



2022 ESRI USER CONFERENCE

# Spatial Analyst: New Surface and Hydro Tools

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# Surface

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# Surface Tools: Aspect, Curvature, Slope Surface Parameters

The image displays three screenshots of the Geoprocessing tool interface for Aspect, Curvature, and Slope, and a fourth screenshot of the Geoprocessing toolboxes showing Surface Parameters highlighted.

**Aspect Tool:** The interface shows the "Aspect" tool with a "Parameters" tab. It includes an "Input raster" field, an "Output raster" field, and a "Method" dropdown menu set to "Planar". A "Run" button is visible at the bottom right.

**Curvature Tool:** The interface shows the "Curvature" tool with a "Parameters" tab. It includes an "Input raster" field, an "Output curvature raster" field, a "Z factor" input field, and two "Output profile curve raster" fields. A "Run" button is visible at the bottom right.

**Slope Tool:** The interface shows the "Slope" tool with a "Parameters" tab. It includes an "Input raster" field, an "Output raster" field, an "Output measurement" dropdown menu set to "Degree", a "Method" dropdown menu set to "Planar", and a "Z factor" input field set to "1". A "Run" button is visible at the bottom right.

**Geoprocessing Toolboxes:** The interface shows the "Geoprocessing" toolboxes with a search bar and a list of tools. The "Surface Parameters" tool is highlighted with a blue arrow. The list includes:

- Surface
  - Add Surface Information
  - Aspect
  - Contour
  - Contour List
  - Contour with Barriers
  - Curvature
  - Cut Fill
  - Geodesic Viewshed
  - Hillshade
  - Interpolate Shape
  - Observer Points
  - Slope
  - Surface Parameters**
  - Viewshed
  - Visibility

# Does One Size Fit All?



# Surface Parameter: A Single Tool

- Many terrain analysis metrics in a single ArcGIS tool
  - Easy to find many methods
  - Easy to rerun with similar parameters
- Neighborhood window size appropriate for DEM resolution
- Support for spatial scaling
- Surface fitting options to improve results from noisy high resolution DEMs
- Remove map projection distortion
- Clarity of curvature names and formulas



Geoprocessing

Surface Parameters

Parameters Environments

\* Input surface raster

\* Output raster

Parameter type

Slope

Local surface type

Quadratic

Neighborhood distance

0 Decimal Degrees

Use adaptive neighborhood

Z unit

Meter

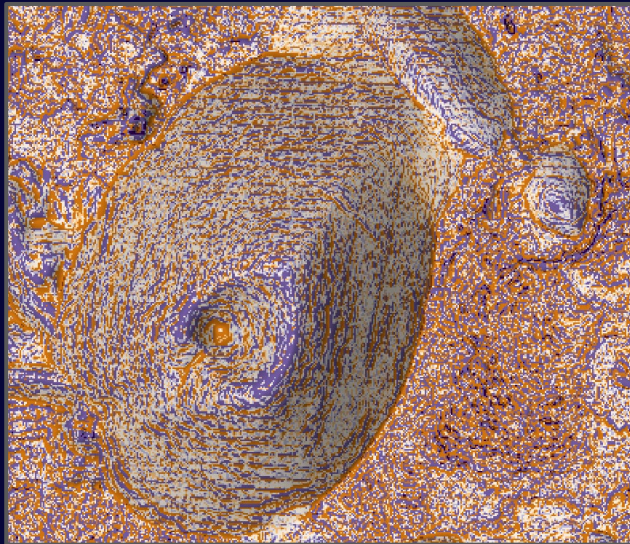
Output slope measurement

Degree

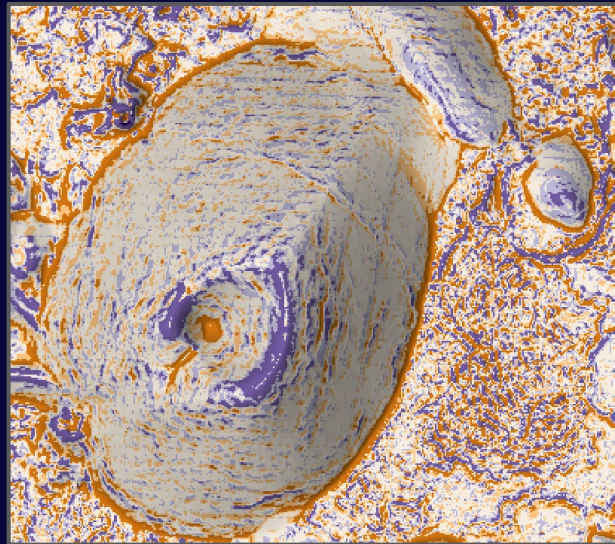
Run

# User Specified Neighborhood Window

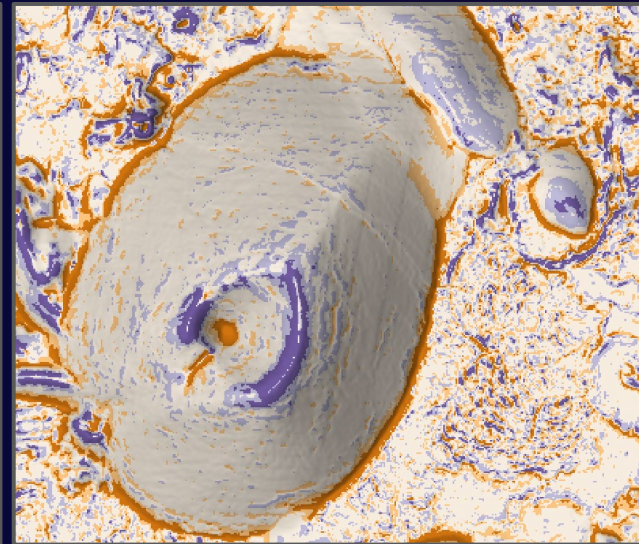
- Specify a window size that matches the cellsize of your elevation and the size of landscape features of interest.
- Run multiple times with different window sizes for multiscale analysis
- The neighborhood window is square, in odd intervals; 3x3, 5x5, etc.



3x3



9x9

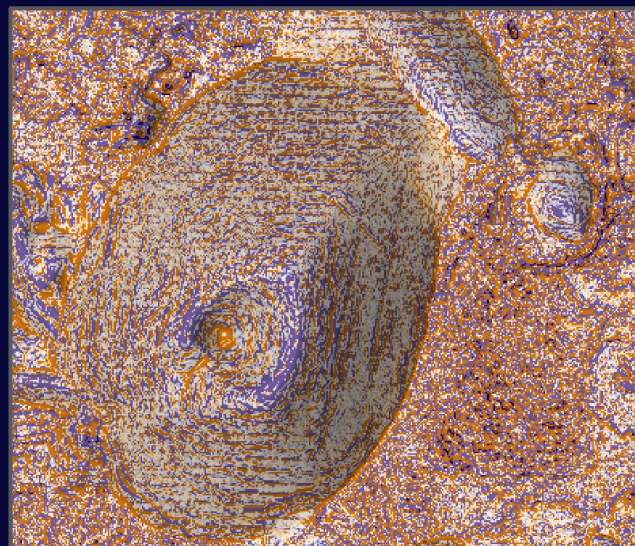


15x15

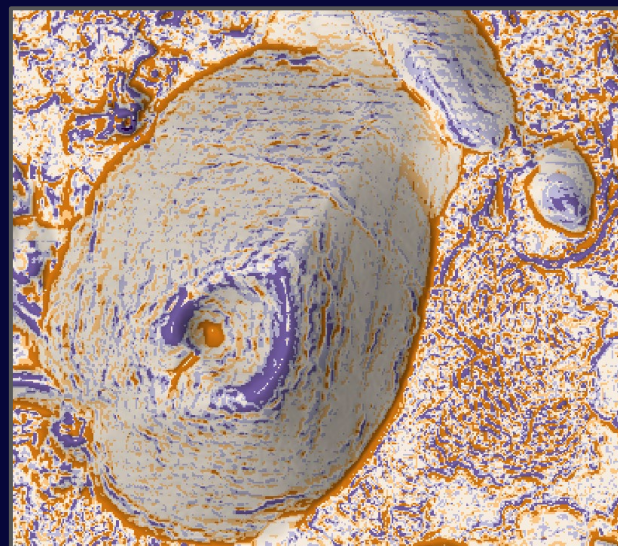
# Optional Adaptive Neighborhood Window

Auto adapts from 3x3 to user specific maximum

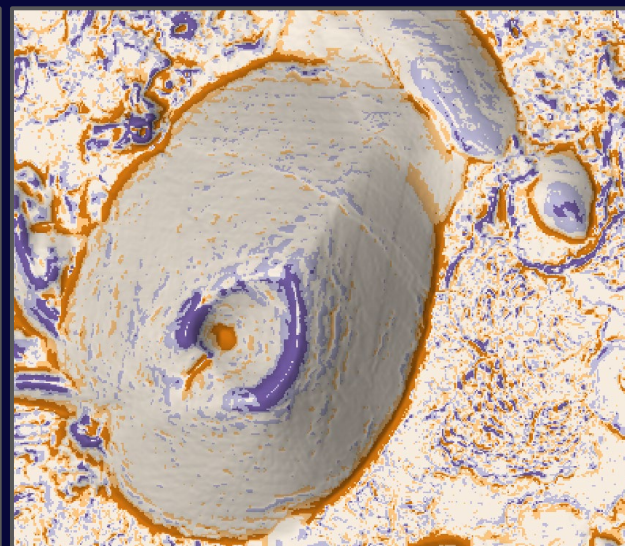
- Evaluates surface complexity for each cell at progressively smaller window sizes until a threshold is met.
- Uses deviation from mean elevation. 
$$\text{DEV} = \frac{z_0 - \bar{z}}{\text{SD}}$$
- Follows approach of *James et al., 2014*



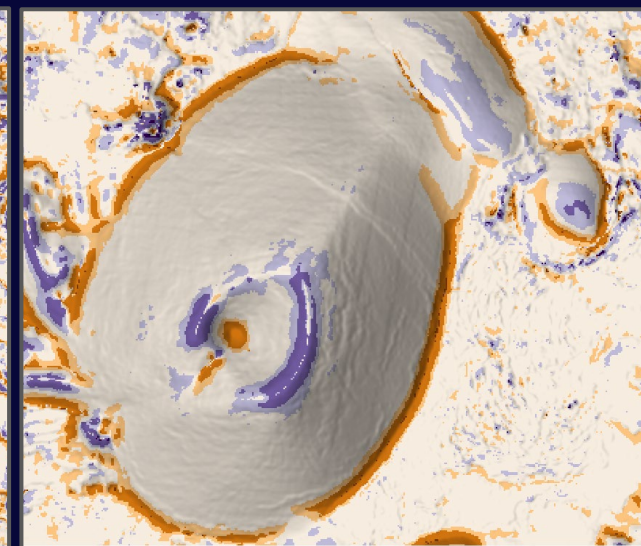
3x3



9x9



15x15



3x3 to 15x15 Adaptive

# Surface Fitting Options

- QUADRATIC (default)

aka second order polynomial

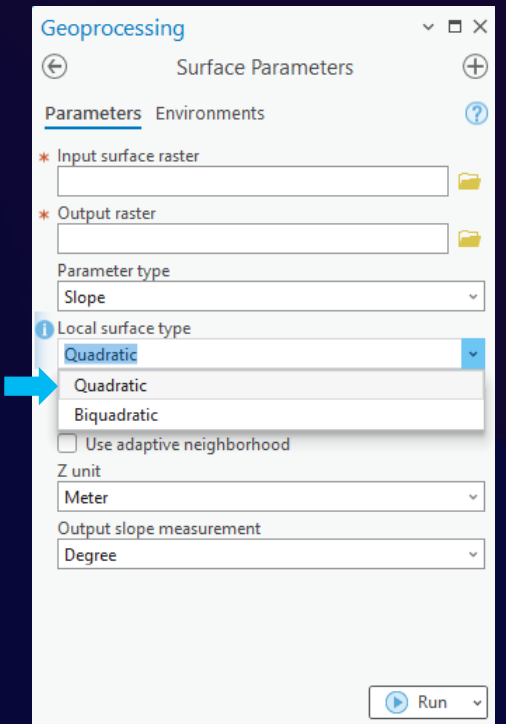
$$z = f(x, y) = a_0 + a_1x + a_2y + a_3xy + a_4x^2 + a_5y^2$$

- BIQUADRATIC

aka fourth order polynomial

aka partial quartic

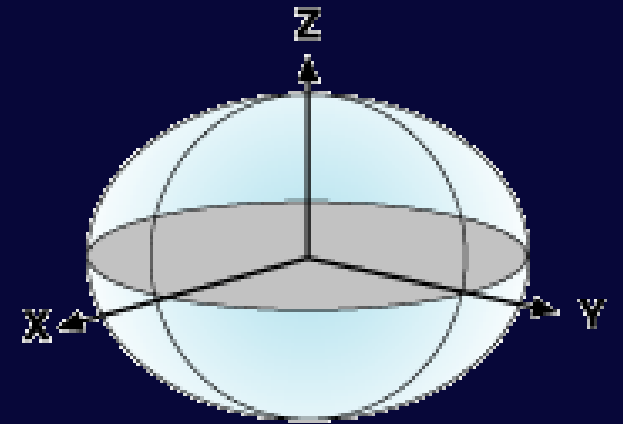
$$z = f(x, y) = a_0 + a_1x + a_2y + a_3xy + a_4x^2 + a_5y^2 + a_6x^2y + a_7y^2 + a_8y^2x^2$$





# No Map Projection Distortion

- All calculations in the ArcGIS Surface Parameters tool are geodesic.
- Coordinate system of input data does not matter (spherical or planar).
- Eliminates map projection distortion of distances and angles.



# New Geometric Curvatures

Following naming system of *Minár, Evans, and Jenčo 2020*

Contour (projected contour) curvature

Profile (normal slope line) curvature

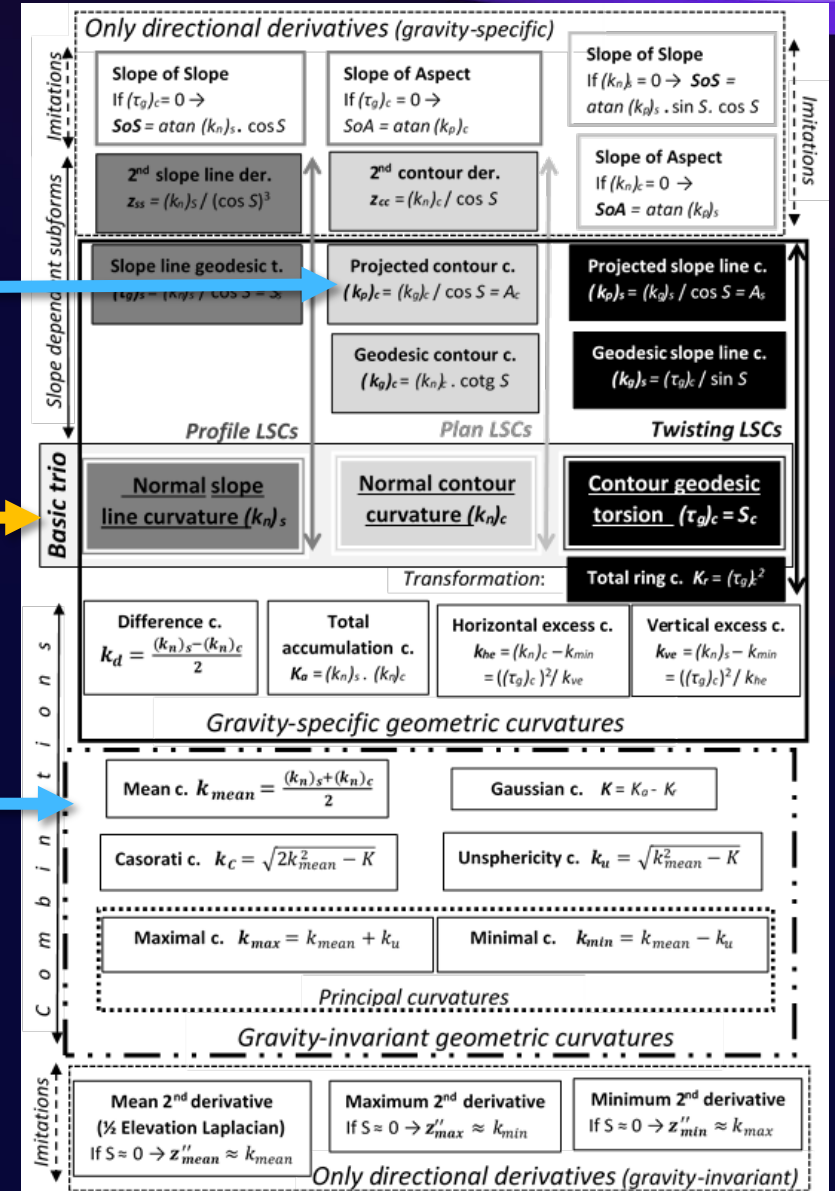
Tangential (normal contour) curvature

Contour geodesic torsion curvature

Mean curvature

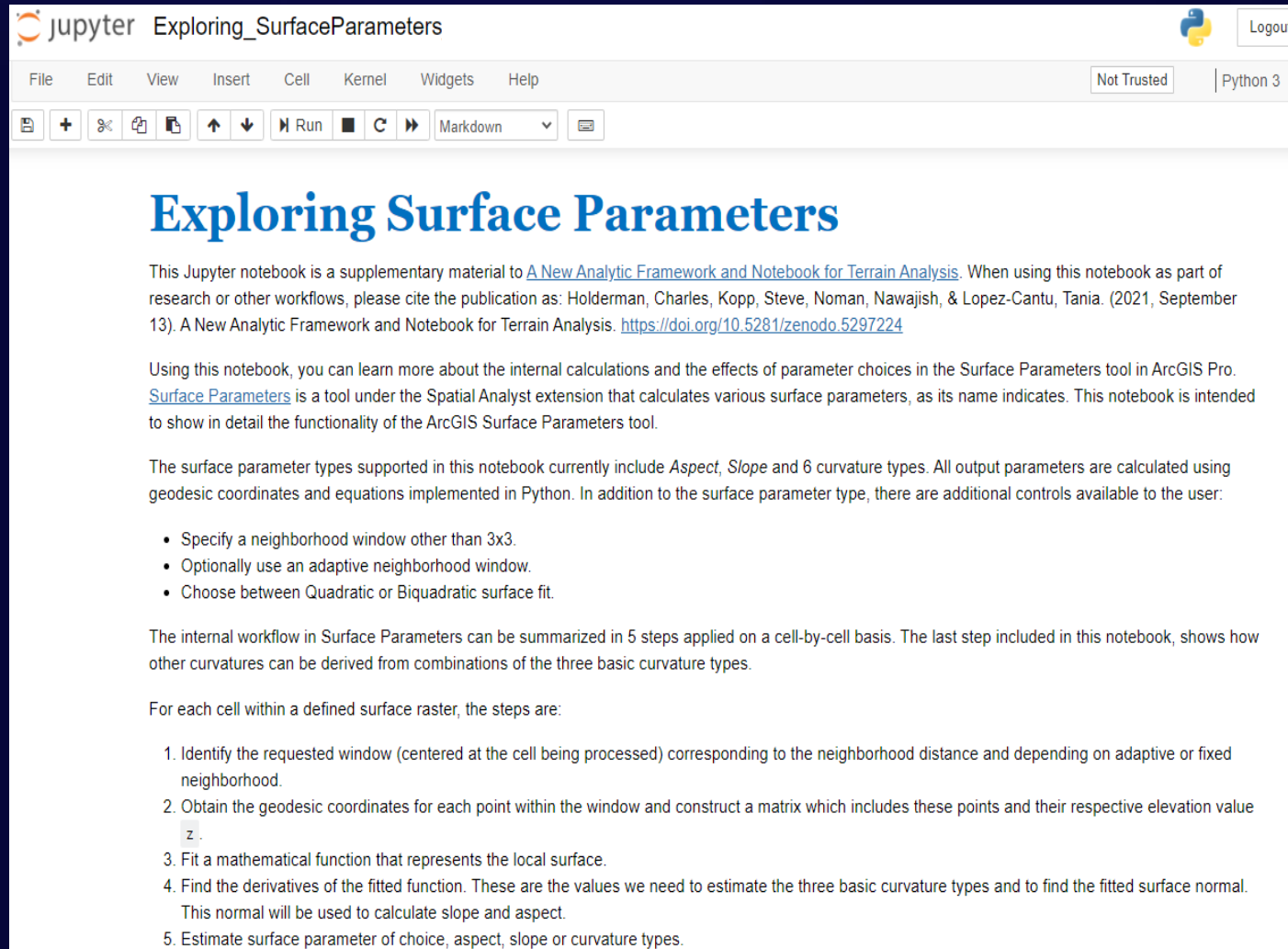
Gaussian curvature

Casorati curvature



# A Jupyter Notebook to Explore Surface Parameters

<https://www.esriurl.com/SurfaceParameters> (download) <https://www.esriurl.com/SurfaceParametersPreview> (preview)



The screenshot shows a Jupyter Notebook interface with the title "Exploring\_SurfaceParameters". The notebook content includes:

## Exploring Surface Parameters

This Jupyter notebook is a supplementary material to [A New Analytic Framework and Notebook for Terrain Analysis](#). When using this notebook as part of research or other workflows, please cite the publication as: Holderman, Charles, Kopp, Steve, Noman, Nawajish, & Lopez-Cantu, Tania. (2021, September 13). A New Analytic Framework and Notebook for Terrain Analysis. <https://doi.org/10.5281/zenodo.5297224>

Using this notebook, you can learn more about the internal calculations and the effects of parameter choices in the Surface Parameters tool in ArcGIS Pro. [Surface Parameters](#) is a tool under the Spatial Analyst extension that calculates various surface parameters, as its name indicates. This notebook is intended to show in detail the functionality of the ArcGIS Surface Parameters tool.

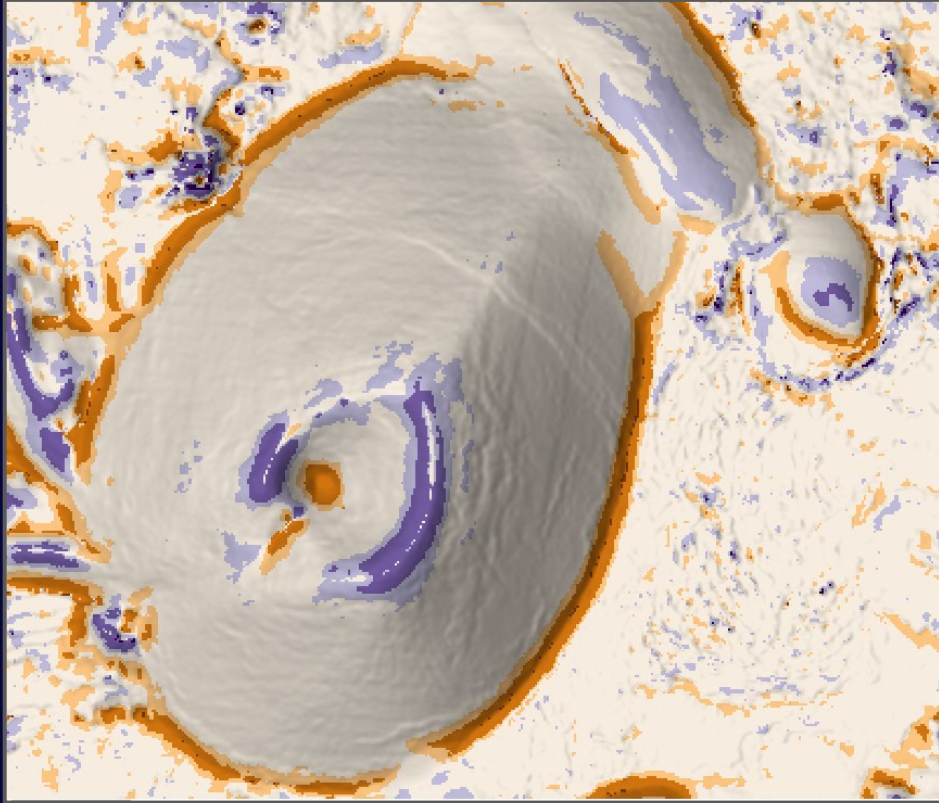
The surface parameter types supported in this notebook currently include *Aspect*, *Slope* and 6 curvature types. All output parameters are calculated using geodesic coordinates and equations implemented in Python. In addition to the surface parameter type, there are additional controls available to the user:

- Specify a neighborhood window other than 3x3.
- Optionally use an adaptive neighborhood window.
- Choose between Quadratic or Biquadratic surface fit.

The internal workflow in Surface Parameters can be summarized in 5 steps applied on a cell-by-cell basis. The last step included in this notebook, shows how other curvatures can be derived from combinations of the three basic curvature types.

For each cell within a defined surface raster, the steps are:

1. Identify the requested window (centered at the cell being processed) corresponding to the neighborhood distance and depending on adaptive or fixed neighborhood.
2. Obtain the geodesic coordinates for each point within the window and construct a matrix which includes these points and their respective elevation value  $z$ .
3. Fit a mathematical function that represents the local surface.
4. Find the derivatives of the fitted function. These are the values we need to estimate the three basic curvature types and to find the fitted surface normal. This normal will be used to calculate slope and aspect.
5. Estimate surface parameter of choice, aspect, slope or curvature types.



# Determine Surface Characteristics

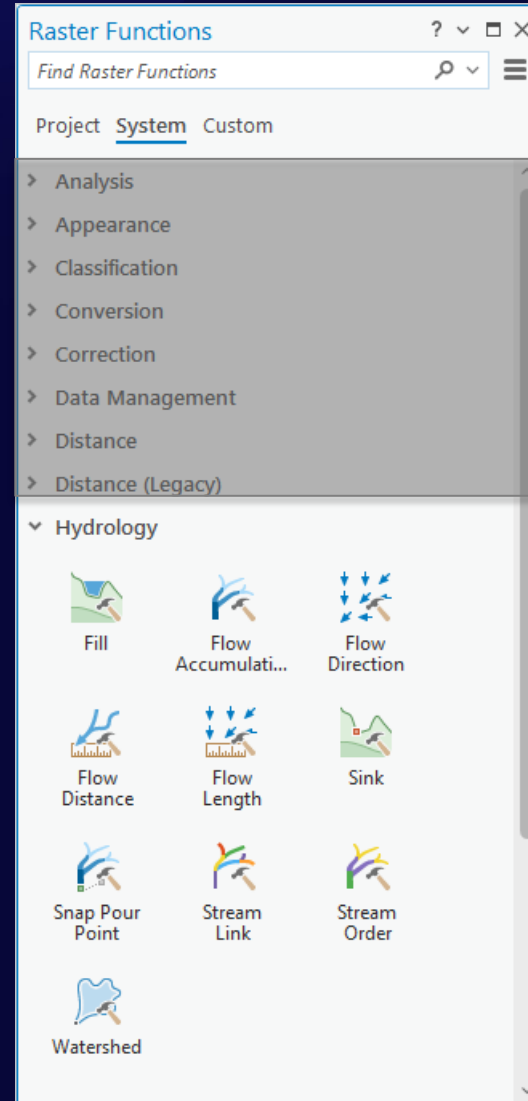
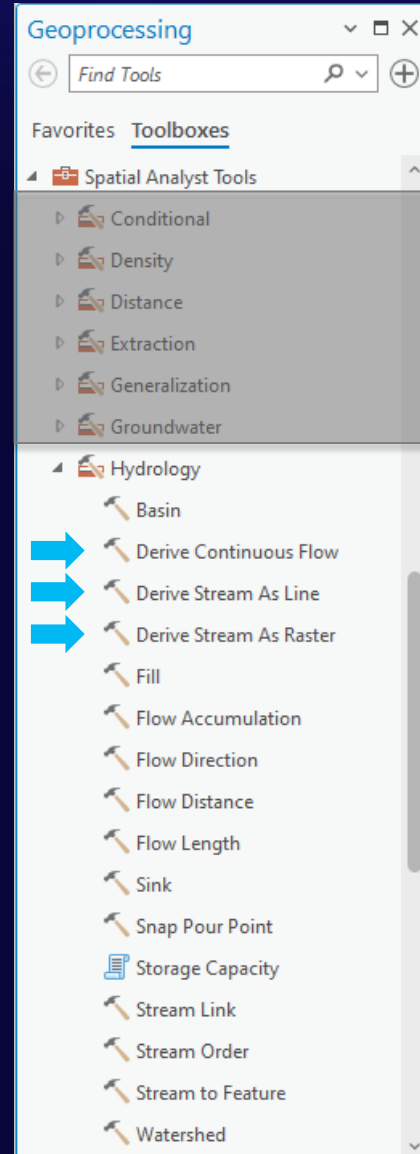
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# Hydrology

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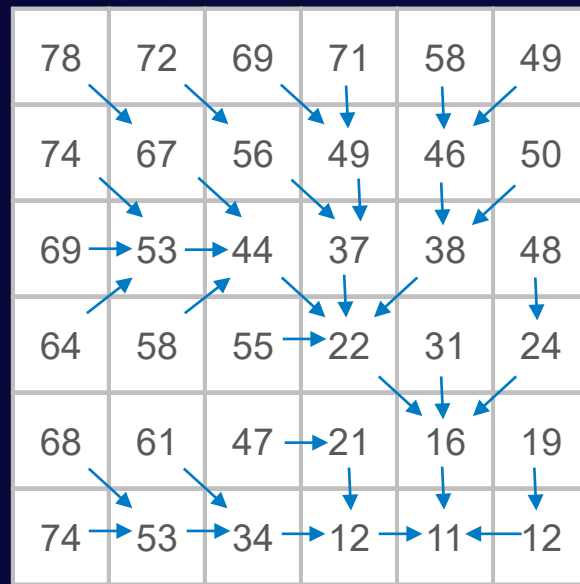


# Hydrology Tools and Raster Functions in Spatial Analyst Extension

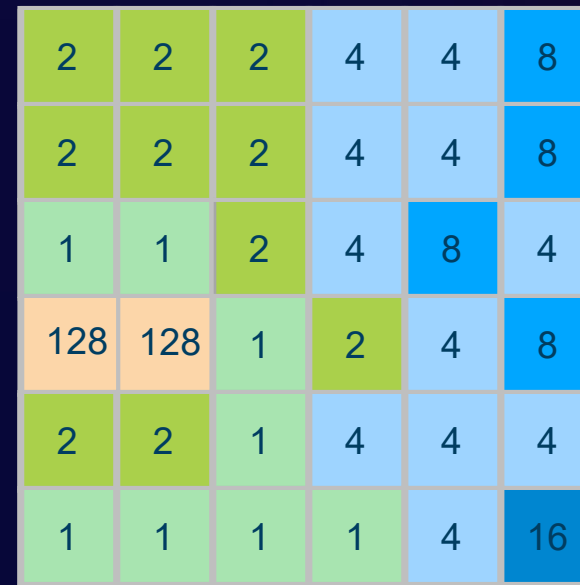


# Flow Direction

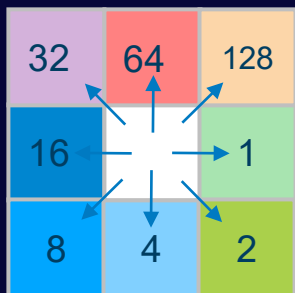
Creates a raster of flow direction from each cell to its downslope neighbor, or neighbors, using D8, Multiple Flow Direction (MFD) or D-Infinity (DINF) methods.



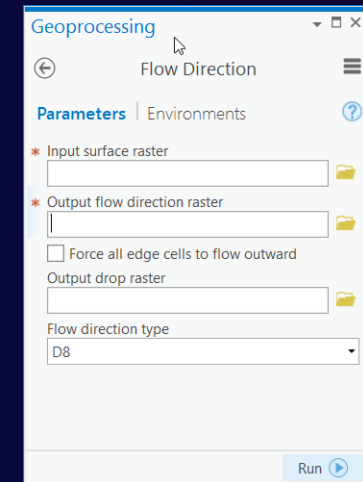
Elevation



Flow Direction

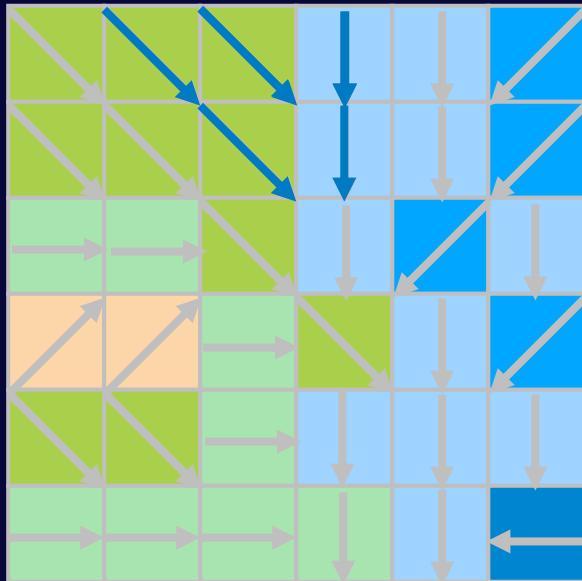


Direction Coding



# Flow Accumulation

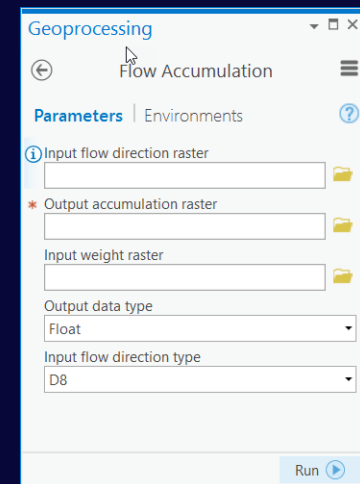
*Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied.*



Flow Direction

0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2

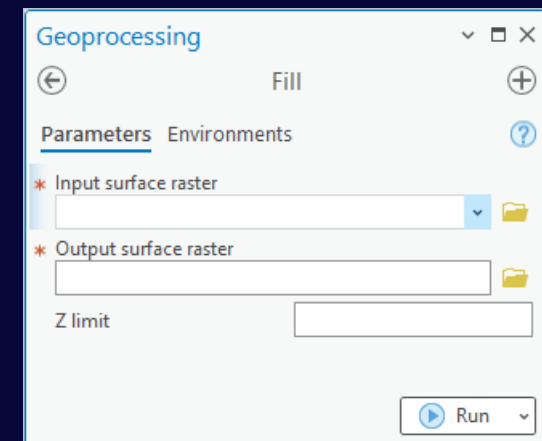
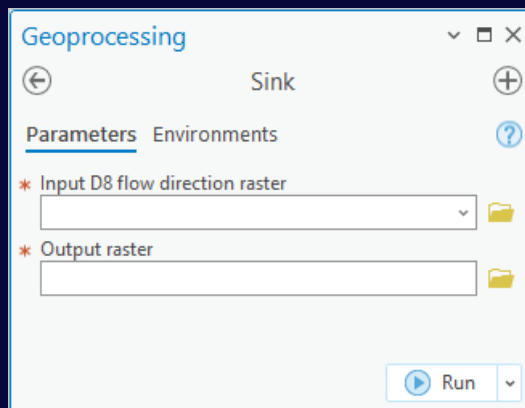
Flow Accumulation





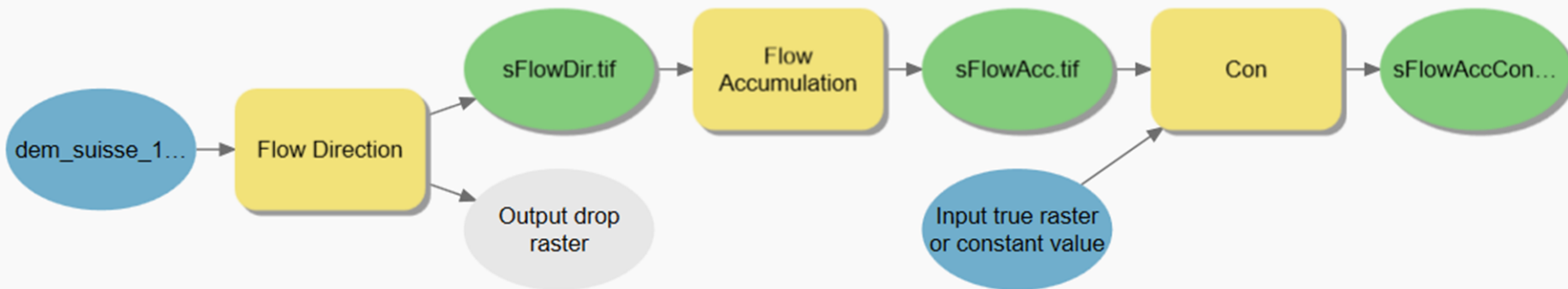
# Sink and Fill

*Fills sinks in a surface raster to remove small imperfections in the data.*

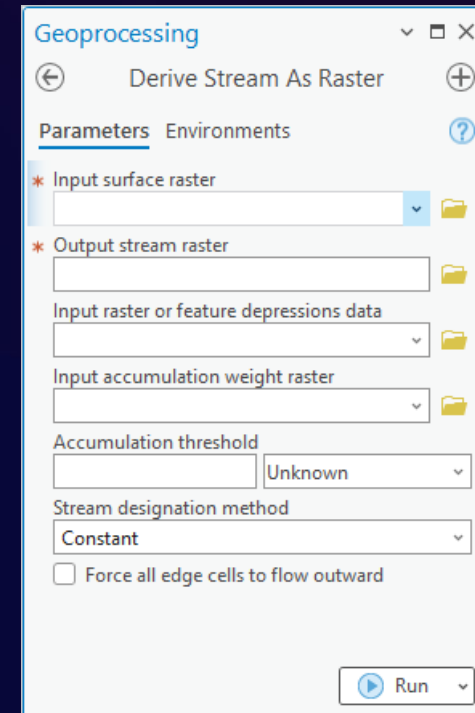
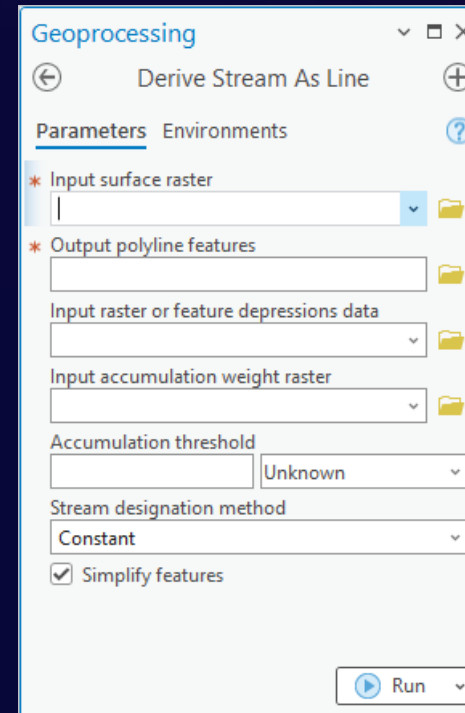
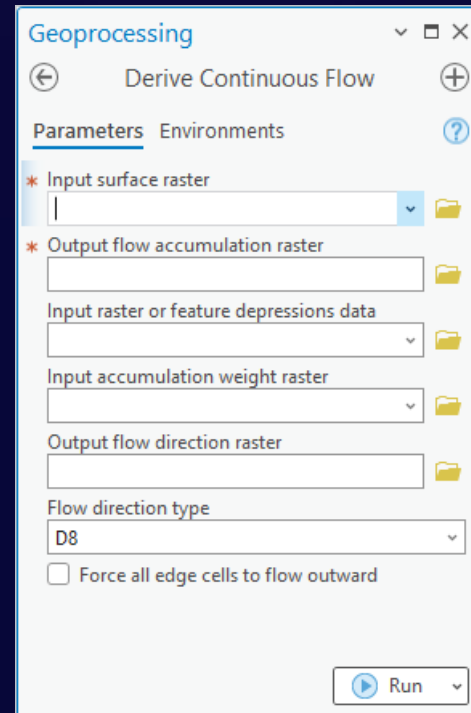
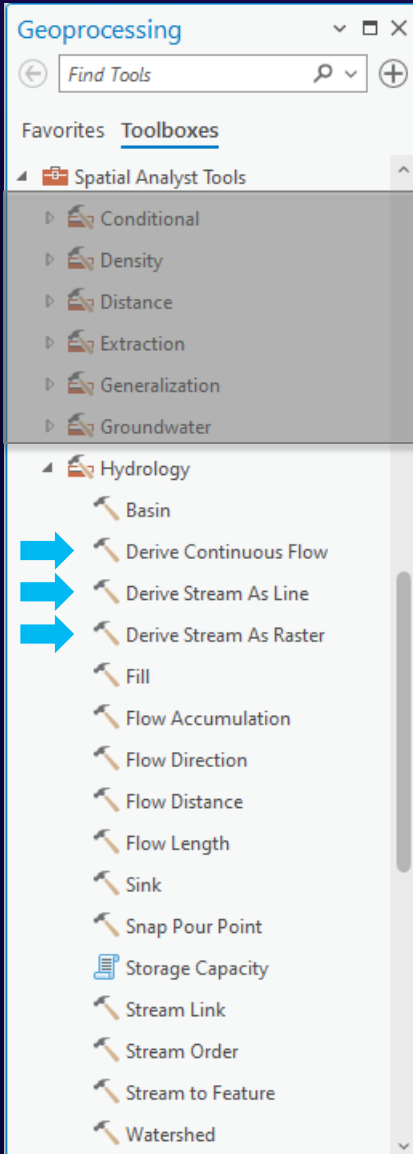


# Stream Extraction from a DEM

- Hydrocondition the DEM (Filling is the easy way out, but not always appropriate)
- Execute a multi-steps process



# Derive Continuous Flow and Streams Tools in Pro 3.0



# Derive Continuous Flow: How it works

- It uses the least-cost path algorithm to move uphill across the surface while minimizing elevation difference.

*Identify outlets around the edge.*

*Identify lowest elevation to start the search.*

*Identify the neighbors, determine flow direction and find the next cell to process.*

*Move towards minimum upslope direction and repeat the process*

12	20	119	18	15	32	28
14	12	22	14	13	15	26
8	11	3	3	5	15	13
9	10	3	12	4	9	14
8	12	8	6	5	3	8
10	15	11	12	10	2	7



12	20	119	18	15	32	28
14	12	22	14	13	15	26
8	11	3	3	5	15	13
9	10	3	12	4	9	14
8	12	8	6	5	3	8
10	15	11	12	10	2	7



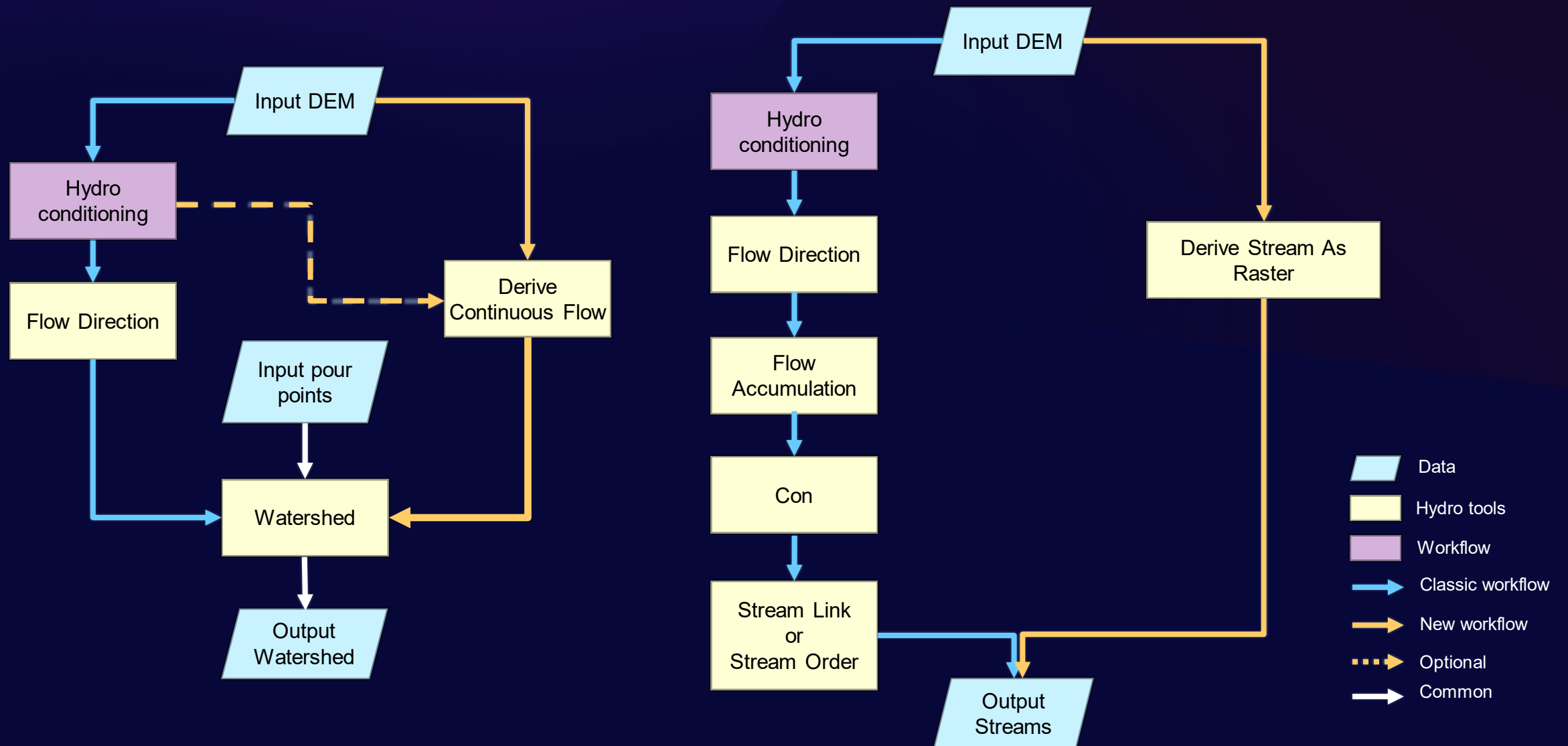
12	20	119	18	15	32	28
14	12	22	14	13	15	26
8	11	3	3	5	15	13
9	10	3	12	4	9	14
8	12	8	6	5	3	8
10	15	11	12	10	2	7

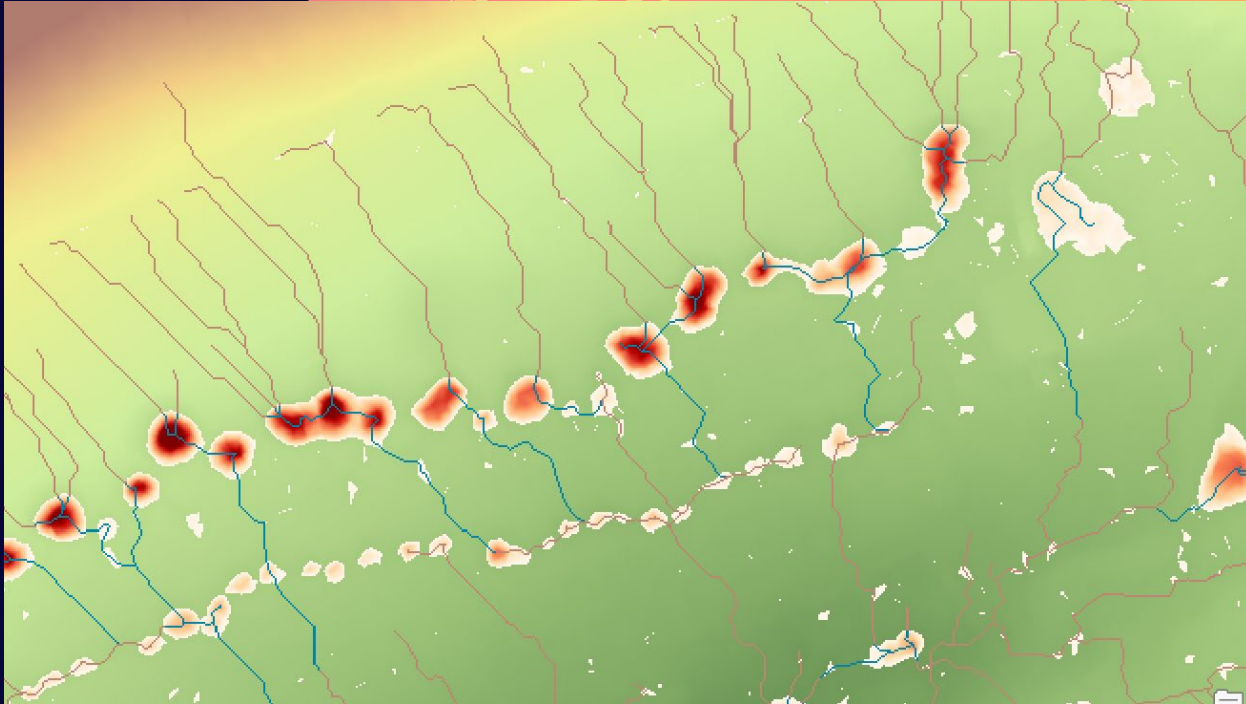


12	20	119	18	15	32	28
14	12	22	14	13	15	26
8	11	3	3	5	15	13
9	10	3	12	4	9	14
8	12	8	6	5	3	8
10	15	11	12	10	2	7

- Depression
- Cells to process
- Starting point (outlet)
- Processed cells
- Minimum upslope direction
- Flow direction

# Watershed Delineation and Stream Extraction





# Extracting Streams and Watershed from DEM

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