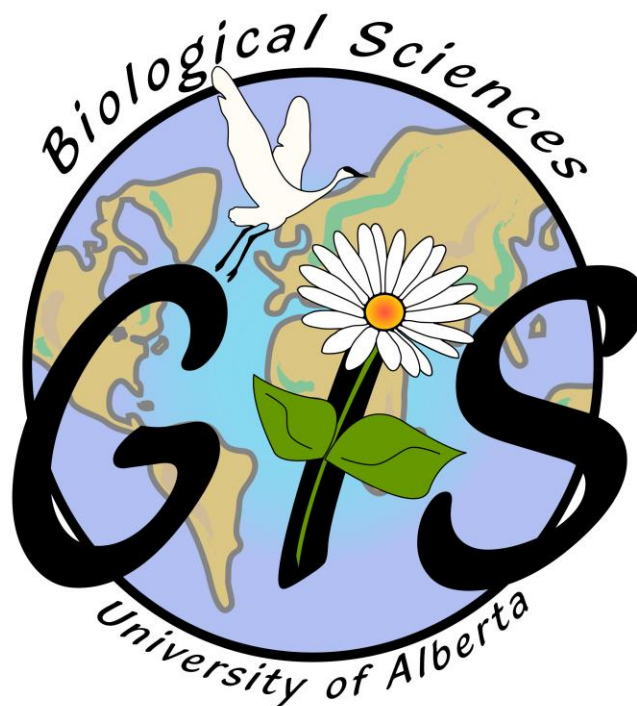


GIS IN ECOLOGY: MORE RASTER ANALYSES



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This is an applied course on how to use the GIS software. It is a continuation of the short course on “Analyzing Raster Data” and involves more functionality of the ***Spatial Analyst*** extension of ***ArcMap***.

References:

McCoy, Jill and Kevin Johnston. 2000. “Using ArcGIS Spatial Analyst.” Environmental Systems Research Institute, Inc. Redlands, CA. 230 pp.

GIS IN ECOLOGY: MORE RASTER ANALYSES

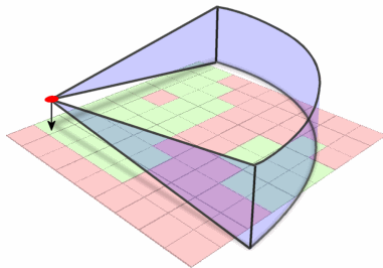
Introduction

In this short course you'll learn more of the functionality in ESRI's ArcGIS software. You may recall that Spatial Analyst tools work on local functions (single cells), focal functions (cells within a neighborhood), zonal functions (cells within zones), global functions (all cells within the raster), and application functions (combined layers of cells to perform a specific application). You'll focus on various application functions, such as viewshed, hydrology modeling, interpolation, and (least) cost path. *Consult the ArcGIS Desktop Help for more thorough information.*

More Raster Application Functions

The following is a brief summary on the application functions you will perform:

Viewshed



Viewshed identifies the observation points that can be seen from each cell in the input raster. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If you have only one observer point, each cell that can see that observer point is given a value of 1. All cells that cannot see the observer point are given a value of 0. Parameters can be set in the attribute table to control the field of view, the height of the observer and target cells, and the view radius.

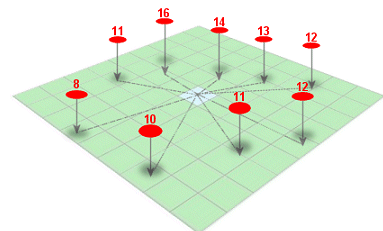
Hydrology Modeling

Some of the hydrology modeling methods includes flow directions, flow accumulation, creating watersheds and stream networks. Filling sinks creates a *depressionless* DEM and is often a prerequisite for the other tools to function properly.

Interpolation

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for most geographic point data: elevation, rainfall, chemical concentrations, noise levels, and so on. There are several ways to create raster surfaces from point data. The interpolation methods in Spatial Analyst are:

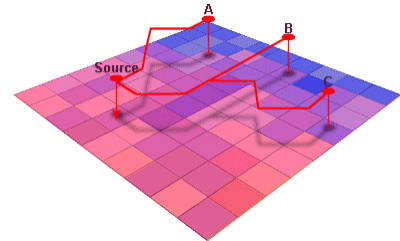
- Inverse Distance Weighted
- Spline
- Kriging



Each interpolation method makes assumptions about how to determine the estimated values. Depending on the phenomenon you are modeling and the distribution of sample points, different interpolators produce better models of the actual surface. Regardless of the interpolator, *the more input points and the more even their distribution, the more reliable the results.*

Cost Path

Also called the Shortest Path and Least Cost Path analysis, the Cost Path function determines the path from a source point to destination(s). Once you have performed the Cost Weighted Distance function, creating distance and direction rasters, you can then compute the least-cost (or shortest) path from chosen destination(s) to your source point.



Data Sources

The data used in this short course are for NTS map sheet 083C (Brazeau), have a scale of 1:250,000, a projection/datum of UTM NAD83 Zone 11, and map units in meters. Source: NRCan and CanSIS (NTDB, CLI, and CDED) digital data from GeoGratis <http://geogratias.cgdi.gc.ca> and GeoBase <http://www.geobase.ca>. The following table provides further metadata for each geographic layer in the course dataset in the [\\bio_print\Courses\GIS-100\4_MRA](#) folder:

Name	Description	Feature	Data Model
locations.dbf	sampling locations (for interpolation)	Point	Table
ivers	streams and rivers	Line	Vector
roads	roads	Line	Vector
crossing	locations of animal road crossings	Point	Vector
destination	end point telemetry location (for cost path)	Point	Vector
source	starting point telemetry location (for cost path)	Point	Vector
boundary	boundary of study area	Polygon	Vector
habitat	forest/ungulate habitat	Polygon	Vector
dem	digital elevation model – 30 m cell size	Raster Grid	Raster

Tasks

Viewshed, hydrology modeling, interpolation, and least accumulated cost path.

Raster Recap

Starting the map document

1. Copy the “4_MRA” folder from [\\bio_print\Courses\GIS-100](#) to **C:\WorkSpace**
2. Start ArcMap by choosing **START >>> PROGRAMS >>> ARCMAP**
3. Start using ArcMap with a new empty map
Enable the Spatial Analyst extension and show the toolbar.
4. Choose **TOOLS >>> EXTENSIONS** and click in the check box beside **Spatial Analyst** to enable the extension and click **CLOSE**
5. Choose **TOOLS >>> CUSTOMIZE** and make sure there is a check beside the **Spatial Analyst** toolbar and click **CLOSE**
6. Click and drag the toolbar so it is positioned where you want
7. Add **ALL** the data from the **\4_MRA\Brazeau.gdb**
8. Symbolize each layer appropriately

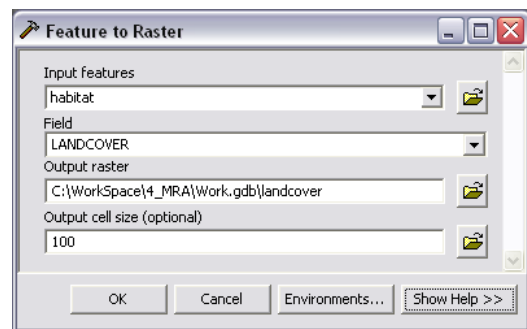
Setting the spatial analysis options

You need to specify the working directory, extent, and cell size defaults you wish to use for your spatial analyses to control the area of analysis and output.

9. CREATE FILE GDB named \4_MRA\Work.gdb
10. SHOW ArcToolbox and right-click its name to choose ENVIRONMENTS
11. Under the GENERAL settings:
 - Set the Working directory to **Work.gdb**
 - Set the Extent “**Same as layer dem**”
 - Set the Snap Raster to “**dem**”
12. Under the RASTER settings:
 - Set the CELL SIZE “**Same as layer dem**”
13. Click OK

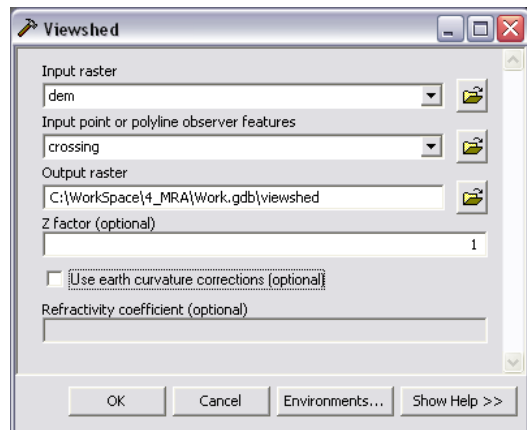
Converting features to raster

14. In ArcToolbox, choose CONVERSION TOOLS >>> TO RASTER >>> FEATURES TO RASTER
15. Select the following:
 - Input features: **habitat**
 - Field: “**LANDCOVER**”
 - Output cell size: **100**
 - Output raster: **landcover**
16. Click OK
17. REPEAT the conversion on habitat using the “**WINTER**” field and save as **winter**
18. SAVE the map document (e.g. \4_MRA\Brazeau_yyyymmdd.mxd) with *relative paths*



Viewshed – Determining Visibility

The viewshed function works with point data (or nodes associated with line coverages) and allows you to identify the cells in an input raster that can “see” an observation point or a number of points. In this example, you wish to determine the cells in the landscape that are visible from the locations of observed wildlife crossings. By determining the area of visibility you can get an estimate of landcover seen by the large mammals that utilize the area. The available data are a DEM, landcover, and crossing points. The following instructions show how to apply viewshed and then intersect with landcover to answer the question: **How much forest is visible from the road crossings?**

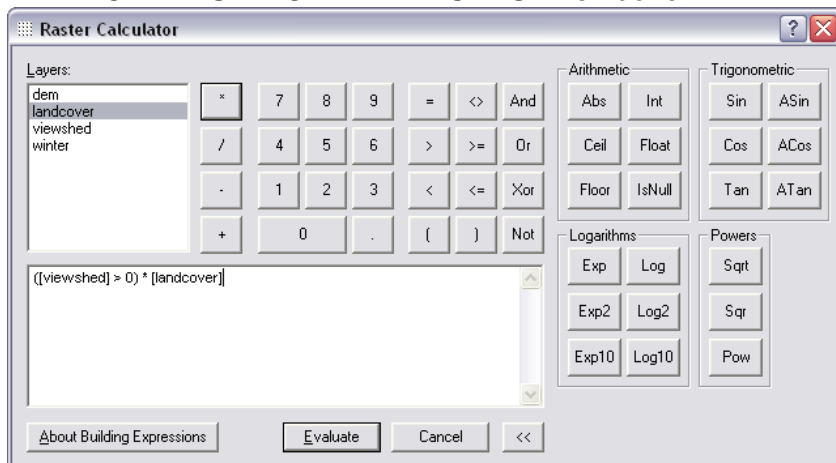


1. In ArcToolbox, choose SPATIAL ANALYST TOOLS >>> SURFACE >>> VIEWSHED
2. Specify the following:
 - Input raster: **dem**
 - Input observer features: **crossing**
 - Output raster: **viewshed**
3. Click OK

The new layer classifies the output raster as *Visible* (all values 1 or greater) or *Not Visible* (cells with a value of zero). You may add specially named fields to the attribute table of the observation layer to set a number of visibility parameters. For example, a distance of 2000 may be added to the “RADIUS2” field to limit the areas outside a 2 km search distance.

Optional viewshed parameters	Defines	Default Value
SPOT	an absolute height for the observer (for example 3,000 meters for an airplane)	Bilinear interpolation estimated elevation
OFFSETA	adds an offset height to the observation point	1
OFFSETB	adds an offset height to all non-observer cells when they are being analyzed for visibility	0
AZIMUTH1 and AZIMUTH2	set the beginning and ending horizontal angles (in degrees from 0 to 360, with 0 being due north) to limit the analysis, which proceeds clockwise from AZIMUTH1 to AZIMUTH2	0 and 360 (entire input raster)
VERT1 and VERT2	set the angles above and below the horizon to limit the visibility; positive angles are above the horizon and negative values are below it	90 for VERT1 -90 for VERT2.
RADIUS1	limits the visible distance outside the search distance from each observation point	1
RADIUS2	limits the visible distance inside the search distance from each observation point	Infinity

4. In the table of contents, right click on **crossing**
5. Choose OPEN ATTRIBUTE TABLE
6. Click OPTIONS >>> ADD FIELD
7. Add a field called **RADIUS2**
8. Keep defaults for **Short Integer** data type and click OK
9. Right click on the “**RADIUS2**” heading
10. Choose CALCULATE VALUES...
11. Enter “**2000**” and click OK
12. REPEAT the Viewshed calculation at *step 2* above but save as **viewshed2**
13. CHALLENGE: Use the SELECT FEATURES tool to highlight a section of the roads layer and run the VIEWSHED tool using the roads as the observer, save as **viewshedr** (*don't do all roads during the short course because this takes a loooong time to process*)
14. CLEAR SELECTED FEATURES when done



Now to calculate the amount of secure habitat available, you must intersect the areas that are visible with the landcover raster. Visible cells that contain forest will have more hiding cover available than other land cover classes.

15. Choose SPATIAL ANALYST (toolbar) >>> RASTER CALCULATOR

16. Enter the expression: (**[viewshed]** > 0) * **[landcover]**
17. Click OK
18. Right click the Calculation and choose DATA >>> MAKE PERMANENT
19. Save to and change the layer name to Work.gdb\landview
20. OPEN ATTRIBUTE TABLE to examine it

Because the cell size is 100 m, each cell has an area of 1 hectare (10,000 square meters); therefore, the “COUNT” field indicates the total area of each landcover class in ha. Cells in the viewshed having the value for Forest (1) will probably provide more secure habitat than open classes. NOTE: The Raster Calculator is a handy alternative to the Map Algebra tools located in ArcToolbox.

Hydrology Modeling – Creating Watersheds from a DEM

These instructions enable you to create watersheds of specified area using a (hopefully, a good quality) Digital Elevation Model (DEM). In this example, you wish to delineate topographic boundaries based on drainage basins that drain to the crossing point features (these points are actually where roads and rivers intersect).

1. Turn off all layers except **dem** and **boundary**

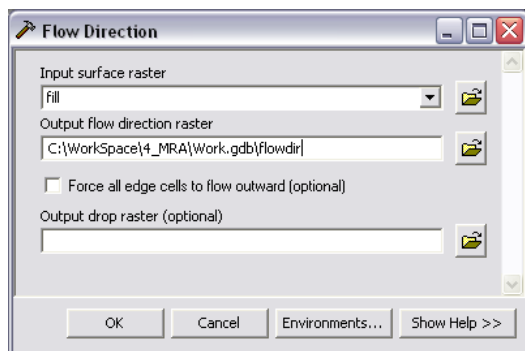
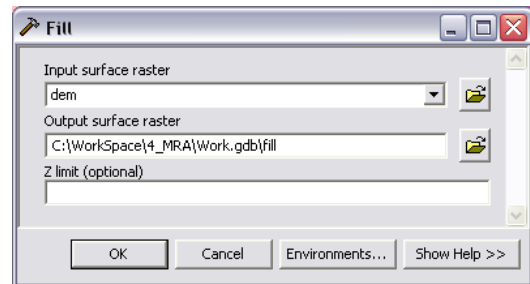
The following four steps are performed in sequence to model watersheds from the DEM using the Hydrology toolset:

- *Fill the sinks in the DEM to create a depressionless surface*
- *Calculate the direction of flow for each cell*
- *Calculate the flow accumulation*
- *Calculate the watersheds based on pour points*

Filling the sinks

2. In ArcToolbox, choose SPATIAL ANALYST TOOLS >>> HYDROLOGY >>> FILL
3. Select **dem** as the input surface
4. Specify an output file \Work.gdb\fill
5. Keep Fill Limit at the default to fill all
6. Click OK

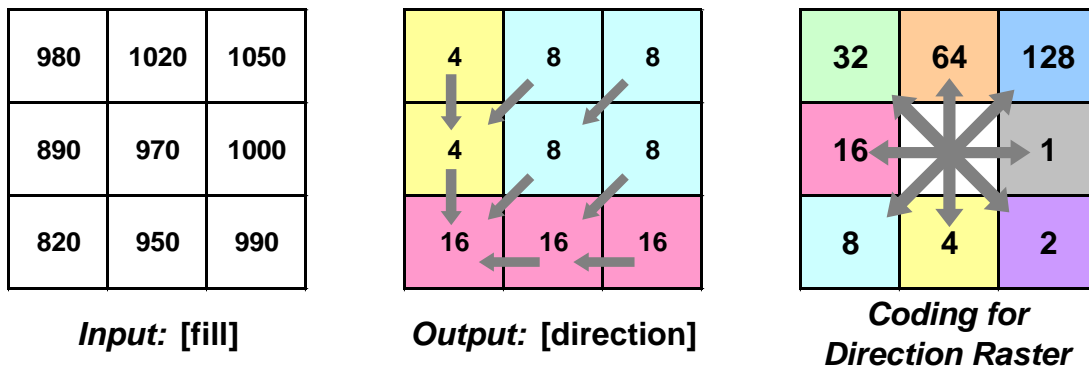
The resulting grid is essentially a smoothed-over DEM in which extreme topographic differences are filled in. This is required so the direction and accumulation algorithms don't get stuck in a hole with nowhere to go.



Calculating flow direction

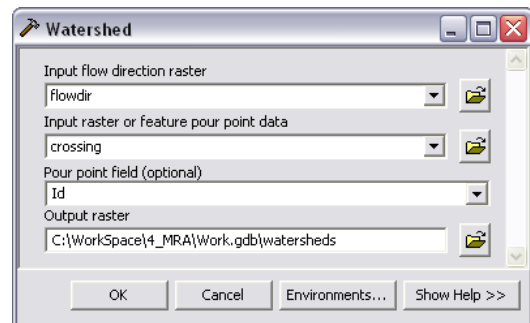
7. Choose SPATIAL ANALYST TOOLS >>> HYDROLOGY >>> FLOW DIRECTION
8. Select **fill** as the input surface
9. Specify an output file \Work.gdb\flowdir
10. Optionally, set the other parameters
11. Click OK

This results in a grid in which each cell is assigned a code indicating the direction of flow based on its neighboring cells. See below.



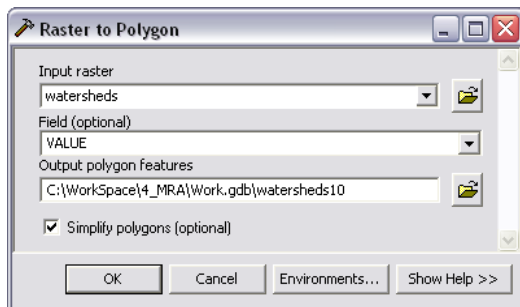
Calculating watersheds

16. Choose SPATIAL ANALYST TOOLS >>> HYDROLOGY >>> WATERSHED
17. Specify the following:
 - Input flow direction raster: **flowdir**
 - Input pour point data: **crossing**
 - Pour point field: **Id**
 - Output raster **\\Work.gdb\watersheds**
 - Click OK



This example yields 10 watershed basins that drain to the crossing locations. Now convert the raster to polygons.

18. Choose CONVERSION TOOLS >>> FROM RASTER >>> RASTER TO POLYGON



19. Select the following:

- Input raster **watersheds** grid layer as the input raster
- Use **Value** as the Field and **Polygon** as the Output Geometry Type
- Optionally, choose to simplify polygons
- Specify a new output shapefile **\\Work.gdb\watersheds10**
- Click OK

Converting to vector features enables editing of the watershed layer, such as moving boundaries or arbitrarily dividing larger watersheds into smaller ones. You may use the layer in vector overlay and other geoprocessing, or as in the next task, as an analysis mask.

20. Select watershed # **8** – interactively with the identify and selection tools or choose SELECTION >>> SELECT BY ATTRIBUTES >>> "**GRIDCODE**" = 8
21. Choose DATA >>> EXPORT DATA and save the selected features as **W8**

Interpolation – Calculating a Continuous Snow Depth Surface

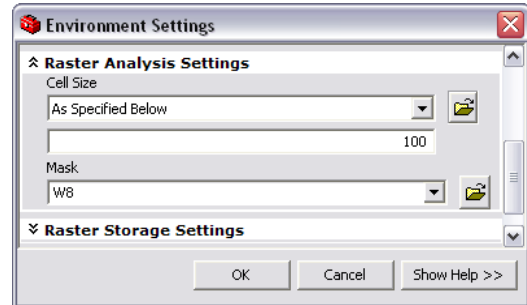
Interpolation is used to create a continuous surface of some phenomena that varies geographically. In this example, you wish to model snow depths within watershed #8 where you had collected snow depth samples. You need this snow depth layer to use in predicting wolf movement in the next section.

The available data are the DEM, a table of GPS locations with snow depth measures in centimeters, and the W8 polygon. You will test the **Spline** interpolation method to develop a continuous snow depth surface. The ArcGIS Desktop Help and **Using ArcGIS Spatial Analyst** manual have very valuable details on all available interpolation methods!

Setting a mask

Specify a raster MASK to restrict the area of analysis and output to within the selected watershed.

- In ArcToolbox's ENVIRONMENT SETTINGS:
 - Set the GENERAL Settings >>> Extent to "**Same as W8**"
 - Set the RASTER Analysis Settings >>> Mask to **W8**
- Click OK



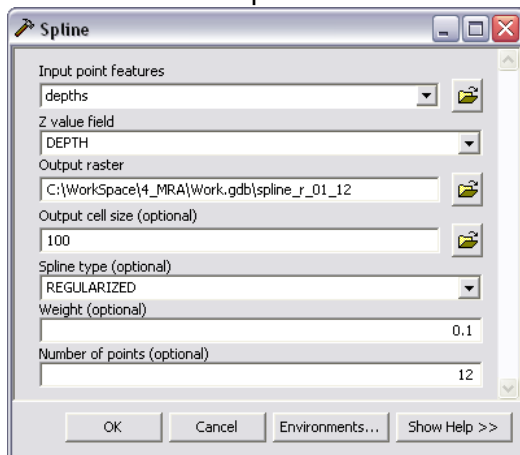
Adding XY data

Add in the tabular point data to be used for the interpolation.

- Choose TOOLS >>> ADD XY DATA
- Browse for the **locations.dbf** file and click ADD
- Select the appropriate X and Y fields
- Click OK
- Right click on **locations Events**
- Choose DATA >>> EXPORT DATA
- Click to 'Use the same Coordinate System as the data frame'
- Save as \\Work.gdb\depths

Interpolating with the spline method

- Choose SPATIAL ANALYST TOOLS >>> INTERPOLATION >>> SPLINE
- Select the following parameters:
 - Input points: **depths**
 - Z value field: **DEPTH**
 - Output raster: **spline_r_01_12**
 - Keep all else at their defaults and click OK



- Examine the output raster

Interpolate a new surface using different parameters.

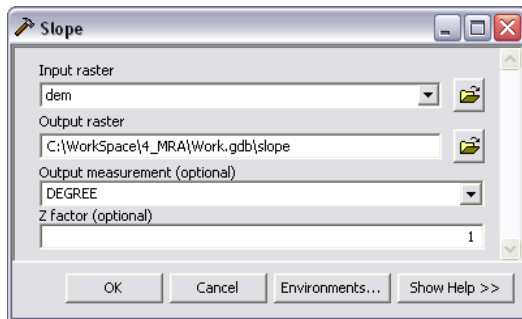
- Choose SPATIAL ANALYST TOOLS >>> INTERPOLATION >>> SPLINE
- Select the following parameters:

- Input points: **depths**
- Z value field: **DEPTH**
- Output raster: **snowdepth**
- Spline type: **Tension**
- Weight: **10**
- Number of points: **5**
- Click OK

Which is the more realistic output? Why?

Cost Path – Determining the Least Cost Movement Path

Cost surface and *cost path* analyses are used here to estimate the movement of a wolf through winter ungulate habitat between two telemetry points. Cost weighted distance mapping finds the least accumulative cost from each cell to the nearest, 'cheapest' source. In this example, cost is based on time or preference of travel through ungulate winter habitat from one telemetry point to the next. By weighting several environmental variables – slope, snow depth, and quality winter ungulate range – you can then apply the cost path (a.k.a. shortest path) function between the start and end points to estimate where the wolf likely traveled. The available data are source and destination points, DEM, snow depth, and habitat layers. The following instructions analyze the data to answer: **Where might the wolf have traveled through the landscape between telemetry points?** Your assumptions are that the wolf prefers lower slopes and shallower snow depths for efficient travel, and higher winter ungulate habitat class to increase chances of finding prey.



Calculating the slope surface

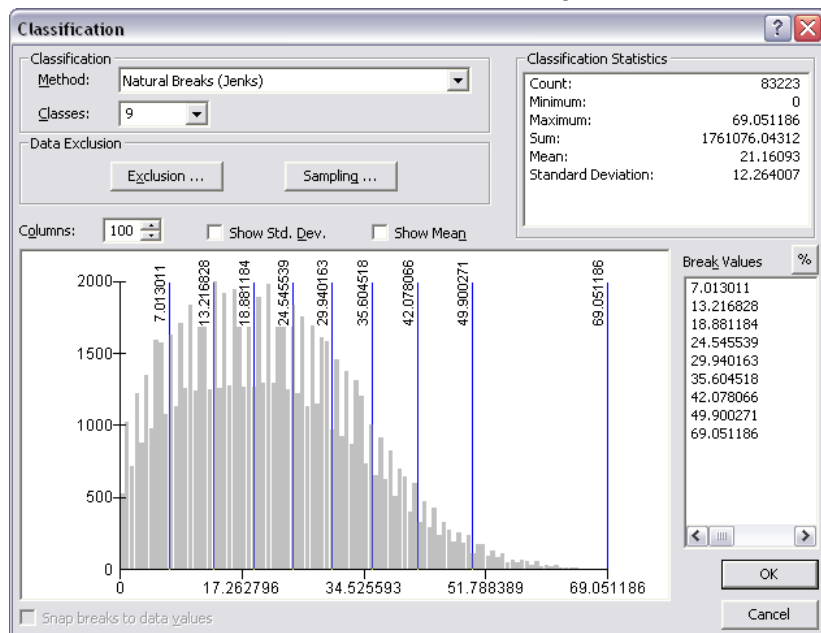
1. Turn off all layers except: **source**, **destination**, **dem**, **winter**, and **snowdepth**
2. Modify the drawing order
3. Choose SPATIAL ANALYST >>> SURFACE ANALYSIS >>> SLOPE
4. Select **dem** as input; enter **slope** as output
5. Leave all else at their defaults and click OK

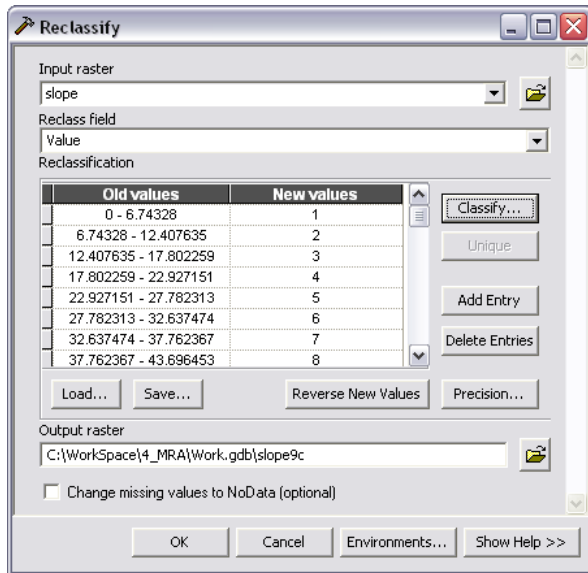
Standardizing the rasters

The raster layers are in different measurement systems (slope is in degrees, snowdepth is in centimeters, and winter is in categories) so they cannot be compared relative to the others. Each layer must be reclassified to a common scale. In this example you will reclassify each layer into a scale of 1 to 9, where 1 indicates low cost and 9 indicates higher cost for movement.

6. Choose SPATIAL ANALYST TOOLS >>> RECLASS >>> RECLASSIFY
7. Select **slope** as the input
8. Click the CLASSIFY button and set **9 Natural Breaks** classes
9. Click OK
10. Enter **slope9c** for the output raster and click OK

The resulting raster has eight classes where 1 means lower slopes and 9 represents steeper slopes. Now apply the reclassification process to the snow depth layer.



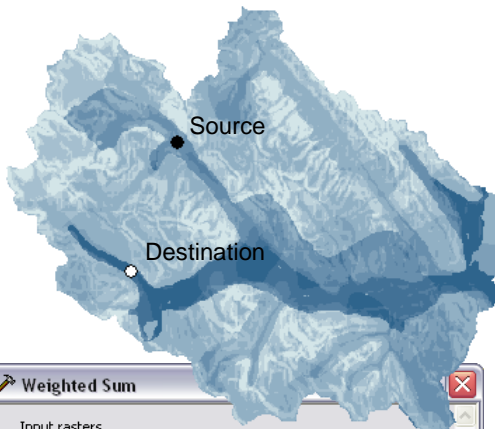


11. Choose SPATIAL ANALYST TOOLS >>> RECLASS >>> RECLASSIFY
12. Select **snowdepth** as the input
13. Click the CLASSIFY button and set **9 Equal Intervals** classes (NOTE: in the right-most box, click on the last break value and type 700)
14. Click OK
15. Type **snow9c** for the output and click OK

The winter layer requires a different reclassification technique since you are dealing with categorical data. Assign lower cost values to the higher quality winter habitat and vice versa.

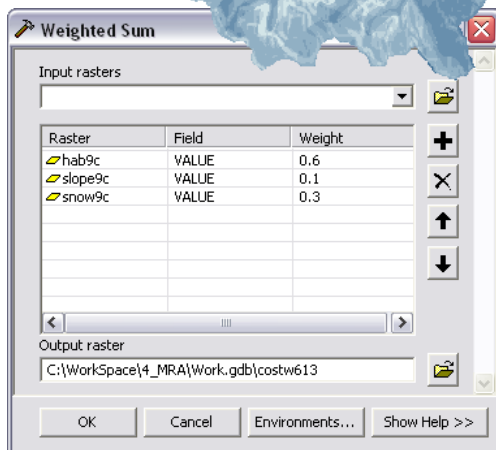
OBJECTID	VALUE	COUNT	WINTER	hab9c
1	1	8635	0	9
2	2	35771	1W	1
3	3	56094	2W	2
4	4	139793	4	6
5	5	186420	3	5
6	6	117538	5	7
7	7	125355	3W	3
8	8	92275	6	8
9	9	11701	2	4

16. EDIT the winter attribute table by adding an integer field named **hab9c** and typing in values 1-9 to rank the habitat
17. Open the RECLASSIFY tool
18. Select **winter** as the input
19. Select "**hab9c**" as the Reclass field
20. Type **hab9c** for the output raster and click OK



Calculating the cost raster

You may simply add the three layers together, but you know that some geographic factors are more important than others. For example, when traveling through the landscape, a hungry wolf may be more interested in staying near prey than avoiding snow and steep slopes. Give each dataset a percent influence that makes the most biological sense when adding the rasters together.



21. Choose SPATIAL ANALYST >>> OVERLAY >>> WEIGHTED SUM
22. Click the drop-down list to select each Input raster and type the weighting value:

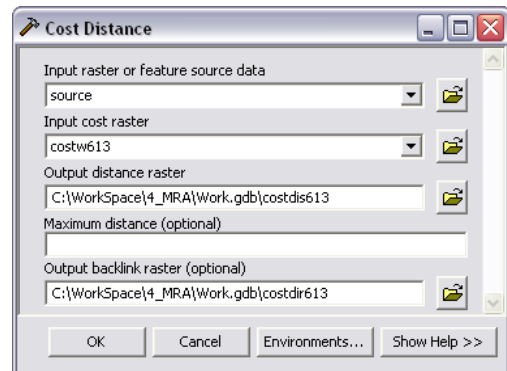
Raster	Weight
hab9c	0.6
slope9c	0.1
snow9c	0.3

23. For the output raster name type **costw613**
24. Click OK

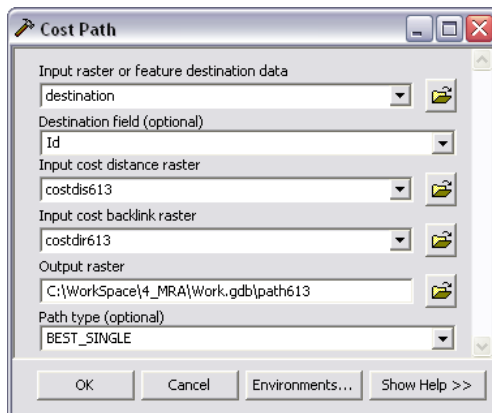
The darker shaded cells indicate the lower costs of movement. TIP: Use the numeric weightings in the filename as a reminder of the values you used (and set up the rasters alphabetically)!

Calculating the cost weighted distance and direction

25. Choose SPATIAL ANALYST >>> DISTANCE >>> COST DISTANCE
26. Select **source** as the Input source data
27. Select **costw613** as the Input cost raster
28. Type **costdis613** as the Output distance raster
29. Type **costdir613** as the Output backlink raster
30. Click OK



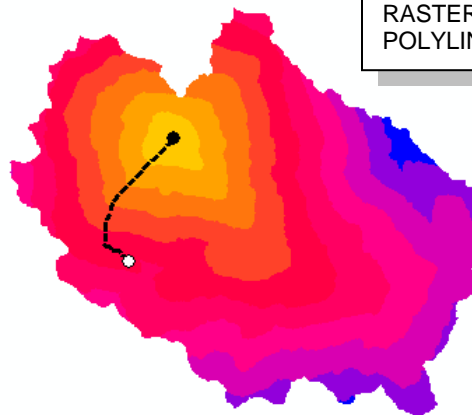
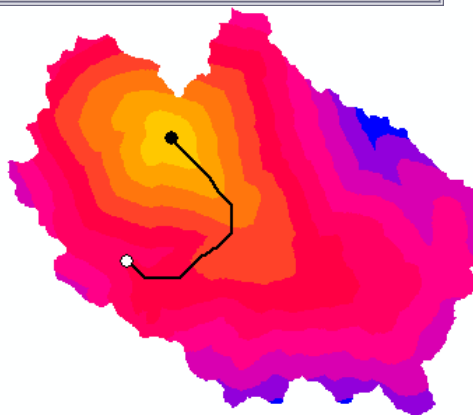
Each cell in the direction raster is assigned a code that identifies which one of its neighboring cells is on the least-cost path back to the nearest source. The direction coding is similar to what is used in the watershed hydrology modeling extension above where each cell is assigned a value representing the direction of the nearest, cheapest cell on the route of the least costly path to the nearest source. Both the cost-weighted distance and direction rasters are required for the final step of calculating the least-cost (shortest) path between source and destination locations.



Calculating the cost path

31. Choose SPATIAL ANALYST TOOLS >>> DISTANCE >>> COST PATH
32. Select the following inputs/parameters:
 - Path to: **destination**
 - Cost distance raster: **costdis613**
 - Cost direction raster: **costdir613**
 - Path type: **Best Single**
 - Output: **path**
33. Click OK

Optionally, convert the path RASTER TO POLYLINE



The solid line path on the left is the result of the above instructions. It was based on weighting the inputs to get the cost raster. The dashed line path on the right was calculated from a cost raster that was created by simply adding the inputs together. The point to understand from this is that it is important to spend time considering how to combine or weight the rasters that make up the cost raster. How you combine or weight your rasters depends on your application and the results you wish to achieve. Be wary of biasing the inputs in a non-biologically meaningful way!