Workshop Exercises for “Digital Terrain Analysis with LiDAR for Clean Water Implementation”

MINNESOTA DEPARTMENT OF AGRICULTURE

Workshop Exercises for "Digital Terrain Analysis with LiDAR for Clean Water Implementation"

This manual is designed to accompany lecture and handout materials provided at a series of workshops offered in multiple Minnesota locations in 2010, as part of a Precision Conservation project administered by the Minnesota Department of Agriculture with Clean Water Funds. The Precision Conservation project aims to help locally led clean water restoration and protection projects target critical areas of the landscape where conservation treatments will be most effective in meeting water quality goals.

Version 1

Contents

Exercise 1: LiDAR DEM Data

A. Basic Properties - Examining Source Data

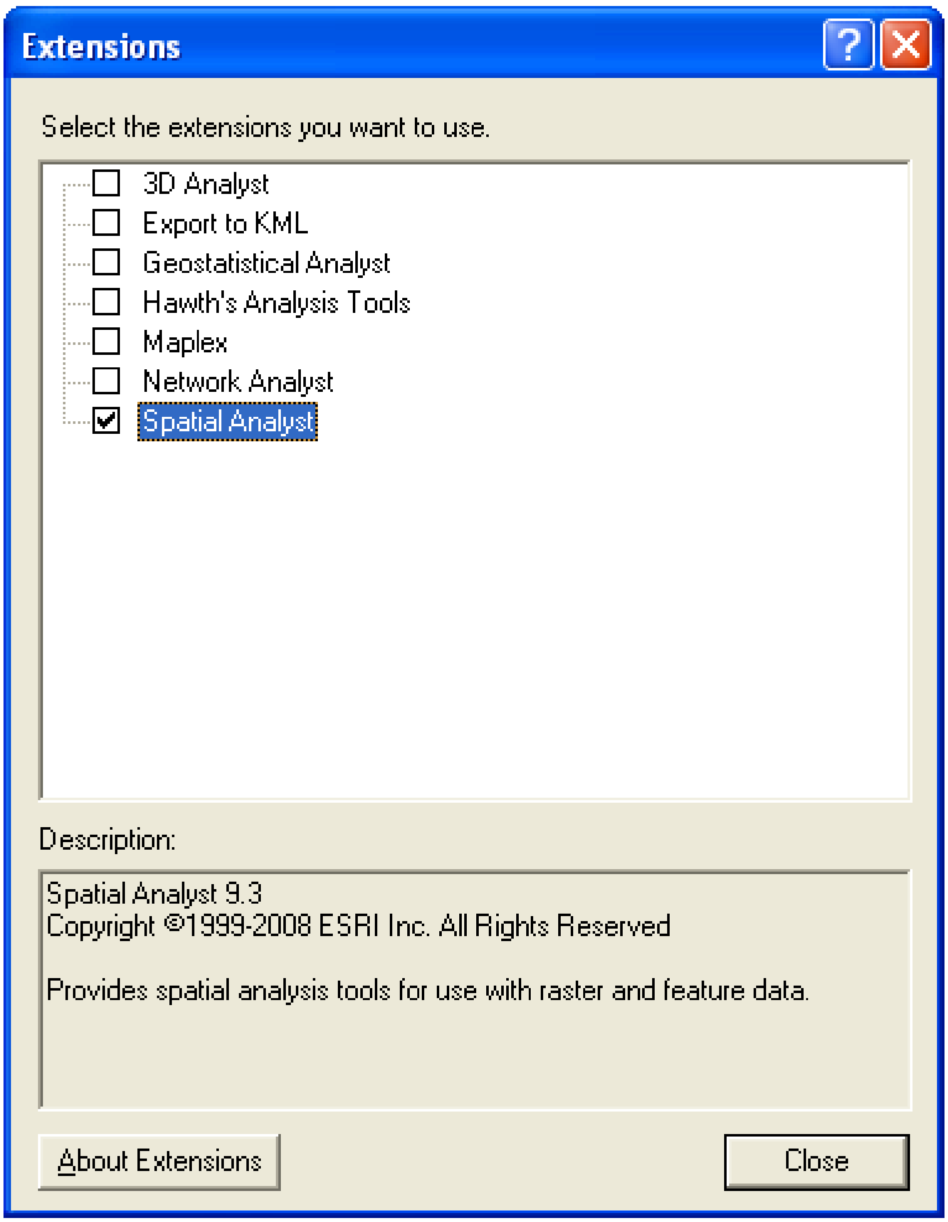
1. Start ArcMap.
2. Add to your map the raster of our area of interest as a new layer.
3. Click the name of the layer in the map Table of Contents and rename it **DEM.**
4. Select this DEM Layer again, right-click > **Properties**.
    - Click the **Source** tab in the properties for the layer to get a full description of the layer including *cell size, format, extent and spatial reference*.
    - Now click the S**ymbology** tab. Here you can change the color ramp.
        - Workshop demonstration - colormap and stretch-type adjustments
    - Check-on the **Hillshade** option to emphasize the terrain features. This does *not affect* the analysis or change the data, but aids in visualization.
    - Once you have examined all layer properties, click **OK** to close the layer properties.

B. DEM and Hydrologic Conditioning

Activate Spatial Analyst Extension

1. From the **Tools** Menu, select **Extensions** and check **Spatial Analyst**.

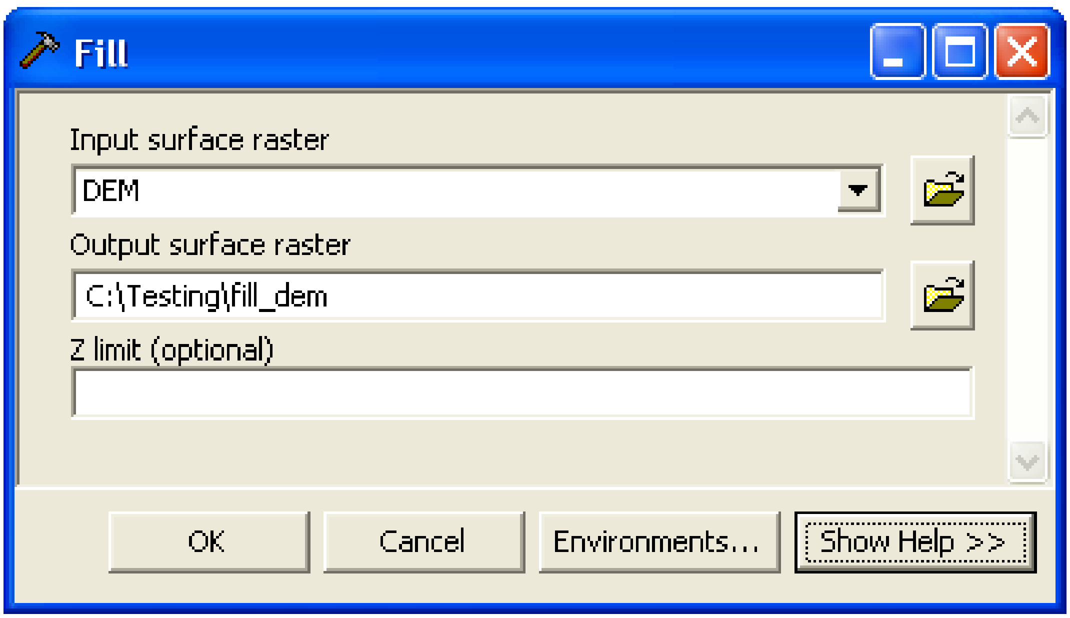
2. Click **Close**.



Pit Filling

1. Launch **ArcToolbox** by clicking the toolbar icon. 
2. Expand the **Spatial Analyst Tools**, then expand the **Hydrology** Toolset. Double-click the **Fill** tool to start it**.**

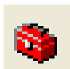
   TIP: *There are several other ways to find this (or any) tool in ArcToolBox:*
   - *Select the **Index** tab at the bottom of ArcToolbox and scroll through the list to find **Fill (sa)**.*
   - *Select the **Search** tab at the bottom and type in **fill** to find any tools with 'fill' in their titles.*

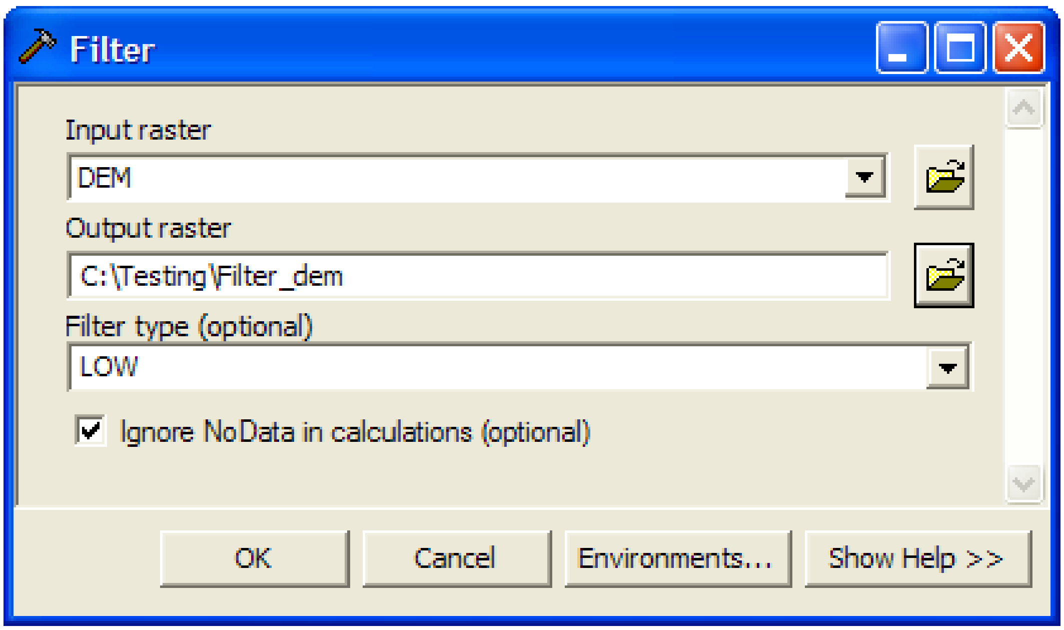


3. **Input Surface Raster**: DEM (select it from the drop-down).
4. **Output Surface Raster**: Browse to output workspace and name **fill_dem**
5. **Z limit**: the maximum elevation difference between a sink and its pour point to be filled.
   - *Note:* The default will fill all sinks regardless of depth.
6. The output surface raster is added to your map as a new layer.

Filter Analysis

At times, LiDAR data expressed in fine-resolution DEMs can contain either errors or spurious features which impede flow analysis and/or other terrain analysis. Using a moving-window 3X3 grid can "smooth" the data and provide more contiguous results.

1.  **ArcToolbox** > **Spatial Analyst Tools** > **Neighborhood** > **Filter**.



2. **Input Raster**: DEM (select it from the drop-down list).
3. **Output Raster**: Browse to your output workspace and name it **filter_dem**
4. **Filter type (optional)**: the enhancement to be performed in the filter analysis.

   Note: The default is LOW which is needed to do the smoothing we require.

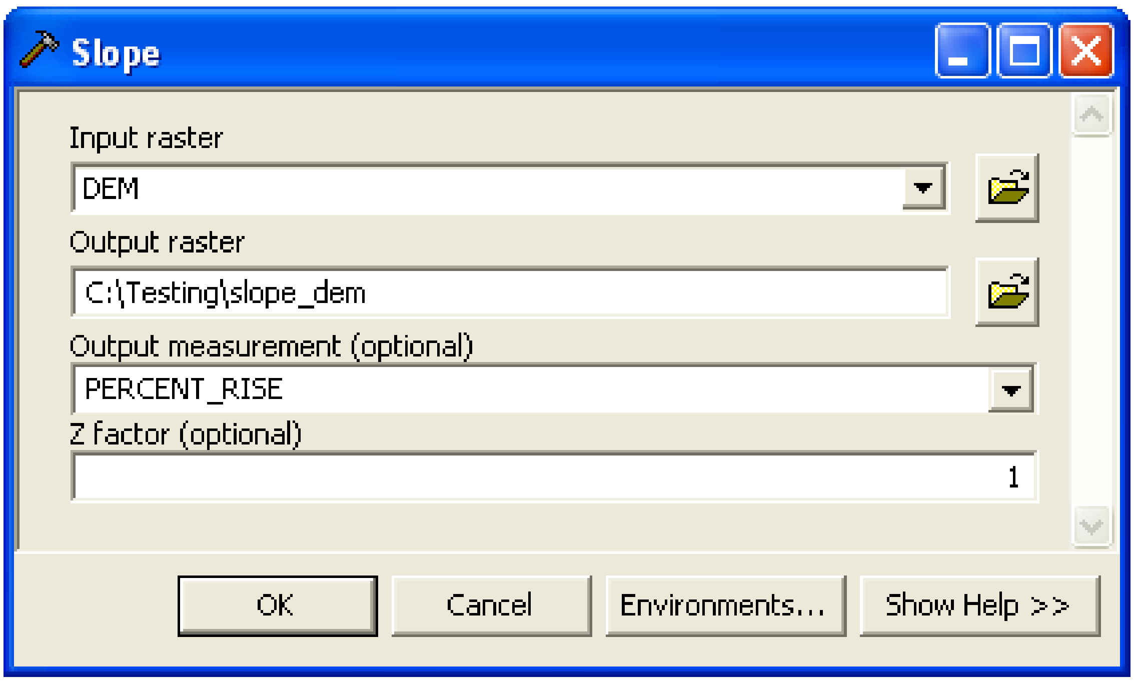
5. The output raster is added to your map as a new layer.

Exercise 2: Terrain Attributes and Calculations

A. Calculate Primary Attributes

Slope

1. **ArcToolbox > Spatial Analyst Tools > Surface > Slope**.



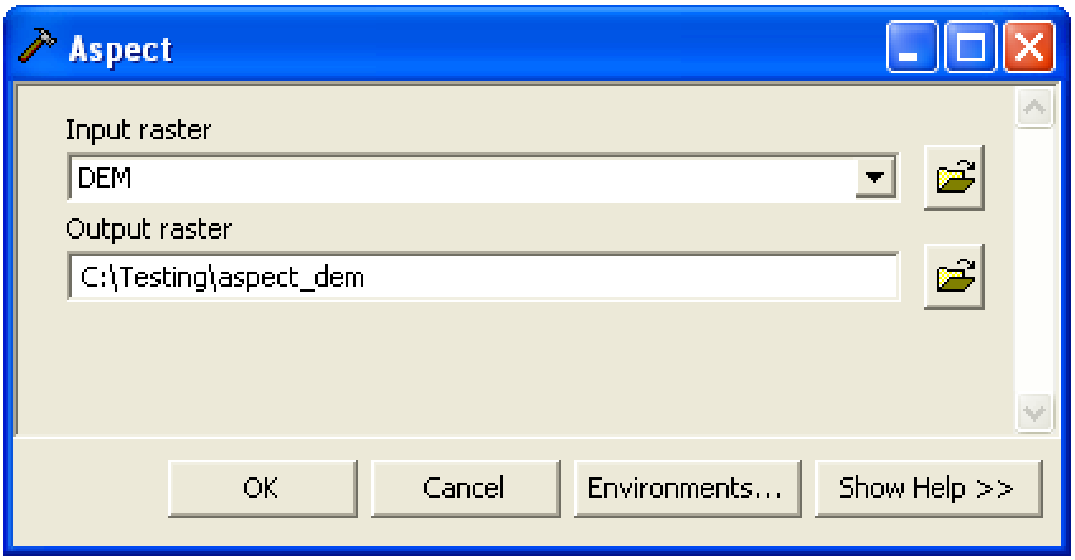
2. **Input Raster**: DEM.
3. Browse to output workspace and name output layer **slope_dem**
4. Select Output Measurement: **PERCENT_RISE**

   Note: It is important for the rest of the analysis that you select PERCENT_RISE, even though the data will look the same.

5. Click **OK** to run.
6. The output raster is added to the map as a new layer.

Aspect

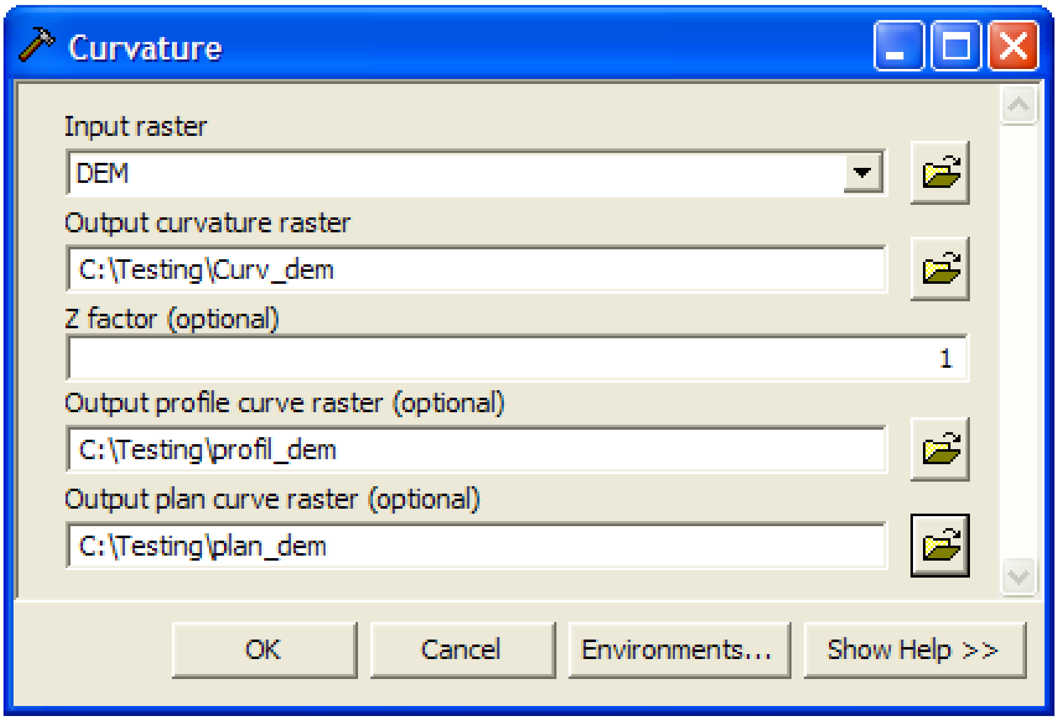
1. **ArcToolbox > Spatial Analyst Tools > Surface > Aspect.**



2. **Input Raster**: DEM.
3. Browse to output workspace and name the output raster **aspect_dem**
4. Click **OK** to run.
5. The output will be added to the map as a new layer.

Plan and Profile Curvature

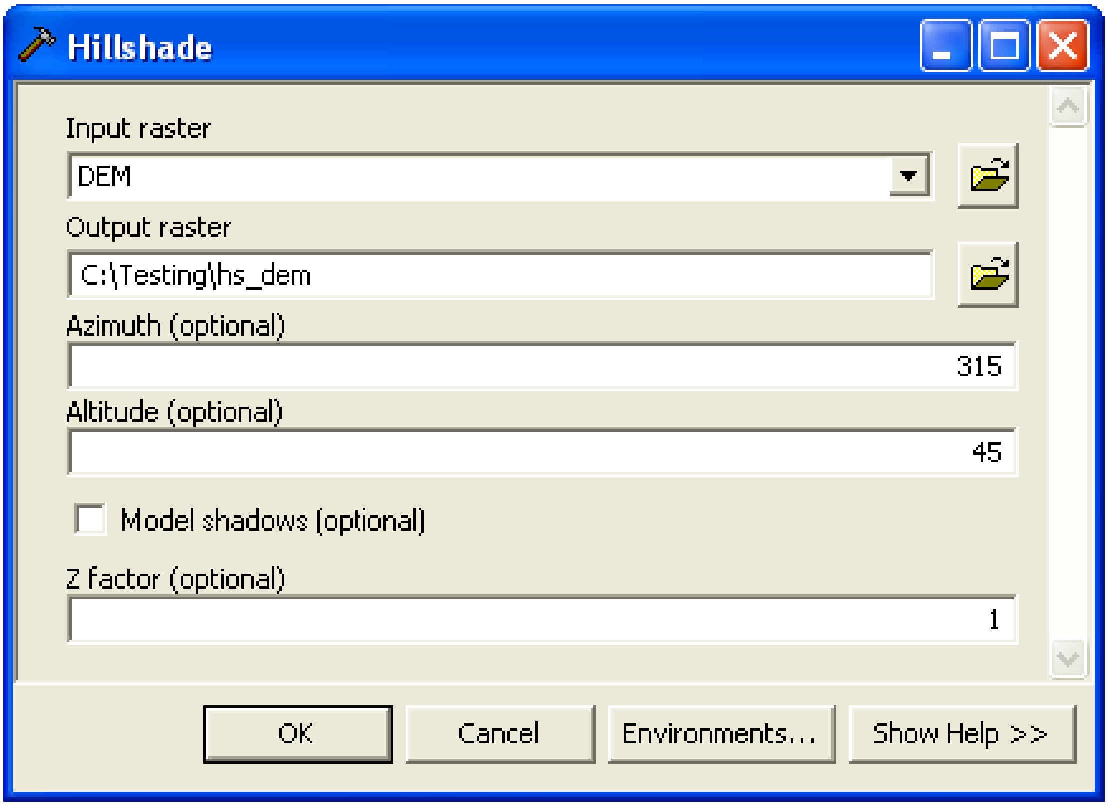
1. **ArcToolbox > Spatial Analyst Tools > Surface > Curvature.**



2. **Input Raster**: DEM.
3. Browse to output workspace and name the output <u>curvature</u> raster **curv_dem**
4. Browse to output workspace and name the <u>profile curve</u> raster **profil_dem**
5. Browse to output workspace and name the <u>plan curve</u> raster **plan_dem**
6. Click **OK** to run.
7. The 3 output rasters are added to the map as new layers.

Hillshade

1. **ArcToolbox** > **Spatial Analyst Tools** > **Surface** > **Hillshade.**



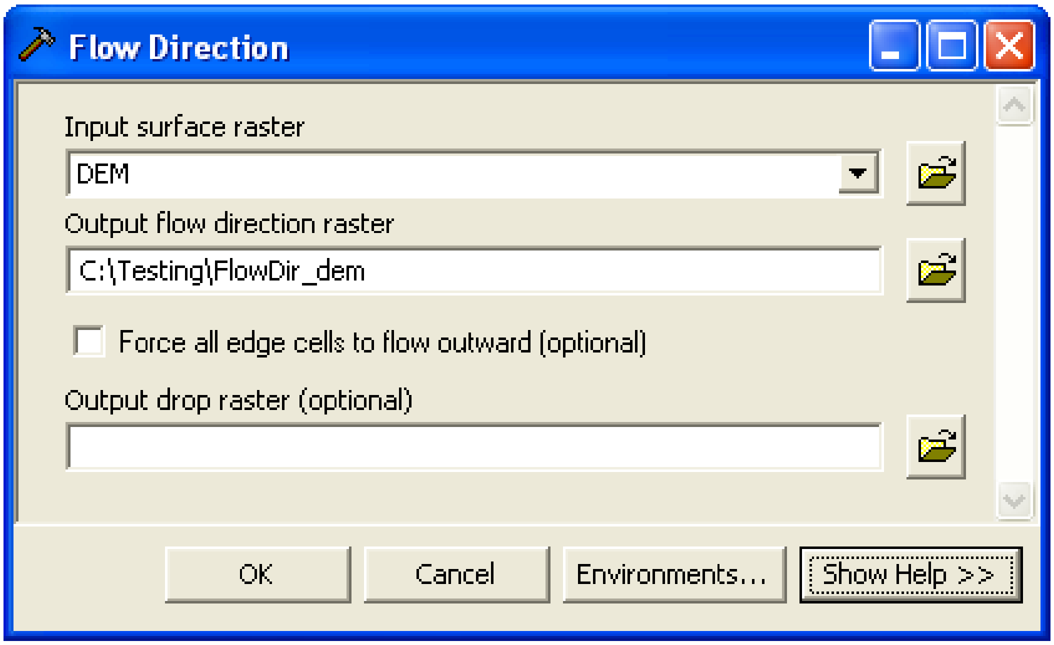
2. **Input Raster**: DEM.
3. Browse to your output workspace and name the output raster **hs_dem**
4. **Accept defaults for Azimuth, Altitude and Z factor.**

   Note: You can try checking on **Model Shadows**, which can aid visualization however, in some cases, it makes little difference.

5. Click **OK** to run.
6. The output raster is added to the map as new layer.

Flow Direction

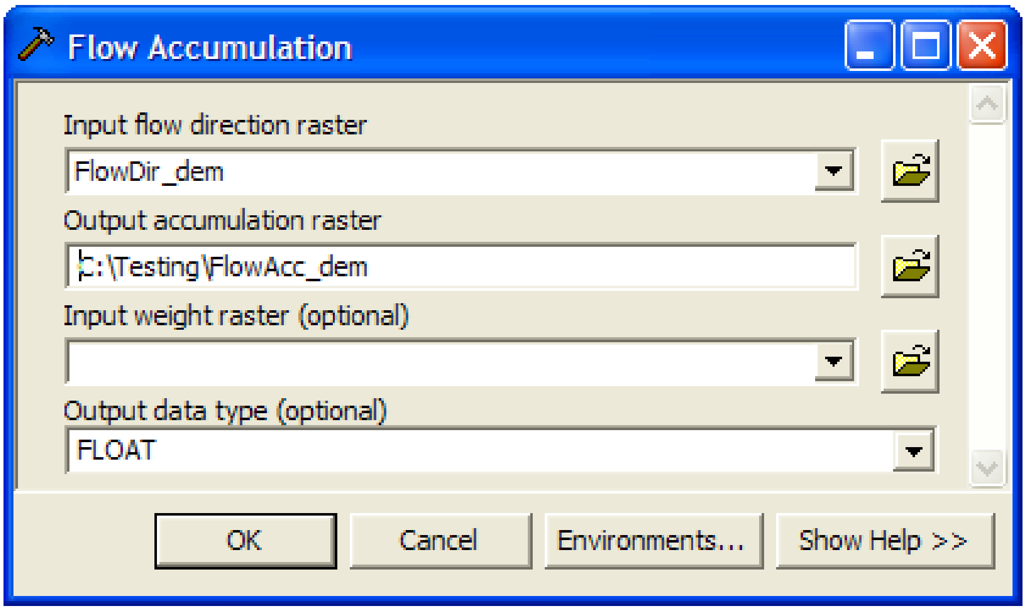
1. **ArcToolbox > Spatial Analyst Tools > Hydrology > Flow Direction.**



2. **Input Raster**: DEM
3. Browse to your output workspace and name output layer **FlowDir_dem**
4. Click **OK** to run.
5. The output raster is added to the map as a new layer.

Flow Accumulation (using output from Flow Direction)

1. **ArcToolbox** > **Spatial Analyst Tools** > **Hydrology** > **Flow Accumulation**.



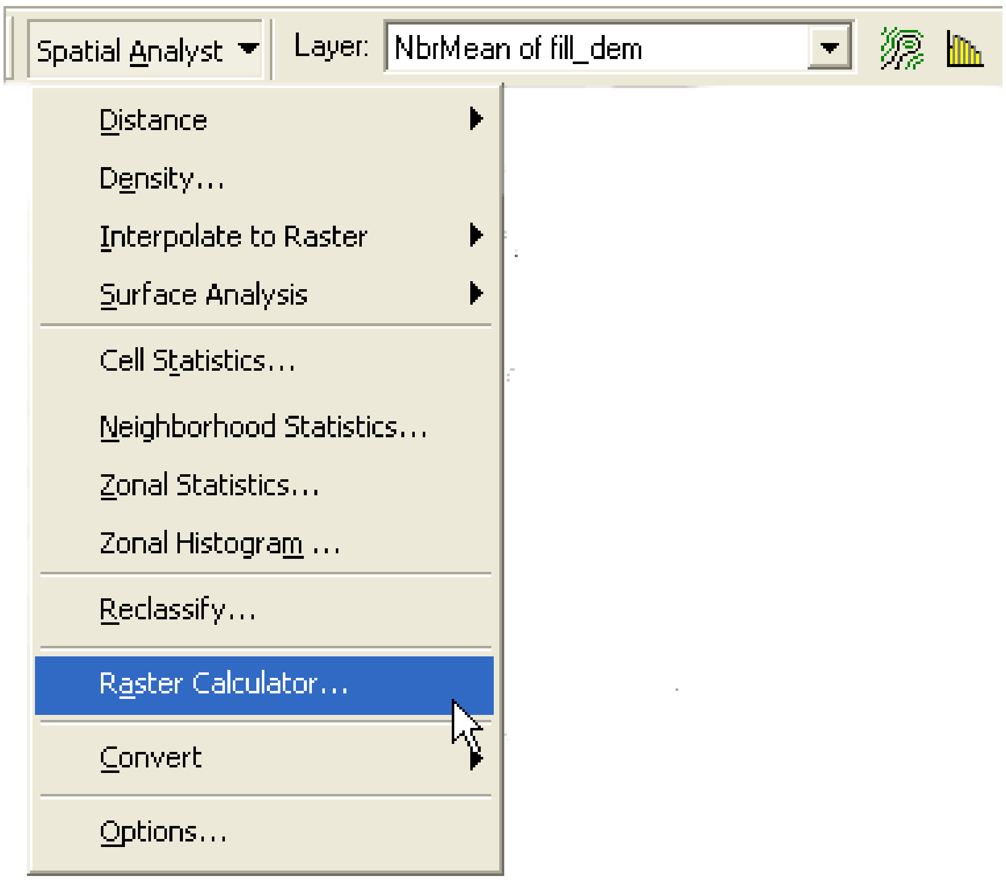
2. For **Input Flow Direction Raster**, use the output of Flow Direction from earlier step. If you kept the suggested name, it will be "FlowDir_dem".
3. Browse to output workspace and name the output raster **FlowAcc_dem**.
4. You can accept defaults for the other factors.
5. Click **OK** to run.
6. The output raster is added to the map as a new layer.

B. Calculate Secondary Attributes

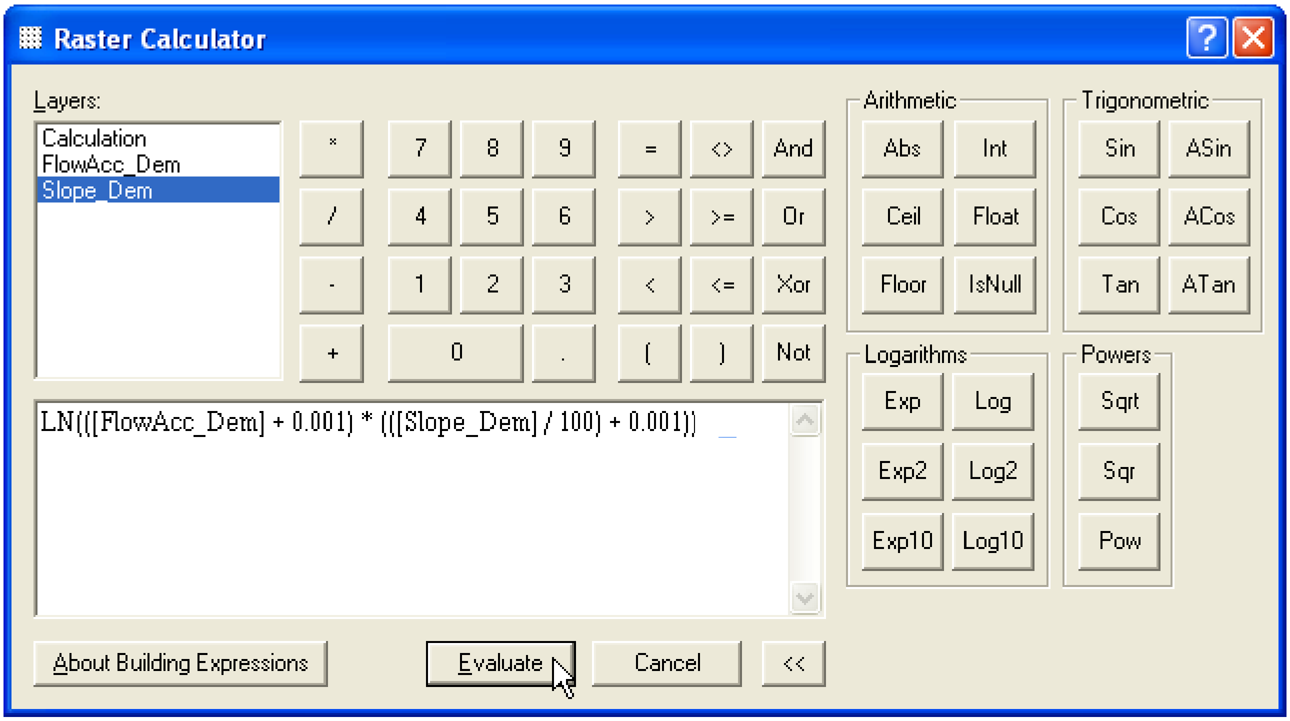
Stream Power Index (SPI)

SPI = LN(([FlowAcc_Dem] + 0.001) * (([Slope_Dem] / 100) + 0.001))

1. From the **Spatial Analyst Toolbar**, open the **Raster Calculator**.



2. Enter formula so the result looks like the example in the screenshot below (next page).
3. Click **Evaluate** to run the calculation.
4. The output is Temporary and will be added to the map layers as "Calculation".
5. Select the layer in the map Table of Contents and rename it as **SPI_Calc**.
6. To **save** it, select the layer, right-click and choose **Data** > **Export**. Set the file type to export as **GRID** rather than the default of Imagine IMG.


Raster Calculator
Layers:
Calculation
FlowAcc_Dem
Slope_Dem
*
7
8
9
=
<>
And
/
4
5
6
>
>=
Or
-
1
2
3
<
<=
Xor
+
0
.
(
)
Not
Arithmetic
Abs
Int
Ceil
Float
Floor
IsNull
Trigonometric
Sin
ASin
Cos
ACos
Tan
ATan
Logarithms
Exp
Log
Exp2
Log2
Exp10
Log10
Powers
Sqrt
Sqr
Pow
LN(([FlowAcc_Dem] + 0.001) * (([Slope_Dem] / 100) + 0.001))
About Building Expressions
Evaluate
Cancel
<<

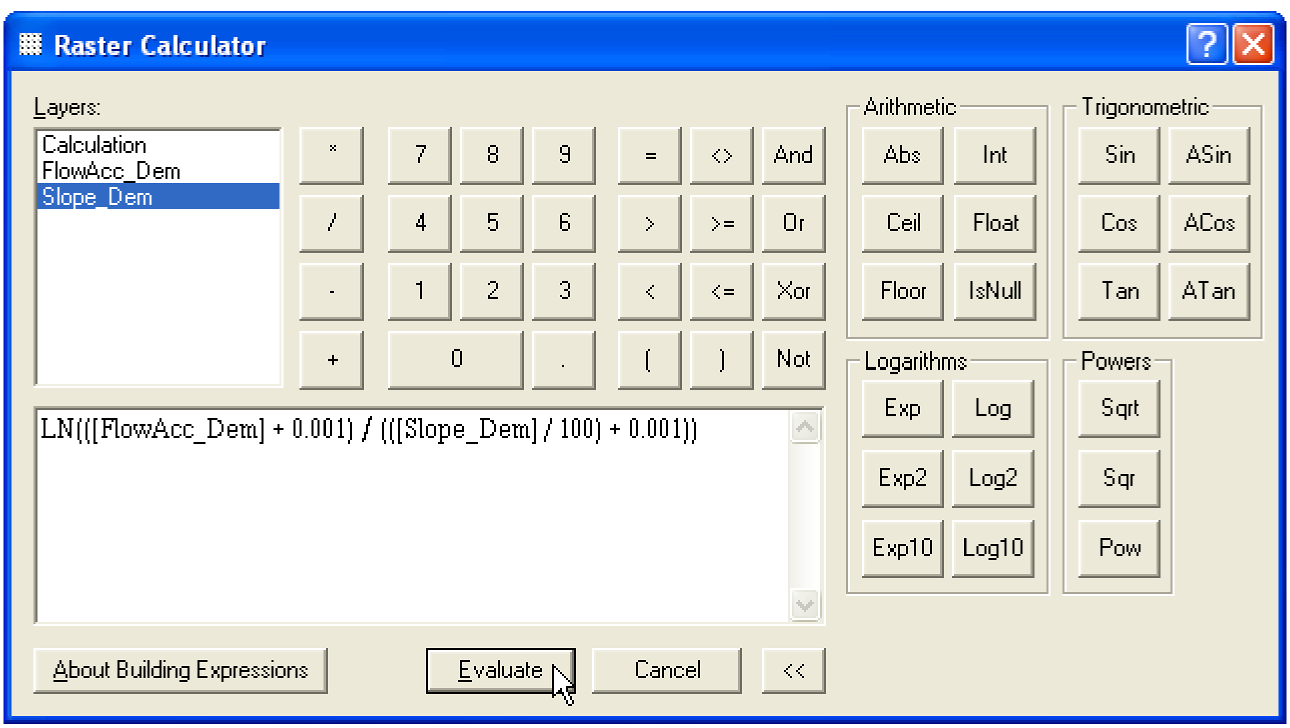
Compound Topographic Index (CTI)

CTI = LN(([FlowAcc_Dem] + 0.001) / (([Slope_Dem] / 100) + 0.001))

1. From the **Spatial Analyst Toolbar**, open the **Raster Calculator**.
2. Enter formula so the result looks like the example in the screenshot below.

   TIP / SHORTCUT*: The CTI formula is almost identical to the Stream Power Index (SPI) formula, so you can shortcut the formula entry process by copying and pasting the SPI formula you entered in the previous exercise.*

   - *To do this, place your cursor anywhere in the formula entry box,* ***right-click*** *and choose* ***Recently Used Formulas****. Select the formula previously entered (in this case, the formula used to calculate SPI). Copy and paste this into the current formula entry box. To calculate CPI, change the multiplication symbol (*) to the division symbol (/).*
3. Click **Evaluate** to run the calculation.
4. The output is Temporary and will be added to the map layers as "Calculation" or "Calculation2".
5. Select the layer in the map Table of Contents and rename it as **CTI_Calc**.
6. To **save** it, select the layer, right-click and choose **Data** > **Export**. Set the file type to export as **GRID** rather than the default of Imagine IMG.



Exercise 3: Interpretation

A. Visualization / Comparative Techniques

Terrain Attribute Comparison

Often, the best way to understand differences in terrain attribute calculations is to view each layer in conjunction with other layers. By paying careful attention to a specific portion of the landscape, one can overlay each of the terrain attributes to gain a better understanding each attribute's value.

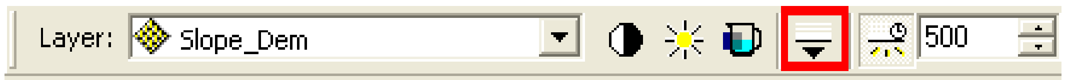
Orthophoto/Terrain Attribute Comparison

Add MNGEO WMS Service:

1. Open **ArcMap** and click on **Add Data**.
2. Look in the Catalog and click on **GIS Servers**.
3. Highlight **Add WMS Server** so it appears in the Name window, and hit **Add**. An 'Add WMS Server' window will pop up.
4. To bring up the Imagery server, type **http://geoint.lmic.state.mn.us/cgi-bin/wms?** in the URL window. You can click on the **Layers** button to see a list of the layers available under the wms. Click **OK**.
5. To bring up the Scanned DRG server, type **http://geoint.lmic.state.mn.us/cgi-bin/wmsz?** in the URL window. You can hit the **Get Layers** button to see a list of the layers available under the wms. Click **OK**.
6. Now when you look under 'GIS Servers' you have two new entries:
   'LMIC WMS server (aerial photography) on geoint.lmic.state.mn.us'
   and 'LMIC WMS server (quad sheet drgs) on geoint.lmic.state.mn.us'
7. Still in the 'Add Data' window under 'GIS Servers', highlight one of the services listed under #6 to bring it into the 'Name' window, then click on **Add**.
   - The service, with all of its layers, has now been added to your ArcMap project.
8. Click on '+' to open the map service and get on the layers. Check them on and off as needed. Click on '-' to close.

Swipe

1. To display the **Effects Toolbar**, right-click and select **View Menu** > **Toolbars** > **Effects**.
2. To "swipe" a layer using a horizontal or vertical line across the screen, select the **Swipe Tool** (outlined in red in the screenshot below).



3. Make sure the layer you want to "swipe" is shown in the "Layer:" box.
4. Click on the map and drag to swipe *(do not release mouse button; the mouse must be depressed to get the swipe effect.)*

   See example of swipe below:

Specific Colormaps for each Terrain Attribute

Often this is a matter of personal preference, but there are a few tips/tricks in display used for specific terrain attributes.

- Slope - Colormap variations
- Flow Accumulation - Visualize upslope contributing area as if it were a watershed boundary
- CTI - Blue/Water - display highest values
- SPI - Brown/Sediment - display highest values

B. Determining Thresholds

Threshold Value Display

1. Add to your map the raster of our area of interest as a new layer.
2. Click the name of the layer in the map Table of Contents and rename it: **DEM.**
3. Select this DEM Layer again, right-click > **Properties**.
    a. Now click the S**ymbology** tab. Here you can change the color ramp.
        i. Workshop demonstration - colormap and stretch-type adjustments

Percentile Analysis

1. **ArcToolbox > Conversion Tools>From Raster>Raster to ASCII**.
2. **Input Raster**: Layer of interest (select from drop-down list).
3. **Output ASCII file**: Browse to your output workspace and name it **percentile**
4. **Field (optional)**:
5. Open Excel
6. Open the ASCII file you just created.

   Note: In Files of Type, select **All Files (*.*)** from the drop-down menu, so the ASCII file will be displayed.
7. In the Import file wizard:
   - Select **delimited**
   - Check the **space** option
   - Click **Next**
   - Click **Finish** to import the file.
8. **DON'T CALCULATE**
9. Add previously calculated dataset as directed
10. In Excel:
    - Note Max records affect ability to input LiDAR data into Excel
    - Excel 2003 max records - 65,569
    - Excel 2007 max records - 1,048,575
    - Statistical Packages – Many around 10 milion
11. **Open "percentile_point.dbf"**

Select unused cell and type **=percentile(array, k)**

- Where array is the highlighted column with point values
- Where "k" is the percentile of interest – e.g. 0.85

Please feel free to continue to work on these data and ask questions as you go.

GENERAL QUESTIONS?

