**Tutorial on using HEC-GeoHMS to develop Soil Moisture Accounting Method Inputs for HEC-HMS**

Prepared by

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## Introduction

The objective of this tutorial is to create the grids necessary to complete HEC-HMS project setup for the Soil Moisture Accounting (SMA) loss method using HEC-GeoHMS tools in ArcGIS. It is expected that you are reasonably adept with ArcGIS and HEC-HMS. This tutorial was designed to supplement the "HMS Model Development using HEC-GeoHMS (ArcGIS 10)" tutorial provided on Dr. Venkatesh Merwade's research page and available at the following address: https://web.ics.purdue.edu/~vmerwade/education/geohms.pdf.

The aforementioned tutorial uses SCS for the Loss Method, but this tutorial will take you through the steps necessary to use SMA for the Loss Method. To continue with this tutorial, you will need to have performed every step listed in Dr. Merwade's tutorial up to the "HMS Inputs/Parameters" section that begins on page 15 of the tutorial.

## Computer Requirements

You must have a computer with windows operating system, and the following programs installed:

1. ArcGIS 10
2. HEC-GeoHMS version 10
3. Microsoft Excel

You can download HEC-GeoHMS for free from the US Army Corps of Engineers Hydrologic Engineering Center website http://www.hec.usace.army.mil/software/.

## Data Requirement

The datasets required beyond those listed in the aforementioned tutorial are:

(1) SSURGO soil data from the Web Soil Survey*

(2) 2006 land cover grid from USGS
(3) 2006 impervious surface percentage grid from USGS
(4) USGS Streamflow data
(5) Evapotranspiration data from NOAA (http://www.ncdc.noaa.gov/IPS/cd/cd.html)

*Before beginning this tutorial, you will need to generate a complete, linked SSURGO geodatabase, as described in the tutorial titled "Downloading SSURGO Soil Data from Internet." This tutorial can be found at: http://web.ics.purdue.edu/~vmerwade/education/ssurgo.pdf.

**Important: Keep track of the units for the datasets you are using. You will need to make sure that all variables are in the correct units once you create the HEC-HMS project file. For your convenience, there is a table in the appendix listing the HEC-HMS units for the SMA parameters. It is often easier to complete this tutorial with whatever units the raw data uses, and then copy out the variables from the HEC-HMS file and convert them to the appropriate units, before pasting them back into HEC-HMS.

**Getting Started**
Add your SSURGO geodatabase, land cover grid, and impervious surface percentage grid to your existing map document.

**Note** that this tutorial is designed as a companion to the HMS Model Development tutorial and you will need to reference it for certain elements.

**Select HMS Processes**
You can specify the methods that HMS should use for transform, routing, and loss using this function. These designations are not final, but can be changed in HMS.

**Select** *Parameters* → *Select HMS Processes*. Confirm input feature classes for Subbasin and River, and **click** OK. Choose SMA for Loss Method, Linear Reservoir for Baseflow Method, and whichever methods you intend to use for transformation and routing. **Click** OK.

**Save** the map document.

**Follow** the instructions for "River Auto Name" and "Basin Auto Name" as outlined in the HMS Model Development Tutorial. Then, continue with this tutorial.

**Subbasin Parameters**
Depending on the method (HMS Processes) you intend to use for your HMS model, each sub-basin must have parameters such as tension zone depth for SMA method. These parameters are assigned using the Subbasin Parameters option. This function overlays subbasins over grids and computes an average value for each basin. We will explore only the grids required for the SMA method.

**Select** *Parameters* → *Subbasin Parameters from Raster*. You will get a window in which you will have to select the rasters that you wish to use for extracting parameters. The rasters listed for the SMA method are as follows:

1. Total Storm Precipitation Grid
2. 2-Year Rainfall Grid
3. Percentage Impervious Grid
4. Max Canopy Storage Grid
5. Max Surface Storage Grid
6. Max Soil Infiltration Grid
7. Max Soil Percolation Grid
8. Soil Tension Storage Gird
9. Max Soil Storage Grid
10. GW1 Max Storage Grid
11. GW2 Max Storage Grid
12. GW1 Max Percolation Grid
13. GW2 Max Percolation Grid

Rasters 1 and 2 are optional for the SMA method and will not be developed over the course of this tutorial. We already have Raster 3, since we downloaded the impervious surface percentage grid from USGS. Rasters 4-9 will be developed during this tutorial. Rasters 10-11 are constant value rasters, and thus do not need to need to be created. We will simply assign the constant values to each subbasin in our Subbasin attribute table. Raster 12 can be taken as equivalent to Raster 7. Raster 13 will not be created, because it is an extremely conceptual parameter. You will simply assign a GW2 Max Percolation Rate during HMS model calibration.

## Parameters estimated from Land Cover Grid

**Raster 4: Max Canopy Storage Grid**
First, clip the land cover raster to the project boundaries. Open the attribute table of the land cover raster. Note that the Value field contains National Land Cover Database (NLCD) Classes. Create a new field of type Double and name it Canopy_int. Use the NLCD values (see Table 1A for NLCD definitions) and the canopy interception values shown in Table 1 to assign canopy interception values to each NLCD. If you are unsure of any values, just use your best judgement.

**Table 1.** Canopy Interception Values

| **Type of Vegetation** | **Canopy Interception** | |
|---|---|---|
| | **in.** | **mm** |
| General Vegetation | 0.05 | 1.270 |
| Grasses and Deciduous Trees | 0.08 | 2.032 |
| Trees and Coniferous Trees | 0.1 | 2.540 |

Your land use attribute table should look something like this:

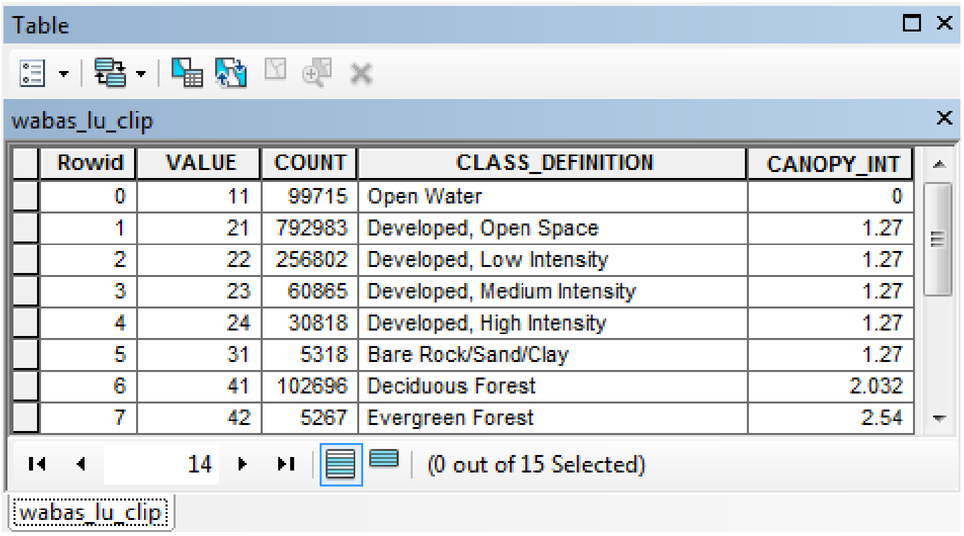


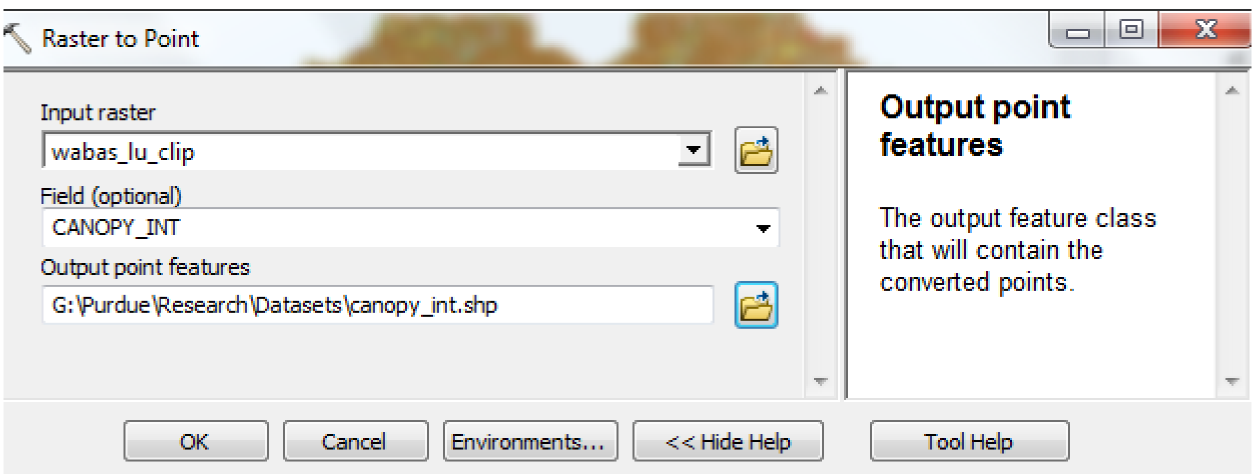
Table — wabas_lu_clip

| Rowid | VALUE | COUNT | CLASS_DEFINITION | CANOPY_INT |
|---|---|---|---|---|
| 0 | 11 | 99715 | Open Water | 0 |
| 1 | 21 | 792983 | Developed, Open Space | 1.27 |
| 2 | 22 | 256802 | Developed, Low Intensity | 1.27 |
| 3 | 23 | 60865 | Developed, Medium Intensity | 1.27 |
| 4 | 24 | 30818 | Developed, High Intensity | 1.27 |
| 5 | 31 | 5318 | Bare Rock/Sand/Clay | 1.27 |
| 6 | 41 | 102696 | Deciduous Forest | 2.032 |
| 7 | 42 | 5267 | Evergreen Forest | 2.54 |

14 (0 out of 15 Selected)

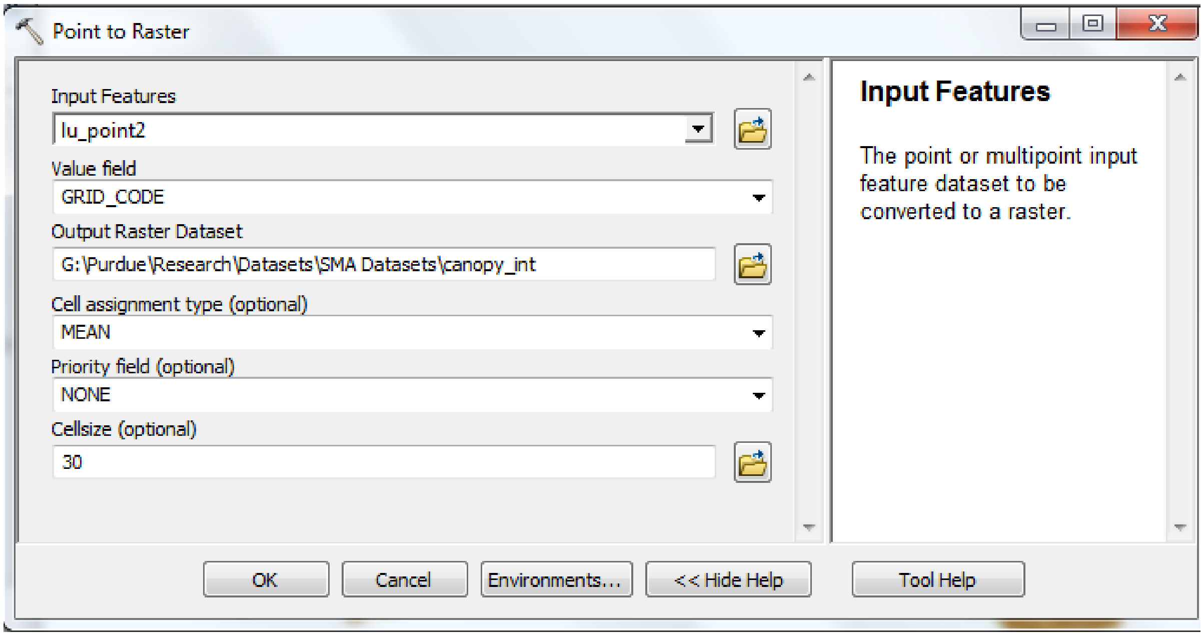
wabas_lu_clip

Unfortunately, ArcGIS is unable to convert one raster directly into another raster based on a different field. So, in order to create the canopy interception raster, we must first create a point feature and then convert it into a raster. To do this, open the ArcToolbox. Go to *Conversion Tools* → *From Raster* → *Raster to Point*. **Select** your clipped land cover raster for Input Raster. **Select** Canopy_int for Field. **Save** the point feature class to your working geodatabase. **Click** OK. Depending on the size of your watershed, this may take a long time.




Once the point feature class has been created, **save** the map document.

Next, we will convert the point feature class into a raster. Go to *ArcToolbox* → *Conversion Tools* → *To Raster* → *Point to Raster*. **Select** your point feature class for Input Features. **Select** GRID_CODE for Value Field. **Save** the raster to your working geodatabase. **Select** MEAN for Cell assignment type. **Type** 30 for the cellsize. **Click** OK.

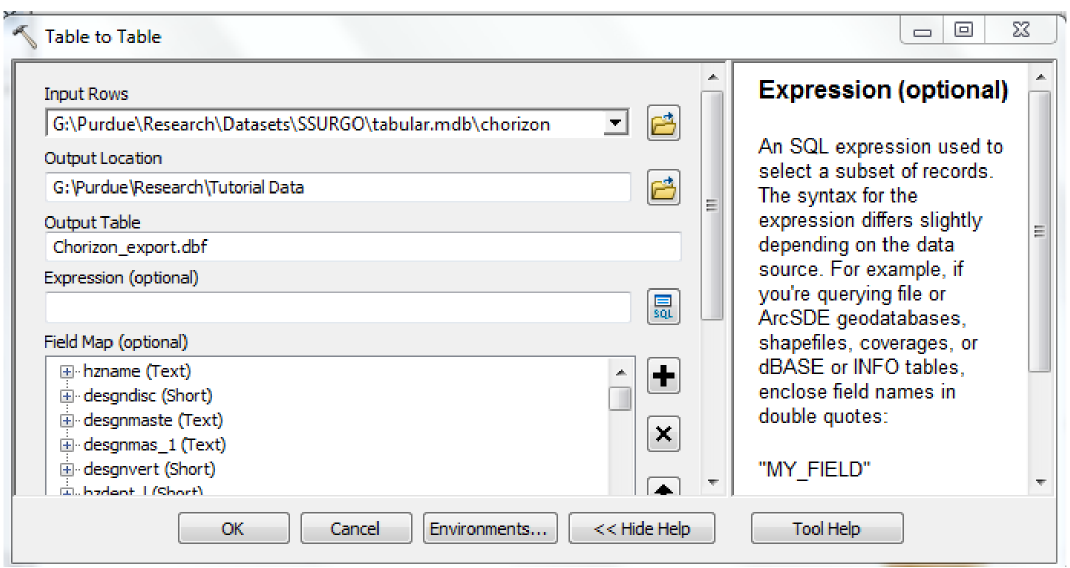



**Save** the map document. The Max Canopy Storage grid is now complete!

## Parameters estimated from SSURGO Data

<u>Preprocessing</u>
Of the tables in your SSURGO Database, chorizon and component are of interest to us.

Export the chorizon table. **Right click** on the chorizon table in the ArcGIS Catalog window. **Select** *Export* → *To dBASE (single)*… **Select** your working geodatabase as the Output Location. **Name** the Output Table Chorizon_export.dbf. **Leave** everything else as default. **Click** OK.



**Open** the Chorizon_export table in Excel. **Save** it as a .xlsx file. In the Chorizon_export table, the only fields you will need are: chkey, cokey, ksat_r, hzdepb_r, wsatiated_r, and wthirdbar_r. If you want, you can delete the remaining fields to make the spreadsheet a little bit cleaner and easier to work with.

**Table 2.** Chorizon Field Definitions

| **Field** | **Definition** |
|---|---|
| chkey | Horizon ID |
| cokey | Component ID |
| ksat_r | Representative saturated hydraulic conductivity |
| hzdepb_r | Representative depth from soil surface to bottom of layer |
| wsatiated_r | Representative soil porosity |
| wthirdbar_r | Representative field capacity |

The Chorizon table contains information about each layer (horizon) of soil within a soil component. Each component, identified with a single cokey, contains multiple layers, each identified by a chkey. So, each cokey is associated with multiple chkeys, as seen below.

| **cokey** | **chkey** | **NoHorizons** |
|---|---|---|
| 1115678 | 1234567 | 1 |
| 1115678 | 1234568 | 2 |
| 1115678 | 1234569 | 3 |
| 1115679 | 1234570 | 1 |
| 1115679 | 1234571 | 2 |

**Sort** the entire spreadsheet so that the chkey field is arranged from lowest to highest. Then, create a new field titled "NoHorizons." Using the cokey field, fill the NoHorizons field with a running count of the number of layers in each component. See the table above for an example.

For each component, find the average ksat_r, wsatiated_r, and wthirdbar_r values. Also, determine the ksat_r value of the topmost horizon for each component and the hzdepb_r value of the bottommost horizon. These values can be determined easily enough by implementing the NoHorizons field and a little bit of creativity with your Excel formulas. Copy the results of this exercise to another sheet. Once this is complete, you should have a table that looks something like this:

| **cokey** | **ksat_avg** | **ksat_Layer1** | **hzdepb_r** | **wsat_avg** | **wthirdbar_avg** |
|---|---:|---:|---:|---:|---:|
| 9391673 | 14.89 | 21.88 | 152 | 57.33 | 44.73 |
| 9391674 | 15.83 | 23.29 | 203 | 67.00 | 33.33 |
| … | … | … | … | … | … |

**Save** your spreadsheet. **Delete** the first sheet with all of your calculations. **Save** the spreadsheet as a .cvs file. Title it chorizon_re.

If you closed your map file, re-open it and import chorizon_re. To do this, **Right click** on your working geodatabase. **Select** *Import* → *Table (single)…* **Browse** to the location of your .cvs table and **select** it for the Input Rows. **Name** the Output Table chorizon_re.

Open chorizon_re in ArcGIS. Create three new fields: (1) titled "comppct" of type Short Integer, (2) titled "slope" of type Float, (3) titled "mukey" of type Text. **Join** the existing component table to the chorizon_re table using the "cokey" field. Comppct stands for component percent and displays the percent of that specific map unit that is occupied by that particular component. See the figure below for a graphical description of the relationship between map units, components, and horizons.

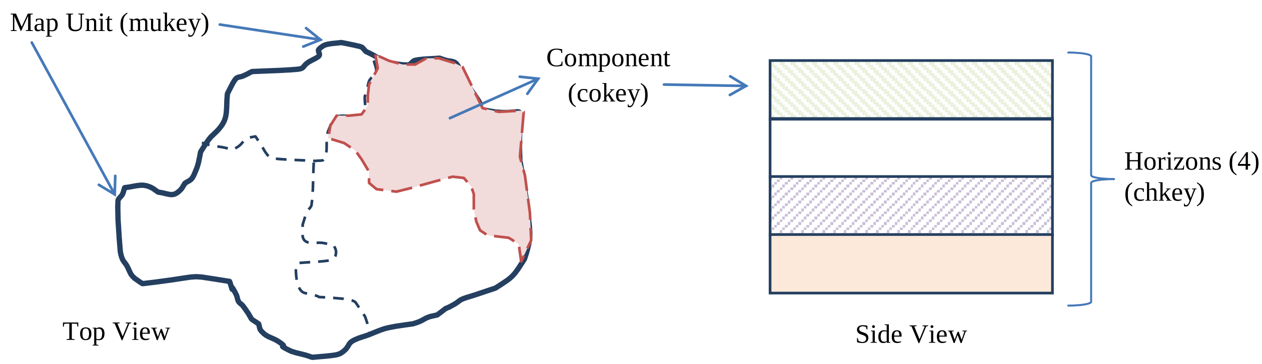



**Figure 1.** SSURGO Organization

Using the field calculator, **equate** chorizon_re.comppct with component.comppct_r, chorizon_re.slope with component.slope_r, and chorizon_re.mukey with component.mukey. Once this is complete, remove the join.

**Save** the map document.

**Re-export** the chorizon_re table. This time, name it SSURGO_Export. As before, open the table in Excel and save it as a .xlsx file. Convert wthirdbar_avg and comppct to decimal form (divide by 100).

You will notice that there are multiple cokeys for each mukey, similar to the multiple chkeys for each cokey that we saw previously. Similar to the horizons, we need to create a running count of the number of components associated with each mukey. Create a new field titled "muIndex" for this purpose. Now we are ready to perform the calculations necessary to create the various grids.

<u>Surface Depression Storage</u>
**Calculate** the weighted slope of each map unit. This can be done by **multiplying** the comppct (in decimal form) by the slope of each component and then **summing** the values for each map unit. Create a new column titled "SurfDepStor" for your surface depression storage values. **Select** the appropriate surface storage value from Table 3 according to the weighted slope you calculated previously. So, you should have only one surface storage value for each map unit.

**Table 3.** Surface Depression Storage Values

| Description | Slope (%) | Surface Storage | |
|---|---|---|---|
| | | **in.** | **mm** |
| Paved Impervious Areas | NA | 0.125-0.25 | 3.18-6.35 |
| Flat, Furrowed Land | 0-5 | 2.00 | 50.8 |
| Moderate to Gentle Slopes | 5-30 | 0.25-0.50 | 6.35-12.70 |
| Steep, Smooth Slopes | >30 | 0.04 | 1.02 |

*taken from Fleming, 2002

<u>Maximum Infiltration Rate</u>
**Calculate** the weighted saturated conductivity of layer one (topmost horizon) for each map unit. Similar to the surface depression storage, this can be done by **multiplying** the comppct (in decimal form) by the ksat_Layer1 of each component and then **summing** the values for each map unit. We will take this weighted form of layer one's saturated conductivity as the maximum infiltration rate. **Title** the column containing these values "MaxInfilRate."

<u>Maximum Soil Profile Storage</u>
For each component, **multiply** the corresponding comppct (decimal form), wsatiated_avg (decimal form), and hzdepb_r together. **Sum** these values for each map unit in a column titled "MaxSoilStor."

<u>Maximum Tension Zone Storage</u>
For each component, **multiply** the corresponding comppct (decimal form), wthirdbar_avg (decimal form), and hzdepb_r together. **Sum** these values for each map unit in a column titled "MaxTensZoneStor."

<u>Percolation Rate</u>
For each component, **multiply** the corresponding comppct (decimal form) by the ksat_avg. **Sum** these values for each map unit in a column titled "PercRate."

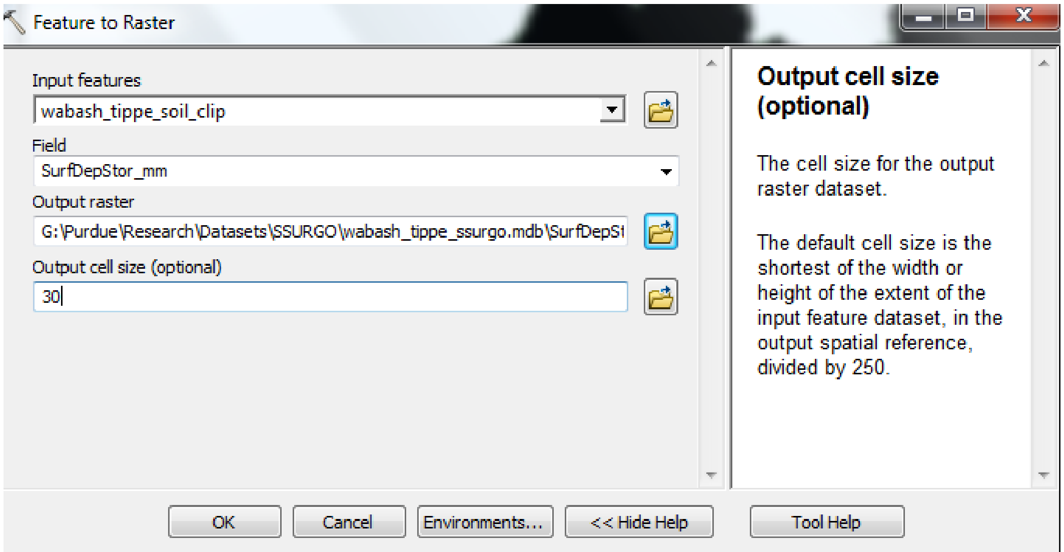
**Save** your spreadsheet. **Copy** the mukey, SurfDepStor, MaxInfilRate, MaxSoilStor, MaxTensZoneStor, and PercRate to a new spreadsheet. **Save** the spreadsheet as a .cvs file. Title it SSURGOImport.

**Import** the SSURGOImport table into your working geodatabase. **Open** your SSURGO polygon feature class you created while building your SSURGO geodatabase. **Create** five new fields of type Float for SurfDepStor, MaxInfilRate, MaxSoilStor, MaxTensZoneStor, and PercRate. **Join** the SSURGOImport table to your SSURGO polygon feature class using the mukey as the common field.

You are now ready to begin creating Rasters 5, 6, 7, 8, 9, & 12!

**Raster 5: Max Surface Storage Grid**
We will convert the SSURGO polygon feature class into a raster. Go to *ArcToolbox* → *Conversion Tools* → *To Raster* → *Feature to Raster*. **Select** your SSURGO polygon feature

class for Input Features. **Select** SurfDepStor for Field. **Save** the raster to your working geodatabase. **Type** 30 for the cellsize. **Click** OK.




The Max Surface Storage Grid is now complete!

**Raster 6: Max Soil Infiltration Grid**
Repeat the steps for Raster 5 but use MaxInfilRate for the Field. **Name** the raster MaxSoilInfiltration, or something similar.

**Raster 7 & 12: Max Soil Percolation and GW1 Max Percolation Grids**
Repeat the steps for Raster 5 but use PercRate for the Field. **Name** the raster .

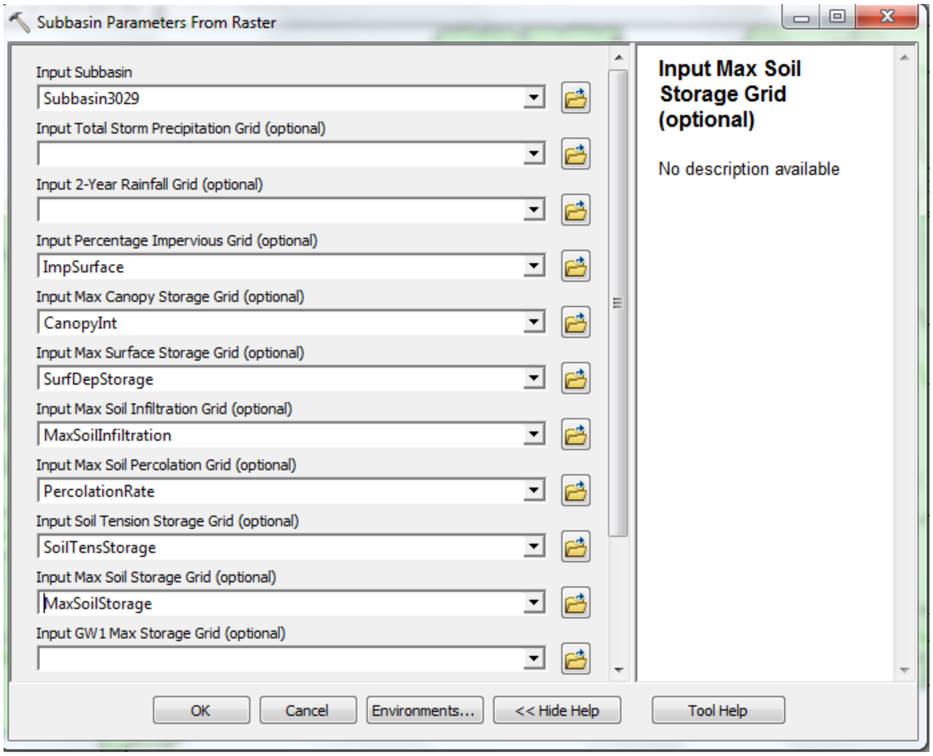
**Raster 8: Soil Tension Storage Grid**
Repeat the steps for Raster 5 but use MaxTensZoneStor for the Field. **Name** the raster.

**Raster 9: Max Soil Storage Grid**
Repeat the steps for Raster 5 but use MaxSoilStor for the Field. **Name** the raster.

You are now finished using ArcGIS tools to create the necessary rasters for the SMA loss method!

**Assign Subbasin Parameters**

**Select** *Parameters* → *Subbasin Parameters from Raster*. You will get a window in which you will have to select the rasters you wish to use for extracting parameters. **Select** the appropriate subbasin feature class for Input Subbasin. **Select** ImpSurface for Input Percentage Impervious Grid. **Select** CanopyInt for Input Max Canopy Storage Grid. **Select** SurfDepStorage for Input Max Surface Storage Grid. **Select** MaxSoilInfiltration for Input Max Soil Infiltration Grid. **Select** PercolationRate for Input Max Soil Percolation Grid and Input GW1 Max Percolation Grid. **Select** SoilTensStorage for Input Soil Tension Storage Grid. **Select** MaxSoilStorage for Input Max Soil Storage Grid. **Click** OK.




This process will calculate average parameter values for each subbasin and copy the values into the subbasin attribute table. If you wish, you can open the subbasin attribute table to see how the values are stored. If any values were not properly transferred, simply run the process again.

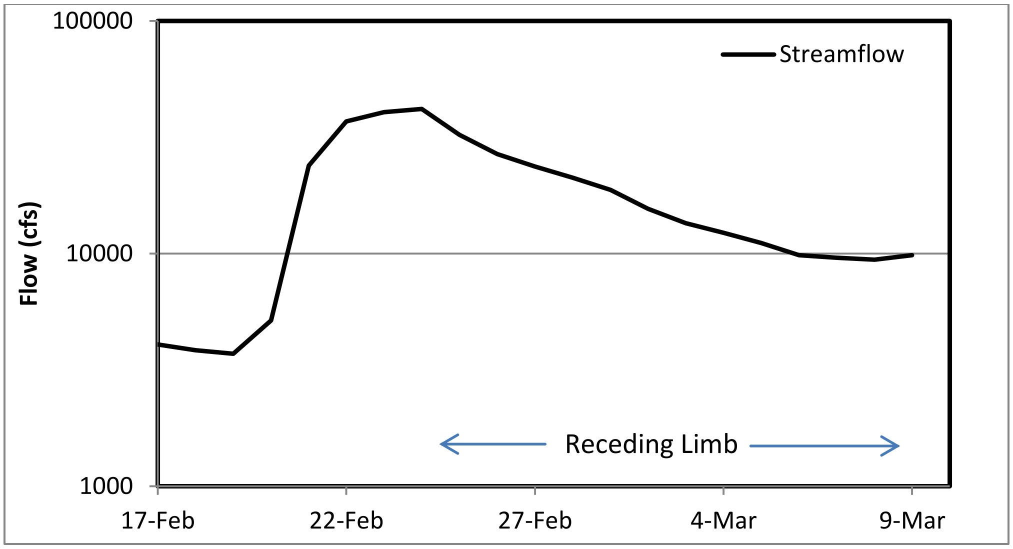
**Save** your map document.

## Parameters estimated from USGS Streamflow Data

For this part of the tutorial, you will need daily streamflow data for 3 to 4 storms occurring during different months of the year. Look for storms that are fairly isolated; storms where the streamflow hydrograph is allowed to return to normal for a couple days before runoff from the next storm is visible.

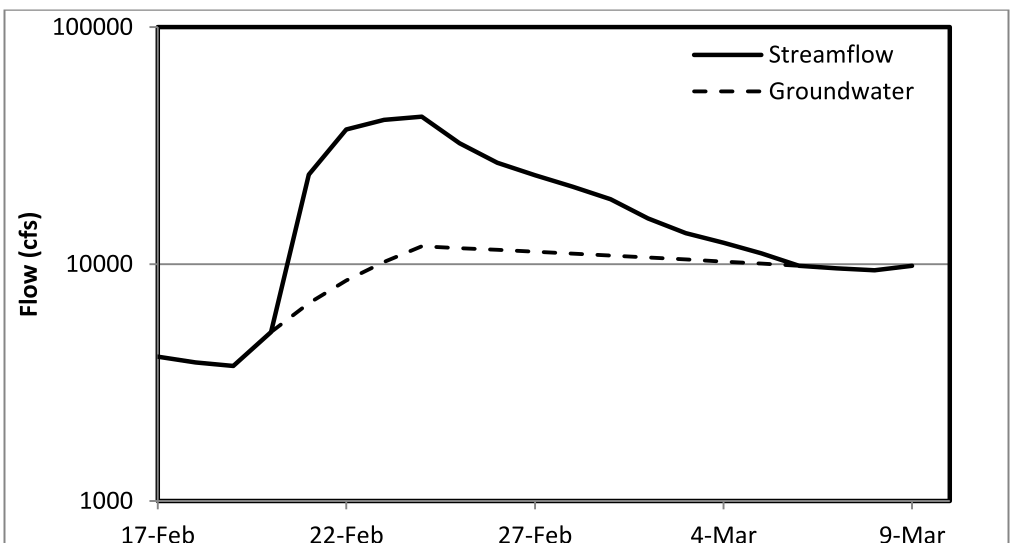
Streams convey stored water from three different sources: stream channels, surface soil (interflow), and groundwater. In this portion of the exercise, we will learn how to break up a streamflow hydrograph into its various components and calculate the variables necessary for soil moisture accounting in HEC-HMS.

Download the streamflow data and open it in Excel. **Save** the file. **Create** a hydrograph of the streamflow data on a semi-logarithmic plot.

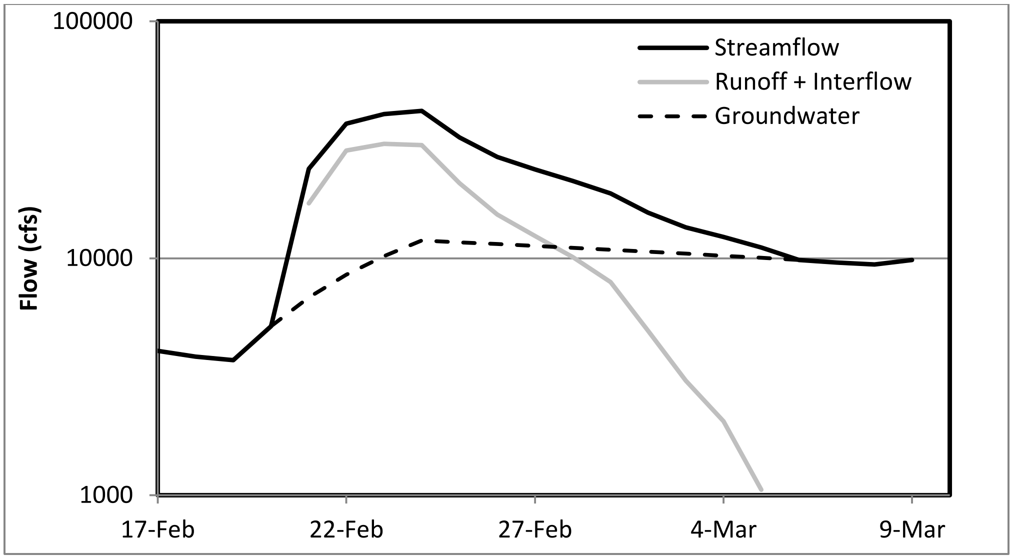



The tail-end of the receding limb represents the time when groundwater is the only source contributing to streamflow, as both surface runoff and interflow have stopped. There should be an inflection point visible in this area of the graph to help you identify the correct portion of the hydrograph.

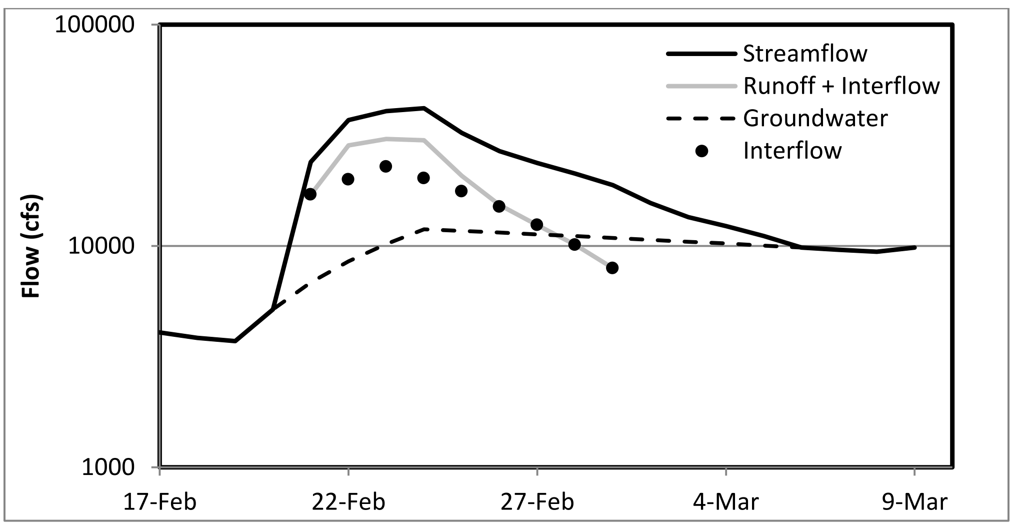
To begin, **project** a line backwards from the tail-end of the receding limb to the time of peak flow, maintaining the slope of that tail-end portion. **Connect** the line to the point at which the hydrograph begins to rise as a result of runoff. This line represents the groundwater contribution to streamflow, or GW2. See the figure below.




Next, **subtract** the groundwater from the streamflow. **Plot** the result on the same graph. This line represents the contribution to streamflow from surface runoff and interflow. See the figure below.




We are only interested in the portion of the runoff + interflow receding limb with the shallowest slope. So, you can either just ignore the tail-end of it, or delete the last few points, whichever is the easiest for you. Using the same method as we used to create the groundwater line, **create** an interflow line, as seen in the figure below. The interflow line represents GW1.




Now that we have the graphs determined, we are ready to begin the calculations. In SMA, Groundwater 1 variables represent interflow, and Groundwater 2 represents groundwater, or baseflow.

The SMA inputs we will be calculating are:

- Groundwater 1 Recession Coefficient
- Groundwater 1 Storage Depth
- Groundwater 2 Recession Coefficient
- Groundwater 2 Storage Depth

The recession curve, or receding limb of a hydrograph, can be described by Equation 1, below.

$$q_1 = q_0 K_r = q_0 * \exp(-\alpha t) \qquad \textbf{(1)}$$

Where $q_0$ is the initial streamflow, $q_1$ is the streamflow at a later time, t, $K_r$ is a recession constant less than 1, and $\alpha = -\ln K_r$ . The recommended time stop for streamflow regression analysis is 1 day, but you can use a shorter time step for a smaller basin. Using the area of shallowest slope of the streamflow hydrograph and Equation 1, **calculate** the Groundwater 2 $\alpha$-value for each step. If the calculation results in any negative $\alpha$-values, simply delete them. **Average** the remaining $\alpha$-values and **calculate** your Groundwater 2 Recession Coefficient using Equation 2, below.

$$Recession\ Coefficient = 1/\alpha \qquad \textbf{(2)}$$

Using the same section of the streamflow hydrograph and Equation 3, **calculate** the Groundwater 2 Storage depth for each step. **Average** the values for your final Groundwater 2 Storage Depth.

$$S_t = \frac{q_t}{\alpha} \qquad \textbf{(3)}$$

Where $S_t$ is the storage in the basin at time, t. Repeat the same calculations using the Runoff + Interflow graph to determine the Groundwater 1 Recession Coefficient and Groundwater 1 Storage Depth.

You have just finished calculating the GW 1&2 Recession Coefficients and Storage Depths for one storm! Repeat the same process for the remaining storms.

Once complete, **summarize** your values in one spreadsheet. This will allow for an easy comparison. Examine how the values change over different months or seasons. Look for any patterns or drastic differences in values; this will be an indication that you may need to consider creating two models, instead of just one. Depending on the climate of the area you are modeling, you may want to create a bi-annual model. You can split the model into wet and dry seasons, spring/summer and fall/winter, etc. Once you have determined how to split your model, if necessary, **average** each set of values for the relevant months. For example, you will have one GW1 Recession Coefficient for your dry model, one GW1 Storage Depth for your dry model, etc.

The best way to create two models is to fully develop one model, and then simply copy it and change the relevant parameters before calibrating the model. For most models, the only variables that will be different are the GW 1&2 Recession Coefficients and Storage Depths. Additional variables will most likely change after you perform an independent sensitivity analysis and calibration of each model.

You are now finished calculating the GW 1&2 Recession Coefficients and Storage Depths!

**Assign Subbasin Parameters**

**Open** the subbasin attribute table. **Start** an edit session. Use the field calculator to assign your GW 1&2 parameters to the appropriate fields. Note that there is no field for the GW 1&2 Recession Coefficients, but these will need to be added to your loss parameters once the HEC-HMS project file is complete.

Table

Subbasin36

| MaxCanopS | MaxSurfS | MaxSurfI | MaxSoilPer | SoilTensS | MaxSoilS | GW1MaxS | GW2MaxS | GW1MaxPer | GW2MaxPer |
|---|---|---|---|---|---|---|---|---|---|
| 1.343393 | 47.157513 | 8.644537 | 4.433418 | 48.052322 | 57.021179 | 2.665 | 24.201 | 4.433418 | 0 |
| 1.383342 | 42.653118 | 15.799266 | 16.278927 | 43.29966 | 58.651566 | 2.665 | 24.201 | 16.278927 | 0 |
| 1.405776 | 43.891254 | 8.73086 | 5.187195 | 47.956463 | 57.707184 | 2.665 | 24.201 | 5.187195 | 0 |
| 1.37388 | 42.627838 | 8.375101 | 4.78117 | 48.570026 | 57.315464 | 2.665 | 24.201 | 4.78117 | 0 |
| 1.38546 | 43.230289 | 9.04467 | 7.472637 | 47.849155 | 59.990242 | 2.665 | 24.201 | 7.472637 | 0 |

**Save** your map document.

You are now finished calculating all of the required input parameters for the SMA method in HEC-HMS!

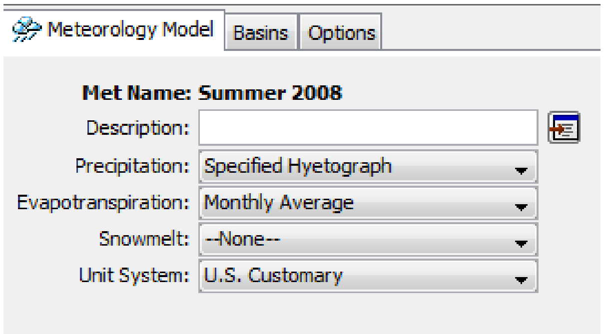
**Note**
If you are using SCS for the transform method, you will need to resume the “HMS Model Development using HEC-GeoHMS (ArcGIS 10)" tutorial exactly where you left off. You will need to repeat the “Select HMS Processes” and “Subbasin Parameters” exactly as the tutorial suggests—including selecting SCS method for loss. This is because you will need to use a curve number grid to calculate the basin lag for the SCS transform method, but for whatever reason, ArcGIS does not include this option while assigning subbasin parameters from raster if SMA is selected for the loss method. So, you need to perform the steps from the tutorial to ensure that the basin lag data is generated. Do not worry; this will not cause problems with any of the parameters we already assigned during this tutorial.

Once this is complete, resume the “HMS Model Development using HEC-GeoHMS (ArcGIS 10)" tutorial from page 18 under the heading “HMS.”

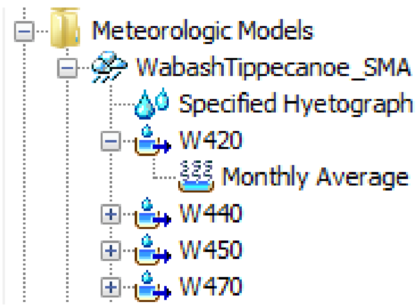
Remember to convert your units once the HEC-HMS project file has been created!

**My HEC-HMS project file has been created! I have converted my units! I am ready to start calibrating the model!**

<u>Evapotranspiration</u>
Not quite so fast. SMA requires the use of evapotranspiration data. In HEC-HMS, **click** on your Meteorologic Model. Next to Evapotranspiration, **select** Monthly Average.




You will notice that each subbasin is now listed beneath the Meteorologic Model. Using the pan evapotranspiration data for your region, provide the appropriate evapotranspiration values for each month for each subbasin. Use 0.70 as the evaporation coefficient. If you do not have data during the winter months, an estimate of 0.5 to 1.0 inches is appropriate.




<u>Baseflow</u>

Earlier in this tutorial, we selected linear reservoir to model the baseflow but did not calculate any parameters for this. For the GW 1 & 2 Coefficients, **select** values that permit the groundwater flow to travel through the reservoirs with little to no attenuation. The GW 1 & 2 initial flows and number of reservoirs are best determined during calibration.

<u>Final Note</u>

When all is said and done, you will notice that you still need values for initial storage for various parameters. If you do not have any specific data pertaining to the actual field values, just use your best judgment to determine these values during calibration.

**Primary Resources**

Bennett, T. (1998). *Development and Application of a Continuous Soil Moisture Accounting Algorithm for the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS).* Davis, CA: University of California, Davis.

Fleming, M. (2002). *Continuous Hudrologic Modeling with HMS: Parameter Estimation and Model Calibration and Validation.* Cookeville, TN: Texas Technological University.

Linsley, R., Kohler, M., & Paulhus, J. (1982). *Hydrology for Engineers.* New York: McGraw-Hill.

**Appendix**

**Table 1A**. NLCD Land Cover Class Descriptions

| Class | Description |
|---|---|
| 11 | Open Water |
| 12 | Perennial Ice/Snow |
| 21 | Developed, Open Space |
| 22 | Developed, Low Intensity |
| 23 | Developed, Medium Intensity |
| 24 | Developed, High Intensity |
| 31 | Barren Land (Rock/Sand/Clay) |
| 41 | Deciduous Forest |
| 42 | Evergreen Forest |
| 43 | Mixed Forest |
| 51 | Dwarf Scrub |
| 52 | Shrub/Scrub |
| 71 | Grassland/Herbaceous |
| 72 | Sedge/Herbaceous |
| 73 | Lichens |
| 74 | Moss |
| 81 | Pasture/Hay |
| 82 | Cultivated Crops |
| 90 | Woody Wetlands |
| 95 | Emergent Herbaceous Wetlands |

For more information, see http://www.mrlc.gov/nlcd06_leg.php

**Table 2A.** SMA Inputs in HEC-HMS (Required Parameters)

| | U.S. Customary | SI Units |
|---|---|---|
| **Loss** | | |
| Initial Soil Storage* | % | % |
| Initial Groundwater 1 Storage* | % | % |
| Initial Groundwater 2 Storage* | % | % |
| Max Infiltration | in/hr | mm/hr |
| Impervious | % | % |
| Soil Storage | in | mm |
| Tension Storage | in | mm |
| Soil Percolation | in/hr | mm/hr |
| GW1 Storage** | in | mm |
| GW1 Percolation | in/hr | mm/hr |
| GW1 Coefficient** | hr | hr |
| GW2 Storage** | in | mm |
| GW2 Percolation | in/hr | mm/hr |

| | | |
|---|---|---|
| GW2 Coefficient** | hr | hr |
| **Surface** | | |
| Initial Storage* | % | % |
| Maximum Storage | in | mm |
| **Canopy** | | |
| Initial Storage* | % | % |
| Maximum Storage | in | mm |

* Calibrated Parameters- don't need to build a raster

**Constant- don't need to build raster