Interpolating Raster Surfaces

You can use interpolation to model the surface of a feature or a phenomenon—all you need are sample points, an interpolation method, and an understanding of the feature or the phenomenon being modeled. This module introduces you to interpolation, as well as to some common interpolation methods.

The idea behind interpolation is simple: estimating unknown values using a sample of known values. Although certain methods of interpolation, such as Inverse Distance Weighted (IDW) and Spline, solve this problem differently, they each work with the same underlying principle, called spatial autocorrelation.

In this part of the lab, you will learn about Spline and Inverse Distance Weighted (IDW), and you will be introduced to Kriging, a more powerful and complex interpolation method. The exercises allow you to experiment with each of these interpolation methods.

Once you complete this module, you should be prepared to apply these methods to your own data—you may even feel encouraged to explore more advanced topics in the realm of geostatistics.

Creating surfaces using interpolation

Lesson goals

Topic: Introduction to interpolation

- **Concepts**
  - **What is interpolation?**
  - **Spatial autocorrelation**
  - **Sample size**
  - **Interpolation barriers**
- **Example**
  - **Creating a terrain surface with sample points**
- **Exercise**
  - **Explore different interpolation methods**

Topic: Interpolation methods

- **Concepts**
  - **Inverse Distance Weighted**
  - **Spline**
  - **Kriging**
- **Exercises**
  - **Model snow depth with IDW**
  - **Model subsurface limestone formation near earthquake faults**
  - **Create a terrain surface with Spline**

Lesson summary

Goals

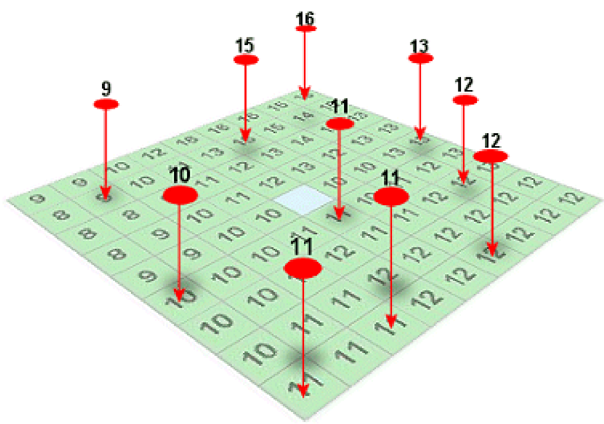
In this lesson, you will learn:

- the basic principles of interpolation
- how to create surfaces using interpolation
- how to control sample points using interpolation
- how to use IDW, Spline, and Kriging
- what the interpolators covered have in common

Introduction to Interpolation

Whether you are concerned with the amount of rainfall, concentrations of pollution, or the differences in elevation, it is impossible to measure these phenomena at every point within a geographic area. You can, however, obtain a sample of measurements from various locations within the study area, then, using those samples, make inferences about the entire geographic area. Interpolation is the process that enables you to make such an inference.

The primary assumption of spatial interpolation is that points near each other are more alike than those farther away; therefore, any location's values should be estimated based on the values of points nearby.



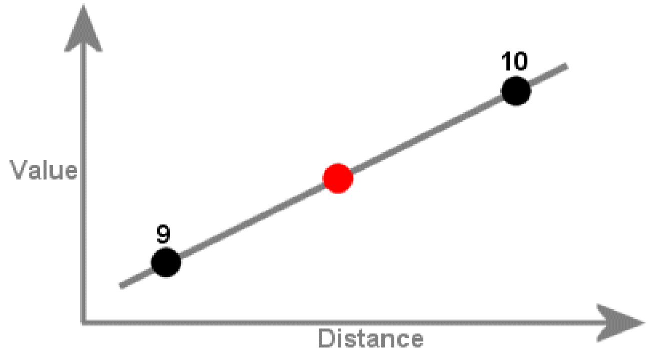
Interpolating the sample points' values creates a surface. As with all of the cells, the unknown value of the light-blue cell in the center will be estimated based on values of the surrounding sample points.

With spatial interpolation, your goal is to create a surface that models the sampled phenomenon in the best possible way. To do this, you start with a set of known measurements and, using an interpolation method, estimate the unknown values for the area. You then make adjustments to the surface by limiting the size of the sample and controlling the influence the sample points have on the estimated values.

Concepts

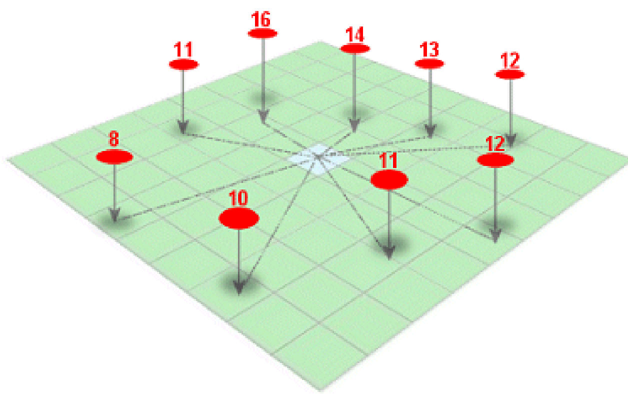
What is interpolation?

Interpolation is the process of estimating unknown values that fall between known values.



In this example, a straight line passes through two points of known value. You can estimate the point of unknown value because it appears to be midway between the other two points. The interpolated value of the middle point could be 9.5.

Spatial interpolation calculates an unknown value from a set of sample points with known values that are distributed across an area. The distance from the cell with unknown value to the sample cells contributes to its final value estimation.



The unknown value of the cell is based on the values of the sample points as well as the cell's relative distance from those sample points.

You can use spatial interpolation to create an entire surface from just a small number of sample points; however, more sample points are better if you want a detailed surface.

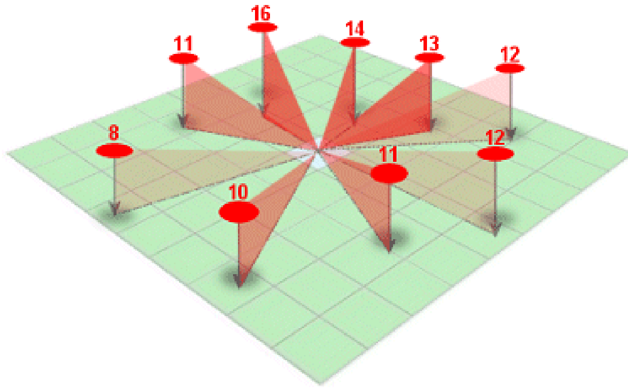
In general, sample points should be well-distributed throughout the study area. Some areas, however, may require a cluster of sample points because the phenomenon is transitioning or concentrating in that location. For example, trying to determine the size and shape of a hill might require a cluster of samples, whereas the relatively flat surface of the surrounding plain might require only a few.

Spatial autocorrelation

The principle underlying spatial interpolation is the First Law of Geography. Formulated by Waldo Tobler, this law states that everything is related to everything else, but near things are more related than distant things.

The formal property that measures the degree to which near and distant things are related is spatial autocorrelation. According to this, if it is raining where you are, it is probably raining 10 feet away from you, is less likely to be raining on the other side of town, and might even be clear and sunny 20 miles away.

Most interpolation methods apply spatial autocorrelation by giving near sample points more importance than those farther away.

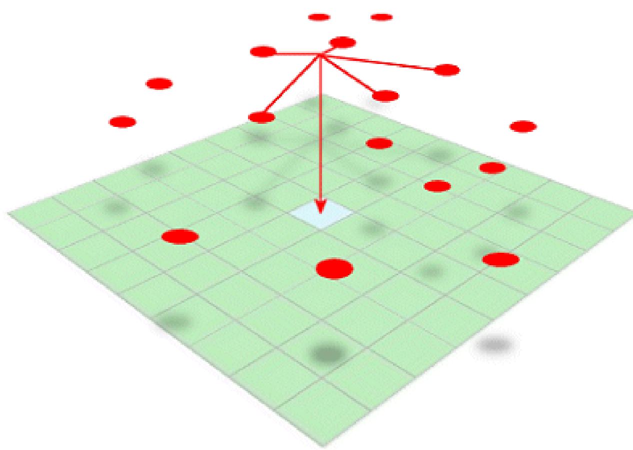


In this graphic, the darkest triangles indicate the most influential sample points.

Sample size

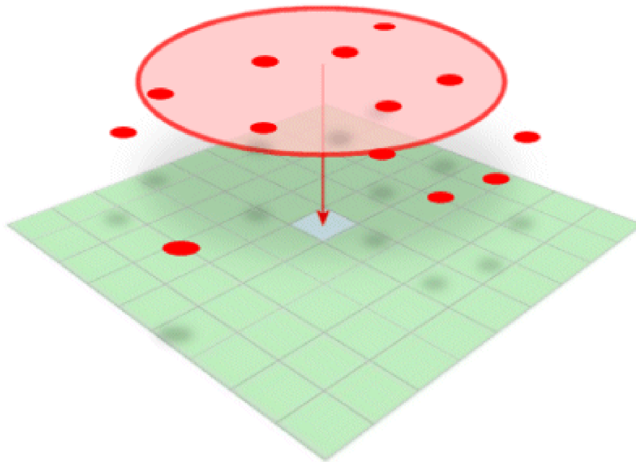
Most interpolation methods allow you to control the number of sample points used to estimate cell values. For example, if you limit your sample to five points, the interpolator will use the five nearest points to estimate cell values.

The distance to each sample point will vary depending on the distribution of the points. If you have a lot of sample points, reducing the size of the sample you use will speed up the interpolation process because a smaller set of numbers will be used to estimate each cell value.



When the sample size is limited to five sample points, as in this case, only the five nearest points are used in the calculation of the estimated cell value. All other points are disregarded.

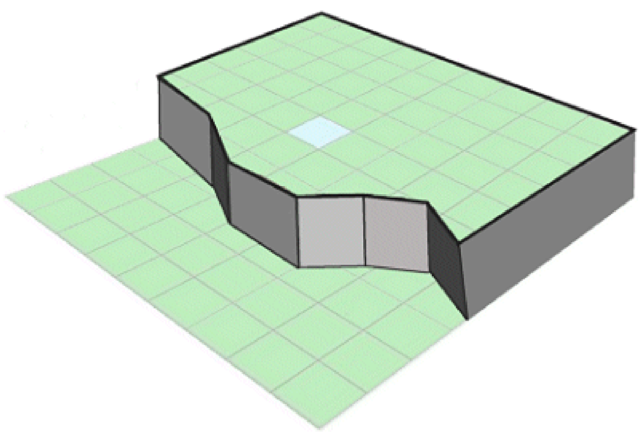
You can also control your sample size by defining a search radius. The number of sample points found within a search radius can vary depending on how the points are distributed. You can choose to use some or all of the samples that fall within this radius to calculate the cell value. A variable search radius will continue to expand until the specified sample size is found. A fixed search radius will use only the samples contained within it, regardless of how many or how few that might be.



If the search radius in this sample were fixed, only the values of the sample points within the radius would be used to calculate the estimated cell value. If the search radius were variable and the minimum sample size were 8, the search radius would expand until it contained eight sample points.

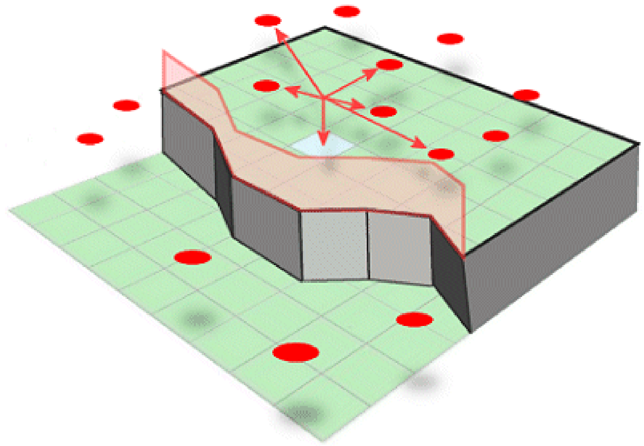
Interpolation barriers

The physical, geographic barriers that exist in the landscape, like cliffs or rivers, present a particular challenge when trying to model a surface using interpolation. The values on either side of a barrier that represents a sudden interruption in the landscape are drastically different.



Elevation values change suddenly and radically near the edge of a cliff. When you interpolate a surface with this type of barrier, you can't use known values at the bottom of the cliff to accurately estimate values at the top of the cliff.

Most interpolators attempt to smooth over these differences by incorporating and averaging values on both sides of the barrier. The Inverse Distance Weighted method allows you to include barriers in the analysis. The barrier prevents the interpolator from using samples points on one side of it.



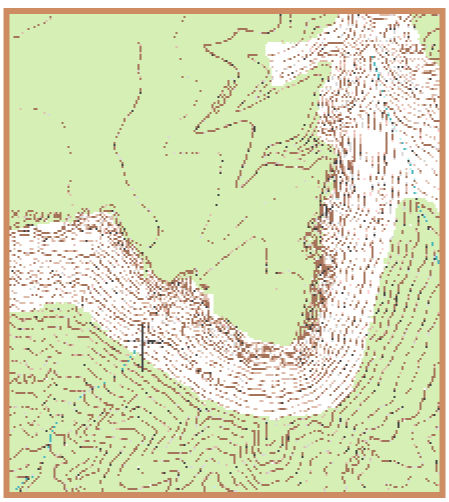
When you use a barrier with interpolation, the estimated cell value is calculated from sample points on one side of the barrier.

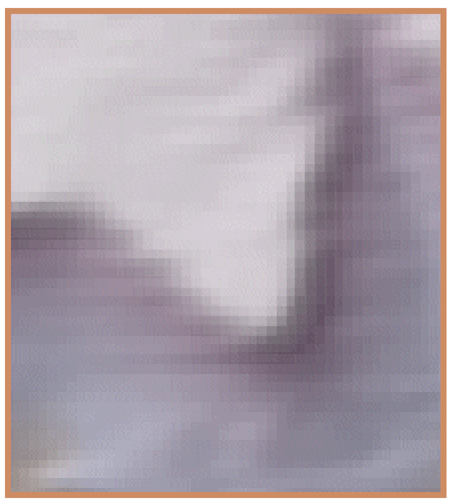
Example

Creating a terrain surface with sample points

ArcGIS™ Spatial Analyst makes it easy to interpolate any type of surface from a set of sample points. Interpolation methods such as Inverse Distance Weighted (IDW) depend on good, quality sample point sets to function properly. For this reason, you should pay attention to spacing and density when assembling a set of sample points.

Take a look at an area on the southern tip of the Shivwits Plateau in Arizona.



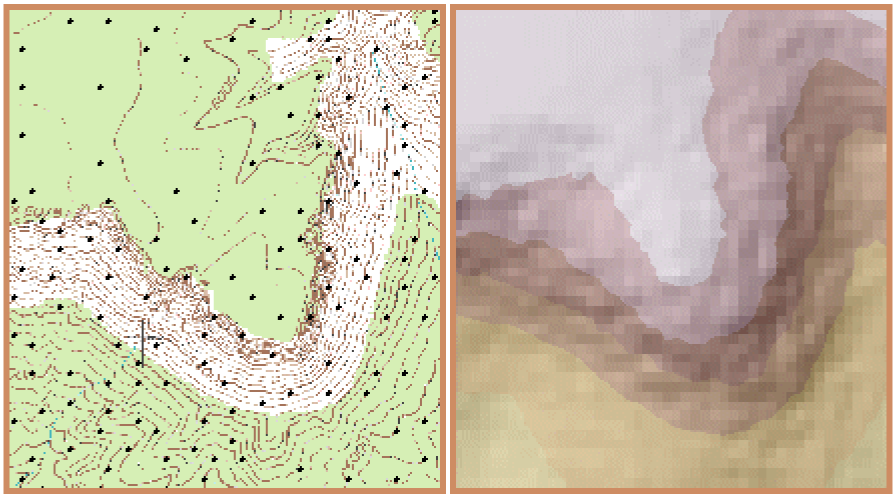


Left: A 7.5' Travertine Rapids topographic map of the Shivwits Plateau. Contours help represent the features and characteristics of the landscape. Right: A surface, 30-meter digital elevation model (DEM) for the same quadrangle. At this scale, you can just see the 30-meter square cells of the raster surface.

For this example, suppose the digital elevation model above does not exist and it's your job to produce it. The only tools you have to create it are your ArcGIS™ software and this digital raster graphic (DRG) of the Travertine Rapids topographic map (left). Lucky for you, that's enough to interpolate a point layer.

First, you need to create enough points to make interpolation worthwhile. Using the contours on the topographic map as a guide, you digitize points and record the elevation values for each location. As you digitize, you make sure to distribute the sample points as evenly as possible throughout the area, placing fewer points on the plateau where it's fairly level, and putting more points in places where the contour lines are closer together.

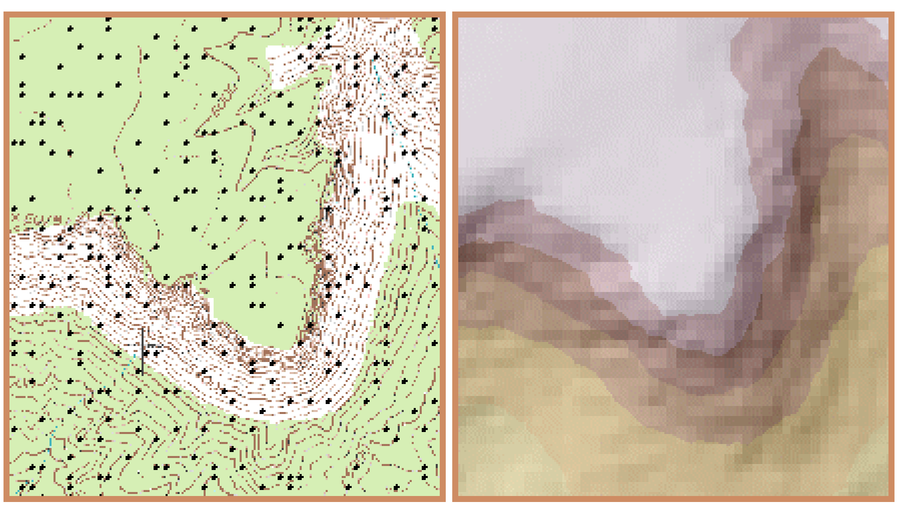
Once you have created an initial set of sample points, you use the IDW function to interpolate the surface.



Left: The black dots on the topographic map are the initial sample point set. Based on the elevation values assigned to each sample point, the IDW function will estimate the elevation values between the points. Right: In this case, the resulting surface is a continuous raster with 30-meter cell size.

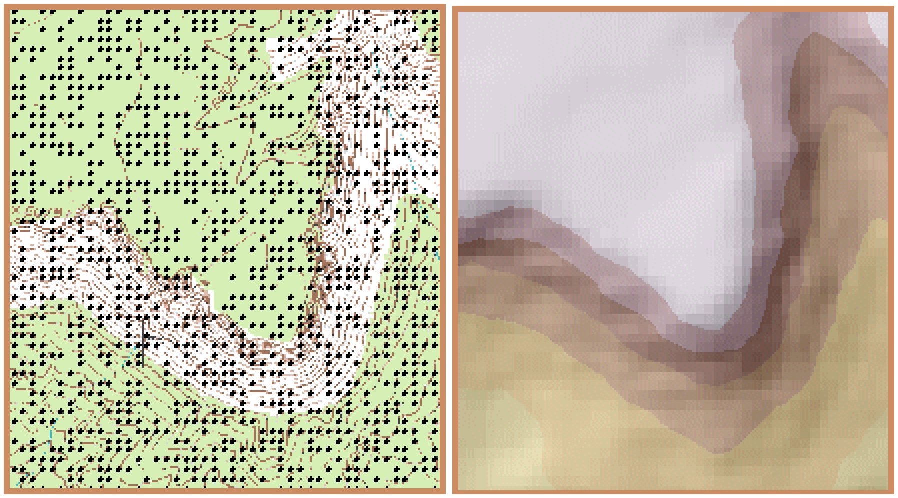
IDW does a good job of estimating the surface with only a limited number of sample points, but when compared to the topographical map, you can see that there is detail missing. You need more sample points.

Using the same method as before, you supplement the sample point set with more points, then run IDW again.



More sample points help the IDW function refine the surface estimation.

Now the plateau, steep cliffs, and variations in the terrain are more apparent. Encouraged by these developments, you continue building the density of sample points and run IDW again.



Left: Notice that this dense set of sample points is made up of clusters of evenly spaced points. Right: In the resulting surface, features such as the plateau, the cliff faces, and the steeply sloping landscape are distinguished from each other.

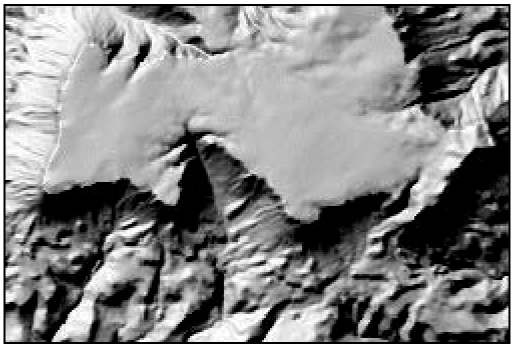
You notice that the more sample points you add, the more accurately the digital surface represents the actual terrain. Remember that the elevation values for each point must be derived from somewhere (e.g., contour lines or field observations). If you had the data and the time, you could create a sample point set for this area from thousands of points at regularly spaced intervals. But you don't have either, so this surface will have to do for now.

From this example, you can see that a surface interpolation function like IDW depends heavily on the quality of the sample point set. The quality increases as the point set becomes sufficiently dense to capture subtle and dramatic changes in the surface.

Exercise

Explore different interpolation methods

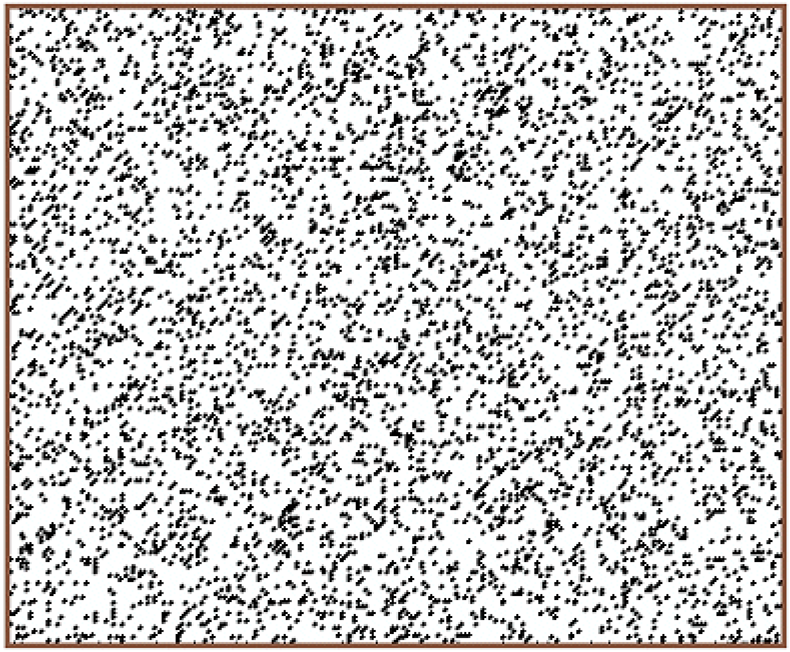
In this exercise, you will use a sample point layer that represents elevation points at specific locations on and around the Shivwits Plateau in Arizona. The graphic below is a hillshade relief map of the area.



After opening the map document you will set the analysis environment and examine a sample point layer. You will then use each of the interpolation methods available in ArcGIS Spatial Analyst to create terrain surfaces from the sample point layer and visually compare the results.

Step 1 Open the map document

Start ArcMap and open the **InterpIntro.mxd** map document from your **Lab6data** folder.



Step 1: Open the map document.

The map document contains two layers: a point layer named Sample points, and a polygon layer named Study area.

If necessary, load the ArcGIS Spatial Analyst extension and make the Spatial Analyst toolbar visible.

Step 2 Set the analysis environment

Set the analysis environment as follows:

- Set the Working directory to your **Lab6data\MyData** folder
- Analysis extent: Same as Layer "Study area"
- Analysis mask: <None>
- Cell size: **30**

Which cell size should I use when interpolating data?

Try setting the cell size to twice the positional accuracy of the input point data. This information is usually found in the metadata for the point data.

In this case, assume that the positional accuracy is plus or minus 15 meters. This means that you are fairly certain that each sample point is within a 15-meter radius of the location indicated in the data. Therefore, when interpolating a surface from this sample point data, set the cell size to 30.

Step 3 Investigate the sample point layer

In the Table of Contents, right-click the Sample points layer and choose Open Attribute Table.

FID*	Shape*	ELEV
1	Point	1222
2	Point	1402
3	Point	1432
4	Point	1466
5	Point	1501
6	Point	1520
7	Point	1520
8	Point	1517
9	Point	1795
10	Point	1804
11	Point	1816
12	Point	1821

Step 3: Investigate the sample point layer.

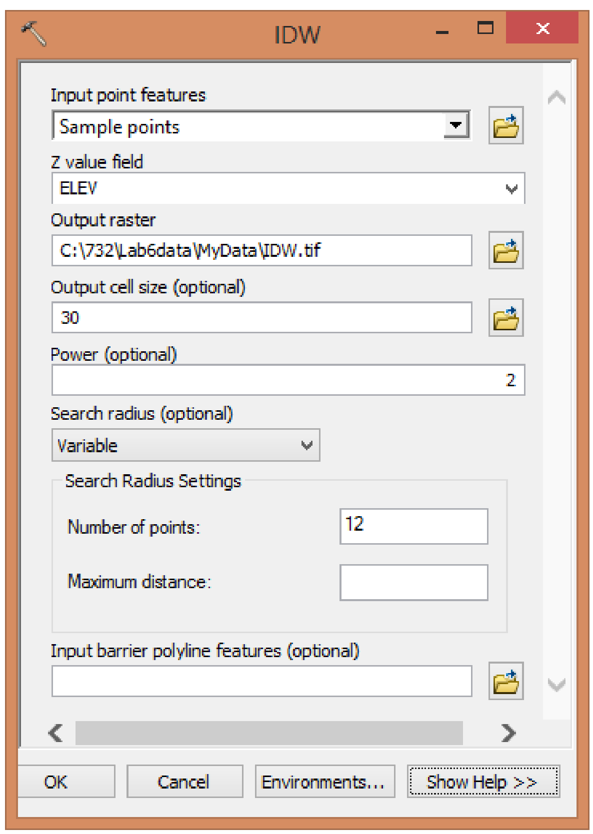
The ELEV field contains an elevation value (z value) for each record. In this case, the elevation values are in meters.

Close the table.

Turn off the Sample points layer.

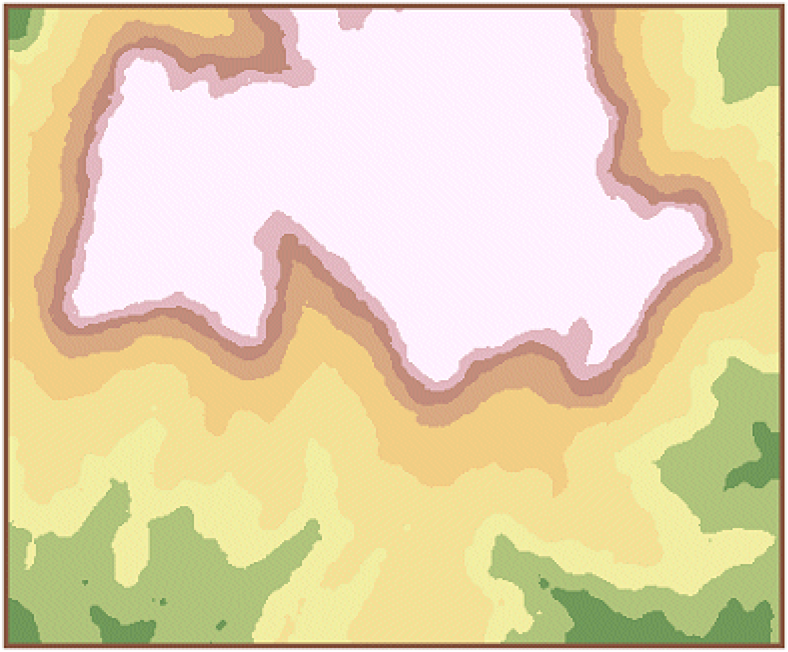
Step 4 Use Inverse Distance Weighted (IDW) to interpolate a surface

From the Spatial Analyst toolbox, choose Interpolation, then click IDW.



Step 4a: Use Inverse Distance Weighted (IDW) to interpolate a surface.

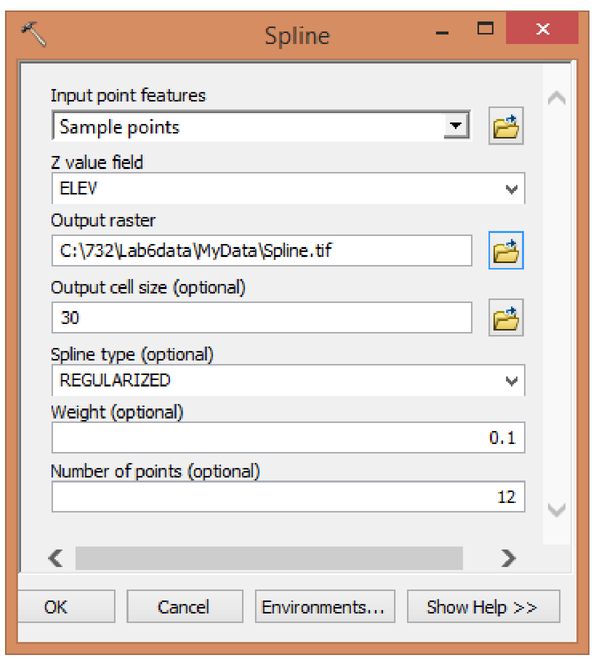
Note the values in the Inverse Distance Weighted dialog, then click OK.



Step 4b: Use Inverse Distance Weighted (IDW) to interpolate a surface.

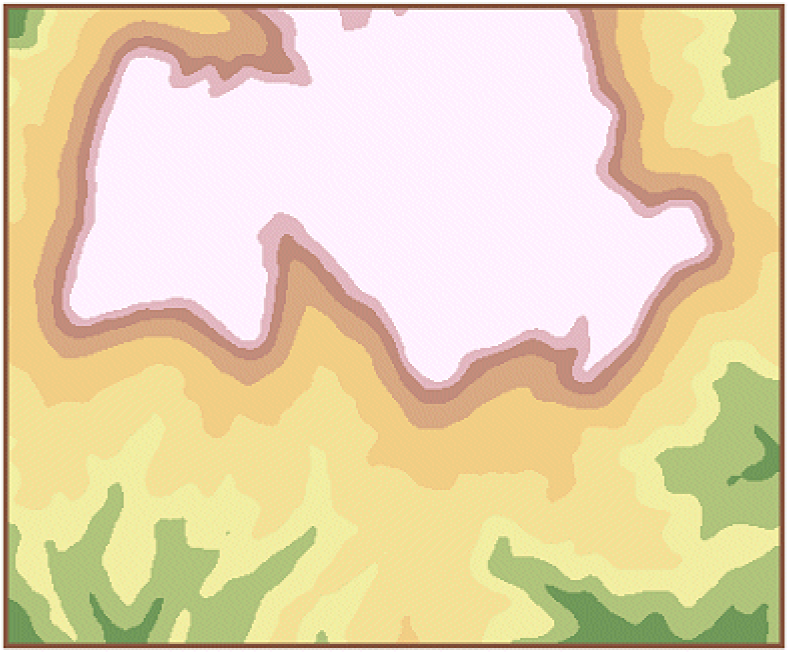
Step 5 **Use Spline to interpolate a surface**

From the Spatial Analyst toolbox, choose Interpolation, then click Spline.



Step 5a: Use Spline to interpolate a surface.

In the Spline dialog, click in the Weight box, change the weight value to **2**, and click OK.

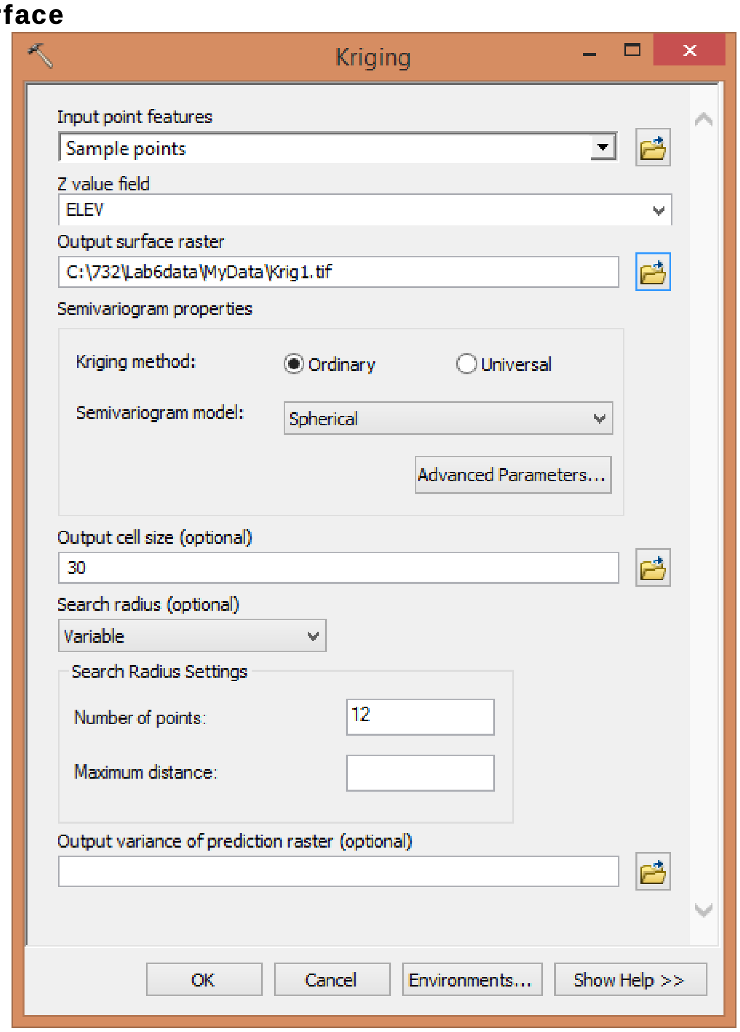


Step 5b: Use Spline to interpolate a surface.

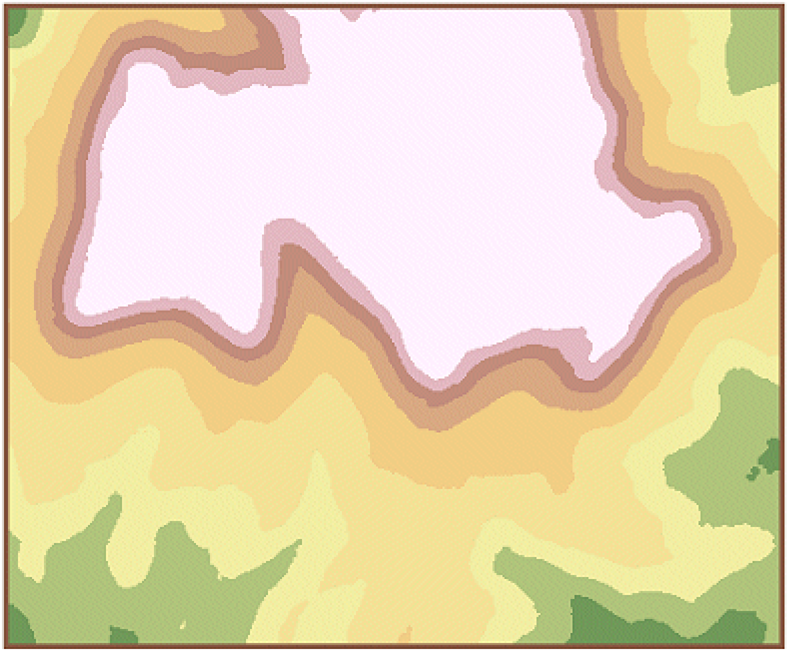
Step 6 Use Kriging to interpolate a surface

From the Spatial Analyst toolbox, choose Interpolation, then click Kriging.

For Kriging method, choose Universal, and click OK.



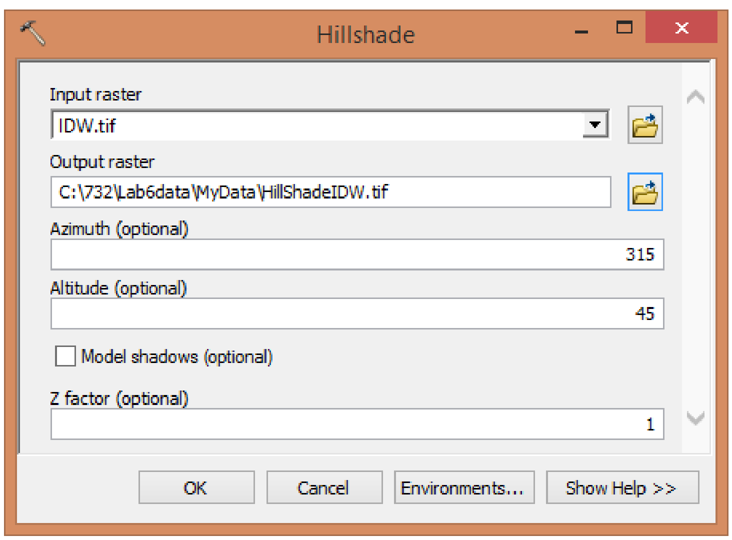
Step 6a: Use Kriging to interpolate a surface.



Step 6b: Use Kriging to interpolate a surface.

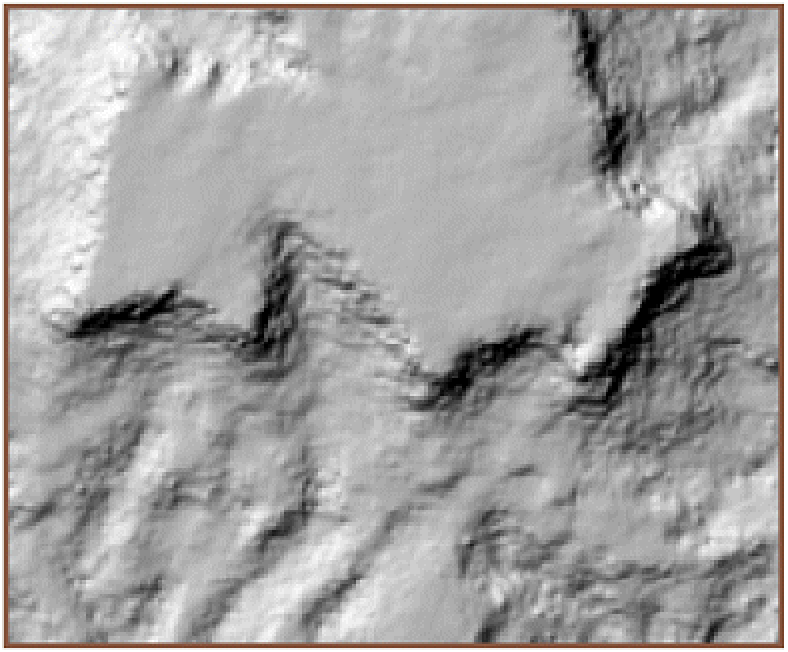
Step 7 Create hillshades for each of the surfaces

From the Spatial Analyst toolbox, choose Surface, then click Hillshade.



Step 7a: Create hillshades for each of the surfaces.

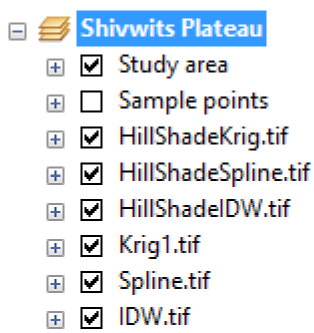
In the Hillshade dialog, click the Input surface dropdown arrow, choose IDW of Sample points, then click OK.



Step 7b: Create hillshades for each of the surfaces.

Follow the same procedure to create a hillshade surface for the Spline of Sample points and Krige of Sample points layers, remembering to select these layer names from the Input surface dropdown list.

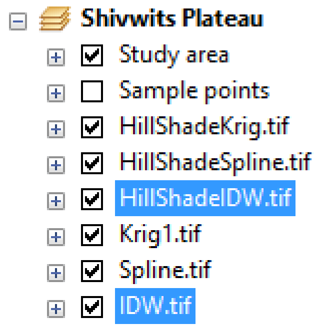
In the Table of Contents, collapse the legends of all of the layers.



Step 7c: Create hillshades for each of the surfaces.

Step 8 **Group the layers and set transparency**

In the Table of Contents, click the IDW layer and, while holding down your Ctrl key, click the HillshadeIDW layer so that both layers are highlighted simultaneously.



Step 8a: Group the layers and set transparency.

In the Table of Contents, right-click the highlighted IDW of Sample points layer, and click Group.

Step 8b: Group the layers and set transparency.

Right-click New Group Layer, and choose Properties.

Click the General tab and rename the layer **IDW**.

If necessary, click the black down arrow to move the HillshadeIDW layer to the bottom of the Layers list.

Step 8e: Group the layers and set transparency.

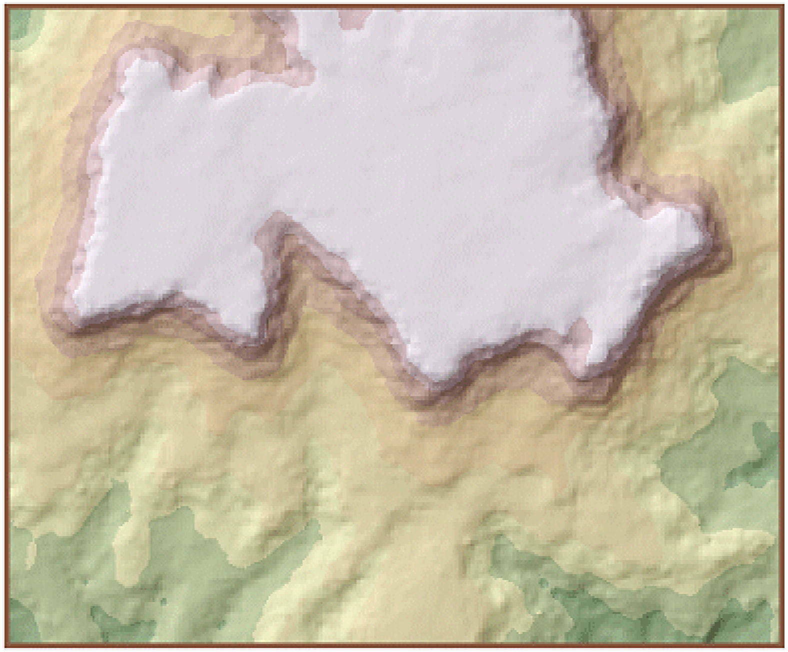
In the Layers list box, click IDW.tif layer.

Click the Properties button. In the Layer Properties dialog, click the Display tab.

In the Transparency text box, type **45** and click Apply.

Step 8f: Group the layers and set transparency.

Click OK to close the Layer Properties dialog. Click OK to close the Group Layer Properties dialog.

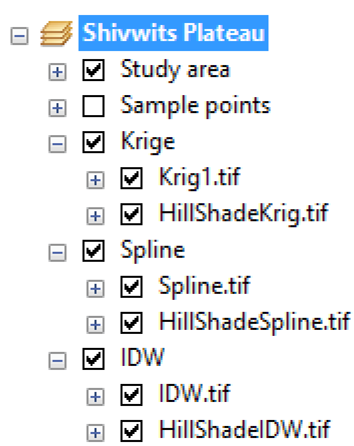


Step 8g: Group the layers and set transparency.

Follow the same procedure to group the Spline layers together, and name the new group layer **Spline**. Move the hillshade layer to the bottom and set the transparency for the interpolated surface to **45** percent.

Group the Krige layers together and name the new group layer **Krige**. Move the hillshade layer to the bottom and set the transparency for the interpolated surface to **45** percent.

When you are done, the Table of Contents should look like the View Result graphic below.



Step 8h: Group the layers and set transparency.

Step 9 Compare the elevation ranges in the interpolated surfaces

At this point, you should have three group layers named IDW, Spline, and Krige. If necessary, arrange the layers in the Table of Contents so that the Krige group layer is above the Spline group layer, which is above the IDW group layer.

Expand the Krig1 layer in the Krige group layer by clicking the plus sign next to the layer name.

Krig1.tif
- 1,183.429199 - 1,260.649393
- 1,260.649394 - 1,337.869587
- 1,337.869588 - 1,415.089782
- 1,415.089783 - 1,492.309976
- 1,492.309977 - 1,569.53017
- 1,569.530171 - 1,646.750364
- 1,646.750365 - 1,723.970558
- 1,723.970559 - 1,801.190752
- 1,801.190753 - 1,878.410946

Step 9a: Compare the elevation ranges in the interpolated surfaces.

Next, expand the Spline layer in the Spline group layer.

Spline.tif
- 1,168.539917 - 1,247.525891
- 1,247.525892 - 1,326.511866
- 1,326.511867 - 1,405.49784
- 1,405.497841 - 1,484.483815
- 1,484.483816 - 1,563.469789
- 1,563.46979 - 1,642.455763
- 1,642.455764 - 1,721.441738
- 1,721.441739 - 1,800.427712
- 1,800.427713 - 1,879.413687

Step 9b: Compare the elevation ranges in the interpolated surfaces.

Finally, expand the IDW layer in the IDW group layer.

IDW.tif
- 1,184.336914 - 1,261.488963
- 1,261.488964 - 1,338.641012
- 1,338.641013 - 1,415.79306
- 1,415.793061 - 1,492.945109
- 1,492.94511 - 1,570.097158
- 1,570.097159 - 1,647.249207
- 1,647.249208 - 1,724.401255
- 1,724.401256 - 1,801.553304
- 1,801.553305 - 1,878.705353

Step 9c: Compare the elevation ranges in the interpolated surfaces.

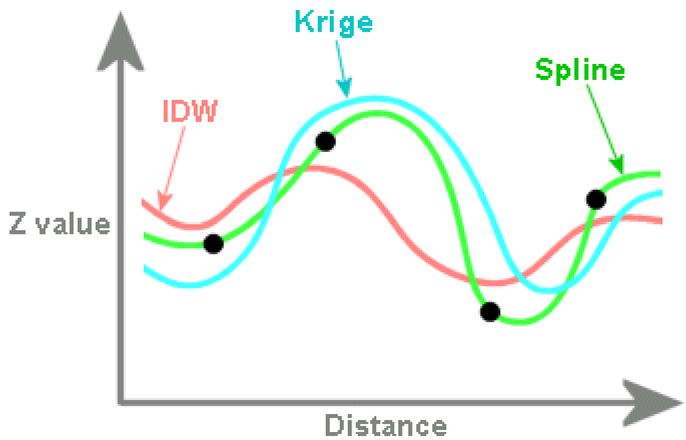
Notice that each interpolation method resulted in a different range of elevation values.

Why do the ranges of values for IDW, Spline, and Kriging surfaces differ?

IDW, Spline, and Kriging methods "fit" the surface to the sample point set. However, the ranges of cell values in the resulting surfaces will differ depending on the method, even though the same sample point set is used.

Remember the following interpolation facts:

- An IDW surface never exceeds the highest or lowest values in the sample point set.
- A Spline surface can exceed the highest and lowest values in the sample point set, but the surface must pass through each sample point.
- A Kriged surface can exceed the highest and lowest values in the sample point set, but does not have to pass through any sample points.



Step 10 **Visually compare the interpolated layers**

Click the minus sign next to all of the layers in the Table of Contents to collapse them.

Step 10: Visually compare the interpolated layers.

Compare the Krige group layer with the Spline group layer by toggling the Krige group layer off and on.

Next, turn off the Krige group layer.

Compare the Spline group layer with the IDW group layer by toggling the Spline group layer off and on.

Finally, turn off the Spline group layer.

Compare the Kriged group with the IDW group layer by toggling the Krige group layer off and on.

You may not see much difference between the layers. Based on the information you have so far, it is difficult to tell whether one interpolation method is better than the other. Although Kriging provides the most complex analysis, this doesn't mean that it is the best method for your project.

The interpolation method you choose to use at any given time is mainly a matter of preference and depends mostly on your familiarity with the data. The purpose of this exercise was to introduce you to basic interpolation methods. You will explore them in more detail in the exercises that follow.

Step 11 Save the map document

Name the map document **final_InterpIntro.mxd** and save it in your **Lab6data\MyData** folder.

Close ArcMap.

Key points

- Using default parameters, all the interpolation methods create good and basically similar surfaces. The differences between them are in the details.
- Your choice of an interpolation method is influenced by your knowledge of the surface you are modeling. You can use your knowledge of reality (or maybe the high-resolution aerial photos you have of it) to check how well the interpolators are doing.

Your understanding of the methodology also influences your choice of method. Kriging is much more sophisticated than IDW (and, as a rule, creates more accurate surfaces), but IDW is easier to understand.

Interpolation methods

Three of the most common interpolation methods are Inverse Distance Weighted (IDW), Spline, and Kriging.

IDW takes the concept of spatial autocorrelation literally. It assumes that the nearer a sample point is to the cell whose value is to be estimated, the more closely the cell's value will resemble the sample point's value.

Spline virtually guarantees you a smooth-looking surface. Imagine stretching a rubber sheet so that it passes through all of your sample points.

Kriging is one of the most complex and powerful interpolators. It applies sophisticated statistical methods that consider the unique characteristics of your dataset. In order to use Kriging interpolation properly, you should have a solid understanding of geostatistical concepts and methods.

How do I determine which interpolation method to use?

The type of interpolation method you use will depend on many factors. Rather than assume one interpolation method is better than another, you should try different interpolation methods and compare the results to determine the best interpolation method for a given project.

Your real-world knowledge of the subject matter will initially affect which interpolation method you use. If you know that some of the features in your surface exceed the z value, for example, and that IDW will result in a surface that does not exceed the highest or lowest z value in the sample point set, you might choose the Spline method.

If you know that the splined surface might end up with features that you know don't exist because Spline interpolation doesn't work well with sample points that are close together and have extreme differences in value, you might decide to try IDW.

The quality of your sample point set can affect your choice of interpolation method as well. If the sample points are poorly distributed or there are few of them, the surface might not represent the actual terrain very well. If you have too few sample points, you might experiment with adding more sample points in areas where the terrain changes abruptly or frequently, then try using Kriging.

Regardless of the method you use, you should thoroughly understand your data and the phenomenon you're trying to model before interpolating.

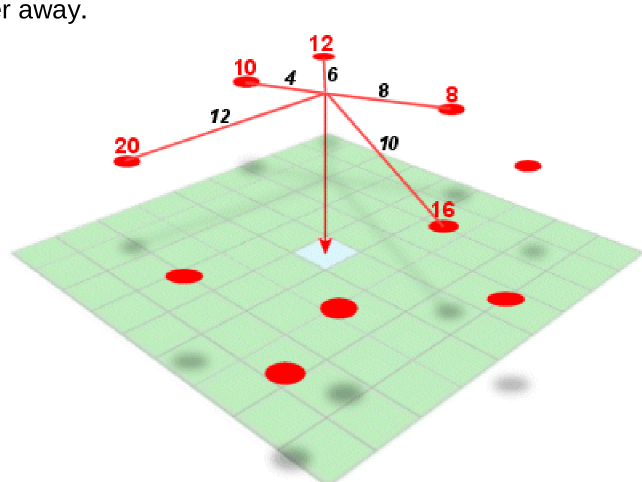
Concepts

Inverse Distance Weighted

The Inverse Distance Weighted method is the practical, easy-to-understand interpolator. When you use IDW, you are applying a "one size fits all" assumption to your sample points.

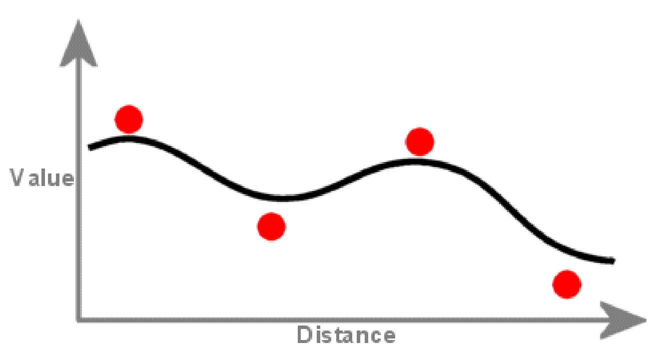
IDW works best for dense, evenly-spaced sample point sets. It does not consider any trends in the data, so, for example, if actual surface values change more in the north-south direction than they do in the east-west direction (because of slope, wind, or some other factor), the interpolated surface will average out this bias rather than preserve it.

IDW interpolation considers the values of the sample points and the distance separating them from the estimated cell. Sample points closer to the cell have a greater influence on the cell's estimated value than sample points that are further away.



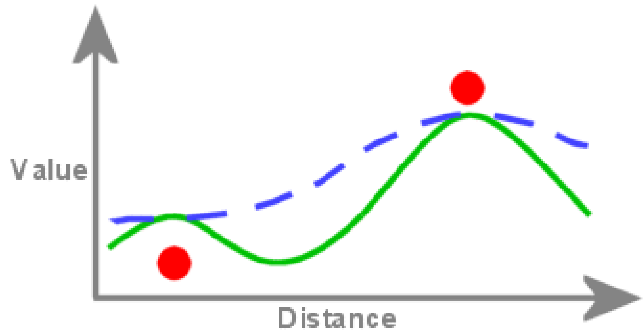
Each of the five sample points in this example have a different value and distance from the estimated cell.

Inverse Distance Weighting cannot make estimates above the maximum or below the minimum sample values. For an elevation surface, this has the effect of flattening peaks and valleys (unless their high and low points are part of the sample). Because the estimated values are averages, the resulting surface will not pass through the sample points.



A surface created with IDW will not exceed the value range of the sample points or pass through those points.

You can adjust the relative influence of sample points. In other words, you can increase how much power the values of sample points have over the interpolation process. Increased power means that the output cell values become more localized and less averaged. Their influence, however, drops off rapidly with distance.

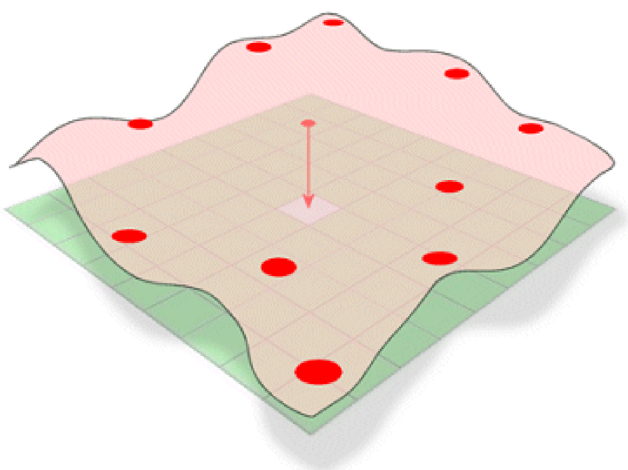


The solid line represents more power and the dashed line represents less power. The higher the power, the more localized an affect a sample point's value has on the resulting surface.

Lowering the power that sample point values have provides a more averaged output because sample points farther away become more and more influential until all of the sample points have the same influence.

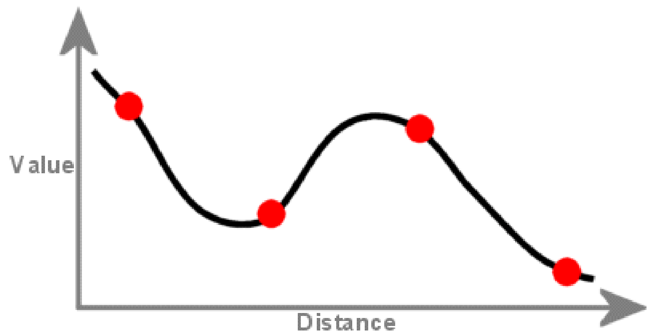
Spline

Instead of averaging values, like IDW does, the Spline interpolation method fits a flexible surface, as if it were stretching a rubber sheet across all the known point values.



The Spline method of interpolation estimates unknown values by bending a surface through known values.

This stretching effect is useful if you want estimated values that are below the minimum or above the maximum values found in the sample data. This makes the Spline interpolation method good for estimating lows and highs where they are not included in the sample data.



A surface created with Spline interpolation passes through each sample point and may exceed the value range of the sample point set.

However, when the sample points are close together and have extreme differences in value, Spline interpolation doesn't work as well. This is because Spline uses slope calculations (change over distance) to figure out the shape of the flexible rubber sheet.

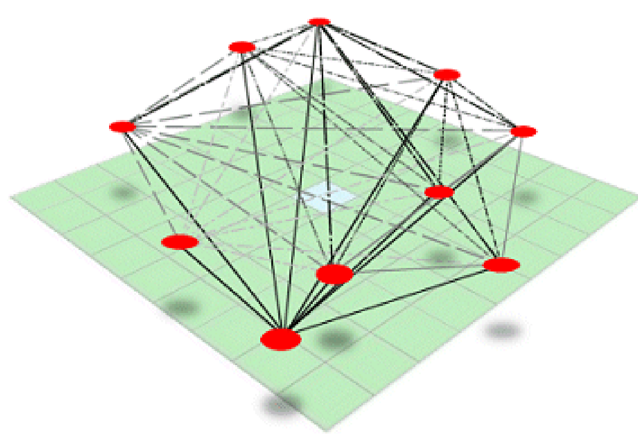
Phenomena that cause surface values to change suddenly, such as a cliff face or a fault line, are not represented well by a smooth-curving surface. In such cases, you might prefer to use IDW interpolation, where barriers can be used to deal with these types of abrupt changes in local values.

There are two types of Spline: Regularized and Tension. A Tension Spline is flatter than a Regularized Spline of the same sample points, forcing the estimates to stay closer to the sample data. You might say that the Tension Spline method produces a surface more rigid in character, while the Regularized Spline method creates one that's more elastic.

Kriging

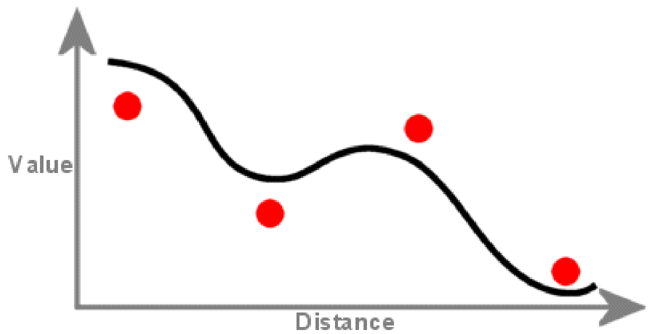
Getting to know the Kriging method involves delving into the mysterious world of probability and prediction, which, depending on your understanding of statistics, could lead either to years of therapy, or to your Ph.D.

Like IDW, Kriging is a weighted average technique, except that the weighting formula in Kriging uses much more sophisticated math. Kriging measures distances between all possible pairs of sample points (that’s right, all of them) and uses this information to model the spatial autocorrelation for the particular surface you're interpolating. In other words, Kriging tailors its calculations to your data by analyzing all the data points to find out how much autocorrelation they exhibit and then factors that information into the weighted average estimation.



When you interpolate a surface using Kriging, the distance and direction of every point pair is quantified to provide information on the spatial autocorrelation of the sample point set. Next, a best-fit model is automatically applied to the data and the unknown values are predicted.

Kriging aficionados consider the initial kriged surface a first draft—a test surface against which they compare future iterations as they search for the perfect surface. Directional influences, such as prevailing winds and random error, can be accounted for using Kriging, but you will need a statistical tool such as ArcGIS™ Geostatistical Analyst to visualize these trends.



A surface created with kriging can exceed the value range of the sample points, but will not pass through the points.

Two general and widely used Kriging methods are Ordinary and Universal Kriging. Universal Kriging assumes that there is an overriding trend in the data. For example, you may know that there is a prevailing wind or a gently sloping hillside across your study area. Ordinary Kriging assumes there is no trend in the data, which should be your standard operating assumption.

Exercise 2

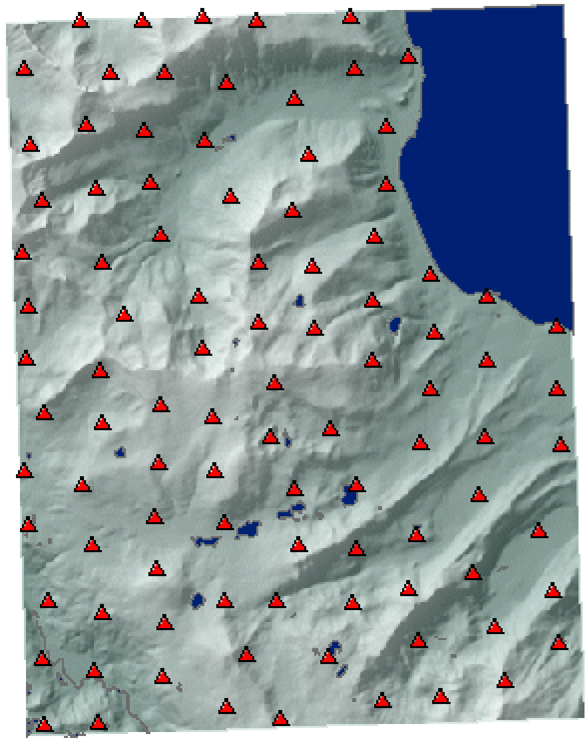
In this exercise, you will use the Inverse Distance Weighted (IDW) interpolation method and experiment with changing different options, such as the Power setting and the search radius.

You will create several surfaces using different IDW options, each time refining the estimated snow depth surface. First, you will decrease the power of the sample points in order to smooth out the resulting surface. You will then constrain the search radius so that the values of sample points beyond a certain distance cannot be used.

You are provided with a set of sample points for snow depth measurements at specific locations throughout the Homewood quadrangle, which includes a portion of southwest Lake Tahoe, California. The sample points are regularly spaced throughout the area and, therefore, any of the interpolation methods may be suitable for creating the surface.

Step 1 Open the map document

Start ArcMap and open the **HomewoodSnow.mxd** map document from your **Lab6data** folder.



Step 1: Open the map document.

The red triangles represent sample points where the depth of snow has been recorded in inches.

If necessary, load the ArcGIS Spatial Analyst extension and make the Spatial Analyst toolbar visible.

Step 2 **Set the analysis environment**

A portion of Lake Tahoe occupies the northeast corner of the Homewood quadrangle. You will begin the exercise by using a mask to exclude Lake Tahoe from the analysis.

Ordinarily, you would create this mask yourself, but to save time it has already been created for you. Only the area where the analysis extent and the mask coincide will be included in the analysis.

Use the following information to set the analysis environment.

- Set the Working directory to your **Lab6data\MyData** folder
- Analysis mask: Mask
- Analysis extent: Same as Layer "Homewood DEM"

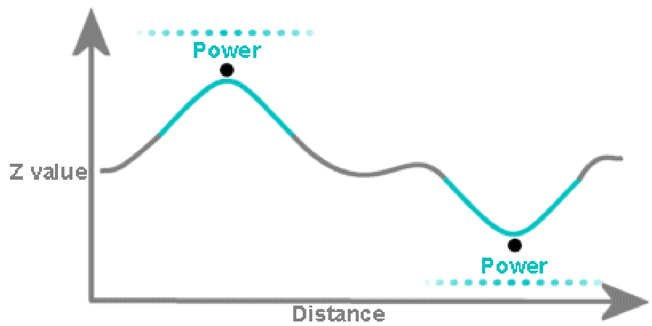
Analysis cell size: Same as Layer "Homewood DEM"

Step 3 **Create a snow depth surface using the IDW interpolation method**

When you use the IDW interpolation method with a Power setting of 2, each sample point exerts a strong influence over the estimated values of cells near it.

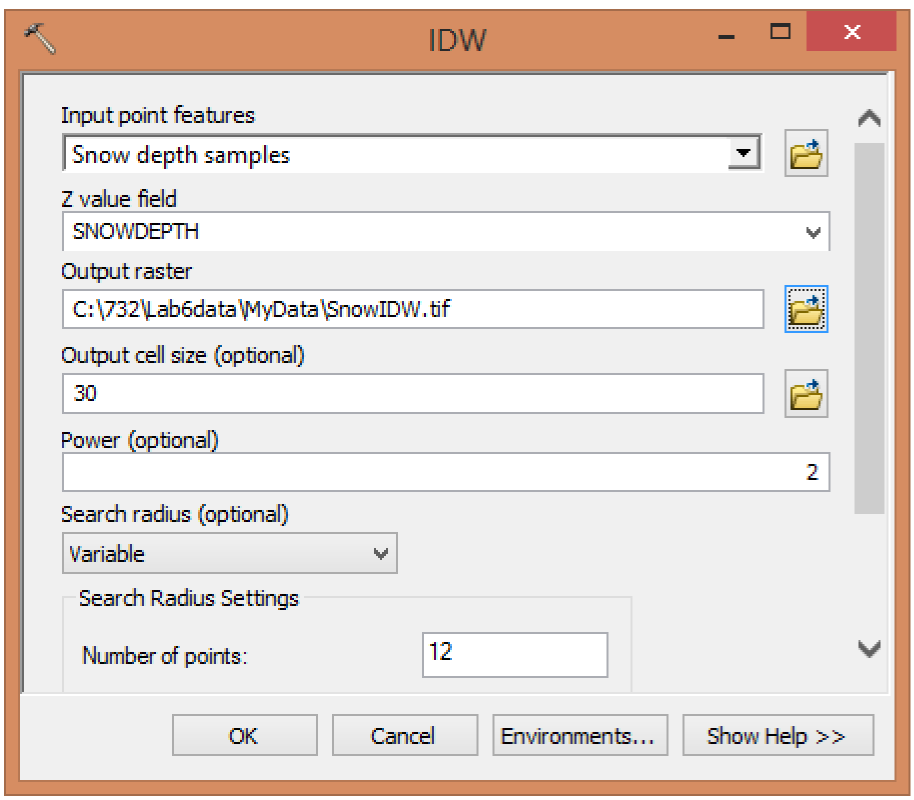
What happens when sample points strongly influence estimated cell values?

Sample points are weighted according to their distance from the cell being evaluated. Closer sample points are given more weight than points farther away. As the Power setting increases, the influence of sample points falls off more rapidly with distance. The output cell values become more localized and less averaged. A high power setting will result in bumps and depressions in the surface, which are localized around sample point locations.



From the Spatial Analyst toolbox, choose Interpolation, then click IDW.

In the Inverse Distance Weighted dialog, click the Z value field dropdown arrow, and choose SNOWDEPTH.

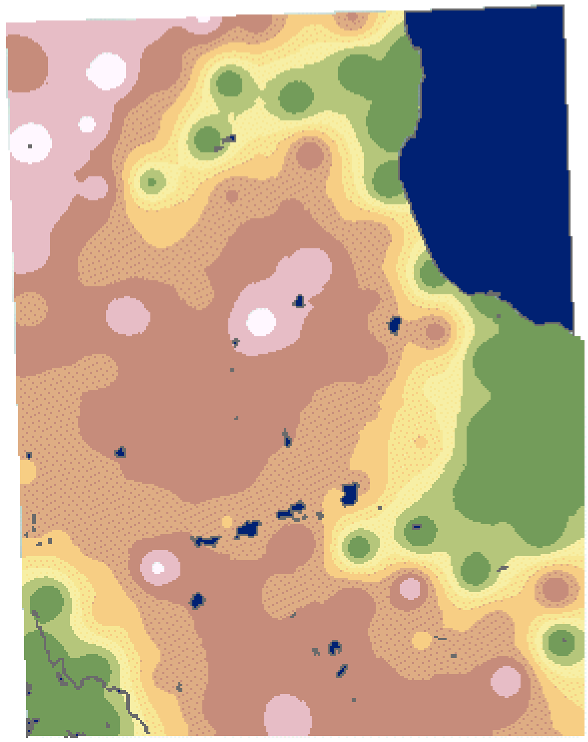


Step 3a: Create a snow depth surface using the IDW interpolation method.

Make sure that Power is set to **2** and the Search radius type is Variable.

Click OK.

Turn off the Snow depth samples layer.



Step 3b: Create a snow depth surface using the IDW interpolation method.

Collapse the legend for this new surface in the Table of Contents.

Rename the new surface **IDW Power 2**.

Turn off the IDW Power 2 layer.

Step 4 **Change the Power setting and run IDW again**

To decrease the influence of the sample points on local cell values, you can reduce the Power setting. Lowering the Power setting is one way to create a smoother surface, that is, a surface with more gradual changes in cell values.

One way to smooth an IDW surface is to decrease the power. What is another way?

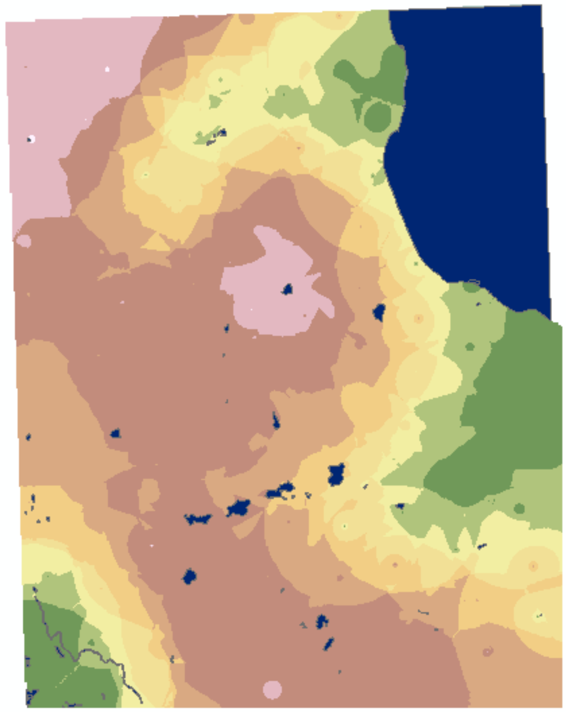
> Increase the number of sample points used in the interpolation, or use all sample points within a radius and use a large radius.

From the Spatial Analyst menu, choose Interpolate to Raster, then click Inverse Distance Weighted.

Click the Z value field dropdown arrow, and choose SNOWDEPTH.

Click in the Power text box and type **0.5**.

Click OK.



Step 4: Change the Power setting and run IDW again.

If your map does not look like the one above, then you probably interpolated the AREA variable rather than the SNOWDEPTH one.

Collapse the legend for the new IDW of Snow depth samples layer in the Table of Contents.

Rename the new surface **IDW Power 0.5**.

Turn off the IDW Power 0.5 layer.

Step 5 Constrain the search radius and run IDW again

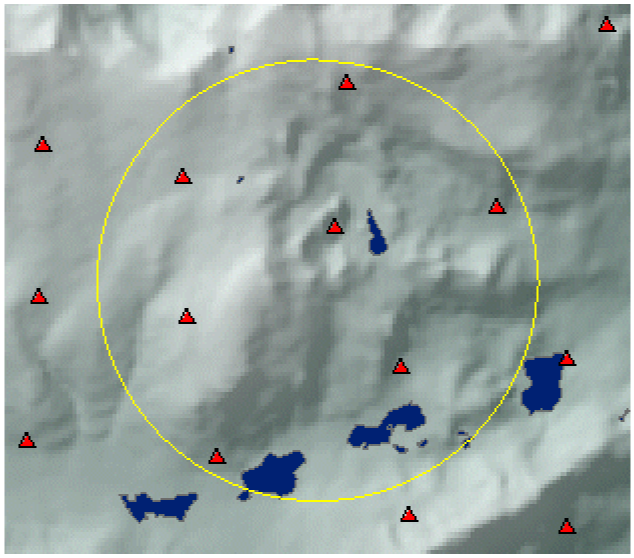
So far, the IDW function has been calculating the value of each cell by searching the entire set of points to find the nearest 12. This means that the value of a cell might be calculated based on point values that are relatively far away.

In this step, you will change the IDW interpolation settings so that its calculations are made based on fewer points and within a specified distance. You will change the settings to reduce the minimum number of nearest points to search to 5, and search for points within a radius of 1609.344 meters (1 mile). Constraining IDW will reveal how the estimated snow depth value of a cell is more like its neighboring sample point values and less like its sample point values further away.

How do you determine which size to make the search radius?

It depends on your sample point data. If the points are evenly distributed but far apart, you may need to use a larger search radius with a smaller number of minimum number of points. If the points are evenly distributed but close together, your search radius can be smaller, depending on what you decide for the minimum number of points. If the points are close together in some places and far apart in others, you should consider using a variable search radius.

You can visually experiment with a search radius by creating a graphic circle (see the Draw toolbar) and setting the width to twice the radius distance. Move the circle to different places on the map, counting the number of sample points contained within it. From this you should be able to determine the appropriate size for a search radius and what the minimum number of sample points should be.



From the Spatial Analyst menu, choose Interpolate to Raster, then click Inverse Distance Weighted.

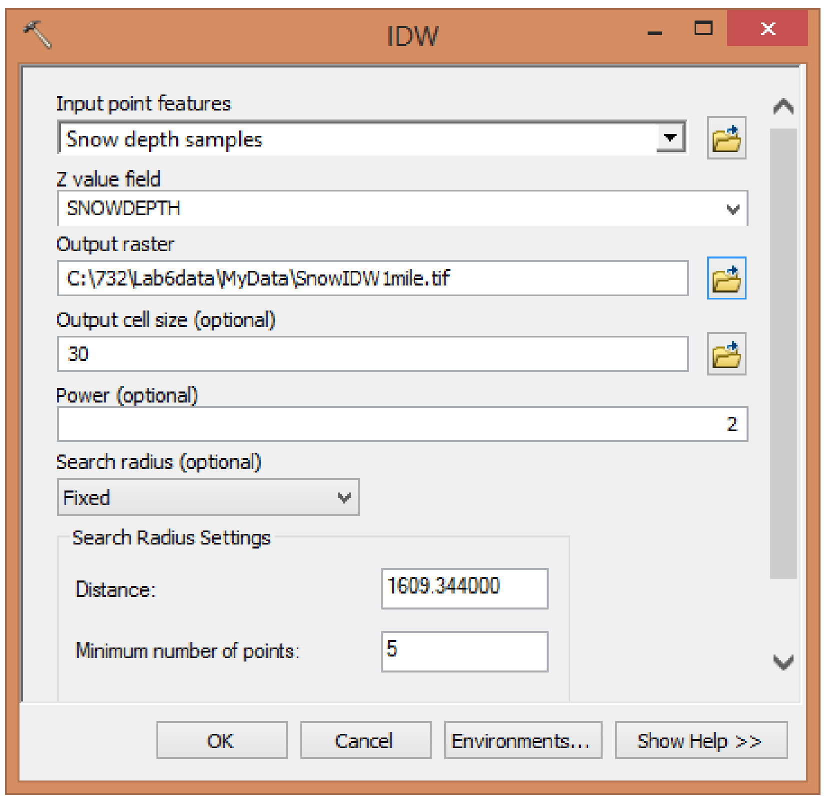
Click the Z value field dropdown arrow and click SNOWDEPTH.

In the Power text box set the power to **0.5**.

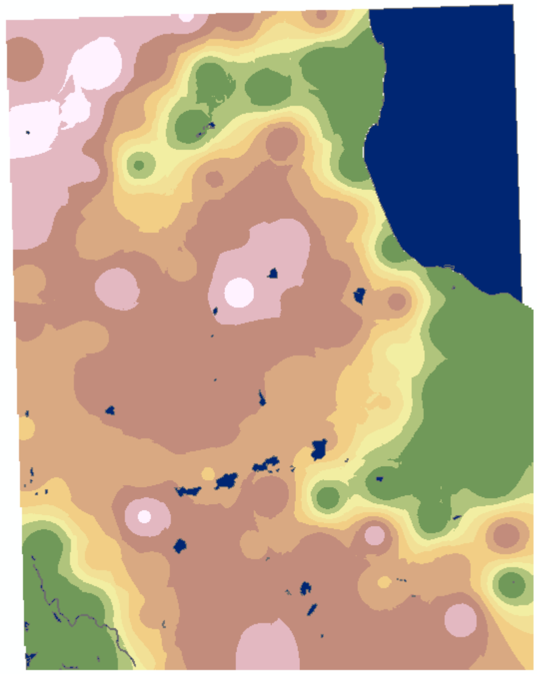
In the Number of points text box, set the number to **5**.

In the Maximum distance text box, type **1609.344**.

Click OK.



Step 5a: Constrain the search radius and run IDW again.



Step 5b: Constrain the search radius and run IDW again.

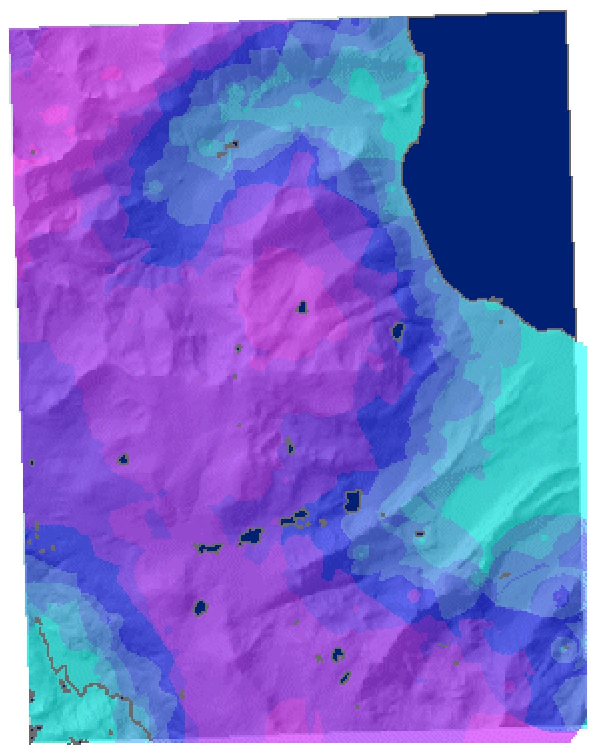
Collapse the legend for the new surface in the Table of Contents.

Rename the new layer **IDW 1609**.

Step 6 Apply a new color ramp and set transparency for the IDW 1609 layer

Symbolize the IDW 1609 layer using the Cyan to Purple color ramp.

Set the transparency for the IDW 1609 layer to **45** percent.



Step 6: Apply a new color ramp and set transparency for the IDW 1609 layer.

Step 7 Save the map document

Name the map document **final_HomewoodSnow.mxd** and save it in your **Lab6data\MyData** folder.

If you are going on to the next exercise, keep ArcMap open; otherwise, close ArcMap.

Key points

- IDW is a good interpolator for a phenomenon whose distribution is strongly correlated with distance. A classic example is noise, which falls off very predictably with distance.

- IDW does less well with phenomena whose distribution depends on more complex sets of variables because it can account only for the effects of distance.
- One potential advantage of IDW is that it gives you explicit control over the influence of distance; an advantage you don't have with Spline or Kriging.
- You can create a smoother surface by decreasing the power, increasing the number of sample points used, or increasing the search radius. To create a more locally influenced surface, do the opposite.

Exercise 3

Model subsurface limestone formation near earthquake faults

Folded rock structures, known as anticlines, form a subterranean architecture similar in shape to the barrel vaults of cathedrals. Given the right conditions, these structures can contain oil, gas, water, or a mixture of each. Geologists study rock deformations to determine the shape and size of oil and gas pockets that may be lying just beneath them.

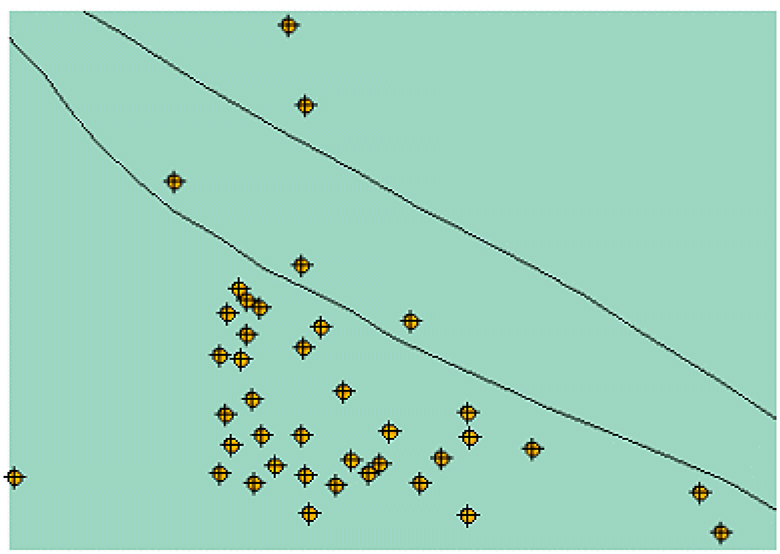
In this exercise, you are provided with a sample point layer that represents drill holes used to penetrate the top of a subsurface limestone formation. In this case, exploratory drilling has indicated the presence of oil, and the depths of the drill holes will be used to model the bending of the limestone surface.

In order to visualize what is going on underground, you will use the Inverse Distance Weighted (IDW) interpolation method to create a surface from the sample point layer; first, without using the barrier option, then using the barrier option.

Step 1 Open the map document

If necessary, start ArcMap and load the ArcGIS Spatial Analyst extension. Make the Spatial Analyst toolbar visible.

Open the **Limestone.mxd** map document from your **Lab6data** folder.



Step 1: Open the map document.

When the map opens you see a number of drill holes, as well as two fault lines cutting through a portion of the anticline. These faults are normal faults, meaning that the section of limestone between the fault lines is moving downward.

Step 2 Set the analysis environment

Set the analysis environment as follows:

- Set the Working directory to your **Lab6data\MyData** folder
- Analysis mask: <None>
- Analysis extent: Same as Layer "Lisbon Valley study area"
- Cell size: **50**

Step 3 Create a surface of the limestone formation using the IDW interpolation method

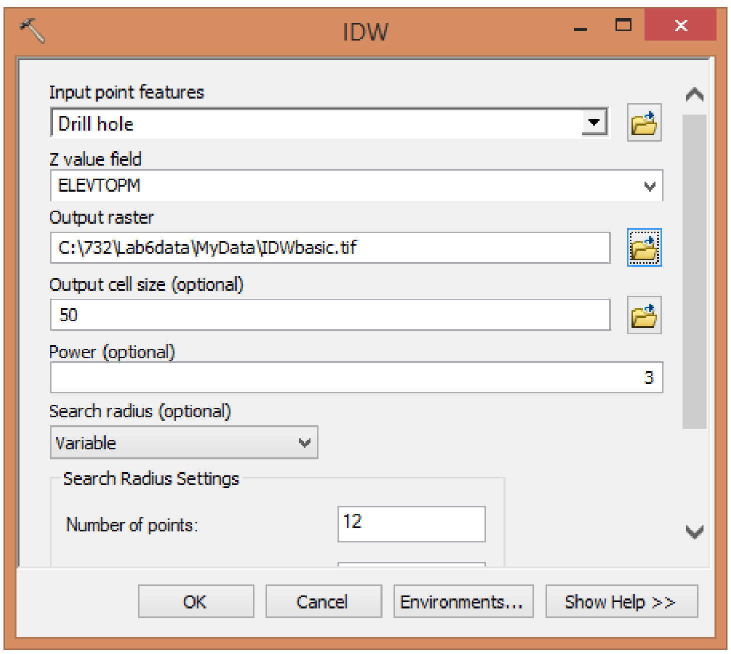
Before creating the IDW surface, turn off the Drill hole and Lisbon Valley study area layers.

From the Spatial Analyst toolbox, choose Interpolation, and click IDW.

Click the Z value field dropdown arrow and click ELEVTOPM.

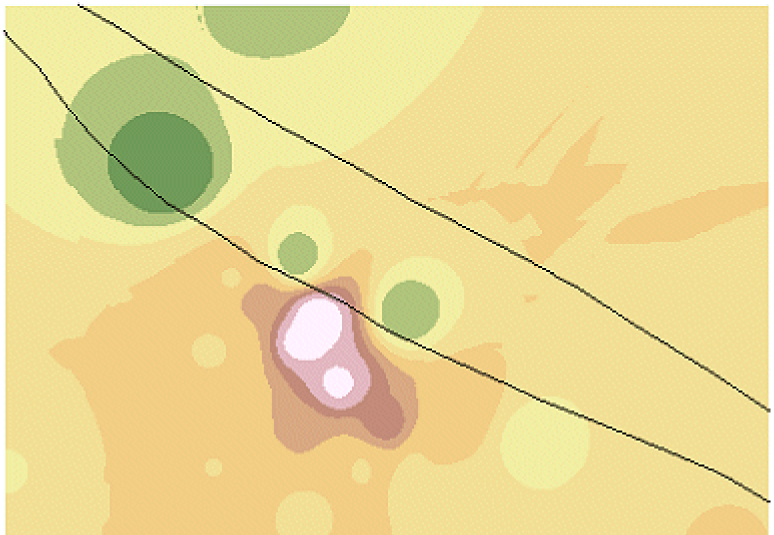
The ELEVTOPM field contains drill hole depth measurements in meters. Because the measurements represent depth (from the top of the drill hole to the top of a subterranean limestone formation), the numbers are negative.

In the Power text box, set the power to **3**.



Step 3a: Create a surface of the limestone formation using the IDW interpolation method.

Click OK.

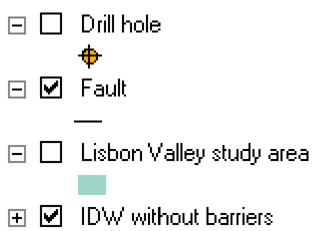


Step 3b: Create a surface of the limestone formation using the IDW interpolation method.

If your map looks different, check whether you still have a mask defined from the previous exercise and if in doubt remove the mask setting in your processing environment specifications.

Collapse the legend for the new IDW layer in the Table of Contents.

Rename the new surface **IDW without barriers**.



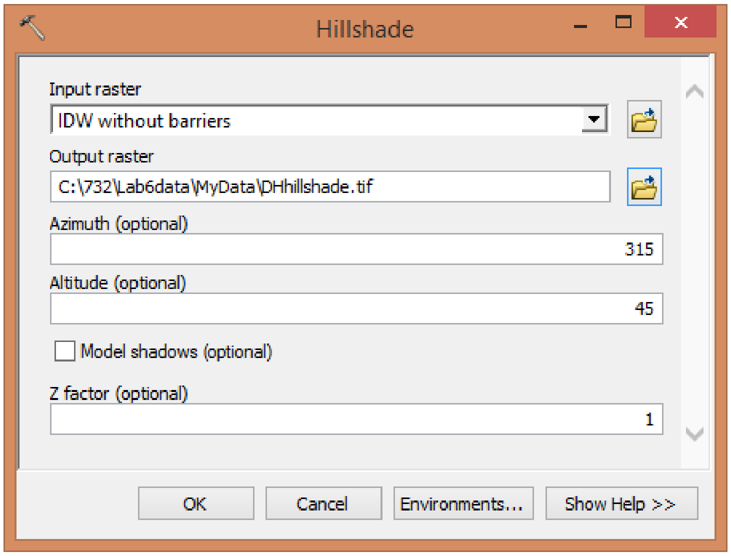
Step 3c: Create a surface of the limestone formation using the IDW interpolation method

Turn off the IDW without barriers layer.

Step 4 **Create a hillshade of the limestone formation**

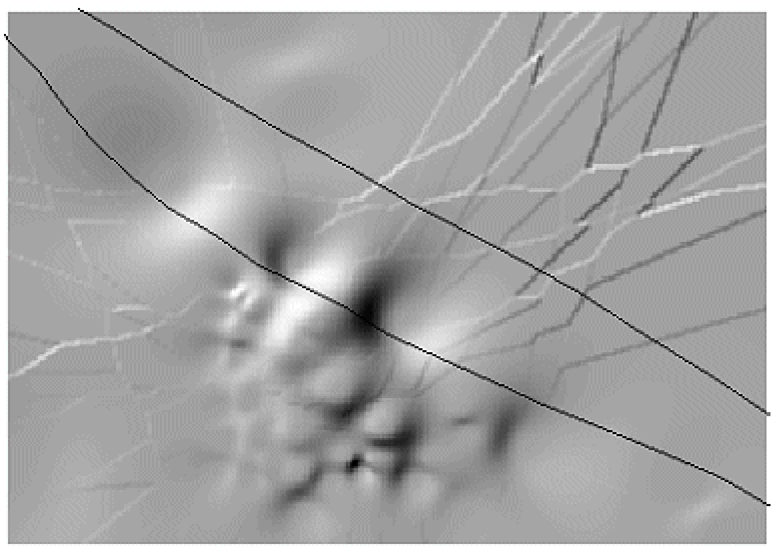
In this step, you will visualize the top surface of the limestone formation by creating a hillshade relief of the IDW without barriers surface. The hillshade will further emphasize the bending of the limestone formation over the oil pocket. You will also notice that there are several sinks and rises in the surface. The bending of the limestone formation helps define the shape of the oil pocket.

From the Spatial Analyst toolbox, choose Surface, then click Hillshade. Make sure the Hillshade dialog matches the View Result graphic below.



Step 4a: Create a hillshade of the limestone formation.

Click OK.



Step 4b: Create a hillshade of the limestone formation.

Collapse the legend for the Hillshade of IDW without barriers layer in the Table of Contents.

Step 5 **Create another surface of the limestone formation using IDW with a barrier**

In this step, you will create another surface representing the limestone formation, but this time you will include two parallel fault lines in the analysis. Deep depressions in the previous surface indicate that the block of limestone between the fault lines is probably lower than the rest of the surface.

This time, the fault lines will serve as barriers that restrict calculations used by IDW. When the fault lines are used as barriers, they restrict the IDW function from using the depth values from drill holes on the other side of the fault. In a sense, they compartmentalize the IDW process. As a result, three compartments are created: the anticline compartment, the block between the fault lines, and the third compartment with only two sample points.

Note: Depending on the processing speed of your computer, using barriers could significantly increase the computational time required to create a surface. The progress meter at the bottom of the ArcMap™ interface will give you an indication of how long the process might take. If you need to exit before the surface creation process is complete, press the Esc key on your keyboard.

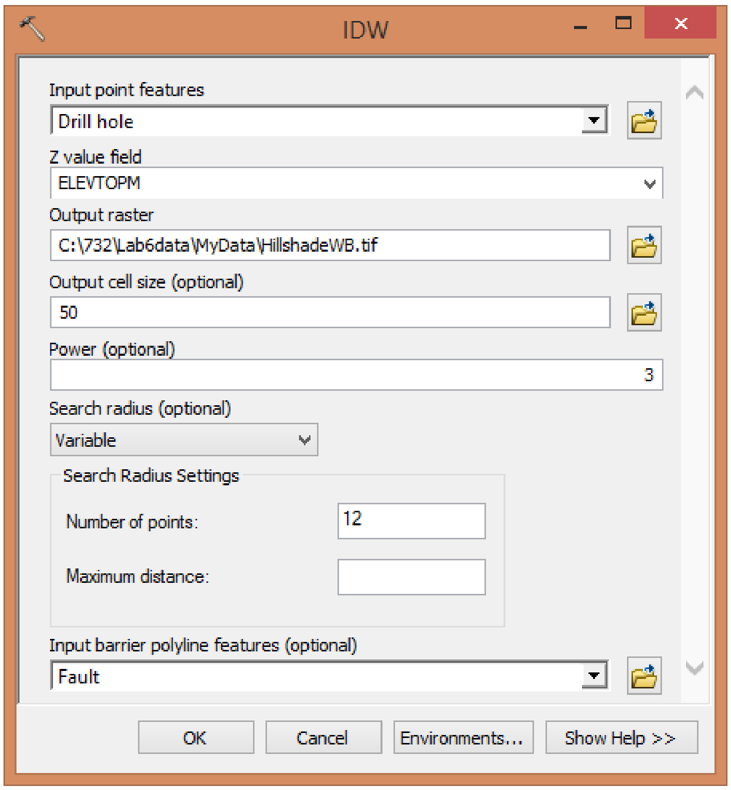
From the Spatial Analyst toolbox, choose Interpolation, then click IDW.

Click the Z value field dropdown arrow and click ELEVTOPM.

In the Power text box, replace the existing number with **3**.

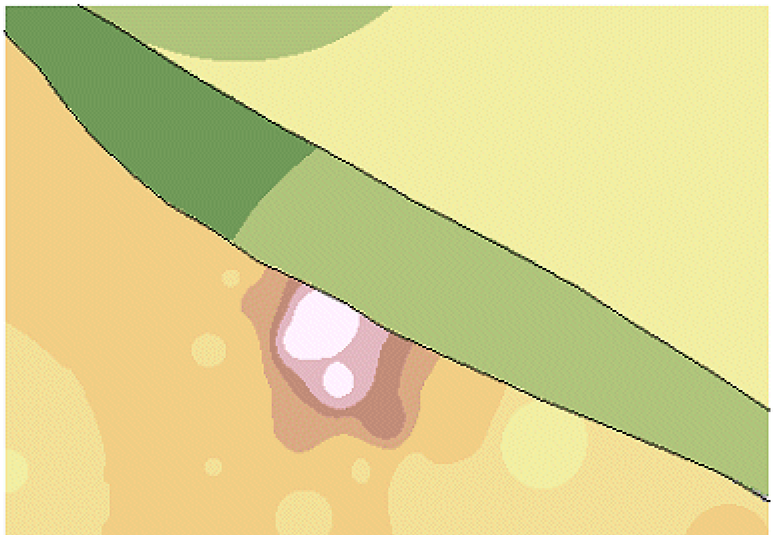
Check the Use barrier polylines box.

The Fault layer is automatically selected because it is the only polylines layer in the Table of Contents.



Step 5a: Create another surface of the limestone formation using IDW with a barrier.

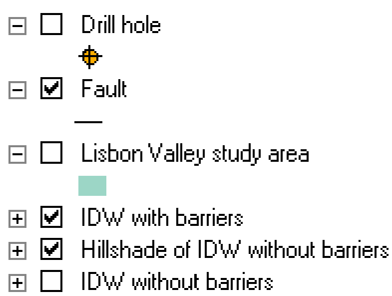
Click OK.



Step 5b: Create another surface of the limestone formation using IDW with a barrier.

Collapse the legend for the new surface in the Table of Contents.

Rename the new IDW of drill holes surface **IDW with barriers**.



Step 5c: Create another surface of the limestone formation using IDW with a barrier.

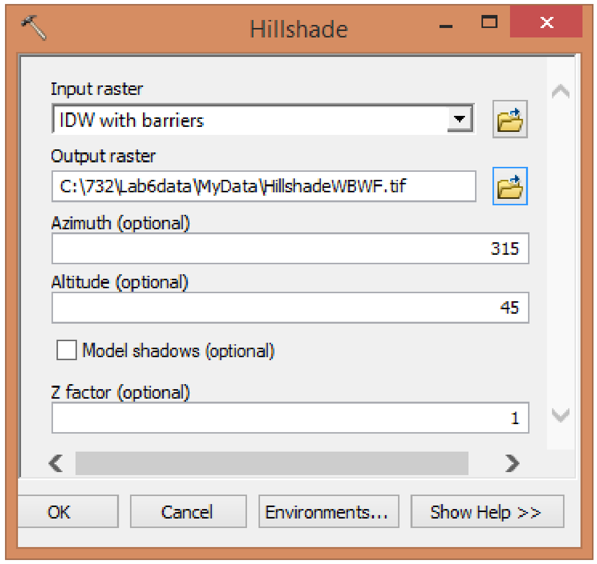
Turn off the IDW with barriers layer.

Step 6 Create a hillshade of the limestone formation with faults

In order to visualize how the limestone formation and the anticline are affected by the parallel faults, you can create a hillshade relief of the IDW with barriers surface. The fault area has cut through a portion of the anticline. As the limestone between the fault lines slipped down, oil may have been forced from the fault area, helping deform the limestone formation further.

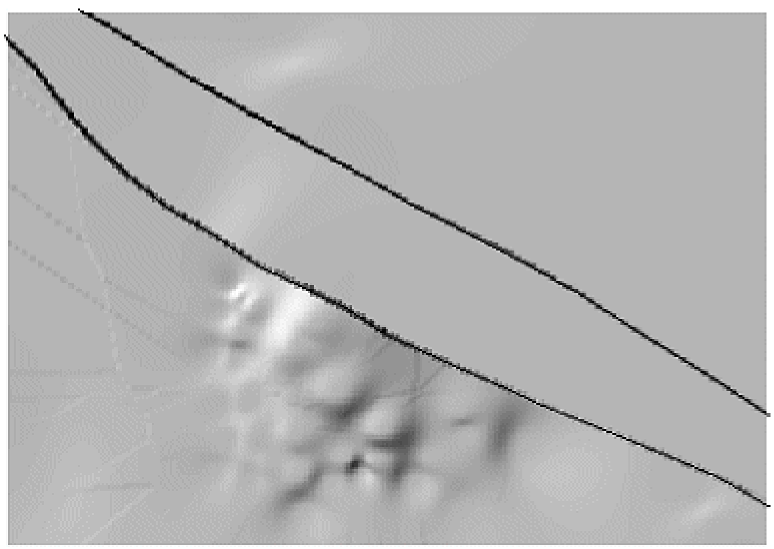
From the Spatial Analyst toolbox, choose Surface, and click Hillshade.

Click the Input surface dropdown arrow, and choose IDW with barriers.



Step 6a: Create a hillshade of the limestone formation with faults.

Click OK.



Step 6b: Create a hillshade of the limestone formation with faults.

Step 7 **Save the map document**

Name the map document **final_Limestone.mxd** and save it in your **Lab6data\MyData** folder.

If you are going on to the next exercise, keep ArcMap open; otherwise, close ArcMap.

Key points

- You may be able to improve the accuracy of an IDW surface by using line layers as barriers. On elevation surfaces, barriers can represent abrupt changes in elevation, such as cliffs.

Exercise 4

Create a terrain surface with Spline

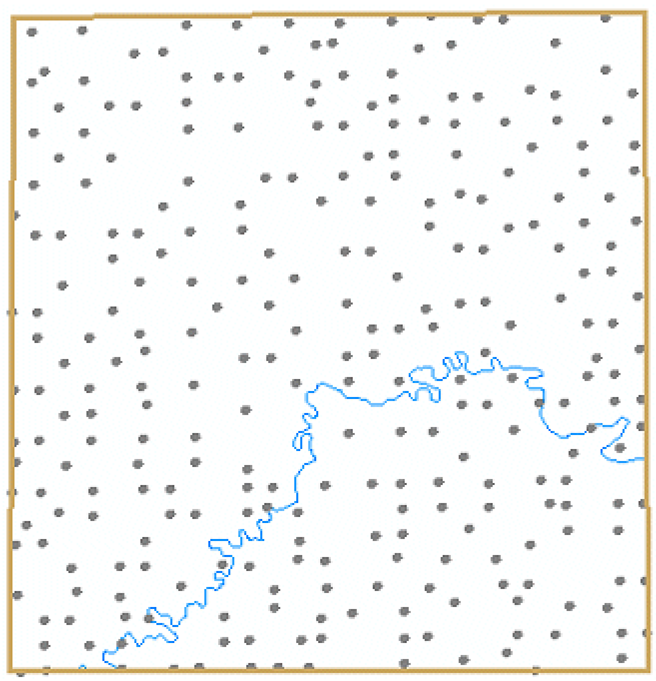
Your goal in this exercise is to create a representative terrain surface from a recently collected sample point dataset. Elevation (in feet) was recorded at each location. A small portion of the Tallgrass Prairie National Preserve in the Flint Hills region of Kansas has been designated the special study area.

The point locations are not very close together, given the size of the study area. The topography for this site is mostly rolling hills and does not include any cliffs or other abrupt changes in elevations; however, every hilltop and every ravine bottom was not surveyed. The elevation for those areas will need to be estimated.

Given these factors, you will use the Spline interpolation method to create surfaces from the sample points.

Step 1 Open the map document

Start ArcMap and open the **Tallgrass.mxd** map document from your **Lab6data** folder.



Step 1: Open the map document.

The map document contains three layers: Study area, Sample points for Tallgrass, and Cottonwood River.

The Sample points for Tallgrass layer represents ground locations at specific elevations.

Turn the Sample points for Tallgrass layer off.

If necessary, load the ArcGIS Spatial Analyst extension and make the Spatial Analyst toolbar visible.

Step 2 Set the analysis environment

Set the analysis environment as follows:

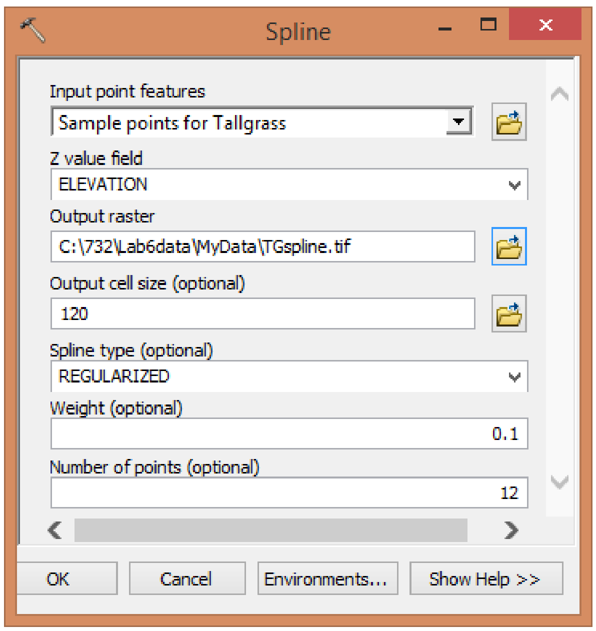
- Set the Working directory to your **Lab6data\MyData** folder
- Analysis mask: <None>
- Analysis extent: Same as Layer "Sample points for Tallgrass"
- Analysis cell size: **120**

Step 3 **Run Spline using default settings**

Spline interpolation can estimate values that are below the minimum or above the maximum values found in the sample data. This makes the Spline interpolation method good for estimating lows and highs where they are not included in the sample data.

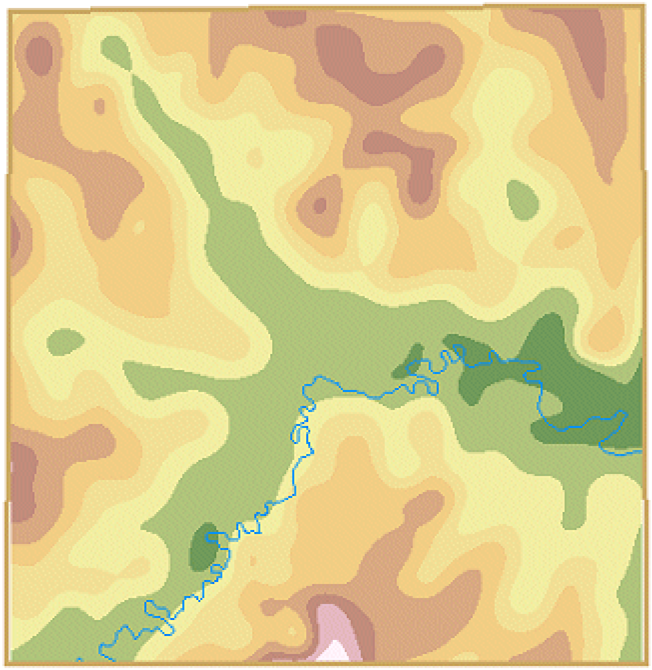
While this surface does pass through all the sample points, estimates of cell values are influenced more by the direction of change inherent in the data. This means that the estimation of values in adjacent cells is less abrupt, resulting in a surface that appears more continuous and smooth.

From the Spatial Analyst toolbox, choose Interpolation, then click Spline.



Step 3a: Run Spline using default settings.

Accept the default settings and click OK.



Step 3b: Run Spline using default settings.

Collapse the legend for the new surface in the Table of Contents.

Rename the new Spline of Sample points for Tallgrass surface **SPLINE Regular 0.1**.

Step 4 **Increase the weight setting and run Spline again**

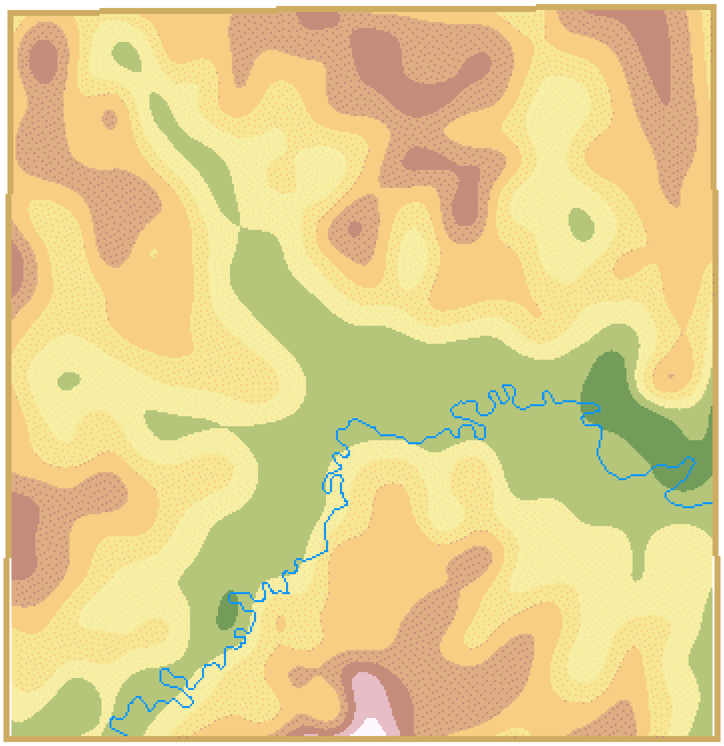
Based on field observations, you might recall that the changes in elevation are more distinct. Increasing the weight setting of the Spline interpolator will cause more dramatic bending of the surface between the sample points.

The difference between this surface and the previous surface is subtle, but a regularized spline with a higher weight should appear smoother than one with a lower weight.

From the Spatial Analyst menu, choose Interpolate to raster, then click Spline.

This time, click in the Weight text box and set it to **1**.

Click OK.



Step 4: Increase the weight setting and run Spline again.

Collapse the legend for the new surface in the Table of Contents.

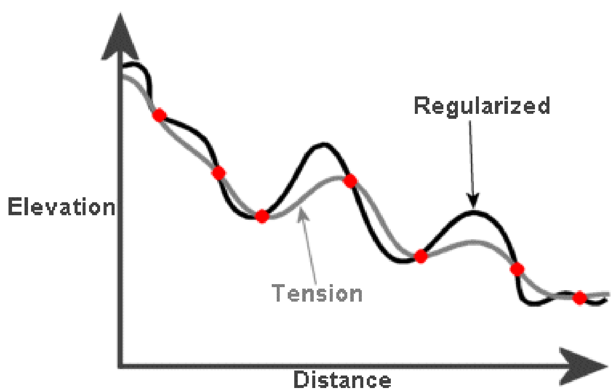
Rename the new Spline of Sample points for Tallgrass surface **SPLINE Regular 1**.

Step 5 **Run Spline again with tension settings**

Regularized Spline interpolation may estimate values that depart too much from the sample data. Running a tension spline will flatten out the surface bending effect (very slightly) around the sample points.

What is the difference between regularized and tension splines?

Perhaps the best way to illustrate the differences between regularized and tension is to examine the following graph.

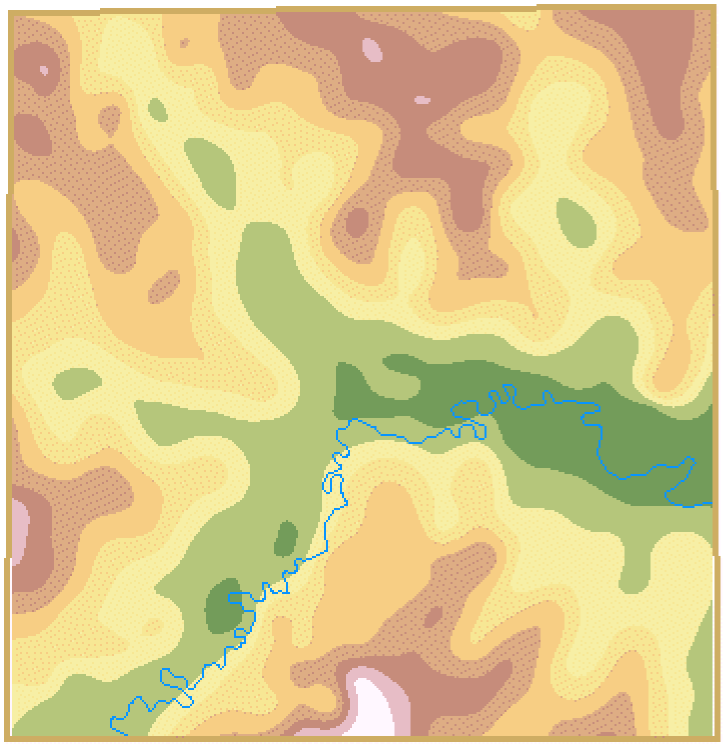


Notice that the tension curve is flatter than the regularized curve. The estimates are forced to stay closer to the sample data. You might say that the Tension Spline method produces a surface more rigid in character, while the Regularized Spline method creates one more elastic in character.

From the Spatial Analyst toolbox, choose Interpolation, then click Spline.

Click the Spline type dropdown arrow and choose Tension.

Click OK.



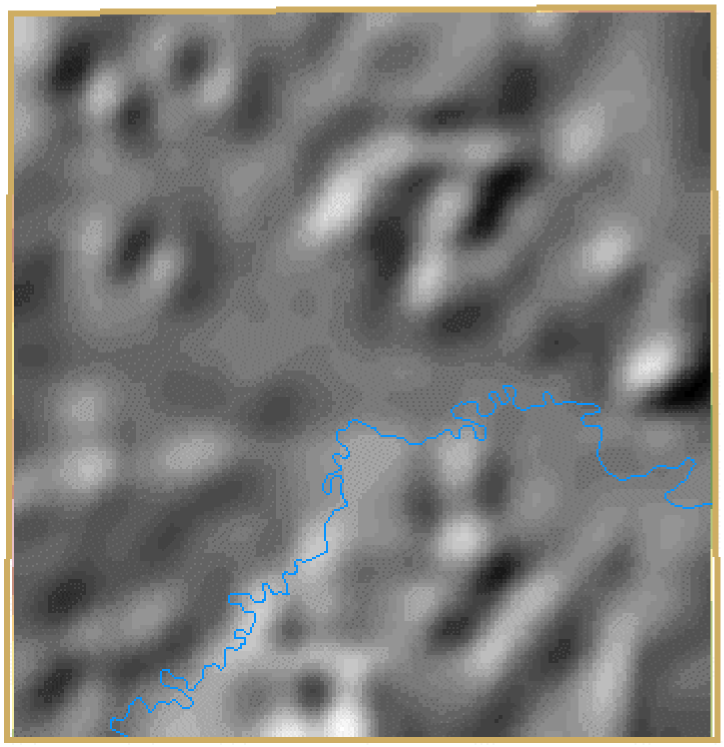
Step 5: Run Spline again with tension settings.

Collapse the legend for the new surface in the Table of Contents.

Rename the new surface **SPLINE Tension 0.1**.

Step 6 **Create hillshade relief surfaces for each of the Spline surfaces**

Create a hillshade relief surface from the SPLINE Regular 0.1 layer.

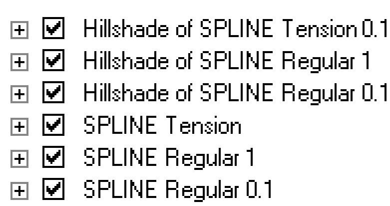


Step 6a: Create hillshade relief surfaces for each of the Spline surfaces.

Next, create hillshade relief surfaces from the SPLINE Regular 1 and SPLINE Tension 0.1 layers.

Note: If any of your resulting hillshade layers are symbolized with unique values, change their symbolization to stretched black and white. To do this, open the layer's properties dialog and click the Symbology tab. For Show, change Unique to Stretched. Make sure the shade ramp is black to white, then, in the Stretch pane, change Type to Minimum - Maximum.

In the Table of Contents, collapse the legends of all the hillshade layers.



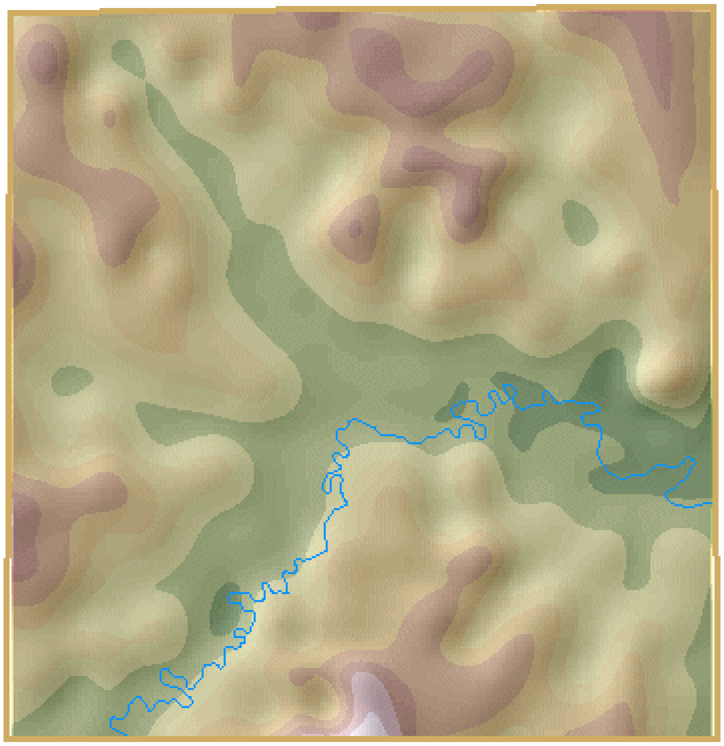
Step 6b: Create hillshade relief surfaces for each of the Spline surfaces.

Step 7 Group the layers and set transparency

Group the SPLINE Regular 0.1 and the Hillshade of SPLINE Regular 0.1 layers.

Name the new group layer **SPLINE default**.

Set transparency for the SPLINE Regular 0.1 layer to **45** percent and stack the layers in the group so that the hillshade is at the bottom.

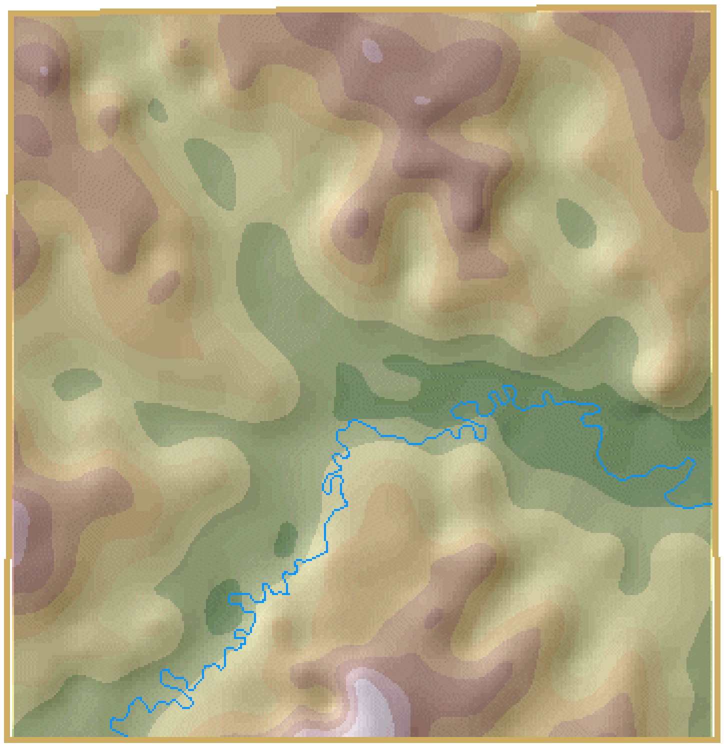


Step 7a: Group the layers and set transparency.

Group the SPLINE Regular 1 and Hillshade of SPLINE Regular 1 layers. Name the new group layer **SPLINE Bend**. Make sure to move the hillshade layer to the bottom of the layer list and set the transparency for the SPLINE Regular 1 layer to **45** percent.

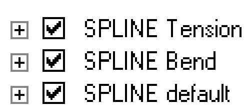
Step 7b: Group the layers and set transparency.

Group the SPLINE Tension 0.1 and Hillshade of SPLINE Tension 0.1 layers. Name the new group layer **SPLINE Tension**. Move the hillshade layer to the bottom of the layer list and set the transparency for the SPLINE Tension 0.1 layer to **45** percent.



Step 7c: Group the layers and set transparency.

In the Table of Contents, collapse the group layers.



Step 7d: Group the layers and set transparency.

Step 8 Compare the splined surfaces

The differences between the splined surfaces are not remarkable, but subtle differences might make a difference for your project. Compare the differences.

Turn off all layers except Tallgrass study area and SPLINE default.

Turn on the SPLINE Bend layer.

Turn on the SPLINE Tension layer.

Step 9 Save the map document

Name the map document **final_Tallgrass.mxd** and save it in your **Lab6data\MyData** folder.

Close ArcMap.

Key points

- An advantage of the Spline interpolator is that it can make estimates outside the range of input sample points.
- There are two types of Spline interpolators. The regularized spline creates a more elastic surface. The tension spline creates a less flexible surface.

Summary

When you measure elevation, the depth of a well, or the level of noise, you make that measurement at a precise location. A point layer can represent a set of measurements. The location of the points and the point values form the basis for interpolation. Interpolation is a method of estimating unknown values based on known values.

There are different methods of interpolation. Choosing an interpolation method is influenced by your knowledge of the surface you are modeling. Each method works differently, but most utilize the concept of spatial autocorrelation; near things are more alike than things far away.

IDW interprets spatial autocorrelation in a literal fashion. A surface created with IDW will not exceed the known value range or pass through any of the sample points. IDW is a good interpolator for phenomena whose distribution is strongly correlated with distance, such as noise. In some cases, the accuracy of an IDW surface can be improved by using line layers as barriers.

The Spline interpolation method incorporates a curvilinear model as part of the calculation. A surface created with Spline can exceed the known value range, but must pass through all of the sample points.

Kriging is one of the most complex interpolators. It measures the relationships between all of the sample points and then predicts the cell value. A surface created with Kriging can exceed the known value range, but does not pass through any of the sample points.

When using any of the interpolation methods, you should thoroughly understand your data and the phenomenon being modeled.