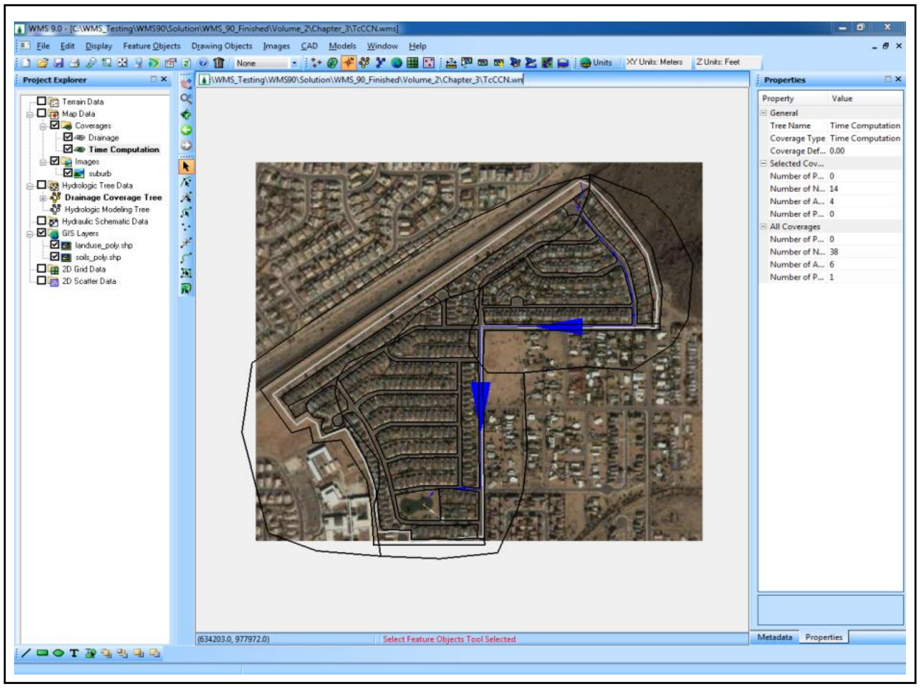
v. 10.1

WMS 10.1 Tutorial

Watershed Modeling – Time of Concentration Calculations and Composite CN

Compute hydrologic parameters such as sub-basin time of concentration and curve number



Objectives

Learn how to compute coverage overlay percentages, time of concentration, and curve numbers for sub-basins and how to apply these parameters to a TR-55 model.

Prerequisite Tutorials

- Watershed Modeling – DEM Delineation

Required Components

- Data
- Drainage
- Map
- Hydrology
- Hydrologic Models

Time

- 30–60 minutes

1 Introduction

This tutorial discusses tools that are helpful in calculating the time of concentration (Tc) and in computing a composite curve number (CN). In particular, two models, the United States Geological Survey's (USGS) National Streamflow Statistics (NSS), and the Natural Resources Conservation Service's (NRCS) TR-55, will be discussed.

2 Getting Started

Starting WMS new at the beginning of each tutorial is recommended. This resets the data, display options, and other WMS settings to their defaults. To do this:

1. If necessary, launch WMS.
2. If WMS is already running, press *Ctrl-N* or select *File* | **New…** to ensure that the program settings are restored to their default state.
3. A dialog may appear asking to save changes. Click **No** to clear all data.

The graphics window of WMS should refresh to show an empty space.

3 Opening the Drainage Basin

First, import a WMS project file containing a DEM previously downloaded from the Internet. A single watershed basin has been delineated from the DEM data and converted to feature objects.

1. Select *File* **| Open** to bring up the *Open* dialog.
2. Select "Project Files (*.wms)" from the *Files of type* drop-down.

3. Browse to the nss\nss\ folder and select “NSS_FL.wms”.
4. Click **Open** to import the project and exit the *Open* dialog.

A pre-delineated basin will appear in the Main Graphics Window (Figure 1).

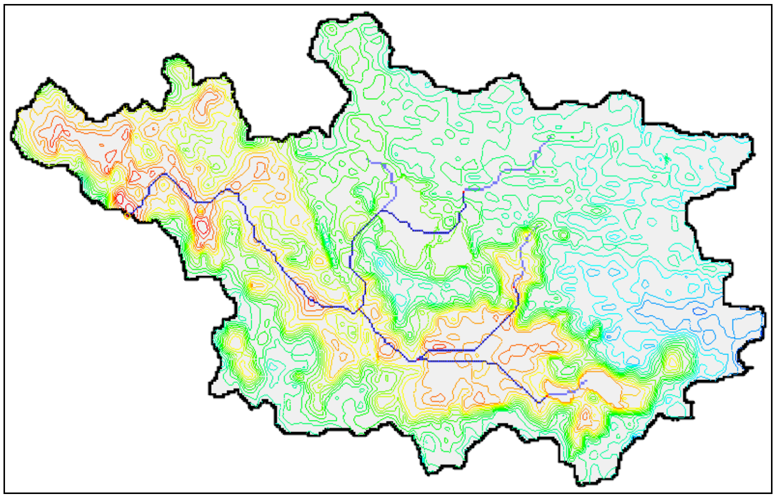


Figure 1 Initial pre-delineated basin

4 Preparing the Basin for Use with NSS

Now use WMS to calculate the basin area, basin slope, and other parameters that can be used in conjunction with NSS.

1. Switch to the **Drainage**  module.
2. Select *DEM* | **Compute Basin Data** to bring up the *Units* dialog.
3. Click **Current Projection...** to bring up the *Display Projection* dialog.
4. In the *Vertical* section, select “Meters” from the *Units* drop-down.
5. In the *Horizontal* section, click **Set Projection…** to bring up the *Select Projection* dialog.
6. On the *Projection* tab, select “METERS” from the *Planar Units* drop-down.
7. Click **OK** to close the *Select Projection* dialog.
8. Click **OK** to close the *Display Projection* dialog.
9. In the *Parameter units* section, select “Square miles” from the *Basin Areas* drop-down.
10. Select “Feet” from the *Distances* drop-down.
11. Click **OK** to compute the parameters and close the *Units* dialog.

4.1 Display Settings and Appearance

In order to see the parameters that will be used with the NSS program, turn them on.

1. Select *Display* | **Display Options…** to bring up the *Display Options* dialog.

2. Select "Drainage Data" from the list on the left.
3. On the *Drainage Data* tab, turn on *Basin Slopes* and *Basin Areas*.
4. Click **OK** to close the Display Options dialog.

Basin attributes are displayed at the centroid of the basin. In order to see the parameters more clearly, turn off the DEM visibility.

5. Expand the " Terrain Data" folder in the Project Explorer and turn off " DEM".

The project should appear similar to Figure 2.

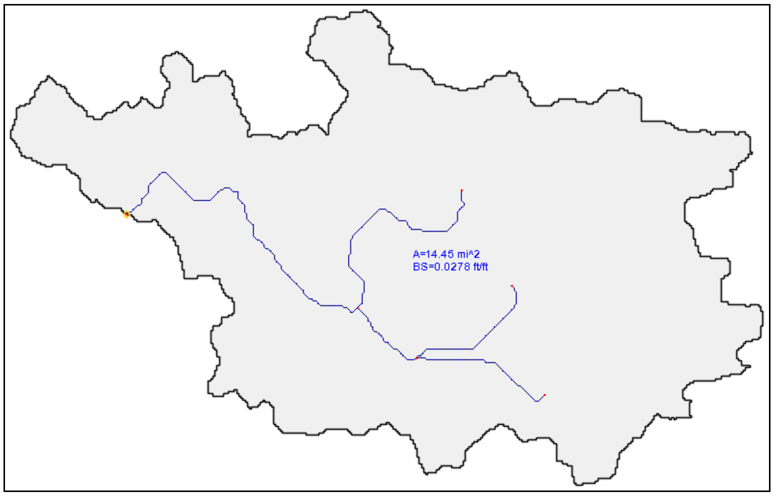


Figure 2   Drainage basin with parameters computed

5 Calculating Percentage of Lake Cover

The regression equation for Rural Region 2 of Florida includes a parameter (LK) to define the ratio of the area of lakes in the basin to the total basin area (as a percent). Use the Compute Coverage Overlay calculator in WMS to calculate the percentage of lake cover in the drainage basin.

The only other parameter in the regression equation for Rural Region 2 of Florida is drainage area (DA). This is automatically computed using the Compute Basin Data command.

5.1 Opening the Land Use Coverage

To compute the percentage of lake cover in the watershed, import land use data from a typical USGS land use file. Each polygon in the coverage is assigned a land use code that corresponds to a land use type. For this land use coverage, the codes for water bodies (lakes, reservoirs, wetlands) include 52, 53, 61, and 62. Look for these codes to determine the value for LK.

1. Right-click on " Coverages" in the Project Explorer and select **New Coverage** to bring up the *Properties* dialog.
2. Select "Land Use" from the *Coverage type* drop-down.

3. Click **OK** to close the *Properties* dialog.
4. Right-click on " GIS Data" and select **Add Shapefile Data…** to open the *Select shapefile* dialog.
5. Select "valdosta.shp" and click **Open** to import the shapefile and close the Select shapefile dialog.
6. Select " Land Use" to make it active.

This land use shapefile was obtained from Web GIS,[1] but the EPA and other websites contain similar information. Alternatively, land use polygons could have been digitized from an image as discussed in the "Introduction – Basic Feature Objects" tutorial.

7. Right-click on " Drainage" and select **Zoom to Layer**.
8. Select " Land Use" to make it the active coverage

Notice that the drainage basin boundary and streams become grayed out.

9. Switch to the **GIS** module.
10. Using the **Select Shapes** tool, drag a selection box surrounding the grayed out border of the drainage basin polygon.
11. Select *Mapping* **| Shapes → Feature Objects** to bring up the *GIS to Feature Objects Wizard* dialog.
12. Select "Land Use" from the *Select a coverage for mapping* drop-down.
13. Click **Next** to go to the *Step 1 of 2* page of the *GIS to Feature Objects Wizard* dialog.
14. In the *Mapping Preview* section, select "Land use" from the *LUCODE* column drop-down.
15. Click **Next** to go to the *Step 2 of 2* page of the *GIS to Feature Objects Wizard* dialog.
16. Click **Finish** to close the *GIS to Feature Objects Wizard* dialog.
17. Turn off " valdosta.shp" in the Project Explorer.

Only the portion of the shapefile that was selected will be used to create polygons in the Land Use coverage. Figure 3 shows the resulting land use polygons and their respective land use codes. This land use classification is consistent among all of the USGS land use data, where codes from 10-19 are urban, 20-29 agricultural, etc. A complete listing of code values can be found in the WMS Help file.

The colors used for each code (Landuse ID) and the associated polygons can be changed, if desired.

1. Click **Display Options** to bring up the *Display Options* dialog.
2. Select "Map Data" from the list on the left.
3. On the right side, turn on *Land Use Legend*.

[1] See http://www.webgis.com/.

4. On the left side, click **Land Use Display Options** to bring up the *Land Use Display Options* dialog.
5. Select the desired “Landuse ID” from the list on the left and use the *Color* drop-down to set the desired color.
6. Repeat step 5 until the desired colors are set, then click **OK** to close the *Land Use Display Options* dialog.
7. Click **OK** to close the *Display Options* dialog.

Figure 3shows a typical set of colors for ease of viewing.

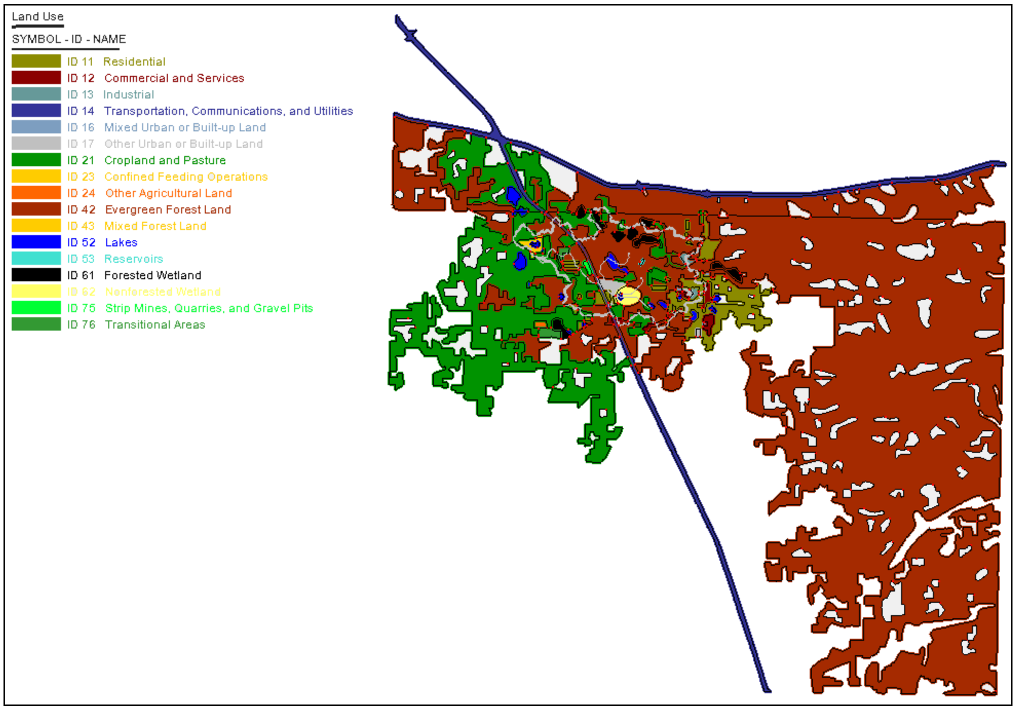


Figure 3 Land use codes used in “valdosta.shp”

5.2 Using the Compute Coverage Overlay Calculator

1. Switch to the **Hydrologic Modeling** module.
2. Select *Calculators* | **Compute Coverage Overlay…** to bring up the *Coverage Overlay* dialog.
3. Select “Drainage” from the *Input Coverage* drop-down.
4. Select “Land Use” from the *Overlay Coverage* drop-down.
5. Click **Compute**.

According to the USGS land use classification, code values in the 50’s and 60’s represent water bodies. To obtain the value for LK, sum together the computed overlay percentages for Land Uses 52, 53, 61, and 62, as shown in Figure 4.

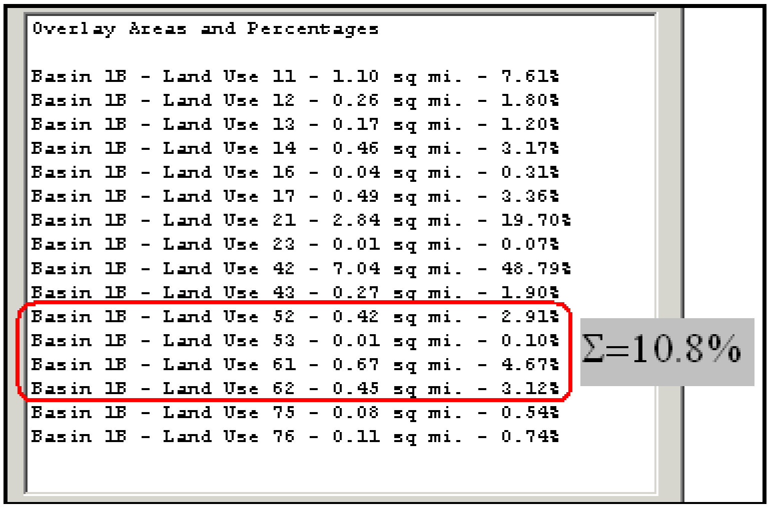


Figure 4 Summing the percentages of the codes representing water cover

This calculator can be used in a similar fashion to determine the percentage of forested areas (codes in the 40's) or any other classification type in a land use or soil file.

6. Click **Done** to close the *Coverage Overlay* dialog.

6 Running NSS

The geometric data computed from the DEM has automatically been stored with the NSS data. Now run a simulation using the derived data.

1. Make sure that the Model drop-down is set to "NSS" (Figure 5).

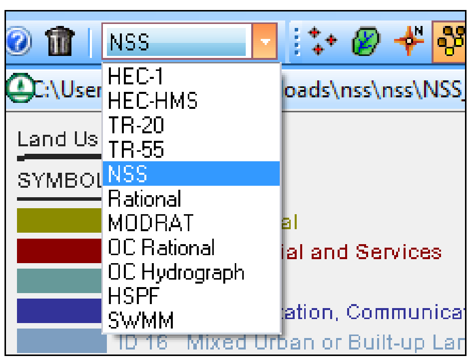


Figure 5 The Model drop-down

2. Using the **Select Basin** tool, double-click on the brown basin icon for Basin 1B (Figure 6) to bring up the *National Streamflow Statistics Method* dialog.

It may be difficult to see the icon with all of the land use data, so **Zoom** in if necessary.

3. In the Basin information section, select "Florida" from the *State* drop-down.
4. In the *Regional regression equations* section, select "Rural Region 2 2011 5034" from the *Available Equations* list.
5. Click **Select→** to move the selected region to the *Selected Equations* list.

6. In the *Variable values* section, enter "10.8" in the *Value* column for the *Percent Storage from NLCD1992* variable.

Resize the dialog, if necessary, to see the *Percent Storage from NLCD1992* variable.

7. In the Results section, click **Compute Results**.

The peak flow (Q) values should appear in the spreadsheet below the **Compute Results** button.

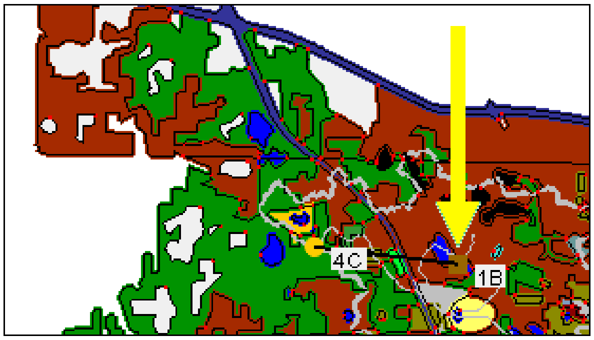


Figure 6 Location of Basin 1B icon (yellow arrow)

6.1 Exporting the Flow Data

Once flow data is computed, it may be exported to a text file in the format shown in the window, along with pertinent information used in computing the peak flow values.

1. Below the spreadsheet, click **Export** to bring up the *Select the file name for the spreadsheet export file* dialog.
2. Select "Comma-Separated Values File (*.csv)" from the *Save as type* drop-down.

The file may be saved in any directory, as desired. In this case, it will be saved with the other project files for this tutorial.

3. Enter "nss_fl_export.csv" as the *File name*.
4. Click **Save** to export the file and close the *Select the file name for the spreadsheet export file* dialog.

Do not close the *National Streamflow Statistics Method* dialog yet. The exported file can be viewed using any word processor or inserted into a separate report document.

7 Time Computation / Lag Time Calculation

The NSS program provides a way to determine an average hydrograph based on the computed peak flow and a basin lag time. A dimensionless hydrograph is used to define a basin hydrograph for the watershed based on the computed peak flow.

1. In the *Results* section, scroll down to and select the "50" in the *Recurrence [years]* column.
2. Click **Compute Hydrograph…** to bring up the *NSS Hydrograph Data* dialog.
3. Click **Compute Lag Time - Basin Data…** to bring up the *Basin Time Computation* dialog.

4. Select "Custom Method" from the Method drop-down. It is the last option.
5. Click **OK** to close the *Basin Time Computation* dialog.

The computed lag time in minutes is shown in the *Basin lag time* field in the *Compute lag time* section. Time of concentration equations can also be used to calculate the basin lag time. WMS will convert the time of concentration to lag time by the equation: $T_{lag} = 0.6*T_{c.}$

6. Click **Compute Lag Time – Basin Data…** to bring up the *Basin Time Computation* dialog.
7. Select "Compute Time of Concentration" from the *Computation type* drop-down.
8. Select "Kerby Method for overland flow" from the *Method* drop-down.
9. Click **OK** to close the *Basin Time Computation* dialog.

Note the difference in the calculated lag time between the two methods. These two equations, along with the other available options in the *Basin Time Computation* calculator, can be used to estimate the lag time of the basin. Compare the results of the different equations available to best describe the characteristics of the basin.

10. Click **OK** to close the *NSS Hydrograph Data* dialog.
11. Click **Done** to close the *National Streamflow Statistics Method* dialog.
12. Select the **Select Hydrograph** tool.

A hydrograph icon will appear next to the basin icon for Basin 1B. Examine the hydrograph in more detail:

13. Using the **Select Hydrograph** tool, double-click on the hydrograph icon to bring up the *Hydrograph* dialog.

The hydrograph for Basin 1B is displayed in the *Hydrograph* dialog.

14. Click the in the top right corner of the *Hydrograph* dialog to close it.
15. Select *File* **| New**.
16. Click **No** if asked to save changes.

8 Using TR-55 to Compute Tc and CN

Travel times (time of concentration, lag time, and travel time along a routing reach) are critical to performing analyses with any of the hydrologic models. There are two different ways WMS can be used to compute time of concentration for a TR-55 simulation:

- Runoff distances and slopes for each basin are automatically computed whenever watershed models are created from TINs, DEMs, or computed basin data. These values can then be used in one of several available equations in WMS to compute lag time or time of concentration
- In order to have more control over the lag time or time of concentration, use a time computation coverage to define critical flow paths. This allows for better documentation of data, as well. Time computation coverages contain flow path arcs for each sub-basin. An equation to estimate travel time is assigned to each

arc. The time of concentration (or lag time) is the sum of the travel times of all arcs within a basin. Lengths are taken from the length of the arc and slopes derived if a TIN or DEM are present.

Lag times are computed in the same ways. In this tutorial, the time of concentration will be calculated for the two sub-basins and the travel time between outlet points in the given watershed. Use the TR-55 library of equations, one of the other pre-defined equations, or enter a new equation.

9 Importing a TR-55 Project

First, import a project file of an urban area that has been processed and delineated as a single basin. The project includes a drainage coverage, a time computation coverage, and two shapefiles for the land use and soil type data.

1. Switch to the **Map** module.
2. Select *File* **| Open** to bring up the *Open* dialog.
3. Browse to the *tr-55\tr-55* folder and select "suburbtr55.wms",
4. Click **Open** to import the project and exit the *Open* dialog.

The project should appear similar to Figure 7.

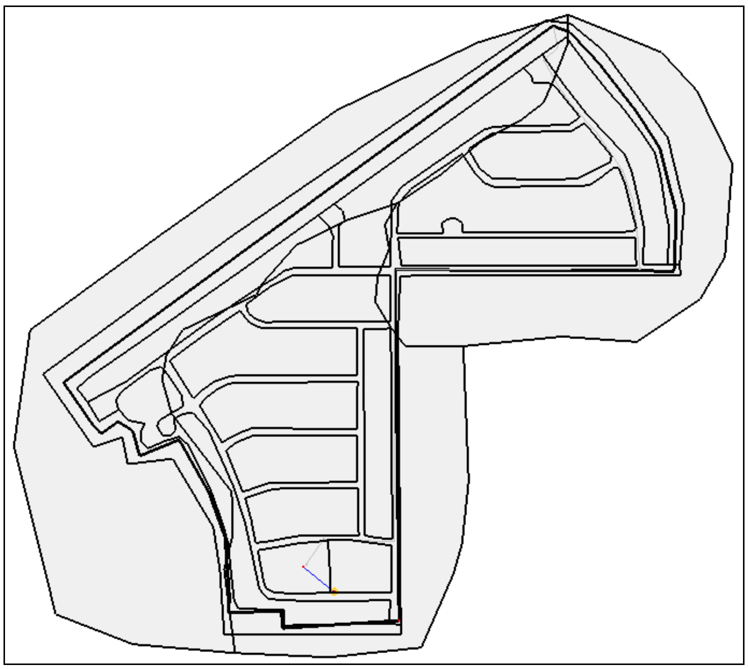


Figure 7 Initial TR-55 project

10 Assigning Equations to Time Computation Arcs

A flow path arc has already been defined for the basin. This arc represents the longest flow path for the urban area, starting from a sandy area at the top of the basin, following along the streets and down towards a detention pond at the bottom of the basin. The arc has been split into four different segments to assign different equations for determining the travel time for the arc. The different equations assigned to the different arc segments represent different runoff flow types such as sheet flow, shallow concentrated flow, and channel flow. Use Figure 8 as a guide while defining the equations.

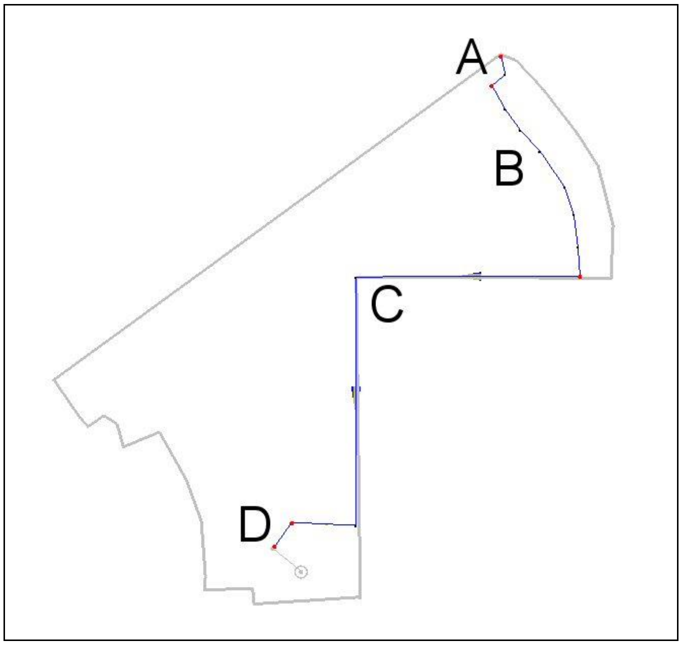


Figure 8 Time Computation Arcs.

1. Turn off "landuse_poly.shp" and "soils_poly.shp" in the Project Explorer.

These shapefiles will be used at a later step to calculate the CN.

2. Select "Time Computation" to make it active.
3. Using the **Select Feature Arc** tool, double-click on the arc labeled "A" in Figure 8 to bring up the *Time Computation Arc Attributes* dialog.
4. Notice that in the *Instructions / Results* section, there are two items which still need to be defined.

By default, "TR-55 sheet flow eqn" will be selected in the Equation Type drop-down. Therefore, only define the overland Manning's roughness coefficient and the 2yr-24hr rainfall. Length and slope were already defined for the selected arc.

5. Select the "n Mannings" line in the *Variables* section to make the *Variable value* field become available.
6. Enter "0.03" as the *Variable value*.
7. Select the "P 2yr - 24hr. rainfall" line in the *Variables* section.
8. Enter "1.1" as the *Variables value*.
9. Select the "S Slope" line in the *Variables* section.
10. Notice that the *Instructions / Results* section now gives a travel time for the selected arc.
11. Click **OK** to close the *Time Computation Arc Attributes* dialog.

An equation has now been defined for the overland sheet flow segment in the basin, and the next segments needs to be defined as shallow concentrated flow.

12. Using the **Select Feature Arc** tool, double-click on arc B (see Figure 8) to bring up the *Time Computation Arc Attributes* dialog.
13. Select "TR-55 shallow conc eqn" from the *Equation Type* drop-down.
14. Select the "Paved" line in the *Variables* section.
15. Enter "YES" as the *Variable value* and click **OK** to close the *Time Computation Arc Attribute* dialog.
16. Repeat steps 10-14 for arc D (see Figure 8), but enter "NO" as the *Variable value* for the "Paved" line in the *Variables* section.

The remaining arc will be defined as an open channel flow arc.

17. Using the **Select Feature Arc** tool, double-click on arc C (see Figure 8) to bring up the *Time Computation Arc Attributes* dialog.
18. Select "TR-55 open channel eqn" from the *Equation Type* drop-down.
19. Select the "n Manning's" line in the *Variables* section.
20. Enter "0.017" as the *Variable value*.
21. Select the "r hydraulic radius" line in the *Variables* section.
22. Click **Hydraulic Radius** to bring up the *Channel Calculations* dialog.

The hydraulic radius will be computed from estimates of the curb in the subdivision.

23. Click **Launch Channel Calculator** to bring up the *Channel Analysis* dialog.
24. In the upper left section, select "Triangular" from the *Type* drop-down.
25. Enter "10.0" as the *Side slope 1 (Z1)*.
26. Enter "0.01" as the *Side slope 2 (Z2)*.
27. Enter "0.010" as the *Longitudinal slope*.
28. In the lower left section, select *Enter depth* and enter "0.5" in the field to the right of the option.

This is an approximated depth since the flow is unknown at this point.

29. Click **Calculate**.
30. Click **OK** to close the *Channel Analysis* window
31. Click **OK** to close the *Channel Calculations* window

The necessary parameters for computing travel time have now been computed using the TR-55 open channel flow (Manning's) equation. Notice the "r hydraulic radius" value in the Variables section has been updated with the calculated value. If desired, continue to experiment with the channel calculator to compute the hydraulic radius rather than entering the given values.

32. Select "S Slope" in the *Variables* section.
33. Notice that the *Instructions / Results* section has updated with a travel time for the arc.

34. Click **OK** to close the *Time Computation Arc Attributes* dialog.
35. Click anywhere outside of the arcs to deselect arc C.

The equations and variable values for each flow path segment have also been defined. Feel free to change these equations and variables, add new flow path segments, etc., in order to determine the best flow paths and most appropriate equations for each basin. In other words, the process is subjective and it may take a few iterations to get the best value.

11 Computing Time of Concentration for a TR-55 Simulation

Before assigning a time of concentration to each basin, decide which model to use. TR-55 will be used for this example, but the same time computation tools learned in this tutorial could be used for any of the supported WMS models (such as in the *TR-20 basin data* dialog, the *HEC-1 Unit Hydrograph method* dialog, and the *Rational Method* dialog).

1. Switch to the **Hydrologic Modeling** module.
2. Select "TR-55" from the Model selector drop-down at the top of the WMS window.
3. Using the **Select Basin** tool, select the basin by single-clicking on it.
4. Select *TR-55* **| Run Simulation…** to bring up the *TR-55* dialog.

In the *TR-55* dialog, notice the two drop-downs at the top. These allow the changing TR-55 information for basins and outlets individually ("Selected") or collectively ("All").

5. Enter "1.5" as the *Rainfall (P) (in)*.
6. Select "Type II" from the *Rainfall Distribution* drop-down.
7. On the Compute Tc – Map Data row, click **Compute…** to bring up the *Travel Time Computation* dialog.

Notice the four time computation arcs that are in the basin. A detailed report of the time computation arcs could be created as a text file by clicking the **Export Data File…** or **Copy to Clipboard** buttons.

Note that the time computation attributes dialog can be brought up and the equation or any of the equation variables can be changed by clicking the **Edit Arcs…** button.

8. Click **Done** to close the *Travel Time Computation* window.

As shown in the *Time of Concentration (TC) (hr)* row, the sum of the travel times for these four arcs will be used as the time of concentration for this basin.

9. Click **OK** to close the *TR-55* window.

12 Computing a Composite Curve Number

Now learn how to overlay land use and soil coverages on the delineated watershed in order to derive a curve number (CN).

12.1 Land Use Table

Create a land use table with IDs and CNs for each type of land used on the map. An incomplete table has been provided. To finish the table with all of the IDs and CNs for the shapefiles in the project—or to edit the table in general—complete the following steps:

1. Select *File* | **Edit File…** to bring up the *Open* dialog.
2. Select “landuse.txt”.
3. Click **Open** to exit the *Open* dialog and bring up the *View Data File* dialog. If the *Never ask this again* option in this dialog has been previously turned on, this dialog will not appear. In that case, skip to step 4.
4. Select the desired text editor from the *Open With* drop-down and click **OK** to open the text file in the selected text editor.

In the text editor, each of the three line shows values for ID, the name of the land use ID in quotation marks, and individual CN values for soil types A, B, C, and D. Each value is separated from the next on the line by a comma followed by a space. This file includes CN values for land use types “Transportation, Communications”, “Other Urban or Built-Up Land”, and “Bare Ground”. The land use shapefile in this project also contains land use polygons for residential areas, with an ID for 11.

Complete the land use table by editing the file to include ID 11 above the existing three lines:

5. Add the following line to the file: 11, "Residential", 61, 75, 83, 87
6. Select *File* | **Save** and close the editor by clicking at the top of window.
7. Return to WMS.
8. Turn on “ landuse_poly.shp” and “ soils_poly.shp” in the Project Explorer.

12.2 Computing Composite Curve Numbers

In order to compute composite curve numbers, WMS needs to know which type of soil underlies each area of land. This requires either a land use and soil type coverage, or a land use and soil type shapefile with the appropriate fields. For this tutorial, land use and soil type shapefiles are used.

1. Select *Calculators* | **Compute GIS Attributes...** to bring up the *Compute GIS Attributes* dialog.
2. In the *Computation* section, select “SCS Curve Numbers” from the drop-down.
3. In the *Using* section, select *GIS Layers*.
4. Select “soils_poly.shp” from the *Soil Layer Name* drop-down.
5. Select “HYDGRP” from the *Soil Group Field* drop-down.
6. Select “landuse_poly.shp” from the *Land Use Layer Name* drop-down.
7. Select “LU_CODE” from the *Land Use ID Field* drop-down.

Land use and soil type tables may be stored in data files, such as the one previously edited. Instead of manually assigning the data as done here, just import the tables using the **Import** button.

Whether the tables are manually created or imported from files, the land use IDs and CNs for each soil type should be visible, and land use descriptions should also be visible in the *Mapping* section.

8. In the *Mapping* section, click **Import** to bring up the *Open* dialog.
9. Select "Land/Soil Table File (*.txt)" from the *Files of type* drop-down.
10. Select "landuse.txt" and click **Open** to exit the *Open* dialog and import the text file.

The assignment of CN values from the previously-edited land use table should now be visible in the *Mapping* section.

11. Click **OK** to compute the composite CNs, close the *Compute GIS Attributes* dialog, and bring up the *View Data File* dialog. If the *Never ask this again* option in this dialog has been previously turned on, this dialog will not appear. In that case, skip to step 13.
12. Select the desired text editor from the *Open With* drop-down. Click **OK** to open the text file in the selected text editor to view the "cn_report.txt" file listed as the *File To Open*. If not wanting to view the report at this time, skip to step 14.

This is a Runoff Curve Number Report. The composite curve number appears at the bottom of the report.

13. When done reviewing the report, it can be saved if desired. Close the editor by clicking at the top of window and skip to step 15.
14. Click **Cancel** to close the *View Data File* dialog.
15. Using the **Select Basin** tool, double-click on the basin to bring up the *TR-55* dialog.

Notice that the *Runoff Curve Number (CN)* has updated with the calculated value from the *Compute GIS Attributes* dialog.

13 TR-55 Hydrographs

While entering the data for the basin, instructions are given in the TR-55 data window to advise what must be entered before a peak Q can be determined. Once all of the data is entered, the peak Q is computed and displayed in the same window.

1. Notice that the TR-55 reference equation for computing peak flow is displayed next to *Peak Discharge*.
2. Click **Compute** to the right of *Compute Hydrograph*.
3. Click **OK** to close the *TR-55* dialog.
4. Using the **Select Hydrograph** tool, double-click on the hydrograph icon next to the basin icon to bring up the *Hydrograph* dialog.
5. After reviewing the hydrograph, click to close the *Hydrograph* dialog.

14 Conclusion

This completes the "Watershed Modeling – Tc Calculations and Composite CN" tutorial. The following key topics were discussed and demonstrated:

- Preparing a basin to be used with the NSS model
- Calculating land use coverage percentages
- Running NSS
- Using the land use and soil coverage to compute a composite CN value
- The TR-55 interface