

Arc Hydro: Advances in Hydro Feature Extraction

Dean Djokic, Finn Swann



Audience view 100%

Sharing

Webcam

Audio

Dashboard

Attendees: 1 of 1001 (max)

Questions

Show Answered Questions

X	Question	Asker
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Send Privately Send to All

Handouts: 0 of 5

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Chat

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To: All - Entire Audience

Arc Hydro in ArcGIS Pro
Webinar ID: 118-253-939

GoToWebinar

Questions

Show Answered Questions

X	Question	Asker	Rec'd	A...
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Send Privately Send to All

Chat

Welcome to the webinar!

To: All - Entire Audience



Have you attended one of our Arc Hydro webinars in the last 3 years?



What ArcGIS Software are you using?

Connecting with Esri Water Resources

Finn Swann



Water Resources Team

Industry Solutions



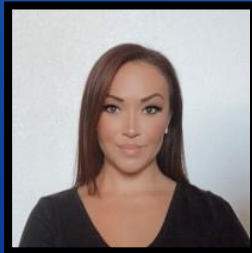
Christa
Campbell



Mariah
Salazar



Finn
Swann



Ciera
Patti

Core Development



Tania
Lopez-
Cantu



Steve
Kopp



Nawajish
Noman

Living Atlas



Caitlin
Scopel



Gonzalo
Espinoza

Professional Services



Dean
Djokic



Gina
O'Neil



Christine
Dartiguenave



Zichuan
Ye



Ezra Bosworth-
Ahmet



Paul
Burgess



Jordyn
Miller



Jakob
Drozd

Training Services, Business Development, Account Management, ...

Navigating Esri Web Sites

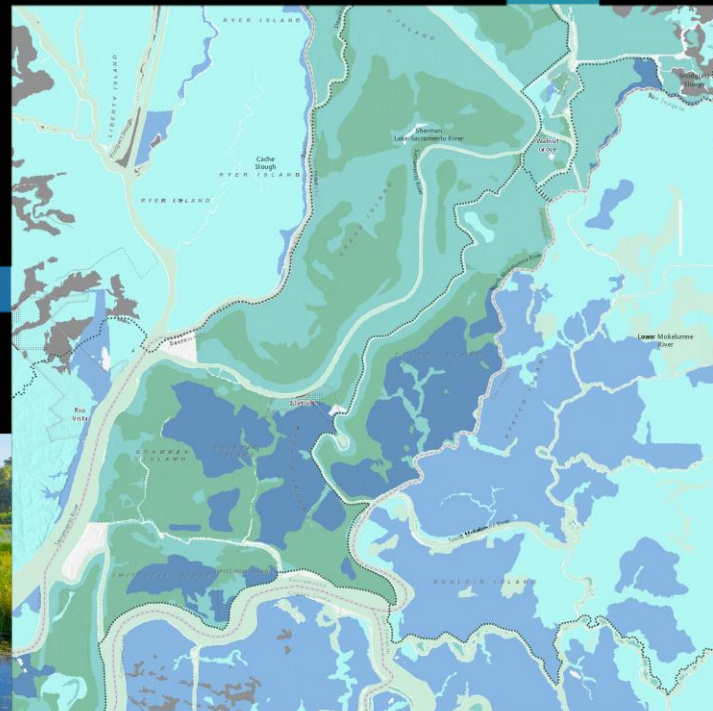
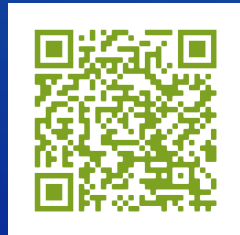
Finding information on Esri websites

- Water Resources
- Arc Hydro



Water Resources
web page

Arc Hydro
web page



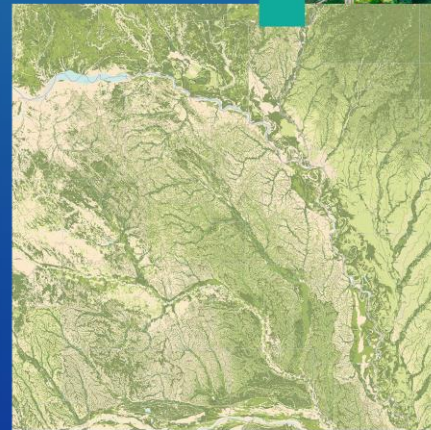
Esri Water Resources Community

Connecting with industry professionals

- Online Q&A
- Blogs
- Videos
- Technical documents



Water
Resources
Community



Industry Events

FFMA

- April 23-26, 2024, Miramar Beach, FL

Webinar: Flood Simulation

- June 26, 2024

WEFTEC

- October 5-9, 2024, New Orleans, LA

AWRA Annual Water Resources Conference

- September 30- October 2, 2024, St. Louis, MO

Connect with our team to ask questions and share your work.

Esri UC: Hydro Meeting

Sunday, July 14, 2024

- New Hydro Functionality in ArcGIS
- ArcGIS Living Atlas of the World Updates
- Arc Hydro Updates
- Streamflow Instant App
- NASA SWOT Updates
- FEMA – HAZUS for ArcGIS Pro
- ...



Esri Water
Meetup

Water Resources Office Hours (Virtual)

Esri's hydro experts host virtual office hours to discuss common water resources workflows and answer questions.

Join us to ask questions, contribute to the community, and vote on Office Hour topics.

Next scheduled on May 2nd



Esri Office Hour
Registration Page

Stay Connected with Esri's Water Team



@EsriWater



Esri Water Resources



Esri Water Meetup



Esri Water eNewsletter



Dean Djokic



27 years



Redlands, CA



Hydroinformatics



Principal
Consultant



Arc Hydro
Team Lead

Introduction to Arc Hydro and 2024 Webinar Series

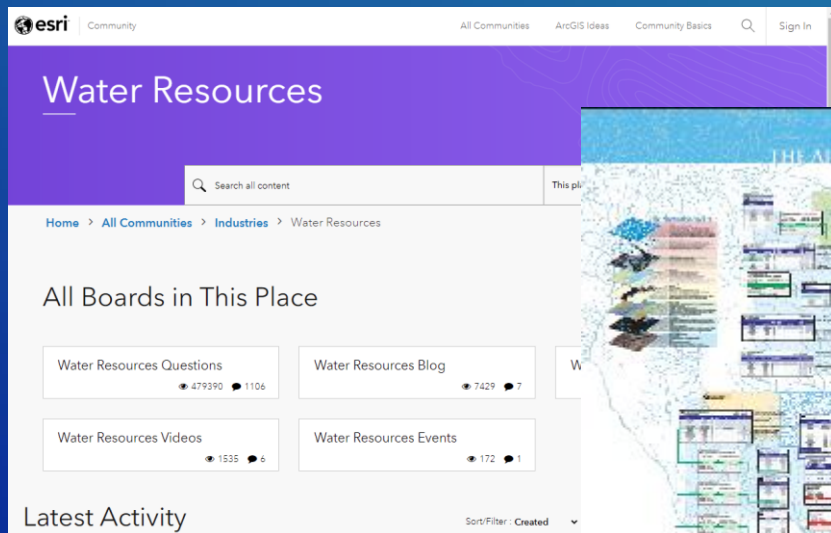
Dean Djokic





Arc Hydro - Vision

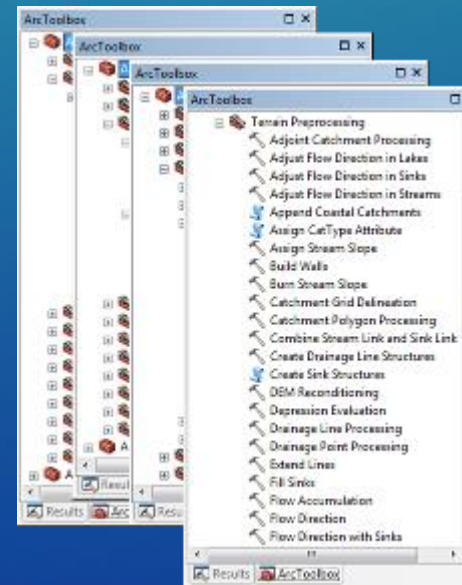
“Provide practical GIS framework for development of **integrated analytical systems** for water resources market.”



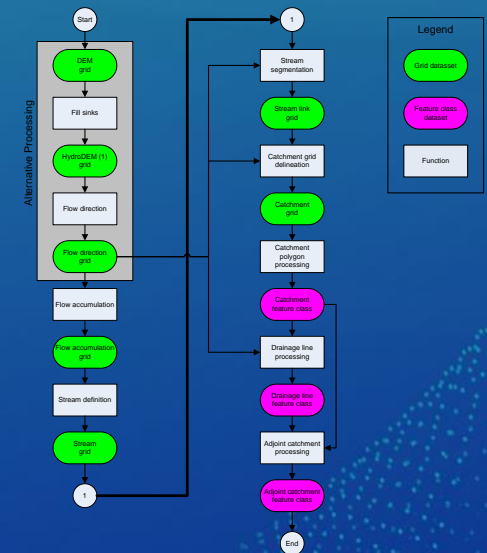
Community



Data Model



Tools



Workflows



Arc Hydro - Product \ Capability Summary

- “No fee” downloadable offerings:
 - Data model
 - Tools
 - Workflows
 - Documentation
 - Available now :
 - Pro tools - all versions up to 3.2
 - ArcMap tools - all versions up to 10.8.2
 - Web services in the Living Atlas
- Optional offerings:
 - Training (paid)
 - Consulting (paid)

The image shows a screenshot of the Esri website's Arc Hydro documentation page. The main heading is "Arc Hydro Downloads for ArcMap and ArcGIS Pro". Below this, there are tabs for "Arc Hydro for ArcMap", "Arc Hydro for ArcGIS Pro" (which is selected), and "Guides". Under the "ArcGIS Pro" tab, there is a list of download links for various versions: ArcGIS Pro 2.5, ArcGIS Pro 2.6, ArcGIS Pro 2.7, ArcGIS Pro 2.8, ArcGIS Pro 2.9, ArcGIS Pro 3.0, and ArcGIS Pro 3.1. An orange arrow points from the top right towards the "ArcGIS Pro" tab. A smaller inset window at the top right shows a document titled "Downloading and Installing Arc Hydro Tools" with a view count of 260 and a label "Arc Hydro".

Home > All Communities > Industries > Water Resources > Water Resources Docum... > D

Downloading and Installing Arc Hydro Tools

260 0 a month ago

Labels: Arc Hydro

Downloading and Installing Arc Hydro Tools

Quick overview of Arc Hydro tools download and installation process.

Labels: Arc Hydro

Arc Hydro Downloads for ArcMap and ArcGIS Pro

Access Arc Hydro tool downloads and guides

Arc Hydro for ArcMap Arc Hydro for ArcGIS Pro Guides

ArcGIS Pro 2.5 ArcGIS Pro 2.8

ArcGIS Pro 2.6 ArcGIS Pro 2.9

ArcGIS Pro 2.7 ArcGIS Pro 3.0

ArcGIS Pro 3.1



Arc Hydro – Tools, tools, tools

Project Map

Point Delineation
Flow Path Tracing
Arc Hydro

Geoprocessing

Find Tools

Favorites Toolboxes

- 3D Analyst Tools
- Analysis Tools
- Arc Hydro Tools Pro
 - Attribute Tools
 - Critical Duration
 - GIS Data Exchange
 - H & H Modeling
 - Network Tools
 - Point Characterization
 - Terrain Morphology
 - Terrain Preprocessing
 - Utility
 - Watershed Processing
 - Wetland Identification
- Aviation Tools
- Business Analyst Tools
- Cartography Tools
- Conversion Tools
- Crime Analysis and Safety
- Data Interoperability Tools
- Data Management Tools
- Data Reviewer Tools
- Defense Tools
- Editing Tools
- GeoAnalytics Desktop
- Geocoding Tools

History Catalog Geoprocessing

Geoprocessing

Find Tools

Favorites Toolboxes

- 3D Analyst Tools
- Analysis Tools
- Arc Hydro Tools Pro
 - Attribute Tools
 - Accumulate A
 - Adjust NextDo
 - Assign River O
 - Calculate Leng
 - Consolidate A
 - Consolidate A
 - Create UpDow
 - Export Table to
 - Find Next Dow
 - Generate Fron
 - Identify Flow S
 - Interpolate fro
 - Interpolate fro
 - Populate Drain
 - ID Manage
 - Time Series
- Critical Duration
- GIS Data Exchange
- H & H Modeling
- Network Tools
- Point Characterization
- Terrain Morphology
- Terrain Preprocessing
- Utility
- Watershed Processing
- Wetland Identification

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Geoprocessing

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History Catalog Geoprocessing

Geoprocessing

Find Tools

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 - Cross-Section C
 - Network Tools
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 - Terrain Morphology
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 - Cross-Section Characterization
 - Network Tools
 - Point Characterization
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History Catalog Geoprocessing

Geoprocessing

Find Tools

Favorites Toolboxes

- Terrain Morphology
- Terrain Preprocessing
 - DEM From LAS
 - DEM Manipulation
 - Build Walls
 - Construct Depression Hi
 - Create Drainage Line Stru
 - Create Sink Structures
 - Create Sinks for Line Stru
 - Create Sinks for Point Str
 - DEM Reconditioning
 - Depression Evaluation
 - Extract Smooth Depressio
 - Fill Sinks
 - Level DEM
 - Sink Evaluation
 - Sink Prescreening
 - Sink Selection
- Global
- Vector QC

History Catalog Geoprocessing

Geoprocessing

Find Tools

Favorites Toolboxes

- Terrain Preprocessing
 - DEM From LAS
 - DEM Manipulation
 - Global
 - Vector QC
- Accumulate Shapes
- Adjoint Catchment Processing
- Adjust Flow Direction in Lakes
- Adjust Flow Direction in Sinks
- Adjust Flow Direction in Streams
- Append Coastal Catchments
- Assign CatType Attribute
- Catchment Grid Delineation
- Catchment Polygon Processing
- Combine Stream Link and Sink Link
- Create Overland Flow Connectors
- Create Pipe Outlets
- Create Snap Data
- Create Stormwater Network
- Drainage Line Processing
- Drainage Point Processing
- Flow Accumulation
- Flow Direction
- Hillslope Width Function
- Link Sink Watershed to HydroJunction
- Longest Flow Path for Adjoint Catchments
- Longest Flow Path for Catchments

History Catalog Geoprocessing



Have you used Arc Hydro?


Arc Hydro: Getting Started

Learning about Arc Hydro: Resources and Documentation

- https://go.esri.com/AH_Resources

Getting Started with Arc Hydro

- https://go.esri.com/AH_Getting_Started



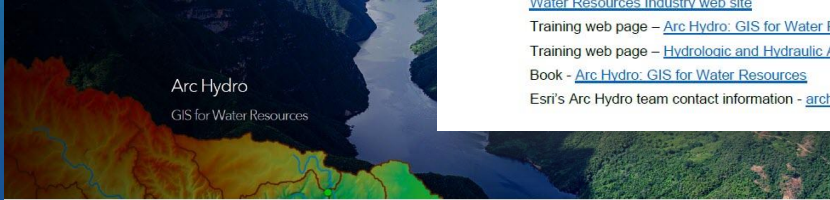
Arc Hydro
GIS for Water Resources

Learning about Arc Hydro: Resources and Documentation

This document provides a list of Esri published resources. Documents developed by Arc Hydro users are not listed. This document will be updated as new resources are released.

Arc Hydro Resources

- [Arc Hydro in Action webinar series web page](#)
- [Arc Hydro web page](#)
- [Esri Community web page for Water Resources and Arc Hydro](#)
- [Water Resources Industry web site](#)
- Training web page – [Arc Hydro: GIS for Water Resources](#)
- Training web page – [Hydrologic and Hydraulic Analyses Using ArcGIS](#)
- Book - [Arc Hydro: GIS for Water Resources](#)
- Esri's Arc Hydro team contact information - archohydro@esri.com



Arc Hydro
GIS for Water Resources

Getting Started with Arc Hydro

Water resource managers use GIS technology to visualize and analyze topographic, hydrographic, and hydrologic data for tasks such as assessing water quality, estimating water availability, planning flood prevention, understanding the natural environment, and managing water resources.

Esri's Arc Hydro consists of a data model, toolset, and workflows developed over the years to support specific GIS implementations in water resources. It offers the latest in innovation in GIS to help you create a deeper understanding of your hydro data. Arc Hydro helps you build a foundational dataset that can be used in water resource analyses and for integration with water resource models. It standardizes water data structures so that data can be used consistently and efficiently to solve a wider range of water resource problems at any scale—regional, national, or international.

This document provides information on how to get started using Arc Hydro. The starting point for each individual will depend on individual interests and how Arc Hydro will be used in their practice. This document will present technical and conceptual guidelines that focus on first steps with Arc Hydro.

Arc Hydro Docs

<https://esrips.github.io/ah-docs/>

The screenshot shows the Arc Hydro Docs website. At the top, there is a navigation bar with links for 'Arc Hydro Docs', 'Arc Hydro Essentials', 'Tool Documentation', and 'User Guides & Workflows'. On the right side of the navigation bar, there is a 'Knowledge Droplets' icon. The main header features the Arc Hydro logo and the text 'Arc Hydro Docs'. Below the header, a grey button says 'Hello from Arc Hydro'. The main content area is divided into three columns, each with an icon and text:

- Install the Tools**: Includes a download icon and the text 'Download Arc Hydro'.
- Contact Us**: Includes an icon of three people and the text 'Ask a Question: Esri Community' and 'Email the Team: archohydro@esri.com'.
- Arc Hydro Happenings**: Includes a calendar icon and the text 'Dean and Gina at AWRA GWT', 'Gina and Jordyn at Esri Dev Summit', and 'Keep an eye out for more at Esri Water Resources Events!'.

The footer is dark and contains three columns of links:

- Docs**: Arc Hydro Essentials, Tool Documentation, User Guides & Workflows.
- Contacts**: Esri Community [↗](#), Team Email [↗](#).
- More Info**: Water Resources at Esri [↗](#).

At the bottom center, there is a copyright notice: 'Copyright © 2024 Esri, Built with Docusaurus.'

Arc Hydro Webinars (2021, 2022, 2023)

- All webinar recordings are available on demand.



Arc Hydro in ArcGIS Pro

Don't miss your opportunity to connect and have your questions answered by Esri's Arc Hydro expert, Dr. Dean Djokic.

Thursday, February 25, 2021
9:00 AM–10:00 AM (PST)

REGISTER TODAY!



Arc Hydro: Flooding & Forecasting

Don't miss this opportunity to learn about Arc Hydro hydraulic capabilities from Esri's hydro expert, Dr. Dean Djokic.

March 11, 2021
9:00 AM (PST)

REGISTER TODAY!



Arc Hydro: Hydrology & Hillslope

Don't miss this opportunity to learn from Esri's hydro experts and special guests Dr. Dana Lapidis & Anneliese Sytsma.

Thursday, March 25, 2021
9:00 AM–10:00 AM (PST)

REGISTER TODAY!



Arc Hydro: Support for Hydrologic and Hydraulic Modeling

Join Esri's hydro expert, Dr. Dean Djokic, to learn what GIS can do for integrated hydrologic and hydraulic modeling.

Thursday, April 15, 2021
9:00 AM–10:00 AM (PST)

REGISTER TODAY!



What's New with Arc Hydro

Don't miss your opportunity to learn about Arc Hydro's new capabilities from Esri's Arc Hydro expert, Dr. Dean Djokic.

Tuesday, February 15, 2022
9:00 AM–10:00 AM (PST)

REGISTER TODAY!



Arc Hydro: Self and Esri Training Opportunities

Join this webinar to discover the available training options for Arc Hydro.

Tuesday, March 3, 2022
9:00 AM–10:00 AM (PT)

REGISTER TODAY!

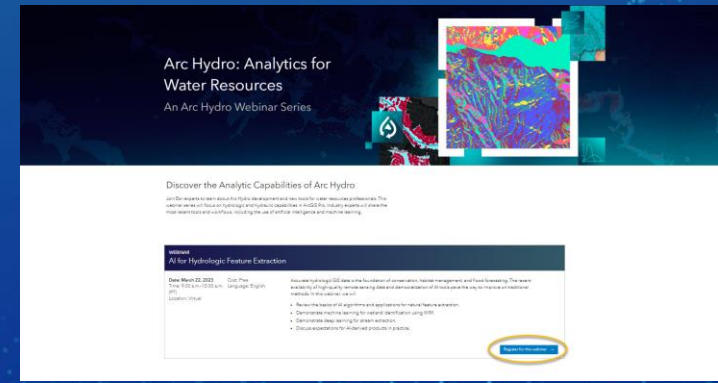


Arc Hydro: Working with the Wetland Identification Model

Don't miss your opportunity to learn about the Arc Hydro Wetland Identification Model toolset from Esri's Arc Hydro team.

October 25, 2022
10:00 AM–11:00 AM PT

REGISTER TODAY!



Arc Hydro: Analytics for Water Resources

An Arc Hydro Webinar Series

Discover the Analytic Capabilities of Arc Hydro

Join Dr. Dean Djokic to learn about the latest developments and new tools for water resource professionals. This webinar series will focus on hydrologic and hydraulic modeling, and the use of AI for hydrologic and hydraulic modeling.

Webinar AI for Hydrologic Feature Extraction

Date: March 22, 2023
Time: 10:00 AM–11:00 AM (PST)
Language: English
Presenter: Dean Djokic

Have you ever used AI to extract features from a raster dataset? In this webinar, you will learn how to use AI to extract features from a raster dataset. This webinar will cover the following topics:

- Overview of machine learning for feature extraction
- Demonstrate machine learning for feature extraction using ArcGIS
- Demonstrate how to use the ArcGIS AI for Hydro toolset
- Discuss opportunities for machine learning in practice.

[Register for this webinar](#)

2024 Webinar Series

- All webinar recordings will be available on demand.
- 2 more in making.
 - June 26th (Flood Simulation)
 - One in late fall.

2023 Webinar Series

- 2 webinars related to today's topic:
 - AI for Hydro Feature Extraction
 - Pragmatic Approach for hydro Feature Extraction



The screenshot shows the Esri Arc Hydro webinar series landing page. At the top, the Esri logo is on the left, and the title "Arc Hydro: Analytics for Water Resources" is prominently displayed. Below the title, it says "An Arc Hydro Webinar Series". The background features a collage of colorful hydrological maps and data visualizations. A central graphic shows a river network overlaid on a terrain map. Below the header, a section titled "Discover the Analytic Capabilities of Arc Hydro" provides an overview of the series. Two webinar details are listed below:

WEBINAR: AI for Hydrologic Feature Extraction

Location: Virtual Cost: No cost Language: English

Accurate hydrologic GIS data is the foundation of conservation, habitat management, and flood forecasting. The recent availability of high-quality remote sensing data and democratization of AI tools pave the way to improve on traditional methods. In this webinar, experts will:

- Review the basics of AI algorithms and applications for natural feature extraction.
- Demonstrate machine learning for wetland identification using WML.
- Demonstrate deep learning for stream extraction.
- Discuss expectations for AI-derived products in practice.

[Request access to the recording](#)

WEBINAR: Pragmatic Approach for Hydro Feature Extraction

Date: May 17, 2023 Cost: No cost Time: 9:00 a.m.-10:00 a.m. (PT) Language: English

Many of the original Arc Hydro tools for terrain analysis focused on hydro network extraction to support watershed delineation, characterization, and tracing. Additional tools and workflows have been recently developed to streamline the process of hydro feature extraction from high-resolution elevation products. In this webinar, experts will:

- Review traditional workflows for hydro feature extraction.
- Introduce new tools and workflows for hydro feature extraction from high-resolution elevation models.
- Compare results of traditional and AI techniques for feature extraction.
- Discuss whether a hybrid approach is the way to go.

[Register for this webinar](#)

Arc Hydro: Advances in Hydro Feature Extraction

Dean Djokic



Topics

- Quick review of “Pragmatic Approach for Hydro Feature Extraction”
 - Why automated “hydro feature extraction” (HFE)
 - Key concepts and data for HFE analyses
- Workflows
 - Purpose
 - Available data
 - Iterative
- Tools
- Discussion / conclusion

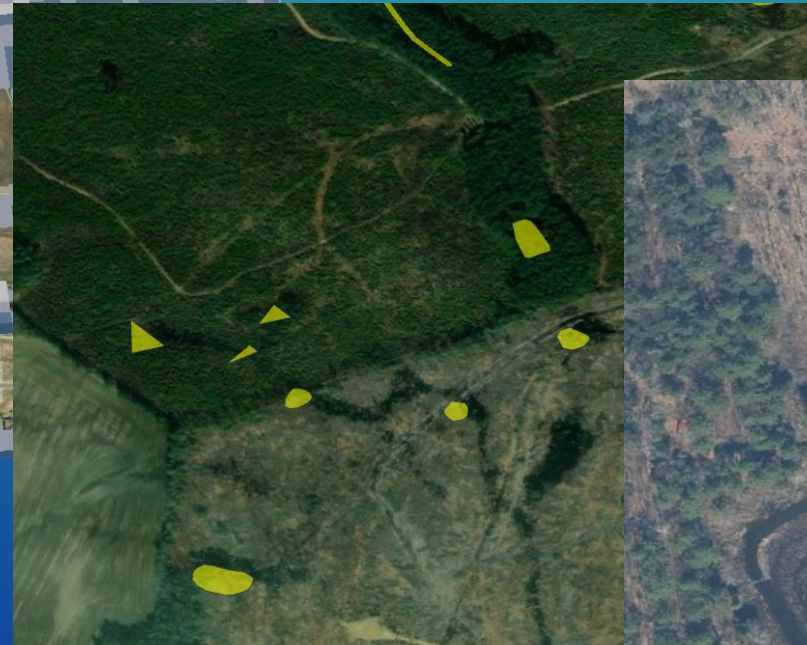
Motivation: Why Hydro Feature Extraction?

- Need data to conserve, manage, and plan.

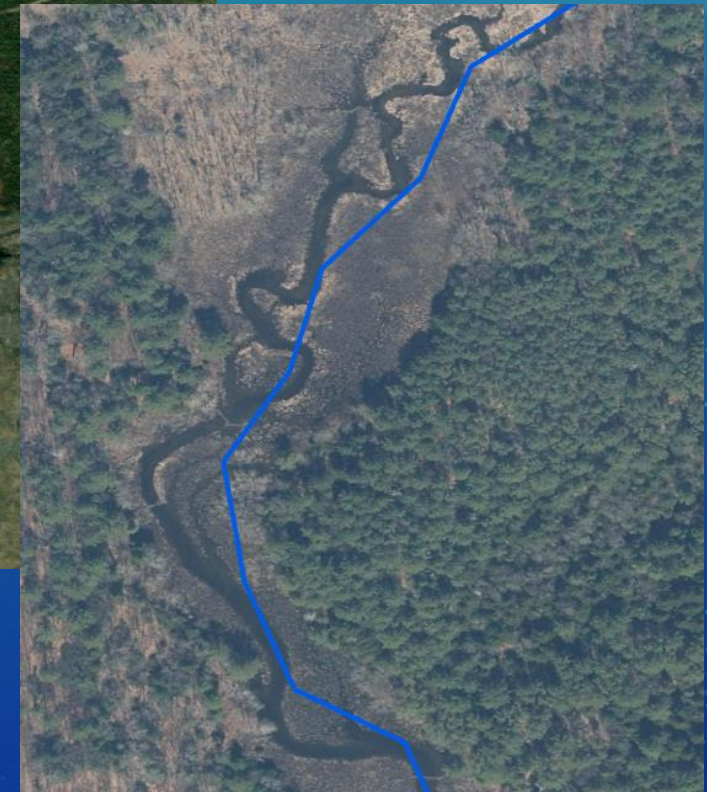
We can do better than the data we've been using...



Impervious surface



Wetlands



Streams



Motivation

- Data, data, data – high resolution digital elevation (DEM) derived from Lidar (laser) or Ifsar (radar) sensors – sub-meter cell sizes.
 - Volume of data to process.
 - Frequency of updates.
- Traditional methods are costly, can't be automated.
 - Elevation / photointerpretation.
 - Data refinement and attribution.
 - Manual confirmation of characteristics.



Motivation

- Techniques, techniques, techniques
- Consistent methodology for consistent results
 - Data driven (“same input data should produce the same output data”)
 - How to minimize “human intervention”
 - Data/interpretation – allow user interpretation to drive the process
 - User controlled; parameter driven process
 - Capture and store user “control” (as parameters or actual features) for reuse
 - Methodology – no change in methodology, change input data and parameters
- And as a technology developer – can we build the required tech to support “production” as opposed to “research”
 - Scalability
 - Performance
 - Maintenance

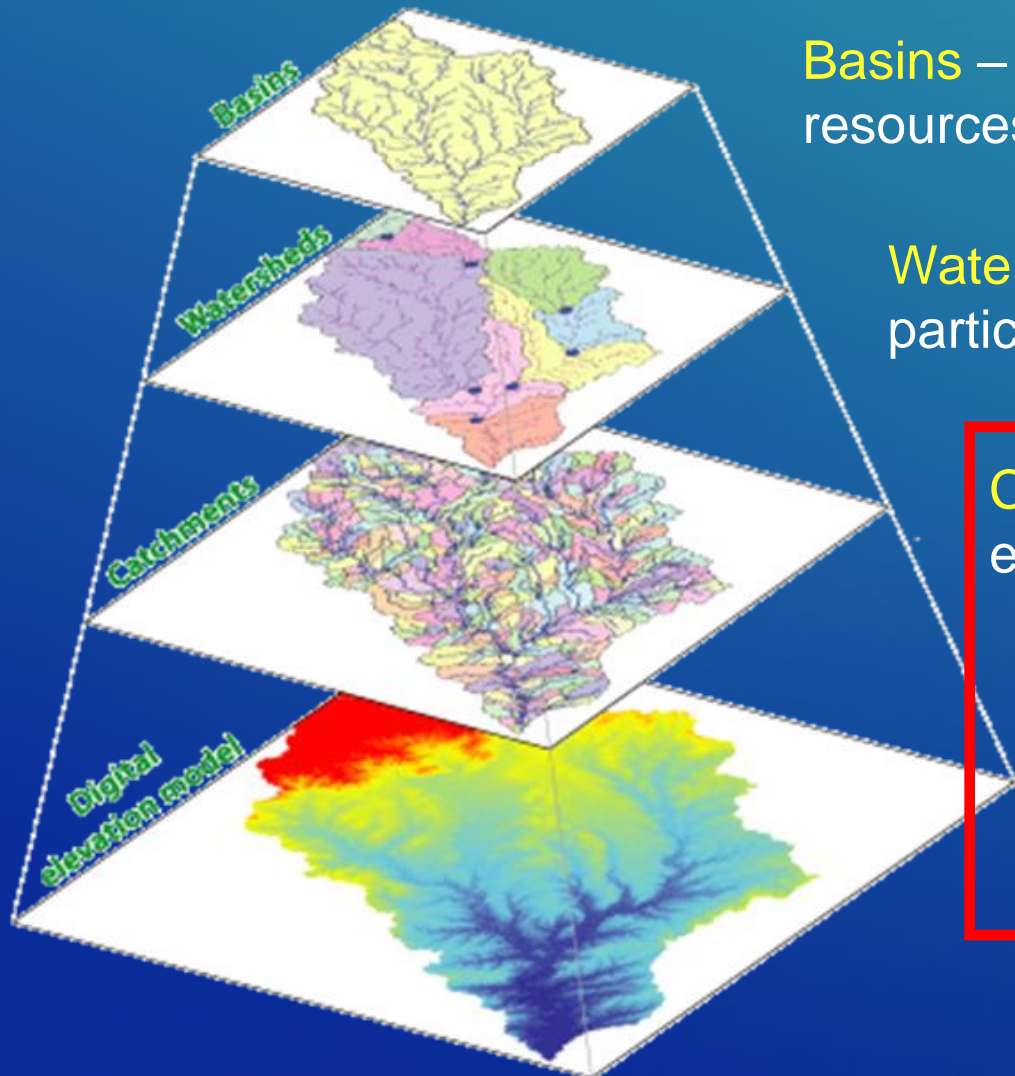
Automated hydro feature extraction in Arc Hydro context

- Any technique used to derive “hydro features” from digital elevation model. Primary types are:
 - **Streams**.
 - **Lakes** – water gets in and gets out from a known lake outlet (e.g. stream).
 - **Sinks** – water gets in but does not get out.
 - **Drainage areas** – areas draining into other type of hydro feature
 - **Wetlands** – can be either lake or sink.
- Hydro features are defined by their type and geometry NOT their properties.
- Scale and problem dependency:
 - Scale dependency – what is sink at one scale might be a lake at another.
 - Problem dependency – what is a sink for one hydro problem “flows” in another (e.g. drought vs. flood analysis).

Automated hydro feature extraction in Arc Hydro context

- **Integrated raster and vector representation** of the features with respect to the underlying DEM.
 - Concept of “Hydrofabric”.
 - No “raster vs. vector” wars
- **Primary role to identify flow patterns within the landscape and support various “hydro” analyses.**
 - Watershed delineation and characterization
 - Flooding
 - Hydrography
 - ...
- **NOT a specific product with specific product specifications** (e.g. USGS’ EDH or 3DHP) but more general constructs that can SUPPORT derivation of specific products.

Drainage system representations – Arc Hydro



Basins – drainage areas for water resources management

Watersheds – subdivision of land surface for a particular hydrologic purpose

Catchments – subdivision of land surface into elementary drainage areas by physical rules

Digital Elevation Model – land surface terrain grid cells

“Program”

- EDH
- 3DHP

“Nature”

Reality check / Myth busters

- Lidar-derived DEMs are NOT that great.
 - Often a blend of different source flights (age, resolution, vendor/processing methodology, ...).
 - Horizontal/vertical accuracy, registration, projection, ...
 - Interpretation of Lidar point cloud and processing into DEM.
 - Removal of bridges, culverts, buildings, vegetation, ...
 - Removal/insertion of water bodies (hydro-flattening).
 - Vendor-specific methods (some are better than others).
- Your other input data are NOT that great.
 - Existing hydrography, built infrastructure (bridges, culverts, ...).
 - Scale, temporal issues, completeness, ...
- Interpretation can be important.
 - “Automation” still needs human touch.
 - Iterative process.

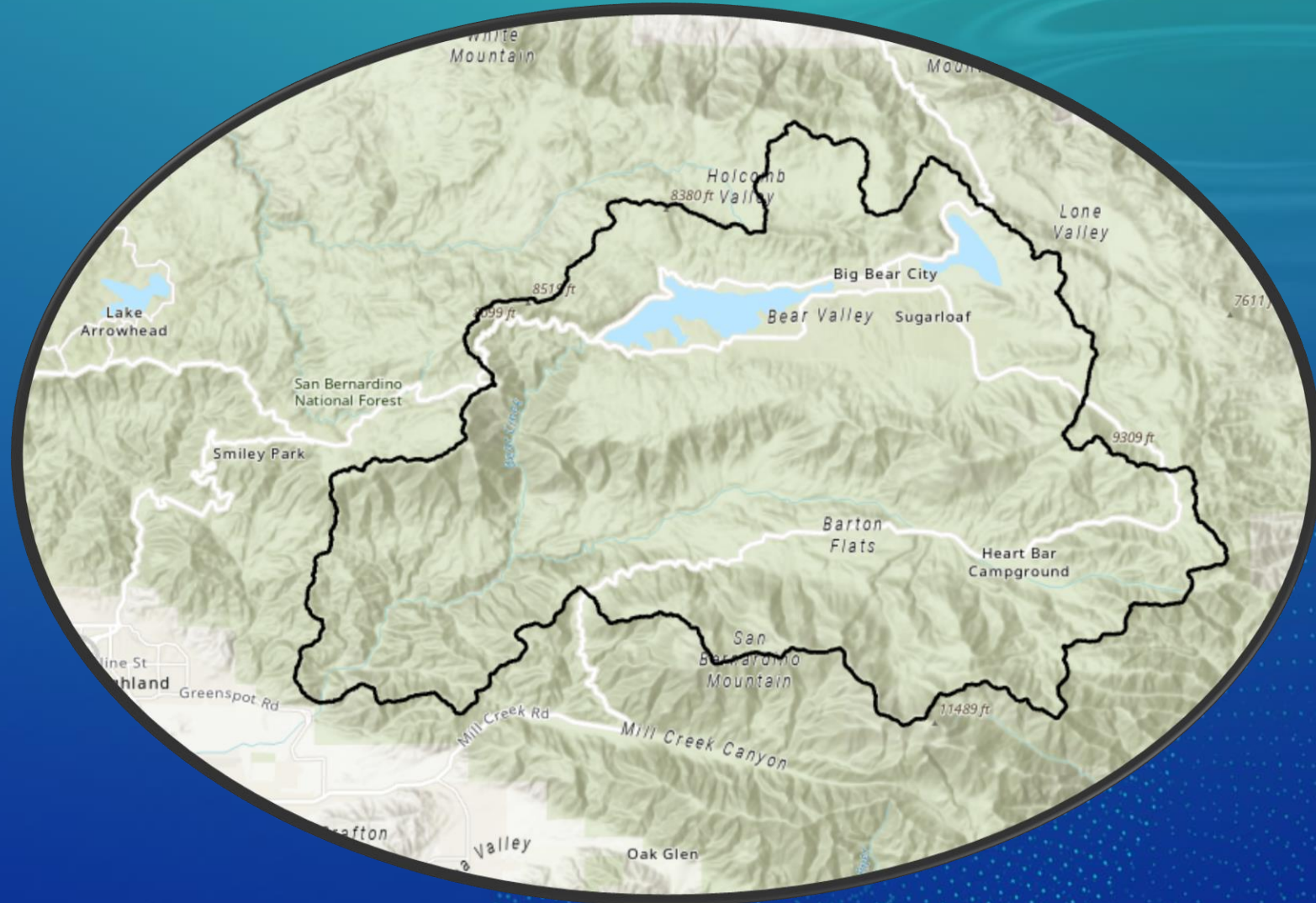


Workflows



Hydro Feature Extraction: In a perfect world ...

- Using 10m NHDPlus HR DEM.
- Seven Oaks Dam watershed in Southern California. Upper portion of Santa Ana River including the Big Bear Lake.
 - Area: ~ 550 km²
 - Elevation range: ~ 600 - 3,500 m
 - Cells: ~ 2,600 by 3,900 (rows by columns)
 - SR: National Albers



1

Use “raw” DEM
to derive flow
direction

3

Finalize
drainage
system

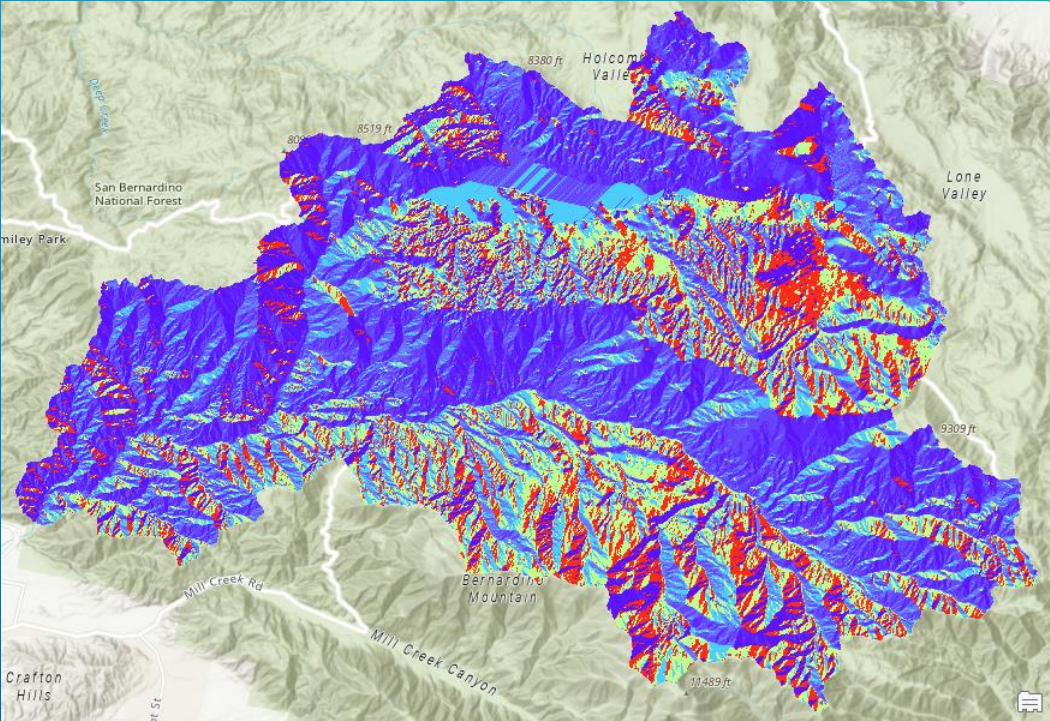
Hydro Feature Extraction: In a perfect world ...

2

Use “few” parameters
to derive base
drainage network

1

Use “raw” DEM to derive flow direction



Geoprocessing

Derive Continuous Flow

Parameters Environments

Input surface raster
elev_m.tif

Output flow accumulation raster
fac.tif

Input raster or feature depressions data

Input accumulation weight raster

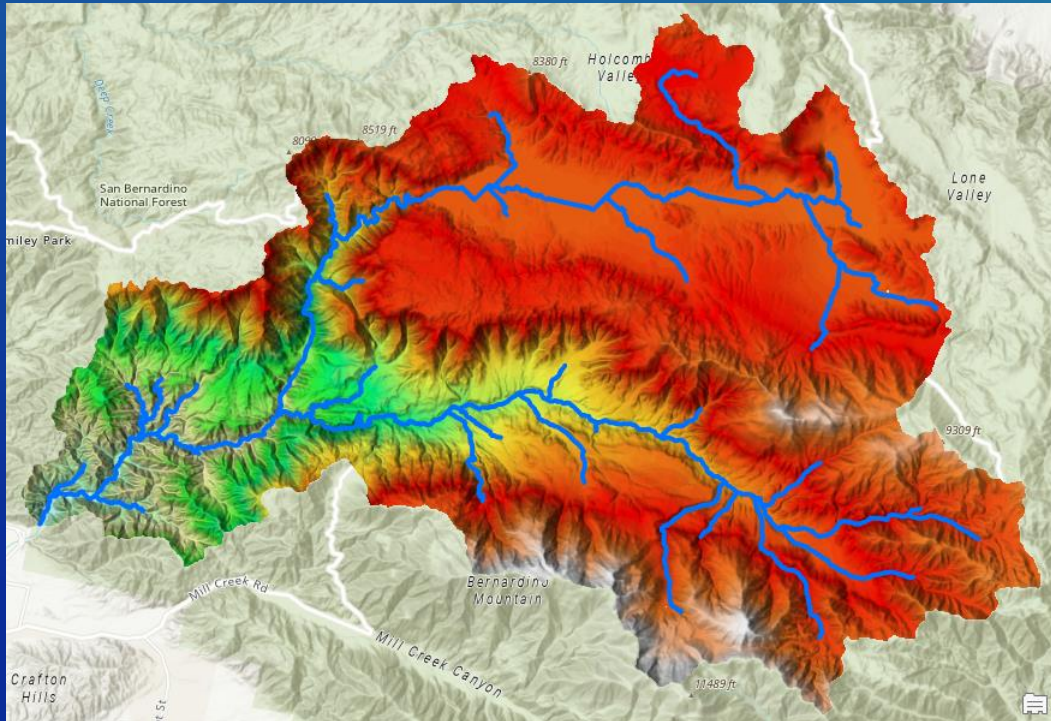
Output flow direction raster
fdr.tif

Flow direction type
D8

Force all edge cells to flow outward

Hydro Feature Extraction: In a perfect world ...

Hydro Feature Extraction: In a perfect world ...



Geoprocessing

Derive Stream As Line

Parameters Environments

Input surface raster
elev_m.tif

Output polyline features
Stream50K

Input raster or feature depressions data

Input accumulation weight raster

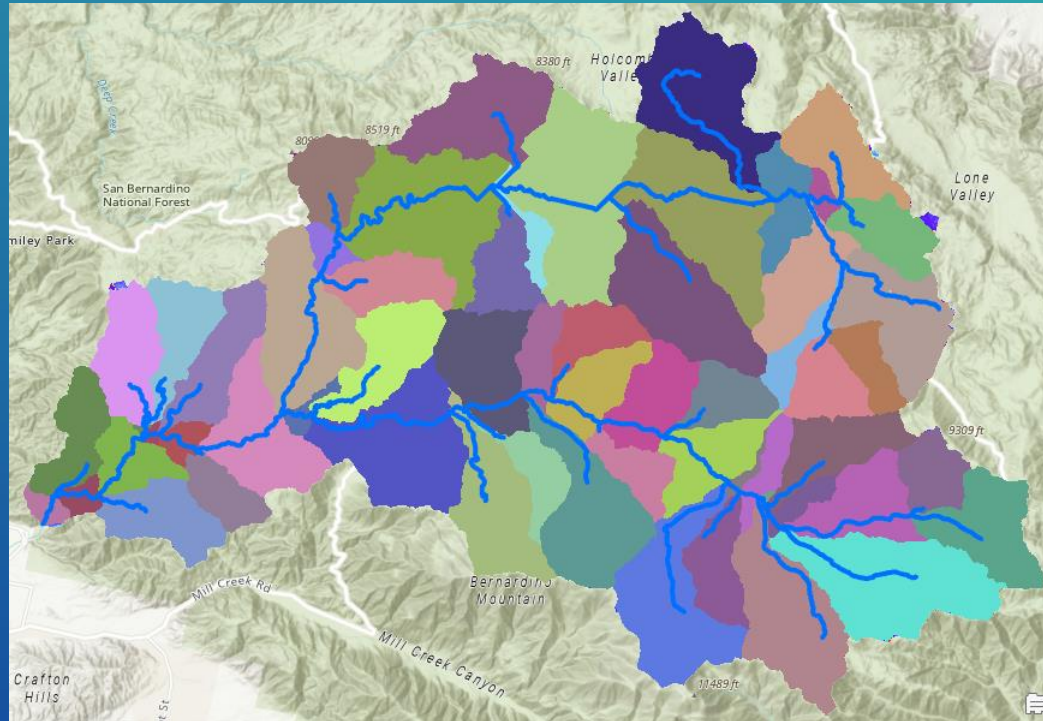
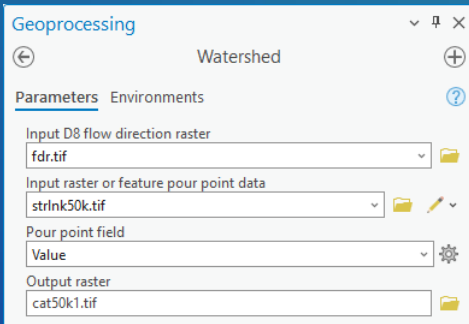
Accumulation threshold
5 Square Kilometers

Stream designation method
Unique

Simplify features

2

Use “few” parameters to derive base drainage network



3

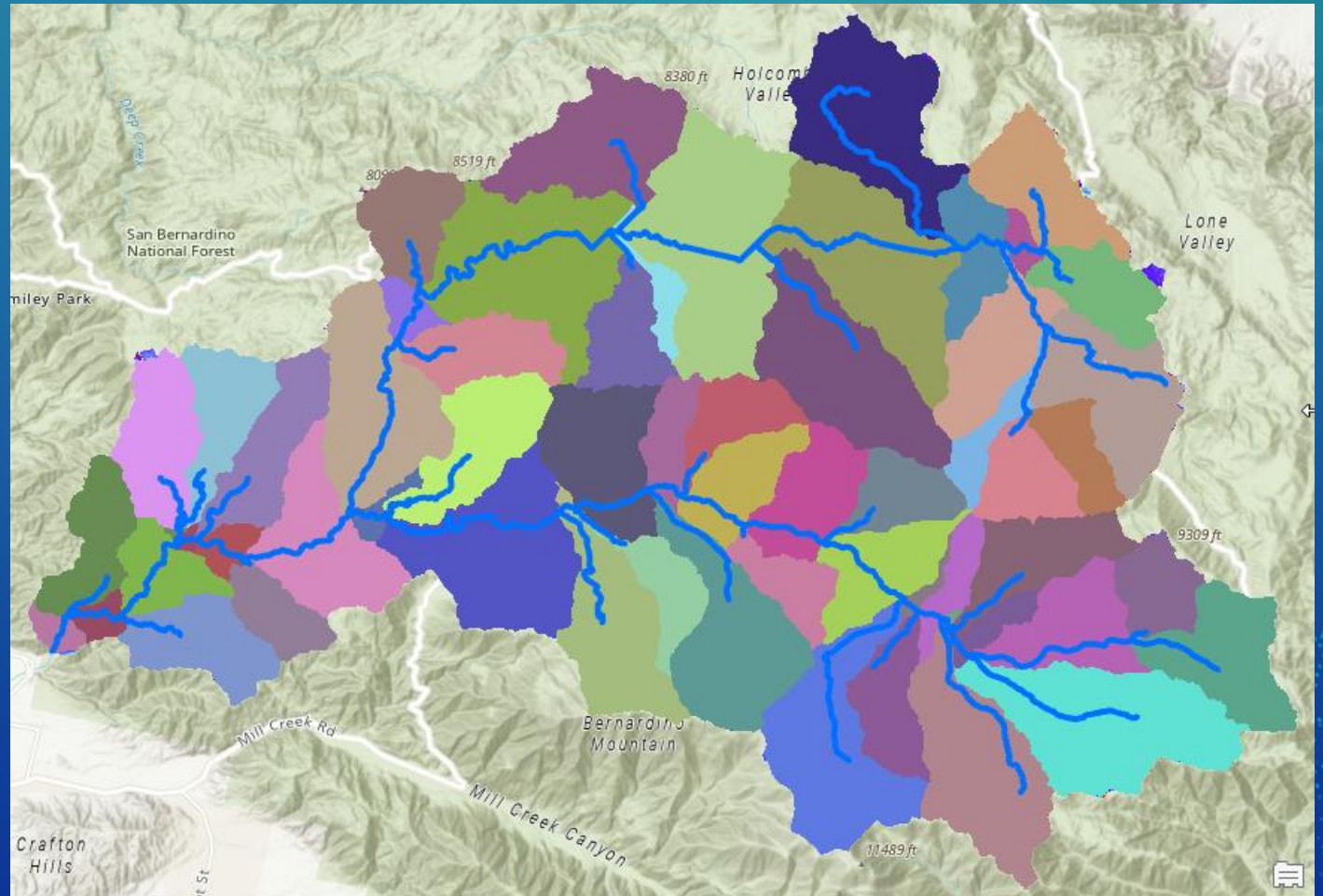
Finalize
drainage
system

Hydro Feature Extraction: In a perfect world ...

In a perfect world ...

One physical parameter controls it all (but few would be OK too)

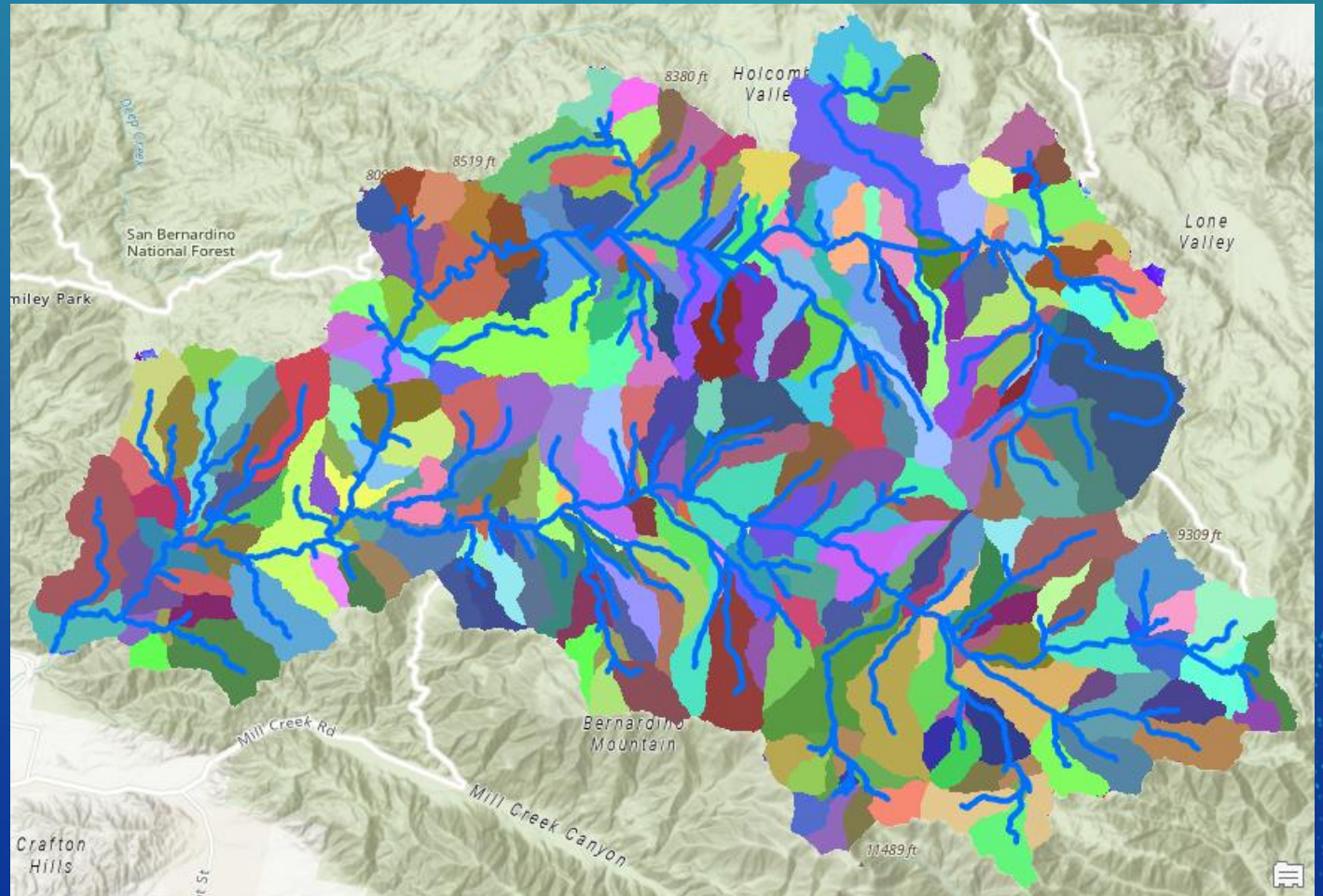
Stream threshold = 5 km sq.



In a perfect world ...

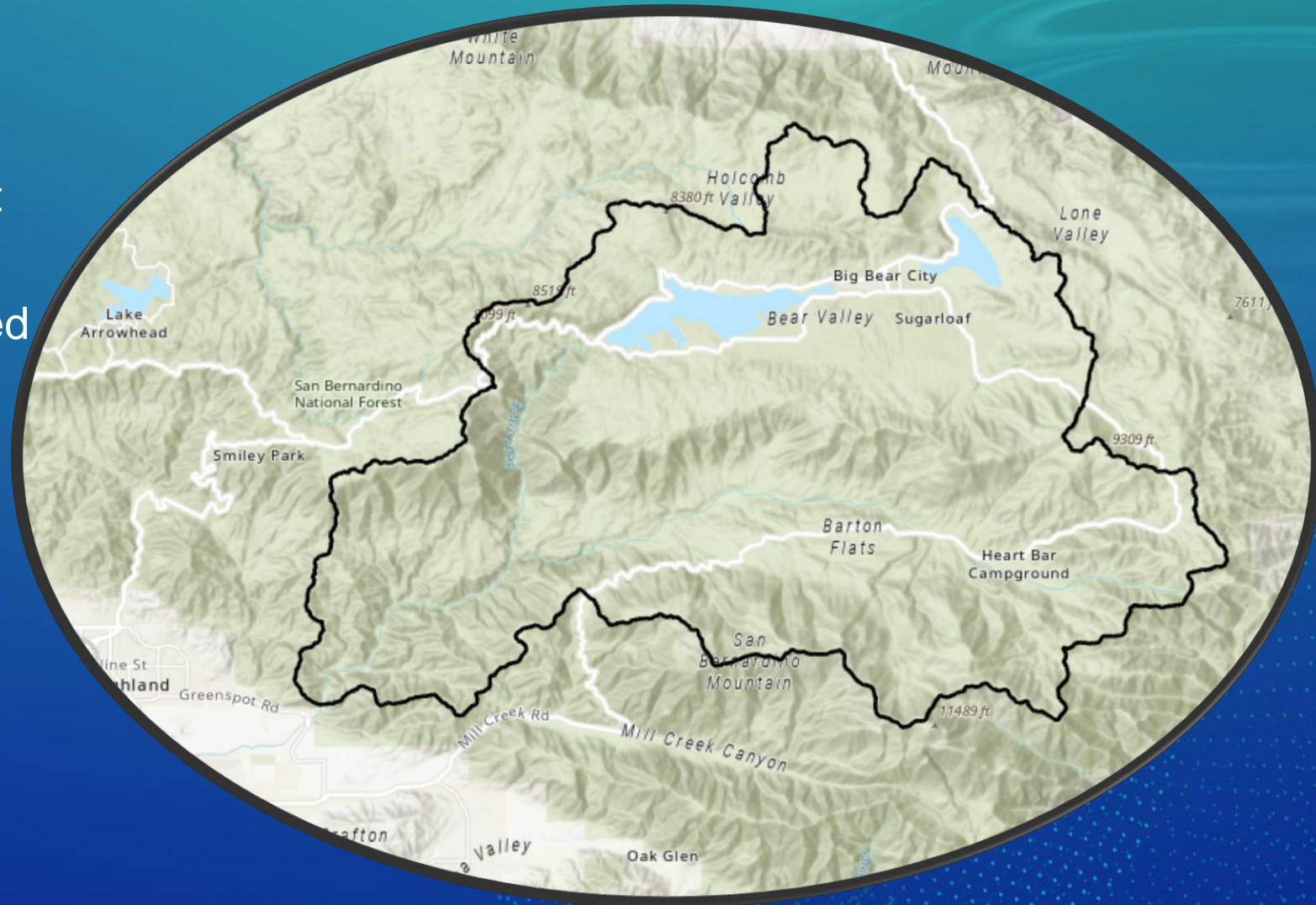
One physical parameter controls it all (but few would be OK too)

Stream threshold = 1 km sq.



In a perfect world – using different DEM

- Using 1m Lidar-derived DEM.
- 2018, consistent collection effort (post fires).
- 13 tiles from USGS 3DEP clipped to the AOI.
 - Cells: ~ 25,000 by 39,000 (rows by columns)
 - ~ 100 times bigger than the 10m DEM
 - SR: UTM Zone 11N



In a perfect world – using different DEMs

5 km² stream origination threshold

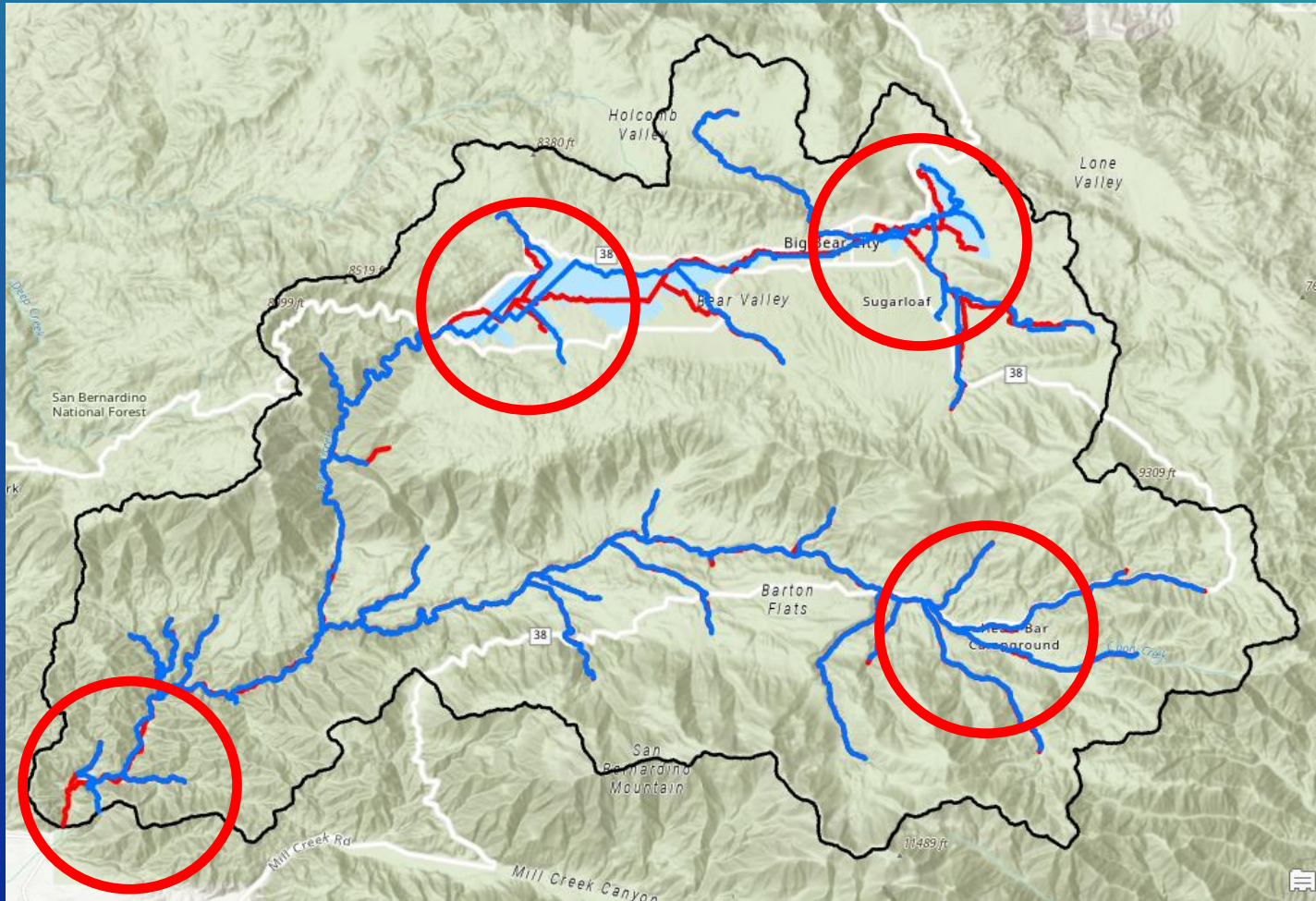
Metrics \ DEM	10m DEM	1m DEM
Cells (rows by columns)	2,600 by 3,900	25,000 by 39,000
Stream threshold (cells)	50,000	5,000,000
Flow direction (time)	9"	10' 14"
Stream definition (time)	9"	9' 16"
Catchment (time)	2"	5' 55"
Number of features	61	67

In a perfect world – using different DEMs

5 km² stream origination threshold

Streams

- 10 m
- 1 m



In a perfect world – using different DEMs

5 km² stream origination threshold

Streams

- 10 m
- 1 m



In a perfect world – using different DEMs

5 km² stream origination threshold



Streams

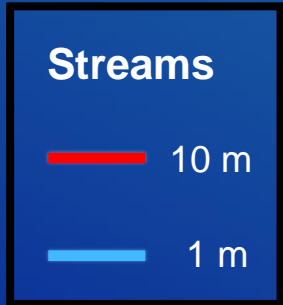
10 m

1 m

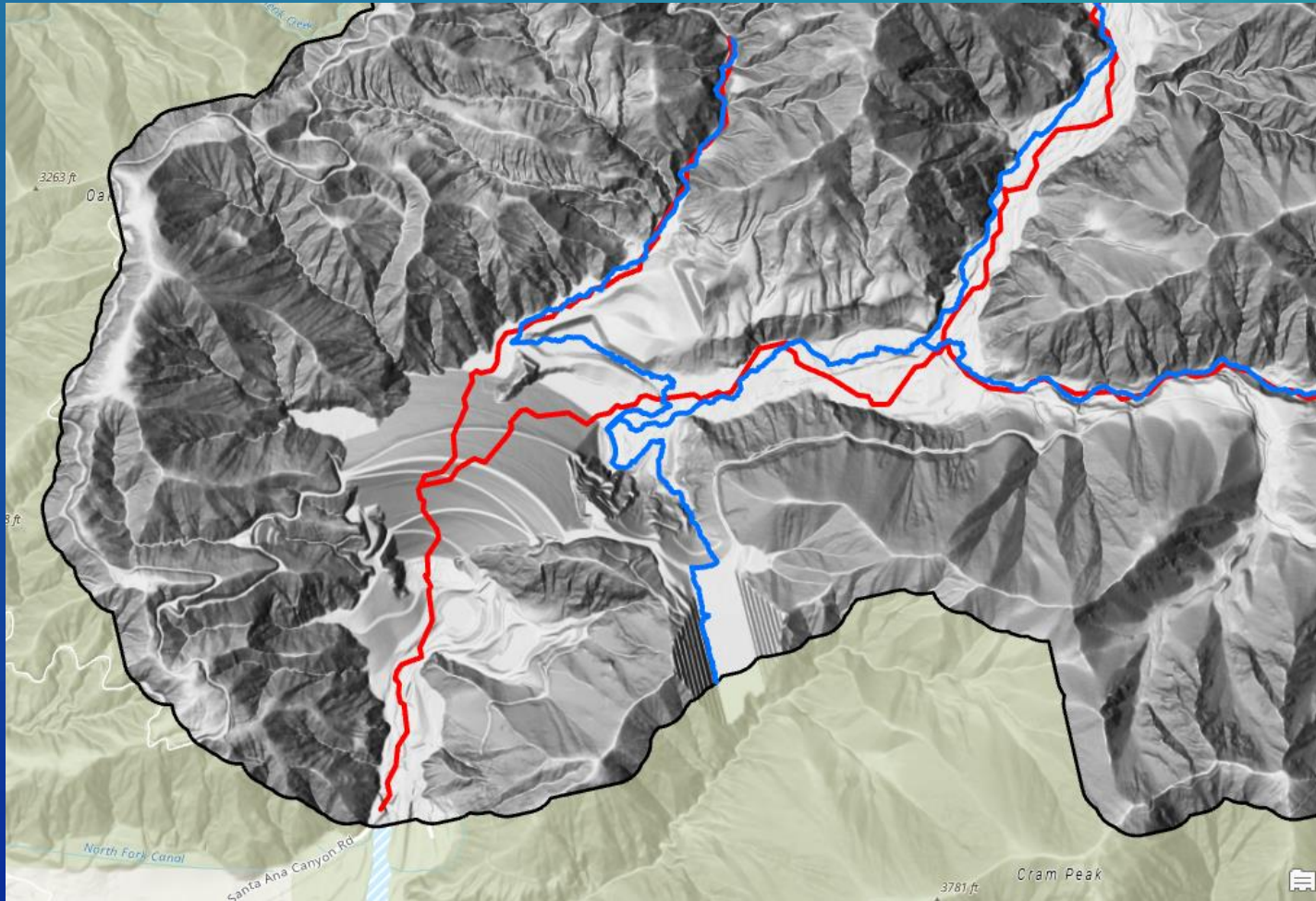
10m hillshade

In a perfect world – using different DEMs

5 km² stream origination threshold



1m hillshade

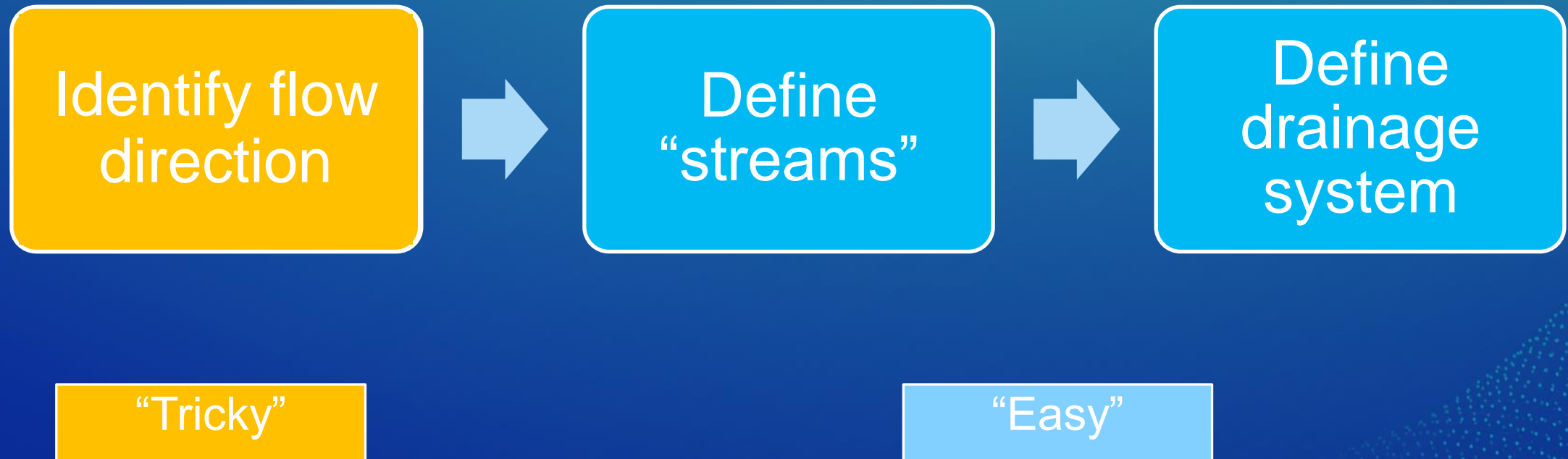


In a perfect world ...

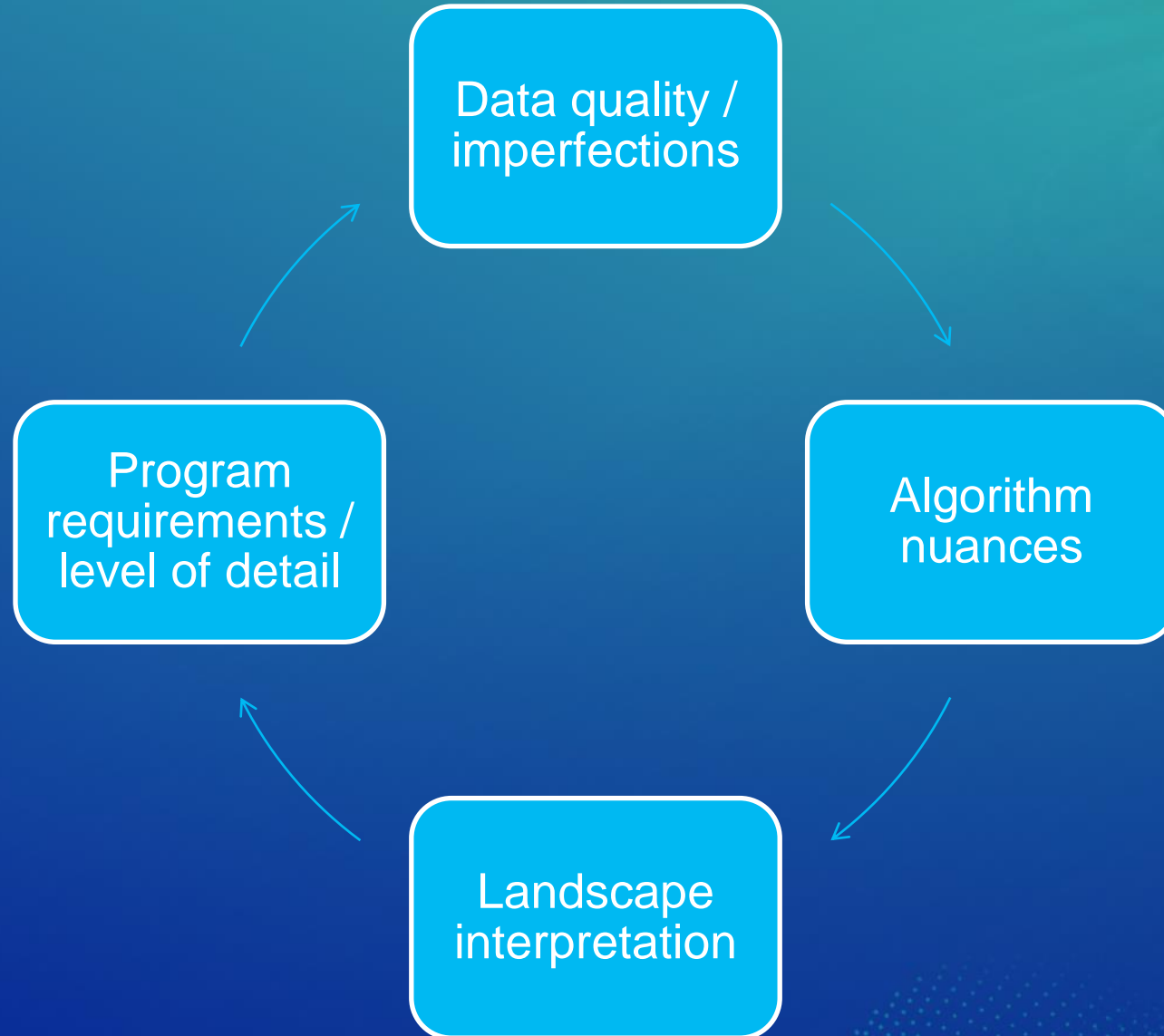
... but that is not the world we live in

Hydro Feature Extraction: In a not so perfect world ...

Basic workflow

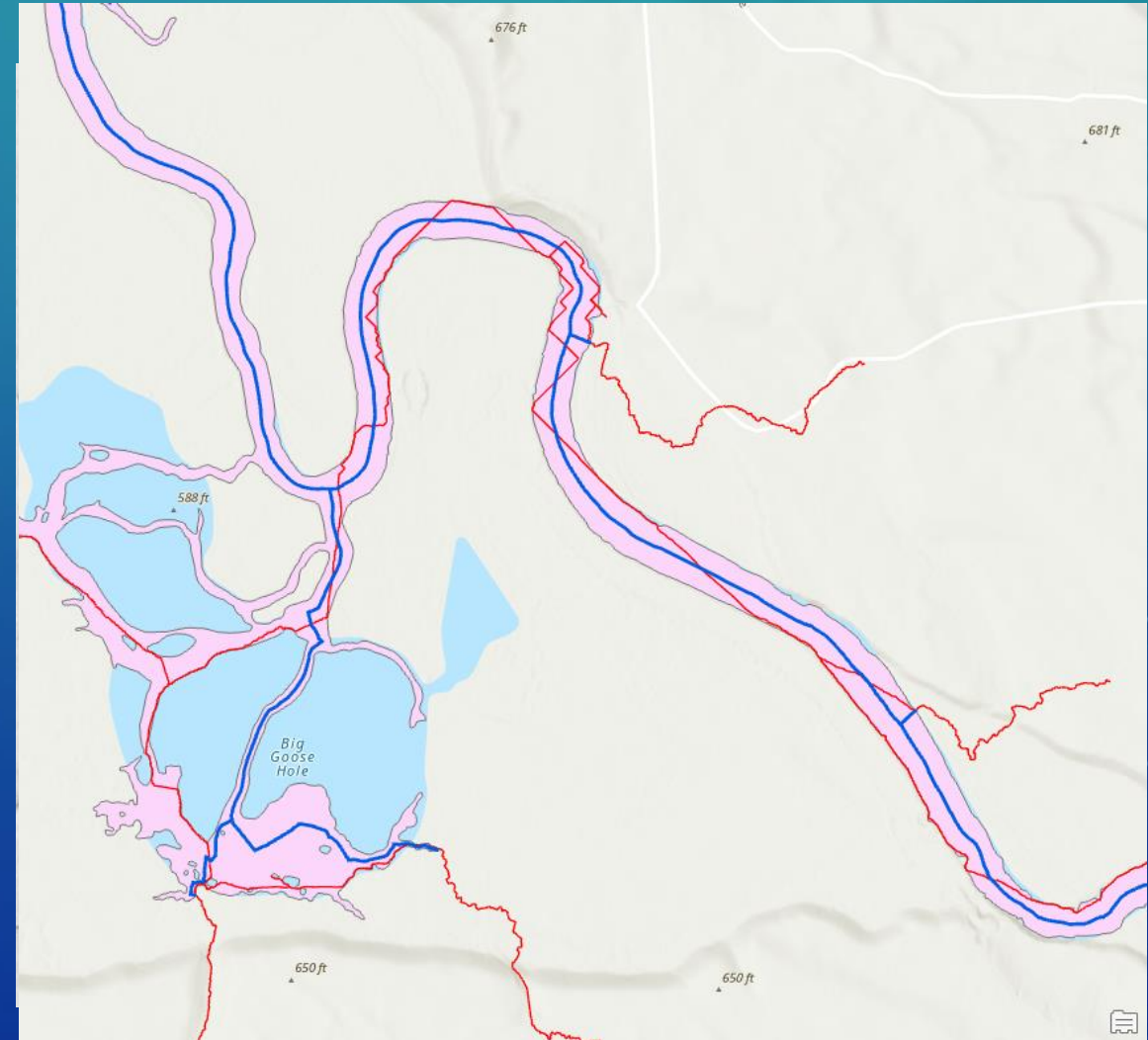


Reality



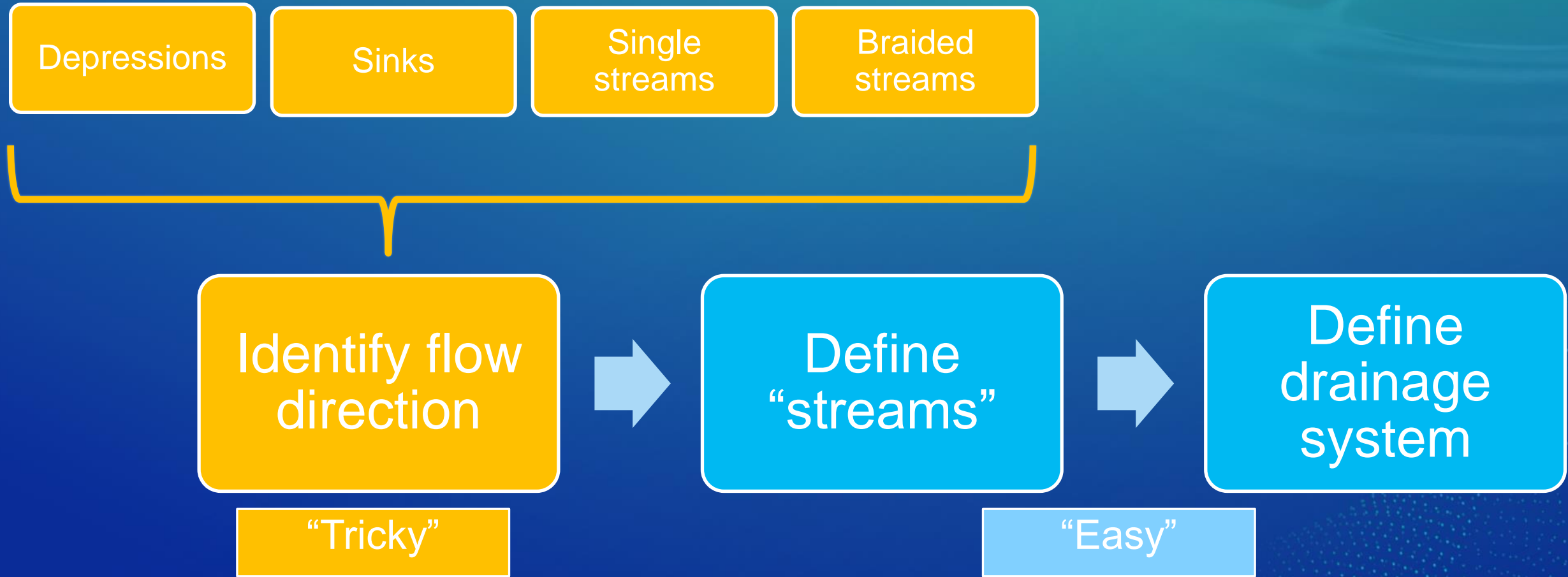
Help thy algorithm

- Some algorithms are better than others depending on the ultimate analysis goal.
- But do not change the algorithm each time something goes wrong. Instead:
 - Control through parameters.
 - Control through data.
- Depressions.
- Flat areas.



Hydro Feature Extraction: In a not so perfect world ...

Extended workflows

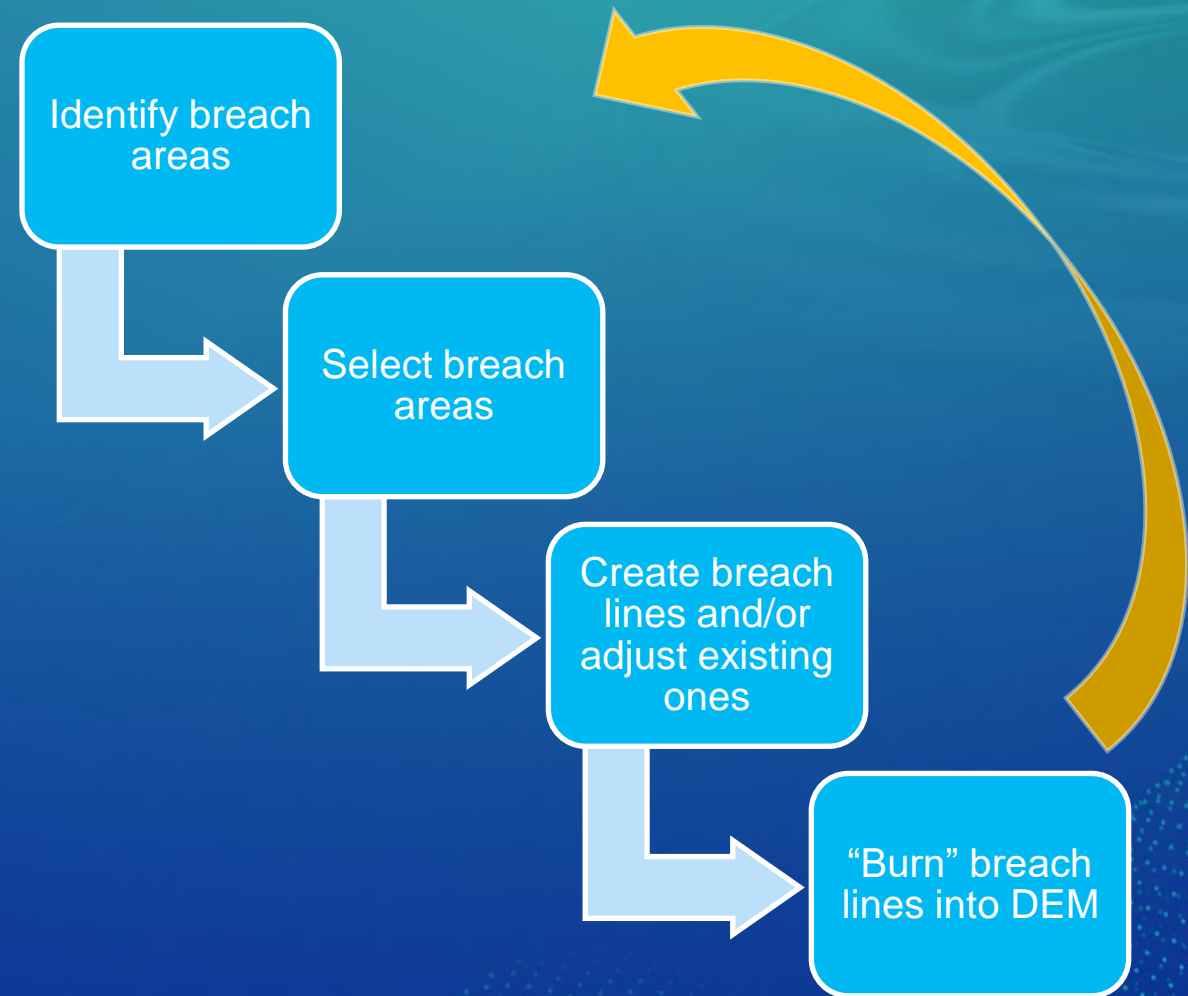


Tools



Depression adjustments: tools

- Depressions – real (keep them) or not (breach)?
 - Known structures
 - Leverage other sources
 - Roads, railroads, imagery, ...
 - Hydrography vs. hydrology
- Breaching process
 - Straight line
 - Something else?



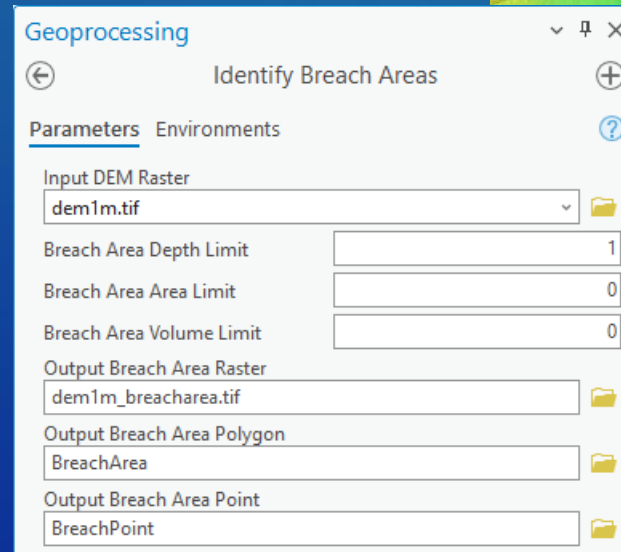
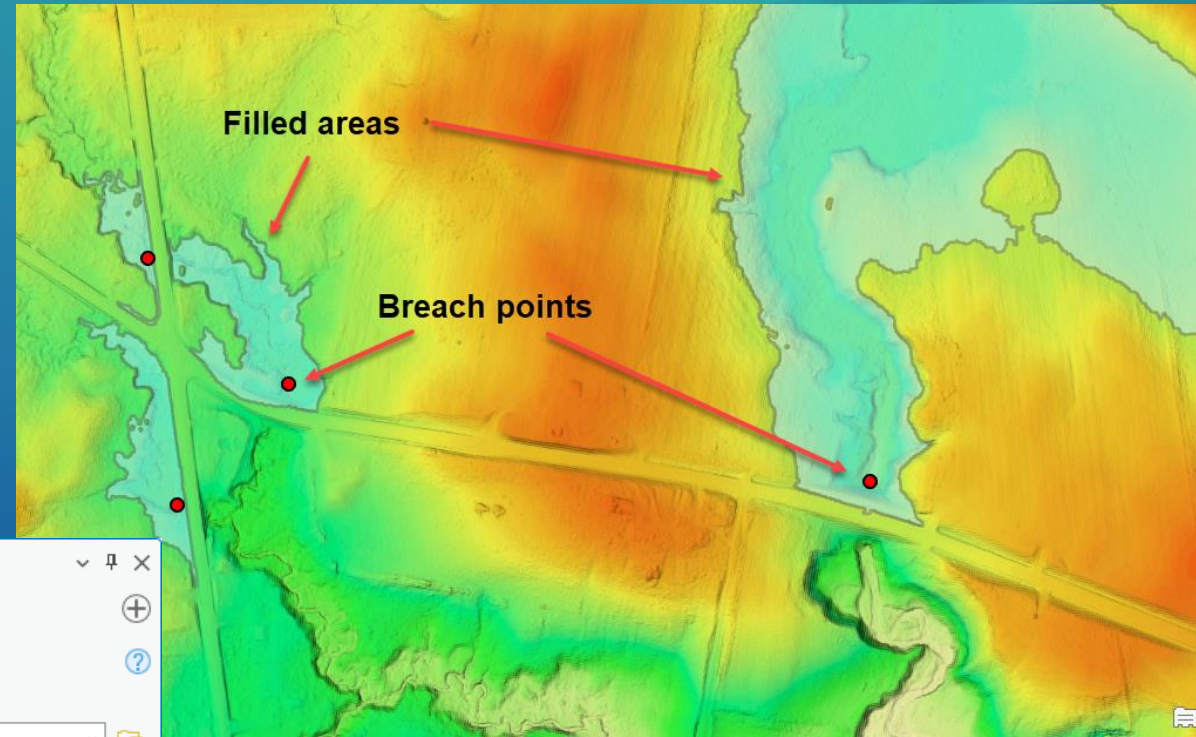
Depression adjustments: overview of steps

1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures (optional)
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address



Identify potential areas needed to be breached

- Arc Hydro tool “Identify Breach Areas”
- Only DEM as input
- Ability to do initial sub-selection based on:
 - Area
 - Depth
 - Volume
 - Area “shape” factors (as a separate analysis)



1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

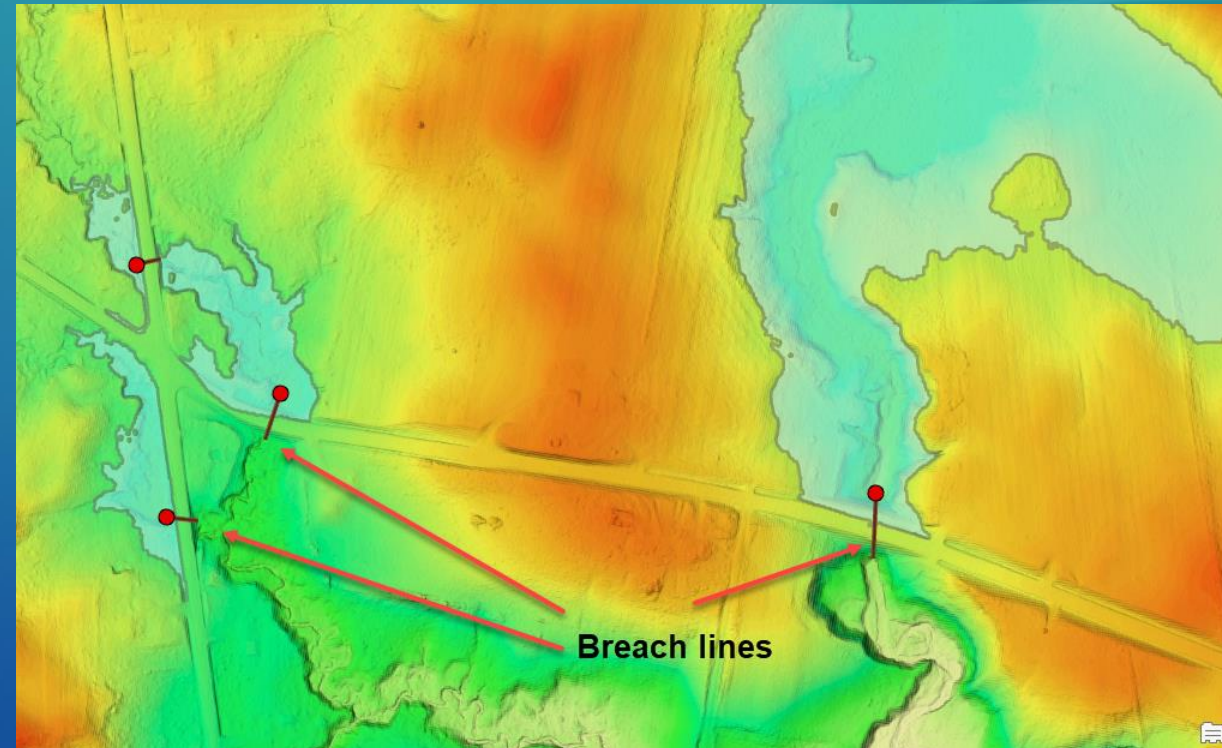
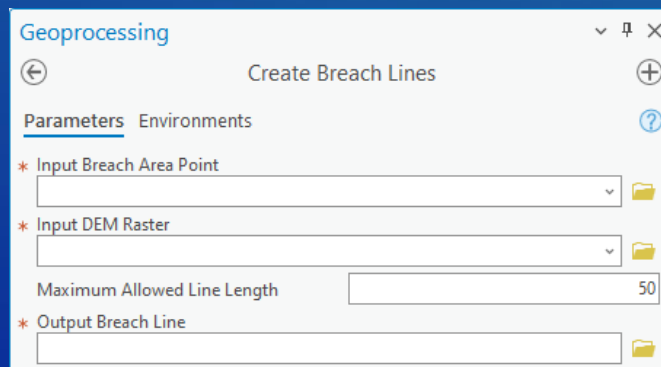
Select areas that need to be breached

- Use standard GIS selection methods
- Leverage additional data such as:
 - Roads
 - Railroads
 - Known sinks and lakes (that do not have to be breached)
 - Soils
 - ...
- Potential for statistical analysis of existing structures w/r to their topographic indicators
 - Would add new rules to “real” depression area selection

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2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures
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7. Revisit #1 and see if there are any remaining problem areas to address

Create breach lines

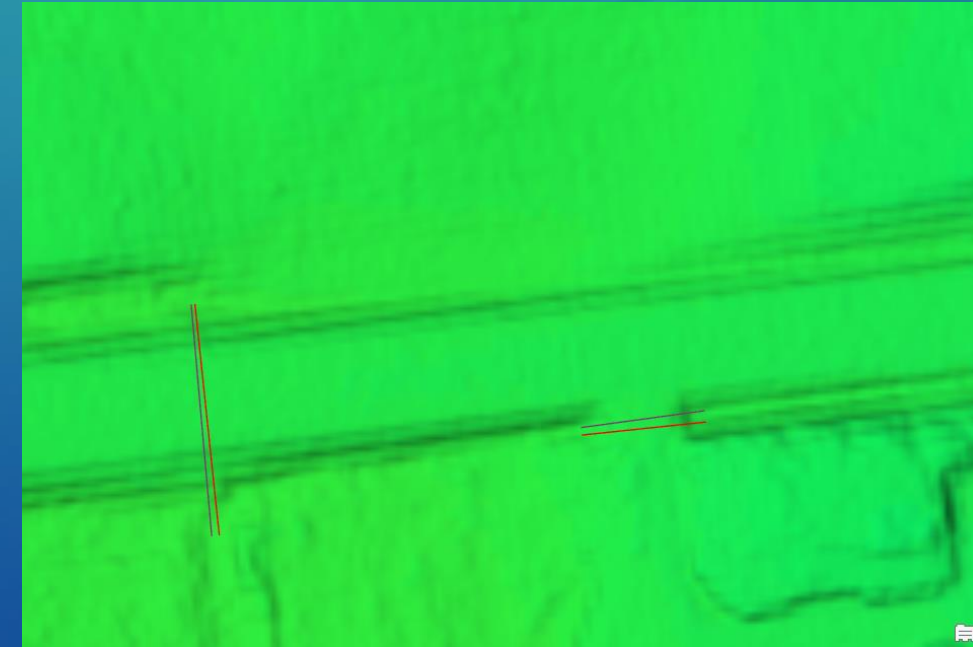
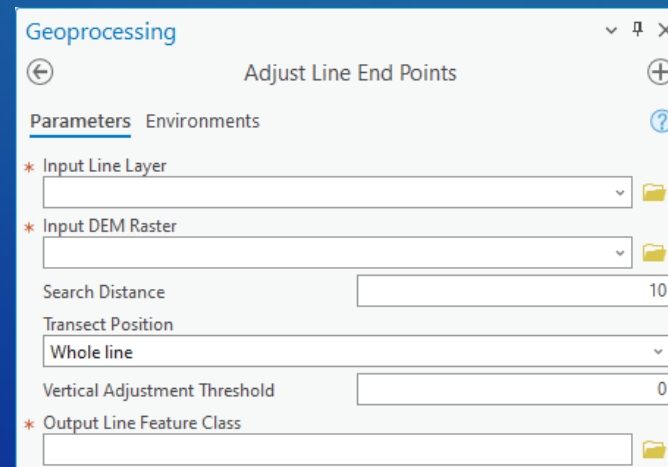
- Arc Hydro tool “Create Breach Lines”
 - Looking for a closest, lower point within specified buffer distance.
- Possible enhancement to implement variable breach length.



1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures
5. “Burn” culverts into DEM
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7. Revisit #1 and see if there are any remaining problem areas to address

Adjust alignment for existing structures

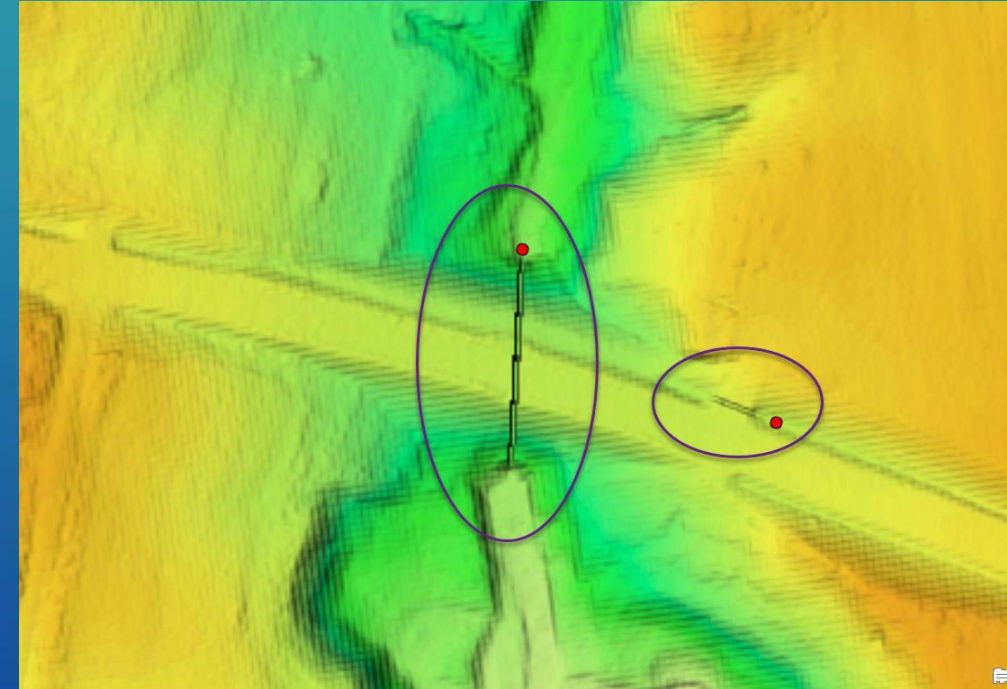
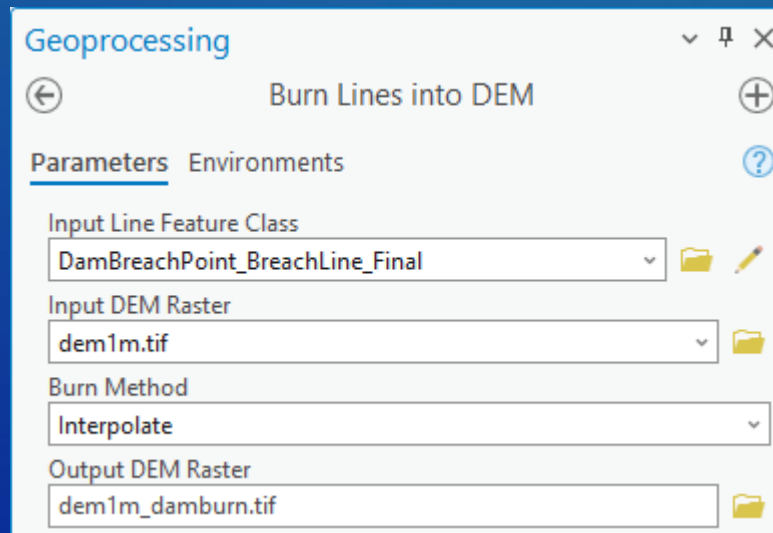
- Arc Hydro tool “Adjust Line End Points”
- Used when culverts have not been derived from current DEM (e.g. digitized) or using different automation techniques that do not guarantee proper alignment of culvert end points.



1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

“Burn” culverts into DEM

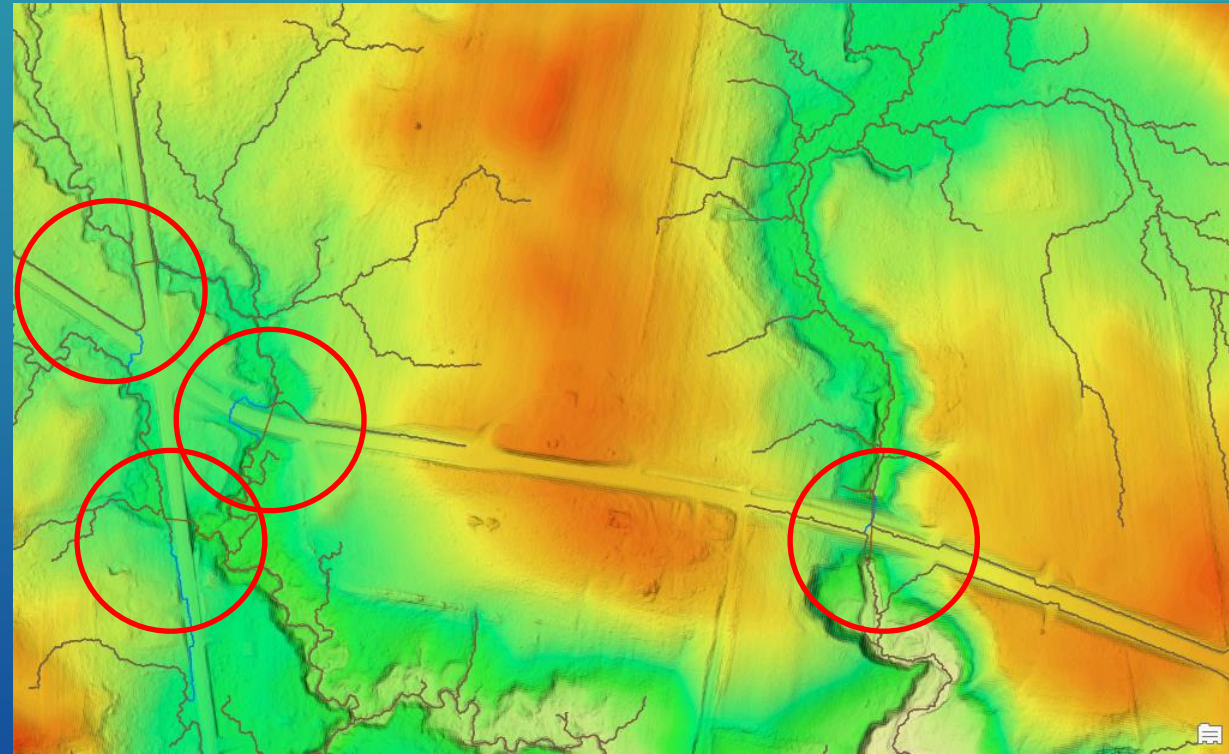
- Arc Hydro tool “Burn Lines into DEM”
- Locally enforce culverts into DEM
- This could be optional, depending on the approach to manage infrastructure (focus on overall flow patterns or explicit management of stormwater infrastructure)



1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Run “stream” extraction on “burned” DEM

- This should be combined with other AH tools/workflows (e.g. for flat area flow enforcement)
- Arc Hydro tools:
 - “Flow Direction and Accumulation Using CF”
 - “Stream Definition”
 - “Stream Segmentation”
 - “Drainage Line Processing”



1. Identify potential areas needed to be breached
2. Select areas that need to be breached
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4. Adjust alignment for existing structures
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
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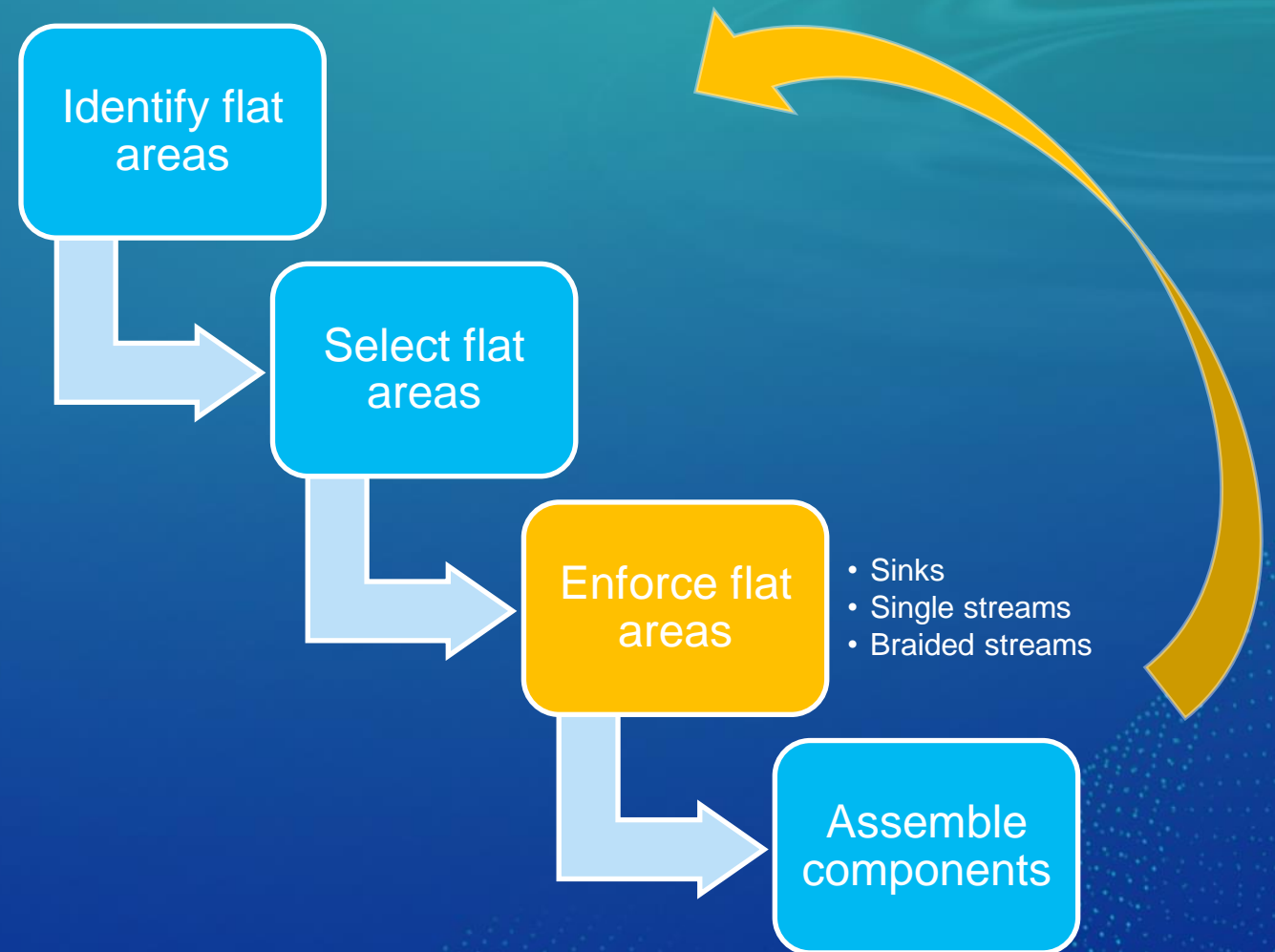
Check for remaining flow path issues

- Back to the “Big Picture” – look at overall flow pattern.
- Check if there are any remaining potential areas needed to be breached.
- Make any necessary adjustments.
- Rerun some aspects of the workflow as necessary.

1. Identify potential areas needed to be breached
2. Select areas that need to be breached
3. Create breach lines
4. Adjust alignment for existing structures
5. “Burn” culverts into DEM
6. Run “stream” extraction on “burned” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

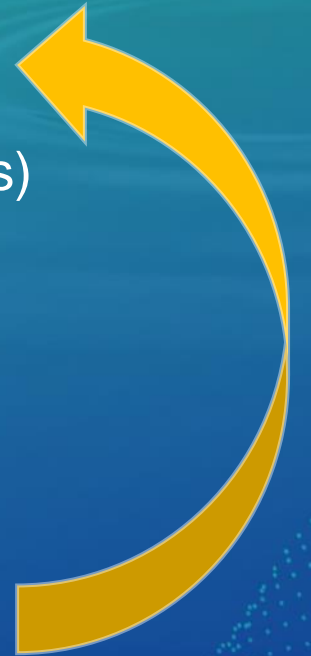
Flat area processing: tools

- Hydro-flattened DEM – where's water (and when)
 - Why don't we have bathymetry – and does it matter?
- Flat area processing
 - Identification
 - Processing
 - Sinks
 - Main stem enforcement
 - Braided system implementation
- Assembling components into a full drainage system



Flat area processing: overview of steps

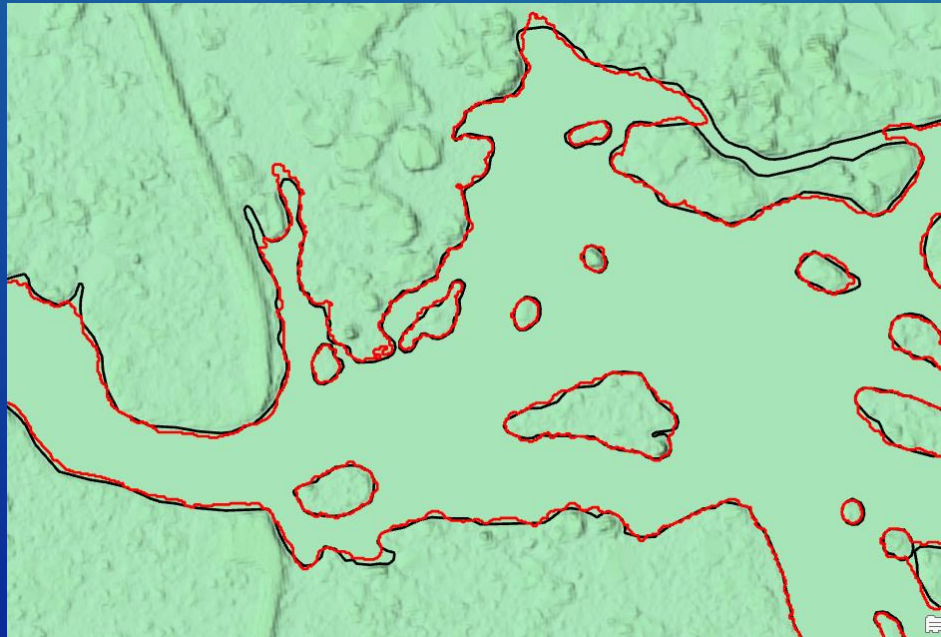
1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
4. Enforce single streams
5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address



Identify potential flat areas

- Polygons might be provided with DEM
- Arc Hydro tool “Identify Flat Areas”
 - Leverage new geomorphon landform tool in Pro 3.1
 - Only DEM as input

Value
Flat
Peak
Ridge
Shoulder
Spur
Slope
Hollow
Footslope
Valley
Pit



Geoprocessing

Identify Flat Areas

Parameters Environments

Input DEM Raster
West_Pilot_DEM_ALBERS_2ft_Meters.tif

Flat Terrain Angle Threshold 1

Search Distance 10

Skip Distance 0

Flat Landform List
Flat

Minimum Flat Area Threshold
2000 Square Meters

Output Landform Raster
West_Pilot_DEM_ALBERS_2ft_Meters_landform.tif

Output Flat Area Raster
West_Pilot_DEM_ALBERS_2ft_Meters_flat.tif

Output Flat Area Polygon
AHFlatPoly

1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
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5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
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Select flat areas that need to be enforced

- Use standard GIS selection methods and understanding of type of terrain processing (dendritic, deranged, combined)
- Differentiate between:
 - Sinks (water comes in, but not out)
 - Lakes with single streams (water can come in from multiple places but exits from one place and there are no braids)
 - Lakes with braids (water can come in and out from multiple places and there can be braids)
- Might be beneficial to generate feature class for each category

1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
4. Enforce single streams
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6. Run "stream" extraction on "hydro-adjusted" DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Enforce sinks – deranged and combined terrains

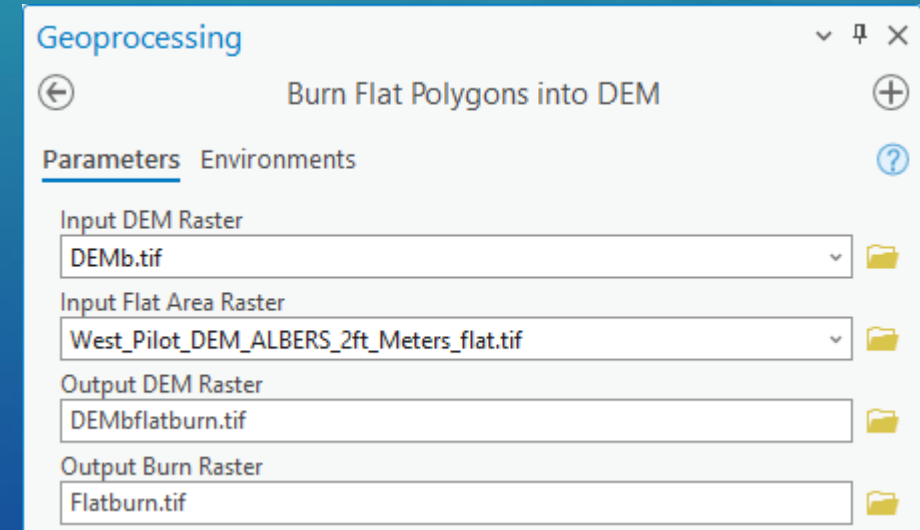
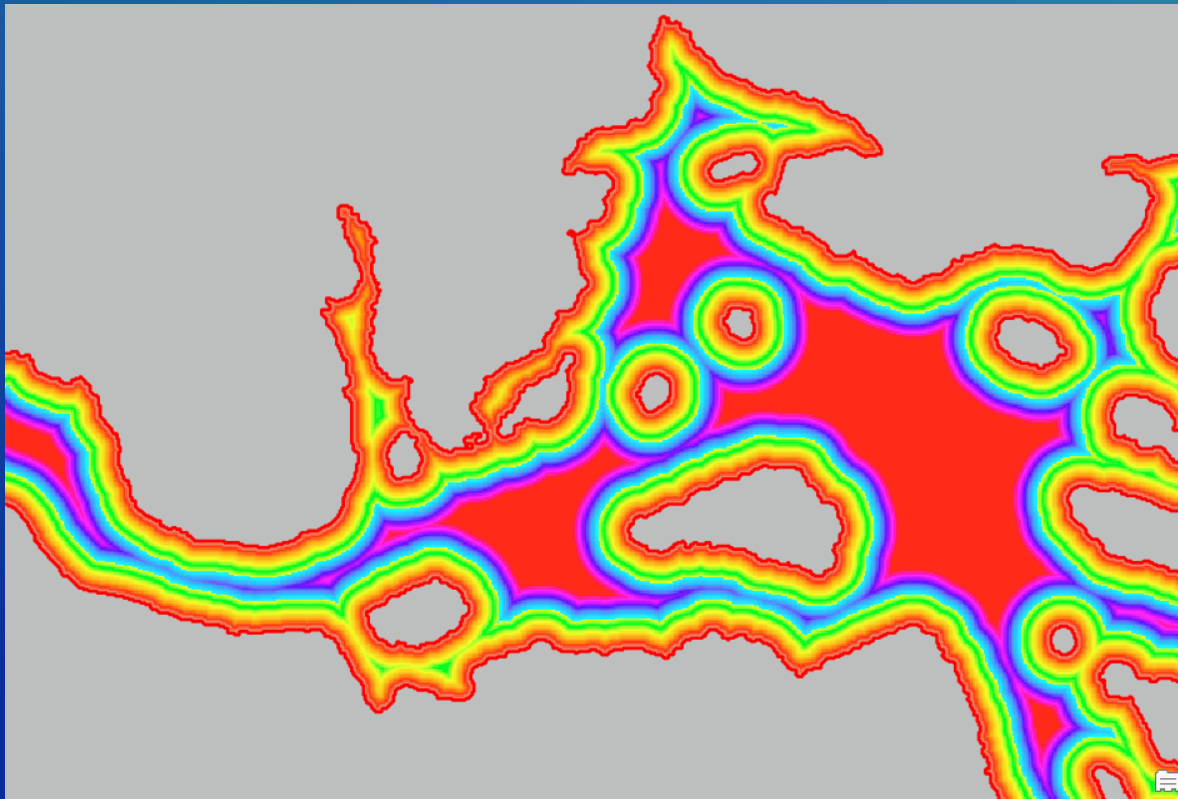
- Use sink feature class as “deranged” polygons in Arc Hydro tools/workflows.
 - Use in deranged and combined processing workflows.
- Also applicable to CF approach with flow direction adjustment in sinks.



1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
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5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Enforce single streams - Burn Flat Polygons into DEM

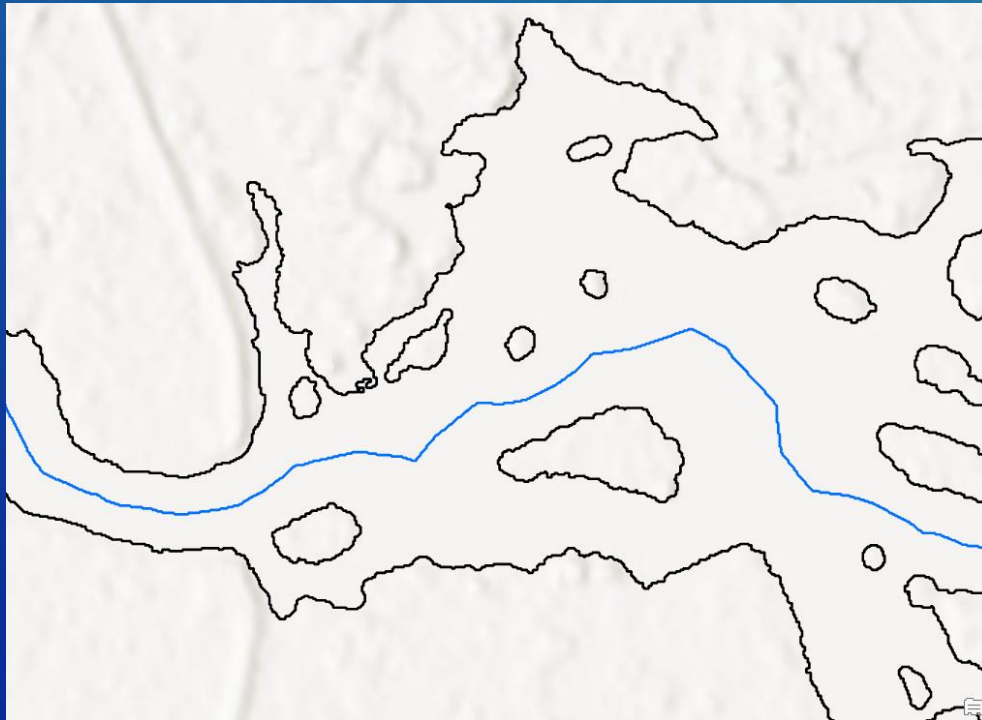
- Arc Hydro tool “Burn Flat Polygons into DEM”
 - Use raster approach to “bowl” flat areas into DEM.



1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
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5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
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Enforce single streams – Continuous Flow approach

- Use SA tool “Derive Stream as Line” with “burned” DEM as input.
- Alternatively, use Arc Hydro stream derivation approach.



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6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

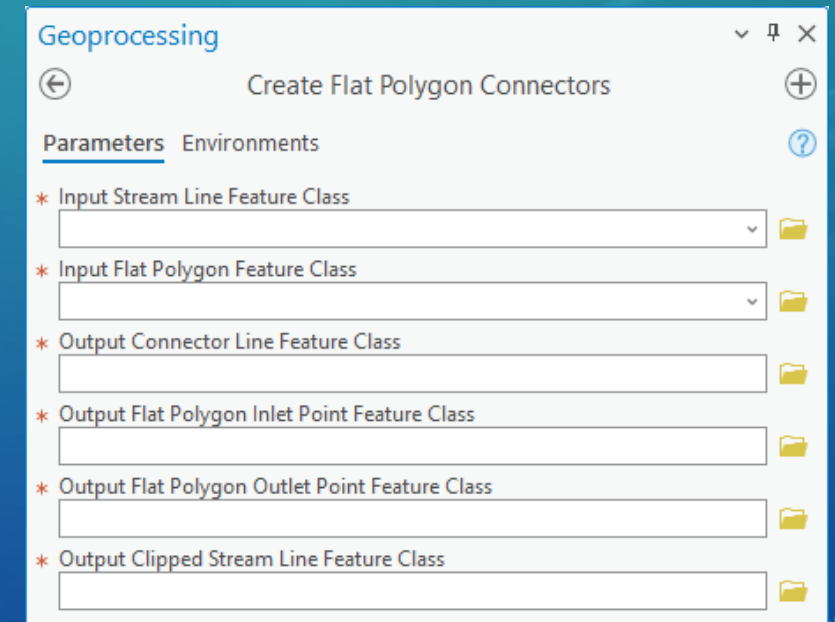
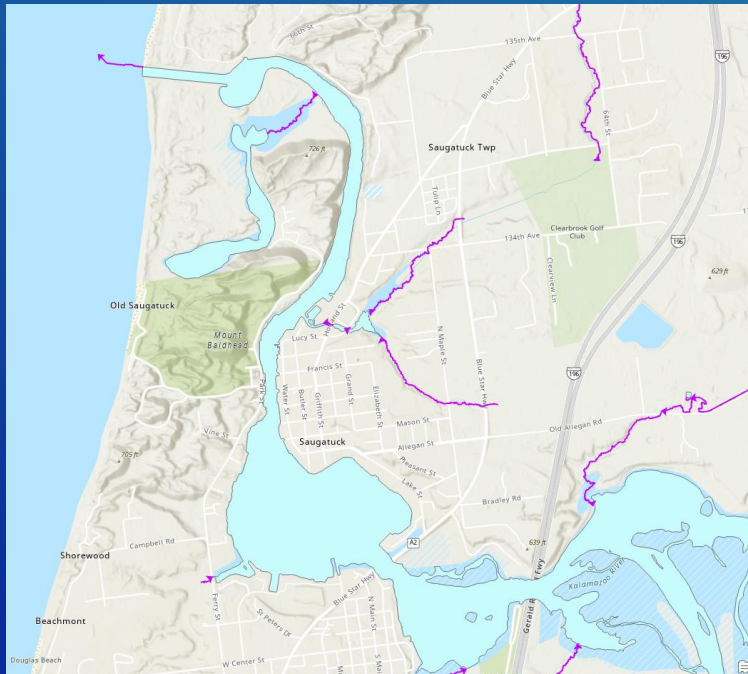
Enforce braided streams – overall workflow

- Multi-step process with user input:
 - Tool “Derive Stream As Line” using “burned” DEM.
 - Arc Hydro tool “Create Flat Polygon Connectors”.
 - Arc Hydro tool “Define Flat Area Outlet Point”.
 - Tool “Collapse Hydro Polygon”.
 - Iterative process to refine loops/streams:
 - Arc Hydro tool “Remove Orphan Lines”.
 - Arc Hydro tool “Fix Line Orientation” (automated and manual).
 - Arc Hydro tool “Remove Line Pseudonodes” (optional).
 - Tool “Flip Line” (manual).
 - Arc Hydro tool “Burn Flat Polygons and Streams into DEM”.
 - Arc Hydro tool “Create Drainage Line Structures”.
 - Arc Hydro tool “Flow Direction and Accumulation Using CF”.
 - Arc Hydro tool “Adjust Flow Direction in Streams”.

1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
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6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Enforce braided streams - Create Flat Polygon Connectors

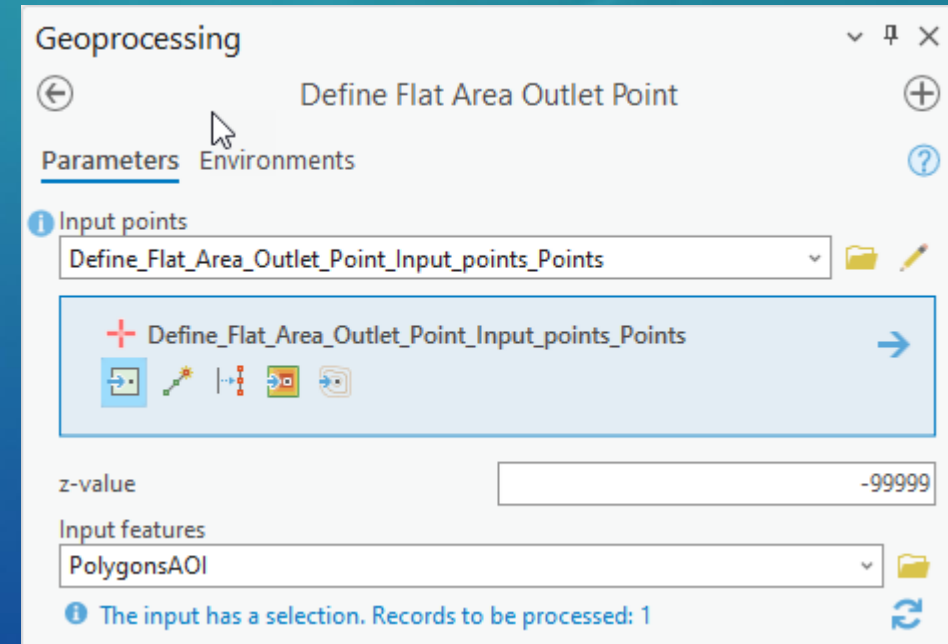
- Arc Hydro tool “Create Flat Polygon Connectors”
 - Create lines outside of flat polygons
 - Must touch at least one flat polygon
 - Creates inlet and outlet points (into the polygons)



1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
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5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Enforce braided streams – Define Flat Area Outlet Point

- Arc Hydro tool “Define Flat Area Outlet Point”
 - New for Pro 3.2 and up.
- Define known most downstream point in the flat polygon system
 - Sets z value to -9999.0, for the vertex in the flat polygon under the outlet point
- Facilitates adjusting line orientation in downstream direction (performed by the next tool)

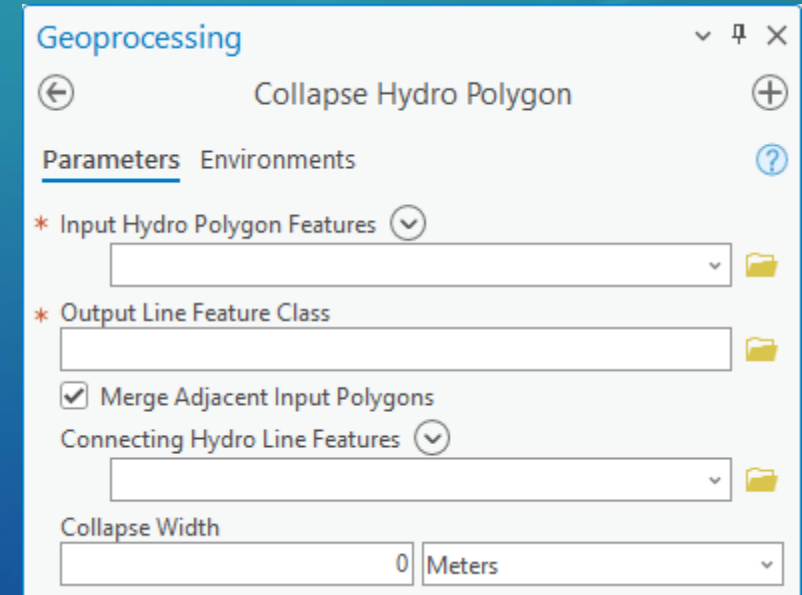
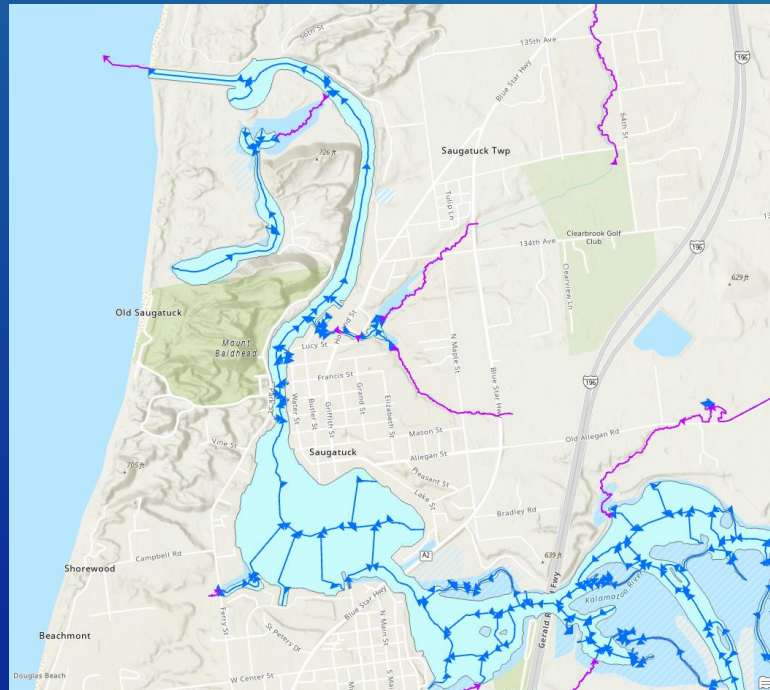


1. Identify potential flat areas
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3. Enforce sinks
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Enforce braided streams – Collapse Hydro Polygon

- Tool “Collapse Hydro Polygon”

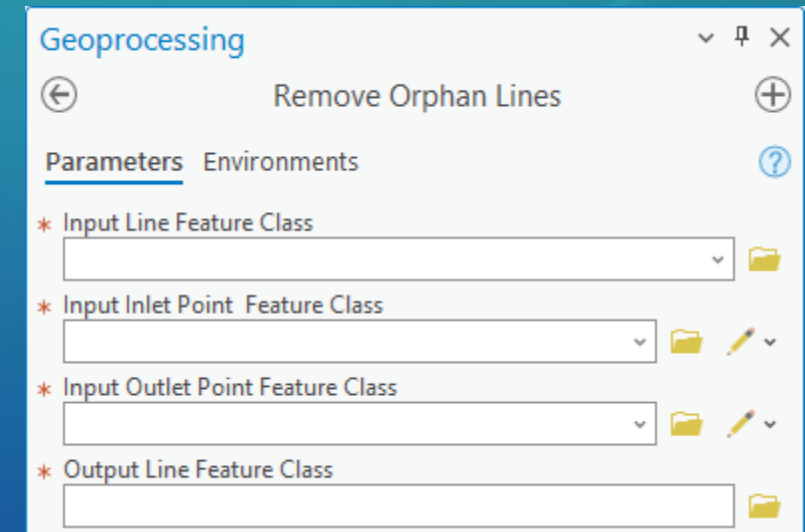
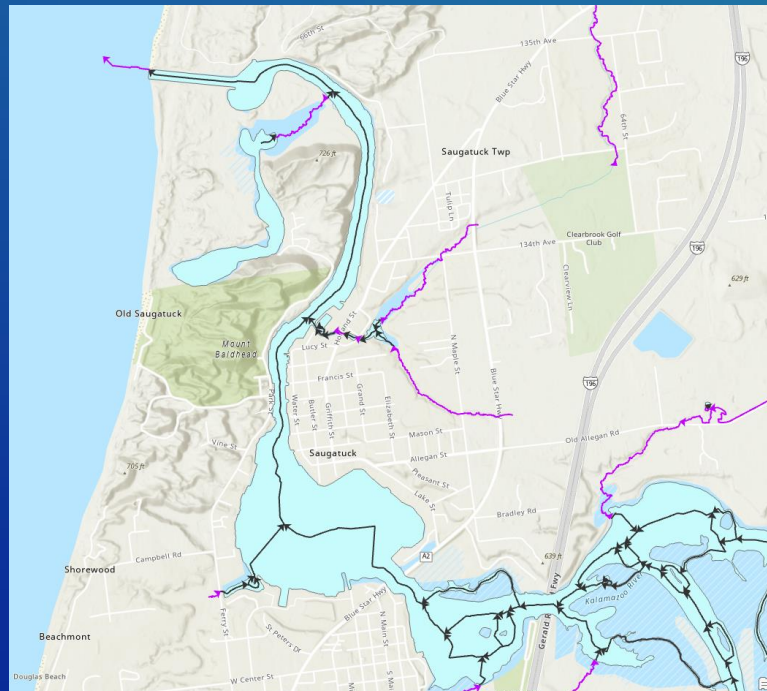
- New in Pro 3.2 - leverage z value of -9999.0 at the global outlet point.



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7. Revisit #1 and see if there are any remaining problem areas to address

Enforce braided streams – Remove Orphan Lines

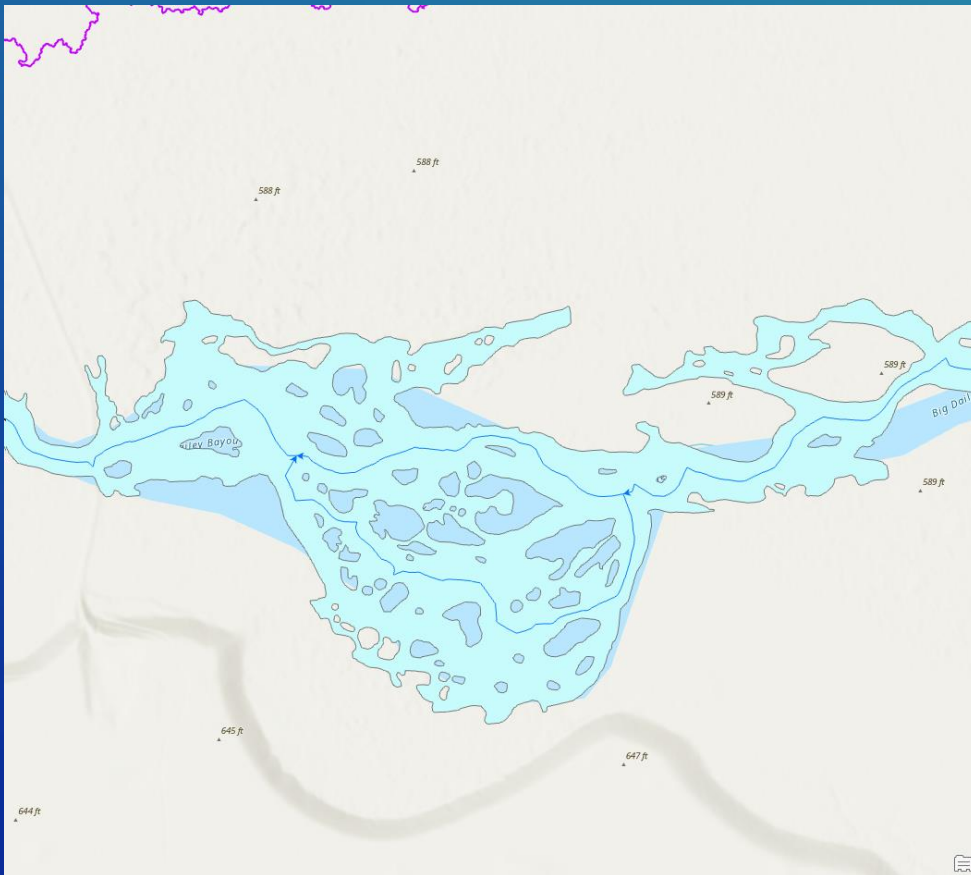
- Arc Hydro tool “Remove Orphan Lines”.
- Removes all lines not directly connected to inflow and outflow points or interconnected loops.
 - Isolated loops are removed.



1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
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5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Enforce braided streams – Remove Orphan Lines

- Complex systems – additional “weeding” !?



Geoprocessing ⌵ ⌵ ✕

← Remove Orphan Lines ⊕

Parameters Environments ?

* Input Line Feature Class 📁

* Input Inlet Point Feature Class 📁 ✎ ⌵

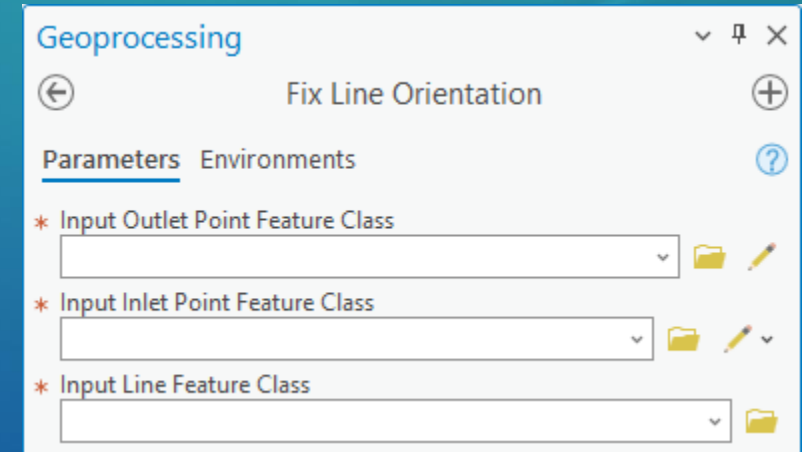
* Input Outlet Point Feature Class 📁 ✎ ⌵

* Output Line Feature Class 📁

1. Identify potential flat areas
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Enforce braided streams – Fix Line Orientation

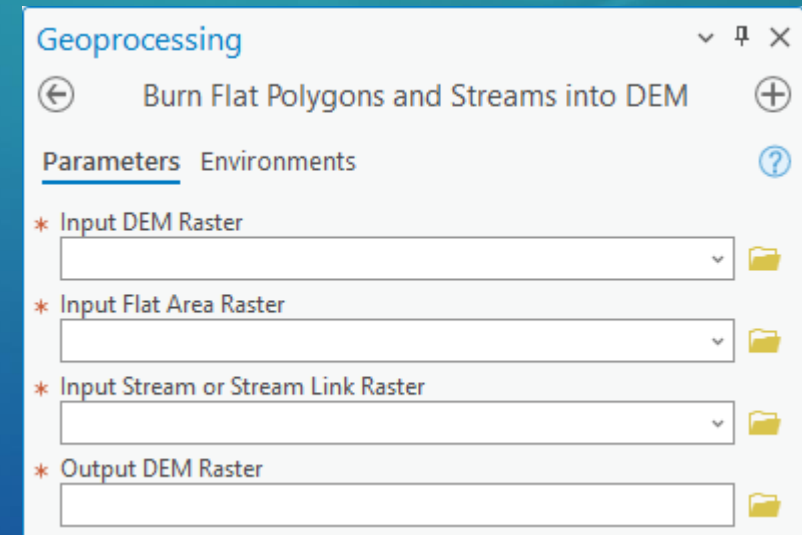
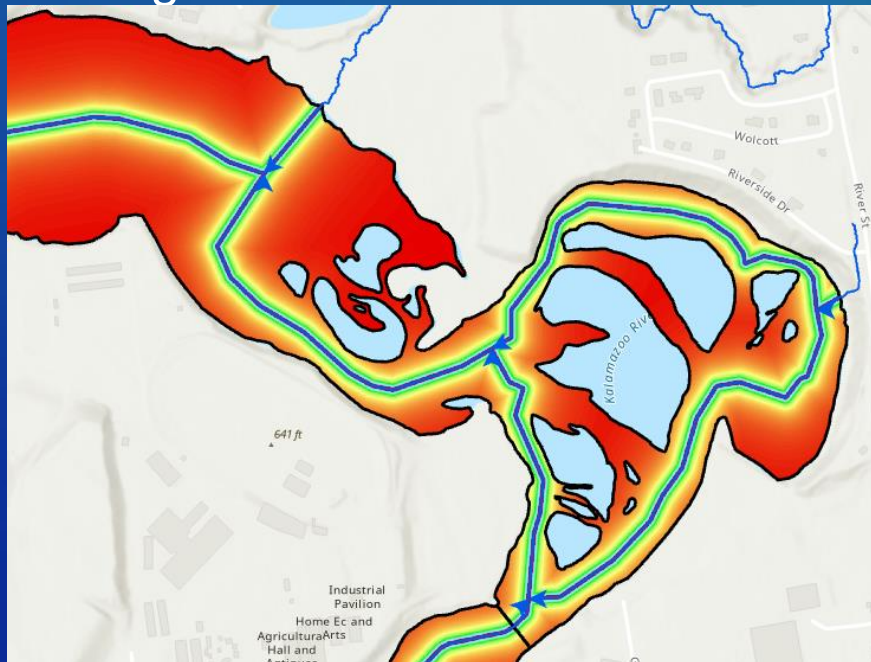
- Arc Hydro tool “Fix Line Orientation”.
- Enforce orientation of lines in the system so they go from inflow to outflow points.
- Might need iterations through complex braided systems with multiple viable alternatives.
 - “DoNotProcess” field.
 - Operation on selected set.



1. Identify potential flat areas
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Enforce braided streams – “Bowl” elevation in flat areas

- Arc Hydro tool “Burn Flat Polygons and Streams into DEM”.
- Enforce elevation in flat areas so that the resulting flow direction flows from the flat area boundary into stream that is draining it.



1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
4. Enforce single streams
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6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

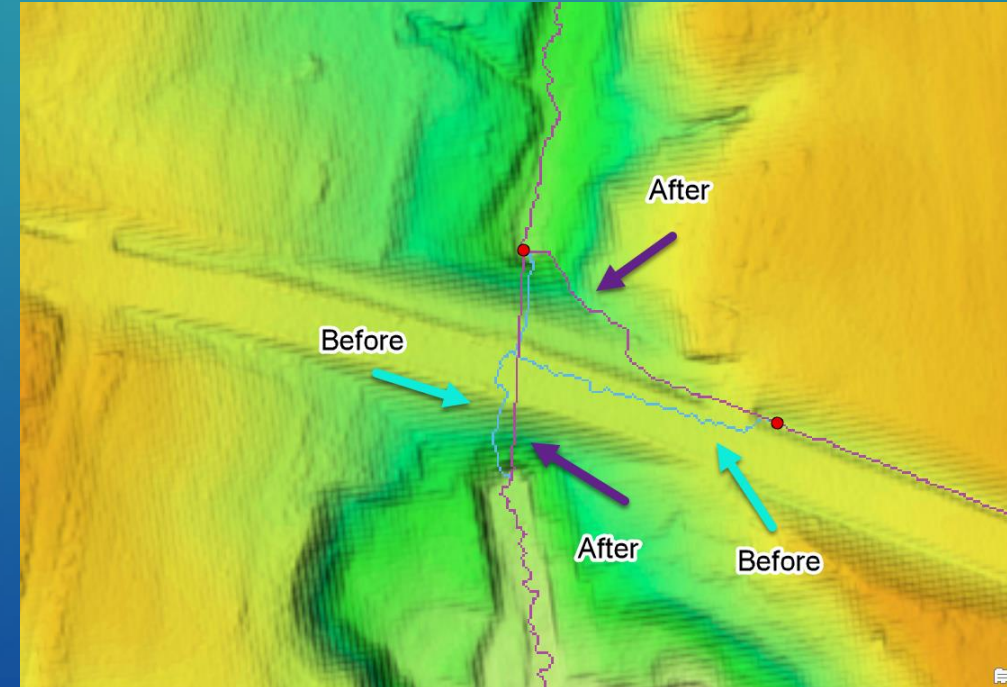
Enforce braided streams – final line enforcement

- Create connected network of stream elements outside flat areas and flat areas.
 - Standard data management operations.
- Arc Hydro tool “Create Drainage Line Structures”.
 - Creates raster and vector representation of the drainage system based on connected braided network.
- Arc Hydro tool “Flow Direction and Accumulation Using CF”.
 - Operating on “bowled” DEM.
- Arc Hydro tool “Adjust Flow Direction in Streams”.
 - Creates final flow direction that enforces braided streams.

1. Identify potential flat areas
2. Select flat areas that need to be enforced (sinks, single streams, braided streams)
3. Enforce sinks
4. Enforce single streams
5. Enforce braided streams
6. Run “stream” extraction on “hydro-adjusted” DEM
7. Revisit #1 and see if there are any remaining problem areas to address

Run “stream” extraction on “hydro-adjusted” DEM

- Needed only for non-braided workflow – braided workflow already has final stream system identified.
- This should be combined with other AH tools/workflows.
- Arc Hydro tools:
 - “Flow Direction and Accumulation Using CF”
 - “Stream Definition”
 - “Stream Segmentation”
 - “Drainage Line Processing”



1. Identify potential flat areas
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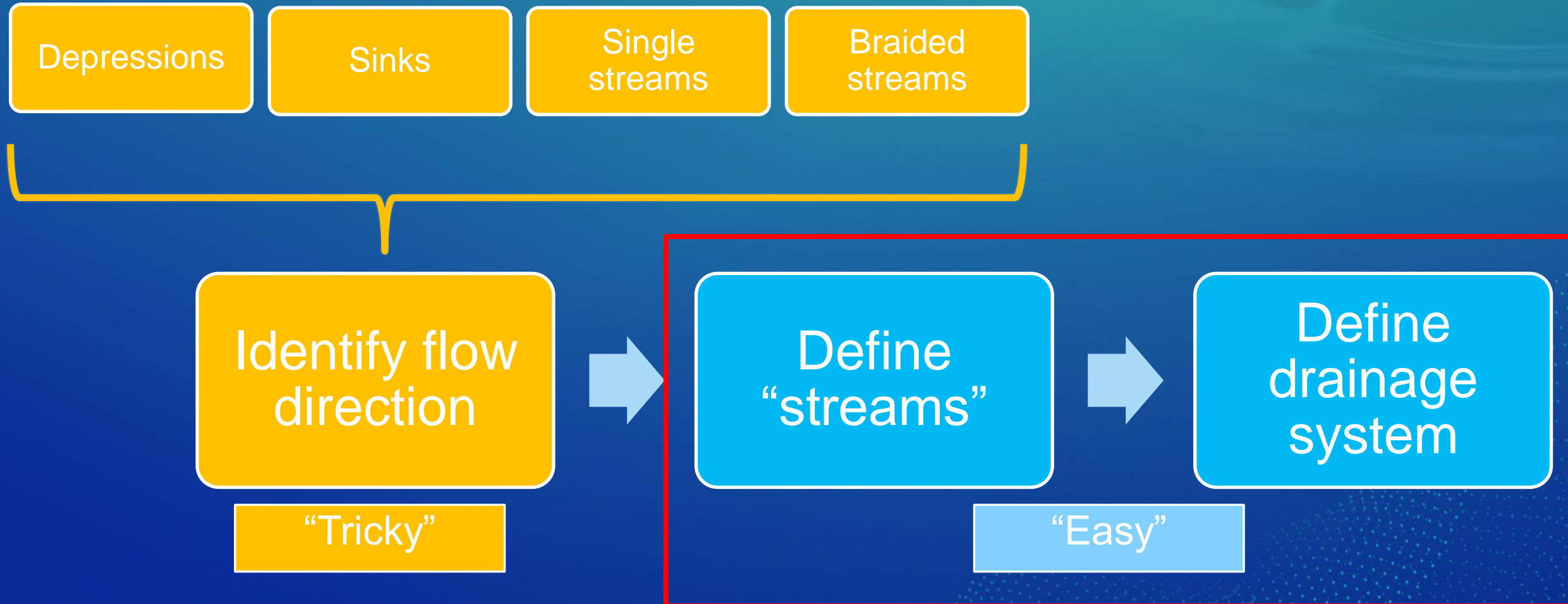
Check for remaining flow path issues

- Back to the “Big Picture” – look at overall flow pattern.
- Check if there are any remaining potential areas needed to be breached.
- Make any necessary adjustments.
- Rerun some aspects of the workflow as necessary.

1. Identify potential flat areas
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Hydro Feature Extraction: In a not so perfect world ...

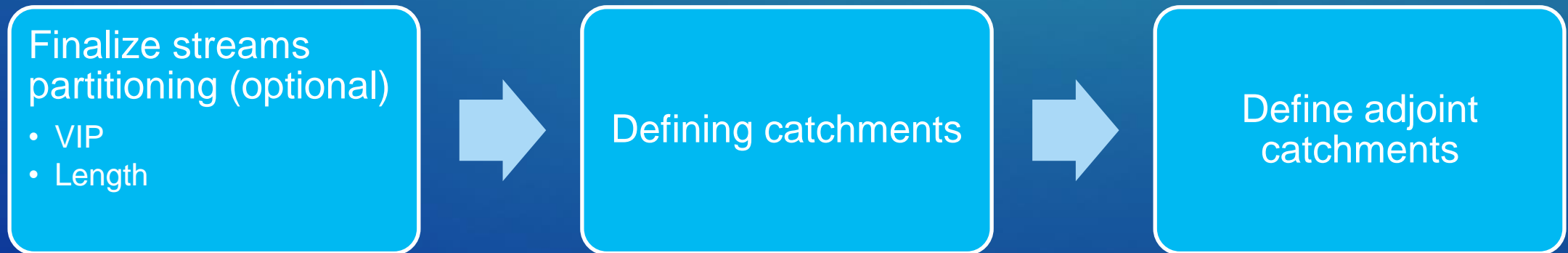
Extended workflows



Finalize drainage system

Extended workflow

- Integrated vector and raster system (matching representation in both formats to maintain consistency and optimize performance of the analyses).

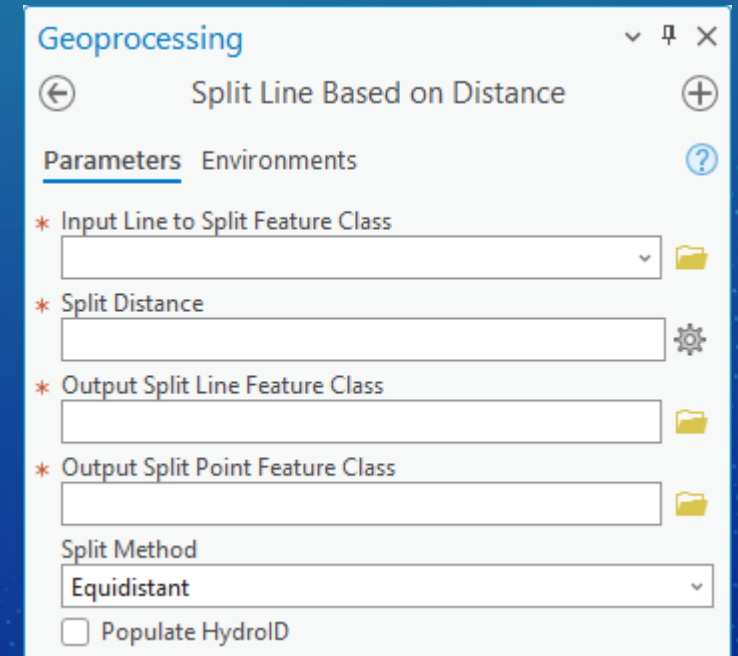
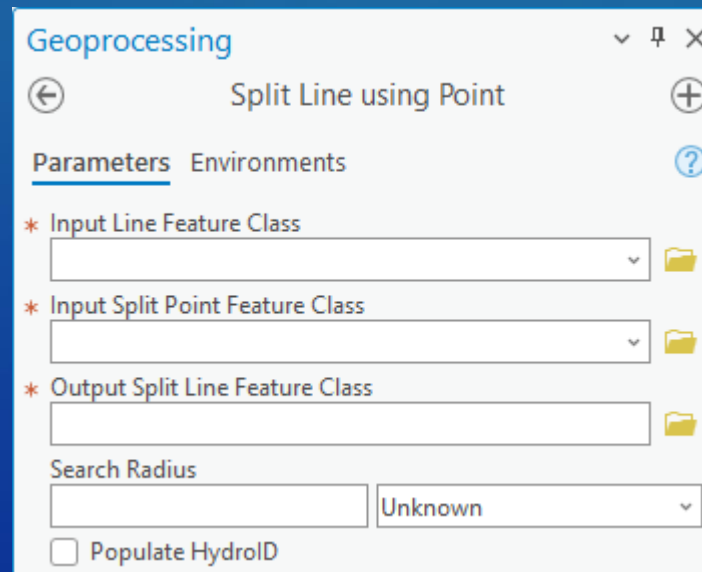


Physical NOT program rules (e.g. slopes, minimum drainage area, stream length, ...)

Final stream partitioning

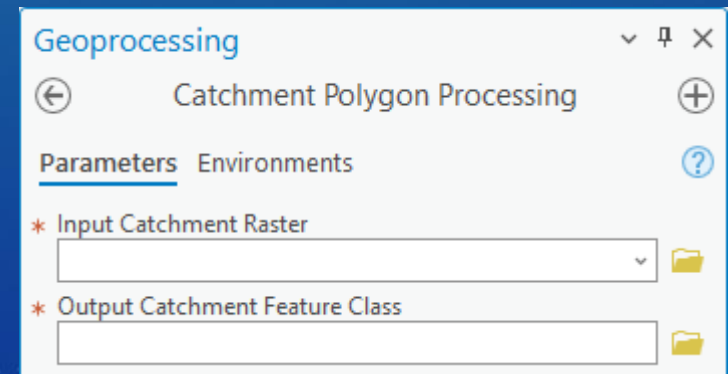
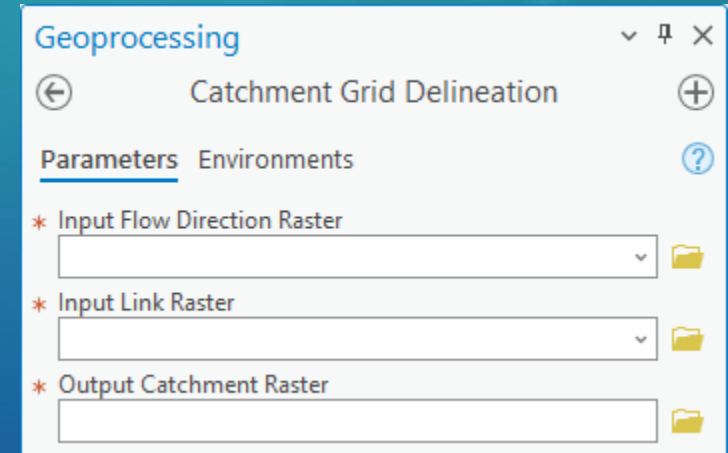
Optional – physically based

- Arc Hydro tools:
 - “Split Line using Point”. (VIP)
 - “Split Line Based by Distance”
- Partition lines while maintaining the orientation and key identifiers (e.g. NextDownID”).



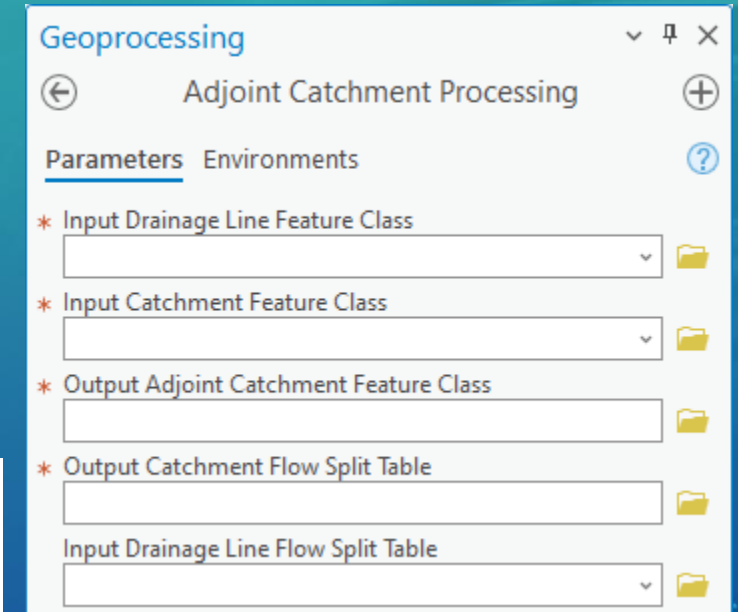
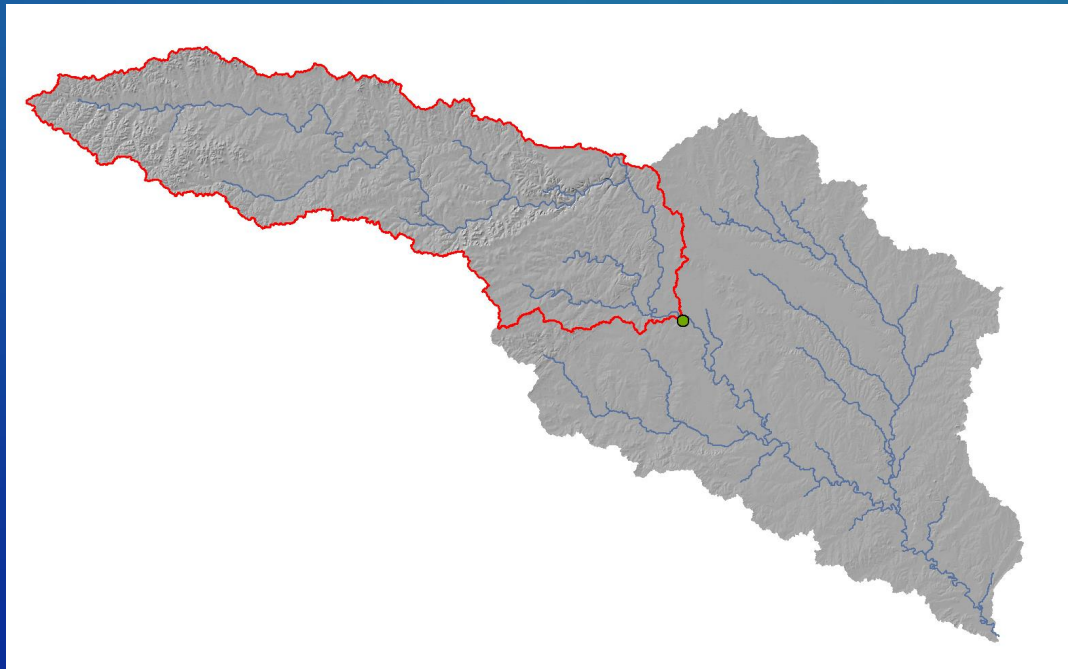
Defining catchments

- Arc Hydro tools:
 - “Catchment Raster Processing”.
 - “Catchment Delineation”
- Identify drainage areas draining into stream segments and sinks.
 - Raster.
 - Vector.



Defining adjoint catchments

- Arc Hydro tool “Adjoint Catchment Processing”.
- Identify upstream contributing area to each catchment/stream segment.
- Vector representation only.
- Performance “tool”.



Review and Summary



Review and Summary

- “Geofabric”.
 - Integrated vector/raster system.
- Foundation for support of specific “products” (e.g. USGS EDH/3DHP) and analyses.
- NOT a super button.

Review and Summary

- “Almost” done with individual tools and workflows.
 - Documentation (workflow document)
 - Line smoothing
 - Inflexion points
- R & D:
 - “Parameters”
 - “Culvert” selection (traditional, AI)
 - Automation
 - Performance

Questions?

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