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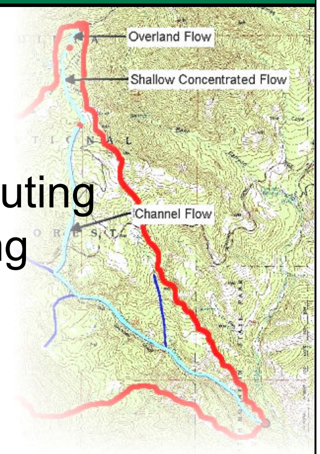
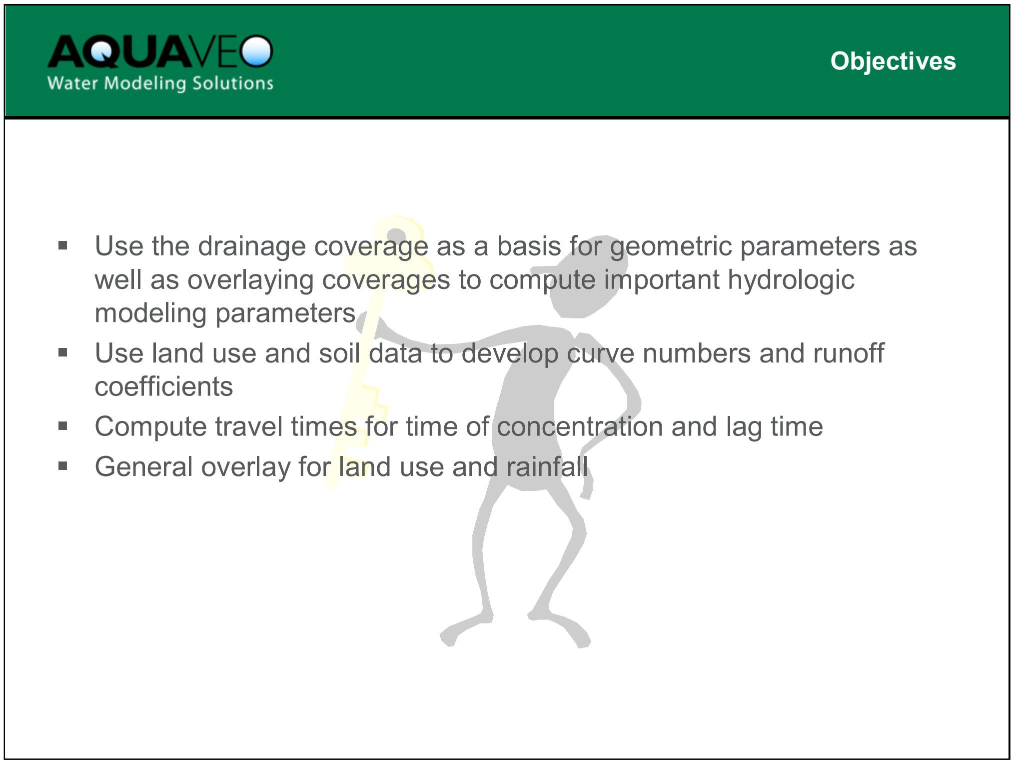
WMS Tools For Computing Hydrologic Modeling Parameters

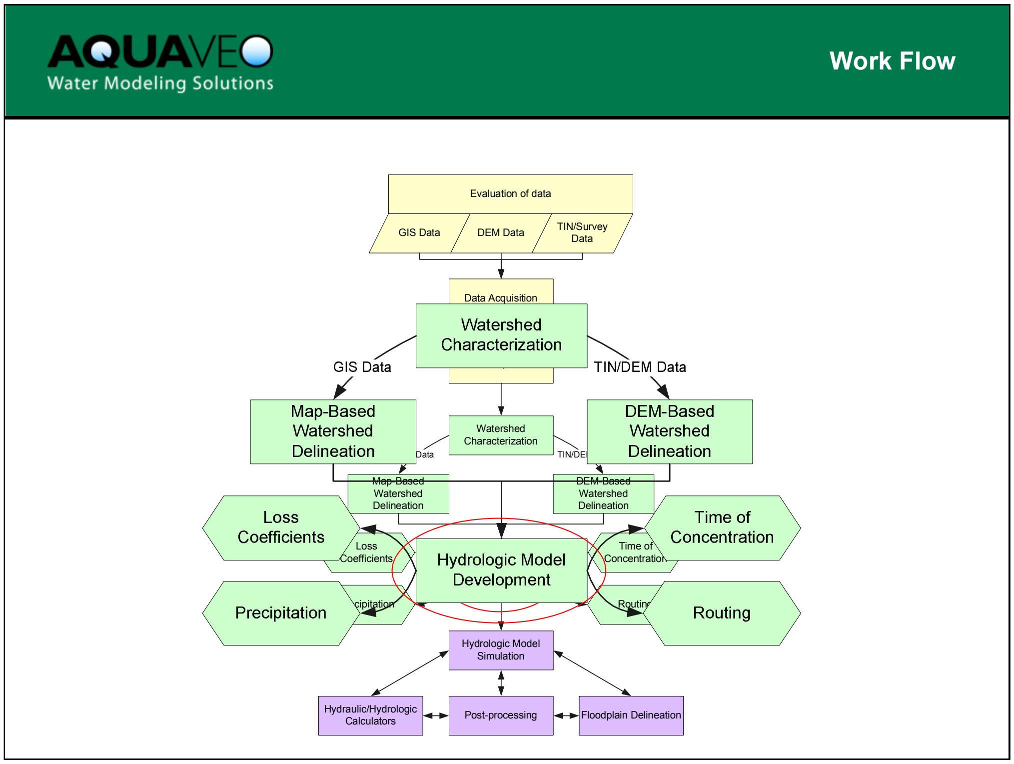


Lesson 9



Upon completion of this module, participants will be able to:

1. Understand the difference between geometric parameters computed from DEMs and other hydrologic parameters.
2. Use land use and soil data to develop curve numbers and runoff coefficients.
3. Understand the basics of overlaying coverages in WMS to compute hydrologic modeling parameters such as land use cover or rainfall depth.
4. Use WMS to compute travel time for hydrologic modeling parameter development.



In addition to the watershed delineation methods, there are important tools for the development of hydrologic modeling parameters. The drainage coverage with the delineated watershed and sub-basins serves as the primary layer of any model. Rainfall, land use, soils, and drainage path geographic data can be overlaid with the drainage coverage to compute important hydrologic modeling parameters such as rainfall depth, curve number (CN), and time of concentration or lag time.

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Hydrologic Modeling

- Precipitation
- Losses
- Runoff
- Storage
- Routing

The hydrologic cycle is a complex set of physical processes that control the distribution and movement of water throughout the environment. The viewpoint taken in this slide is that of the processes modeled by typical hydrologic simulation models. While there is no distinct point of beginning in the hydrologic cycle, a hydrologic simulation program always begins with precipitation. From there initial abstractions and losses (transpiration, evaporation, and infiltration) are subtracted to determine runoff volume. Transformation of runoff is generally modeled using unit hydrograph theory. Storage and stream routing are important features of most simulation programs.

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Hydrologic Models

- Statistical
  - National Streamflow Statistics
- Deterministic
  - HEC-1 and HMS
  - TR-55 and TR-20
  - Rational

There are two primary classes of hydrologic simulation models: statistical and deterministic. Statistical models use an analysis of historical records such as stream flow or precipitation to infer design values for different return periods (e.g. 10 year or 100 year). A deterministic model on the other hand uses a series of input parameters such as rainfall depth, watershed infiltration parameters and unit hydrographs to determine runoff from physical processes.

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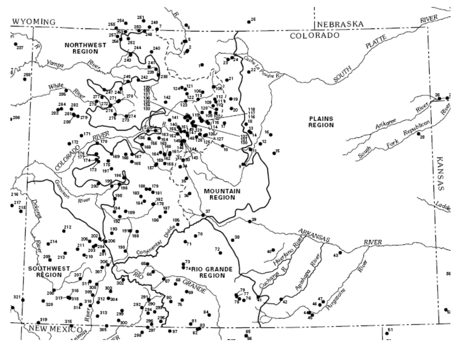
Statistical Modeling – National Streamflow Statistics (NSS)

Historical records are used from gaged basins to estimate peak discharge in ungaged basins. Indicator variables such as area, precipitation, slope, and land cover are used. For example:



$$Q_T = aA^bS^cP^d$$

where:

Q_T - T-year peak discharge
A - drainage area
S - channel slope
P - mean annual precipitation
a,b,c,d - regression coefficients

The FHWA, FEMA, and USGS have combined to develop a database of regional regression equations for each state. The database is referred to as the National Streamflow Statistics or NSS program. These equations are applied to similar hydrologic regions (as shown for Colorado in this picture) by using historical information from gages within the region. Peak discharges for ungaged basins lying within the region can be determined by using indicator variables such as area, slope, and precipitation.

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NSS Required Parameters

- Geometric
  - Area
  - Slope
  - Elevation
- Hydrologic
  - Land Cover (forested, water, etc.)
  - Rainfall depth (annual or event)
  - Lag Time

All of the regression equations require area as a basic indicator variable. Many require other geometric parameters such as slope or elevation. Some require other hydrologic parameters that cannot be derived from a DEM. These parameters might include the percentage of a certain type of land cover (for example forested, or water), soil type, or a rainfall depth (annual average or some event like the 2-yr 24-hour).

In order to estimate a runoff volume a lag time must be computed from empirical equations.

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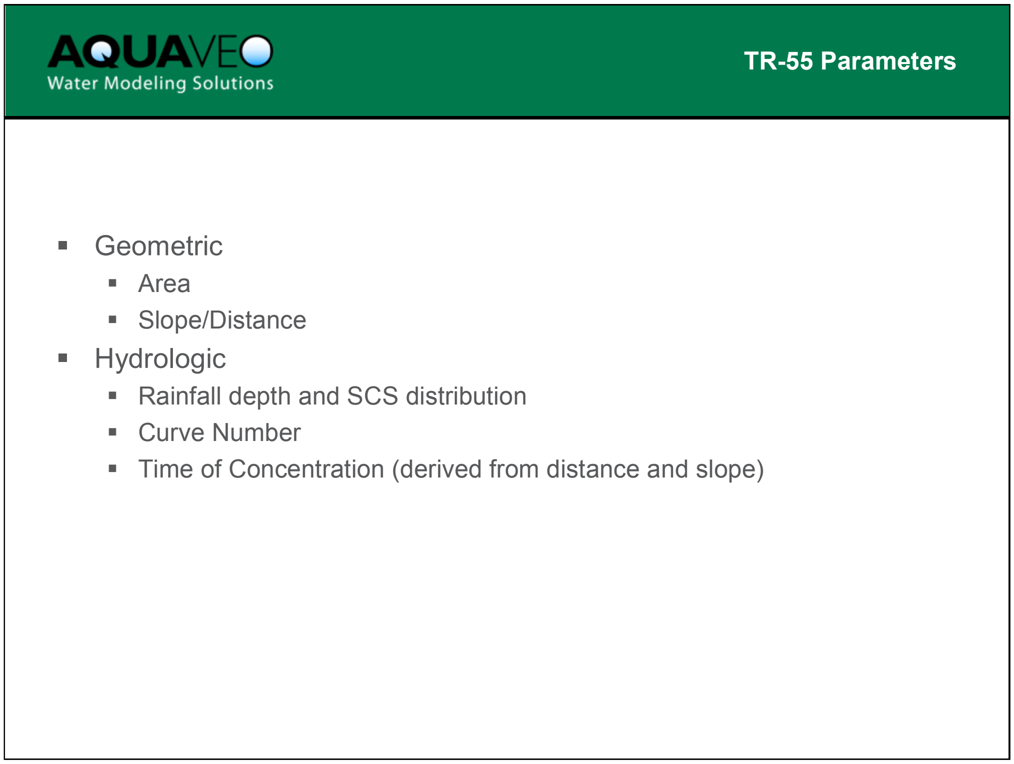
Deterministic Models – SCS Methodologies (TR-55)

- Rainfall
  - Depth plus distribution
- Losses
  - SCS Curve Number (CN)
  - Runoff coefficient
  - Indexed infiltration
- Transformation
  - Unit Hydrograph
  - Needs time of concentration or lag time

The SCS methodologies will be used here to illustrate the kinds of hydrologic parameters typically required of deterministic models. Some of these parameters include rainfall depth (and an included temporal distribution), losses from a runoff coefficient or CN value, and a time of concentration or lag time used in conjunction with a unit hydrograph.



Like the statistical models a deterministic model such as TR-55 requires the area to be delineated first. In order to complete the parameterization of TR-55 a rainfall depth and SCS temporal distribution must be defined, a CN is used for calculating losses, and a time of concentration is used in conjunction with the SCS unit hydrograph.

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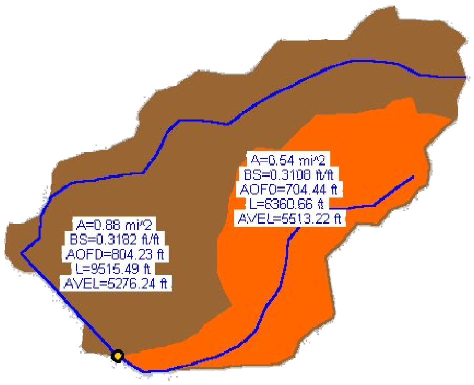
Hydrologic Modeling Parameters

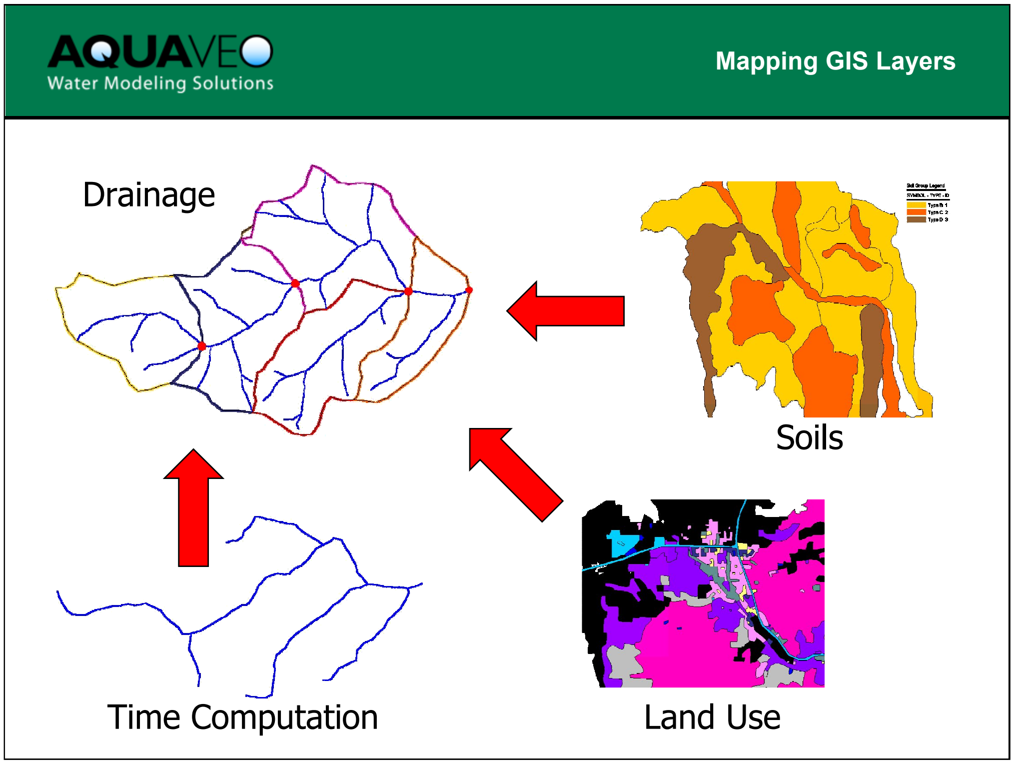
Geometric Parameters

Hydrologic Parameters



Curve Number
Runoff Coefficient
Rainfall Depth
Time of Concentration

As can be seen, both types of hydrologic models have two classes of input: geometric watershed parameters such as slope, area, etc. and hydrologic watershed parameters such as runoff coefficient, rainfall depth, and time of concentration. So far you have learned how to use WMS to automate the calculations of many of the geometric parameters while creating a drainage coverage. In this lesson you will learn how to overlay rainfall grids, or stations to develop rainfall depth for modeling. You will also learn how to use land use and soils coverages to compute weighted CN or runoff coefficient numbers and flow paths for developing time of concentration or lag time.



Some of the coverages that can be used to overlay with the drainage coverage include: Land Use, Soil, Rainfall, Time Computation (lines rather than polygons). Most coverages are vector data, but some such as rainfall can be raster.

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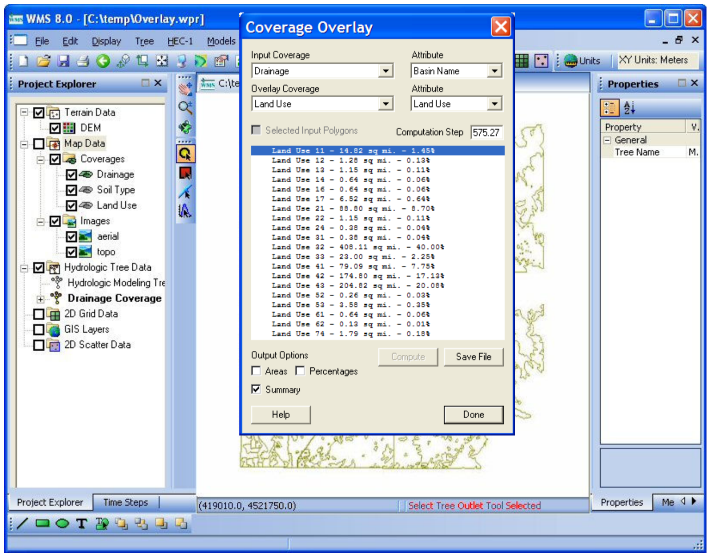
Applications

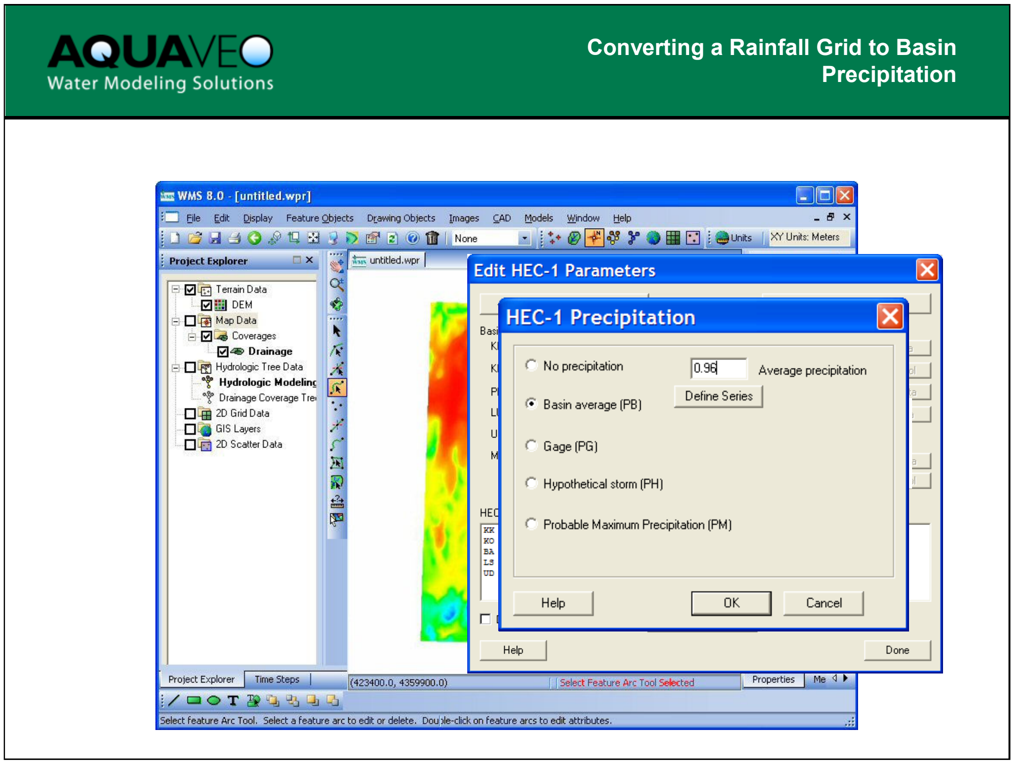
- General Overlay Percent Area Classifications
- Rainfall
  - Using Grids
  - Thiessen Polygons
- NRCS (SCS) Curve Numbers
- Rational Runoff Coefficients
- Green-Ampt Parameters
- Time of Travel (T_c and T_{lag})
- Time Area Curves

Applications of map overlay include computing composite parameters for hydrologic models, such as Curve Number (CN), Green-Ampt parameters, runoff coefficients, and travel times.

General Polygon Overlay for Land Use Classification



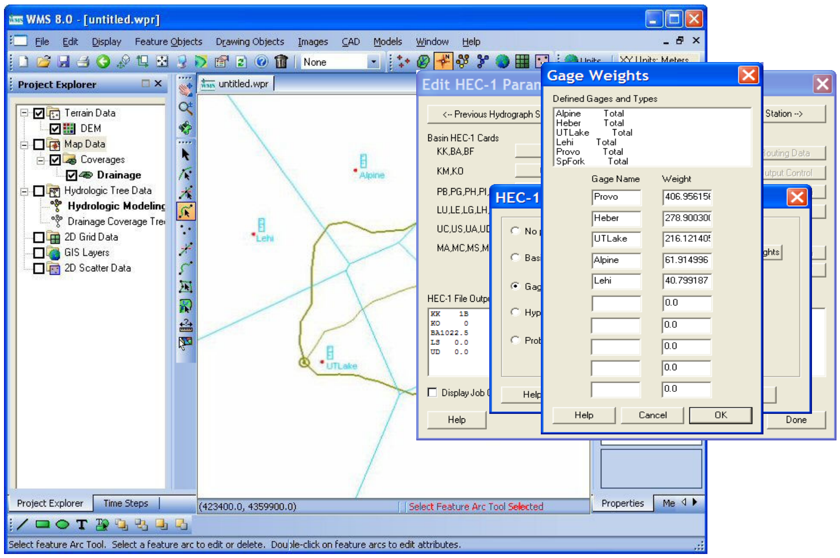
While WMS has specific functionality to compute CN, runoff coefficients, and Green and Ampt Parameters, you can also overlay any two coverages to determine the area/percent of coverage between the two. For example if you wish to know the percentage of forest cover or lake cover for a drainage basin, you can overlay a land use coverage with the drainage coverage and determine the area/percent of each land use classification, including forests or lakes as long as they are properly designated within the land use coverage.



Grids as well as coverages can be used to interpolate land use, soil, or even rainfall to basin averages. NOAA has available the 2-year and 100-year 6 hour and 24 hour rainfall maps for the 11 western states covered by Atlas 2 and will likely publish other products as they are available. This site is accessible through the GSDA site at http://www.xmswiki.com/wiki/GSDA:GSDA. In the case of the NOAA Atlas 2 maps, the precipitation values are in units of inches*100,000 so you will need to divide the value computed by WMS by 100,000 in order to have the correct value in inches. When reading in the maps, you will be prompted to convert the coordinate system, because the native coordinate system is geographic (latitude/longitude). Since you cannot convert the rainfall grid separately, it is suggested that you read it in at the beginning of the project so that the coordinate system can be converted without affecting other data. If you have GIS you may also prefer to process the files once (coordinate system and units of rainfall) and store it in ASCII grid format so that it is not necessary to do so each time you use the data in WMS.

Other local agencies may also have rainfall data that can be converted to an ASCII grid format and used with WMS.

Using Gages to Define Thiessen Polygons



You can use a rain gage coverage to define rainfall at a point and have WMS automatically calculate Thiessen polygon weights for watersheds. Currently, this option is only supported within the HEC-1 model, which allows at most five gages per basin. For this reason the smallest percentage polygon (SpFork) in the figure above does not appear in the list. Areas are displayed for the weights, but HEC-1 always normalizes the values.

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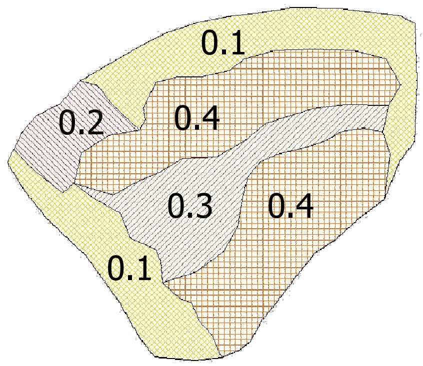
Automating Runoff Coefficient Calculations

- Soil Type or Runoff Coefficient Coverage (Grid or Polygons)
- Table Relating ID to Runoff Coefficient

Runoff Coefficient	Soil Description
0.10	Type1
0.20	Type2
0.30	Type3
0.40	Type4
0.50	Type5
0.60	Type6
0.70	Type7



Runoff coefficients for use with the Rational Method can be computed in WMS by:

• Delineating a watershed

• Reading a Soil coverage/grid

• Importing or creating a table relating soil ID to runoff coefficient (0.0 –1.0)

• Compute Runoff Coefficient

WMS will report composite runoff coefficients for each basin based on these data.

The runoff coefficient coverage can also be used to map CN values to basins. While it is not common to find a map of CN values, they have been generated by some local agencies. To use the runoff coefficient coverage to map CN, values for CN should be entered as numbers between 0.0 and 1.0 rather than 0 and 100. For example a CN of 75 would be defined in the runoff coefficient coverage as .75.

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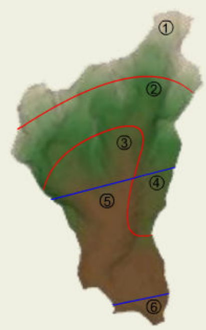
The Curve Number

Soil Type

Land Use

Curve Number



LU	Land Use Description	A	B	C	D
1	Dense Forest	64	69	74	77
2	Agricultural	52	58	66	75
3	Urban Area	82	87	93	98

Site	Area	Soil	Land Use	CN	CN Weighted
①	10	A	Dense Forest	64	11.4
②	17	B	Dense Forest	69	20.9
③	9	D	Dense Forest	77	12.4
④	4	B	Agricultural	58	4.1
⑤	14	D	Agricultural	75	18.7
⑥	2	D	Urban Area	98	3.5
	56		Composite CN=		71

A task that is commonly automated with spatial data (especially when you have existing GIS data for soil types and land use) is the computation of a composite (area-weighted) curve number. The Curve Number, commonly referred to simply as CN, is based on two physical properties: Soil type and Land Use. A table relating these two physical properties to the CN value, a number ranging from no runoff of 0 to complete runoff at 100, is used to perform the calculations.

The curve number is used in several models, including HEC-1, HMS, TR-20, and TR-55.

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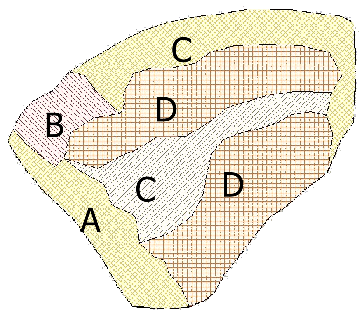
Hydrologic Soil Classifications

- A - High Infiltration Rates
- B - Moderate Infiltration Rates
- C - Slow Infiltration Rates
- D - Very Slow Infiltration Rates



The soil type coverage should contain the hydrologic soil classifications for each soil type represented. The following are four classifications with representative infiltration rates given:

A - high infiltration rates

.30 - .45 in/hr (sands, deep loess, aggregated silts)

B - moderate infiltration rates

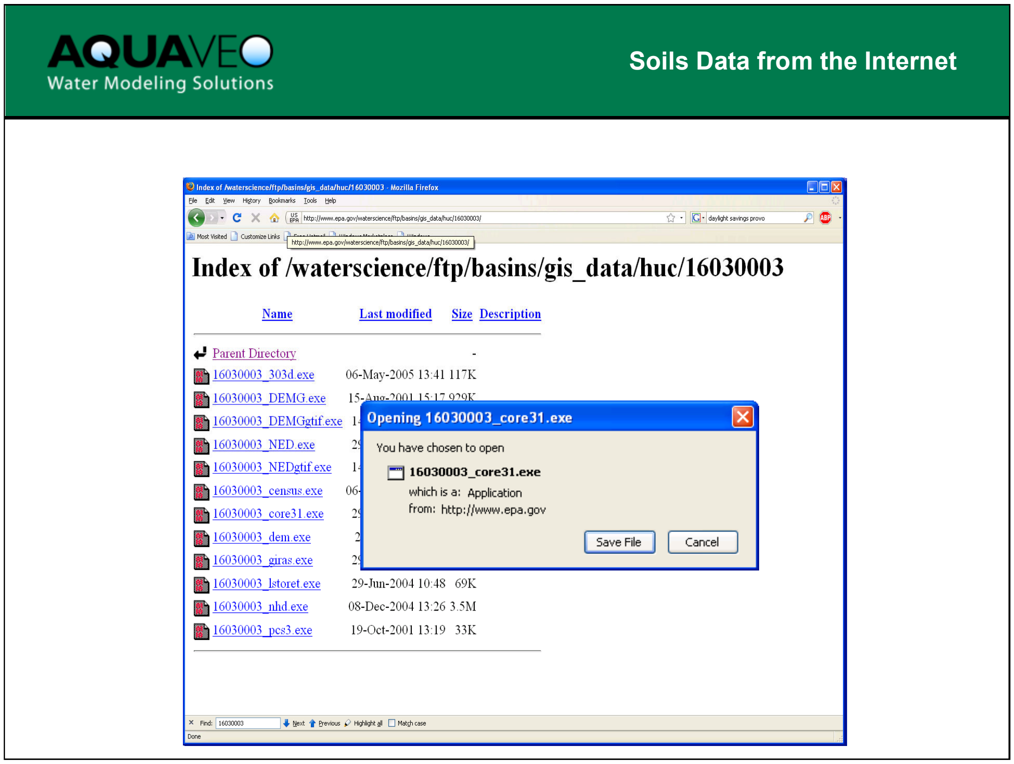
.15 - .30 in/hr (shallow loess and sandy loams)

C - slow infiltration rates

.05 - .15 in/hr (clay loams, low organics, high clay)

D - very slow infiltration rates

0.0 - .05 in/hr (high water table, clay layer near surface)



Start at the geospatial data acquisition site:
http://www.xmswiki.com/wiki/GSDA:GSDA

As part of the EPA's BASINS program the NRCS Statsgo data have been compiled in shapefile format so the best location for download is the EPA Basins site. You will need to get your watershed HUC (A watershed ID number), so use the link on the GSDA website to find the watershed containing your modeling area. Once you have the HUC code you can go to the EPA ftp site and download the "core" data for your watershed. This will include the NRCS soils file in addition to many other datasets that cover your watershed.

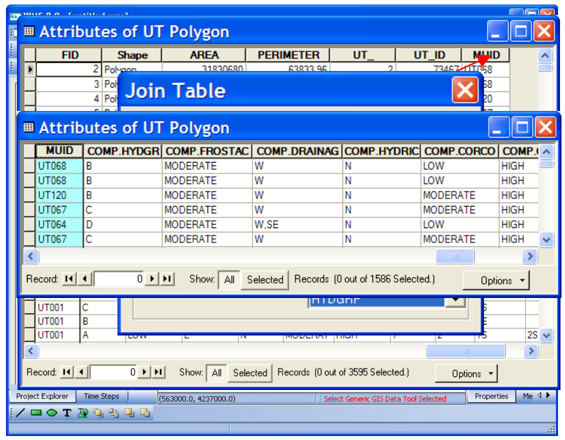
Some counties or other local agencies may also distribute Statsgo, or even better Ssurgo data (Statsgo is lower resolution at a statewide level whereas Ssurgo is higher resolution at a county level) so you may wish to check locally to see if you can obtain these products.

The data will be in latitude and longitude (geographic) coordinates so you will need to convert the shape file to UTM, state plane, or some other planimetric coordinate system.

Water Modeling Solutions

Joining Tables

- Joining the HYDGRP attribute
  - Open soils file as a GIS layer
  - Join to COMP.DBF based on MUID



In the shape file database file for Statsgo soils only part of the attributes are stored. The Hydrologic soil group attribute, necessary to compute a CN is stored in a separate table that needs to be “joined” to the feature attribute table. The geometry table always has an attribute named MUID and the accompanying table holding the additional attributes (usually named statsgoc.dbf or comp.dbf) also as a field named. In the GIS module you can join two tables based on a common field. With ArcObjects enabled the standard ArcView DLL’s are used to perform the join.

Joining the HYDGRP attribute to the feature table involves the following steps:

• Open the soils database you wish to use in the GIS module

• Right click on the soils layer in the Tree Data Window and choose the Join Table to Layer… option.

• Specify the table you wish to join (almost always this will be called statsgoc.dbf, or COMP.DBF).

• Make sure that the fields from both databases are set to MUID.

• If you want you can join all attributes, or you can just join the HYDGRP attribute (without ArcObjects only).

You are now ready to convert the layer to a soils coverage and use it for mapping.

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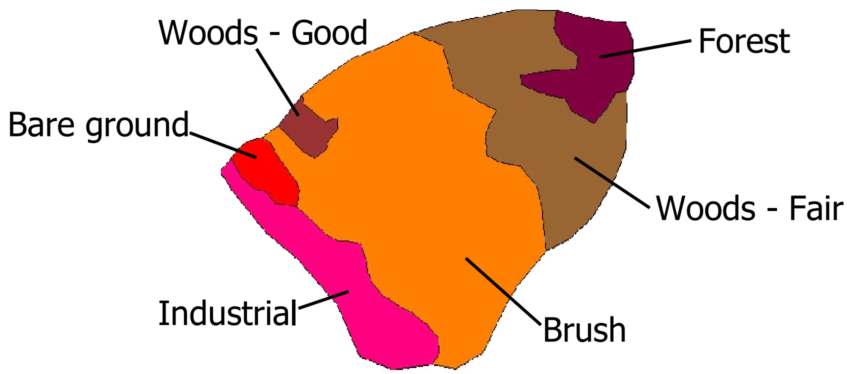
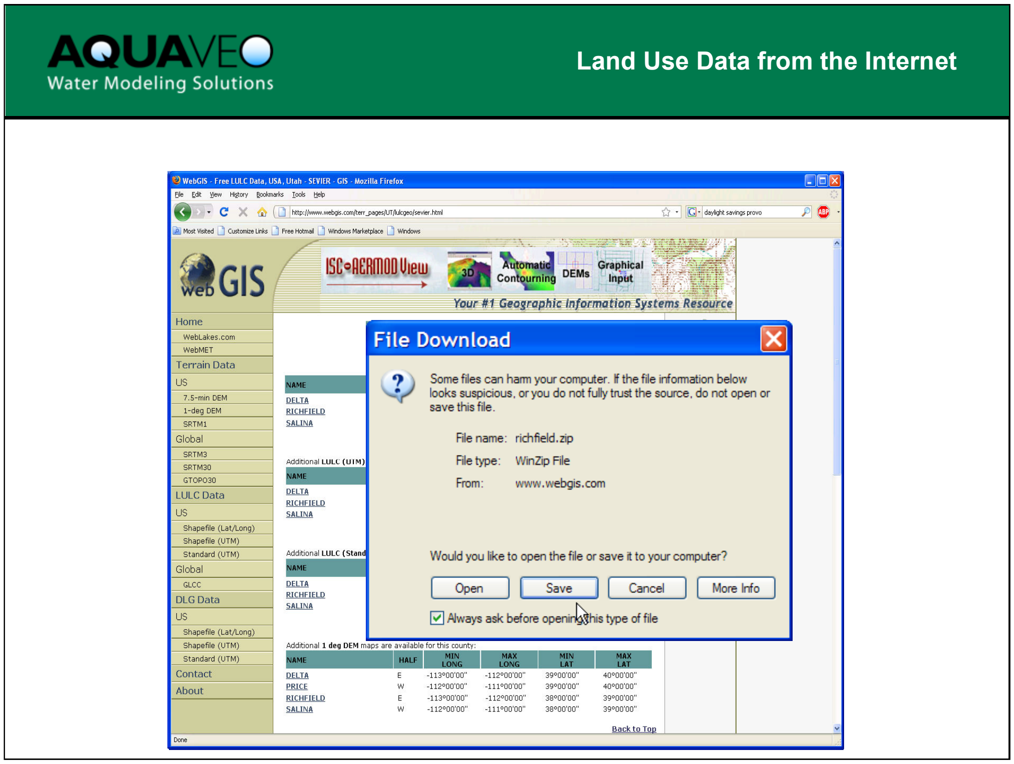
Land Use

- How well water is retained on the land surface until it can transpire, evaporate, or infiltrate



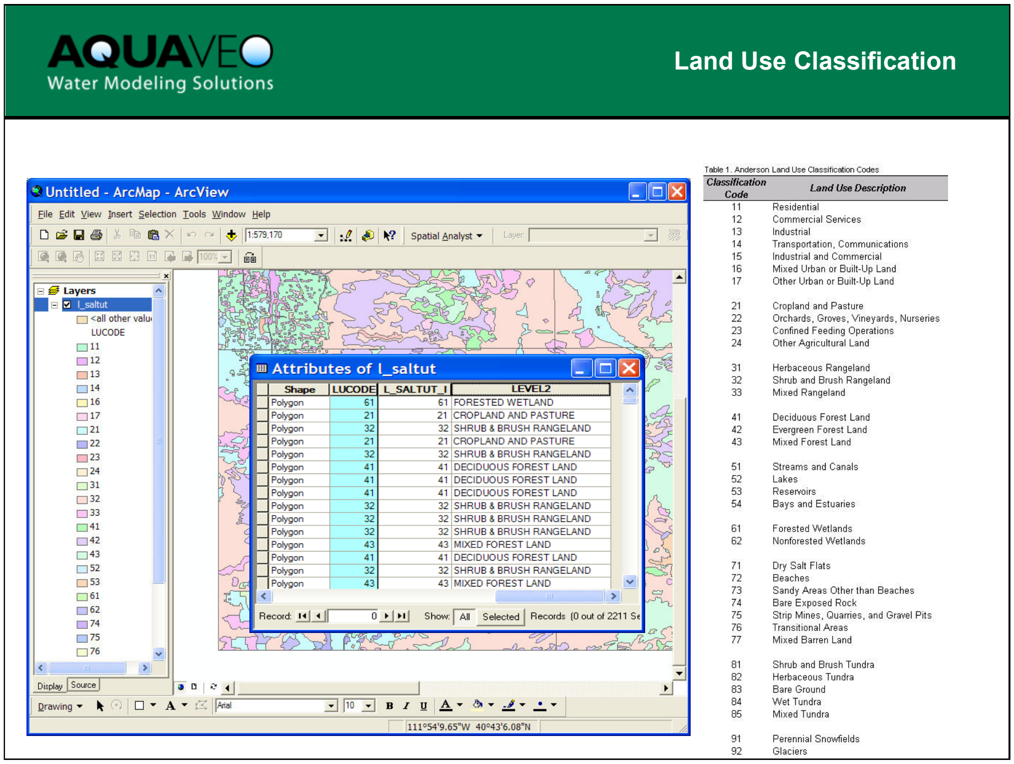
The land use affects how water is retained on the land surface until it can transpire, evaporate, or infiltrate. Thus, the curve number is affected by the land use.

Note that care should be used when accounting for impervious areas. An impervious area would have a high CN value. If the impervious area is factored into the composite CN, then you should not enter the percent impervious separately as is possible in many hydrologic models (like HEC-1).



The EPA BASINS website provides land use shapefiles by watershed. Data is retrieved similar to STATSGO data retrieval. First locate the HUC code for your watershed and then find the link corresponding to your HUC code. Land use data is stored in the “giras” dataset.

The WebGIS website (one of the popular sites for downloading USGS DEMs) also has the land use files in shapefile format in geographic or UTM coordinates. This site also has the files in “standard” USGS format, but WMS cannot open/read this file format. Once you download the files from either site you will need to open directly into a land use coverage (WMS should recognize and map the land use classification code LUCODE automatically), or load as a GIS layer, select the polygons that overlap your watershed, and convert to a WMS land use coverage.



The EPA BASINS website provides land use data in shapefile format for individual watersheds. As with the soils data, you must first locate your HUC.

The USGS has a standard classification system to describe different types of land use. The downloadable land use files all use this classification system and you will find an attribute in the feature attribute table (you don't need to join a separate table as with the soils) named LUCODE that has the classification ID and an attribute named LEVEL2 that has the description. As can be seen values in the 10-19 range are reserved for developed/urban land use, 20-29 are agricultural, 30-39 are rangeland, 40-49 are forested land, 50-59 are water covered land uses, 60-69 wetlands, 70-79 barren land, 80-89 tundra, and 90-99 perennial snow or ice covered. The image above which shows the complete description may be hard to read, but a complete listing in a text file can be found in the WMS "docs" directory with the rest of the model documentation.

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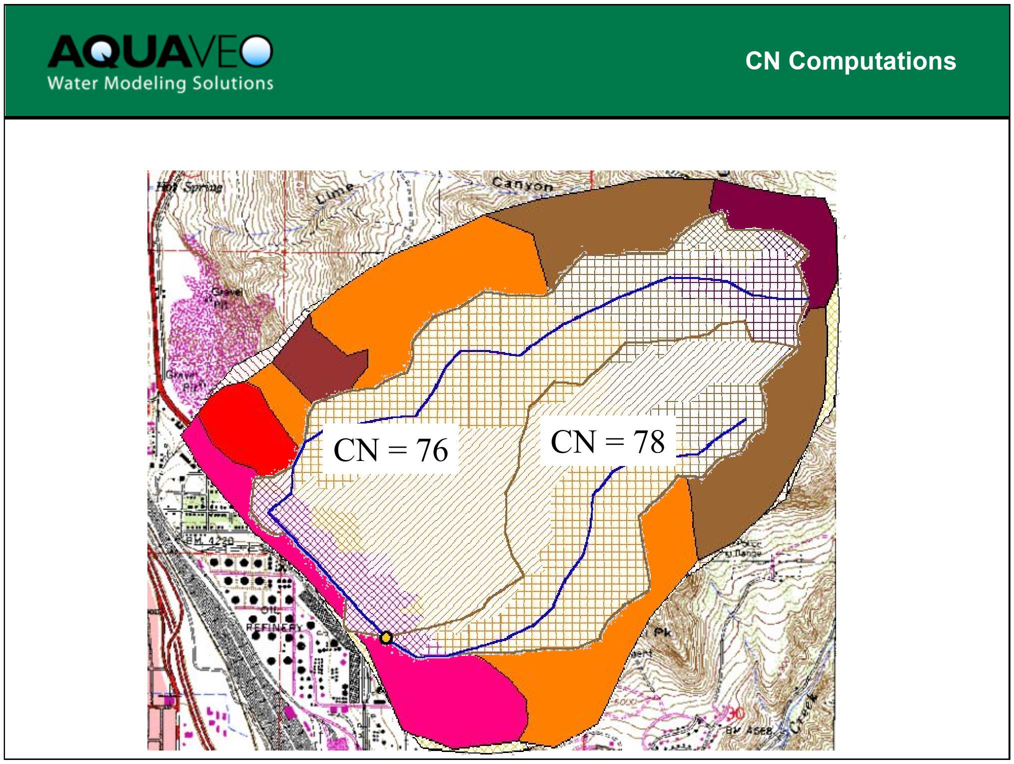
Curve Number Table

ID	Land Use	A	B	C	D
11	Residential	94	95	97	99
12	Commercial and services	96	97	98	99
21	Cropland and pasture	68	79	86	89
22	Orchards, groves, vineyards, etc.	49	69	79	84
23	Confined feeding operations	39	61	74	80
31	Herbaceous rangeland	30	58	71	78
41	Deciduous forest land	57	73	82	86
42	Evergreen forest land	43	65	76	82
43	Mixed forest land	32	58	72	79

For each of the land use classifications, a curve number for each of the four hydrologic soil groups must be defined in a table. This table can be defined once and then used for all studies. The data can be entered in the WMS interface, or by direct input into a text file. A portion of a curve number table is shown here.

Most hydrology texts/handbooks include tables which can be used for defining your own CN values for the Anderson, or other land use classification systems.



The steps to compute composite Curve Numbers in WMS are:

1. Delineate a watershed.
2. Create/Read soil type and land use data (grid or polygon coverages).
3. Read in a table relating land use and soil type to curve number.
4. Compute CN.

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Automating Green-Ampt Parameter Calculations

- Soil Type (Grid or Polygon)
- Land Use (Grid or Polygon)
- Two Tables

Soil type to XKSAT, RTIMP, %Effective

ID	XKSAT	RTIMP	Pct. Effective	Soil Description
3	0.58	0.00	0.00	Antho-Carrizo-Maripo complex
6	0.62	50.00	0.00	Anthony-Arizo complex
8	0.96	50.00	0.00	Arizo cobbly sandy loam
10	0.94	50.00	0.00	Brios-Carrizo complex, 1-5% Slopes
13	0.01	50.00	0.00	Carefree-Beardsley complex
22	0.04	50.00	0.00	Contine clay loam
24	0.02	50.00	0.00	continental clay loam, 0-3% Slopes

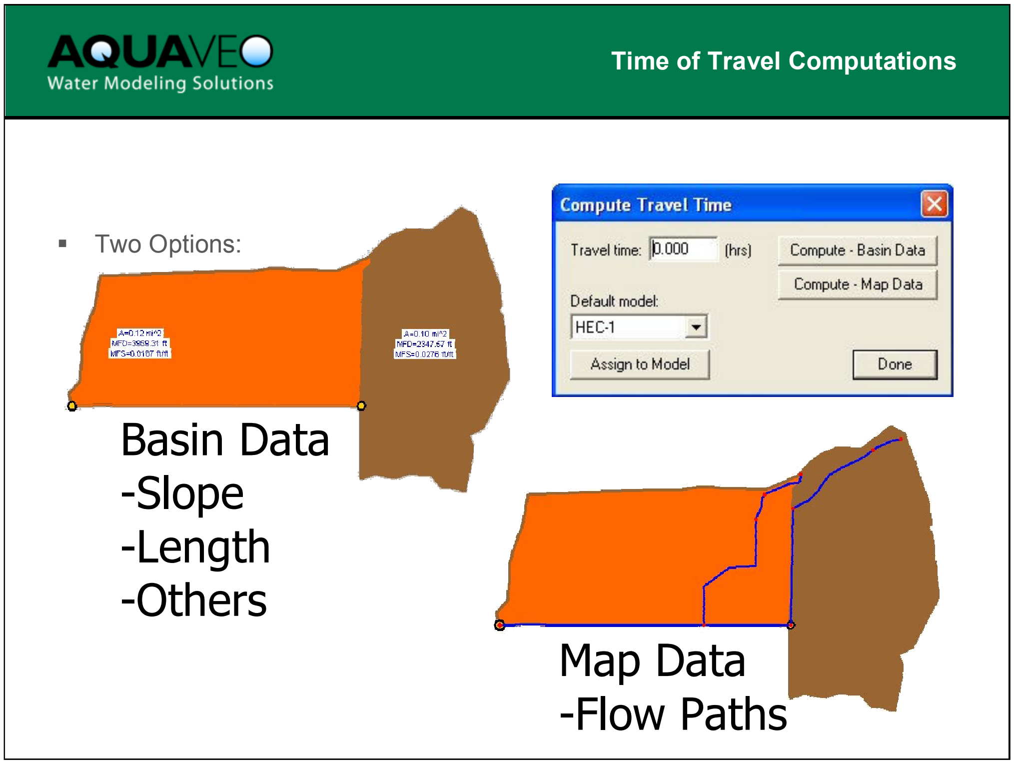
Land use to Ia, RTIMP, %Vegetation

ID	IA	RTIMP	Percent Veg.	Land Use Description
76	0.300	15.00	50.00	Low Density Residential
77	0.250	30.00	50.00	Medium Density Residential
80	0.300	15.00	50.00	Public and Quasi-Public
82	0.150	55.00	60.00	Retail/Commercial
86	0.250	45.00	50.00	Vacant

Green-Ampt parameters may be used with HEC-1 to model losses. These parameters can be computed in WMS by:

- Delineating a watershed.
- Defining land use and soil type.
- Reading two tables relating: Soil type ID to XKSAT, RTIMP, % Effective and Land use ID to Ia, RTIMP, % Vegetation.
- Compute Green-Ampt parameters.

Based on these data, WMS will compute composite values of Ia, DTHETA, PSIF, XKSAT, and RTIMP.



WMS offers two methods of time of travel computations:

1. Basin Data – an equation can be chosen which computes time of travel based on general basin data such as maximum flow length, slope, and other such parameters. This is the easiest way to compute time of travel.
2. Map Data – equations are applied to flow path arcs which compute time of travel based on flow type, slope, length, etc. This can be a more accurate way of computing time of travel, but it is more time consuming.

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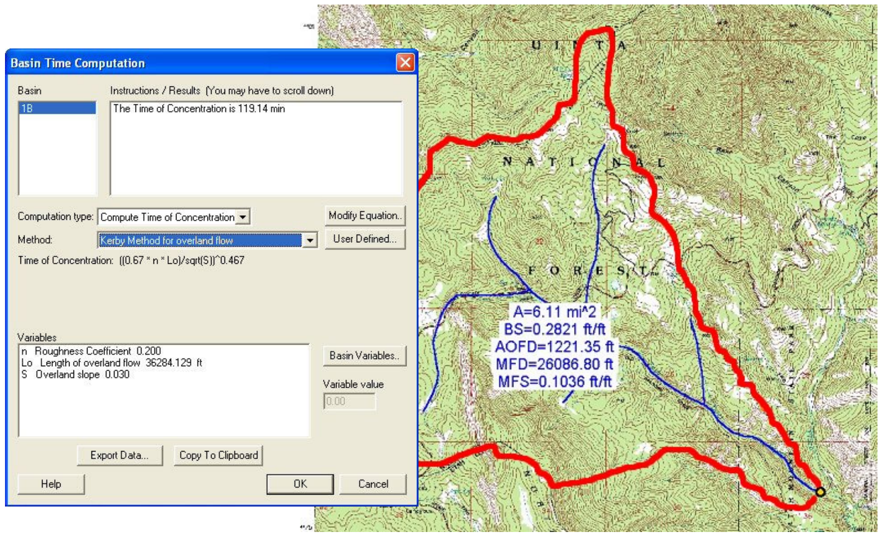
T_{lag} and T_c – Basin Data



Once a watershed has been delineated and basin data computed, Tc or lag time can be computed quickly by selecting one of the methods in the Basin Time Computation dialog. If you have a specialized equation for your area, this equation can be entered in this dialog by selecting the User-Defined method, then entering the equation.

The value for each variable used in the selected equation can be reviewed or changed in this dialog. The time of travel will be computed once all variables have been assigned a value.

Equations are organized into two groups: Time of Concentration equations and Lag Time equations. You may use either set of equations, but WMS will use the conversion 0.6Tc = Tlag if one type of equation is used to compute a time for the other.

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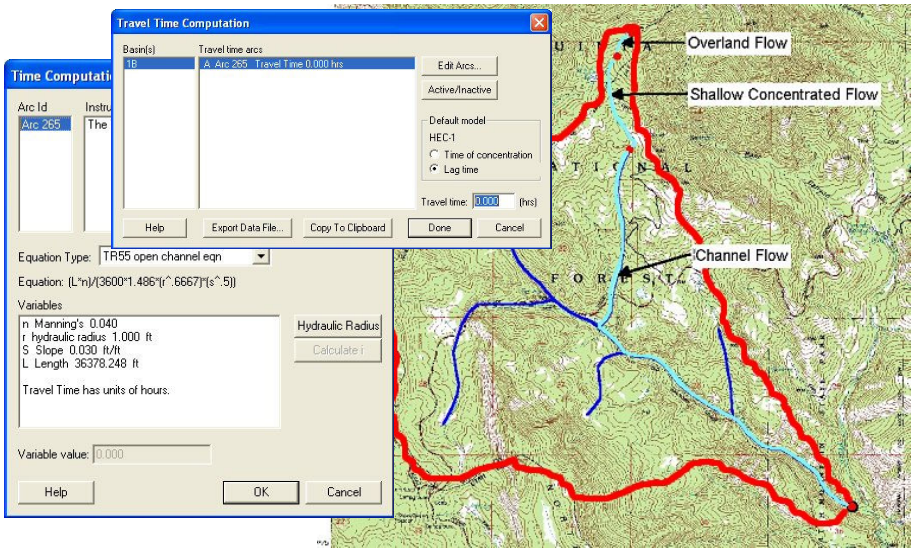
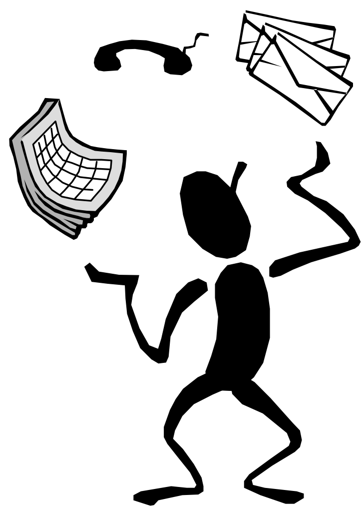
T_{lag} and T_c – Map Data

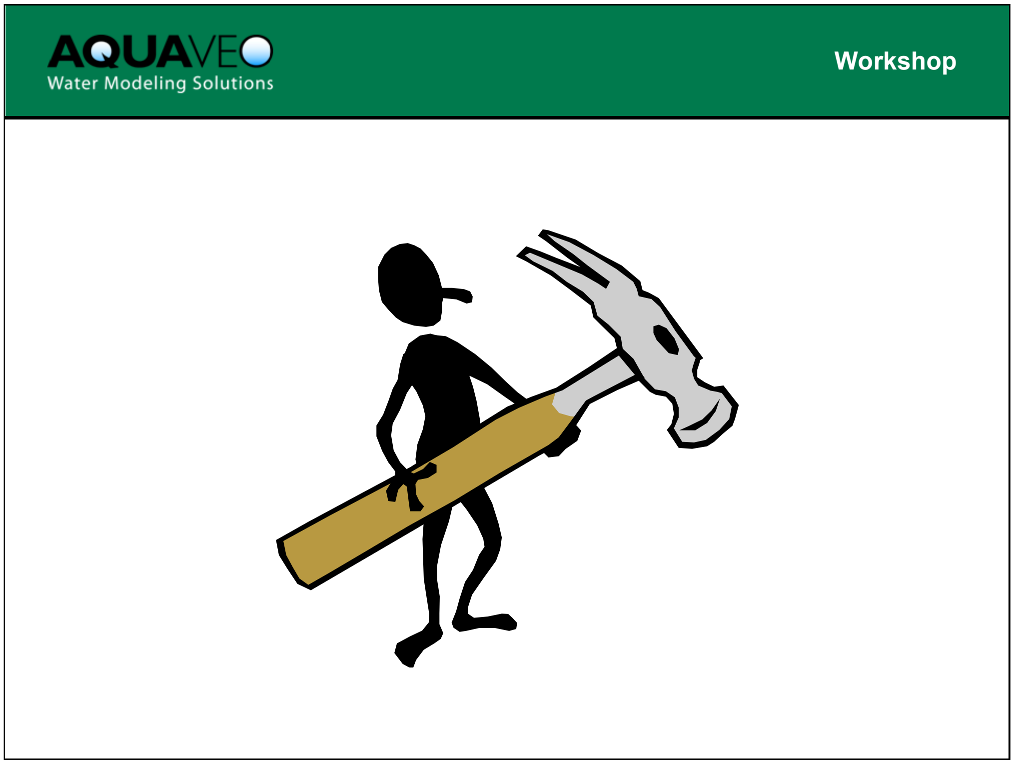


Time of travel computed from Map Data (feature objects) is based on arcs that represent flow paths (likely the longest) in a basin. An equation is assigned to each arc (equations may be chosen from a library of common equations or user defined). Length and slope are determined automatically, but other parameters such as Manning's n, channel size, etc. must be defined manually. Finally, travel time for each arc is computed and then summed with times from other arcs in a given basin to define the basin travel time.

Water Modeling Solutions

Demonstration





There are two workshops in this lesson. The files used for these workshops can be found in the tutorials directory in the folder named **tr-55**.

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Review & Discuss

- Objectives
  - Use land use and soil data to develop curve numbers and runoff coefficients.
  - Understand how WMS overlays coverages to compute important hydrologic modeling parameters.
  - Use WMS to compute travel time for hydrologic modeling parameter development.
- Applications