User Guide

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Domain: https://erams.com/map/

WATERSHED DELINEATION

CATENA ANALYTICS

One Water Solutions Institute

Colorado State University

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EXECUTIVE MESSAGE

Catena Analytics offers powerful platforms for building accessible and scalable analytical tools and simulation models that can be accessed via desktop or mobile devices. Our team has spent the last decade developing the Environmental Resource Assessment and Management System (eRAMS), an open source technology that provides cloud-based geospatially-enabled software solutions as online services and a platform for collaboration, development, and deployment of online tools. Our services are used to assist with strategic and tactical decision making for sustainable management of land, water and energy resources. Thank you for choosing Catena Analytics and the eRAMS platform to meet your data, modeling, analysis and geospatial needs.

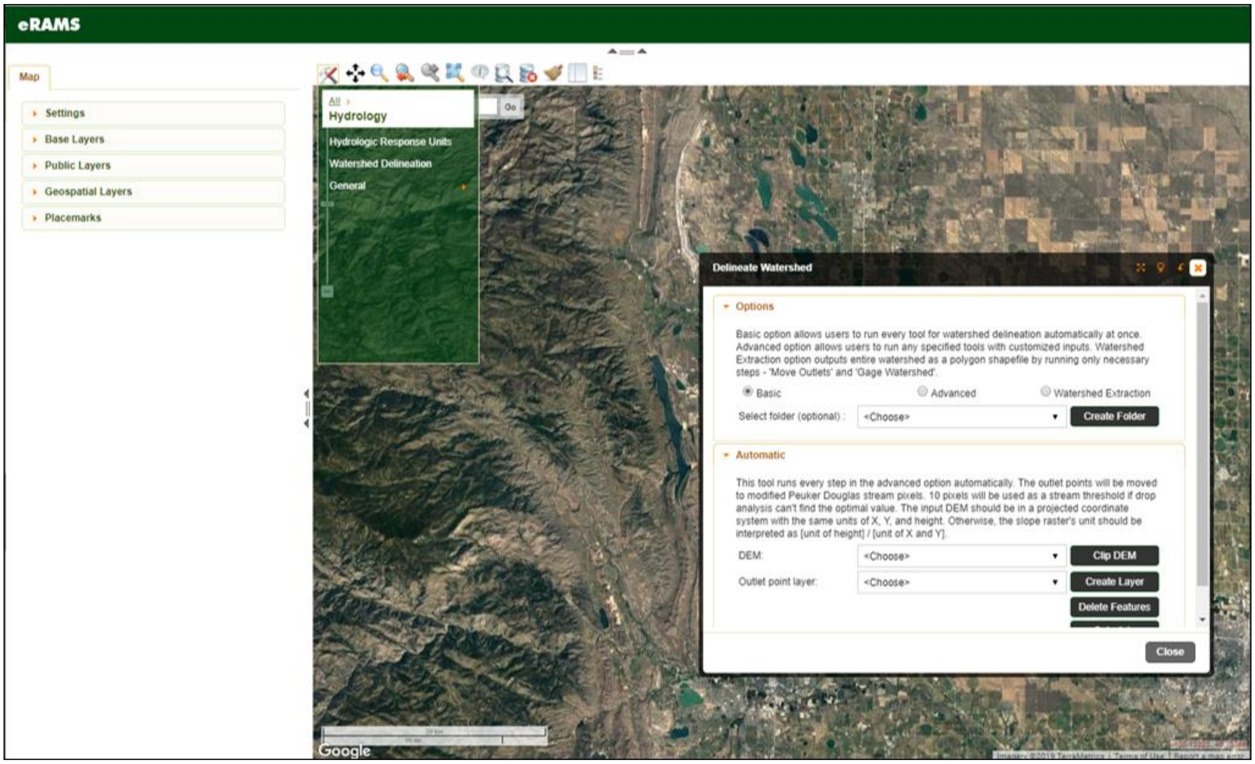
WHO SHOULD USE THIS GUIDE

This guide is a tutorial to get you started using eRAMS and the Watershed Delineation tool. The guide provides instructions for commonly performed tasks and uses of the tool. This tool is intended for use by urban planners and water managers, academic groups, regulatory officials, consultants as well as state, local and federal agencies planning for the future of water resources.

NEED HELP?

After reviewing the guide if you need additional assistance we are here to help! This guide is designed to provide instruction on commonly performed operations and answers to many frequently asked questions. If you find any aspect of the tool challenging or missing information from this guide, please engage an eRAMS expert to guide you through any hurdles. Contact us at: eramsinfo@gmail.com

INTRODUCTION



Purpose

The Watershed Delineation Toolkit processes and analyzes Digital Elevation Model (DEM) and DEM-driven rasters to delineate a watershed.

Description

The eRAMS Watershed Delineation Toolkit includes three delineation options to accommodate a variety of user needs. The basic option allows users to simultaneously run individual procedures and automatically execute every step using default inputs. The advanced option allows users to execute any individual steps but customize their inputs. The simplified watershed extract option can be used to rapidly create a watershed boundary.

The core of this tool is [TauDEM version 5] (Tarboton, 2013). A majority of the applications were developed based on 5.0.6 (Tarboton, 2012) except Modified Peucker Douglas, which is based on TauDEM5.1.2 (Tarboton, 2014). More detailed information of input and output of TauDEM5 is explained in the [Tarboton web documentation section].

Software Availability

Domain

https://erams.com/map/

Documentation URL

https://erams.com/catena/tools/river-basin-planning/watershed-delineation/

Publication/Citation

Kim, J. S., Arabi, M., Patterson, D. (2015). eRAMS Watershed Delineation Tool [Software].

System Requirements

A modern web-browser is required to connect and run this tool. Browser options include: Google Chrome v.69, Mozilla Firefox v.62, Safari v.11.1, and Microsoft Edge v.17.

Authorized use permission

The information contained in the Watershed Delineation Toolkit (the "Service") is for general information purposes only. Colorado State University's One Water Solutions Institute ("CSU-OWSI") assumes no responsibility for errors or omissions in the contents of the Service. In the Service, you agree to hold neither the creators of the software platform nor CSU-OWSI liable for any action resulting from use or misuse of the Service. In no event shall CSU-OWSI be liable for any special, direct, indirect, consequential, or incidental damages or any damages whatsoever, whether in an action of contract, negligence or other sort, arising out of or in connection with the use of the Service or the contents of the Service. CSU-OWSI reserves the right to make additions, deletions, or modification to the contents of the Service at any time without prior notice.

USING THE TOOL

ACCESS THE TOOL

Public Access

The Watershed Delineation toolkit can be accessed without registering an eRAMS account. In the public-facing version the data and analysis will only be available for the duration of the browser session. Once the browser is closed the project will no longer be available (i.e. users cannot save their work or share their project).

If a user prefers to save their project, share it with collaborators or revisit their analysis, an account is required. Follow the instructions below to create your free account and save your projects or visit our website to get started: https://erams.com/account/

Create an eRAMS Account

1. From the eRAMS Registration page, select "Register Now" from the top menu and enter a username, password, your first and last name, and your email address. Click "Create Account".
    - eRAMS will display a popup box alerting you that an email confirmation has been sent to the provided email address
2. Open the email account provided in the registration form from either a new browser window or from your local email application.
    - Search for an email from eRAMS with the subject line "eRAMS Email Check"
3. Open this email and click on the provided link to confirm your email address.
    - ***Note**: If you do not see the confirmation email appear in your email inbox immediately, check your spam or junk email folder to ensure that the confirmation message wasn't automatically discarded. You may also need to wait a few moments to ensure the email is delivered successfully.*
4. Once you click on the provided email link, you should be redirected to eRAMS, where you'll be automatically logged in

Select Method of Analysis

Modify Base Layer (optional)

With the GIS interface open, click the "Map" tab on the left dashboard

1. Select the "Base Layers" drop-down
2. Select the desired base layer
    - Options include: None , Google, Bing or USGS National Map (Figure 1)

Note: *It is recommended to use Hydro-NHD layer as a base layer / ground truth for outlet if a user clipped input DEM from NHD+V2 DEM by 'Clip DEM' tool*

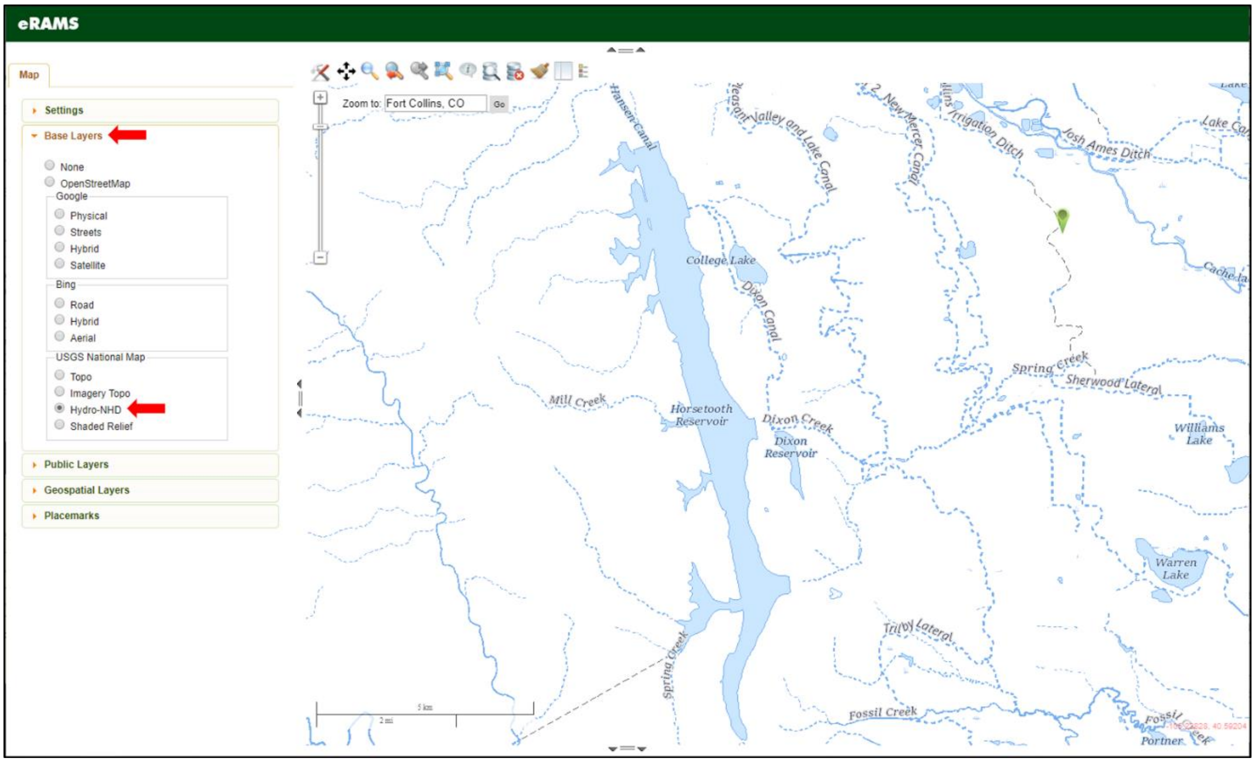


Figure 1: Modify base layer in eRAMS geographic interface

Select Analysis

Figure 2 demonstrates how to activate the watershed delineation toolkit. User's are presented with three analytical options: basic, advanced and watershed extraction (described in greater detail below).

1. With the GIS interface open, click the "Map Tools" icon located along the top of the map interface (Figure 1).
2. Select "Hydrology" from the drop-down menu
3. Select "Watershed Delineation" to open the analysis interface
4. Select from one of the analysis and corresponding toolkit options described below:

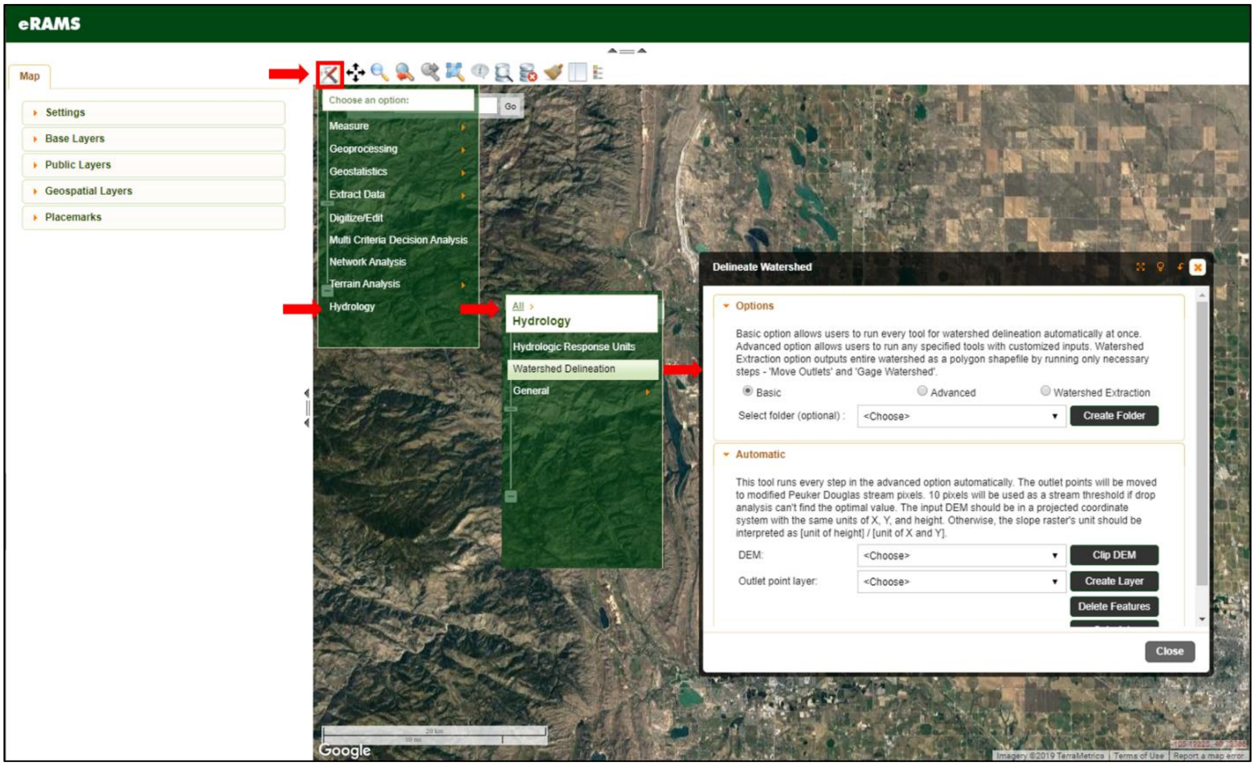


Figure 2: Accessing the watershed delineation toolkit

BASIC ANALYSIS

The basic option allows users to simultaneously run individual procedures and automatically execute every step using default inputs (Figure 2).

For simplicity purposes, stream burning procedure was excluded in the basic option. It is highly recommended to use input DEM in a projected coordinate system with consistent X, Y, and height unit. Otherwise, the unit should be assigned to the result slope raster.

For example, if input DEM is in geographic coordinate system with X [degree], Y [degree], and Z [meter], the unit of slope raster should be interpreted as [meter/degree]. To fully automate the procedures, two conditions were given. First, the outlet points moves to 'Modified Peuker Douglas' stream pixels automatically. Next, 10 pixel was used as threshold for 'stream raster – threshold' if drop analysis can't find a threshold value (e.g. if the watershed is too small). Therefore, it is advised to check drop analysis result after each running.

If outlet point shapefile is not available, a user can choose any point(s) on the map. Since there is no ground truth (such as flow accumulation or modified Peuker Douglas raster) for outlet points before running the basic option, a user must use base layer as a reference. It is recommended **to use Hydro-NHD layer as a base layer** / ground truth for outlet if a user clipped input DEM from NHD+ V2.0 DEM by 'Clip DEM' tool (see above instructions on how to modify the base layer).

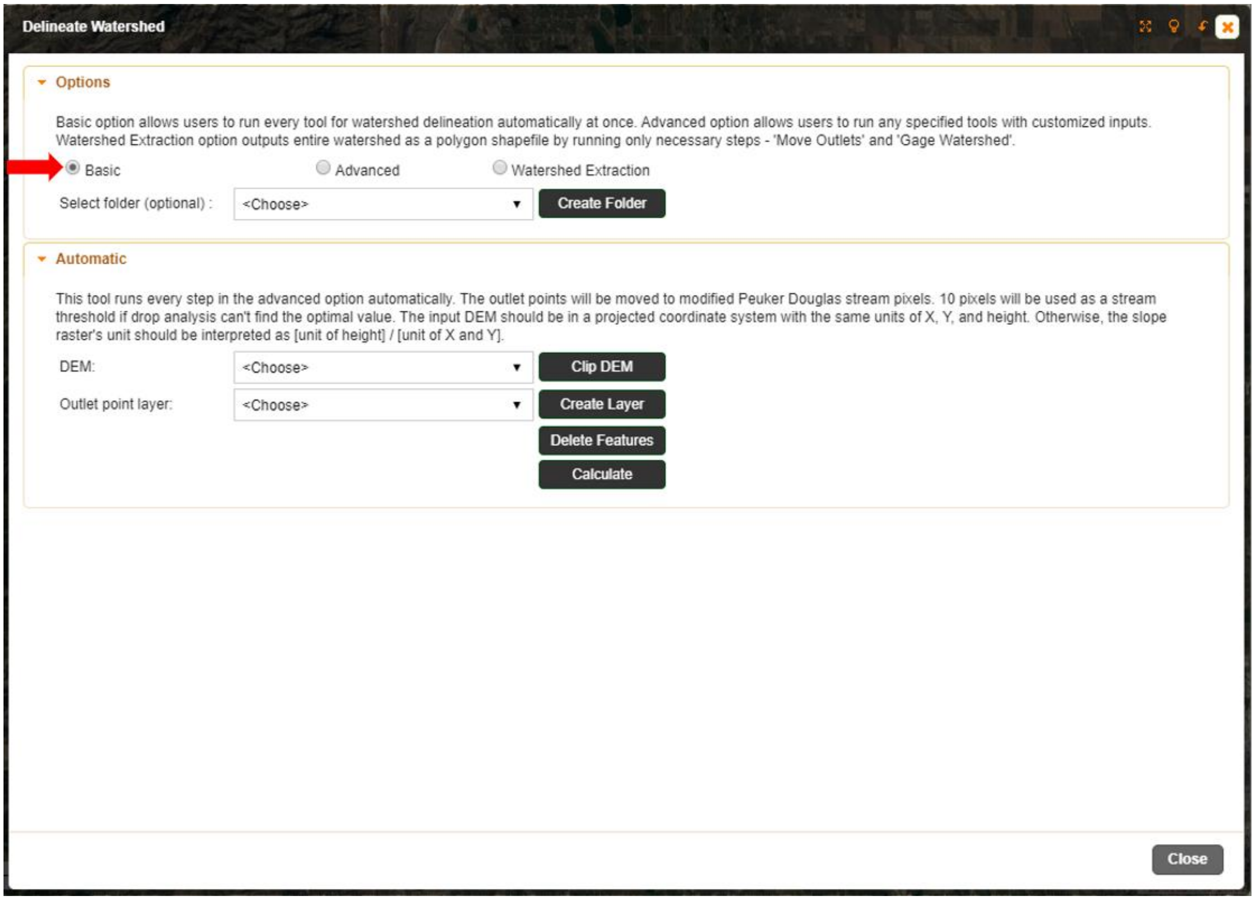


Figure 3: The basic option allows users to automatically execute all steps to delineation a watershed

ADVANCED ANALYSIS

Advanced option (Figure 4) allows users to run any specified tools with customized inputs. Each optional tool is described in greater detail below. Additional details regarding tool inputs and outputs can be found under the API Notes section of this guide.

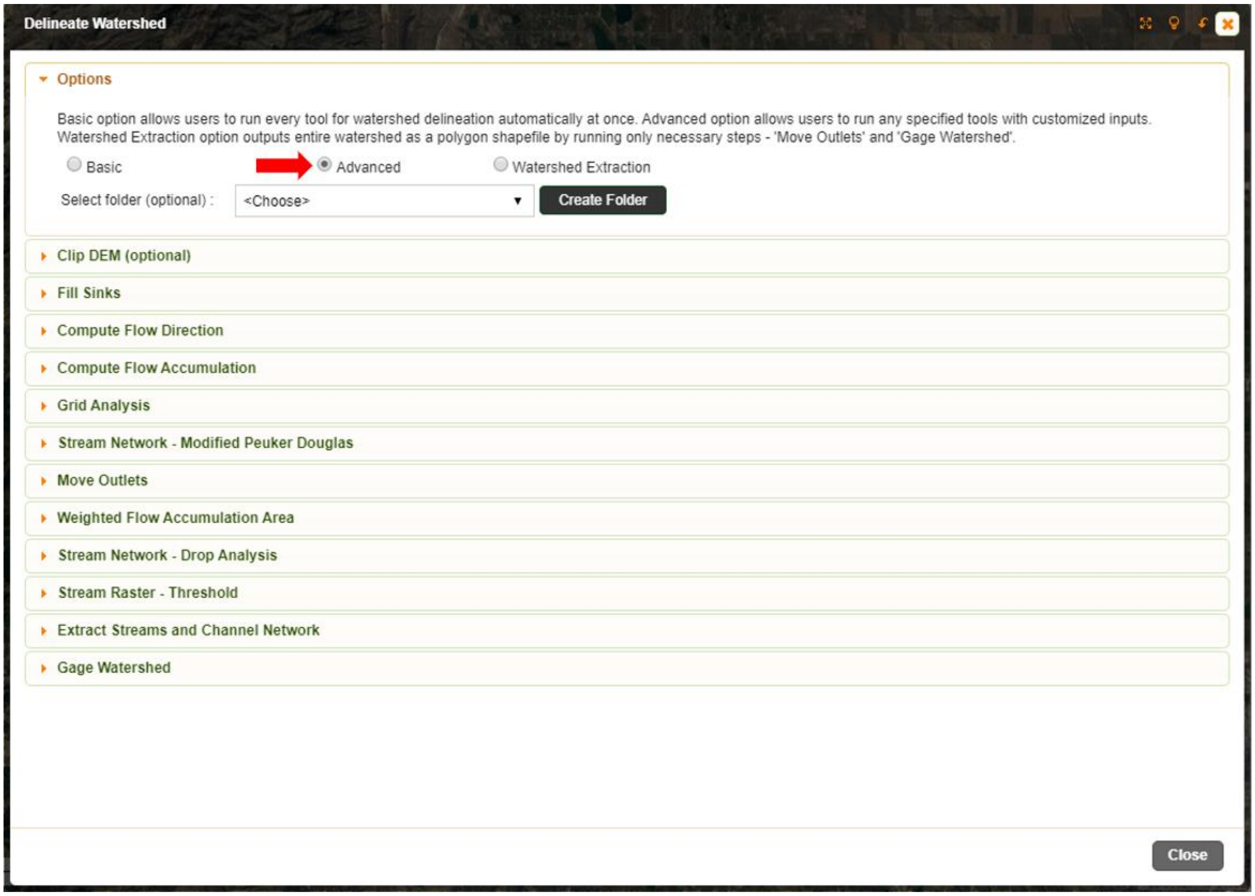


Figure 4: The advanced option allows users to customize inputs

Clip DEM

This tool clips out NHD+ V2.0 DEM for input DEM (Note: This DEM is not burned DEM). Users must drag mouse to the extent less than HUC 10 because clipping size is limited (i.e. the unit of DEM is 'meter' and it has 30m resolution; the maximum size of the supporting area is 1 square degrees, which covers most of HUC 10).

If a user has input DEM and has created a free eRAMS account, it can be uploaded by clicking Project Layers > Spatial Layers > Add Layer > Add Raster (Figure 5). It should be noted that DEM should be in the projected coordinate system to get correct slope raster. If DEM is not projected, the unit of slope raster will be the unit of height / the unit of X and Y. Also, 'Stream Network – Drop Analysis' and 'Stream Raster – Threshold' tools accept only rasters in projected coordinate system.

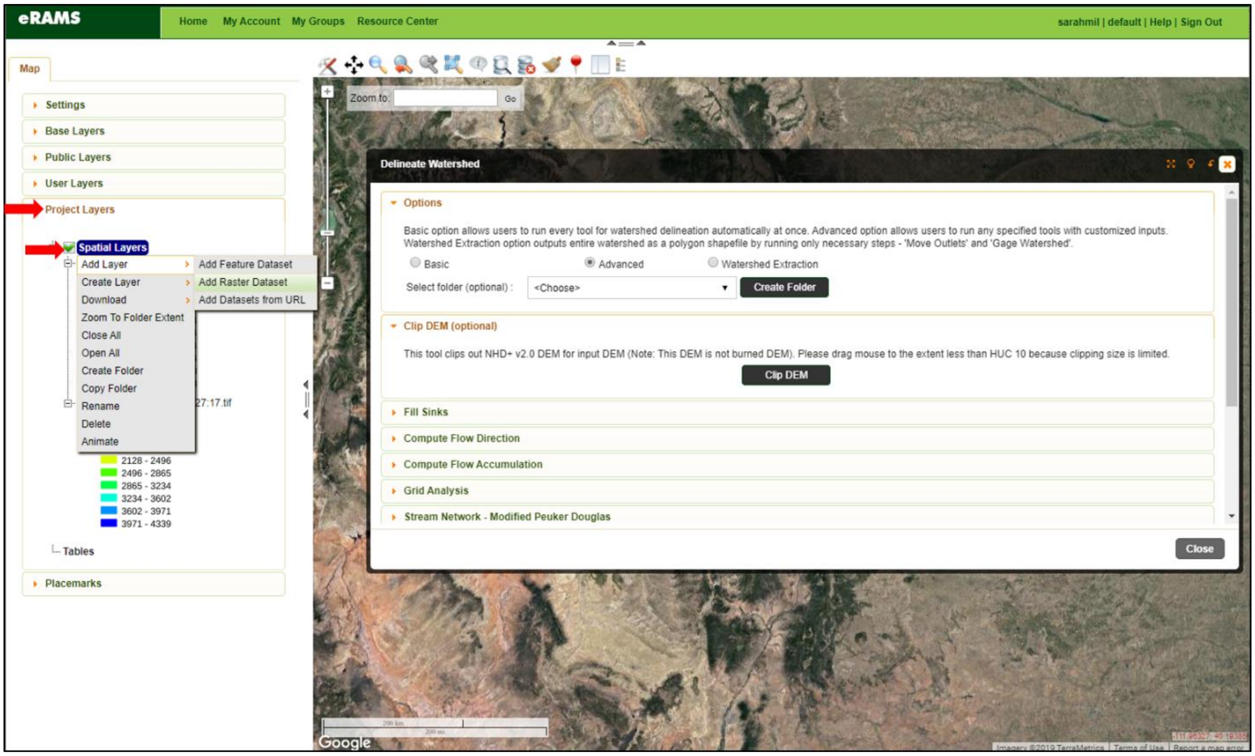


Figure 5: Upload raster DEM (note: this feature is only available to registered account holders)

Fill Sinks

This tool fills out pits of input DEM to make input DEM hydrologically reasonable. The input DEM should be in a projected coordinate system. Later ['Stream Network - Drop Analysis'](#) and ['Stream Raster - Threshold'](#) tools accept only rasters in a projected coordinate system.

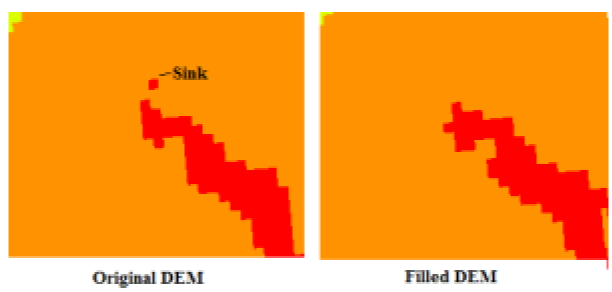


Figure 6: Original DEM with sink (left) and sink-filled DEM (right)

Optionally, users can burn streams on pits-removed DEM. The rule of burning stream on DEM is to add the maximum elevation to non-stream pixels. It should be noted that DEM should be projected to the coordinate system with consistent X, Y, and height units to get correct slope raster if the user wants to upload their own DEM.

Compute Flow Direction

This tool creates two output grids - flow direction raster and slope raster, both in eight directions. The input DEM should be in a projected coordinate system. If input DEM is not in a projected coordinate system, the slope raster's unit should be interpreted as [unit of height] / [unit of X and Y].

With pits-removed DEM, flow direction (out of eight directions) is calculated at each pixel by ‘Compute flow direction’ procedure. This tool uses ‘d8flowdir’ module of TauDEM5. The value of 1 in flow direction raster means stream flows to the east direction. The direction increases by 45 degrees counter clockwise as direction value increases by 1. The slope raster is created at the same time as the direction. The value of slope raster is the maximum slope calculated at each pixel.

Compute Flow Accumulation

Flow accumulation is calculated by summing up contributing numbers of pixels, through which stream flows into the target pixel. Please choose eight direction - flow direction raster as an input file.

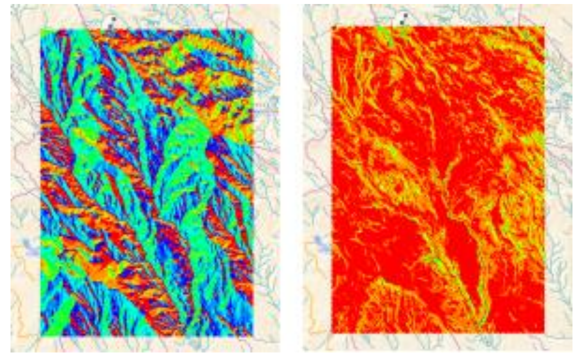


Figure 7: Flow direction raster (left) and slope raster (right)

Flow accumulation raster shows the total contributing numbers of stream pixels summed at the target pixel based on flow direction raster by using 'aread8' module of TauDEM5. Eight different colors represent each flow accumulation range (minimum range: red, maximum range: blue) as shown in Figure 7. Also, this raster is recommended to be used as a ground truth for outlets selection for large scale watershed in later step – 'Move Outlets'.

Grid Analysis

This tool gives three outputs such as the longest flow path, total length of flow path, and Strahler Grid Network order by using 'gridnet' module of TauDEM5. The pixel value of the longest flow path raster represents the length of the longest upstream flow path from the cell.

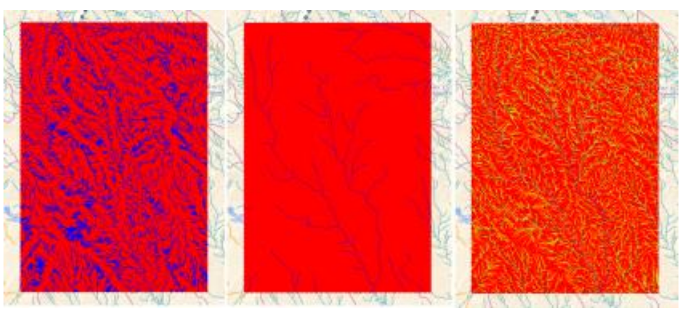


Figure 8: Longest flow path (left), total flow paths (center) and grid network order (right) rasters

The pixel value of the total flow paths raster shows the total length of the upstream paths from the cell. Total flow paths raster is recommended as a ground truth for outlets selection for mid – large scale watershed in later step – 'Move Outlets'.

The pixel value of the grid network order raster shows the Strahler order number (Strahler, 1952, 1957). Strahler order is 1 for the source flow path. If two flow paths with identical order meet, it increases by one. Otherwise, the order is the highest order out of merged flow paths. If more than two flow paths join, the order is the either 1) the highest order if there is one highest rank stream; or 2) one plus the order of the highest rank if there are two or more streams of the highest rank. (Tarboton, 2013).

Stream Network – Modified Peuker Douglas

This tool delineates stream pixels by the Modified Peuker Douglas Tool, which uses flow accumulation pixels in addition to original Peuker Douglas pixels.

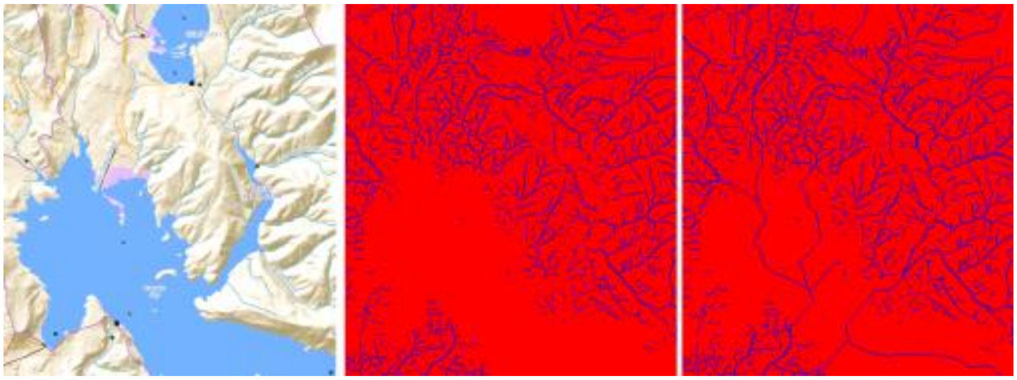


Figure 9: USGS Hydro NHD map (left), stream pixel from Peuker Douglas tool (center), stream pixels from modified Peuker Douglas tool (right)

'Stream Network – Modified Peuker Douglas' tool represents stream pixels as value of one. TauDEM5's original 'peukerdouglas' module implemented the stream delineation of Peucker & Douglas'(1975) research. Original 'peukerdouglas' module in TauDEM5 turned off the flat regions. This seemed to underestimate stream pixels in relatively flat area (e.g. the location where river meets lake). Therefore, TauDEM5's 'peukerdouglas' module was edited to include stream pixels in flat area(s) by adapting prior knowledge of flow accumulation.

The pixels in flat area(s) with the flow accumulation values larger than the defined threshold was added to the original Peuker Douglas stream pixels. The threshold was determined as the average of flow accumulation on the original Peuker Douglas stream pixels. It is important to include these stream pixels in flat area(s) because the outlet will be moved to stream pixels in later steps. Not enough stream pixel can increase the chance of 1) failing moving outlets to stream pixels; and 2) moving outlets to stream pixel in unreasonably far distance. We determined that 'Modified Peuker Douglas' tool properly added stream information to the original Peuker Douglas tool. Therefore, we can have more rigorous results in later steps – 'Move Outlets' and 'Weighted Flow Accumulation', which requires stream raster as an input.

Move Outlets

This tool moves user-uploaded or user-defined outlet points to stream pixels. To upload outlet points shapefile, right click on folders or Spatial Layers in the 'Project Layers' section (Figure 5). Alternatively, click 'Create Layer' button and add outlets on the map. If you choose to upload shapefile, please upload files with formats - .shp, .shx and .dbf.

This tool uses 'moveoutletstostrm' module of TauDEM5. This step is highly recommended for the outlet points which are not located on stream pixels.

If an outlet point shapefile is not available, users can add outlet points directly to the map. It should be noted that the location of outlet (even one-pixel difference) can make a significant difference in the final watershed delineation results. Therefore, it is highly recommended to zoom in to the maximum scale when choosing outlet points from the ground truth.

It is also important to use proper ground truth for choosing outlet points. For the delineation of large scale (e.g. HUC12) watershed, the flow accumulation raster is highly recommended for choosing outlet points. If a user wants to delineate small scale watershed, the 'Modified Peuker Douglas' stream pixel will be the most suitable ground truth for choosing outlet points since it includes all possible stream skeletons.

Weighted Flow Accumulation Area

Weighted flow accumulation sums up the number of contributing stream (such as Peuker Douglas) pixels at target pixel. The stream should eventually flow to the outlets.

By default, Modified Peuker Douglas stream raster is used as weight grid, which defines the contribution values of each grid cell. There is a condition that streams on contributing pixels should eventually flow into the outlets. Therefore, the boundary of this raster will be the watershed to be delineated in later steps. If the result is not satisfactory, please adjust the location of outlet points.

Stream Network – Drop Analysis

Drop analysis finds the threshold value for stream raster by T test, which evaluates the significant difference between the average drops of the first and higher order streams created based on the threshold assumption. (Note: the input DEM should be in a projected coordinate system.)

Optimum Threshold Value: 51903.23 m^2. Click the other rows if you want to use another threshold for the next 'stream raster -threshold' procedure.

Threshold (m^2)	Drain Density (1.0E-2, m^{-1})	1st order stream				Higher Order Stream			T value
		No.	Ratio(%)	Mean Drop (m)	σ of Drop (m)	No.	Mean Drop (m)	σ of Drop (m)	
4503.72	0.31	291	78.65	5.74	6.45	79	11.09	9.89	-5.77
6768.75	0.25	185	78.06	6.49	7.17	52	13.00	11.00	-5.09
10172.92	0.21	119	79.33	8.16	7.84	31	15.03	10.11	-4.08
15289.13	0.18	93	76.86	7.88	7.93	28	14.78	9.62	-3.84
22978.41	0.14	58	81.69	10.33	8.38	13	18.66	8.38	-3.24
34534.82	0.12	36	80.00	11.47	8.89	9	22.46	9.56	-3.27
51903.23	0.11	27	84.38	13.77	9.13	5	18.88	12.37	-1.09
78006.65	0.09	20	83.33	12.65	10.40	4	19.30	13.20	-1.12
117238.12	0.07	12	75.00	14.98	10.57	4	13.39	10.54	0.26
176200.06	0.06	10	71.43	12.80	8.03	4	11.80	8.36	0.21

Figure 10: Drop analysis table results; the yellow row represents the optimal threshold value, which is the minimum area passing t-test (t value < 2).

This tool uses 'dropanalysis' module of TauDEM5. The lowest and the highest threshold values for drop analysis were set to each 5 and 1500 pixels. Drop analysis will provide a result table as shown in Figure 10. The highlighted yellow row represents the optimal threshold value, which is the minimum area passing t-test (t value < 2). Also, the table shows related statistics such as number, mean, standard deviation of drops, the ratio of 1st order stream and t values. It should be noted that drop analysis should not be implemented for stream-burned DEM because the drop of the first order stream will be significantly larger than higher order stream.

Stream Raster – Threshold

Stream Raster - Threshold tool defines stream raster by choosing pixels from a weighted flow accumulation grid with the values larger than the given threshold. This tool was created using 'threshold' module in TauDEM5. By default, the threshold is given by drop analysis. However, a user can choose other values by clicking another row in drop analysis table if more rigorous or lenient criteria is required. Figure 11 shows the example of stream raster – threshold.

Extract Streams and Channel Network

This tool outputs stream network and subwatersheds shapefiles. Each stream segment is defined by the links in stream network and subwatersheds are created based on each stream segment.

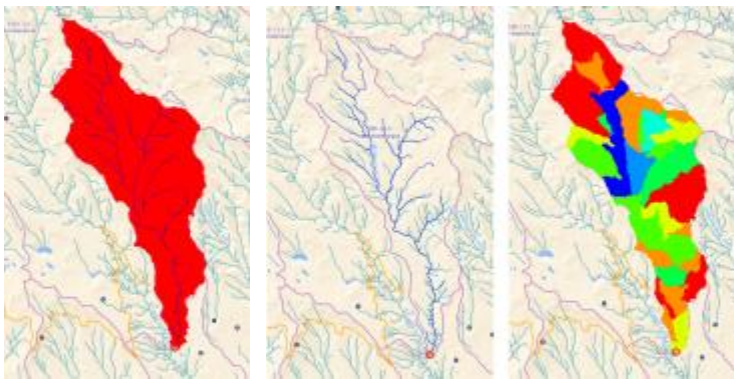


Figure 11: Stream raster (left), stream network (center) and subwatershed (right) shapefiles

This procedure outputs stream network and sub-watersheds as shapefile formats using 'streamnet' module of TauDEM5. The table of stream network shapefile has been updated so that the attributes should be consistent with NHD+ V2.0 file format – plusflowlinevaa.dbf (US EPA, 2015). 'Streamnet' module creates a subwatershed raster, which has a unique subwatershed id as digital number (dn) of pixels. By definition, subwatershed drains to each stream network link (Tarboton, 2013). TauDEM's output subwatershed raster was converted to polygon shapefile using python module of gdal – gdal_polygonize.py (Open Source Geospatial Foundation, 2015). Figure 11 shows examples of stream network and subwatershed shapefiles.

Gage Watershed

This tool creates the entire watershed shapefile for a given outlet using 'gagewatershed' module in TauDEM5. The output watershed raster was converted to shapefile using gdal module – gdal_polygonize.py.

WATERSHED EXTRACTION

The simplified watershed extract option can be used to rapidly create a watershed boundary. This option outputs entire watershed as a polygon shapefile by running only necessary steps - ['Move Outlets'](#) and ['Gage Watershed'](#). Users can create a working directory by clicking 'Create New Folder'. Output files will be stored in the directory if the folder is chosen in the box next to the 'Select folder' (Figure 12).

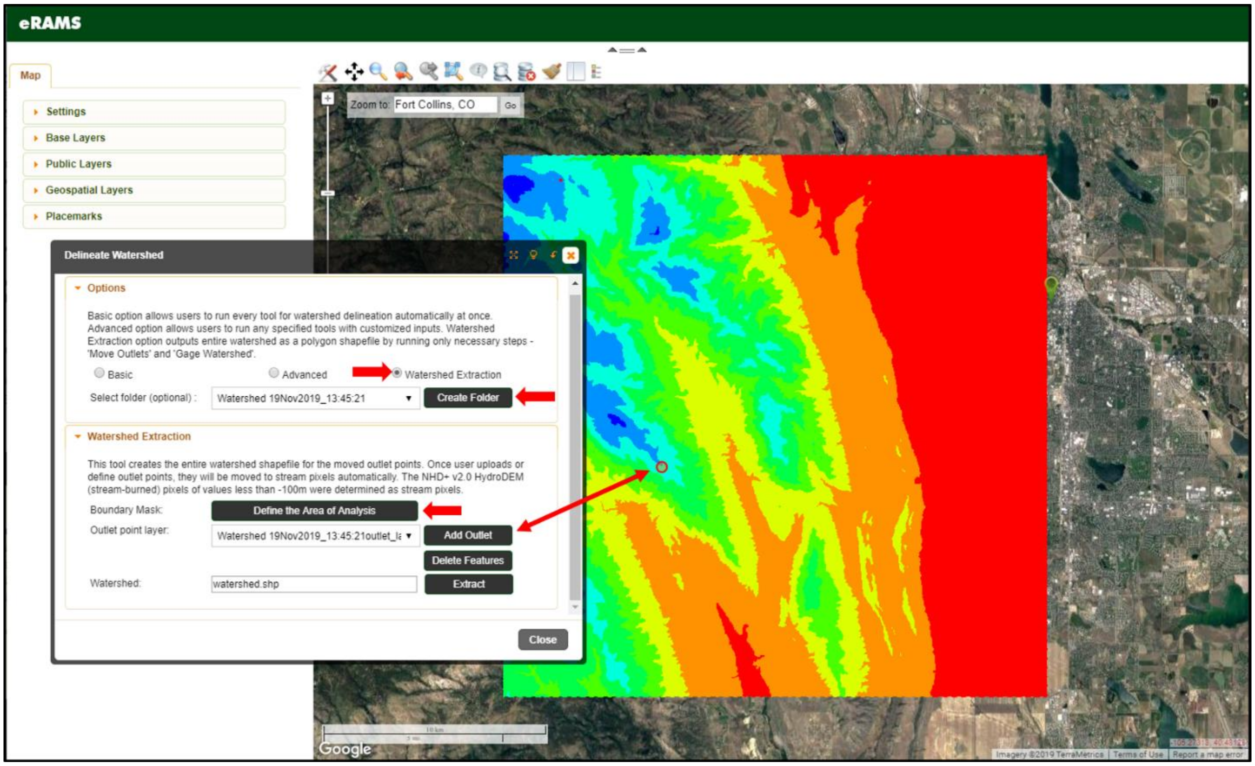


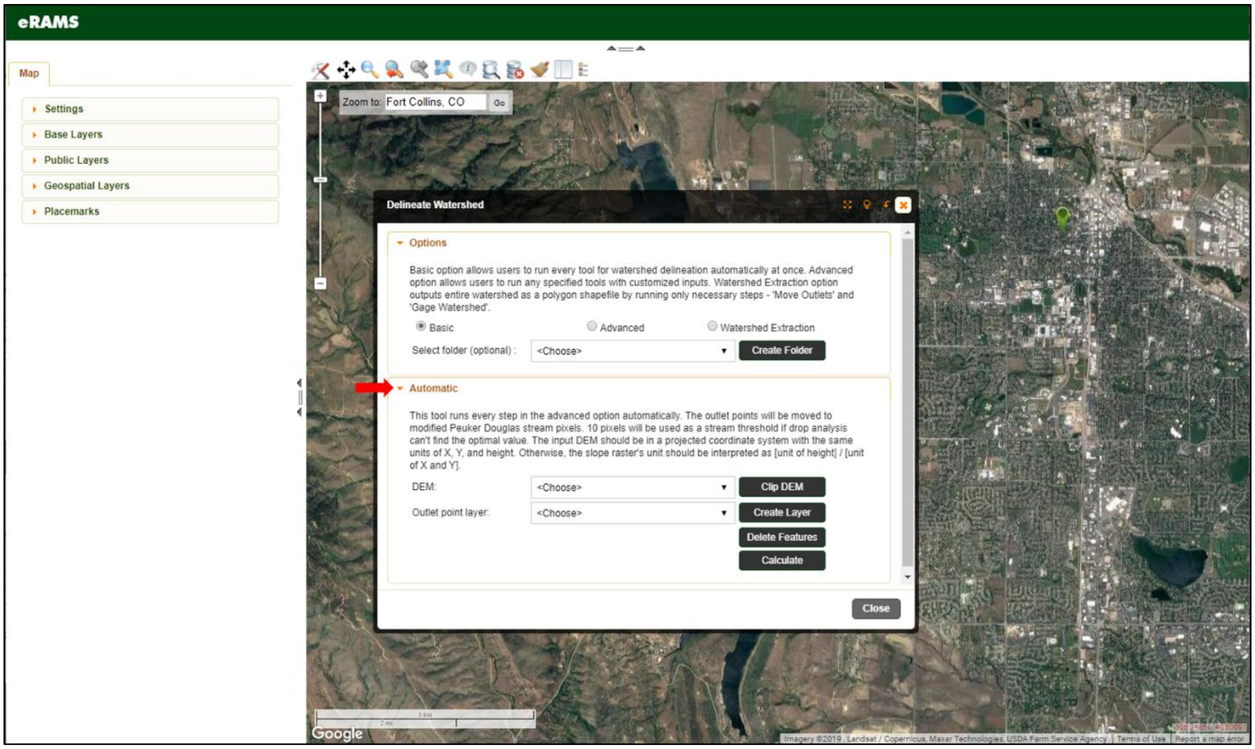
Figure 12: Watershed extraction only runs 'move outlets' and 'gage watershed' to rapidly create a watershed boundary

The inputs for this option are "outlet points" and "the area of analysis", which can be defined by the bounding box, which user created. User can click 'Define the Area of Analysis' button shown in figure 12 and draw bounding box (colored rectangle). The requested service may take approximately 30 seconds. Red dot shows the outlet point user chooses on the map canvas. Once a user defines the outlet points (by uploading shapefile or marking on map) and the area of analysis, the bounding box coordinates are transformed to EPSG:5070 (NAD1983 Conus Albers, the projection of NHD+ V2.0 data). Then, NHD flow direction VRT (GDAL, n.d.) is created and clipped for the bounding box.

Since direction notations of NHD+ V2.0 are different from TauDEM5's, the flow direction values were modified to conform to TauDEM5's standard by gdal_calc.py. To move outlet's to stream pixels, stream VRT from NHDP+ V2.0 HydroDEM was created. The threshold value for the extraction of streams from HydroDEM was -100m. After moving outlets to stream pixels, a watershed raster was extracted by 'gage_watershed' and transformed to polygon shapefile format. It should be noted that the projection of original flow direction (NHD+ V2.0 flow direction raster) should be preserved since the re-projection of flow direction raster will decrease the accuracy of flow direction.

After extraction of watershed, the area of analysis layer (colored rectangle) can be removed by clicking 'Clear all graphic from map' (broom) button.

AUTOMATIC



This tool runs every step in the advanced option automatically. The outlet points will be moved to modified Peuker Douglas stream pixels. 10 pixels will be used as a stream threshold if drop analysis can't find the optimal value. The input DEM should be in a projected coordinate system with the same units of X, Y, and height. Otherwise, the slope raster's unit should be interpreted as [unit of height] / [unit of X and Y].

Clip DEM

Create DEM layer from NHD+ v2.0 DEM (note: this is not a burned DEM). Drag mouse to the extent less than HUC 10 because clipping size is limited.

Create Layer

Create a GIS layer for storing outlet points.

Delete Features

Remove all outlets.

Calculate

Finish the analysis and run the model(s).

API NOTES

Input/Output Table

Basic

Category	Description	Input/Output	Parameter	Type	Description
Basic	*This tool executes the series of watershed delineation procedures automatically. The input data are DEM and Outlet Points layer. Outlet points are moved to stream pixels by default. For stream raster – Threshold procedure in basic tool, threshold was set to 10 pixels if threshold is not found by drop analysis. Optionally, user can clip DEM from NHDPlusV2 DEM (not burned).*	Input	JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "dem", "value": "dem.tif"}, {
		Output	demcoord	dat	Channel network tree coordinates
			demtree	dat	List of links in channel network tree
			dem_fill	tif	Filled DEM raster
			streamnet	shp, shx, dbf	Channel network shapefile. This file includes from node, to node, and reach code for network analysis.
			demw	tif	Subwatershed raster
			gage_watershed	tif	Watershed boundary raster
			gorder	tif	Strahler order raster
			ord	tif	Strahler order raster for stream cell
			PD_stream	tif	Modified Peuker Douglas stream raster
			lngst_path	tif	The longest flow path raster
			dir	tif	Eight flow direction raster
			slope	tif	Eight direction slope raster
			stream	tif	Thresholded stream raster
			subwatershed	shp, shx, dbf	Subwatershed polygons shapefile
			area_wg	tif	Weighted flow accumulation raster
			outlet_moved	shp, shx, dbf	The moved outlets shapefile
			drop	txt	Drop analysis table. The unit of threshold in drop.txt is pixels. However, drop tables in GUI shows the thrshold with meter units.
			watershed	shp, shx, dbf	watershed boundary

Fill Sinks

Category	Description	Input/Output	Parameter	Type	Description
Fill_Sinks	*The application removes pits in input DEM using 'pitremove' module of Taudem5.*	Input	DEM raster	tiff	Digital Elevation Model in tiff format (Project to coordinate system consistent with Z-unit of DEM).
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "dem", "value": "dem_input.tif"
		Output	DEM – pit removed	tiff	The output DEM is create by filling out sinks of input DEM.

d8flowdir

Category	Description	Input/Output	Parameter	Type	Description
d8flowdir	*The application creates (eight direction) flow direction raster and slope raster using 'd8flowdir' module of Taudem5.*	Input	DEM – pit removed	tiff	Digital Elevation Model (pit removed) in tiff format.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "dem_fill", "value": "dem_fill.tif" }] }
		Output	Flow direction raster	tiff	The output flow direction raster. Pixel value "1" means the direction of East. And the value of pixel increases by one whenever the direction angle increases by 45 degree to counter-clockwise.
			Slope raster	tiff	The output slope raster. The slope value is calculated by dividing the drop by distance.

Flow Accumulate

Category	Description	Input/Output	Parameter	Type	Description
flow_accumulate	*The application creates flow accumulation raster using 'aread8' module of Taudem5.*	Input	Flow direction raster	tiff	Flow direction raster in eight directions.
			JSON request	JSON	JSON file, which defines input parameters. request = { "metainfo": { }, "parameter": [{ "name": "flow_8_dir", "value":
		Output	Flow accumulation raster	tiff	The output flow accumulation raster. The value of targe cell is the sum of contributing numbers of pixels, through which stream eventually flows into the target cell.

Grid Analysis

Category	Description	Input/Output	Parameter	Type	Description
grid_analysis	*The application creates the longest flow path, total length of flow path, and grid network order raster using 'gridnet' module of Taudem5.*	Input	Flow direction raster	tiff	Flow direction raster in eight directions.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "flow_8_dir", "value": "p.tif" }] }
		Output	Longest flow path raster	tiff	The value of cell is the length of the longest upstream flow path from the
			Total length of flow pah raster	tiff	The value of cell is the total length of the upstream paths from the cell.
			Grid network order	tiff	Stream order defined by Strahler (1952, 1957)

Modified Peuker Douglas

Category	Description	Input/Output	Parameter	Type	Description
mod_Peuker_Douglas	*The application creates stream raster using the tool – 'mod_peukerdouglas ', which was updated from 'peukerdouglas'module of Taudem5.*	Input	DEM – pit removed	tiff	Digital Elevation Model (pit removed) in tiff format.
			Flow accumulation raster	tiff	The value of targe cell is the sum of contributing numbers of pixels, through which stream eventually flows into the target cell.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "dem_fill", "value": "dem_fill.tif" }, { "name":"flow_acc", "value": "ad8.tif" }] }
		Output	Modified Peucker-Douglas stream raster	tiff	The pixels of value 1 means that they are either 1) stream defined by Taudem5's Peuker-Douglas model or 2) flat region with significant flow accumulation. Taudem5's PeukerDouglas' stream pixels.

Outlet

Category	Description	Input/Output	Parameter	Type	Description
Outlet	*The application moves outlet points not on stream to a stream pixel following flow direction raster using "moveoutletstostrm" module of Taudem5. This procedure is highly recommended for the outlet points, which is not on stream pixels.*	Input	outlets	shp, shx, dbf	shapefile including outlet points.
			Flow direction raster	tiff	When outlet points move, they move following flow direction raster.
			Peucker-Douglas stream raster	tiff	Outlet points will move to the pixels of stream raster.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "flow_8_dir", "value": "p.tif" }, {
		Output	outlets moved	shp, shx, dbf	Shapefile including outlet points (optionally moved to stream raster pixels).

W Flow Accumulate

Category	Description	Input/Output	Parameter	Type	Description
w_flow_accumulate	*This application sums up the number of contributing stream pixels at target cell using "aread8" module of Taudem5. There is a condition that stream of contributing pixels should eventually flow into the defined outlet points.*	Input	Flow direction raster	tiff	Flow direction raster in eight directions.
			Peucker-Douglas stream raster (optional)	tiff	Stream raster will be used as weight raster.
			outlets	shp, shx, dbf	Shapefile of outlet points.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "flow_8_dir", "value": "p.tif" }, { "name": "peuker_douglas", "value": "peuker_douglas.tif" }, { "name":"outlet_shp", "value": "outlet_2.shp" }, { "name":"outlet_shx", "value": "outlet_2.shx" }, { "name":"outlet_dbf", "value": "outlet_2.dbf" }]
		Output	Weighted flow accumulation raster	tiff	The cell value of the weighted flow accumulation is the sum of the number of pixels, through which stream flows to the target cell. Another condition is the stream will eventually flows into the outlet points defined.

Stream Network

Category	Description	Input/Output	Parameter	Type	Description
stream_network	*The application evaluates the significant difference between the first and higher order streams created based on the stream threshold assumption using 'dropanalysis' module of taudem5. It should be noted that drop analysis should not be implemented for stream-burned DEM because the drop of the first order stream will be significantly larger than higher order stream.*	Input	DEM – pit removed	tiff	Digital Elevation Model (pit removed) in tiff format.
			Flow accumulation raster	tiff	The value of targe cell is the sum of contributing numbers of pixels, through which stream eventually flows into the target cell.
			Flow direction raster	tiff	Flow direction raster in eight direction.
			outlets	shp, shx, dbf	Shapefile of outlet points
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "dem_fill", "value": "dem_fill.tif"}, { "name": "flow_acc", "value": "ad8.tif"}, { "name": "flow_dir", "value": "p.tif"}, { "name": "outlet_shp", "value": "outlet_2.shp"}, { "name": "outlet_shx", "value": "outlet_2.shx"}, {
		Output	Drop analysis table	txt	Drop analysis evaluates the significant difference by T test between the mean drops of the first and higher order streams created based on the threshold assumption. It finds the minimum threshold which let the model pass the T test.

Stream Raster

Category	Description	Input/Output	Parameter	Type	Description
stream_raster	*The application creates stream raster using threshold values and weighted flow accumulation raster with 'threshold' tool in Taudem5. Unless input dem is stream-burned, drop analysis tool will provide the optimal threshold value. Also, user can choose customized threshold values in drop analysis table.*	Input	Weighted flow accumulation raster	tiff	The cell value of the weighted flow accumulation is the sum of the number of pixels, through which stream flows to the target cell. Another condition is the stream will eventually flows into the outlet points defined.
			Threshold	float	The threshold for defining stream. By default, the threshold from drop analysis is used.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "w_flow_acc", "value":
		Output	Flow Raster Grid	tiff	The pixels of the values larger than the given threshold are chosen from weighted flow accumulation grid .

Extract Stream

Category	Description	Input/Output	Parameter	Type	Description
extract_stream	*This application creates stream network shapefile and sub watersheds raster using 'streamnet' module of Taudem5. Each stream segment is defined by the links in stream network and sub-watershed raster is created based on each stream segment. The sub watersheds raster is converted to shapefile by gdal_polygonize.py.*	Input	DEM – pit removed	tiff	Digital Elevation Model (pit removed) in tiff format.
			Flow direction raster	tiff	Flow direction raster in eight directions.
			Flow accumulation raster	tiff	The value of targe cell is the sum of contributing numbers of pixels, through which stream eventually flows into the target cell.
			Stream threshold raster	tiff	The stream raster of which the pixel values are larger than threshold such as Flow Raster Grid.
			Outlets	shp, shx, dbf	Shapefile of outlet points.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{"name": "flow_dir", "value": "p.tif"}, {"name": "filled_dem", "value": "dem_fill.tif"}, {"name": "flow_acc", "value": "ad8.tif"}, {"name": "src", "value": "src.tif"}, { "name": "outlet",
		Output	Stream network	shp	The polyline shapefile which describes the link information of streams.
			Subwatersheds	shp	Subwatersheds shapefile. Unique ID numbers are assigned to each subwatershed.

Gage Stream

Category	Description	Input/Output	Parameter	Type	Description
gage_watershed	*This application creates entire watershed shapefile for a defined outlet using 'gagewatershed' module in Taudem5 and gdal_polygonize.py. The output watershed can be used as a boundary layer for HRU delineation tool.*	Input	Flow direction raster	tiff	Flow direction raster in eight directions.
			JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{"name": "flow_dir", "value": "p.tif"}, {"name": "outlet", "value": "outlet_2.shp"}] }
		Output	Watersheds	tiff	For the given outlets, entire watershed is delineated by the pixel value 1.

Extract Watershed

Category	Description	Input/Output	Parameter	Type	Description
extract_watershed	*This application creates entire watershed shapefile for a defined outlet using 'gagewatershed' and 'moveoutletstostrm' modules in Taudem5 and gdal_polygonize.py. The stream raster was created from*	Input	JSON request	JSON	JSON file, which defines input parameters. { "metainfo": { }, "parameter": [{ "name": "outlet", "value": "outlet_pt.shp"}, { "name": "bound_wkt", "value": input_list[1][1]}, { "name": "bound_wkt_2", "value": input_list[2][1]}] }
		Output	Watersheds	tiff	For the given outlets, entire watershed is delineated by the pixel value 1.
			Moved outlet points	shp	The outlets moved to stream pixels.

Extract DEM

Category	Description	Input/Output	Parameter	Type	Description
extract_DEM	*This application clips and extracts DEM from NHDPlusv2 DEM. The input is Well Known Text (WKT) in EPSG:4326 (WGS84 geographic coordinate system)*	Input	JSON request	JSON	JSON file, which defines input parameters. {"metainfo": {},"parameter": [{ "name": "bound_wkt", "value": input_list[0][1]}]}
		Output	DEM_clip.tif	tiff	Clipped DEM, the projection is consistent with NHDPlusV2 DEM

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