User Guide

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

HYDROLOGIC RESPONSE UNIT

CATENA ANALYTICS

One Water Solutions Institute

Colorado State University

CONTENTS

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.

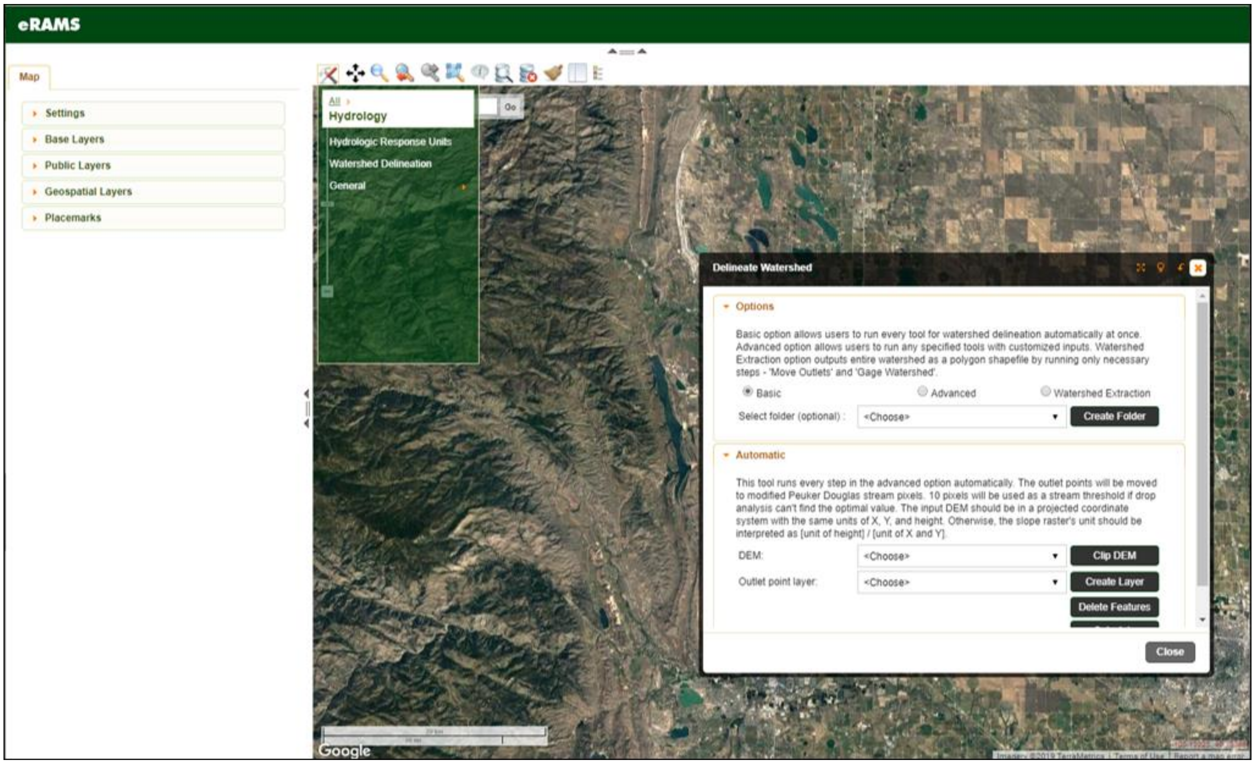
Who Should Use This Guide

This guide is a tutorial to get you started using eRAMS and the Hydrologic Response Unit 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 Hydrologic Response Unit (HRU) delineation tool calculates HRUs as a vector format by intersecting several input layers

Description

Hydrologic Response Unit (HRU) Delineation Tool creates HRUs based on soil, land use and slope layers to calculate slope length, manning's overland flow coefficient, C factor and time of concentration. The HRU layers include information on land use, hydrologic soil group, soil texture, average slope, curve number, area, and perimeter. HRUs are calculated as adjacent and unique combinations of pixels from input layers. Users can also merge smaller HRUs less than given threshold to the adjacent and larger HRUs. This tool allows users to select from a wide variety of prepopulated data inputs (NLCD, NASS CropScape, NASS Cropland, SSURGO).

Software Availability

Domain

https://erams.com/map/

Documentation URL

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

Publication/Citation

Kim, J. S., Arabi, M., Patterson, D. (2015). eRAMS Hydrologic Response Unit (HRU) 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 Hydrologic Response Unit (HRU) Delineation Tool (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 Hydrologic Response Unit (HRU) Delineation Tool 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

CREATE HRU LAYER

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)

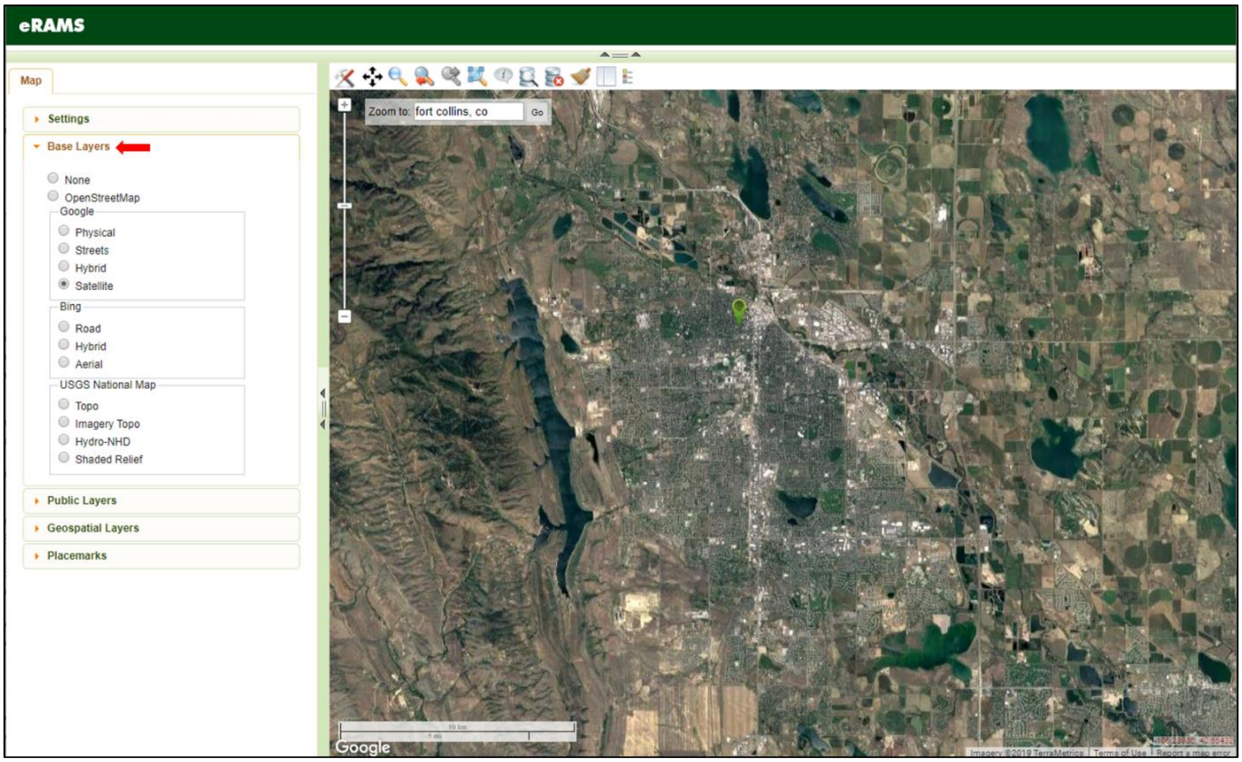


Figure 1: Modify base layer in eRAMS geographic interface

Create New Layer

Figure 2 demonstrates how to activate the Hydrologic Response Unit (HRU) interface. User's are presented with prompts to move through the workflow (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 "Hydrologic Response Unit" to open the analysis interface
4. Follow the workflow prompts described below

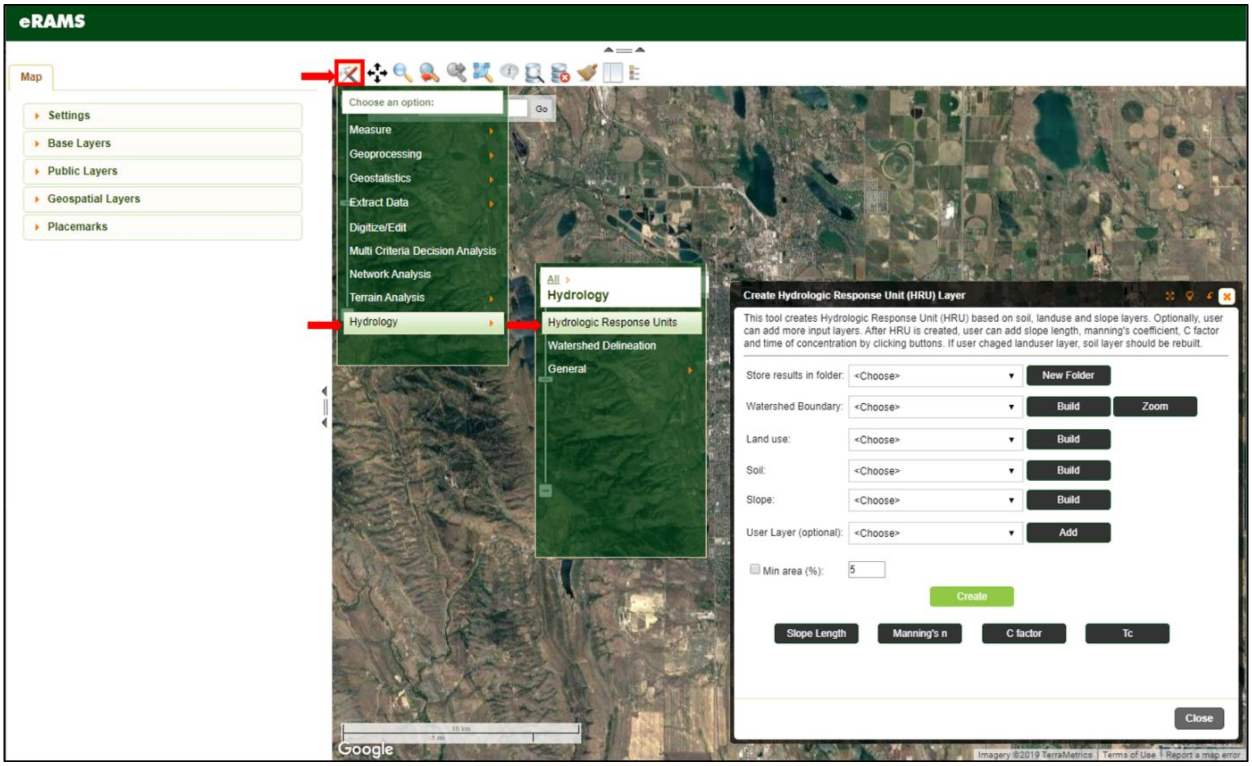


Figure 2: Accessing the Hydrologic Response Unit interface

Create Folder

First, users are required to create a folder to store results and organize files needed for each HRU delineation. It is highly recommended that users create separate folders for each HRU boundary. To create a folder, select "New Folder" and enter a title *OR* choose location from drop down list if you have already generated a folder.

Watershed Boundary

After creation of folders, users need to define input boundary. This can be implemented in three ways:

Option 1: Users can trace the watershed on the map by using the circle, rectangle or polygon tool. Select "Build" and preferred drawing tool under "Option 1" (Figure 3). Users can draw circles, rectangles or polygons using this tool.

Option 2: Alternatively, users can choose HUC polygons HUC 12, HUC10 or HUC 8 (Figure 3-2a), then select any HUC available in the drop down list (Figure 3-2b).

Option 3: The last way to define the input boundary is to upload your own polygon vector data.

After the HUC polygon selection has been made, press '"Go" and the resulting HUC layer will be displayed on the map.

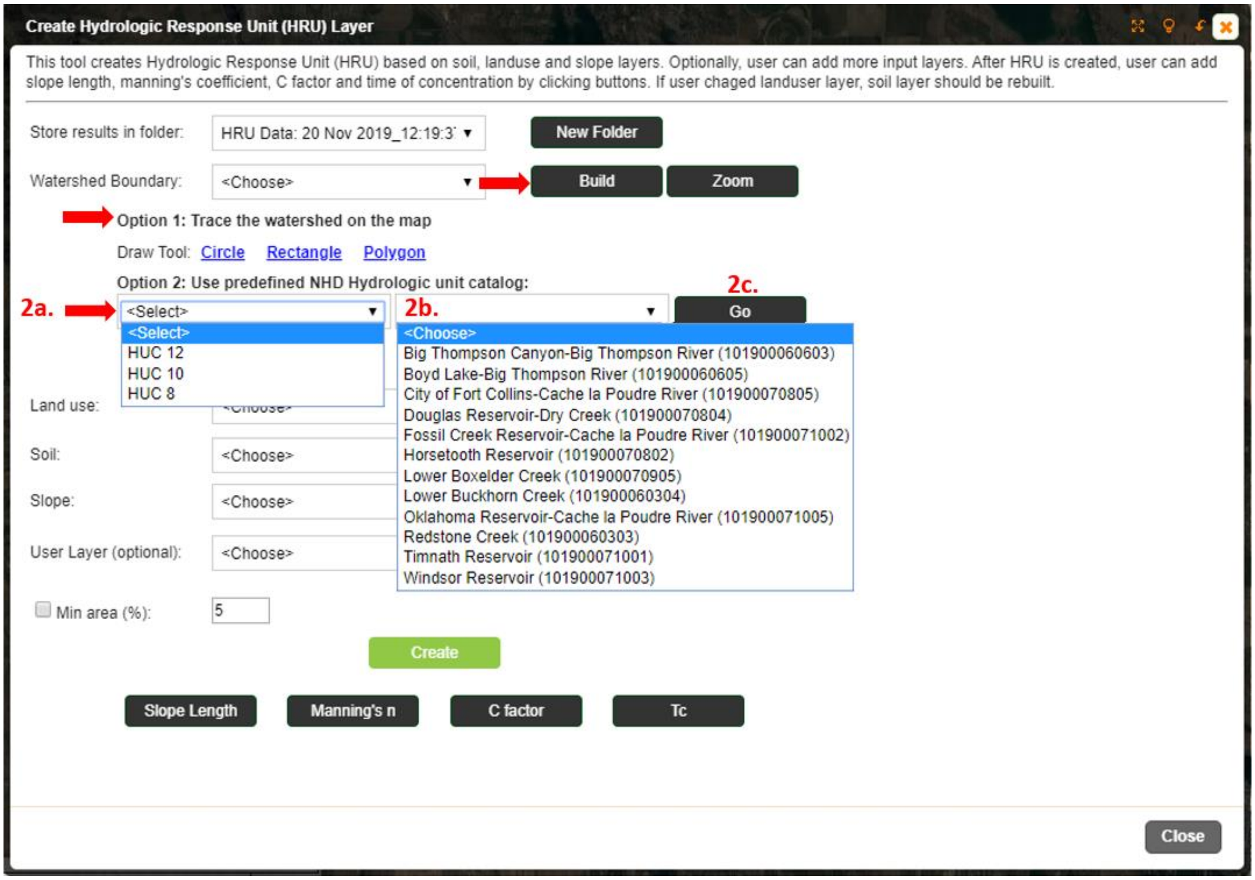


Figure 3: Selecting a watershed boundary

Land Use

User can select either National Land Cover Database (NLCD) (MRLC, 2016) or NASS CropScape and Cropland Data Layer (CDL) (USDA, 2016). Both layers have Albers Equal Area projection and 30m GSD. Currently, HRU delineation tool provides NLCD 2001, 2006 and 2011 and NASS CDL from 2003 to 2014. See Figure 4 for examples.

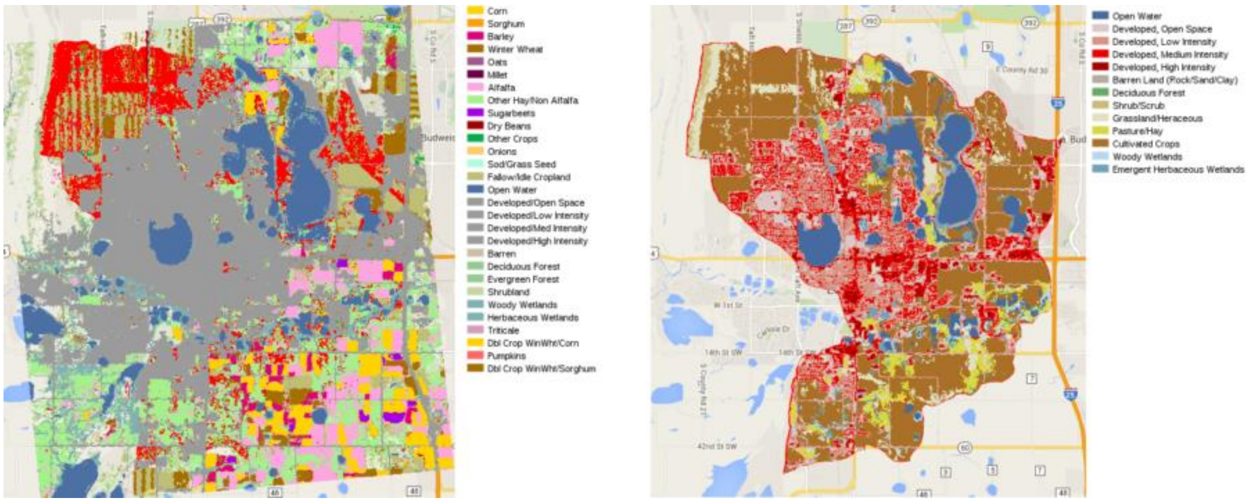


Figure 4: NASS 2014 CDL (left, unclipped) and NLCD 2011 (right, clipped by boundary)

Soil

eRAMS HRU delineation tool provides Soil Survey Geographic (SSURGO) (USDA, 2016) data to generate a soil layer. The SSURGO polygon layer is clipped by boundary and converted to rasters using gdal_rasterize (GDAL, n.d.) using mukey as pixel values. According to USDA (2012), the purpose of mukey in SSURGO database is to link map unit boundary spatial record to the corresponding map unit table record. Figure 5 shows the example of soil raster layer created using HRU delineation tool in eRAMS.

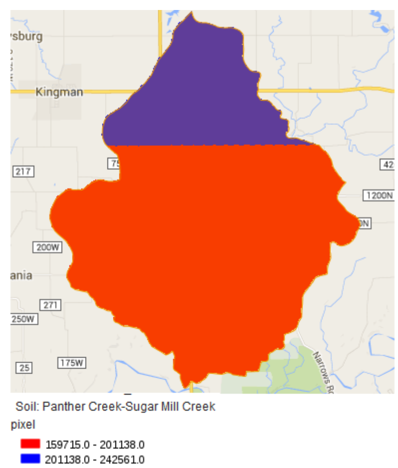


Figure 5: Soil layer example

Slope

The slope layer is created using 'gdaldem' (GDAL, n.d.) with NHDPlusV2 (US EPA, 2015) DEM. 'gdaldem' is the tool for analysis and visualization of DEM. (GDAL, n.d.) and NHDPlus is a geospatial and hydrologic framework dataset created by US EPA with assistance of USGS (US EPA, 2015). Since gdaldem outputs slope layer with percentage unit, the value of pixels were divided by 100 using gdal_calc.py (GDAL, n.d.). Figure 6 shows the example of Slope layer created in eRAMS HRU delineation tool.

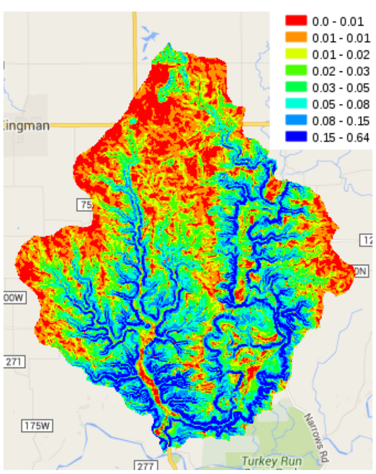


Figure 6: Slope layer example

User Layers

Users can also add any raster layer by clicking the "Add" prompt and selecting the desired layer. To remove a user layer, simply click the "x" at the end of the layer name.

***Note:** it may take longer to complete delineation of HRU if user adds multiple 'User Layer(s)'.*

HRU Delineation

After the desired watershed boundary, land use, soil and slope have been identified, click "Create" to generate the HRU output layer.

First, the slope layer is reclassified to 5 classes since there are too many unique values of slope. Using 'gdalinfo' (GDAL, n.d.), the maximum and minimum slope values are extracted, the difference is calculated and the interval is estimated by dividing the difference by 5. Then, each class is defined by the average of minimum and maximum of each class.

After slope layer is reclassified, the input layers are intersected and unique pixel combinations are calculated using gdal_combine (Toney, 2016). The output raster from gdal_combine is convereted to polygons by gdal_polygonize (GDAL, n.d.). When using gdal_polygonize, eight direction option was included to define surrounding eight pixels as adjacent pixels (default is four directions). The output polygon layer was masked by boundary layer in this step not to clip vectors in later step using SQL, which is computationally expensive for a large number of rows.

After getting HRU polygon vector, the required information is added to the table of HRU layers which includes landuse code (landuse), mukey (mukey), slope (slope), landuse string (landuse_str), hydrologic soil group (hydgrpdcd), soil texture (texture), curve number (curve_no), area (hru_area) and perimeter (hru_perimeter).

The table can be viewed by selecting "Geospatial Layers" from the left dashboard then right-click on the desired layer and select "Open Attribute Table" (Figure 7).

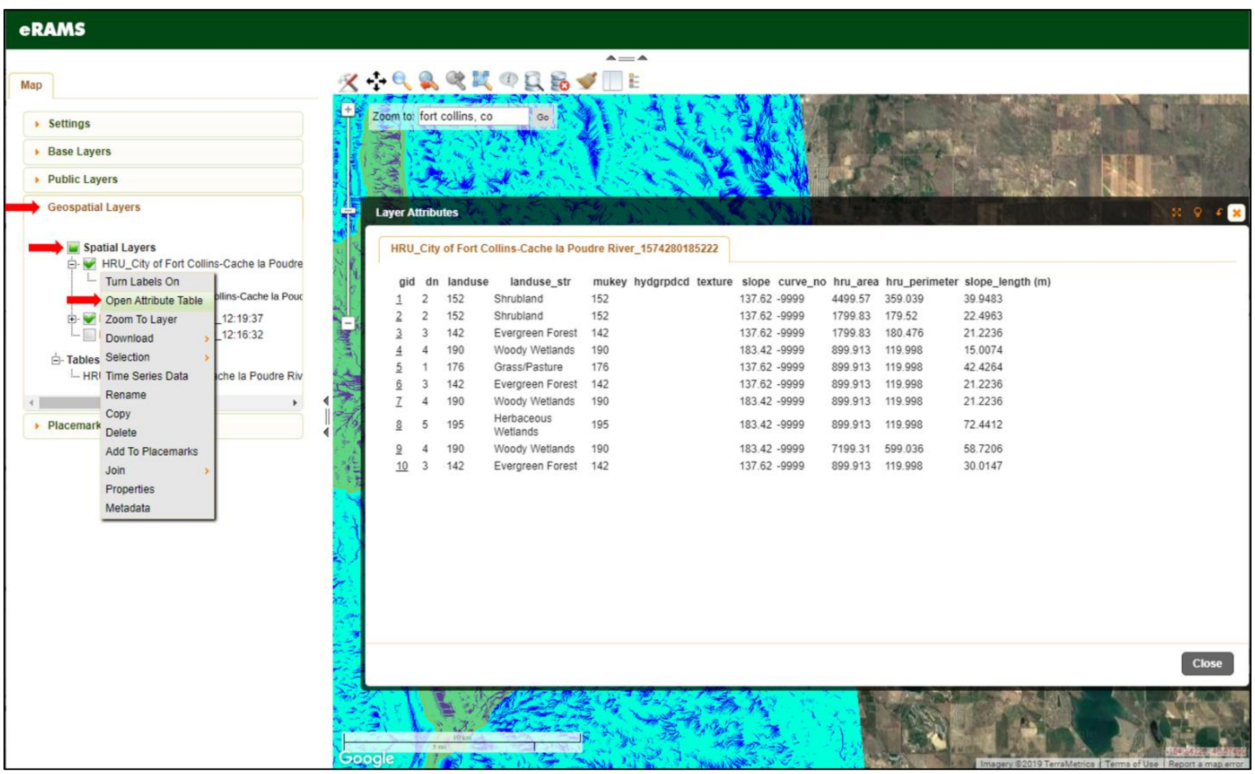


Figure 7: Display layer attribute table

The landuse code, mukey, slope are added directly from the pixel values of input layers. Then landuse string is read from landuse table in eRAMS and added to HRU table. Hydrologic soil group and soil texture are read from SSURGO database by joining component, chorizon and chtexturegrp tables. Chorizon table includes components' data by horizon and component table includes map unit components' interpretations and properties (USDA, 2014a). Chtexturegrp includes the texture ranges for the horizon as a concatenated value of horizon texture and texture modifier(s) (USDA, 2014b). It should be noted that soil horizon data only at the surface (hzdept_r=0) was used for determining hydrologic soil group and soil texture. After hydrologic soil group is determined, curve number is read from look up tables which relate landuse code, hydrologic soil group and curve number.

If user adds optional User Layers, the values of user layers will be assigned to the column, which is named of layer name (excluding file extension, space of colon, if any).

Optionally, user can choose to add small HRUs to adjacent large HRU polygon. If any HRU polygon is 1) less than the given threshold; and 2) adjacent to any polygon larger than given threshold, the small polygons will be unioned to the larger polygons. To implement this, the adjacency is defined as the distance less than 9.259 × 1.0e-6 degree (approximately 1m). The distance between each HRU polygon is checked using PostGIS (PostGIS, 2016) function ST_Distance (). Next, small and large polygons are unioned using another PostGIS function ST_Union(). Figure 8 shows the cases with or without minimum area threshold (1%).

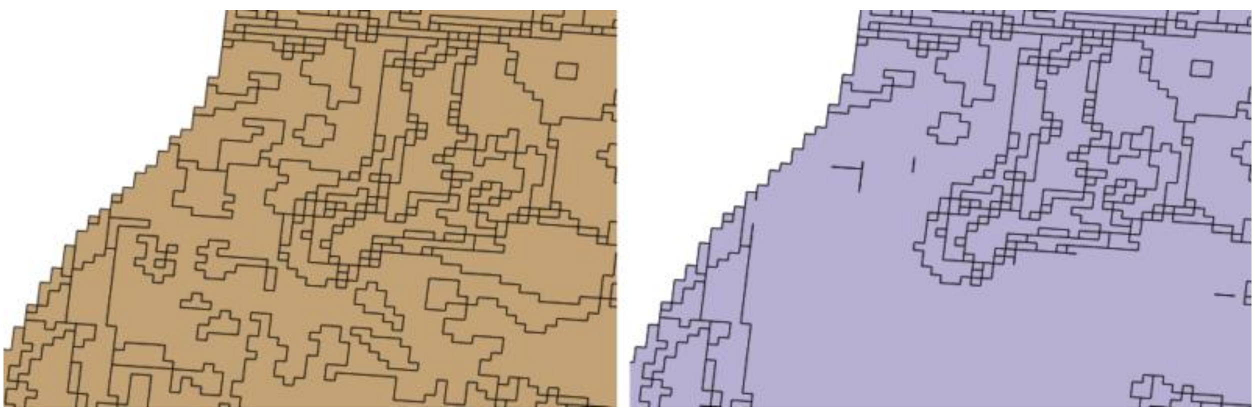


Figure 8: Examples of HRU polygons (left: without minimum area threshold, right: with minimum area threshold [1%]).

Optional Columns

After HRU polygons are calculated, slope length, Manning's roughness coefficient (n) for overland flow, C factor, and time of concentration can be calculated by pressing corresponding buttons in the HRU layer interface (Figure 9).

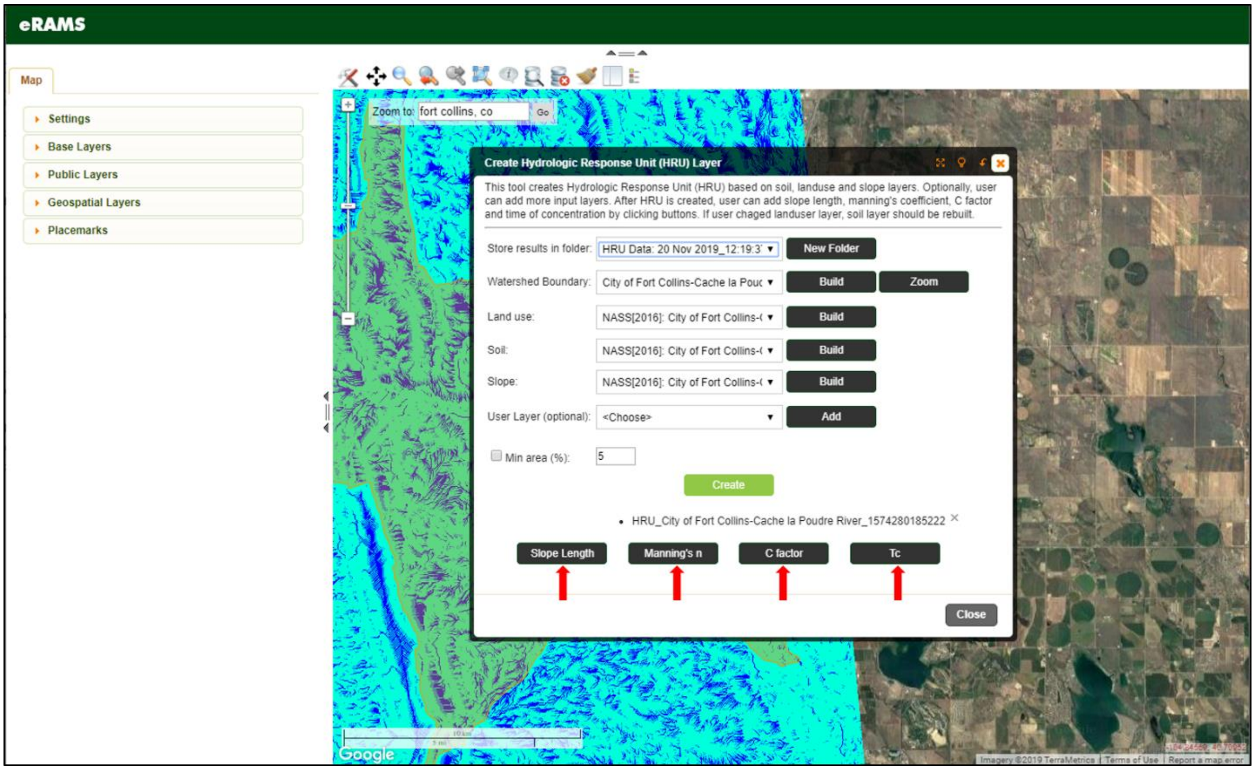


Figure 9: Optional columns in HRU layer interface

Time of concentration (Tc) is the time for rainfall at the hydraulically most remote location in the watershed to reach the outlet point(Wurbs and James, 2002) and it is calculated using equation (1) according to USDA (2002). In equation (1), cn' is retardance factor, which can be substituted by Curve Number (USDA, 2002). The slope length, curve number, slope layers are extracted for defined boundary in eRAMS and they are used to calculate Tc.

$$T_c = \frac{l^{0.8}(S+1)^{0.7}}{1{,}140Y^{0.5}} \qquad \text{Eq (1)}$$

where l is flow length,

S is maximum potential retention = $\left(\frac{1000}{cn'} - 10\right)$,

Y is the watershed slope.

The other options, including slope length, Manning's roughness coefficient (n) for overland flow, C factor are calculated using CSIP services, which are described in detail as in the Appendix.

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APPENDIX

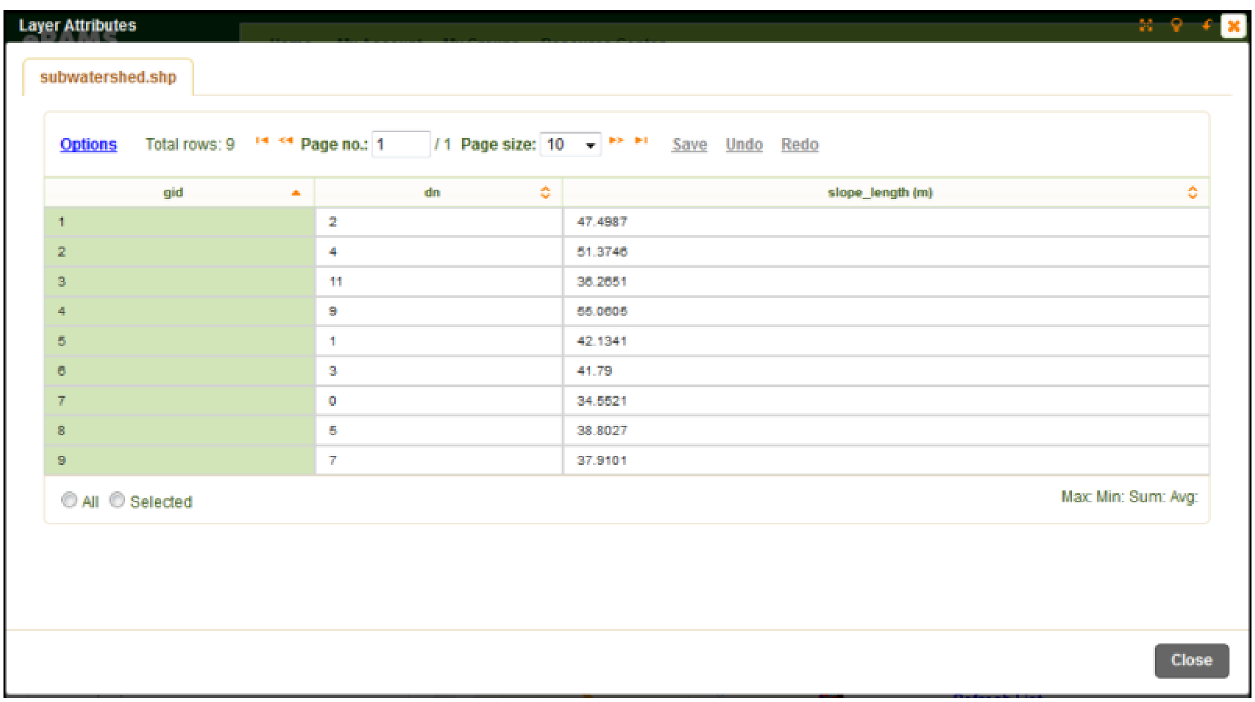
Slope Length

Summary

This tool calculates the average slope length of each feature in a polygon vector layer. If a user defines the boundary, NHDPlus V2 DEM (US Environmental Protection Agency, 2015) is clipped using GDAL Utility – gdalwarp (GDAL, n.d.) and input to Taudem's "pitremove" module (Tarboton, 2014) to create DEM without sinks. Next, flow direction raster is calculated by Taudem's "d8flowdir" module. And slope length raster is calculated by Taudem's "gridnet" module. According to Hickey (2000), 50% slope decrease ratio was set as the criteria for cutoff pixel, where slope length should be reset to zero. It is implemented by replacing flow direction value at cutoff pixel with nodata value (-32768) before running Taudem's "gridnet" module. For the starting pixel (where slope length was calculated as zero until this step), the slope length was calculated as each 1/2 of pixel resolution for horizontal or vertical flow direction pixels and sqrt(2)/2 of pixel resolution for diagonal flow direction pixels. Finally, the average slope length for each feature is calculated using python program – zonal_stats (Python Software Foundation, 2015). Above procedures are implemented as a service in CSIP (David et al., 2015) environment.

Example

Figure 10 shows the table of polygon layer, whose slope length were calculated and appended in the column – slope_length(m).



gid	dn	slope_length (m)
1	2	47.4987
2	4	51.3746
3	11	36.2651
4	9	55.0605
5	1	42.1341
6	3	41.79
7	0	34.5521
8	5	38.8027
9	7	37.9101

Figure 10: Example of slope length values added to polygons layer

Calculate Slope Length

From toolbox menu, choose Hydrology > Terrain Analysis, and Slope Length (Figure 11). In the interface choose input layer for 'Polygon'. Optionally, a user can create polygon or choose a HUC12 polygon by clicking 'Build' button. After choosing input polygon layer, click 'Calculate'. The average slope will be appended to the attribute table of input feature as shown above (Figure 10).

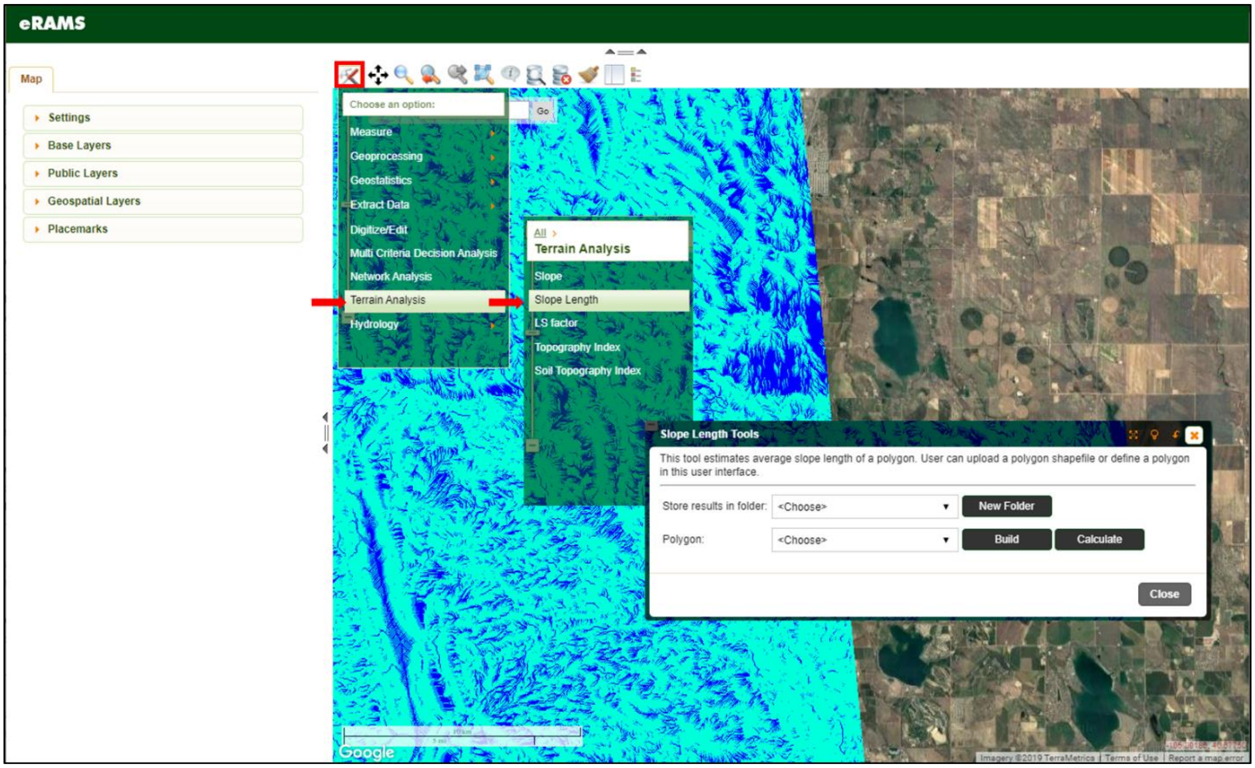


Figure 11: Access slope length interface

API Notes

slope_length
The input data is polygon shapefile, which defines input boundary. .shp, .shx and .dbf files should be posted.

Input/Output	Parameter	Type	Description
Input	JSON request	JSON	{ “metainfo”: { }, “parameter”: [{“name”: “boundary”,”value”: “polygon_boundary.shp”}, {‘name’: ‘r’, ‘value’: x_max}, {‘name’: ‘l’, ‘value’: x_min}, {‘name’: ‘b’, ‘value’: y_min}, {‘name’: ‘t’, ‘value’: y_max}] }
Output	plen	tif	Slope Length Raster
	dir_cut	tif	Cutoff Flow Direction Raster
	results	csv	Zonal statistics of slope length

References

David, O., Lloyd, W., Arabi, M., and Rojas, K. (2015). Cloud Service Innovation Platform User Manual and Technical Documentation [draft].

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Python Software Foundation (2015). Rasterstats 0.7.0, Retrieved from https://pypi.python.org/pypi/rasterstats/0.7.0

Tarboton, D., David Tarboton Hydrology Research Group, Utah State University. (2014). Taudem version 5.1.2 [Software]. Retrieved from http://hydrology.usu.edu/taudem/taudem5/downloads.html

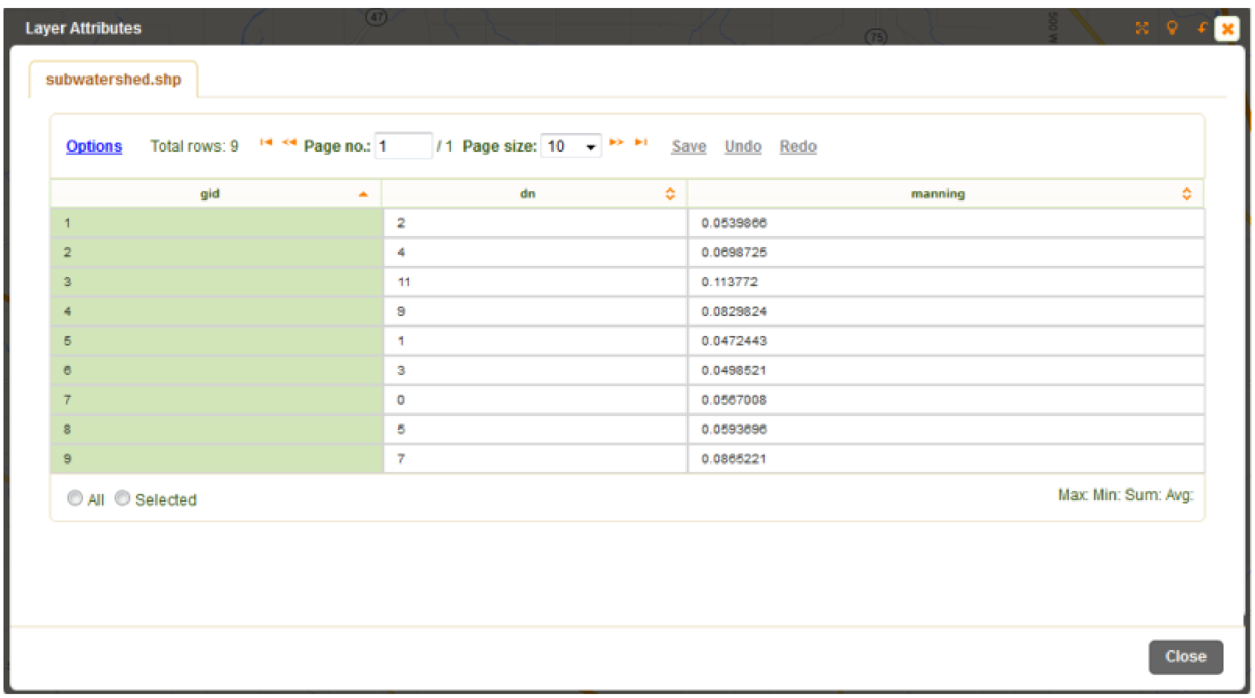
US Environmental Protection Agency (2015). NHDPlus Version 2: User Guide (Data Model Version 2.1). Retrieved from: ftp://ftp.horizon-systems.com/nhdplus/NHDPlusV21/Documentation/NHDPlusV2_User_Guide.pdf

Summary

This tool estimates Manning's overland flow roughness coefficient (n) based on NLCD landuse layer. This tool was created in CSIP (David et al., 2015) environment. The look up table for NLCD landuse classes and n was created in the python code inside CSIP service. The relationship between n and NLCD landuse layer was established according to the research of Kalyanapu et al. (2010) except non-available classes such as 'Dwarf Scrub', 'Sedge/Herbaceous', 'Lichens', 'Moss' and 'Cultivated Crop'. The n of 'Shrub/Scrub' class was used for 'Dwarf Scrub' class and the n of 'Grassland/Herbaceous' was used for 'Sedge/Herbaceous', 'Lichens', 'Moss' classes because they are under same super classes. For the 'Cultivated Crop' class, n was determined as 0.04, which was used for normal mature field crops in cultivated area from Hydraulics Design Manual of Oregon Department of Transportation and Highway Division (2014) . Once Manning's coefficients are read from look up table for each NLCD class, the average for each polygon is calculated by zonal_stats (Python Software Foundation, 2015).

Example

Figure 12 shows the Manning's roughness coefficient for overland flow calculated for each polygon features and added to boundary polygons vector layer table.



gid	dn	manning
1	2	0.0539866
2	4	0.0698725
3	11	0.113772
4	9	0.0829824
5	1	0.0472443
6	3	0.0498521
7	0	0.0567008
8	5	0.0593696
9	7	0.0865221

Figure 12: Manning's overland flow roughness coefficient

Calculate Manning's Roughness Coefficient

Click the toolbox icon > Hydrology > General and select "Overland Manning's" (Figure 13). Follow the prompts to create user folder, select or create boundary layer, create NLCD land use layer and click 'Calculate' (Figure 14).

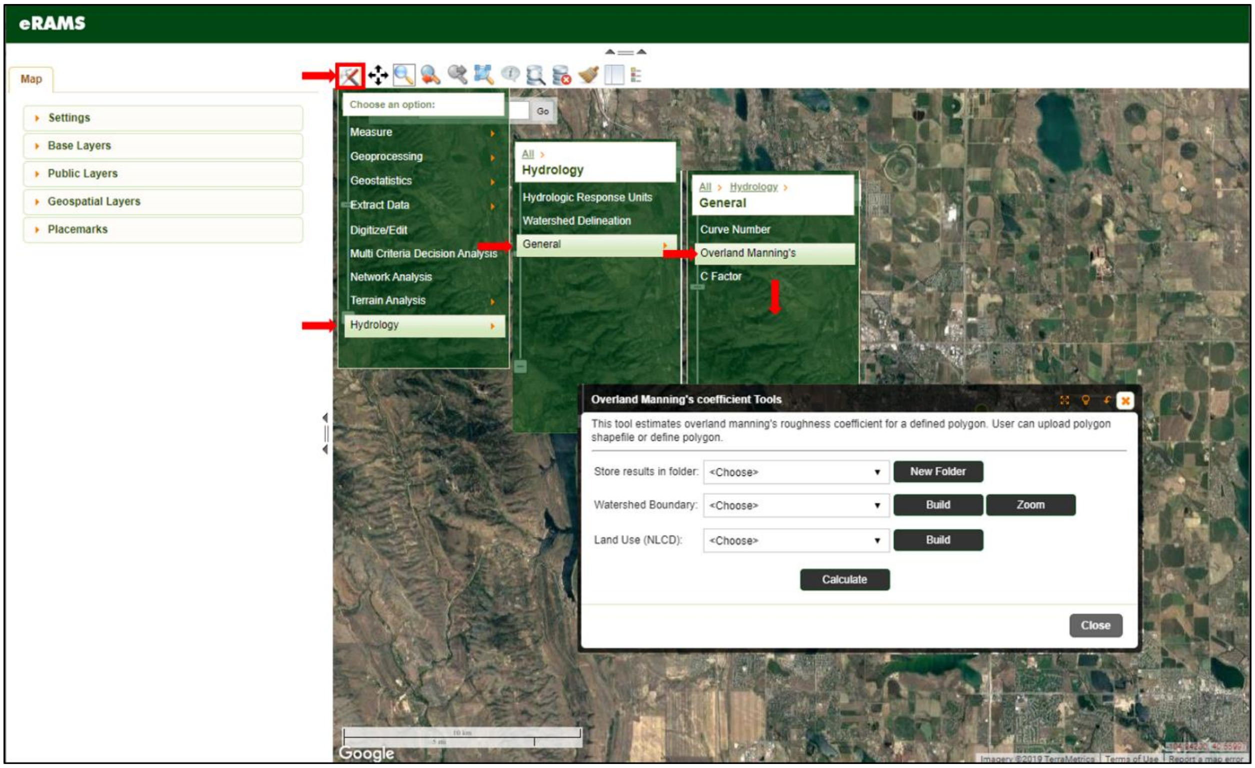


Figure 13: Access Manning's Roughness Coefficient interface

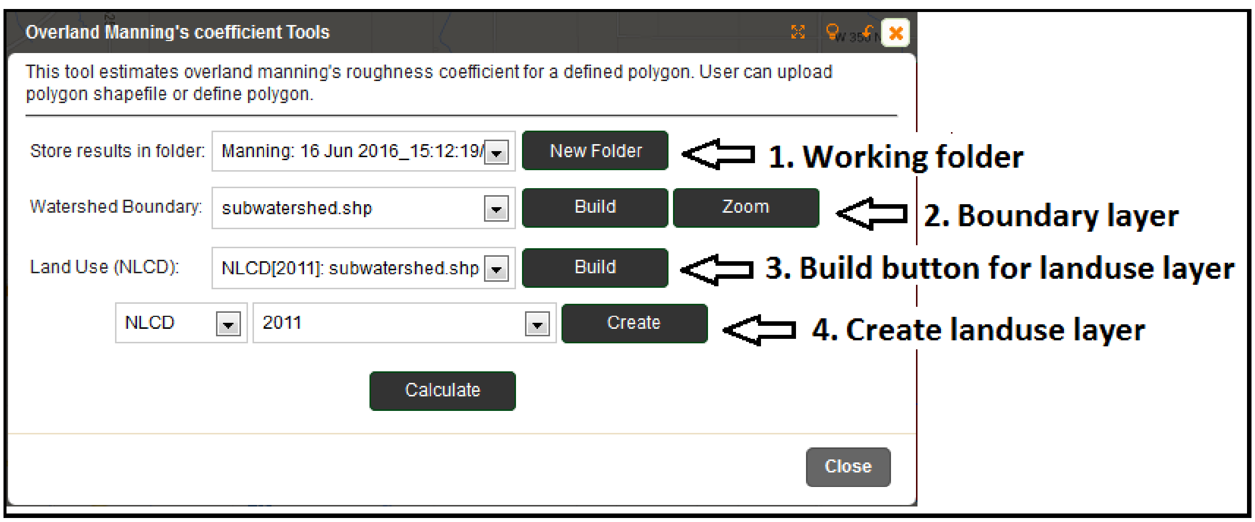


Figure 14: User interface of Manning's Coefficient tool

API Notes

manning

The input data are landuse raster(.tif) and boundary polygon shapefile. For boundary polygon shapefile, shp, .shx and .dbf files should be posted.

Input/Output	Parameter	Type	Description

Input	JSON request	JSON	{ “metainfo”: { }, “parameter”: [{ “name”: “landuse”, “value”: “landuse.tif”} , { “name”: “boundary”, “value”: “polygon_boundary.shp” }] }
Output	Results	csv	zonal statistics of manning’s n

References

David, O., Lloyd, W., Arabi, M., and Rojas, K. (2015). Cloud Service Innovation Platform User Manual and Technical Documentation [draft].

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Oregon Department of Transportation Highway Division (2014). Hydraulics Design Manual, Retrieved from https://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/docs/Hydraulics/Hydraulics%20Manual/Chapter_08_Appendix_A.pdf .

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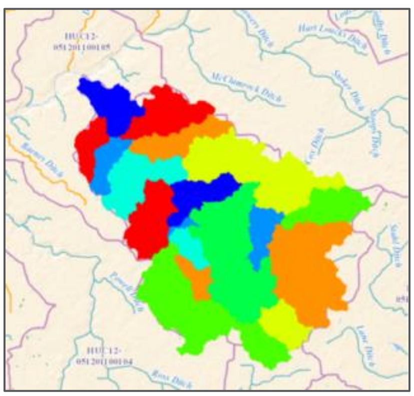
C Factor

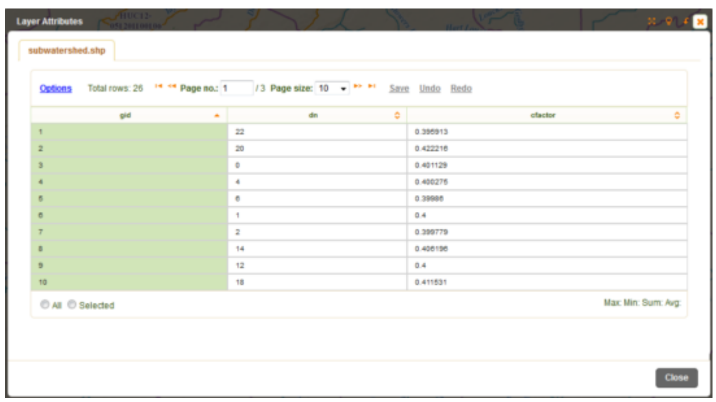
Summary

This tool estimates C factor (runoff coefficient) based on NLCD (MRLC, 2016) landuse layer. C factor (runoff coefficient) is the essential parameter for calculating peak discharge from rainfall intensity and watershed area. Most C factor values for NLCD classes (except classes – 'Perennial Ice/Snow', 'Dwarf Scrub' , 'Sedge/Herbaceous', 'Lichens', 'Moss') were decided based on Dhakal et al.(2012)'s research. The C factors of unavailable classes were chosen from the C factors of the classes under the same super classes (C factor of 'Shrub/Scrub' class was used for 'Dwarf Scrub' class and C factor of 'Grassland/Herbaceous' was used for 'Sedge/Herbaceous', 'Lichens', 'Moss' classes). However, C factor for 'Perennial Ice/Snow' is not available. The lookup table for C factor and NLCD classes were created in python code in CSIP (David et al., 2015) service. If there are multiple polygons in input file, C factor values will be assigned to each polyon by zonal_stats (Python Software Foundation, 2015).

Example

Figure 15 shows the c factor calculated for each polygon in input boundary vector layer. Subwatershed vector layer was used as an input layer.





gid	dn	cfactor
1	22	0.396913
2	20	0.422216
3	0	0.401129
4	4	0.400276
5	6	0.39986
6	1	0.4
7	2	0.399779
8	14	0.406196
9	12	0.4
10	18	0.411531

Figure 15: Input boundary vector layer (subwatershed polygons – left, each color represents multiple (3 or 4) subwatersheds) and C factor (right) calculated for each polygon

Calculate C Factor

Click the toolbox icon > Hydrology > General and select "C Factor" (Figure 16). Follow the prompts to create user folder, select or create boundary layer, create NLCD land use layer and click 'Calculate' (Figure 17).

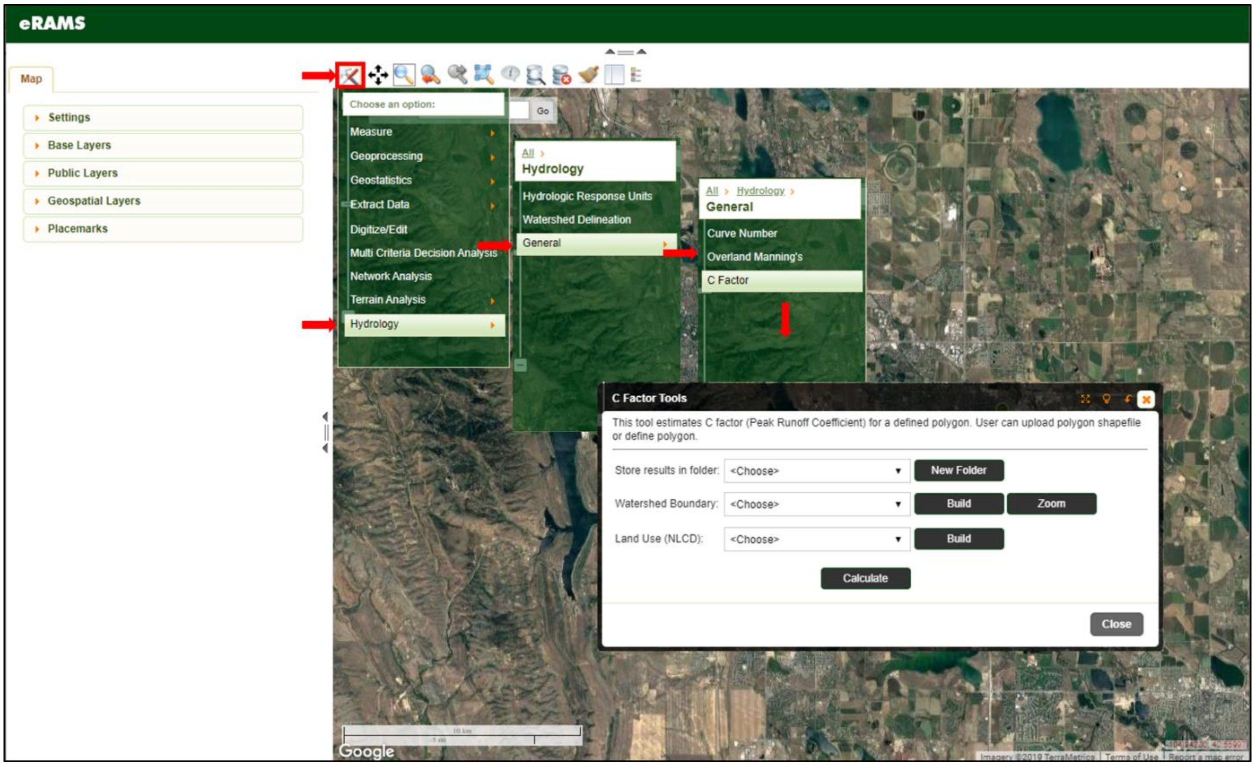


Figure 16: Access C Factor user interface

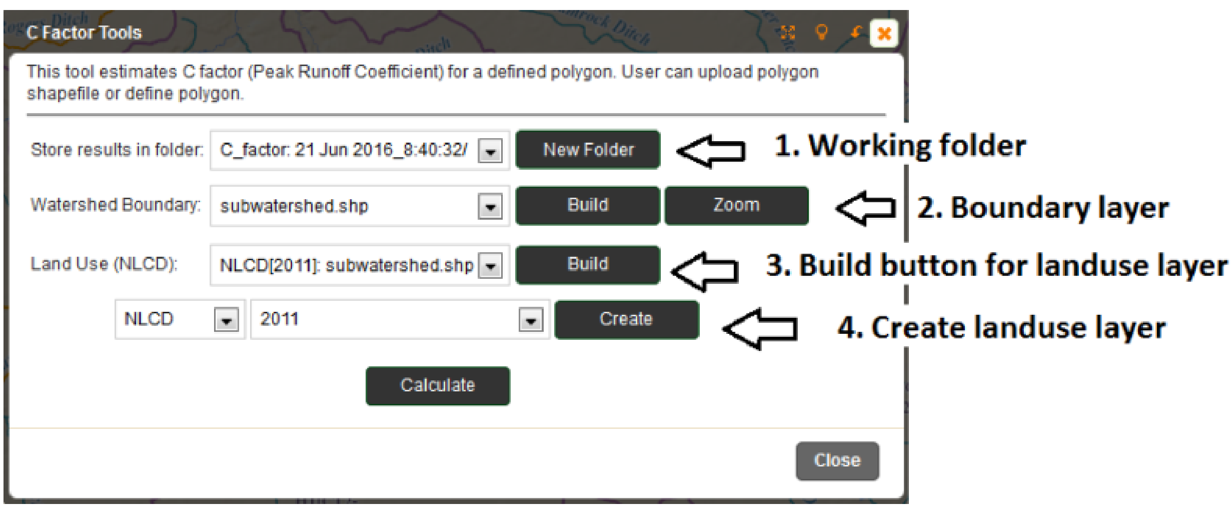


Figure 17: C Factor user interface

API Notes

cfactor

The input data are landuse raster(.tif) and boundary polygon shapefile. For boundary polygon shapefile, shp, .shx and .dbf files should be posted.

Input/Output	Parameter	Type	Description
Input	JSON request	JSON	{ "metainfo": { }, "parameter": [{ "name": "landuse", "value": "landuse.tif"} , { "name": "boundary", "value": "polygon_boundary.shp" }] }
Output	Results	csv	zonal statistics of c factor

References

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