

Exercise 10: Intermediate Cartographic Design

In this exercise, you will produce four separate maps using a variety of data. The goal of this lab is to expand your knowledge of map production in ArcGIS Pro and to introduce you to a variety of options, tools, and techniques for producing maps in this software package. This lab has been designed to expand upon introductory digital cartography lab exercises. If you are completing these labs for Geography 149: Digital Earth Lab at WVU, this lab will serve as the final lab project.

Topics covered in this exercise include:

1. How to produce a well formatted map
2. How to edit and manipulate symbology of geospatial data.
3. How to create a layer file
4. How to design legends
5. How to insert graphics into a map image
6. How to edit scale bars
7. How to add grids to a map frame
8. How to insert multiple map frames in a map
9. How to insert extent indicators
10. How to improve labels in ArcGIS Pro
11. How to export a map using post scripting

Before starting this lab, you should know how to do the following in ArcGIS Pro:

1. Add a new map layout to a project.
2. Add a map frame to the layout and adjust the map frame size and position.
3. Insert scale bars, north arrows, titles, and text.
4. Change the symbology of vector and raster data layers.
5. Change the name of data layers in the Contents Pane.
6. Export your map as a graphic file.

If you do not know how to complete these tasks, please complete or review a basic cartography lab for ArcGIS Pro (such as Exercise 3). If you know how to do these things, this lab should be appropriate for you.

From previous cartography lectures or lab assignments, you should remember the general rules for making maps:

1. You should use the map space well and have a balance on the page. The layout should be neither too crowded nor too empty. Make sure you do not have a lot of empty space on your layout.
2. Make sure you use an appropriate projection for the spatial extent of your map.
3. The north arrow should be large enough to be interpreted, but not excessively large, as this is not the focus of the map. Simple north arrows are generally preferable to complex north arrows. In some cases, a north arrow may be misleading, such as when map projections cause the direction of north to vary over the map space. In such cases, you can use graticules or a coordinate grid instead.
4. The scale bar should be legible and in appropriate units. Preferably, you should use breaks on multiples of five or ten.
5. Appropriate titles and text should be provided. You should use a font that is legible and an appropriate font size.
6. No file names should appear in the legend. All names should be edited to be meaningful.
7. You should include all map layers in the legend that are required to understand the map. You do not need to include all layers. For example, it is often not necessary to include a base image or hillshade in the legend.
8. If you are using someone else's data in your map, it is important to reference the data source. You can do this using a text box.
9. You should use appropriate colors and symbology for your layer features. It is important to think about the perception of color and symbols.
10. If you are making a map to be printed or reproduced in black-and-white, make sure that colors are distinguishable when printed as such.
11. You should use colors with an appropriate contrast, so that they are discernable.
12. Maps should not be provided in project files. Instead, they should be exported as a graphic file, such as JPEG, TIFF, or PDF.
13. Remember that maps are a form of communication. So, your goal should be to appropriately communicate something to an audience. It is important to think about your audience.

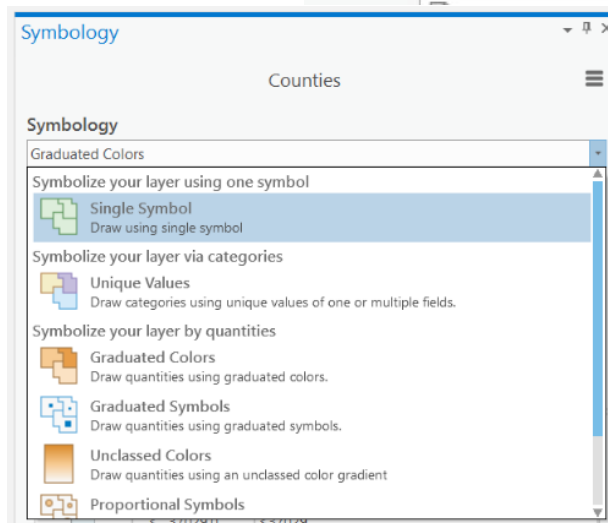
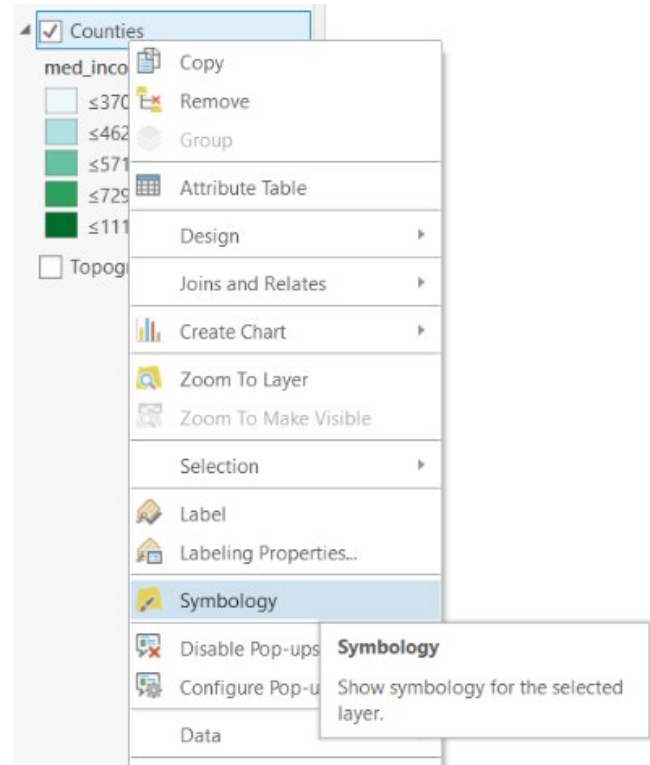
The goal of this lab is to expand upon these basic skillsets so that you can produce well formatted maps of a professional quality. We will introduce and explain some map production techniques as a series of tips. You will then be asked to produce four map layouts as the deliverables for this lab.

Some of the examples used here are demonstrated in this YouTube video: <https://www.youtube.com/watch?v=j3Ih0MHq9Rc&t=7s>.

Tip 1: Editing and Manipulating Layer Symbology

In ArcGIS Pro, it is best to prepare your layer symbology in the map before adding the map frame to a map layout. As a review, you can change the layer symbology by right-clicking on the layer in the Contents Pane and selecting Symbology. This will open the Symbology Pane. Within this Pane, you can change many features of the symbology.

1. You can change the symbology. For example, you could display a polygon vector layer using the same color for each feature or you could produce a choropleth map, in which values or quantities from an attribute column are symbolized using different colors. You could also choose to show quantities using graduated or proportional symbols. For categorical data, you can display different categories using unique colors.



- If you used a classified legend, you can change the classification method (Natural Break, Quantiles, Equal Interval, Standard Deviation, Manual, etc.), the number of classes, and the color scheme.

The Symbology pane shows the following settings:

- Method: Natural Breaks (Jenks)
- Classes: 5
- Color scheme: A sequential color ramp from light blue to dark green.

Symbol	Upper value	Label
	≤ 37029.0	≤37029
	≤ 46293.0	≤46293
	≤ 57143.0	≤57143
	≤ 72931.0	≤72931
	≤ 111582.0	≤111582

Natural Breaks (Jenks)
Numerical values of ranked data are examined to account for non-uniform distributions, giving an unequal class width with varying frequency of observations per class.

Quantile
Distributes the observations equally across the class interval, giving unequal class widths but the same frequency of observations per class.

Equal Interval
The data range of each class is held constant, giving an equal class width with varying frequency of observations per class.

Defined Interval
Specify an interval size to define equal class widths with varying frequency of observations per class.

Manual Interval
Create class breaks manually or modify one of the preset classification methods appropriate for your data.

Geometric Interval
Mathematically defined class widths based on a geometric series, giving an approximately equal class width and consistent frequency of observations per class.

Standard Deviation
For normally distributed data, class widths are defined using standard deviations from the mean of the data array, giving an equal class width and varying frequency of observations per class.

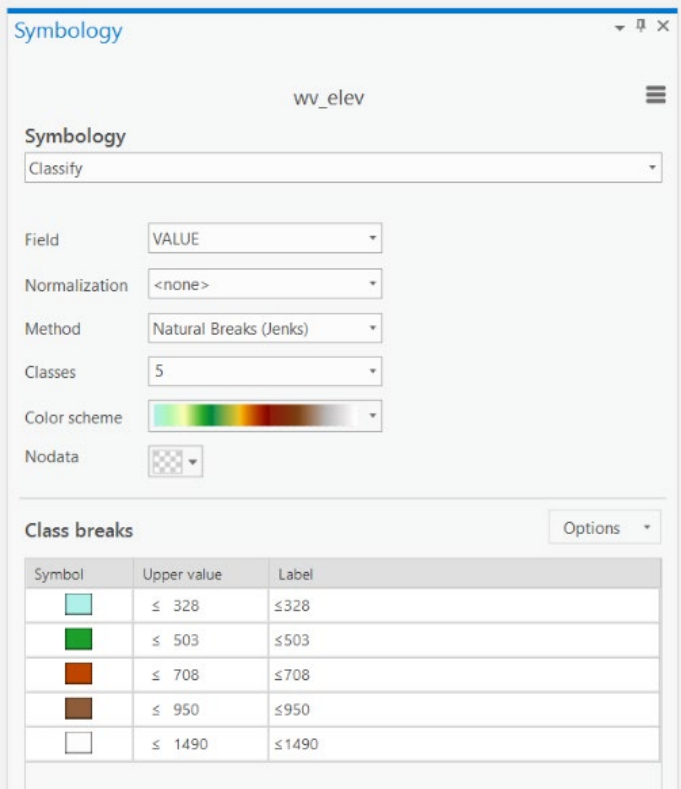
- In the label column in the table, you can change the label used for each category or classification bin by simply typing into the table. The label will be used in the Contents Pane and in the map layout, including the legend.
- Clicking on the symbols in the symbol column will open the Format Symbol Pane and allow you to edit the symbol, such as the color, outline color, and outline width.

Raster data layer symbology can also be changed using the Symbology Pane. For example, the symbology of a continuous raster can be altered from a stretched to a classified symbology.

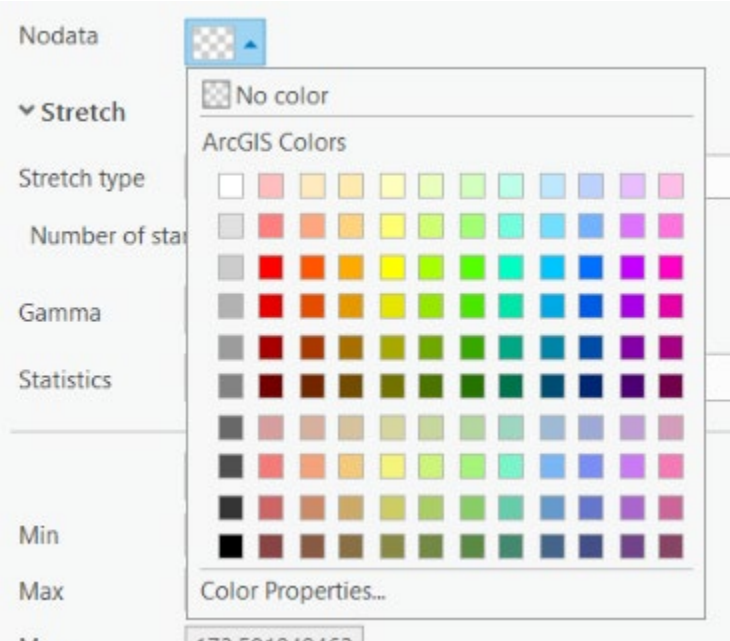
The Symbology pane shows the following options:

- Stretch**: Stretches values along a color ramp.
- Discrete**: Groups data based on a selected number of colors and applies a color scheme.
- Classify**: Assigns a color for each group of values.
- Unique Values**: Assigns a color for each value.
- Vector Field**: Displays values as vector symbols.

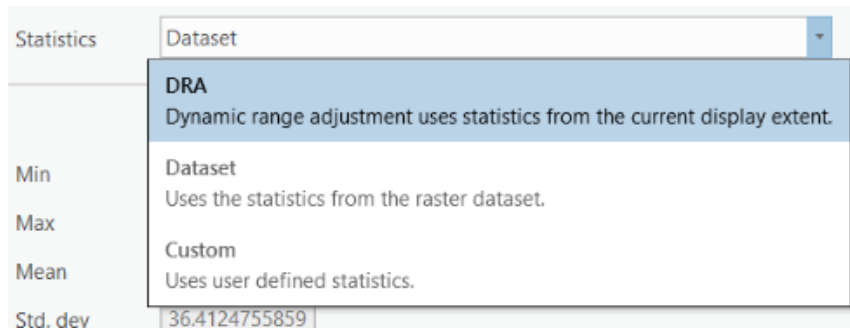
The color scheme used to symbolize raster data can also be changed in the Symbology Pane. You can also edit the legend labels.



You can also apply a color to symbolize NoData values.

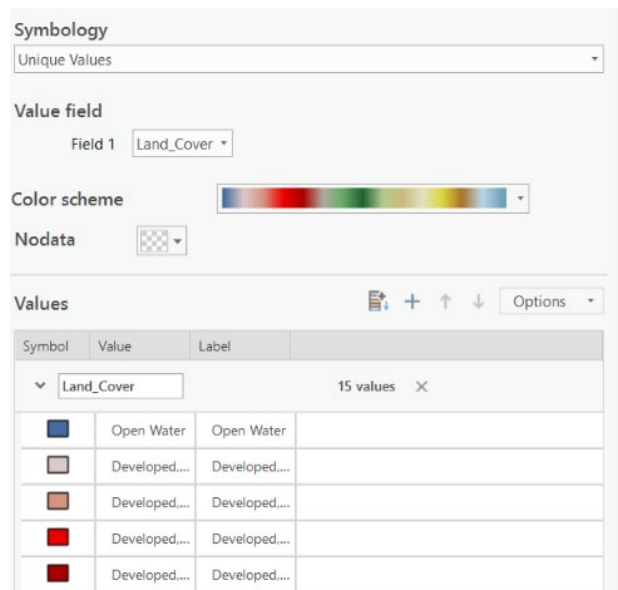


Using the Stretch Method, you can change the data range to be dynamic based on what values are in the current display extent. This can be done by setting the Statistics option to DRA (dynamic range adjustment using statistics from the current display extent). This can be useful when you want to use the full range of colors in the color scheme in the display extent.



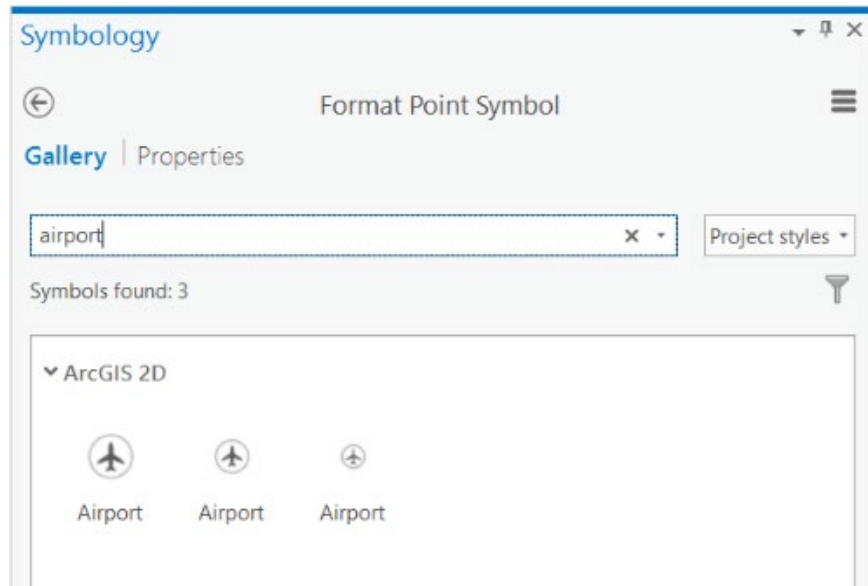
Categorical raster data are generally symbolized using unique values, or a different color for each category. You can change the label and the color/symbol used to represent categories.

You may find that the default symbology may not be optimal for your intended purpose. So, you will commonly need to manipulate symbology using the options available in the Symbology Pane.



Tip 2: Changing Colors and Symbols

You can change the symbol used to show points, lines, or polygons by double-clicking the symbology in the Contents Pane. This will open the Symbology Tab. You can then Use the Gallery or Properties to change the symbology. The image below provides an example of a point layer. Here, we have searched for airport symbols.



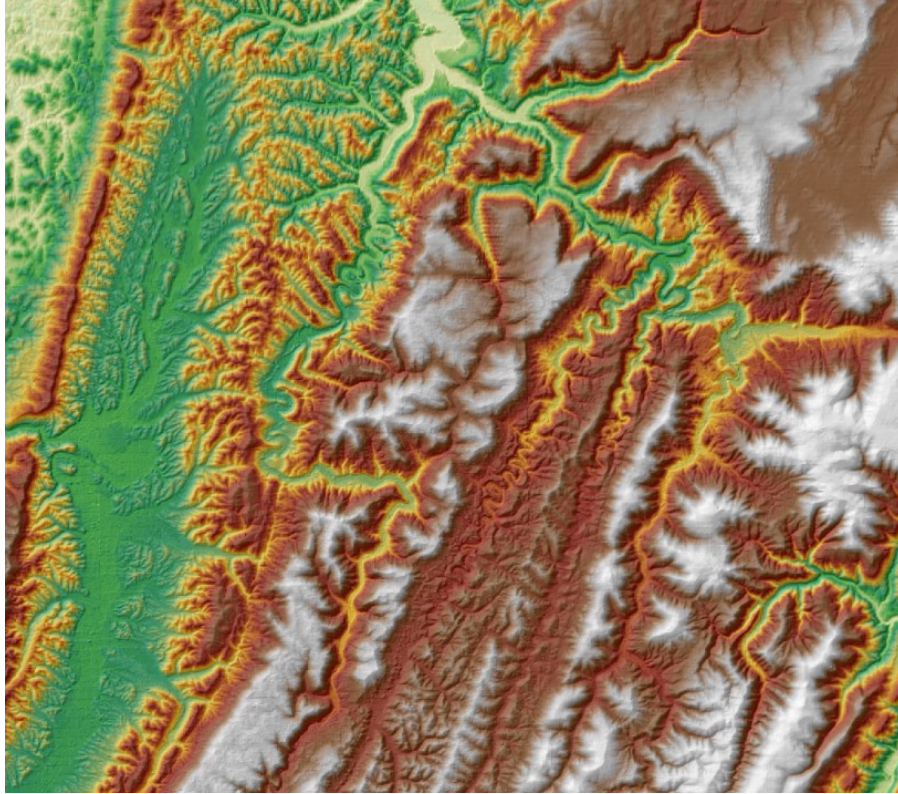
Alternatively, right-clicking on the symbol for the layer in the Contents Pane will open a menu that allows you to change symbol properties.

So, there are many ways to change the layer symbology. Again, we would encourage you to experiment with the options available.

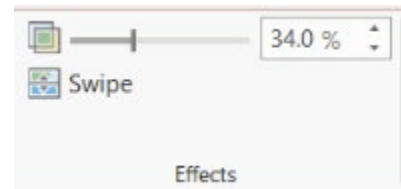


Tip 3: Changing Layer Transparency

You may want to make one of your layers partially transparent. For example, the image below was created by making a digital elevation model (DEM) partially transparent and displaying it over a hillshade image.

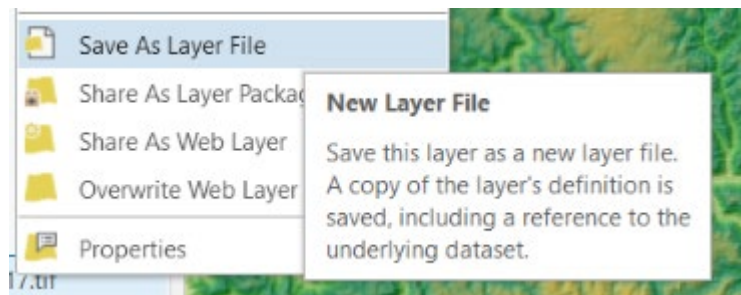


To add transparency to a layer, use the transparency slider under the Appearance Tab.



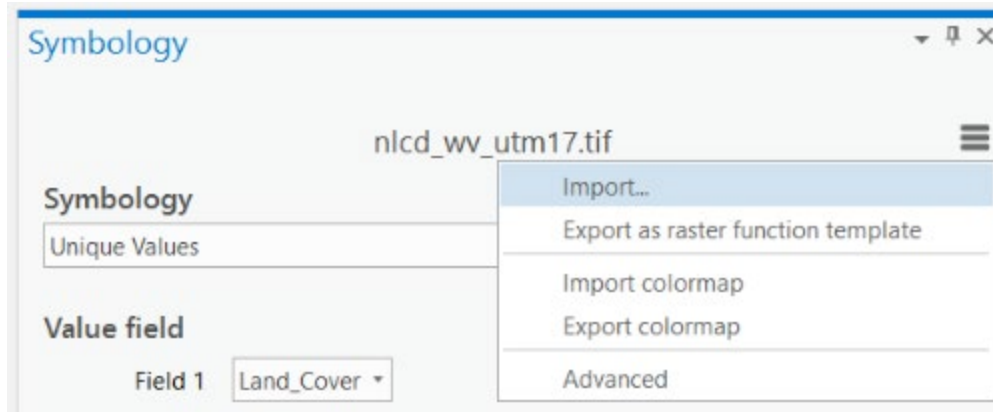
Tip 4: Creating a Layer File

Once you have created a layer symbology that you find to be effective, you can save it to a Layer File. This can be done by right-clicking on the layer in the Contents Pane then selecting Save As Layer File.



Note: You are not saving a copy of the data. Instead, you are saving a file that stores the symbology for later use.

If you would like to apply the saved layer symbology to a new layer, this can be done in the Symbology Pane using the Import Option.



We have found that layer files offer a very useful and efficient means for storing and saving data symbology for later use. For example, when you create a new data layer to share with a colleague, you could also provide a layer file so that the data can be symbolized as you intend it to be symbolized.

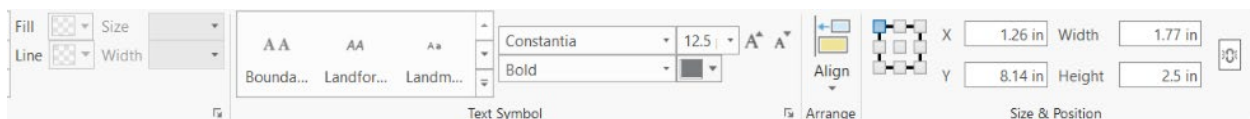
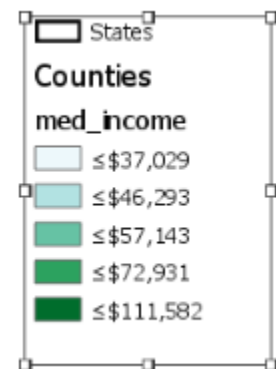
Tip 5: Legend Design

You should already know how to add a legend to a map. Here, we will discuss some means to further edit and enhance legends. Legends are very important components of maps, so it is important that you think about how the legend is presented.

Once a legend has been added to the map layout it can be resized and moved by selecting it. Once selected, you can move and resize it using the selection box. The legend should always be intentionally placed.

Under the Format Tab for the legend, you can alter the legend in many ways including:

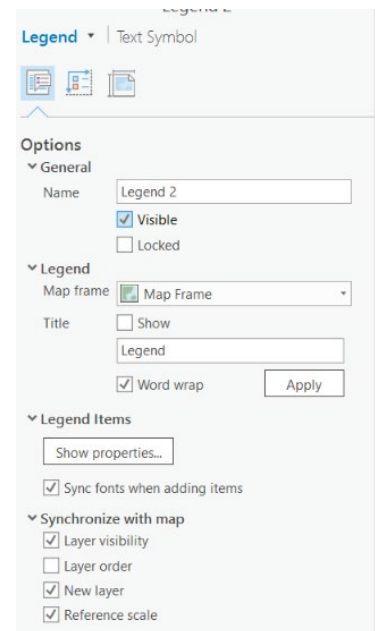
1. Changing the fill and outline color.
2. Changing the font style, boldness, size, and color.
3. Changing the alignment of the legend.
4. Changing the position and size of the legend.



You can also edit the legend by selecting it in the Contents Pane for the map layout. This should open the Format Legend Pane. In this pane, you can do the following:

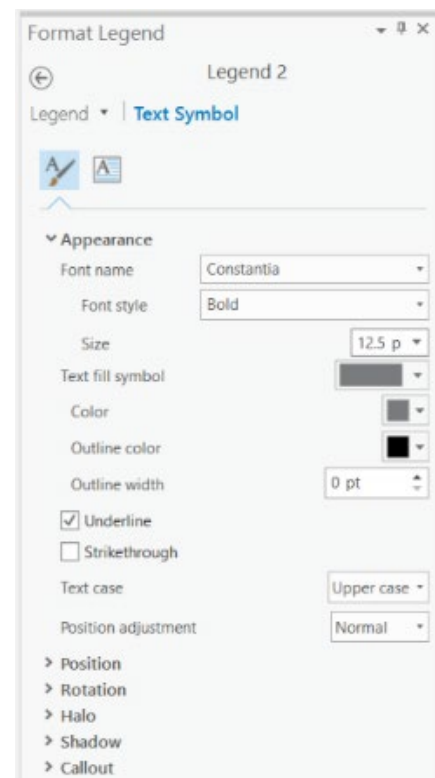
Under the Legend options:

1. Change the name of the legend as displayed in the Contents Pane.
2. Lock it or change the visibility of it on the layout.
3. Add and show a legend title.
4. Change how the legend is synchronized with the associated map.

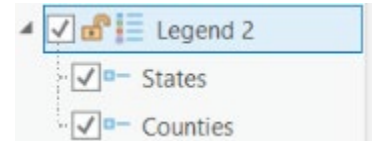


Under the Text Symbol Options:

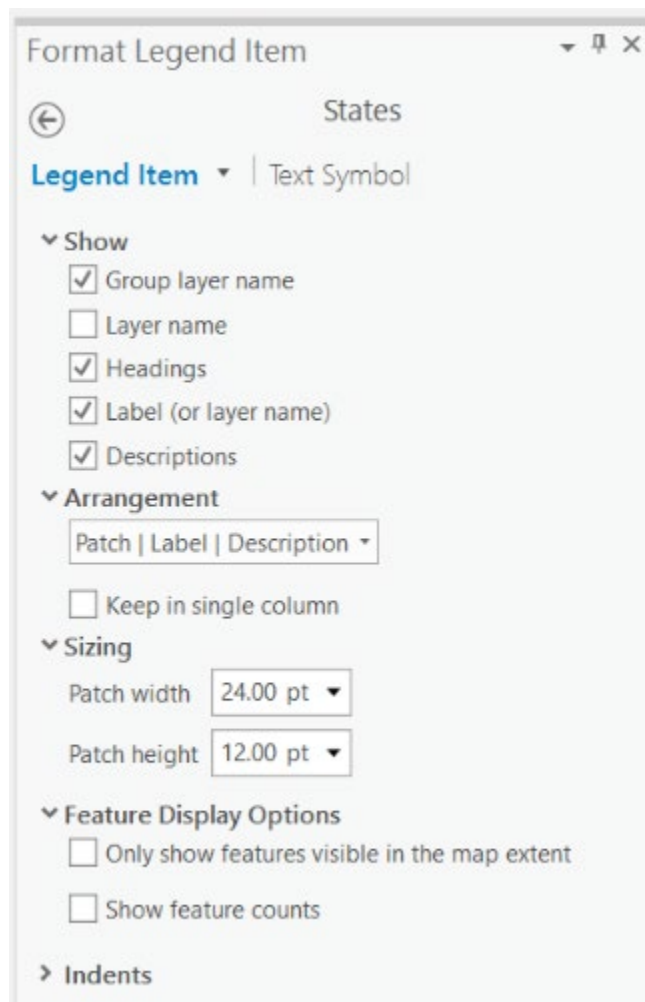
1. Change the text appearance. For example, you can change the font type, boldness, size, color, and case. You can also underline the text.
2. Change the text alignment, such as changing the horizontal and vertical alignment or applying offsets.
3. Rotate the text by a defined angle.
4. Add a halo to the text.
5. Add a shadow.
6. Add callouts.



You can also change individual elements in a legend. Within the Contents Pane for the map layout, you can expand the legend element to see what features are included. If you click off a layer, it will no longer be shown in the legend. If you click a layer, the Format Legend Item Pane should open. This allows you to make changes to just this item in the legend, not the entire legend.



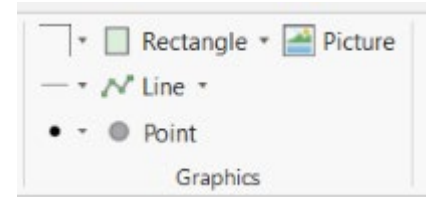
For example, if you do not want to display the layer name or attribute heading for a layer in a legend, you can turn these features off in the Legend Items options. You can also change the arrangement of the legend elements. And the size of the symbology. Under the Text Symbols options, you can edit the text symbols as described above.



There are many options available for editing legends and individual legend elements. The best way to learn is to simply experiment with the options available.

Tip 6: Inserting Graphics

You can insert graphics, such as logos or graphs into a map layout. This is easy. To insert a graphic, navigate to the Insert Tab while the map layout is active and selected Picture in the Graphics Area. This will allow you to insert a graphic element from a file.



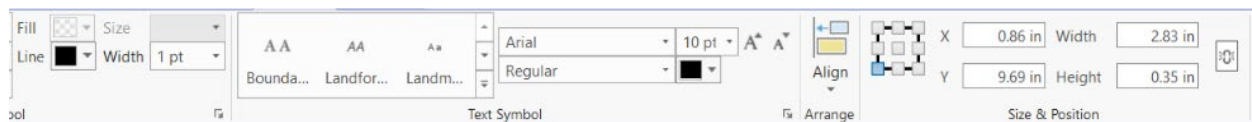
Make sure that the graphic file you want to add is high enough resolution. You don't want it to look blurry once the map layout has been produced.

This menu also allows you to add additional map elements. For example, you can draw areal features (rectangles, circles, ellipses, and polygons), points, and lines. Once these features have been drawn, you can edit their appearance by clicking on them in the map space to open the associated formatting pane. For example, if you draw a rectangle, you can change the color, outline color, and outline size.

Tip 7: Editing Scale Bars

Similar to editing legends, you can also edit elements of a scale bar. Once a scale bar has been added and while it is selected, you can navigate to the Format Tab to edit it. This tab allows you to:

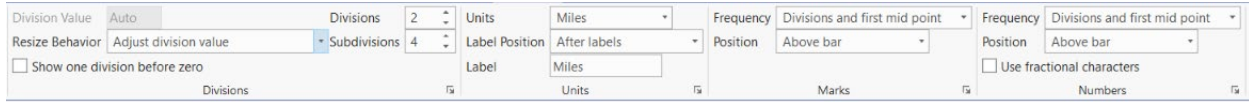
1. Change the font type, boldness, size, and color.
2. Change the scale bar alignment and size.
3. Add a fill color.
4. Add an outline and change its width and color.



The Design Tab allows you to further edit the scale bar. Here, you can change the following:

1. Resizing behavior
2. Number of divisions
3. Number of subdivision
4. Units of measurement
5. Placement of measurement units
6. How the measurement units are labeled (for example, miles vs mi)
7. The frequency of marks
8. The position of the marks

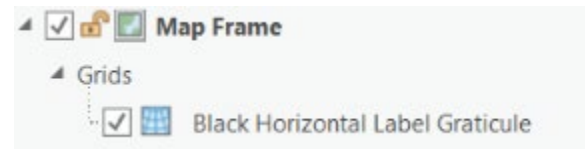
- 9. Frequency of numbers
- 10. Position of numbers



You can also manipulate the legend by selecting it from the Contents Pane for the map layout. This will open the Format Scale Bar Pane. Again, the default settings may not be optimal, so you may need to use these tools and settings to manipulate the scale bar to meet your needs. Again, we encourage you to experiment with the available options.

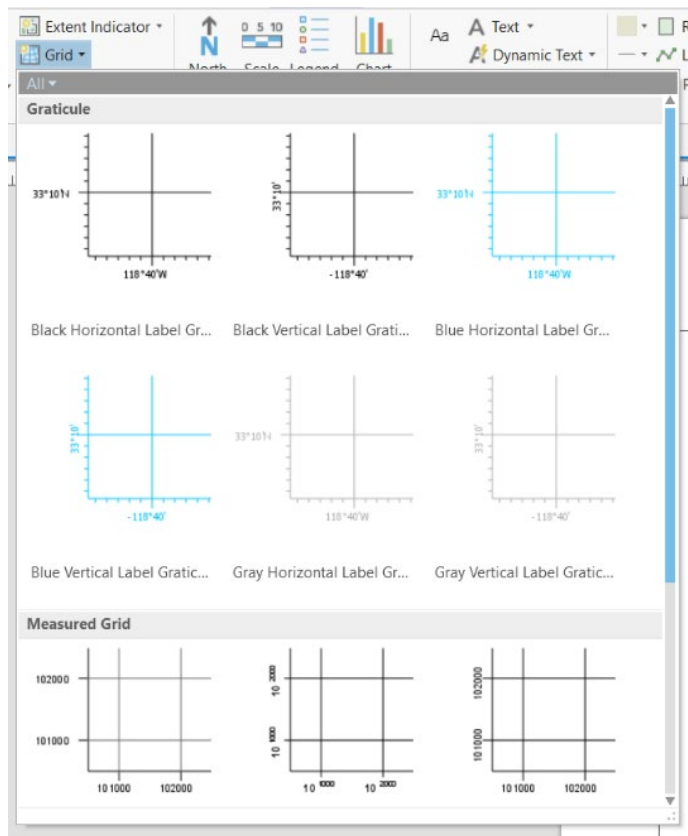
Tip 8: Creating Graticules and Coordinate Grids

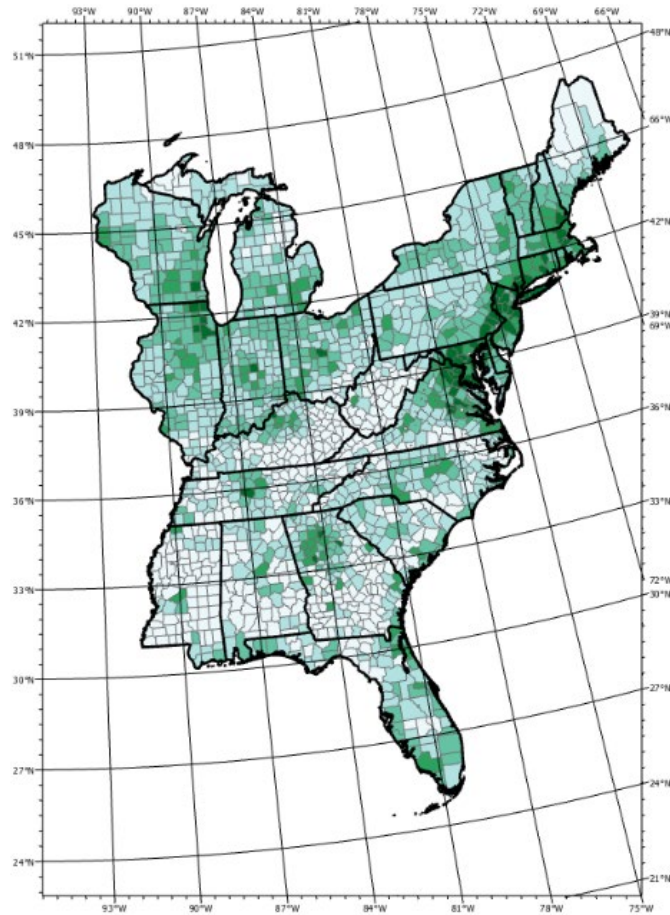
You can add a longitude and latitude reference (graticules) to a map frame on a layout. You can also add coordinate system grids (for example, a UTM grid). With the map frame of interest selected, navigate to the Insert Tab and click the dropdown arrow next to Grid in the Map Frame area. This will open a list of available grids.



If you select the grid object in the Contents Pane, the Format Map Grid Pane will load.

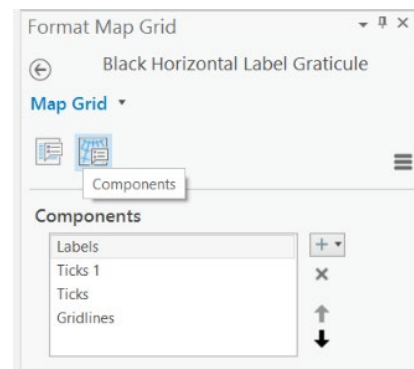
Selecting one of these options will add it to the map frame.





The grid can be edited. It is listed in the Contents Pane under the map frame to which it has been added. You may have to expand the map frame in the Contents Pane to see the grid element. This menu provides a set of options for editing the elements associated with the grid. Some features that can be changed include the following:

1. The font type, size, boldness, and color of the labels
2. Where labels will be placed
3. The presentation of the coordinates (for example, degrees minutes and second or degrees and decimal degrees)
4. The interval of tick marks, labels, and gridlines



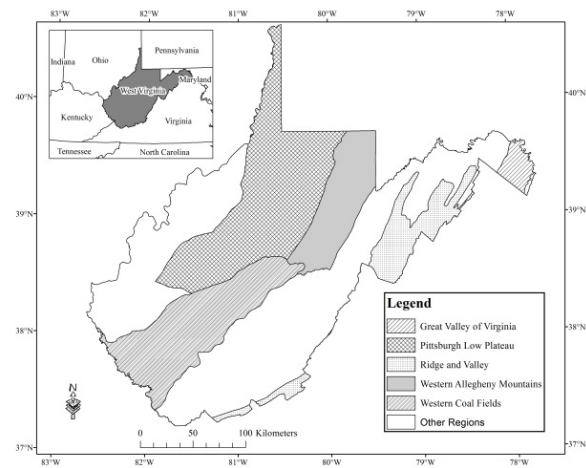
We have found that the Components options offer the most efficient means to edit grids.

Note: The projection used can have a large impact on the map layout and the patterns of the graticules or coordinate grid. It is important to think about what projection is appropriate for a map.

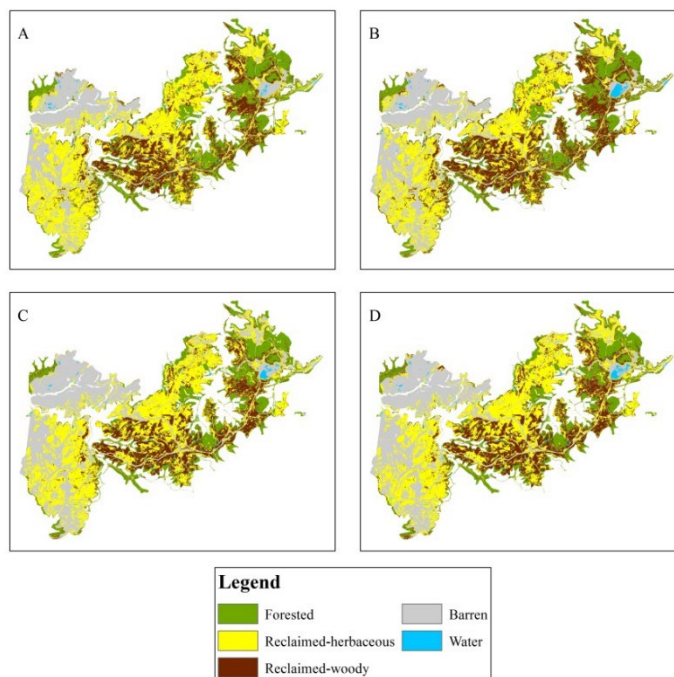
Tip 9: Adding Multiple Data Frames and Inset Maps

You may want to create a layout that contains more than one map frame. For example, you may want to add an inset map showing the location of your larger map within a broader geographic extent. You may want to add multiple maps to compare data or show change over time.

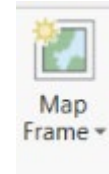
The image to the right shows a layout in which an inset map has been added to show the extent of the larger map within a geographic area.



This map provides an example of a layout in which one map frame has been duplicated to compare different outputs.



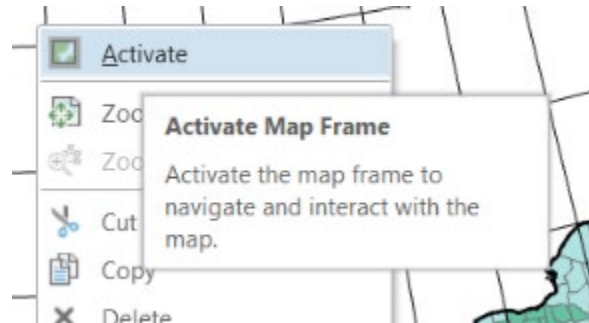
Adding multiple map frames to a layout is easy. Once the first frame is added, a second frame can be added by navigating back to the Insert Tab and selecting the dropdown arrow associated with the Map Frame Button. This will open a list of available maps within the project that can be added to the layout.



Once frames have been added, they can be selected to change their position and size in the layout.

If you want to pan or zoom the map within the map frame, you can right-click on it and make it active.

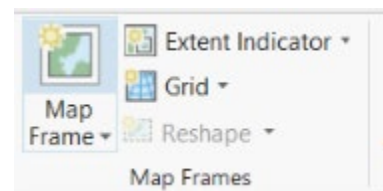
Once you have navigated within the map space, you will need to close the active map frame.



Tip 10: Inserting Extent Indicators

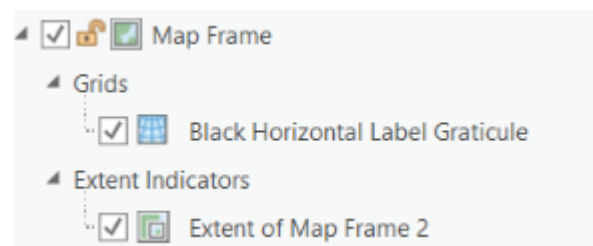
It is possible to indicate the extent of one map frame within another map frame. For example, you could highlight the location of your main map on the inset map. This can be done by adding an extent indicator.

Extent indicators can be added by clicking on the Extent Indicator button within the Map Frame area of the Insert Tab when a layout is active. You will want to make sure the map frame to which you want the extent indicator to be added is selected. Using the dropdown arrow associated with the Extent Indicator button, you can select which map you want to indicate on the selected map. This will add an extent indicator.

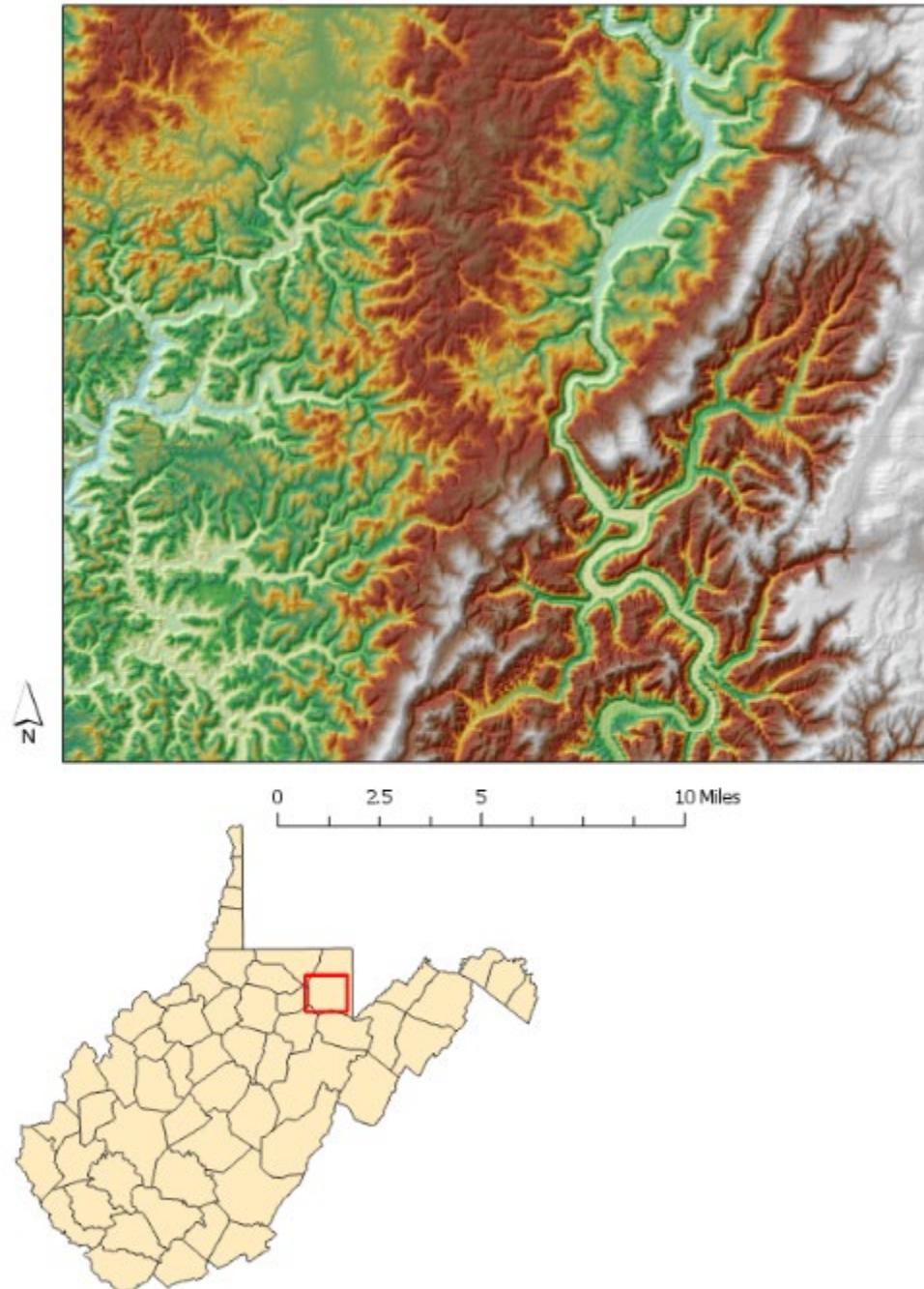


To edit the added extent indicator, you will need to find it in the Content Pane for the map layout. It will be listed under the map frame to which it has been added.

Click on it in the Contents Pane will open the Format Extent Indicator Pane so that it can be edited.

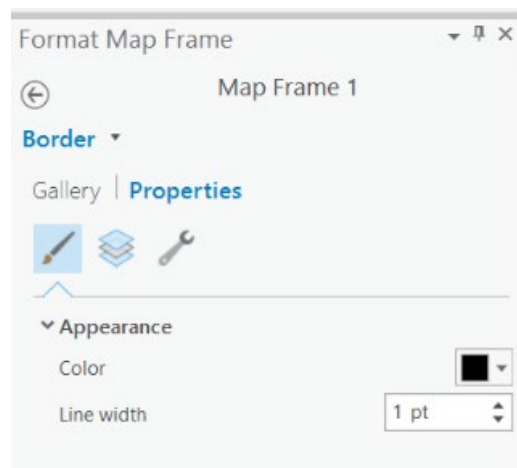


The map below provides an example of an extent indicator. The red rectangle on the smaller state map shows the extent of the larger map above it. Note that the extent indicator symbology was changed using the Format Extent Indicator Pane.



Tip 11: Editing and Removing Map Frame Borders

You may want to edit or remove the border around a map frame. To do this, click on the map in the Contents Pane for the map layout. This should open the Format Map Frame Pane. Click on the dropdown arrow next to Map Frame then select border. This will provide Gallery and Properties options for changing the map frame border.



Using the options available in the Format Map Frame Pane, you can also make changes to the map frame, background, and shadow. For example, you could add a shadow behind the frame. Again, it is worth taking some time to experiment with the options available.

Tip 12: Improving Labelling

There are many options for working with and manipulating labels. Here, we will just provide a brief introduction.

First, it is easier to begin working with labels within a map as opposed to a map layout. So, you should navigate back to the map that contains the layer to which you are interested in applying labels. You will then need to click on the layer for which you want to add labels in the Contents Pane.



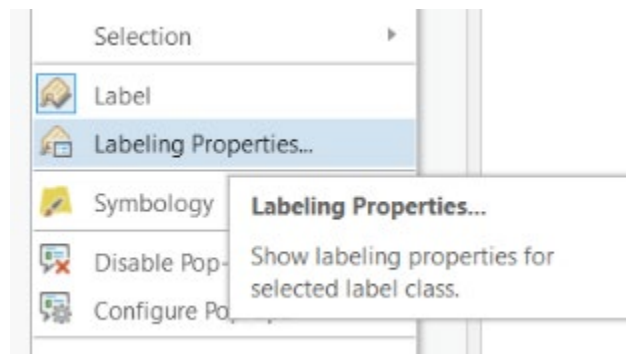
Navigate to the Labeling Tab. This provides options for labeling features. Here are a few options available for labeling features:

1. Turn labels on
2. Pick an attribute column from which to obtain labels
3. Choose scales at which to show or not show labels
4. Change the font type, size, boldness, and color of the labels
5. Make use of default label placement options



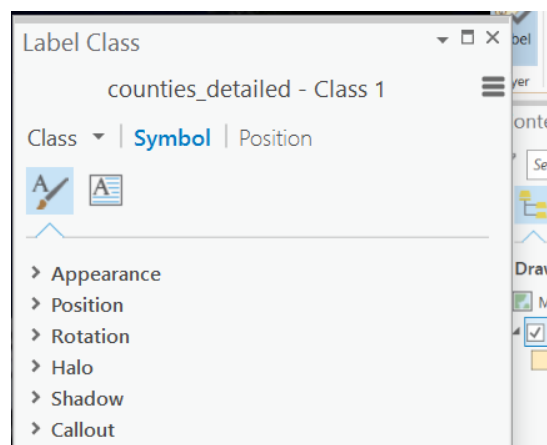
Note: In ArcGIS Pro, the Maplex Labeling Engine is used to label features. This engine takes into account rules and cartographic principles to label features.

If you click on the arrow in the corner of the Text Symbol area of the Labeling Tab, this should open the Label Class Pane. This pane provides additional options for changing the text labels. You can also access this pane by right-clicking on the layer of interest in the Contents Pane and selecting Labeling Properties.



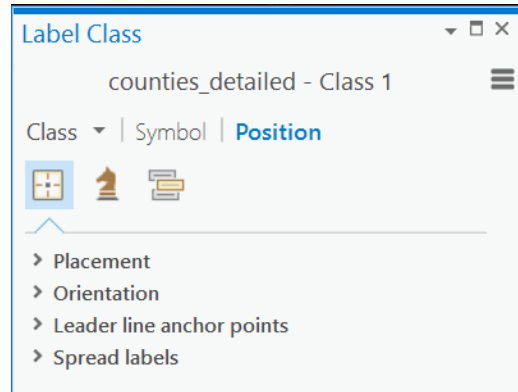
This menu allows you to make changes to the label text using the Symbol options including the following:

1. Changing the font type, size, boldness, and color
2. Changing the positioning and alignment of the labels
3. Rotating the labels
4. Adding a halo
5. Adding a shadow
6. Adding a callout



You can also edit the location and placement of the labels using the Position options.

Labeling positioning can be a complex topic. We will not cover positioning in detail here. However, feel free to experiment with the positioning options.



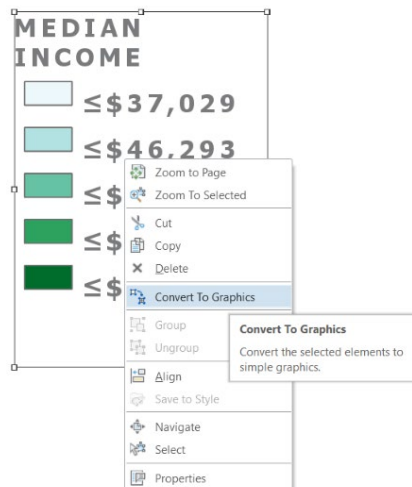
Another topic that will not be covered here is using annotations. Under the Map Tab, you can use the Convert To Annotation button to convert labels to annotations. Annotations allow individual text elements to be edited and stored in a geodatabase.

You may find that additional labeling may be required to obtain the desired results. Some of this editing may have to take place outside of ArcGIS Pro in vector graphics editing software, such as Adobe Illustrator. We will discuss how to export a file to a vector format for additional editing in a vector graphics editing software below.

Tip 13: Convert to Graphic, Group, Ungroup

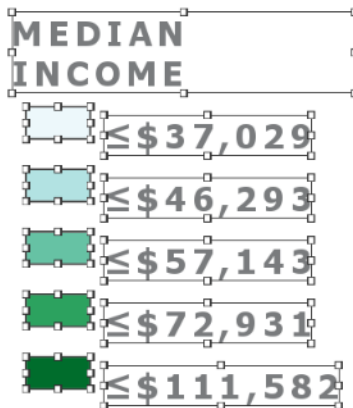
Some map elements can be converted to graphics. They can then be edited like graphics. Here we will provide an example with a legend.

To convert a map element into a graphic, simply right-click on it and select Convert to Graphic.



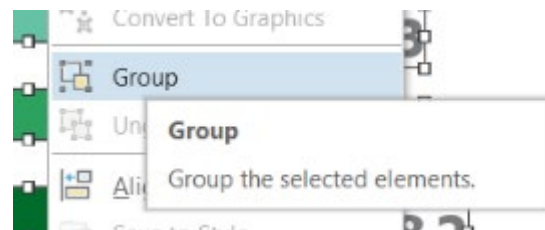
Note: Once a map element has been converted to a graphic, it is no longer dynamic and will not automatically update as the map is changed. For example, if you convert a scale bar to a graphic then change the scale of the map, the legend scale bar will not update to reflect the new map scale. So, if you need to convert a map element to a graphic, you should not do this until your map layout is complete and you will no longer make changes to scale or symbology.

Once a map element is converted to a graphic, its components can be ungrouped so that they can be moved and edited separately. This can be accomplished by right-clicking on the element of interest and selecting Ungroup. Below, is an example of the legend elements once they have been Ungrouped.



Again, the reason why you may choose to convert map elements to graphics and ungroup them is so that they can be edited like graphic elements. Clicking on the elements will open formatting panes to edit the characteristics of the object, such as the text.

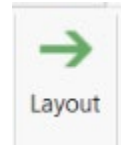
Once a graphic object has been ungrouped, it can be grouped again. This can be accomplished by selecting multiple objects, right-clicking, then selecting Group.



Tip 14: Exporting to a Vector Format

You may find that you need to do additional map editing in a vector graphics editing software, such as Adobe Illustrator or Inkscape. To do this, you will need to export your map to a vector format that maintains the vector graphic components, such as text.

To export to a vector format, navigate to the Share Tab. Click on the Layout button.

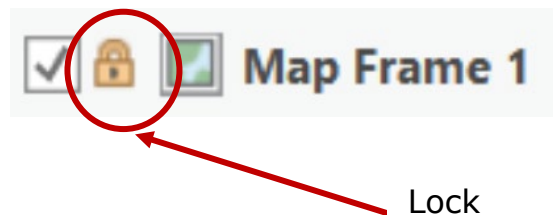


You will then need to save the file in a vector format, such as EPS, SVG, or AI. This will allow for later editing in a vector graphics editing software.

Tip 15: Locking Map Elements

If you do not want to be able to further change map elements, they can be locked. This is useful if you want to make sure you do not accidentally alter a map element.

To lock a map feature, simply click on the lock symbol next to it in the Contents Pane for the map layout. If you want to be able to edit it later, you can click on the lock again to unlock it.



Final Comments

We hope that you find these tips helpful. Note that there are many other components of map design in ArcGIS Pro that we do not have space to cover here. The best way to learn how to produce effective maps is to practice. So, we encourage you to make maps in ArcGIS Pro. With some practice and patience, you can become an effective cartographer.

Deliverables

You will be asked to deliver four maps for this assignment. Please deliver them as PDF files. Before you begin, we would suggest the following:

1. Make a new project in which to create your maps.
2. Create the four maps in four separate map layouts.
3. Insert maps for each of the required map frames for the layouts.
4. Save your work often.

Map Exercise 1: Map of Visited European Countries (30 Points)

Data for this map have been provided in the [Exercise_10_Map1.gdb](#) file geodatabase in the [Exercise_10](#) folder downloaded from <https://www.wvview.org/>. You will need the following files: [European_Countries](#) and [World_Countries](#).

The "visited" field contains "0" and "1" values. "1" indicates countries that were visited during a hypothetical trip whereas "0" denotes European countries that were not visited.

Your Task: Create a map of Europe showing what countries were visited and which weren't.

Grading Rubric:

1. Data frame background color is changed to blue. (3 points)
2. Countries are labeled with a halo and with no overlap between labels. (3 points)
3. A coordinate grid in latitude and longitude is provided, and no north arrow or scale bar is provided. (6 points)
4. An appropriate projection is used for continental Europe. The projection is listed on the map in a text box. (2 points)
5. The [World_Countries](#) layer is included in the map layout behind the [European_Countries](#) layer. (2 points)
6. The [European_Countries](#) layer is symbolized to show countries visited and those not visited. The legend labels have been changed to "Visited" and "Not Visited" as opposed to "1" and "0." (4 points)
7. The legend displays only the [European_Countries](#) layer and no file names are included in the legend. (2 points)
8. A descriptive title and your name are provided. (2 points)
9. The map is overall very neat and well organized. Spaced is utilized well, and the data are well presented (6 Points)

Map Exercise 2: Colorado River Basin (30 Points)

Data for this map have been provided in the **Exercise_10_Map2.gdb** file geodatabase in the **Exercise_10** folder downloadable from <https://www.wvview.org/>. You will need the following files: **Colorado River**, **Colorado_River_Drainage_Basins**, **Colorado_River_States**, and **Colorado_River_Tributaries**.

A WVU logo has also been provided in the **Same** folder. It is called **wvu_logo.jpg**.

Use of on the available base maps. You can use whichever you think is appropriate. Remember to cite the source of the base map.

Your Task: Create a map of the Colorado River Basin that highlights the Colorado River, its tributaries, and the states that its basin intersects.

Grading Rubric:

1. The Colorado River and its tributaries are symbolized as blue lines. The Colorado river is displayed thicker than its tributaries. (2 points)
2. The basin boundary is hollow with the lines symbolized in a color other than blue. It is above the state boundaries. The state boundaries should also be displayed as hollow with an outline and in a different color than the state outlines. (4 points).
3. In the legend, the features are named as follows and in the following order: Colorado River, Tributary Rivers, States, Drainage Basin. (4 points)
4. Scale bar is provided in miles with the bar ending on an even one-hundred value (for example, 200 mi). In the scale bar, mi is used instead of spelling out miles. (3 points)
5. A north arrow is provided. The north arrow should not be large or take up a lot of space on the layout. (2 points)
6. The WVU logo is added to the map. (2 points)
7. The base imagery is used; however it does not appear in the legend. A text box is used to denote the source of the data. (3 points)
8. An appropriate projection is used for the western United States. The projection is listed on the map in a text box. (2 points)
9. A descriptive title and your name are provided. (2 point)

10. The map is overall very neat and well organized. Spaced is utilized well, and the data are well presented (6 Points)

Map Exercise 3: Subdivision Map (30 Points)

Data for this map have been provided in the **Exercise_10_Map3.gdb** file geodatabase in the **Exercise_10** folder downloadable from <https://www.wvview.org/>. You will need the following files: **Narra_block**, **Narra_foot**, and **Narrabundah**.

You will display the **Narra_block** layer using the "LIFE_STG" field.

Use of on the available base maps. You can use whichever you think is appropriate. Remember to cite the source of the base map.

Your Task: Create a map of this development showing the life stage of the parcels.

Grading Rubric:

1. Parcels are symbolized using the LIFE_STG field. A different color is used to show each class. (4 points)
2. Class names have been changed to lower case in the legend. (3 points)
3. No file names are used in the legend. (3 points)
4. The Narrabundah boundary is displayed as a hollow polygon with an outline color different from the other features. (3 points)
5. The building footprints are displayed as solid polygons in a different color than the other features. (2 points)
6. A scale bar is displayed in kilometers with km used in the scale bar as opposed to kilometers. (2 points)
7. A transparency of 30% is used to display the parcels. (2 points)
8. The base imagery is displayed beneath the vector layers. (1 point)
9. The legend has only the vector features listed. The base imagery is not listed. Any file names have been removed. (2 points)
10. A descriptive title and your name are provided. (2 points)
11. The map is overall very neat and well organized. Spaced is utilized well, and the data are well presented (6 Points)

Map Exercise 4: Mine Expansion Model (30 Points)

Data for this map have been provided in the [Exercise_10_Map4.gdb](#) file geodatabase in the [Exercise_10](#) folder downloadable from <https://www.wvview.org/>. You will need the following files: [Study_Extent](#), [us_states](#), [us_counties](#), and [mine_probabilities](#).

The [mine_probabilities](#) raster grid represents a spatial prediction of the likelihood of mine expansion in the portions of the study area extent that have coal seams present. A value of 1 represents high probability and a value of 0 represents low probability. These data were developed and used in the following publication:

Strager, M.P., J.M. Strager, J.S. Evans, J.K. Dunscomb, B.J. Kreps, and A.E. Maxwell, 2015. Combining a spatial model and demand forecasts to map future surface coal mining in Appalachia, *PLoS ONE*, 10(6): e0128813.

Your Task: Create a map of the probability of surface mine expansion.

Grading Rubric:

1. The map is zoomed to the extent of the entire study area, not the entire country. (2 points)
2. The raster probability surface has been symbolized using a stretch and a color ramp other than grey scale that is appropriate for these data. (2 points)
3. The study area extent has been displayed as a hollow polygon with a red outline and is labeled "Study Area Extent" in the legend. (2 points)
4. The United States counties are displayed behind the study area extent and raster output. They are not shown in the legend. (3 points)
5. The states layer is hollow and displayed above the counties with thicker lines to highlight the state boundaries above the county data. They are not shown in the legend. (3 points)
6. A second data frame is used to show a subset of the data of your choice (should be zoomed in relative to the other frame). An extent indicator is used to show where this subset is on the larger map. (4 points)
7. Text box with short text indicating why you chose the zoom extent. Example: "Highest probability of expansion" or "West Virginia" (2 points)
8. An appropriate projection is used for the eastern United States. The projection is listed on the map in a text box. (2 points)

9. An appropriate north arrow and scale bar are provided. The north arrow should not be large or take up a lot of space on the layout (2 points)
10. A descriptive title and your name are provided. (2 points)
11. The map is overall very neat and well organized. Spaced is utilized well, and the data are well presented (6 Points)

Deliverables

For this lab, provide your four maps in PDF format. They will be graded against the rubrics above.

END OF EXERCISE