Tutorial: Modeling Unconfined Valley Bottoms with the Valley Confinement Algorithm (VCA)

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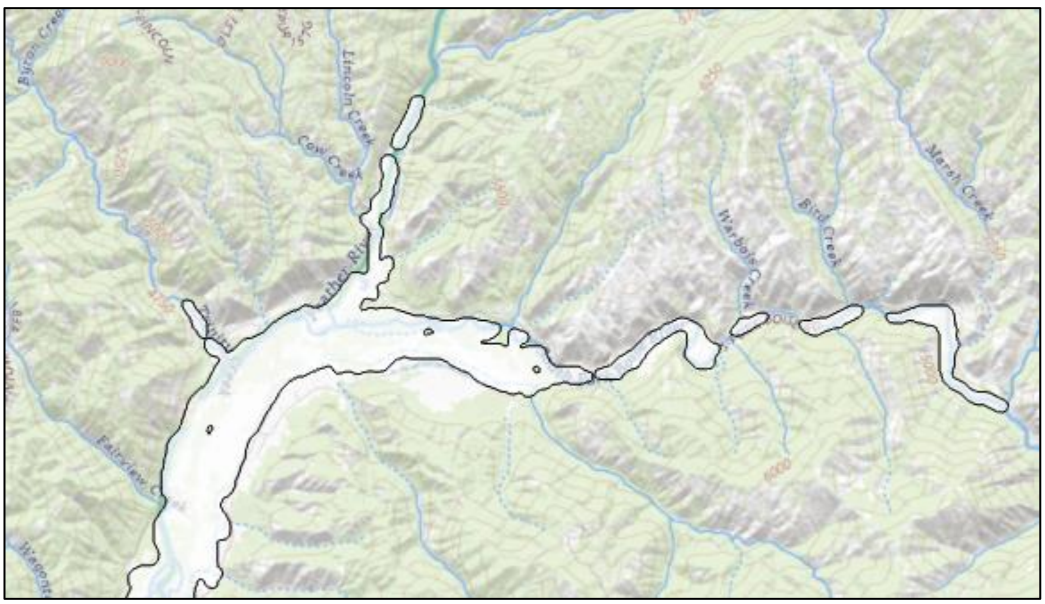

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Rocky Mountain Research Station
Air, Water, & Aquatic Environments Program

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1.0 Introduction

This document supplements the General Technical Report: **A landscape scale valley confinement algorithm: Delineating unconfined valley bottoms for geomorphic, aquatic, and riparian applications.** Link: https://research.fs.usda.gov/treesearch/45825

The General Technical Report was published in 2014 and describes the valley confinement algorithm (VCA) development and validation, along with geomorphic concepts concerning unconfined valley bottoms. This document is an updated tutorial for using the VCA, which incorporates new information related to the release of ArcGIS Pro software, and updates to the NHDPlus dataset.

The VCA requires three input GIS data types:

1) A digital elevation model (DEM)
2) Streamlines
3) Waterbodies, such as lakes and reservoirs

It's recommended that the GIS layers are acquired from the NHDPlusV2 dataset.
Link: https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data

These data are the 1:100,000 scale, medium resolution streamlines and waterbodies from the USGS quadrangle maps. The associated DEM data are the 30 m resolution (1 arc second) elevation rasters.

Other input GIS data such as the 1:24,000 scale NHDPlus HR dataset, along with USGS 10 m 3DEP DEMs may be used, however these data have not been validated with the VCA and output results must be verified by the user.

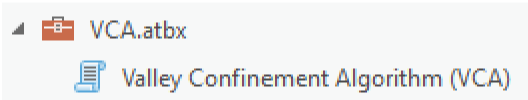
2.0 Software Requirements and Installation

2.1 Software Requirements

The VCA was written for ArcGIS Pro version 3.1.4. A working knowledge of ArcGIS Pro and spatial analysis fundamentals is required to complete this tutorial.

2.2 Installation

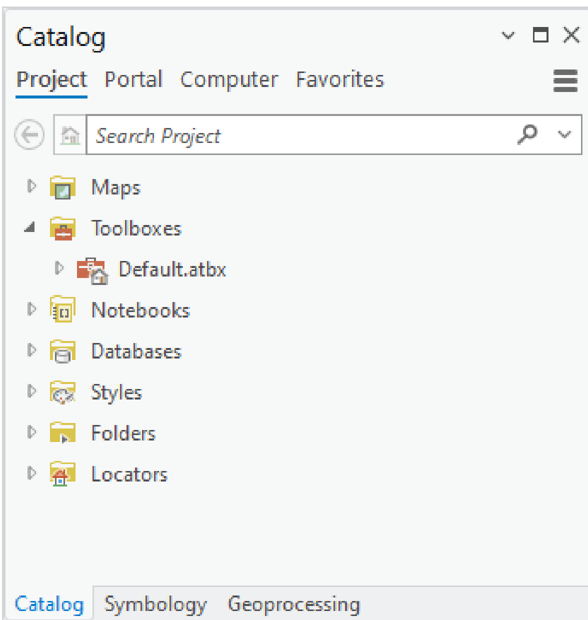
The VCA is distributed as an ArcGIS Pro Toolbox. The Toolbox is called VCA.atbx and the algorithm script is called Valley Confinement Algorithm (VCA).



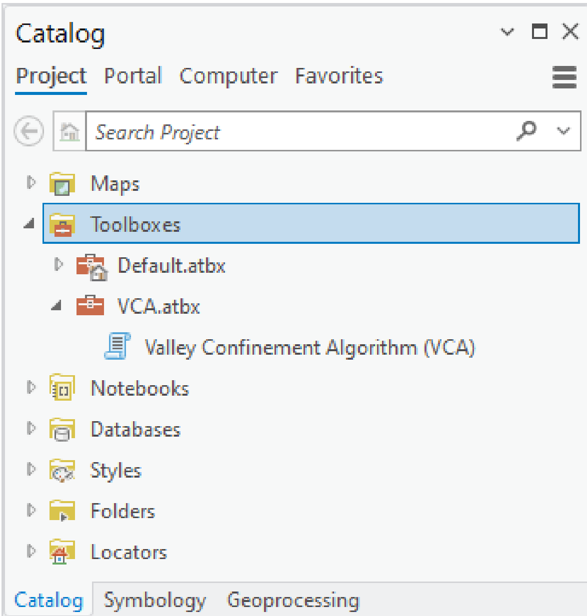
The toolbox can be downloaded from this location:
https://research.fs.usda.gov/rmrs/products/dataandtools/valley-bottom-confinement-data

To install the toolbox:

1) Download the .zip file from the website and unzip it.
2) In an ArcGIS Pro Catalog pane, navigate to the Project tab and open the Toolboxes folder.



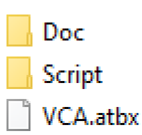
3) Right click the Toolboxes folder and select Add Toolbox.
4) Navigate to VCA.atbx and click it to select. Click OK. The Toolbox will appear in the Catalog pane.



5) Double click the script to open the VCA dialog box.

2.3 Folder Content

When unzipped, the VCA zip content looks like this:



\Doc contains this tutorial and the VCA General Technical report.
\Script contains the VCA Python script
VCA.atbx is the ArcGIS Pro toolbox file. The script is embedded in the toolbox, so setting the path the script is not required.

3.0 Download and Process NHDPlusV2 Data

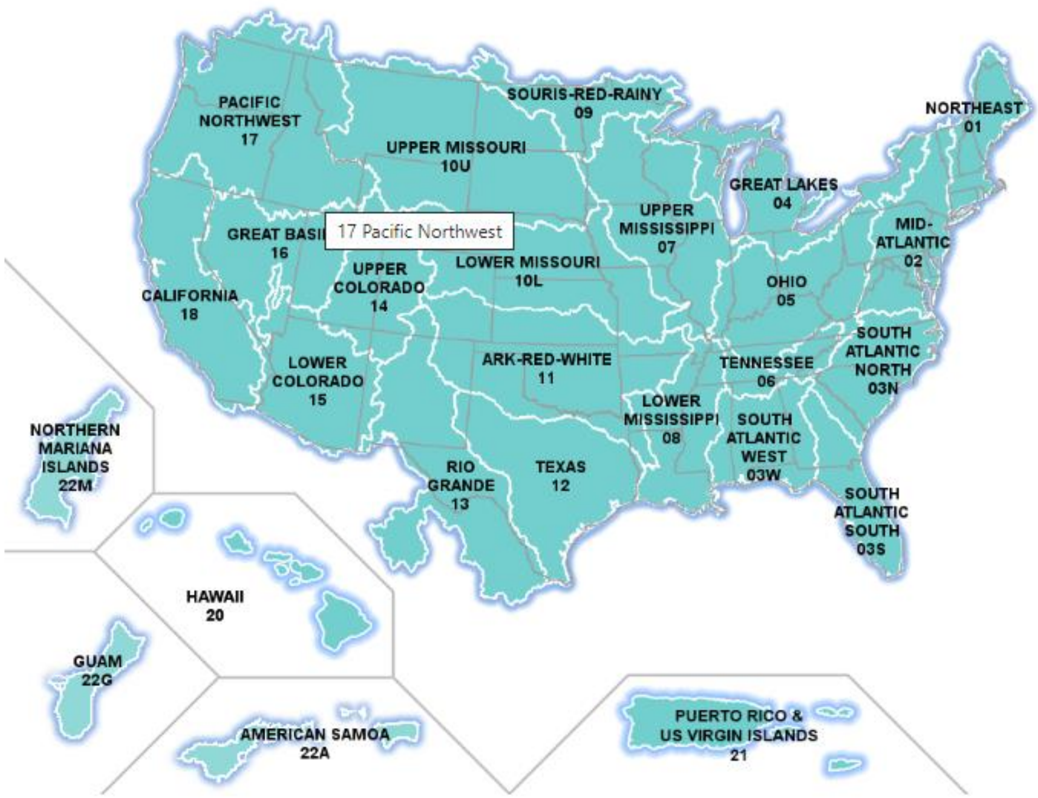
3.1 Download

The NHDPlusV2 data can be downloaded from this website: https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data

Choose the link here:

Download NHDPlus Version 2 (NHDPlusV2) Data

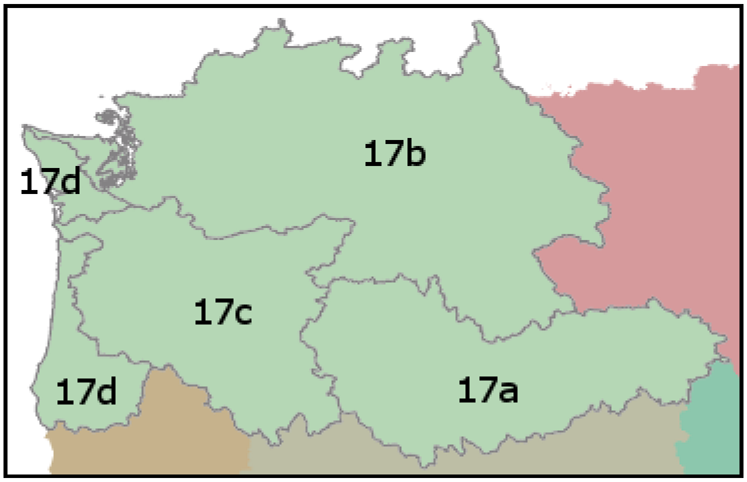
Scroll down to the NHDPlusV2 Data Map



Note that the US is divided into hydrologic regions or Vector Processing Units (VPUs). Select the region for your study area. For this example, we'll look at VPU 17.

Vector and table features are downloaded for an entire VPU. For example, to download the streamlines and waterbodies for all VPU 17, the file NHDPlusV21_PN_17_NHDSnapshot_08.7z will be downloaded.

Also on VPU 17 page, note that the unit is further subdivided into Raster Processing Units (RPUs).



DEM data are downloaded by RPU. For example, by downloading NHDPlusV21_PN_17_17a_NEDSnapshot_01.7z, the resultant DEM will cover the entire geographic area for 17a.

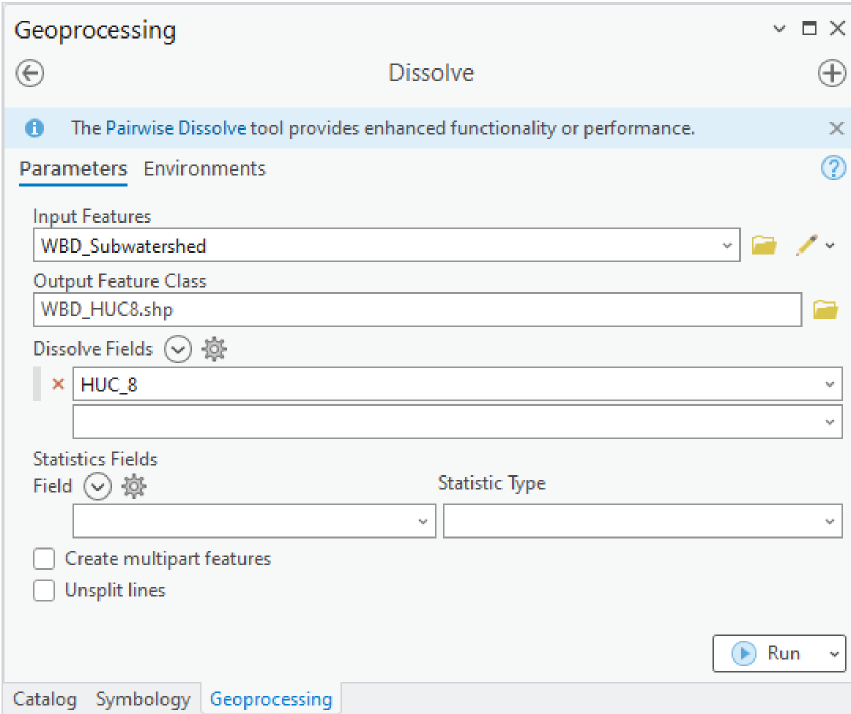
3.1.1 Watershed Boundary Dataset

The Watershed Boundary Dataset (WBD) defines nested watersheds of various sizes for the VPU. We will select an 8-digit or HUC8 watershed for processing in this example.

Download and unzip this file from the NHDPlusV2 website for VPU 17:

NHDPlusV21_PN_17_WBDSnapshot_04.7z(64.1 MB)

After unzipping, drill down through the folders to find the shapefile WBD_Subwatershed.shp.
Open the attribute table and note the field called HUC_8. We'll want to use the Dissolve tool on this shapefile for the HUC_8 field.
Geoprocessing > Toolboxes > Data Management Tools > Generalization > Dissolve



In this case we'll be processing the Salmon River HUC8, 17060201. Display WBD_HUC8.shp and select HUC_8 = 17060201. Write the polygon to a new shapefile called HUC_17060201.shp.

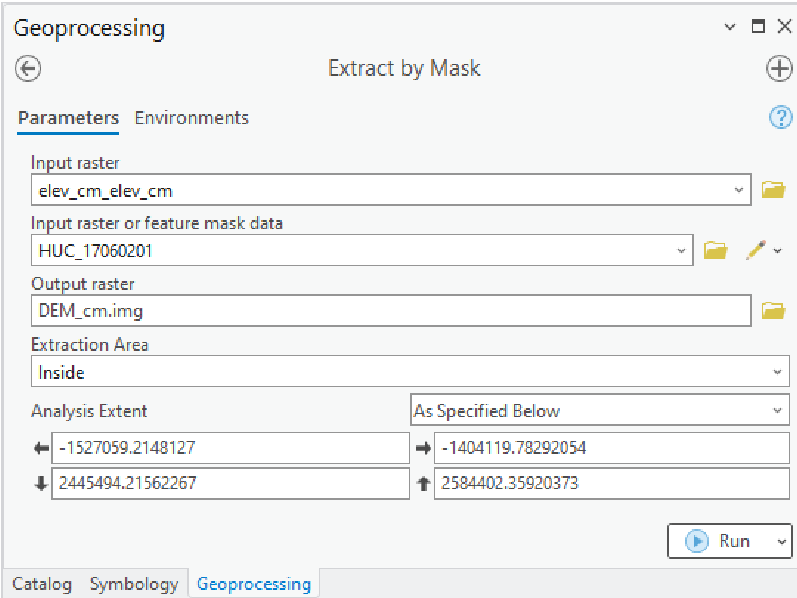
Important: It's recommended that watersheds are processed at the HUC8 or HUC6 level, but not larger. All data must be clipped to the same watershed boundary for the script to run properly.

3.1.2 DEM

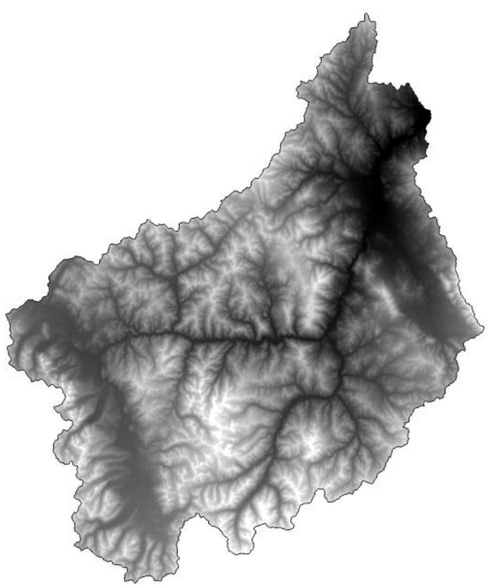
Since HUC 17060201 is in RPU 17b, we'll download this file from the NHDPlusV2 website:
NHDPlusV21_PN_17_17b_NEDSnapshot_01.7z(977.4 MB)

Unzip the DEM. Look for the GRID called elev_cm and display it. Also display the HUC8 polygon.

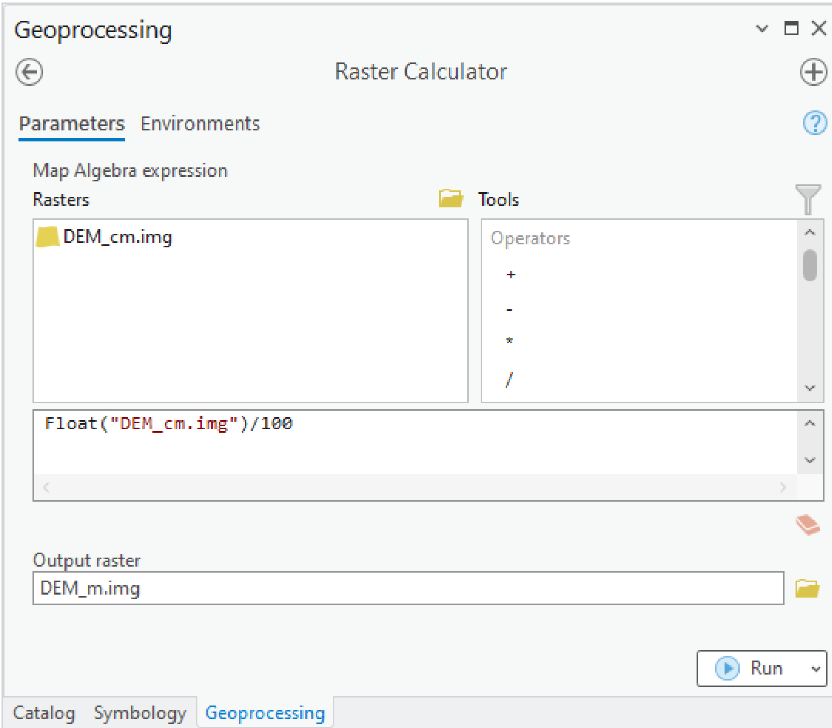
Extract the HUC8 area from the DEM using the tool:
Spatial Analyst Tools > Extraction > Extract by Mask



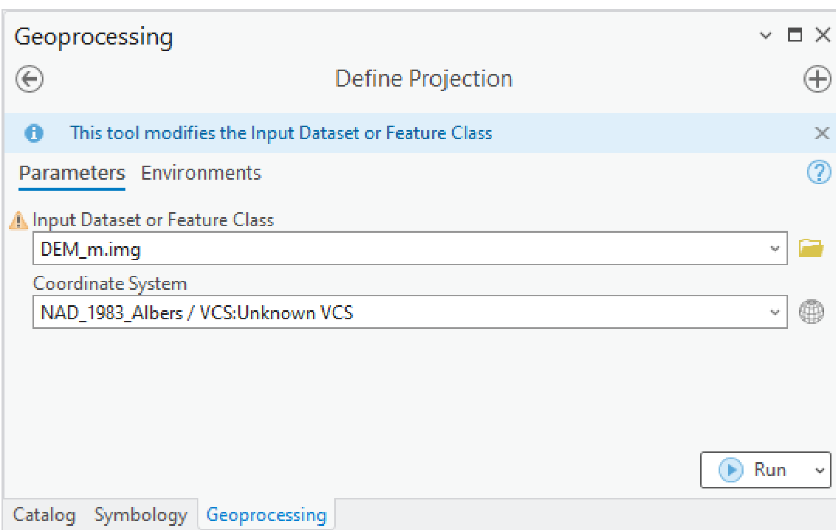
Note that the output image name has the .img extension.



The DEM is in units of centimeters and need to be converted to meters. To do the conversion, use the Raster Calculator tool:
Spatial Analyst Tools > Map Algebra > Raster Calculator

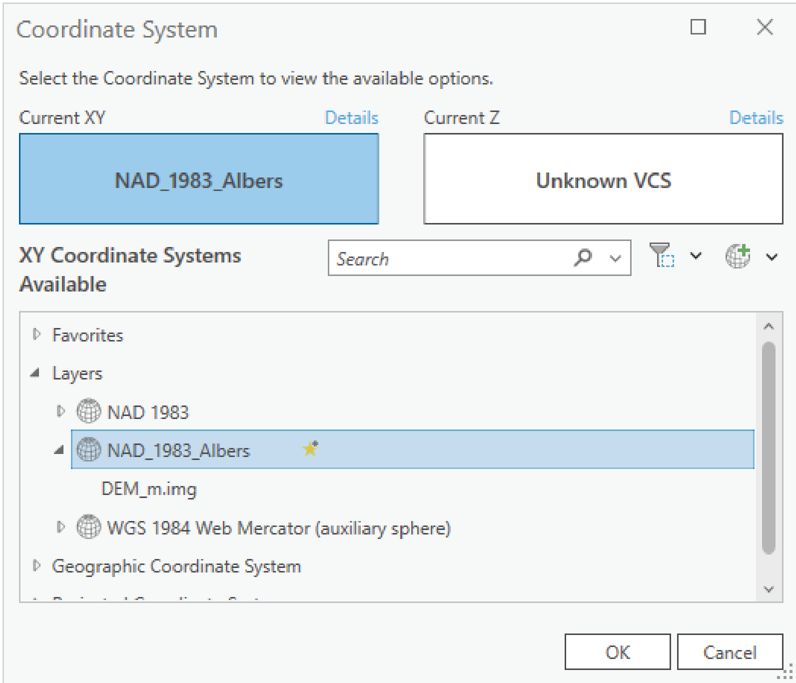


Important: Next the projection must be defined to change the vertical units to meters. To do so: Data Management Tools > Projections and Transformations > Define Projection

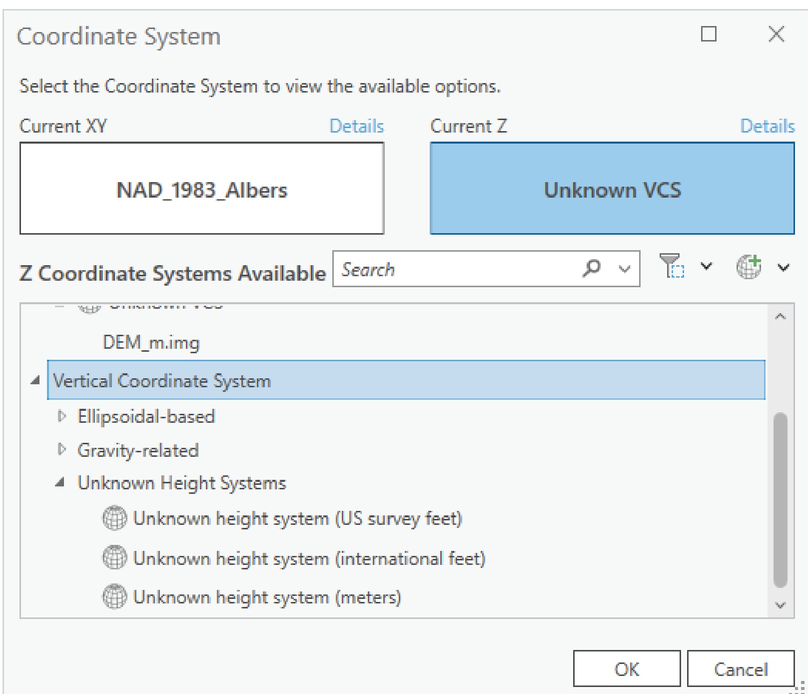


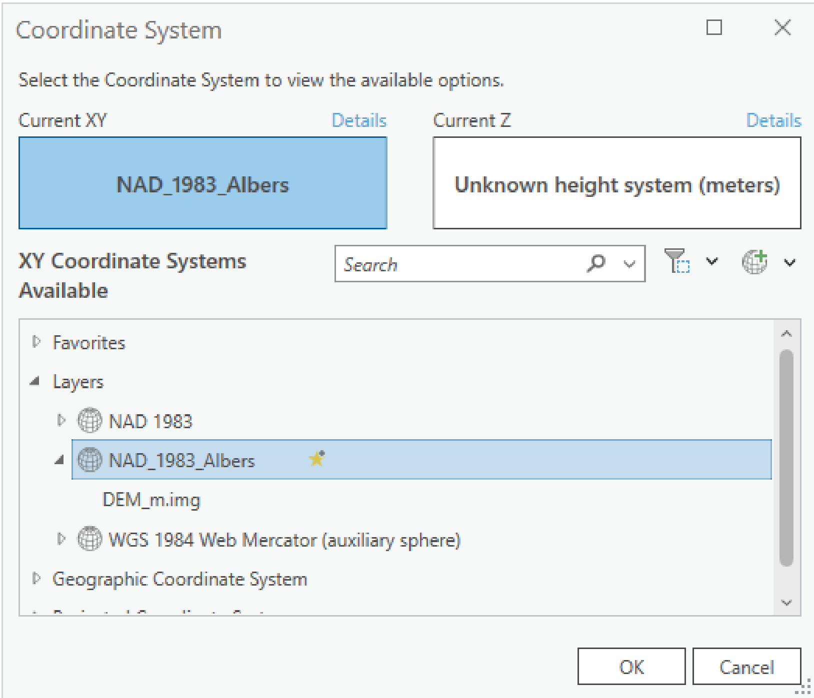
Before hitting Run, select the globe icon to the right of the second input box.

Under Current Z in the selection box, we want to change the selection from Unknown VCS to Unknown Height System Meters. To do so, click in the box under Current Z.



Then open Vertical Coordinate System and Unknown Height Systems in the lower pane. Then choose Unknown height system (meters).





Click OK. Then hit Run on the Define Projection dialog box.

Important: The DEM is now ready to use. The NHDPlusV2 DEM data are in the Standard Albers Project for the Contiguous United States, with a central meridian of -96 degrees through the center of the country. If you wish to use another projection, now is the time to reproject to another Albers projection or UTM. The DEM must be in a rectangular coordinate system and can not be in a geographic system such as decimal degrees. To reproject the DEM, use the following tool:
Data Management Tools > Projections and Transformations > Raster > Project Raster
Use the Cubic convolution Resampling Technique and an Output Cell Size of 30 m.

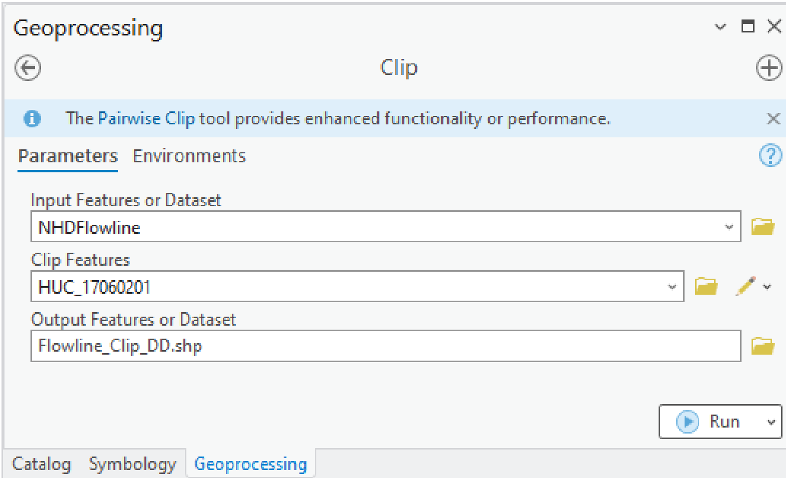
3.1.3 Flowlines and Waterbodies

Download the following file from the website:
NHDPlusV21_PN_17_NHDSnapshot_08.7z(102.1 MB)

Unzip and drill down to the \Hydrography folder and find NHDFlowline.shp and NHDWaterbody.shp

Display both shapefiles along with the HUC_17060201.shp file.

Use the Clip tool to clip both shapefiles:
Analysis Tools > Extract > Clip



Clip both the flowlines and waterbodies in this fashion. The _DD suffix indicates that the shapefiles are in the decimal degrees coordinate system. These will be projected to the Albers projection to match the DEM data.

Display the DEM data.
Project both the clipped flowlines and waterbodies shapefiles:
Data Management Tools > Projections and Transformations > Project
For Output Coordinate System, choose the DEM

Important: The DEM, flowlines, and waterbodies must all be in the same projection.

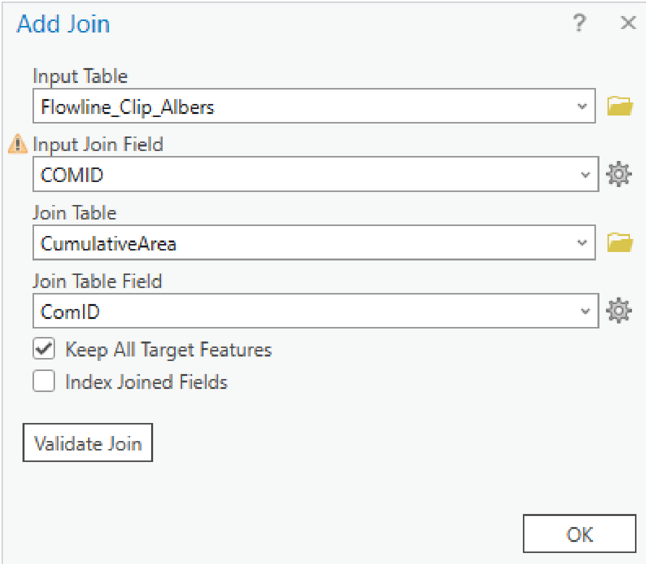
3.1.4 Drainage Area

The total drainage area for each stream reach in the flowline shapefile must be joined to the reaches.

Download the following file from the website and unzip:
NHDPlusV21_PN_17_NHDPlusAttributes_10.7z(21.7 MB)

Display Flowline_Clip_Albers.shp.
Drill down to the table called CumulativeArea.dbf and add the table to the viewer with the flowline shapefile.

Right click Flowline_Clip_Albers.shp > Joins and Relates > Add Join

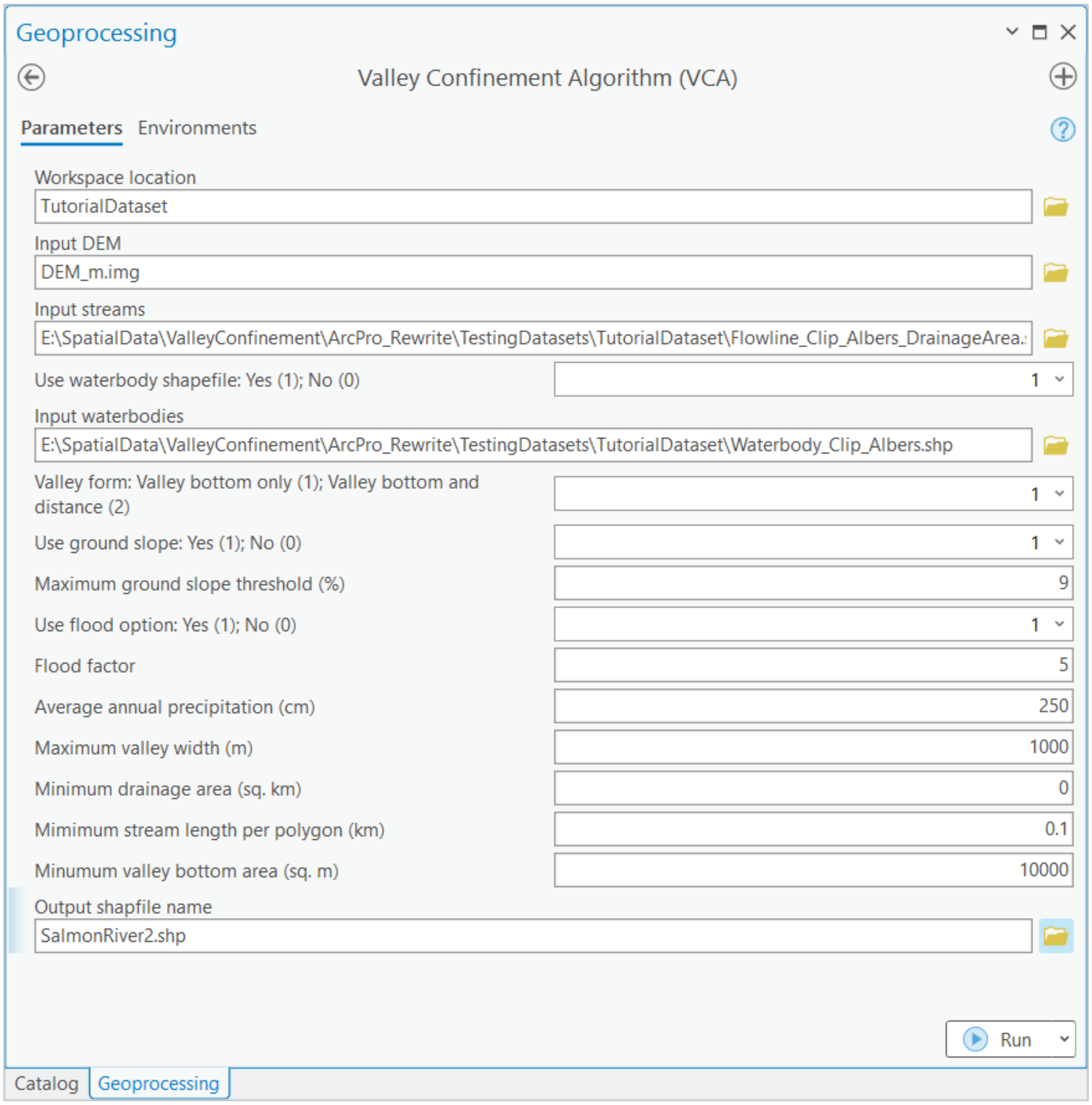


Hit OK. Right click Flowline_Clip_Albers.shp and choose Data > Export Features.
Save as file name: Flowline_Clip_Albers_DrainageArea.shp

Check to be sure the attribute table as a field called TotDASqKM. This field is required for the VCA to run properly.

3.0 Run the VCA

Start the VCA script by double clicking on it in the Project > Toolboxes folder.



Enter inputs in the dialog box as follows:

Workspace location: The folder where the input data resides (DEM, flowlines, waterbodies) and the output will be saved. Temporary files are stored in a folder named \Temp

Input DEM: The DEM in units meters with the vertical units defined as meters. Must be in a rectangular coordinate system such as Albers or UTM.

Input Streams: The flowlines in the same projection as the DEM and with the field TotDASqKM joined.

Use waterbody shapefile: Always use a waterbody shapefile if available. If there are no waterbodies in the HUC, answer No (0) and a shapefile will be created.

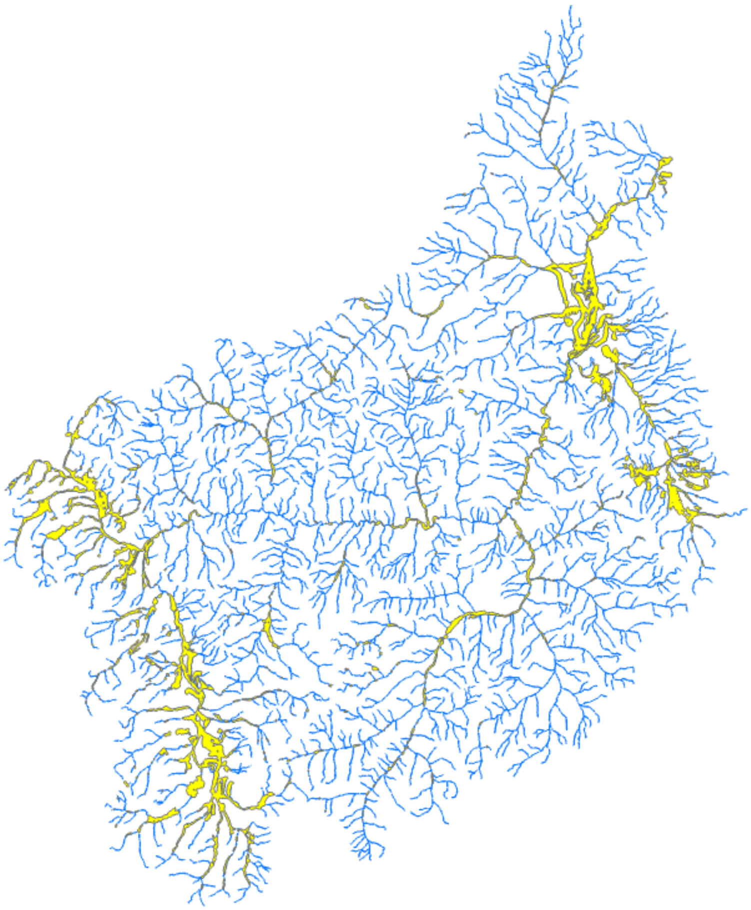
Valley form: The default is now hard coded to always use Valley form = 1 in the algorithm. In the new version of the script both the valley bottom and distance products will always be generated.

Use ground slope: Recommended to always use the default.

Maximum ground slope threshold: Percent ground slope value that will initialize flat valley bottoms. 9% slope is a good value for the 30 m DEMs as it will include the outer pixels as the valley bottom approaches the valley side-slope. This result will be moderated by the flood option below.
Use flood option: Recommended to use the default. The flood option simulates flooding the valley from the stream channel outward and will help moderate the maximum ground slope threshold value of 9%.
Flood factor: The height above the stream channel to flood the valley. If the stream channel is modeled to be 1 m deep, the flood value will be 5 meters.
Average annual precipitation: The mean annual precipitation for the watershed. The algorithm is not extremely sensitive to this input, but it is used to model channel depth, and therefore influences the flood depth. Recommended source dataset is PRISM.
Maximum valley width: The maximum width an unconfined valley polygon can expand to (units meters).
Minimum drainage area: The smallest drainage area to initiate flat valley bottoms. Increasing the value will initiate valley bottom polygons lower in the watershed. The default of 0 will initiate all valley bottoms, even those in headwater channels with intermittent streams.
Minimum stream length per polygon: Used to eliminate valley bottom polygons where valleys may be insignificant because they do not contain enough channel length. The default is 100 m or 0.1 km.
Minimum valley bottom area: Again, used to eliminate small valley bottom polygons, but using area rather than stream length.
Output shapefile name: Name like: SalmonRiver.shp. Two output files will be generated. SalmonRiver_VB.shp and SalmonRiver_DISTANCE.shp. Both the valley bottom extent and distance from valley bottom shapefiles will be generated.

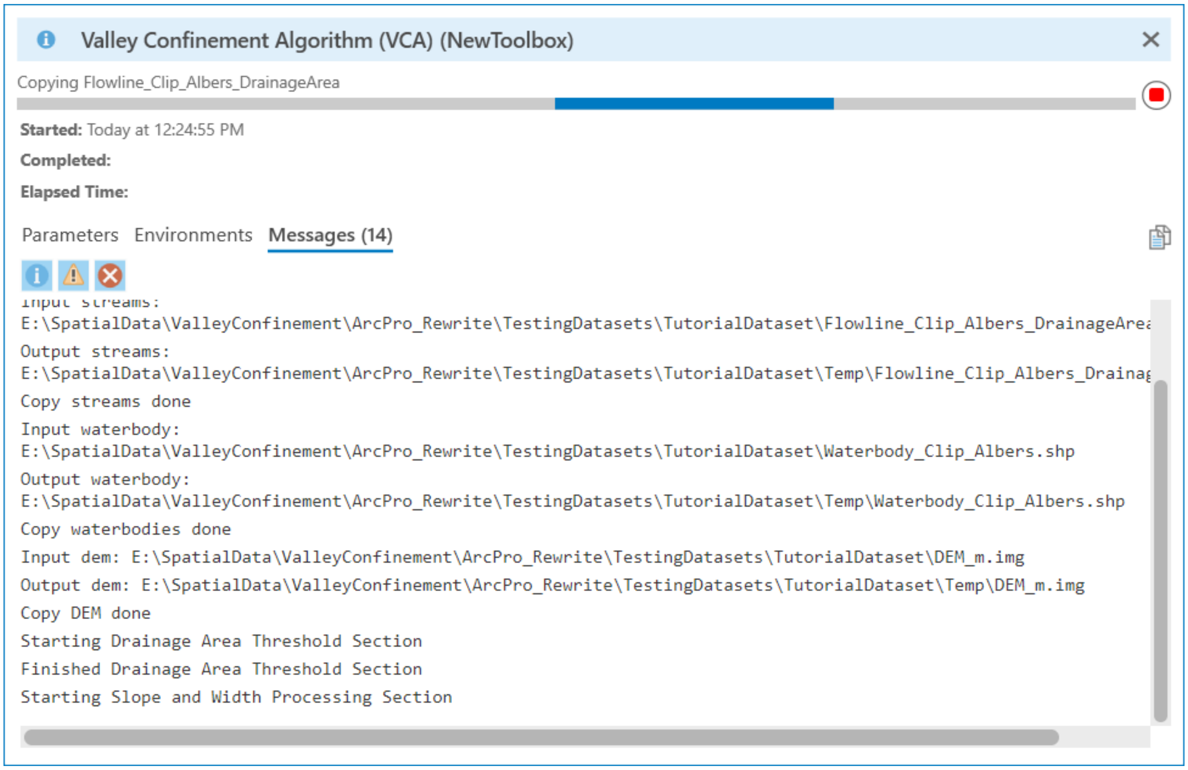
To initiate, hit the Run button.

The output should look something similar to below. Yellow is unconfined valley bottoms and blue represents distance from unconfined valley bottom. The distance values are:
0 - Valley bottom polygon
1-30 - Distance from valley bottom (km)
31 - Distance greater than 30 km
50 - Lakes and reservoirs



4.0 Trouble Shooting

Status messages are displayed as the program is being executed. To view them, click the View Details text at the bottom of the VCA dialog box while the program is running. Expand the box so that the messages are clearly visible.



If an error occurs, view the error message to assess the potential problem. If the error cannot be corrected, select the copy button on the right of the message box:

Copy the full message history to a Word document and send to David Nagel (david.nagel@usda.gov).