Assignment 1 Part A

Exploring Interpolation with the Spatial Analyst Extension in ArcGIS Pro

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GEOM 105 Environmental Modeling | Fleming College

ArcGIS Pro [2.8.0]

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1.0 Introduction

This assignment aims to help students explore and understand the Spatial analyst toolbox, specifically, the interpolation tools in ArcGIS Pro. In simple words, Interpolation is a technique to find or predict the values at unknown locations from the values given at known locations. Interpolation is a useful topic to learn and understand especially because data is usually not perfect or complete. In addition, this topic is useful for all continuous data regardless of the field of study. The students chose to work on this assignment in ArcGIS Pro because they were more comfortable using this compared to ArcMap.

The assignment introduces students to the application of three out of numerous interpolation methods- Inverse distance weighted (IDW), Spline and Topo to Raster. The interpolation methods considered, use local methods as a sample of known data is being used. Spline and IDW are deterministic methods that use thin plate splines and inverse distance weighing respectively for interpolation (Chang 2018). Topo to raster is used regularly in Australia and produces digital elevation models (DEMs) with a focus on retaining drainage structures (Stein 2002). Topo to Raster is a stochastic model as errors in the drainage patterns can be determined. The application and exploration of these different methods enables students to understand concepts more easily. Students were allowed to choose one more interpolation method that they could investigate. In this case, the interpolation method chosen was Kriging. This is also a local method, but it uses stochastic methods that can determine the accuracy of the DEM produced (Chang 2018). This method was chosen as it piqued our curiosity after watching the ESRI seminar.

The four different interpolation methods were then compared to determine the method that the students felt was best suited to the data provided to them. The best method of interpolation was based on the ease of understanding and accuracy of the digital elevation model that is produced by using these different interpolation methods.

2.0 Methodology

Before proceeding to interpolation methods, we need to look at our data. Raw Dataset used here is the clipped dataset of NTS 031D07 spatial data (Kawartha Lakes, Ontario) provided as a material in this course by Fleming college. After preparing the data, four interpolation tools are used that are available in Spatial Analyst Toolset of ArcToolbox. Description of data and the interpolation methods are discussed further. The output coordinate system was always set to the current map.

2.1 Data Preparation

The NTS 031D07 spatial data is in Universal Transverse Mercator projection (Zone 17) and North American Datum 1983, so the other layers derived from this dataset has also been kept in UTM Zone 17 projection and NAD83 Datum. The table is given in appendices that gives a brief of the data layers category, their feature types, total number of records found and their minimum and maximum values. The data layers of water bodies, wetlands, railways, roads and esker are used to just understand the topology and terrain of the area. Environmental settings of the project space is shown in the Figure 1.

Further to use contour layer for interpolation and to create 20 m DEM, contour lines are converted to the contour point layer using "Feature Vertices to Point" tool. This process creates around 28,000 points. Then, to reduce the number of points, simplification is done using "Simplify Line" tool by changing some parameters to watch the accuracy of the produced DEMs.

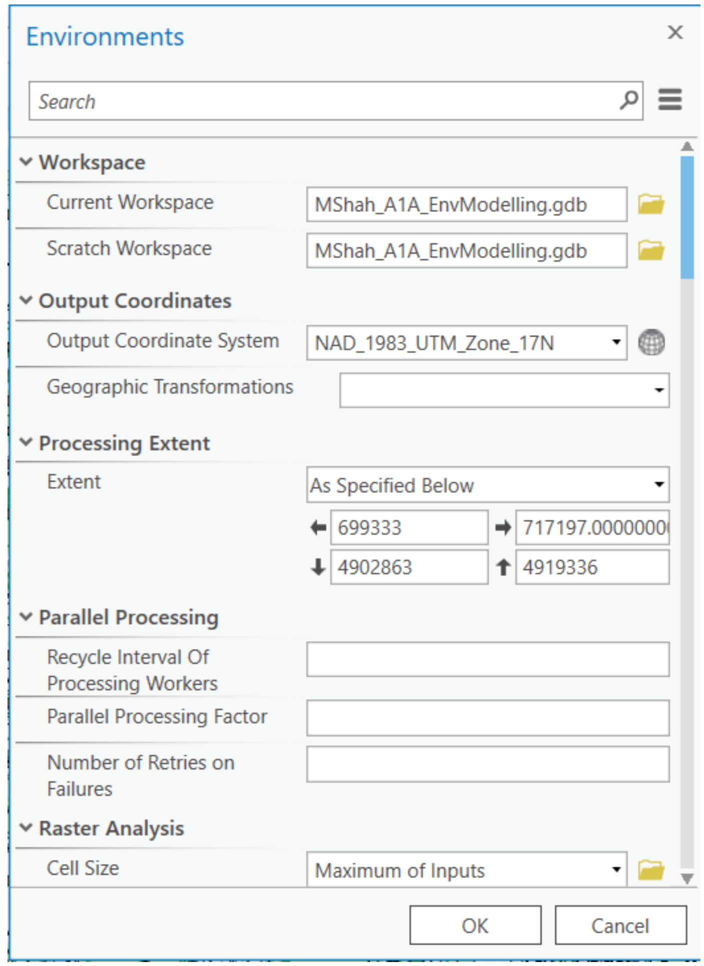


Figure 1. Environmental settings for the project space.

Simplify Line tool: It simplifies lines by giving smooth vertices and bends to lines while maintaining the required shape. Two simplification algorithms checked here are "Retain Critical Points" and "Retain Critical Bends".

Retain Critical Points (Douglas-Peucker) uses "Point_Remove" algorithm in python and removes extra vertices to simplify data at smaller scales and this is the fastest of the simplification algorithms. For both methods we need to provide tolerance value which determines the degree of simplification. For this method the tolerance is the maximum allowable perpendicular distance between each vertex and the created new line. So, three tolerance values of 50 m, 100 m and 200 m are tested. After the tool is run and then using "Feature Vertices to Point" tool, number of contour points we get were around 5000, 3000 and 3000 respectively.

Retain Critical Bends (Wand-Muller) uses "Effective-area" algorithm in python and it identifies the effective area for each vertex to remove the extra part. Here the tolerance is the diameter of a circle that approximates a significant bend. Two tolerance values of 50 m and 200 m were tested here. After the tool is run and then using "Feature Vertices to Point" tool, number of contour points we get were around 25,000 and 22,000 respectively. So, we decided to select the contour points layers created using Retain Critical Points method as they gave reasonable number of contour points.

An example of the set of parameters for one of the Simplify line tool is in Figure2.

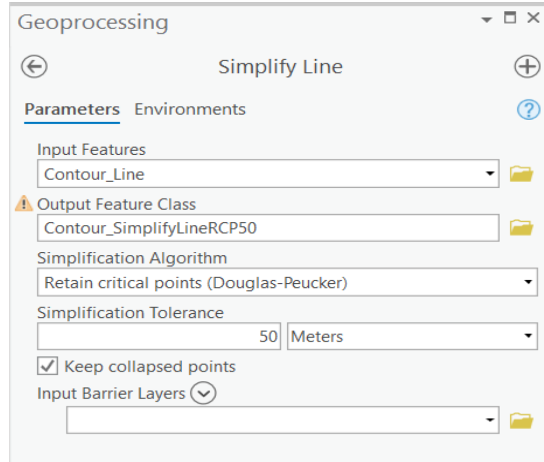


Figure 2. Simplify Line tool example

2.2 Interpolation Methods

We have used 4 interpolation methods of Spatial Analyst toolbox to create 20 m Digital Elevation Models (DEMs). These are discussed below.

1. Inverse Distance Weighting (IDW)

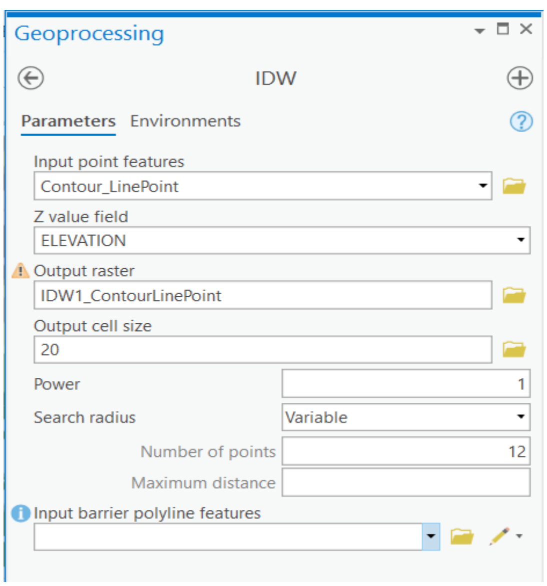


Figure 3. Inverse Distance Weighting (IDW) Method Parameters

Here an unknown value at any location is determined by using the weighted average distances of some known values. The weight here is the inverse distance of a point to the known values. This weightage cannot be greater than the highest or less than the lowest input. This is the most basic method of interpolation and is best when we have dense sampled data. An example of the parameter settings for this method is shown below. Here, for parameter 'Z value field' elevation data is selected to create DEM and output raster of 20 m, all other parameters are kept as the default ones.

2. Spline

This method uses a mathematical function that minimizes the overall surface curvature, resulting in a smooth surface that passes exactly through the input points. The curve fits to nearest input points while passing through the sample points. Spline curve method has two types, Tension and Regularized. We have used here Tension method as it controls the stiffness of the output raster and therefore a more accurate result is obtained than Regularized method. Parameter settings for one of the DEM obtained is shown in Figure 4. This method does not work with too many sample points in the dataset.

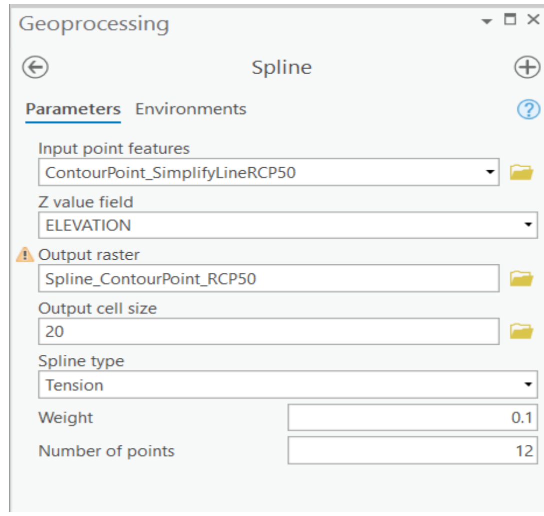


Figure 4. Spline Method Parameters

3. Topo To Raster

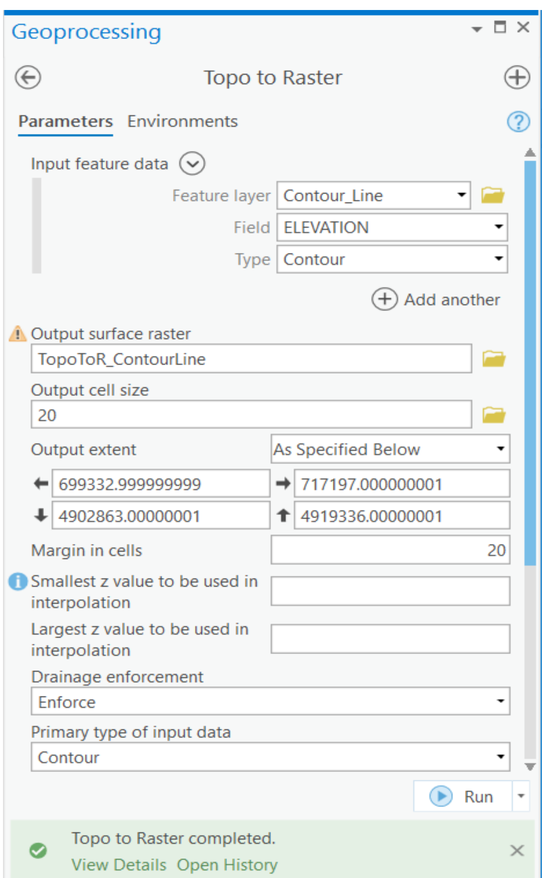


Figure 5. Topo to Raster Method Parameters

The main advantage of this tool is that it does not require contour lines to be converted to points and we can give multiple inputs for this tool settings. An example is shown in Figure 5. This tool is run for 3 datasets, contour lines, contour points and elevation spot heights.

4. Kriging

This is the geostatistical method of interpolation that is based on autocorrelation which means it uses statistical relationships among measured points. Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface.

Ordinary Kriging was selected as the Kriging method. The semi-variogram model used is the most common one i.e., spherical because the curve here is not steeper near the origin which shows that the nearest neighbors will have lesser influence on predictions and the output surface will be stiffer.

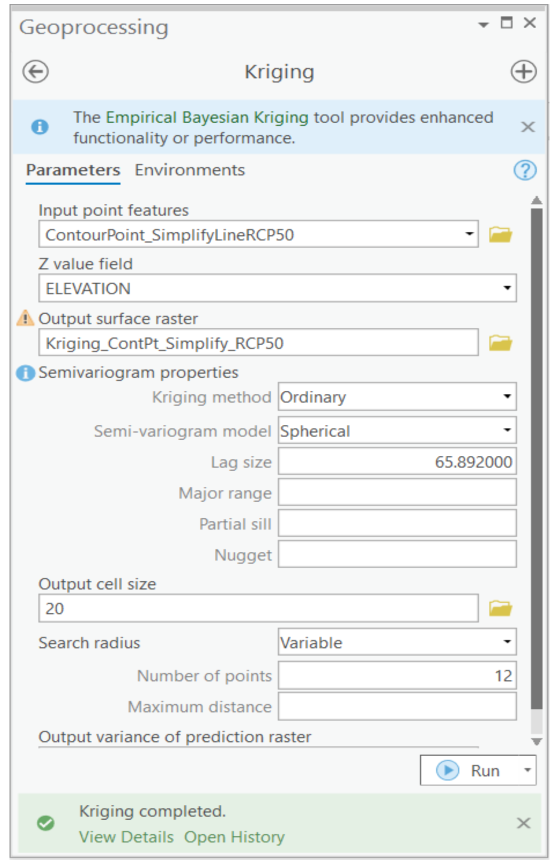
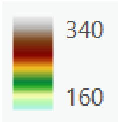


Figure 6. Kriging Method Parameters

3.0 Results

In this section, results are evaluated according to the methods of interpolation used. Below is the Digital Elevation Models obtained through 4 different interpolation methods.

The color ramp used here depicts the Elevation in the range of, 

in metres.

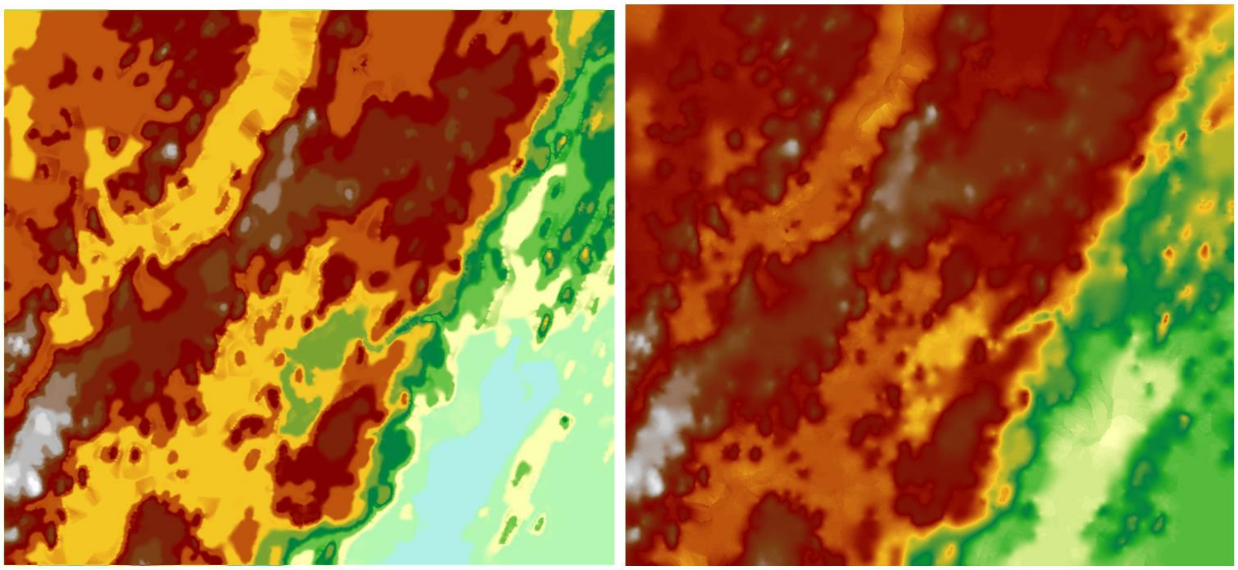


Figure 7. Inverse Distance Weighted Method DEM and Topo to Raster Method DEM

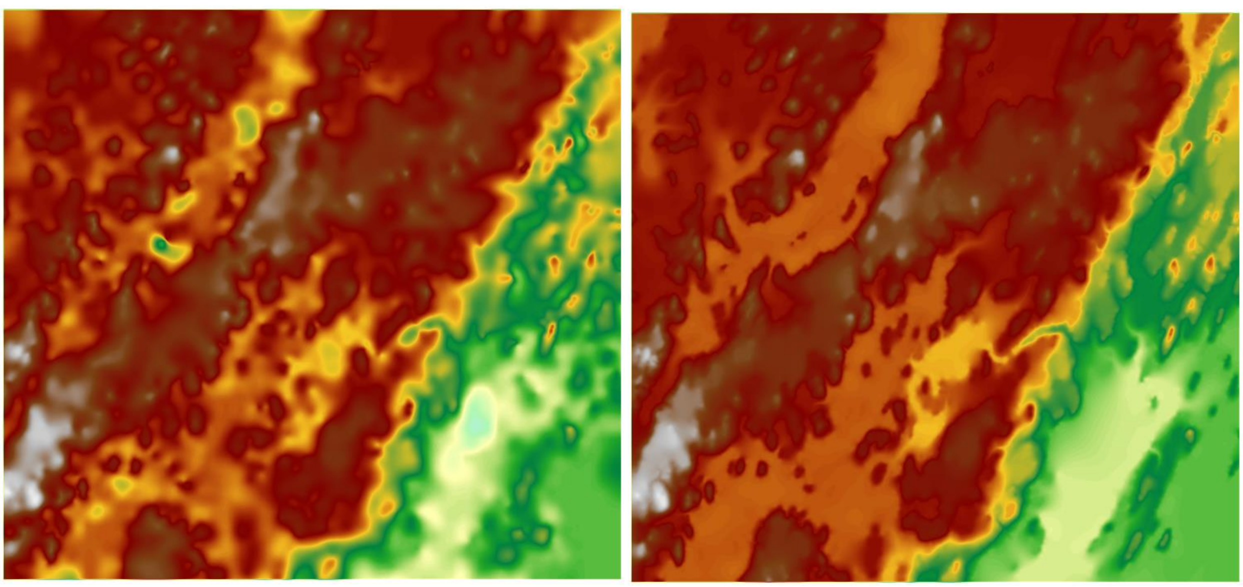


Figure 8. Spline Method DEM and Kriging Method DEM

So, first Inverse Distance Weighted method results are shown in Table 1. for some randomly selected points of known Elevation Spot Heights and three of the different IDW parameters (Power of weight) used.

Table 1. Comparison of Elevation Spot Height values with DEM obtained through IDW method

	Elevation Spot Heights (m)	IDW Weight Power 1 (m)	IDW Weight Power 2 (m)	IDW Weight Power 3 (m)
FID 357	262	270.00	270.00	270.00
FID 392	298	286.73	286.85	287.02
FID 32	211	208.91	209.33	209.66
FID 447	267	261.44	261.23	262.04

Table 2. compares results of Elevation spot heights with elevation values from Spline interpolation method of two data, i.e. simplified contour line points file with simplification tolerance of 50 m and 200 m.

Table 2. Comparison of Elevation Spot Height values with DEM obtained through Spline method

	Elevation Spot Heights (m)	Spline- Contour Line Points 50 m (m)	Spline- Contour Line Points 200 m (m)
FID 366	315	316.52	316.11
FID 477	251	249.46	249.76
FID 100	198	165.61	170.38
FID 99	326	320.66	320.88

Table 3. compares results of Elevation spot heights with elevation values from Topo to Raster interpolation method of contour line points file without simplification.

Table 3. Comparison of Elevation Spot Height values with DEM obtained through Topo to Raster method

	Elevation Spot Heights (m)	Topo to Raster- Contour Line Points (m)
FID 391	256	250.71
FID 17	226	220.02
FID 44	333	330.48
FID 425	277	270.32
FID 237	245	248.07
FID 173	265	260.93

Table 4. compares results of Elevation spot heights with elevation values from Kriging interpolation method of two data, i.e. simplified contour line points file with simplification tolerance of 50 m and contour points file without simplification.

Table 4. Comparison of Elevation Spot Height values with DEM obtained through Kriging method

	Elevation Spot Heights (m)	Kriging- Contour Line Points (No simplification) (m)	Kriging- Contour Line Points 50 m (m)
FID 449	261	260.74	260.33
FID 425	277	270.00	270.28
FID 237	245	250.00	248.77
FID 37	191	190	189.43
FID 9	317	311.14	310.77

4.0 Discussion

Here is where you can elaborate on why you think the results look the way they do and discuss which interpolation method turned out the 'best' or most appropriate for creating a digital elevation model of this landscape. This section ends with a concluding paragraph (see next section).

By just observing the DEMs of all four methods, it is seen that Kriging DEM seems to be the smoothest one and in addition, IDW DEM looks very different from others if compared to the color of all other DEMS, especially the left half of the elevation model.

Then considering the results of the random point locations, the best fit DEM for IDW method obtained is the one which was obtained by weight power of 3 because it has the nearest elevation values to actual spot heights.

The best Elevation model for Spline method is the DEM derived from simplified contour line points file with simplification tolerance of 200 m. The difference in elevation was seen between a wide range of 1 m to 10 m.

For Topo to Raster Interpolation Method, only one elevation model was derived and the difference of elevation at 6 random points was observed between 3 m to 7 m.

Then at last for Kriging Interpolation method, elevation difference was observed around 1 m than actual spot height for 3 point locations and other 2 point locations had around 5 m difference. Also, there was not much difference in models of contour points files with and without simplification.

5.0 Conclusion

All in all, Interpolation techniques makes the complicated function of predicting data at unknown geographic locations from very less amount of available known data very easy and smooth. And the Spatial Analyst Interpolation Toolbox just makes this task simpler and quick. After the careful review of the results, it was found that *Kriging Interpolation* turned out to be the best one as the predicted elevation values were nearest to the actual ones. Though there are errors in prediction and given any of the methods, no algorithm can correctly identify the missing values, still it helps a lot to understand the landscape as a whole and use these models for future topographic analysis of that area.

6.0 References

Stein, J. L., Stein, J. A., & Nix, H. A. (2002). Spatial analysis of anthropogenic river disturbance at regional and continental scales: identifying the wild rivers of Australia. *Landscape & Urban Planning*, *60*(1), 1. https://doi-org.sandford.idm.oclc.org/10.1016/S0169-2046(02)00048-8

Simplify Line (Cartography)—ArcGIS Pro | Documentation

IDW (Spatial Analyst)—ArcGIS Pro | Documentation

How Spline works—ArcGIS Pro | Documentation

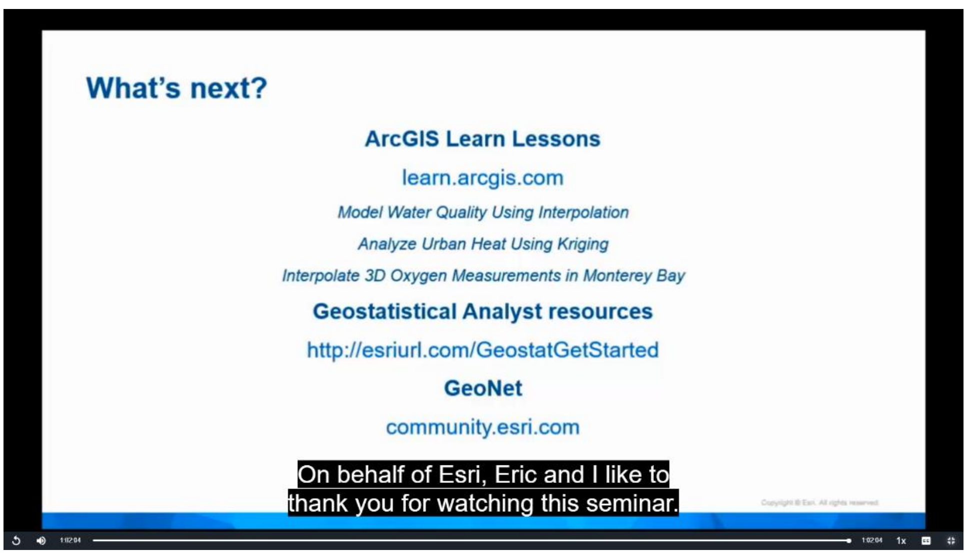
Topo to Raster (Spatial Analyst)—ArcGIS Pro | Documentation

Kriging (Spatial Analyst)—ArcGIS Pro | Documentation

Appendices

Screen captures showing completion of ESRI seminar.

A. Mansi Shah



B. Sunayana Sashikumar

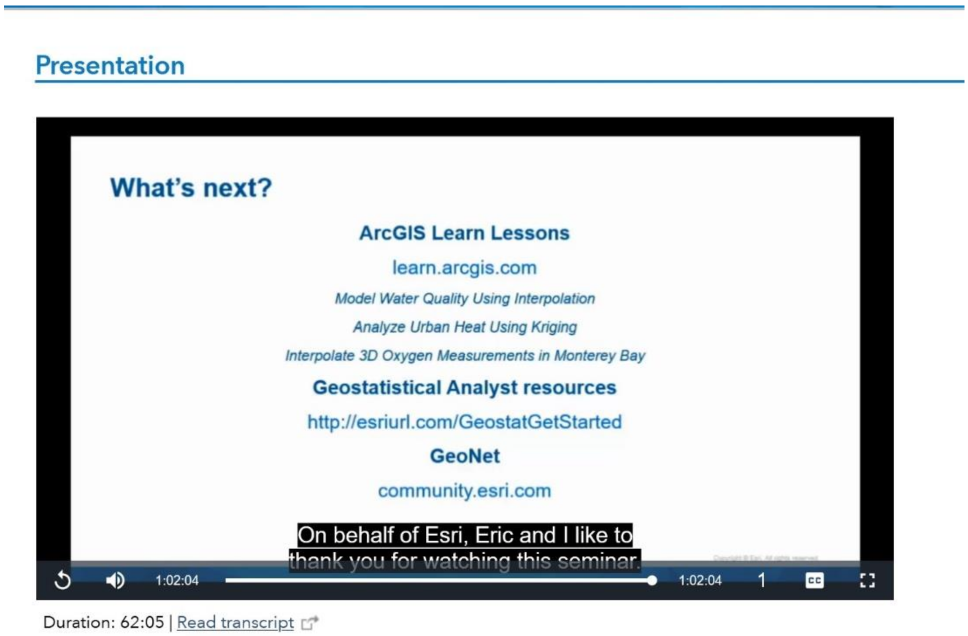


Table 5. Raw Data Description

	Category	Feature Class Type	Number of records	Minimum value	Maximum value
031D08_elev_pt_p.shp	Spot heights	Point	486	188	333
031D08_contour_l.shp	Contours	Line	533	190	330
clip_031D08_elev_pt_p	Clipped Spot heights	Point	486	188	333
clip_031D08_water_b_a	Clipped Water bodies	Polygon	107		
clip_031D08_water_c_l	Clipped Water Course	Line	376	183	307
clip_031D08_wetland_a	Clipped Wetland	Polygon	129		
clip_031D08_road_l	Clipped Roads	Line	3016		
clip_031D08_railway_l	Clipped Railway	Line	44		
clip_031D08_esker_l	Clipped	Line	8		