

Flow Direction Arrows for a Better Visual Representation of a Flow Direction Raster (FDIR)

GIS – 4500K (Application Development)
Final Report

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Abstract:

This project was developed in Python and put into an Arcpy Tool Box to be used with Arc GIS Pro Desktop as a user based visual enhancements for a Flow Direction Raster (FDIR). FDIRs are derived from Digital Elevation Model (DEM) and are commonly used for stream and channel network delineation according to Tarboton (1997). The tool box developed in this project is named FDIR_Arrows.pyt, and it also has an attached module utils.py, that carries the necessary functions for it to work. This tool box also calls the math, arcpy, and the NumPy modules as well. It takes the colorful FDIR and converts the orientation values for each cell into a polyline that is centered in the middle of each cell. The length of this polyline is dynamic such that it is 0.0325% shorter than the distance that it spans. In the case of horizontal and vertical directions it will be 0.0325% shorter than the cell width and or height, and the same holds true if the flow direction is diagonal, it will be that much shorter than the diagonal length of the cell. This allows for the optimal distance from the edges of the cell for minimal overlap. The symbology will need to be changed from the output polyline to any arrow of choice so that the flow direction can be determined. Due to the cell by cell processing nature of this tool it is advised to

either use a small study area or resample the study area to a larger cell size to diminish processing time and so that the flow direction arrows can be visible.

Introduction:

With the improvement of hydraulic tools in Arcpy and the wider spread use of them as well, this tool will become very useful. The purpose of this tool is to take a Flow Direction Raster that was created using Arc products and make them more visually accessible to the user. To understand how it works we need to first understand what a flow direction raster is and where it comes from, and then how this tool reads it and what it does in the end with it. The DEM is one of the most important data sets that represents earth's surface and is useful for any form or type of hydraulic analysis, and it is becoming more widely used in a variety of other areas as well as noted by Jenson (1991). One of the most common uses is fining stream networks and there are many ways and different models that have been used for this but as Montgomery, and Foufoula-Georgiou (1993) points out very little effort has apparently been put into ground truthing the results. That said though, for this project we are more concerned about accuracy than precision because repeatability is our moto for now.

Literature Review:

Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis

S.K. Jenson and J. O. Domingue TGS Technology, Inc., EROS Data Center, Sioux Falls, SD 57198 (1988).

In this article Jenson, and Domingue do a masterful job in unpacking the DEM and its close kin FDIR. The tools they used, and their entire platform was built on a Formula Translation (FORTRAN) program interface that set up to work with Relational Data Base Management (RDBM) programed for vector and raster spatial analysis so that the data can be displayed visually analyzed Jenson and Domingue (1988). FORTRAN is a relic of the past century, developed in 1954 for IBM by John Backus to be a high-level scientific language, *Meet John Backus. (2019)*. Because this work was done in

The analysis in this article is divided into three parts as follows. First, they deal with filling the holes or depressions in the DEM as a preparation phase in their analysis. Then they develop how the flow direction raster is created, and the third phase is the flow accumulation data set. With these three sets of data the world of hydraulic modeling and analysis is 'literally' at your fingertips. As is also pointed out in this article the use of these packages greatly reduces the monotonies and pain-staking work of digitizing and or analyzing the data manually.

To be able to derive a flow direction raster the physiographic data is needed to delineate the stream network, the length of individual streams, and the subcatchment areas as well as the slope. In times past this data was obtained through expensive surveys or pain staking digitizing of the maps. The DEM is, simply put, a matrix of small grid cells in a two-dimensional array with the average elevation stored as its cell value and the spatial location of each cell is determined by which column and row it occupies in the array within a known or georeferenced grid or array as noted by Garbrecht and Martz, (2000). So, with the raise of the

DEM there was also the raise of many new uses in a variety of different types of analysis but for now hydrology is our focus.

One such new tool was the flow direction tool that takes the DEM and converts its cell values from average elevation to one of eight numbers being (1, 2, 4, 8, 16, 32, 64, 128) as shown in *Figure: 1*, based on the surrounding cell elevation. This new flow model raster is usually referred to as an eight- direction (D8) approach according to How Flow Direction works—Help | ArcGIS Desktop. (2019).

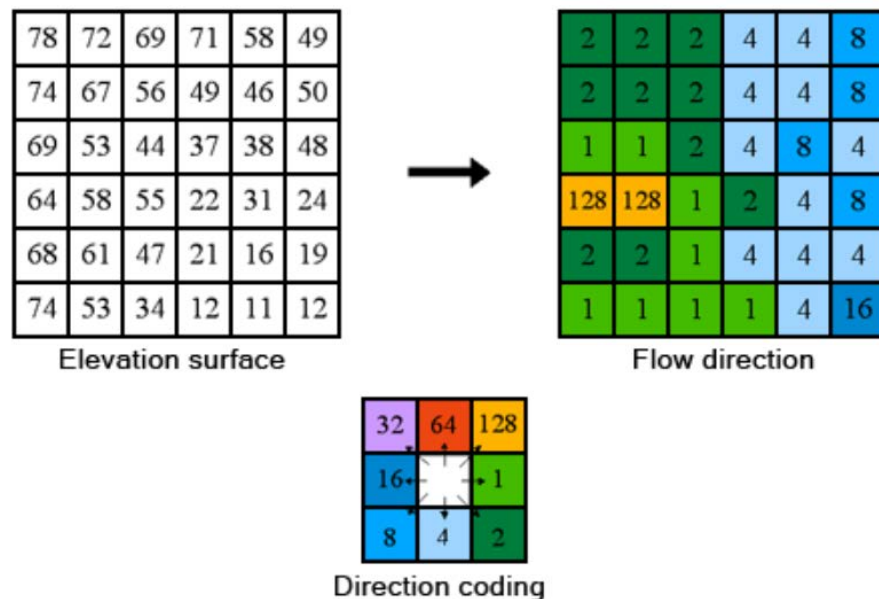


Figure 1: The coding of the direction of flow [How Flow Direction works—Help | ArcGIS Desktop. (2019)].

There are however some preliminary steps to be taken in producing this flow direction raster for it to be created properly.

First, since most DEM's are not perfect and may have depressions in the that are ether data gaps or simply the geomorphology of the surface. These depressions tend cause a break in the flow of digression in the cell elevation causing flow path interruptions. To fix this problem the cell elevation values must be increased at least to one of the minimum surrounding ridge cell values so that the flow will not be interrupted as noted by Jenson and Domingue (1988).

Then comes the building of the flow directions raster that is simply the direction that the water will flow out of or when leaving the cell. And this direction is toward one of the lowest surrounding eight cell elevation values. The new orientation for this cell is then encoded in power of two values to ensure that the sum of any direction will maintain a unique value and avoid repetition and/or duplicate orientations in different directions. If all the surrounding eight cells have higher values than the cell it will encode a negative value because the flow is not able to be defined. This is often referred to as "single cell depression" and if the first step is performed properly these will be removed. If only one of the surrounding cells is lower and the other seven are greater than or equal to the cell value, then the lowest is logically chosen for the direction. Also, if there are two or more cells that are equal and the lowest of the eight

surrounding cells, then one of them will be arbitrarily picked for the flow direction of the center cell. And last of all, if the eight surrounding cells are equal to the center cell (in which case the surface would be flat) the flow direction is unknown. In this case the flow direction for the center cell is assigned to any one of the neighboring cells that do not have a flow direction coming back to it. The processing of flat cells usually takes the longest because it is done last after all the surrounding cells have been determined Jenson and Domingue (1988).

And the last part that is created with this tool is the flow accumulation data set. This data set is vital for the delineation of watersheds and catchment areas as it assigns to each cell the number of cells that flow into it. Cell with no other cells flowing into them are usually ridges because they are the highest cell in their vicinity. And that is how the catchment area is outlined and determined as stated by Jenson and Domingue (1988).

Project Objectives:

This project was developed as a final project for the under-graduate course of GIS – 4500K (Application Development) in the Institute of Environmental Spatial Analysis at The University of North Georgia.

The resulting tool from this project is intended to be used as an add for better visual analysis of any given FDIR raster. This tool is essentially a Python script inside an Arcpy Tool Box shell that operates in the Arc GIS Pro Desktop GUI interface.

Materials and Methods:

This tool is divided into two parts and it also requires an import of the math, the arcpy, and the NumPy modules for it to function properly. The first part is the main arcpy tool box shell with all the built-in options for various types of tools and operations. It is in this part that I have scripts like the arcpy Create Feature class management, and for geometry in this script we set it equal to POLYLINE. This first half also takes the spatial Reference and applies it to the feature class so that it can be located with reference system. For iterating through the cells one at a time I used the arcpy da Insert Cursor in a “with” statement so that as the code is read row and column the 2-dimensional location is preserved. This part is the interface side of the tool and it takes as input a flow directional raster, a file path, and a name for the new feature class that is created. It is also where I have all the class functions, the first one being the Toolbox and the second being the actual Flow Direction Arrows tool.

The second half of this tool is the actual functions that do the work. So first I define a function that gets the raster coordinates so that the new feature class that will be created has a coordinate attached to each one at the center of the cell and at the center of each line. This coordinate is determined by taking the extent of the raster at the Min X plus the width and times the column plus width divided by two, and the Max Y minus the height times the row minus the height divided by two. The dividing by two is to get the center of the cell. The second definition query is the one that draws the line. This one is comprised of an “if” statement and

seven “elif” statements that determine the angle of the line depending on which of the base two numbers that are assigned to that cell. Then there is one more “if” statement that determines the length of the line based on whether it is vertical, horizontal, or diagonal. And for each line I divide the total length by 3.25 to keep the ends inside the cell for tidy reasons.

Results and Conclusion:

As stated earlier, there is a need for an optimal cell size with the placement of arrows in each cell. This in part is because as shown in *Figure 2*, the arrows are so small that it almost impossible to determine which way they are pointing and if you are trying to cover a large area it will take a considerable amount of time to run this tool.

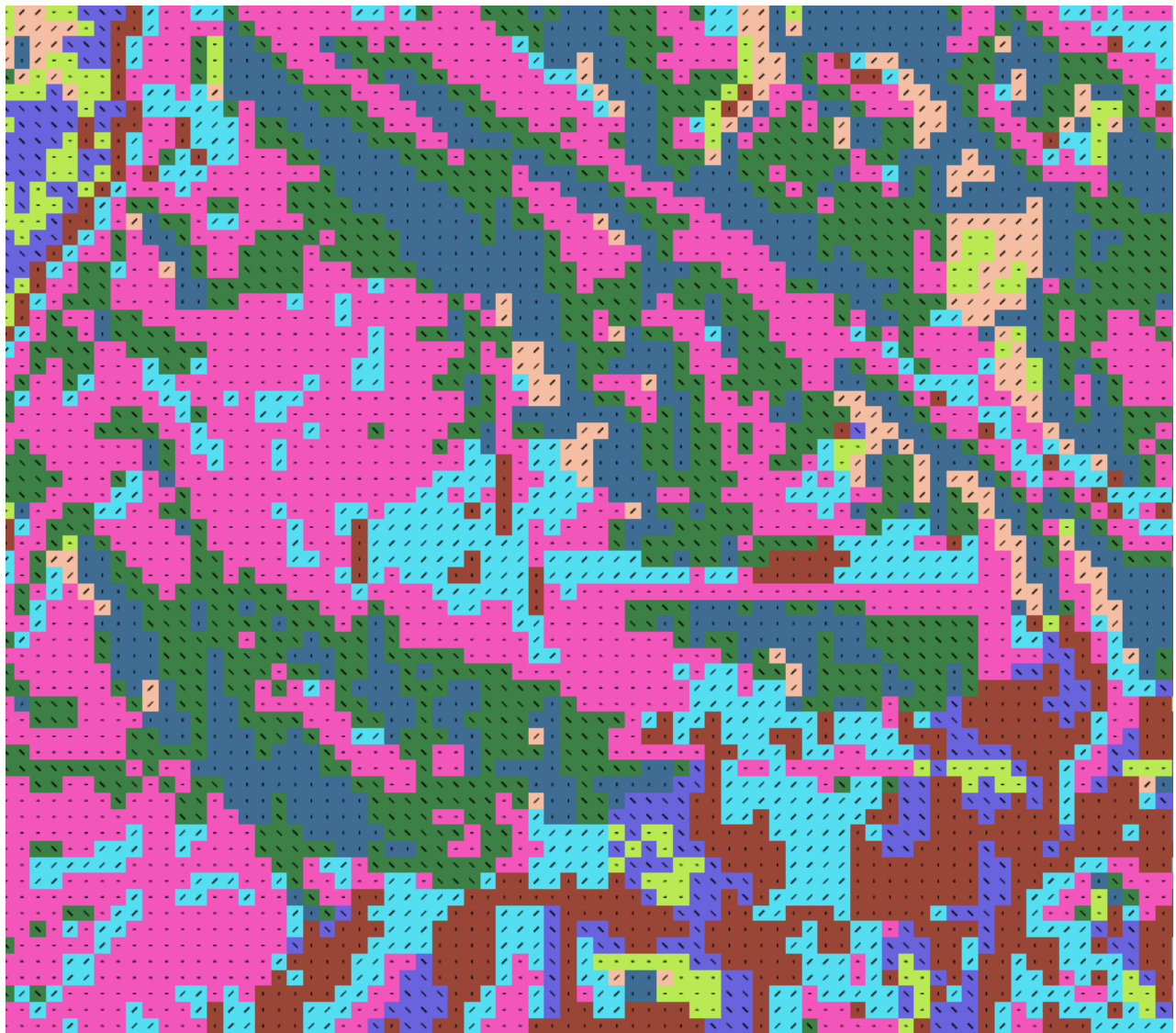


Figure 2: A 10 X 10 cell Flow Direction Raster with arrows.

Even though Arc Pro Desktop has a dynamic zoom and the arrows will enlarge as you zoom in, you are still left with viewing a smaller area and zooming in and out can also be annoying because of the time Arc Pro Desktop takes to draw all the arrows.

Resampling the cell size was the best fix I found, and one size might work better in one place and not so much in another. In areas that were very busy and had lots of abrupt elevation changes, it was found to be easier to understand with a larger cell size as shown in *Figure 4*, and the same is true that if the area does not have much varying elevation that it is possible to use a smaller cell size and still be able to understand the flow direction on the raster tile as shown in *Figure 3*.

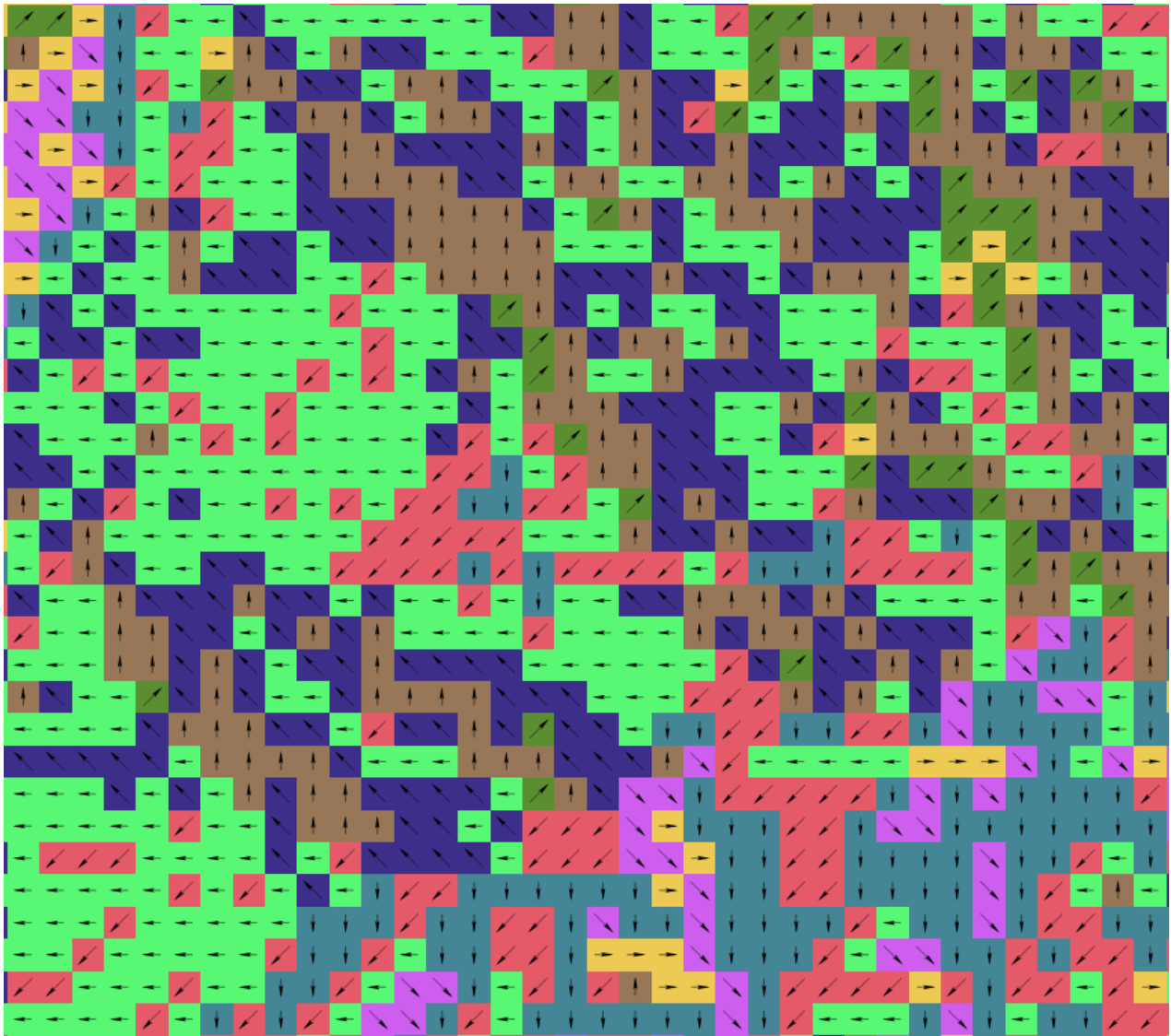


Figure 3: A 20 X 20 cell Flow Direction Raster with arrows.

Resampling the cell size is easily done with the resample tool in Arc Pro Desktop and can be applied to the DEM elevation raster prior to creating the flow direction raster to save on processing time. It would be possible to include resampling in this tool, but if the user is simply

trying to find the optimal cell size it would be better to do the resampling alone and not clutter the users folder with overwrites of unused data and it would save on processing time as well. There is however something to be said about loss of data, when the user resamples a raster there is inevitably a loss of the original data in the raster. This can be undone by resampling to a smaller cell again, but that is not advised as it will essentially be guessing at what the cells should be. If there is a need to down size, the best way to do it is to start over with the original raster and that way you will have all the original data included.

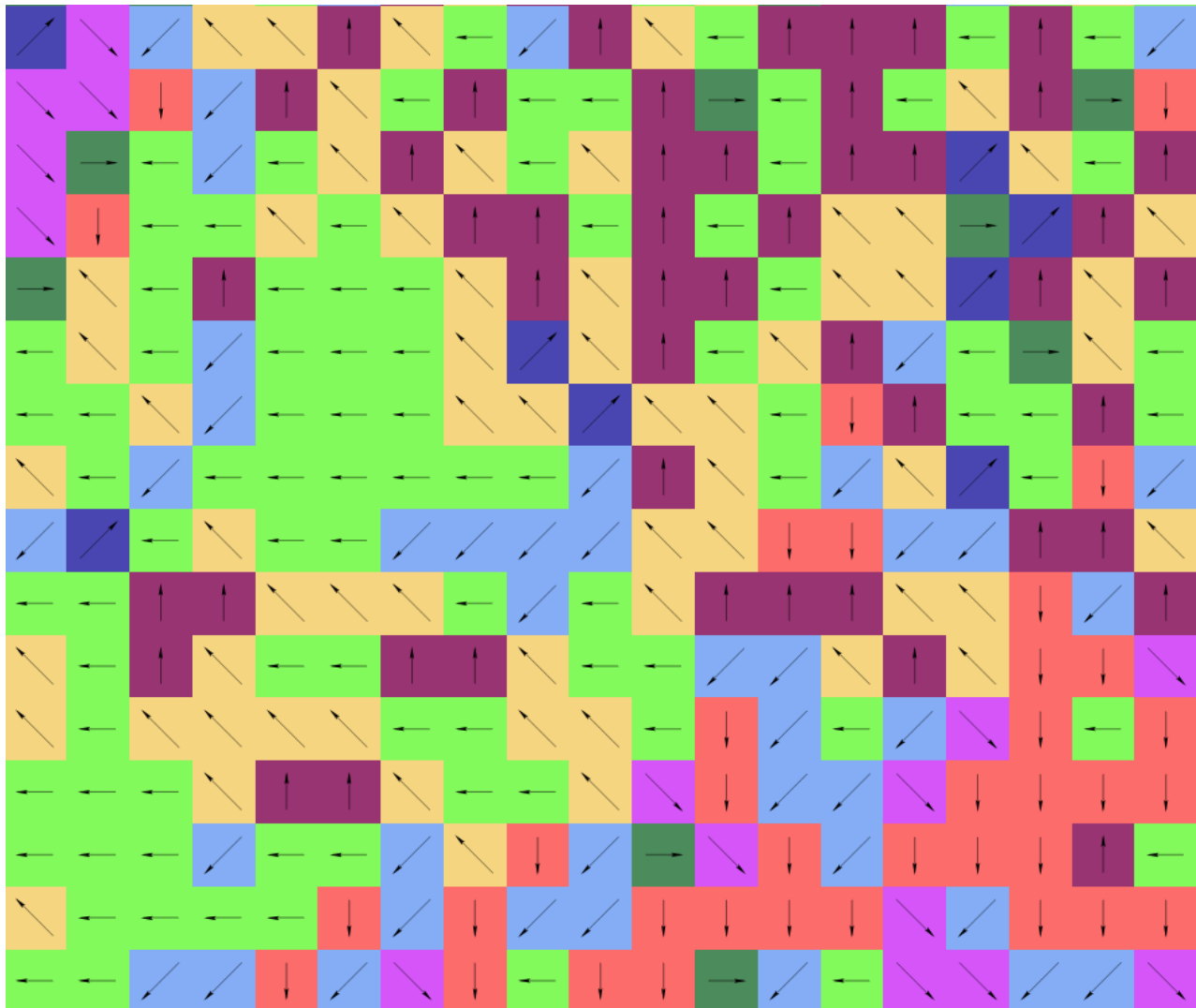


Figure 4: A 40 X 40 cell Flow Direction Raster with arrows.

So, in conclusion this tool worked very well, and it was almost exactly what we had originally purposed. In the future it would be of interest to perhaps add the code that would draw the arrow instead of just an oriented line. This would require so more advanced coding and possible something that may involve using another programming language as well. That said I was very pleased to be able to build this tool and I hope to continue to improve my coding skills to be able to use them in the work force in the future.

Acknowledgments:

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