

## Kriging Artifact Density Surfaces in ArcGIS

### 1. The ingredients.

- A data file -- in .dbf or .csv format -- containing the counts of different artifact types in each quadrat and the northing and easting coordinates of the quadrat centroids.
- A set of vector files -- dxf extensions, in our case -- containing the outlines of structures and other feature on the site.

### 2. Bring the data into ArcMap.

- Open ArcMap.  AddData. Navigate to the .dbf with the numeric data:
- Repeat for the .dxf's.

### 3. Create a shape file for the limits of excavation.

- Now we create a shape file that will contain the limits of excavation. Get into Arc

Toolbox . Right Click on the Folder in which you want to store the shapefile.

- New > Shapefile > Polygon. Name it something sensible -- try "Limits\_of\_Excavation" -- *no quotes or spaces.*

- Now import the shapefile into ArcMap using Add Data. To add the limits of excavation to the empty shape file of the same name, proceed as follows:

- Right click anywhere on the tool bar. Make sure Editor is selected (checked).

- Editor > Start Editing
- Task > Create New Feature
- Target should be .... Limits\_of\_Excavation
- Click on the Pencil tool.
- Draw the polygon -- double click on the last point.
- Go back to Editor > Save Edits. Editor > Stop Editing -- **NEVER hit Stop Editing before you Save Changes.**

Ta... Da...!

### 4. Adding Quadrat Centroids

- First we need to add the center point of each excavation unit or quadrat. This information is contained in the data table (along with the artifact counts).

- Right click on the data table and select the Display XY Data option.
- In the "X Field" drop down box, select the Easting coordinate. In the "Y Field" drop down box, select the Northing coordinate. Hit the OK button.
- The data will be displayed as a new layer is added to your map (named "... Events" and added to the top of the layers list. You may click on the symbol to change its shape, size and color.

## 5. Kriging

- Now it is time to generate artifact distribution maps. We will be using Kriging. Recall that this is weighted average method, where the weights are estimated to that they minimize the sum of squared prediction errors. The weights are constructed using information on the character of spatial autocorrelation in the known data points. This information is summarized in the variogram. So a first step to kriging is to estimate the variogram for the data in question.
- We will use ArcGIS's *Geostatistical Wizard* to do this (you can also krig in Spatial Analyst and 3D Analyst. The implementations look simpler and more user friendly -- because you don't have to look at variograms -- but harder to use intelligently -- for the same reason.
- Make sure Geostatistical Analyst is active: Tools > Extensions > Geostatistical Analyst . and that its toolbar is visible, View > Toolbars .
- Choose Geostatistical Wizard from the Geostatistical Analyst menu.
- Specify the Input Dataset and the Attribute (variable) you want to interpolate (e.g. RedPipes . Under Methods, choose Kriging . Click Next .
- Choose Ordinary Kriging , Prediction Map, without transformations or trend removal. Click Next
- Now we can check out the semivariogram (or variogram for short) and its cousin, a graph of autocovariance. Check out the semivariogram cloud plot. Under Models, stick with the default: Spherical . This is a particular kind of mathematical function that is being fit to semivariogram cloud -- it is graphed in yellow on the semivariogram panel. When there is positive spatial autocorrelation, the yellow line should slope up. Note the Major Range . This is an estimate, based on the Spherical Model, of the distance over which there is positive spatial autocorrelation -- the point at which the yellow line is flat.
- Check out the other parameters: Nugget and Partial Sill. (the partial sill is the difference between the nugget and the sill.
- You can also choose Lag Size and Number of Lags . Take a minute to experiment with Lag Size and Number of Lags .
- Click Next .
- Now we look at the search neighborhood. This offers information on what data points are going to be considered in doing the interpolating a value at the given spot.
- Note the choice of two Preview Types: Surface and Neighbors .
- Take some time to play with the Shape Type and Neighbors to Include parameters -- can you see what is happening here? The default value will work well. Check out their effects on the Surface and Neighbors previews.

-Click Next .

-The next window gives you some indication of how good a job kriging is going to do. It does this by dropping each known point from the data set, then estimating its value by kriging from the remaining known data points. This is called *cross-validation*.

-Click Finish. You get a summary of the model. Check out all you hard work!

-Complete the process by clicking on OK in the last dialog. Note that the resulting interpolated surface covers a bounding rectangle around the sample points. Rearrange the layers so that you can see the quadrat centroids and features on top of the predicted surface.

## 6. Better Display

There are several ways you can make the display more sensible.

-You can change the extent of the rectangle containing the predicted surface. In the Ordinary Kriging layer (i.e., the one containing the predicted surface), right click and select Properties; select the Extent tab. Check out the options in the Set the extent to drop down list. Choose Limits of Excavation

-You can also change the color ramp and contour intervals of the display. In the Ordinary Kriging layer right click and select Properties; select the Symbology tab. Right click Filled Contours

-The interpolated surface can be portrayed in a number of different ways. This is set in the Symbology Property of the layer. The default is Filled Contours, but you can also choose Hillshade, Contours, or Grid.

- right click on the Ordinary Kriging layer and select Properties
- select the Symbology tab
- uncheck Filled Contours and check Contours instead; click OK to see the effect
- experiment with the other types of symbology for the predicted surface

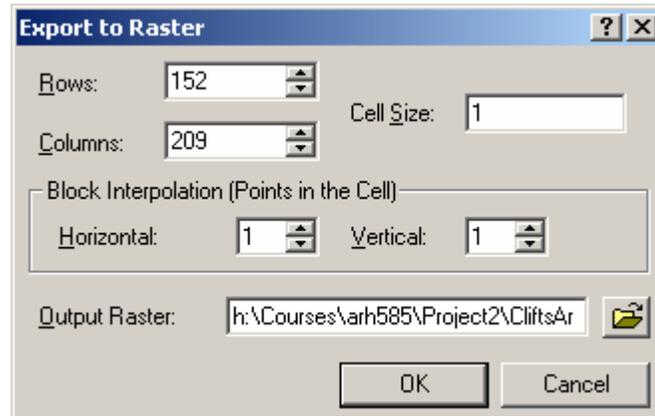
-To limit the interpolated surface map to the area with the Limits of Excavation, you need to change the Properties of the Layers:

- Right click on Layers, select Properties and click on the Data Frame tab.
- In the Data Frame Properties dialog, find the Clip to Shape item and check the Enable box. Choose the LimitsofExcavation layer as the shape to use to clip with Click OK.

## 7. Saving your kriged surface to a raster file

The predicted surface can be turned into a permanent feature class or shape file by means of the Data Export function. This will allow you to then use the predicted surface in other analyses. For example, once you have several surfaces, you will probably want to do things like compute the percentage of Red Clay Pipes. If you have exported grid surfaces (or rasters), you can do these kinds of analyses using the ArcGIS Spatial Analyst Extension Raster Calculator:

-Select the kriging layer. Right click, choose Data > Export to Raster. In the Export to Raster dialog box, note the Output Raster field. You can change this to something more sensible than the default, which will be something like ga\_gridN. **Make sure you know what directory the raster file will be saved in – you can change this in the dialog box.** You can change the cell size of the output raster – I used 1. This yields one interpolated value every 1 foot, when the x and y coordinates are given in feet.



-When ArcMap asks if you want to add the raster to the new map, click Yes .

-The new raster will appear as a black and white continuous tone rendering. UUUUUGLY! We will fix it later.

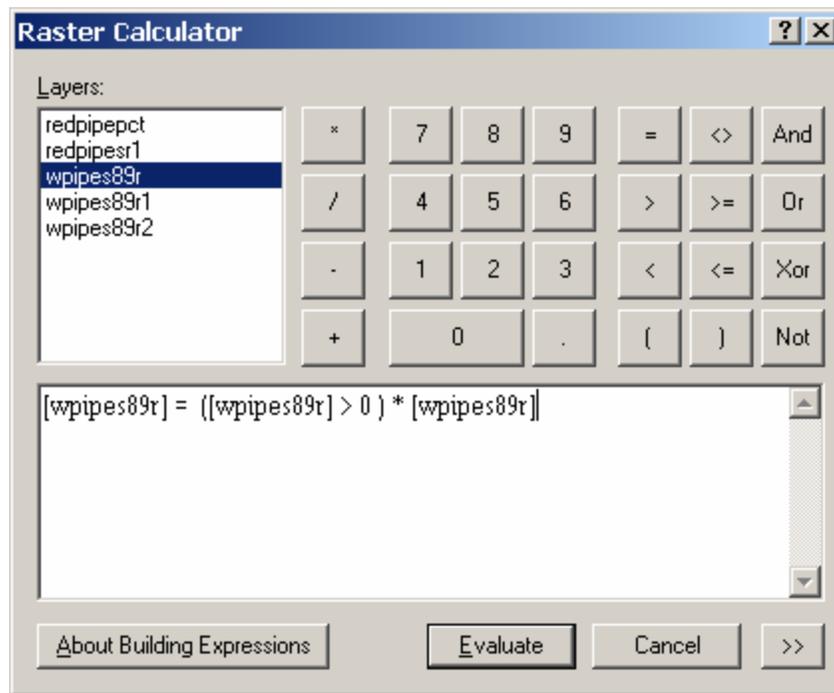
## 8. Use the Raster Calculator to clean up interpolation errors

Check out the numeric scale to the raster -- it probably has negative values, which is a problem, since it's hard to have negative artifact counts. So we need to change the negative interpolated values to 0's. To do this, we use the Raster Calculator

The Raster Calculator implements the notion of "Map Algebra" -- which allows you to create new raster surfaces as algebraic combinations of other raster surfaces. This is very cool and potentially quite powerful. Raster Calculator is part of the Spatial Analyst module. Make sure that the Spatial Analyst menu button is available. If not, choose Tools > Extensions and check Spatial Analyst .

***Once you see the Spatial Analyst menu, choose Options. On the General tab, make sure the working directory is the directory that contains your files.***

The Raster Calculator dialog box is shown below:



The Layers window lists the rasters that you have created. The box below it contains a map algebra formula -- note how the rasters are used as terms in the equation. The formula here uses on one raster: [wpipes89r]. The first term on the right ([wpipes89r] > 0) is a logical formula. It tells Raster Calculator to look at every cell in the input raster and check if the condition is true (the cell value is > 0). When it is, the corresponding cell in the output raster is a 1, 0 otherwise. Multiplying this logical (1/0) raster by the original raster leaves values greater than 0 unchanged, and put 0's in cells that are less than or equal to 0. Finally this result is assigned (saved) to a raster called [wpipes89r2] -- Spatial Analyst will add the "2" automatically.

**Warning:** The Raster Calculator is VERY particular about how you write formulas. Make sure you have a space on each side of any operator, e.g. :

$$[wpipes89r] = ([wpipes89r] > 0) * [wpipes89r]$$

## 9. Making the raster look good.

Now that we have gotten rid of the whacky negative values, we want to make the raster look good.

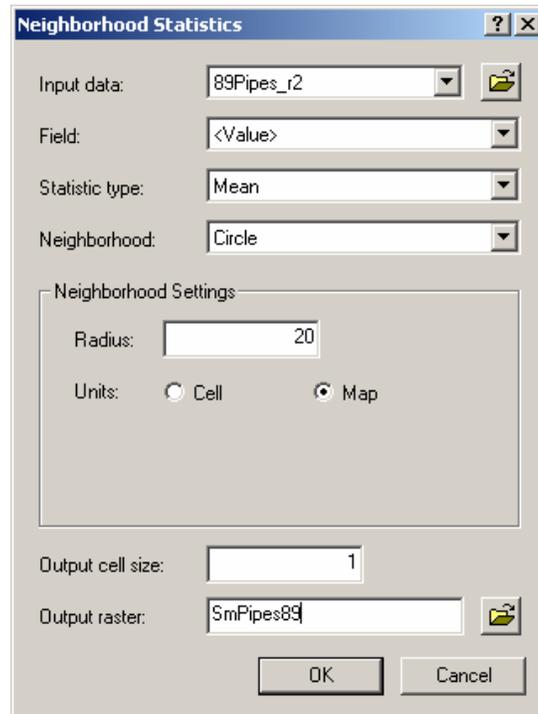
- Select the raster in the Display panel, right click, choose Properties > Symbology. In the Symbology panel, change the display (under Show:) from Stretched to Classified.

- Change the number Classes to 10 (the default is 5, which is too few). Click the Classify button. Check out the options. Which do you think works best? Why? Quantiles works well -- it places the class boundaries at artifact counts so that equal numbers of quadrats fall into each of chosen number of classes. Why might this be cool?

## 10. Use the neighborhood filters to smooth maps and highlight trends.

Does your map look a little bumpy? You can smooth away some of the noise -- to highlight the underlying trend.

-Click the Spatial Analyst Button and choose Neighborhood Statistics



-Fill in the blanks, making sure that Statistic Type: Mean and Neighborhood: Circle. Specify the Radius of the circle in Map units (in this case feet). I used 20. Finally, name the Output raster. Click OK and ArcMap will replace each cell value in the raster with the average of all the values at cells within 20 feet.

## 11. Compute maps of artifact proportions from several smoothed rasters.

Now that you have your smoothed maps, let's say you want to compute a map of the proportion of red-clay pipes in each square (relative to white ones of the same date). The Raster Calculator lets you do it. Here's the formula I used:

$$[SMpropred] = [SMredpipes] / ([SMpipes89] + [SMredpipes])$$

Once you compute this, you will want to make it look good, using the tricks in section 9 above.