

Selections, Joins and Relates

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Selections: Why and How

- 1) Slide 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12: Overview; briefly why we want to select features and how we do it.

- a) Why do it?

- i) **Zooming to features:** ArcGIS Pro offers easy tools to zoom in right to selected features. This is especially useful if I select a feature in the attribute table, but don't know where it is on the landscape. For example, suppose I can't remember exactly where Yavapai County is in Arizona. I could find and select that county in the attribute table, then zoom my map right to it.

Or, as I'm doing in this slide, I can select a few features I'm interested in and expand the map so that I get the closest view possible of the landscape that contains all those features.

- ii) **Statistics on Subsets of features:** Remember that GIS is all about getting information on objects in the landscape. As part of this, there must be some way to decide which features you want to analyze.

Most analyses are done on only a subset of all available features. For example, I might be interested in the amount of roadless areas in a forest. Therefore I want to identify all parts of the forest that are greater than some specified distance from a road. **But**, I might not want to consider administrative-use-only roads in the analysis. Therefore I would **select** only those roads that are not admin roads, and then run the analysis on the selected set of roads.

In this example I'm interested in whether some counties have higher median ages than others, and I can easily open up a histogram to see the distribution.

- iii) **Running tools on subsets of features:** There are many tools like the "Statistics" tool described above, which you might want to run on only a subset of features. For example, I might have a set of Spotted owl locations collected during both the day and night. I can compare both nocturnal and diurnal behavior and habitat use by selecting the day or night locations before running my tools, and the tools will only consider those selected features.

- iv) **Saving subsets of features:** Sometimes a dataset has far more data in it than you want to work with. For example, you might have a road network dataset of the entire country, but you only want to work with the roads in your forest or town. You could select those roads you are interested in, then save them to a new (much smaller) feature class. This has the advantage of making the feature class much quicker to work with because ArcGIS is not having to examine the road network for the entire country every time you change the map view.

Also, with regards to (iii) above, there are inconsistencies in the hundreds of ArcGIS tools and commands with regards to selections. Some will work on only the selected features, some work on all features regardless of whether there is a selection, and some give you the option. If a tool does not give you the option to only work with selected features, then you can save a subset of the features to a new feature class and then run the tool on your new feature class.

- b) How to select:

- i) By clicking or drawing on the screen

- ii) By clicking on records or rows in a table
 - iii) By using the “Select by Location” tool to select features based on proximity to other features.
 - iv) By using the “Select by Attributes” tool to build complex queries for tables.
- 2) Slide 13: What is a selection? Suppose I have a road network on the Coconino National Forest and I am curious about how much road is available and open to all vehicles, including ATVs and snowmobiles, throughout the year.
 - 3) Slide 14: By selecting just those roads which are defined as “Roads Open to All Vehicles, Yearlong”, I can now analyze them as a group. Selected features usually show up in cyan, but you can change this if you want.
 - 4) Slide 15, 16: For example, I can easily calculate how much of the Coconino road network is classified this way (5,103 miles) and how much is not (2,670 miles). You may also find it interesting that the Coconino National Forest has over 7,700 miles of road on it, which, if you stretched them all out in a straight line, is enough to take you 1/3 of the way around the planet.
 - 5) Slide 17: I can also easily zoom or pan to selected features. For example, I can search for a particular feature in the attribute table, select that feature and then quickly zoom to it to find it in the map.
 - 6) Slide 18: Some ArcGIS Pro tools will only work on selected features and other tools give you the option between selected and all features. It is hard to predict which tools check for selection and which don't. You have to read up on them individually, and even then they don't always say.

When in doubt, just select the features you want to analyze and export the selected features to a new feature class (as illustrated in the slide), then run the tool on that new feature class.

Selecting in the Map

- 7) Slide 19: There are several tools available to select features by clicking on them or drawing shapes around them in the map. These 6 options in the slide basically are just different shapes you can draw on the screen, and the three grayed-out options are specific tools for selecting 3-dimensionally.
- 8) Slide 20: It is just as easy to clear the selection in the map. Just click the **Clear** command.
- 9) Slide 21: The layer must be set as **selectable** in order to use the Map Selection tools.

Do you wonder why would you disable the on-screen selection tools? Primarily because:

- a) You often have several vector layers in your map, and
- b) You only want to select from a subset of them, and
- c) It is distracting and time-consuming for ArcGIS Pro to make a selection on all layers in the map.

For example, say you have 30 feature classes loaded up, and you are only wanting to analyze one of them. If you draw a box around the features you are interested in, then ArcGIS Pro will also select all the intersecting features from the other 29 feature classes. You then have to wait for all that selecting to finish, and you have to wait even longer for Pro to symbolize all the newly-selected features with the cyan Selection color. You would have saved yourself a lot of time by just setting only that single feature layer to be selectable at the start.

Selecting by Attributes

- 10) Slide 22: Selecting by Attributes: This particular tool makes it easy to select features based on attribute values.
- 11) Slide 23: There are two ways to use this tool.
- 12) Slide 24: The simplest way is called the “Clause” mode, and
- 13) Slide 25: ... the more sophisticated way is the SQL version.
- 14) Slide 26: Both versions have their pros and cons. The Standard version, in “Clause” mode,
- 15) Slide 27: ... makes it easy to make simple queries, such as finding all features with an attribute value greater than, equal to or less than some specific value.
- 16) Slide 28: The tool will give you the names of all the attribute fields in a drop-down list, which is nice because we often don’t remember the exact name of the attribute field we want to query against.
- 17) Slide 29: The tool even samples the data as you build the query, to offer you some attribute values to compare against in a second drop-down list.
- 18) Slide 30: The tool does offer a method for building complex queries with multiple sub-queries, but it’s a little clunky.
- 19) Slide 31: And it doesn’t give any way to use the more interesting SQL operators.
- 20) Slide 32, 33: The SQL window, on the other hand, is in general much more powerful. It’ll do everything you can do in “Clause” mode, and sometimes easier.
- 21) Slide 34: Unfortunately you need to know SQL to take full advantage of it.
- 22) Slide 35: The tool does try to help. Once you start typing, it’ll offer auto-complete suggestions such as listing the field names and SQL functions it thinks you want to type.
- 23) Slide 36: This tool makes it a lot easier to build compound queries. You just need to put things in parentheses like you would do with mathematical terms in Algebra, and put “AND”, “OR” or “NOT” between each set of parentheses.
- 24) Slide 37: Take a look at <https://pro.arcgis.com/en/pro-app/latest/help/mapping/navigation/sql-reference-for-elements-used-in-query-expressions.htm> for a list of SQL Operators used by ArcGIS Pro. Or you can just do a web search for “ArcGIS Pro SQL”.
- 25) Slide 38: A few things to remember about SQL queries:
- 26) Slide 39: First, if you are querying for Text values (such as “State Name = Arizona” or “Ranger District = the Mormon Lake District”, then you have to enclose your text value in Single quotes! Don’t use double-quotes.
- 27) Slide 40: You can include wildcard characters, which allow you to search for any text that is contained inside longer strings of text, and the wildcard characters also have to be enclosed in single quotes.
- 28) Slide 41: This raises a problem when you want to include a single quote character in your text search. If this happens, you need to add a second apostrophe in front of your original apostrophe. This serves as an “Escape” character that tells ArcGIS that you want the original apostrophe in the query itself.

29) Slide 42: Wildcards are pretty cool. They stand in for unknown or unspecified text, and they allow you to search for text inside of longer text.

Queries that use wildcards are called “Like” queries, and they use the “Like” operator. Notice you do **not** use the “=” character in these types of queries.

There’s two types of wildcards. One stands for any number of characters, including zero characters, and the second stands for exactly one single character.

ArcGIS uses the “%” symbol as the wildcard that stands for any number of characters. In this slide we are querying for all features that have “Coconino” anywhere in the site name.

Slide 43: ArcGIS uses the “_” symbol as the wildcard that stands for exactly one character. In this slide we are querying for all features that the text “304” as the 2nd, 3rd, and 4th characters in the name.

By the way, there are ways to “Escape” these wildcard characters, too, in case you want to search for text that actually as a % or Underscore character in the text. It’s a little more complicated than just popping an apostrophe in front of it, but SQL does give you tools for it.

30) Slide 44: There are issues with SQL queries, though! This function is very powerful in that Selecting by attributes lets you build complex SQL (Structured Query Language) queries, far beyond the simple operators included in “Clause” mode.

HOWEVER, the query string format depends on the data type! Shapefiles and File Geodatabases follow different rules than Microsoft Access databases, and high-end databases like Oracle, MySQL and SQL Server might have their own formatting quirks.

Slide 45: For example, wildcard characters might be different. Shapefiles and File Geodatabases use the “%” and “_” characters, like we just saw, but Microsoft Access databases use the “*” for multiple characters, and “?” for single characters.

Slide 46: Attribute field names should sometimes be enclosed in double-quotes, sometimes in square brackets, sometimes in the backwards apostrophe (`), and sometimes not enclosed in anything. All depends on the rules of that particular database format.

Slide 47: If your data are stored in an Esri format (such as shapefiles and file geodatabases), then the **Select by Attributes** tool will automatically format the query correctly.

Slide 48: If you are connecting to other types of databases, though, you’ll need to know the rules for that database format.

Slide 49: A nice feature, if you are using Python, is the “AddFieldDelimiters” function. This will check the database for you, then make sure your field names are formatted correctly.

31) Slide 50: Regarding NULL values:

Slide 51: These are a special data value that specifically means “No Value”. Such value are important, because sometimes we actually haven’t recorded data for some attribute.

Slide 52: The SQL query is [Attribute] IS NULL. There is no “=” sign in a Null query. They use the “IS” operator.

Slide 53: Shapefiles can’t hold Null values, which is a real mark against them. If you don’t have a numeric value, Shapefiles store a Zero. This is a problem if the attribute field is a numeric value that has only been measured intermittently. For example, if the attribute field holds the measured flow

of a spring, then that number represents the actual amount of water coming out of the ground. If we didn't measure it one day, then we'd like to store a NULL value for that day. Shapefiles will force you to store a "Zero" value instead, which has implications for later calculations of, say, average or minimum flow.

- 32) Slide 54: **Bonus!** Once you've mastered the "Select by Attributes" tool, you can use a very similar one to set a **Definition Query** on a feature dataset. This particular tool makes it easy to select features based on attribute values.
- 33) Slide 55: Definition Queries are part of the Layer definition (and remember that layers are just sets of instructions telling ArcGIS where to find and how to draw the data). The layer definition is part of the instructions ArcGIS Pro follows when drawing the data, and specifically Definition Queries tell ArcGIS Pro exactly which parts of the dataset to show.

We may not want to see all the data in the dataset. For example, suppose we have the Coconino National Forest Road network, but we only want to show those roads that are defined as being open to all vehicles.

- 34) Slide 56: By setting a definition query, we can tell ArcGIS Pro that this layer should only show the roads that are classified as "Roads Open to All Vehicles, Yearlong" and "Roads Open to All Vehicles, Seasonal".

Selecting by Location

- 35) Slide 57: The **Select by Location** tool lets you select features based on spatial relationships with other features. For example we can select all the survey points that lie within the Elden Small Project Area boundary.
- 36) Slide 58: There are several spatial relationships besides "Intersects".

By the way, you might be wondering what the Clementini relationships are. These are interesting. It turns out that different software packages actually defined some spatial relationships differently. One software package might say that Polygon A contains Polygon B, while another software package says the opposite. The problem came down to different definitions for spatial relationships, and Clementini tried to standardize them. Therefore, if different software packages offer these "Clementini" versions, you should be confident that they are using the same methods and should produce the same results. If you are interested in learning more about this, I've posted Clementini's original manuscript in the class module online. I've also got a short description in the Appendix at the end of the Selections, Joins and Relates Lecture Notes document.

- 37) Slide 59: Back to ArcGIS Pro: There are also some very simple spatial selection options available when you select on the screen (i.e. Interactive Selection).
- 38) Slide 60: See the Appendix on Spatial Relationships in this document for details on several of the most useful types of spatial relationships.

Selection Types

- 39) Slide 61, 62, 63, 64, 65, 66: Selection Types: The various **Selection Types** allow you to make new selections, add to current selections, remove selected features from current selections, select only a subset of the current selection, or flip the selection. You will get the hang of these in the lab exercises.

- a) Slide 67: The selection types are available in both the *Select By Attributes* and *Select By Location* tools.
 - b) Slide 68: **Making a new selection** will first clear out any currently existing selection. The new set of selected features will therefore be completely unrelated to any selection that may have existed previously. Existing selections are wiped clean.
 - c) Slide 69: **Adding to the current selection** will leave your current selection (if any) unchanged, and then simply add any newly-selected features.
 - d) Slide 70: **Removing from the current selection** will only affect currently selected features. If any features in your selection area are currently selected, then they will be unselected. If they are **not** currently selected, then they will be left unselected.
 - e) Slide 71: **Selecting from the current selection** will only affect currently selected features. If any features in your new selection area **are** currently selected, then they will be **left selected** (i.e. left unchanged). If features in your new selection area are **not** currently selected, then they will be left unselected. Any originally-selected features outside of your new selection area will be unselected. **Note:** If you do not have any features selected before you try this selection type, then by definition you will have no features selected afterwards. This is actually a common problem; forgetting that the selection type is set to select a subset, when no features are currently selected.
 - f) Slide 72: Switching the selection simply flips the selection state of all features. If a feature was selected, it becomes unselected. All unselected features become selected.
 - g) Slide 73: Switching the Selection can be done in the Feature Attribute Table (in the “Switch Selection” button), or by right-clicking on the Layer Name in the Contents Pane, then clicking “Selection”, and then “Switch Selection”.
 - h) Slide 74: Selection Types are also available when selecting on the screen.
- 40) Slide 75: How do you know how many features are selected? There are two good places to find it:
- a) In the Attribute table
 - b) In the Contents Pane, after switching to **List by Selection**.
- 41) Slide 76: A quick note on determining how many features are in a feature class. The easiest way to get the number of features is to just open the table and look at the bottom of the table. However, sometimes you will see “*2000” instead of the true number of records. This is because ArcGIS Pro is only looking at the first 2,000 records, and has not checked the table further to see how many records there really are. It does this for performance reasons. It can show you the table quicker if it only looks at the first 2,000 records.
- However, this means that you need to force ArcGIS Pro to look at the entire table before you can see how many records there are. Just click the  button to go to the end of the table, and you will now see the correct number of records.
- 42) Slide 77: **A Common Mistake!** Be careful with the number in the lower right corner! This is the number of **all** the selected features from **all** the layers in the map. If you just care about the number of selected cities, then the correct value here is 110. This number shows the number of selected cities plus the number of selected states.

43) Slide 78: If you want your selection color to be something other than Cyan, there are ways to change it.

44) Slide 79: Now, **Selecting by Multiple Criteria**: Usually your selection is based on multiple criteria, like this example here. These squares are selected based on three criteria: 1) legislative constraints (must be ≥ 6 nautical miles from the coast), 2) fuel capacity constraints (must be ≤ 20 nautical miles from a port), and 3) equipment constraints (must be $\leq 200\text{m}$ in depth). The set of possible fishing places are those that meet all three criteria simultaneously.

45) Slide 80, 81, 82, 83, 84, 85, 86, 87: Selecting by Multiple Criteria

- a) This type of selection is a very common thing to do; maybe even more common than just selecting by a single criteria. And these multiple criteria can include both spatial and attribute queries.
- b) If you are making a compound selection by attributes on a single feature class or table, you can build multiple criteria into a single SQL query.
- c) You can also add multiple clauses when using “Clause Mode”
- d) This is different than selecting by location. When selecting by location, you can’t apply several spatial criteria in a single batch. You need to do several consecutive selections, where each step contains only a single query.
- e) The first selection type is always “New Selection”
- f) Slide 88 ... and all the selections after that will either add to the currently selected set, subtract from it, select a subset from it, or flip the selection.

46) Slide 89, 90, 91: When selecting by both Attributes and Location, you need to do consecutive selections. You can’t do both at one time.

As with Selecting by Location, you just do several queries in a row, using different selection types each time.

Slide 92: The first selection type is always “New Selection”

Slide 93 ... and all the selections after that will either add to the currently selected set, subtract from it, select a subset from it, or flip the selection.

47) Slide 94: For example, a single criteria would look like this. We’re asking how many cities have a population greater than 100,000.

48) Slide 95: We find that 264 cities had more than 100,000 people in 2007.

Sometimes this is all we need to do, but a more common scenario might be ...

49) Slide 96: ... “How many cities in **Arizona** had more than 100,000 people in 2007?”. This criteria takes 3 steps.

First we have to select the state of Arizona. In this slide I’m using a “Select by Attributes” query.

Second we make an initial selection of cities, returning all cities that meet our population constraint.

Finally we apply a spatial query to our cities, selecting a **subset from the currently selected cities**, namely those currently selected cities that lie within the state of Arizona.

Note: If we had not selected the state of Arizona in Step 1, then in Step 3 we would have selected cities in all states. We needed to make that initial selection of Arizona in order to force ArcGIS to only consider the state of Arizona in Step 3.

50) Slide 97: We see that 9 cities in Arizona meet the criteria.

51) Slide 98: Things to watch for when building a multi-criteria selection:

a) Slide 99: In a single SQL Query, [Slide 100] each sub-query must be a complete query:

b) Slide 101: This is Correct:

```
"STATE_NAME" = 'Arizona' OR "STATE_NAME" = 'New Mexico'
```

We have two criteria, and each of them are stated in a fully workable query (first "STATE_NAME" = 'Arizona', and second "STATE_NAME" = 'New Mexico')

c) Slide 102: To contrast, this is Not Correct:

```
"STATE_NAME" = 'Arizona' OR 'New Mexico'
```

d) Slide 103: A common mistake! And reasonable. [Human minds understand the query "STATE_NAME" = 'Arizona' OR 'New Mexico'] just fine, but computers do not. We need to think like the computer does, in order to give it instructions that it will understand.

52) Slide 104: Another Common Mistake!

a) Slide 105: Trying to select more than one attribute value from a single attribute field using the "AND" operator.

b) Slide 106: This is Not Correct:

```
"STATE_NAME" = 'Arizona' AND "STATE_NAME" = 'New Mexico'
```

c) Slide 107: How many single states are named both Arizona and New Mexico?

d) Slide 108: This will not trigger an error, but it will always give you zero results.

e) I recommend thinking about it like this. When you set a query, then ArcGIS will go through your feature class row by row to see if each row meets that query. Therefore the query is being applied to a single row. Within that single row, you can only have a single value for that attribute field. Therefore this query, which is basically asking for cases where a row has multiple values for a single attribute, will find it logically impossible to ever find such cases.

53) Slide 109: Remember to watch the map as you make your selection! Take advantage of the fact that you are running a world-class GIS that will instantly show you visually a map of your results.

Many errors are obvious if you only remember to look. In this example, I want to select all points that are both **within** the polygon **and** 200m from a road. Obviously I have done something wrong since so many points outside the polygon are selected.

Take advantage of the fact that you are working in a GIS, and you have maps immediately available after you make selections.

Joins

Slide 110, 111: **Joining tables** means to create a connection between tables such that the attribute values from one table (or feature class) become directly available in another table or feature class.

- Slide 112: Especially useful when many records have the same attribute value (perhaps a code for a forest stand type), and another table has single records for each stand type, and has extensive data within that row, describing each stand type.
- Slide 113: Putting the extensive data in a separate table lets you avoid repeating that data over and over in the first table, and I'll show you an example in just a second.
- Slide 114: Good for 1-to-1 (1:1) or Many-to-1 (M:1) relationships. For example, you might have many timber survey points that classify the forest type as, say, "Ponderosa Pine", and another table containing a single record describing the "Ponderosa Pine" forest type. You join the many points to the single record with Ponderosa Pine info.
- Slide 115: A similar concept called a "Relate" is good for 1-to-Many (1:M) and Many-to-Many (M:M) relationships, and we'll get to that in a second.

Slide 116: Here's a scenario crying out for a join: We have a polygon feature class with very little data in the attribute table.

Slide 117: Notice that this polygon feature class has a very large number of records.

Slide 118: We use the Identify command on a spot and learn very little about it. How useful is it to us, really, to know that this polygon has a "gridcode" value of 3159? Doesn't do much for me.

Slide 119: However, we also happen to have a table just filled with great information about each vegetation class, but which has no spatial objects (polygons) telling us where that information occurs on the ground. Notice that this table only has 91 records. Remember that the original feature class had over 745,000 polygons, and every polygon had one of these 91 possible vegetation classes.

Question: Can you see the logic in putting these 91 records in a separate table? We can either record these vegetation records 91 times, or 745,000 times. The first option uses much less space on your hard drive, but it does require that you connect your polygons to this table.

Slide 120: We see that lots of polygons may correspond with a single table record. This means that we have a "Many-to-1" (M:1) relationship.

Slide 121: Joins work just fine for M:1 relationships. We join the table to the polygon feature class, and essentially we have added a bunch of new attribute fields to the polygon attribute table.

- **Important:** And it's important to remember that, even though we see this as a single table, with all the veg type info showing up in all 745,000 polygon features, neither the polygon feature class, nor the attribute table, has been modified on the hard drive! This "Join" relationship occurs entirely in your computer memory and only exists in this ArcGIS Pro Project.

Slide 122: But ArcGIS Pro can analyze the feature class and the veg type attribute table as if they were a single dataset. Now when we click on a point, we see all the joined attribute data as well.

Relates and Relationship Classes

Slide 123: **Relates** and **Relationship Classes** are [Slide 124] similar conceptually to **Joins**, in that you link tables together. [Slide 125] This allows you to get information on a feature by pulling data from different tables. [Slide 126] However, they are different than joins in that the linked tables are not merged together. If you open a table that participates in a *Relate* or *Relationship Class*, it will not look any different than it would if it were not participating.

Slide 127: **Relates** and **Relationship Classes** are good for 1-to-1 (1:1), 1-to-Many (1:M), Many-to-1 (M:1) and Many-to-Many (M:M) relationships.

Slide 128: **Relates** and **Relationship Classes** are almost identical to each other. [Slide 129] They both define the same types of relationships between tables and/or feature classes, and [Slide 130] you use them exactly the same way.

Slide 131: The difference between them is that *Relates* are created in-memory in ArcGIS Pro, while [Slide 132] *Relationship Classes* are saved into a geodatabase. You create a [Slide 133] *Relate* while within your current ArcGIS Pro session, and you can only use it when working with that particular ArcGIS Pro project. *Relationship Classes*, [Slide 134] on the other hand, are permanently saved to a geodatabase (until you deliberately choose to delete them) and are accessible at any time from any ArcMap or ArcGIS Pro session.

Note: [Slide 135] You need an ArcGIS “Standard” or “Advanced” license to create **relationship classes**. You cannot create them using the “Basic” license. However, you can create [Slide 136] **relates** using any license level.

Slide 137: The Explore tool takes advantage of relates. If your feature class has any relates or relationship classes, then you can see all related features and records by when you click on a feature.

Slide 138: You can also “push” selections from one dataset to another. In this example, we have 27 springs selected. We push that selection to the Surveys table, and find that there have been 74 surveys performed on these 27 springs. We can further push the Surveys selection to the Invert Sampling table and find that invertebrates have been recorded 655 times over the course of those 74 surveys. Finally we can push the Invert Sampling selection to the Invert Taxa table and see that 203 unique invertebrate species have been observed at these 27 springs.

Slide 139: Demonstration of Relationship Classes using
...\Class_GIS_Data\Relationship_Classes\Coconino_August_2022.gdb: **Note:** You will see how to do these functions in Lab Exercise 7.

- What does Chimney Spring (Site ID 802) look like?
- What Vertebrate Species have been observed at springs on the Mormon Lake district?
 - Query: LandUnitDetail = 'Coconino NF, Mormon Lake RD'
- What springs have Western Tanagers been observed at?
 - Query: FaunaCommonName = 'Western Tanager'

Slide 140: For a more extensive description of how the Springs Geodatabase takes advantage of relationship classes, please take a look at the video *The Springs Geodatabase (Presented at SCGIS 2020)*.
https://youtu.be/OXp2h_mL-rg

Lab Exercises

Exercise 1: Select Forest Service Roads

Objectives

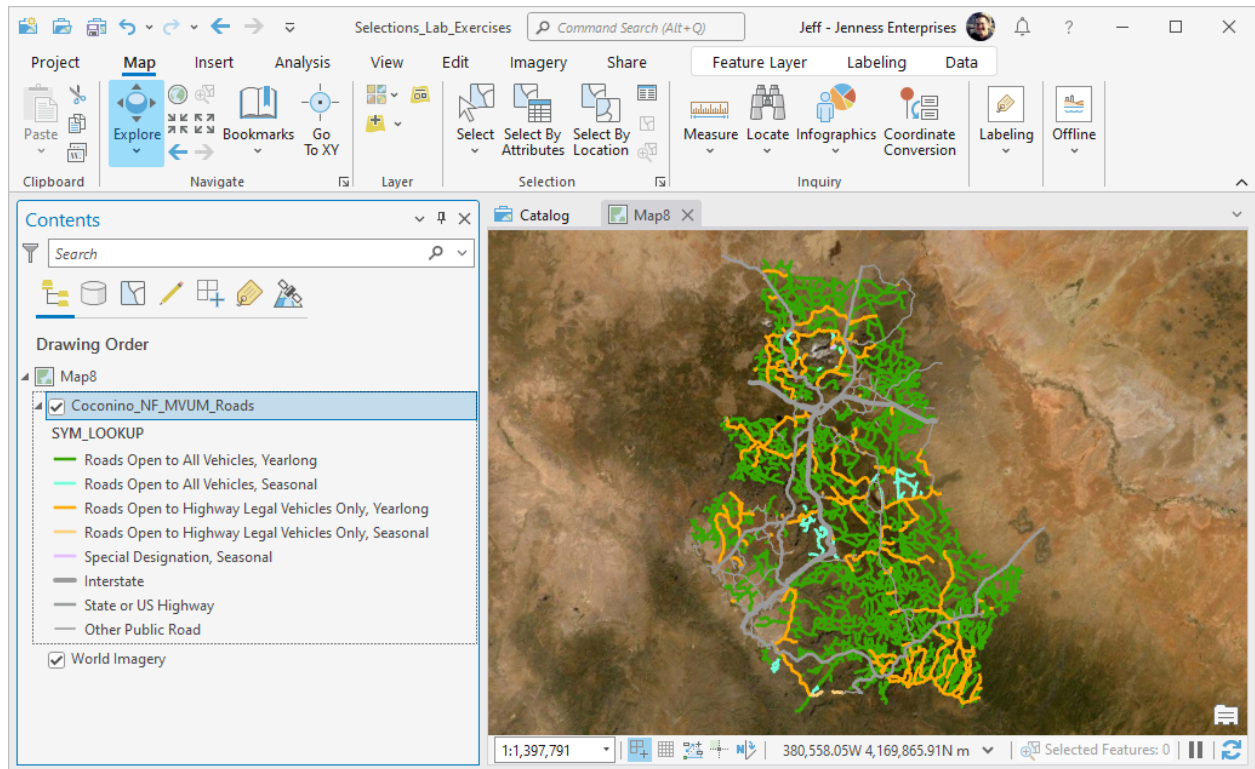
- Learn to set layer selectability
- Learn to use on-screen selection tools
- Learn the table selection tools
- Learn to use the “Select by Attributes” tool
- Learn the “Statistics” tool
- Learn how to save only selected features

Data used:

- Esri Basemap layer **World Imagery**
- Polyline feature class **Coconino_NF_MVUM_Roads** (this is the Coconino road status as of 2022) in workspace **Additional_Data**.

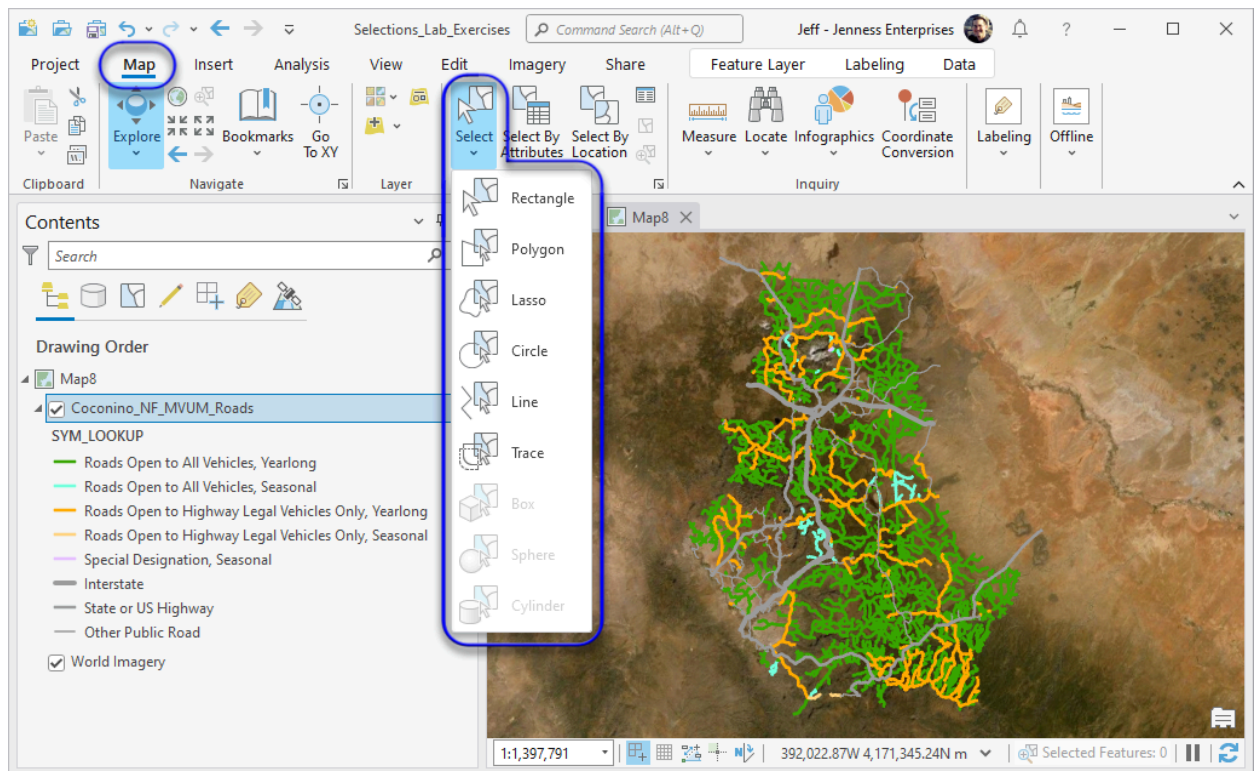
Exercise:

- ☐ Open **ArcGIS Pro** to a new empty map.
- ☐ Add the **Layer** file **Coconino_NF_MVUM_Roads.lyr** (from workspace **Additional_Data**).
- ☐ Add the basemap **World Imagery** (aka **Imagery**) (If you do not remember how, click the “Map” tab, then the “Basemap” command).
- ☐ Zoom to the extent of **Coconino_NF_MVUM_Roads**.



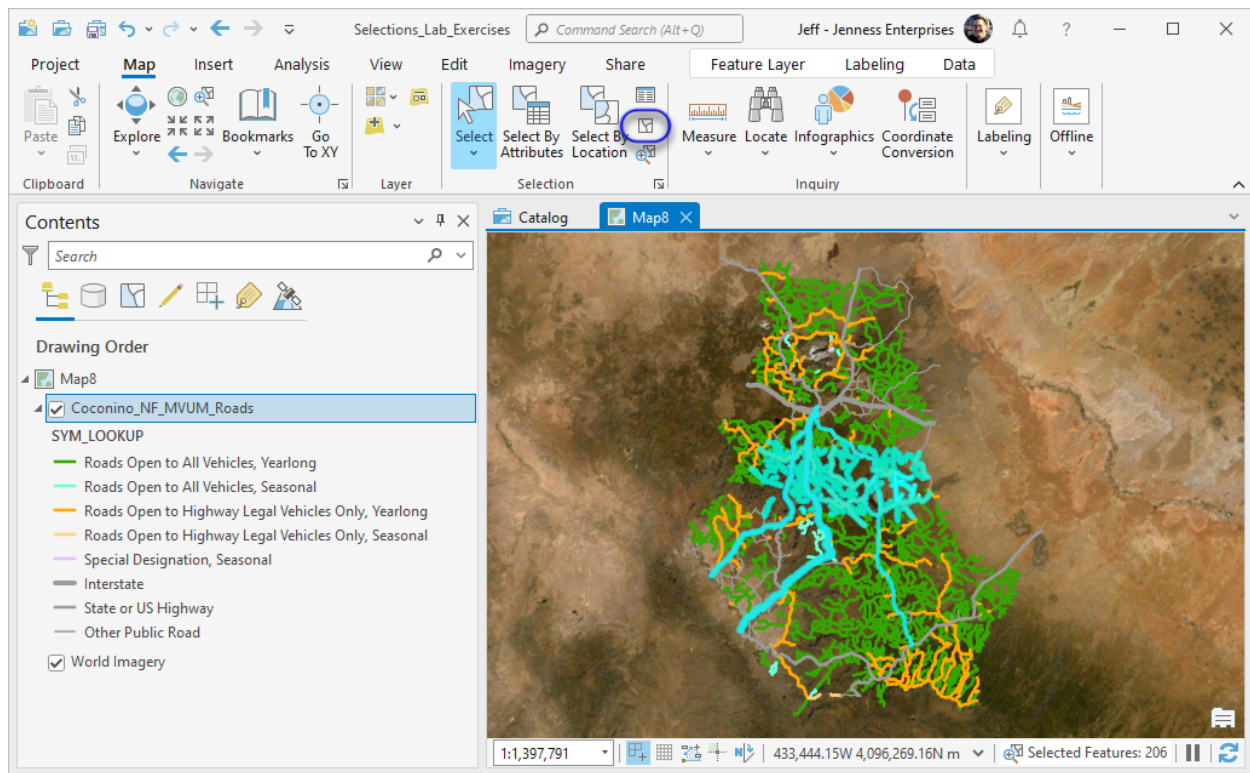
On-Screen Selection Tools

- Try all the on-screen selection tools. Become familiar with how they work.

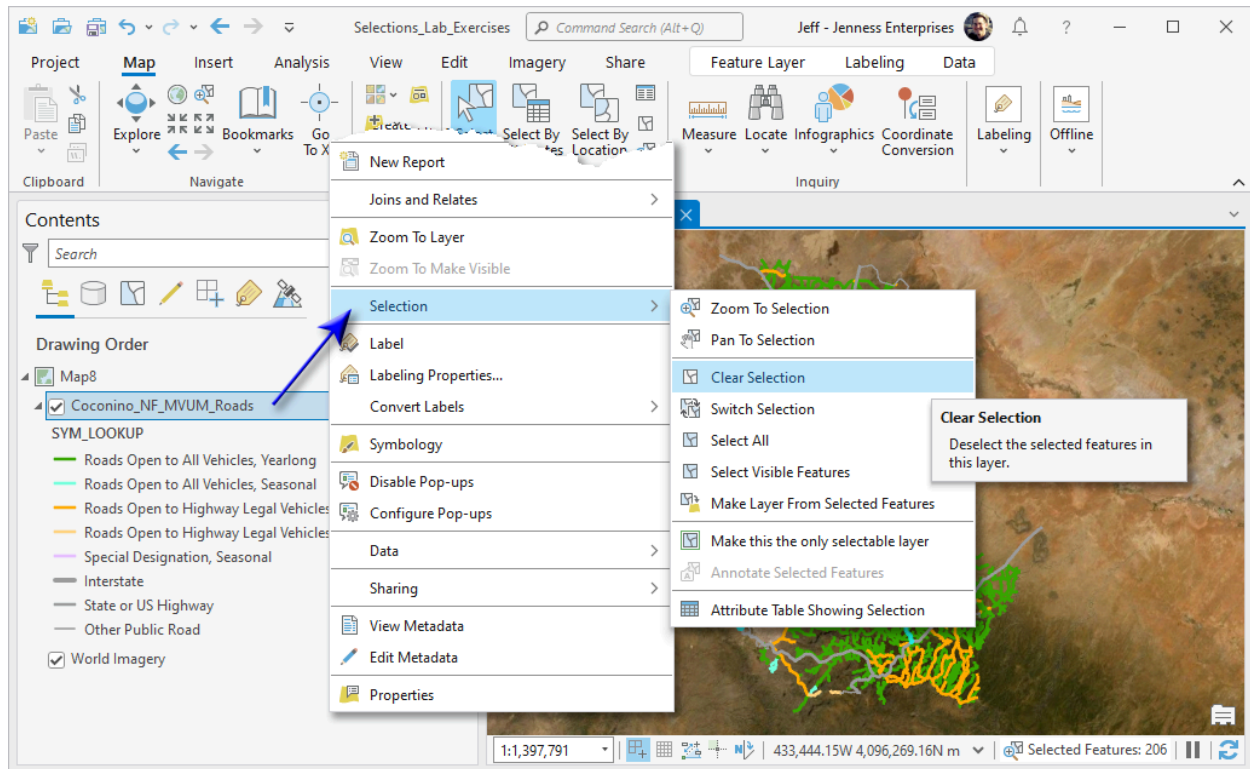


❑ After making a selection, try the different ways to use the “Clear Selected Features” tool.

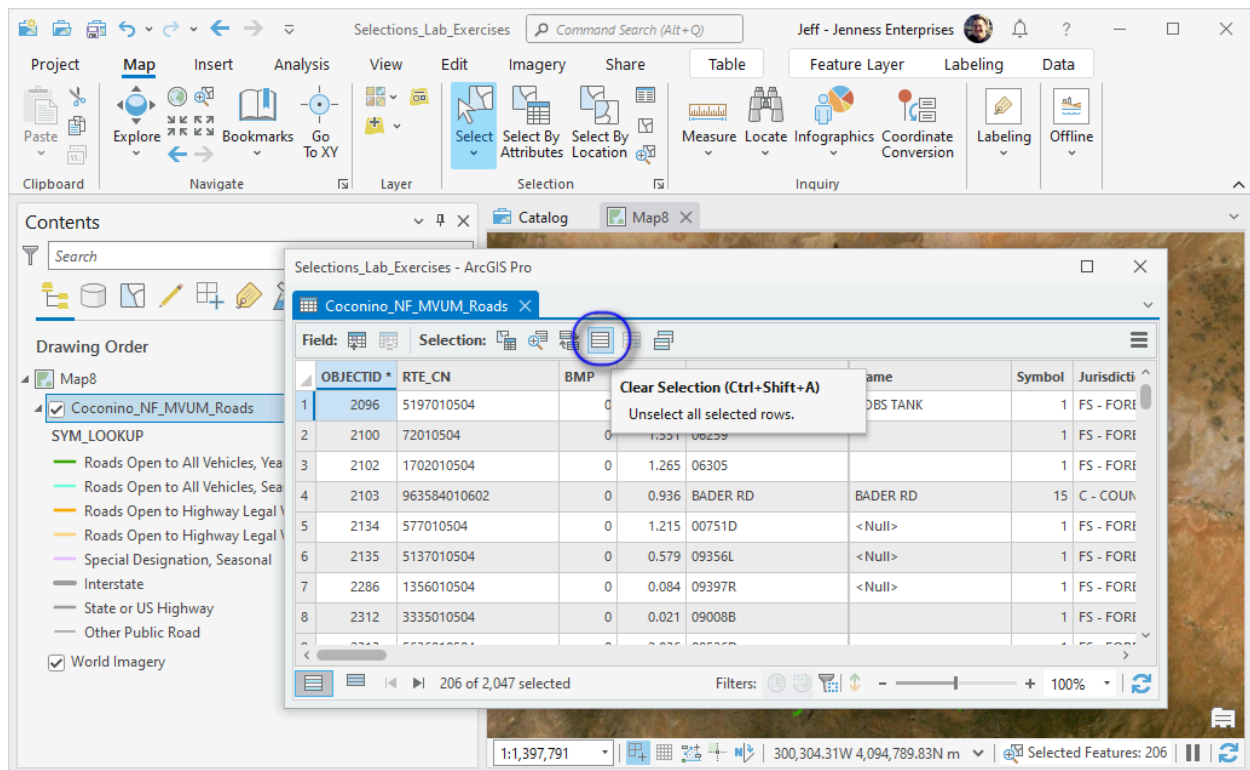
○ From Ribbon:



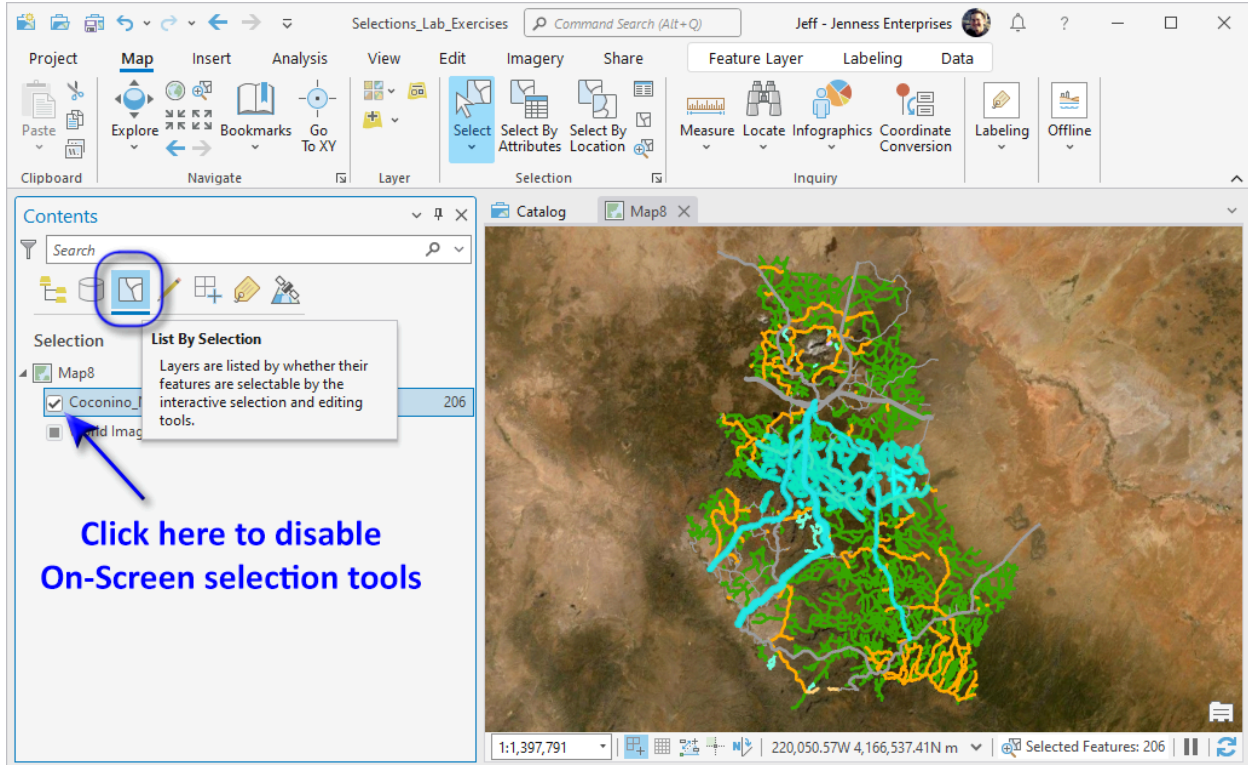
○ From Right-clicking on layer, then going to “Selection”:



○ From the Attribute Table:



- ☐ Change the Contents Pane Sort option to “List by Selection”.

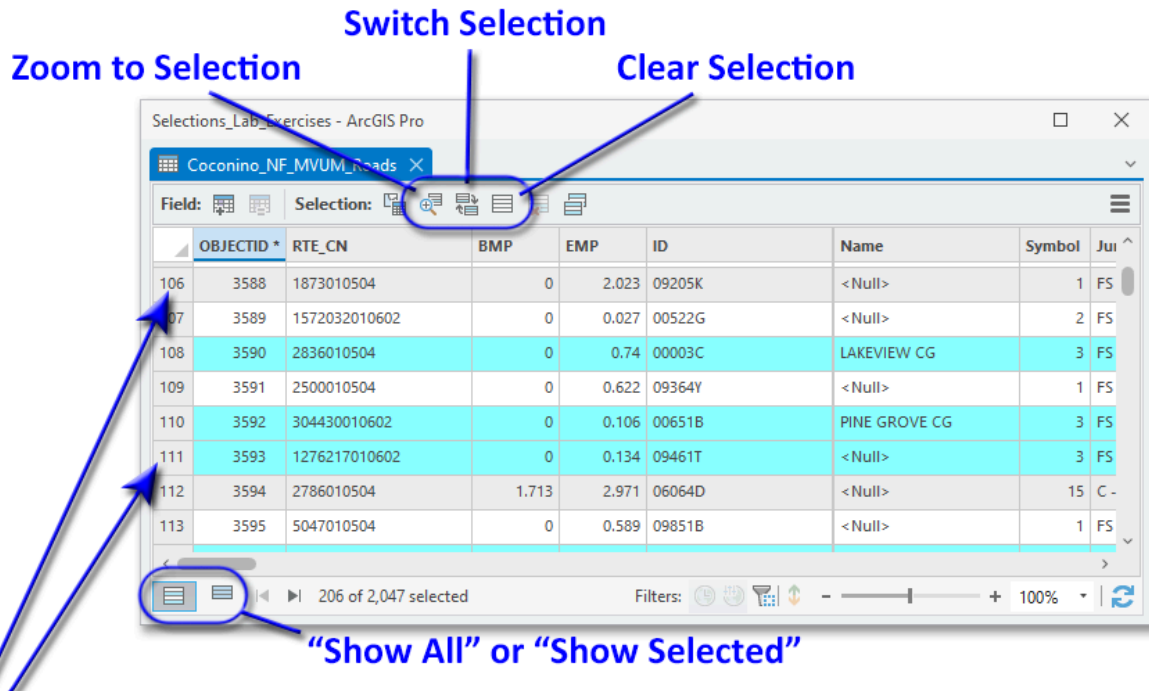


- ☐ Disable the on-screen selection tools as illustrated above. Try the on-screen selection tools to confirm they do not work, then re-enable the on-screen selection tools.
- ☐ Why would you disable the on-screen selection tools? Primarily because:
 - You often have several vector layers in your map, and
 - You only want to select from a subset of them, and
 - It is distracting and time-consuming for ArcGIS Pro to make a selection on all layers in the map.

Your work becomes both simpler and faster if you disable the selectability on all the layers you are not analyzing.

Table Selection Tools

- ☐ Make a selection and open the attribute table, and observe how the selected features also show up in blue in the Attribute table.

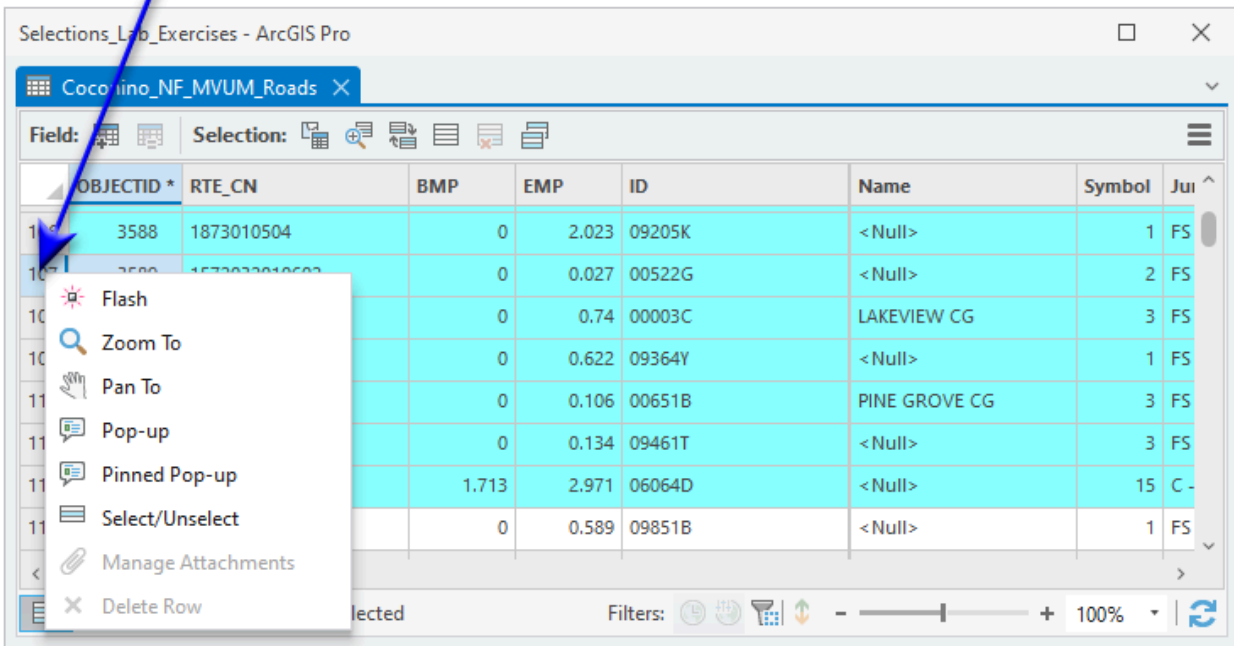


Manually select by clicking here

(and see what happens when you hold down the [Control] and [Shift] keys as you click)

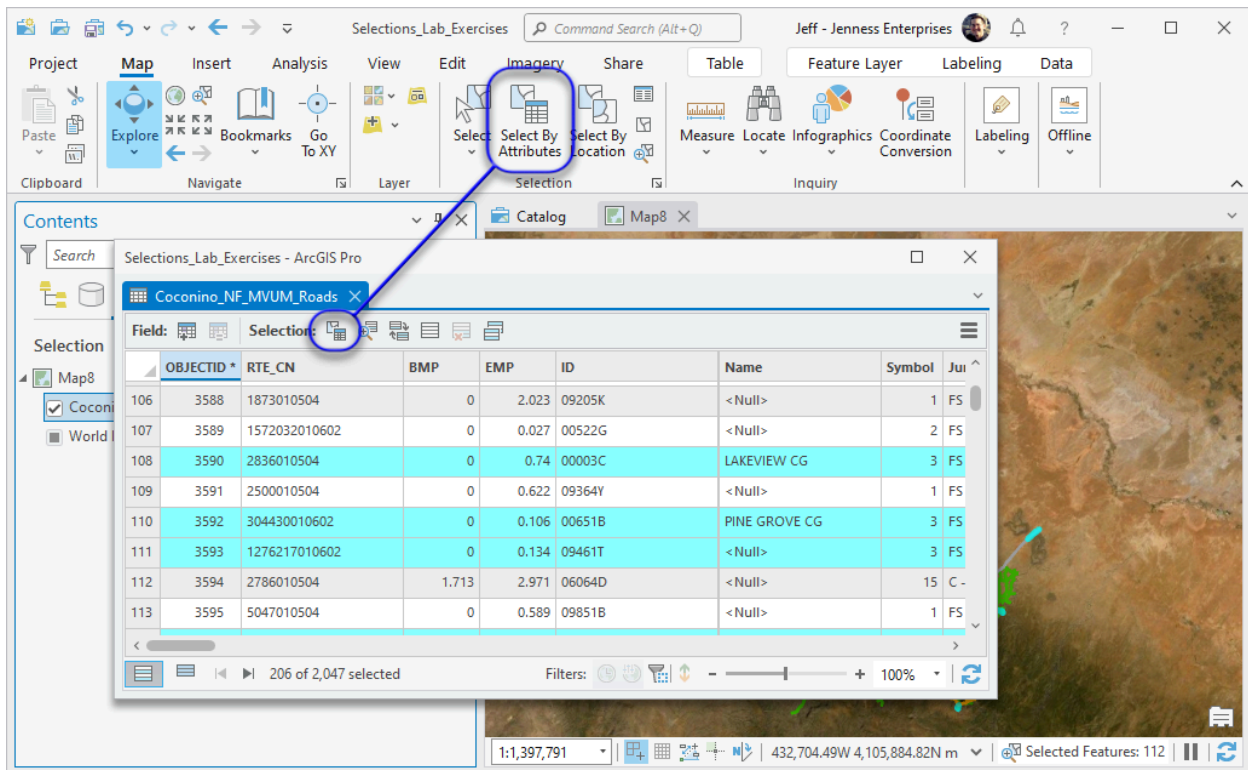
- ☐ Try the "Switch Selection" and "Zoom to Selection" tools and observe the behavior in the map.
- ☐ Try switching between "Show All" and "Show Selected". These options only affect how you see the table. Setting "Show Selected" won't make any difference to what shows up in your map.
- ☐ Try manually selecting features in the table by clicking on the gray box on the left side of each feature.
- ☐ Try manually selecting features in the table while holding down the [SHIFT] and [CONTROL] keys, and understand what those keys do.
- ☐ Learn how to zoom to a feature from the table, or pan to a feature from the table, by right-clicking the gray box on the left side of the feature.

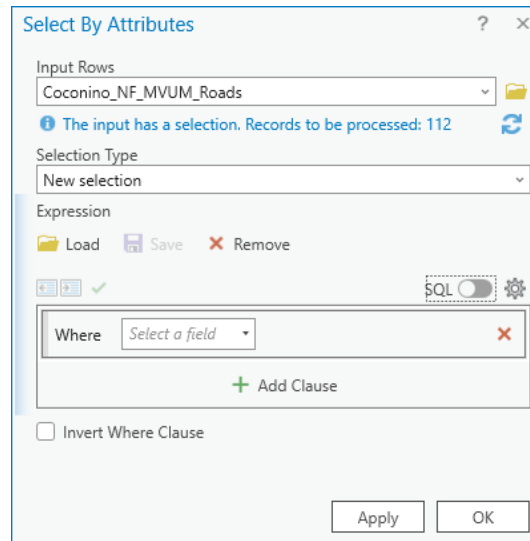
Right-Click Here



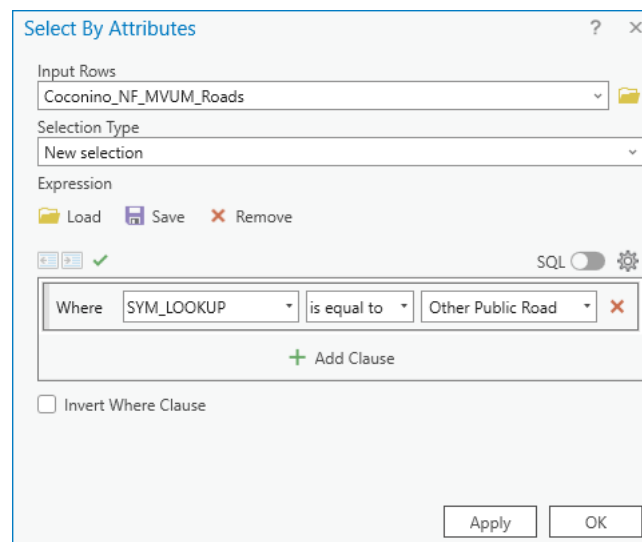
The "Select by Attributes" tool

- Open the "Select by Attributes" window from either the Map or the Table.

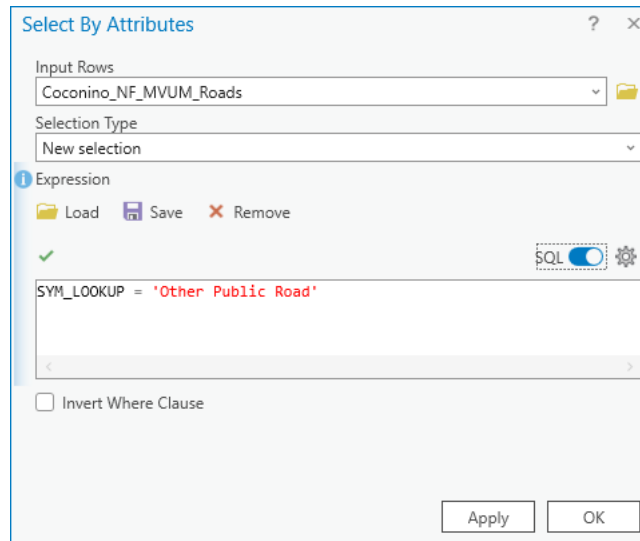




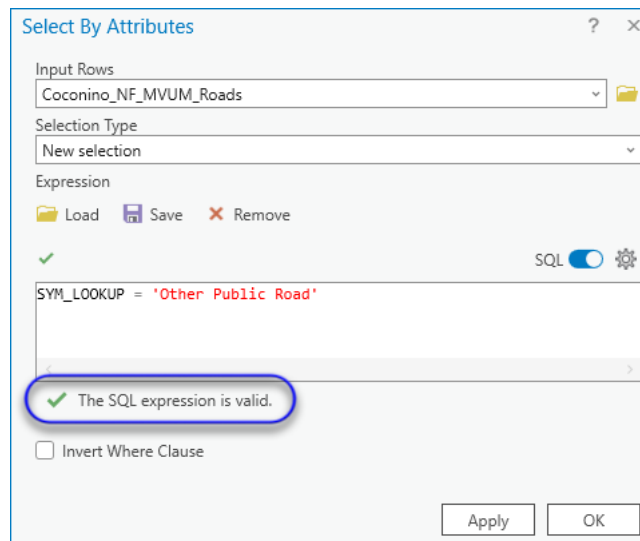
- ☐ This is a handy tool, and makes selecting a lot easier than it might be otherwise.
- ☐ Make sure the “Layer” is set to **Coconino_NF_MVUM_Roads**
- ☐ Make sure the “Selection type” is set to “New selection”
- ☐ Click the *Select a field* dropdown box and select the attribute field “SYM_LOOKUP”
- ☐ For the comparison operator, choose “is equal”
- ☐ For the value to compare to, choose “Other Public Road”



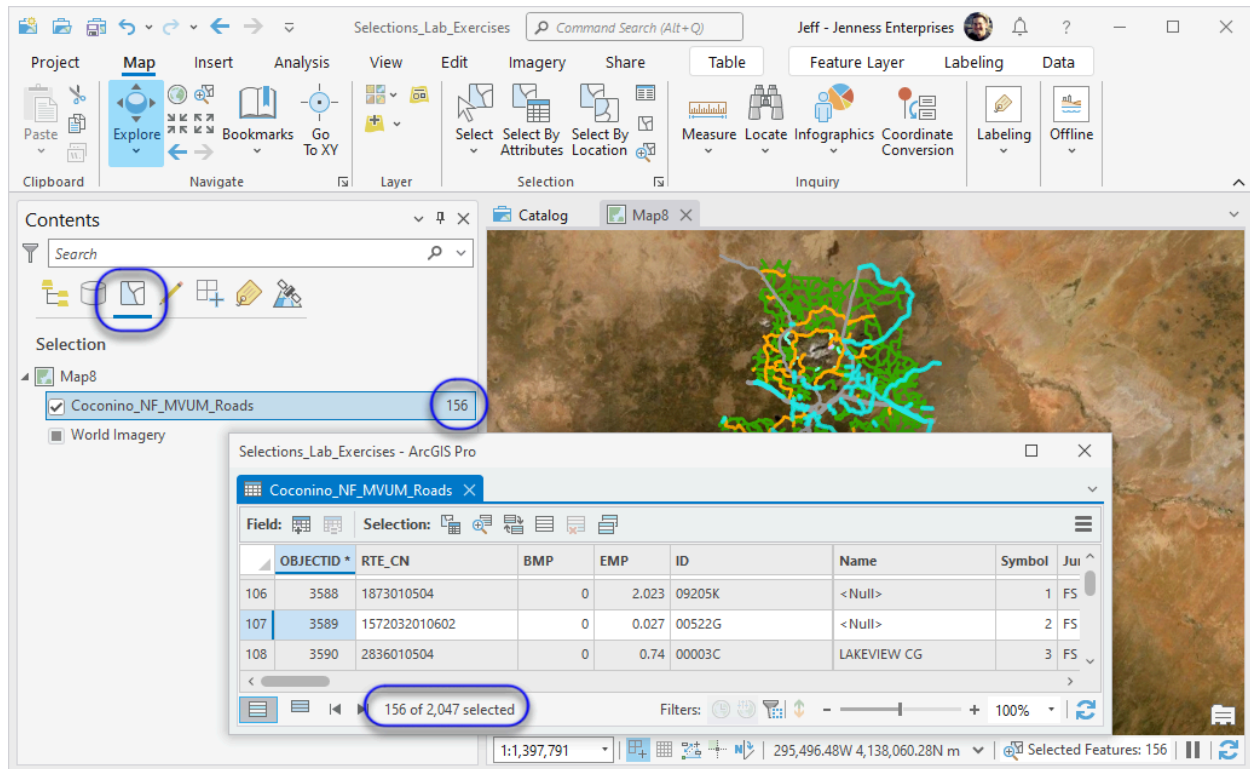
- ☐ Click the **SQL**  button to make it view the query in SQL mode.



- Click the “Verify” button  to make sure your query string is valid:



- Then click “OK” to make the selection and close the “Select by Attributes” window.
 - **Note:** If you just clicked “Apply”, then the tool would make the selection and leave the “Select by Attributes” window open. This would let you make further selections, probably either adding to or removing from your current selection.
- You should now have 156 road polyline features selected.



- ☐ Try the “Like” operator. This allows you to search for text inside other text using wildcard characters.
 - For Esri data formats such as **Shapefiles** and **File Geodatabases**, the wildcard character for any number of characters is a percent sign (%), and the wildcard character for a single character is an underscore (_).
- ☐ Select all Coconino Roads with “Highway Legal” in the name. **Hint:** The SQL query string is:

SYM_LOOKUP LIKE '%Highway Legal%'

Select By Attributes ? x

Input Rows
Coconino_NF_MVUM_Roads

The input has a selection. Records to be processed: 156

Selection Type
New selection

Expression
Load Save Remove

SQL ☒

`SYM_LOOKUP LIKE '%Highway Legal%'`

☐ Invert Where Clause

Apply OK

... alternatively, in “Clause” mode, use the operator “contains the text”

Select By Attributes ? x

Input Rows
Coconino_NF_MVUM_Roads

The input has a selection. Records to be processed: 156

Selection Type
New selection

Expression
Load Save Remove

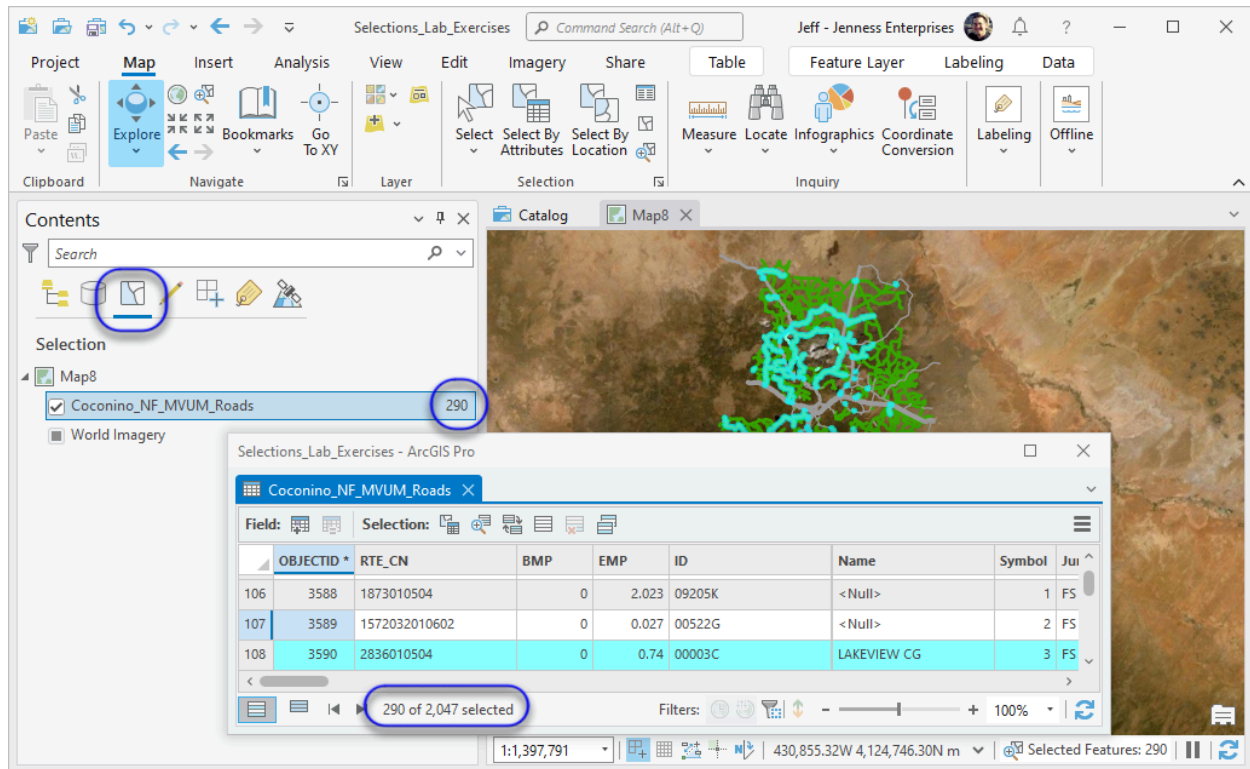
Where SYM_LOOKUP contains the Highway Legal

+ Add Clause

☐ Invert Where Clause

Apply OK

- ☐ You should now see 290 road polylines selected.



Potential Problem: Do you see 0 roads selected? Then you might have searched for “highway legal” instead of “Highway Legal”. Searches on this feature class are case sensitive, so you need to capitalize both “Highway” and “Legal”.

The Statistics Tool

- ☐ The Statistics tool is a nice little tool that gives you quick statistics on any attribute field in a table. If any records are selected, then the statistics only reflect those selected records.
- ☐ You should have 290 roads selected right now. How many miles of road is that?
 - Right-click on the attribute field “Miles” and choose “Statistics”.

Selections_Lab_Exercises - ArcGIS Pro

Coconino_NF_MVUM_Roads

Field: Selection:

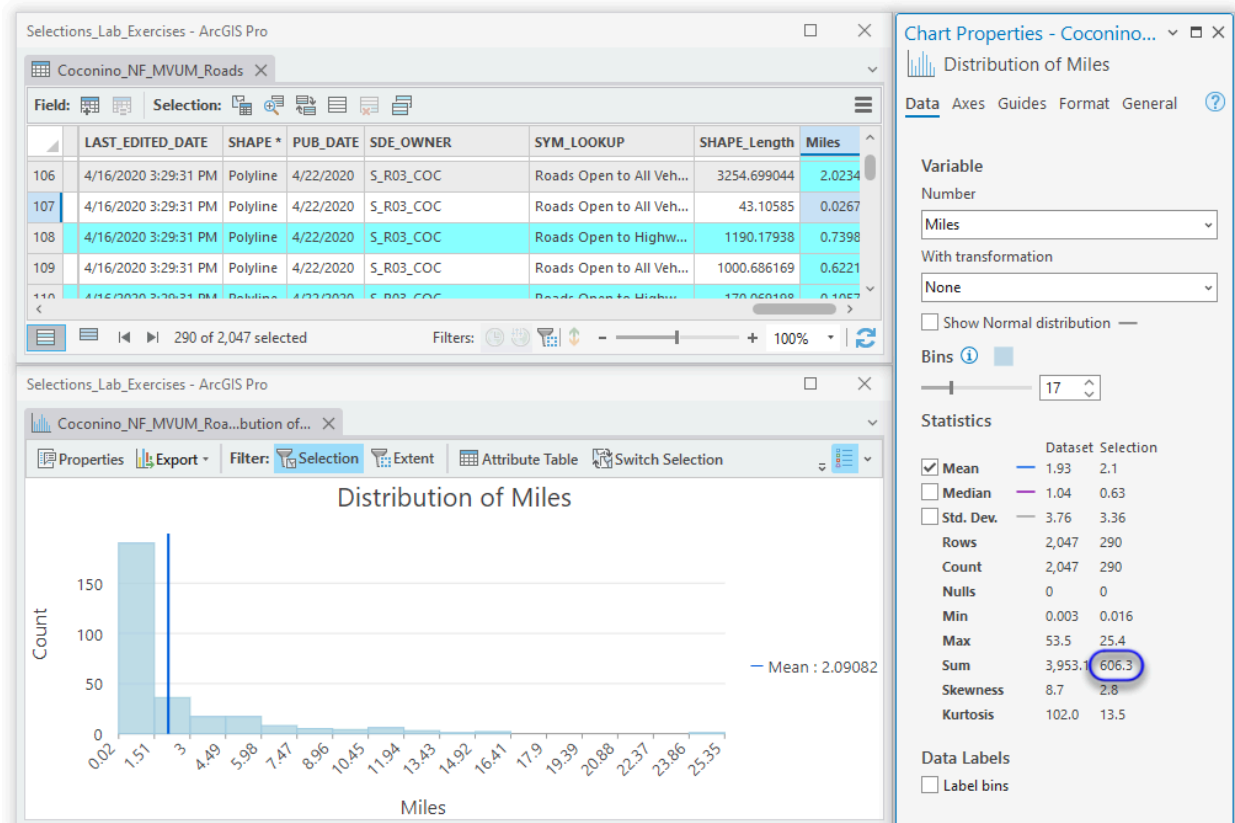
	LAST_EDITED_DATE	SHAPE *	PUB_DATE	SDE_OWNER	SYM_LOOKUP	SHAPE_Length	Miles
106	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to All Veh...	3254.699044	2.0234
107	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to All Veh...	43.10585	0.0267
108	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to Highw...	1190.17938	0.7398
109	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to All Veh...	1000.686169	0.6221
110	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to Highw...	170.069198	0.1057
111	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to Highw...	214.833578	0.133
112	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Other Public Road	2024.854483	1.2586
113	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to All Veh...	947.11174	0.5888
114	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to All Veh...	4275.951033	2.6582
115	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to All Veh...	2744.449905	1.7062
116	4/16/2020 3:29:31 PM	Polyline	4/22/2020	S_R03_COC	Roads Open to Highw...	123.711442	0.0769

290 of 2,047 selected

Filters: 100%

Sort Ascending
Sort Descending
Custom Sort
Hide Field
Freeze/Unfreeze Field
Calculate Field
Calculate Geometry
Statistics
Summarize
Fields
Delete

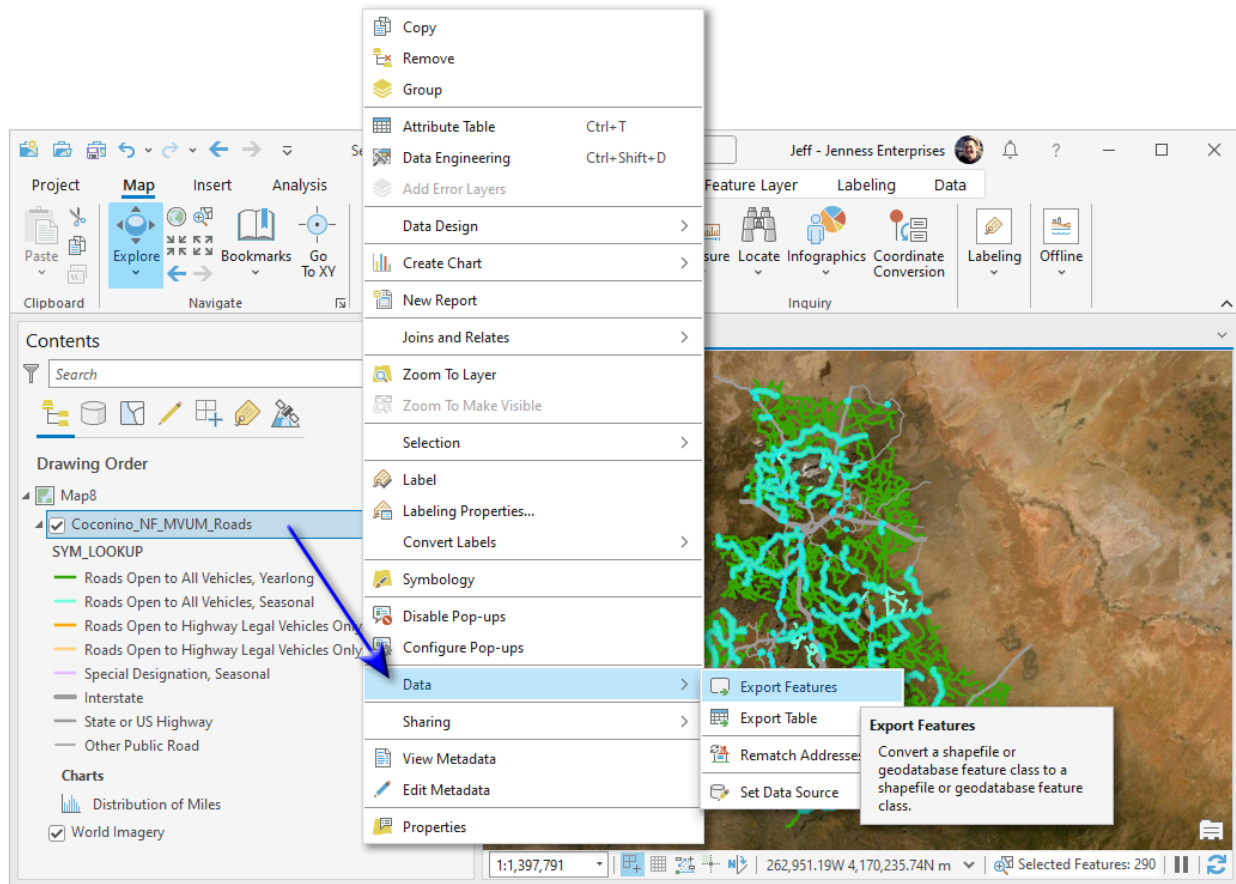
Create Field Statistics Chart
Group numbers into bins to visualize distribution, date/time values into time bins to visualize change over time or string categories into bars to compare data counts.



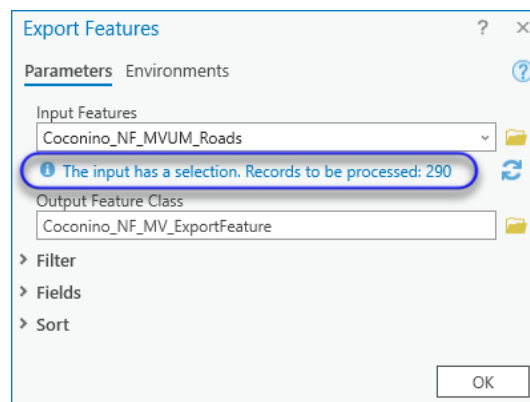
- Based on the “Statistics” window, we can easily see that there are about 606 miles of roads classified as *Highway Legal* roads (see the **Sum** in the **Selected** column).

Exporting Selected Records

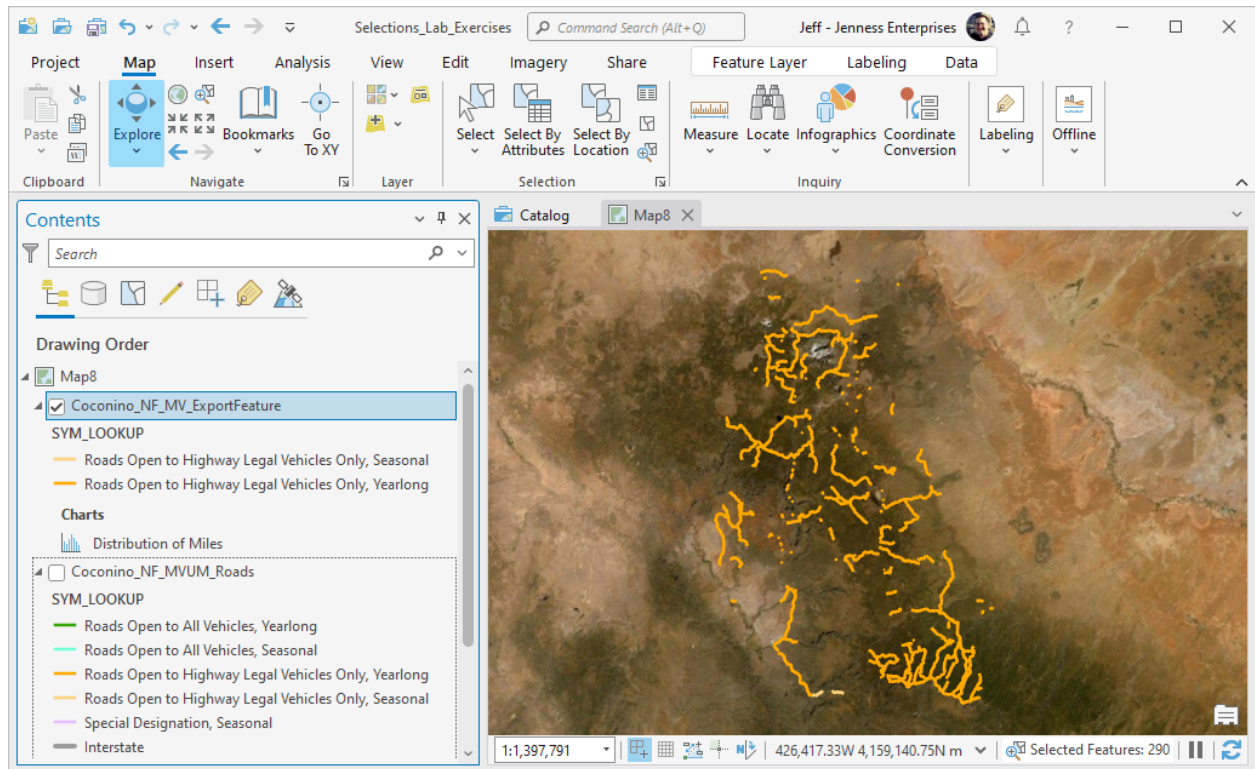
- With those same 290 roads selected, go back to your map and right-click on the **Coconino_NF_MVUM_Roads** layer. Click “Data”, then “Export Data”.



- Because you have some feature selected, the tool will only export those selected records.



- ArcGIS Pro will likely add the new layer directly to your map. Observe that you have now created a new feature class containing only those 290 roads classified as *Highway Legal* roads.



Exercise 2: Select Survey Points by Location

Objectives

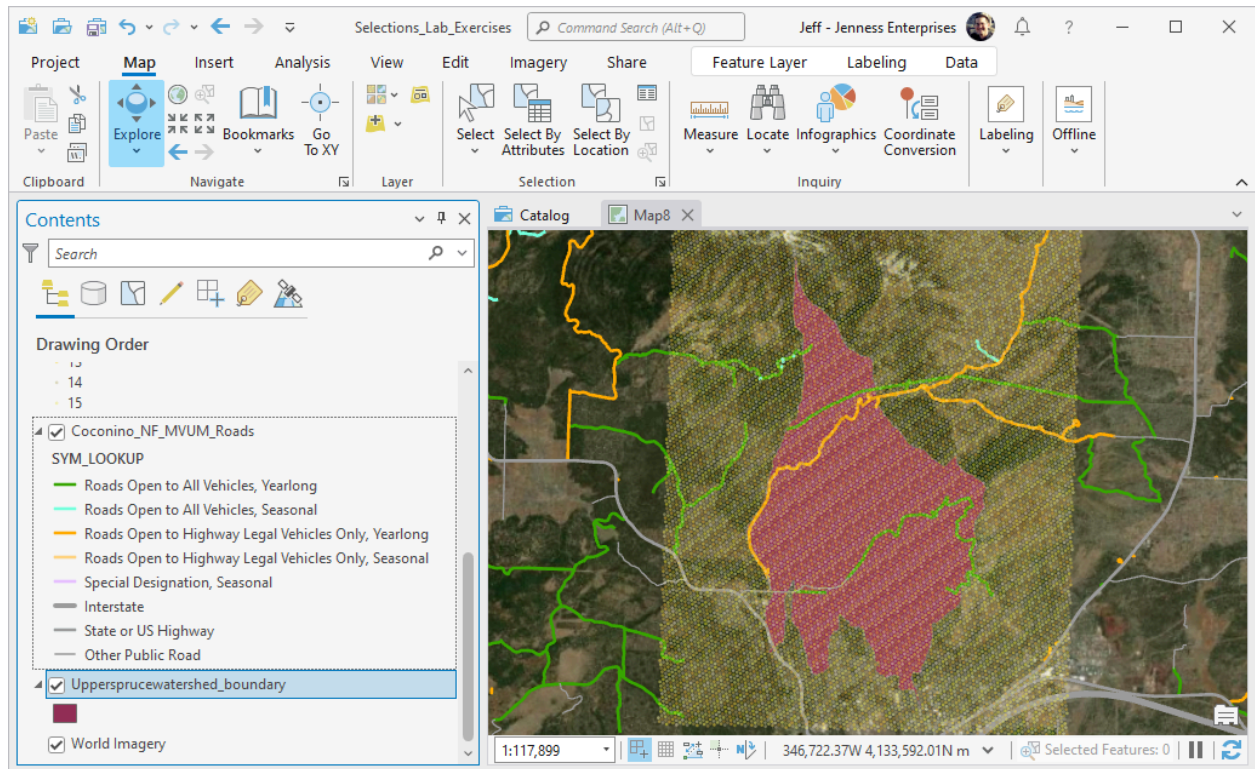
- Learn to use the “Select by Location” tool
- Learn the different Selection Types

Data used:

- Esri Basemap layer **World Imagery**
- Polyline feature class **Coconino_NF_MVUM_Roads** in workspace **Additional_Data**.
- Polygon feature class **Uppersprucewatershed_boundary** in workspace **Dry_Lake_Hills**.
- Point feature class **Survey_Points** in workspace **Selecting_and_Creating_Data**.

Exercise:

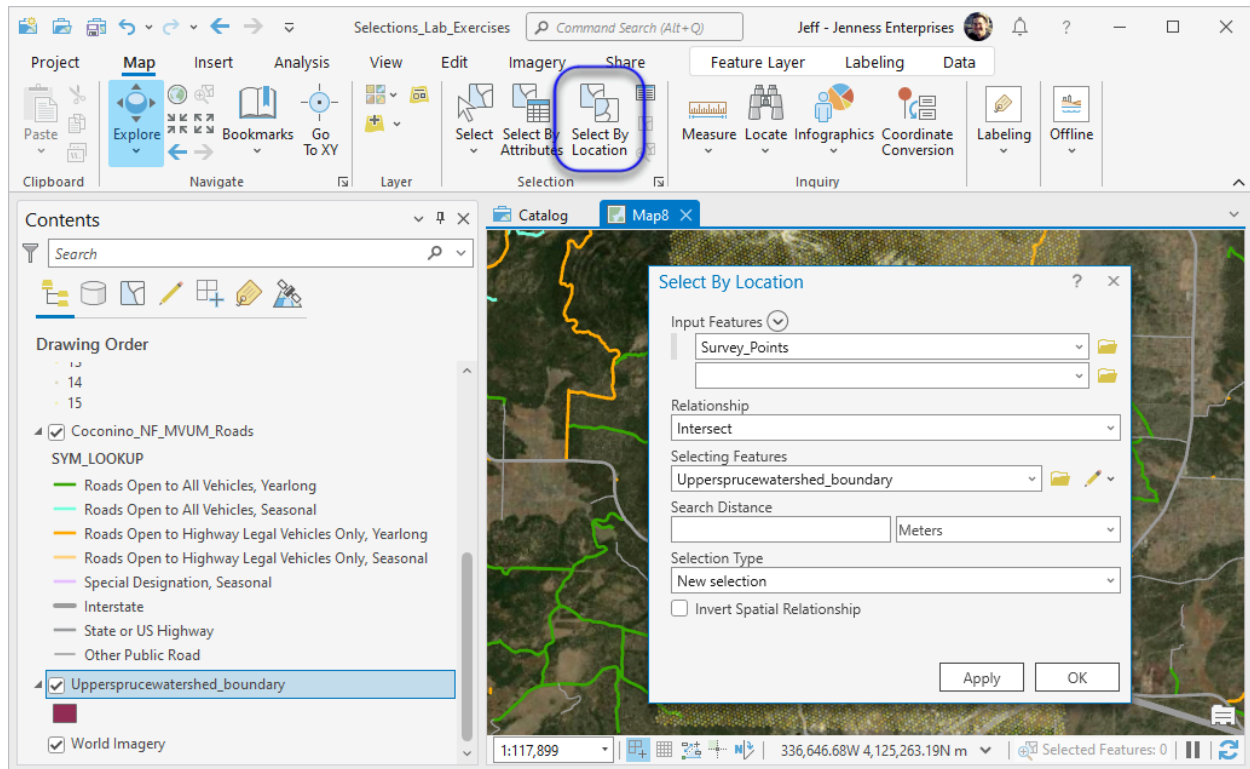
- ☐ Open **ArcGIS Pro** to a new empty map.
- ☐ Add the **Layer** file **Coconino_NF_MVUM_Roads** (from workspace **Additional_Data**).
- ☐ Add the **Layer** file **Survey_Points** (from workspace **Selecting_and_Creating_Data**).
- ☐ Add the Feature Class **Uppersprucewatershed_boundary** (from workspace **Dry_Lake_Hills**).
- ☐ Add the basemap **World Imagery** (aka **Imagery**) (If you do not remember how, click the “Map” tab, then the “Basemap” command).
- ☐ Zoom to the extent of **Uppersprucewatershed_boundary**.



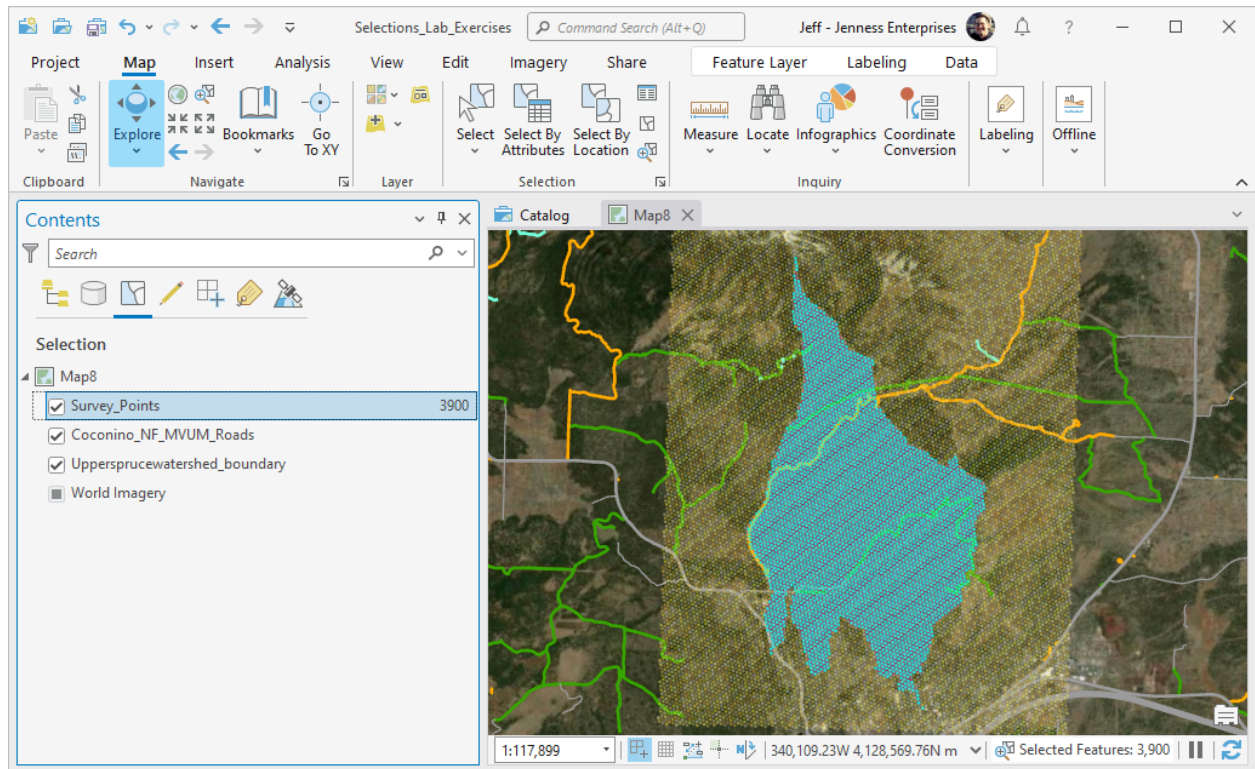
- ☐ This exercise will demonstrate how to select features from one dataset based on spatial relationships with features from another layer. We will make complex multi-criteria selections on the point feature class **Survey_Points**, based on intersections and proximity to various other datasets.
- ☐ Specifically, we are interested in **Survey_Points** locations that are Class 8 or greater, located inside of the Upper Spruce Watershed polygon, and located between 250m and 1km of Coconino National Forest Roads that are open yearlong to all vehicles.

Select by Intersection

- ☐ First select all **Survey_Points** that intersect **Uppersprucewatershed_boundary**.
- ☐ Open the "Select By Location" tool.
- ☐ In the "Select By Location" tool, set the following options:
 - **Input Features** = "Survey_Points"
 - [Spatial] **Relationship** = "Intersect"
 - **Selecting Features** = "Uppersprucewatershed_boundary"
 - **Search Distance** left blank because we are only interested in survey points that intersect the watershed polygon.
 - **Selection Type** = "New selection"



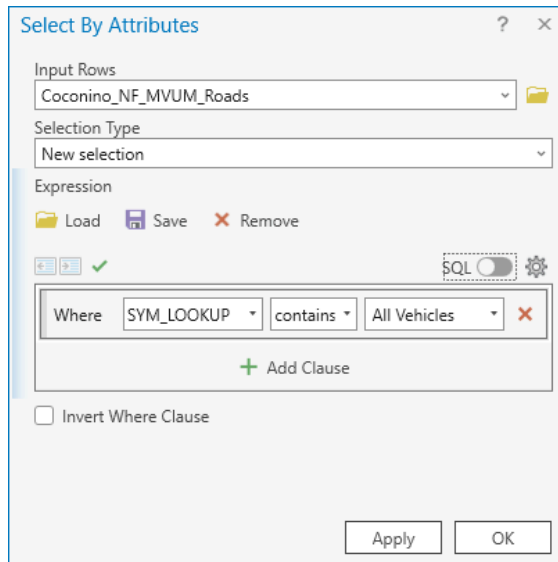
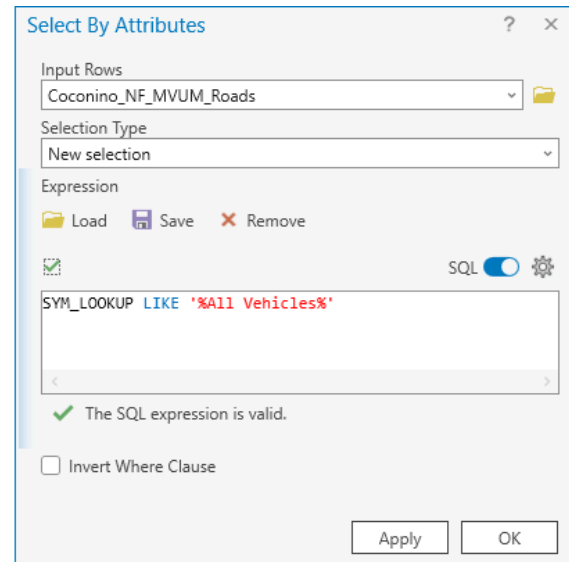
- ☐ Now all the **Survey_Points** locations inside **Uppersprucewatershed_boundary** should be selected.
- ☐ This should give us 3,900 out of 16,002 survey points selected.



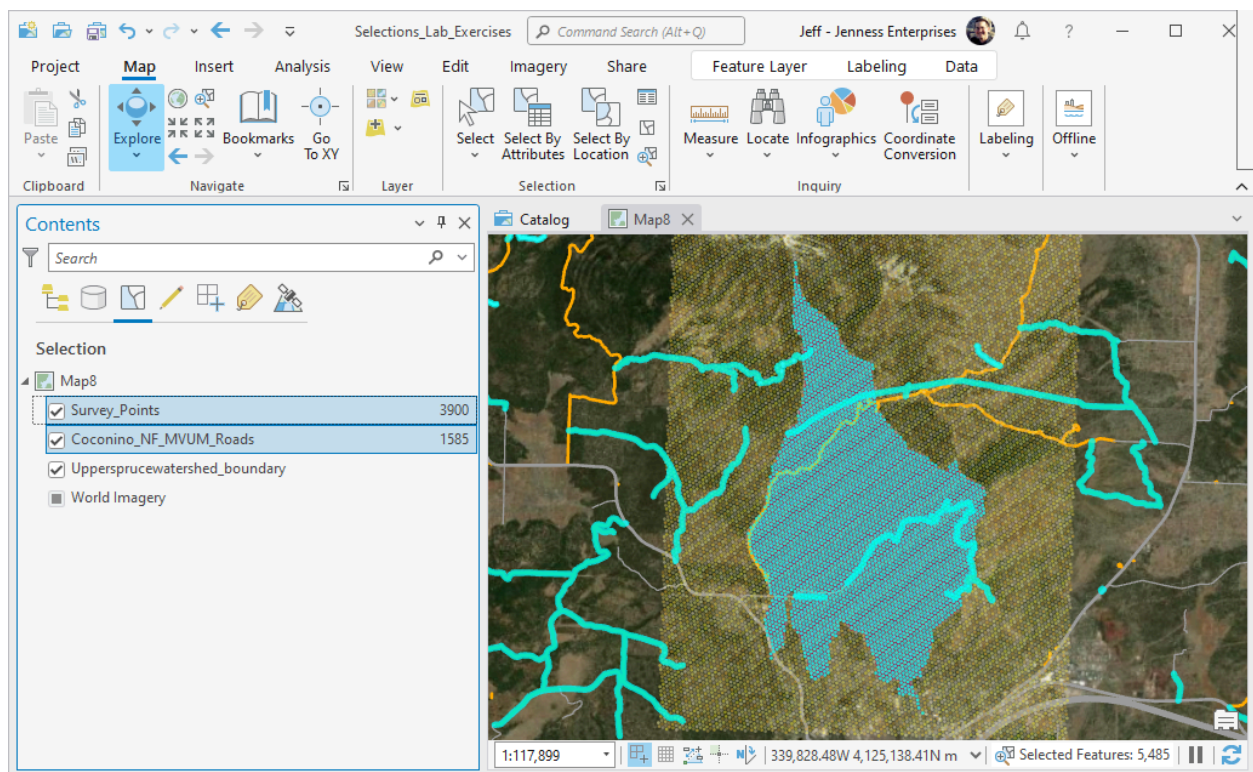
Select by Proximity and Select From Selection

- ☐ Next we are interested in identifying areas that are reasonably close to publicly-accessible Coconino National Forest roads. Therefore we will reduce our selection to only those **Survey_Points** locations that are currently selected, and are also within 1km of roads open to all vehicles on the Coconino National Forest.
- ☐ First select the roads accessible to all vehicles from the Coconino NF Road layer **Coconino_NF_MVUM_Roads**, similar to the way you selected the Highway-Legal vehicles in the last exercise.
 - Open the “Select by Attributes” window and use the following query string:

SYM_LOOKUP LIKE '%All Vehicles%'



- ☐ You should now have 1,585 roads accessible to all vehicles selected from the Coconino NF Roads layer.



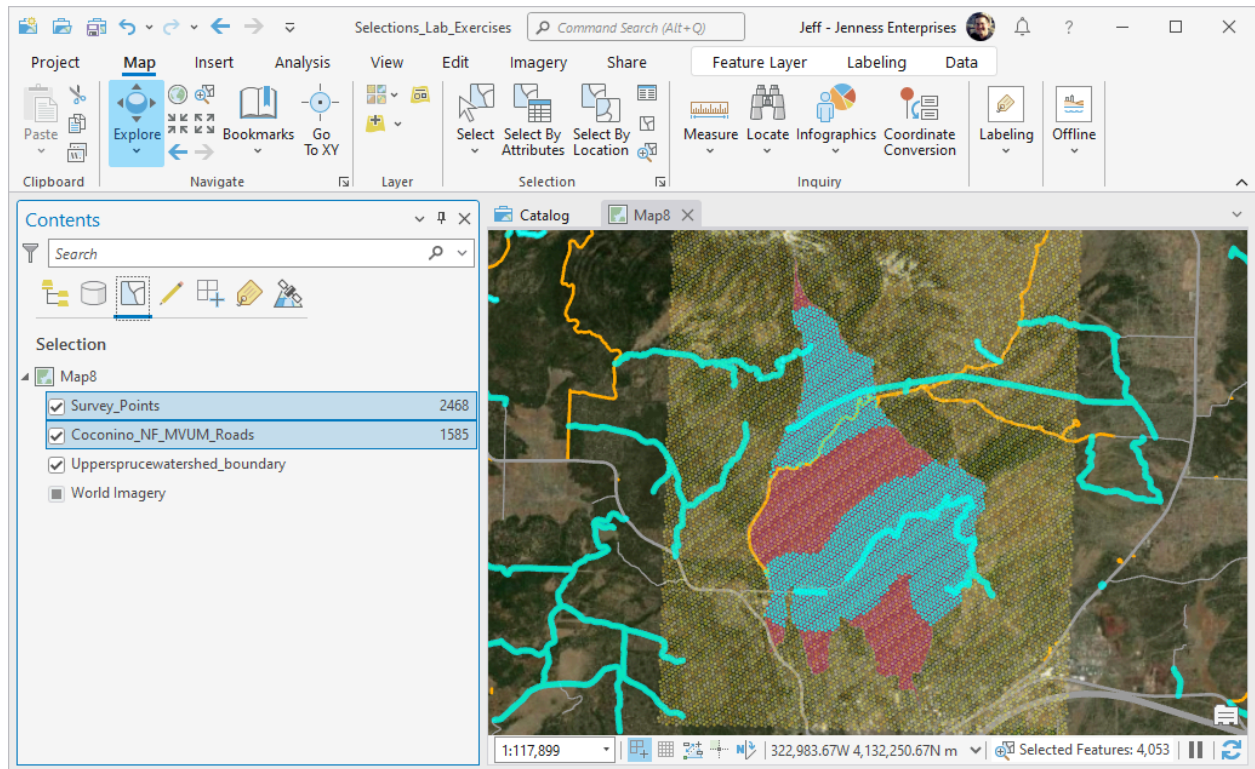
- ☐ Next open the “Select By Location” tool and select according to the following criteria:
 - **Input Features** = “Survey_Points”
 - [Spatial] **Relationship** = “Within a distance geodesic”
 - **Selecting Features** = “Coconino_NF_MVUM_Roads”

- **Note:** We will discuss why **Geodesic** distances are best in the lecture on Projections and Datums.
- **Search Distance** = 1000m
- **Selection Type** = “Select subset from the current selection”
- **Question:** Why do we choose this selection type instead of “New selection”? What is the difference between these two selection types? If the answer is not clear to you, please review slides 61 – 72.

The screenshot shows the 'Select By Location' dialog box. It has the following fields and values:

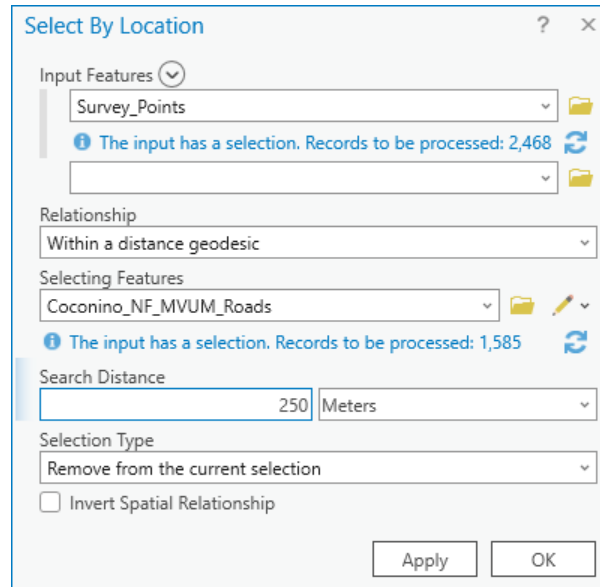
- Input Features:** Survey_Points (3,900 records to be processed)
- Relationship:** Within a distance geodesic
- Selecting Features:** Coconino_NF_MVUM_Roads (1,585 records to be processed)
- Search Distance:** 1000 Meters
- Selection Type:** Select subset from the current selection
- Invert Spatial Relationship:** (unchecked)

- Apply the selection and notice that the selection set has reduced to only those that intersect the Upper Spruce Watershed polygon and which are within 1km of the “Open to All Vehicles” roads. Make sure you see this pattern in your map.
- We should now have 2,468 of 16,002 **Survey_Points** locations selected.
 - **Question:** Did you get 2,471 points selected, instead of 2,468? If so, then you probably used the spatial relationship “Within a distance” instead of “Within a distance geodesic”. For this question you should be using the most accurate relationship “Within a distance geodesic”, so go back up and reselect the points within the Upper Spruce Watershed polygon (Selection type should be “New selection”), and then redo this last step using “Within a distance geodesic”.

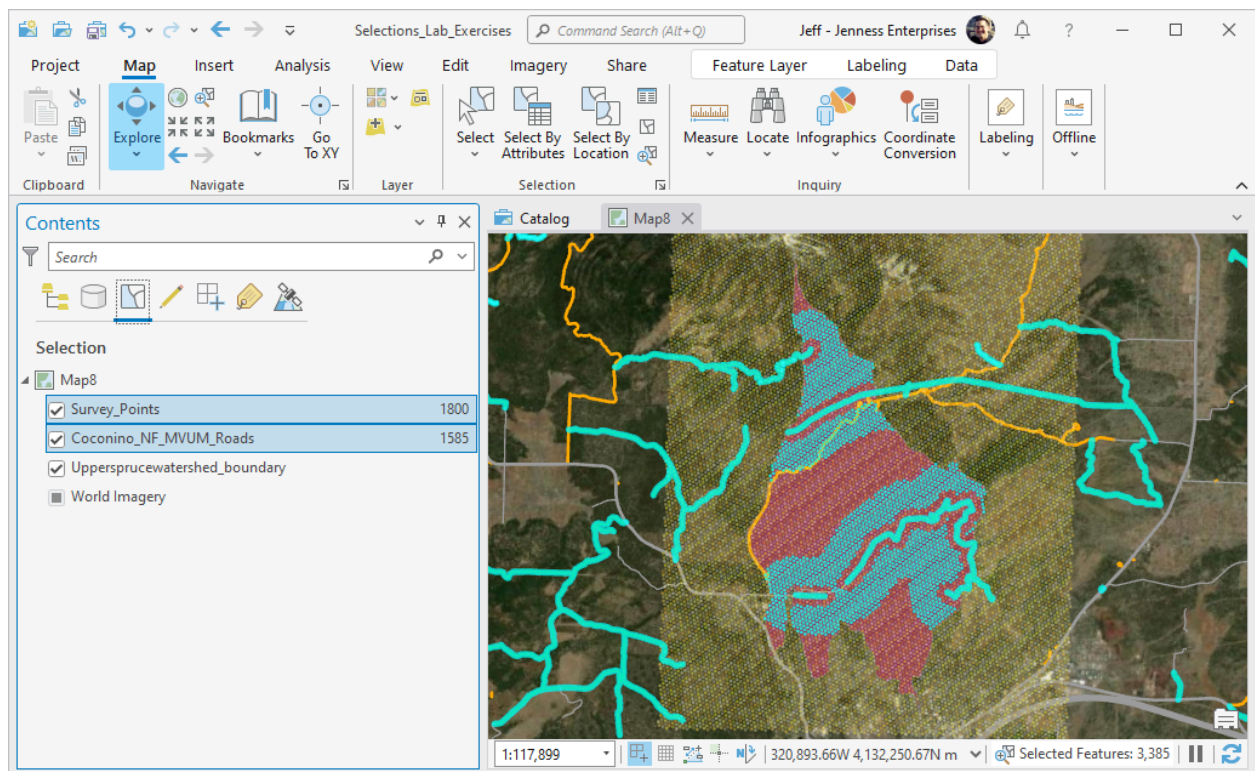


Remove From Selection

- ☐ Now we will **exclude** all those selected points that are within 250m of the road by unselecting them.
- ☐ Go back to the “Select By Location” tool and select according to the following criteria:
 - **Input Features** = “Survey_Points”
 - [Spatial] **Relationship** = “Within a distance geodesic”
 - **Selecting Features** = “Coconino_NF_MVUM_Roads”
 - **Search Distance** = 250m
 - **Selection Type** = “**Remove** from the current selection”

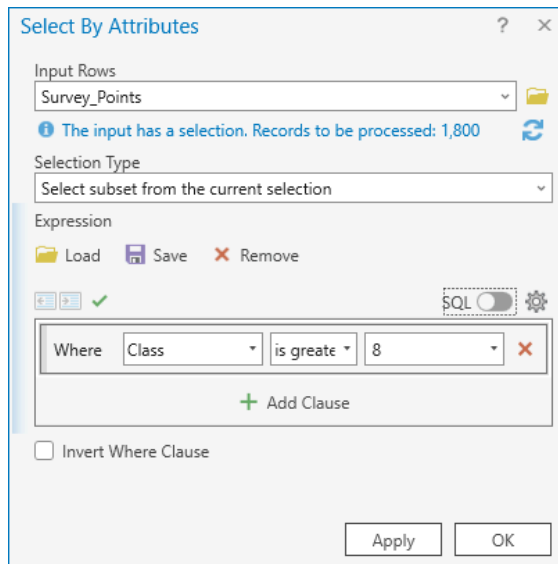
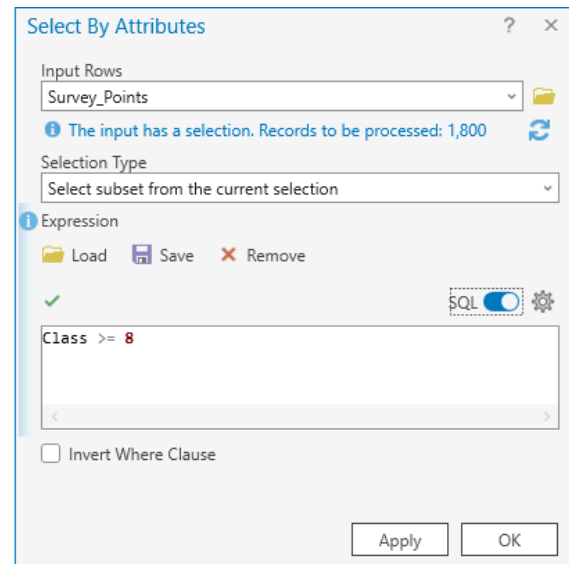


- ☐ Apply the selection and notice that the selection set has reduced to only those that intersect the Upper Spruce Watershed polygon and which are between 250m and 1km of MVUM roads.
- ☐ We should now have 1,800 of 16,002 **Survey_Points** locations selected.
 - **Note:** Observe the changes on your map! It is always a good idea to visually confirm that you accomplished what you intended.



Select from Selection

- ☐ Finally, we are only interested in those **Survey_Point** locations with a Class value ≥ 8 .
- ☐ Use the “Select by Attributes” and select by the following criteria:
 - **Layer** = “Survey_Points”
 - **Selection type** = “Select subset from the current selection”
 - **Query String:** "Class" $\geq$ 8



- ☐ Click “OK” or “Apply” to apply this final selection criteria.
- ☐ Our final selection is 964 of 16,002 points.

Selections_Lab_Exercises - ArcGIS Pro

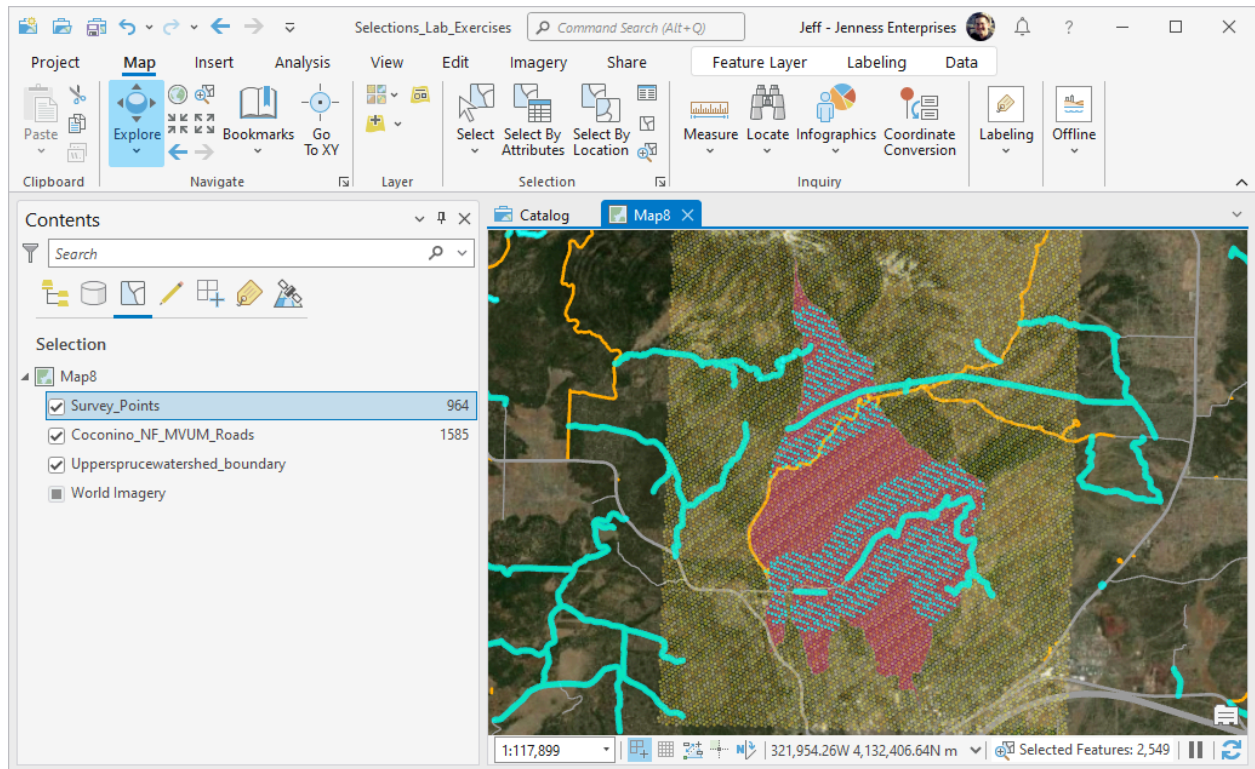
Survey_Points

Field: Selection:

	FID	Shape *	Unique_ID	X_Coord	Y_Coord	Class
1	0	Point	1	437157.934022	3896402.95711	1
2	1	Point	2	437252.191236	3896369.55685	2
3	2	Point	3	437346.44845	3896336.15659	3
4	3	Point	4	437139.730892	3896501.28639	4
5	4	Point	5	437233.988106	3896467.88612	5

964 of 16,002 selected

Filters: 100%



Selections_Lab_Exercises - ArcGIS Pro

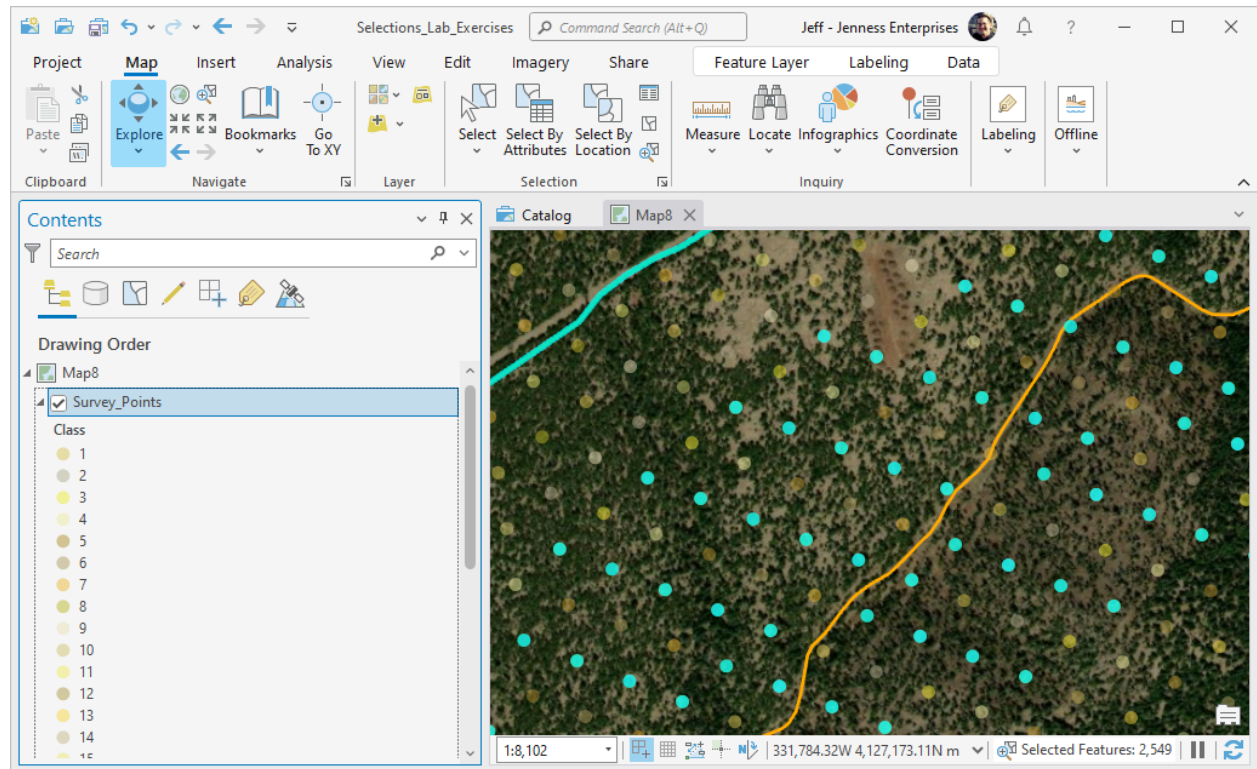
Survey_Points

Field: Selection:

	FID	Shape *	Unique_ID	X_Coord	Y_Coord	Class
1	0	Point	1	437157.934022	3896402.95711	1
2	1	Point	2	437252.191236	3896369.55685	2
3	2	Point	3	437346.44845	3896336.15659	3
4	3	Point	4	437139.730892	3896501.28639	4
5	4	Point	5	437723.088106	3896467.88612	5

964 of 16,002 selected Filters:

- ☐ Zoom in to the selection to see the distribution of selected points.



Exercise 3: Practice Selecting by Location and by Attribute

Objectives

- Practice “Select by Attributes” tool
- Practice “Select by Location” tool
- This lab exercise will give you the opportunity to test the selection tools and check your answers against the true answers.

Data used:

- Polygon feature class **Census_Counties** in workspace **Additional_Data\Additional_FGDB**.
- Polygon feature class **States** in workspace **Additional_Data\Additional_FGDB**.
- Point feature class **Cities** in **Additional_Data\Additional_FGDB**.

Exercise:

- ☐ Open **ArcGIS Pro** to a new empty map.
- ☐ Add the point feature class **Cities** (from workspace **Additional_Data\Additional_FGDB**).
- ☐ Add the polygon feature class **Census_Counties** (from workspace **Additional_Data\Additional_FGDB**).
- ☐ Add the polygon feature class **States** (from workspace **Additional_Data\Additional_FGDB**).
- ☐ These questions will use the following attribute fields:
 - o **Cities:**
 - **NAME:** The name of this city.
 - **POP2007:** The population of this city in 2007.
 - **Age_18_21:** The number of people in this city between the ages of 18 and 21.
 - **AGE_30_39:** The number of people in this city between the ages of 30 and 39.
 - **AGE_65_UP:** The number of people in this city over the age of 65.
 - **MED_AGE:** The median age of all residents in this city.
 - **MED_AGE_M:** The median age of the males in this city.
 - **MED_AGE_F:** The median age of the females in this city.
 - o **Census_Counties:**

- **NAME:** The name of this county.
- o **States:**
 - **STATE_NAME:** The name of this state.
- ☐ Try the following selection criteria and see if they match what I got:
- 1) How many **Cities** point features are there?
 - a) **Answer:** 3557
- 2) How many **Census_Counties** polygon features are there?
 - a) **Answer:** 3141
- 3) How many **States** polygon features are there?
 - a) **Answer:** 51
- 4) How many **Cities** point features have a 2007 population > 150,000?
 - a) **Answer:** 158
- 5) How many **Cities** point features have > 20,000 people between the ages of 18 and 21?
 - a) **Answer:** 68
- 6) How many **Cities** point features have a median age of Females which is greater than the median age of Males?
 - a) **Answer:** 3403
- 7) How many **Cities** point features have more people between the ages of 18 – 21 than they do between the ages of 50 – 64?
 - a) **Answer:** 198
- 8) How many **Cities** point features meet both criteria at the same time:
 - a) More 18 – 21-year olds than 50 – 64-year olds.
 - b) Median age of females > median age of males.
 - c) **Answer:** 139
- 9) How many **Cities** point features meet both criteria at the same time:
 - a) Median Age > 50
 - b) Median age of females > median age of males.
 - c) **Answer:** 31
- 10) How many **Cities** point features are in Arizona?
 - a) **Answer:** 48
- 11) How many **Cities** point features are in Arizona, New Mexico or California?
 - a) **Answer:** 512

- 12) How many **Cities** point features meet both criteria at the same time:
- a) Are in Arizona, New Mexico or California
 - b) Median Age > 50
 - c) **Answer: 10**
- 13) How many **Cities** point features meet all criteria at the same time:
- a) Are in Arizona, New Mexico or California
 - b) Median Age > 50
 - c) Median age of females > median age of males.
 - d) **Answer: 5**
- 14) How many **Cities** point features are either in Arizona, New Mexico or California, or within 300 US Survey Miles (Geodesic distance) of these states?
- a) **Answer: 742**
- 15) How many **Cities** point features are within 300 US Survey Miles (Geodesic distance) of Arizona, New Mexico or California, but **not** actually inside these states?
- a) **Answer: 230**
- 16) How many **Cities** point features meet all criteria at the same time:
- a) are within 300 US Survey Miles (Geodesic distance) of Arizona, New Mexico or California
 - b) are **not** actually inside Arizona, New Mexico or California
 - c) Median age < 25
 - d) **Answer: 14**
- 17) How many **Census_Counties** polygons have one or more **Cities** point features inside them?
- a) **Answer: 1154**
- 18) How many **Census_Counties** polygons do **not** have any **Cities** point features inside them?
- a) **Answer: 1987**
- 19) How many **Census_Counties** polygons are **within** Arizona, New Mexico or California?
- a) **Answer: 106**
- 20) How many **States** polygons contain the following:
- a) A **Cities** point with median age > 55
 - b) **Answer: 5**
- 21) How many **Census_Counties** polygons contain the following:
- a) A **Cities** point with median age > 55
 - b) **Answer: 16**
- 22) How many **Census_Counties** polygons meet all criteria at the same time:

- a) Are within 200 US Survey Miles (Geodesic distance) of a **Cities** point feature that meets the following criteria:
 - i) Has a median age > 40
 - ii) Is within Arizona, New Mexico or Colorado
- b) **Answer:** 177
- 23) How many **Census_Counties** polygons meet all criteria at the same time:
 - a) Contain a **Cities** point feature that meets the following criteria:
 - i) Has a median age > 40
 - ii) Is **outside of** Arizona, New Mexico or Colorado
 - b) **Answer:** 190
- 24) How many **Cities** point features have **Glad** somewhere in the name? **Note:** The first letter in “Glad” is capitalized.
 - a) **Answer:** 5
- 25) How many **Census_Counties** polygons are named “Liberty”?
 - a) **Answer:** 4
- 26) How many **Census_Counties** polygons are named “Liberty” and “San Juan”?
 - a) **Answer:** 0
- 27) How many **Census_Counties** polygons are named “Liberty” **or** “San Juan”?
 - a) **Answer:** 8

Exercise 4: Practice Selecting by Location and by Attribute Part 2

Note: Write down the answers to the questions below as you answer them! The homework for this lecture will ask these exact questions.

Objectives

- Practice “Select by Attributes” tool
- Practice “Select by Location” tool
- Practice the “Statistics” tool

Data used:

- Esri Basemap layer **World Imagery**
- Polyline feature class **Coconino_NF_All_Roads** in workspace **Additional_Data**.
- Polygon feature class **EldenSmallprojectarea** in workspace **Dry_Lake_Hills**.
- Point feature class **Survey_Points** in workspace **Selecting_and_Creating_Data**.

Exercise:

- ☐ Open **ArcGIS Pro** to a new empty map.
- ☐ Add the **Layer** file **Coconino_NF_All_Roads** (from workspace **Additional_Data**).
- ☐ Add the **Layer** file **Survey_Points** (from workspace **Selecting_and_Creating_Data**).
- ☐ Add the Feature Class **EldenSmallprojectarea** (from workspace **Dry_Lake_Hills**).
- ☐ Add the basemap **World Imagery** (aka **Imagery**) (If you do not remember how, click the “Map” tab, then click the “Basemap” command).
- ☐ Zoom to the extent of **EldenSmallprojectarea**.
- ☐ This exercise will give you more practice using the “Select by Attributes” and “Select by Location” tools, both individually and in conjunction. **The answers to the questions below will be part of your homework so write the answers down as you do the exercise.**

Note: The questions below use the symbol $\leq$ for “Less Than or Equal”, and $\geq$ for “Greater Than or Equal”. These are the standard mathematical symbols. However, SQL queries in the “Select by Attributes” tool do not use these exact symbols. In a SQL query, you must use “<=” for “Less Than or Equal” ($\leq$), and you must use “>=” for “Greater Than or Equal” ($\geq$). Please ask me if you get confused by these symbols.

Question 1:

- ☐ Open the table for **Coconino_NF_All_Roads**.

- **Question for Homework:** How many road features are there in this feature class? If you do not remember how to answer this question, take a look back at slides 75 – 77. **Hint:** The answer more than 7,000 roads.
 - Do you only see 2,047 roads? Then you may have the wrong layer loaded. Make sure you have the layer **Coconino_NF_All_Roads** loaded, not **Coconino_NF_MVUM_Roads**.
- **Question for Homework:** Using the Statistics tool on the attribute field “Miles”, what is the total mileage of all Coconino roads?
- Use the “Select by Attributes” tool to select all **Coconino_NF_All_Roads** roads that have an **OPER_MAINT_LEVEL** value equal to **1 - BASIC CUSTODIAL CARE (CLOSED)**.
- **Question for Homework:** What is the total mileage of all these “Basic Custodial Care” roads?

Question 2:

- Use the “Select by Attributes” tool to select all **Survey_Points** features that have a class value ≥ 6 .
 - **Question for Homework:** How many **Survey_Points** features have a class value ≥ 6 ?
- Use the “Select by Location” tool to select all **Survey_Points** features that intersect **EldenSmallprojectarea**. Make a new selection.
 - **Question for Homework:** How many **Survey_Points** features intersect **EldenSmallprojectarea**?
- Combine the two queries above (**Note:** When I say “combine queries”, I only mean that you need to identify features that meet multiple sets of criteria. Usually this means to make a series of attribute and/or spatial queries before you reach your final answer):
 - Question: How many **Survey_Points** features have a class value ≥ 6 **and** intersect the **EldenSmallprojectarea** polygon?

Question 3:

- Use the “Select by Attributes” tool to select all **Coconino_NF_All_Roads** roads that have an **OPER_MAINT_LEVEL** equal to **1 - BASIC CUSTODIAL CARE (CLOSED)**.
- Use the “Select by Location” tool to select all **Survey_Points** features that are within 400m of the currently selected set of **Coconino_NF_All_Roads** road features (in other words, select those **Survey_Points** features that are within 400m of roads [Geodesic Distances] that are classified as “1 - BASIC CUSTODIAL CARE (CLOSED)”).
 - **Question for Homework:** How many **Survey_Points** features are within 400m of roads that are designated “1 - BASIC CUSTODIAL CARE (CLOSED)”?

- ☐ Use the “Select by Location” tool to **Select subset from the current selection** of **Survey_Points** that also intersect **EldenSmallprojectarea**.
 - **Question for Homework:** How many **Survey_Points** features meet **both** the following criteria:
 - (a) Within 400m of roads [Geodesic Distances] that are classified as “1 - BASIC CUSTODIAL CARE (CLOSED)”, and
 - (b) Inside the **EldenSmallprojectarea** polygon?
 - Answer:

Question 4:

- ☐ Question: How many **Survey_Points** features meet **all** the following criteria:
 - i) Within 400m of roads [Geodesic Distances] that are classified as “1 - BASIC CUSTODIAL CARE (CLOSED)”, and
 - ii) Inside the **EldenSmallprojectarea** polygon, and
 - iii) Have a Class value ≥ 6
- ☐ Answer:

Exercise 5: Join Tables

Objectives

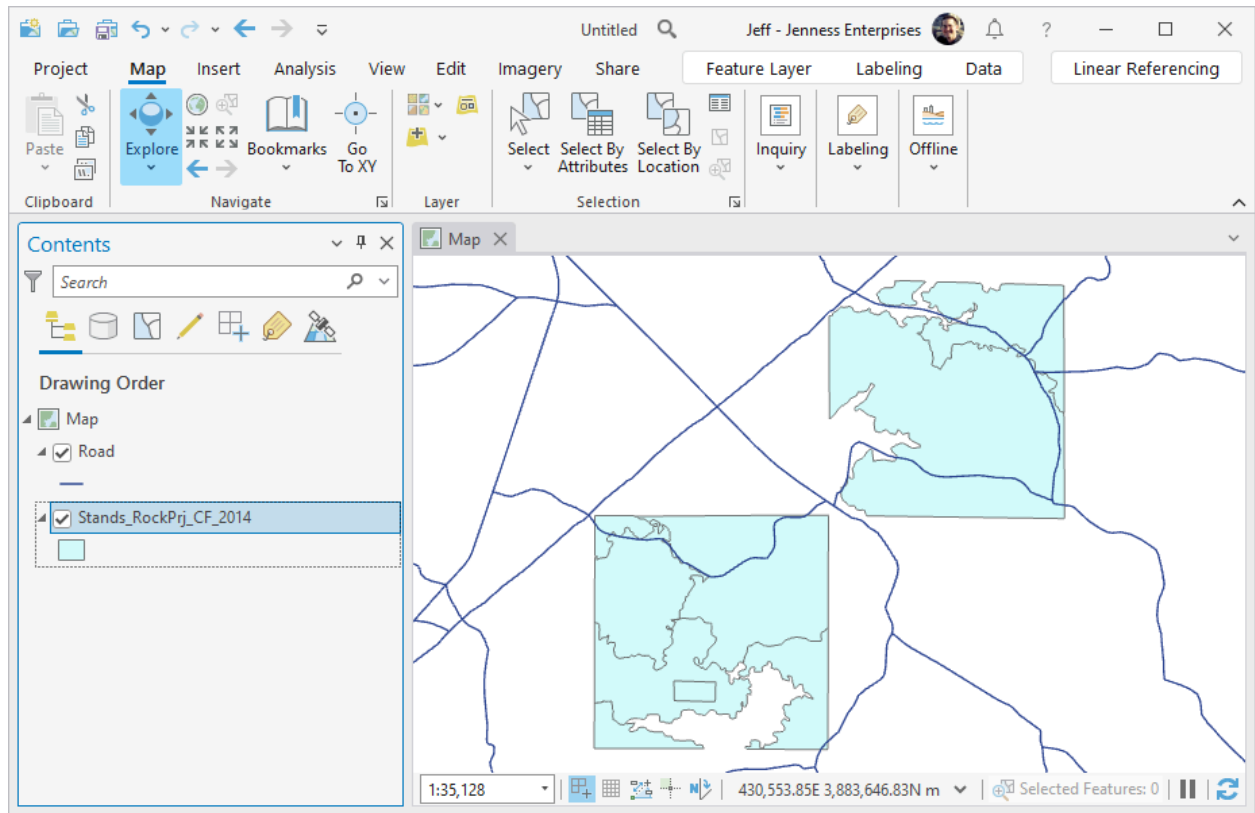
- This exercise will show how to join tables together. In this instance, a set of road attribute values will be joined to a Road feature class. After doing this, you will be able to get a lot more information about each road.
- **Note:** This exercise will also be used in your homework. You will need to figure out what the joined attribute values are for a particular road.

Data used:

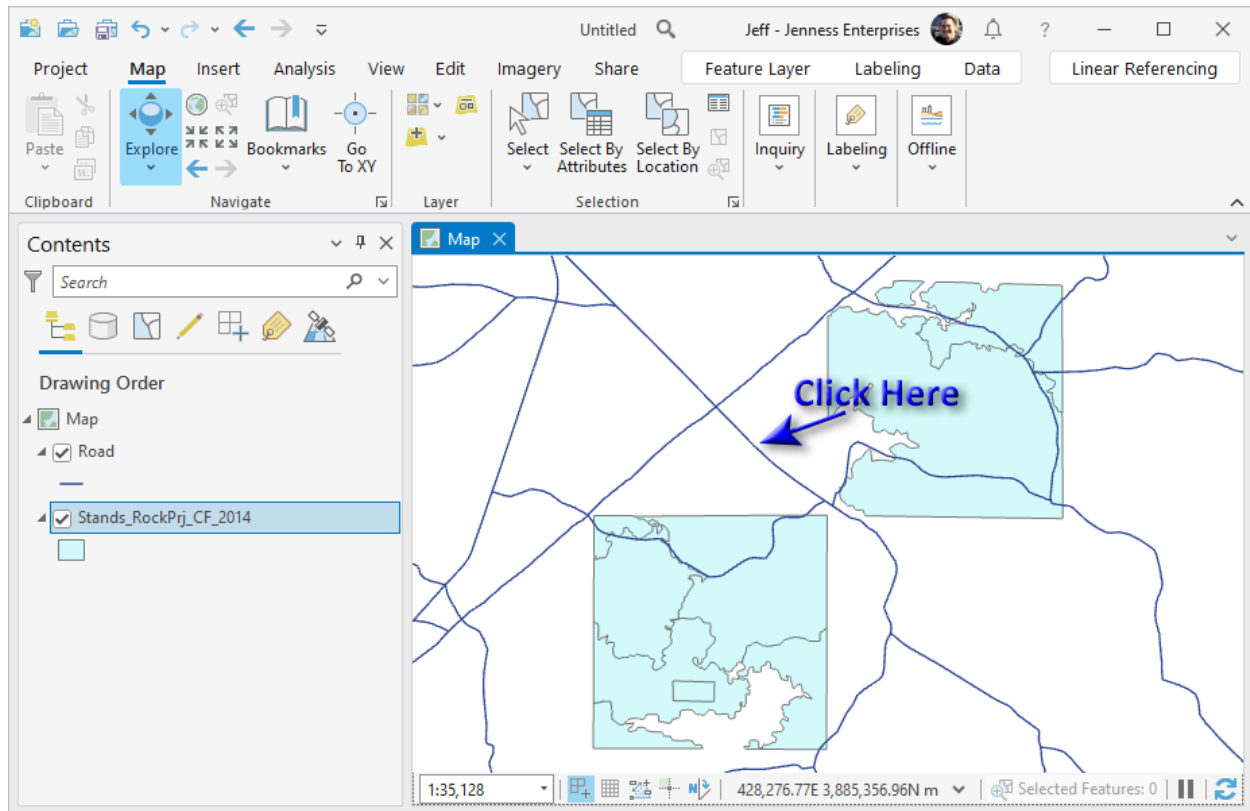
- Forest Stands shapefile **Stands_RockPrj_CF_2014** in `..\Data\RockPrj_CF_2014\..`
- Forest Road shapefile **Road** in `..\Data\ RockPrj_CF_2014\..`
- Forest Road Attributes table in `..\Data\ RockPrj_CF_2014\iweb_GC_ROADS_V.gdb\..`

Exercise:

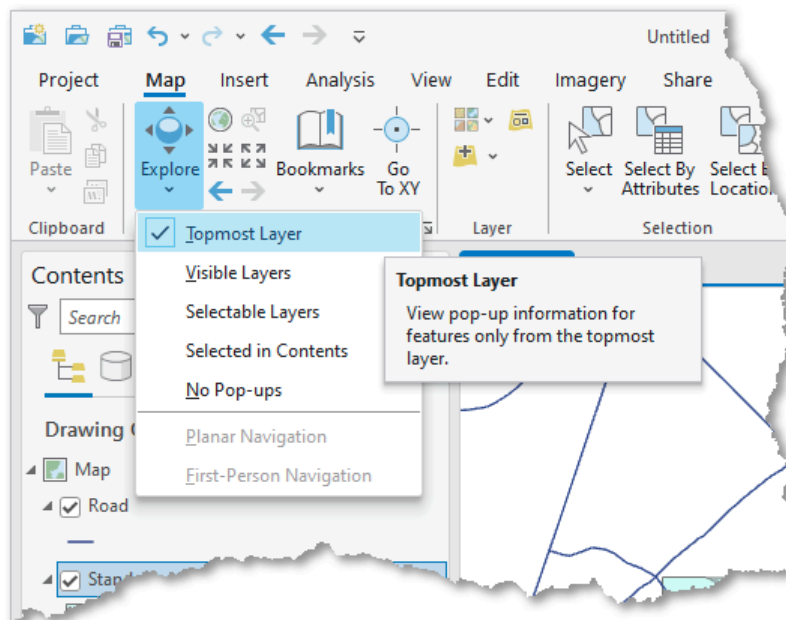
- ☐ Open a blank ArcGIS Pro map and load the feature classes **Stands_RockPrj_CF_2014** and **Road**.
- ☐ If you like, load some background imagery to help locate yourself (click the little down arrow on the right side of the “Add Data” button, then click “Add Basemap” or “Add Data from ArcGIS Online”).
- ☐ Zoom to the extent of **Stands_RockPrj_CF_2014**.

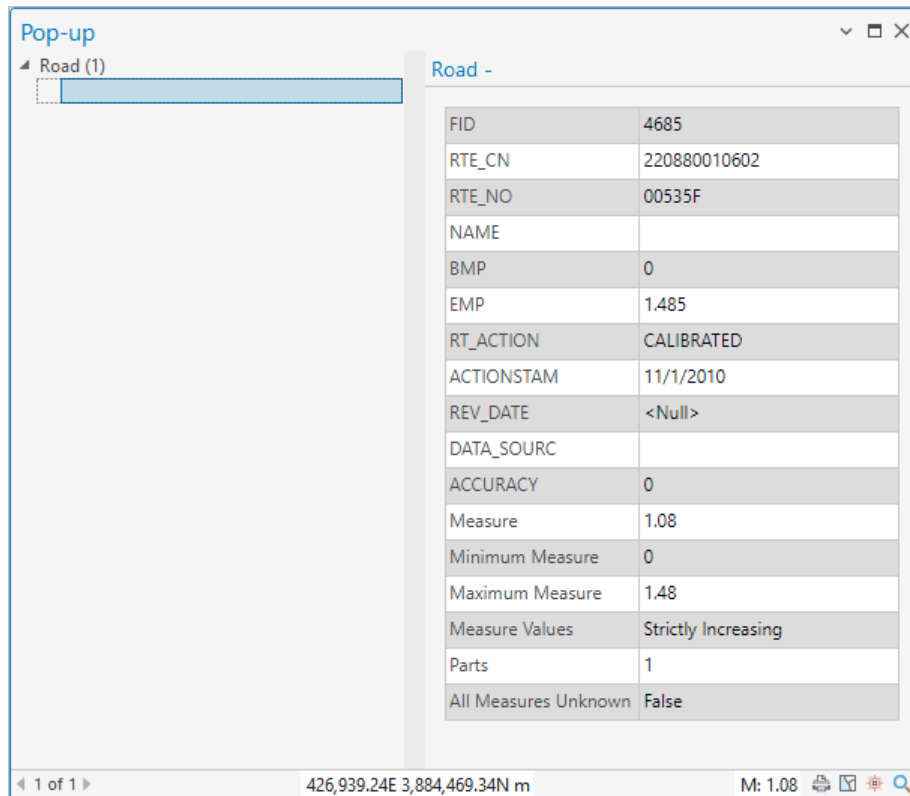


- ☐ Use the **Explore** command **Explore** to get the attributes on the road illustrated below:



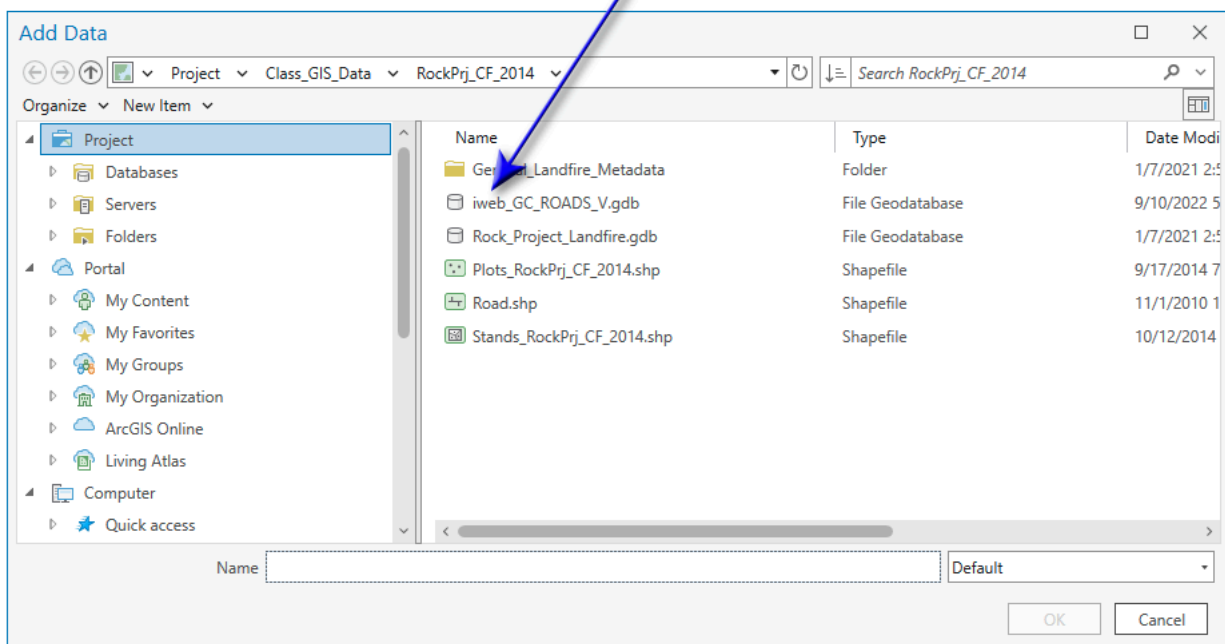
- ☐ You should see the attributes for Feature ID (FID) 4685. Confirm that this is the case. **Only if necessary,** make sure your **Road** feature class is drawing on top, and then set the "Identify From" feature class to specifically use the **Top-most layer**.



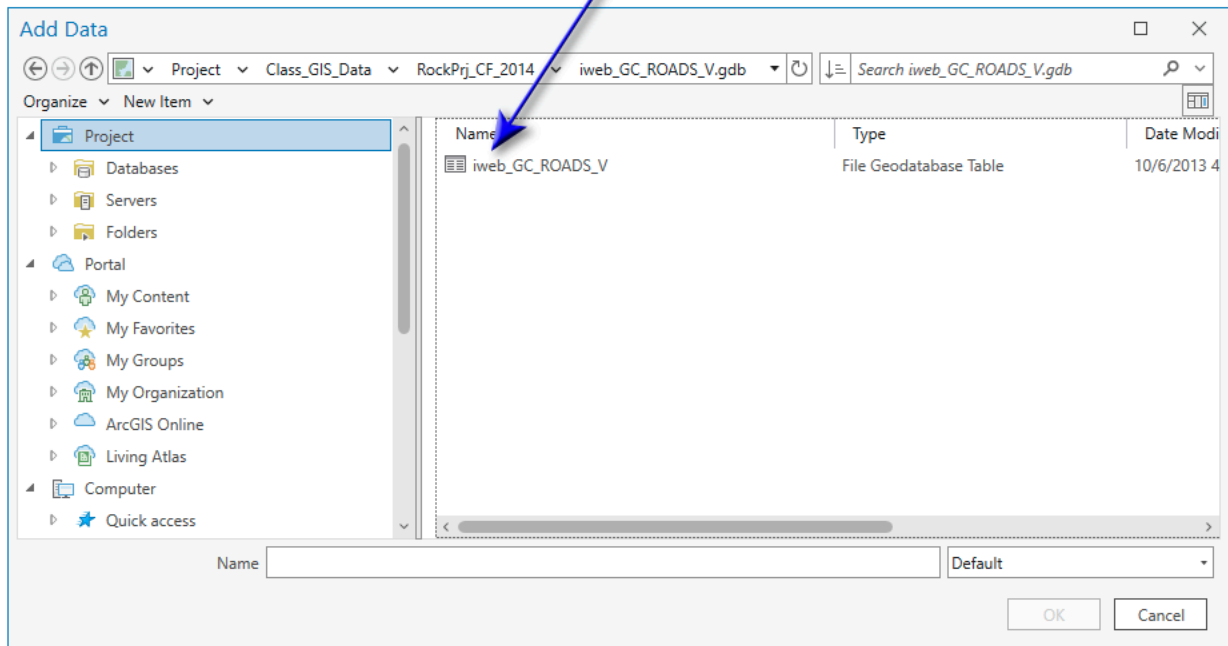
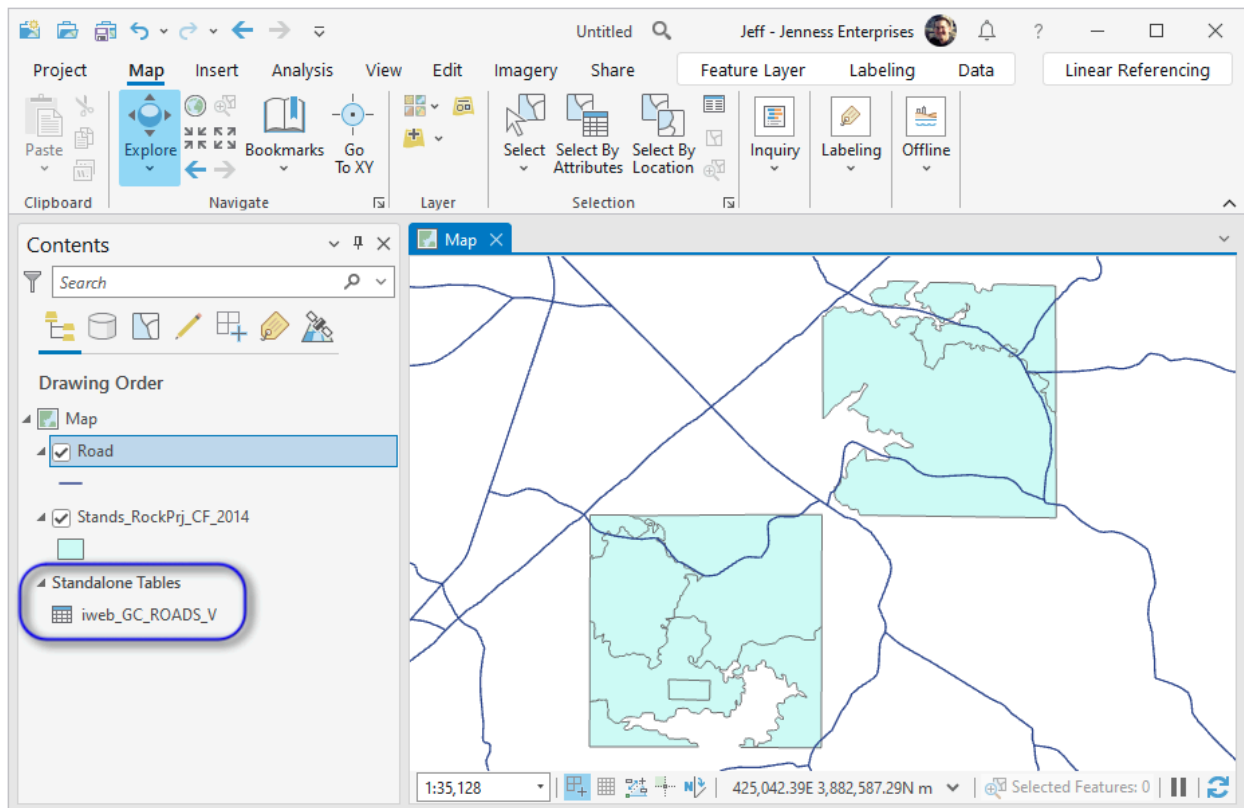


- ☐ Observe which attribute values are available that describe this road. There is really very little information about that road in the actual **Road** feature class.
- ☐ Add the table **iweb_GC_ROADS_V** from the file geodatabase **iweb_GC_ROADS_V.gdb**:

Open this file geodatabase



Then add this standalone table



- ☐ Open the table **iweb_GC_ROADS_V** and observe that there is a lot of information on each road, but no actual road feature to display. This is just a table, not a feature class.

Untitled - ArcGIS Pro

iweb_GC_ROADS_V

Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy Rows: Insert

	OBJECTID *	RTE_CN *	ID	BMP	EMP	SEG_LENGTH	ADMIN_ORG	CONGRESSIONAL_DIS...	COUNTY	LANES	MANAGING
1	1	2105010504	09734W	0	0.3	0.3	030407	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030407
2	2	2106010504	09803D	0	0.1	0.1	030406	1ST CONG. DIST. OF A...	AZ - YAVAPAI	1 - SINGLE LANE	030406
3	3	2128010504	09020	0	1.72	1.72	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
4	4	2130010504	09021H	0	0.4	0.4	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
5	5	2080010504	00320A	0	1.4	1.4	030407	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030404
6	6	2102010504	09707F	0	1.044	1.044	030407	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030407
7	7	2125010504	09118K	0	0.1	0.1	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
8	8	2287010504	00211F	0.352	1.045	0.693	030407	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030407
9	9	231010504	09487K	0	1.1	1.1	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
10	10	2313010504	09143H	0	0.8	0.8	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
11	11	2322010504	09145F	0	0.4	0.4	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
12	12	2329010504	09147E	0	0.43	0.43	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
13	13	2335010504	09154A	0	0.6	0.6	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
14	14	2338010504	09155F	0	0.3	0.3	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
15	15	5985010504	09137C	0	1.3	1.3	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402

0 of 7,906 selected

Filters: 100%

- Notice that both the feature class **Road** and the table **iweb_GC_ROADS_V** include an attribute field named **RTE_CN**. This is actually an ID field that is used to connect the records from the **iweb_GC_ROADS_V** table to the road features in the **Road** feature class.

Untitled - ArcGIS Pro

Road

Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy

	FID	Shape *	RTE_CN *	RTE_NO	NAME	BMP	EMP	RT_ACTION	ACTIONSTAM	REV_DATE	DATA_SOURC	ACCURACY
1	0	Polyline M	6850010504	00003G		0	1.065	CALIBRATED	11/1/2010	<Null>		0
2	1	Polyline M	656010504	00003H		0	1.038	CALIBRATED	11/1/2010	<Null>		0
3	2	Polyline M	2837010504	00003J		0	0.8	CALIBRATED	11/1/2010	<Null>		0
4	3	Polyline M	3495010504	00003K		0	0.3	CALIBRATED	11/1/2010	<Null>		0
5	4	Polyline M	657010504	00003L		0	0.3	CALIBRATED	11/1/2010	<Null>		0

0 of 6,743 selected

Filters: 100%

iweb_GC_ROADS_V

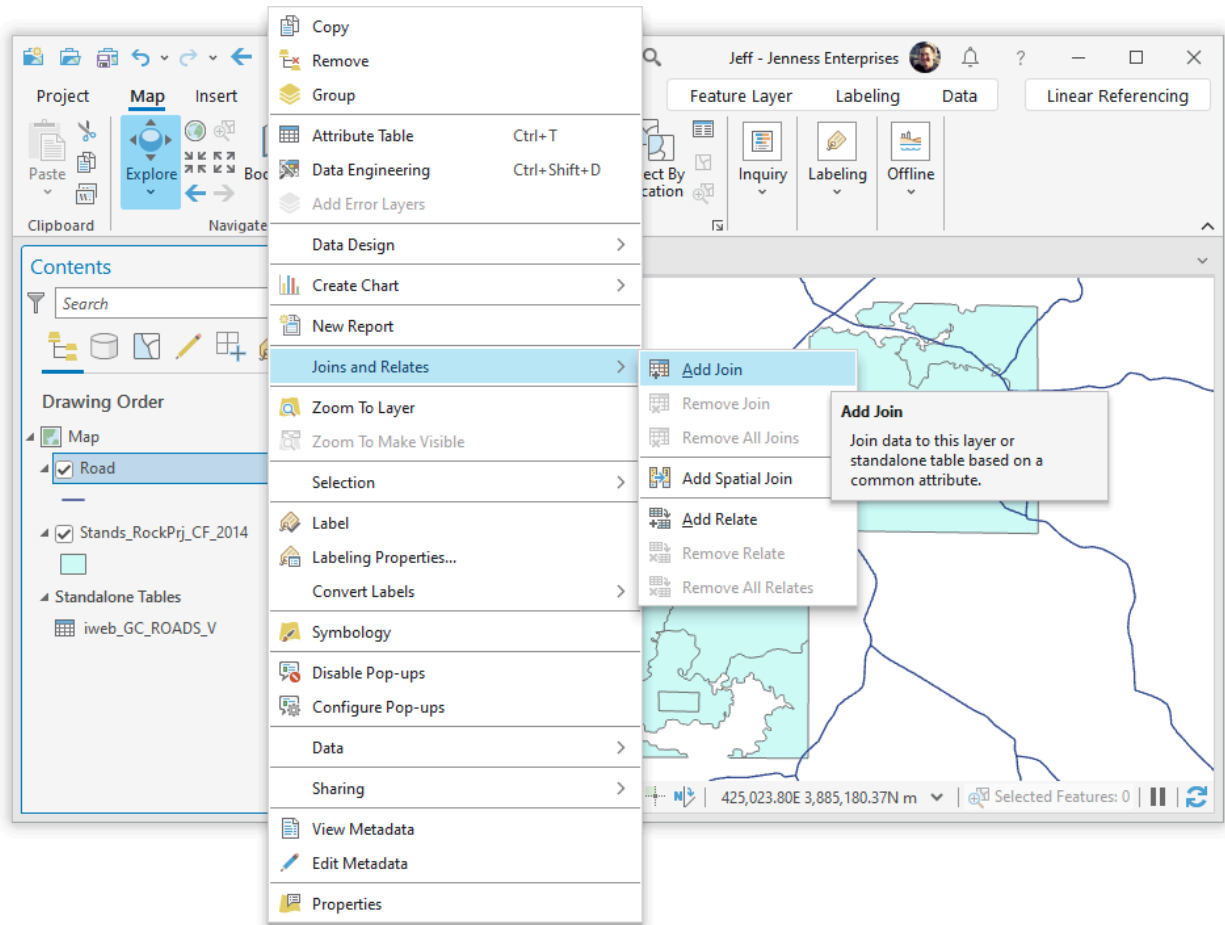
Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy Rows: Insert

	OBJECTID *	RTE_CN *	ID	BMP	EMP	SEG_LENGTH	ADMIN_ORG	CONGRESSIONAL_DIS...	COUNTY	LANES	MANAGING
1	1	2105010504	09734W	0	0.3	0.3	030407	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030407
2	2	2106010504	09803D	0	0.1	0.1	030406	1ST CONG. DIST. OF A...	AZ - YAVAPAI	1 - SINGLE LANE	030406
3	3	2128010504	09020	0	1.72	1.72	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
4	4	2130010504	09021H	0	0.4	0.4	030402	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030402
5	5	2080010504	00320A	0	1.4	1.4	030407	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030404

0 of 7,906 selected

Filters: 100%

- Join the table **iweb_GC_ROADS_V** to the feature class **Road**.
 - In the ArcGIS Pro Contents pane, right-click on the layer **Road** and choose “Joins and Relates”, and then “Join...”



- 2) Fill out the “Join Data” window as follows. Note that you are using the field “RTE_CN” in both the **Road** feature class and the **iweb_GC_ROADS_V** table.

Add Join
?
X

Input Table
Road

Input Join Field
RTE_CN

Join Table
iweb_GC_ROADS_V

Join Table Field
RTE_CN

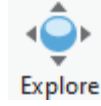
☒ Keep All Target Features

☒ Index Joined Fields

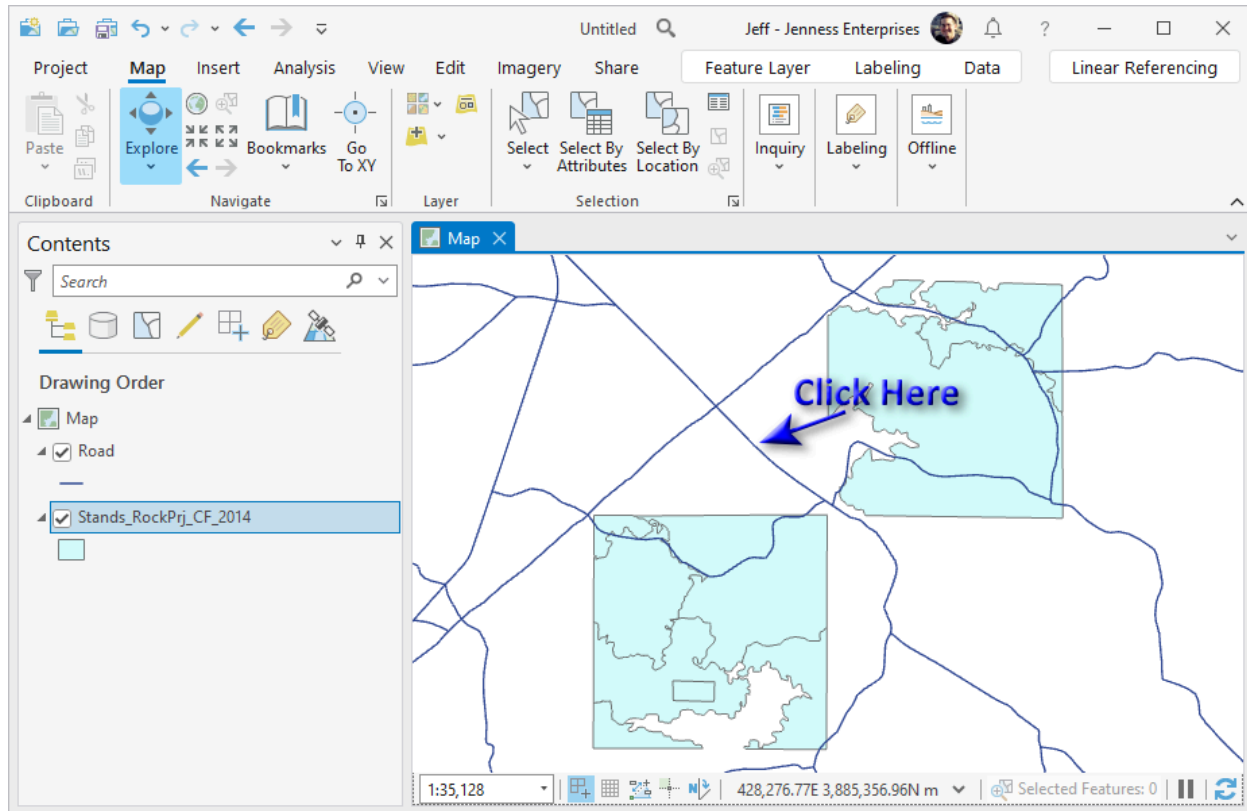
Validate Join

OK

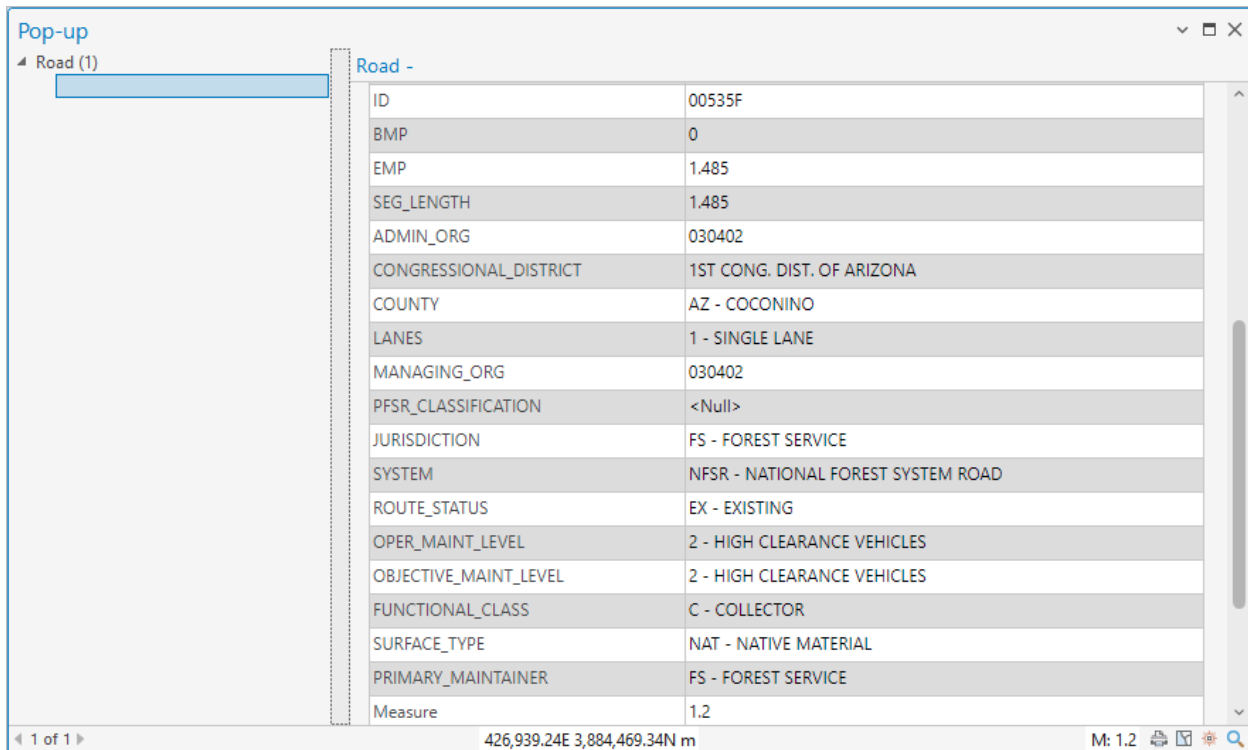
- 3) Click “OK” to finish the join.



- Once the join is completed, use the **Explore** command again to get the attributes on the same road you clicked on before:



- 4) Observe that you now have a **lot** more information on that road:



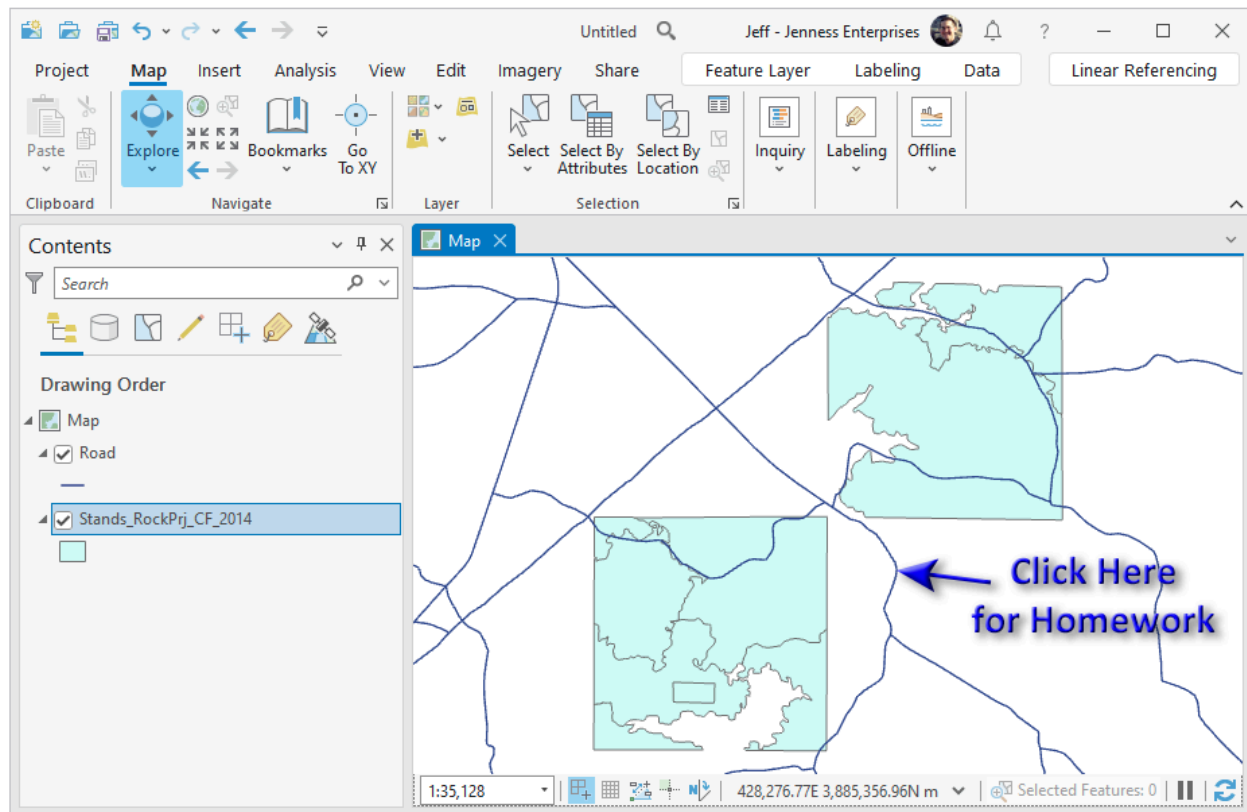
- Observe that the “OPER_MAINT_LEVEL” value for the road you just clicked on suggests that road is intended for high clearance vehicles only. You could not have known this without joining the **iweb_GC_ROADS_V** table to the **Road** feature class.
- Open your **Road** attribute table and observe that you now have all attribute fields from the original **Road** feature class, plus all the attribute fields from the **iweb_GC_ROADS_V** table.

FID	Shape	RTE_CN	RTE_NO	NAME	BMP	EMP	RT_ACTION	ACTIONSTAM	REV_DATE	DATA_SOURCE	ACCURACY	OBJECTID	RTE_CN	ID	BMP	EMP	SEG_LENGTH	ADMIN
1	0	Polyline M	6850010504	00003G	0	1.065	CALIBRATED	11/1/2010	<Null>		0	5348	6850010504	00003G	0	1.065	1.065	030405
2	1	Polyline M	656010504	00003H	0	1.038	CALIBRATED	11/1/2010	<Null>		0	2970	656010504	00003H	0	1.038	1.038	030405
3	2	Polyline M	2837010504	00003J	0	0.8	CALIBRATED	11/1/2010	<Null>		0	4594	2837010504	00003J	0	0.8	0.8	030405
4	3	Polyline M	3495010504	00003K	0	0.3	CALIBRATED	11/1/2010	<Null>		0	7467	3495010504	00003K	0	0.3	0.3	030405
5	4	Polyline M	657010504	00003L	0	0.3	CALIBRATED	11/1/2010	<Null>		0	4153	657010504	00003L	0	0.3	0.3	030405
6	5	Polyline M	1806010504	00003M	0	0.3	CALIBRATED	11/1/2010	<Null>		0	6654	1806010504	00003M	0	0.3	0.3	030405
7	6	Polyline M	3496010504	00003N	0	1.464	CALIBRATED	11/1/2010	<Null>		0	572	3496010504	00003N	0	1.464	1.464	030405
8	7	Polyline M	1807010504	00003P	0	1	CALIBRATED	11/1/2010	<Null>		0	4395	1807010504	00003P	0	1	1	030405
9	8	Polyline M	5482010504	00003R	0	0.2	CALIBRATED	11/1/2010	<Null>		0	7895	5482010504	00003R	0	0.2	0.2	030405
10	9	Polyline M	6599010504	00003T	0	0.837	CALIBRATED	11/1/2010	<Null>		0	6302	6599010504	00003T	0	0.837	0.837	030405
11	10	Polyline M	6401010504	00004	0	6.5	CALIBRATED	11/1/2010	<Null>		0	891	6401010504	00004	6	6.5	0.5	030402
12	11	Polyline M	658010504	00004B	0	3.539	CALIBRATED	11/1/2010	<Null>		0	1004	658010504	00004B	0	3.539	3.539	030402
13	12	Polyline M	4469010504	00004D	0	5.84	CALIBRATED	11/1/2010	<Null>		0	6023	4469010504	00004D	0	5.84	5.84	030402
14	13	Polyline M	1808010504	00009E	0	1.7	CALIBRATED	11/1/2010	<Null>		0	2152	1808010504	00009E	0	1.7	1.7	030406
15	14	Polyline M	659010504	00009F	0	1.58	CALIBRATED	11/1/2010	<Null>		0	1938	659010504	00009F	0	1.58	1.58	030402

- For Your Homework:** What is the “OPER_MAINT_LEVEL” value for the road indicated **in the**

illustration below? Hint: Use the **Explore** command  again to click on that road.

Another hint: The “OPER_MAINT_LEVEL” value for this new road is **not** “2 – HIGH CLEARANCE VEHICLES”!



Hint: You should have clicked on FID 4579, and the rest of the Identify window should look like this:

Pop-up

▲ Road (1)

Road -

ADMIN_ORG	030402
CONGRESSIONAL_DISTRICT	1ST CONG. DIST. OF ARIZONA
COUNTY	AZ - COCONINO
LANES	1 - SINGLE LANE
MANAGING_ORG	030402
PFSR_CLASSIFICATION	POT - POTENTIAL PFSR
JURISDICTION	FS - FOREST SERVICE
SYSTEM	NFSR - NATIONAL FOREST SYSTEM ROAD
ROUTE_STATUS	EX - EXISTING
OPER_MAINT_LEVEL	
OBJECTIVE_MAINT_LEVEL	
FUNCTIONAL_CLASS	C - COLLECTOR
SURFACE_TYPE	IMP - IMPROVED NATIVE MATERIAL
PRIMARY_MAINTAINER	FS - FOREST SERVICE
Measure	2.16
Minimum Measure	0
Maximum Measure	10.32
Measure Values	Strictly Increasing
Parts	1

What is this value?

1 of 1

428,461.28E 3,879,167.88N m

M: 2.16

Exercise 6: Create and Use a Relate

Relates and *Relationship Classes* are the same, functionally. The difference is that *Relates* are created in-memory in ArcGIS Pro, similar to a *Join*, while *Relationship Classes* are saved into a geodatabase. They both define the same types of relationships between tables and/or feature classes.

Objectives

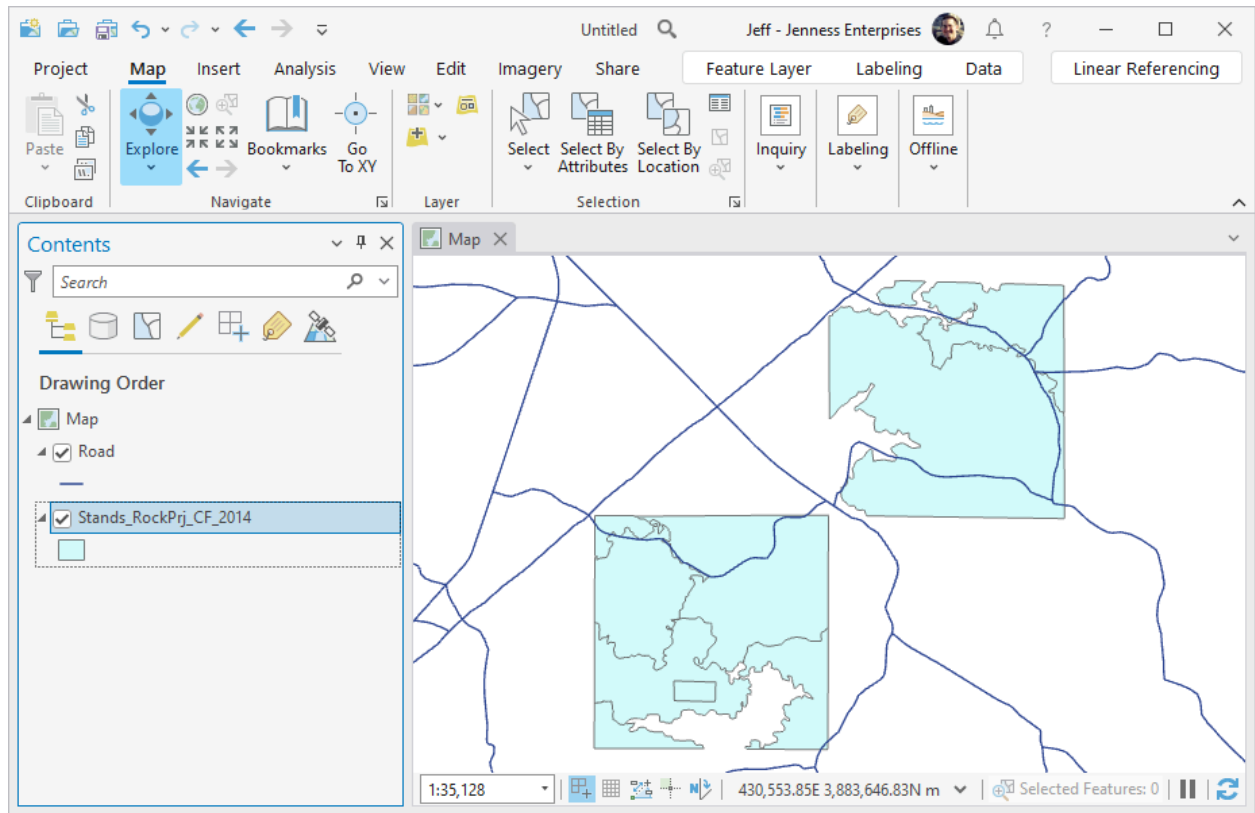
- This exercise will show how to create a relate that connects tables together. To make it more familiar, this lab exercise will use the same data used in Lab Exercise 5 (on joining tables). As before, a set of road attribute values will be connected to a Road feature class. After doing this, you will be able to get a lot more information about each road.

Data used:

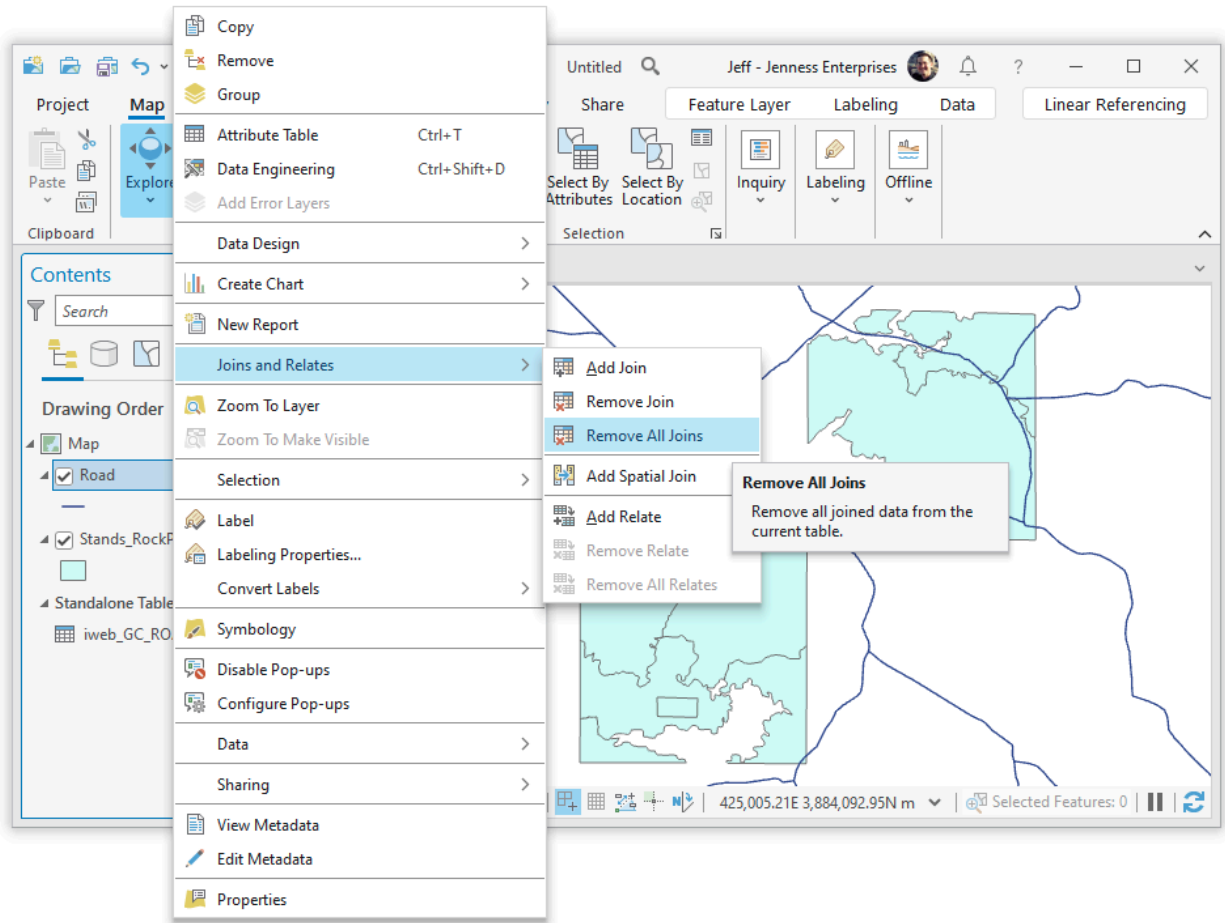
- Forest Stands shapefile **Stands_RockPrj_CF_2014** in **..\Data\RockPrj_CF_2014\..**
- Forest Road shapefile **Road** in **..\Data\ RockPrj_CF_2014\..**
- Forest Road Attributes table in **..\Data\ RockPrj_CF_2014\iweb_GC_ROADS_V.gdb\..**

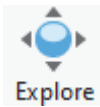
Exercise:

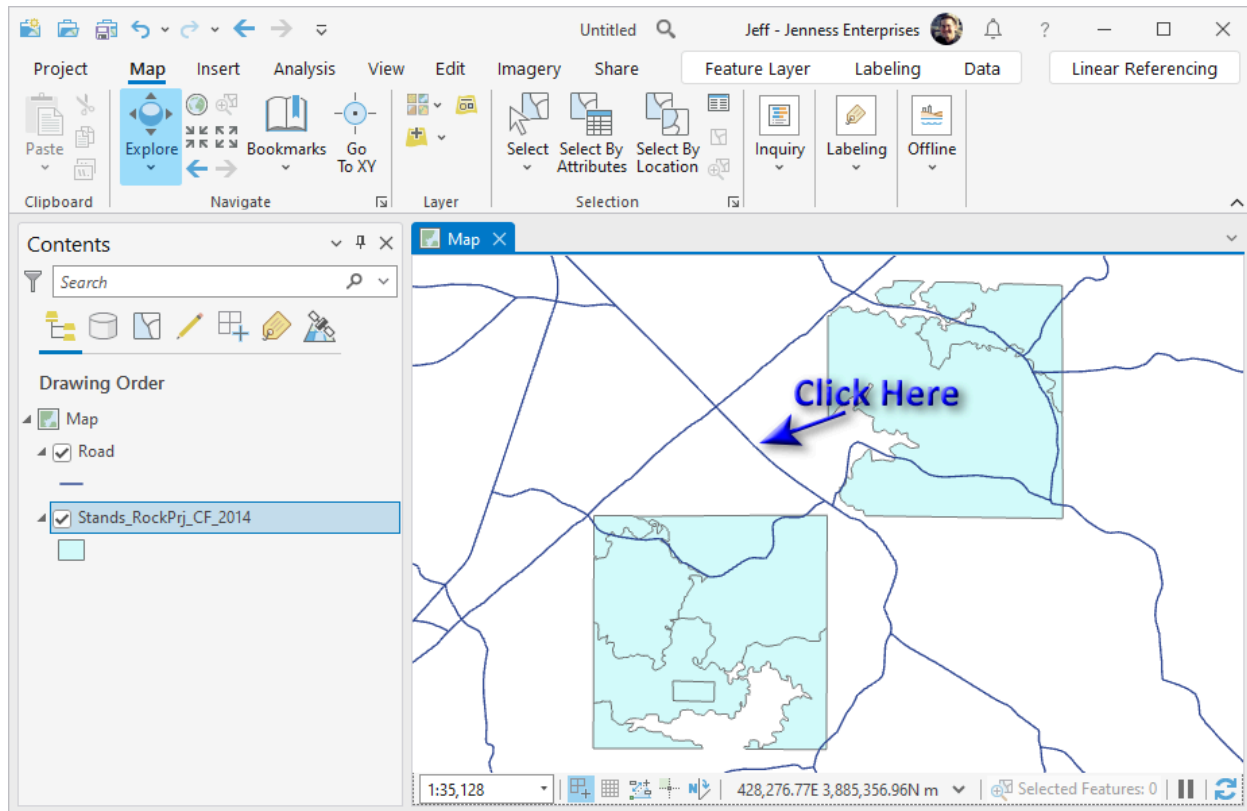
- ☐ Open a blank ArcGIS Pro map and load the feature classes **Stands_RockPrj_CF_2014** and **Road**.
- ☐ If you like, load some background imagery to help locate yourself (click the little down arrow on the right side of the “Add Data” button, then click “Add Basemap” or “Add Data from ArcGIS Online”).
- ☐ Zoom to the extent of **Stands_RockPrj_CF_2014**.



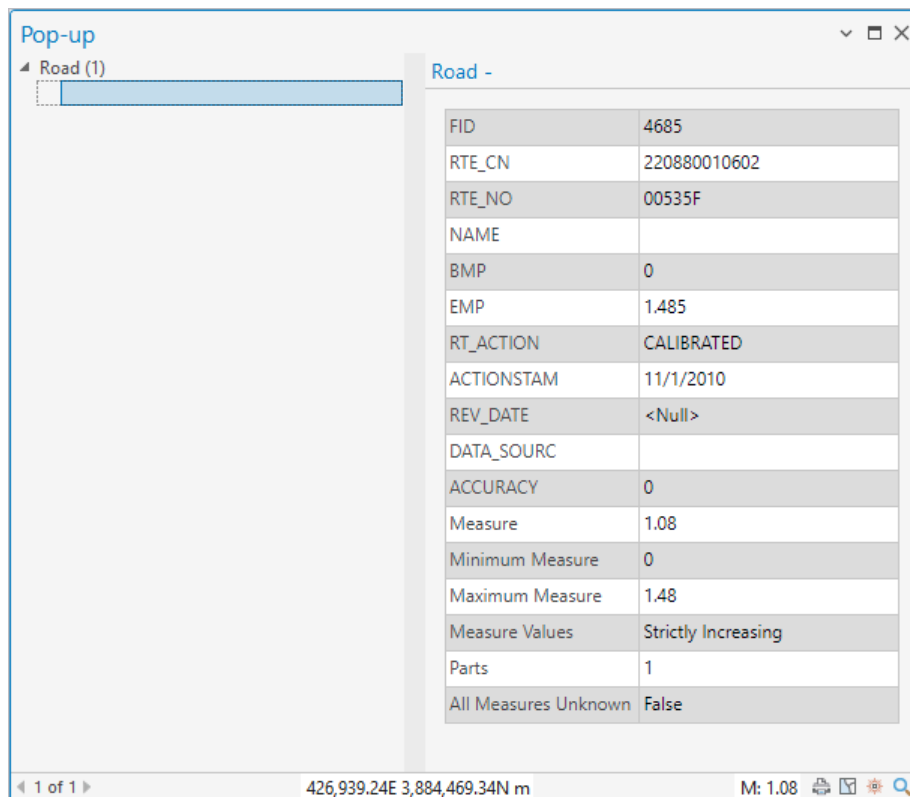
- ☐ If you still have your Join in place from Lab Exercise 5, remove it now. If not, then ignore the next image.

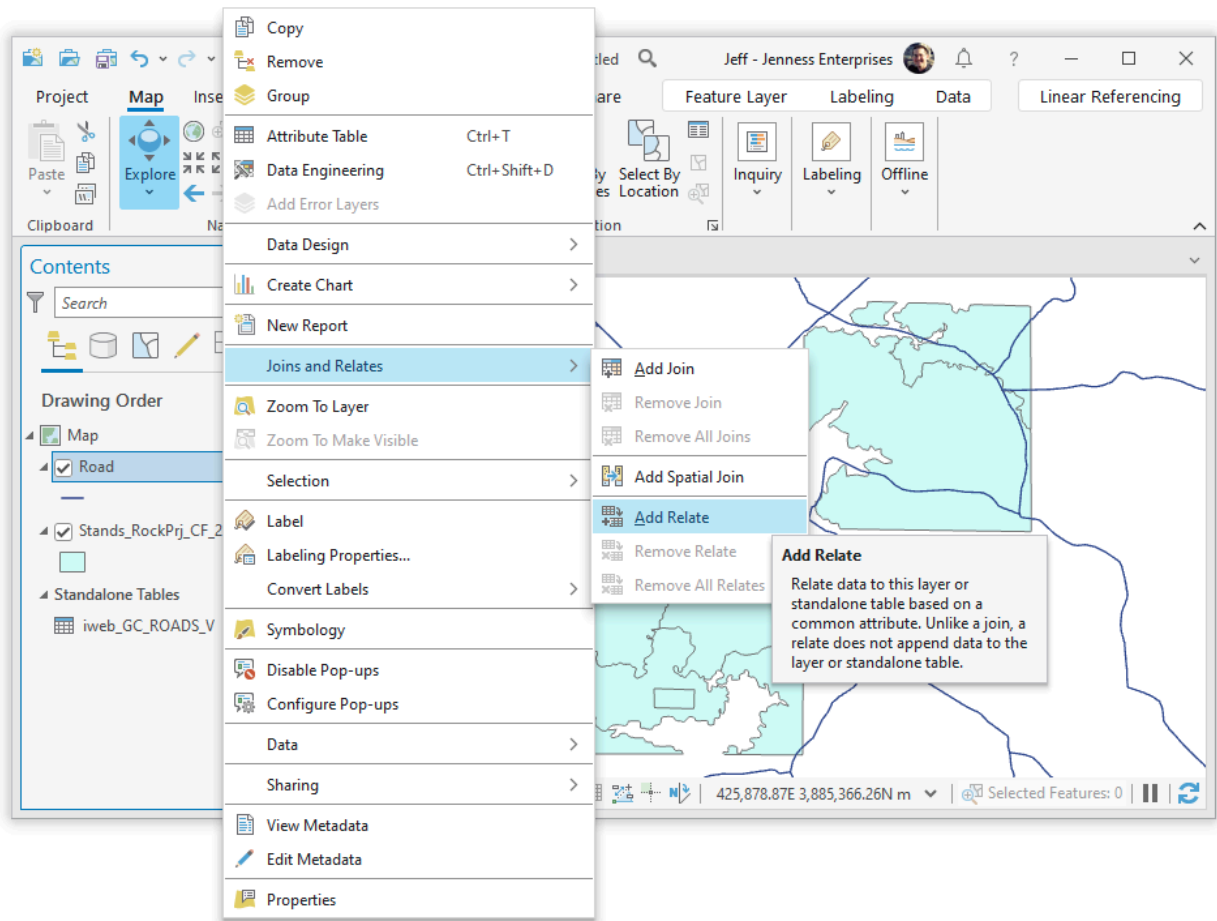


☐ Use the **Explore** command  to get the attributes on the road illustrated below:



- ☐ You should see the attributes for Feature ID (FID) 4685, just like you did last time.





- 2) In the “Relate” dialog box, set the following values:
 - a) The field in this layer that the relate will be based on = **RTE_CN**
 - b) The table or layer to relate to this layer = **iweb_GC_ROADS_V**
 - c) The field in the related table or layer to base the relate on = **RTE_CN**
 - d) The name for the relate = anything you want. I’ll go with the default **Relate1**
 - e) Cardinality = **One to one**: There is only one record in the standalone table **iweb_GC_ROADS_V** that corresponds to each road .

Add Relate ? x

Layer Name or Table View
Road

Input Relate Field
RTE_CN

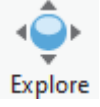
Relate Table
iweb_GC_ROADS_V

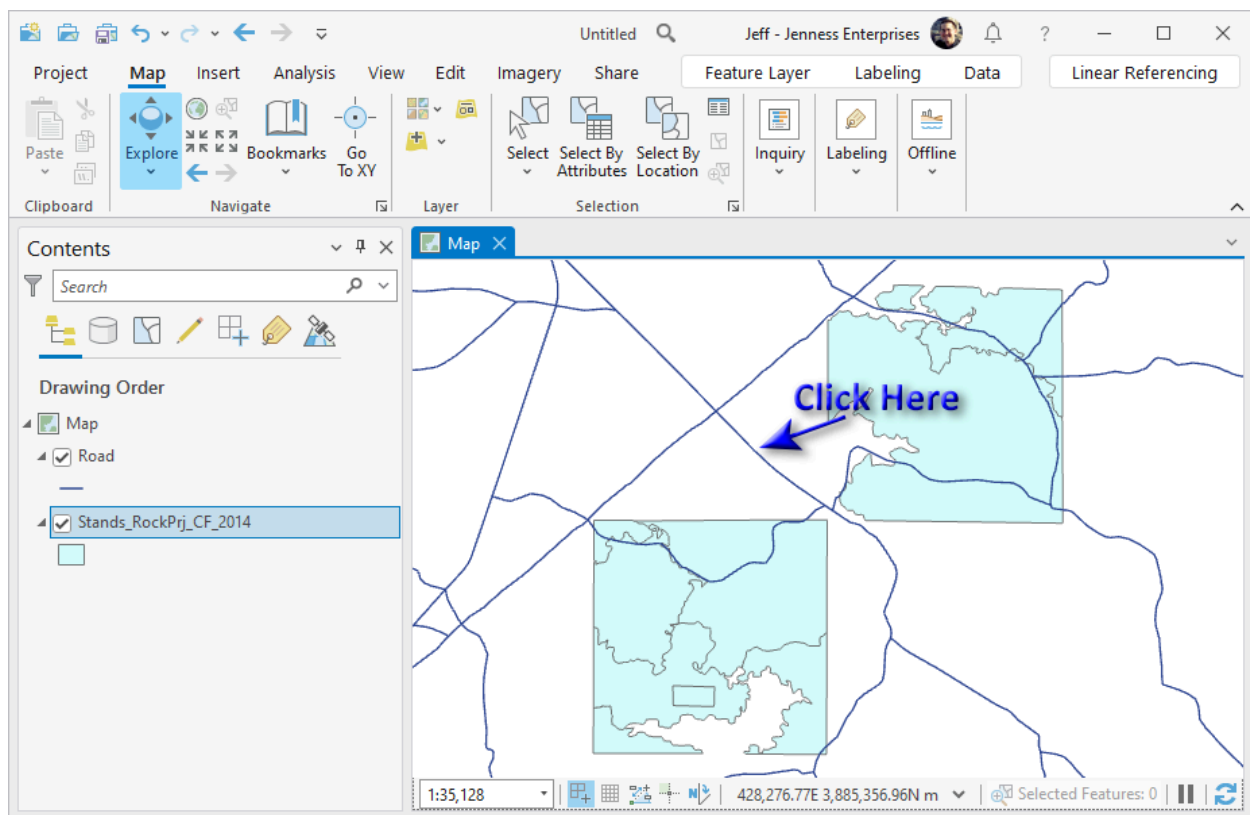
Output Relate Field
RTE_CN

Relate Name
Relate1

Cardinality
One to one

OK

- Once the relate is created, use the **Explore** command  again to get the attributes on the same road you clicked on before:



- Observe that you now have a lot more information on that road. The Identify window looks similar to what you saw in the *Join* lab, but the additional road info is now accessible by clicking progressively nested sublinks in the Identify window:

Pop-up

▲ Road (1)

▲ iweb_GC_ROADS_V (1)
220880010602

Click here to see information on the road feature

Road -

FID	4685
RTE_CN	220880010602
RTE_NO	00535F
NAME	
BMP	0
EMP	1.485
RT_ACTION	CALIBRATED
ACTIONSTAM	11/1/2010
REV_DATE	<Null>
DATA_SOURC	
ACCURACY	0
Measure	1.18

1 of 1 426,939.24E 3,884,469.34N m M: 1.18

Pop-up

▲ Road (1)

▲ iweb_GC_ROADS_V (1)
220880010602

Click here to see information on the related table record

iweb_GC_ROADS_V - 220880010602

CONGRESSIONAL_DISTRICT	1ST CONG. DIST. OF ARIZONA
COUNTY	AZ - COCONINO
LANES	1 - SINGLE LANE
MANAGING_ORG	030402
PFSR_CLASSIFICATION	<Null>
JURISDICTION	FS - FOREST SERVICE
SYSTEM	NFSR - NATIONAL FOREST SYSTEM ROAD
ROUTE_STATUS	EX - EXISTING
OPER_MAINT_LEVEL	2 - HIGH CLEARANCE VEHICLES
OBJECTIVE_MAINT_LEVEL	2 - HIGH CLEARANCE VEHICLES
FUNCTIONAL_CLASS	C - COLLECTOR
SURFACE_TYPE	NAT - NATIVE MATERIAL
PRIMARY_MAINTAINER	FS - FOREST SERVICE

1 of 1

- ☐ Open the attribute table for your **Road** layer and observe that, unlike a Join, no new attribute fields are appended to the table. The attribute table looks exactly is it did before.
- ☐ Select some of your roads. Which ones do not matter; this step will just show you how to push the selection from your **Road** feature class to your related **iweb_GC_ROADS_V** table.

Untitled - ArcGIS Pro

Road

Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy

	FID	Shape *	RTE_CN *	RTE_NO	NAME	BMP	EMP	RT_ACTION	ACTIONSTAM	REV_DATE	DATA_SOURCE	ACCURACY
1	0	Polyline M	6850010504	00003G		0	1.065	CALIBRATED	11/1/2010	<Null>		0
2	1	Polyline M	656010504	00003H		0	1.038	CALIBRATED	11/1/2010	<Null>		0
3	2	Polyline M	2837010504	00003J		0	0.8	CALIBRATED	11/1/2010	<Null>		0
4	3	Polyline M	3495010504	00003K		0	0.3	CALIBRATED	11/1/2010	<Null>		0
5	4	Polyline M	657010504	00003L		0	0.3	CALIBRATED	11/1/2010	<Null>		0
6	5	Polyline M	1806010504	00003M		0	0.3	CALIBRATED	11/1/2010	<Null>		0
7	6	Polyline M	3496010504	00003N		0	1.464	CALIBRATED	11/1/2010	<Null>		0
8	7	Polyline M	1807010504	00003P		0	1	CALIBRATED	11/1/2010	<Null>		0
9	8	Polyline M	5482010504	00003R		0	0.2	CALIBRATED	11/1/2010	<Null>		0
10	9	Polyline M	6599010504	00003T		0	0.837	CALIBRATED	11/1/2010	<Null>		0
11	10	Polyline M	6401010504	00004		0	6.5	CALIBRATED	11/1/2010	<Null>		0
12	11	Polyline M	658010504	00004B		0	3.539	CALIBRATED	11/1/2010	<Null>		0
13	12	Polyline M	4469010504	00004D		0	5.84	CALIBRATED	11/1/2010	<Null>		0
14	13	Polyline M	1808010504	00009E		0	1.7	CALIBRATED	11/1/2010	<Null>		0
15	14	Polyline M	659010504	00009F		0	1.58	CALIBRATED	11/1/2010	<Null>		0

8 of 6,743 selected

Filters: 100%

- Click on the Burger icon  in the upper right corner of your table, and go to “Related Data”, and then “iweb_GC_ROADS_V”:

Untitled - ArcGIS Pro

Road

Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy

	FID	Shape *	RTE_CN *	RTE_NO	NAME
1	0	Polyline M	6850010504	00003G	
2	1	Polyline M	656010504	00003H	
3	2	Polyline M	2837010504	00003J	
4	3	Polyline M	3495010504	00003K	
5	4	Polyline M	657010504	00003L	
6	5	Polyline M	1806010504	00003M	
7	6	Polyline M	3496010504	00003N	
8	7	Polyline M	1807010504	00003P	
9	8	Polyline M	5482010504	00003R	
10	9	Polyline M	6599010504	00003T	
11	10	Polyline M	6401010504	00004	
12	11	Polyline M	658010504	00004B	
13	12	Polyline M	4469010504	00004D	
14	13	Polyline M	1808010504	00009E	
15	14	Polyline M	659010504	00009F	

- ☒ Show Field Aliases
 - Show All Fields
 - Reset Field Order
- ☐ Fields View
- ☒ Show domain and subtype descriptions
 - Contingent Values
 - Joins and Relates
- Related Data**
 - Select related records
- ☐ Find and Replace
- ☐ Go to row number
- ☐ Open Data Engineering
- Export

iweb_GC_ROADS_V

8 of 6,743 selected

Filters: 100%

- This will open up your table **iweb_GC_ROADS_V**, with the related records selected.

Untitled - ArcGIS Pro

Road twweb_GC_ROADS_V

Field: Selection: Highlighted: Rows:

	OBJECTID *	RTE_CN *	ID	BMP	EMP	SEG_LENGTH	ADMIN_ORG	CONGRESSIONAL_DIS...	COUNTY	LANES	MANAGING_ORG
1	572	3496010504	00003N	0	1.464	1.464	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
2	2970	656010504	00003H	0	1.038	1.038	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
3	4153	657010504	00003L	0	0.3	0.3	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
4	4395	1807010504	00003P	0	1	1	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
5	4594	2837010504	00003J	0	0.8	0.8	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
6	5348	6850010504	00003G	0	1.065	1.065	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
7	6654	1806010504	00003M	0	0.3	0.3	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405
8	7467	3495010504	00003K	0	0.3	0.3	030405	1ST CONG. DIST. OF A...	AZ - COCONINO	1 - SINGLE LANE	030405

8 of 7,906 selected

Filters: 100%

Exercise 7: Use Relationship Classes to get extensive information on a feature.

Objectives

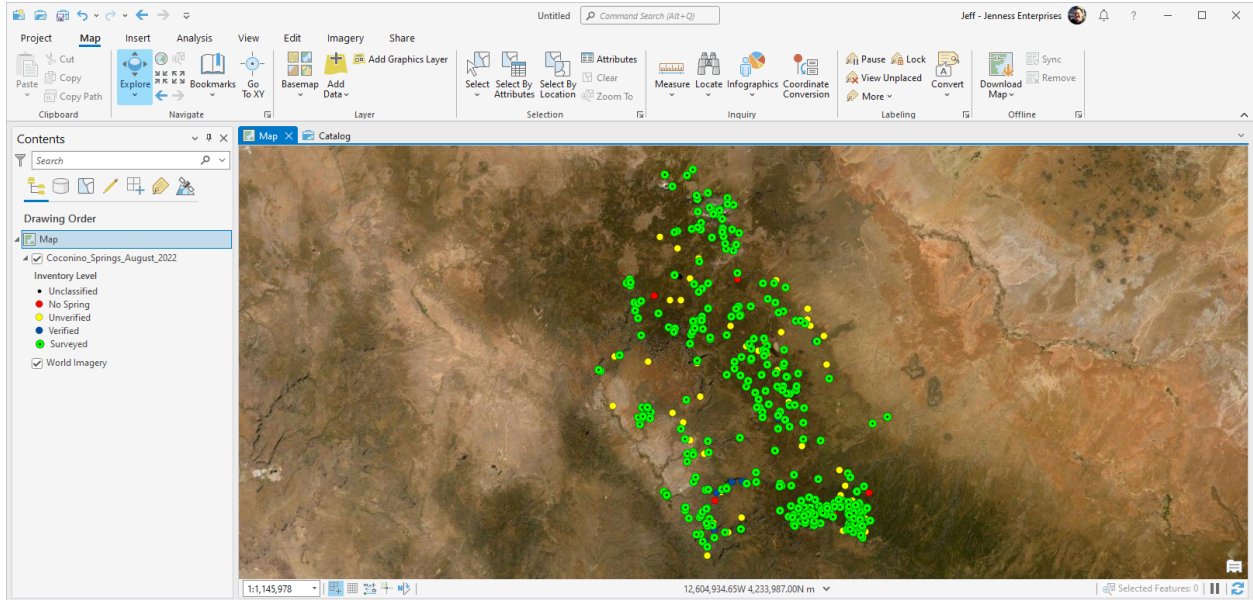
- This exercise will show how to get extensive information on features based on a large number of connected tables.
- You will learn how to find the flow measured at a particular spring, get an image of a particular spring, find the number of species observed in a region, and find the springs where a particular species has been observed.
- **Note:** This exercise will also be used in your homework. You will need to find the flow measured at a particular spring, get an image of a particular spring, find the number of species observed in a region, and find where a particular species has been observed.

Data used:

- Point feature class of springs on the Coconino National Forest
Coconino_Springs_August_2022.lyr, located in the folder **..\Class_GIS_Data\Relationship_Classes\...**
- Poster **Springs_Database_Relationship_Classes_Poster.pdf**, located in the folder **..\Class_GIS_Data \ Relationship_Classes\...**
- Standalone table of surveys conducted on the Coconino springs .
- Roughly 100 related tables in the same geodatabase.

Exercise:

- ☐ Open ArcGIS Pro to a new map.
- ☐ Add the layer **Coconino_Springs_August_2022.lyr**, located in the folder **..\Class_GIS_Data\Relationship_Classes\...**
- ☐ If you like, load some background imagery to help locate yourself).
- ☐ Zoom to the extent of **Coconino_Springs_August_2022**.



Important! Do this first!

As of ArcGIS Pro 3.0.1, the software has a bug that causes part of this exercise to fail. This bug causes ArcGIS Pro to report incorrect results, and sometimes crash, if certain tables are not loaded up into the map when using the **Explore** tool.

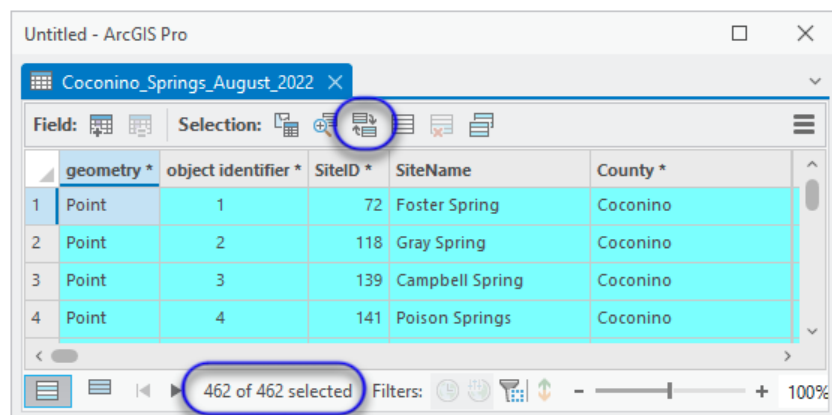
The workaround is to load these tables before you try the exercise. Specifically, you need to load the tables **tlu_TaxaInvert**, **tbl_InvertSampling**, **tbl_images**, **tbl_Surveys** and **tbl_Flow** from your file geodatabase ...\\Class_GIS_Data\\Relationship_Classes\\Coconino_August_2022.gdb.gdb.

If you like, you can load these manually using the “Add Data” command in your Map tab. Alternatively, the steps below pre-load the correct tables. **The lab exercise will begin once you have loaded these tables.**

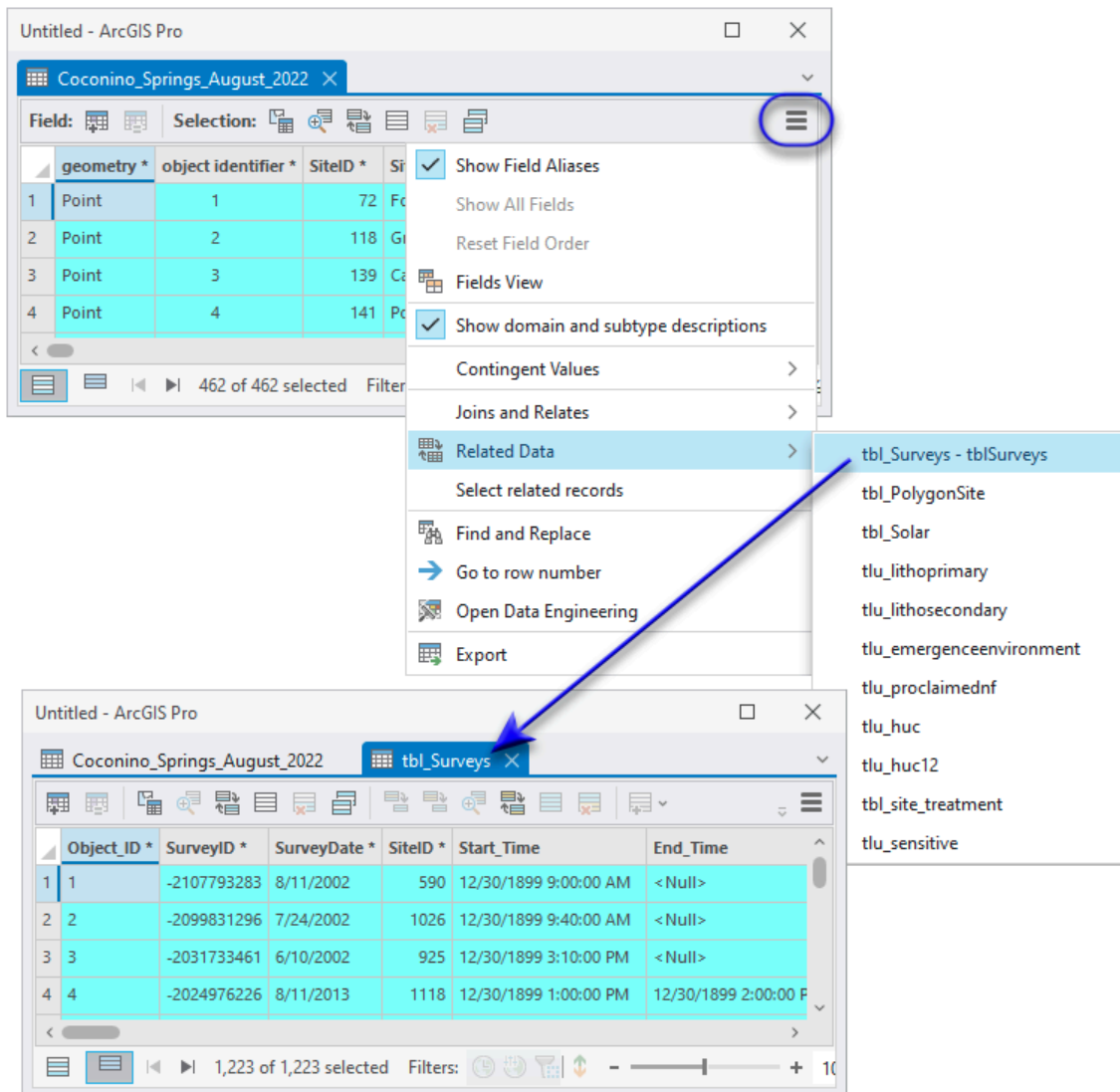
- 1) Open the attribute table for **Coconino_Springs_August_2022**, and click the **Switch** command



to select all springs.



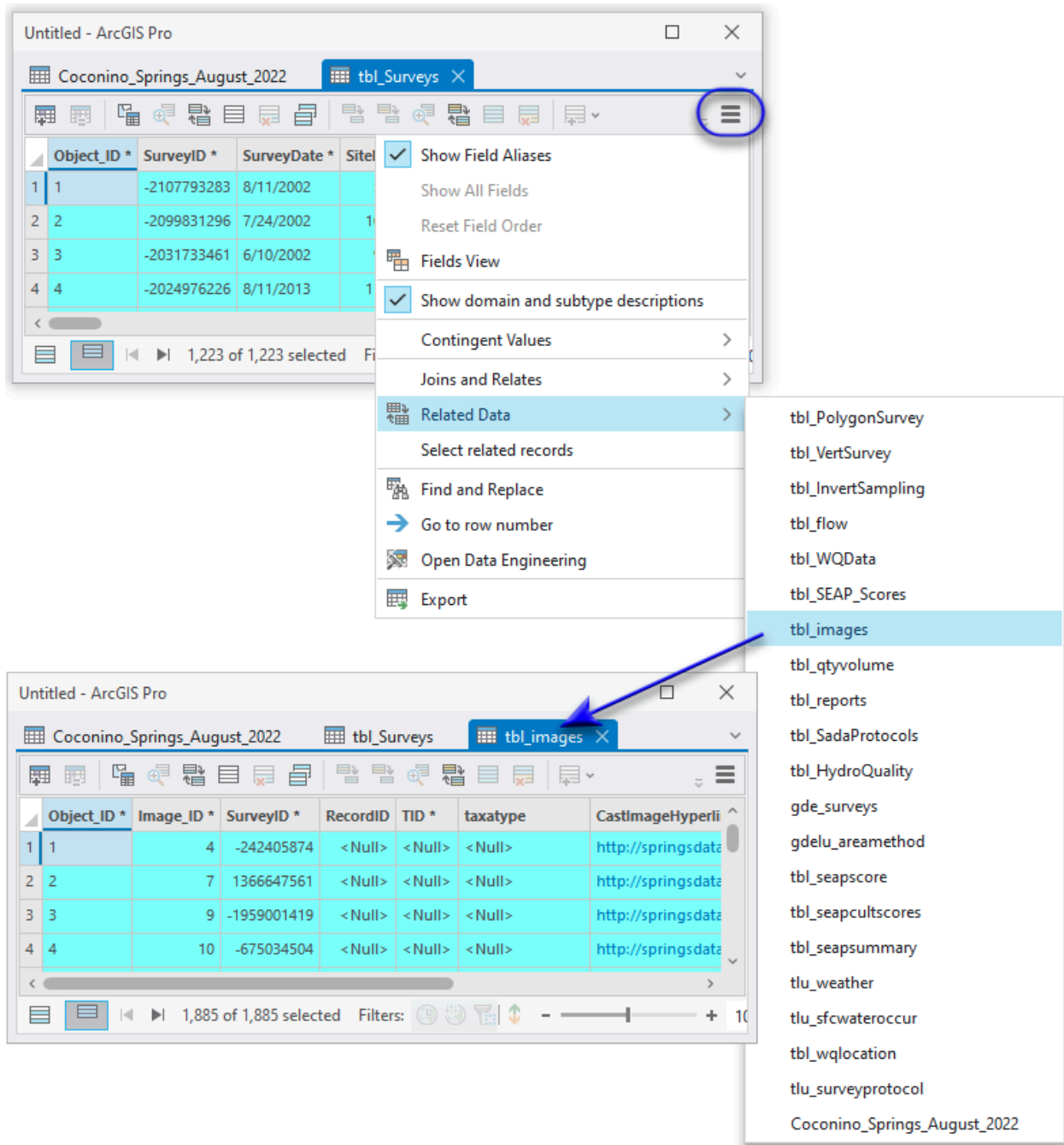
- 2) Click the Burger icon  in the upper right corner of your table, go to “Related Data”, then choose “tbl_surveys tbl_surveys”. This will automatically load the table **tbl_surveys** and open it, with all survey records selected.



The top screenshot shows the 'Coconino_Springs_August_2022' table in ArcGIS Pro. The 'Related Data' menu is open, and the 'tbl_Surveys - tblSurveys' option is selected. The bottom screenshot shows the 'tbl_Surveys' table loaded, with all records selected. The table contains the following data:

Object_ID *	SurveyID *	SurveyDate *	SitID *	Start_Time	End_Time
1	-2107793283	8/11/2002	590	12/30/1899 9:00:00 AM	<Null>
2	-2099831296	7/24/2002	1026	12/30/1899 9:40:00 AM	<Null>
3	-2031733461	6/10/2002	925	12/30/1899 3:10:00 PM	<Null>
4	-2024976226	8/11/2013	1118	12/30/1899 1:00:00 PM	12/30/1899 2:00:00 PM

- 3) With **tbl_Surveys** open, click on the burger icon  again, go to “Related Data”, then “tbl_images”:



The screenshot shows the ArcGIS Pro interface with the **tbl_Surveys** table open. The **Related Data** menu is open, and the **tbl_images** option is selected. The **tbl_images** table is then displayed, showing a list of image records with their associated survey data.

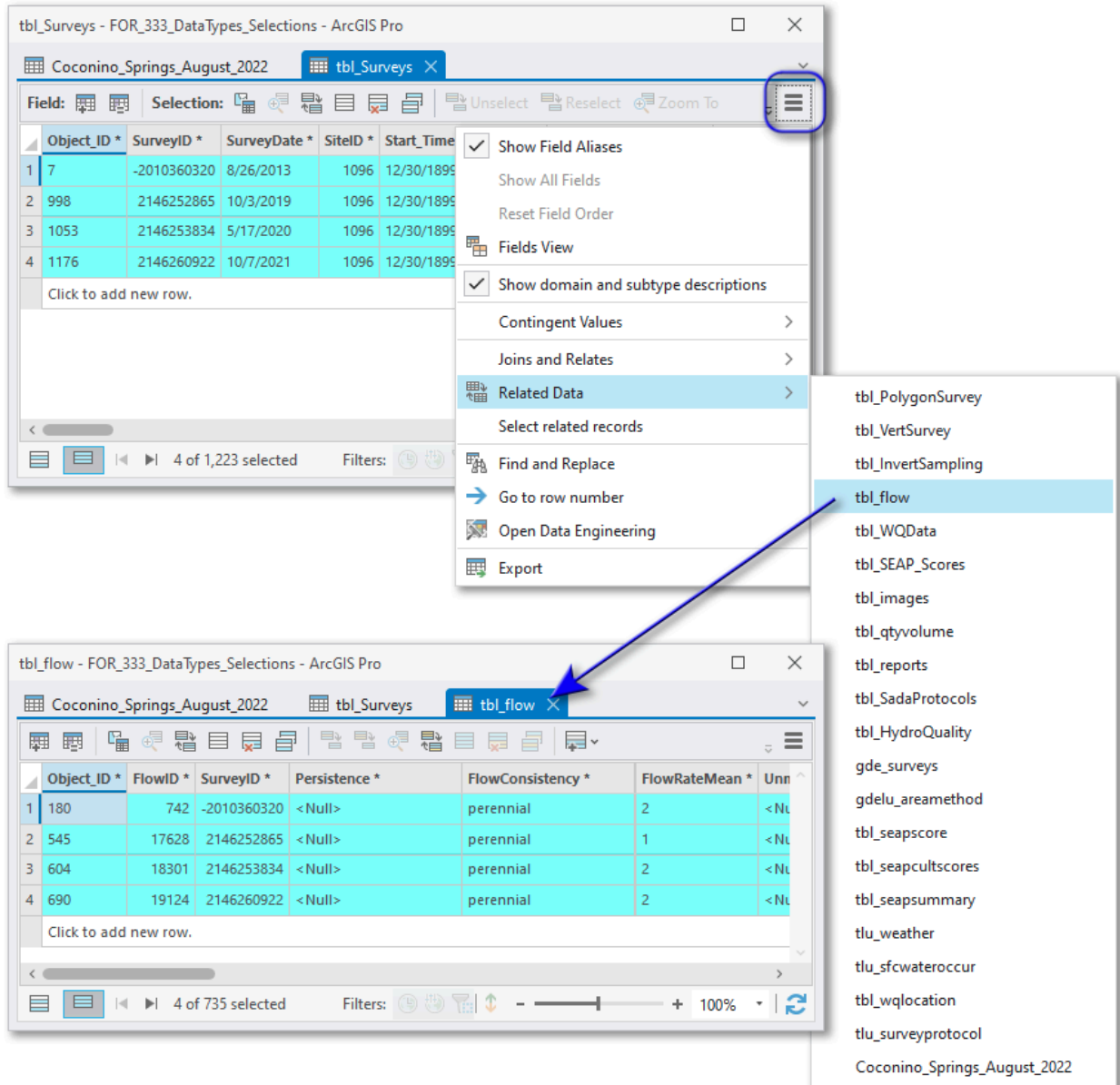
tbl_Surveys Data:

Object_ID *	SurveyID *	SurveyDate *	SiteID *
1	-2107793283	8/11/2002	
2	-2099831296	7/24/2002	1
3	-2031733461	6/10/2002	
4	-2024976226	8/11/2013	1

tbl_images Data:

Object_ID *	Image_ID *	SurveyID *	RecordID	TID *	taxatype	CastImageHyperli
1	4	-242405874	<Null>	<Null>	<Null>	http://springsdata
2	7	1366647561	<Null>	<Null>	<Null>	http://springsdata
3	9	-1959001419	<Null>	<Null>	<Null>	http://springsdata
4	10	-675034504	<Null>	<Null>	<Null>	http://springsdata

4) Click back on **tbl_surveys**, click the burger icon  again, go to “Related Data”, then “tbl_flow”:



The image shows two screenshots from the ArcGIS Pro interface. The top screenshot shows the 'tbl_surveys' table with a context menu open, highlighting the 'Related Data' option. The bottom screenshot shows the 'tbl_flow' table, with a blue arrow pointing from the 'tbl_flow' option in the 'Related Data' menu of the top screenshot to the 'tbl_flow' tab in the bottom screenshot.

tbl_surveys - FOR_333_DataTypes_Selections - ArcGIS Pro

Coconino_Springs_August_2022 | **tbl_surveys**

Field: Selection: Unselect Reselect Zoom To

Object_ID * SurveyID * SurveyDate * SiteID * Start_Time

Object_ID *	SurveyID *	SurveyDate *	SiteID *	Start_Time
7	-2010360320	8/26/2013	1096	12/30/1895
998	2146252865	10/3/2019	1096	12/30/1895
1053	2146253834	5/17/2020	1096	12/30/1895
1176	2146260922	10/7/2021	1096	12/30/1895

Click to add new row.

4 of 1,223 selected | Filters:

Related Data menu options:

- Show Field Aliases
- Show All Fields
- Reset Field Order
- Fields View
- Show domain and subtype descriptions
- Contingent Values
- Joins and Relates
- Related Data**
- Select related records
- Find and Replace
- Go to row number
- Open Data Engineering
- Export

tbl_flow - FOR_333_DataTypes_Selections - ArcGIS Pro

Coconino_Springs_August_2022 | **tbl_surveys** | **tbl_flow**

Object_ID * FlowID * SurveyID * Persistence * FlowConsistency * FlowRateMean * Unn

Object_ID *	FlowID *	SurveyID *	Persistence *	FlowConsistency *	FlowRateMean *	Unn
180	742	-2010360320	<Null>	perennial	2	<Nu
545	17628	2146252865	<Null>	perennial	1	<Nu
604	18301	2146253834	<Null>	perennial	2	<Nu
690	19124	2146260922	<Null>	perennial	2	<Nu

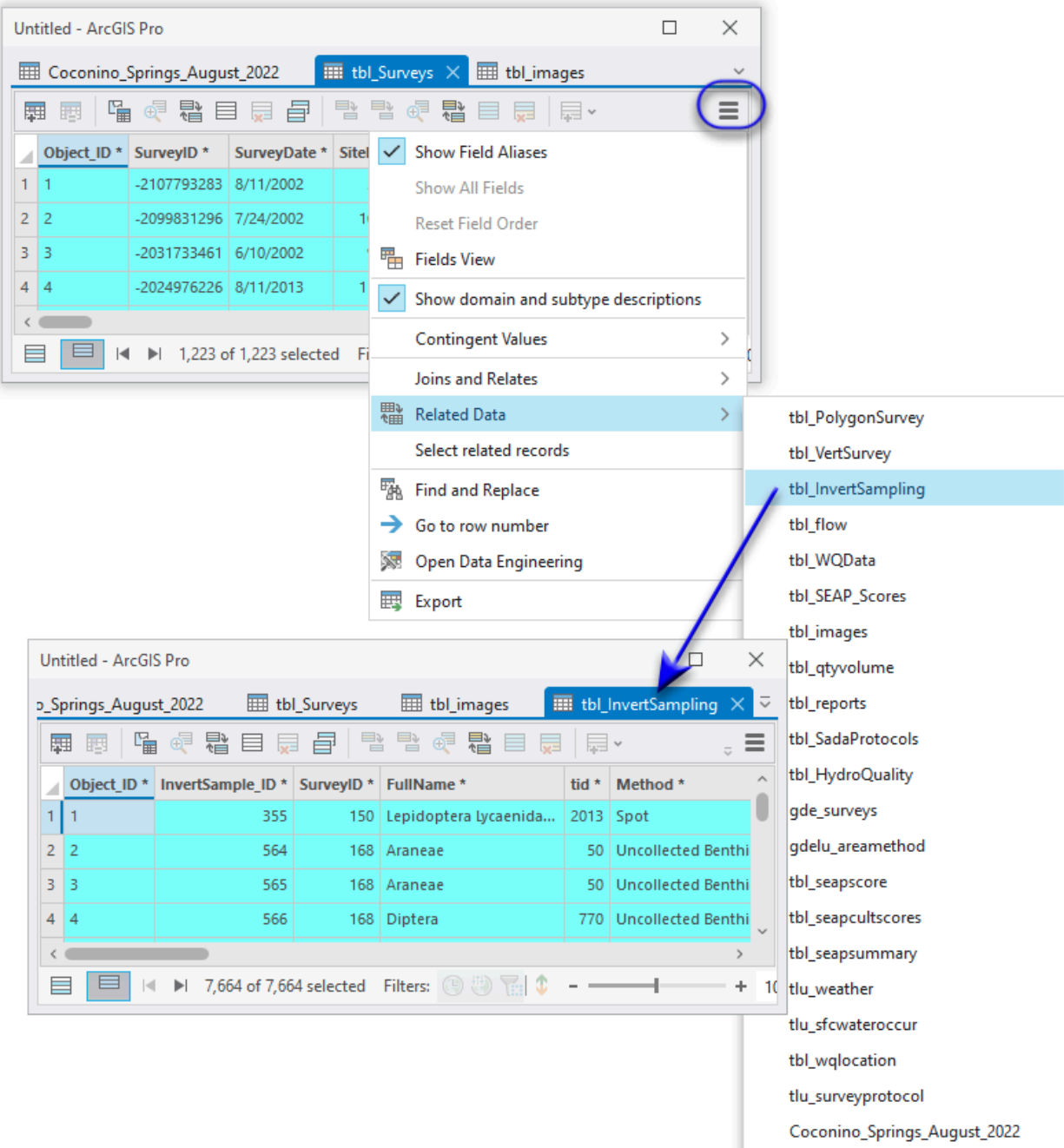
Click to add new row.

4 of 735 selected | Filters: 100%

Related Data menu options (continued):

- tbl_PolygonSurvey
- tbl_VertSurvey
- tbl_InvertSampling
- tbl_flow**
- tbl_WQData
- tbl_SEAP_Scores
- tbl_images
- tbl_qtyvolume
- tbl_reports
- tbl_SadaProtocols
- tbl_HydroQuality
- gde_surveys
- gdelu_areamethod
- tbl_seapscore
- tbl_seapcultscores
- tbl_seapsummary
- tlu_weather
- tlu_sfcwateroccur
- tbl_wqlocation
- tlu_surveyprotocol
- Coconino_Springs_August_2022

- 5) Click back on **tbl_surveys**, click the burger icon  again, go to “Related Data”, then “tbl_InvertSampling”:



The image shows two screenshots of the ArcGIS Pro interface. The top screenshot shows the **tbl_surveys** table selected in the table of contents. A right-click context menu is open, and the **Related Data** option is highlighted. A blue arrow points from the **Related Data** option to the **tbl_InvertSampling** table in the bottom screenshot. The bottom screenshot shows the **tbl_InvertSampling** table selected in the table of contents, displaying its data.

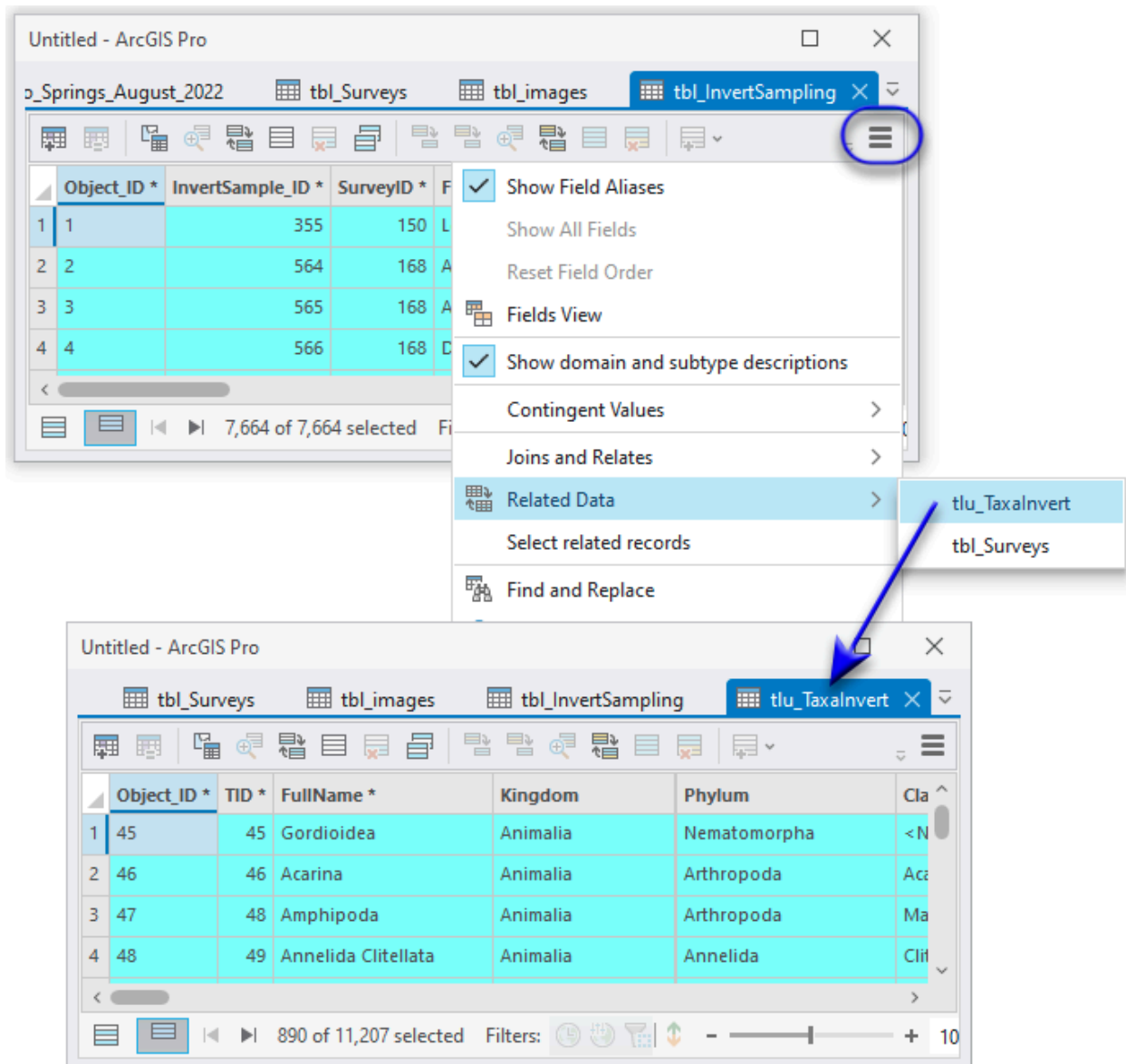
tbl_surveys Data:

Object_ID *	SurveyID *	SurveyDate *	SiteID *
1	-2107793283	8/11/2002	
2	-2099831296	7/24/2002	1
3	-2031733461	6/10/2002	
4	-2024976226	8/11/2013	1

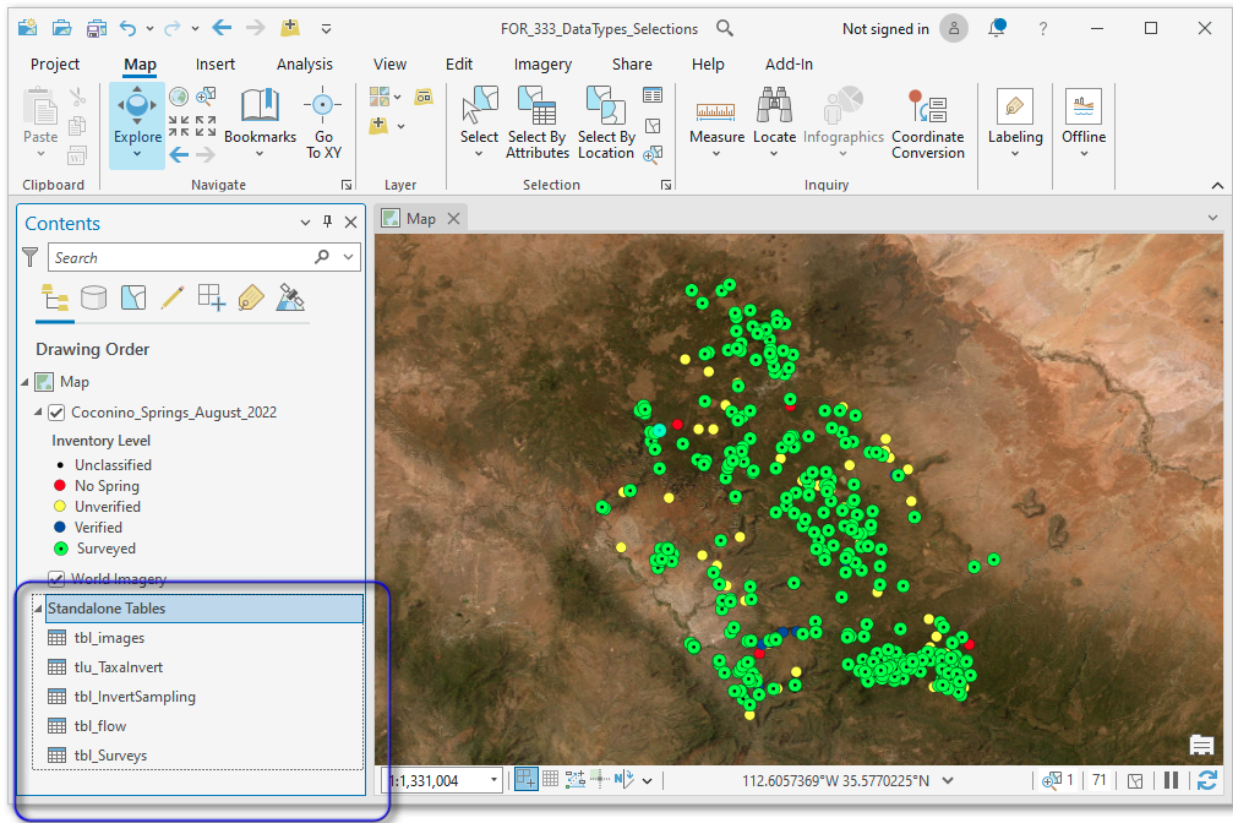
tbl_InvertSampling Data:

Object_ID *	InvertSample_ID *	SurveyID *	FullName *	tid *	Method *
1		355	Lepidoptera lycaenida...	2013	Spot
2		564	Araneae	50	Uncollected Benth...
3		565	Araneae	50	Uncollected Benth...
4		566	Diptera	770	Uncollected Benth...

- 6) With **tbl_InvertSampling** open, click the burger icon  again, go to “Related Data”, then “tlu_TaxalInvert”:



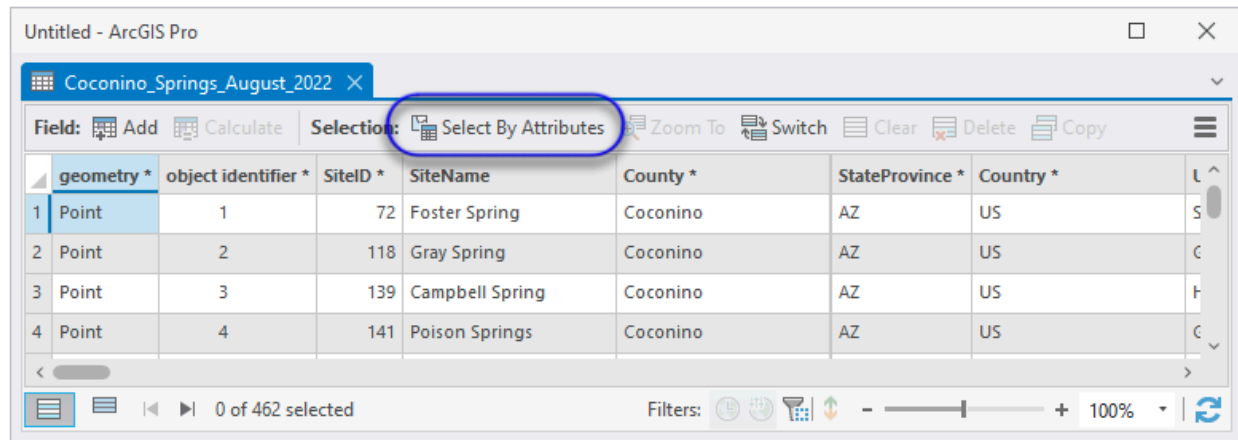
- 7) Close all tables and clear the selection. You should now see the following tables listed in your Standalone Table section of your Contents pane.



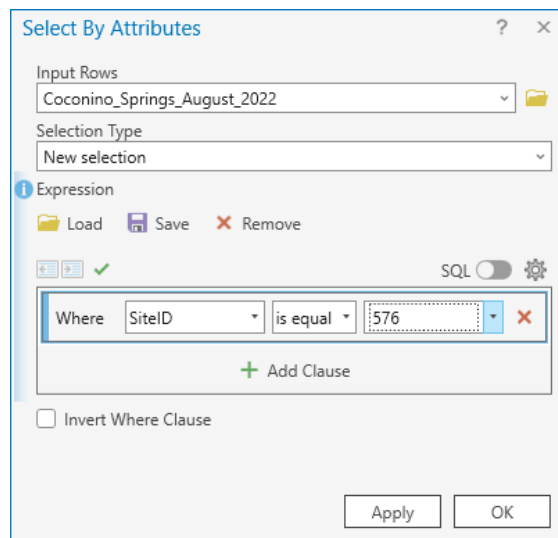
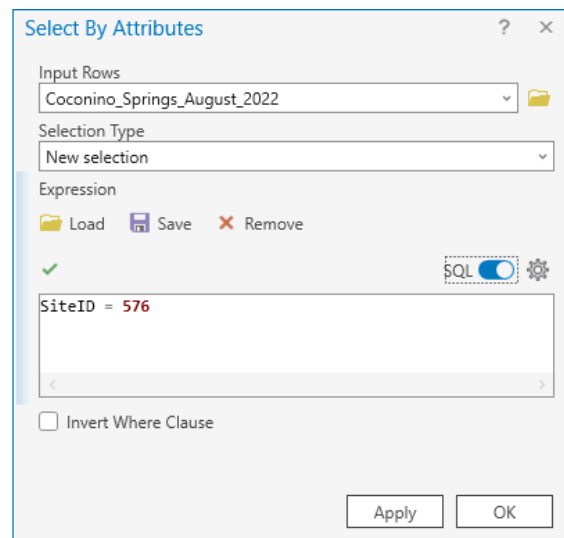
Lab Exercise:

A) Find the measured spring flow at Black Bear Spring [Site ID = 576].

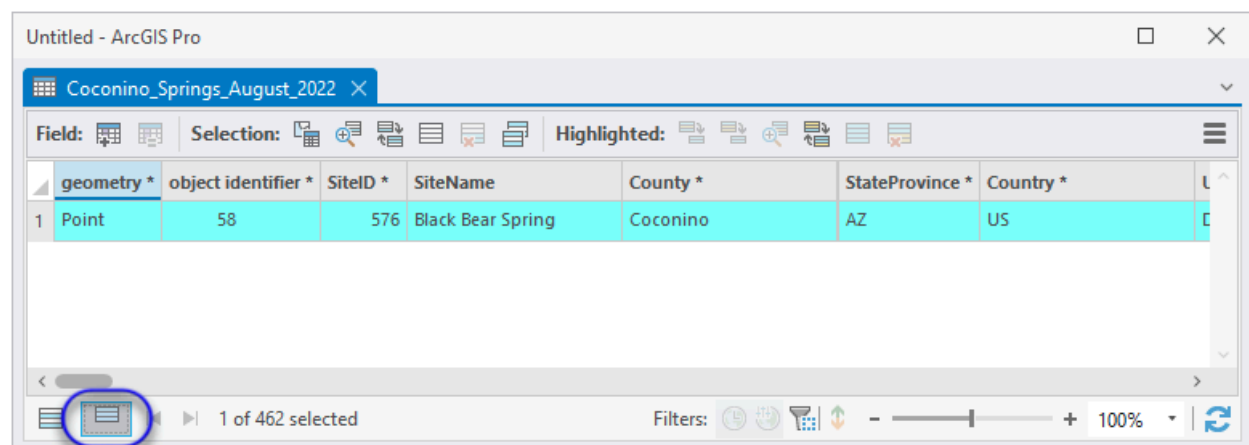
- ☐ Find and navigate to Black Bear Spring [Site ID = 576]. This spring is located near the southeastern corner of the Coconino National Forest, on the Mogollon Ranger District. The images below show the spring with the Imagery basemap layer in the background, at a scale of 1:1,000.
 - Open the attribute table for **Coconino_Springs_August_2022** by either:
 - Selecting the layer in the ArcGIS Pro Contents pane, and hitting the [CONTROL]-T keys
 - Right-clicking on the layer and choosing “Open Attribute Table” in the dropdown menu.
 - In the attribute table window, click the *Select by Attributes* command at the top:



- In the *Select by Attributes* window, select the spring with “SiteID = 576”:

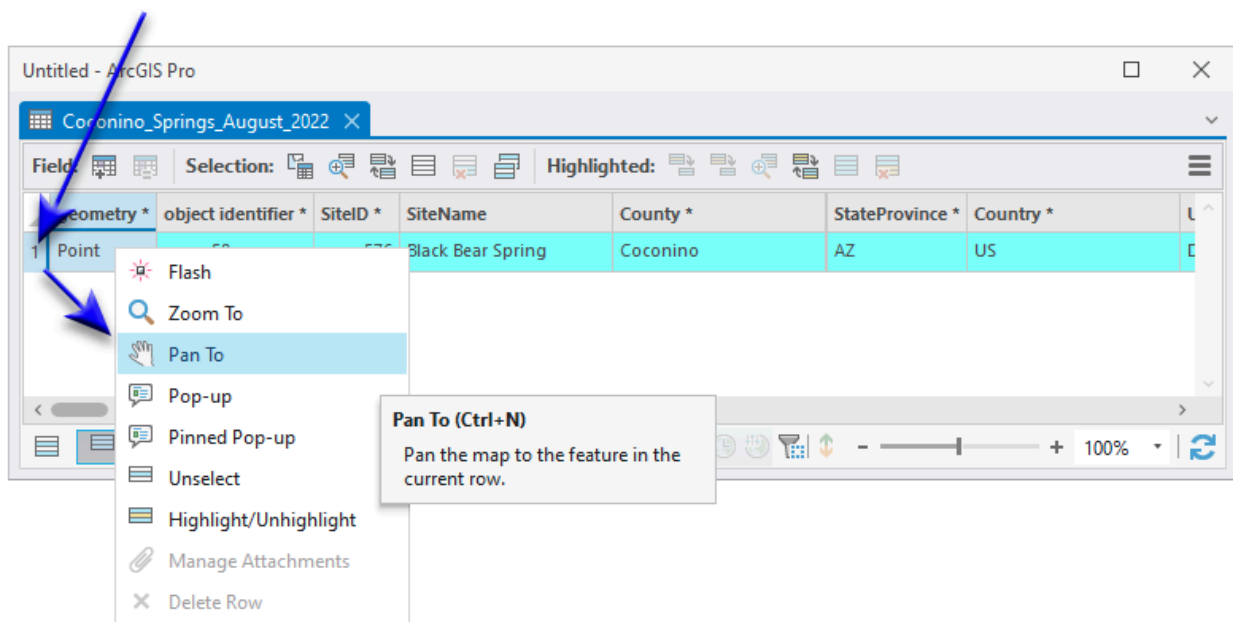


- You should now have a single spring selected. Click the *Show selected records* command to show only that single spring in the table.

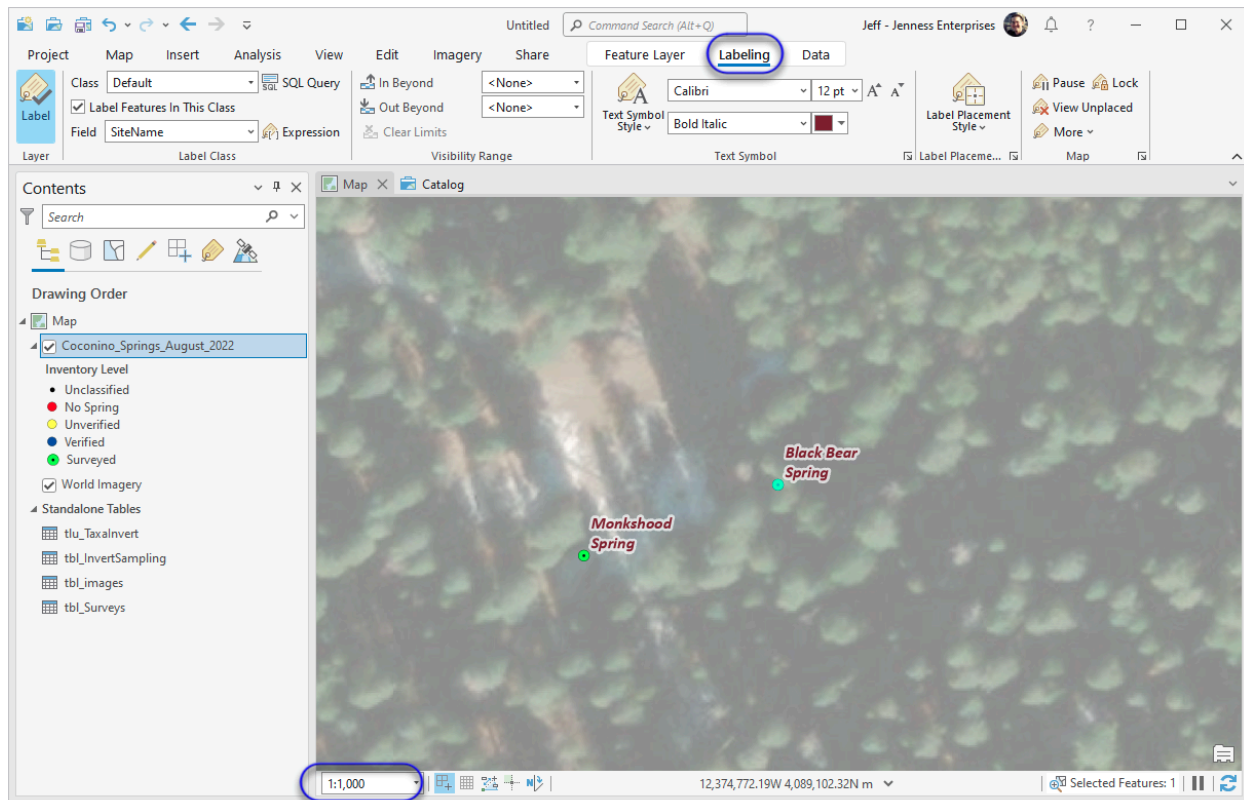


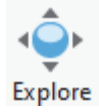
- Pan to the location of Black Bear Spring by right-clicking the gray box on the left side of the record, then choosing *Pan To* in the dropdown menu:

Right-click Here



- Set your map scale to 1:1000. If you like, you can turn on the spring labels by right-clicking the layer **Coconino_Springs_August_2022** and choosing *Label*.





- Use the **Explore** command to click on Black Bear Spring. In the pop-up window, click on the little triangle ▶ on the left side of “Black Bear Spring” to open up all the related tables. Next open the ▶ triangle next to **tblSurveys - tblSurveys**, then open the first survey, and keep on going until you have opened the Flow record. In the illustration below, the Flow record is identified as “174” in the table **tbl_flow**. The measured flow, in Liters per Second, is in the attribute field *MeasuredFlowLS*, and in this case is 0.071 liters per second.

Pop-up

Coconino_Springs_August_2022 (1)

- Black Bear Spring
 - tbl_Surveys - tblSurveys (2)
 - 655558104
 - tbl_PolygonSurvey
 - tbl_VertSurvey
 - tbl_InvertSampling
 - tbl_flow (1)
 - <Null>
 - tbl_WQData
 - tbl_SEAP_Scores
 - tbl_images
 - tbl_qtyvolume
 - tbl_reports
 - tbl_SadaProtocols
 - tbl_HydroQuality
 - gde_surveys
 - gdelu_areamethod
 - tbl_seapscore
 - tbl_seapcultscores
 - tbl_seapsummary
 - tlu_weather
 - tlu_sfcwateroccur
 - tbl_wqlocation
 - tlu_surveyprotocol

<Null>

Object_ID	174
FlowID	726
SurveyID	-655558104
Persistence	<Null>
FlowConsistency	perennial
FlowRateMean	1
Unmeasurable	<Null>
FlowVariability	<Null>
FlowMeasureTech	volume
MsrmtTechDetail	<Null>
UncorrectedFlowLS	<Null>
AverageOrCumulativeFlow	<Null>
SitePercentCaptured	75.00
MeasuredFlowLS	0.07100
MeasurementLocation	Measurements were taken 20m downstream at the western source
SprBrookLnghM	<Null>
WaterDenthCM	<Null>

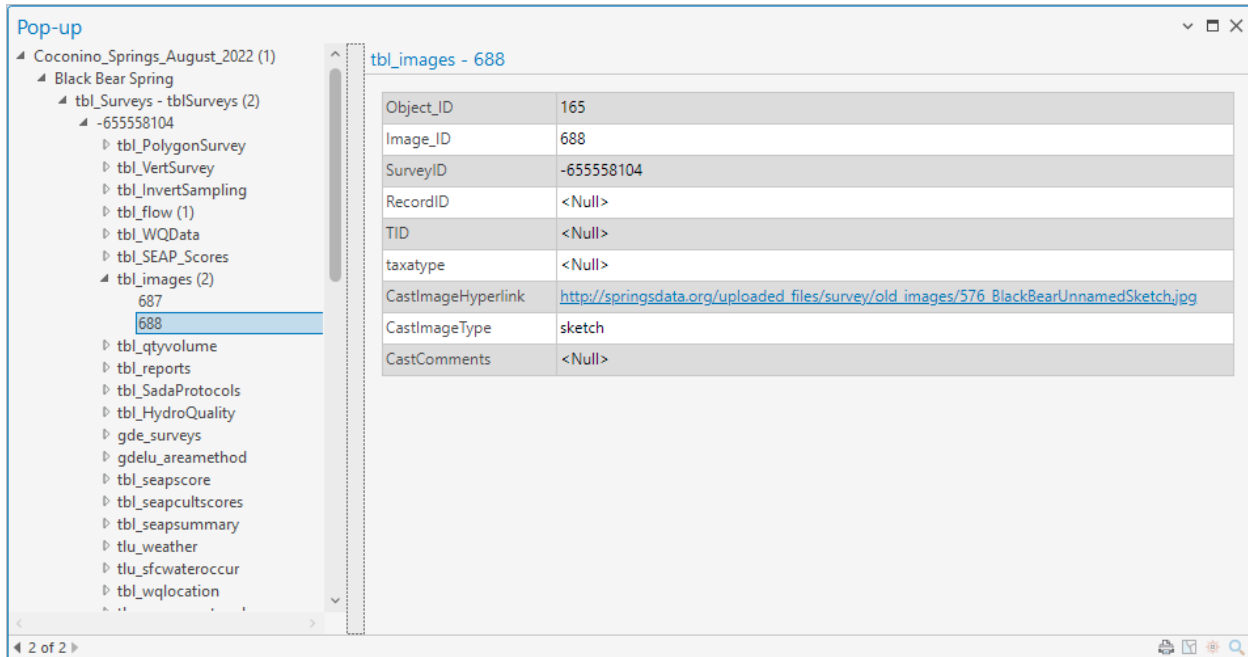
- Keep the *Identify* dialog open for the next exercise.

B) View an Image of Black Bear Spring

- ☐ Black Bear spring has two images associated with it, both accessible from the **Explore** pop-up window.
- ☐ If you have closed the **Explore** pop-up window after the last exercise, then use the **Explore**



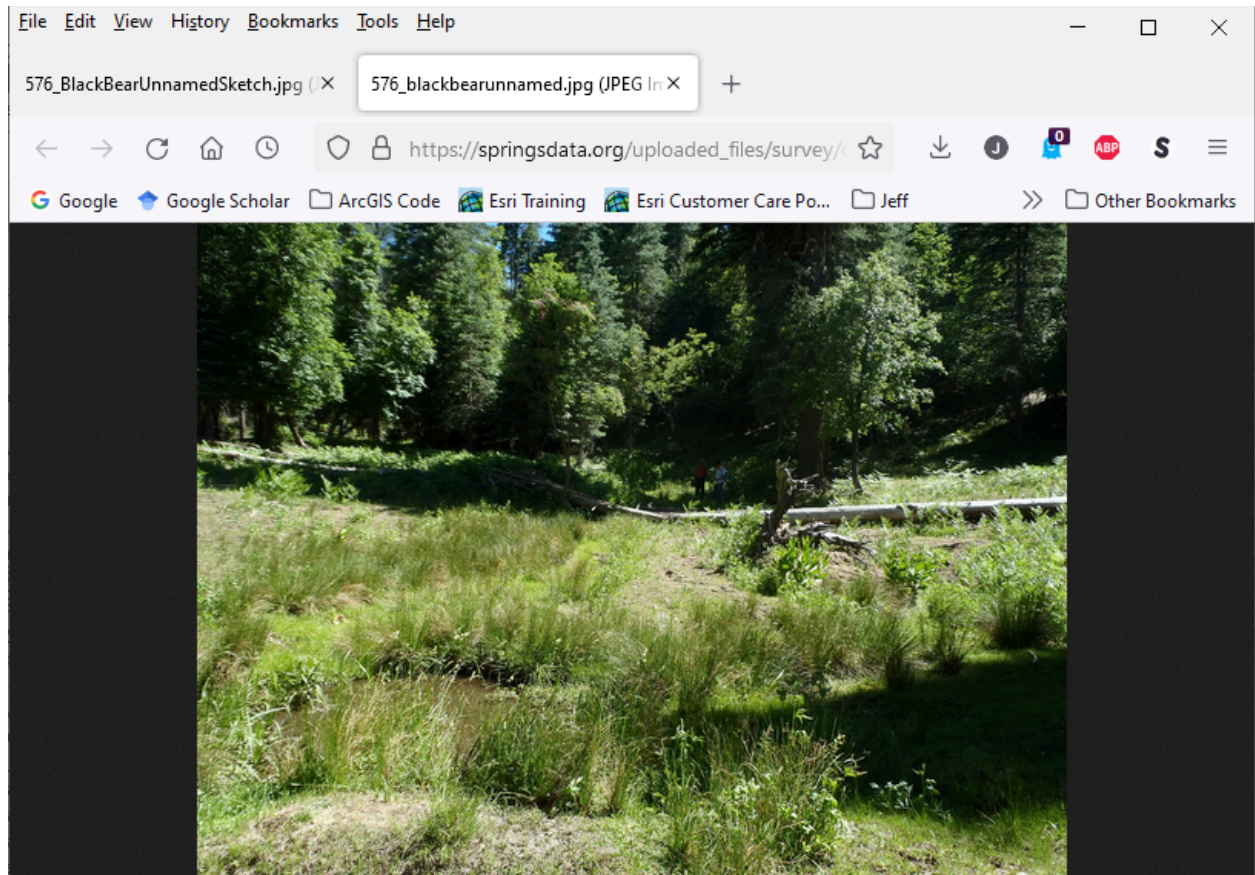
command **Explore** again to click on Black Bear Spring. In the pop-up window, click on the little triangle ▶ on the left side of “Black Bear Spring” to open up all the related tables. Next open the ▶ triangle next to **tblSurveys - tblSurveys**, then open the first survey, and finally open **tbl_images**. You should see two records to click on. One is a sketchmap and the other is a photograph of Black Bear Spring.



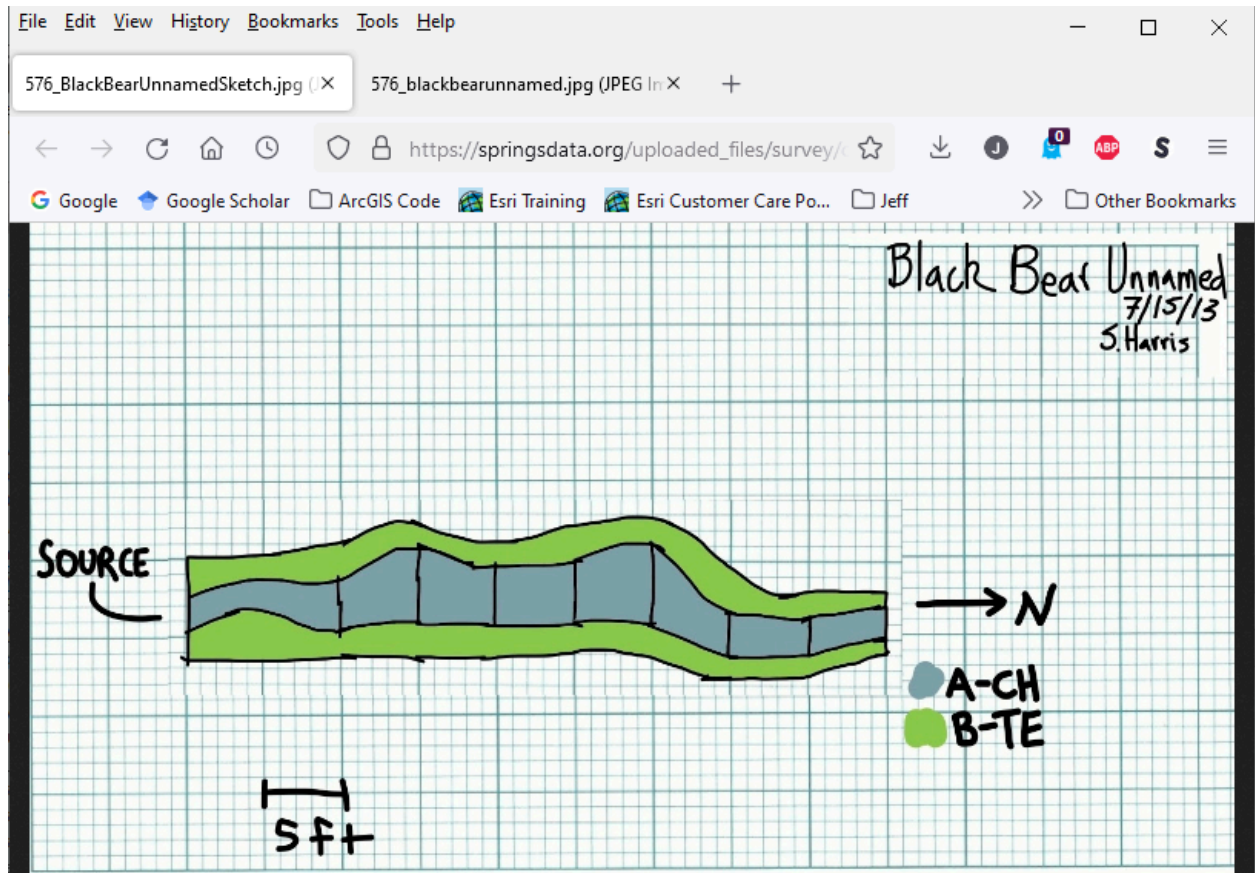
- ☐ In both cases, there is an attribute field named **CastImageHyperlink** that has a link to the web address of the image. If there is a value in this field (and fortunately there is for Black Bear Spring; not all springs have images recorded), it will appear in blue, similar to how hyperlinks usually appear.

CastImageHyperlink	http://springsdata.org/uploaded_files/survey/old_images/576_BlackBearUnnamedSketch.jpg
--------------------	---

- ☐ Simply click the **CastImageHyperlink** value to open the image in a web browser.

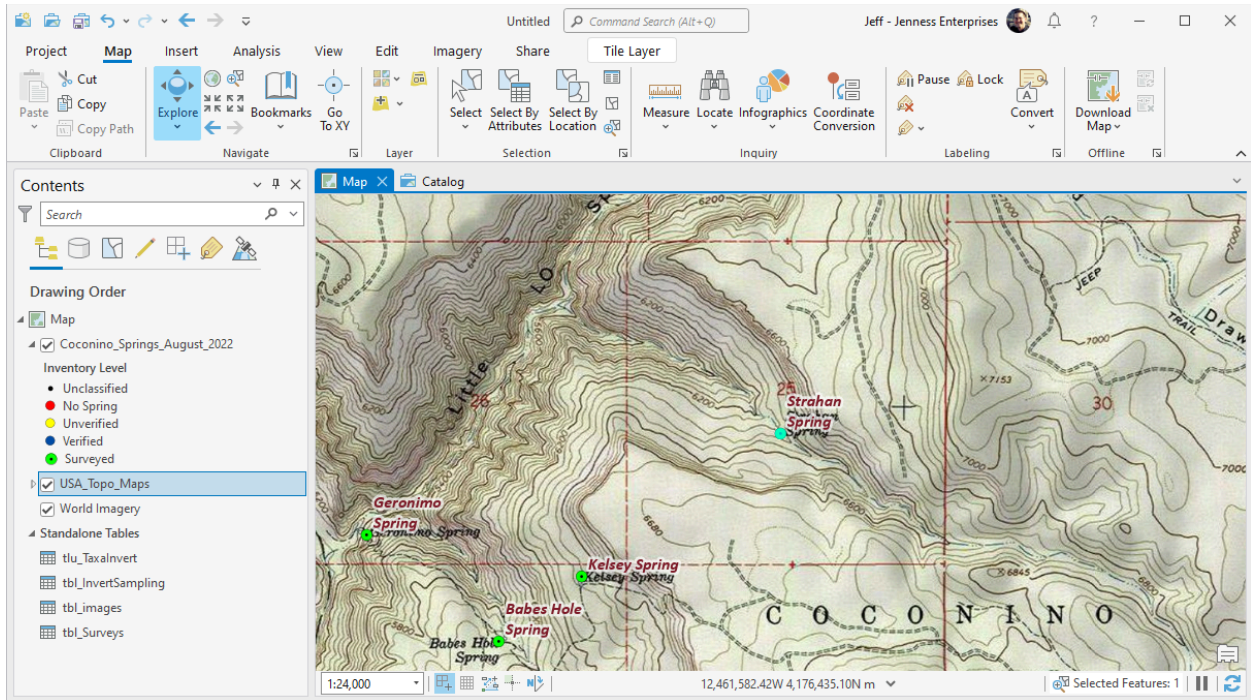


☐ The sketch map looks like this:



□ For Your Homework:

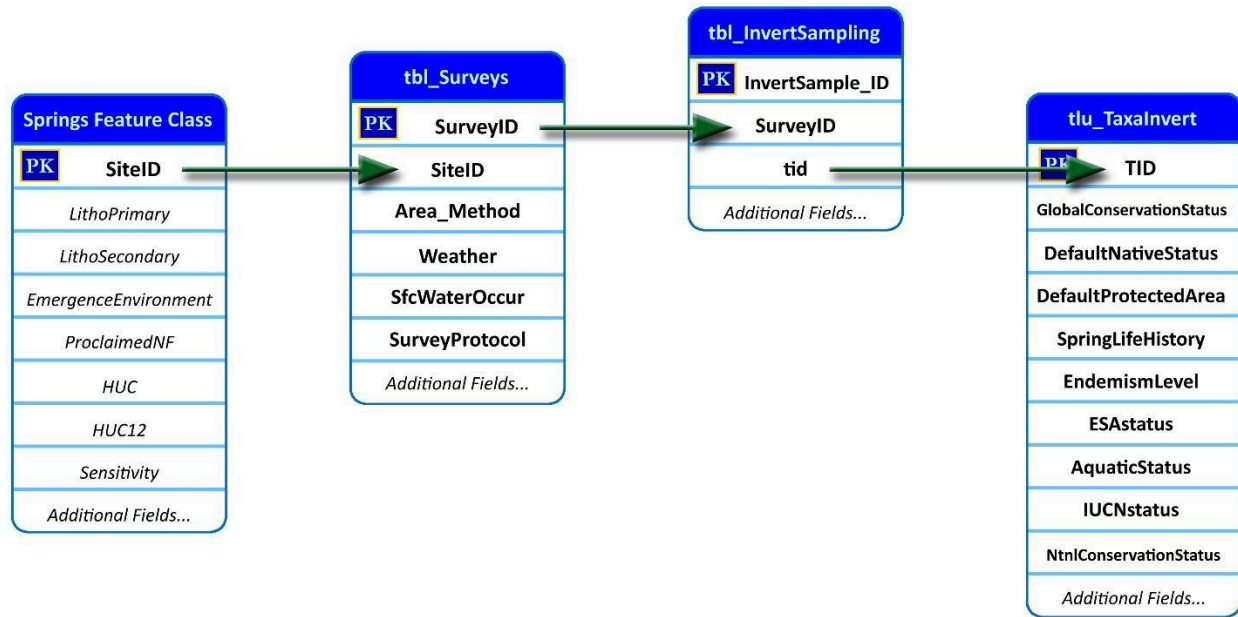
- Repeat the steps above to find the flow and an image for **Strahan Spring (Site ID 1096)**, which is located in Sycamore Canyon south of Camp Navajo. At 1:24,000 scale, with a topo map background, Strahan Spring looks like this:



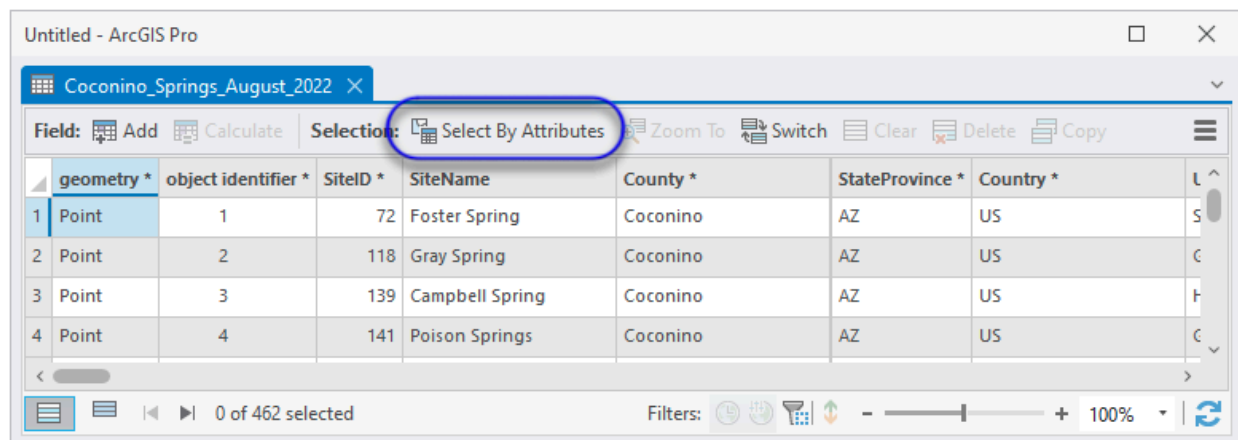
- **Note:** To copy an image for your homework, you should be able to right-click on the image in your Web Browser and just choose “Copy” or “Copy Image”. If not, just take a screen shot and paste it into your homework document. Let me know if you have trouble with this step.

C) Find the Number of Invertebrate Species in a Region

- Find the total number of invertebrate species observed at springs in the Mogollon Ranger District of the Coconino National Forest.
 - We will answer this question by selecting the springs in question, then “pushing” that selection through a series of related tables. Therefore this question requires some knowledge of the structure of the Coconino Springs geodatabase, in order to see how tables are linked. Please open the poster **Springs_Database_Relationship_Classes_Poster.pdf** located in the folder **..\Class_GIS_Data\Relationship_Classes\..**
 - Springs are connected to Invertebrates via a route through several tables. The Spring points are connected to **tbl_Surveys**, which are then connected to **tbl_InvertSampling**, and then to **tlu_TaxaInvert**. Please refer to the poster for the full diagram, but the basic path is as follows:



- ArcGIS Pro provides a simple way to select all species in **tlu_TaxaInvert** based on an initial selection of springs in **Coconino_Springs_August_2022**. Do the following:
- Select all the springs on the Mogollon Ranger District. Open your **Coconino_Springs_August_2022** attribute table by either:
 - Selecting the layer in the ArcGIS Pro Contents pane, and hitting the [CONTROL]-T keys
 - Right-clicking on the layer and choosing “Open Attribute Table” in the dropdown menu.
- In the attribute table window, click the *Select by Attributes* command at the top:



- In the *Select by Attributes* window, select the springs with “LandUnitDetail” = 'Coconino NF, Mogollon Rim RD':

LandUnitDetail = 'Coconino NF, Mogollon Rim RD'

Select By Attributes

Input Rows
Coconino_Springs_August_2022

Selection Type
New selection

Expression
Load Save Remove

SQL ☐

Where LandUnitDetail is equal to 'Coconino NF, Mogollon Rim RD'

+ Add Clause

☐ Invert Where Clause

Apply OK

Select By Attributes

Input Rows
Coconino_Springs_August_2022

Selection Type
New selection

Expression
Load Save Remove

SQL ☒

LandUnitDetail = 'Coconino NF, Mogollon Rim RD'

☐ Invert Where Clause

Apply OK

- With the table open, we see that we have 194 of 462 springs selected.

Untitled - ArcGIS Pro

Coconino_Springs_August_2022

Field:	Selection:	Highlighted:					
geometry *	object identifier *	SitID *	SiteName	County *	StateProvince *	Country *	US
1 Point	1	72	Foster Spring	Coconino	AZ	US	St
2 Point	3	139	Campbell Spring	Coconino	AZ	US	Ha
3 Point	5	143	Clover Spring east	Coconino	AZ	US	Lo
4 Point	6	144	Pivot Rock Spring	Coconino	AZ	US	Pir
5 Point	12	162	Clover Spring West	Coconino	AZ	US	Lo
6 Point	13	392	Dane Spring	Coconino	AZ	US	Da
7 Point	14	393	West Moonshine Spring	Coconino	AZ	US	Da
8 Point	15	411	Merritt Springs	Coconino	AZ	US	Da

194 of 462 selected

Filters: 100%

- Spring features are connected to **tbl_Surveys**, so the next step is to select all surveys that are connected to these selected springs. Click the Burger icon  in the upper right corner of your table, go to "Related Data", then choose "tbl_surveys tbl_surveys". This will automatically load the table **tbl_surveys** and open it, with 580 related survey records selected.

Untitled - ArcGIS Pro

Coconino_Springs_August_2022

Field: Selection: Highlighted:

	geometry *	object identifier *	SiteID *	SiteName	County *
1	Point	1	72	Foster Spring	Coconino
2	Point	3	139	Campbell Spring	Coconino
3	Point	5	143	Clover Spring east	Coconino
4	Point	6	144	Pivot Rock Spring	Coconino
5	Point	12	162	Clover Spring West	Coconino
6	Point	13	392	Dane Spring	Coconino
7	Point	14	393	West Moonshine Spring	Coconino
8	Point	15	411	Merritt Springs	Coconino

194 of 462 selected

Filters:

Related Data

- tbl_Surveys - tblSurveys
- tbl_PolygonSite
- tbl_Solar
- tlu_lithoprimary
- tlu_lithosecondary
- tlu_emergenceenvironment
- tlu_proclaimednf
- tlu_huc
- tlu_huc12
- tbl_site_treatment
- tlu_sensitive

Untitled - ArcGIS Pro

Coconino_Springs_August_2022

tbl_Surveys

Field: Selection: Highlighted: Rows:

	Object_ID *	SurveyID *	SurveyDate *	SiteID *	Start_Time	End_Time	CastSurveyors	SurveyProtoc
1	1	-2107793283	8/11/2002	590	12/30/1899 9:00:00 AM	<Null>	Stephen Flora / Rebec...	9
2	6	-2013827055	6/11/2013	1116	12/30/1899 10:30:00 AM	12/30/1899 11:45:00 AM	Kyle Paffett, Krista Spa...	4
3	9	-1954228068	9/20/2009	424	12/30/1899 12:00:00 PM	12/30/1899 1:30:00 PM	Jeri Ledbetter, Eric Nor...	4
4	10	-1941029280	9/18/2009	431	12/30/1899 10:45:00 AM	12/30/1899 12:30:00 PM	RJ Johnson, Eric North...	8
5	14	-1862946008	8/9/2012	1018	12/30/1899 3:00:00 PM	12/30/1899 4:00:00 PM	Kyle Paffett and Vera...	8
6	16	-1832500695	8/10/2012	549	12/30/1899 10:00:00 AM	12/30/1899 11:00:00 AM	Kyle Paffett, Vera Mark...	4
7	17	-1802687155	9/11/2009	419	12/30/1899 1:00:00 PM	12/30/1899 2:15:00 PM	Jeri Ledbetter, Eric Nor...	4
8	18	-1788189249	8/20/2010	595	12/30/1899 9:30:00 AM	12/30/1899 11:00:00 AM	Jeri Ledbetter, Glen Ri...	4

580 of 1,223 selected

Filters:

- This means that 580 surveys have been conducted on the original set of 194 springs.
- The next table in the chain is **tbl_InvertSampling**, so click back on the table **tbl_surveys**, click the burger icon  again, go to “Related Data”, then “tbl_InvertSampling”. We see the table **tbl_InvertSampling** open with 4,894 selected records.

Untitled - ArcGIS Pro

Coconino_Springs_August_2022

Field: Selection: Highlighted: Rows:

tbl_Surveys

Object_ID * SurveyID * SurveyDate * SiteID * Start_Time End_Time

1 1 -2107793283 8/11/2002 590 12/30/1899 9:00:00 AM <Null>

2 6 -2013827055 6/11/2013 1116 12/30/1899 10:30:00 AM 12/30/1899 11:30:00 AM

3 9 -1954228068 9/20/2009 424 12/30/1899 12:00:00 PM 12/30/1899 1:30:00 PM

4 10 -1941029280 9/18/2009 431 12/30/1899 10:45:00 AM 12/30/1899 12:00:00 PM

5 14 -1862946008 8/9/2012 1018 12/30/1899 3:00:00 PM 12/30/1899 4:00:00 PM

6 16 -1832500695 8/10/2012 549 12/30/1899 10:00:00 AM 12/30/1899 11:00:00 AM

7 17 -1802687155 9/11/2009 419 12/30/1899 1:00:00 PM 12/30/1899 2:00:00 PM

8 18 -1788189249 8/20/2010 595 12/30/1899 9:30:00 AM 12/30/1899 11:00:00 AM

580 of 1,223 selected

Filters:

Show Field Aliases

Show All Fields

Reset Field Order

Fields View

Show domain and subtype descriptions

Contingent Values

Joins and Relates

Related Data

Select related records

Find and Replace

Go to row number

tbl_PolygonSurvey

tbl_VertSurvey

tbl_InvertSampling

tbl_flow

tbl_WQData

tbl_SEAP_Scores

tbl_images

tbl_qtyvolume

tbl_reports

tbl_SadaProtocols

tbl_HydroQuality

gde_surveys

gdelu_areamethod

tbl_seapscore

tbl_seapcultscores

tbl_seapsummary

tlu_weather

tlu_sfcwateroccur

tbl_wqlocation

tlu_surveyprotocol

Coconino_Springs_August_2022

Untitled - ArcGIS Pro

Coconino_Springs_August_2022

Field: Selection: Highlighted: Rows:

tbl_InvertSampling

Object_ID * InvertSample_ID * SurveyID * FullName * tid * Method * SampleArea RepAmt TotalReps Qt

1 1 355 150 Lepidoptera lycaenida... 2013 Spot <Null> <Null> <Null> 1

2 2 564 168 Araneae 50 Uncollected Benthic 0.0929 1 3 1

3 3 565 168 Araneae 50 Uncollected Benthic 0.0929 1 3 1

4 4 566 168 Diptera 770 Uncollected Benthic 0.0929 1 3 2

5 5 567 168 Diptera 770 Uncollected Benthic 0.0929 1 3 1

6 6 568 168 Mollusca 2433 Uncollected Benthic 0.0929 1 3 3

7 7 569 168 Mollusca 2433 Uncollected Benthic 0.0929 1 3 1

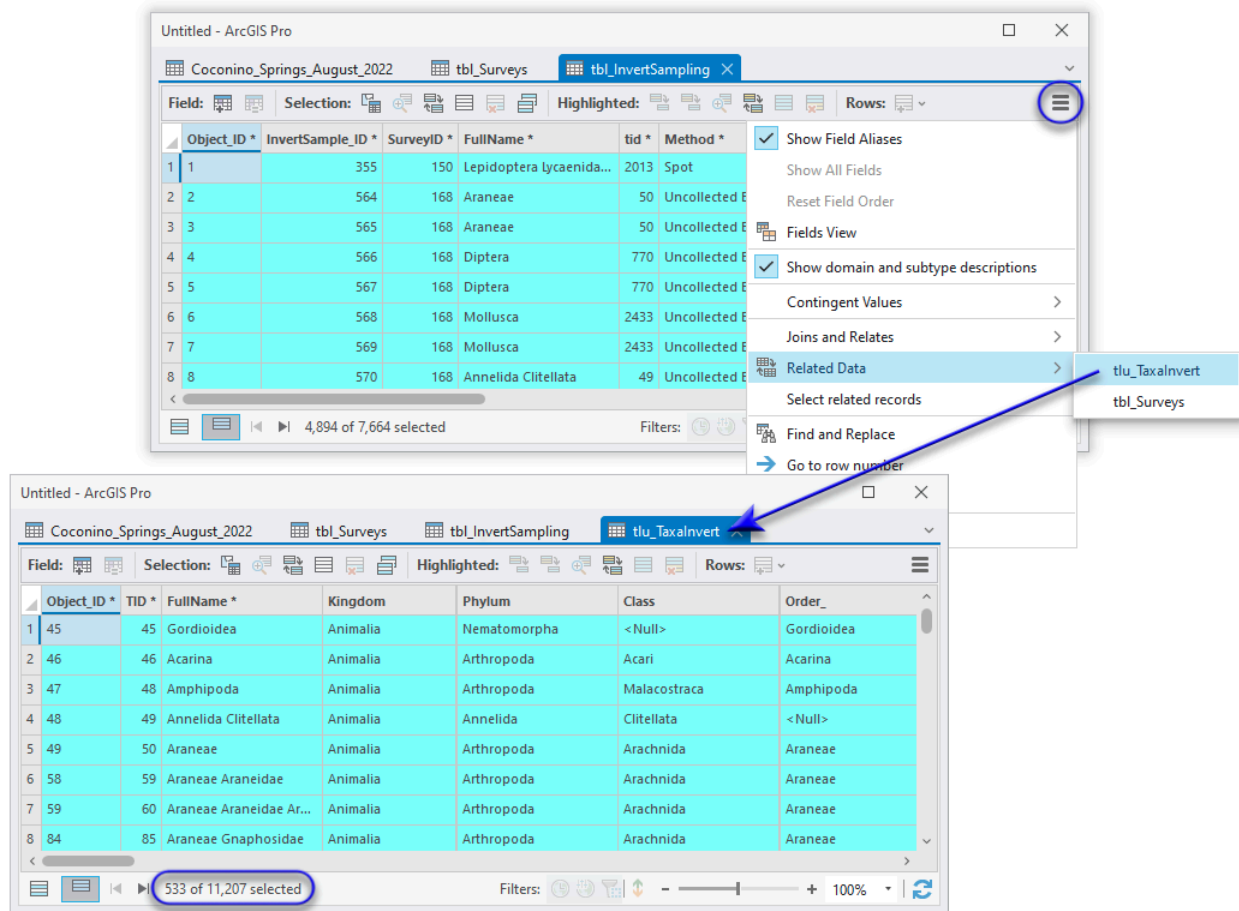
8 8 570 168 Annelida Clitellata 49 Uncollected Benthic 0.0929 1 3 2

4,894 of 7,664 selected

Filters:

100%

- This means that, over the course of those 580 surveys, some invertebrate has been recorded 4,894 times.
- The last table in the chain is **tlu_TaxaInvert**, so with **tbl_InvertSampling** open, click the burger icon  again, go to “Related Data”, then “tlu_TaxaInvert”. We see the table **tlu_TaxaInvert** open with 533 selected records.



- And now we have our final table, with our final selection. This tells us that there are 533 unique invertebrate species distributed amongst the 4,894 recorded observations from **tbl_InvertSampling**, and therefore there are 533 unique invertebrate species observed in all surveys conducted on the Mogollon Ranger District springs.

- **For Your Homework:** Repeat the steps above to find the total number of invertebrate species recorded at springs on the **Mormon Lake Ranger District** of the Coconino National Forest. First open your **Coconino_Springs_August_2022** attribute table, click the *Select by Attributes* command, and make an initial selection of springs with the following query string:

LandUnitDetail = 'Coconino NF, Mormon Lake RD'

Select By Attributes

Input Rows
Coconino_Springs_August_2022

Selection Type
New selection

Expression
Load Save Remove

SQL ☐

Where LandUnitDetail is equal to no NF, Mormon Lake RD

+ Add Clause

Apply OK

Select By Attributes

Input Rows
Coconino_Springs_August_2022

Selection Type
New selection

Expression
Load Save Remove

SQL ☒

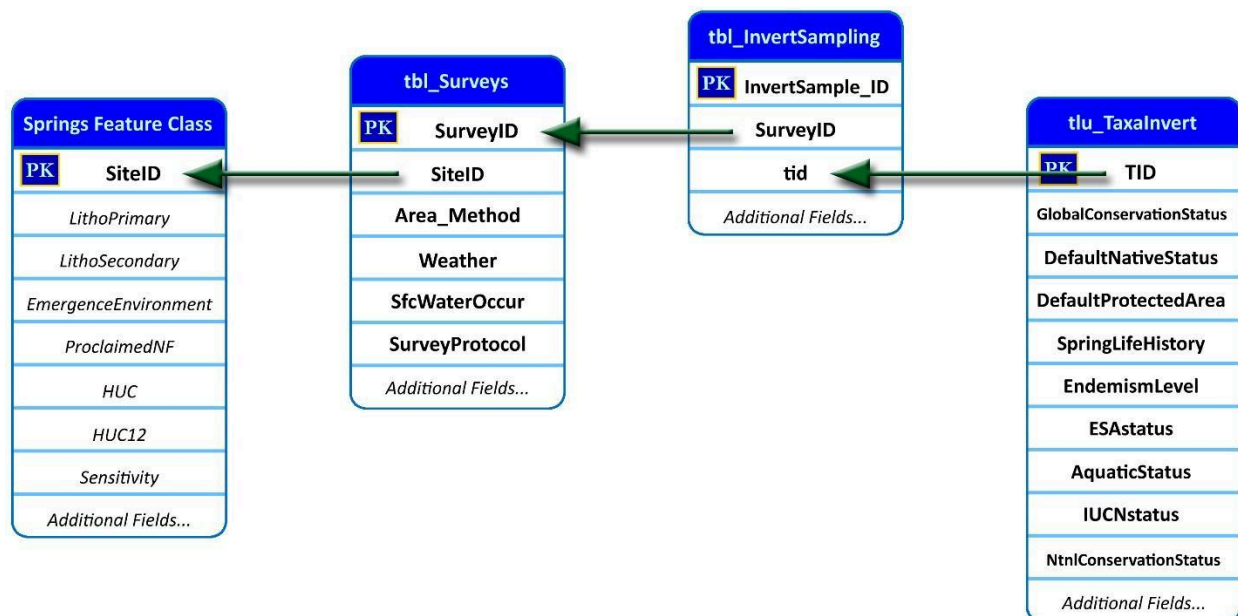
LandUnitDetail = 'Coconino NF, Mormon Lake RD'

Apply OK

- ☐ **Hint:** I am expecting between 250 and 300 unique invertebrate species.

D) Find the spatial distribution of a species

- Find the total number and distribution of springs where Western Tiger Swallowtail butterflies (*Lepidoptera Papilionidae Papilio rutulus*) have been observed.
 - In the previous example, we found all species that were observed at a set of springs. A related task is to identify all springs at which a species (or multiple species) have been observed. We can take advantage of the same series of related tables as in the last example, but going in the opposite direction.
 - We will answer this new question by selecting the **species** in question, then pushing that selection through the same series of related tables but in reverse order. Please refer back to the poster **Springs_Database_Relationship_Classes_Poster.pdf** located in the folder **..\Class_GIS_Data\Relationship_Classes\...** In this case we will traverse the network of linked tables in this order:



- Open **tbl_TaxaInvert** and select the species you wish to analyze. This example will find all springs where the Western Tiger Swallowtail (*Lepidoptera Papilionidae Papilio rutulus*) have been observed. In this case your query string will likely be something like this (and note that you can also query on any other attribute field if you wish):

CommonName = 'Western Tiger Swallowtail'

Select By Attributes

Input Rows
tlu_TaxalInvert

Selection Type
New selection

Expression

Load Save Remove

SQL ☐

Where CommonName is equal to Western Tiger Swallowtail

+ Add Clause

☐ Invert Where Clause

Apply OK

Select By Attributes

Input Rows
tlu_TaxalInvert

Selection Type
New selection

Expression

Load Save Remove

SQL ☒

CommonName = 'Western Tiger Swallowtail'

☐ Invert Where Clause

Apply OK

- With the table open, we see that we have 1 species selected.

Untitled - ArcGIS Pro

tlu_TaxalInvert

Field:

Selection:

Highlighted:

Rows:

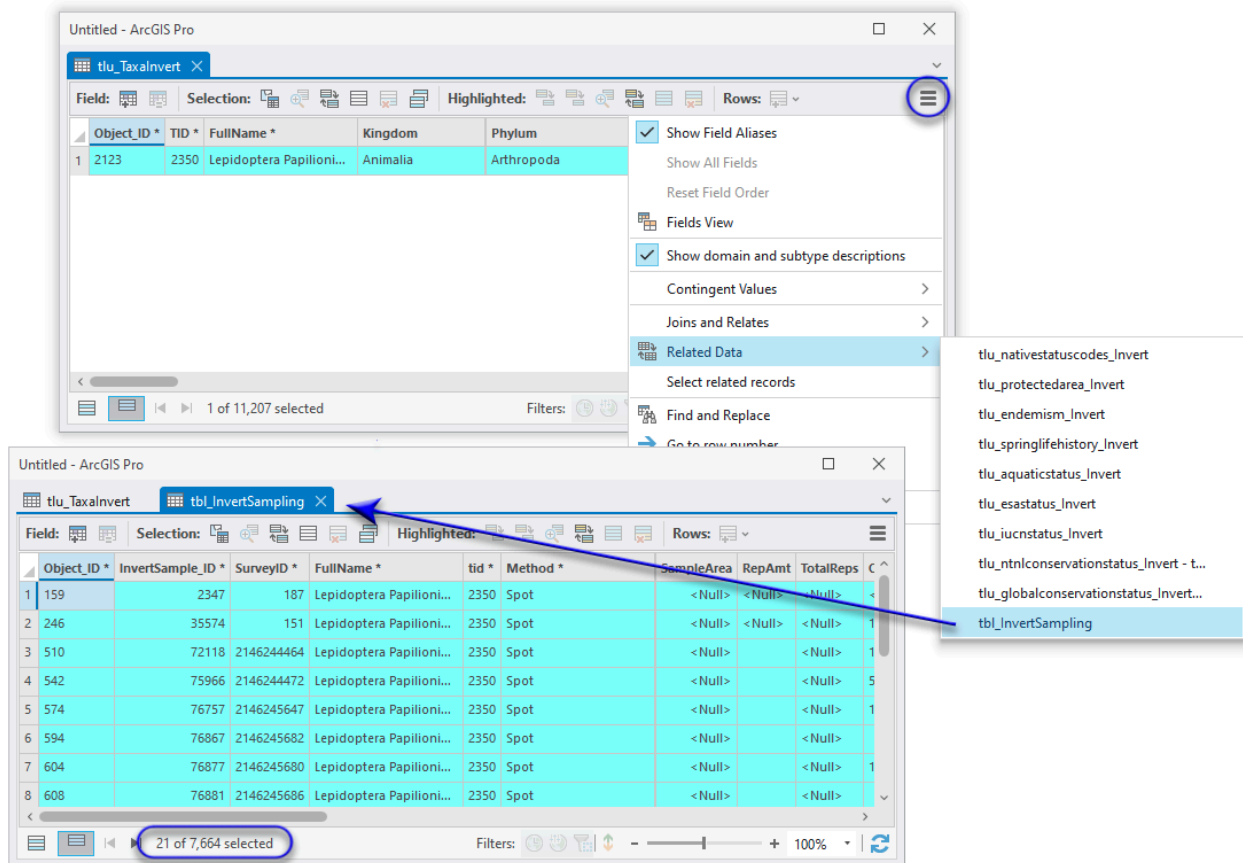
Object_ID *	TID *	FullName *	Kingdom	Phylum	Class	Order_
1	2123	Lepidoptera Papilioni...	Animalia	Arthropoda	Insecta	Lepidoptera

1 of 11,207 selected

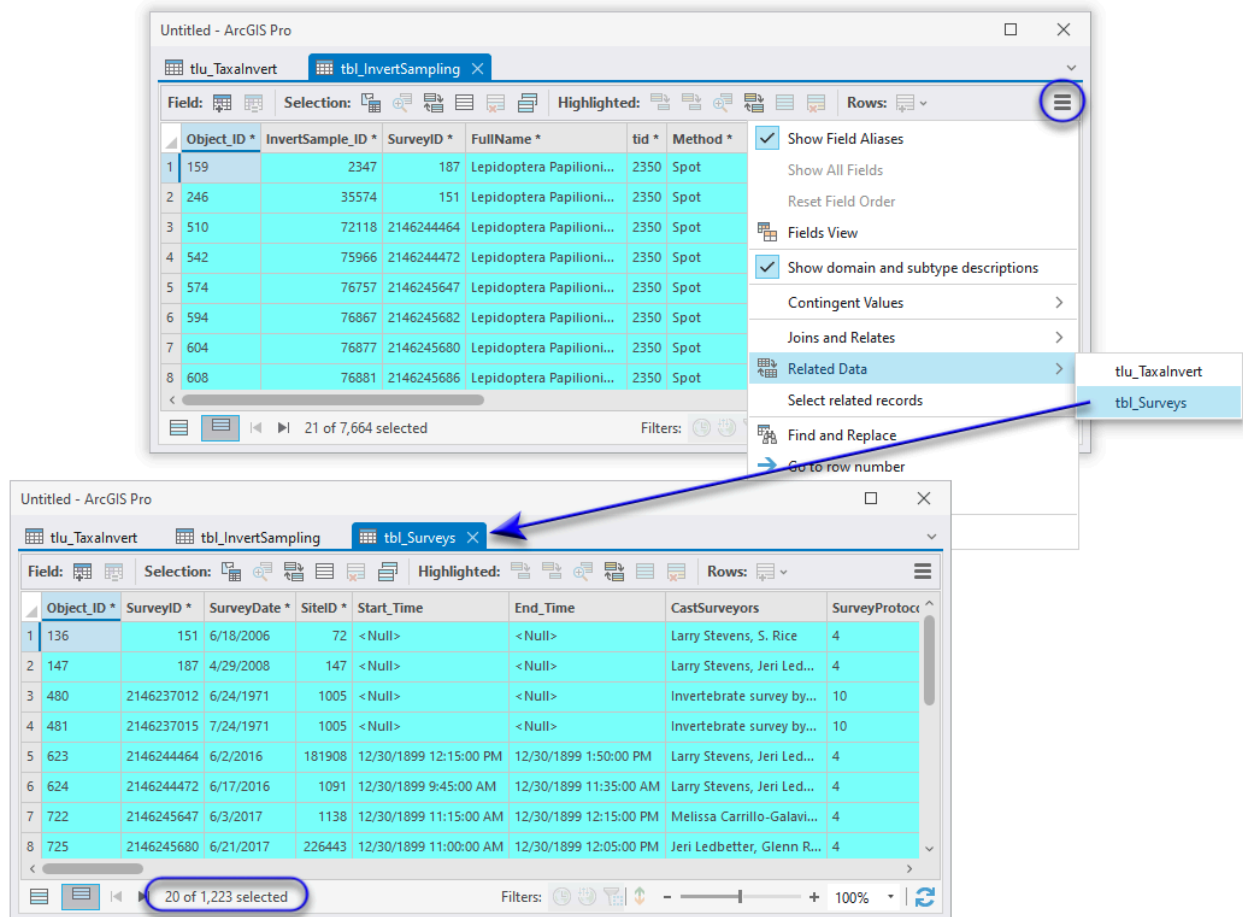
Filters: 100%

- tlu_TaxalInvert records are connected to tbl_InvertSampling, so the next step is to select all Invertebrate Sampling records that are connected to the Western Tiger Swallowtail record.

With tlu_TaxalInvert open, click the burger icon  again, go to "Related Data", then "tbl_InvertSampling". We see the table tbl_InvertSampling open with 21 selected records:

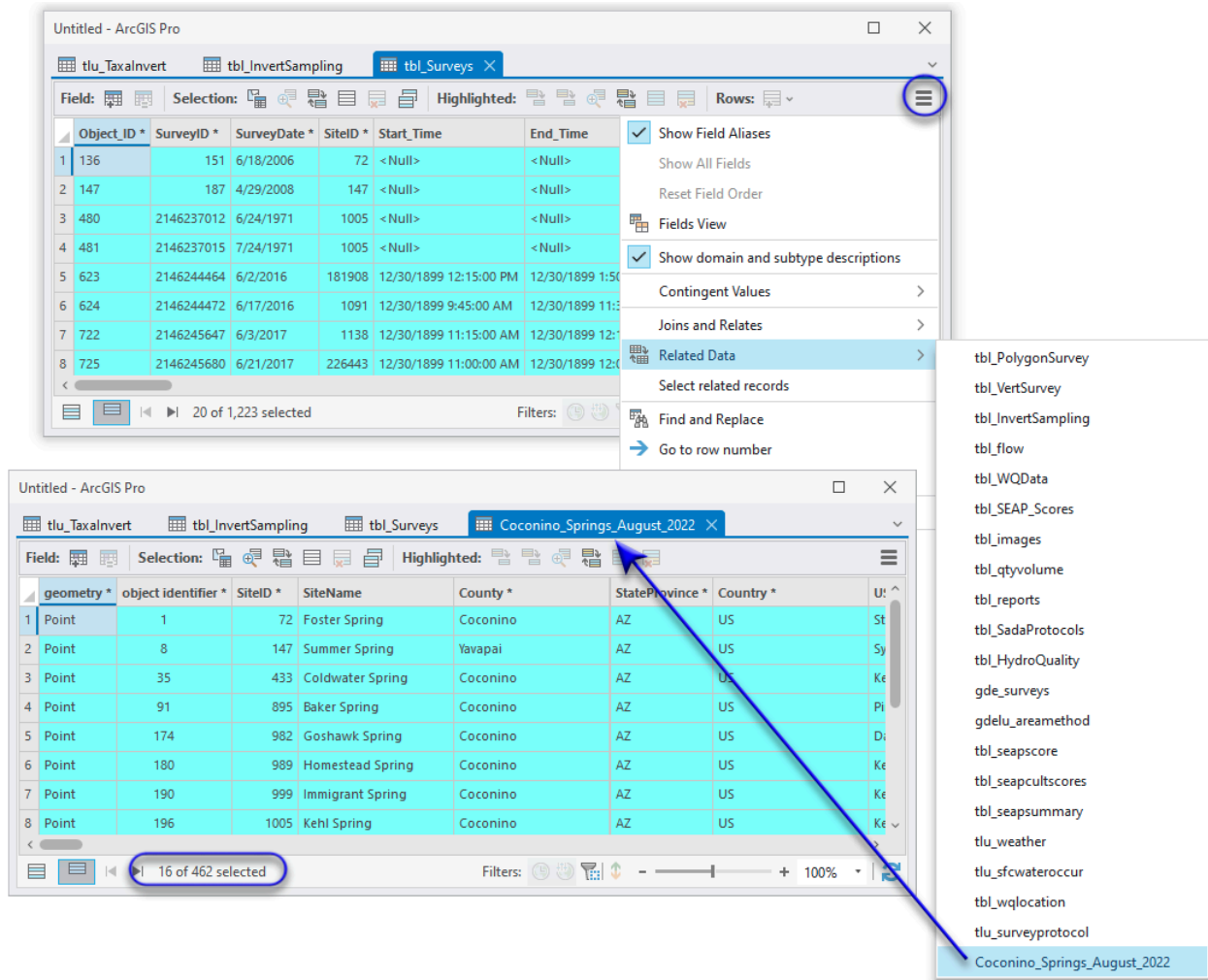


- This means that Western Tiger Swallowtails have been recorded 21 times.
- The next table in the chain is **tbl_Surveys**, so With **tbl_InvertSampling** open, click the burger icon  again, go to “Related Data”, then “tbl_Surveys”. We see the table **tbl_Surveys** open with 20 selected records:



- This means that those 21 recorded observations of Western Tiger Swallowtails occurred on 20 different surveys.
- The last table in the chain is the actual springs feature class

Coconino_Springs_August_2022, so With **tbl_Surveys** open, click the burger icon  again, go to “Related Data”, then “tbl_Surveys”. We see the attribute table for **Coconino_Springs_August_2022** open with 16 selected spring features:



- And now we are back to our Springs feature class, with all the springs selected that have recorded an observation of Western Tiger Swallowtail. This tells us that this species has been recorded at 16 of 462 springs.
- We may easily see where these springs are by viewing our Springs feature class in the map. Right-click in the gray box on the left side of the attribute table, of any of the selected springs, and choose “Zoom to Selected”.

Zoom to Selected

Untitled - ArcGIS Pro

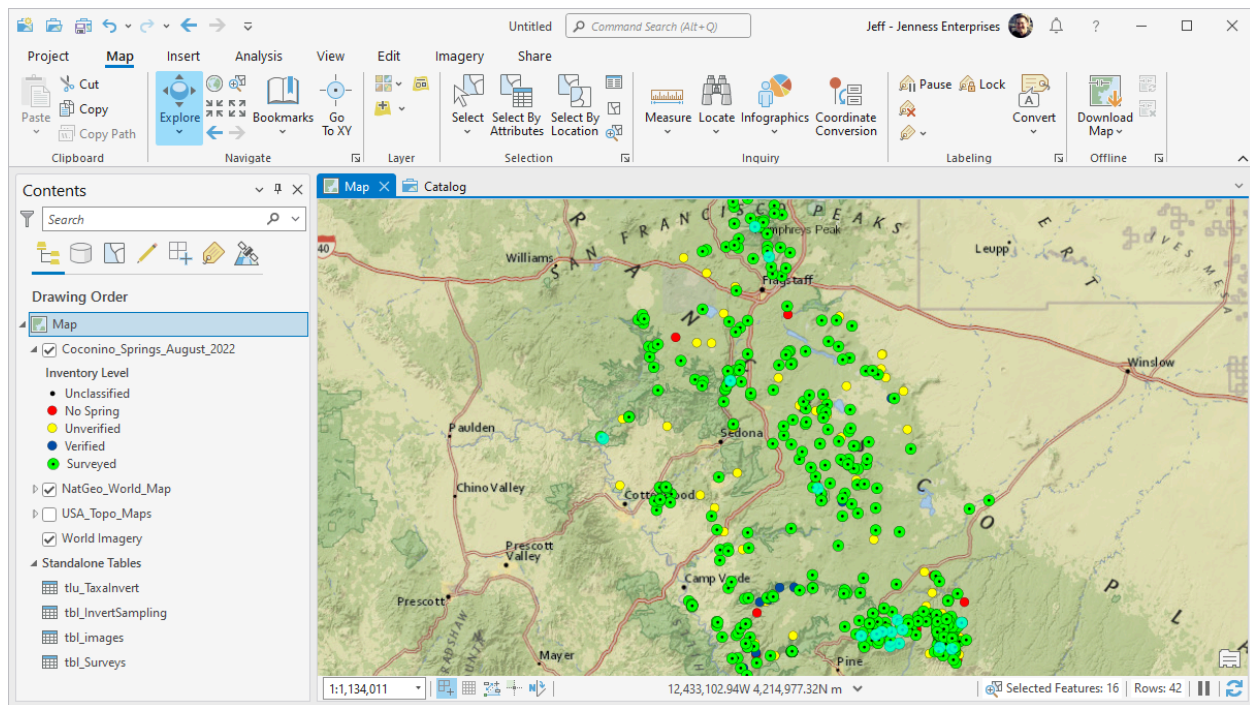
Field: Selection: Highlighted:

	geometry *	object identifier *	SiteID *	SiteName	County *	StateProvince *	Country *	U:
1	Point	1	72	Foster Spring	Coconino	AZ	US	St
2	Point	8	147	Summer Spring	Yavapai	AZ	US	Sy
3	Point	35	433	Coldwater Spring	Coconino	AZ	US	Ke
4	Point	91	895	Baker Spring	Coconino	AZ	US	Pl
5	Point	174	982	Goshawk Spring	Coconino	AZ	US	Di
6	Point	180	989	Homestead Spring	Coconino	AZ	US	Ke
7	Point	190	999	Immigrant Spring	Coconino	AZ	US	Ke
8	Point	196	1005	Kehl Spring	Coconino	AZ	US	Ke

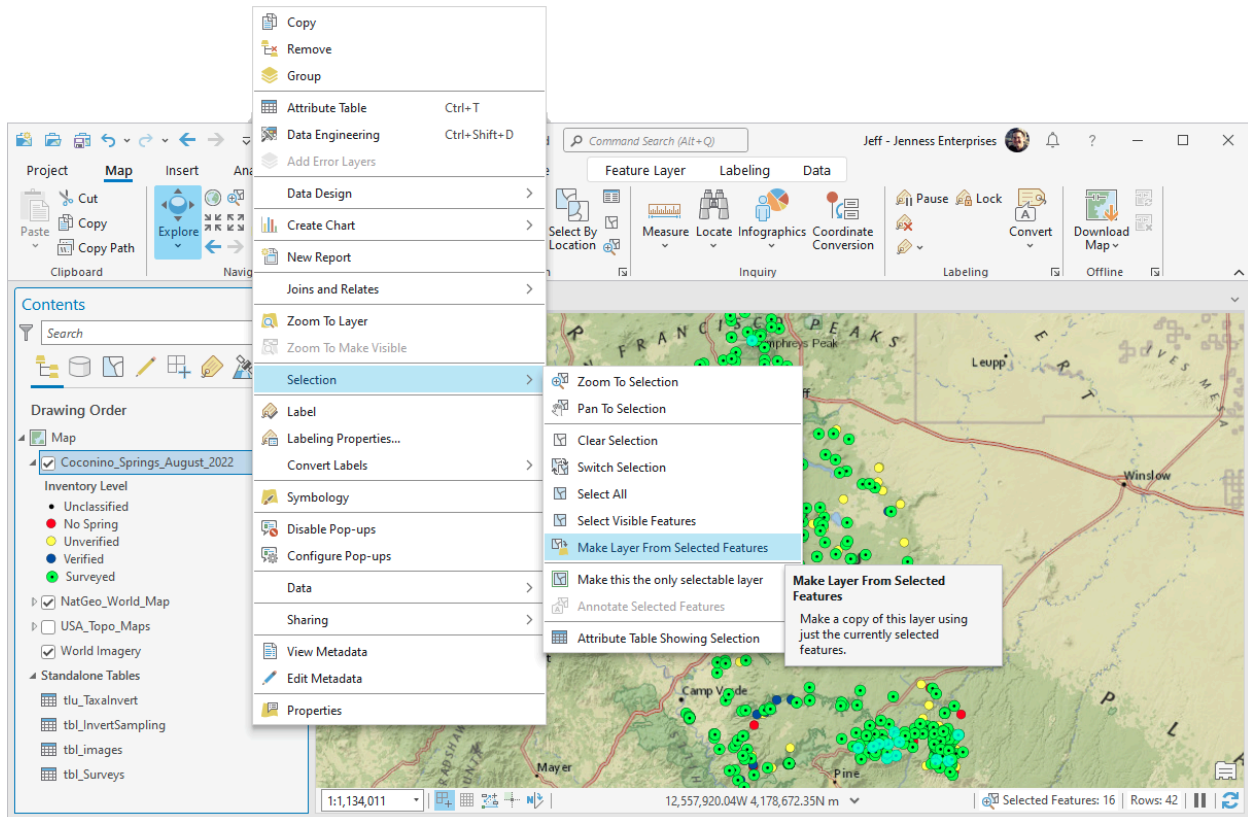
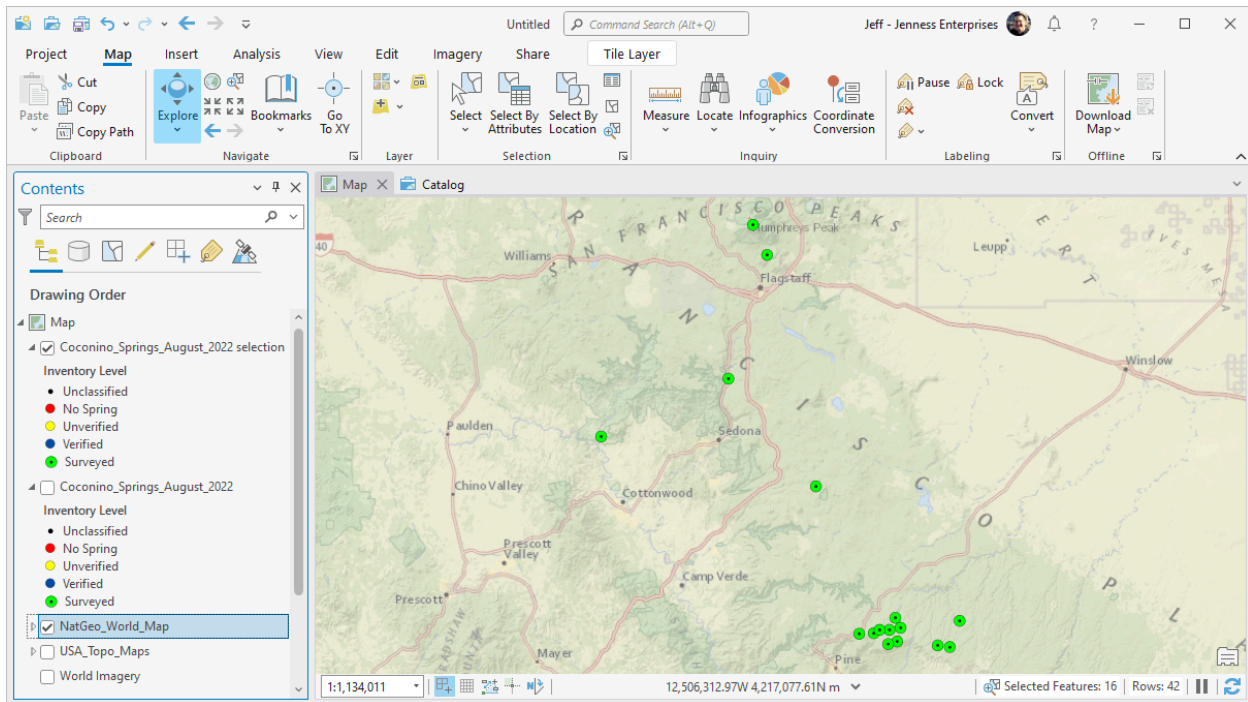
16 of 462 selected

Filters: 100%

- Now you will see the spatial distribution of these 16 springs (and the map below uses the National Geographic basemap as a background).



- It is hard to see selected features sometimes in ArcGIS Pro. If you like, you can create a new layer out of just the selected features. If you want to try this, just right-click on the layer **Coconino_Springs_August_2022** and go to "Selection", then "Make Layer from Selected Features". ArcGIS Pro will add a new layer to your map, symbolized the same way the original was, so just turn off visibility for your original layer:



- ❑ **For Your Homework:** Repeat the steps above to find the total number of springs where the *pleasing fungus beetle* (*Coleoptera Erotylidae Megalodacne heros*) has been observed. First open your **tlu_TaxalInvert** table, click the *Select by Attributes* command, and make an initial selection of Invertebrate species with the following query string:

CommonName = 'pleasing fungus beetle'

Select By Attributes

Input Rows
tlu_TaxalInvert

Selection Type
New selection

Expression
Load Save Remove

Where CommonName is equal to pleasing fungus beet

+ Add Clause

☐ Invert Where Clause

Apply OK

Select By Attributes

Input Rows
tlu_TaxalInvert

Selection Type
New selection

Expression
Load Save Remove

CommonName = 'pleasing fungus beetle'

☐ Invert Where Clause

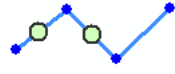
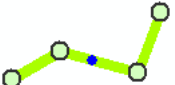
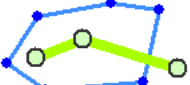
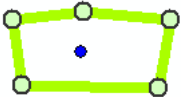
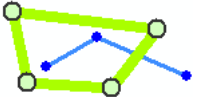
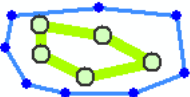
Apply OK

- ❑ **Hint:** I am expecting between 1 and 10 springs.

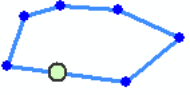
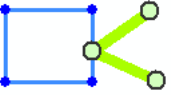
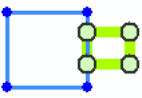
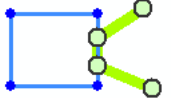
Appendix: Spatial Relationships

Intersect:

Intersect occurs when two features touch or overlap each other at any point. This relationship applies to all combinations of point, multipoint, polyline and polygon feature classes.

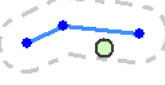
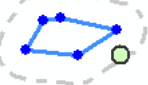
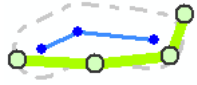
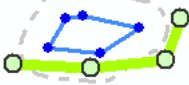
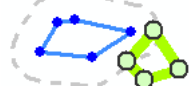
Intersect – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points 	Polylines 	Polygons 
Points 			
Polylines 			
Polygons 			

The table below illustrates several scenarios:

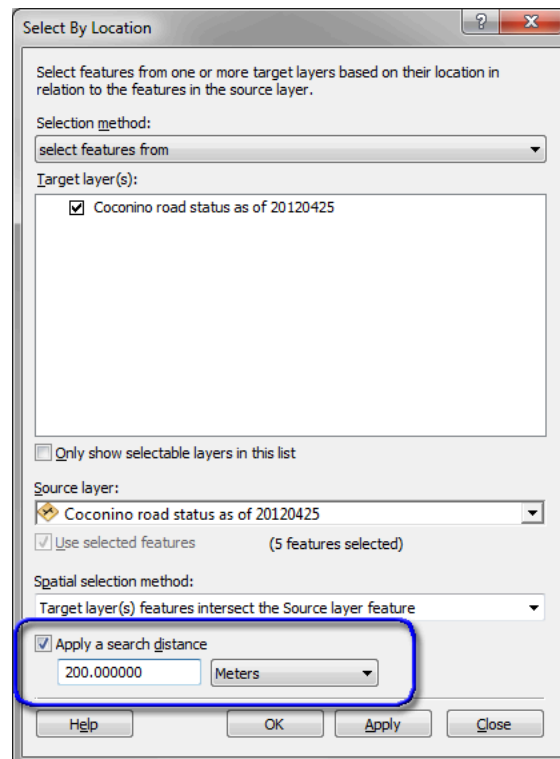
Intersects = <i>TRUE</i> 	Intersects = <i>TRUE</i> 	Intersects = <i>TRUE</i> 
Intersects = <i>TRUE</i> 	Intersects = <i>TRUE</i> 	Intersects = <i>TRUE</i> 

Are Within a Distance Of:

Two features are within some specified buffer distance from each other. Applies to all combinations of point, multipoint, polyline and polygon feature classes.

Are Within Distance Of – Possible Relationships			
Comparison Geometry	Base Geometry		
	Points 	Polylines 	Polygons 
Points 			
Polylines 			
Polygons 			

When using the “Select by Location” function, the Distance value in this relationship is defined with a buffer size at the bottom of the dialog.



Select By Location

Select features from one or more target layers based on their location in relation to the features in the source layer.

Selection method:
select features from

Target layer(s):
☒ Coconino road status as of 20120425

☐ Only show selectable layers in this list

Source layer:
☒ Coconino road status as of 20120425

☒ Use selected features (5 features selected)

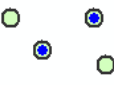
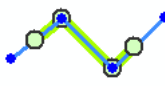
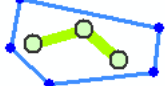
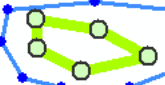
Spatial selection method:
Target layer(s) features intersect the Source layer feature

☒ Apply a search distance
200.000000 Meters

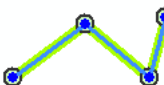
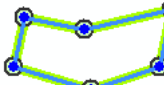
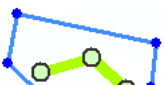
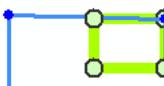
Help OK Apply Close

Contains:

Features in the Input layer will be selected if they contain other features inside them.

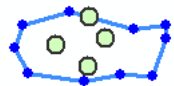
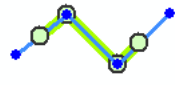
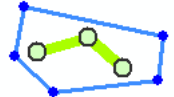
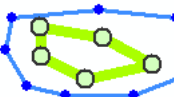
Contain – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points	Polylines	Polygons
Points 			
Polylines 	- None - <i>Invalid relationship</i>		
Polygons 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	

Features that are identical to each other also contain each other. Polygons can contain both points and other polygons that lie along the edge.

Contains = TRUE 	Contains = TRUE 	Contains = TRUE 
Contains = TRUE 	Contains = TRUE 	Contains = TRUE 
Contains = TRUE 	Contains = TRUE 	Contains = FALSE 

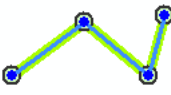
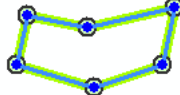
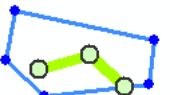
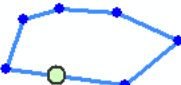
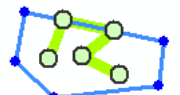
Completely Contains:

Features in the Input layer will be selected if they completely contain other features inside them. A base feature only needs to contain a single comparison feature to have this relationship. The base feature does not need to contain all comparison features. This is similar to “Contains” except that polylines and polygons cannot share a common edge.

Completely Contains – Possible Relationships			
Comparison Geometry	Base Geometry		
	Points 	Polylines 	Polygons 
Points 	- None - <i>Invalid relationship</i>		
Polylines 	- None - <i>Invalid relationship</i>		
Polygons 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	

Unlike the “Contains” relationship, features that are identical to each other are not considered to completely contain each other

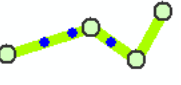
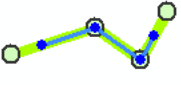
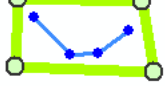
Also, the Help windows state that this relationship requires that the base feature be a polygon, but this is not true. Polylines can completely contain both points and smaller polylines.

Completely Contains = <i>FALSE</i> 	Completely Contains = <i>FALSE</i> 	Completely Contains = <i>FALSE</i> 
Completely Contains = <i>FALSE</i> 	Completely Contains = <i>FALSE</i> 	Completely Contains = <i>FALSE</i> 
Completely Contains = <i>FALSE</i>		

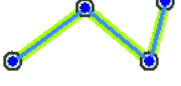
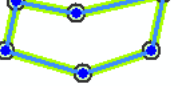


Are within:

This relationship is the exact inverse of the “Contains” relationship. If Feature A **contains** Feature B, then Feature B **is within** Feature A.

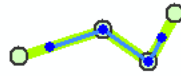
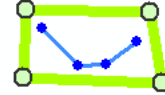
Are Within – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points 	Polylines 	Polygons 
Points 		- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>
Polylines 			- None - <i>Invalid relationship</i>
Polygons 			

As with the “Contains” operator, “Are Within” includes features that are identical and which lie on or touch the edge of the container features.

Are Within = TRUE 	Are Within = TRUE 	Are Within = TRUE 
Are Within = TRUE 	Are Within = TRUE 	Are Within = TRUE 
Are Within = TRUE 	Are Within = TRUE 	

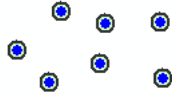
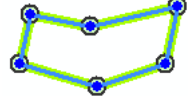
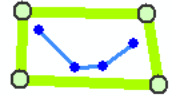
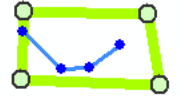
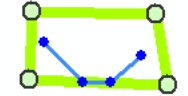
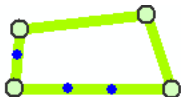
Are Completely Within:

This is identical to the “Are Within” operator, except that the internal features cannot touch the boundary of the container feature:

Are Completely Within – Possible Relationships			
Comparison Geometry	Base Geometry		
	Points 	Polylines 	Polygons 
Points 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>
Polylines 			- None - <i>Invalid relationship</i>
Polygons 			

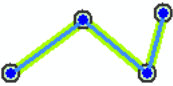
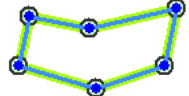
Unlike the “Contains” relationship, features that are identical to each other are not considered to completely contain each other. Features cannot touch the boundary of the container feature.

Also, the Help windows state that this relationship requires that the container feature be a polygon, but this is not true. Both points and polylines can be contained within polylines.

Are Completely Within = <i>FALSE</i> 	Are Completely Within = <i>FALSE</i> 	Are Completely Within = <i>FALSE</i> 
Are Completely Within = <i>TRUE</i> 	Are Completely Within = <i>FALSE</i> 	Are Completely Within = <i>FALSE</i> 
Are Completely Within = <i>FALSE</i> 	Are Completely Within = <i>FALSE</i> 	

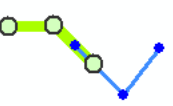
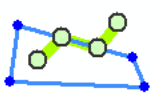
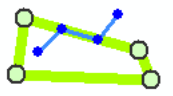
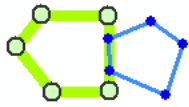
Are Identical To:

This relationship finds the special cases where features are spatially exactly alike, with exactly the same vertices in the same locations.

Are Identical To – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points 	Polylines 	Polygons 
Points 		- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>
Polylines 	- None - <i>Invalid relationship</i>		- None - <i>Invalid relationship</i>
Polygons 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	

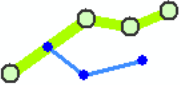
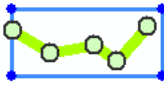
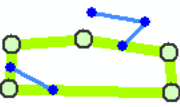
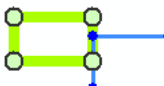
Share a Line Segment With:

This relationship is True whenever the intersection of two features produces a line. It is only possible between polylines and polygons.

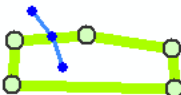
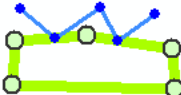
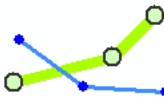
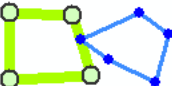
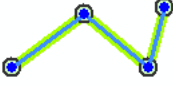
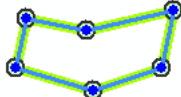
Share a Line Segment With – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points 	Polylines 	Polygons 
Points 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>
Polylines 	- None - <i>Invalid relationship</i>		
Polygons 	- None - <i>Invalid relationship</i>		

Touch The Boundary Of:

This function identifies all polylines and polygons that touch, but do not cross, the boundary of other polylines or polygons. More specifically, the intersection between two features should not be empty, but the intersection of their interiors should be empty. There is an exception for polylines and polygons that lie within larger polygons and touch the boundary. This function is not available for point features.

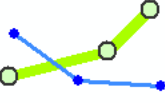
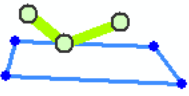
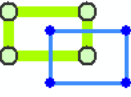
Touch the Boundary Of – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points 	Polylines 	Polygons 
Points 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>
Polylines 	- None - <i>Invalid relationship</i>		
Polygons 	- None - <i>Invalid relationship</i>		

This relationship can be a little confusing. If a polyline touches a polygon with an internal vertex, then “touch the boundary of” returns **True**. However, if a polyline touches another polyline with an internal vertex, then “touch the boundary of” returns **False**. Polygons and polylines may touch while lying inside or outside other polygons, but not laying across the boundary. Identical polylines do **not** touch the boundary of each other, but identical polygons **do**. The following chart illustrates some scenarios:

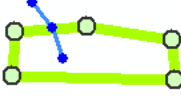
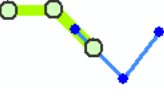
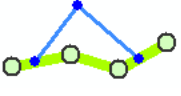
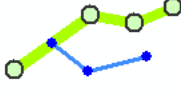
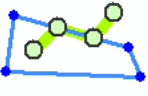
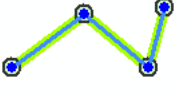
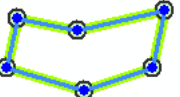
Touch the Boundary = <i>FALSE</i> 	Touch the Boundary = <i>TRUE</i> 	Touch the Boundary = <i>FALSE</i> 
Touch the Boundary = <i>FALSE</i> 	Touch the Boundary = <i>FALSE</i> 	Touch the Boundary = <i>TRUE</i> 
Touch the Boundary = <i>TRUE</i> 	Touch the Boundary = <i>FALSE</i> 	Touch the Boundary = <i>TRUE</i> 

Are Crossed By The Outline Of:

This is a complex relationship in which the intersection of two features must have a dimensionality less than the two intersecting features (i.e. the intersection of two polygons must be a polyline or point, and the intersection of anything with a polyline must be a point), and that intersection object must be in the interior of both features. This relationship is only available for polyline and polygon features.

Crossed By The Outline Of – Possible Relationships			
Comparison Geometry	Base Geometry		
	Points 	Polylines 	Polygons 
Points 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>
Polylines 	- None - <i>Invalid relationship</i>		
Polygons 	- None - <i>Invalid relationship</i>		

Identical objects are **not** considered to be crossed by the outline of each other. If the intersection region between a polyline and a polygon is a polyline, or is the endpoint of the polyline, then this relationship returns **false**.

Crossed by the Outline Of = TRUE 	Crossed by the Outline Of = TRUE 	Crossed by the Outline Of = TRUE 
Crossed by the Outline Of = FALSE 	Crossed by the Outline Of = FALSE 	Crossed by the Outline Of = FALSE 
Crossed by the Outline Of = FALSE 	Crossed by the Outline Of = FALSE 	Crossed by the Outline Of = FALSE 

Have their centroid in:

This relationship is True when the centroid of the comparison feature is contained within, or intersects, the base feature. The centroid of a point is that point. The centroid of a polyline is that point that is 50% along its length. The centroid of a polygon is the center of mass of the polygon, and is not necessarily inside the polygon itself.

Have Their Centroid In – Possible Relationships			
	Base Geometry		
Comparison Geometry	Points	Polylines	Polygons
Points			
Polygons			
Polylines			
Points			

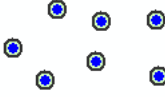
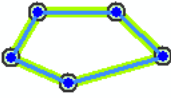
Clementini Relationships:

With ArcGIS 9.3, ESRI has begun to introduce a new type of spatial relationship called Clementini relationships, named for Eliseo Clementini of the Università di L'Aquila in L'Aquila, Italy. The new Clementini operators are intended to adjust ArcGIS spatial relationships to meet new ISO standards for topological operators.

Clementini operators have long been available from within ArcObjects, and used by programmers who develop customized ArcGIS applications. ArcGIS 9.3 is the first release that includes Clementini operators in the “Select by Location” function available to all users. ArcGIS 9.3 includes the Clementini versions of “Contain” and “Are Within”.

The Clementini operators differ from the standard operators in how they treat the boundary of the geometry. For polylines, the “boundary” is comprised of the start point and the end point. For polygons, the boundary is the polyline that defines the edge. Points do not have a boundary.

If the only place of intersection is on the boundary, then the standard operations consider the “Contain” and “Within” relationships to be **True**, while the Clementini operators “Contain” and “Within” relationships to be **False**. For example, the following scenarios are all **True** according to the standard “Contain” operator, and **False** according to the Clementini “Contain” operator:

<i>True for “Contains”, False for “Clementini Contains”</i>			
	Base Geometry		
Comparison Geometry	Points 	Polylines 	Polygons 
Points 			
Polylines 	- None - <i>Invalid relationship</i>	No difference between Standard and Clementini operators	
Polygons 	- None - <i>Invalid relationship</i>	- None - <i>Invalid relationship</i>	No difference between Standard and Clementini operators

In practice, there are few differences between the Clementini and Standard versions of “Contain” and “Are Within”, and few instances where they will produce different results.

For more information on Clementini operators, users are referred to “Spatial Relationship” and “Select by Location: graphical examples” in the ArcGIS help files, and the paper “A small set of formal topological relationships suitable for end-user interaction” by Eliseo Clementini, Paolino De Felice and Peter van Oosterom (see below for reference).

Clementini, E., P. De Felice and P. van Oosterom. 1993. A small set of formal topological relationships suitable for end-user interaction. p. 277 – 195 in “Advances in Spatial Databases”, Third International Symposium, SSD '93 Singapore, June 24 – 25, 1993. Available at <http://www-de.csd.auth.gr/~alex/sdb/artSSD93.pdf>.

