Exercise 5. Building ArcGIS Tools using Python

GIS in Water Resources, Fall 2014

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Purpose

The purpose of this exercise is to illustrate how to build ArcGIS tools using the Python programming language. Python is included with ArcGIS. This exercise will guide you through the processes of collecting data via ArcGIS services, creating and running an ArcGIS Python script and creating a model builder tool interface for the script. The purpose of the ArcGIS tool is to provide you with an example of how to manipulate shapefiles, iterate over raster datasets, execute native ArcGIS tools, as well as define ArcGIS tool parameters. Overall, it will provide guidance on how to build your own ArcGIS tool. The tool outlined in this exercise will trace a user-defined point downstream until it hits a watershed outlet.

Learning Objectives

- To be able to create and run a python script using ArcGIS functions in the arcpy library
- To be able to configure a user interface for an ArcGIS python script
- To be able to split a problem into individual steps and program these steps into a Python script that executes them in sequence to solve the problem

Computer and Data Requirements

To carry out this exercise, you need to have a computer that runs ArcGIS 10.2 or higher and includes the Spatial Analyst extension. No data is required to start this exercise. All the necessary data will be extracted from ArcGIS.com services. To use these services you need an ArcGIS.com account that has been linked to an ArcGIS license.

This exercise is divided into the following activities:

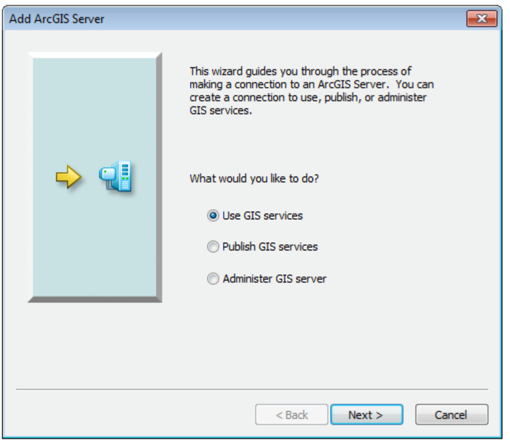
1. Data Collection
2. Developing a python script
3. Developing a toolbox interface for a python script

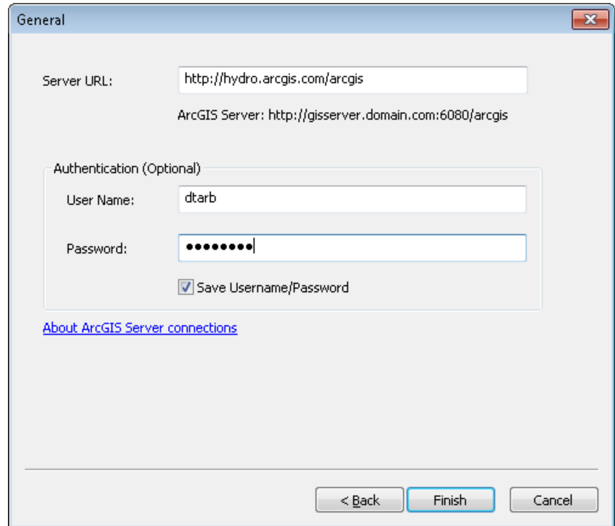
Part 1: Data Collection

This section of the exercise uses ArcGIS.com tools to delineate a watershed and extract the DEM as you have done in previous exercises. This gets us the data for using in the model building and python scripting part that follows

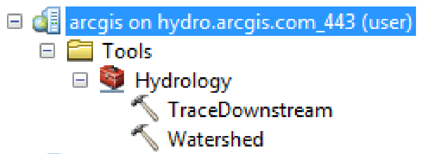
Open ArcMap.

Connect to the ArcGIS hydrology server http://hydro.arcgis.com/arcgis. We will use this to delineate a watershed.

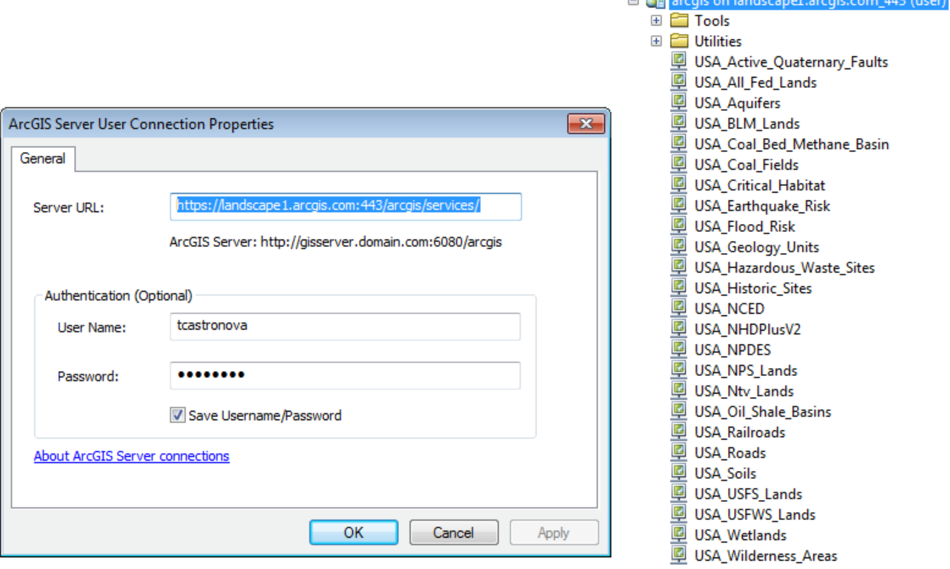




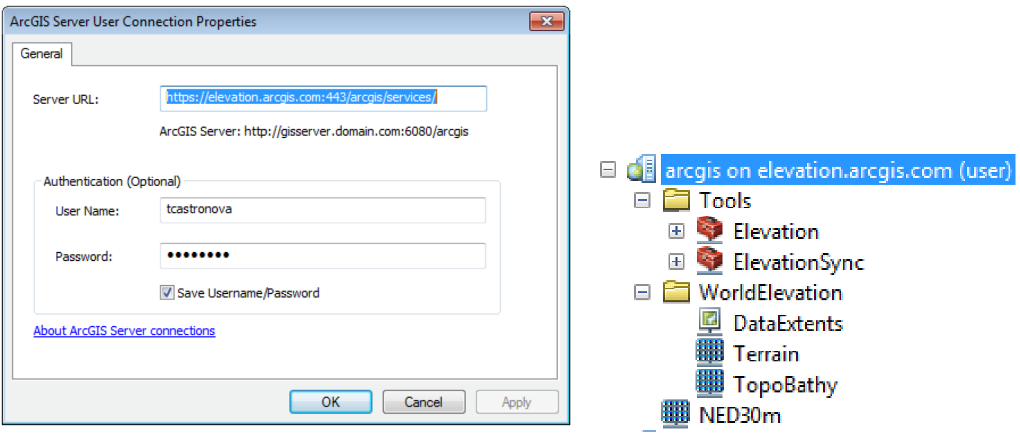
If added correctly, you should see the following tools listed in ArcCatalog.



Next, add a connection to the ArcGIS landscape1 server. We will use this web service to download and visualize National Hydrography Dataset (version 2) rivers. Use https://landscape1.arcgis.com/arcgis/services as the URL. If added correctly, you will see long list of datasets under the landscape1 service in ArcCatalog.

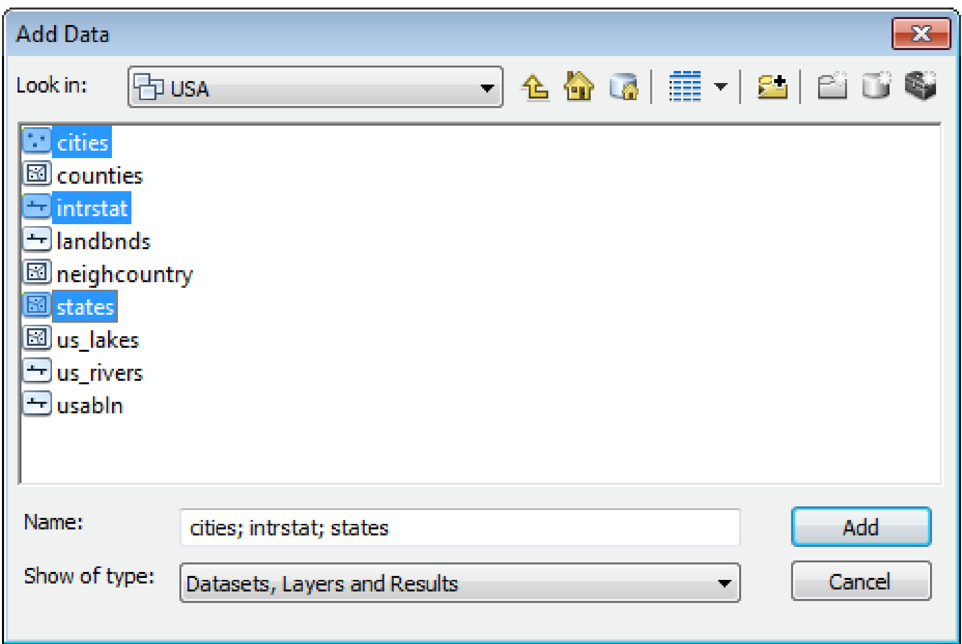


Finally, connect to the ArcGIS elevation web service. This will be used to downloading elevation data for the exercise. Use http://elevation.arcgis.com/arcgis/services as the URL. If added correctly, you will see a short list of tools and data available under the elevation service in ArcCatalog.

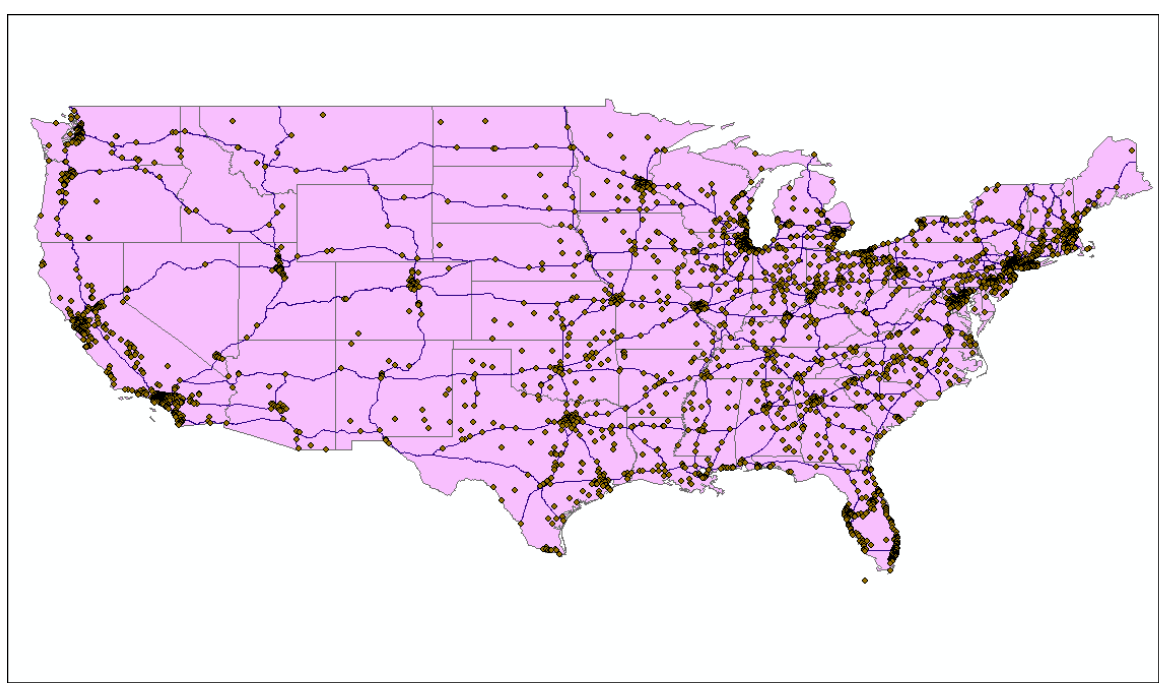


Add some template data so that we can zoom into the location that we would like to download data. Select the **Add Data** button:

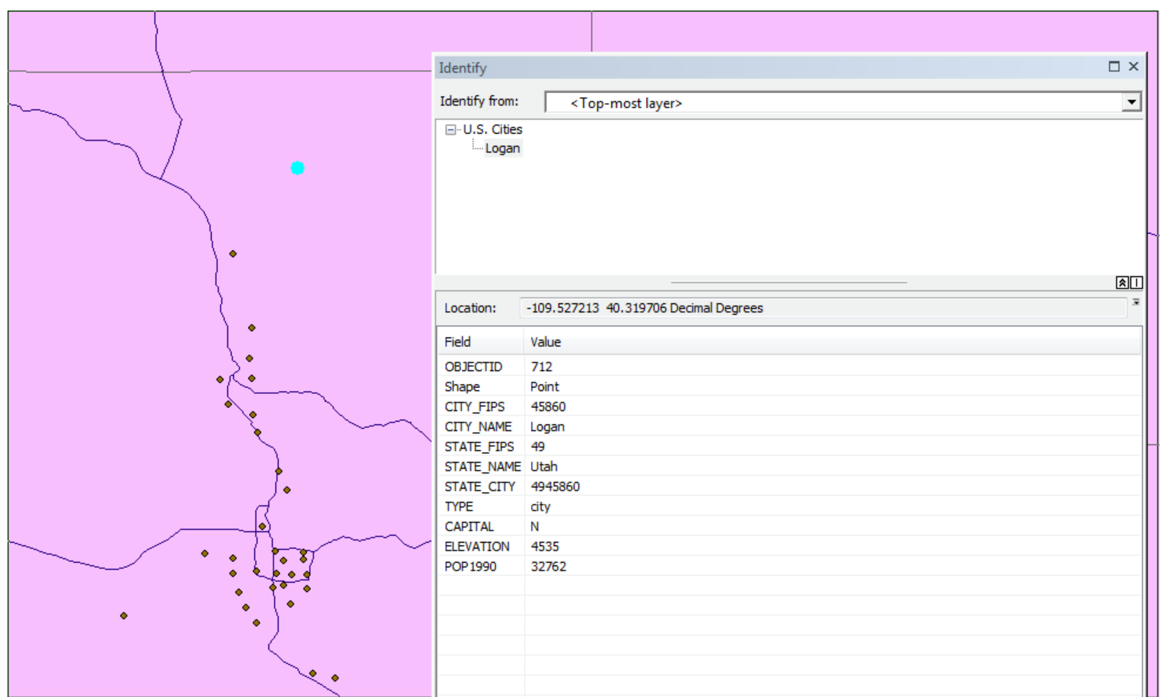
Navigate to the ArcGIS template data directory (C:\Program Files (x86)\ArcGIS\Desktop10.2\TemplateData\TemplateData.gdb\USA) and add US cities, interstates, and states.



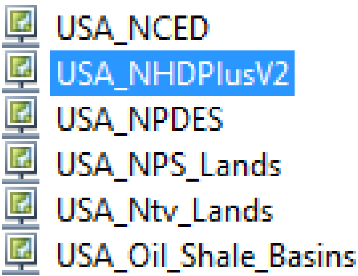
The map should now look like this:



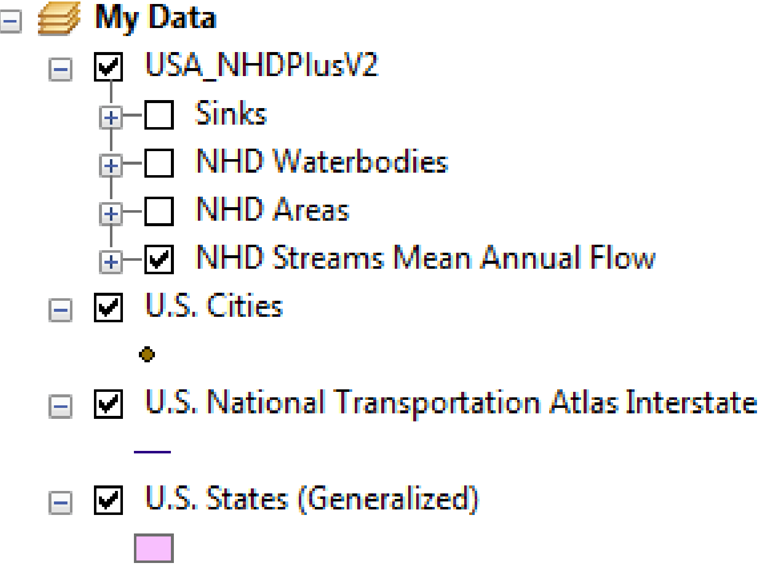
Zoom into Logan, UT. Use the **Identify** tool to determine which of these dots is Logan. This will give us an idea of where we are, before we start loading ArcGIS web service datasets.



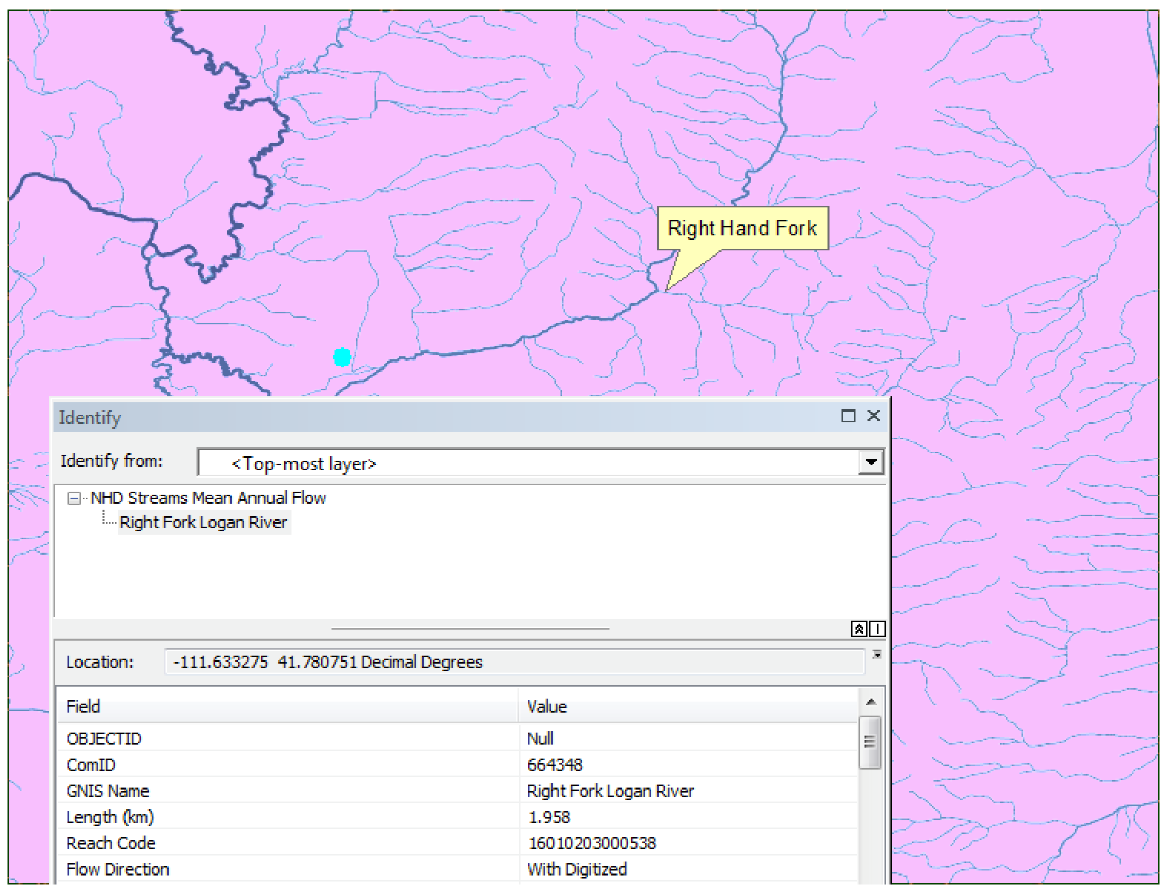
Add the NHDPlus (version 2) data set from the landscape1.arcgis.com web service.



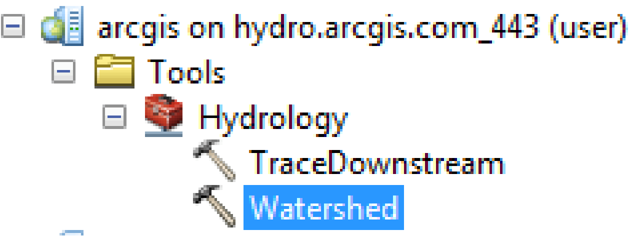
We are only interested in the stream data, so turn off all NHD layers except Streams. This will help speed up the data load time. The layers in your table of contents should look like this:



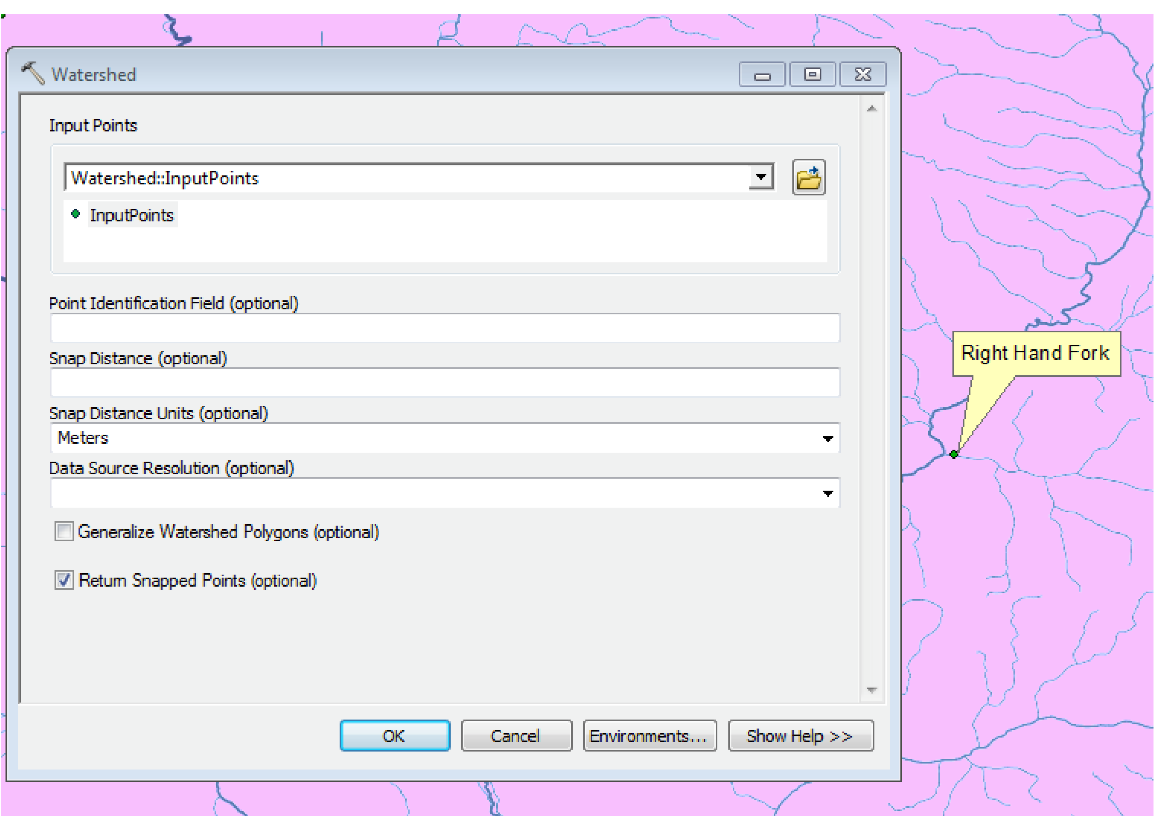
Now that we have the NHD rivers loaded, we can zoom into Right Hand Fork.



To delineate a watershed at Right Hand Fork, we will use the ArcGIS online watershed delineation tool. Double click on the ArcGIS server watershed tool.

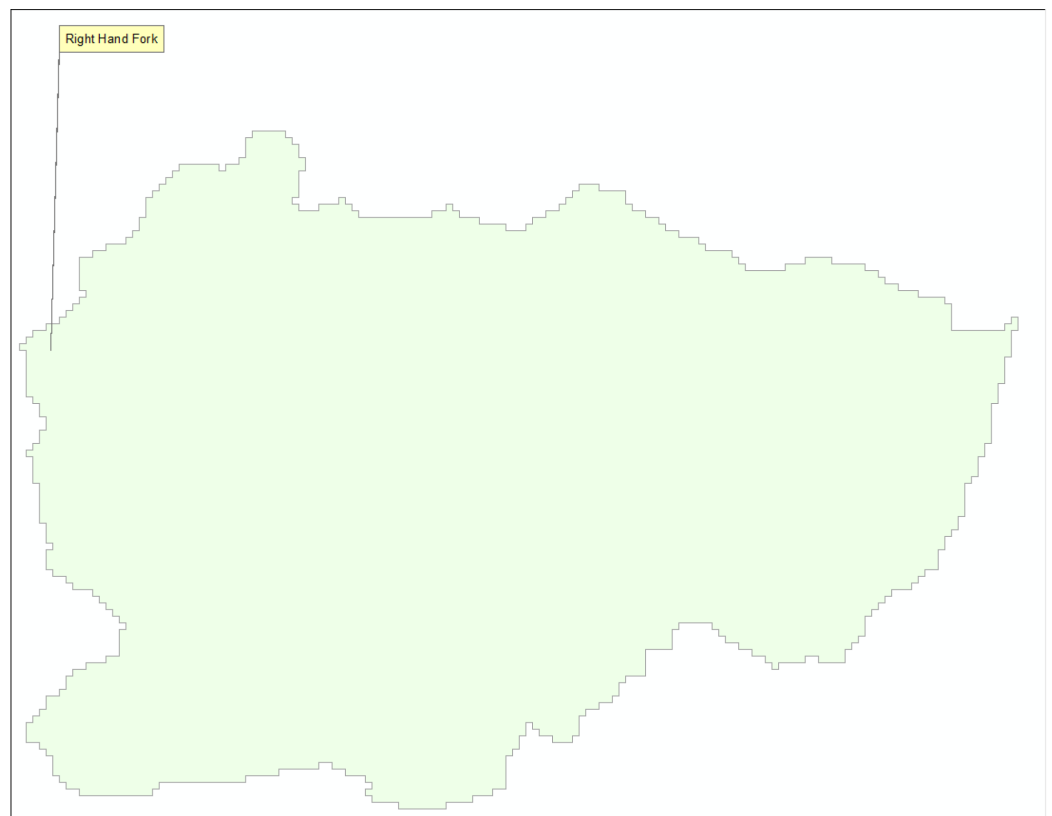


Select an input point near the outlet of Right Hand Fork (see green dot on map). Don't get too close to the Logan river (downstream), or the delineation tool will snap the outlet to the wrong reach. To ensure that this does not happen, you may have to adjust the snap distance (try 100 meters)

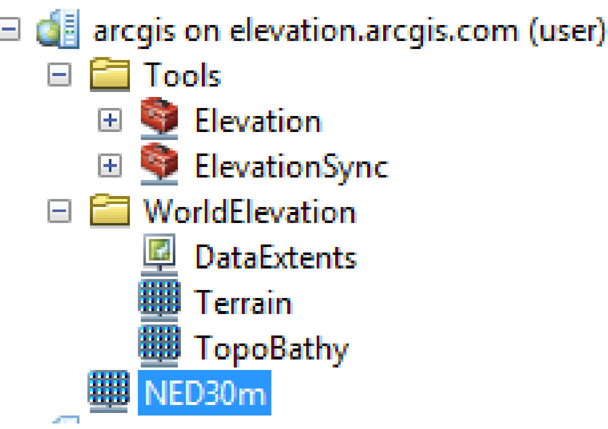


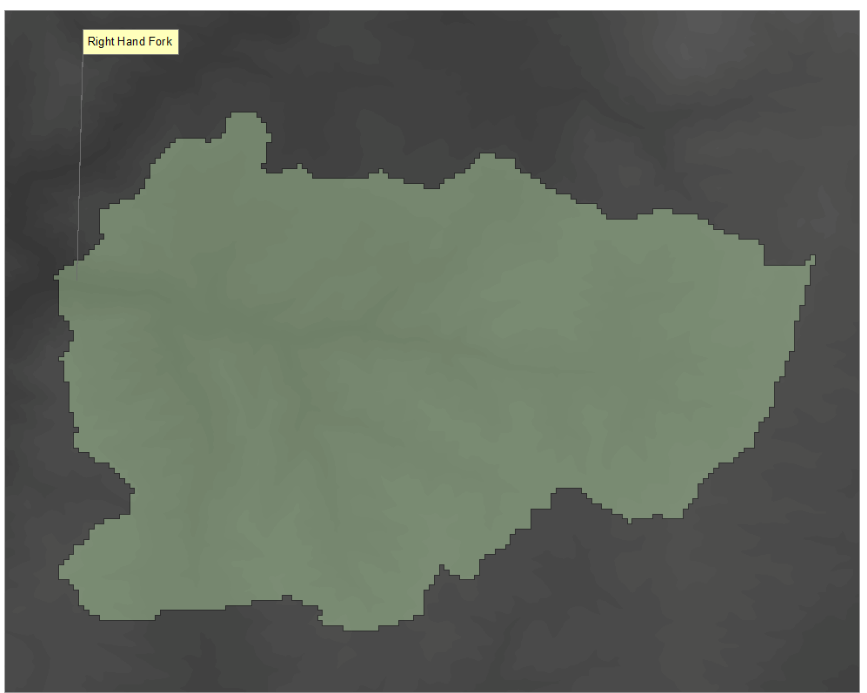
This operation will result in the Right Hand Fork watershed. Go ahead and turn off all unnecessary layers and change the watershed color to something more meaningful. Export the in-memory watershed data to create a new shapefile, called watershed.shp.

We will use this new watershed.shp file in the following step to extract elevation data over the watershed.

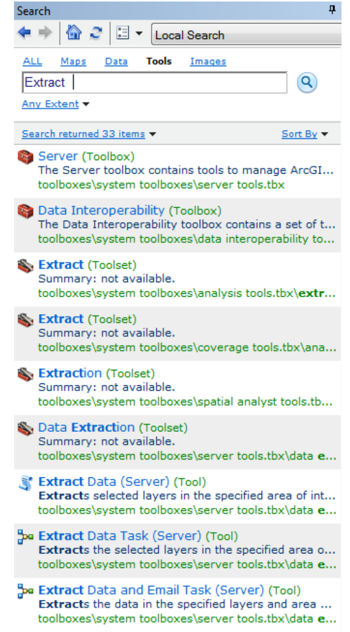


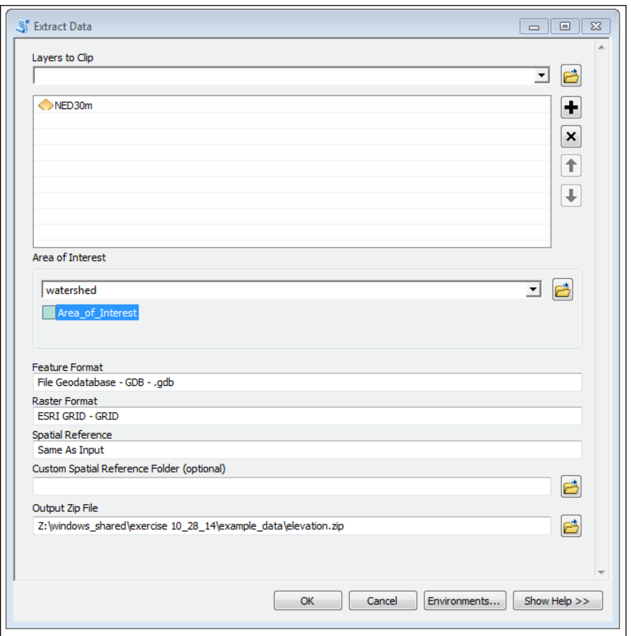
Add NED30m elevation from the elevation.arcgis.com server.





Next we want to extract the elevation data within the boundary of our watershed. This will make future data processing faster since we will be using a small subset of the national elevation dataset. In addition, this file will be stored locally so we won't need an Internet connection to perform our processing tasks. To do this, open the search menu and enter "Extract". Make sure to choose the search by "Tools" option above the search textbox. This will limit the search results ArcGIS tools. Since we are dealing with elevation data from an ArcGIS server, we want to select the "Extract Data (server)" tool.

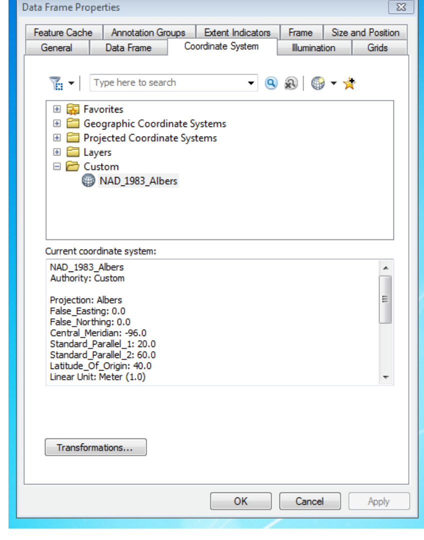


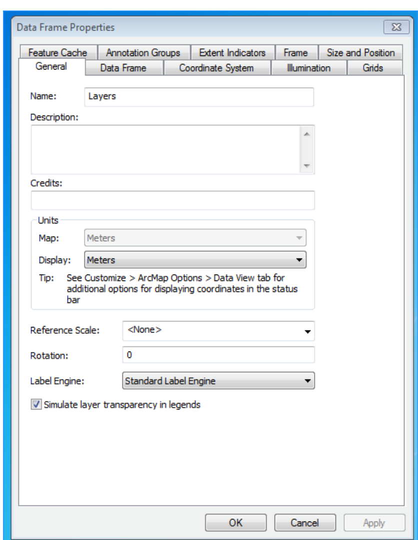


Select the NED 30m elevation raster as the layer to clip. The Area of Interest that will be used to extract the data (i.e. cookie cutter) should be the watershed that you delineated in previous steps. Leave the default options for Feature Format, Raster Format, Spatial Reference, and Custom Spatial Reference Folder. Specify an output ZIP file where the extracted data will be saved.

Open Windows Explorer and navigate to the directory of your output ZIP. Extract the contents, and you should now have an elevation dataset that covers only the watershed area.

This is a good time to change the projection of our data frame to match the coordinate system of this elevation data. Also be sure to change the map units to be consistent with the units of the coordinate system.





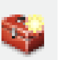
Part 2: Developing a python script

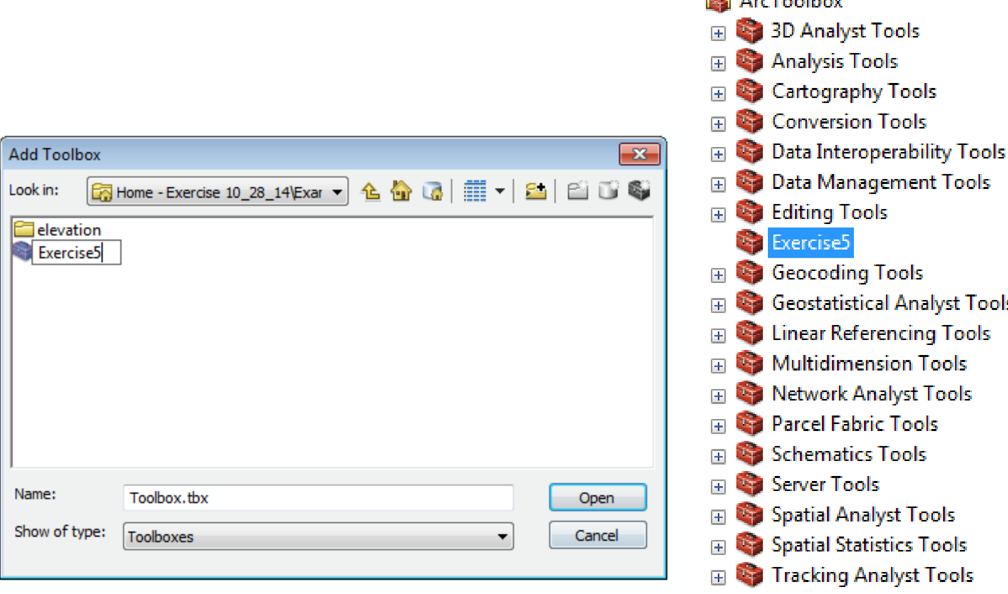
The goal of our scripting tool is to trace any point within the watershed downstream to the watershed outlet. This can later be modified to provide statistics regarding the flow path. This example will demonstrate (1) how ArcGIS tools can be used to create a custom model, (2) how to include custom data processing and functionality, and (3) how to build the ArcGIS tool interface for a custom tool.

An effective way to learn programming is by example. ArcGIS models built using model builder can be exported as python scripts that serve as examples that show how ArcGIS functions are used in python. The exported file also serves as a template for you to edit to develop the tool you want to use. The strategy will be to

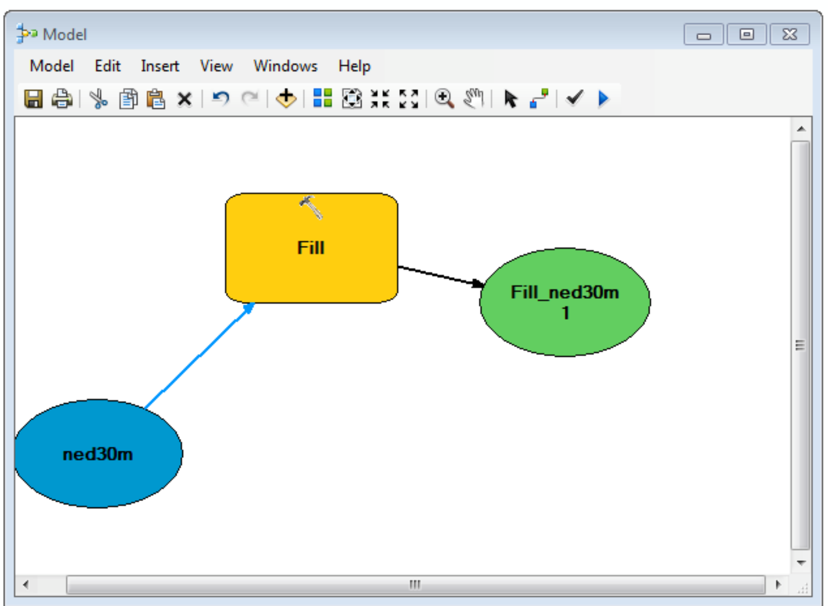
(1) create a model using model builder
(2) export it as a python script
(3) set the inputs and outputs and run the script
(4) make incremental changes to the script running after each change to ensure that the script still works

Note that developing Python scripts for ArcGIS is hard and sometimes you encounter errors that appear insurmountable. If this should happen to you do not waste too much time on this. A complete set of scripts from this exercise have been posted in http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2014/Ex5Scripts.zip. These are named trace1.py, trace2.py … up to trace5.py then the final script is trace.py. The exercise below has check points and indicates which script applies for work up to that point. If you get stuck feel free to go to the next check point and start with the corresponding script and move on. The questions at the end can be done with small changes to the final script trace.py.

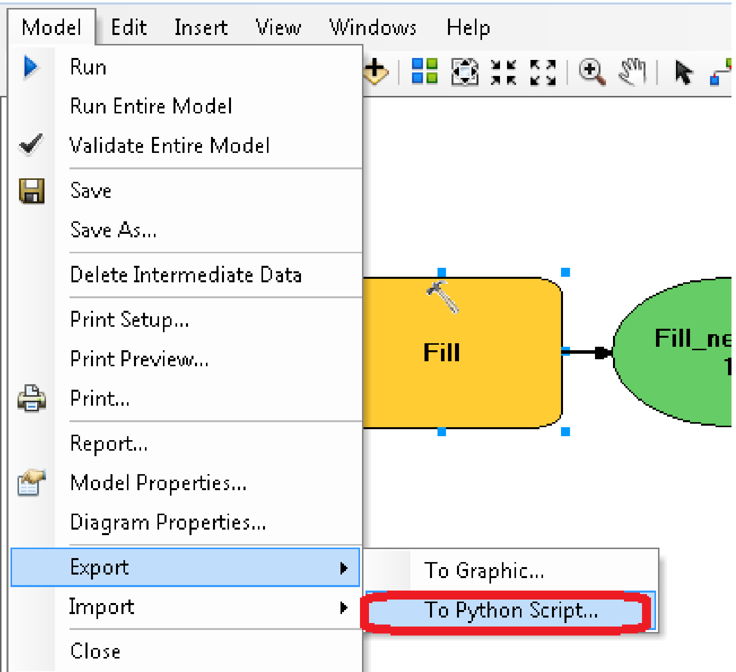
Activate the ArcToolbox by clicking . Create a new toolbox by right clicking inside the window and selecting Add Toolbox from the context menu. This will open a dialog for you to search for an existing toolbox. Instead, navigate to any directory that you like and select the create New Toolbox button in the top right corner .



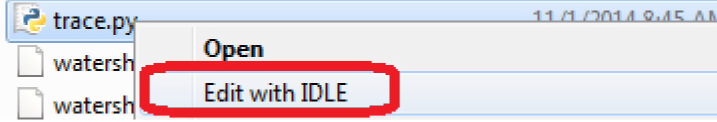
After creating your toolbox (i.e. Exercise 5), right click on it and select New -> Model. You will end up with an empty model. Drag and drop the Fill tool onto the canvas, along with the clipped elevation raster.



From the menu, select Model -> Export -> To Python Script and save the script with the name trace.py. (Named trace.py because that is the ultimate goal of our work)



Close the ArcMap model. From the Windows Explorer open the exported Python file to view the code that was written for us by ArcGIS. We can do this using the IDLE application by simple right clicking on the file and selecting "**Edit with IDLE**."



You should see the following Python Idle editing window.

trace.py - C:\Users\dtarb\Desktop\Ex5\trace.py

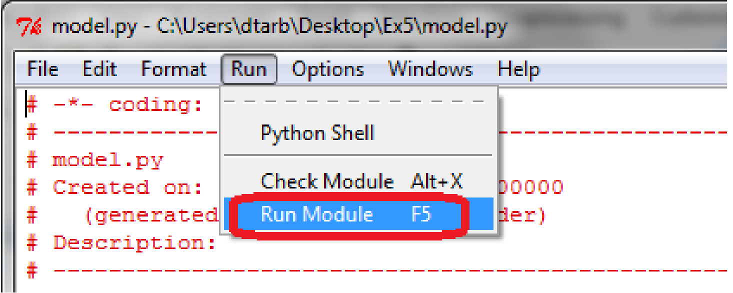
File Edit Format Run Options Windows Help

```
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# trace.py
# Created on: 2014-11-01 08:45:34.00000
#   (generated by ArcGIS/ModelBuilder)
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")


# Local variables:
ned30m = "C:\\Users\\dtarb\\Desktop\\Ex5\\ned30m"
Fill_ned30m2 = "C:\\Users\\dtarb\\Documents\\ArcGIS\\Default.gdb\\Fill_ned30m2"

# Process: Fill
arcpy.gp.Fill_sa(ned30m, Fill_ned30m2, "")
```

Ln: 1 Col: 0

Although cryptic to a reader new to Python this is readable. Comment lines are preceded by # and are not run. You can see the line to import the arcpy library that tells the script to use ArcGIS functions. Then there is the line to use the spatial analyst extension, two lines to specify the input variables. These are files on your disk. Then there is the command to run the Fill function.

Lets run this script. Select Run -> Run Module



The Python Shell should open and your script will run. There is no output from this script to the shell so your only indication that it is done is the appearance of the third >>> prompt.

```
Python 2.7.5 Shell
File Edit Shell Debug Options Windows Help
Python 2.7.5 (default, May 15 2013, 22:43:36) [MSC v.1500 32 bit (Intel)] on w
32
Type "copyright", "credits" or "license()" for more information.
>>> ================================ RESTART ================================
>>>
>>>
```

Note the following lines in the script.

```
# Local variables:
ned30m = "C:\\Users\\dtarb\\Desktop\\Ex5\\ned30m"
Fill_ned30m2 = "C:\\Users\\dtarb\\Documents\\ArcGIS\\Default.gdb\\Fill_ned30m2"

# Process: Fill
arcpy.gp.Fill_sa(ned30m, Fill_ned30m2, "")
```

These define ned30m and Fill_ned30m2 as variables with values to the right. Then the line below executes the Fill function with these as input and output. If your script ran correctly you can look in the destination location "C:\users\dtarb\Documents\ArcGIS\Default.gdb" above and see the result.

You may get an error due to input files not being correct. If you get the error do not worry about it as our next step will be to change the location of inputs and outputs.

Note that in Python \ is an "escape" character so to get folder paths that include it you need double \\. Alternatively you can use "/".

Now lets modify this code so that the variable names and files used make a bit more sense

Change the file to the following and rerun it

Note the F5 shortcut for running this script that is handy as you will be doing this a lot. Click OK when prompted to save the file.

Note that now the output file "Fill" is produced in the folder you have designated and that the script prints 'done' when it is finished. Congratulations! You have just modified a script and been able to execute it. This is a small but important step as it establishes your capability to change and execute ArcGIS functions from a script file. You are now programming and limited only by your creativity in the programming lines you can write.

The script to this point is trace1.py in http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2014/Ex5Scripts.zip.

Now lets edit the code to add additional functionality as follows. This imports **numpy**, **math, json,** and **os** libraries that we will need later as well as **env** and **sa** classes from the **arcpy** library.

```
print 'importing arcpy (this takes a while)...'
# Import arcpy module
import arcpy
from arcpy import env
from arcpy.sa import *
import numpy
import math
import json
import os

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
env.overwriteOutput=True
# This allows the code to overwrite results - handy while developing

# Local variables:  (CHANGE THESE TO PATHS ON YOUR COMPUTER)
elevation = "C:/Users/dtarb/Desktop/Ex5/ned30m"
fill_outpath = "C:/Users/dtarb/Desktop/Ex5/Fill"

# Process: Fill
print 'Run Fill!'
#arcpy.gp.Fill_sa(elevation, fill_outpath, "")
outFill = Fill(elevation,"")
# The Fill class function that returns an object that can be used later
outFill.save(fill_outpath)

print 'done'
```

Run this code and see what kind of output we get. If the script ran successfully, we should have a new raster called **fill** that can be opened in ArcMap. Note: the original script used the **gp.Fill_sa** tool whereas the documentation states that we should use the **arcpy.sa.Fill** tool. If you encounter this, I suggest that you use the tools outlined in the ArcGIS documentation.

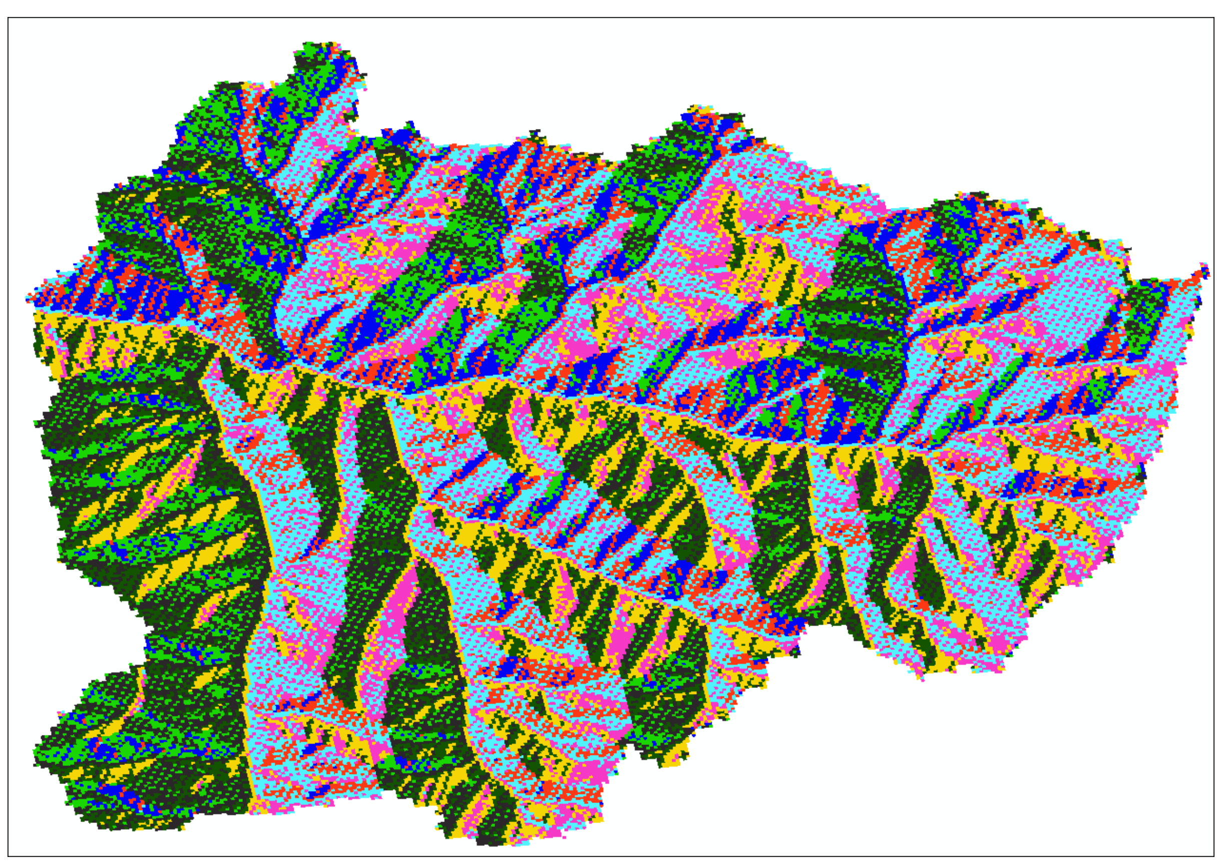
Note that the line env.overwriteOutput = True sets the script to overwrite any output files that already exist. This is useful when repeatedly running a script to incrementally develop it as we are doing here. However if you leave one of the files loaded into ArcMap while you do this you may get an error that corrupts the raster file. If this happens you need to delete the raster file to get it working again.

Next, lets add to our script the function to calculate flow direction. To determine the syntax for this operation we can google "ArcGIS Flow Direction": http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z00000052000000.htm

```
print 'importing arcpy (this takes a while)...'
# Import arcpy module
import arcpy
from arcpy import env
from arcpy.sa import *
import numpy
import math
import json
import os

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
env.overwriteOutput=True
# This allows the code to overwrite results - handy while developing

# Local variables:  (CHANGE THESE TO PATHS ON YOUR COMPUTER)
elevation = "C:/Users/dtarb/Desktop/Ex5/ned30m"
fill_outpath = "C:/Users/dtarb/Desktop/Ex5/Fill"
fdr_outpath = "C:/Users/dtarb/Desktop/Ex5/fdr"

# Process: Fill
print 'Run Fill!'
#arcpy.gp.Fill_sa(elevation, fill_outpath, "")
outFill = Fill(elevation,"")
# The Fill class function that returns an object that can be used later
# outFill.save(fill_outpath)

# Process: FDR
print 'Run FDR'
outFlowDirection=FlowDirection(outFill,"NORMAL")
outFlowDirection.save(fdr_outpath)

print 'done'
```

The script to this point is trace2.py in
http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2014/Ex5Scripts.zip.

Notice that the output from the fill operation was not **Saved**, but it can still be used in the following step! This is because it is saved temporarily in memory. We can utilize this feature to “hide” intermediary processing outputs. Lets look at the output from the flow direction process.



Now that we have some of the basic raster processing done, lets create a point that can be traced to the outlet. This will be hardcoded for now, but we can change it to a user input later.

```
print 'importing arcpy (this takes a while)...'
# Import arcpy module
import arcpy
from arcpy import env
from arcpy.sa import *
import numpy
import math
import json
import os

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
env.overwriteOutput=True
# This allows the code to overwrite results - handy while developing

# Local variables:  (CHANGE THESE TO PATHS ON YOUR COMPUTER)
elevation = "C:/Users/dtarb/Desktop/Ex5/ned30m"
fill_outpath = "C:/Users/dtarb/Desktop/Ex5/Fill"
fdr_outpath = "C:/Users/dtarb/Desktop/Ex5/fdr"

# create a point object
my_x= -1216071.141
my_y=307660.098
pnt=arcpy.Point(my_x, my_y)

# Process: Fill
print 'Run Fill!'
#arcpy.gp.Fill_sa(elevation, fill_outpath, "")
outFill = Fill(elevation,"")
# The Fill class function that returns an object that can be used later
# outFill.save(fill_outpath)

# Process: FDR
print 'Run FDR'
outFlowDirection=FlowDirection(outFill,"NORMAL")
outFlowDirection.save(fdr_outpath)

print 'done'
```

In order to relate this point coordinate with the raster data, we need to do two things: (1) represent the raster grids as arrays of data, and (2) convert the x,y point coordinate into array indices. To convert the raster grids (i.e. **fill** and **fdr**) into arrays, we use the numpy library, specifically RastertoNumPyArray.

```
print 'importing arcpy (this takes a while)...'
# Import arcpy module
import arcpy
from arcpy import env
from arcpy.sa import *
import numpy
import math
import json
import os

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
env.overwriteOutput=True
# This allows the code to overwrite results - handy while developing

# Local variables:  (CHANGE THESE TO PATHS ON YOUR COMPUTER)
elevation = "C:/Users/dtarb/Desktop/Ex5/ned30m"
fill_outpath = "C:/Users/dtarb/Desktop/Ex5/Fill"
fdr_outpath = "C:/Users/dtarb/Desktop/Ex5/fdr"

# create a point object
my_x= -1216071.141
my_y=307660.098
pnt=arcpy.Point(my_x, my_y)

# Process: Fill
print 'Run Fill!'
#arcpy.gp.Fill_sa(elevation, fill_outpath, "")
outFill = Fill(elevation,"")
# The Fill class function that returns an object that can be used later
# outFill.save(fill_outpath)

# Process: FDR
print 'Run FDR'
outFlowDirection=FlowDirection(outFill,"NORMAL")
outFlowDirection.save(fdr_outpath)

# convert rasters to arrays
fdr = arcpy.RasterToNumPyArray(outFlowDirection, nodata_to_value=0)
fill = arcpy.RasterToNumPyArray(outFill, nodata_to_value=0)

print 'done'
```

Examine the value of the **fdr** value to see what it looks like. You can do this by typing the object name fdr in the Python Shell after the script has been run.

```
Python 2.7.5 Shell
File Edit Shell Debug Options Windows Help
Python 2.7.5 (default, May 15 2013, 22:43:36) [MSC v.1500 32 bit (Intel)] on win
32
Type "copyright", "credits" or "license()" for more information.
>>> ================================ RESTART ================================
>>>
importing arcpy (this takes a while)...
Run Fill!
Run FDR
done
>>> fdr
array([[0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       ...,
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0]], dtype=uint8)
>>> |
Ln: 17 Col: 4
```

It looks like there are lots of 0's, however this is just because we are seeing a small subset of the data. In fact most of the cells near the edge of the raster will be zero. Lets look at some values elsewhere:

```
>>> fdr[100:110,100:110]
array([[16,  4,  4,  4,  4,  4,  8,  4,  4,  8],
       [ 4,  4,  4,  4,  4,  8,  8,  4,  4, 16],
       [ 2,  2,  4,  4,  4,  8,  4,  8,  8, 16],
       [ 2,  2,  2,  4,  4,  8,  8,  8, 16, 32],
       [ 2,  1,  2,  4,  8, 16,  8, 16, 16, 16],
       [ 1,  2,  2,  4,  8, 16, 16, 32, 32, 16],
       [ 4,  2,  4,  8, 16, 16, 16, 32, 16, 32],
       [ 2,  2,  4,  8, 16, 16, 32, 16, 32, 32],
       [ 2,  1,  4, 16, 16, 32, 32, 16, 32, 16],
       [ 1,  4,  8, 16, 16, 32, 16, 32, 32, 16]], dtype=uint8)
```

Before we do anymore processing of the raster data, we need to extract some metadata that will enable us to loop over the raster cells. The numpy arrays only contain raster values, so we will need to use the ArcGIS Raster type to retrieve this information.

```
...
...

# convert rasters to arrays
fdr  = arcpy.RasterToNumPyArray(outFlowDirection, nodata_to_value=0)
fill = arcpy.RasterToNumPyArray(outFill, nodata_to_value=0)

# create raster object to get metadata
upperLeft = outFill.extent.upperLeft
ux = upperLeft.X
uy = upperLeft.Y
cell_width = outFill.meanCellWidth
cell_height = outFill.meanCellHeight

...
...
```

We can transform our point coordinates into array indices, now that we have the upper left (x,y), cell width, and cell height. This will enable us to access the raster value of the cell associated with our point.

```
# ...
# ...

# convert rasters to arrays
fdr  = arcpy.RasterToNumPyArray(outFlowDirection, nodata_to_value=0)
fill = arcpy.RasterToNumPyArray(outFill, nodata_to_value=0)

# create raster object to get metadata
upperLeft = outFill.extent.upperLeft
ux = upperLeft.X
uy = upperLeft.Y
cell_width = outFill.meanCellWidth
cell_height = outFill.meanCellHeight


# convert point coordinates into raster indices
c = abs(int((ux - pnt.X) / cell_width))
r = abs(int((uy - pnt.Y) / cell_height))

print 'done'
```

Lets see where our point lives in the raster array (again, this is easy to do using the IDLE Python Shell). Your coordinates may be different than those below due to the extent of your watershed raster.

```
>>> print (pnt.X,pnt.Y), '--->',(c,r)
(-1216071.141, 307660.098) ---> (60, 209)
```

Now we are ready to start moving our point around within the raster. Specifically, we want to move our point from its current location (62,210) to the next downstream cell. In order to accomplish this, we need to add a function at the **top** of our script to check the value of our flow direction grid and move the point accordingly. Place this function right below the import statements.

```
def move_to_next_pixel(fdr, row, col):

    # get the fdr pixel value (x,y)
    value = fdr[row, col]

    #
    #| 32 |  64  | 128 |
    #| 16 |  X   |  1  |
    #|  8 |  4   |  2  |
    #

    # move the pixel
    if value == 1:
        col += 1
    elif value == 2:
        col += 1
        row += 1
    elif value == 4:
        row += 1
    elif value == 8:
        row += 1
        col -= 1
    elif value == 16:
        col -= 1
    elif value == 32:
        row -= 1
        col -= 1
    elif value == 64:
        row -= 1
    else: #value == 128:
        row -= 1
        col += 1

    return (row, col)
```

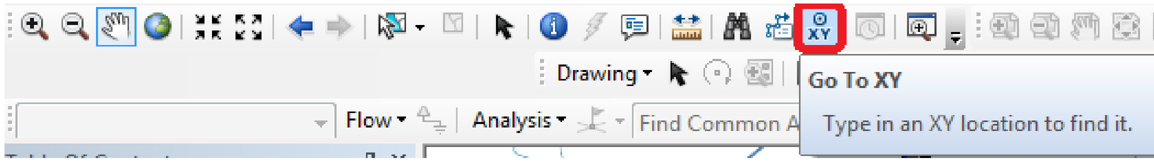
This function takes in three arguments: fdr (flow direction array), row (current row index), col (current col index). The first thing that it does is extract the value of the flow direction grid at the current (row, col) location. It then checks this value against all the possible flow direction combinations to determine the next downstream neighbor. It increments the current (row, col) pair and returns the result.

Lets pass in the coordinates of our point and see which direction our cell will flow.

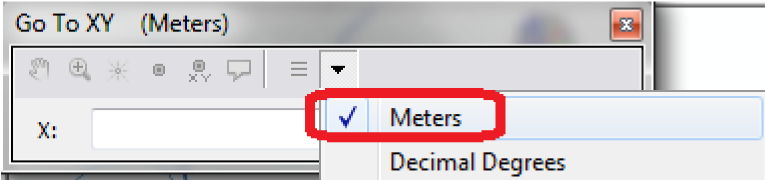
```
>>> r,c
(209, 60)
>>>
>>> move_to_next_pixel(fdr, r, c)
(209, 61)
>>>
```

We can verify this by loading the flow direction raster into ArcMap.

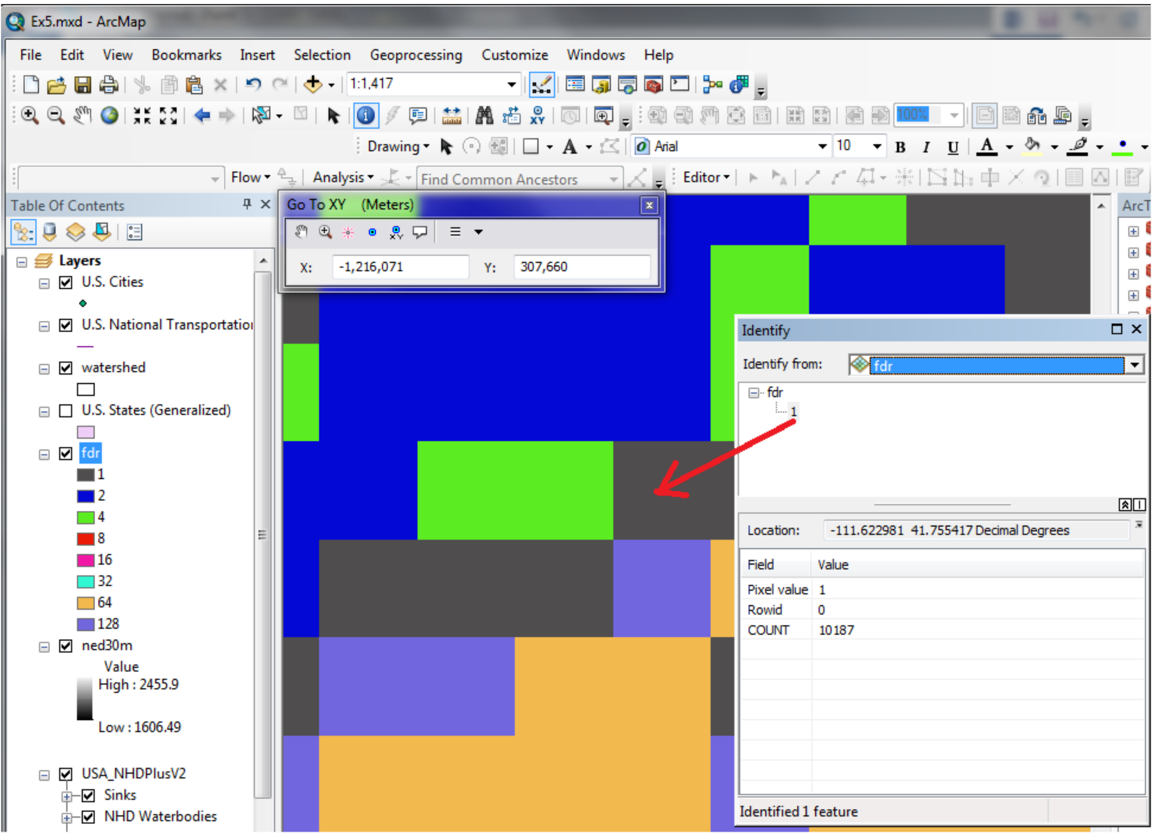
Use the Go To XY Tool on the Tools Menu



Set the units to Meters



Zoom in and look at the value of fdr at the selected location (using the coordinates of our point)



Note the fdr value of 1 which corresponds to a flow direction the east consistent with the direction that the function is moving the point

Lets modify our code to repeat this process until the point moves beyond the extent of our raster grid (e.g. through the outlet). In order do so, we need to create a loop that will run until the value at location (r,c) is equal to NoDATA (in this case 0).

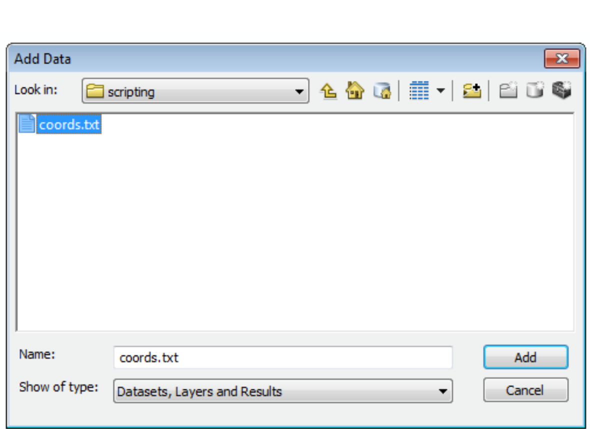
```
# convert point coordinates into raster indices
c = abs(int((ux - pnt.X) / cell_width))
r = abs(int((uy - pnt.Y) / cell_height))

print 'Tracing Downstream'
z = fill[r,c]                  # get the initial Z
while (z != 0):

    # move to downstream cell
    r,c = move_to_next_pixel(fdr, r, c)

    # get the Z value of the current (r,c) coordinate
    z = fill[r,c]

print 'done'
```

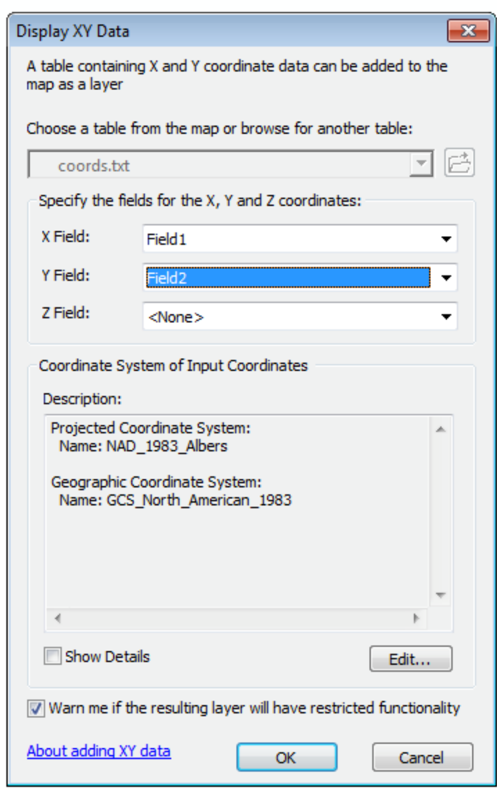
This loop will continue to run while the value of z does not equal 0 (i.e. no data value). When a value of z=0 is encountered the while statement will be false and the loop will stop. This code will thus move the point (r,c) to its downstream neighbor, and continue to do so until we reach the edge of the DEM. Unfortunately, we have no output to visualize. Let's save these points in a list and then create a shapefile that we can visualize in ArcMap.

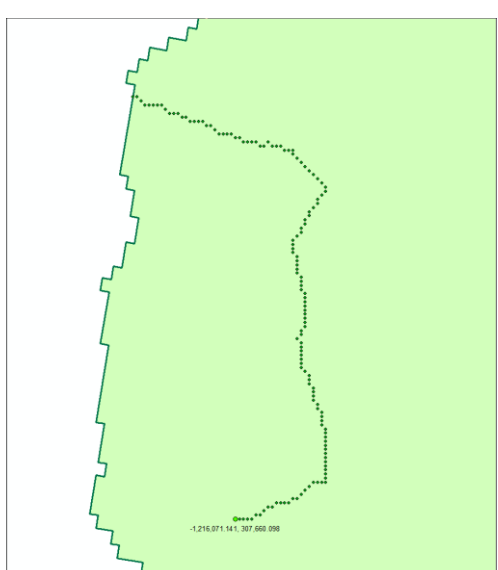
```
# ...

# convert rasters to arrays
fdr  = arcpy.RasterToNumPyArray(outFlowDirection, nodata_to_value=0)
fill = arcpy.RasterToNumPyArray(outFill, nodata_to_value=0)

# create raster object to get metadata
upperLeft = outFill.extent.upperLeft
ux = upperLeft.X
uy = upperLeft.Y
cell_width = outFill.meanCellWidth
cell_height = outFill.meanCellHeight

# convert point coordinates into raster indices
c = abs(int((ux - pnt.X) / cell_width))
r = abs(int((uy - pnt.Y) / cell_height))

print 'Tracing Downstream!'
pntX = pnt.X                        # get the initial X
pntY = pnt.Y                        # get the initial Y
z = fill[r,c]                       # get the initial Z
coords = [(pntX,pntY,z)]            # create a list to store our coordinates
while (z != 0):

    # move to downstream cell
    last_r = r       # store current r value
    last_c = c       # store current c value
    r,c = move_to_next_pixel(fdr, r, c)

    # recacluate the coordinates of x and y (in map units)
    pntX += (c - last_c)*cell_width
    pntY += (last_r - r)*cell_height

    # get the Z value of the current (r,c) coordinate
    z = fill[r,c]

    # save this coordinate to our list
    coords.append((pntX,pntY,z))

# write the output to text file (csv)
with open('coords.txt','w') as f:
    for c in coords:
        f.write('%5.5f, %5.5f, %5.5f\n' % (c[0],c[1],c[2]))

print 'done'
```

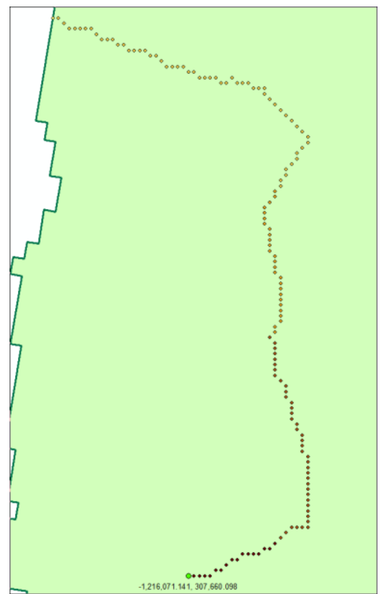
The script to this point is trace3.py in
http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2014/Ex5Scripts.zip.

To visualize our output in ArcMap, add the **coords.txt** file to an ArcMap document. Right click on it and select **Display X,Y data**. Choose **Field1** as the X field and **Field 2** as the Y field. You can also symbolize these points by their elevation, **Field 3**





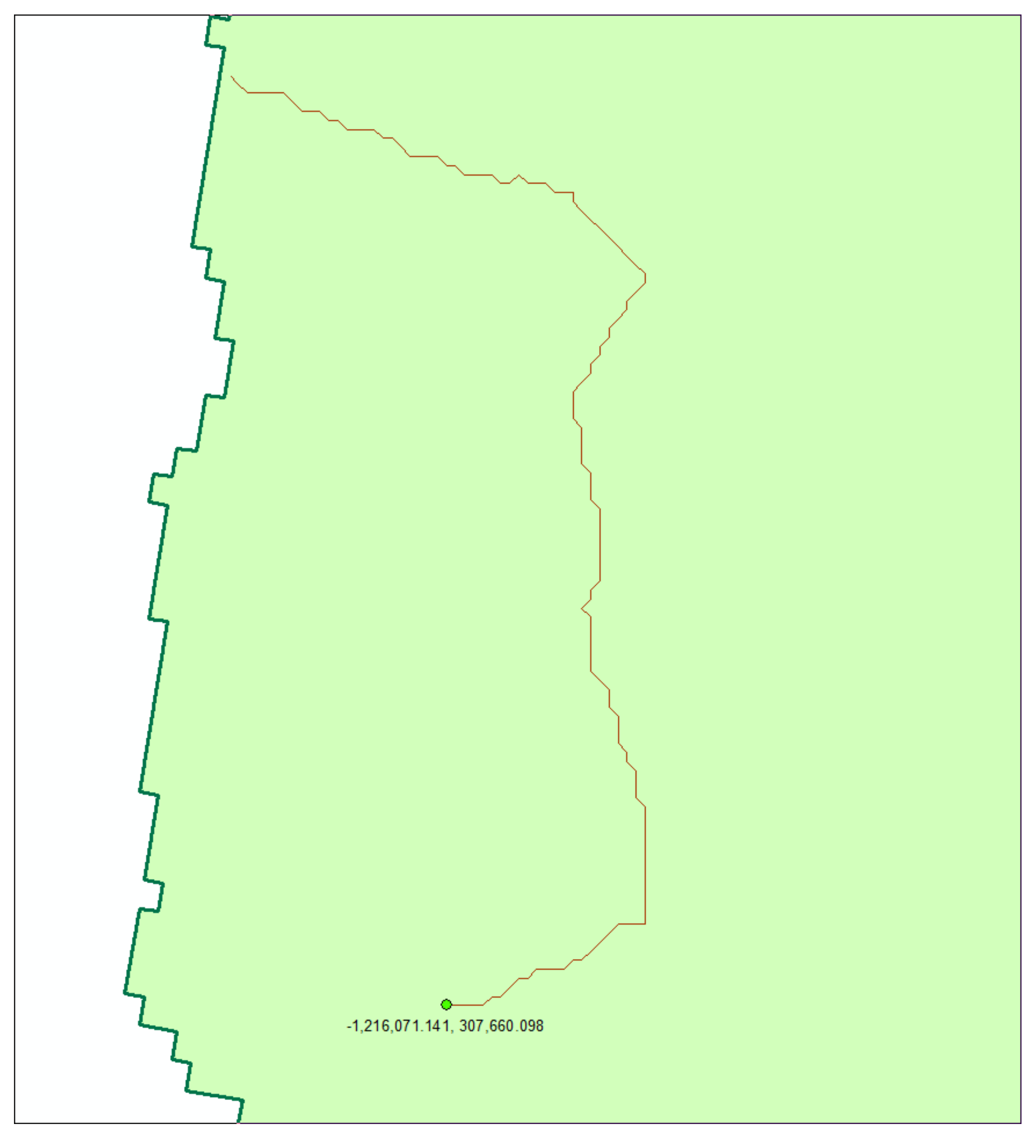




Since point text file is not an ideal output, lets format it as a PolyLine Shapefile, http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00170000002p000000. In the code snippet below, we first create the polyline feature class that will hold our results. Next we loop over our coordinates are create line segments between each pair. These line segments are then added to the feature class as a polyline. Add the following code to replace the 3 lines that create coords.txt.

```
# ...

# Create a PolyLine Shapefile #

# create the output feature class
arcpy.CreateFeatureclass_management('.','path.shp', "POLYLINE")

# define the point and line segment objects
point = arcpy.Point()
line_seg = arcpy.Array()

featureList = []
cursor = arcpy.InsertCursor('path.shp')
feat = cursor.newRow()

for i in range(1, len(coords)-1):
    # Set X and Y for start and end points
    point.X = coords[i-1][0]
    point.Y = coords[i-1][1]
    line_seg.add(point)
    point.X = coords[i][0]
    point.Y = coords[i][1]
    line_seg.add(point)

    # Create a Polyline object based on the array of points
    polyline = arcpy.Polyline(line_seg)

    # Clear the array for future use
    line_seg.removeAll()

    # Append to the list of Polyline objects
    featureList.append(polyline)

    # Insert the feature
    feat.shape = polyline
    cursor.insertRow(feat)
del feat
del cursor

print 'done'
```

This produces an output Shapefile called path.shp. We can view this in ArcMap:



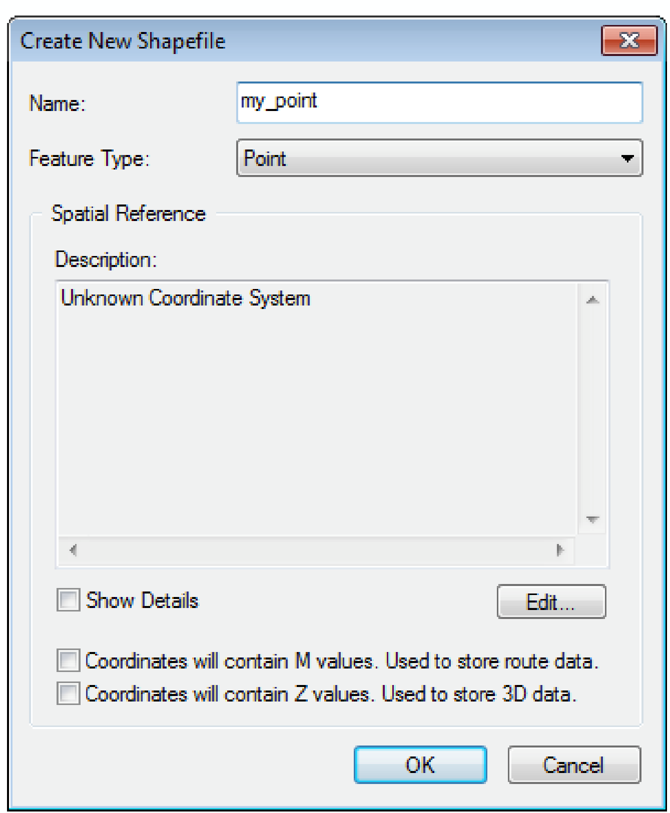
The script to this point is trace4.py in
http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2014/Ex5Scripts.zip.

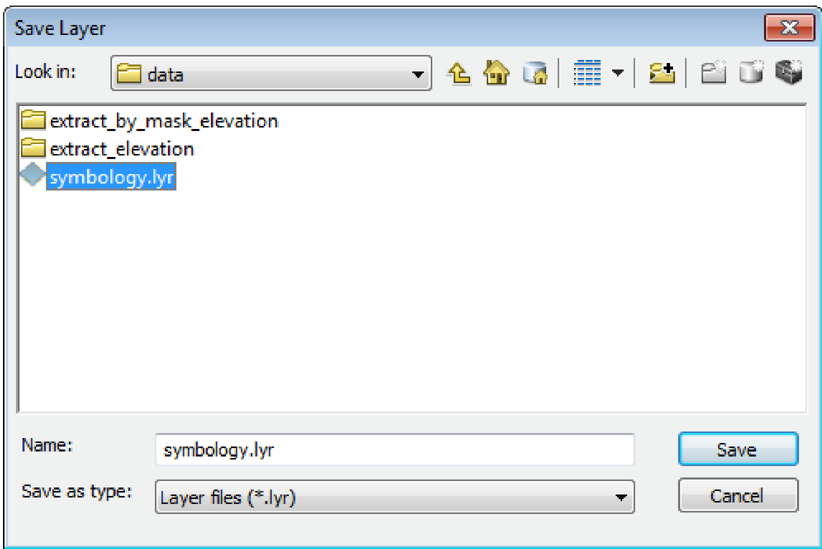
Wow! Now we have a function that can trace a path from an arbitrary point to the edge of the DEM. Pretty impressive. This is the functionality we set out to achieve. However it is not very easy to use. The next section will build an interface.

Part3: Developing toolbox interface

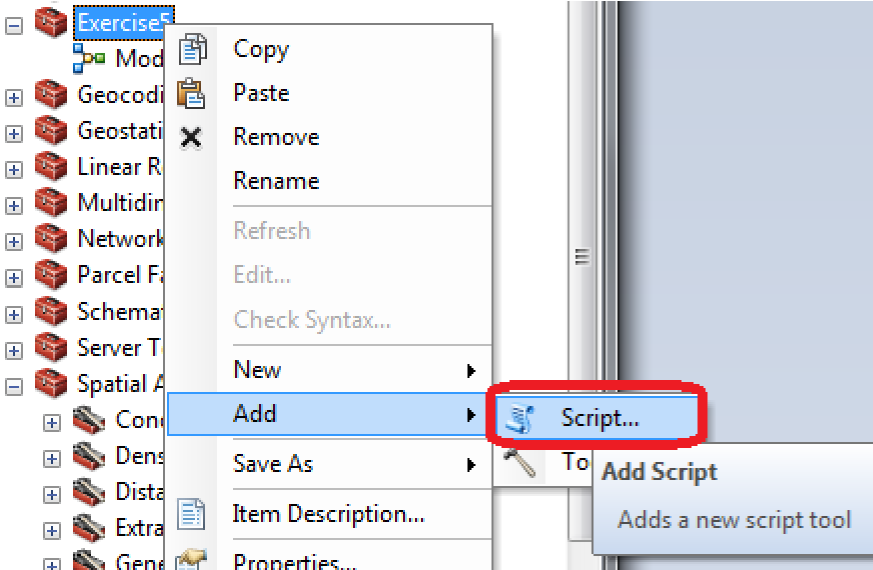
First create a symbolic layer, which will be used in the next step, to assign a theme to one of our inputs. This will also allow us to incorporate an interactive point input selection feature. To do this, right click inside ArcCatalog and select **New -> Shapefile.**

Set a name for this file (e.g. my_point.shp) and set the feature type to **Point.** Change the symbology of this point however you would like. Lastly, right click on the my_point.shp in the Table of Contents and select **Save as Layer File**.

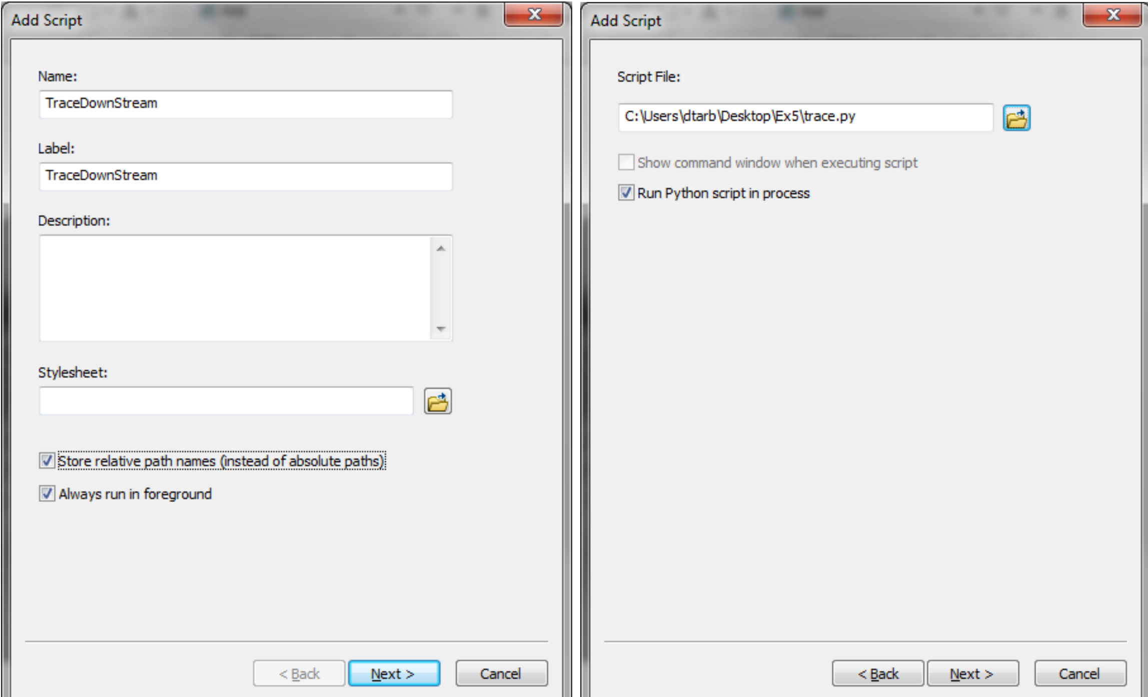




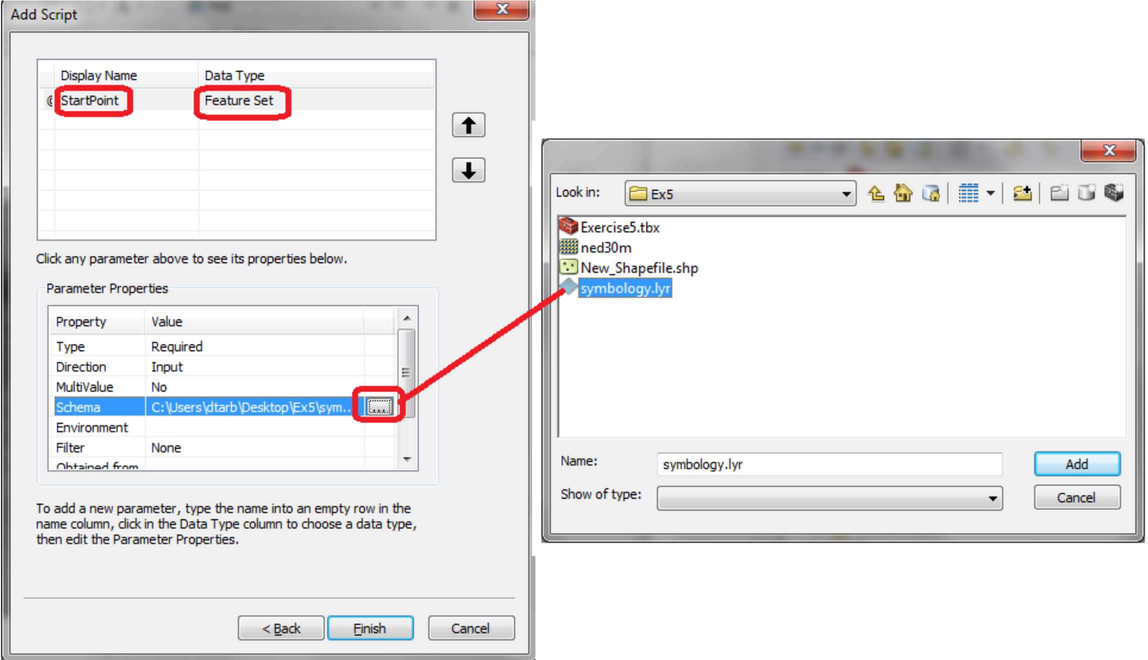
Now let's add our new script to the ArcGIS toolbox, so that we can run it like any other tool. Right click on your toolbox (e.g. Exercise5) and select **Add -> Script**.



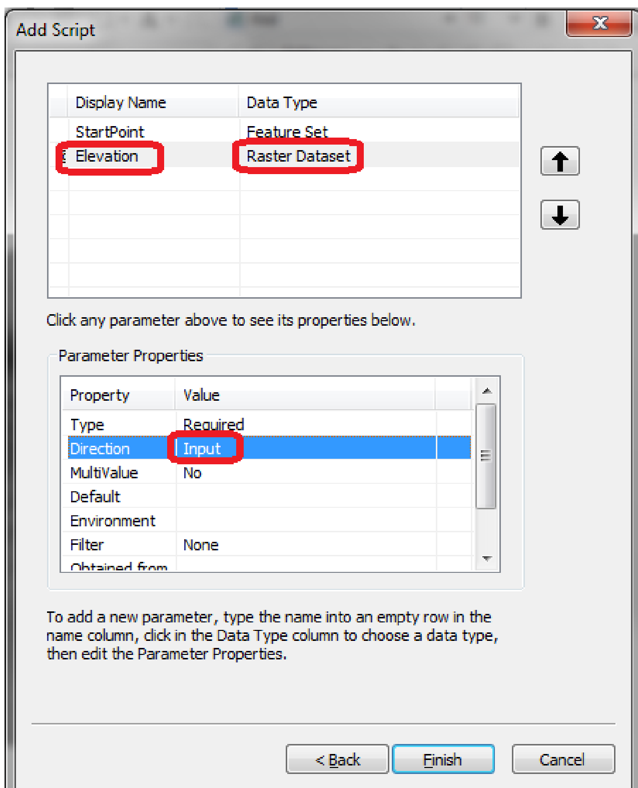
Give it a name and a label. Note that I also checked Store relative path names so that if I put the toolbox and script in a different location they will work together. Then select next. Specify the location of the python file and select next.



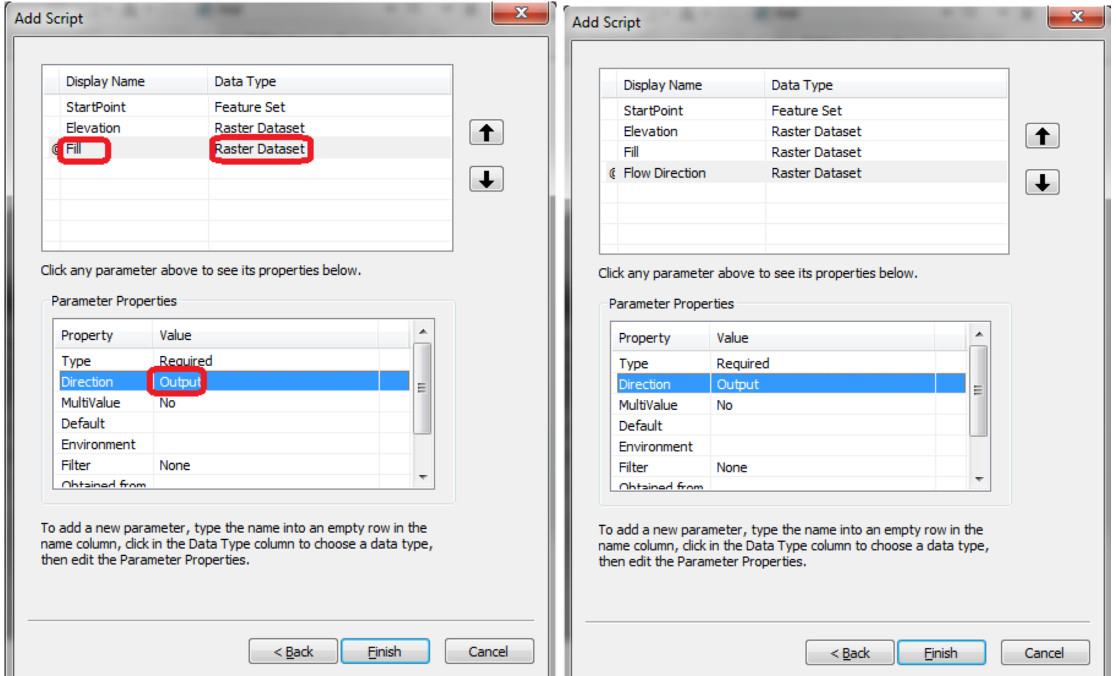
At the next dialog add input parameters. The first input parameter will be the start point of the trace operation. Specify a **Display Name** (such as StartPoint) and set the datatype to **FeatureSet**. Next select the **Schema** property and set its value to the symbology layer that we created in the previous step. (e.g. symbology.lyr)



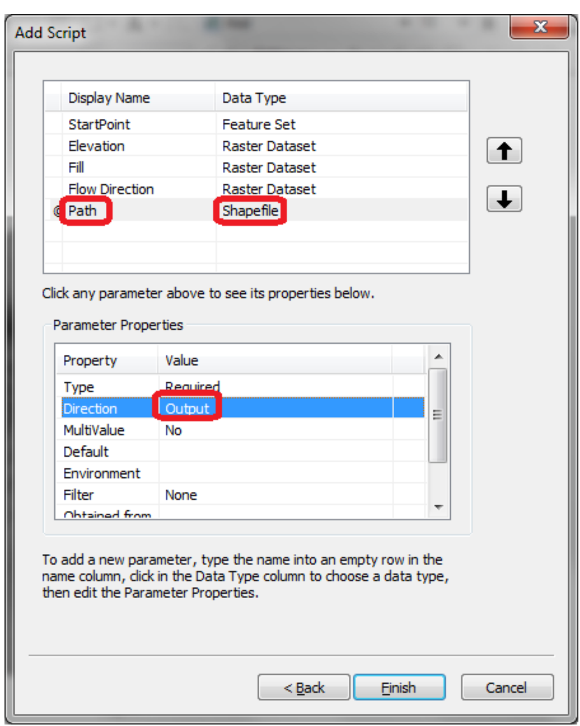
Next add the parameter for **Elevation (input)**.



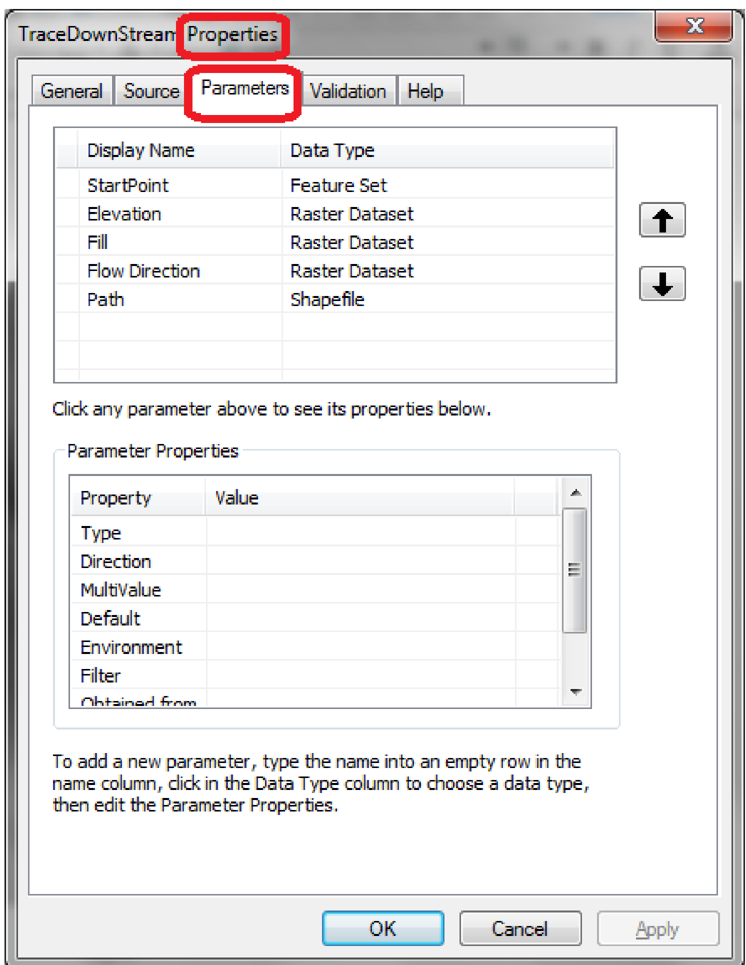
Next add the parameter for **Fill (output)** and **Flow Direction (output)**.



Lastly add **Path** as a **shapefile (output).** When all five parameters are correctly set click Finish.



If you do not get these settings right the first time you can get back to these controls by right clicking on the script in the toolbox and selecting properties then the parameters tab.



Now we need to add some code to our python script to utilize these parameters. We use the **arcpy.GetParameter(index)** function to grab user inputs from the ArcGIS UI. The following snippet gets the first parameter (i.e. Start Point) as a feature set, and extracts the (x,y) coordinates. This code should be placed directly under the **move_to_next_pixel(fdr, row, col)** function.

```
fs = arcpy.GetParameter(0)
if fs == '#' or not fs:
    fs = "in_memory\\{87AF799A-1608-483B-9022-3AA58EFEF329}" # provide a default value if unspecified

# create feature set
f = arcpy.FeatureSet(fs)

# parse out the geometry
geom = json.loads(f.JSON)['features'][0]['geometry']
pnt = arcpy.Point(geom['x'], geom['y'])
arcpy.AddMessage('Selected Point = (%5.3f,%5.3f)'% (geom['x'], geom['y']))
```

Next, let's add some code to get the rest of our inputs and outputs:

```
# get elevation input
elevation = arcpy.GetParameterAsText(1)

# get output fill path
fill_outpath = arcpy.GetParameterAsText(2)

# get output fdr path
fdr_outpath = arcpy.GetParameterAsText(3)

# get output trace path
trace_outpath = arcpy.GetParameterAsText(4)
```

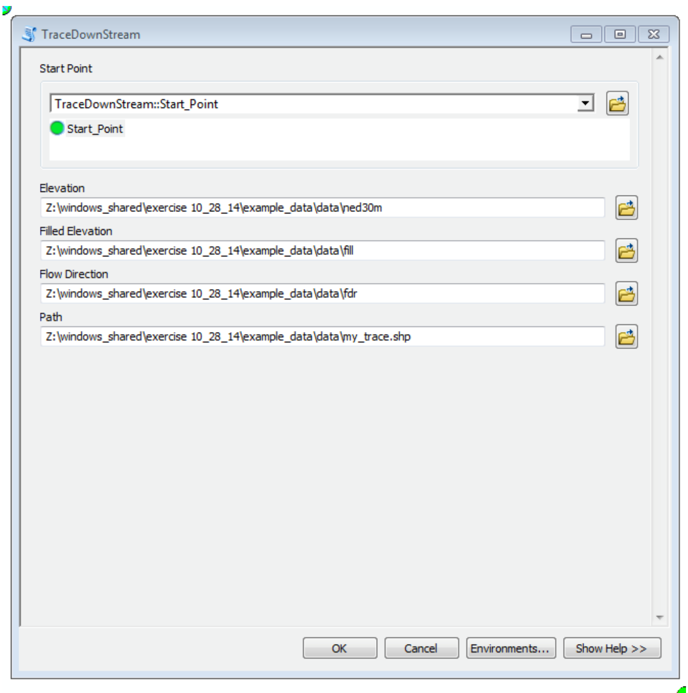
Since we are getting these parameters from ArcGIS, we need to remove our old hardcoded paths. We should also add some messages, since our print statements will not appear anywhere. The final script should look like this:

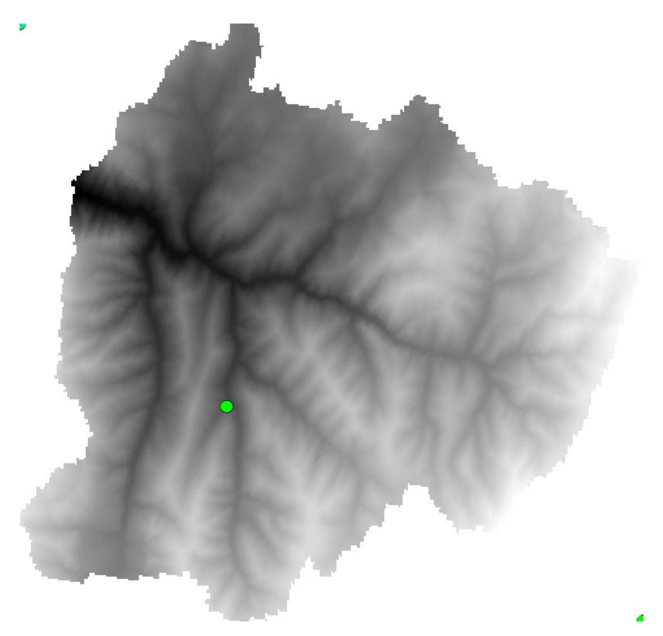
```python
print 'importing arcpy (this takes a while)...'
import arcpy
from arcpy import env
from arcpy.sa import *
import numpy
import math
import json
import os

def move_to_next_pixel(fdr, row, col):

    # get the fdr pixel value (x,y)
    value = fdr[row, col]

    #
    #| 32 |  64  | 128 |
    #| 16 |  X   |  1  |
    #|  8 |  4   |  2  |
    #

    # move the pixel
    if value == 1:
        col += 1
    elif value == 2:
        col += 1
        row += 1
    elif value == 4:
        row += 1
    elif value == 8:
        row += 1
        col -= 1
    elif value == 16:
        col -= 1
    elif value == 32:
        row -= 1
        col -= 1
    elif value == 64:
        row -= 1
    else: #value == 128:
        row -= 1
        col += 1

    return (row, col)


# Get Script arguments
###############################################
fs = arcpy.GetParameter(0)
if fs == '#' or not fs:
    fs = "in_memory\\{87AF799A-1608-483B-9022-3AA58EFEF329}" # provide a default value if unspecified

# create feature set
f = arcpy.FeatureSet(fs)

# parse out the geometry
geom = json.loads(f.JSON)['features'][0]['geometry']
pnt = arcpy.Point(geom['x'], geom['y'])
arcpy.AddMessage('Selected Point = (%5.3f,%5.3f)'% (geom['x'], geom['y']))

# get elevation input
elevation = arcpy.GetParameterAsText(1)
```

```
# get output fill path
fill_outpath = arcpy.GetParameterAsText(2)

# get output fdr path
fdr_outpath = arcpy.GetParameterAsText(3)

# get output trace path
trace_outpath = arcpy.GetParameterAsText(4)

##############################################

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")
env.overwriteOutput = True

# Process: Fill
arcpy.AddMessage('Running DEM Fill...')
#arcpy.gp.Fill_sa(ned30m, Fill_ned30m1,"")
outFill = Fill(elevation, "")
outFill.save(fill_outpath)

# Process: FDR
arcpy.AddMessage('Running FDR...')
outFlowDirection = FlowDirection(outFill, "NORMAL")
outFlowDirection.save(fdr_outpath)

# convert rasters to arrays
fdr  = arcpy.RasterToNumPyArray(outFlowDirection, nodata_to_value=0)
fill = arcpy.RasterToNumPyArray(outFill, nodata_to_value=0)

# create raster object to get metadata
upperLeft = outFill.extent.upperLeft
ux = upperLeft.X
uy = upperLeft.Y
cell_width = outFill.meanCellWidth
cell_height = outFill.meanCellHeight

# convert point coordinates into raster indices
c = abs(int((ux - pnt.X) / cell_width))
r = abs(int((uy - pnt.Y) / cell_height))

arcpy.AddMessage('Tracing Downstream...')
pntX = pnt.X                          # get the initial X
pntY = pnt.Y                          # get the initial Y
z = fill[r,c]                         # get the initial Z
coords = [(pntX,pntY,z)]              # create a list to store our coordinates
while (z != 0):

    # move to downstream cell
    last_r = r        # store current r value
    last_c = c        # store current c value
    r,c = move_to_next_pixel(fdr, r, c)

    # recacluate the coordinates of x and y (in map units)
    pntX += (c - last_c)*cell_width
    pntY += (last_r - r)*cell_height

    # get the Z value of the current (r,c) coordinate
    z = fill[r,c]

    # save this coordinate to our list
    coords.append((pntX,pntY,z))
```

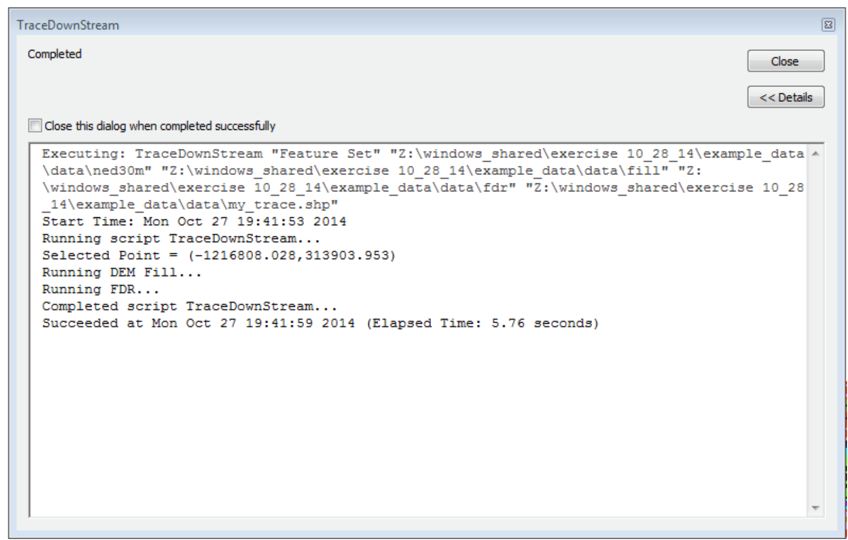
```
arcpy.AddMessage('Creating Output Path Shapefile...')
# create the output feature class
directory_path = os.path.dirname(trace_outpath)                    # get the dir from trace_output
file_path = os.path.basename(trace_outpath)                        # get file name from trace_output
# create feature class
arcpy.CreateFeatureclass_management(directory_path,file_path, "POLYLINE")

# define the point and line segment objects
point = arcpy.Point()
line_seg = arcpy.Array()

featureList = []
cursor = arcpy.InsertCursor(trace_outpath)
feat = cursor.newRow()

for i in range(1, len(coords)-1):
    # Set X and Y for start and end points
    point.X = coords[i-1][0]
    point.Y = coords[i-1][1]
    line_seg.add(point)
    point.X = coords[i][0]
    point.Y = coords[i][1]
    line_seg.add(point)

    # Create a Polyline object based on the array of points
    polyline = arcpy.Polyline(line_seg)

    # Clear the array for future use
    line_seg.removeAll()

    # Append to the list of Polyline objects
    featureList.append(polyline)

    # Insert the feature
    feat.shape = polyline
    cursor.insertRow(feat)
del feat
del cursor
```

With these changes to our python script, we should be able to successfully run our tool from the ArcGIS toolbox.

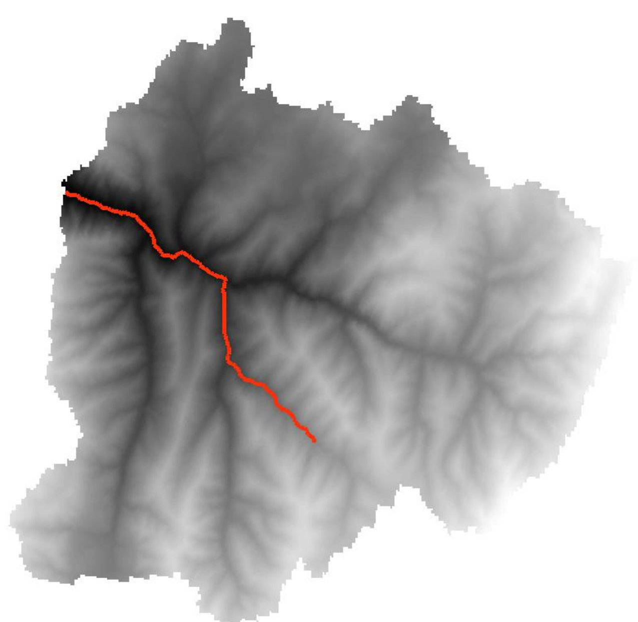




Notice that our output messages appear in the standard ArcGIS output dialog.



Our end result is a PolyLine shapefile that shows that path water would flow (using D8 flow direction) to the watershed outlet.



The complete script is **trace.py** in http://www.neng.usu.edu/cee/faculty/dtarb/giswr/2014/Ex5Scripts.zip and the script tool interface is in **Exercise5.tbx** in this zip file. If you have trouble developing your own script you may use these in answering the questions below though you will need to introduce small modifications to answer some of the questions. You will need to add Exercise5.tbx to your map document and keep trace.py in the same folder. I have found

that unless after doing this I save the document then close and reopen ArcMap, I get an error.

Homework Questions

1. Prepare a layout showing the elevation grid and two trace downstream paths. Include a scale and label the length of each trace in the layout.

2. Write statements to determine and print the value of the flow direction array at location with map coordinates (-1214936, 309638). You will need to determine the array coordinates corresponding to this and then look up and print the value of the fdr array at this location. Give the code you changed to achieve this and show a screen shot of your output, either from print statements to the shell or arcpy.Addmessage statements to the ArcGIS output.

3. Modify the script to compute and print out the length of the flow path being traced. Give the code you changed to achieve this and show a screen shot of your output.

4. Explain (without doing) how could you modify this code to determine the longest flow path in the entire watershed?