

AN ESRI  
WHITE PAPER

AUGUST 2019

# Arc Hydro: Overview of Terrain Preprocessing Workflows

380 New York Street  
Redlands, California 92373-8100 usa  
909 793 2853  
info@esri.com  
esri.com



**esri**

THE  
SCIENCE  
OF  
WHERE™

Copyright © 2019 Esri

All rights reserved.

Printed in the United States of America.

The information contained in this document is the exclusive property of Esri. This work is protected under United States copyright law and other international copyright treaties and conventions. No part of this work may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage or retrieval system, except as expressly permitted in writing by Esri. All requests should be sent to Attention: Contracts and Legal Services Manager, Esri, 380 New York Street, Redlands, CA 92373-8100 USA.

The information contained in this document is subject to change without notice.

Esri, the Esri globe logo, The Science of Where, ArcGIS, [esri.com](http://esri.com), and @esri.com are trademarks, service marks, or registered marks of Esri in the United States, the European Community, or certain other jurisdictions. Other companies and products or services mentioned herein may be trademarks, service marks, or registered marks of their respective mark owners

# Table of Contents

Section Title	Page
<b>1.0 Introduction.....</b>	<b>2</b>
1.1 Document history .....	2
<b>2.0 Solution Overview.....</b>	<b>3</b>
<b>3.0 Overview of Arc Hydro Terrain Preprocessing Workflows.....</b>	<b>4</b>
<b>4.0 Use Cases .....</b>	<b>5</b>
4.1 Use case 1: Completely deranged terrain with unknown sink location and no filling of sinks.....	5
4.2 Use case 2: Completely deranged terrain with unknown sink location and some filling of sinks (always needs filling when not keeping all sinks).....	6
4.3 Use case 3: Completely deranged terrain with known sink location and some filling of sinks (always needs filling when not keeping all sinks).....	6
4.4 Use case 4: Combined dendritic/deranged terrain with unknown initial sink and stream locations.....	7
4.5 Use case 5: Combined dendritic/deranged terrain with known sink and stream locations (using synthetic streams).....	8
4.6 Use case 6: Combined dendritic/deranged terrain with known sink and stream locations (using user specified streams) - this needs to be verified on Iceland dataset.....	9
4.7 Use case 7: Completely dendritic terrain with unknown stream locations .....	9
4.8 Use case 8: Completely dendritic terrain with known stream locations (using synthetic streams).....	10
4.9 Use case 9: Completely dendritic terrain with known stream locations (using user specified streams).....	11
4.10 Use case model builder implementation in Arc Hydro tools (Terrain Preprocessing Workflows toolset).....	11
<b>5.0 Selected Arc Hydro Terrain Preprocessing Functions .....</b>	<b>13</b>
5.1 Indirectly called Arc Hydro functions .....	14
5.2 Function input and output.....	14

## 1.0 Introduction

Arc Hydro consists of a data model, toolset, and workflows developed over the years to support specific geographic information system (GIS) implementations in water resources. The initial implementation of Arc Hydro was in 2002 with the data model, Arc Hydro book published by Esri Press, and an initial set of about 30 tools. Since then, Arc Hydro has been used in many projects, and in the process, new tools and workflows have been developed. There are more than 300 Arc Hydro tools now, and they continue to be expanded based on work in specific implementations.

This document describes key steps for using Arc Hydro tools for preprocessing deranged, combined, and dendritic terrains. The steps are organized into workflows based on the key geomorphologic characteristic of the terrain being processed. This document describes multiple use cases and determines which tools to use to generate "proper" results. Not all Arc Hydro terrain preprocessing tools are presented here; there are other tools that can be used in specific morphologies and processing requirements. The use cases presented here are the most commonly encountered ones.

While the screen captures are based on an ArcMap product, this document is not focused on a specific version of ArcGIS or Arc Hydro—it is a set of generic recommendations that transcend specific versions.

### 1.1 Document History

Table 1. Document Revision History

Version	Description	Date
1	First version	6/2012
2	Major revisions	3/2013
2.1	Minor revisions	1/2014
3	Minor revisions, new look, ArcGIS Pro reference	8/2019

## 2.0 Solution Overview

Terrain preprocessing capabilities are implemented as many Arc Hydro tools organized in the Terrain Preprocessing toolset. Some of the basic tools described in this document are also present on the Arc Hydro toolbar in ArcMap (but not on the Arc Hydro ribbon in ArcGIS Pro). When options are available, use the Python version of the tools.

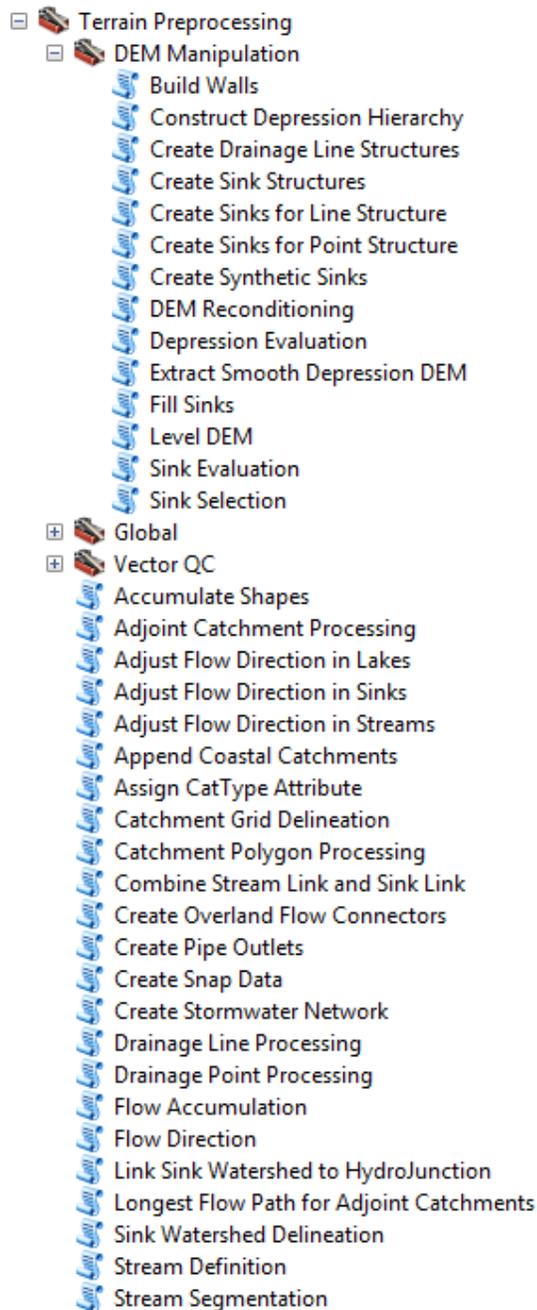


Figure 1. Arc Hydro Terrain Preprocessing toolset (Arc Hydro Tools Python toolbox)

The tools discussed in this document have been part of the Arc Hydro 10.x platform since version 10.2.0.68, and they are in the Arc Hydro Tools Pro toolbox supporting ArcGIS Pro 2.3.3 and later. There are no differences in behavior or functionality between all versions of the tools. This document uses screenshots from the ArcMap version of the tools.

### 3.0 Overview of Arc Hydro Terrain Preprocessing Workflows

Geomorphologic (use case) terminology includes the following:

- Completely deranged terrain—This contains only sinks. Streams are not represented in Arc Hydro.
- Completely dendritic terrain—There are no sinks in the system, only streams.
- Combined dendritic/deranged terrain—There are streams and sinks in the system. Streams can be independent from the sinks and/or flow into them.

There can be additional steps—such as sink prescreening or walling—in terrain preprocessing that are not explicitly discussed in this document, or data development steps using tools such as Create Sinks for Line Structure or Create Synthetic Sinks. These techniques do not impact the order of execution or tool capabilities presented in this document. These operations can be inserted into the presented workflows with minimal impact. The placement, though, needs to be correct to obtain proper effect (e.g., first fence and then burn if you want the fenced area to flow out, or first burn and then fence if you do not want the area to flow out).

**Table 2. Overview of Terrain Processing Use Cases/Workflows**

	<b>Deranged only</b>	<b>Combined</b>	<b>Dendritic only</b>
<b>DEM only (no stream or sink information)</b>	Use case 1 Use case 2	Use case 4	Use case 7
<b>DEM and known sinks</b>	Use case 3		
<b>DEM and known streams and sinks</b>		Use case 5 Use case 6	
<b>DEM and known streams</b>			Use case 8 Use case 9

Note that the tools are designed for use with clean and consistent data. For example, streams that are to be burned in must extend to the edge of the DEM or end in a sink, have to be snapped at confluences, and should be digitized in a downstream direction.

The tools leverage existing Arc Hydro database design for feature identification and default layer naming. Due to the integrated nature of terrain preprocessing, the tools and data structures are designed to be closely tied together and executed in a specific sequence. The tools presented below should be executed in the provided order.

## 4.0 Use Cases

### 4.1 Use Case 1: Completely Deranged Terrain with Unknown Sink Location and No Filling of Sinks

1. Sink Evaluation
2. Create Sink Structures
3. Flow Direction
4. Adjust Flow Direction in Sinks
5. Sink Watershed Delineation

6. Append Coastal Catchments
7. Assign CatType Attribute to Catchment FC (optional)

#### **4.2 Use Case 2: Completely Deranged Terrain with Unknown Sink Location and Some Filling of Sinks (always needs filling when not keeping all sinks)**

1. Sink Evaluation
2. Selection of sinks process—Note that this is not an Arc Hydro tool but rather a process. Any technique for selecting sinks can be used. The end result is a polygon feature class with polygon features defining sink polygons to keep as sinks.
  - a. Use the Arc Hydro Sink Selection tool.
  - b. Interactively pick polys.
3. Create Sink Structures
4. Fill Sinks
5. Flow Direction
6. Adjust Flow Direction in Sinks
7. Sink Watershed Delineation
8. Append Coastal Catchments
9. Assign CatType Attribute to Catchment FC (optional)

#### **4.3 Use Case 3: Completely Deranged Terrain with Known Sink Location and Some Filling of Sinks (always needs filling when not keeping all sinks)**

1. Create Sink Structures
2. Level DEM
3. Fill Sinks
4. Flow Direction
5. Adjust Flow Direction in Sinks

6. Sink Watershed Delineation
7. Append Coastal Catchments
8. Assign CatType Attribute to Catchment FC (optional)

#### **4.4 Use Case 4: Combined Dendritic/Deranged Terrain with Unknown Initial Sink and Stream Locations**

1. Sink Evaluation
2. Selection of sinks process
3. Create Sink Structures
4. Fill Sinks
5. Flow Direction
6. Adjust Flow Direction in Sinks
7. Adjust Flow Direction in Lakes—Using this tool is an optional step if there are lakes that are being drained by the streams. Note that these are not sink lakes.
8. Sink Watershed Delineation
9. Flow Accumulation
10. Stream Definition
11. Stream Segmentation
12. Combine Stream Link and Sink Link
13. Drainage Line Processing
14. Catchment Grid Delineation
15. Catchment Polygon Processing
16. Adjoint Catchment Processing
17. Append Coastal Catchments
18. Assign CatType Attribute to Catchment FC (optional)

#### **4.5 Use Case 5: Combined Dendritic/Deranged Terrain with Known Sink and Stream Locations (using synthetic streams)**

1. Create Drainage Line Structures
2. DEM Reconditioning
3. Create Sink Structures
4. Level DEM
5. Fill Sinks
6. Flow Direction
7. Adjust Flow Direction in Sinks
8. Adjust Flow Direction in Streams
9. Adjust Flow Direction in Lakes (optional)
10. Sink Watershed Delineation
11. Flow Accumulation
12. Stream Definition
13. Stream Segmentation
14. Combine Stream Link and Sink Link
15. Drainage Line Processing (Use combined Stream Link Grid and Sink Link Grid as inputs.)
16. Catchment Grid Delineation
17. Catchment Polygon Processing
18. Adjoint Catchment Processing
19. Append Coastal Catchments
20. Assign CatType Attribute to Catchment FC (optional)

#### **4.6 Use Case 6: Combined Dendritic/Deformed Terrain with Known Sink and Stream Locations (using user-specified streams)**

1. Create Drainage Line Structures
2. DEM Reconditioning
3. Create Sink Structures
4. Level DEM
5. Fill Sinks
6. Flow Direction
7. Adjust Flow Direction in Sinks
8. Adjust Flow Direction in Streams
9. Adjust Flow Direction in Lakes (optional)
10. Sink Watershed Delineation
11. Combine Stream Link and Sink Link (Make sure you specify optional Drainage Line feature class as input.)
12. Catchment Grid Delineation
13. Catchment Polygon Processing
14. Adjoint Catchment Processing
15. Append Coastal Catchments
16. Assign CatType Attribute to Catchment FC (optional)

#### **4.7 Use Case 7: Completely Dendritic Terrain with Unknown Stream Locations**

1. Fill Sinks
2. Flow Direction
3. Flow Accumulation
4. Stream Definition
5. Stream Segmentation

6. Drainage Line Processing
7. Catchment Grid Delineation
8. Catchment Polygon Processing
9. Adjoint Catchment Processing
10. Append Coastal Catchments
11. Assign CatType Attribute to Catchment FC (optional)

#### **4.8 Use Case 8: Completely Dendritic Terrain with Known Stream Locations (using synthetic streams)**

1. Fill Sinks
2. DEM Reconditioning
3. Fill Sinks (Use to get rid of the sinks potentially introduced by DEM Reconditioning.)
4. Flow Direction
5. Flow Accumulation
6. Stream Definition
7. Stream Segmentation
8. Drainage Line Processing
9. Catchment Grid Delineation
10. Catchment Polygon Processing
11. Adjoint Catchment Processing
12. Append Coastal Catchments
13. Assign CatType Attribute to Catchment FC (optional)

#### 4.9 Use Case 9: Completely Dendritic Terrain with Known Stream Locations (using user-specified streams)

1. Create Drainage Line Structures
2. Fill Sinks
3. DEM Reconditioning
4. Fill Sinks
5. Flow Direction
6. Adjust Flow Direction in Streams
7. Catchment Grid Delineation
8. Catchment Polygon Processing
9. Adjoint Catchment Processing
10. Append Coastal Catchments
11. Assign CatType Attribute to Catchment FC (optional)

#### 4.10 Model Builder Implementation in Arc Hydro Tools (Terrain Preprocessing Workflows toolset)

Several of the variants of the presented use cases are implemented in the Arc Hydro Terrain Preprocessing Workflows toolset as Model Builder models. These models are intended more as a starting point for your modification of the specific process required by your data than as a turnkey tool. The toolset content might vary with versions of the Arc Hydro tools.

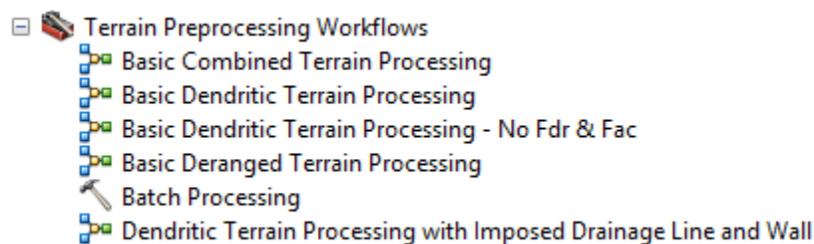


Figure 1. Toolset Organization Structure for Specific Terrain Preprocessing Use Cases (Arc Hydro tools)

**Table 3. Model Names for Specific Terrain Preprocessing Use Cases in Arc Hydro Terrain Preprocessing Workflows Toolset (Arc Hydro Tools.tbx)**

<b>Use Case</b>	<b>Description</b>	<b>Model Builder Name</b>
2	Completely deranged terrain with unknown sink location and some filling of sinks (always needs filling when not keeping all sinks)	Basic Deranged Terrain Processing
4	Combined dendritic/deranged terrain with unknown initial sink and stream locations	Basic Combined Terrain Processing
7	Completely dendritic terrain with unknown stream locations. Starting point is the known filled DEM.	Basic Dendritic Terrain Processing
7	Completely dendritic terrain with unknown stream locations. Starting points are known flow direction and flow accumulation grids (typical situation for NHDPlus dataset).	Basic Dendritic Terrain Processing—No Fdr & Fac
9	Completely dendritic terrain with known stream locations (using user-specified streams).	Dendritic Terrain Processing with Imposed Drainage Line and Wall

## 5.0 Selected Arc Hydro Terrain Preprocessing Functions

This is a list of Arc Hydro preprocessing functions identified in use cases 1–9. There are other preprocessing functions that are not presented here but might be needed for the implementation of additional capabilities.

Table 4. Overview of Functions Used per Use Case/Workflow

Function \ Use Case	Deranged			Combined			Dendritic		
	1	2	3	4	5	6	7	8	9
Sink Evaluation	X	X		X					
Create Sink Structures	X	X	X	X	X	X			
Flow Direction	X	X	X	X	X	X	X	X	X
Adjust Flow Direction in Sinks	X	X	X	X	X	X			
Sink Watershed Delineation	X	X	X	X	X	X			
Append Coastal Catchments	X	X	X	X	X	X	X	X	X
Assign CatType Attribute to Catchment FC	X	X	X	X	X	X	X	X	X
Fill Sinks		X	X	X	X	X	X	X	X
Level DEM			X		X	X			
Flow Accumulation				X	X		X	X	
Stream Definition				X	X		X	X	
Stream Segmentation				X	X		X	X	
Combine Stream Link and Sink Link				X	X	X			
Drainage Line Processing				X	X		X	X	
Adjust Flow Direction in Lakes				X	X	X			
Catchment Grid Delineation				X	X	X	X	X	X
Catchment Polygon Processing				X	X	X	X	X	X
Adjoint Catchment Processing				X	X	X	X	X	X
Create Drainage Line Structures from Stream Grid					X	X			X
DEM Reconditioning					X	X		X	X
Adjust Flow Direction in Streams					X	X			X

## 5.1 Indirectly Called Arc Hydro Functions

The above-mentioned preprocessing functions call the following additional Arc Hydro functions:

- Assign HydroID
- Generate From/To Nodes for Lines
- Find Next Downstream Line

## 5.2 Function Input and Output

This section presents inputs and outputs for each listed preprocessing function. For a detailed description, consult each tool's help.

### 1. Sink Evaluation

- a. Input: Raw DEM
- b. Output: Sink Polygon Feature Class
- c. Output: Sink Drainage Area

### 2. Create Sink Structures—This generates DEM-compliant sink elements. HydroID, FeatureID, SinkID, and IsSink fields (and potentially others) need to be managed. The input sink polygon feature class can have a selected set that will be obeyed.

- a. Input: Raw DEM
- b. Input: Sink Polygon (this can be a user-digitized deranged polygon or result from the Sink Evaluation function.)
- c. Output: Sink Polygon (jagged poly based on the input polys and selected set; IsSink = 1)
- d. Output: Sink Polygon Grid (what we call now Sink Link Grid)
- e. Output: Sink Point Feature Class
- f. Output: Sink Point Grid
- g. Input (optional): Stream Feature Class (use the TO\_NODE of the stream as the sink if the stream ends in the sink poly.)

- h. Input (optional): Draft Sink Point Feature Class (use those points as sinks if they fall into the sink poly)

### 3. Flow Direction

- a. Input: DEM
- b. Output: Flow Direction Grid
- c. Input (optional): External Wall Polygon

### 4. Adjust Flow Direction in Sinks

- a. Input: Flow Direction Grid
- b. Input: Sink Point Grid
- c. Input: Sink Polygon Grid
- d. Output: Flow Direction Grid (adjusted)

### 5. Sink Watershed Delineation

- a. Input: Flow Direction Grid
- b. Input: Sink Point Grid
- c. Input: Sink Point Feature Class
- d. Output: Sink Watershed Grid
- e. Output: Sink Watershed Polygon

### 6. Append Coastal Catchments—This is an optional step that should be done for large DEMs with large portions of coastal areas—areas defined as not draining into the streams. This function defines coastal catchments and appends them to the catchment feature class.

- a. Input: DEM Grid
- b. Input: Catchment Grid
- c. Input/Output: Catchment Feature Class

### 7. Assign CatType Attribute—This is an optional step. This function assigns CatType attribute to catchment features.

- a. Input/Output: Catchment Feature Class

- b. Input (optional): Drainage Line Feature Class
- c. Input (optional): Sink Point Feature Class

## **8. Fill Sinks**

- a. Input: Raw DEM
- b. Output: Filled DEM
- c. Input (optional): Fill Threshold (depth)
- d. Input (optional): Deranged Polygon (sink polygon from Create Sink Structures)

## **9. Level DEM**

- a. Input: Raw DEM
- b. Input: Lake Polygon (in this case, the sink polygon feature class from the Create Sink Structures function)
- c. Output: Level DEM
- d. Input (optional): Fill Elevation Field (for this workflow, a mandatory field that should contain a deep burn elevation [depth])
- e. Input (optional): Fill Elevation Offset in Linear Units

## **10. Flow Accumulation**

- a. Input: Flow Direction Grid
- b. Output: Flow Accumulation Grid

## **11. Stream Definition**

- a. Input: Flow Accumulation Grid
- b. Input: Number of Cells to Define Stream (alternatively, the threshold can be defined as area in km<sup>2</sup>)
- c. Output: Stream Grid

## **12. Stream Segmentation**

- a. Input: Stream Grid
- b. Input: Flow Direction Grid
- c. Output: Stream Link Grid

- d. Input (optional): Sink Watershed Grid
- e. Option: Raise Negative Values

### **13. Combine Stream Link and Sink Link**

- a. Input: Stream Link Grid
- b. Input: Sink Link Grid (should be sink point grid)
- c. Output: Link Grid (combined)
- d. Input (optional): Drainage Line Feature Class

### **14. Drainage Line Processing**

- a. Input: Stream Link Grid (in this case, link grid with streams and sinks)
- b. Input: Flow Direction Grid
- c. Output: Drainage Line Feature Class

**15. Adjust Flow Direction in Lakes**—This is an optional step if there are lakes that are being drained by the streams. Note that these are not sink lakes; sink lake flow direction adjustment was done in step 6.

- a. Input: Flow Direction Grid
- b. Input: Lake Polygon Feature Class—Note that these are lake polygons that are not sink lakes.
- c. Input: Stream grid (in this case, drainage line grid created by the Crate Drainage Line Structures function)
- d. Output: Bowled Flow Direction Grid

### **16. Catchment Grid Delineation**

- a. Input: Flow Direction Grid
- b. Input: Link Grid (in this case, the link grid from the previous step)
- c. Output: Catchment Grid

### **17. Catchment Polygon Processing**

- a. Input: Catchment Grid
- b. Output: Catchment Feature Class

## **18. Adjoint Catchment Processing**

- a. Input: Drainage Line Feature Class
- b. Input: Catchment Feature Class
- c. Output: Adjoint Catchment Feature Class

## **19. Create Drainage Line Structures**

- a. Input: Raw DEM
- b. Input: Stream
- c. Output: Stream Flow Direction Grid
- d. Output: Stream Link Grid
- e. Output: Drainage Line Feature Class
- f. Option: Clear Right Angles
- g. Option: Use Raster Extent

## **20. DEM Reconditioning**

- a. Input: Raw DEM
- b. Input: Stream Link Grid
- c. Input: Number of Cells for Stream Buffer
- d. Input: Smooth Drop in Z Units
- e. Input: Sharp Drop in Z Units
- f. Output: AGREE DEM
- g. Option: Raise Negative Values

## **21. Adjust Flow Direction in Streams**

- a. Input: Flow Direction Grid
- b. Input: Stream Flow Direction Grid
- c. Output: Adjusted Flow Direction Grid