Exercise 15: Intermediate Raster Analysis

Since raster data have a fundamentally different data structure compared to vector data, different tools and techniques are used to work with, process, and analyze these data. In this exercise, you will undertake a variety of raster analysis techniques. The first part of the lab is a guided exercise in which you will use raster analysis techniques to determine suitable locations to potentially build a rare earth elements treatment facility for mine slug. Special thanks to Chris Vass for creating the synthetic rare earth element data. The second part of the lab will be less guided, and you will be asked to find suitable habitat for a salamander across a seven county area in West Virginia.

Topics covered in this exercise include:

1. Create a variety of raster analysis outputs including: Euclidean distance grids, topographic slope grids, topographic aspect grids, binary grids, and kernel density grids
2. Convert vector data to raster data
3. Use a variety of raster analysis tools and techniques including: Euclidean distance, raster calculator, reclassify, kernel density, slope, and aspect
4. Answer spatial analysis questions by combining raster analysis tools

---

Step 1. Open a Map Project

First, we need to download and open the **Exercise_15.aprx** file.

☐ Download the **Exercise_15** data from https://www.wvview.org/. All lab materials are available on the course webpage and linked to the exercise. You will need to extract the compressed files and save it to the location of your choosing.

☐ Open ArcGIS Pro. This can be done by navigating to All Apps followed by the ArcGIS Folder. Within the ArcGIS Folder, select ArcGIS Pro. Note that you can also use a Task Bar or Desktop shortcut if they are available on your machine.

☐ After ArcGIS Pro launches, select "Open another project."

Open another project

☐ Navigate to the directory that houses the material for this course. The project files are in the **Exercise_15** folder where it was saved on your local machine.

☐ Select **Exercise_15.aprx**. Click OK to open the project.

☐ If necessary, navigate to the WV map.

Note: If you'd prefer, you can also just click on the **Exercise_15.aprx** file within the uncompressed folder directly to launch ArcGIS Pro.

This project should contain two maps that house the data needed for the lab: Part1 and Part2. The data have already been symbolized. However, feel free to change the symbology. Throughout the lab, you may want to turn layers on and off so that it is easier to visualize the results of your analysis.

The Part1 map houses the data required for the first, more guided, part of the lab. It includes the following layers:

counties: polygon county boundaries representing the extent of your study area in southern West Virginia

mine_discharge_points: point locations of discharge sites (note that this is synthetic data and they do not represent true measurements)

**elevation:** digital elevation model (DEM) of the region in meters

rail_lines: line features representing railroads

towns: point location of towns

pub_lands: polygon features of public lands

Your goal will be to create a binary (0/1 or FALSE/TRUE) surface in which cells coded as 1 would be adequate to locate a rare earth elements treatment facility for mine slug. Here are the criteria:

1. Not in public lands
2. Within 2 miles of railroads
3. Greater than 2 but less than 10 miles from towns
4. On slopes of less than 15 degrees
5. With a high density of mine discharge points nearby
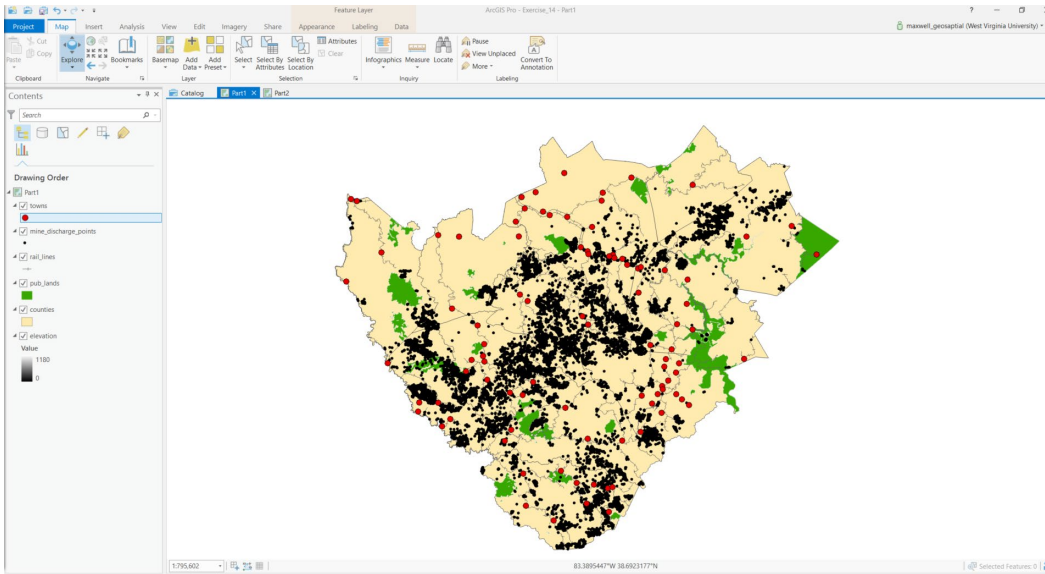
The Part2 map houses the data required for the second, less guided, part of the lab. It includes the following layers:

landcover: categorical land cover raster grid from the 2011 National Land Cover Database (NLCD)

elevation: DEM of the study area extent in meters.

In the second part you will predict the occurrence of a salamander species in a seven county area in West Virginia as a binary output. In this seven county area, prior research suggests that this salamander species is only found in evergreen or mixed forests, at elevations greater than 800 meters, and on southeast to southwest facing slopes (112.5 to 247.5 degrees).
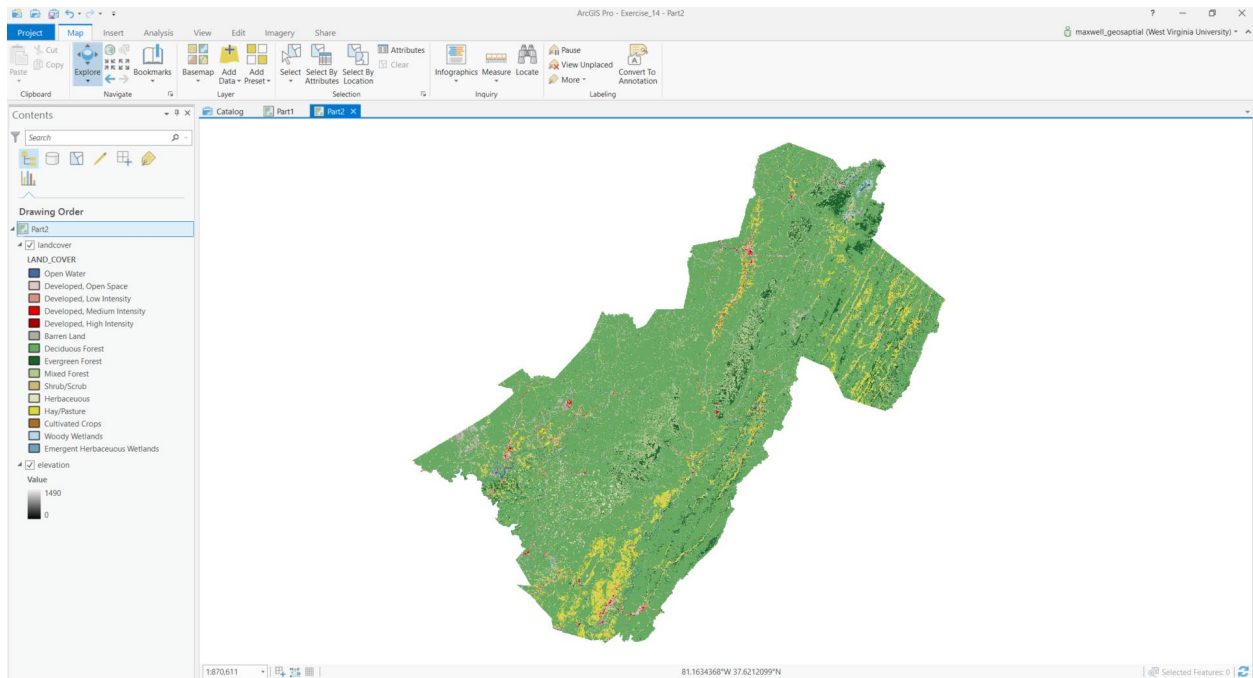
We will begin with the guided exercise using the Part1 Map.

Step 2. Defining Environment Settings

Since you will perform many spatial analysis operations in this lab, you will start by setting the environment settings. It is generally a good idea to set environment settings any time you will perform spatial analysis operations in a project. Also, this can speed up your processing, as you will not need to set environments for each tool individually. In short, we highly recommend this.

☐ Make sure the Part1 map is active.
☐ Navigate to the Analysis Tab then select Environments in the Geopocessing Area.

☐ Change the Current Workspace and the Scratch Workspace to the **Exercise_15.gdb** geodatabase in the **Exercise_15** folder. This will cause all of the outputs to automatically be saved to this location.
☐ Set the Output Coordinate System to Current Map [Part1] (should be NAD 1983 UTM Zone 17 North) under Output Coordinates.
☐ Set the processing extent to be the same as the **counties** layer under Processing Extent.
☐ Also under processing extent, set the Snap Raster to the **elevation** layer.
☐ Set the cells size to be the same as the **elevation** layer (should be 30, meaning 30 by 30 meters) under Raster Analysis.

4
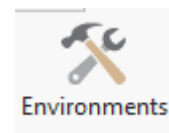
☐ Also under Raster Analysis, set the Mask to the **counties** layer.
☐ Click Okay to accept these settings.
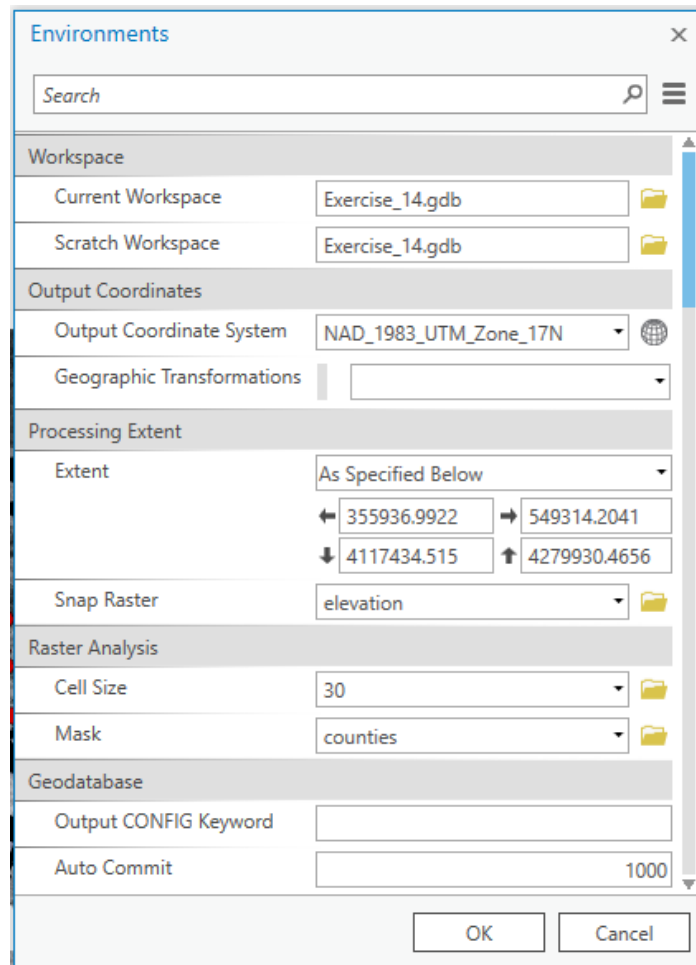
Note: Setting the snap raster to the **elevation** layer means that all the raster grids you create will align perfectly with the **elevation** layer. We recommend setting a snap raster, especially if you plan to perform any raster overlay, as you will do here, since this results in a cleaner overlay, as the cells align perfectly.

Step 3. Create Euclidean Distance Grids

Two of the criteria in this simple model is distance from railroads and distance from towns. So, you will need to create Euclidean distance grids relative to these variables. Euclidean distance calculates the straight line (Euclidean) distance from a source to the created cell. This is accomplished using the **Euclidean Distance Tool**.

Note: In this lab, we will access tools from ArcToolbox. However, there are many ways to access tools in ArcGIS Pro. For example, some of the more common tools are provided in the Tools list in the Analysis Tab.
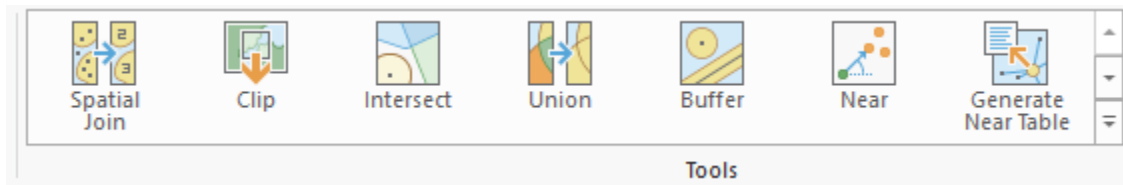

Once you open the Geoprocessing Pane, you can access favorite tools or search for Tools.
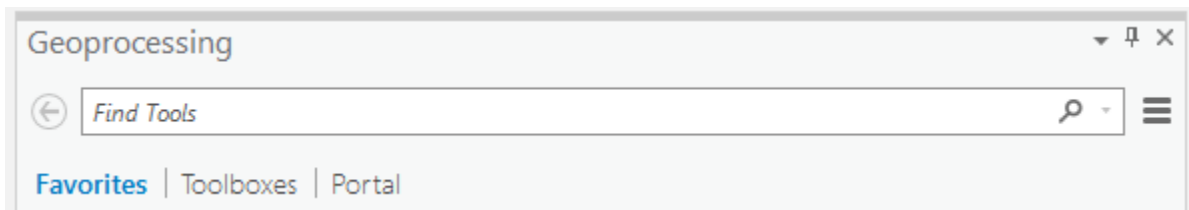
We have decided to demonstrate ArcToolbox here so that you get a sense of where the tools are located in the Toolbox directory. You can also create your own tools and toolboxes, which will be investigated in later labs.

☐ In the Analysis Tab, select Tools from the Geoprocessing Area. This should open the Geoprocessing Pane.

☐ In the Geoprocessing Pane, navigate to the Toolboxes.
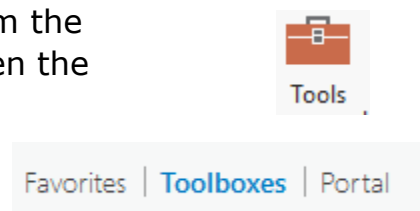
Note: We will not provide these directions for accessing other tools. We will just tell you where to find them within ArcToolbox.

We will start by calculating distance from towns.

☐ Navigate to Spatial Analyst Tools followed by the Distance subtoolbox.
☐ Click on the **Euclidean Distance Tool**.
☐ Set the Input Raster or Feature Source Layer to the **towns** layer.
☐ Name the Output Distance Raster **town_dist** (this will save to the **Exercise_15.gdb** geodatabase, as defined in the environment settings).
☐ You do not need to change any of the other settings.
☐ Click Run to execute the tool. The output should automatically be added to your map.
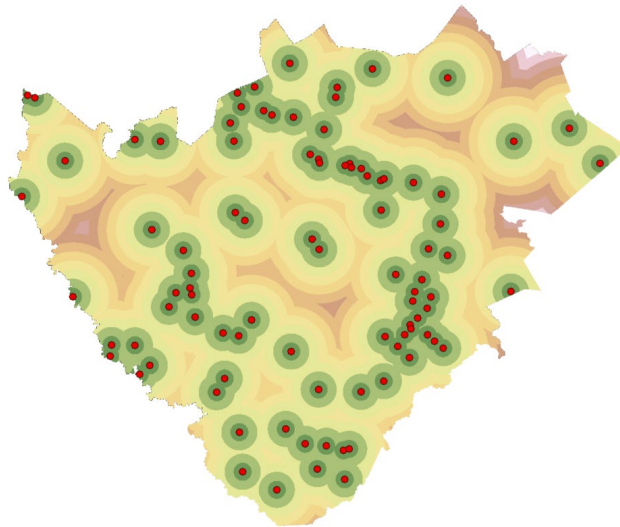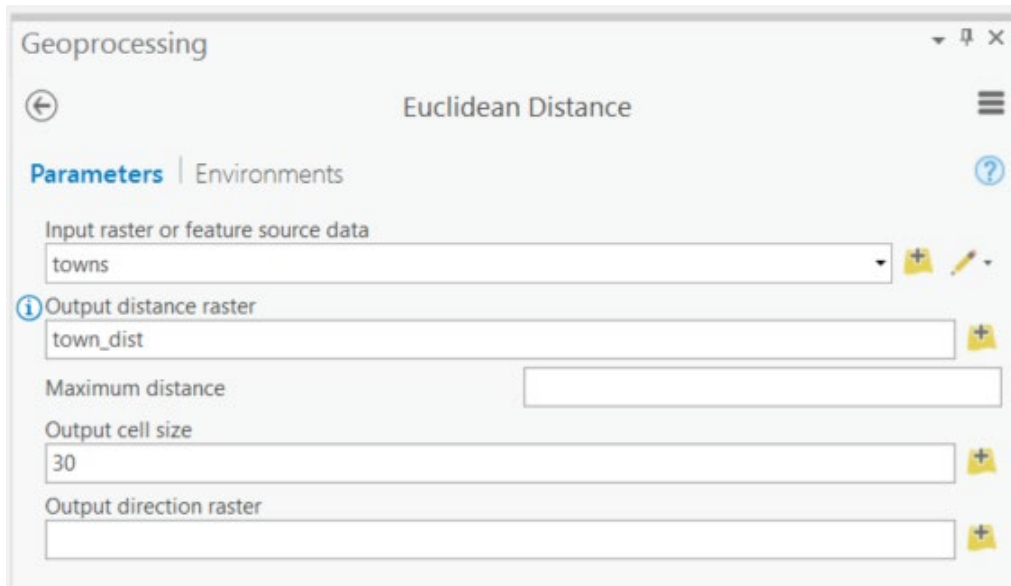
☐ Complete a similar process to obtain the distance from railroads. Name the output **rail_dist** and make sure the cell size is 30.

Question 1. Explain what is meant by Euclidean in relation to calculating a distance. (4 Points)

Step 4. Calculate Topographic Slope from a DEM

You have been provided with a DEM, which represents elevation measurements. However, in this model, you need topographic slope, not elevation. Luckily, you can easily derive topographic slope from raster-based elevation data using the **Slope Tool**.

☐ Navigate to Spatial Analyst Tools followed by the Surface subtoolbox.
☐ Click on the **Slope Tool**.
☐ Set the Input Raster to the **elevation** layer.
☐ Name the Output Raster **slp_d**.
☐ Make sure the Output Measurement is set to "Degrees."
☐ You do not need to change any of the other settings.
☐ Click Run to execute the tool. The output should automatically be added to your map.
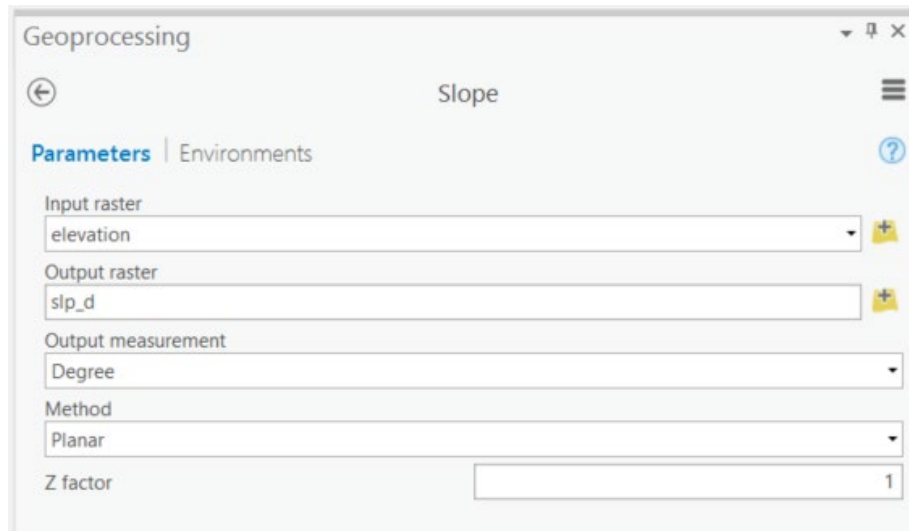
Question 2. Explain the difference between degrees and percent slope. (4 Points)

Question 3. When would you need to set a Z factor when calculating slope? (4 Points)

Step 5. Using Raster Calculator to Produce Binary Grids

You have now created surfaces that represent the distance from towns, distance from railroads, and topographic slope. However, you have not found cells that meet the model criteria. To obtain this, you will use the **Raster Calculator Tool**. This tool allows you to perform mathematical and logical operations on cells and write the result to a new raster grid. Here we will make use of the logical operators to find cells that meet a certain criteria. Cells that meet the criteria will be coded as 1, or TRUE, whereas cells that do not meet the criteria will be coded as 0, or FALSE. These 1/0 or TRUE/FALSE grids are known as binary raster grids. Let's start by finding all the cells that are within 2 miles of a railroad.

- ☐ Navigate to Spatial Analyst Tools followed by the Map Algebra subtoolbox.
- ☐ Click on the **Raster Calculator Tool**.
- ☐ Provide the following syntax: **rail_dist** <= 3218.7 (This number is roughly equivalent to 2 miles. You have to specify the distance in meters because the horizontal units of this map are in meters, and that is how the distance units in the Euclidean distance grid are defined).
- ☐ Name the Output Raster **rail_dist_re**.

☐ Click Run to execute the tool. The output should automatically be added to your map.
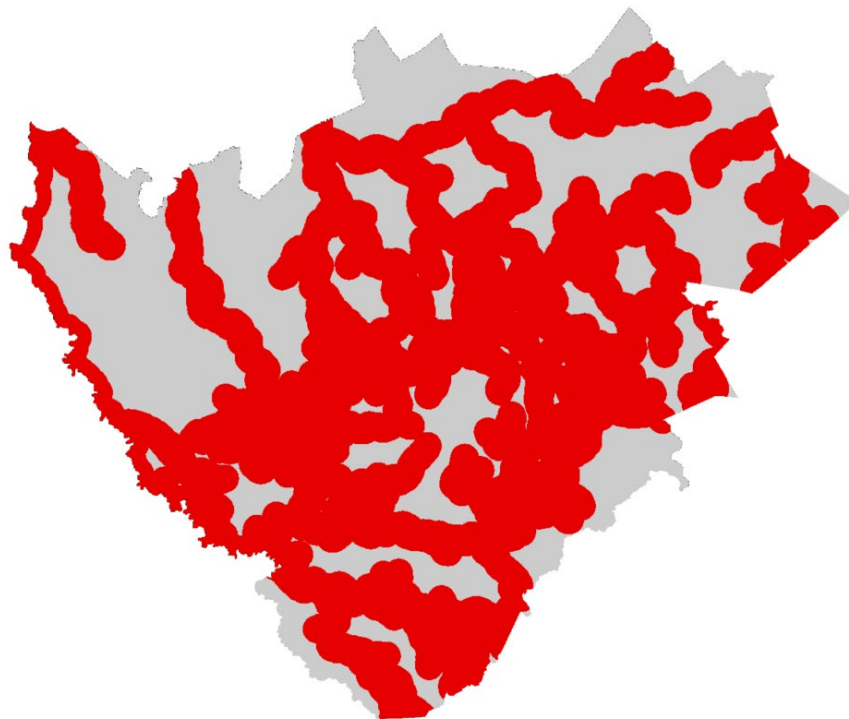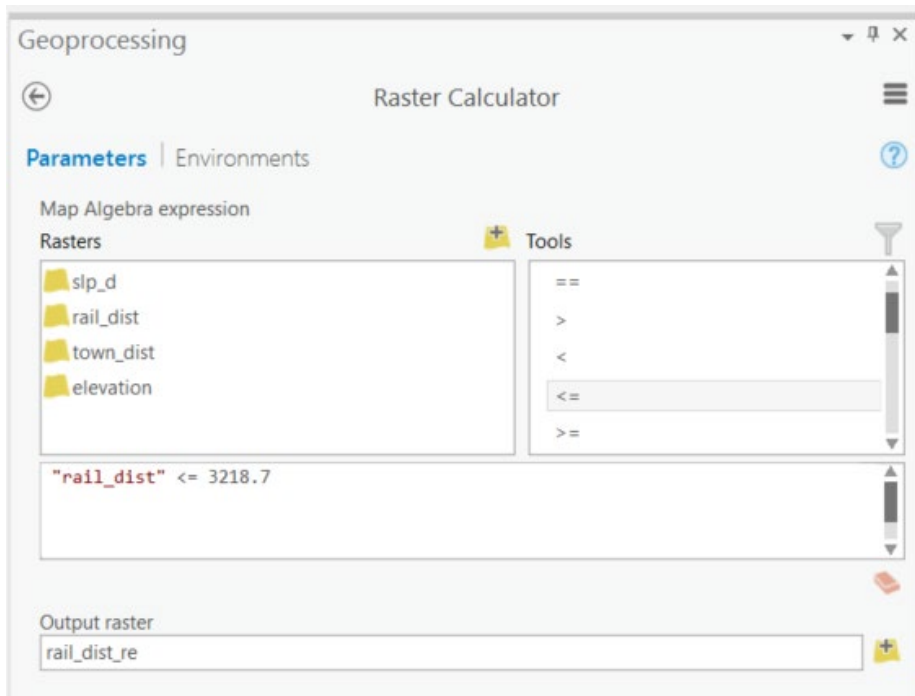
- Complete a similar analysis to find all of the cells that meet the topographic slope criteria (The slope must be less than 15 degrees). Name the output **slp_d_re**.

Question 4. What was your syntax for obtaining the binary surface for the slope criteria? (2 Points)

You can use the raster attribute table to answer the following questions.

**Question 5.** How many cells met the railroad distance criteria? (2 Points)

Question 6. How many cells met the topographic slope criteria? (2 Points)

Step 6. Using Reclassify to Produce Binary Grids

Instead of using the **Raster Calculator Tool** to obtain the binary grid for the railroad distance criteria, we will use the **Reclassify Tool**. This tool allows you to reclassify values or ranges of values to a new value or code. For example, you could use this tool to generalize a land cover dataset from many classes to just a few classes, such as forest vs. not forest. Here, we will use the tool to recode a range of values.

First, you will change the classification scheme for the **town_dist** layer.

- Right-click on the **town_dist** layer in the Contents Pane then select Symbology. This will open the Symbology Pane.
- Change the Method to Manual and the number of classes to 3.
- The criteria is that the location should be more than 2 but less than 10 miles from a town. In the Class Breaks table, change the upper values of the first break to 3,218.7 (equivalent to 2 miles) and the middle break to 16,093.4

Symbol	Upper value	Label
	≤ 3218.7	≤ 3218.7
	≤ 16093.4	≤ 16093.4
	≤ 28164.13671875	≤ 28164.136719

(equivalent to 10 miles). Do not change the upper value of the last column.
- This will update the symbology.
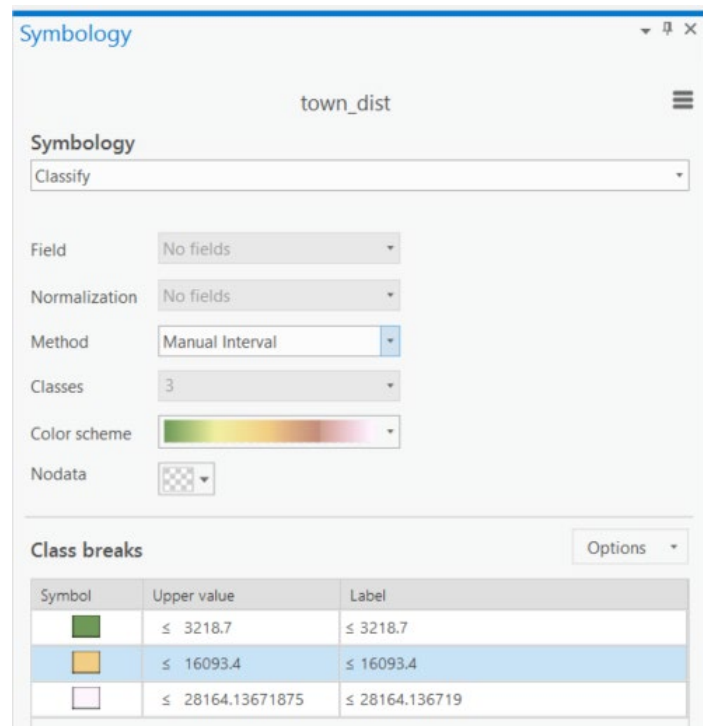
You are now ready to perform a reclassify.

- ☐ Navigate to Spatial Analyst Tools followed by the Reclass subtoolbox.
- ☐ Click on the **Reclassify Tool**.
- ☐ Set the Input Raster to the **town_dist** layer.
- ☐ Make sure the Reclass Field is set to "VALUE."
- ☐ In the New column of the Reclassification Table the first row should be coded to 0, the second to 1, and the third to 0. So, low and high values will be coded as 0 or FALSE while the middle values (between 2 and 10 miles) will be coded to 1 or TRUE. Note that the table was automatically populated with the manually defined values you entered when changing the symbology.
- ☐ Name the Output Raster **town_dist_re**.
- ☐ Click Run to execute the tool. The output should automatically be added to your map.
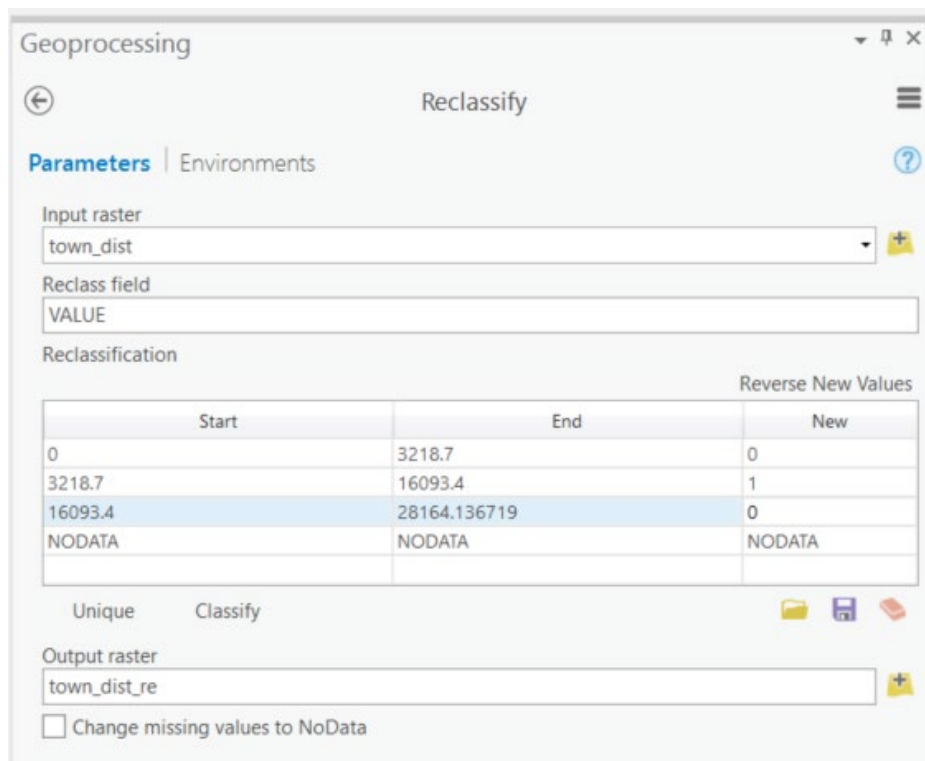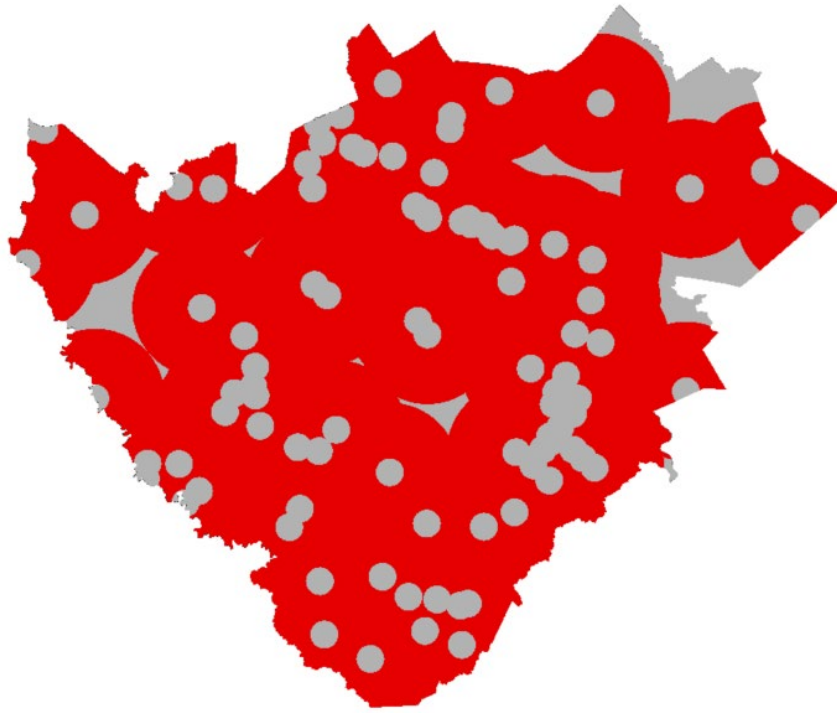
Use the attribute table of the resulting layer to answer the following question.

Question 7. How many cells meet the distance from towns' criteria?
(2 Points)

Step 7. Convert Vector Data to Raster Data

You now have three of the five criteria prepared. You will now find all areas that are not in public land. The **pub_lands** layer is a polygon vector layer that provides the public land extents. You will start by converting this vector layer to a raster layer.

- ☐ Navigate to Conversion Tools followed by the To Raster subtoolbox.
- ☐ Click on the **Polygon to Raster Tool**.
- ☐ Set the Input Raster to the **pub_lands** layer.
- ☐ Set the value field to the "code" field. This field is populated with 1, so each cell in the output will hold a value of 1.
- ☐ Name the Output Raster Dataset **public_r**.
- ☐ You do not need to change any of the other settings, but make sure that the Cell Size it set to 30.
- ☐ Click Run to execute the tool. The output should automatically be added to your map.
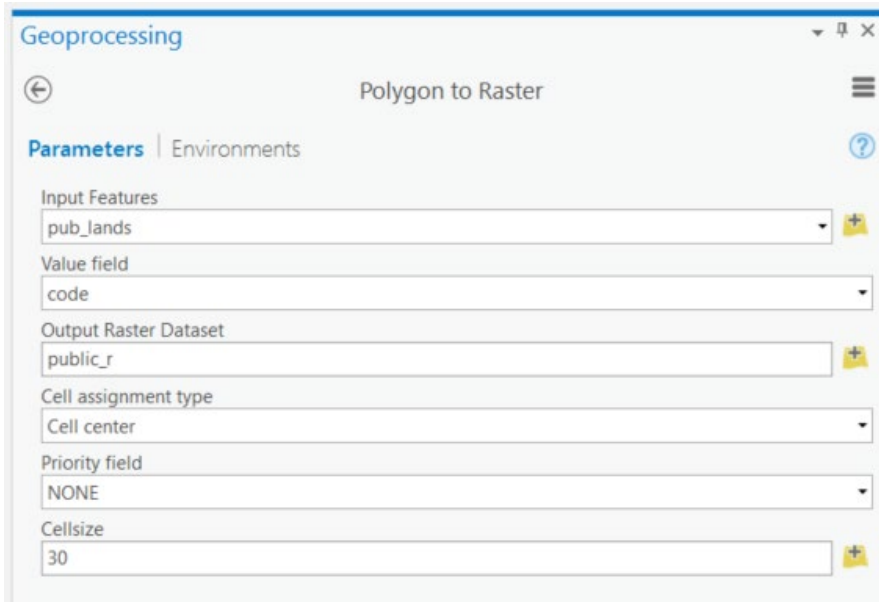
The public lands boundaries have now been converted to a raster grid where each cell in the extent of public lands is coded as 1. However, this is not what you need. Instead, you need a raster in which cells outside of public lands are coded as 1 and cells in public lands are coded as 0. Currently, the cells outside of public lands are coded as NULL or NoData. You will fix this using the **Reclassify Tool**. Note that there are many ways to accomplish this task. We are demonstrating Reclassify here so that you can get more practice using this tool.

 Use the **Reclassify Tool** to code all NoData cells (those outside of public lands) in the **public_r** grid as 1 and all cells currently coded as 1 (those inside of public lands) as 0. Name the output **public_r_re**.


14

Use the attribute table of the result to answer the following question.

Question 8. How many cells in the study area extent are not in public lands? (2 Points)

Step 8. Create Kernel Density Grid

You only have one more criteria to model. Here we will find all cells with an estimated density of greater than 200 tons per year per square kilometer of rare earth elements produced. Again, this is simulated data. You will do this using the **Kernel Density Tool**. This tool calculated the density of features or a phenomena. We will explore this tool in more detail in a later lab exercise.

- ☐ Navigate to Spatial Analyst Tools followed by the Density subtoolbox.
- ☐ Click on the **Kernel Density Tool**.
- ☐ Set the Input Point or Polyline Features to the **mine_discharge_points** layer.
- ☐ Set the Population Field to "REE-yr." Note that this is simulated data that estimates the tonnage of rare earth elements produced at that location in a year.
- ☐ Name the Output Raster **dis_den**.
- ☐ Make sure the Output Cell Size is set to 30.
- ☐ Set the search radius to 2000 (this is equivalent to 2,000 meters or 2 kilometers).
- ☐ Set the Area Units to "Square Kilometers." So, the density estimate will be the tones of rare earth elements produced per year per square kilometers.
- ☐ Make sure the Output Cell Values is set to "Densities."
- ☐ Click Run to execute the tool. The output should automatically be added to your map.
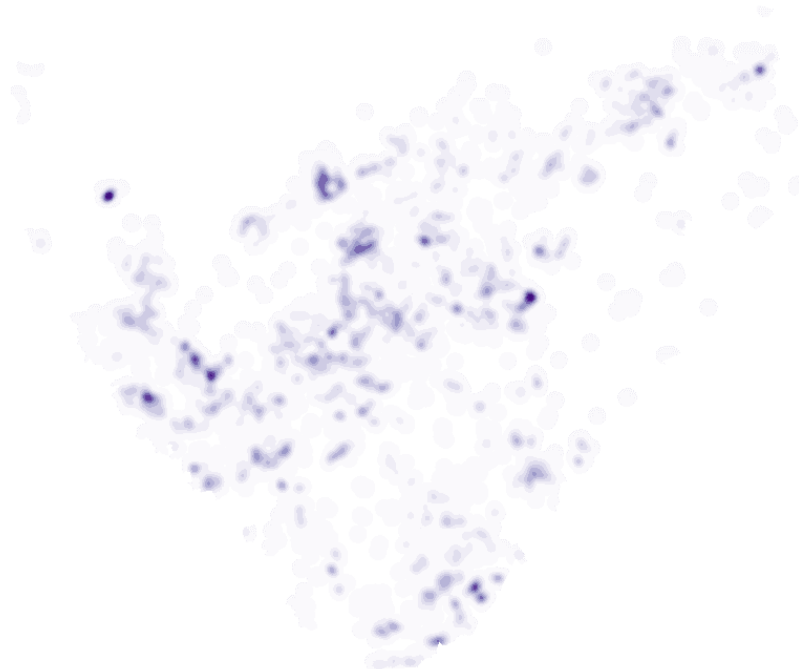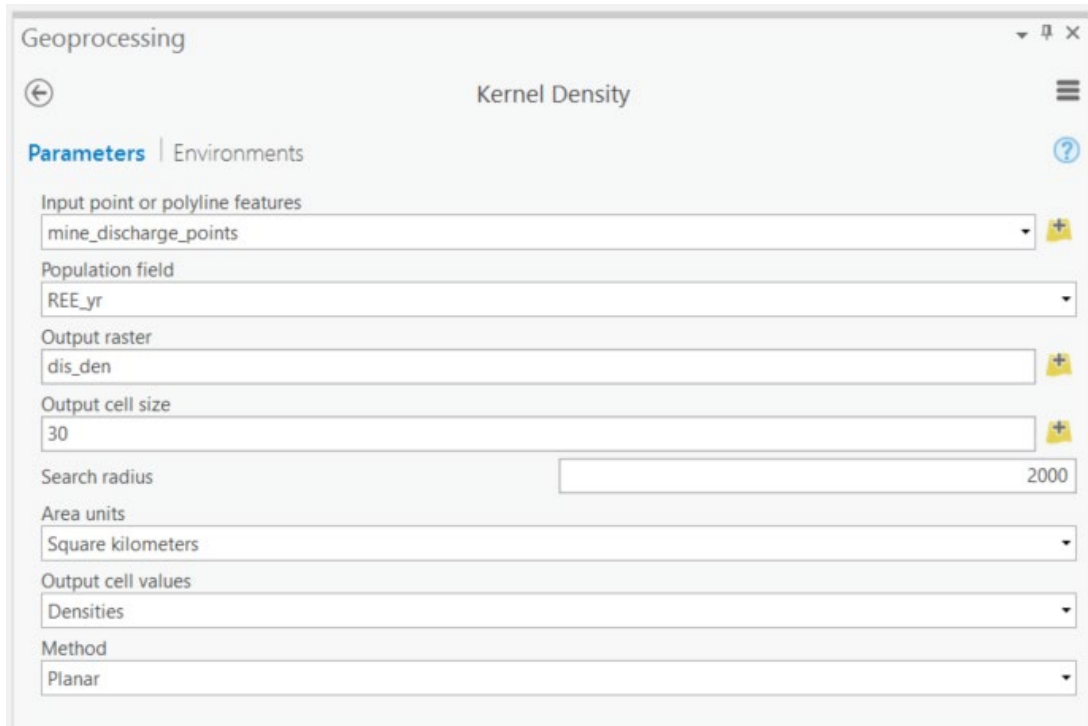
You have now produced a kernel density surface. However, you still need to produce the binary surface. For this model, let's find all cells with an estimate greater than 200 tons per year per square kilometer.

▢ Use the **Raster Calculator Tool** to produce this surface. Save your output as **kd_re**.

Question 9. What raster calculator syntax did you use? (4 Points)

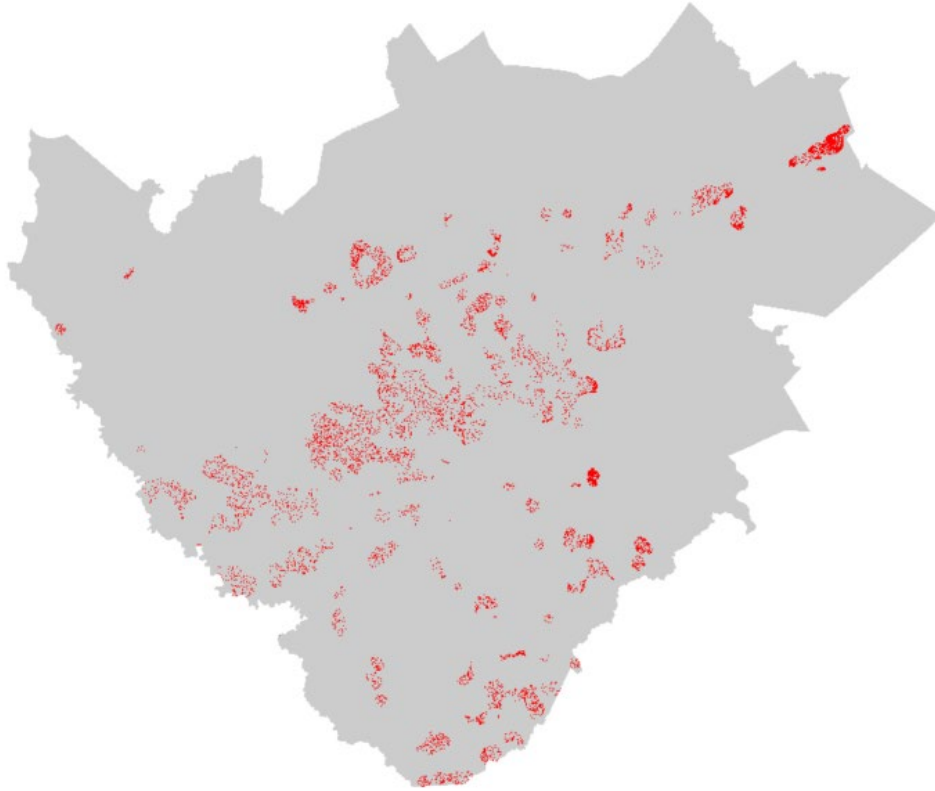**Question 10.** How many cells met this criteria? (2 Points)
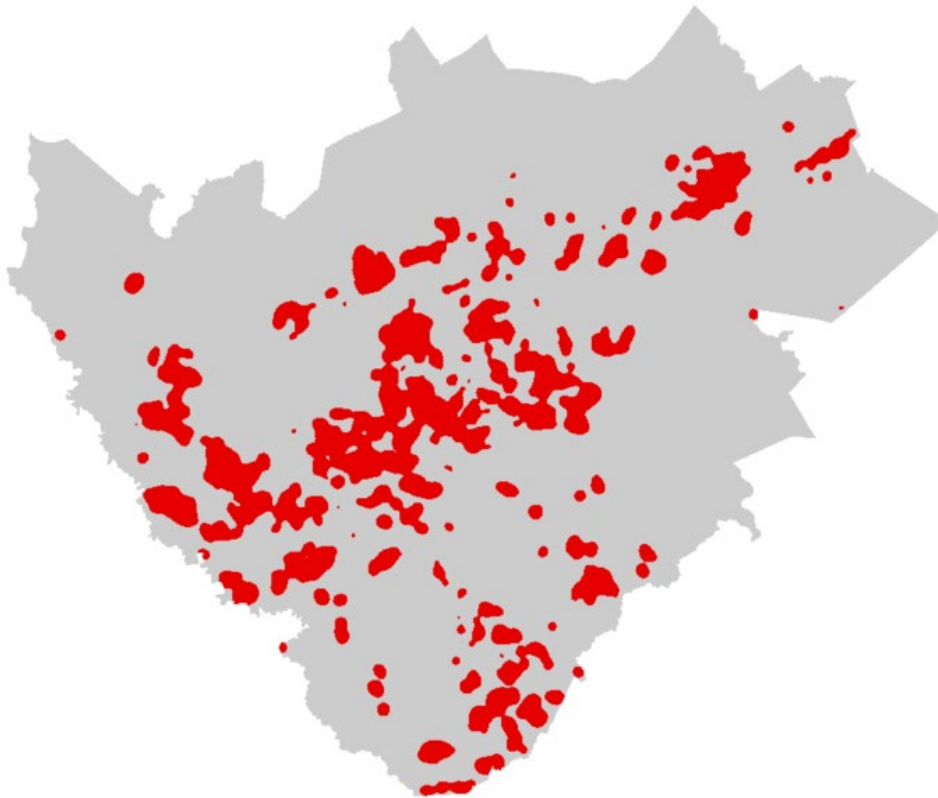
Step 9. Create Final Suitability Model

You have now produced all of five of the required binary grids. Now, you are ready to produce the final model. This can be accomplished by simply multiplying all of the binary grids together using the **Raster Calculator Tool**. Any cell in the final grid that is coded as 1 has met all of the criteria and is thus suitable to build a rare earth elements treatment facility for mine slug.

- ☐ Use the **Raster Calculator Tool** to multiply the five binary raster grids together and obtain the final model. Name the output **result_p1**.

"kd_re" * "public_r_re" * "town_dist_re" * "slp_d_re" * "rail_dist_re"

Use the attribute table of the result to answer the following question.

Question 11. How many cells met all criteria? (2 Points)

Question 12. What is the total area in square meters? (2 Points)

Hint: The cell size is 30 by 30 meters.

Question 13. What is the total area in acres (1 square meter = 0.000247105 acres)? (2 Points)

Question 14. List two other variables that may be of use for creating this model and explain why you think they may be of value. (4 Points)

Question 15. List and explain two sources of error or uncertainty in this model. (2 Points)

Note: Again, this a purely hypothetical example.

Step 10. Create Final Suitability Model

You will now complete a raster-based modeling exercise on your own. This is a hypothetical exercise and does not represent real data or a real species distribution.

You have been asked to predict the occurrence of a salamander species in a seven county area in West Virginia as a binary output. In this seven county area, prior research suggests that this salamander species is only found:

1. In evergreen or mixed forests
2. At elevations greater than 800 meters
3. On southeast to southwest facing slopes (112.5 to 247.5 degrees)

You have been provided two layers:

landcover: categorical land cover raster grid from the 2011 National Land Cover Database (NLCD)

elevation: DEM of the study area extent in meters

Here are some hints.

1. You will need to create a topographic aspect grid from the **elevation** layer. This can be accomplished using the **Aspect Tool**, which can be found under Spatial Analyst Tools and in the Surface subtoolbox.
2. In the NLCD data, evergreen forest is coded as 42 and mixed forest is coded as 43.
3. You will need to alter the environment settings. You can use the same Current and Scratch Workspace. You will need to change the extent and mask relative to one of the input raster grids. You need to make sure a cell size of 30 is used. We would recommend that you set one of the input grids as the snap raster.

Produce the model and use it to answer the following questions.

Question 16. How many pixels met the elevation criteria? (2 Points)

Question 17. How many pixels met the aspect criteria? (2 Points)

Question 18. How many pixels met the land cover criteria? (2 Points)

Question 19. How many pixels met all criteria? (2 Points)

Question 20. How many acres of habitat were estimated in this seven county area? (2 Points)

Question 21. List the steps you use to complete your analysis. (5 Points)

END OF EXERCISE