

# Geographic Information Systems in Water Resources

## Slope Exercise

CUAHSI Virtual University, 2019

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### Goal

The goal of this exercise is to understand the calculation of topographic slope from a raster digital elevation model in geographic information systems.

### Objectives

- Calculate slope from a grid digital elevation model
- Apply model builder geoprocessing capability to program a sequence of ArcGIS functions

### Computer and Data Requirements

To carry out this exercise, you need to have a computer, which runs ArcGIS Pro. The necessary data are provided in the accompanying zip file, **SlopeExerciseData.zip**.

## 1. Hand Calculation of Slope

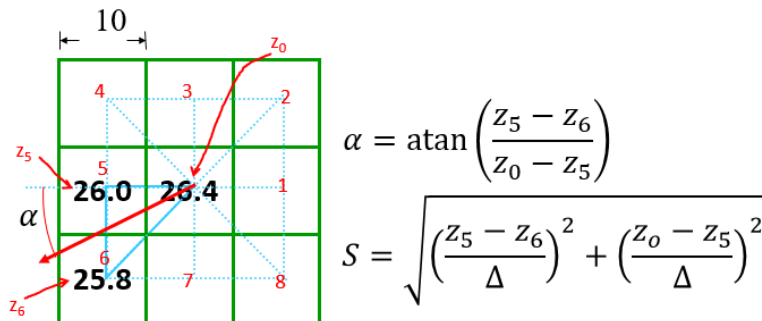
Given the following grid of elevations, refer to the slides GISWR\_CVU\_Lecture3.pptx from lecture 3 <https://cuahsi.instructure.com/courses/73/pages/material-for-lecture-3-spatial-analysis-9-slash-10-slash-19> and calculate by hand the slope and aspect (slope direction) at the grid cell labeled **A** using

- (i) The standard ESRI surface slope function (slides 39-42)
- (ii) The 8 direction pour point model (slides 43-44)
- (iii) The Dinfinity algorithm (slides 47-48).

Grid cell size 10m

25.4	26.1	27	28.6	27.7
25	26.0	26.4 A	27.9	27.4
25.1	25.8	26.8 B	28.6	27.6
27.5	28	27.7	30.6	28.3

Hint: For Dinfinity you only need to consider the single triangle bounded by values 26.0, 26.4 and 25.8 in the calculation



Comment on the differences and indicate which you think is a better approximation of the direction of water flow over the surface.

*To turn in: Hand calculations of slope at point A using each of the three methods and comments on the differences.*

## 2 Verifying calculations using ArcGIS

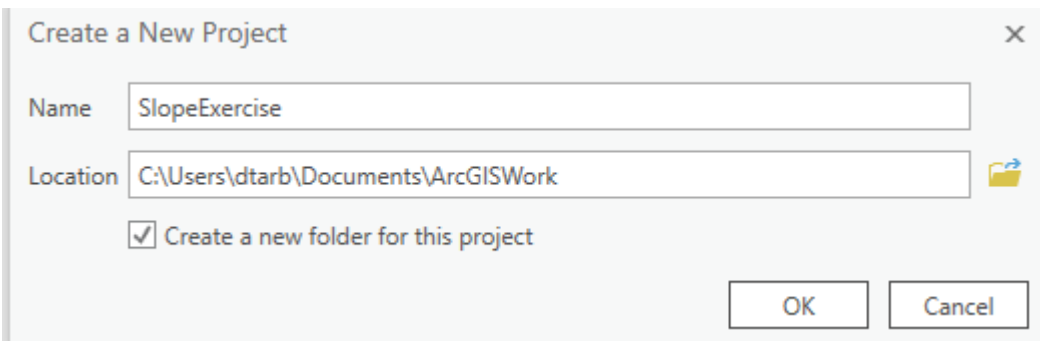
Verify the calculations in (1.1) using ArcGIS Hydrology and Surface Toolbox functions.


Save the following to a text file 'elev.asc' (This file is also included in **SlopeExerciseData.zip**).

```
ncols      5
nrows      4
xllcorner  0
yllcorner  0
cellsize   10
NODATA_value -9999
25.4  26.1  27    28.6  27.7
25    26.0  26.4  27.9  27.4
25.1  25.8  26.8  28.6  27.6
27.5  28    27.7  30.6  28.3
```

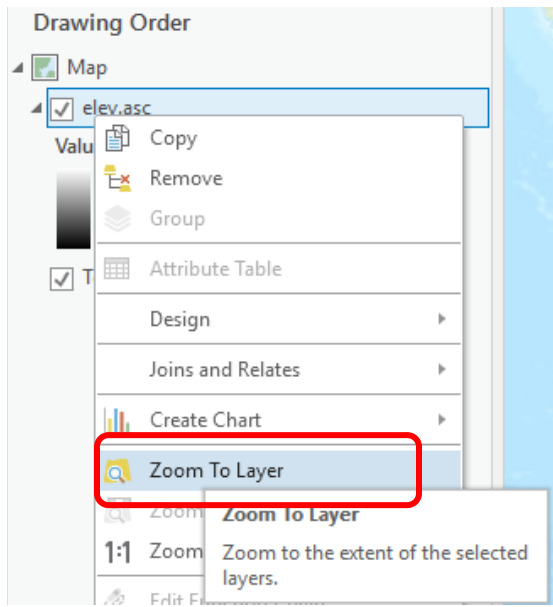
This shows how raw grid data can be represented in an ASCII text format that ArcGIS can import. Knowing how to get raw information into a form where it can be imported and analyzed using GIS is a useful skill.

Open **ArcGIS Pro**, establish a new map project called **SlopeExercise**

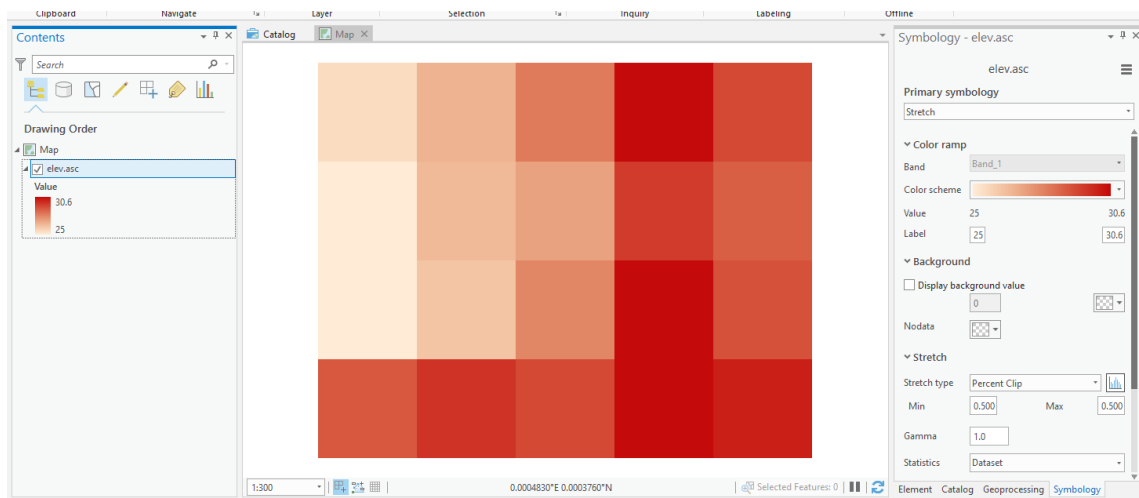


and use **Add Data**  in the Map tab to add this file to the map. Note that ArcGIS interprets files with the .asc type extension as raster files in this ASCII format and can work with them directly.

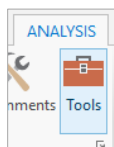
Zoom to the raster layer that was added.



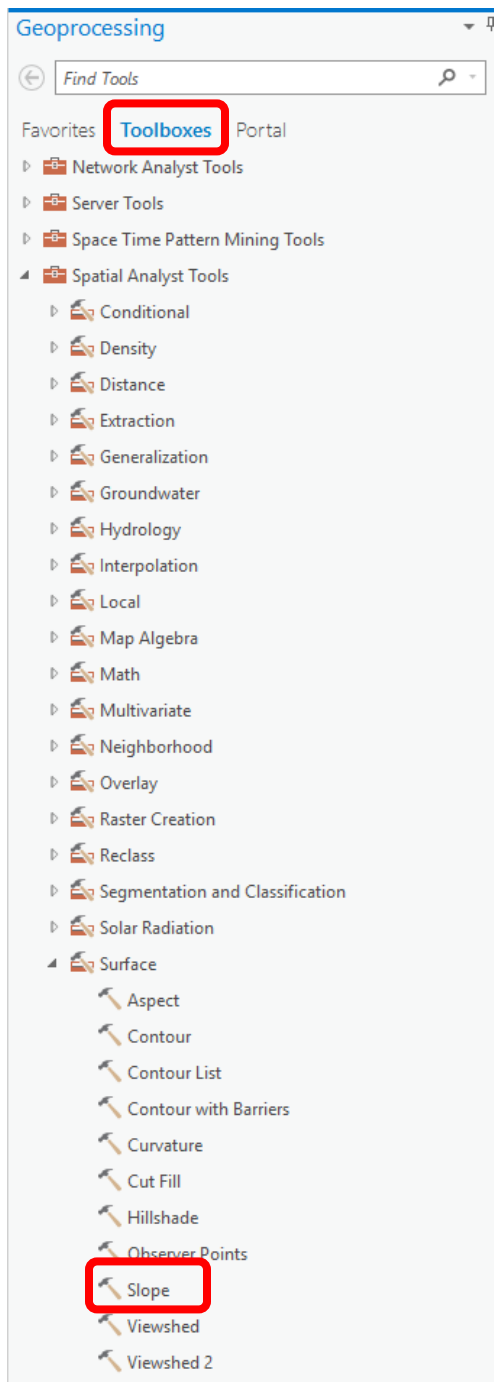
The first thing you'll notice is that this grid is in the middle of the ocean. This is because its corner coordinates (0, 0) are not linked to a specific coordinate system and position on the Earth. This is fine in this example and illustrates ArcGIS ability to perform generic raster calculations. Turn off (or Remove) the Topography layer because the background map is not needed. Right click on the elev.asc layer and using Symbology, color the layer so that the range in elevation values is more readily visualized. You can click on any of these cells to verify that the numbers correspond to the values in the table above.





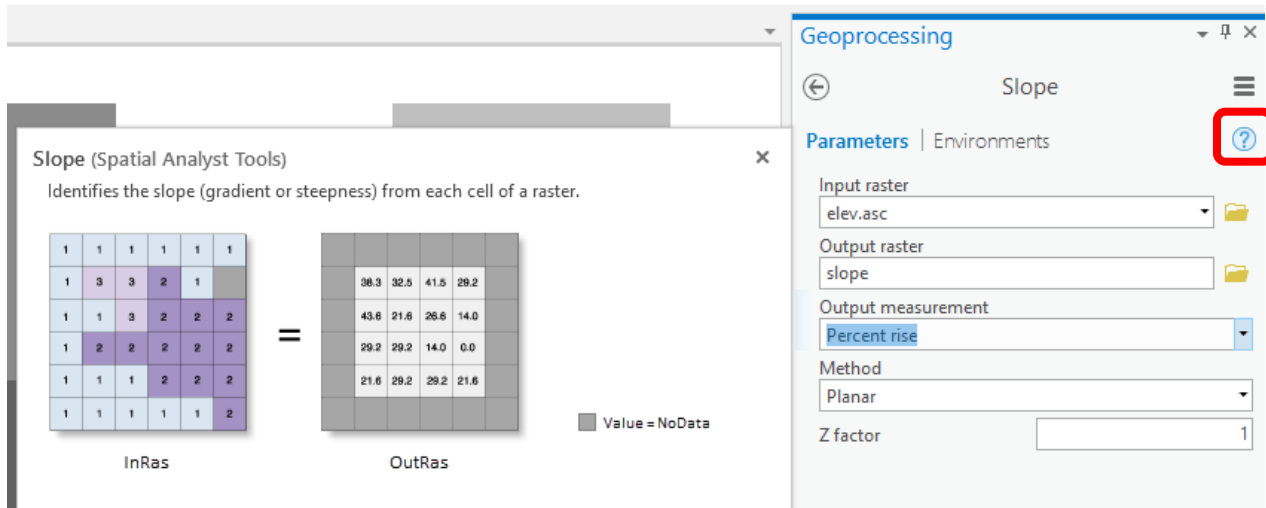
Select **Analysis/Tools** to add **Geoprocessing** to the right panel



In the **Geoprocessing** panel, select the **Toolboxes** header and open the tool **Spatial Analyst Tools** → **Surface** → **Slope**.

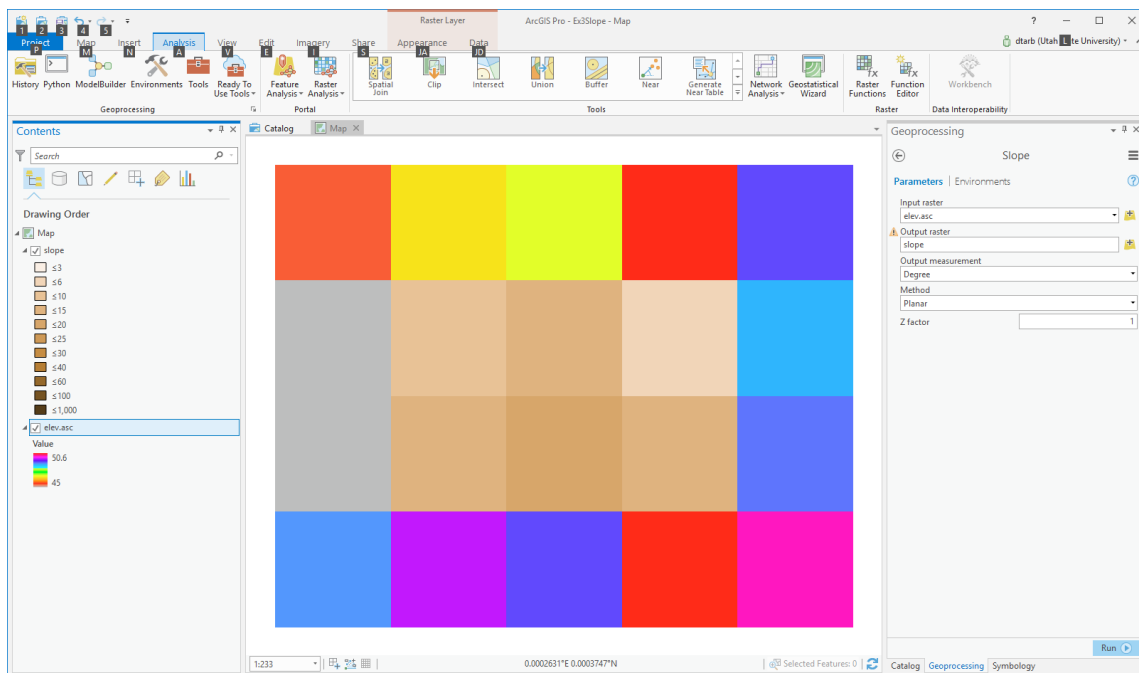


Hover over the  to see help information, and click on the  to open up a webpage with more details.



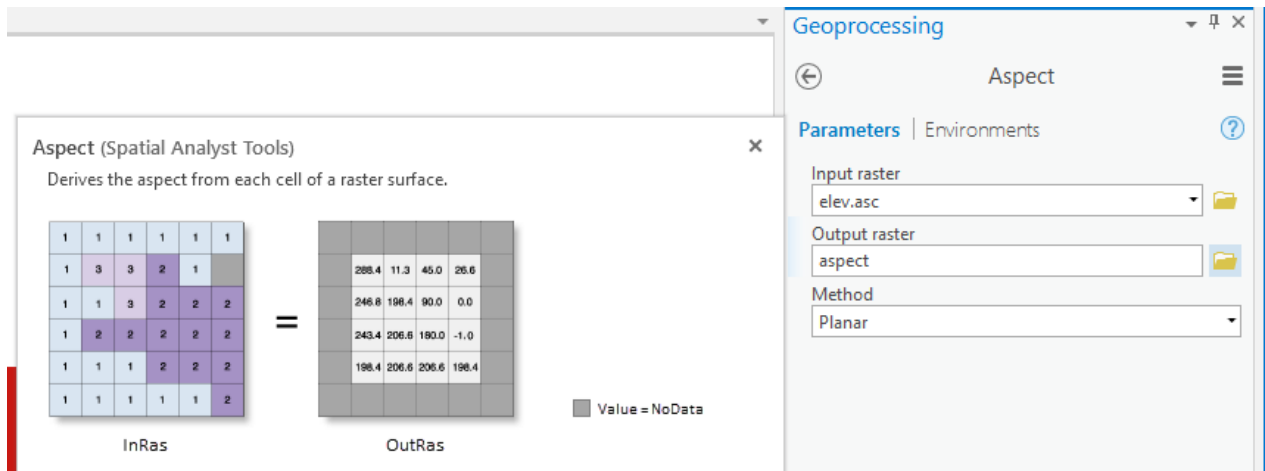
Select **elev.asc** as the input raster and specify names for the output raster (e.g. **slope**). Note that the extension you put on an output raster name designates its type. (e.g. no extension for an ESRI grid, .tif for a geotiff file, .img for an Image file). Note that ESRI GRID file names outside of Geodatabases cannot exceed 13 characters. Set the Output measurement to **PERCENT\_RISE** and leave the Z factor at **1** and method as Planar. Click **Run**.

The resulting Slope grid should be added to the display. Click on the raster to verify your hand calculation for grid cell A and note the value of slope for grid cell B.

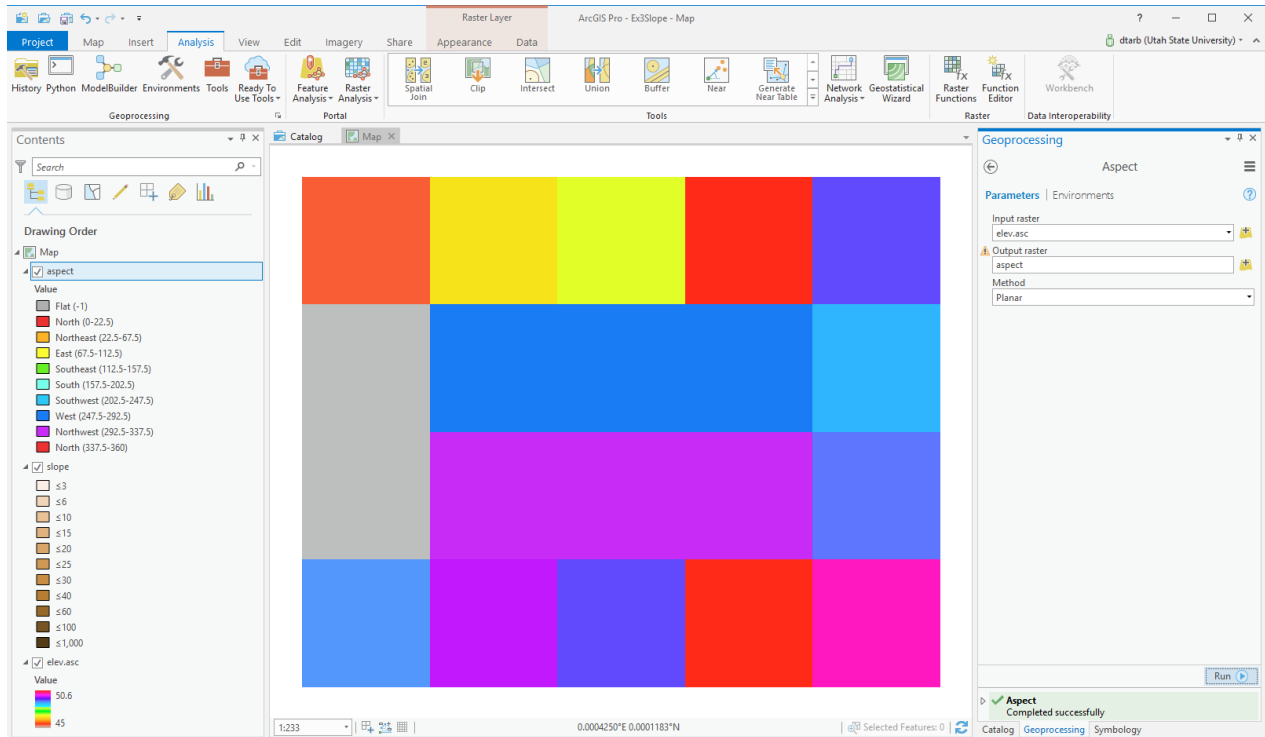


Note also that slope was not computed for the edge cells due to insufficient information.

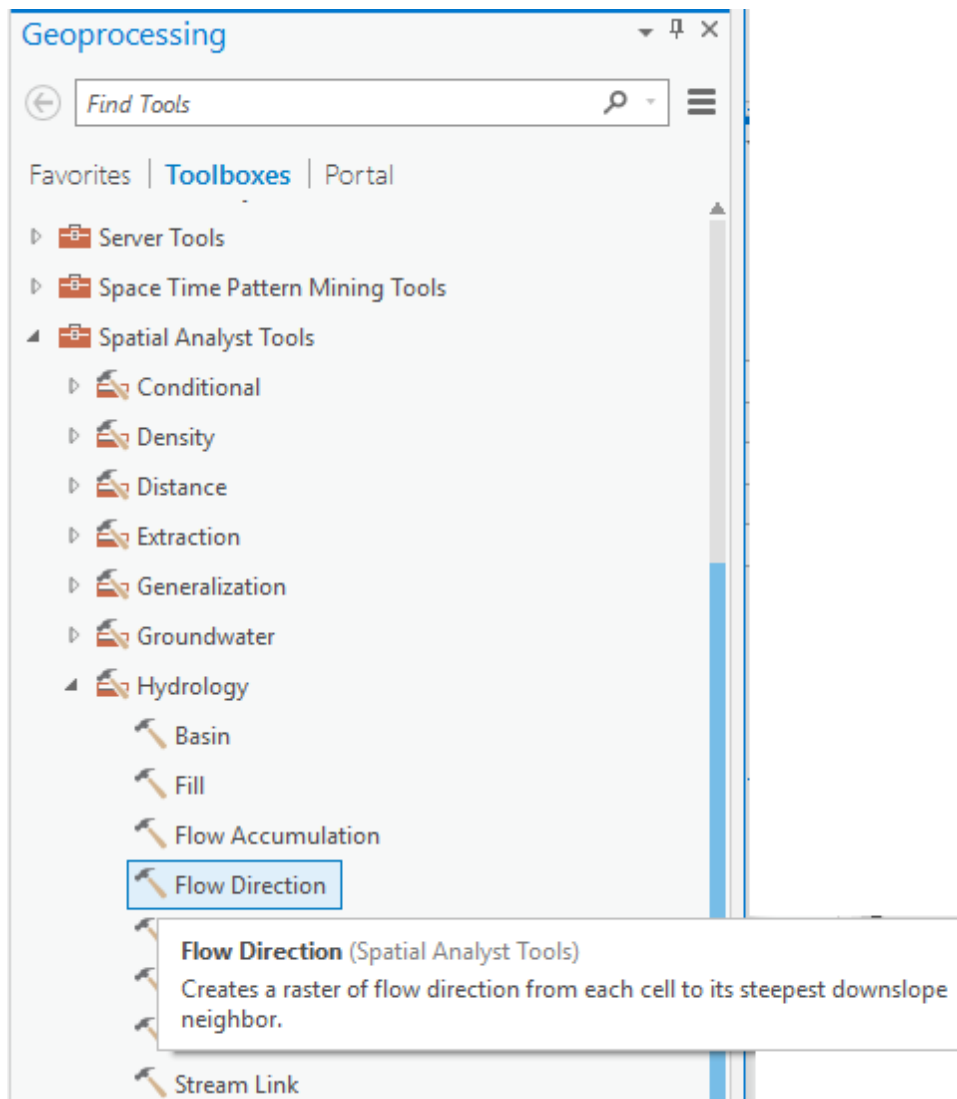
Open the tool **Spatial Analyst Tools** → **Surface** → **Aspect**. Select **elev.asc** as the Input raster and specify a name for the output raster (e.g. **aspect**). Click **Run**.



The resulting Aspect grid should be computed and added to the display. Click on the raster to verify your hand calculation for grid cell A and note the value of aspect for grid cell B.



Open the tool **Spatial Analyst Tools** → **Hydrology** → **Flow Direction**



Select **elev.asc** as the input raster and specify names for output rasters (e.g. **FlowDir** and **PercDrop**). Leave the Flow direction type as D8. Note that the help explanation that appears when click on the output drop raster field in the dialog box explains that the Output drop raster is really the slope expressed as a percentage. Click **Run**.



**Flow Direction (Spatial Analyst Tools)**

Creates a raster of flow direction from each cell to its downslope neighbor, or neighbors, using D8, Multiple Flow Direction (MFD) or D-Infinity (DINF) methods.

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

Elev\_Ras

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Flow\_Dir

**Geoprocessing**

**Flow Direction**

Parameters | Environments

Input surface raster: elev.asc

Output flow direction raster: FlowDir

Force all edge cells to flow outward

Output drop raster: PercDrop

Flow direction type: D8

**Output drop raster (Optional)**

An optional output drop raster.

The drop raster returns the ratio of the maximum change in elevation from each cell along the direction of flow to the path length between centers of cells, expressed in percentages.

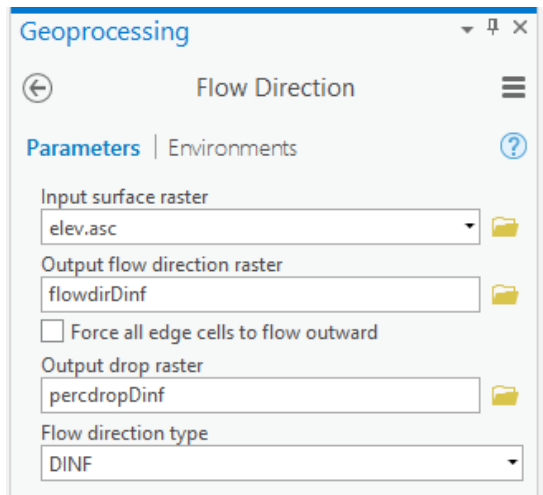
This output is of floating-point type.

Output drop raster: PercDrop

Click on the FlowDir and PercDrop grids that are created to verify that the numbers correspond to the values you calculated by hand; resolve or reconcile any differences. Note that the PercDrop value that the Flow Direction tool reports is different from hand calculations. This is a discrepancy that I have pointed out to ESRI and they acknowledged it is a problem, but have not yet corrected.

Record in a table the ArcGIS calculated flow direction and hydrologic slope (Output drop) at grid cells A and B.

Now set the Flow direction type to DINF in the Flow direction tool, and set different names for Output flow direction raster and Output drop raster, and Run.



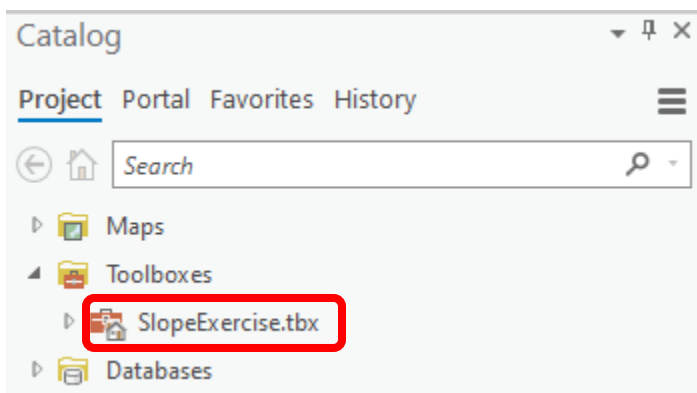
Click on the FlowDirDinf and PercDropDinf grids that are created and record the values at grid cells A and B.

*To turn in: Table giving slope, aspect, hydrologic slope and flow direction at grid cells A and B. For hydrologic slope report results from both D8 and DINF methods. Include in your solution diagrams or sketches that define or indicate what each of these numbers means for the specific values obtained for cells A and B.*

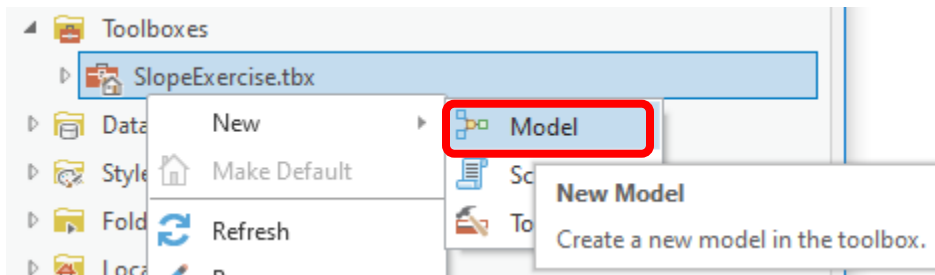
### 3 Automating procedures using ModelBuilder

ModelBuilder provides a convenient way to automate and combine together geoprocessing tools in ArcToolbox. Here we will develop a ModelBuilder tool to automate the importing of the ASCII grid and calculation of Slope, Aspect, Hydrologic Slope and Flow direction.

ArcGIS Pro projects come with toolboxes already created, where you can create new models, scripts, and toolsets. In the **Catalog** panel **Project** tab expand Toolboxes and find the **SlopeExercise** toolbox.

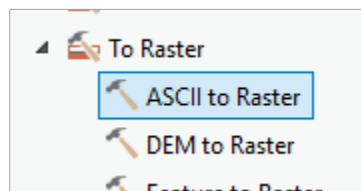


Right-click on **SlopeExercise.tbx** and select **New → Model**.

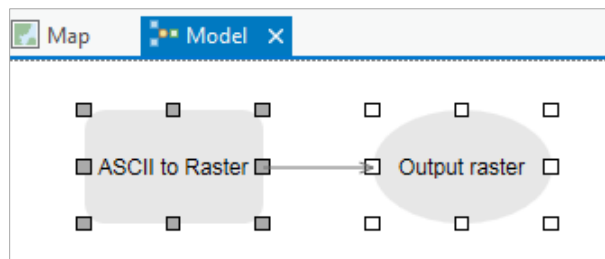


The model window should open in the main part of the display. This is a window where you can drag, drop and link tools in a visual way much like constructing a flow chart.

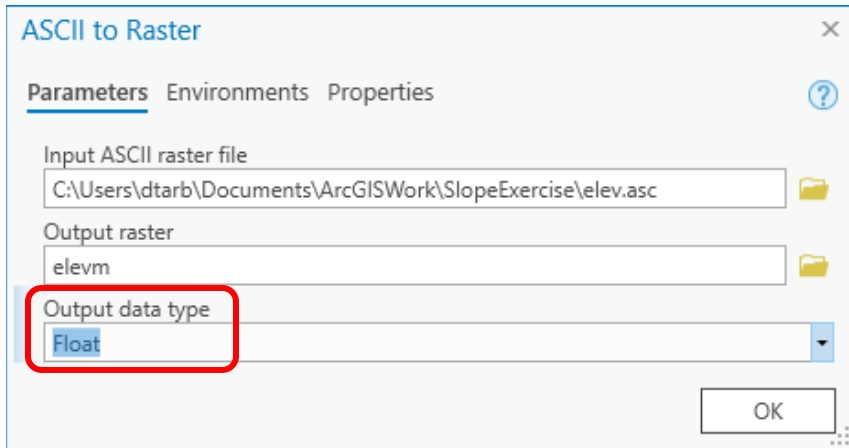
In the **Geoprocessing** panel, browse to **Conversion Tools → To Raster → ASCII to Raster**.



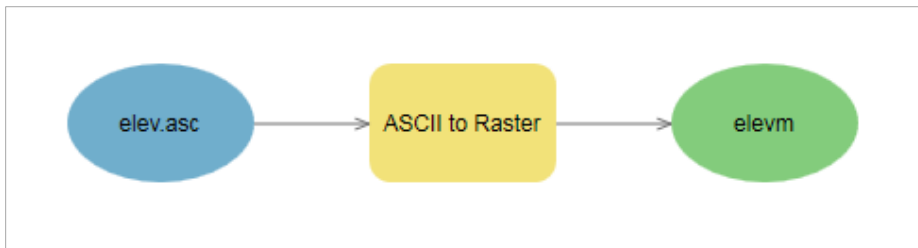
Drag this tool onto the model window (middle of screen). Note that in this model I am choosing to first import the ASCII text file to an ESRI GRID format, rather than work with it in text format. It is faster to work with binary formats like .tif or ESRI GRID.



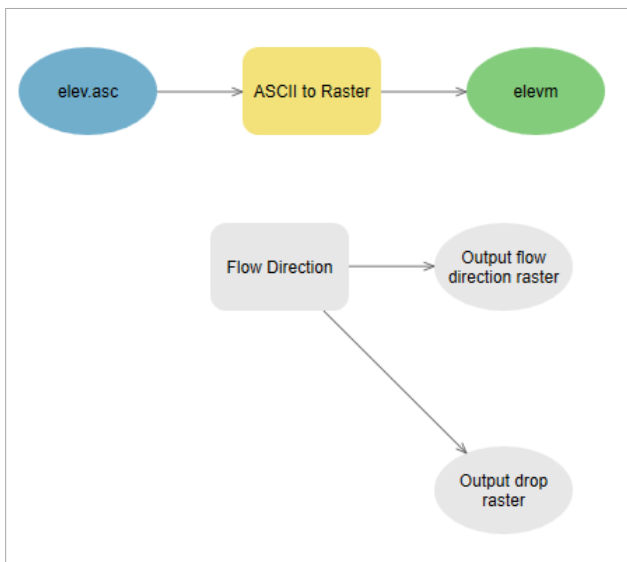
Double click on the **ASCII to Raster** rectangle to set this tool's inputs and outputs.



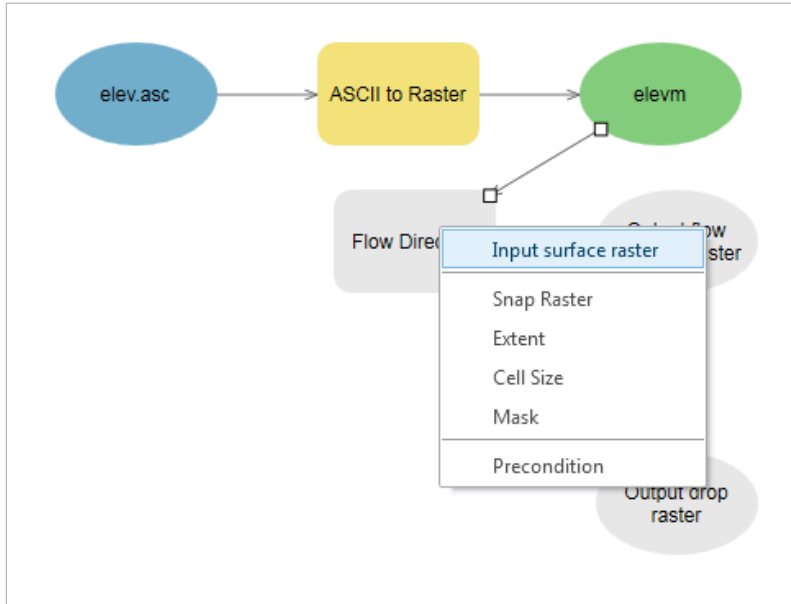
Set the Input ASCII raster file to **elev.asc** and Output raster to **elevm** (I used elevm to indicate this is a result from the model). Set the output data type to be **Float**. Click OK to dismiss this dialog. Note that the model elements on the ModelBuilder palette are now colored indicating that their inputs are complete.



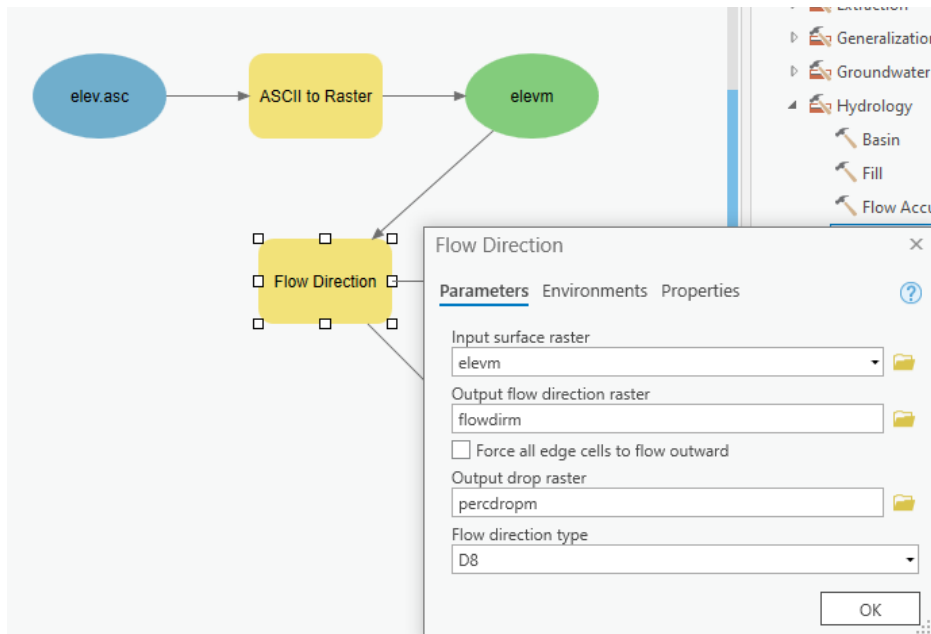
Locate the tool **Spatial Analyst Tools** → **Hydrology** → **Flow Direction** and drag it on to your window. Your window should appear as follows.



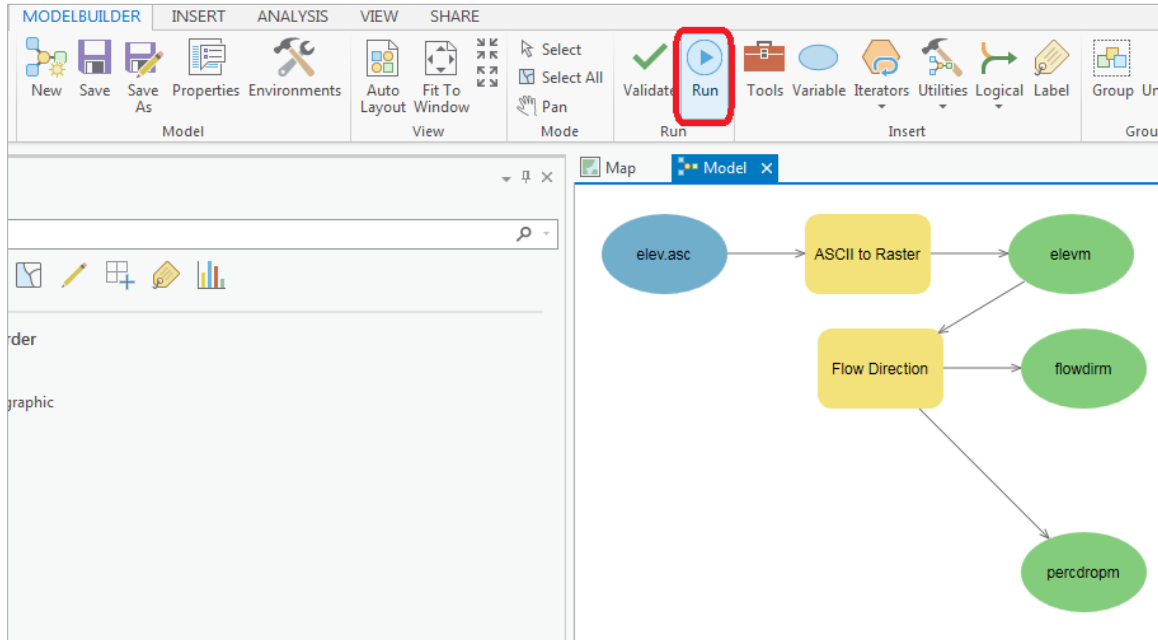
The output from the ASCII to raster function needs to be taken as input to the Flow Direction function. To do this click-and-drag a line from **elevm**, the Output raster of ASCII to Raster, to the **Flow Direction** tool rectangle. At the dialog that pops up select **Input surface raster** to indicate that elevm is to be used as the input Surface raster for the Flow Direction tool. The “m” in these names is to signify that the results are being created from a model rather than by using the tools one by one.



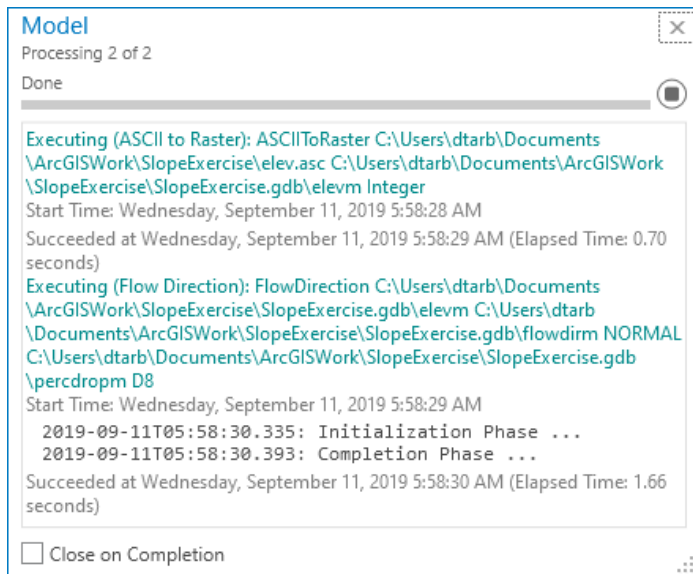
Notice that the "output drop" oval is gray. This is because this is an optional output that has not been specified. Double click on the Flow Direction tool and specify names for both the Output flow direction raster and optional Output drop raster.



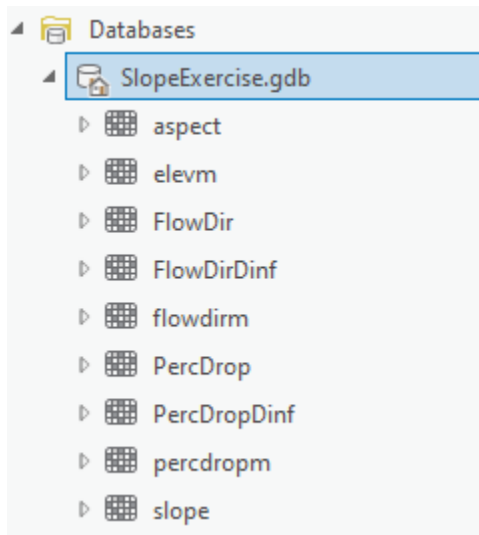
Click OK. Alternatively you could double click on output ovals individually to specify the output rasters. The model is now ready to run. Run the model by clicking the **Run** button in the ModelBuilder tab.



The yellow boxes will briefly flash red as each step is executed. The Model progress box opens and the progress bar indicates when the model completes. Note that ModelBuilder can be a bit finicky, and may take a few runs to work correctly! Also note that, if the ModelBuilder fails midway through (e.g. if the model fails after creating the elevm file), you will either need to re-name any previously computed outputs, or delete them using the Catalog panel.




Verify that your files were created successfully in the **Catalog** pane. You may need to right click and Refresh the SlopeExercise.gdb.

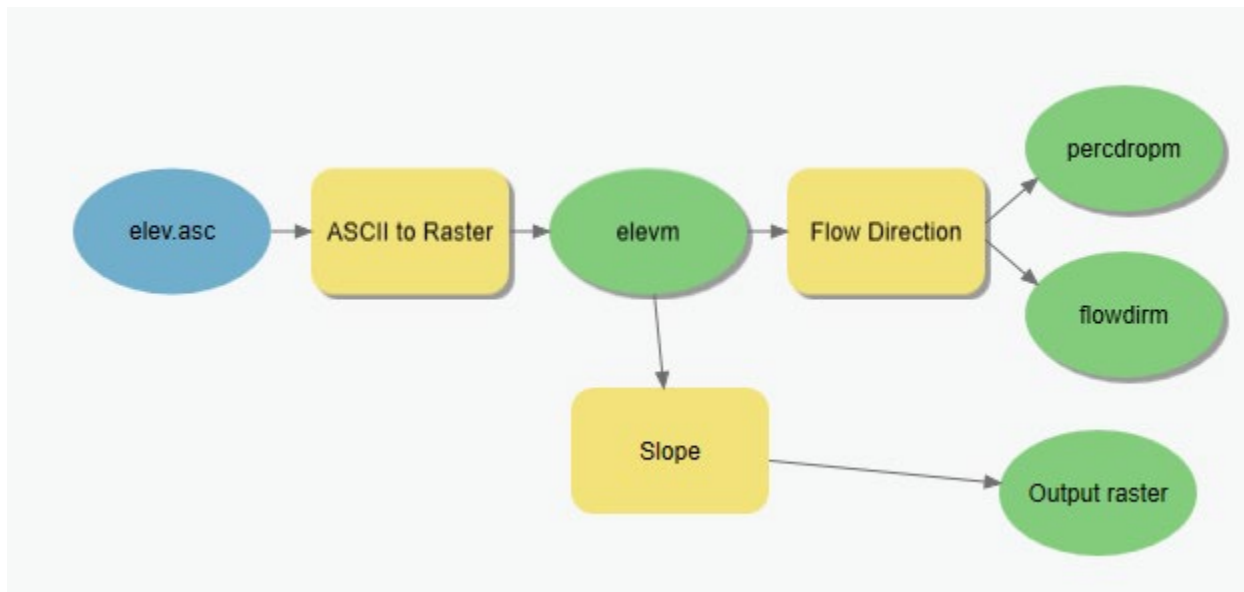


You can now add the outputs to the map and examine the results.

Save your Project to make sure you don't lose what you've done.

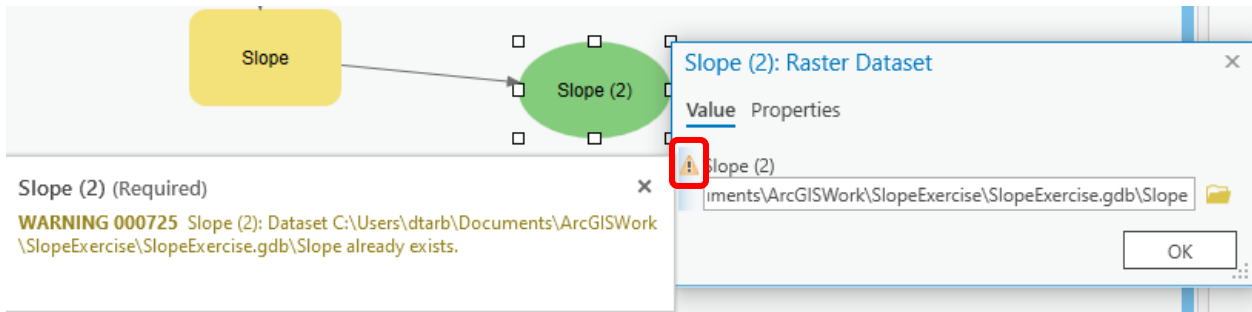
In the model, use the **Auto Layout** tool  in the **ModelBuilder** pane to organize the layout.

Add the **Spatial Analyst** → **Surface** → **Slope** tool to your model by dragging it onto the model window. Connect the elevm output to this tool, specifying that it is the Input Raster for the Slope Tool.

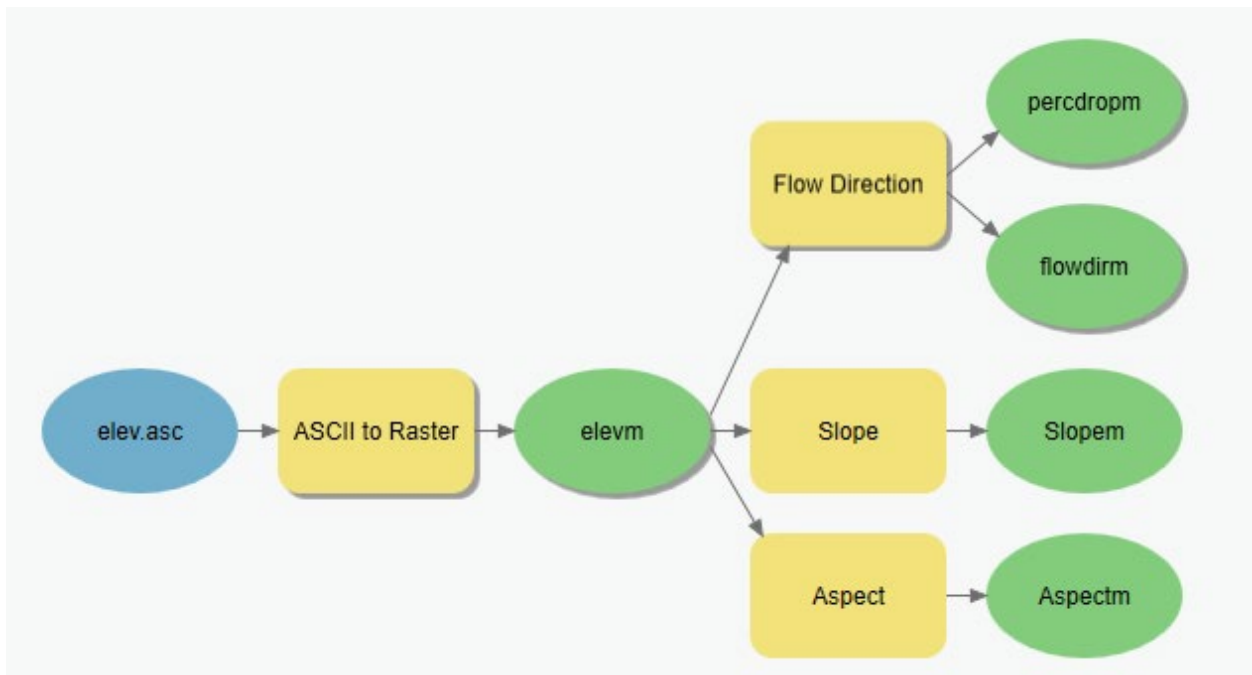


Add the **Spatial Analyst** → **Surface** → **Aspect** tool to your model connecting it to elevm as an input in a similar way. Double click on the Slope and aspect tool outputs and specify file names for the outputs.

When setting names you need to be careful that you do not use a name of a grid that already exists, or else you will get a yellow warning sign in the display as shown below and the model may not run.

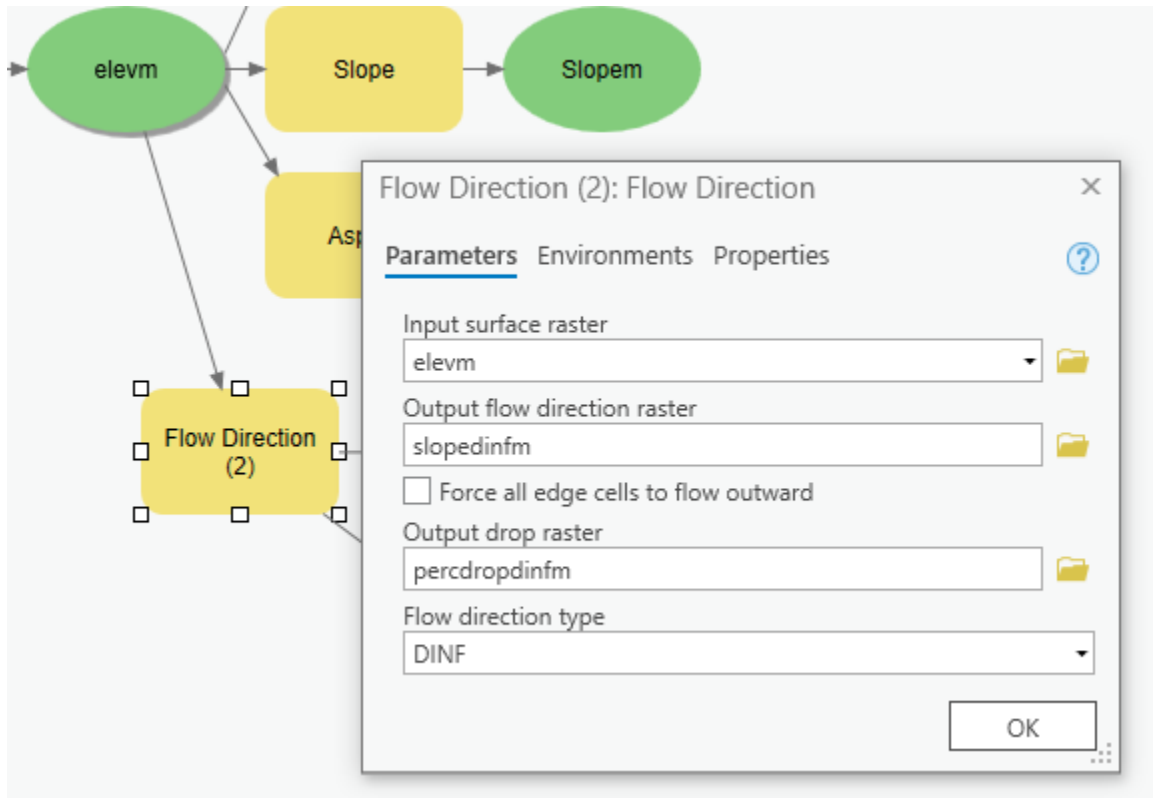


Double click on the Slope tool and set the Output measurement to **Percent\_Rise**. Your model should appear as follows.





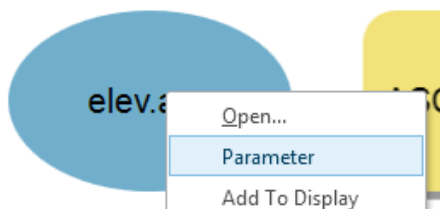
Finally add another copy of the Flow Direction tool to the model connected to take input from elevm and set output flow direction and drop raster filenames. Set the flow direction type as DINF.



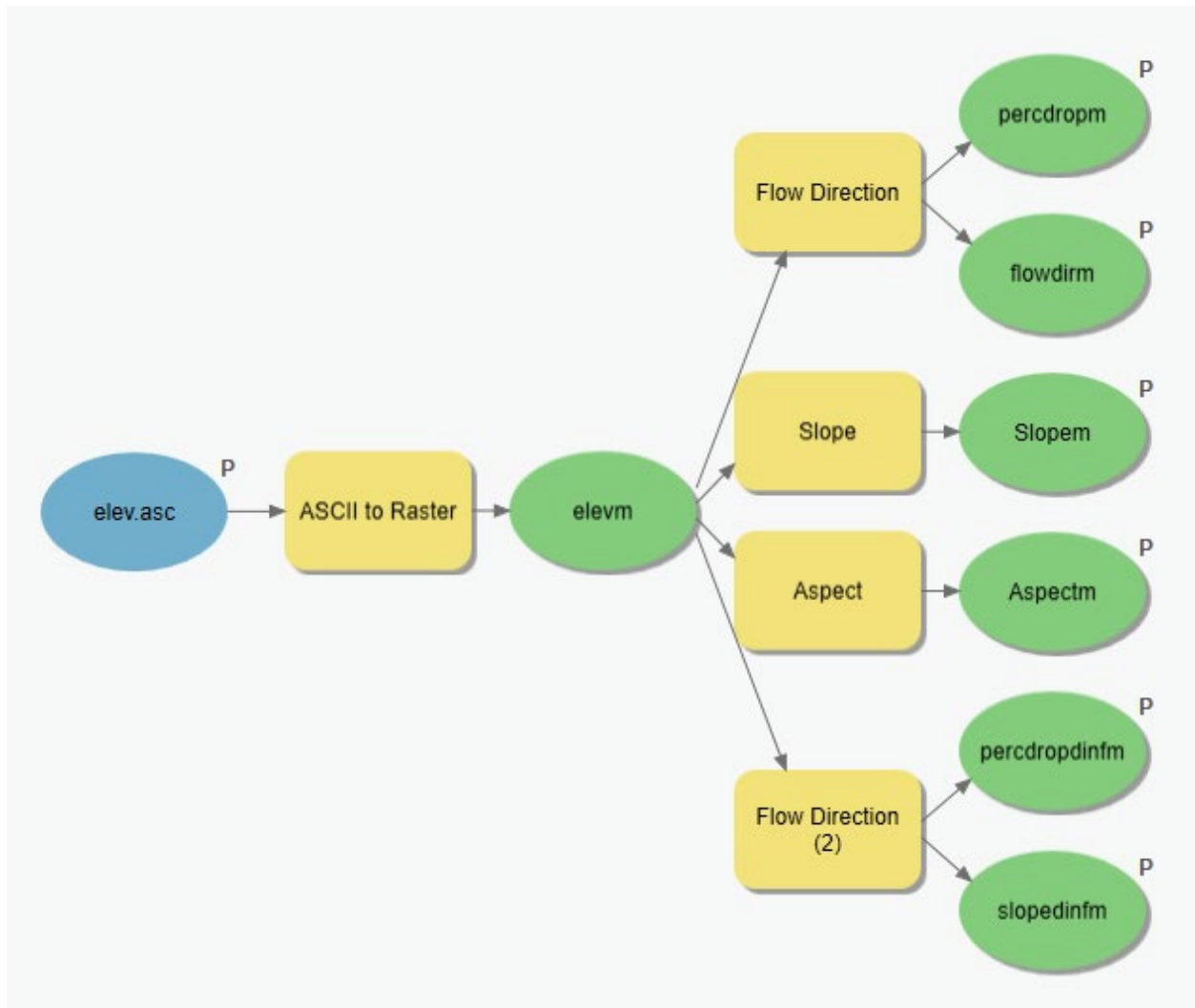
You can now click run and do all the processing required to import the data, compute Slope, Aspect, Flow Direction and Hydrologic Slope at the click of a single button. Pretty slick!

But wait, there is more. You can set the model to take other inputs.

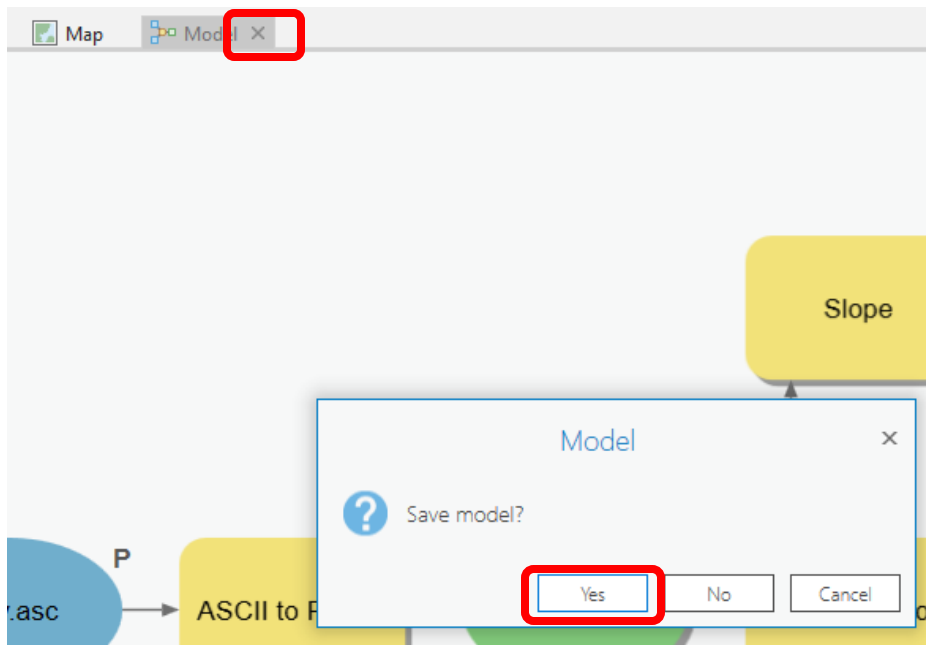
Right click on elev.asc and select Parameter.



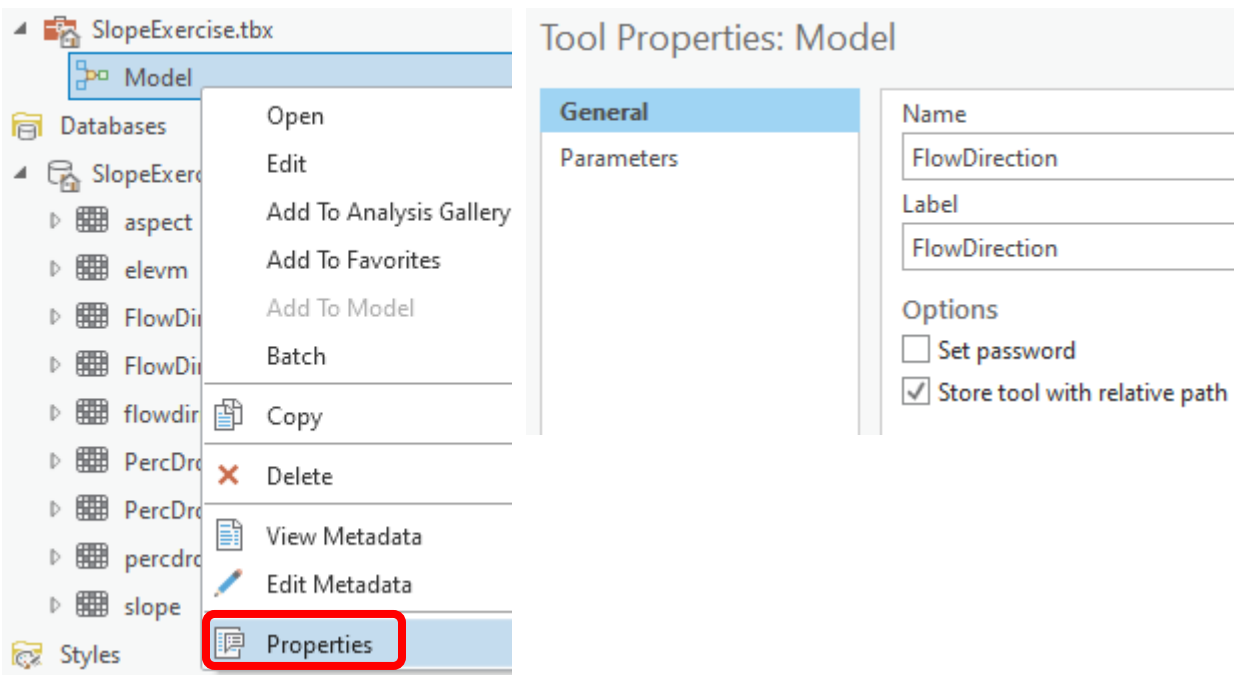
Right click on each of the outputs **flowDirm**, **percdropm**, **slopem**, **aspectm**, **slopedinfmt**, and **percdropdinfm**, in turn and select **Parameter** and **Add to Display**. Also select Parameter for the input file (elev.asc)



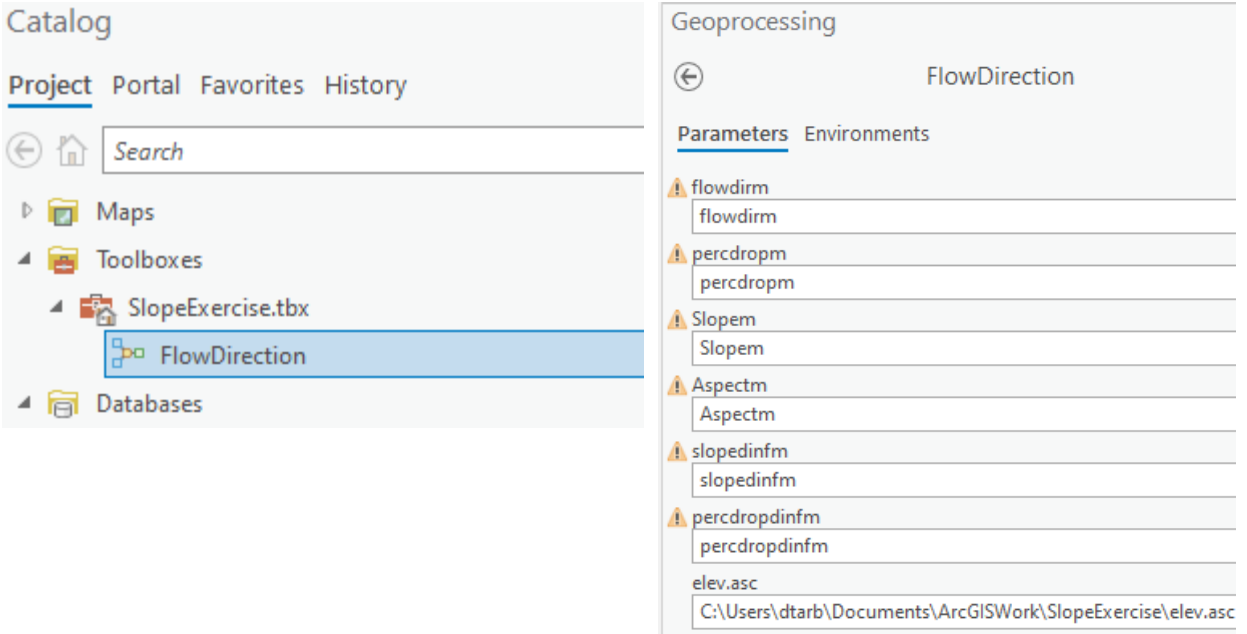
A P now appears next to these elements in the diagram indicating that they are 'parameters' of the model that may be adjusted at run time. Also note that by selecting "Add to Display", the parameters that you previously computed are now on the Map. Close your model clicking on Yes to Save.



Click on the model in the **Catalog** Project window and select **Properties** to rename it something you like (e.g. **FlowDirection**).

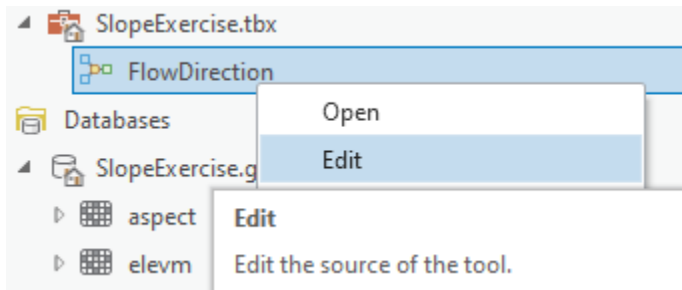


If you go back to your model and now **double click** on it or right-click and **Open** it, you'll see that the input files are shown as parameters of the model just like when you execute a tool in Geoprocessing.



Where you see warnings near one of your files, it usually either means that there is already a file of that name in the place where you propose to put the output, or there is no input file. These can be resolved by setting the inputs and outputs correctly.

If at some point you want to go back and modify your model you should open it to **Edit** and make the changes you want.



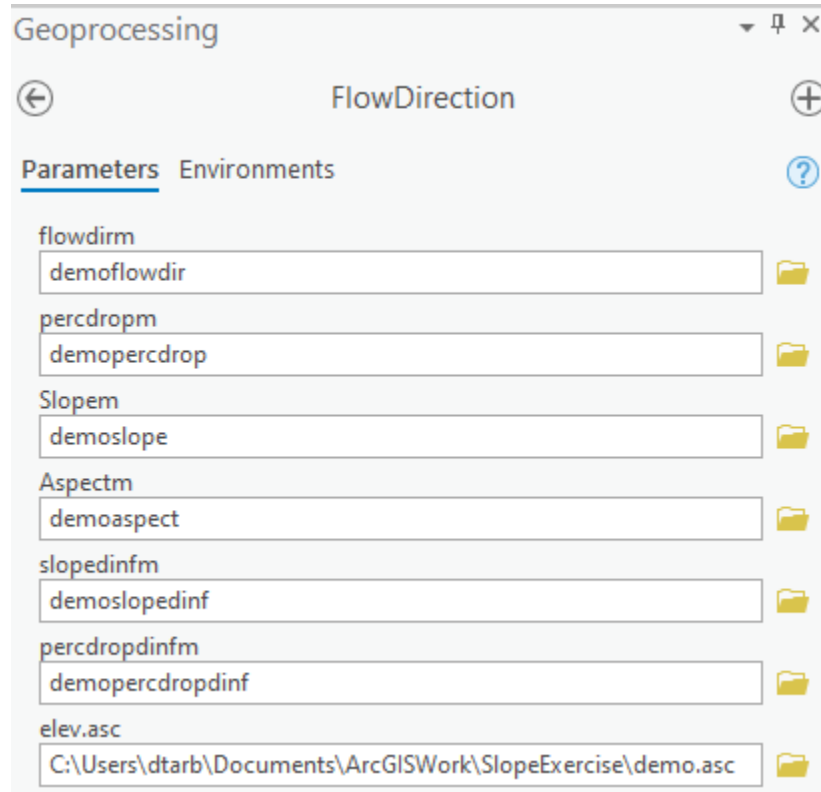
You are done creating this model. Save your Project.

**ModelBuilder** is a very powerful way of creating complex analyses, and documenting your “workflow” in a form that is visual and can readily be described. In this way, analyses that you’ve done can be passed on to other analysts, and you can also use the visual palette display in your term project report or thesis to document how you’ve done your analysis, so the visual aspect of the display helps with documenting your work, as well as in organizing it.

*To turn in: A screen capture of your final model builder model.*

Close ArcGIS Pro.

We will now use this model for different data. Reopen ArcGIS Pro. Close the Map tab and from the Insert tab open a new map. Double click on your **FlowDirection** model in the project toolbox to run it. Locate the file **demo.asc** extracted from the zip file of data provided at the beginning of this exercise to use as input. Set alternative names for the parameter outputs.



Click Run and the model should generate results for each of the outputs and add these to the map. Turn off the topographic basemap because the spatial reference information for this data is not consistent with the web Mercator projection of the basemap. Examine the **Raster Layer Properties > Source > Statistics** and record the minimum and maximum values associated with each of the outputs. If you don't see anything in your screen once this function is complete, right click on one of the new layers produced and select "**Zoom to Layer**" and you'll see the new information show up.

*To turn in: A table giving the minimum and maximum values of each of the six outputs Slope, Aspect, Flow Direction and Hydrologic Slope (Percentage drop) by D8 and Flow Direction and Hydrologic Slope (Percentage drop) by DINF for the digital elevation model in demo.asc.*

*Also turn in a screen shot of the FlowDirDinf raster calculated using this model*

Congratulations, you have just built a Model Builder geoprocessing program and used it to repeat your work for a different (and larger) dataset. If you would like to save this tool to take to another computer or share with someone else you can copy the file SlopeExercise.tbx from its location to a removable media to take with you. If you are going to be sharing this tool more widely there are additional steps to take to clean up the interface, label the input fields and write help documentation for it. Close ArcGIS Pro.

## Summary of Items to be Turned in:

1. *Hand calculations of slope at point A using each of the three methods and comments on the differences.*
2. *Table giving slope, aspect, hydrologic slope and flow direction at grid cells A and B. For hydrologic slope report results from both D8 and DINF methods. Include in your solution diagrams or sketches that define or indicate what each of these numbers means for the specific values obtained for cells A and B.*
3. *A screen capture of your final model builder model.*
4. *A table giving the minimum and maximum values of each of the six outputs Slope, Aspect, Flow Direction and Hydrologic Slope (Percentage drop) by D8 and Flow Direction and Hydrologic Slope (Percentage drop) by DINF for the digital elevation model in demo.asc.*
5. *A screen shot of the FlowDirDinf raster calculated using this model*