Perform a site suitability analysis for a new wind farm

Determine the optimal location for a set of new high-efficiency wind turbines in Colorado.

Author	Duration	Difficulty
Joseph Kerski	1hr(s)	Intermediate

In this tutorial, a Colorado-based wind energy company has hired you to identify several potential sites in the state for the installation of high-efficiency wind turbines. Selecting an appropriate site is key to the success of any renewable energy project, playing a crucial role in financial returns and ease of construction as well as ongoing operations, maintenance, and overall safety. Using ArcGIS Online, you'll locate and filter potential sites, investigate routing and site accessibility factors to and from the identified locations, and make a final decision.

This tutorial was last tested on October 28, 2022.

VIEW FINAL RESULT

Requirements

- ArcGIS organizational account with a Publisher, Facilitator, or Administrator role in an ArcGIS organization (see options for software access)

Outline

Conduct a site suitability analysis — 30 minutes

Find the optimal site for a high-efficiency wind farm in Colorado.

Route to prospective sites — 15 minutes

Create efficient routes to visit planned sites.

Create a web app — 15 minutes

Create a web app to communicate analysis results and site visits.

Conduct a site suitability analysis

A Colorado-based wind energy company has hired you to identify several potential sites in the state for the installation of high-efficiency wind turbines. The selected site must meet several characteristics:

- Located in the state of Colorado
- In counties where the population as of 2010 is at least 20,000
- In areas where the wind power class is at least 4 (Annual wind speeds in these areas at 10 meters off the ground are generally at least 5.6 meters per second [12.5 mph], and at 50 meters off the ground are generally 7.0 meters per second

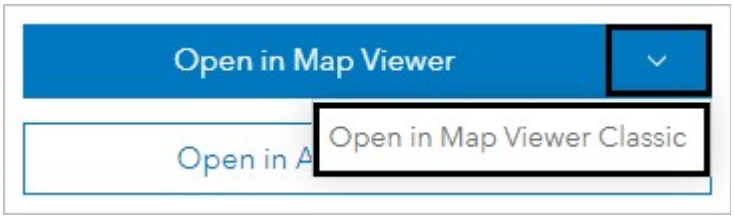
[15.7 mph].)
- Within 10 miles of existing power lines that have a capacity of at least 400 kilovolts (kV)
- Within 5 miles of existing wind farms containing turbines where the rotor diameters span at least 100 feet

To meet these criteria, you'll save a copy of the map and explore the data you have on population, existing wind farms and power lines, and average wind speeds around the state. Next, you'll start querying these layers to narrow down locations with the characteristics you want. Finally, you'll combine these into a single layer on which you can conduct a multicriteria analysis to locate a few viable sites.

Save a copy of the map

In this section, you'll open a map illustrating current wind turbine locations and wind power potential across the state of Colorado. The map will familiarize you with the features and attributes you'll be using to locate a new site for the development of a high-efficiency wind farm. After exploring this map, you'll save your own version of the map for further analysis.

1. Go to the item details page for the web map Wind Power Study in Colorado Starting Point.
2. Next to **Open in Map Viewer**, click the down arrow and choose **Open in Map Viewer Classic**.



> **Note:**
>
> If **Open in Map Viewer Classic** is not visible, you may need to click the arrow next to **Open in Map Viewer** and choose **Open in Map Viewer Classic**. ArcGIS Online offers two map viewers for viewing, using, and creating maps. This tutorial uses Map Viewer Classic. For more information on the map viewers available, see FAQ.

The map opens in Map Viewer Classic to the state of Colorado.

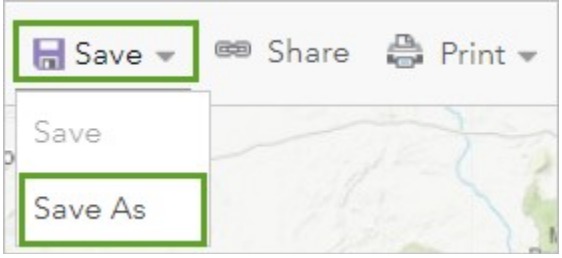
3. If necessary, click **Sign In** and sign in to your ArcGIS organizational account.

> **Note:**
>
> If you don't have an organizational account, see options for software access.

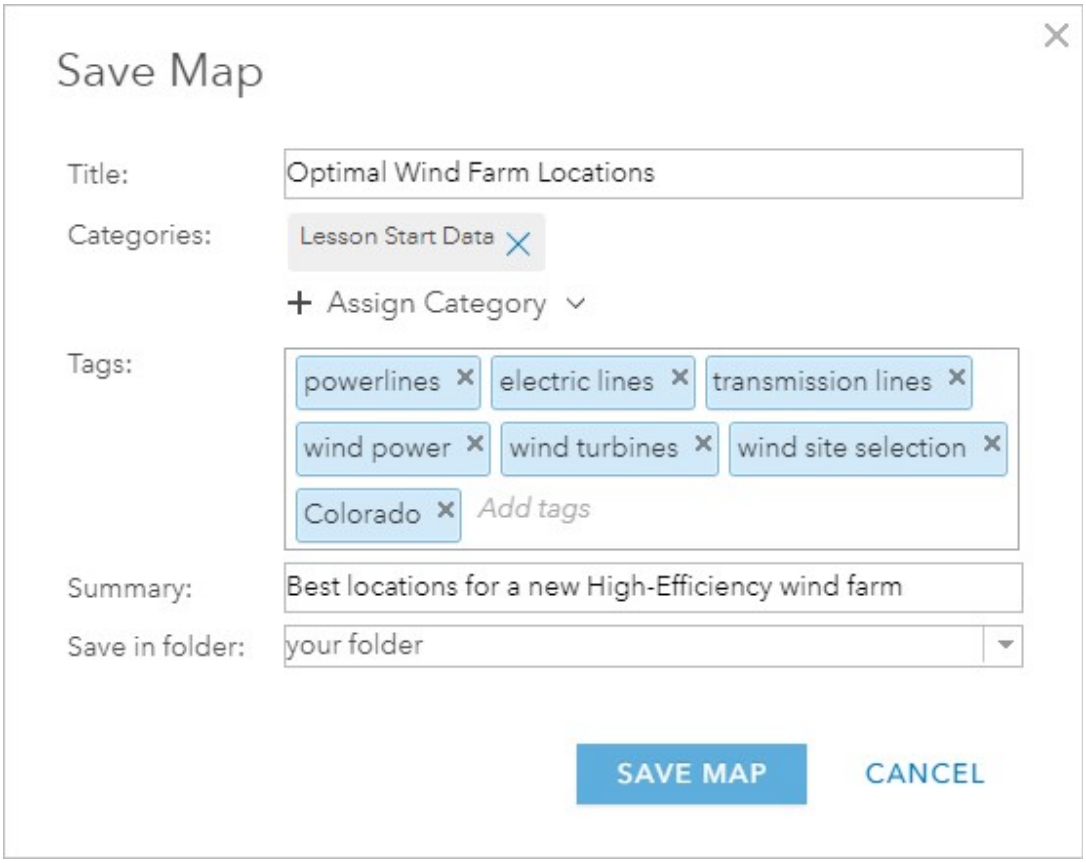
4. In the **Details** pane, click **Content**.

The map contains data on existing wind farms in Colorado. Before exploring the map and the layers that you'll query and analyze, you'll create a personal copy of the map.

5. On the ribbon, click **Save** and choose **Save As**.



6. In the **Save Map** window, for **Title**, type Optimal Wind Farm Locations.
7. For **Summary**, type Best locations for a new High-Efficiency wind farm.
8. For **Save in folder**, verify that you are saving to your own folder.



9. Click **Save Map**.

   A copy of the map is now saved to your **Content** folder. You can access it at any time through the **Content** tab on the home page. Now that you've saved your map, you'll look at the data you have available to work with.

Check wind farm data

The map has five layers: the state boundary, Colorado counties, the locations of current wind turbines, the location of power lines, and the average strength of the wind based on geographical location. Now you'll evaluate the available data to determine whether it is enough to satisfy the criteria listed above.

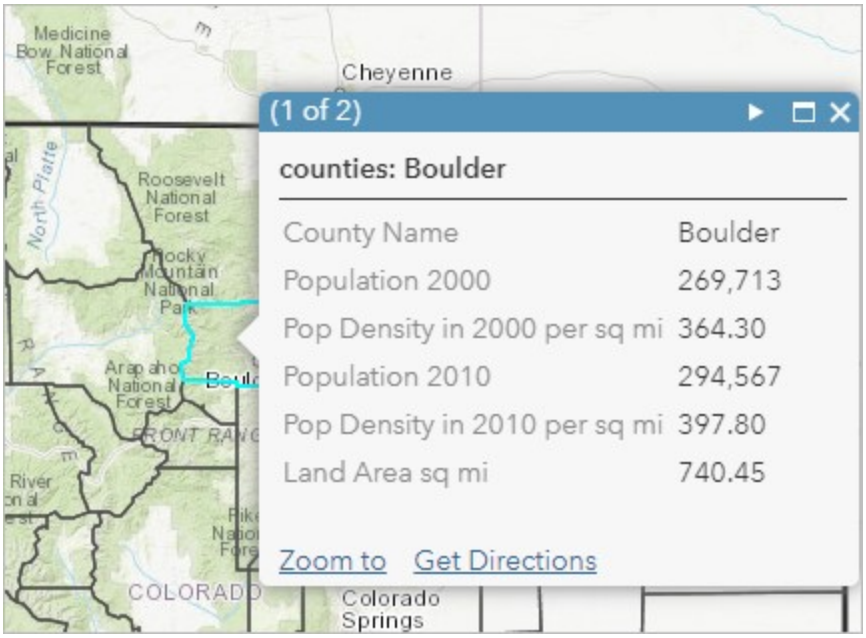
1. In the **Contents** pane, check the **Counties** layer to turn it on.

   The **Counties** layer has population data for all 64 counties in Colorado. Some counties have higher population densities than others, which means higher energy demands. Because building new transmission lines is costly and detrimental to the environment, you want to identify locations with high demand for power to reduce the need to build additional transmission lines. This layer contains data that will allow you to check the first and second criteria: that the wind farm site

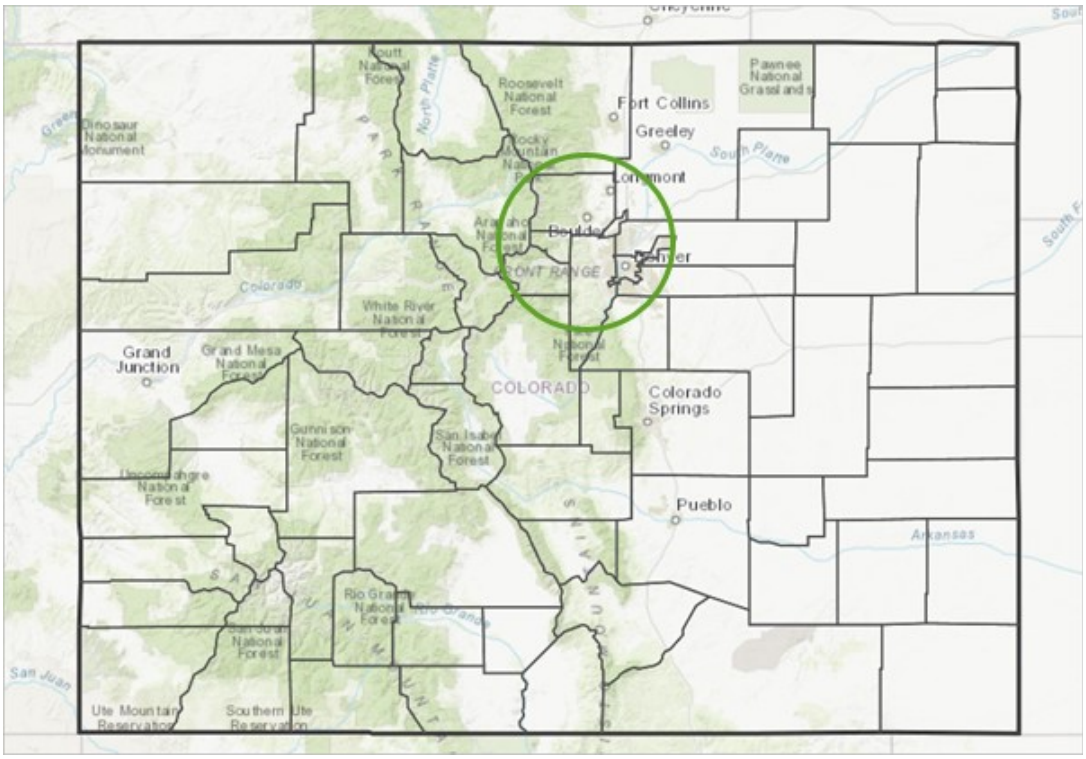
is in the state of Colorado and has a high enough population density.

2. Click a few counties along the Front Range (the mountain range west of Denver) between Fort Collins and Pueblo and note their population densities.

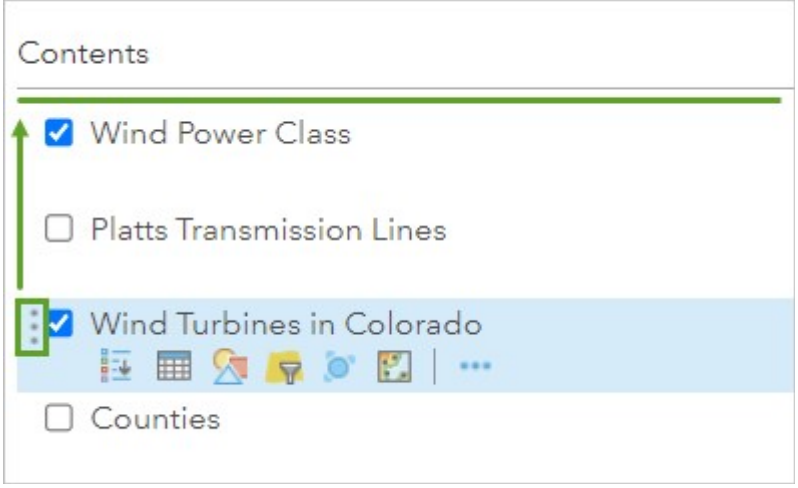
   Pop-ups appear as you click the counties with additional information about each county, such as population density.



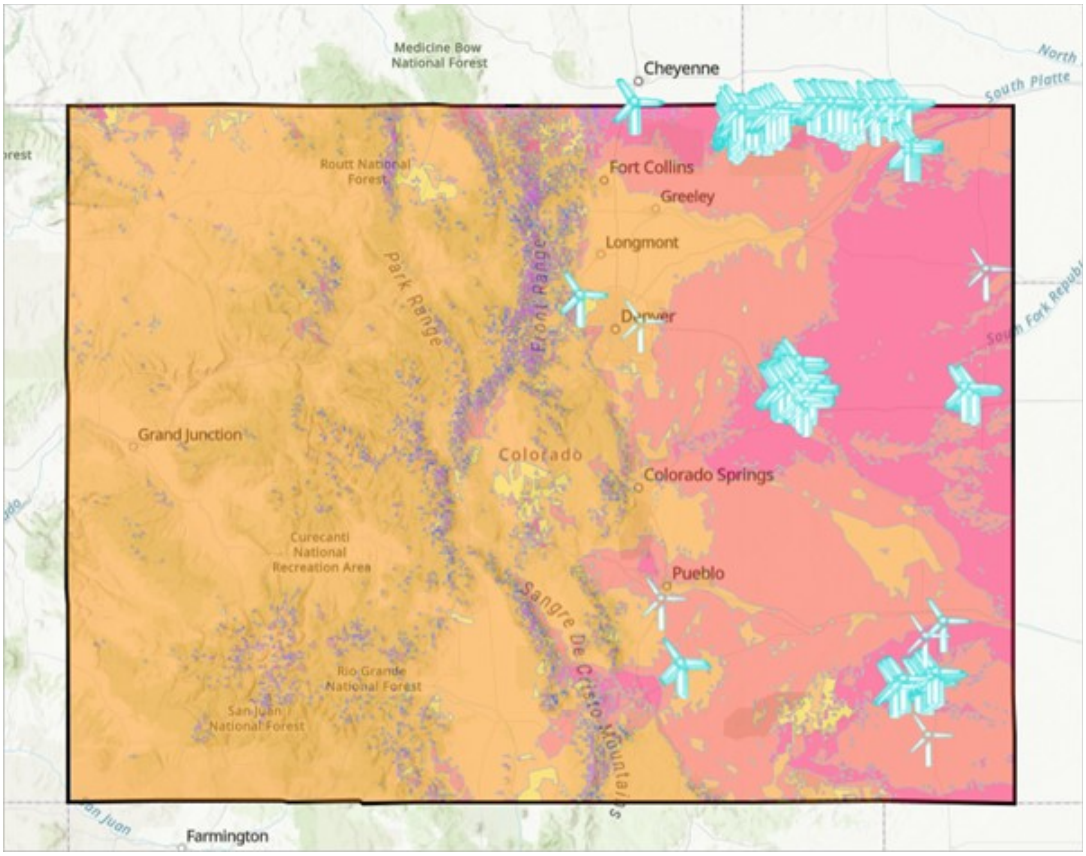
   The counties along the Front Range, including Boulder and Denver, have the highest population densities in the state.



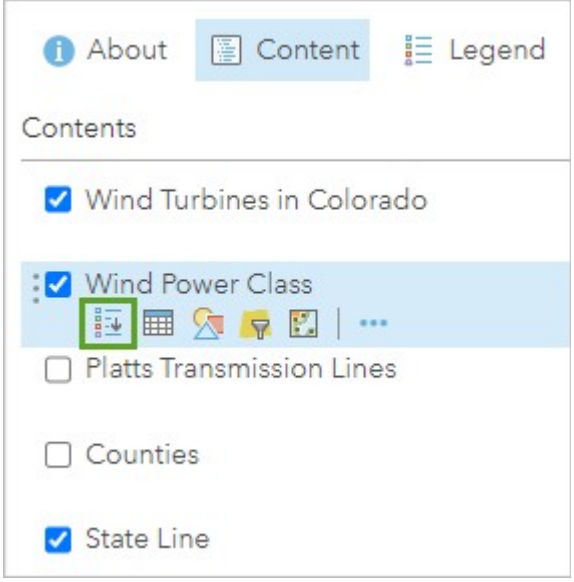
3. Close the pop-up.
4. In the **Contents** pane, uncheck the **Counties** layer to turn it off, and turn on the **Wind Power Class** and the **Wind Turbines in Colorado** layers.
5. In the **Contents** pane, drag the **Wind Turbines in Colorado** layer to the top of the list.



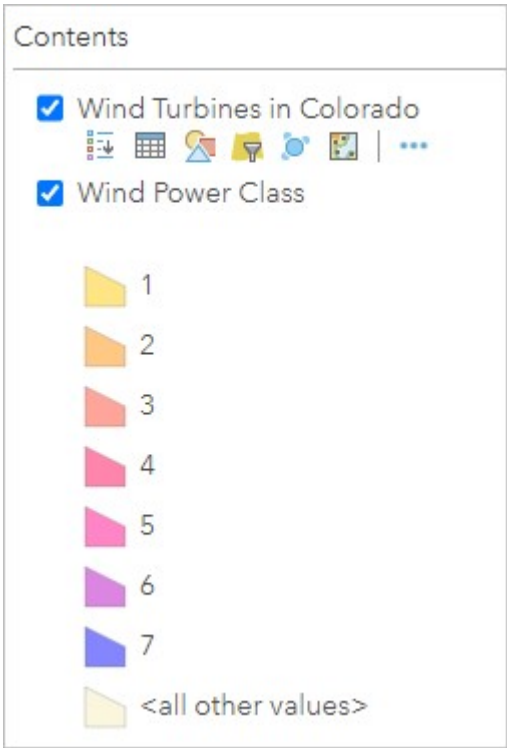
The turbines are now visible.



6. Point to the **Wind Power Class** layer and click **Show Legend**.



The legend for **Wind Power Class** appears in the **Contents** pane.



The **Wind Power Class** layer data is classified into seven classes. These classes represent average (mean) wind speed as calculated for heights of 10 meters (33 feet) and 50 meters (164 feet). Wind speed is a good indicator of the power generating capacity of wind. Generally, the higher the wind speed, the greater the power generating capacity at a location.

The following table illustrates wind speed for heights at 10 meters (33 feet) and 50 meters (164 feet):

Wind power class	**Wind power density10 m (33 ft.)**	**Speed10 m**	**Speed33 ft.**	**Wind power density50 m (164 ft.)**	**Speed50 m**	**Speed164 ft.**
1	100	4.4	9.8	200	5.6	12.5
2	150	5.1	11.5	300	6.4	14.3

Wind power class	Wind power density10 m (33 ft.)	Speed10 m	Speed33 ft.	Wind power density50 m (164 ft.)	Speed50 m	Speed164 ft.
3	200	5.6	12.5	400	7.0	15.7
4	250	6.0	13.4	500	7.5	16.8
5	300	6.4	14.3	600	8.0	17.9
6	400	7.0	15.7	800	8.8	19.7
7	1000	9.4	21.1	2000	11.9	26.6

Note:

The degree of certainty with which the wind power class can be specified depends on three factors: the abundance and quality of wind data, the complexity of the terrain, and the geographical variability of the resource.

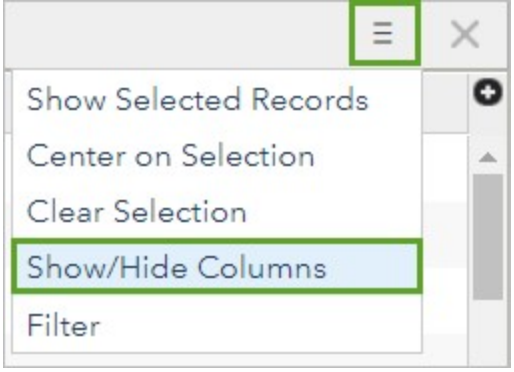
A certainty rating was assigned to each grid cell based on these three factors and is included in the National Renewable Energy Laboratory (NREL) Renewable Energy (RE) Atlas for the United States Department of Energy (DOE).

Notice that the wind power class is generally light to moderate in the western part of the state, with a narrow windy zone on the lee (east) side of the continental divide (running generally north-south in the central part of the state), a lower wind power class in a band to the east of this, and then changing to windier conditions as you get closer to the borders of Kansas and Nebraska.

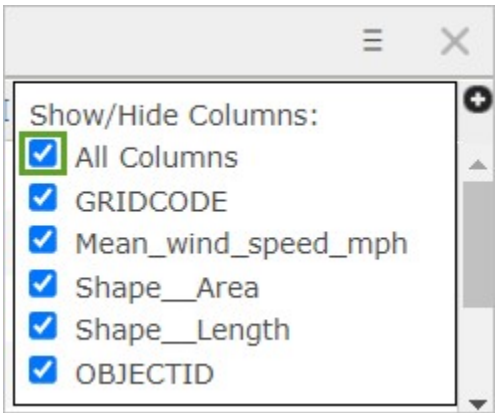
7. Point to the **Wind Power Class** layer and click **Show Table**.

The attribute table appears for the layer.

8. In the table, click the **Options** button and click **Show/Hide Columns**.



9. Check **All Columns**.



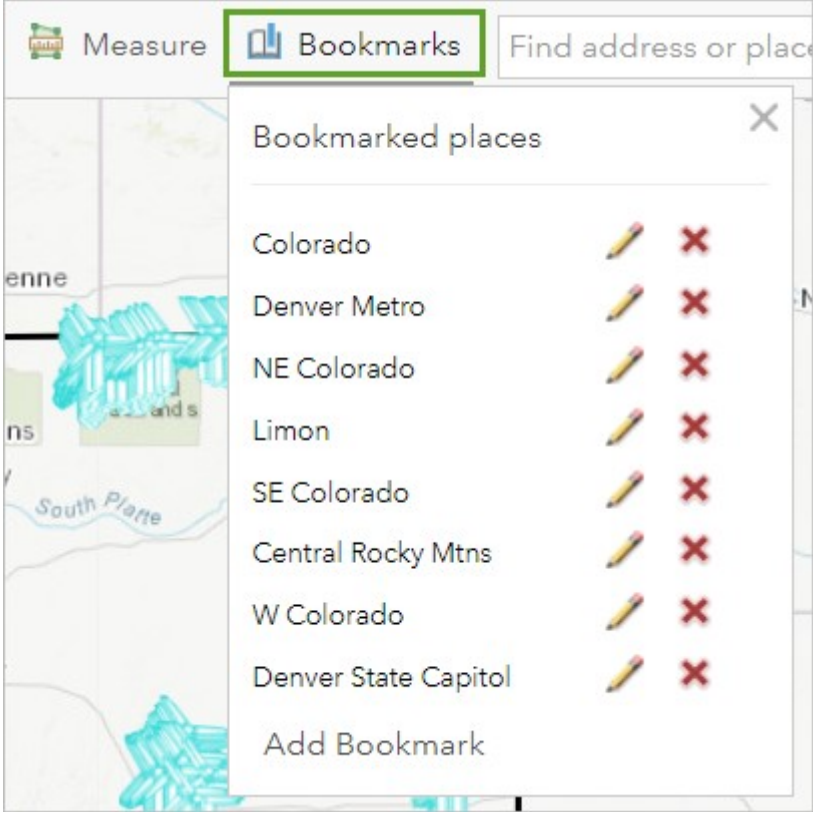
All the attributes in the layer are now visible in the table.

Wind power class is stored in an attribute named **GRIDCODE**, and the corresponding mean wind speeds are given in miles per hour.

- Areas designated as Gridcode 1 (Class 1) are generally not suitable, although a few locations with adequate wind resource for wind turbine applications may exist in some Class 1 areas.
- Areas designated as Gridcode 2 (Class 2) are marginal for utility-scale applications but may be suitable for rural applications.
- Areas designated as Gridcode 3 (Class 3) or greater are suitable for most utility-scale wind turbine applications.

The prevalence of high wind speeds indicates that you have the wind power needed to satisfy the third requirement.

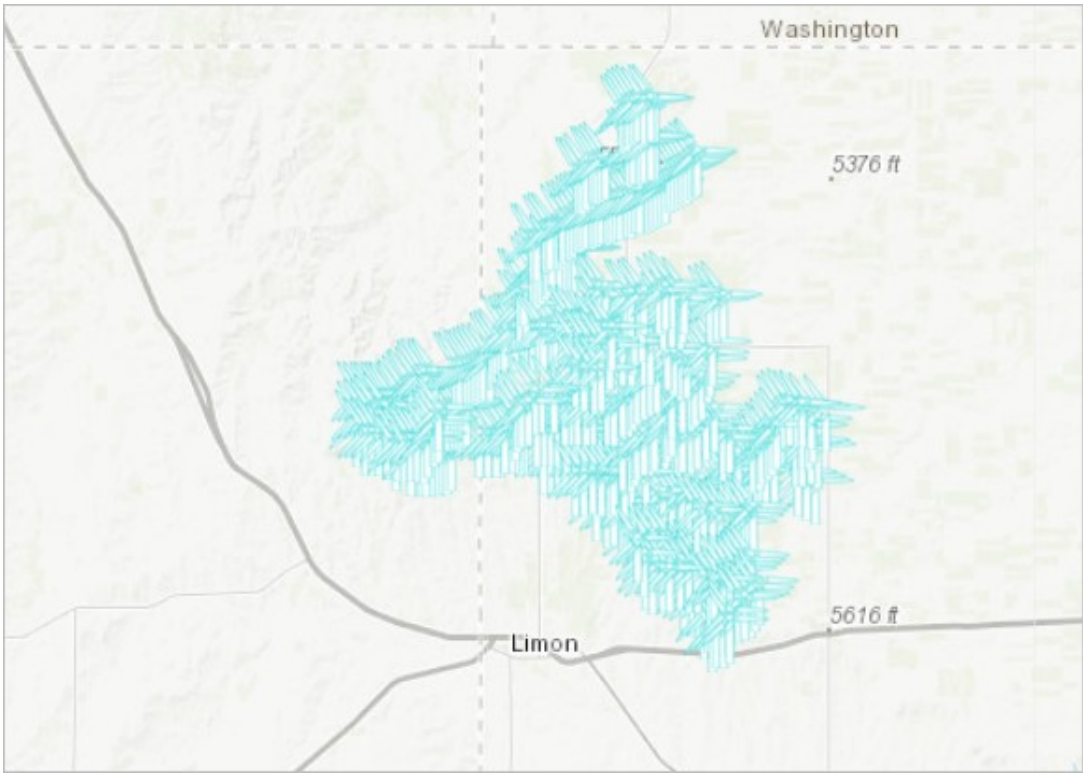
10. Close the table.
11. In the **Contents** pane, uncheck **Wind Power Class** to turn it off.
12. On the ribbon, click **Bookmarks** and click various places to explore.



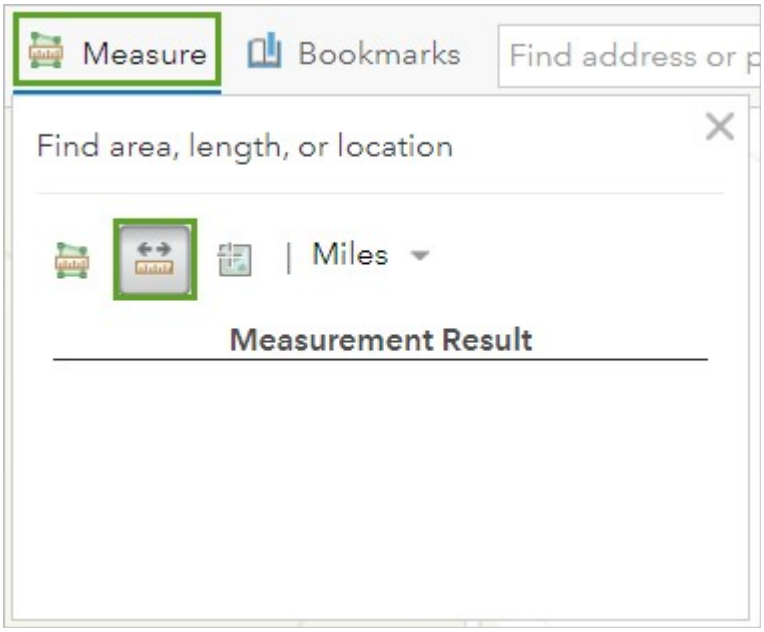
Bookmarks allow you to zoom quickly to various parts of the state where there are existing turbines. The **Wind Turbines in Colorado** layer shows the location of several large installations of turbines within the state boundaries. To build the infrastructure that these wind farms need to run and to have a staff to keep them running, it is easiest to clump them together. Most of these clumps are in the eastern part of the state, where you saw greater wind speeds.

13. Click the bookmark for **Limon**.

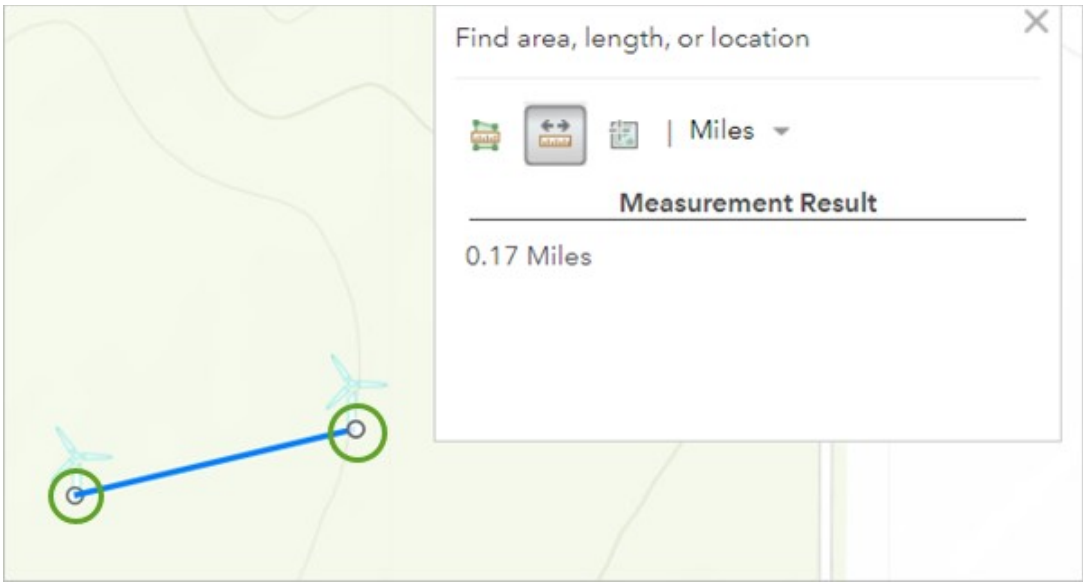
    The map zooms to Limon, a small community in northeastern Colorado that has a sizable number of wind turbines located nearby.



14. Zoom in until you see individual turbines.
15. On the ribbon, click **Measure** and click **Distance**.



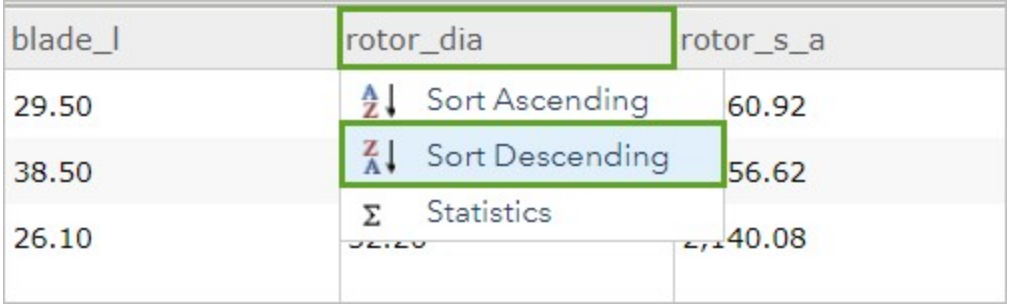
16. Click one turbine, and double-click another turbine next to it.



The turbines near Limon tend to be between 0.18 and 0.25 miles apart. Newer high-efficiency wind turbines have a very long rotor diameter, sometimes more than 100 meters (328 feet), and require extra logistical and spatial considerations. Next, you'll examine the rotor diameter of installed turbines represented in the **Wind Turbines in Colorado** layer.

17. In the **Contents** pane, for the **Wind Turbines in Colorado** layer, click **Show Table** to display layer attributes.

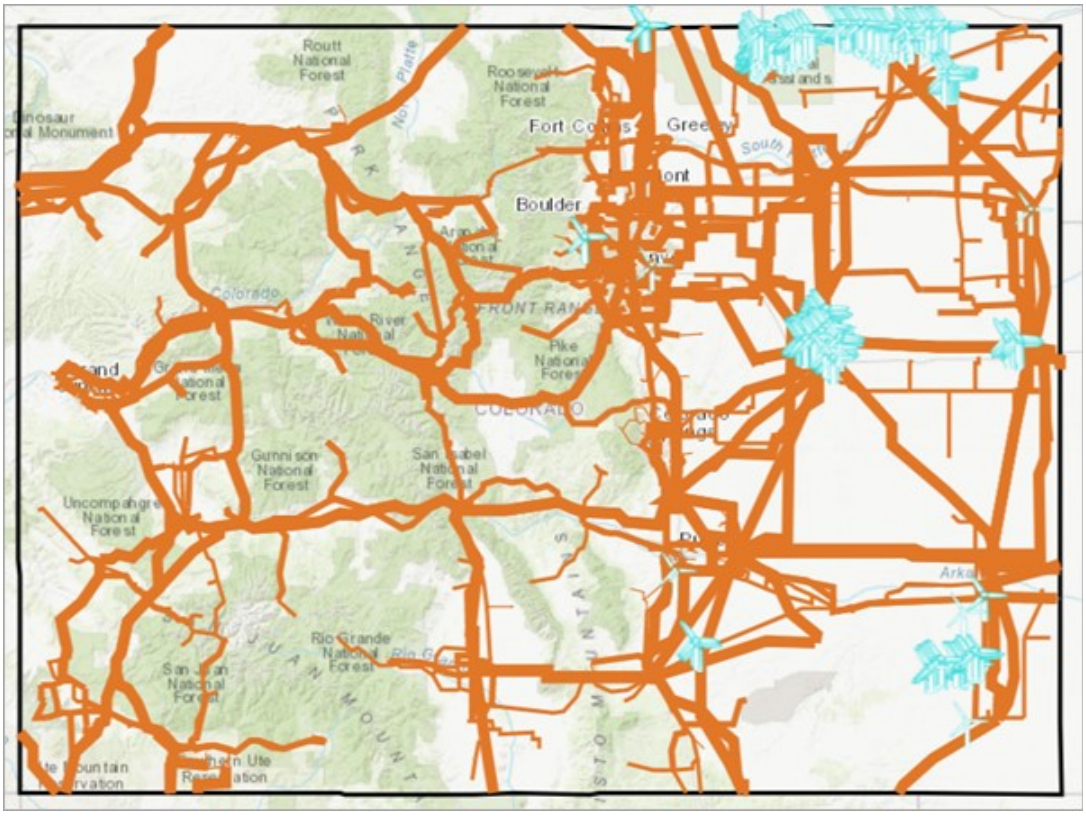
18. In the attribute table, locate and examine the **rotor_dia** (rotor diameter) field.
19. Click the **rotor_dia** field and choose **Sort Descending**.



Several existing turbines have rotor diameters of 100 feet. This, along with the many clusters you observed in the state, signifies that there are several areas that may satisfy the fourth criterion.

20. Close the attribute table, and on the ribbon, click **Bookmark** and choose the **Colorado** bookmark to zoom out and view the entire state.
21. Turn on the **Platts Transmission Lines** layer.

In the layer, transmission lines have been symbolized by voltage capacity. Lines with a capacity of 138 to 500 kV have the thickest line symbol, while lines with a capacity of 10 kV or less have the thinnest line symbol.



These high-voltage lines are present throughout the state, but they are especially concentrated toward the eastern half. This suggests that the criterion for sites to be within 10 miles of an existing power line could be met.

Now that you have explored the data layers necessary to identify potential sites for high-efficiency wind turbines, you are ready to perform the analysis to identify specific sites. The Public Energy Commission has defined several site-specific criteria that you should consider.

An ideal site should meet these conditions:

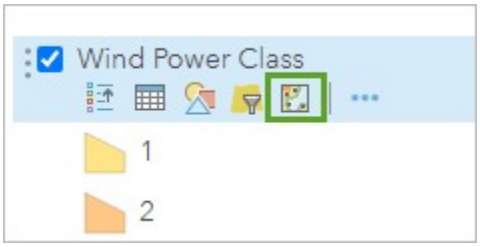
- Located in the state of Colorado
- In counties where the population as of 2010 is at least 20,000, to ensure an adequate demand

- In areas where the wind power class is at least 4 (Annual wind speeds in these areas at 10 meters off the ground are generally at least 5.6 meters per second [12.5 mph], and at 50 meters off the ground are generally 7.0 meters per second [15.7 mph].)
- Within 10 miles of existing power lines that have a capacity of at least 400 kilovolts (kV)
- Within 5 miles of existing wind farms containing turbines where the rotor diameters span at least 100 feet

Combine layers for analysis

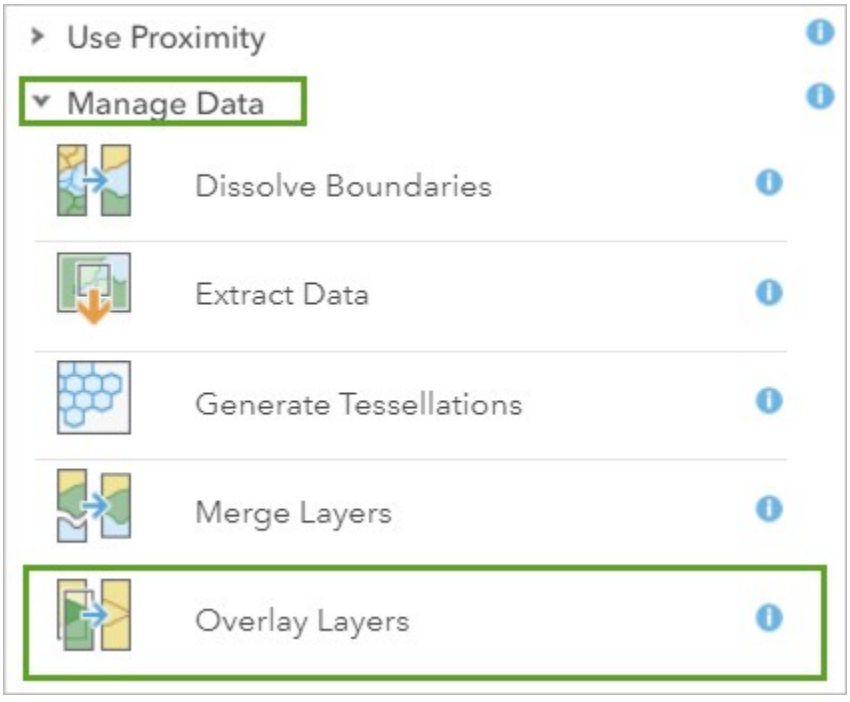
Because you have all the necessary data, you can now start the site selection analysis. To make sure all the criteria are being met, you ultimately want to merge all the layers into a single layer that you can query using the **Find Existing Locations** tool. To prepare for that, you'll start combining layers. The **Counties** layer, with the population data, and the **Wind Power Class** layer only require queries, so first you'll combine them using the **Overlay Layers** tool. The requirements for the **Wind Turbines in Colorado** and **Platts Transmission Lines** layers both specify certain distances from existing features, so you'll use the **Create Buffer** tool to calculate those distances. Then you'll use the **Overlay Layers** tool again to combine the layers.

1. In the **Contents** pane, turn off the **Platts Transmission Lines** layer, and turn on the **Wind Power Class** layer.
2. Point to the **Wind Power Class** layer and click **Perform Analysis**.

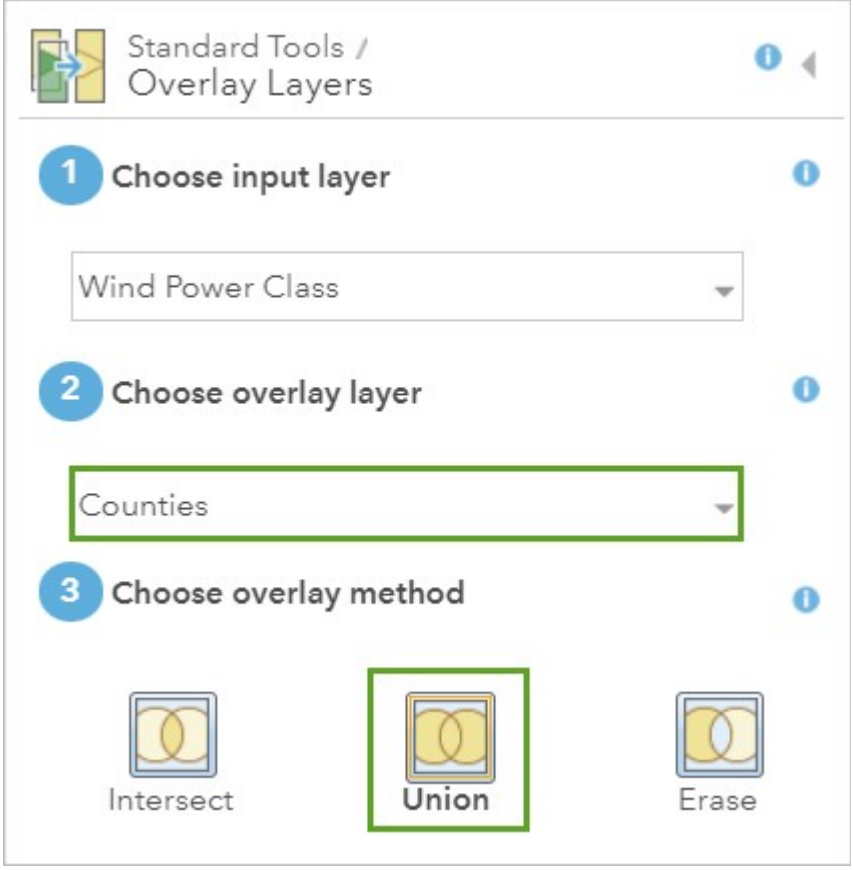


The **Perform Analysis** pane appears.

3. In the **Perform Analysis** pane, click **Feature Analysis**.
4. Expand **Manage Data** and choose **Overlay Layers**.

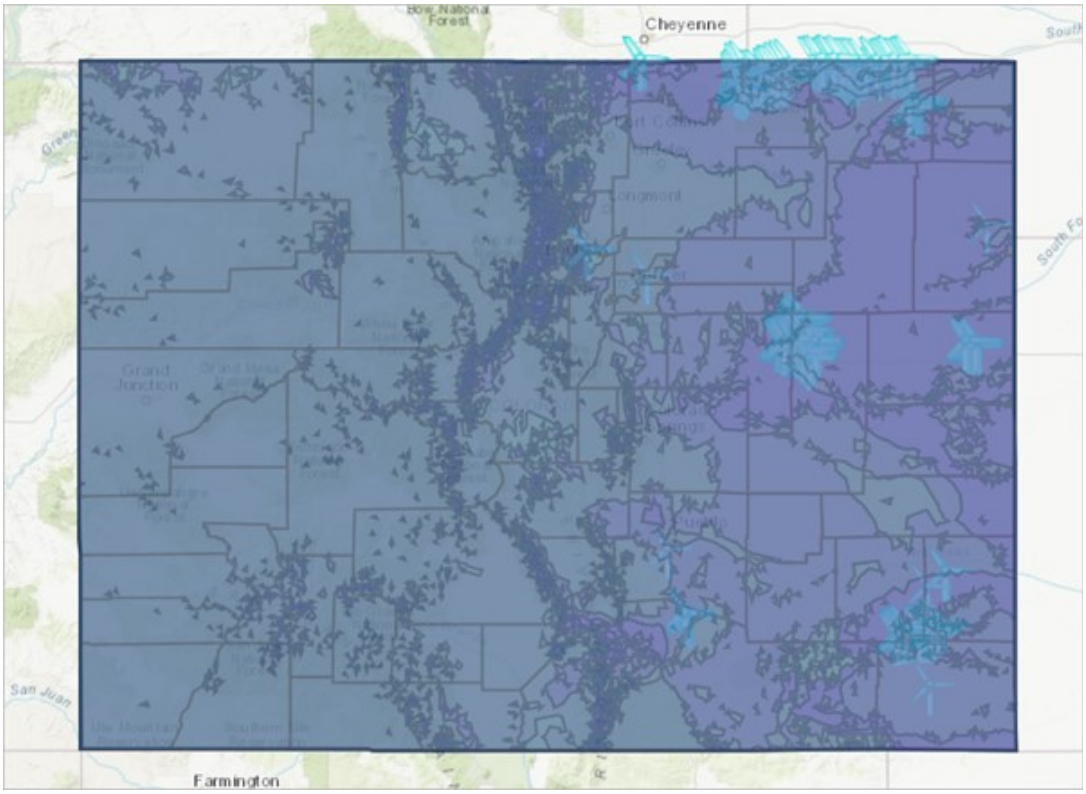


5. In the **Overlay Layers** tool pane, verify that **Choose input layer** is set to **Wind Power Class**.
6. For **Choose overlay layer**, choose **Counties**, and for **Choose overlay method**, click **Union**.



7. For **Result layer name**, type Union of Wind Power Class and Counties and add your initials to make the name unique in your organization. Click **Run Analysis**.

   The resulting layer shows the combination of the **Counties** and **Wind Power Class** features.

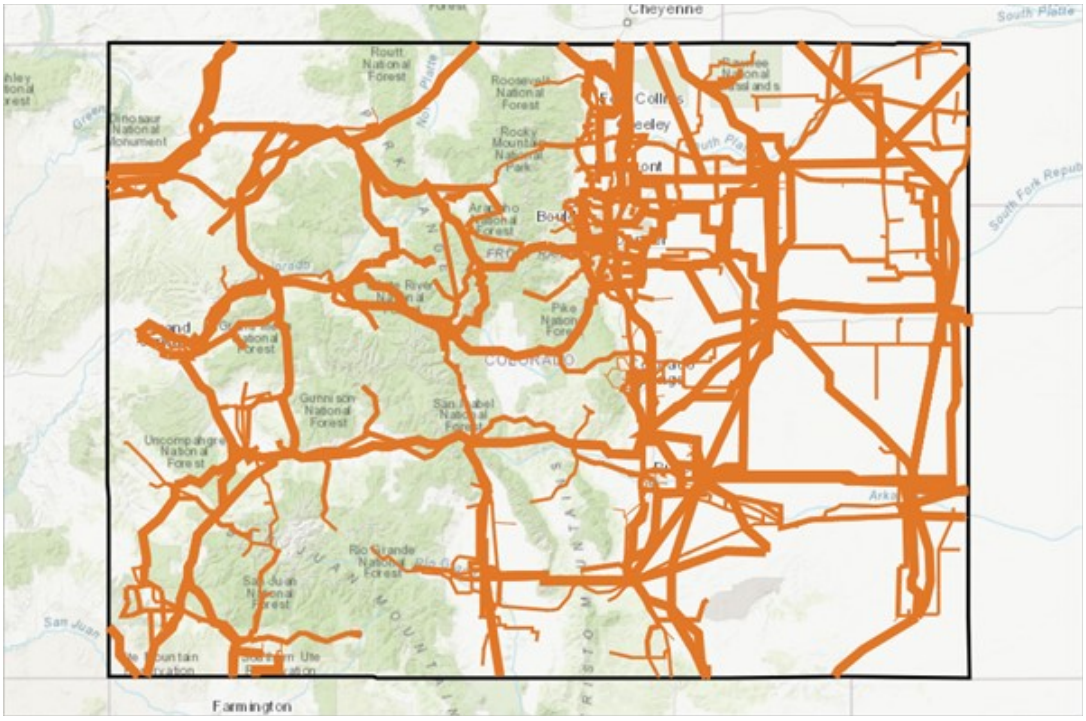


This combined layer allows you to select all locations with wind power classes greater than and equal to 4 and counties with populations greater than 20,000.

Next, you'll buffer the transmission lines layer. Since the transmission line data shows all lines in the state, you'll need to

apply a filter. The first of your analysis criteria is to filter out transmission lines with a voltage of at least 400 kilovolts.

8. In the **Contents** pane, turn on the **Platts Transmission Lines** layer and turn off the **Union of Wind Power Class and Counties**, **Wind Turbines in Colorado**, and **Wind Power Class** layers.

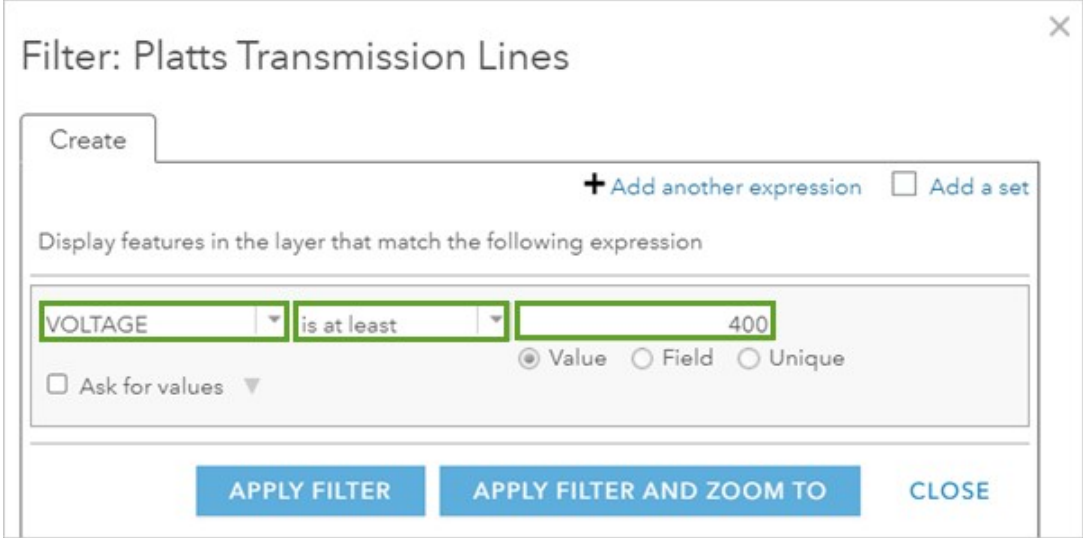


9. In the **Contents** pane, point to the **Platts Transmission Lines** layer and click **Filter**.

The **Filter** window appears.

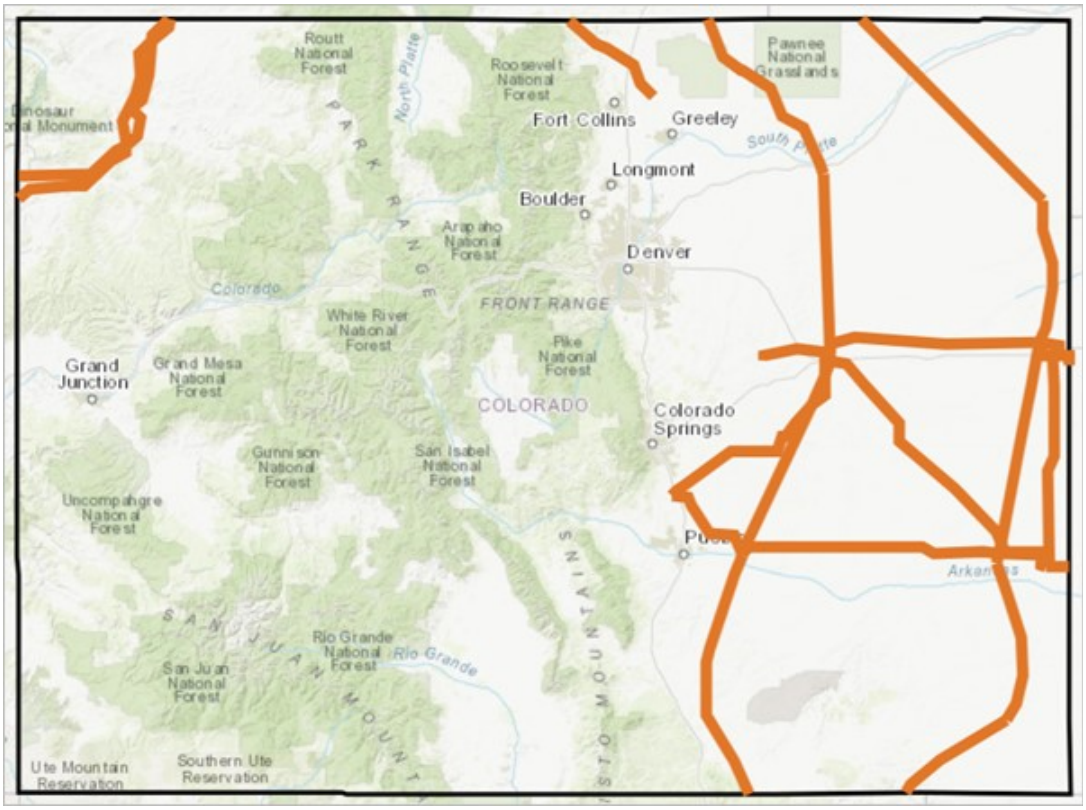
Filter expressions use the general form of <Field_name> <Operator> <Value, Field or Unique>.

10. In the **Filter** window, build the expression **VOLTAGE is at least 400**.



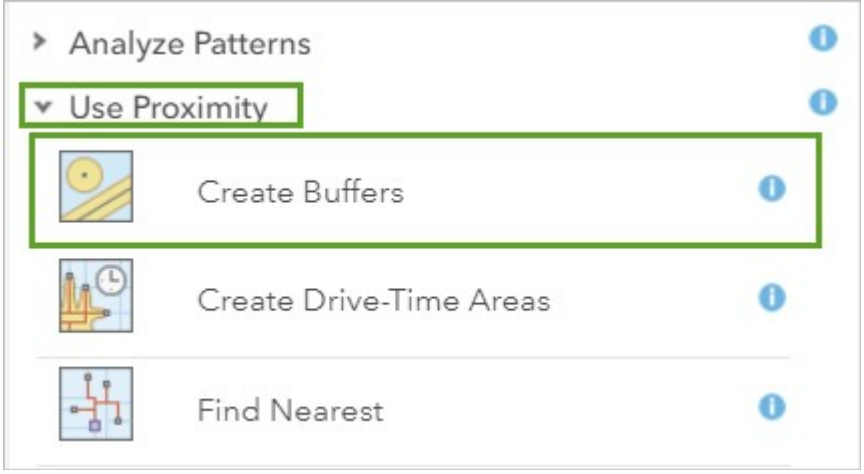
11. Click **Apply Filter**.

    The filtered view is displayed on the map.

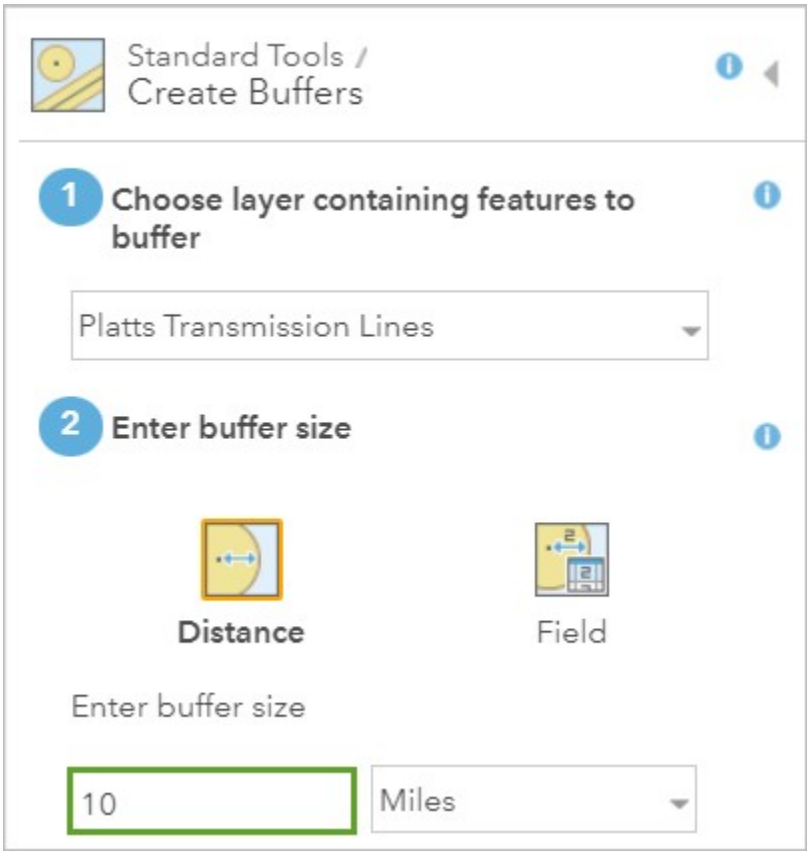


    The layer has now been filtered to only display transmission lines that have a voltage of 400. Now, to verify that locations you choose are within 10 miles from existing power lines you'll generate a 10-mile buffer zone around these transmission lines using the **Create Buffers** tool.

12. In the **Contents** pane, point to **Platts Transmission Lines** and click **Perform Analysis**.
13. In the **Perform Analysis** pane, click **Feature Analysis**.
14. Expand **Use Proximity** and click **Create Buffers**.



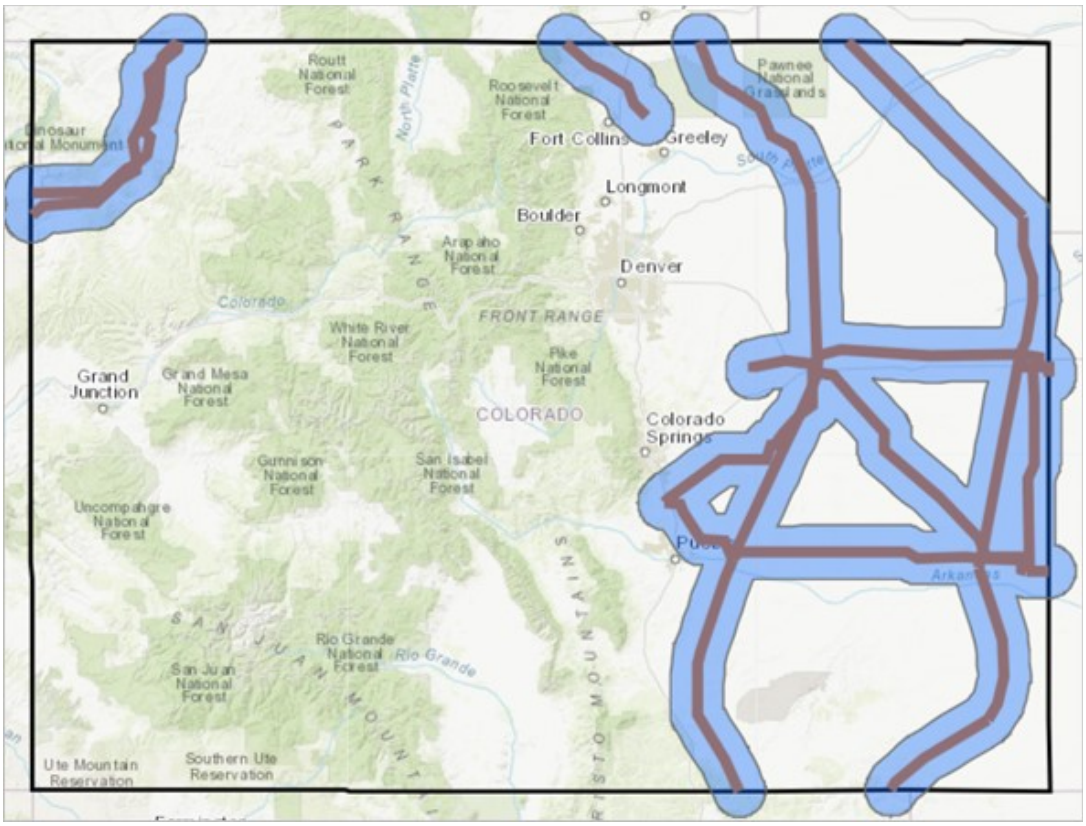
15. In the **Create Buffers** tool pane, for **Choose layer containing features to buffer**, ensure that the layer is set to **Platts Transmission Lines**.
16. For **Enter buffer size**, type 10 and confirm the unit is set to **Miles**.



17. Expand **Options** and for **Buffer type**, choose **Dissolve**.

18. For **Result layer name**, type Transmission Lines 10 Mi Zone and add your name or initials to make sure the name is unique within your organization.
19. Click **Run Analysis**.

    The tool may take a moment to complete. When the operation finishes, the **Transmission Lines 10 Mi Zone** layer is added to the map.



    The **Transmission Lines 10 Mi Zone** layer represents both the location of high-capacity transmission lines and a 10-mile zone around them. The location of your new wind farm should be within one of these 10-mile zones close to a high-capacity transmission line.

20. Turn off the **Platts Transmission Lines** and **Transmission Lines 10 Mi Zone** layers.

To take advantage of existing infrastructure, now you'll find locations within 5 miles of existing wind farms.

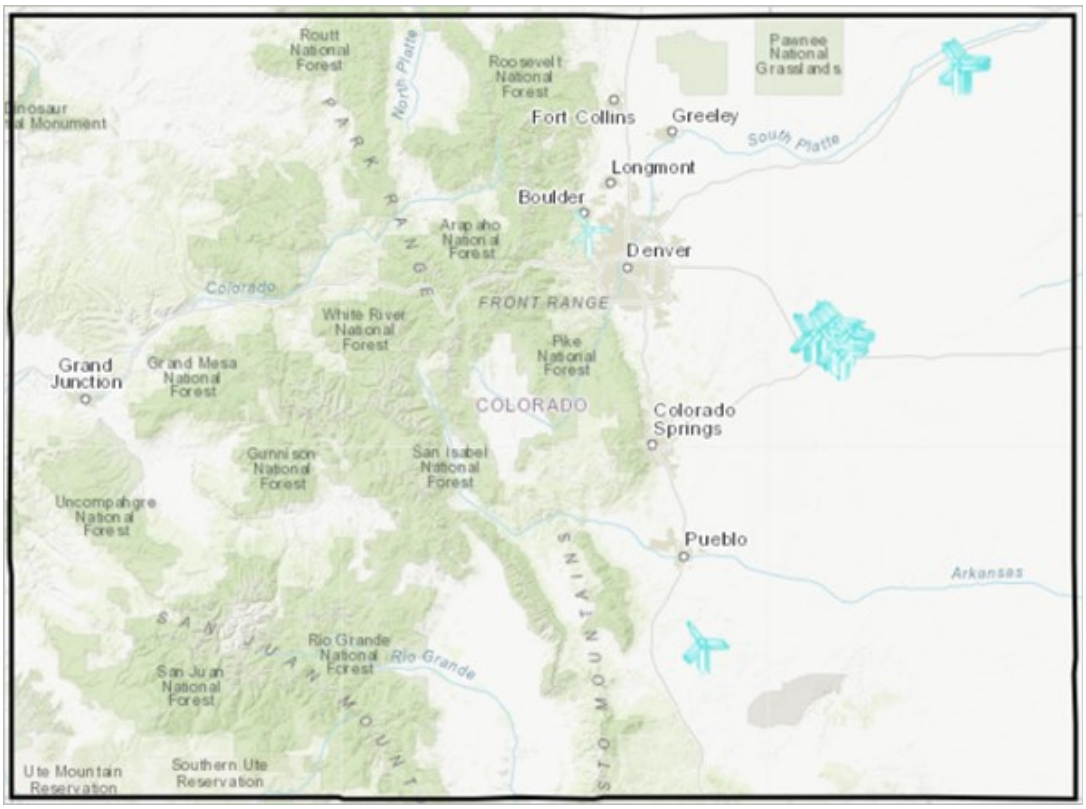
Identify turbines that meet criteria

One of the criteria for a new site location is that it must be within 5 miles of existing wind farms containing turbines where the rotor diameters span at least 100 feet. As earlier in the tutorial, you'll use the filter and buffer tools to identify these areas.

1. In the **Contents** pane, turn on and point to the **Wind Turbines in Colorado** layer and click **Filter**.
2. In the **Filter** window, create the expression **roto_dia is at least 100**.

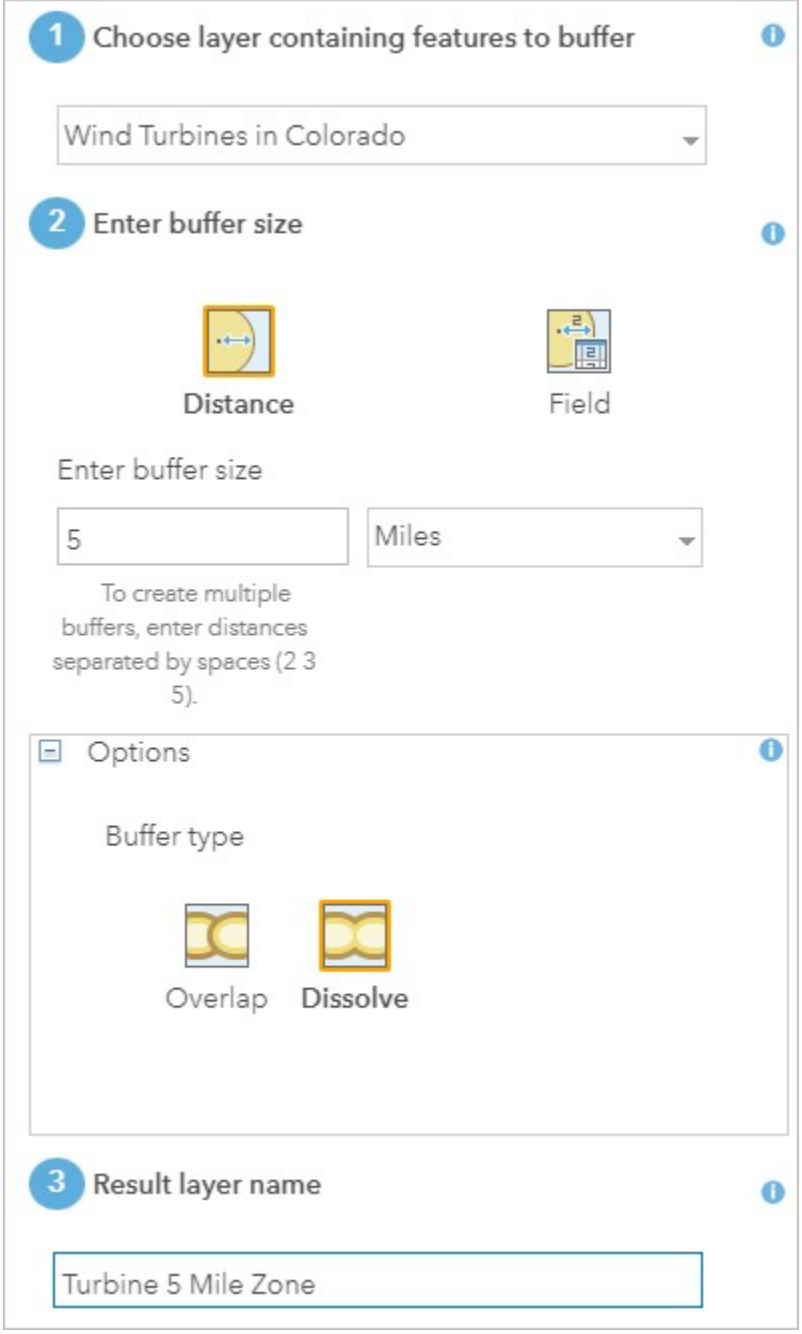
3. Click **Apply Filter**.

   Your layer now displays only existing wind turbines with a rotor diameter of 100 meters or greater. There are four turbine clusters.



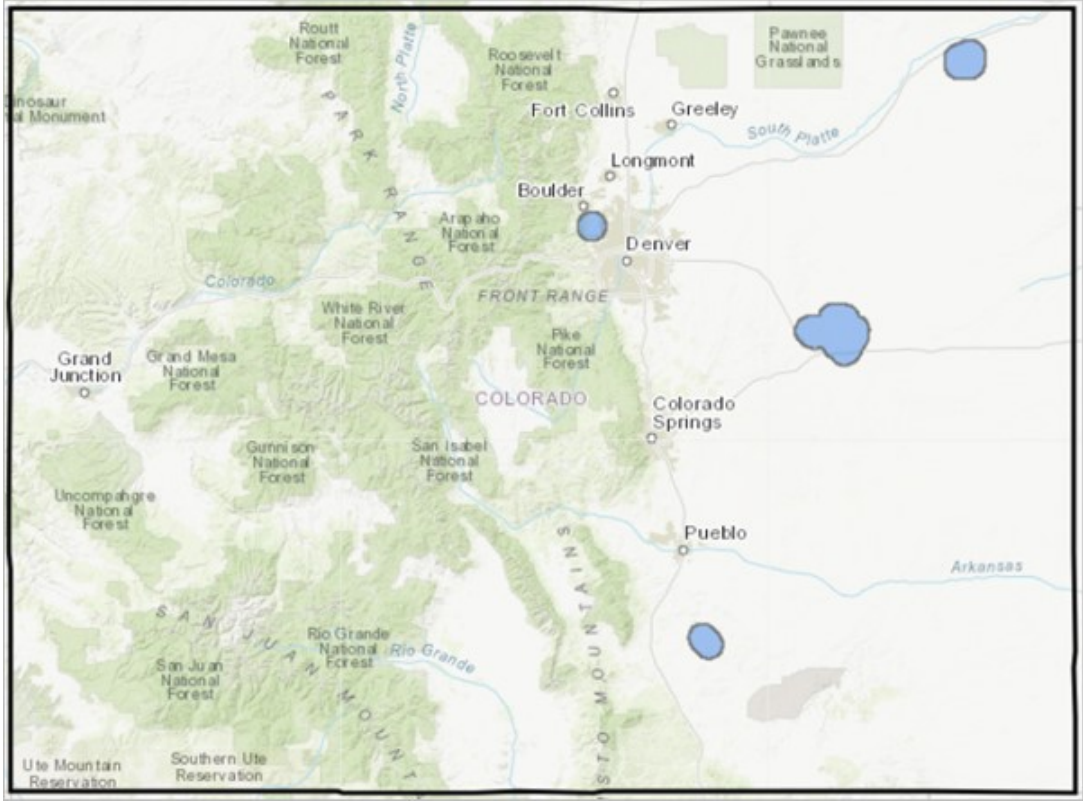
   Next, you'll generate 5-mile zones around the filtered turbines.

4. In the **Contents** pane, turn off the **Wind Turbines in Colorado** layer, point to the layer and click **Perform Analysis**.
5. In the **Perform Analysis** pane, click **Features Analysis**. Expand **Use Proximity** and click **Create Buffers**.
6. In the **Create Buffers** tool pane, enter the following parameters:
   - For **Choose layer containing features to buffer**, ensure the layer is set to **Wind Turbines in Colorado**.
   - For **Enter buffer size**, change the buffer size to 5 miles.
   - Expand **Options** and set **Buffer type** to **Dissolve**.
   - For **Result layer name**, type Turbine 5 Mile Zone and add your initials.



7. Click **Run Analysis**.

   The **Turbine 5 Mile Zone** layer is added to your map.

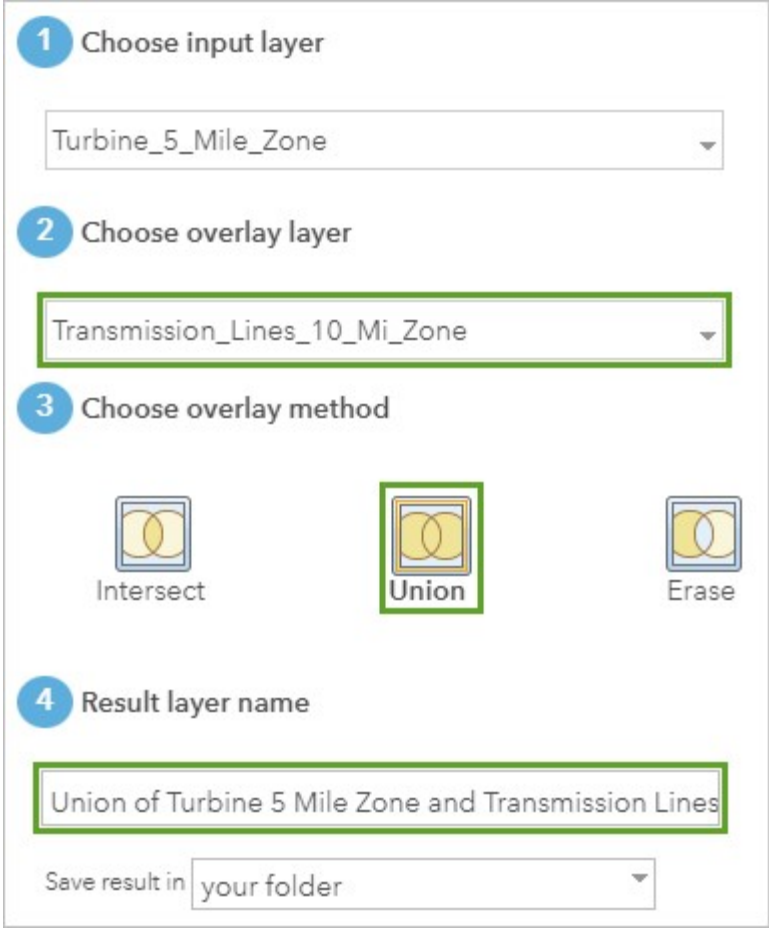


There are four turbine clusters, three of which appear to meet your criteria so far. To finalize your selection, look at the populations of the counties in which these clusters are located. Now you'll combine the buffered transmission lines and the buffered wind turbines into a separate layer using the **Union** tool.

8. In the **Contents** pane, point to the **Turbine 5 Mile Zone** layer and click **Perform Analysis**.
9. In the **Perform Analysis** pane, click **Feature Analysis**. Expand **Manage Data** and click **Overlay Layers**.
10. In the **Overlay Layers** tool pane, enter the following parameters:

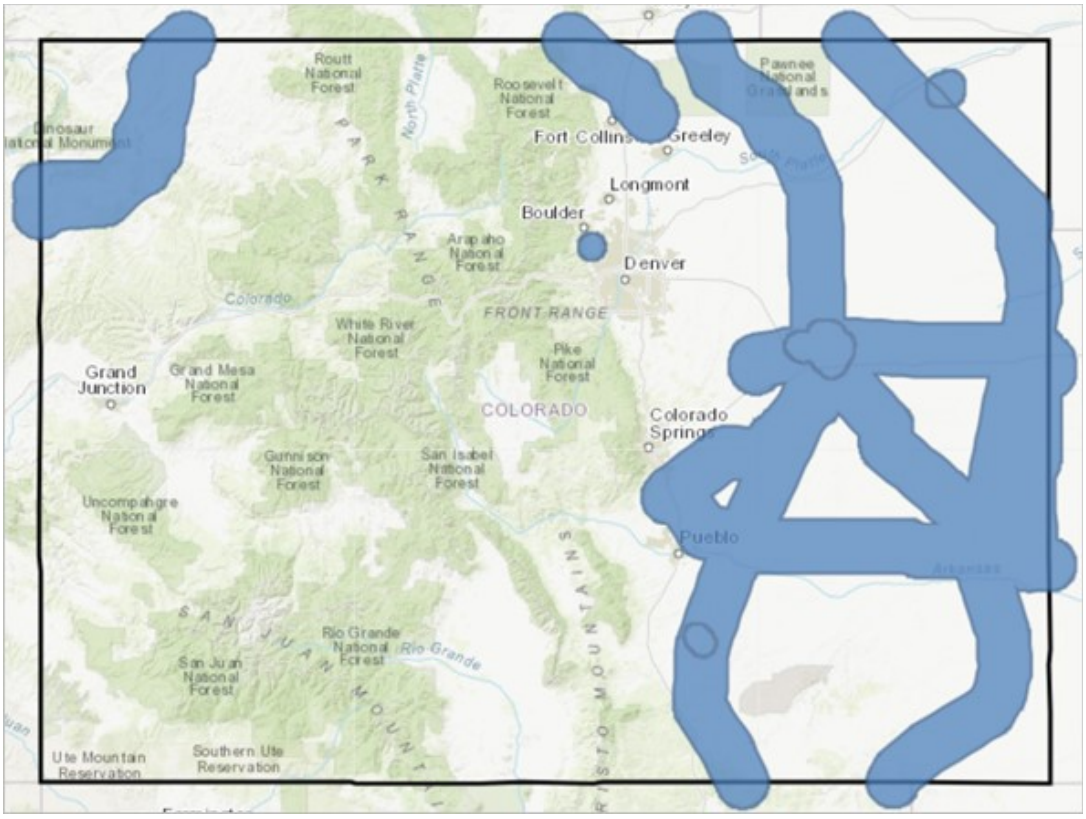
> **Note:**
>
> In the **Perform Analysis** tool pane, the layer names will include an underscore in between each word of the layer name. It will not affect the analysis results.

    - For **Choose input layer**, confirm the **Turbine 5 Mile Zone** layer is selected.
    - For **Choose overlay layer**, choose **Transmission Lines 10 Mi Zone**.
    - For **Choose overlay method**, choose **Union**.
    - For **Result layer name**, type Union of Turbine 5 Mile Zone and Transmission Lines 10 Mi Zone and add your initials.



11. Click **Run Analysis**.

    The resultant layer now contains all the buffered features for the transmission lines as well as the buffered wind turbine locations.



Using this layer, you'll be able to select all locations within 10 miles of a 400-volt transmission line as well as within 5 miles

of wind turbines with a rotor diameter of 100 feet.

12. On the ribbon, click **Save** and choose **Save** to save the map.

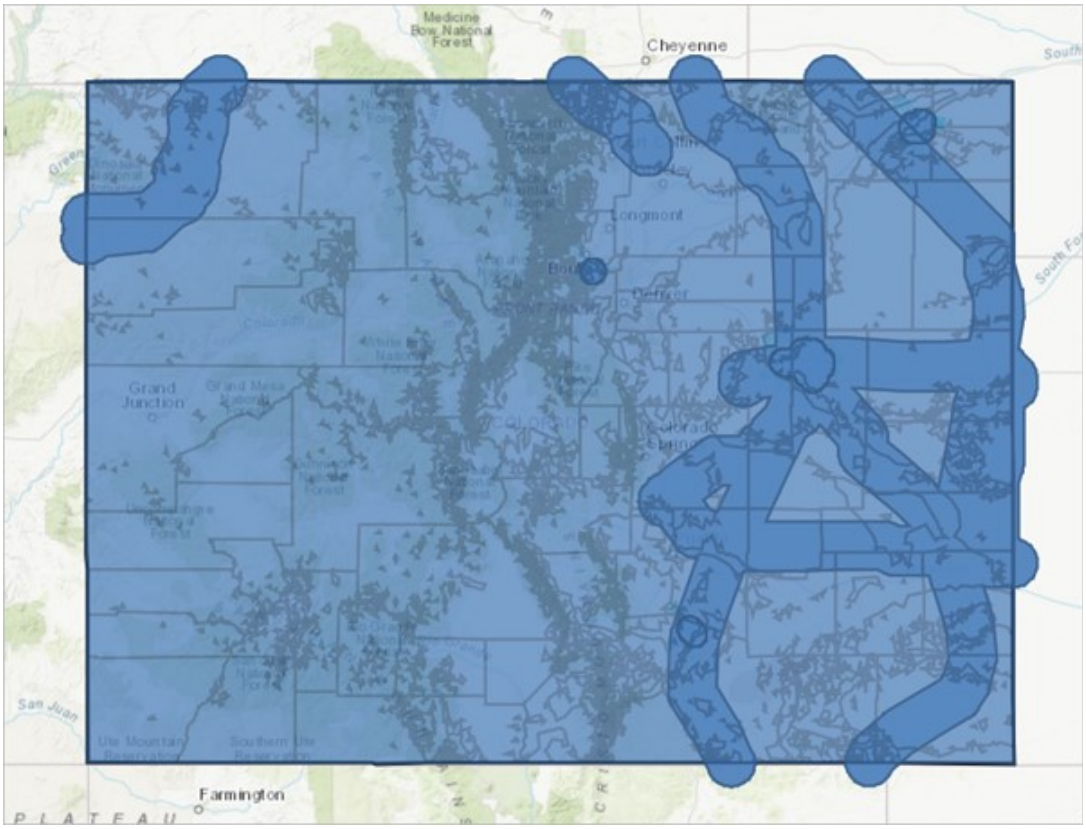
Next, you'll combine the two union layers into a single layer that contains all the required information: wind power class and counties and the 5-mile and 10-mile buffers, from which your final site selection can be made. This final layer will have all the criteria necessary for you to select suitable sites for your client to consider developing and installing high-capacity wind turbines.

Find locations for wind farms

Now that you've combined several of the layers and filtered them, you'll use the Find Existing Locations tool, which is designed to select existing features in your study area that meet a series of criteria you specify from a single layer. These criteria can be based on attribute queries (for example, wind power class areas with generating capacity greater than 4) and spatial queries (for example, areas within 10 miles of current transmission lines with a voltage greater than 400).

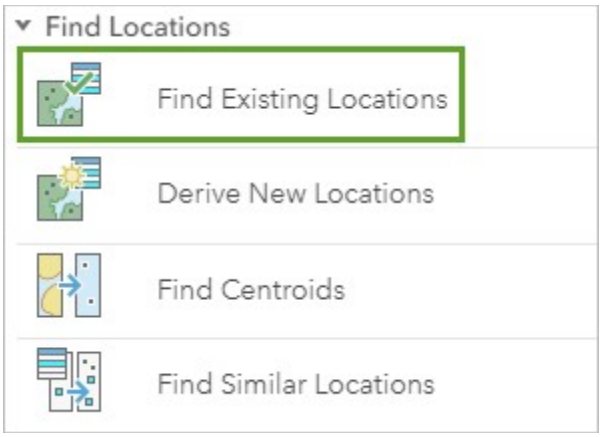
1. In the **Contents** pane, point to the **Union of Turbine 5 Mile Zone and Transmission Lines 10 Mi Zone** layer and click **Perform Analysis**.
2. In the **Perform Analysis** pane, click **Feature Analysis**. Expand **Manage Data** and click **Overlay Layers**.
3. In the **Overlay Layers** tool pane, enter the following:
    - Verify that **Choose input layer** is set to **Union of Turbine 5 Mile Zone and Transmission Lines 10 Mi Zone**.
    - For **Choose overlay layer**, choose **Union of Wind Power Class and Counties**.
    - For **Choose overlay method**, choose **Union**.
    - For **Result layer name**, type TargetSites and add your initials.
4. Click **Run Analysis**.

    The resulting **TargetSites** layer displays the combination of all features and their attributes that you would need to include in your analysis to determine suitable locations for your client.

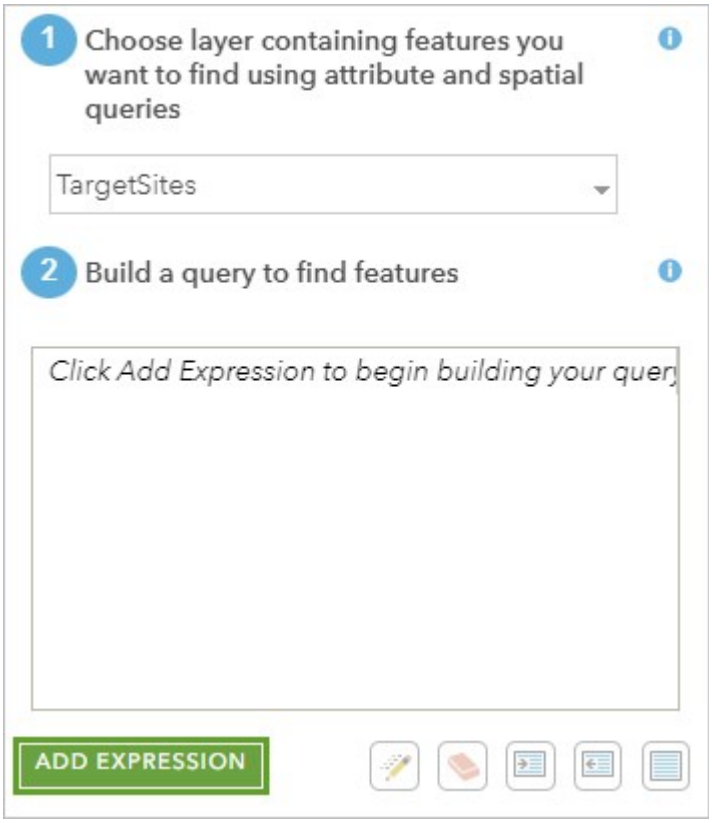


Now you'll use the Find Existing Locations tool, which allows you to combine the attribute and spatial selections in a single statement by adding a set of expressions, one at a time. These selection criteria can be based on attribute queries (for example, counties with a population greater than 20,000) and spatial queries (locations 10 miles from transmission lines).

5. In the **Contents** pane, point to **TargetSites** and click **Perform Analysis**.
6. In the **Perform Analysis** pane, click **Feature Analysis**. Expand **Find Locations** and click **Find Existing Locations**.



7. In the **Find Existing Location** tool pane, enter the following:
   - Verify that the layer for **Choose layer containing features you want to find using attribute and spatial queries** is set to **TargetSites**.
   - In **Build a query to find features**, click **Add Expression**.



The **Add Expression** window appears.

You can add multiple expressions to the query box as needed. When they are all entered in the **Find Existing Locations** tool pane, clicking the **Run Analysis** button will execute the list of expressions. Features in your input layer are then filtered through each expression, and those features that satisfy the expressions are written to a results layer.

As you did earlier, you'll build expressions, but these will query the **TargetSites** layer. You'll start with two spatial expressions to locate suitable sites within the 5-mile zone of turbines and the 10-mile zones of transmission lines. A spatial expression establishes a relationship between two layers. In this case, you're searching for all target sites in the first layer that are completely within the second layer, the 5-mile buffer zone of 100-foot rotor diameter wind turbines.

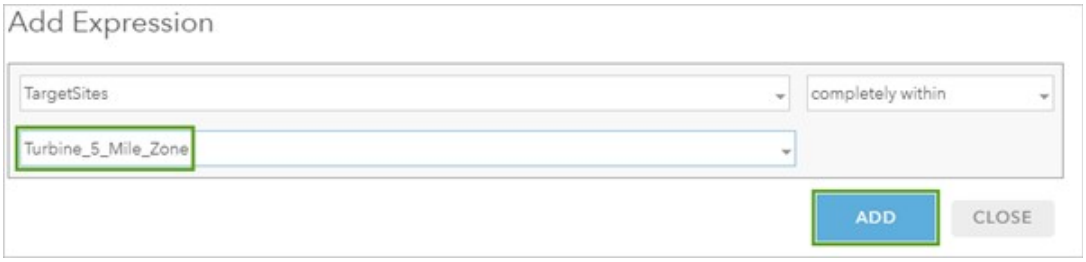
8. In the **Add Expression** window, ensure **TargetSites** is the first layer.

   The analysis layer (**TargetSites**) represents the source layer you are selecting from.

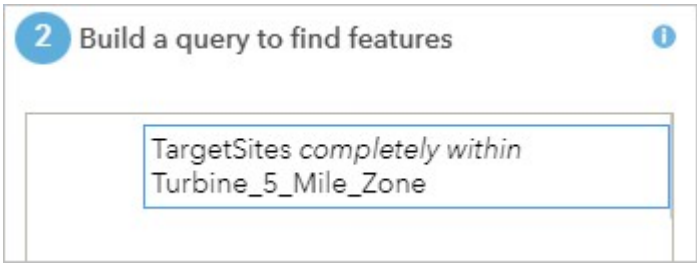
9. Choose **completely within** for the spatial relationship.

   Choosing **completely within** specifies that if a feature in the first layer is completely within a feature in the second layer, the location is included in the output. Once you establish a spatial relationship to other layers, they will be listed in the drop-down menu.

10. For the second layer, choose **Turbine 5 Mile Zone** and click **Add**.



    The first expression has been added to the expressions query box in the **Find Existing Locations** pane.



    Now you'll build the expression to locate target sites completely within the **Transmission Lines 10 Mi Zone** layer.

11. Click **Add Expression** and ensure that **TargetSites** is specified as the first layer.
12. Choose **completely within** for the spatial relationship and choose **Transmission Lines 10 Mi Zone** for the second layer.
13. Click **Add**.

    The second spatial expression is added to the expression query box and is combined with the first expression by the connector **and**. In queries, the operator **and** requires that each expression or condition must be true for a location to be

selected. The other operator, **or**, requires that one or the other condition, but not both conditions, can be true for a location to be selected.

Note:

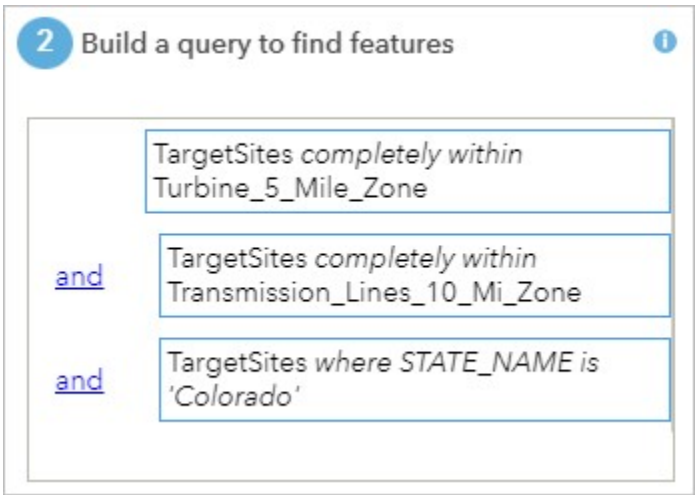
You can click the operator to switch between **and** and **or**.

Now you'll add a series of attribute selection expressions to further refine the locations that will be selected within the 5- and 10-mile zones.

14. Click **Add Expression** and build the expression **TargetSites where STATE_NAME is Colorado**.

15. Click **Add**.

The third expression is added to the expression query box and is combined with the first and second expressions by the **and** connector.

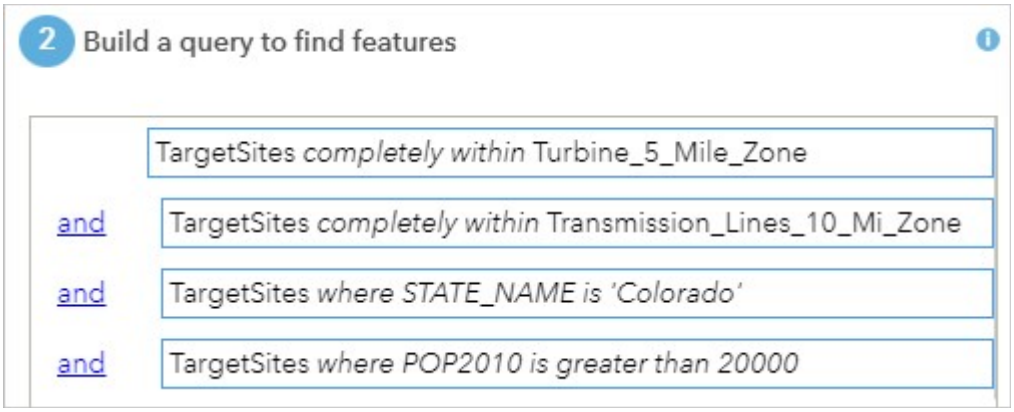


16. Click **Add Expression** and build the query **TargetSites** where **POP2010** is greater than 20,000, and click **Add**.

There will be four expressions in the query box list. The final expression you need to add will filter only the highest wind speeds.

17. Click **Add Expression** and build the query **TargetSites** where **GRIDCODE** is between 4 and 7, and click **Add**.

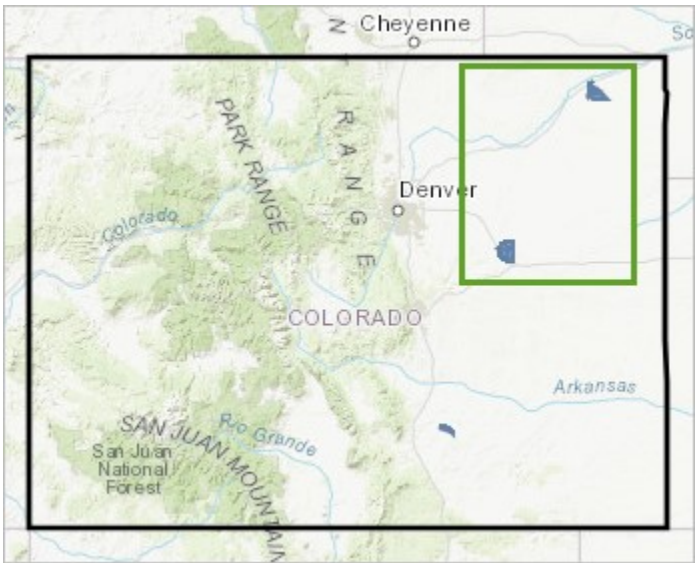
    The final expression is added to the query box.



> **Note:**
>
> The order of the expressions does not affect the result of the analysis.

18. In **Results Layer name**, type SuitableSites, add your initials, and click **Run Analysis**.
19. On the **Contents** tab, turn off all the layers except for the **SuitableSites**, **State Lines**, and the basemap layers.

    The two final sites are in the northeast corner of the state.



    There is also a smaller third site near Pueblo, but for the purposes of this tutorial, you'll focus on the two larger sites. One is in the northeast corner of the state and the other is southeast of Denver and northeast of Colorado Springs, near a town called Limon.

20. On the ribbon, click **Bookmarks** and explore the **Limon** and **NE Colorado** bookmarks.

    These sites both meet the criteria you need:

    - Located in the state of Colorado
    - In counties where the population as of 2010 is at least 20,000
    - In areas where the wind power class is at least 4 (Annual wind speeds in these areas at 10 meters off the ground are generally at least 5.6 meters per second [12.5 mph], and at 50 meters off the ground are generally 7.0 meters per second [15.7 mph].)

- Within 10 miles of existing power lines that have a capacity of at least 400 kilovolts (kV)
- Within 5 miles of existing wind farms containing turbines where the rotor diameters span at least 100 feet

21. Save the map.

Next, you'll create drive-time routes to each site to help make your final decision. Because transportation to and maintenance of the site are important, it should be easily accessible.

Route to prospective sites

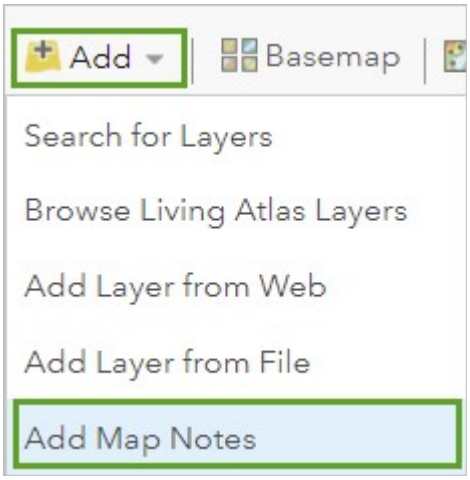
Previously, you explored site selection criteria for siting high-efficiency wind turbines and identified two potential sites in the state of Colorado. Selecting an appropriate site is key to the success of any renewable energy project and affects its financial viability.

Next, you'll perform a drive-time analysis between the potential sites and the company headquarters in Denver. This will be an important consideration, as engineers and other logistic staff involved in the installation and maintenance of the wind turbines are based at the company headquarters and not on-site in remote locations. Therefore, minimizing drive time and the availability of fast and efficient transportation routes to and from a new site are crucial to successfully maintaining and running equipment at these sites.

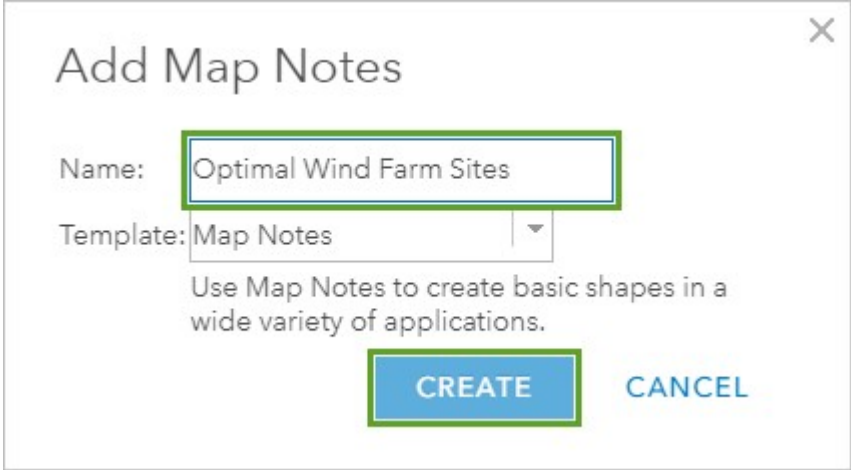
Add map notes

Now that you have identified suitable sites for the wind turbines, you need to conduct site visits and access routes between the sites and the company headquarters. First, you'll add map notes, and then you'll conduct drive-time analyses.

1. On the ribbon, click **Bookmarks** and choose **Limon**.
2. On the ribbon, click **Add** and choose **Add Map Notes**.



3. In the **Add Map Notes** window, name the notes Optimal Wind Farm Sites and click **Create**.



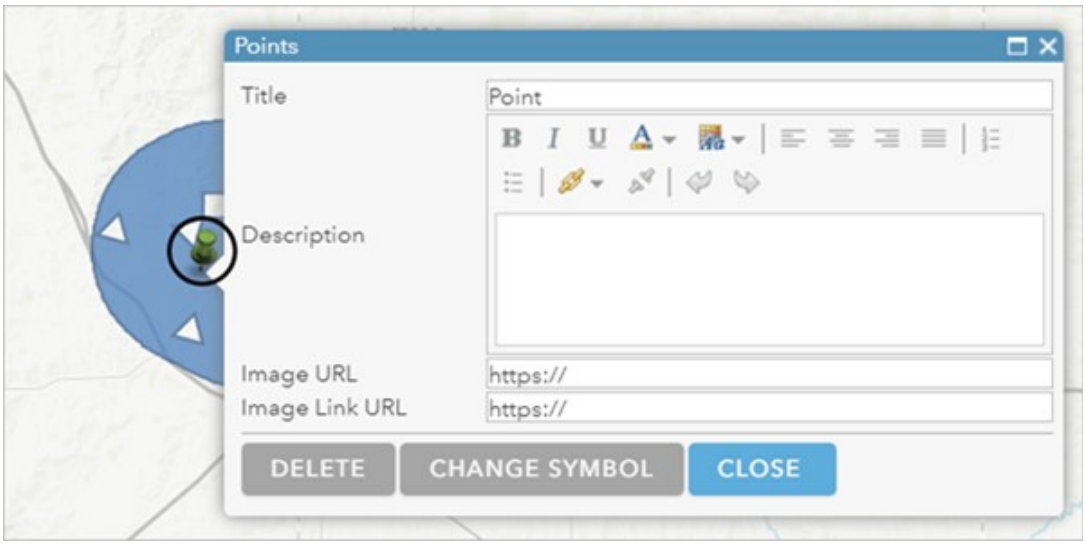
The **Map Notes** template allows you to create basic shapes and symbols.

> **Note:**
>
> There are other options for **Template**, including **Citizen Requests**, **Disasters**, and **Oil and Gas Infrastructure**, that provide additional specialized symbols.

4. In the **Add Features** pane, click **Pushpin**.

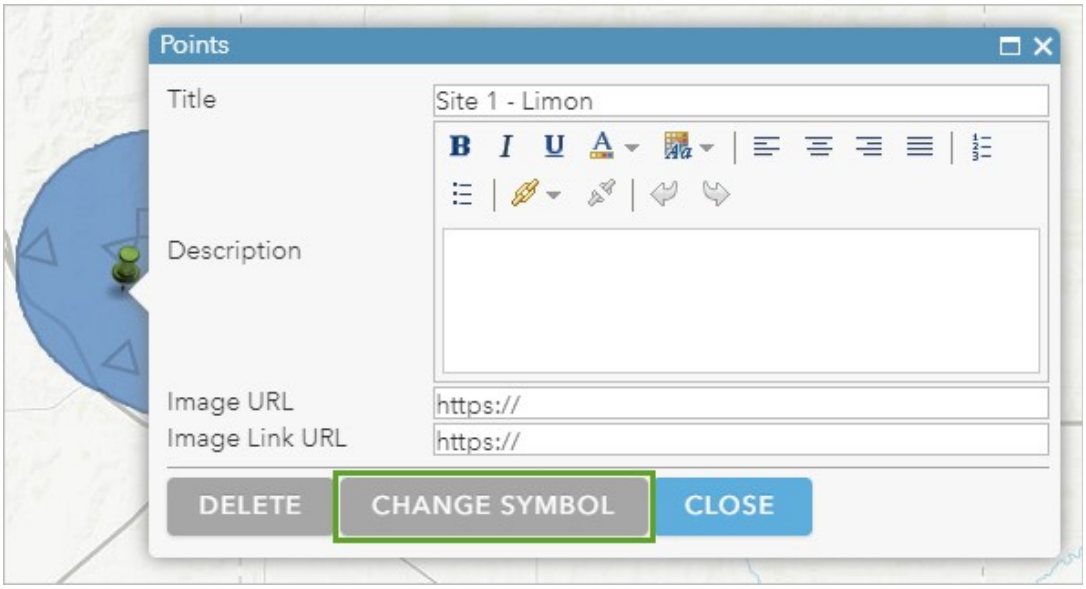
5. On the map, click anywhere within the Limon wind farm site to place the pushpin.

   When you have placed the pushpin, a pop-up window appears with additional options to input location information.



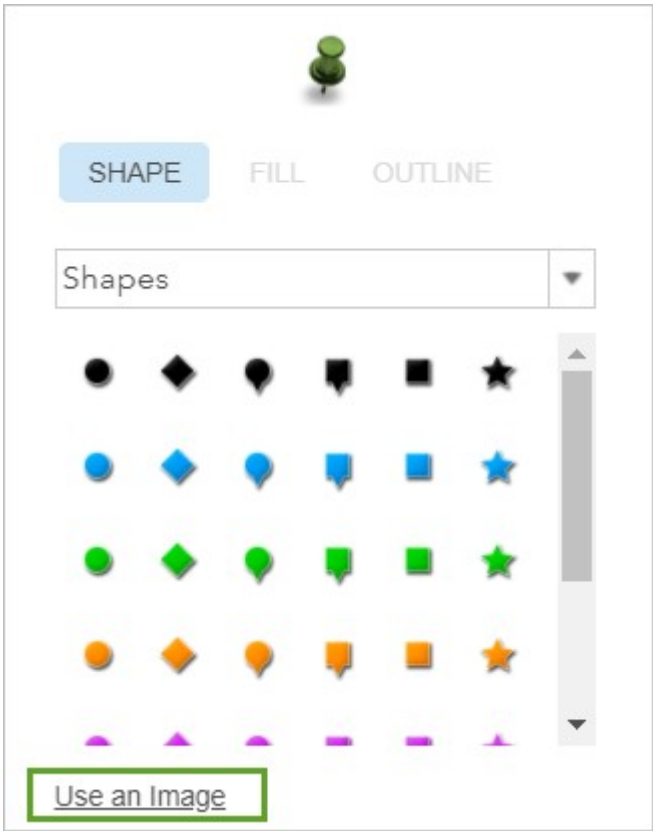
6. In the **Points** pop-up, for **Title**, type Site 1 - Limon.

7. Click **Change Symbol**.

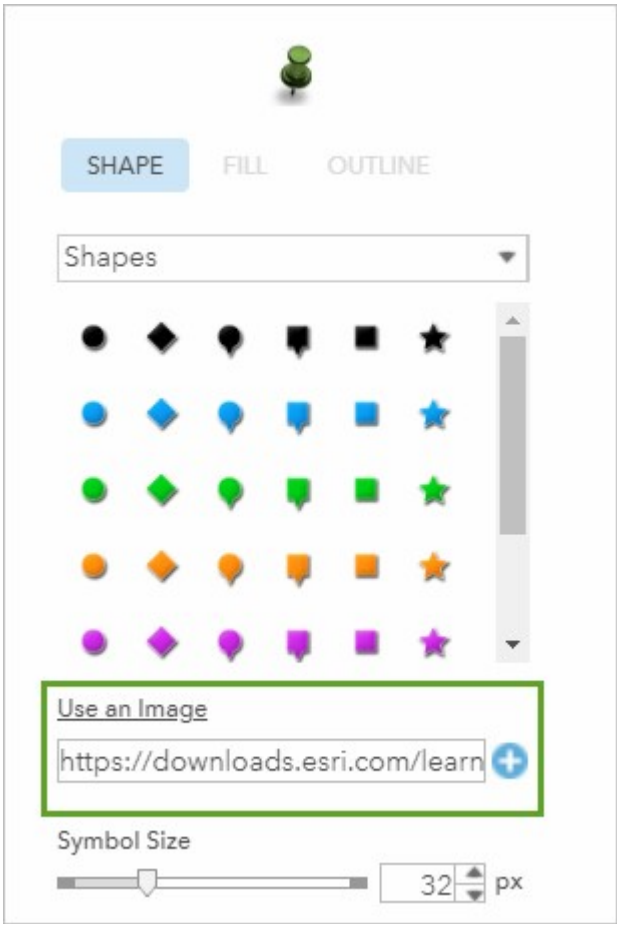


A symbol style window appears.

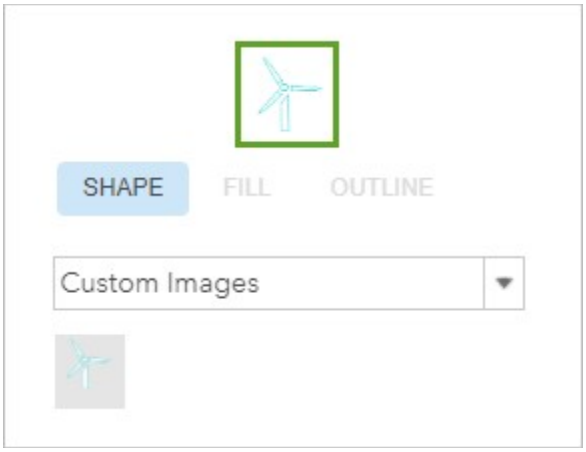
8. Click **Use an Image**.



9. In the text box that appears, copy and paste http://downloads.esri.com/learnarcgis/perform-a-site-suitability-analysis-for-a-new-wind-farm/wind-farm.png and press Enter.

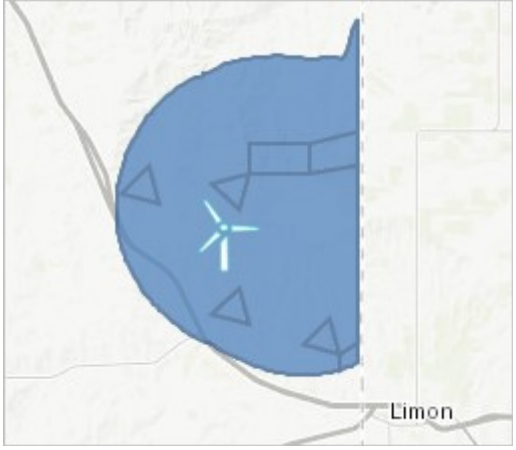


The symbol changes to a windmill.



10. Click **OK** and in the pop-up, click **Close**.

The point feature is now symbolized as a windmill.



Now you will add another point for the Fleming site.

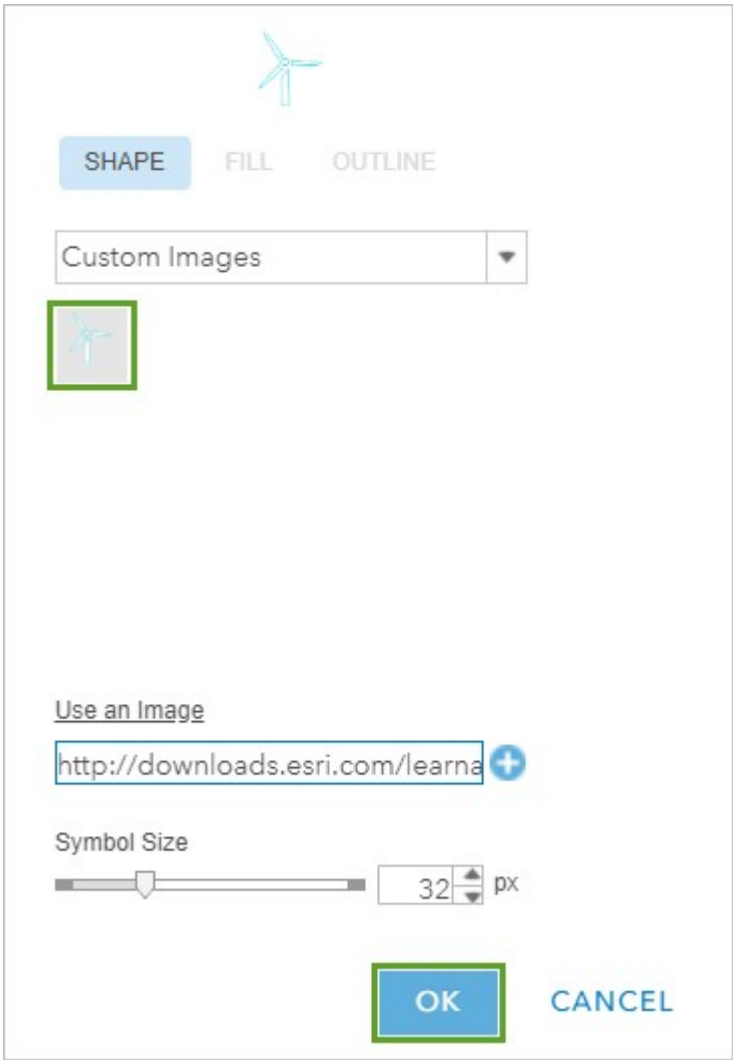
11. On the ribbon, click **Bookmarks** and choose **NE Colorado**.

    The map zooms to northeast Colorado and the Fleming site is visible.

12. In the **Add Features** pane, click **Pushipin** and add a pushpin anywhere within the Fleming wind farm site.
13. In the **Points** pop-up, for **Title**, type Site 2 - Fleming.
14. Click **Change Symbol**.

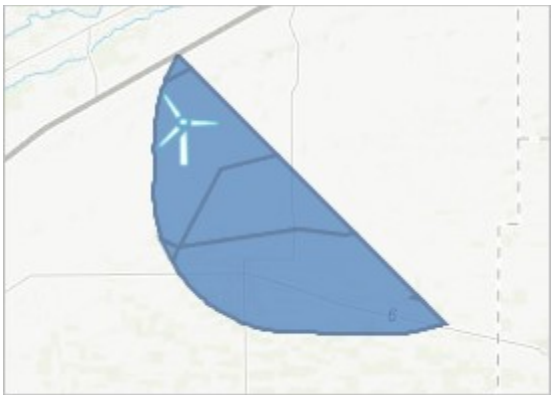
    In the symbol style window that appears, the custom shape you uploaded for the Limon site is available.

15. Click the windmill shape and click **OK** to update the symbol.



16. In the **Points** pop-up, click **Close** to save the point.

    The symbol for the Fleming site is changed to the windmill.

    You now have point locations for each site and are ready to perform a drive-time analysis.

17. On the ribbon, click **Details** to return to the **Contents** pane.
18. Save the map.

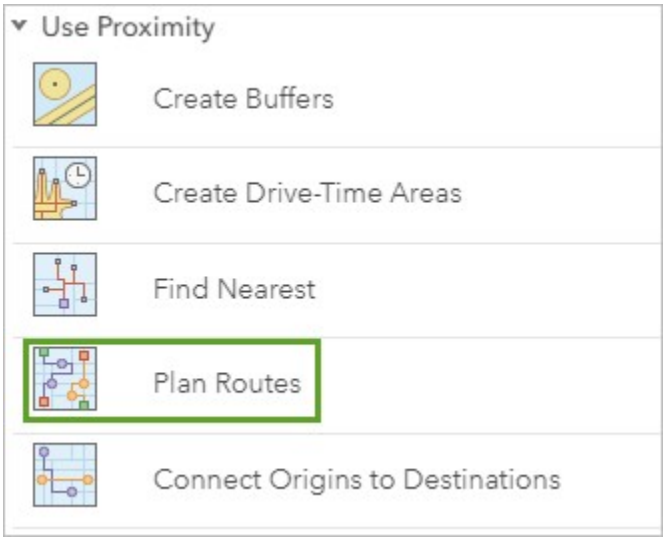
Calculate drive time

Now that you have point locations for each site, you can perform the drive-time analysis. You are ready to compute the optimal route so that you can visit the sites.

1. On the ribbon, click **Analysis**.

2. In the **Perform Analysis** pane, click **Feature Analysis**. Expand **Use Proximity** and choose **Plan Routes**.

    The **Plan Routes** tool determines how to efficiently route a vehicle to the stops that you specify.

3. In the **Plan Routes** tool pane, for **Choose point layer representing stops to visit**, ensure **Optimal Wind Farm Sites** is selected.
4. For **Travel mode for routes**, ensure **Driving Time** is selected and accept the default date and time settings for all routes.

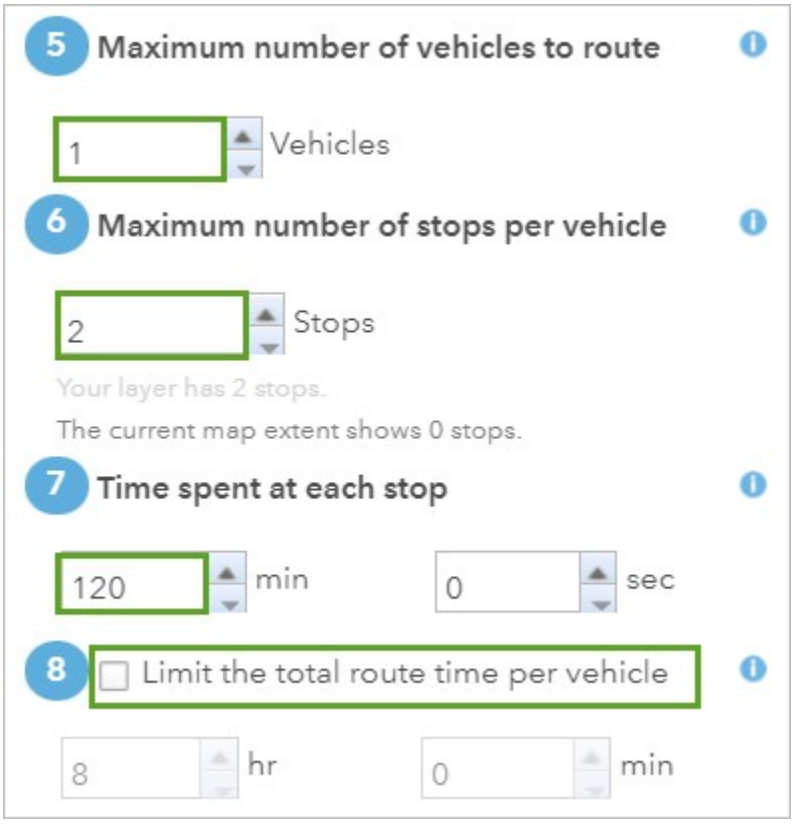
5. On the ribbon, click **Bookmarks** and choose **Denver State Capitol**.

   The map zooms in to the State Capitol building in Denver.

6. In the **Plan Routes** tool pane, for **Routes begin at stops**, click the **Draw** button and click the State Capitol building.

7. For **Routes end at stops**, ensure **Return to start** is checked.

8. Continue entering the following parameters in the **Plan Routes** tool pane:
   - For **Maximum number of vehicles to route**, type 1.
   - For **Maximum number of stops per vehicle**, type 2.
   - For **Time spent at each stop**, type 120 minutes.
   - Uncheck the box next to **Limit the total route time per vehicle**.



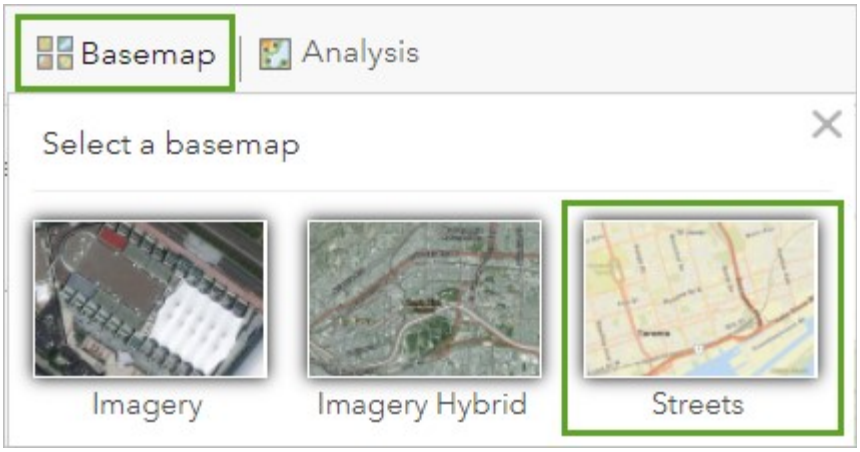
You anticipate that it will take you 2 hours, or 120 minutes, to inspect each site, but depending on the time of day you're using, the traffic might cause the total route time to vary.

9. For **Result layer name**, type Routes to Optimal Wind Farm Sites and add your initials. Check **Include route layers** and if necessary, choose the folder in which you want to save the result.

10. On the ribbon, click **Bookmarks** and choose **Colorado**.
11. In the **Plan Routes** tool pane, click **Run Analysis**.

Several layers showing driving routes to the wind farms are added to your map. Next, you will change the basemap to more clearly show driving routes.

12. On the ribbon, click **Basemap** and choose **Streets**.



The basemap updates on your map.

Note:

Results may vary slightly depending on time of day and where each site point was created.

The assigned stops for the route are numbered 1 to 4. The first and fourth stops are both located at the State Capitol. Since you set the **Route end at stops** option to **Return to start**, your route will visit all stops in sequence and return to the point of origin.

13. In the **Contents** pane, point to the **Routes to Optimal Wind Farm Sites – Assigned Stops** layer and click **Show Table**.

    This table contains four records, one for the start and end points, and one for each site under consideration. Your distances and times may vary slightly depending on where you placed your map notes.

14. For the **Routes to Optimal Wind Farm Sites** layer, click **Show Table** to display layer attributes.

Note:

Your values will likely be different than the values shown in the following table.

Stop Count	Total Time (Minutes)	Total Service Time (Minutes)	Total Travel Time (Minutes)	Total Miles	Total Kilometers	Start Time	End Time
2	607.62	240.00	367.62	382.26	615.19	5/10/2022, 2:01 PM	5/11/2022, 12:08 AM

This table contains one record for your entire route. Note that it states that two stops are included, and that the total time is approximately 607 minutes. This includes travel time and service time to inspect the sites. Of the 607 minutes, your total travel time is 367 minutes and service time is 240 minutes, making up the 120 minutes you would use to inspect each site.

If you subtracted your end time from your start time, you would notice that completing the route as planned would take around 10 hours. Therefore, even if you take a break from driving for 30 minutes, you would still be able to complete the travel and the site inspection in under one day.

15. Close the table.

Your route analysis would need to be included in your report to your client, along with your recommended site. Now you'll

evaluate the two sites and make a decision.

Recommend a site

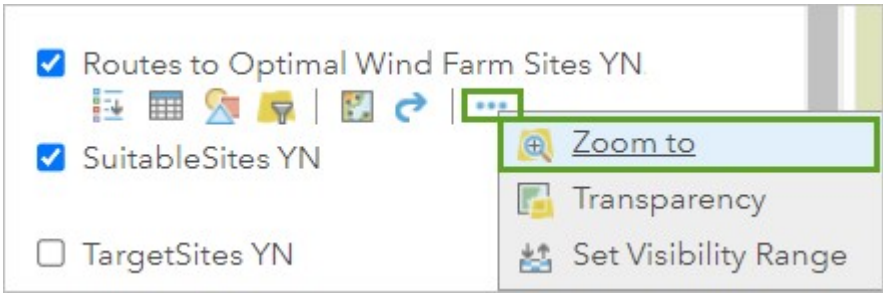
After your initial inspection, other visits will need to be conducted to look for soils, drainage, and other site factors. GIS will be helpful for assessing climate, slope and aspect, land ownership, historical incidence of tornadoes, performance of existing wind turbines, permits and permissions, and other factors. When these factors are considered, you can make an additional recommendation of how many turbines each site can accommodate.

1. In the **Contents** pane, point to the **SuitableSites** layer and click **Show Table** to display layer attributes.

   If you can only choose one of the sites due to budget constraints, and you are told to choose the larger of the two, the southern site, near Limon, much larger than the site in Fleming.

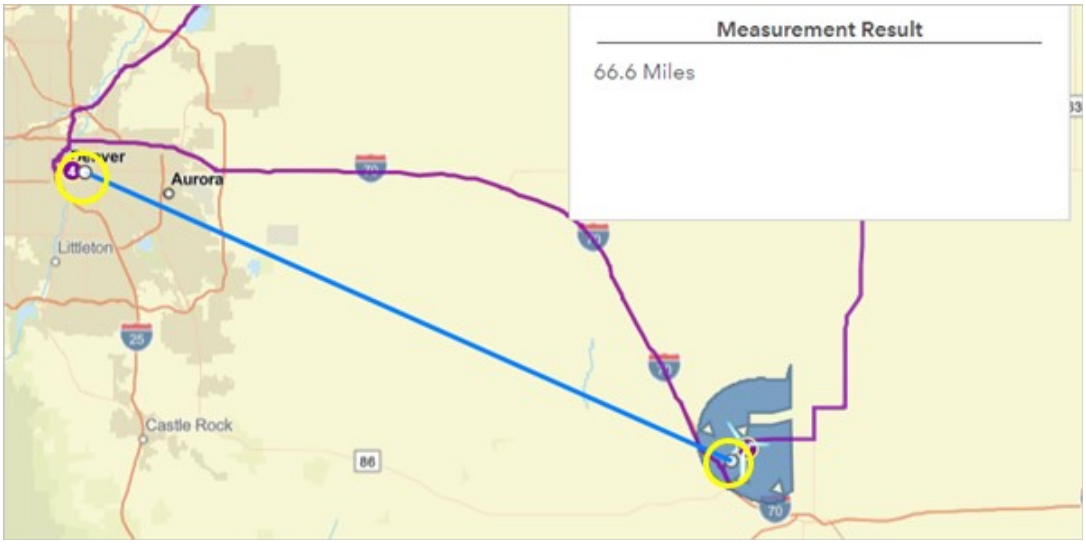
   If you are instructed to choose the site that is closer to Denver and its major population, you could use the route results or the measure tool to get a straight-line distance.

2. In the **Contents** pane, point to **Optimal Wind Farm Sites**, click the **More Options** button, and click **Zoom to**.



   Next, you will determine the straight-line distance from both the Limon site and the Fleming site to Denver with the **Measure** tool.

3. On the ribbon, click **Measure**, and click **Distance**.
4. On the map, click the Limon site, then click Denver. Take note of the distance under the **Measurement Result**.



5. Click the Fleming site, then click Denver and take note of the distance.

   The Limon site is closer, approximately 70 miles (113 kilometers) straight-line distance, compared to approximately 133 miles (214 kilometers) for the Fleming site. In other respects, such as mean wind speed and population per square miles,

the two sites are quite similar.

6. Save the map.

   It is most likely that you would recommend the Limon site, but there are additional considerations. GIS will be critically important in the logistics of transporting large wind turbines to the site. This may be the most difficult part of the operation because wind turbine blades often have to be transported by rail, and then by a convoy of two or three trucks, to accommodate the length. In this respect, the Fleming site may be better, because it is located near a major U.S. Highway (U.S. 6), whereas the Limon site, while near Interstate 70, has no exits directly to the site, and is located largely off unimproved county roads.

   Thus, there are pros and cons about both sites. But spatial analysis with GIS helped to narrow the decision to these two sites.

   Are other considerations important? Certainly, and if you were truly choosing a site for a client, you would consider additional factors and conduct additional analysis to qualify your recommended site to the client.

You've considered logistics about your site visits, using spatial thinking and GIS in the process.

Create a web app

Previously, you calculated drive time to each of the sites. Now, your client has requested preliminary results of the high-efficiency wind turbines site analysis study you are conducting. One of the best ways to efficiently share your results is to create a web app, allowing your client to explore and investigate your data and analysis results.

Share results as a web app

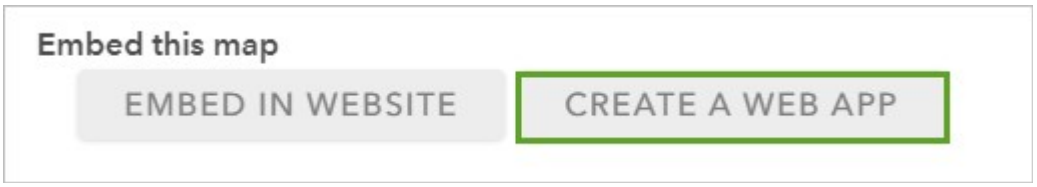
A web app is a customized map that you can present to the client to include and symbolize the data as you feel would best enable the commission members to understand the problem and the solution. To create a web app, you'll share your map publicly and choose a configurable app template. First, you'll choose the layers you want included in the app. These should convey your story to the commission members without overwhelming them.

1. In the **Contents** pane, ensure the following layers are turned on:
   - **Optimal Wind Farm Sites**
   - **Routes to Optimal Wind Farm Sites - Assigned Stops**
   - **Routes to Optimal Wind Farm Sites**
   - **SuitableSites**
   - **Platts Transmission Lines**
   - **Wind Turbines in Colorado**
   - **State Line**
2. Save the map.
3. On the ribbon, click **Share**.
4. In the **Share** window, check **Everyone (public)**.

   Note:

   If you are prompted to share layers, check **Update Sharing**.

5. Under **Embed this map**, click **Create a Web App**.



The **Create a New Web App** window appears. It includes a gallery of configurable apps, organized into categories based on purpose and functionality. You can filter the app templates by category or search for one. You want your map to be the primary focus of your app, but you also want to show the legend and a map description in a side panel.

6. On the **Configurable Apps** tab, search for side panel to find a suitable template.

The gallery of ArcGIS Instant Apps templates is filtered. **Sidebar** is a good choice.

7. Click **Sidebar**, and in the pane that appears, click **Create Web App**.

> **Note:**
> If your organization has configured custom galleries, you may not see these same configurable apps.

8. In the **Create a New Web App** window, for **Title**, type Wind Turbines in Colorado Impact Study. For **Summary**, type Optimal Wind Farm Sites.
9. Click **Done**.

The web app is created. The ArcGIS Instant Apps configuration window appears for the **Sidebar** template, which includes several app settings and an interactive preview of your app. By default, this template includes a side panel that displays a legend, map details, and pop-ups.

The app also has a header with sharing options, map navigation tools, and a search tool to find locations on the map.

You want to provide a description in the **Details** panel that helps app users understand the data in the app.

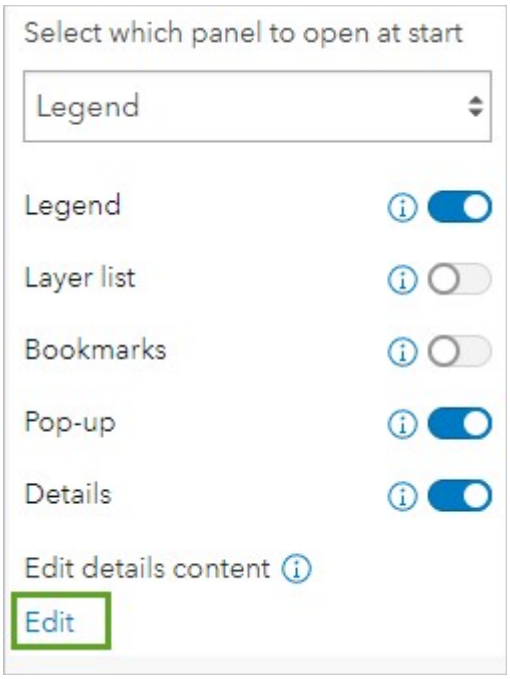
10. In the **Express** panel, click the **Sidebar** step.

> **Tip:**
> You can click **Search settings** and type a keyword, such as description, to display a list of suggestions that you can click to go directly to a specific setting.

The **Sidebar** settings provide options to include the side panels with information about the map. **Details** is turned on, and

there is an option to customize it.

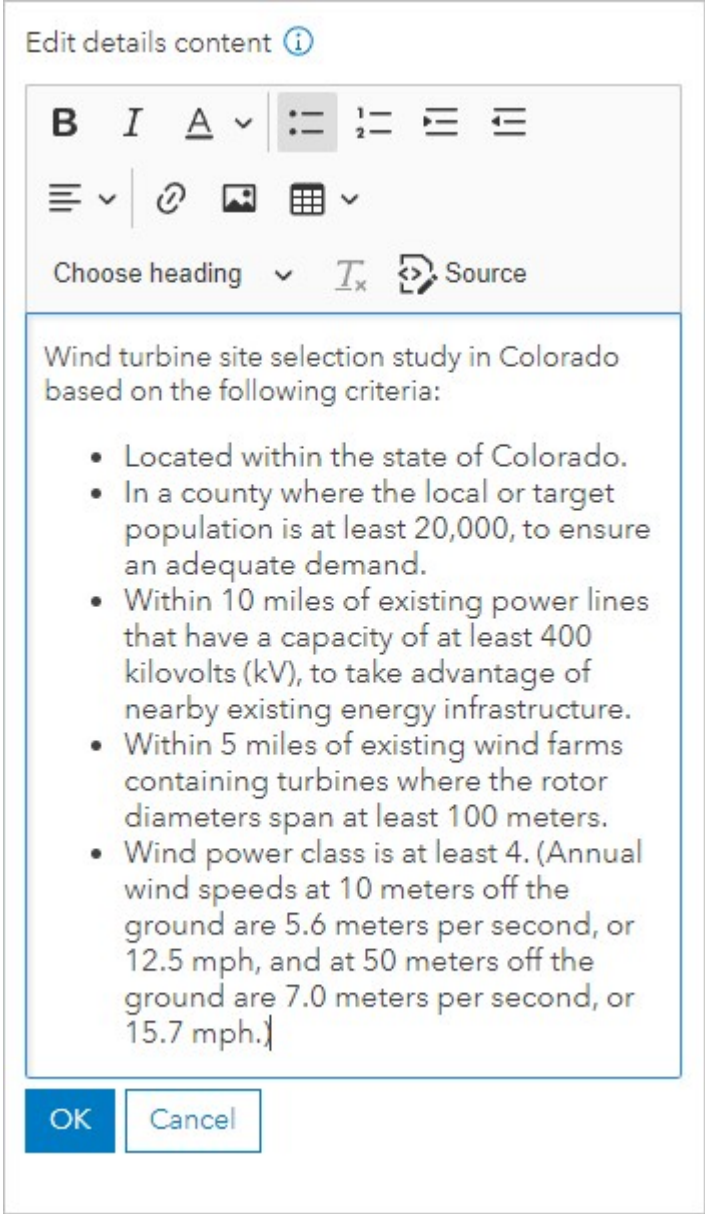
11. For **Edit details content**, click **Edit**.



12. In the text box that appears, copy and paste the following description, formatting it with bullets where necessary:

    Wind turbine site selection study in Colorado based on the following criteria:

    - Located within the state of Colorado.
    - In a county where the local or target population is at least 20,000, to ensure an adequate demand.
    - Within 10 miles of existing power lines that have a capacity of at least 400 kilovolts (kV), to take advantage of nearby existing energy infrastructure.
    - Within 5 miles of existing wind farms containing turbines where the rotor diameters span at least 100 meters.
    - Wind power class is at least 4. (Annual wind speeds at 10 meters off the ground are 5.6 meters per second, or 12.5 mph, and at 50 meters off the ground are 7.0 meters per second, or 15.7 mph.)



13. Click **OK**.
14. In the app preview, click the **Details** button.

    The app preview updates with your new content in the **Details** panel. The app automatically saves as noted next to the **Draft** badge that appears in the configuration panel.

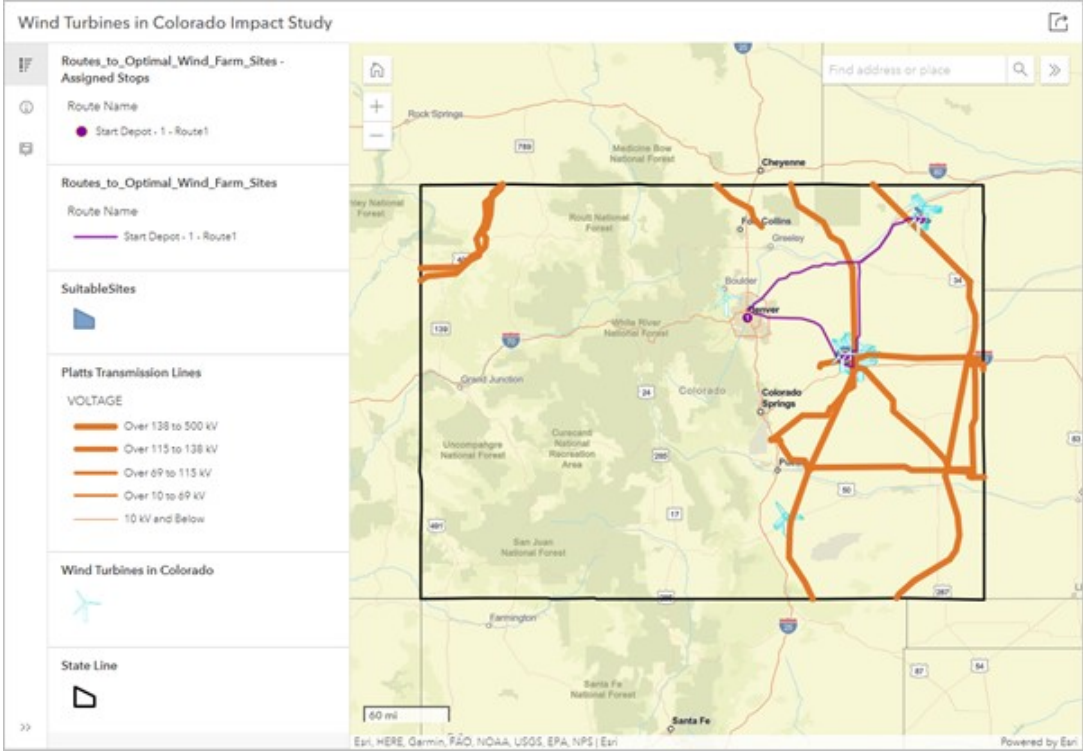
15. In the configuration panel, click **Back**, and then click the **Theme & Layout** step.
16. For **Select a mode**, choose **Light**.

    The color scheme of your app changes from the default dark theme to a light theme, which works better with the symbols in your legend.

17. Click **Publish**, and in the **Publish** window that appears, click **Confirm**.

    A success message appears when publishing is completed and the **Draft** badge changes to a **Published** badge with the date and time you published. The **Share** window appears, which includes a link that you can send to your client to access your app.

18. Click **Launch** to open your app in another window.



19. Explore the app and the layers.

    You could share this app with the company who hired you to show them the potential sites and the driving routes from Denver.

20. Return to the app configuration window and close the **Share** window. Click **Exit**. When prompted, confirm that you want to exit.

    The app's item page appears, where you can add more details such as a description of the app, terms of use, and any necessary data attribution.

In this tutorial, you examined spatial relationships to conduct a site suitability analysis. You ran a series of spatial analysis functions, determined how you would conduct site visits, and prepared a web app to communicate your results to your client.

You can find more tutorials in the tutorial gallery.

Acknowledgements

Data used for this tutorial was derived from the National Renewable Energy Laboratory (NREL) Renewable Energy (RE) Atlas.

Send Us Feedback

Please send us your feedback regarding this tutorial. Tell us what you liked as well as what you didn't. If something in the tutorial didn't work, let us know what it was and where in the tutorial you encountered it (the section name and step number). Use this form to send us feedback.

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