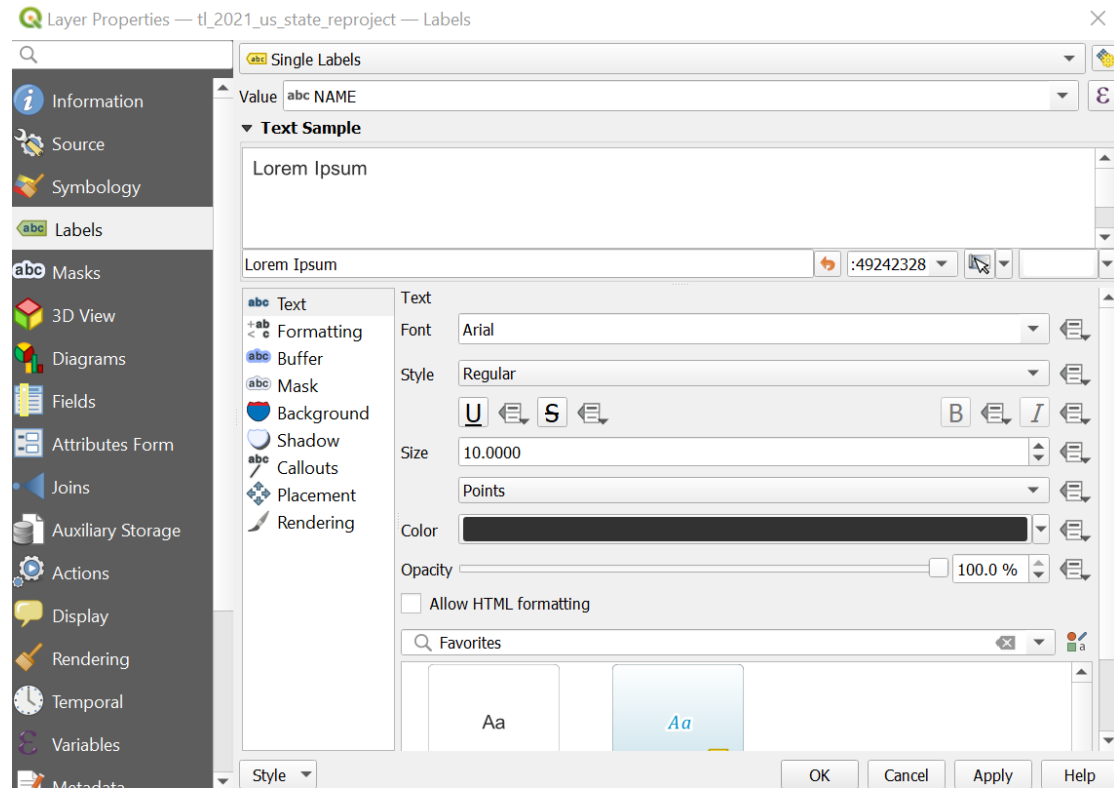
7. Labeling

7.1. Single label editing

Layer labels can be edited by double clicking a layer to open the Properties panel, then selecting Labels. QGIS will automatically set No Labels.

When you begin editing labels, you are prompted to select one of the attribute table fields as a *primary key*. The chosen field should have a unique value for every feature so that label data (e.g., position, rotation, color) is stored with the correct feature.

Some of the basic labeling options are shown below:

More detailed labeling options are found under the other tabs. Of note are
- *Formatting:* Change paragraph alignment and spacing
- *Buffer:* Adds a buffer around text; able to customize the size of buffer around text; especially useful to highlight labels over a background of a similar color
- *Shadow:* Adds a shadow behind text; able to customize the size and location of shadow around text; especially useful to highlight labels over a background of a similar color
  Note: buffer and shadow have similar effects, but different settings; shadow provides more detailed adjustments, but is not always necessary
- *Callouts:* Add callouts (lines from features to labels and/or boxes around labels)
- *Placement:* Sets general location for all labels on/around the features
- *Rendering:* Allows scale dependent visibility for labels (e.g., labels for smaller features remain invisible until zooming in to the chosen scale)

7.2. Rule-based labels

Similar to rule-based symbology, rule-based labels allow more control over labels for different features. This option allows you to enter an expression to define what features are grouped for labels.

*Note: As of QGIS version 3.22.6, rule-based labels may appear to function properly before disappearing from the map later. The simplest alternative is manually adding labels from the final Layout as textboxes (see section 8.1 below).

7.3. Editing labels

To edit individual labels, first select the pencil from the digitizing toolbar to enter editing mode. You can edit labels with the labeling toolbar tools by selecting the tool and clicking the label to edit.

From left to right:
- *Pin/Unpin Labels and Diagrams:* Pinned labels are fixed to a location on the map, so they cannot move on their own (labels are initially *unpinned*)

- *Show/Hide Labels and Diagrams:* With this tool, you can click labels to make them visible or invisible

- *Move a Labe, Diagram, or Callout:* Allows you to click and drag labels to new locations; when labels are moved, they also become pinned to their new location

- *Rotate a Label:* Allows you to click and rotate labels; to rotate with more accuracy, open the Change Label Properties tool to type in a rotation angle.

- *Change Label Properties:* Allows more accurate adjustments to properties like placement (x, y coordinates for labels) and rotation; also allows individual label changes in font, color, and other basic label properties (see sample form to right)

8. **Layouts**

The layout is used to design the final display for a map product, including additional labels, images, map legend, and other features. The layout can be printed directly or exported as a pdf, image, or png.

To create a new layout, go to Project => New Print Layout. You will be prompted to give the layout a name, then a blank layout will open.

The default layout size is 297 x 210 mm with landscape orientation. This is shown in the Item Properties tab, which is found by clicking on the blank layout page.
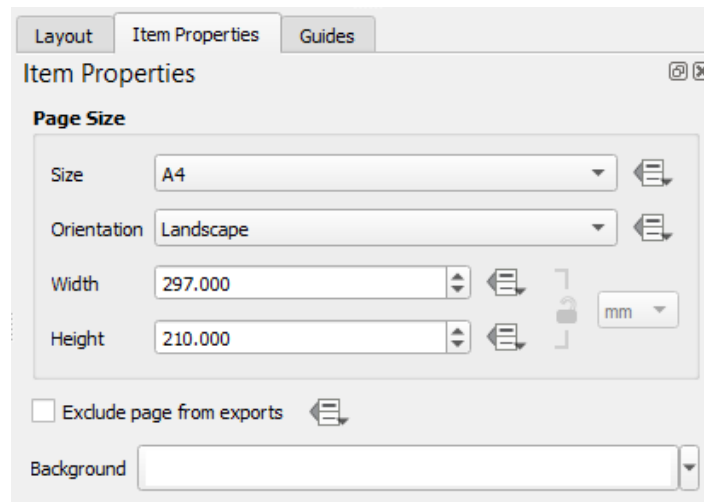
To edit the layout size, use the drop-down menu next to Size. You can select a pre-made format or select custom to input a unique layout size. Selecting custom also allows you to change the default units (mm).

8.1. Layout tools

The map Toolbox toolbar defaults to be down vertically along the left side of the layout. However, you can also click and drag the toolbar to position it horizontally above the layout with the other toolbars. The Toolbox toolbar is shown here:

(1) *Select/Move item*

(2) *Move item content*

This tool allows you to click and drag a map to adjust what part of the map is shown. This is different from moving the map to a new location on the layout; the map location does not change, only what part of the map is shown.
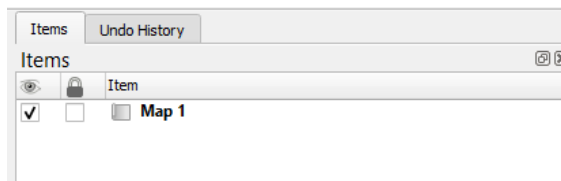
Any content added to the layout is shown in the Items tab. The first check box makes an item visible/invisible. The second check box locks and unlocks an item for editing

(3) *Add Map*

You can select this tool, then click and drag over the layout area to add a map. To change the scale at which the map is displayed, edit the Scale found in Main Properties (Item Properties tab).

Under Layers, checking Lock Layers allows you to freeze the map's appearance based on the current symbology. Unchecking this allows the map to update with any changes to symbology.
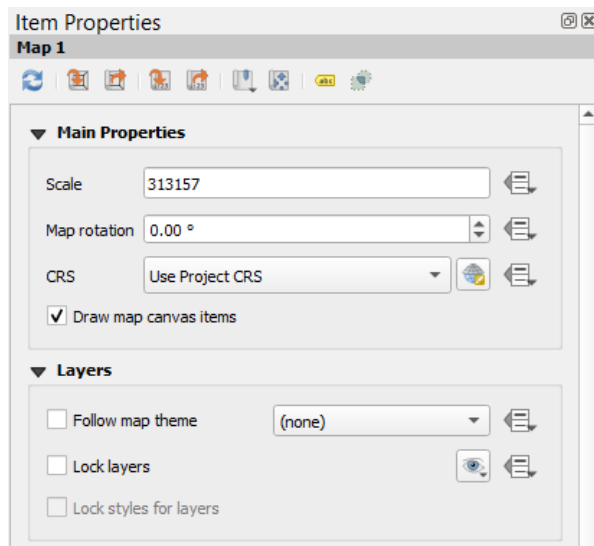
(4) *Add Picture*

Images cannot be copied and pasted into a QGIS layout. To add a picture, select this tool and click and drag to create an empty picture box. You can add a pre-made SVG image or change it to a raster image.

To use a raster image, select the drop-down arrow and choose how the find the image (select file, embed file, or from url).
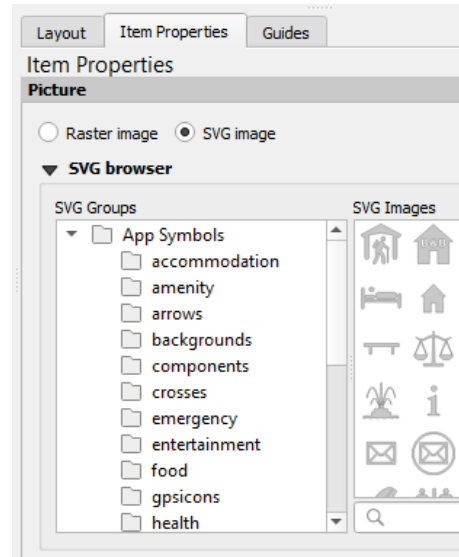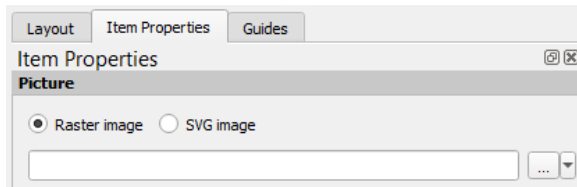
(5) *Add Label*
This allows addition of text labels.

(6) *Add Legend*

(7) *Add Scale Bar*

(8) *Add North Arrow*

(9) *Add Shape*

(10) *Add Node Item*
Node items include polygons and lines.

Another useful toolbar is the Actions Toolbar:
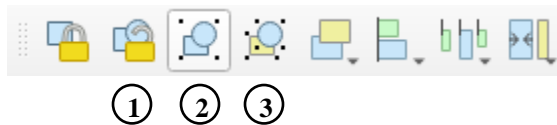
(1) *Unlock All Items*
This unlocks all items, allowing them to be edited.

(2) *Group Items*

(3) *Ungroup Items*

8.2. Exporting a layout

You can export a layout to share with others electronically by going to Layout (top menu) and selecting Export as Image, SVG, or PDF. You can also print a layout by going to Layout and selecting Print.

9. Useful Tools

9.1. Check Validity & Fix Geometry

When using some vector tools that are based on feature shapes and relationships, you may get an "invalid geometry" error (e.g., a polygon overlaps itself).

If you want to know what features have invalid geometries, then use the Check Validity tool (Vector => Geometry Tools => Check Validity), which outputs a new shapefile and corresponding attribute table listing the reason for any invalid geometries.

To fix invalid geometries, use the Fix Geometry tool (Processing Toolbox => Vector Geometry => Fix Geometries), which outputs a new, corrected layer.

9.2. Centroids

The centroids tool allows you to create a new point layer, where each point represents the center of each input feature. For example, given a polygon shapefile for counties, centroids could be used to create a point shapefile layer where each point represents the center of a county.

9.3. Create points layer from table

The create points layer from table tool (Processing toolbox => Vector Creation => Create points layer from table) allows you to create a point shapefile layer from a table (e.g., .dbf, .csv, .xlsx). The table must contain a column of x and y coordinates and these columns are then specified as part of the tool input.

9.4. Join Tools

Join tools copy data from one layer's attribute table to another. The following tools join data by different methods. Each relies on a common attribute between 2 layers, either spatial or based on a data field in the attribute table.
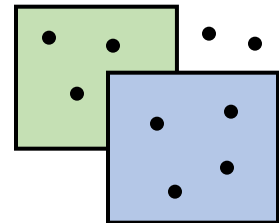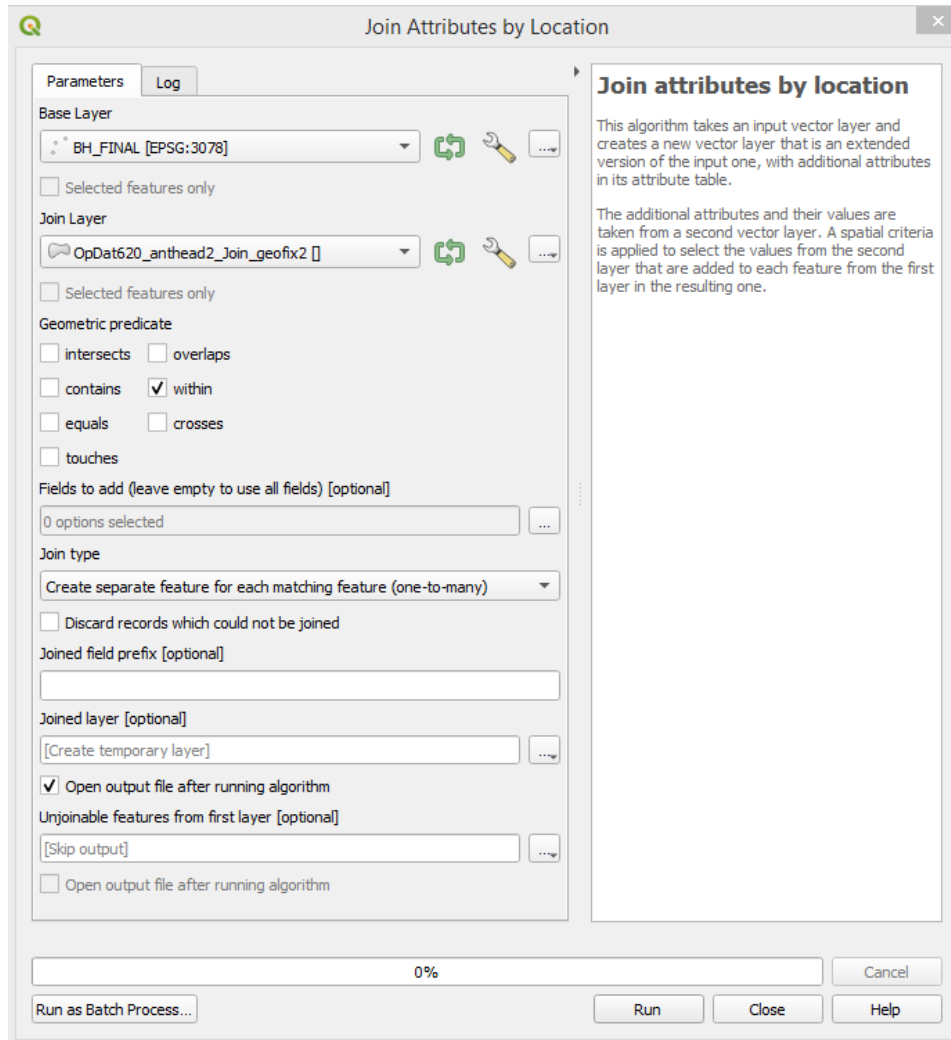
Join Attributes by Location
(Vector => Data Management Tools => Join Attributes by Location)

This tool allows data to be joined based on the spatial relationship between 2 layers.

Example
You want to copy data from a polygon layer to a point layer, such as illustrated to the right. The tool input form is shown below.

Base: This is the layer you are *adding data to*, the point layer

Join: This is the layer you are *copying data from*, the polygon layer

Geometric Predicate: This defines what spatial relationship is used to select which polygon features are joined to which point features. In this example, selecting "within" means that points that are within a polygon are joined to that polygon. Data from the green polygon would be copied to the three points within that polygon. Data from the blue polygon would be copied to the four points within that polygon. The two points outside the polygons would remain *unjoined*.

Join Type: This indicates whether one feature is joined with one or many features from the second layer. In this example, *one-to-many* is used because each point is related to one polygon, and one polygon has many points. *One-to-one* could be used if each polygon only had one point.

The output from this tool includes a new joined layer and may include an unjoinable features layer. In the example above, the output joined layer would be a new points layer where the attribute table has been extended to include the copied data from the polygon layer. The two points outside polygons would be in the unjoinable layer.

Join Attributes by Field Value
(Processing Toolbox => Vector General => Join Attributes by Field Value)

This tool is very similar to the Join Attributes by Location tool. The major difference is that the 2 layers being joined are related to each other by a common field in the attribute table, instead of by location. This means that the layers being joined have an identical field with unique identical values for each feature. These unique values allow data to be matched from one layer to the other.

The input form is shown below:
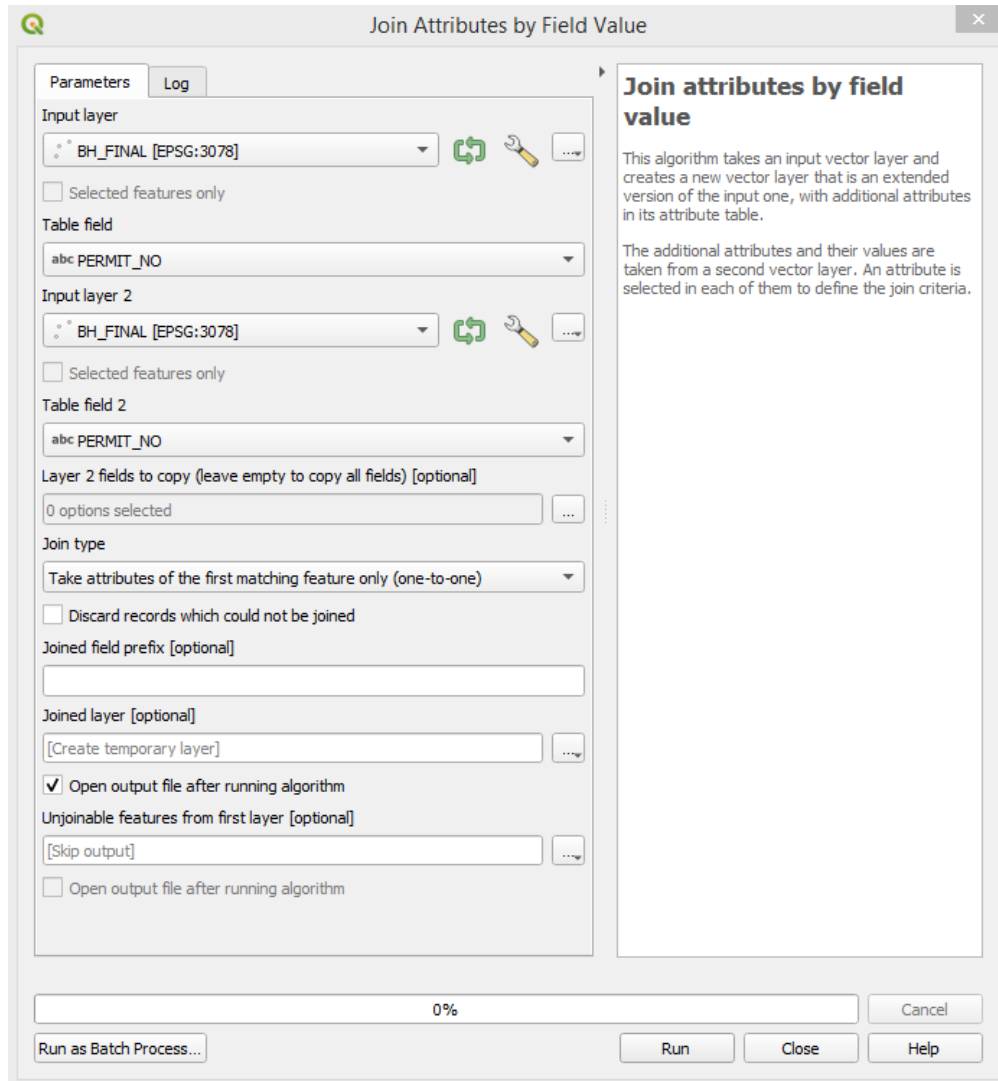
Input Layer: This is the layer you are *adding data to*

*Input Layer 2:* This is the layer you are *copying data from*

Table Field & Table Field 2: These inputs are the fields that are identical in both layers. The field type seen left of the name (e.g. text *abc*, number *123*) must also be identical.

The join type and output options are the same as discussed above for the Join Attributes by Location tool.

Join by Lines (hub lines)
(Processing Toolbox => Vector Analysis => Join by Lines (hub line)
>   This tool is used to create lines between 2 point layers (identified as the *Hub layer &*
>   *Spoke layer* inputs in the form below). As with the Join Attributes by Field Value tool,
>   this Join by Lines tool relies on a common field in each attribute table (identified by *Hub*
>   *ID field & Spoke ID field* inputs in the form below).
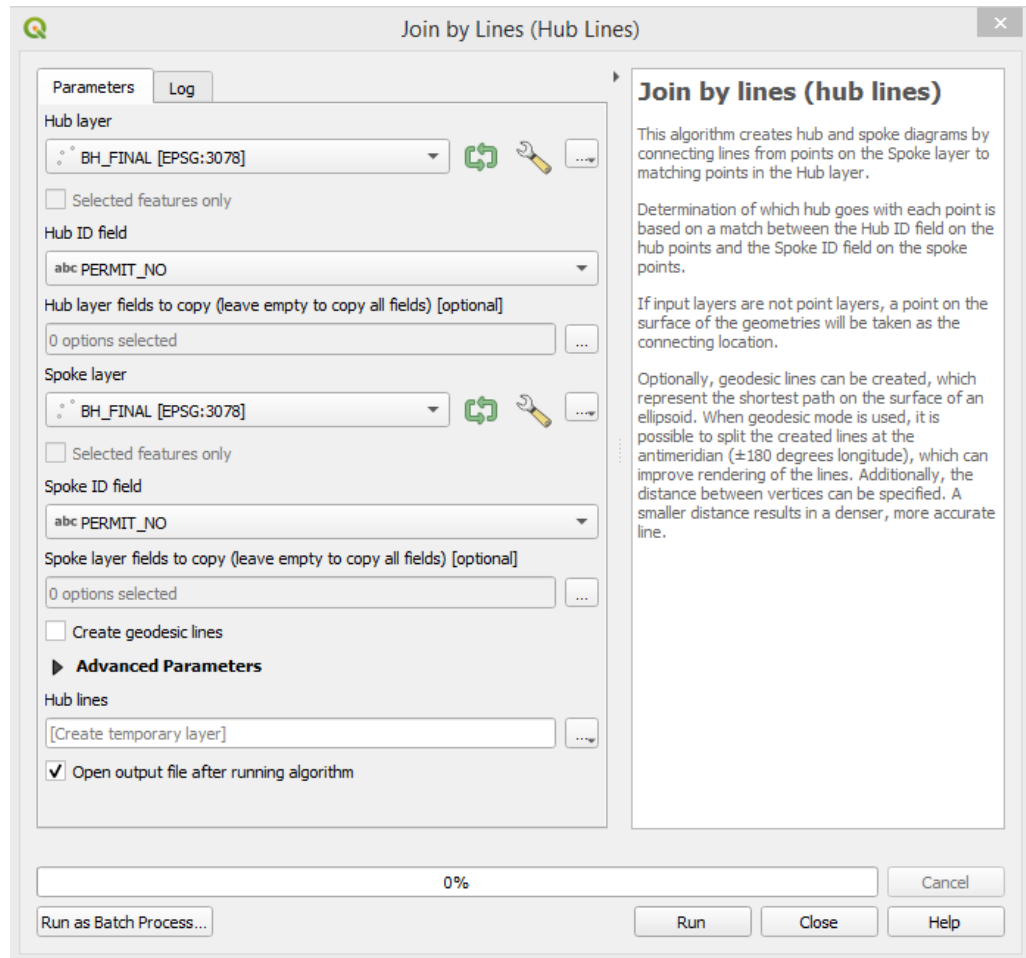
>   One point may connect with a single point, or multiple points. This means one point can
>   have multiple lines coming from it. The output is only a new *Hub lines* layer.

>   Left: 2 point layers (black circles & orange triangles)
>   Right: Point layers with hub lines layer
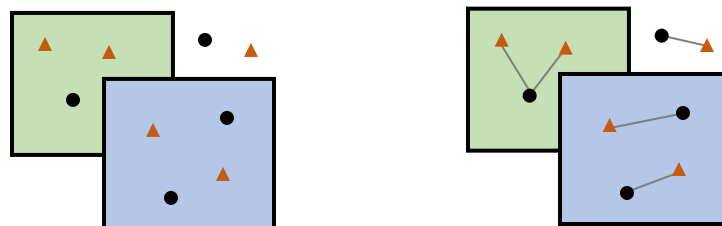
10. **Sharing Projects as a GeoPackage**

In this guide, you have seen that you can copy, save, and share layer symbology (section 6), and create and share layouts (section 8). However, what if you need to share the data itself?

First, make sure you have the original files saved. You can export a copy to share by right clicking on the layer to be shared and selecting Export. Here you will see a couple of options: Save Feature As, Save as Layer Definition File, and Save as QGIS Layer Style File. For a detailed explanation of the Layer Definition File and QGIS Layer Style File, see this page from the QGIS User Manual. Essentially, these two file formats are unique to QGIS, meaning they are not immediately compatible with other GIS software, such as ArcGIS Pro.

To see what other file formats are available, select Save Feature As (shown to right). In this case, the options shown are for a vector layer.

Here, I will discuss how to save and share layers in a GeoPackage. First, this file format is useful because it can be used in any GIS software (see https://www.geopackage.org/). In addition, you reduce the number of files being shared, making it easier for others to find the layer(s) they need. Finally, you can share the data *and* maintain all symbology in the shared file. This means that the person you are sharing the file with does not have to take the time to redo all the symbology themselves. Essentially, you are giving them the finished map product in a format they can continue to edit.
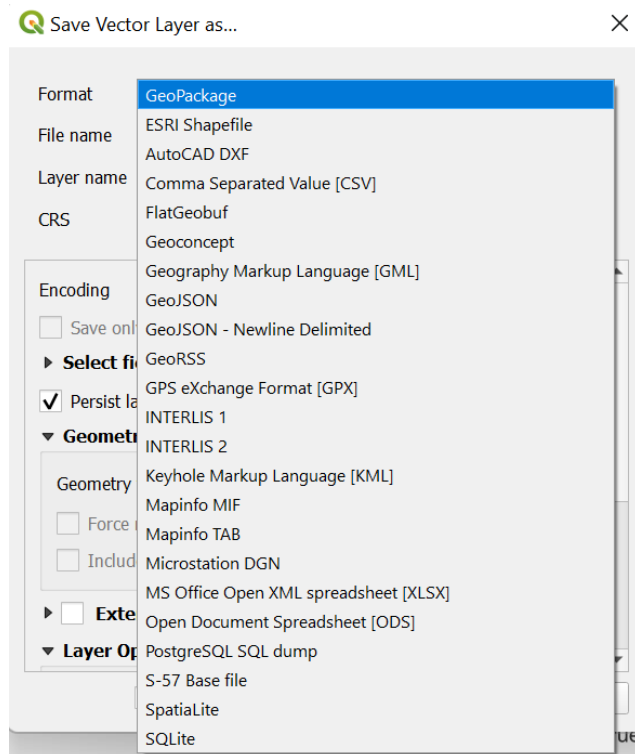
You can save multiple layers within a single GeoPackage. To create the GeoPackage, right click on the first layer to be shared and go to Export => Save Feature As and select GeoPackage as the format. For file name, navigate to where you want the GeoPackage to be saved and give it a name. Next, layer name is the name of the layer you selected (it does not have to be identical). Select the appropriate coordinate system (CRS). Under the dropdown to select fields, you may choose what attribute table fields to save from the selected layer. You may also select the geometry type or leave it as automatic. At the bottom, check whether or not you want to add the file to your current project map view. Finally, select OK. Now, you have created a GeoPackage and it contains one layer.

To add additional layers to the same GeoPackage, right click the layer, go to Export => Save Feature As and select GeoPackage. *For file name, navigate to the GeoPackage you just created and select it.* Fill in the remaining options as necessary, then select OK. Repeat for each layer to be shared. Now, only the single GeoPackage file needs to be shared for someone else to have access to each layer saved within it.