Using HMS-PrePro

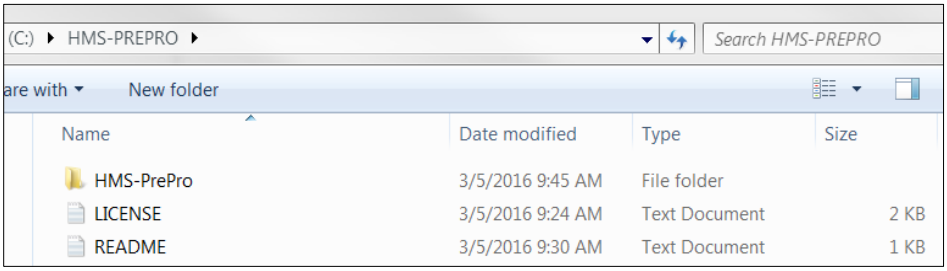
Prepared By: Cynthia V. Castro

HMS-PrePro contains ArcGIS geoprocessing script tools for extracting data from Esri's Living Atlas, deriving a watershed network, estimating hydrological parameters, and storing results in a .BASIN output ASCII file that may be used as input for the HEC-HMS watershed modeling software.

Download: https://github.com/cvcastro/HMSPrePro

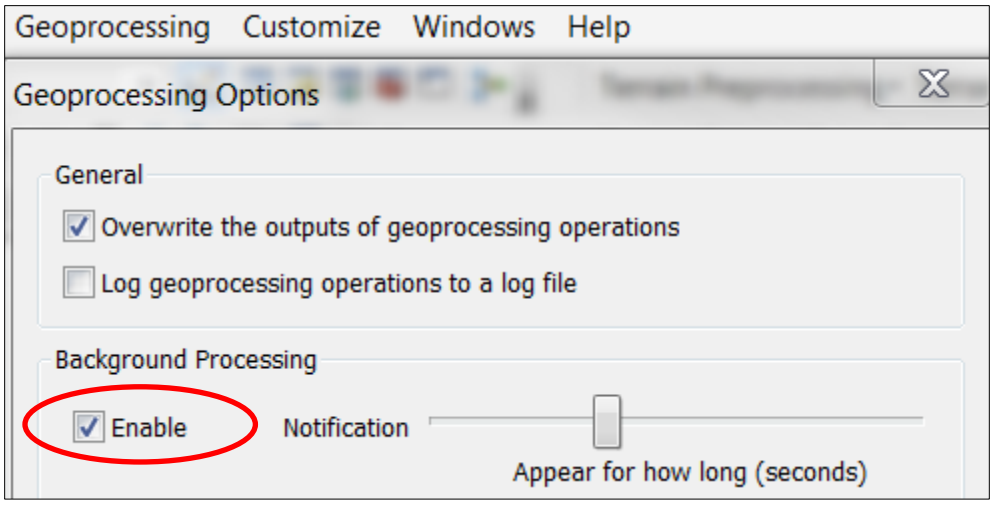
Installation / Set-Up

1) Copy or unzip the HMS-PREPRO folder to any location on your hard drive



2) Ensure you have 64-bit geoprocessing capabilities by looking for a folder containing **ArcGISx64** in *C:\Python27*. If you do not see this folder, contact your system administrator for installation. Running HMS-PrePro without the 64-bit background geoprocessing may cause failures or a notably longer execution time.

   Enable background geoprocessing (64-bit) by clicking the **Geoprocessing** tab from the ArcMap toolbar and selecting the **Enable** box under Background Processing. Click **OK**.



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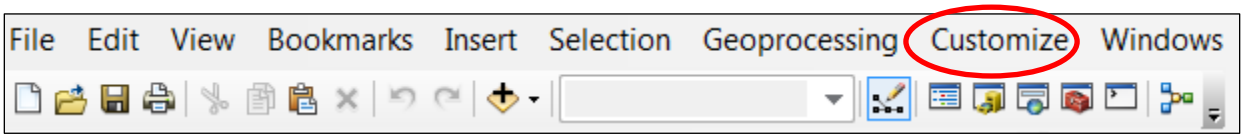
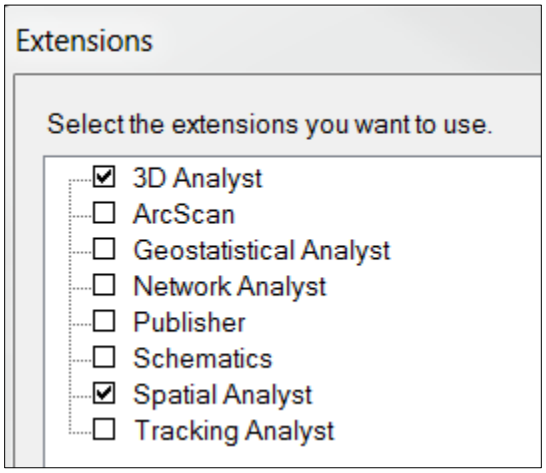
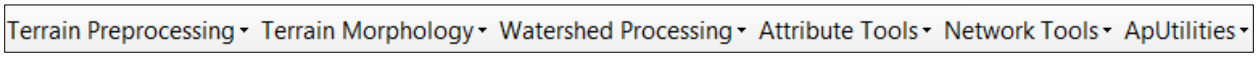
3) Enable the 3D Analyst and Spatial Analyst extensions by selecting the **Customize** tab from the ArcMap toolbar and choosing **Extensions**. Select the box next to 3D Analyst and Spatial Analyst.





4) Ensure **ArcHydro** is installed. In ArcMap you will see this toolbar:



   a. If not, download and install the appropriate version of Arc Hydro tools here: http://downloads.esri.com/archydro/ArcHydro/Setup/
   b. If you have a 64-bit computer, use the "x64" version for faster background processing.

5) The use of Esri Living Atlas landscape layers requires an ArcGIS Online **organizational account**. This is different than an ArcGIS Online personal or global account. You may have been invited to become a member of an ArcGIS organizational account through your university or workplace. If so, it is recommended to use the login credentials registered with that organization when using HMS-PrePro. Contact your organization's administrator for access.

   If you have not been invited to join an existing organizational account, you may create a temporary one by signing up for the developer trial here:
   c. https://developers.arcgis.com/sign-up/
   d. NOTE: Access to the landscape layers within the Living Atlas is free and does not consume any of your organizational credits/tokens.

   ** Prior to running HMS-PrePro, ensure that you are logged into your organizational account in ArcMap by selecting File >> **Sign In…**

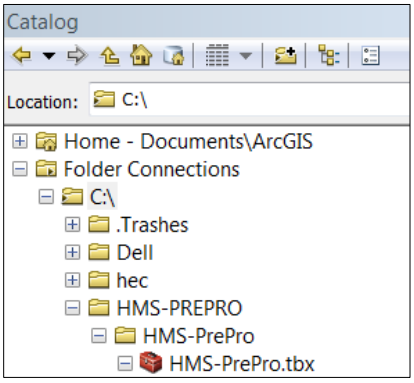
Using HMS-PrePro

Open HMS-PrePro

Using ArcCatalog:

Open ArcCatalog within ArcMap

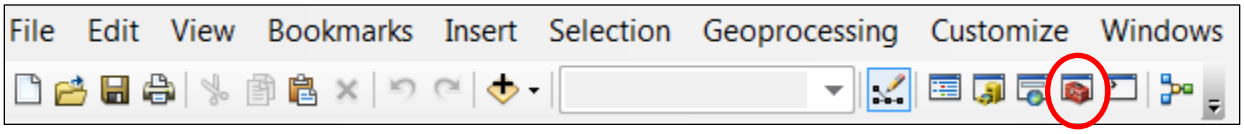
Navigate to the installation directory in ArcCatalog and expand the HMS-PrePro folder.



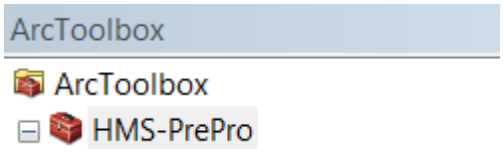
Double-click on the script tool to run.

Or, using ArcToolbox:

Open ArcToolbox within ArcMap



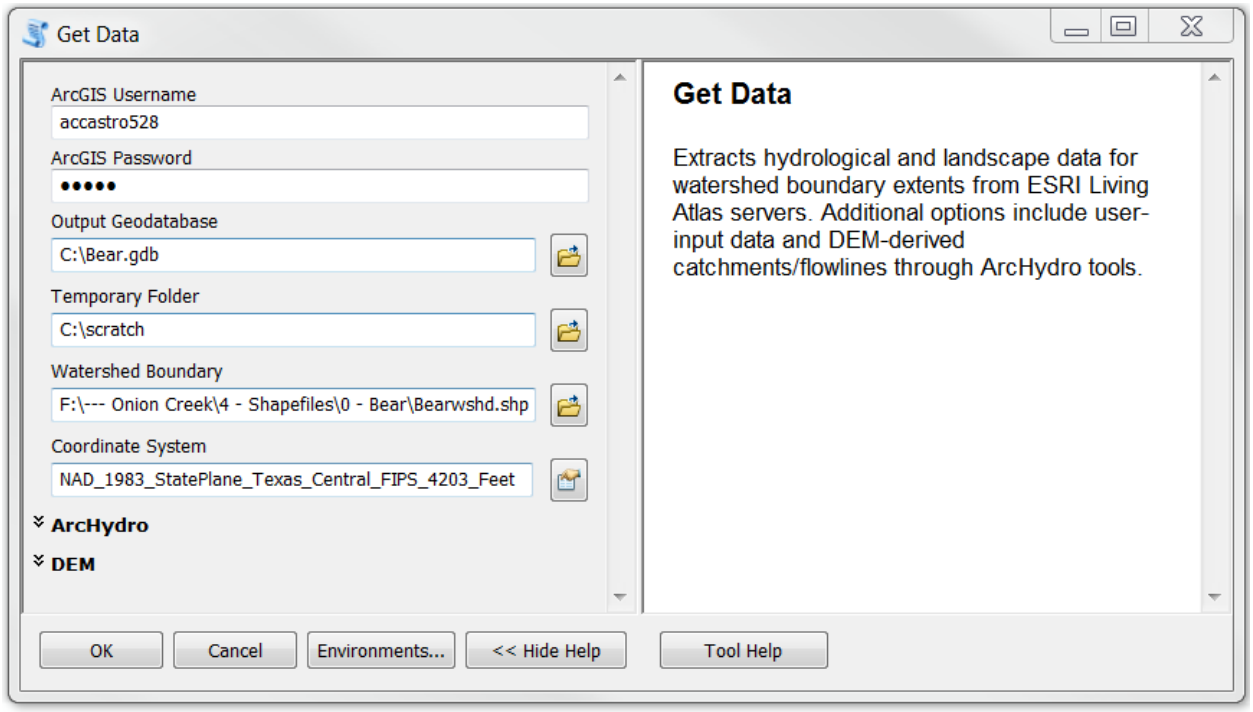
Right-click the **ArcToolbox** folder and select **Add Toolbox**.
Navigate to the HMS-PREPRO directory and select the **HMS-PrePro.tbx**. Click **Open**.



Using HMS-PrePro

Using the HMS-PrePro *GetData* Tool

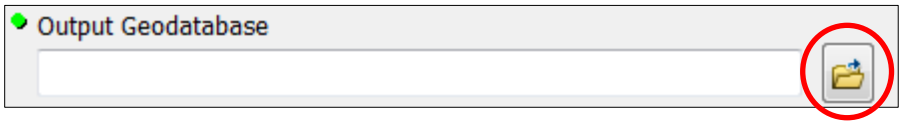
1) Double-click on the ***GetData*** script



NOTE: If you encounter an error, first try closing out of ArcMap and re-opening a blank project.

2) ArcGIS Username / ArcGIS Password
   a. Input your ArcGIS organizational username and password.

3) Output Geodatabase
   a. Create an empty geodatabase and navigate to that directory. This is where the output layers will be saved. (NOTE: It is possible to create an empty geodatabase within the tool by selecting the **New File Geodatabase** icon, as shown below.)

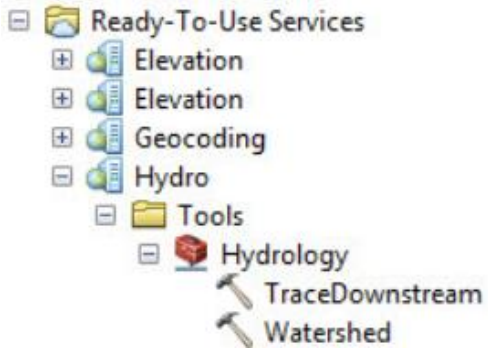


After selecting **New File Geodatabase**, rename the *New File Geodatabase.gdb* and select the icon only once to add the .gdb to the Name field. Select **Add**.

Using HMS-PrePro

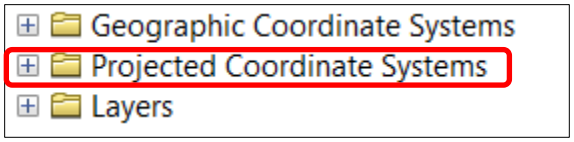
4) Watershed Boundary
   a. Navigate to the watershed boundary layer. This layer may be a shapefile (.shp) or a feature class within a geodatabase.
   b. If you do not have a watershed boundary layer, you may create one for an area of interest using the ArcGIS Watershed service tool (not part of this tutorial).

      For more information about using the Watershed tool, visit:
      http://www.arcgis.com/home/item.html?id=8e48f6209d5c4be98ebbf90502f41077



   c. NOTE: Do not select a watershed that is too large for your computer RAM and/or internet connectivity speeds.
   d. The watershed boundary may not be edited after execution of HMS-PrePro (without having to re-calculate all sub-catchments, reaches, junctions, and catchment parameters). Initial selection of the intended watershed boundary is very important.
   e. Ensure that your watershed contains a projected coordinate system prior to execution.

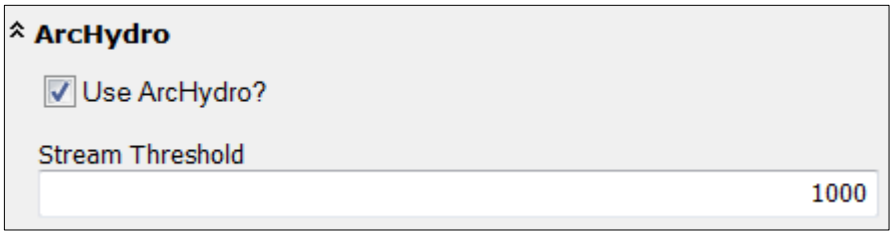
5) Output Coordinates
   a. Select the desired output coordinate system.
      i. For hydrological purposes, ensure the output coordinate system preserves spatial area. Examples include the Albers Equal Area Conic projection or the State Plane systems.
      ii. For use with the HMS-PrePro processing script, a Projected Coordinate System must be selected.
      iii. NOTE: The projected coordinate system only applies to the Subbasin and Reach layers. The landscape rasters (soils, land use, impervious, and DEM) will remain in the North America Albers Equal Area Conic projection for spatial analysis.



Using HMS-PrePro

6) ArcHydro

Provide a **Stream Threshold** based on the number of DEM cells that you wish to define the stream. The default value is 1000. Smaller stream thresholds will produce more drainage units.



After execution of the *GetData* script, carefully analyze the size of your catchments and reaches. If these are too large or small, re-run the script and adjust the "Stream Threshold" value.

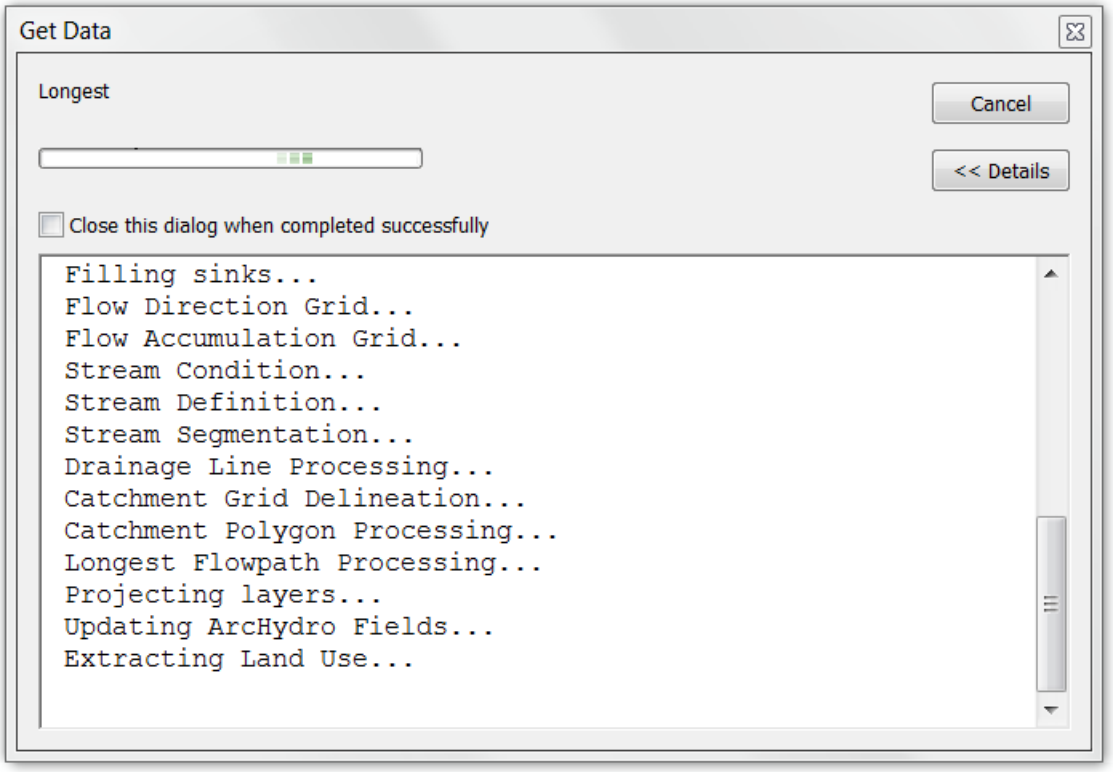
Manual editing of catchments/reaches/junctions prior to running the next script is technically possible, however, if any of the Fields are edited (i.e. Name/HydroID, To_Node, From_Node, NextDownID, NodeID) and the topology does not match perfectly, HMS-PrePro will be unable to run the parameterization script. Manual editing of the basin catchments after running ArcHydro is very typical for land-development projects, because the Node of interest typically lies at a specific location. Care should be executed in updating the Watershed topology connections if manual edits are desired.

7) DEM

The Esri Living Atlas may be used to obtain a 30-meter DEM, which is standard across the United States. A high-resolution DEM may be uploaded by the user from local data.

Click **OK** to run *Get Data*.

You will see a dialog box describing the current processing steps and a status bar. Do not close this box until you see "Completed" at the top.

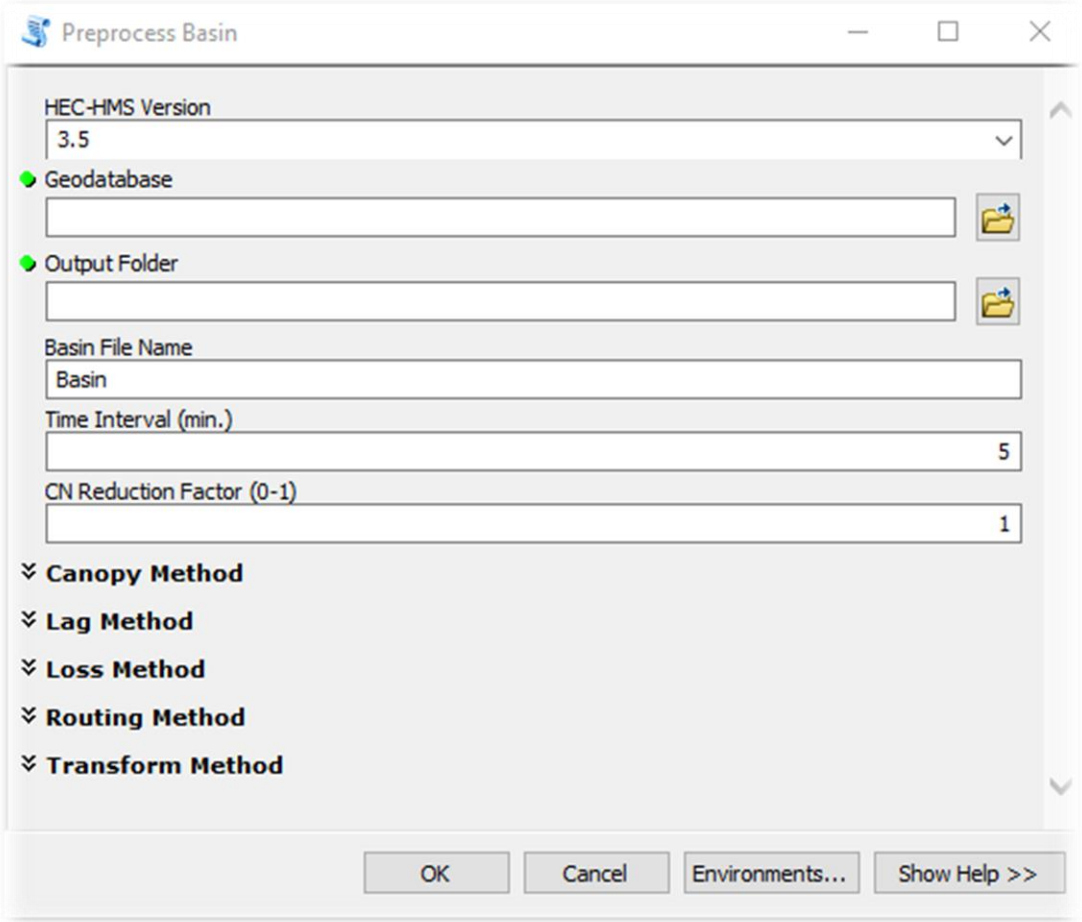


Once the script has completed, you may navigate to the output folder directory to view the hydrological geodatabase with landscape layers, subbasins, and reaches. Each of these layers may be added to ArcMap for viewing.

Using HMS-PrePro

Using the *Preprocess Basin* Script

Double-click on the **Preprocess Basin** script



NOTE: If you encounter an error, first try closing out of ArcMap and re-opening a blank project. Sometimes, background processing will crash if the layer being processed is open.

1) Select version of HEC-HMS.
2) Select the geodatabase created with the *Get Data* tool.
3) Select an output folder for the .BASIN HEC-HMS file.
4) Choose a name for the .BASIN file.
5) Select a time interval (whole number) for the HEC-HMS simulation.
6) Choose a Curve Number reduction factor (optional) according to observed/calibrated data.
7) You may choose to employ various Methodologies for basin losses and routing. See HEC-HMS User's Manual for more information.
8) Read the "Help" dialogue box for information regarding each Methodology and required input. ** This step is particularly important if you wish to execute the TR-55 Lag Time script. Follow the user-steps listed under the "Help" screen, and then run the Optional "TR-55 Method" script after fully executing the "Preprocess Basin" script and updating necessary parameters.
9) Select **OK**.

Using HMS-PrePro

Opening .BASIN File in HEC-HMS

Now that you have created a .BASIN file from the hydrological geodatabase, you may use this to *initialize* a HEC-HMS model. Further calibration and engineering optimization is necessary to accurately model the watershed response. These results should not be used for design or judgment purposes without further analysis by a professional engineer.

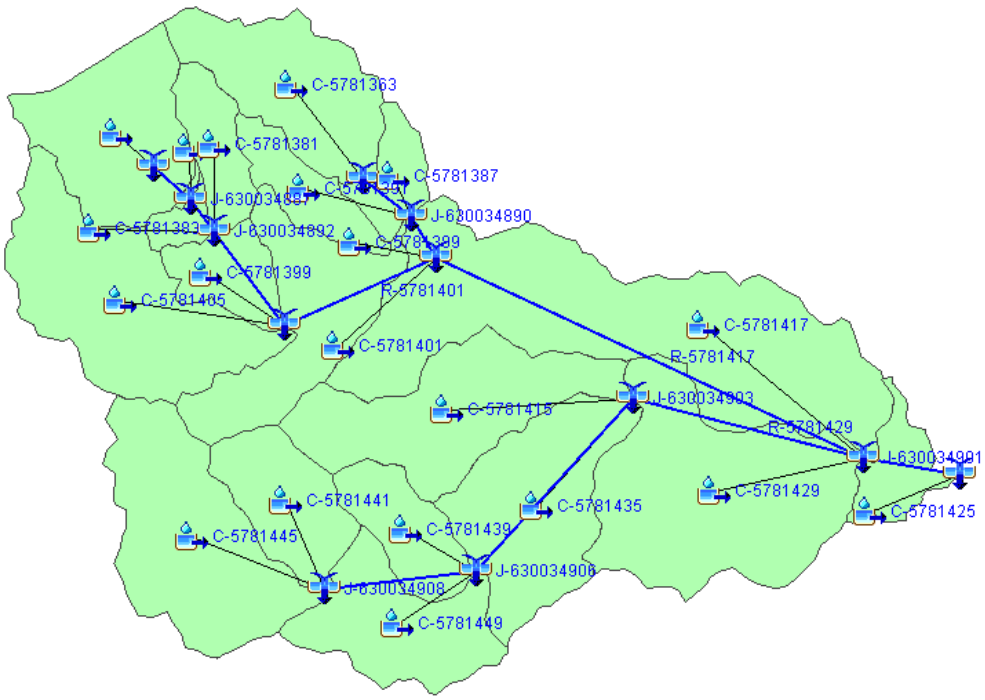
1) Open HEC-HMS
   Download available: http://www.hec.usace.army.mil/software/hec-hms/downloads.aspx

2) Create a New Project (File >> New…). Choose the U.S. Customary units.

3) Import the .BASIN file (File >> Import >> **Basin Model**).
   Navigate to the directory where you saved the .BASIN file in the HMS-PrePro tool.

4) In the legend, open the Basin Models folder and select your basin. You may optimize the view by selecting View >> Maximum Extents and changing the percentage value.

   You may also import background images (i.e. subbasin, longest flowpath) by selecting View >> Background Maps >> Add. When importing background images to HEC-HMS, the layer cannot be contained in a geodatabase. You will need to export the data as a shapefile first.



5) To fully execute a HEC-HMS model, you will need to create a meteorological model, control specifications, and a simulation run. Refer to the HEC-HMS manual for further information.

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Questions

For questions regarding this product, please contact:

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castrocv@uh.edu

Please note that no requested coding updates will be conducted on this tool by the Author. The current tool is compatible with ArcMap 10.7.1. If you wish to update the script codes for improved performance or for future versions of ArcGIS/ArcPro/HEC-HMS/additional software, you *must* upload the modified script back into GitHub for public use and contact the Author, per licensing agreement.

HMS-PrePro
TR-55 Background & User's Guide

Prepared By: Cynthia V. Castro

A common approach for determining the runoff time over a watershed is the TR-55 method. According to the Urban Hydrology for Small Watersheds TR-55 Manual, the time of concentration may be calculated as the sum of travel times along the longest flow path (USDA, 1986[1]). The longest flow path is split into three segments that are differentiated by sheet flow (t_{sh}), shallow concentrated flow (t_{sc}), and channelized flow (t_{ch}).

$$t_c = t_{sh} + t_{sc} + t_{ch}$$

$$t_{sh} = \frac{0.007(n_{ol}L_{sh})^{0.8}}{{P_2}^{0.5}{S_{sh}}^{0.4}} \qquad t_{sc} = \frac{L_{sc}}{3600\,K\,{S_{sc}}^{0.5}} \qquad t_{ch} = \frac{L_{ch}}{\left(3600\frac{1.49}{n}R^{2/3}{S_{ch}}^{1/2}\right)}$$

Where:

P_2 = 2-yr, 24-hr rainfall depth (in)
n_{ol} = overland flow roughness coefficient
L = length of longest flow path (ft)
S = slope of longest flow path (ft/ft)
K = 16.13 for unpaved surfaces, 20.32 for paved surfaces
n = Manning's roughness coefficient for channel
R = channel hydraulic radius (ft)
t_c = time of concentration (hr)

Sheet flow represents the planar flow that occurs at the headwater of a stream near the most hydraulically-remote point. Typically, sheet flow occurs for 100 feet or less before transitioning into shallow-concentrated flow. The TR-55 sheet flow approximation is a simplified version of the kinematic wave Manning's equation, developed by Welle and Woodward (1986[2]). Shallow-concentrated flow is then collected in small swales and gullies. Shallow-concentrated flow is considered to be between 0.1 and 0.5 feet in depth. When flow is collected in a well-defined stream, channel flow is assumed to occur. The transition between shallow-concentrated and channelized flow is typically assumed to begin where channels are visible on aerial photography or where surveyed cross-sections establish bankfull conditions (USDA, 2010[3]). Since detailed channel geometry is unlikely from a DEM, GIS-preprocessors require user-input for certain channel properties. Field observations, as-built drawings, aerial imagery, and survey datasets are used to specify channel parameters such as the roughness coefficient and the hydraulic radius (USACE, 2009[4]).

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[1] USDA (1986). Urban Hydrology for Small Watersheds: TR-55. 210-VI-TR-55, Second Ed., June 1986. Washington, D.C.

[2] Welle, P.J., and D.E. Woodward (1986). Time of concentration. Hydrology, Technical Note No. N4. U.S. Department of Agriculture, Soil Conservation Service, NENTC, Chester, PA.

[3] USACE (2010). Hydrologic Modeling System HEC-HMS: User's Manual, Version 3.5. August 2010. US Army Corps of Engineers, Hydrologic Engineering Center.

[4] USACE (2009). HEC-GeoHMS Geospatial Hydrologic Modeling Extension: User's Manual, Version 4.2. May 2009. US Army Corps of Engineers, Hydrologic Engineering Center.

TR-55 User's Guide

The following figure shows the user-defined parameters required in HMS-PrePro for the TR-55 lag method. These values should be modified by the user according to local observations.

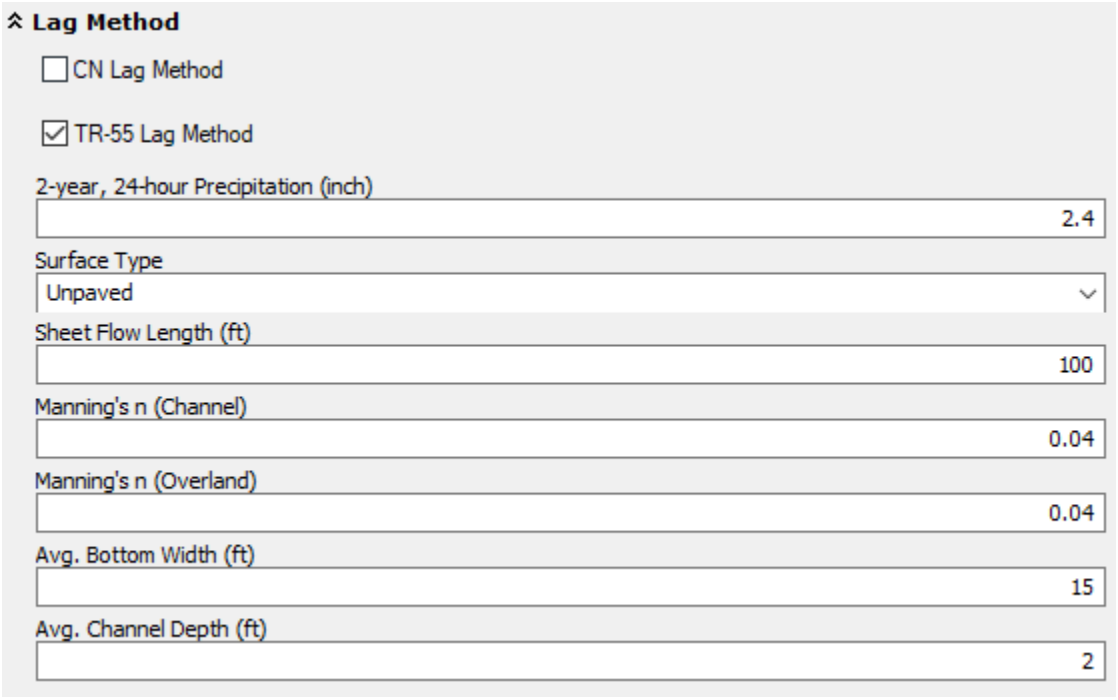

Figure 1: User-Input for TR-55 Script No. 1

Instructions:

In HMS-PrePro, the TR-55 method uses two separate scripts to allow user-input regarding the flowpath properties. First, run the *Preprocess Basin* script tool where fields are automatically added to the longest flowpath layer and populated according to uniform values from the user-input in Figure 1. For a given location, the 2-year, 24-hour precipitation may be obtained from a depth-duration-frequency atlas. The length of sheetflow is specified by the user for values up to 300 feet (typically 100 feet). Average Manning's roughness coefficients should be provided for channel and overland flow. The surface type may be chosen as 'paved' or 'unpaved', used to determine the *K* value for shallow-concentrated flow.

Segmented flowpaths for sheet flow, shallow-concentrated flow, and channelize flow are estimated from the longest flowpath layer. A GIS point feature class called "TR55pts" is created from the *Preprocess Basin* script to represent the transition locations between sheet flow, shallow-concentrated flow, and channel flow. After the *Preprocess Basin* script is run, the "TR55pts" shapefile points should be edited by the user and moved to reasonable locations along the longest flowpath layer, according to observed data. After the point locations are updated, the user should modify Manning's n-values for channelized flow (field 'n_ch') and overland flow (field 'n_ol') and the channel hydraulic radius (field 'R') in the longest flowpath layer. The hydraulic radius may be estimated using spatial tools such as 3D-Analyst.

Next, the *TR-55* script should be run once the flowpath transition points have been modified and the longest flowpath layer fields have been optimized. Select the same geodatabase created by *Preprocess Basin* that contains the modified TR-55 points and longest flowpath layers. In the *TR-55* script, the user-defined point locations are used to update the flowpath segment lengths and slopes. The flowpath is interpolated onto the DEM where elevations are extracted for each upstream and downstream endpoint. The three TR-55 flowpath equations are solved and summed to determine the time of concentration in each subbasin and appended to the "Subbasin" layer.

The user should take care to select the same basin file options (i.e. Curve Number Method, Canopy Method, Unit Hydrograph Method, etc.) when running the *TR-55* script as when running the initial *Preprocess Basin* script. The resulting basin output text file from the *TR-55* tool will be importable into HEC-HMS. If the user selects the TR-55 method in *Preprocess Basin* and forgets to update the pertinent data and run the subsequent *TR-55* script, the output .BASIN file will result in an error with instructions to guide the user in next steps.

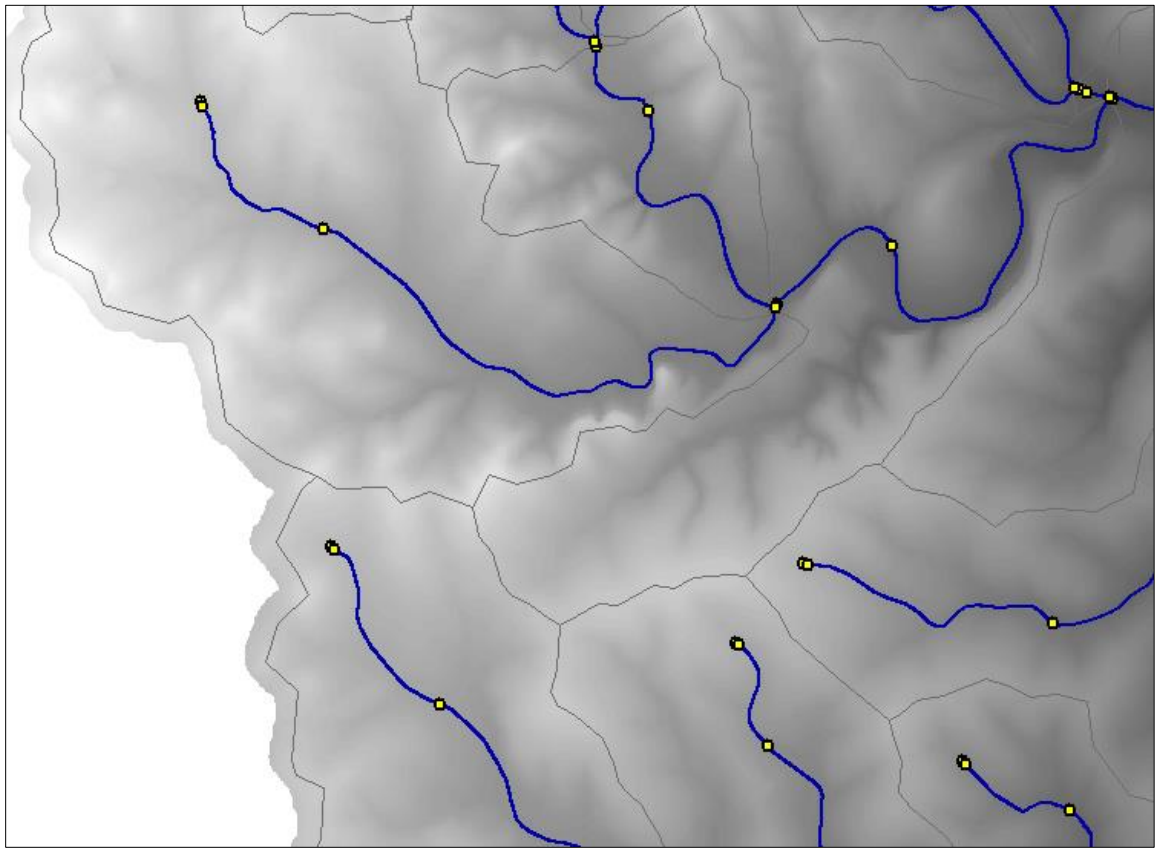

Figure 2: Longest flowpath and point output, used to define transition from sheet flow to shallow-concentrated flow to channelized flow. Points are initially created by the Preprocess Basin script and should be modified per the user. The Manning's roughness and Hydraulic Radius (R) attribute values should also be manually updated by the user. Then, the TR-55 script is run for updated calculations and a new .BASIN output file.