Exercise 29: Density Surfaces and Spatial Interpolation

This exercise explores spatial density estimation and spatial interpolation methods. Both techniques allow you to estimate a continuous surface from discrete measurement. You will be asked to create a kernel density surface from disease data simulated from the famous 1854 Broad Street Cholera Outbreak in London. You will also create interpolated raster surfaces using inverse distance weighting (IDW), spline, and Thiessen (Voronoi) polygons for temperature and precipitation data for Ontario. Finally, you will interpolate a bathymetry surface for Lake Erie using IDW.

Topics covered in this exercise include:

1. Create and interpret a density map using kernel density
2. Interpolate a surface using inverse distance weighting (IDW), spline, and Thiessen polygons

Before you begin the exercise, please answer the following conceptual questions.

Question 1. Explain the difference between kernel density and point density estimation. (5 Points)

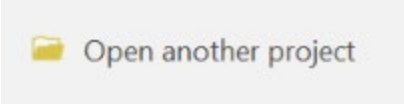
Question 2. Conceptually explain how inverse distance weighting interpolation works. (5 Points)

Question 3. Conceptually explain how spline interpolation works. (5 Points)

Step 1. Open a Map Project

First, we need to download and open the **Exercise_29.aprx** file.

- Download the **Exercise_29** 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 them 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."



- Navigate to the directory that houses the material for this course. The project files are in the **Exercise_29** folder where it was saved on your local machine.
- Select **Exercise_29.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_29.aprx** file within the uncompressed folder directly to launch ArcGIS Pro.

This project contains three maps. The John Snow map contains the data required to complete the kernel density portion of the lab. The following data layers are included:

Water_Pumps: point features representing historic locations of water pumps, including the Broad Street water pump

Death_Addresses: point locations with recorded cholera deaths

buildings: polygon building footprints

Study_Area: a rectangular study area extent

John_Snow_Map: a georeferenced historic street map

Note that these data were created by Dr. Robin Wilson of the School of Geography at the University of Southampton, United Kingdom.

The Ontario map will be used to perform spatial interpolation. The following layers are included:

clim_points: point locations where climate data are collected, including temperature and precipitation.

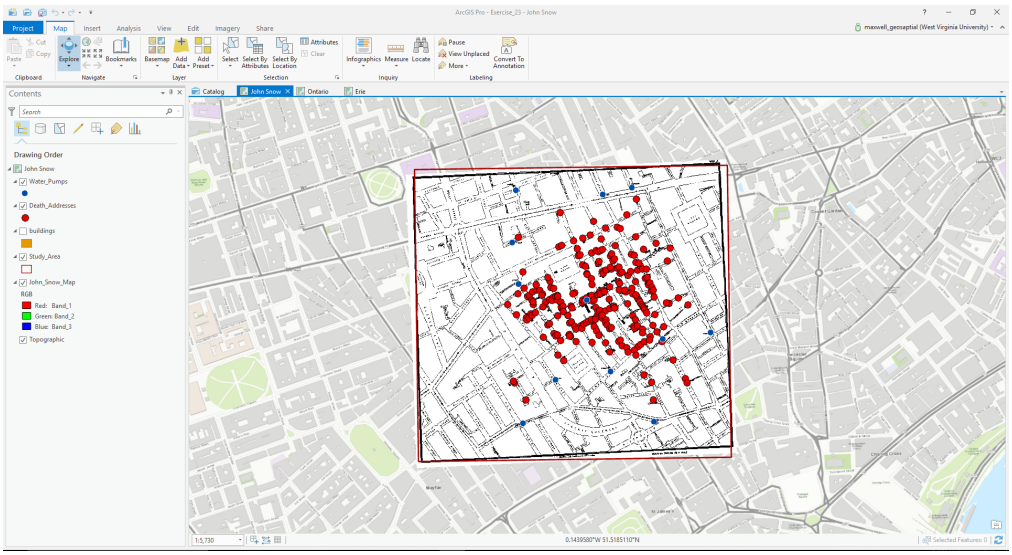
ontario: boundary of the province of Ontario

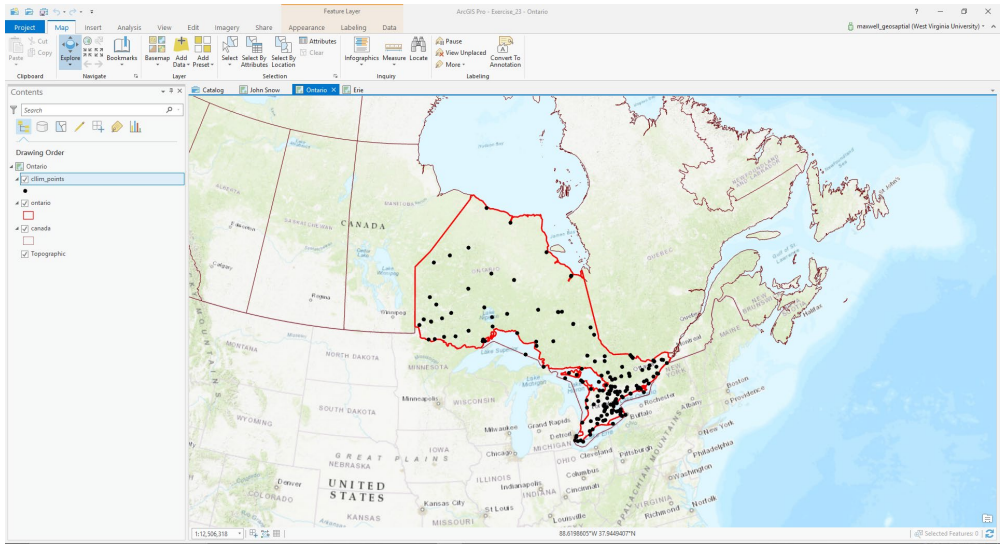
canada: Canadian provinces boundaries

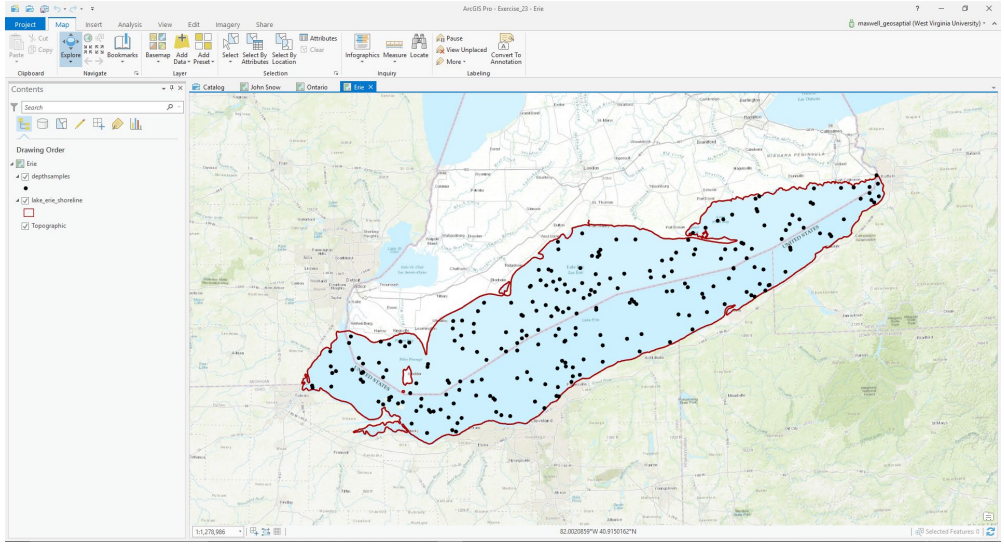
The Erie map will also be used to perform spatial interpolation. The following layers are included:

depthsamples: polygon boundary of Lake Erie

lake_erie_shoreline: point locations with depth measurements in feet







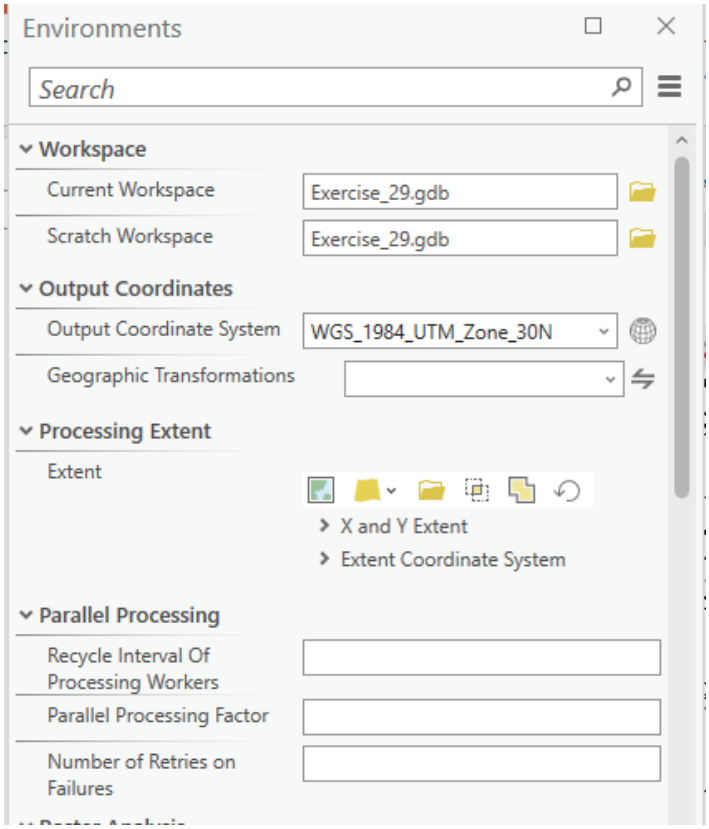
Step 2. Kernel Density

You will start this exercise by investigating kernel density.

- Navigate to the John Now Map.

You will need to set some environment settings before you begin.

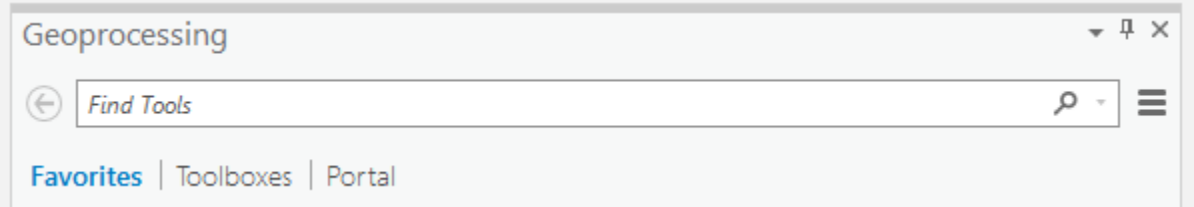
- Navigate to the Analysis Tab and click the Environments button in the Geoprocessing area.
- Under Workspace, change the Current Workspace and Scratch Workspace to the **Exercise_29.gdb** geodatabase in the **Exercise_29** folder.
- Under Output Coordinates, set the Output Coordinate System to be the same as the **Death_Addresses** layer. This should be WGS 1984 UTM Zone 30 North.
- Under Processing Extent, set the Extent to be the same as the **Study_Area** layer. You do not need to set a Snap Raster.
- Under Raster Analysis set the Cell Size to 3, meaning 3 meters. Also, set the Mask to the **Study_Area** layer.
- Click OK to save the Environment settings.



You are now ready to create the kernel density surface. You will do this using the **Kernel Density Tool**.

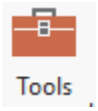
Note: In this lab, we will access tools from ArcToolbox. However, there are many ways to access tools in ArcGIS Pro. For example, some of the more common tools are provided in the Tools list in the Analysis Tab.

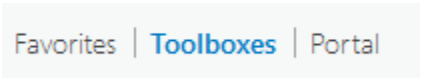
Once you open the Geoprocessing Pane, you can access favorite tools or search for Tools.



We have decided to demonstrate ArcToolbox here so that you get a sense of where the tools are located in the Toolbox directory.

- In the Analysis Tab, select Tools from the Geoprocessing Area. This should open the Geoprocessing Pane.
- In the Geoprocessing Pane, navigate to the Toolboxes.

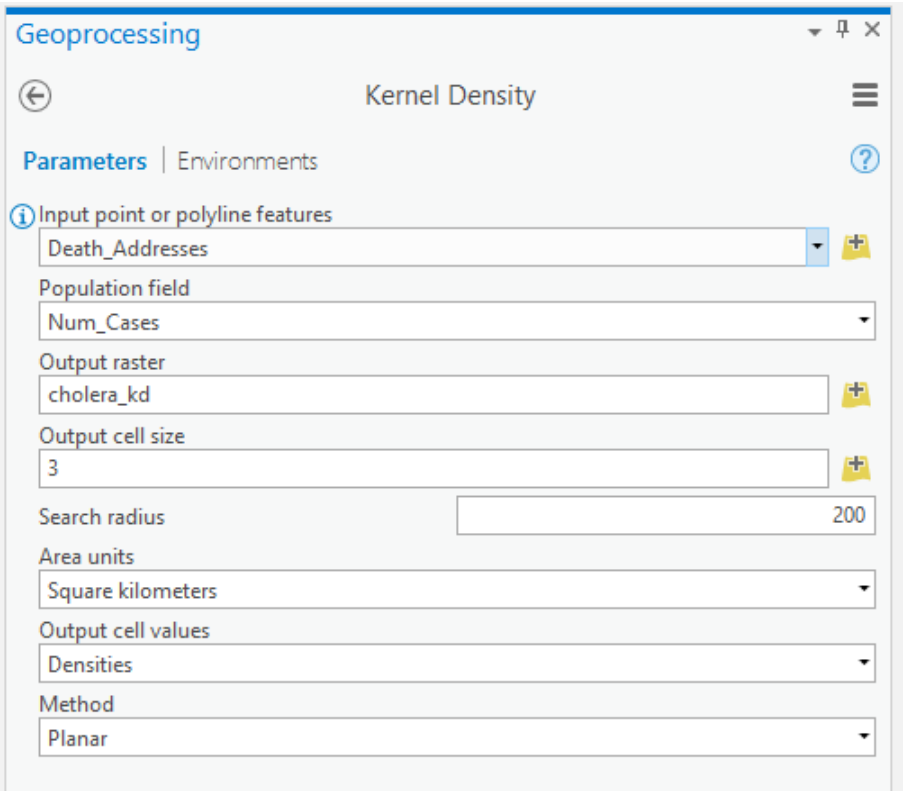




Note: We will not provide these directions for accessing other tools. We will just tell you where to find them within ArcToolbox.

- 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 **Death_Addresses** layer.
- Set the Population field to "Num_Cases" (this represents the number of cholera cases at that address).
- Name the output **cholera_kd**. This will save to the workspace defined in the Environment settings: the **Exercise_29.gdb** geodatabase in your downloaded **Exercise_29** folder.

- The Output Cell Size should already be set to 3, as specified in the environments.
- Set the Search Radius to 200 (meaning 200 meters).
- Make sure the Area Units is set to Square kilometers, the Output Cell Value is set to Densities, and the Method is set to Planar. These should be the defaults.
- Click Run to execute the tool. The result should be added to the map automatically.



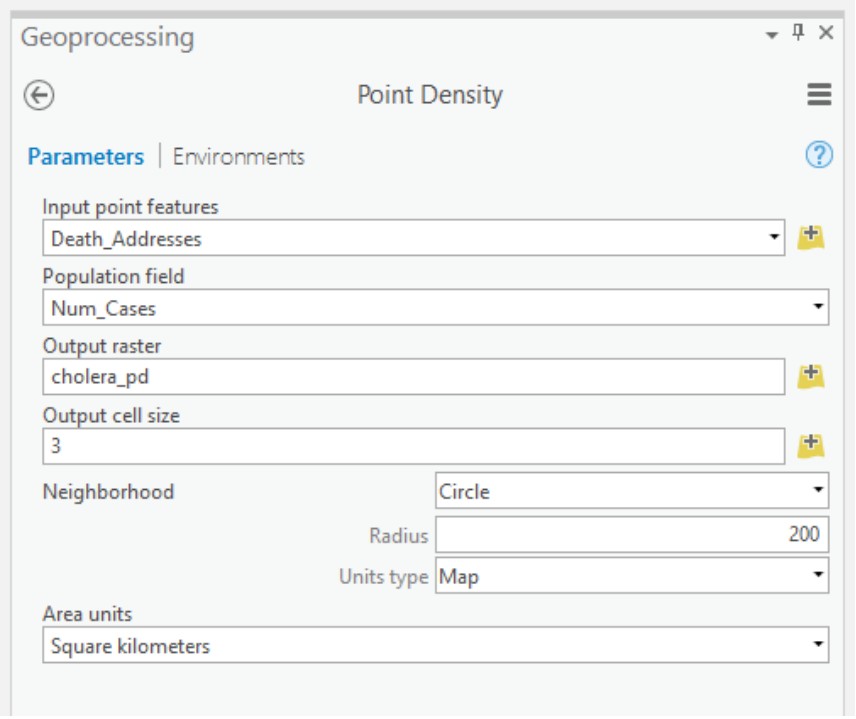
Note: The defined search radius can have a large impact on the resulting kernel density surface and estimates. Larger values indicate a larger search radius and will produce a more generalized pattern. In contrast, smaller values indicate a smaller search radius and will produce a less generalized pattern that shows more local variability. If you are unsure what search radius to use, we would recommend experimenting with different settings.

Question 4. Using early spatial analysis techniques, Dr. John Snow attributed the cholera outbreak to a specific well on Broad Street. Does your kernel density analysis confirm Dr. Snow's earlier work? Please explain by providing an interpretation of the kernel density result. (5 Points)

Question 5. What is the unit of measurement in your output kernel density grid? (2 Points)

A similar analysis could be completed using point density as opposed to kernel density. For comparison, you will now create this surface using the **Point Density Tool**.

- Navigate to Spatial Analyst Tools followed by the Density subtoolbox.
- Click on the **Point Density Tool**.
- Set the Input Point Features to the **Death_Addresses** layer.
- Set the Population field to "Num_Cases."
- Name the output **cholera_pd**.
- The Output Cell Size should already be set to 3, as specified in the environments.
- Define the Neighborhood as a Circle.
- Set the Search Radius to 200 (meaning 200 meters) using the Map units.
- Make sure the Area Units is set to Square kilometers.
- Click Run to execute the tool. The result should be added to the map automatically.



Question 6. Does the point density result support Dr. Snow's prior results and your prior kernel density analysis? Explain your reasoning. (5 Points)

Step 3. Spatial Interpolation with IDW and Spline

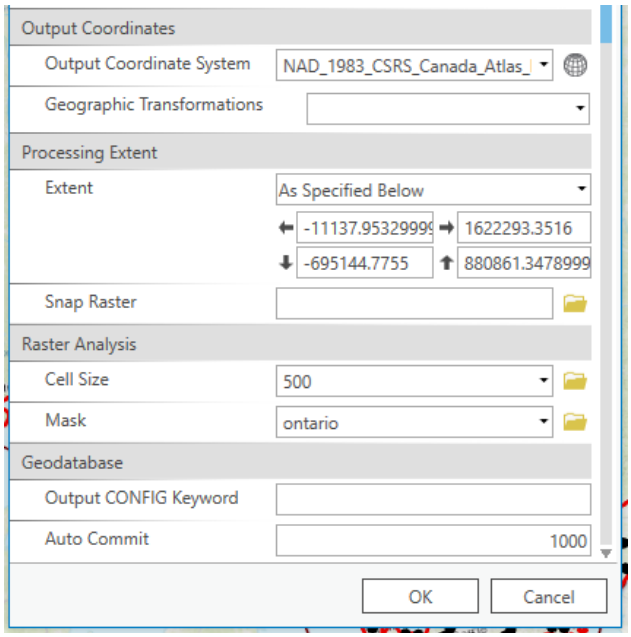
You are now done analyzing the cholera data. You will now work with the Ontario climate data.

- ☐ Navigate to the Ontario map.

You will now interpolate surfaces from the climate data. The **clim_points** layer contains two climate variables for November 2016. The "Tm" field represents mean temperature for the month in Celsius while the "P" field represents the total precipitation in millimeters (mm) for the month. These data were obtained from the Canadian government: http://climate.weather.gc.ca/.

Before you can begin creating interpolated surfaces, you will need to change the Environments settings again.

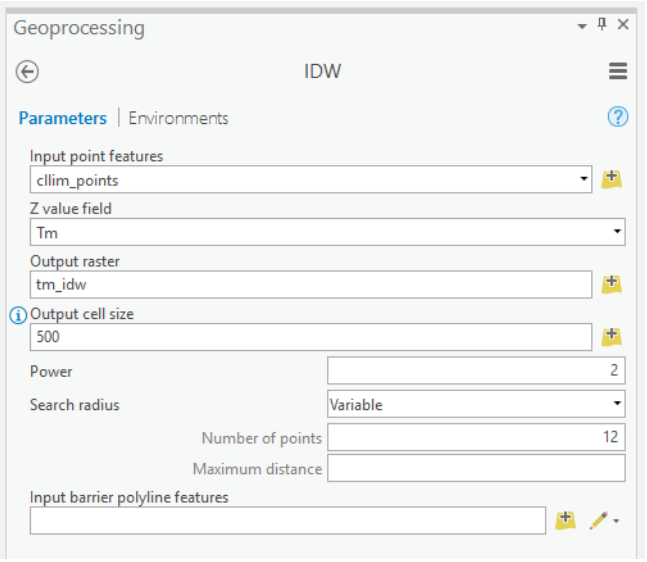
- ☐ Navigate to the Analysis Tab and click the Environments button in the Geoprocessing area.
- ☐ Under Workspace, leave the Current Workspace and Scratch Workspace set to the **Exercise_29.gdb** geodatabase in your downloaded **Exercise_29** folder.
- ☐ Under Output Coordinates, set the Output Coordinate System to be the same as the **clim_points** layer. This should be NAD 1983 CSRS Canada Atlas Lambert.
- ☐ Under Processing Extent, set the Extent to be the same as the **ontario** layer. You do not need to set a Snap Raster.
- ☐ Under Raster Analysis set the Cell Size to 500, meaning 500 meters. Also, set the Mask to the **ontario** layer.
- ☐ Click OK to save the Environment settings.

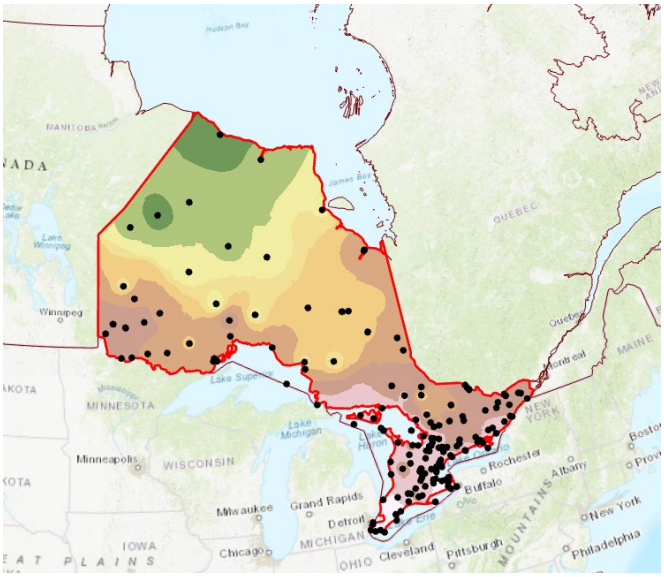


You are now ready to interpolate a raster surface. You will begin by interpolating the temperature data using IDW.

- ☐ Navigate to Spatial Analyst Tools followed by the Interpolation subtoolbox.
- ☐ Click on the **IDW Tool**.

- Set the Input Point Features to the **clim_points** layer.
- Set the Z Value Field to the "Tm" field.
- Name the Output Raster **tm_idw**.
- The Output Cell Size should already be set to 500, as specified in the Environment settings.
- Leave the Power set to 2, the Search Radius set to Variable, and the Number of Points set to 12.
- You do not need to change any additional settings.
- Click Run to execute the tool. The result should be added to the map automatically.





Note: Because you specified the extent and mask in the Environments relative to the **ontario** layer, the interpolated surface fills the extent of the province and is also masked to its boundary. This highlights one of the

benefits of defining environment settings. Note that the cell size is also 500, as specified in the Environments. Again, we highly recommend specifying the environments before undertaking an analysis.

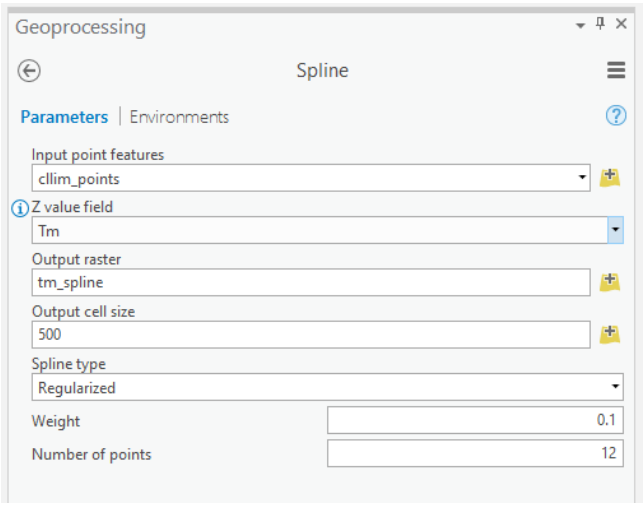
Answer the following questions relating to the IDW interpolation method.

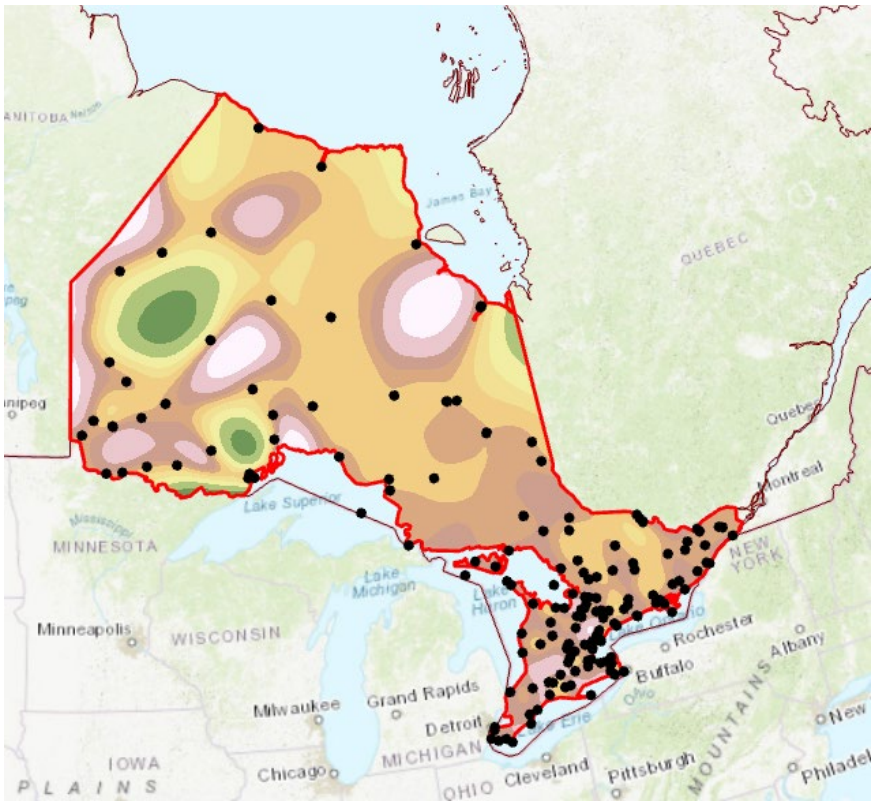
Question 7. What is the purpose of the power option for the IDW method? (5 Points)

Question 8. Explain the difference between a fixed and a variable search radius for IDW. (5 Points)

Now, you will perform a spline interpolation for the same data using the **Spline Tool**.

- Navigate to Spatial Analyst Tools followed by the Interpolation subtoolbox.
- Click on the **Spline Tool**.
- Set the Input Point Features to the **clim_points** layer.
- Set the Z Value Field to the "Tm" field.
- Name the Output Raster **tm_spline**.
- The Output Cell Size should already be set to 500, as specified in the Environment settings.
- You do not need to change any additional settings.
- Click Run to execute the tool. The result should be added to the map automatically.





Answer the following question relating to the spline interpolation method.

Question 9. What are the two options for the spline type? (2 Points)

Now, compare the results of the IDW and spline interpolations for the temperature data.

Question 10. Which method do you think is most appropriate to interpolate the temperature data? Please explain your reasoning. (5 Points)

- Perform the IDW and spline interpolations for the total monthly precipitation using the "P" field. Use the same settings as those used to interpolate the temperature data.

Question 11. Which method do you think is most appropriate to interpolate the precipitation data? Please explain your reasoning. (5 Points)

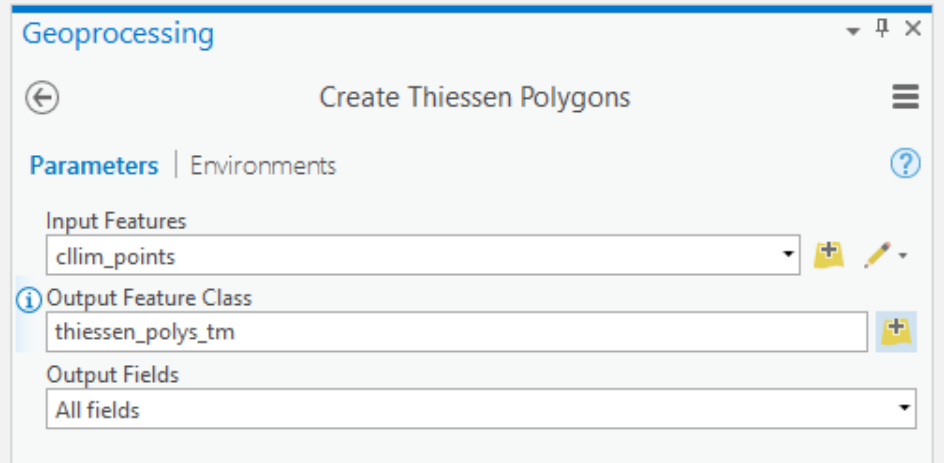
Step 4. Spatial Interpolation with Thiessen (Voronoi) Polygons

Thiessen (Voronoi) polygons offers another means to interpolate data.

Question 12. Describe the concept of a Thiessen (Voronoi) polygon. (5 Points)

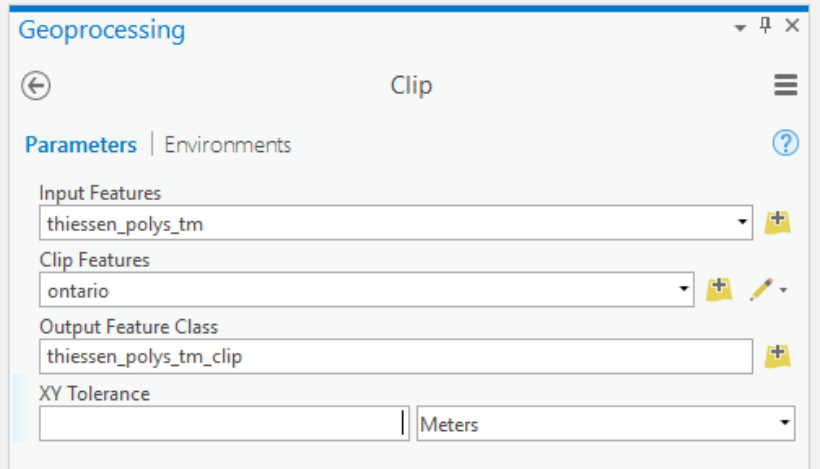
This method can be applied using the **Create Thiessen Polygons Tool**.

- Navigate to Analysis Tools followed by the Proximity subtoolbox.
- Click on the **Create Thiessen Polygons Tool**.
- Set the Input Features to the **clim_points** layer.
- Name the Output Feature Class **thiessen_polys_tm**.
- Set the Output Fields to All Fields.
- Click Run to execute the tool. The result should be added to the map automatically.



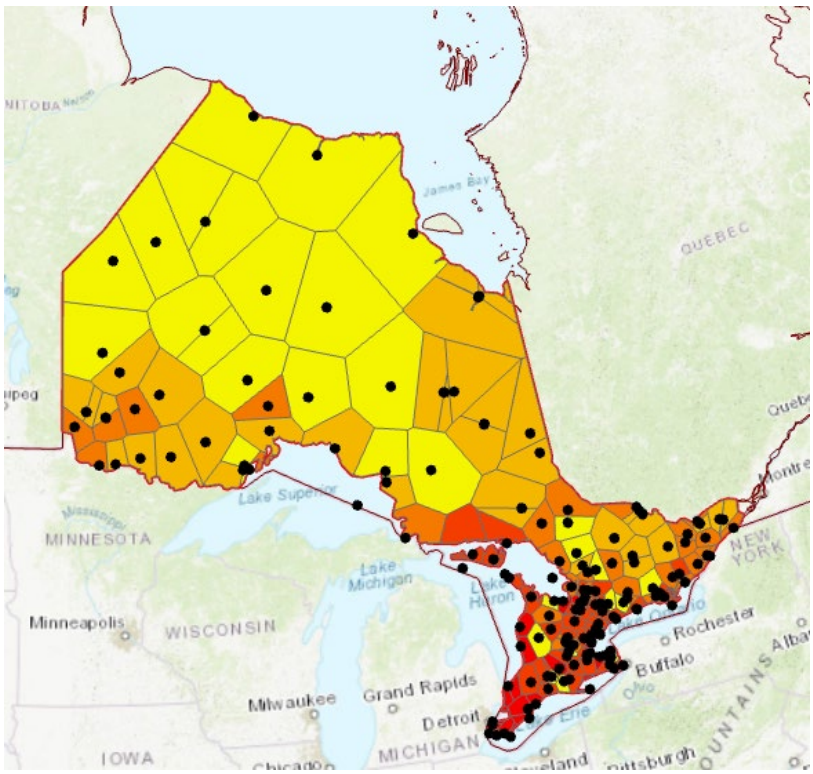
The polygons are not clipped to the extent of the province. To do this, you can use the **Clip Tool**. The mask setting in the environments is not honored here since this is not a raster output.

- Navigate to Analysis Tools followed by the Extract subtoolbox.
- Click on the **Clip Tool**.
- Set the Input Features to the **thiessen_polys_tm** layer.
- Set the Clip Features to the **ontario** layer.
- Name the Output Feature Class **thiessen_polys_tm_clip**.
- Click Run to execute the tool. The result should be added to the map automatically.



You will now want to symbolize the output using the "Tm" field.

- Symbolize the "Tm" field and graduated colors.



Note: In contrast to IDW and spline, the output here is a vector polygon layer as opposed to a raster grid. If you would like to convert this surface to a raster, you can use the **Polygon to Raster Tool**. You do not need to perform the conversion here.

Question 13. For Interpolating the temperature data, which method do you think is best: IDW, spline, or Thiessen (Voronoi) polygons? Explain your reasoning. (5 Points)

Note: These are not the only interpolation methods available. For example, we will not investigate kriging or co-kriging method in this exercise. Kriging is a geostatistical interpolation method that takes into account spatial autocorrelation.

Step 5. Unguided IDW Interpolation

Lastly, you will perform an unguided IDW interpolation to predict bathymetry for Lake Erie. Make sure to do the following.

- Navigate to the Erie map.
- Change the environment settings. You will need to set the extent and mask to be the same as the **lake_erie_shoreline** layer. Use a cell size of 200 meters. Make sure to use the same coordinate system as the **depthsamples** layer.
- You can use the default IDW settings. However, make sure to set the Z Value Field to the "depth" field. Note that these depths are reported in feet.

Deliverable 1 (18 Points)

Make a map of your output. Submit it as a PDF. This map will be graded against the rubric below.

1. Your name, a title, a scale bar, and a north arrow are provided (3 Points)
2. An ESRI basemap is used as the background (3 points)
3. A legend is provided with the values rounded off to one decimal point (3)
4. Legend notes that the depth is in feet (3 Points)
5. An appropriate color ramp is used to display the depth data (3 Points)
6. The map is well designed, neat, and uses the space well (3 Points)

END OF EXERCISE