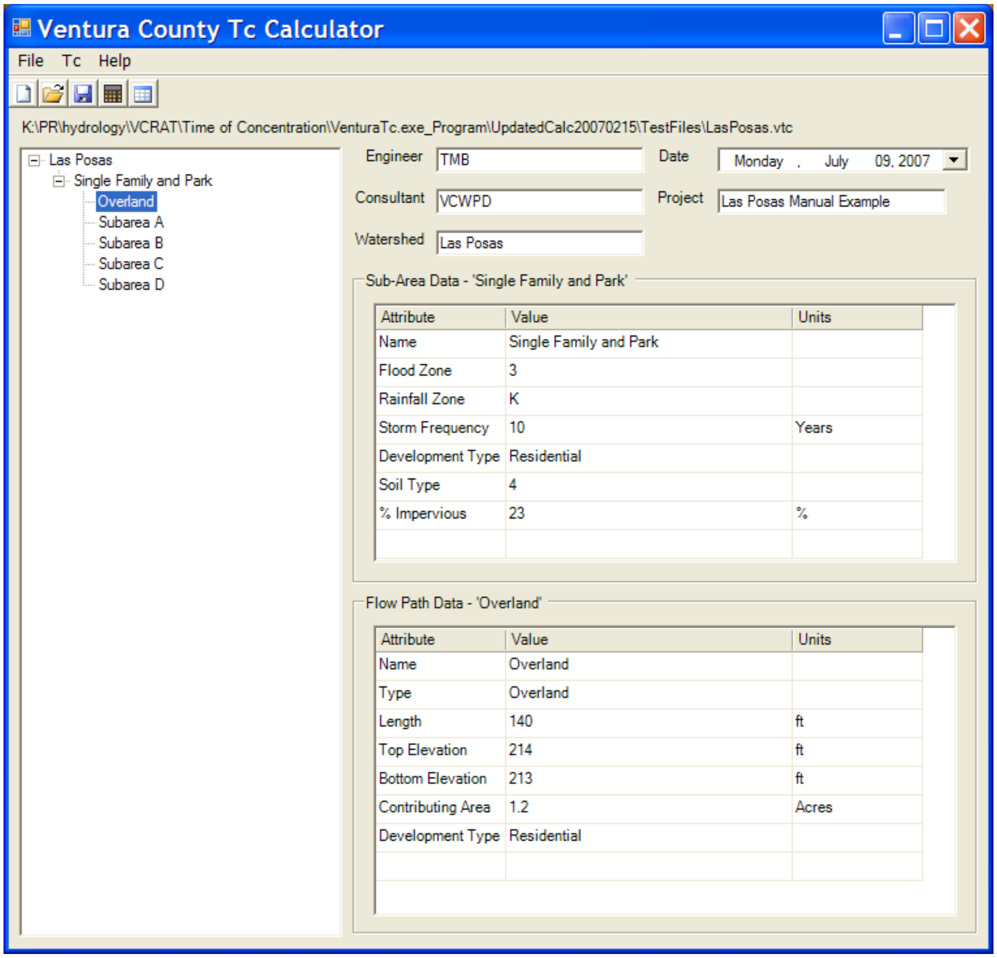
Time of Concentration Calculator
Ventura County Watershed Protection District



Developed by:
Environmental Modeling Systems, Inc (EMS-I)
Revised November 2008

EXECUTIVE SUMMARY

Time of Concentration Calculator
Ventura County Watershed Protection District

Ventura County Watershed Protection District's (VCWPD) VCRat program requires a Time of Concentration (Tc) value as model input for a sub-area. Currently this calculation is lengthy and this has led to a recommended methodology where Tc calculations are done for only about 20% of the sub-areas with the remaining 80% of the sub-areas being left to engineering judgment. With the development of the Tc Calculator program, it is easier to calculate Tc's, and more sub-area Tc's can be calculated.

The VCWPD Tc methodology involves dividing the watershed into sub-areas and gathering applicable data for these areas. The sub-area is further divided into flow-paths. An initial sub-area Tc is then assumed. The travel time in each flow-path reach is computed using the assumed information and the sum of the travel times in the sub-area calculated. If the sum does not equal the assumed Tc, the assumed Tc is adjusted and the iteration continues until the assumed Tc and the calculated Tc are equal within a predefined tolerance.

Environmental Modeling Systems, Inc. (EMS-I, hereafter) was contracted by the VCWPD to develop a computer program to automate Tc calculations and develop a simple graphical interface for data input/output. This document describes the Tc Calculator program and interface.

Ventura County Watershed Protection District
Tc Calculator
TABLE OF CONTENTS

1 Introduction

This document describes the Time of Concentration (Tc) calculator developed for Ventura County Watershed Protection District. The program was developed by EMS-I in 2006 to automate the process of calculating time of concentration of a watershed for hydrologic studies according to the Ventura County Hydrology Manual and methodology described therein. The hand-calculation process is an iterative one and as such is tedious and can be time consuming. The Tc calculator eliminates much of the tedious work required to compute a Tc and more time can be dedicated to other aspects of the hydrology model.

The Tc calculator was developed using Microsoft Visual Studio.NET 2003 and was written in Visual Basic programming language. The program consists of several parts. The variable collection loop goes through the input and creates an input file to be read by the computation loop. Several parameters are collected from data files that contain necessary information and are also read in as variables. The next part is a computation loop that iterates through the Time of Concentration process until a specified tolerance is reached. This loop goes through each flow-path and utilizes the appropriate equations and parameters to complete the computations. The information is then passed to the output loop that writes an output file consisting of the travel times for each flow-path and the time of concentration for each sub-area in the watershed. The program has an interface that facilitates inputting the data. The interface uses a data tree style of organizing the watershed with its sub-areas and flow-paths. The calculator is a user-friendly tool to facilitate hydrologic studies in Ventura County.

2 Installation/System Requirements

The Tc Calculator program is a self-contained executable intended to be run from a folder on your PC's hard drive. The following files are required for program execution:

- VenturaTc.exe – the program executable
- VCRAIN.DAT – data file containing soil and rainfall data

These 2 files are installed in the appropriate folders on your local computer when you install the latest version of VCRat (VCRat2.6 as of December, 2008). The program is run by executing VenturaTc.exe (double-click this file or create a desktop shortcut).

The Tc Calculator was programmed with Microsoft Visual Studio .NET 2003 – Visual Basic. The program was designed to run on computers with Microsoft Windows 2000/XP with .NET Framework. The Tc Calculator should run on any Microsoft Windows OS platforms newer than this version.

3 Tc Calculation Methodology

Time of Concentration as defined by the Ventura County Watershed Protection District Hydrology Manual is "The time required for runoff to become established and flow from the hydraulically most remote part of the drainage area to the point under design." The method to compute time of concentration in a sub-area is explained in this document.

Information about the basin is collected according to the hydrology manual requirements. It is then required that the basin be subdivided into flow-path segments. These flow-paths are created according to the type of flow that exists (existing or undeveloped condition) or the proposed type (proposed or developed condition) of flow. After necessary data are collected and the sub-area is divided into an appropriate number of flow paths according to the various types of flow in the sub-area, the time of concentration is calculated. This process will be described briefly below along with a description of the preparatory work that is done to collect data.

3.1 Preparation

The primary purpose of a hydrologic analysis is to find the amount of runoff that will be produced in a given area. The time of concentration is used in estimating the amount of water that will be accumulated and its distribution over time as it passes a point of outlet.

Collection of data usually involves obtaining a representation of the terrain and creating a map of the watershed boundaries, and sub-dividing it into sub-areas and direct runoff areas that contribute to each time of concentration flow-paths. This delineation of watersheds and sub-areas can be done manually using physical maps, or using a Geographic Information System (GIS) based computer program with much more accuracy and time efficiency.

As shown in the below figure, the most hydraulically-distant flow-path from the outlet in each sub-area must be evaluated for Tc calculations. This flow-path sub-area should be subdivided based on flow type (overland, natural channel, street, pipe, etc.) and the direct runoff area to each segment determined. The overland flow-path length is limited to 1,000 ft or to the point where contours indicate that a channel has formed. For undeveloped sub-areas, flow-paths should terminate at points where significant changes in slope occur and where side tributary confluences significantly change the flow in the main channel. For developed subareas, flow-paths should also terminate at points where significant changes in slope occur or where side tributary confluences significantly change the flow, or where the conveyance type changes. These flow-path and runoff area data are the basics needed for the calculation of Tc with the Tc Calculator program.

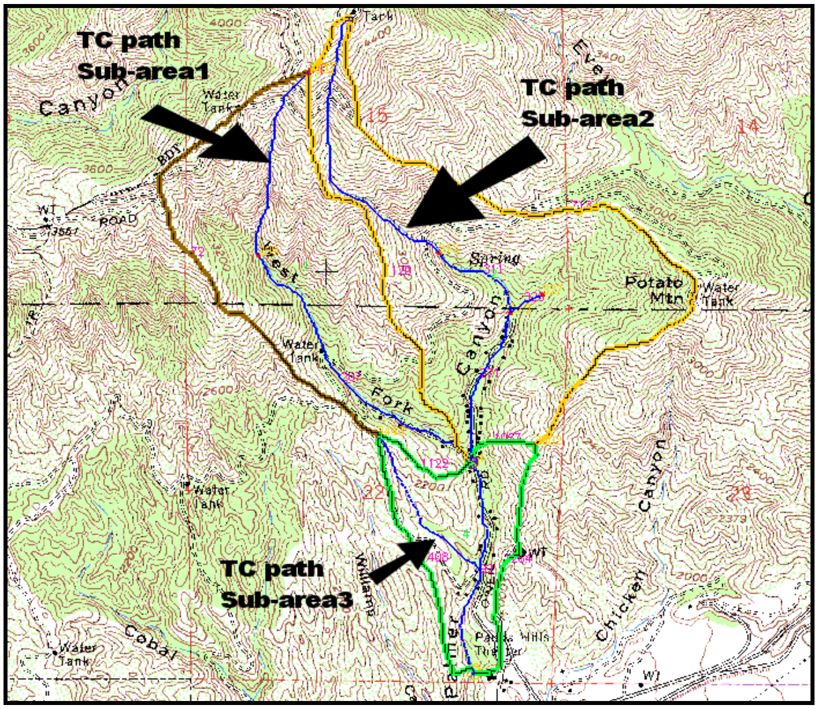


Figure 3.1: Sub-areas with Tc flow-paths (WMS)

3.2 Calculation Process

Once a watershed has been delineated and flow-paths determined, the Tc calculation is performed based on flow-path properties (length, slope, type, etc.), rainfall, and soil data.

1. District Zone number and rainfall zone designation (J, K, L, J') are obtained by locating the project area on maps in the Ventura County Hydrology Manual or by using the provided shapefiles.
2. The soil type (1-7; 1=NRCS Type D, 7=NRCS Type A) is determined using the same map or provided shapefile. If several soils are found across the project area and one soil does not occur in more than 75% of the watershed, calculate an areally-weighted soil number. Because the VCRat program does not allow the use of areally-weighted soil numbers at this time, round your result to the nearest whole soil number.
3. A desired rainfall frequency storm is selected for analysis.
4. The fraction of effective impervious area is determined based on Hydrology Manual guidelines or calculations from development plans.
5. A generalized development type of the area is needed.
6. Each sub-area is divided into flow path segments and each flow path is specified as one of the following types and required data must be entered for each selected path:
   - Overland Flow
   - Natural Channel
   - Street
   - Pipe

- Improved Channel

7. Each flow path needs a contributing area in acres. The contributing area is an incremental area that contributes to the specific flow path and NOT the total area draining to the specified flowpath.
8. A Tc between 5 and 30 minutes based on the required range in the Hydrology Manual is assumed. If the results of your calculation fall outside of this range, you must adjust your sub-area boundaries to comply with this requirement. In some cases hydrologists use the modified Rational Method for small sub-areas that provide a Tc of 5 minutes or less to use for drainage design, but these results should not be submitted to the District for review unless prior approval is received from the District.
9. Rainfall Intensity for the assumed Tc is obtained from the file VCRAIN.DAT corresponding to the rainfall zone and design storm recurrence interval.
10. Runoff coefficient for the basin is determined automatically from the file VCRAIN.DAT from 14 pairs of intensity-pervious area runoff coefficient data for each soil type. For intermediate intensities, the program linearly interpolates between the intensity data to provide a pervious area runoff coefficient. The runoff coefficient that is used in the Tc calculations is altered by the given % effective impervious area according to the following equation:

    C total = C * (1-% Impervious/100) + 0.95*(%. Impervious/100)

11. Total sub-area peak flow for the assumed Tc is calculated using the rational equation.

    Q total = C total * Intensity * Area

12. Amount of flow for each flow path is calculated based on fraction of total area for each flow path:

    Q segment = Q total * Fraction of total area

13. Wave velocity is calculated for each flow path except for the initial overland flow-path segment.
14. Travel time for each flow path is computed.

    Travel Time = Length / Wave Velocity

15. Summation of travel times is equal to the calculated Tc
16. If calculated Tc is within 0.5 minutes of the initially assumed Tc, Tc can be used in a hydrology calculation.
17. If calculated Tc is not within 0.5 minutes of assumed Tc, the assumed Tc is adjusted as follows, then repeat steps 4 through 10:
18. If calculated Tc is greater than the assumed Tc – increase assumed Tc
19. If calculated Tc is less than the assumed Tc – decrease assumed Tc
20. Tc must be greater than or equal to 5.0 minutes and less than or equal to 30 minutes. Sub-area extents should be adjusted to produce a Tc in this range. If the project area is too small to meet this requirement, contact the hydrology section.

3.3 Changes to 1991 Hydrology Manual TC Methodology

A number of changes have been made to the Tc methodology as follows:

- The main influence on the Tc time is generally the initial overland flow assumption used in the calculation because street, pipe, and channel flow velocities are usually much higher than the overland flow velocity. In the past, overland flow path lengths were left up to engineering judgment. To minimize the effects of engineering judgment on the Tc calculations, the initial overland flow path length for residential, commercial, and industrial development is limited to 200 ft. For undeveloped flow segments, the maximum flow path length is limited to 1,000 ft or the length that provides a mountain or valley channel flow velocity of 6.0 fps or greater at the overland flow-path area concentration point.
- Instead of using effective slope to calculate the minimum overland flow velocity, map slope is used to better match velocities that were used in historic Tc calculations. If the slope is less than 0.1 ft/ft, map slope is equal to effective slope and this assumption has no effect on the calculations. However, effective slope is still used to check the scour velocity using the mountain channel nomograph for slopes greater than 0.1 ft/ft because it is assumed that the natural channel will develop drop structures over time that will reduce the channel slope.
- Map slope is limited to 0.35 ft/ft in the overland flow calculation because the equation developed to relate map slope to overland flow velocity is only valid up to 0.35 ft/ft. If elevation and length data are entered that provide a map slope of greater than 0.35 ft/ft, the slope used in the calculation will be reset to 0.35 ft/ft.

3.4 Revisions to TC Calculator August 2007 and December 2008

The TC Calculator was updated to reflect the following changes;

- The old program used to have a percent of total subarea as input. In order to make it easier for the user, the actual incremental area is now use as the input and the program internally calculates the percent of the incremental area to the total area as of August, 2007.

- The output file now has a summary table that clearly shows if the Tc calculation for a sub-area is invalid because it is outside the 5-30 min limits, or has not passed the scour check. The output file has page breaks at the beginning of each subarea calculation.

- The way the program stored information in memory was changed to make it easier to insert and delete subarea calculations in the Tc Calculator input file.

4 Variables

The following section will describe each variable that is used for input into the Tc calculator and the output results. The variables are categorized into watershed variables, sub-area variables, and flow path variables.

4.1 Watershed Variables

1. Engineer name or other ID
2. Date of preparation
3. Consultant company
4. Project name
5. Watershed name

4.2 Sub-Area Variables

This is the level on which the time of concentration calculations will take place. The watershed will be divided into sub-areas and the calculator will compute the Tc in each sub-area.

1. Subarea name
2. Flood/County Zone – Obtained from maps in Hydrology Manual or using provided shapefiles. Flood zones are integers 1 through 4.
3. Rainfall Zone -- Obtained from maps in Hydrology Manual or using provided shapefiles. Rainfall zones are J, J', K, and L.
4. Storm Frequency – Currently the storms that have rainfall data available for calculation are 10-yr, 25-yr, 50-yr, and 100-yr storms.
5. Development Type – Currently the program allows four types- undeveloped, residential, commercial, or industrial. If you have a mix of uses in a developed situation, just enter the primary type here. This description does not affect the Tc calculation.
6. Soil Type – Obtained from GIS files or Hydrology Manual maps. Soil types can range from 1.0 through 7.0 and can have 1 decimal place. Results will be interpolated for soil numbers with a decimal. Because the VCRat programs only allow whole number soil types, it is acceptable to round your weighted soil type to a whole number.
7. % Impervious – This variable controls the amount of runoff that is infiltrated into the soil. If the % impervious were 100.0%, there would be no infiltration and all of the precipitation would turn to runoff. However, in this case the upper limit on the runoff coefficient is 0.95 because it is assumed that some of the rainfall will not become runoff due to evaporation and depression storage effects. If the % impervious were 0.0%, the runoff volume is equal to the precipitation minus the infiltration.

4.3 <u>Flow-Path Variables</u>

4.3.1 Overland

1. Development Type – Undeveloped, residential, commercial, or industrial. This parameter controls which equation to use in finding the velocity of the overland flow-path. If Development Type is undeveloped, the scour velocity is checked in the calculations to make sure the channelized flow at the overland flow-path area concentration point does not exceed 6 fps.
2. Length (ft) – Linear length of the area contributing to the overland flow-path. Overland length cannot be more than 200-ft unless the development type is undeveloped (1,000 ft limit). An error message in the Tc calculator will occur if length is greater than 200-ft in residential, commercial, or industrial overland flow-paths, or greater than 1,000 ft for an undeveloped flow-path.
3. Top Elevation (ft) – Elevation of the upstream end of the flow length. This elevation should (but is not required to) match the bottom elevation of the flow-path directly upstream.
4. Bottom Elevation (ft) – Elevation of the downstream end of the flow length. This elevation should (but is not required to) match with the top elevation of the flow-path directly downstream. As discussed above, map slope is limited to 0.35 ft/ft.
5. Contributing area in acres.

4.3.2 Natural Channel (if slope greater than 0.05 ft/ft, Mountain Channel assumed; otherwise Valley Channel data are used by the program)

1. Length (ft) – Length of the channel.
2. Top Elevation (ft) – Elevation of the upstream end of the flow length. This elevation should (but is not required to) match the bottom elevation of the flow-path directly upstream.
3. Bottom Elevation (ft) – Elevation of the downstream end of the flow length. This elevation should (but is not required to) match with the top elevation of the flow-path directly downstream.
4. Contributing area in acres.

4.3.3 Street

1. Length (ft) – Length of the flow on the street.
2. Top Elevation (ft) – Elevation of the upstream end of the flow length. This elevation should (but is not required to) match the bottom elevation of the flow-path directly upstream.
3. Bottom Elevation (ft) – Elevation of the downstream end of the flow length. This elevation should (but is not required to) match with the top elevation of the flow-path directly downstream.
4. Contributing area in acres.
5. Width (ft) – Width of street can be set at standard widths- 32-ft or 40-ft.
6. Curb Height (in) – Curb height can be standard heights- 6-in. or 8-in.

4.3.4 Pipe

1. Length (ft) – Length of the pipe.
2. Top Elevation (ft) – Elevation of the upstream end of the flow length. This elevation should (but is not required to) match the bottom elevation of the flow-path directly upstream.
3. Bottom Elevation (ft) – Elevation of the downstream end of the flow length. This elevation should (but is not required to) match with the top elevation of the flow-path directly downstream.
4. Contributing area in acres.
5. Diameter (in) – If the specified diameter is too small for the discharge accumulated in the pipe section to occur as open channel flow, a larger diameter will be calculated by the program based on the maximum flow rate – this new diameter will be reported in the output of the calculation. Pipe diameters available are in standard increments of 3-in. up to 42-in. and in increments of 6-in. up to 96-in, the maximum pipe size allowed in the VCRat program. If designer provides known diameter of pipe providing open-channel flow, program will use that pipe size in the calculation.
6. Mannings "n" value– Roughness value to be used in Manning's equation for pipe flow. Standard values are available in the District Design Manual. Design values are 0.012 for reinforced concrete pipes and 0.015 for reinforced concrete boxes.

4.3.5 Improved Channel

1. Length (ft) – Length of the channel.
2. Top Elevation (ft) – Elevation of the upstream end of the flow length. This elevation should (but is not required to) match the bottom elevation of the flow-path directly upstream.
3. Bottom Elevation (ft) – Elevation of the downstream end of the flow length. This elevation should (but is not required to) match with the top elevation of the flow-path directly downstream. Note: the program will automatically assign this bottom elevation to the top of the next downstream flow length.
4. Contributing area in acres.
5. Bottom Width (ft) – Bottom width of channel.
6. Side Slope – Calculated as horizontal/vertical ratio of the side slope of the channel. A rectangle channel has a side slope of 0.0 while a 45° angle slope has a side slope of 1.0.
7. Mannings "n" value– Roughness value to be used in Manning's equation for channel flow. Standard values are available to choose from. Design values are 0.015 for reinforced concrete boxes and 0.035 for channels lined with rock riprap.

5 Program Methodologies

The following sections describe the procedures and methodology used by the Tc Calculator program to solve for Tc. The program will run and then show a report screen with the results of the calculations. Note that if there is an error reported, the program will report erroneous answers in the report screen. Errors must be fixed and the calculator rerun to get accurate results. This methodology can also be used with the exhibits provided in the 2006 Hydrology Manual Update or 1991 Hydrology Manual to perform the Tc Calculation by hand. The methodology consists of the following steps:

5.1 Initial Tc Assumption

The program begins with an assumed initial Tc of 17 min. For hand calculation, used initial estimate based on experience and sub-area size and slope.

5.2 Rainfall Zone, Soil Type, Percent Imperviousness, and Storm Frequency

Establish rainfall zone, soil type, and design storm frequency as described in Section 4. Find percent imperviousness from Hydrology Manual or by analyzing development plan.

5.3 Find Sub-Area Intensity

Calculate maximum intensity from VCRAIN.DAT corresponding to selected Tc value or find in provided intensity tables provided in Hydrology Manual.

1. The program finds the rain curve corresponding to the soil type (J, J', K, or L) and the storm frequency (10, 25, 50, or 100).
2. The data corresponding with the Rainfall Zone and storm frequency are read into the program for the calculation of intensity. The program searches the entire rainfall mass curve for the maximum intensity (inches/hour) for the assumed Tc value.

5.4 Find Sub-Area Runoff Coefficient

Find pervious area runoff coefficient from VCRAIN.DAT or use the exhibits provided for each soil type in the Hydrology Manual. The exhibits show the runoff coefficients for four standard % effective imperviousness values.

1. For the program, the data contained in this section of the file are in rows with intensities provided in the first row and the associated pervious area runoff coefficient in the second row. The runoff coefficient is interpolated from the soil type and intensity. The coefficient used is adjusted with the percent effective impervious for the sub-area entered by the user using the following equation.

   Ctotal = C * (1 - % Impervious/100) + 0.95 * % Impervious/100

5.5 Calculate Total Sub-Area Peak Flow

Calculate total peak flow in sub-area with:

Q total = C total * Intensity * Area

5.6 Overland Flow-Path Travel Time

Compute travel time using the following steps:

5.6.1 Calculate Map Slope

Slope = (Top elevation-bottom elevation)/length

5.6.2 Calculate Flow at the Bottom of the Flow-Path:

Q = Q total *overland flow-path area percentage/100

5.6.3 Effective Slope Calculation

If the overland flow-path is undeveloped the effective slope is calculated for the purpose of performing a scour velocity check using the map slope-effective slope exhibit in the Hydrology Manual. If map slope is less than 0.1 ft/ft, then effective slope is equal to the map slope. Program uses the following regression equation:

$$y = 1.2683*x^3 - 2.0672*x^2 + 1.1595*x$$

Where: y = effective slope (ft/ft) and x = map slope (ft/ft)
Map slope is limited to 0.60 ft/ft in this calculation.

5.6.4 Check Scour Velocity in Undeveloped Overland Flow-Path

For undeveloped overland flow-paths, scour velocity is checked and a scour velocity of greater than 6.0 fps is not allowed. If the calculated velocity is greater than 6.0 fps, the program will display an error message – but will proceed with calculations and display erroneous results.

- Natural mountain channels – map slope greater than 0.05 ft/ft. Use flow-path Q and slope with natural mountain channel velocity-discharge-slope exhibit to find velocity. Program uses regression equation:

  V = 5.6(Q^0.333)(S^0.500)

- Natural valley channels - map slope less than or equal to 0.05 ft/ft. Use flow-path Q and slope with natural valley channel velocity-discharge-slope exhibit to find velocity. Program uses regression equation:

  V = (7.0 + 8.0Q^0.352)(S^0.500)

5.6.5 Calculate Overland Flow-Path Velocity

Minimum overland flow velocity for all development types is computed using map slope. Velocities should be increased using engineering judgment based on slopes and cover:

- 100-year storm:

y = -67.855x3 + 32.753x2 + 0.8791x + 0.7902

y= overland flow velocity in fps; x=map slope limited to 0.60 ft/ft;

Minimum velocity for commercial or industrial areas= 1.0 fps except in flat areas where downstream street velocity is less than 0.5 fps- then can use 0.5 fps overland velocity. Because the Calculator program does not currently have this capability, this calculation must be done by hand.

- 50-year storm:

y = -70.841x3 + 34.459x2 + 0.6252x + 0.5943

y= overland flow velocity in fps; x=map slope limited to 0.60 ft/ft;

Minimum velocity for commercial or industrial areas= 1.0 fps except in flat areas where downstream street velocity is less than 0.5 fps- then can use 0.5 fps overland velocity. Because the Calculator program does not currently have this capability, this calculation must be done by hand.

- 25-year storm:

y = -69.403x3 + 35.066x2 + 0.3861x + 0.5089

y= overland flow velocity in fps; x=map slope limited to 0.60 ft/ft;

Minimum velocity for commercial or industrial areas= 0.5 fps

- 10-year storm:

y = -67.605x3 + 35.825x2 + 0.0873x + 0.4021

y= overland flow velocity in fps; x=map slope limited to 0.60 ft/ft;

Minimum velocity for commercial or industrial areas= 0.5 fps

5.6.6 Calculate Overland Flow-Path Travel Time

Travel time is computed:

Travel Time = Length of path / Overland Flow-Path Velocity

5.7 Natural Channel (Mountain or Valley) Flow-Path

Calculate map and effective slope as above. Flow-path is undeveloped, so the effective slope is used for the velocity calculation. If slope is less than 0.1, then effective slope is equal to the map slope.

5.7.1 Calculate Flows at Channel Top and Bottom

Qtop = Q total *accumulated sub-area percentage to top of flow-path/100

Qbott= Q total * accumulated sub-area percentage to bottom of flow-path/100

5.7.2 Calculate Velocities at Channel Top and Bottom:

Use effective slope and equations or exhibits discussed above.

5.7.3 Compute Average Velocity

Vave = (Vtop+Vbottom)/2

5.7.4 Compute Wave Velocity:

Vwave = Vave * 1.5

5.7.5 Compute Travel Time:

Travel time = Length / Vwave

5.8 Street Flow-Path

Calculate map slope and use this for velocity calculations. Calculate flow at top and bottom of the flow-path as discussed above for natural channels.

5.8.1 Calculate Velocities at Street Section Top and Bottom

- 32-ft Street Section with 6-in. Curb- use discharge-slope-velocity exhibits in Hydrology Manual or program uses regression equation:
  V=10^.97103*Q^.25150*S^.37742
- 32-ft Street Section with 8-in. Curb- use discharge-slope-velocity exhibits in Hydrology Manual or program uses regression equation:
  V=10^.93956*Q^.26616*S^.36768
- 40-ft Street Section with 6-in. Curb - use discharge-slope-velocity exhibits in Hydrology Manual or program uses regression equation:
  V=10^.9969*Q^.23222*S^.38224
- 40-ft Street Section with 8-in. Curb - use discharge-slope-velocity exhibits in Hydrology Manual or program uses regression equation:
  V=10^.98475*Q^.24114*S^.3798

5.8.2 Compute Average and Wave Velocities, Travel Time

Compute average velocity, wave velocity, and travel time using equations provided above for natural channels

5.9 Pipe Flow-Path

Calculate map slope for use in calculations, flow at the pipe top and bottom of flow-path, and average flow as discussed above.

5.9.1 Calculate Pipe Size

The peak flow from the bottom of the pipe flow path is used to estimate the pipe size with:

$$\textbf{Pipe Diameter}^{8/3} = Q*n / (S^{.5} * 0.463)$$

The calculated diameter is increased to the next standard pipe size (3-in. increments up to a 42-in. diameter pipe and 6-in. increments up to 96-in. diameter pipes). For hand calculations, use Manning’s Equation. Program will calculate required pipe size in case inadequate pipe size is specified by the user. If designer provides known diameter of pipe providing open-channel flow, program will use that pipe size in the calculation.

5.9.2 Compute Full Pipe Flow

Full flow is calculated using the following form of the pipe equation:

$$\mathbf{Qfull = (0.463 * (Diameter)^{8/3} * Slope^{0.5} / n}$$

5.9.3 Compute Full Pipe Velocity:

$$\mathbf{Vfull = Qfull / Area}$$

5.9.4 Compute Percentage of Flow:

$$\mathbf{\%Qave = Qave / Qfull}$$

5.9.5 Compute Wave Velocity

Percentage of average flow is used to obtain percentage of wave velocity from “Table for Wave Velocity, Circular Pipe” in Hydrology Manual. Program has this table in memory to provide the desired results.

5.9.6 Compute Wave Velocity:

$$\mathbf{Vwave = \%Vwave * Vfull}$$

5.9.7 Compute Travel Time:

$$\mathbf{Travel\ time = Length / Vwave}$$

5.10 <u>Improved Rectangular or Trapezoidal Channel</u>

Calculate map slope and flow at the top and bottom of the channel flow path as discussed above. Velocities at the top and the bottom of the channel are computed using Manning’s Equation- default “n” value is 0.015 per District Design Manual.

5.10.1 Compute Channel Depth

This step of the program involves finding the depth in the channel at the top and bottom of the section using the Newton-Raphson numerical method and using the depths to compute the velocities in the channel.

5.10.2 Compute Average Velocity:

$$\mathbf{Vave = (Vtop+Vbottom)/2}$$

5.10.3 Compute Wave Velocity

Wave Velocity is computed using the following empirical equations valid only for default n values.

- Rectangular channel

$$Vwave = Vave * (5 * b + 6 * y) / (3 * b + 6 * y)$$

Where: b = bottom width and y = depth

- Trapezoidal channel

$$\Theta = \tan^{-1}(1 / z)$$

$$WP = b + 2 * y * (1 + z ^ 2)^{1/2}$$

$$Vwave = Vave * (5 / 3 - 4 / 3 * (y / (WP * \cos\Theta)))$$

Where: z = ratio of horizontal to vertical lengths on channel sidewall.

5.10.4 Compute Travel Time:

$$Travel\ time = Length / Vwave$$

5.11 Sum Travel Times for All Flow-Paths

The summation of travel times of all the flow-paths is the Time of Concentration. Calculated Tc is compared with the assumed Tc and if the difference is greater than 0.5 minutes, the assumed Tc is changed and the process is started over at step 1. If the calculated Tc is higher than the assumed Tc, the assumed Tc is increased by 0.5 minutes. If the calculated Tc is lower than the assumed Tc, the assumed Tc is decreased by 0.5 minutes. Final Tc cannot be less than 5.0 minutes or greater than 30.0 minutes. If Tc is not within these limits, the sub-area should be altered to produce a valid Tc unless the project area is too small to meet this requirement. In this case, a Tc of 5-minutes should be used in the calculation.

5.12 Calculating Tc's for a Different Storm Frequency

Once the physical data are entered for a sub-area, a Tc can easily be calculated for different storm frequencies by changing the storm interval in the sub-area data window, saving the file under a different name, and re-computing the Tc's. However, due to the different rain intensities for each design storm, the runoff from each flow-path area may be different. If going from a 10-yr to a 100-yr calculation, the increase in flow at the overland flow concentration point could cause the velocity scour limit of 6.0 fps to be exceeded. This would require the hydrologist to decrease the overland flow-path length and associated area. To avoid this, the hydrologist can always start with the 100-yr calculation and then use those data for other storm frequencies. A change in runoff at various storm frequencies may also change the pipe size calculated in the program to provide for open-channel flow but this has not been found to change the resultant Tc in a significant way.

5.13 Land Development Study Submittal Materials to VCWPD

When doing a hydrology study that is to be submitted to VCWPD for review, the 2006 Hydrology Manual specifies a number of items that should be included in the submittal. For studies done using the Tc calculator, the following items should be included with your submittal:

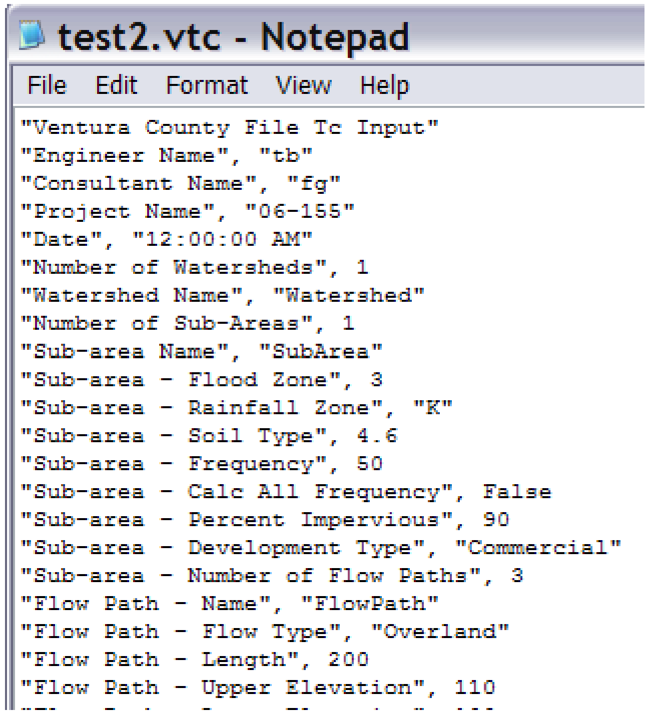
1. Tc Calculator electronic input and output files
2. Workmap with scale for each Tc calculation showing sub-area boundaries, flow-path boundaries and lengths, topo used to determine elevations, and soil types
3. Spreadsheet showing calculations of flow-path areas and percents of total sub-area acreage used in Tc calculation

5.14 Tc Calculator Topics and Planned Program Updates

The following topics may affect a Tc Calculation and may be addressed in a future program update:

1. The Tc Calculator output cannot be printed from within the Tc Calculator program. A text output file is stored in the directory that was specified for the input file (*.vtc).

2. Multiple watersheds and sub-areas can be evaluated within one input file. Deleting the watersheds and sub-areas can possibly corrupt the input file. Experience has shown that deleting sub-areas and watersheds from the bottom of the project window does not corrupt the file, but that deleting sub-areas in the middle of a project can corrupt the file. However, the *.vtc file can be edited to reflect the desired changes by opening the TC input file (*.vtc) using a text editor. The *.vtc file should look like the figure below. Change the "number of watersheds" and remove/add the "watershed name" and its components (i.e. sub-area flowpath, sub-area flood zone, flow path – name, flow path – flow type, etc.).



test2.vtc - Notepad

File Edit Format View Help

```
"Ventura County File Tc Input"
"Engineer Name", "tb"
"Consultant Name", "fg"
"Project Name", "06-155"
"Date", "12:00:00 AM"
"Number of Watersheds", 1
"Watershed Name", "Watershed"
"Number of Sub-Areas", 1
"Sub-area Name", "SubArea"
"Sub-area - Flood Zone", 3
"Sub-area - Rainfall Zone", "K"
"Sub-area - Soil Type", 4.6
"Sub-area - Frequency", 50
"Sub-area - Calc All Frequency", False
"Sub-area - Percent Impervious", 90
"Sub-area - Development Type", "Commercial"
"Sub-area - Number of Flow Paths", 3
"Flow Path - Name", "FlowPath"
"Flow Path - Flow Type", "Overland"
"Flow Path - Length", 200
"Flow Path - Upper Elevation", 110
```

3. Once the physical data for a sub-area have been entered, Tc's for another storm frequency can be calculated by changing the storm recurrence interval in the sub-area window, saving the file under another name, and recomputing as discussed above.

4. The development type specified in the sub-area data window does not affect the calculation and is for the hydrologist's information only. In the future, the program may be altered to allow the hydrologist to enter additional information about mixed land uses in this field. The development type in the overland flow-path window is used to set the limits on the overland flow-path length and whether a scour check should be performed and so should be properly selected.

5. The maximum map slope that can be used in the program at this time is 0.35 ft/ft. Elevation and length information leading to slopes greater than this can be entered, but the overland flow velocity associated with the 0.35 ft/ft slope will be used to calculate the travel time.

6. The minimum overland velocity for 100-yr and 50-yr storms is 1.0 fps. If the hydrologist can justify the use of a smaller velocity (possibly due to very flat slopes leading to low velocities in a downstream street flow-path), the calculation must be done by hand. The minimum overland velocity for 10-yr and 25-yr storms is 0.5 fps.

7. Tc Calculator program input file (*.vtc) cannot be launched by double-clicking on the file- it must be opened from the program once it is started.

8. Help -> Contents tab in the program is intended to open the pdf Manual file but does not currently do this. The Manual can be opened by browsing to the directory with the Tc Calculator program and opening the pdf file directly.

9. The current program requires the first flowpath to be an overland flow segment. Multiple overland flow segments are not allowed. It should be noted that for a developed subarea, the overland flow path length limit is 200 feet and for undeveloped subarea, the limit is 1,000 feet.

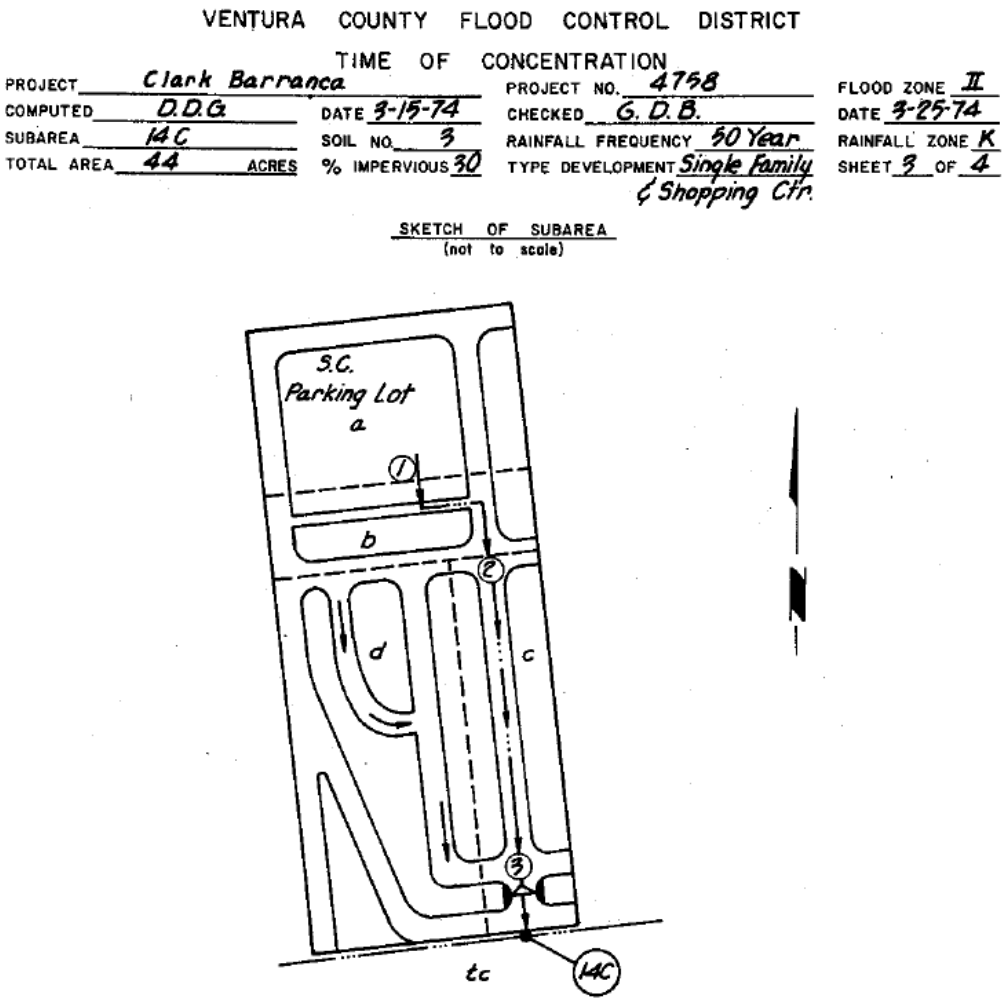
10. Map slope is used to calculate the overland flow velocity using the regression equations. Effective slope is used to calculate velocity of flow in natural mountain channels with slopes greater than 0.05 ft/ft to account for formation of natural drop structures in natural channels leading to a decrease in effective slope.

11. When Tc's are computed, the program will show any error messages and then perform the calculations and display an output file. The input data should be revised until no error messages are displayed when the Tc's are computed- at that point the output file can be considered final and provided as calculation backup.

6 Tc Calculator Examples/Tutorials

This section contains two example of using the Tc Calculator. Each example shows how to input data to the calculator, how to run the calculation, and how to review results of the calculator.

6.1 <u>Tutorial #1 – Clark Barranca Developed</u>



6.1.1 Tc Calculator Input

1. Launch Tc calculator (VenturaTc.exe).

2. Right click in the project explorer (the white box on the left hand side of the window) and select *New Watershed.*

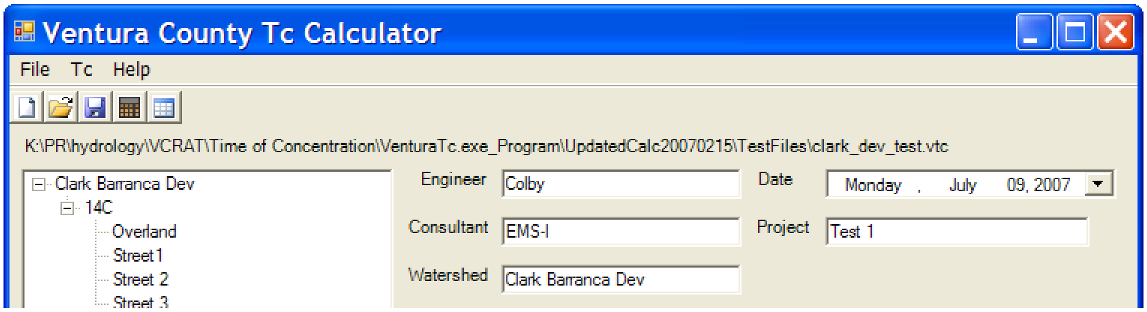


Figure 6-1: Watershed/Project information

3. Project parameters assignment
    - Enter engineer – Your name
    - Date – Assigned automatically to current date
    - Enter consultant name – EMS-I
    - Enter project name – Test 1
    - Select ”Watershed” in the project explorer
    - Enter watershed name – Clark Barranca Dev
4. Sub-area parameters assignment
    1. Right click on the watershed name in the project explorer and select *New Sub-Area for Watershed*
    2. Select “Sub-Area” in the project explorer – note that the sub-area data fields become active.
    3. Enter or choose the following information into the appropriate fields:
        - Name – 14C
        - Flood Zone – 2
        - Rainfall Zone – K
        - Storm Frequency – 50
        - Development Type – Residential
        - Soil Type - 3
        - % Impervious – 30

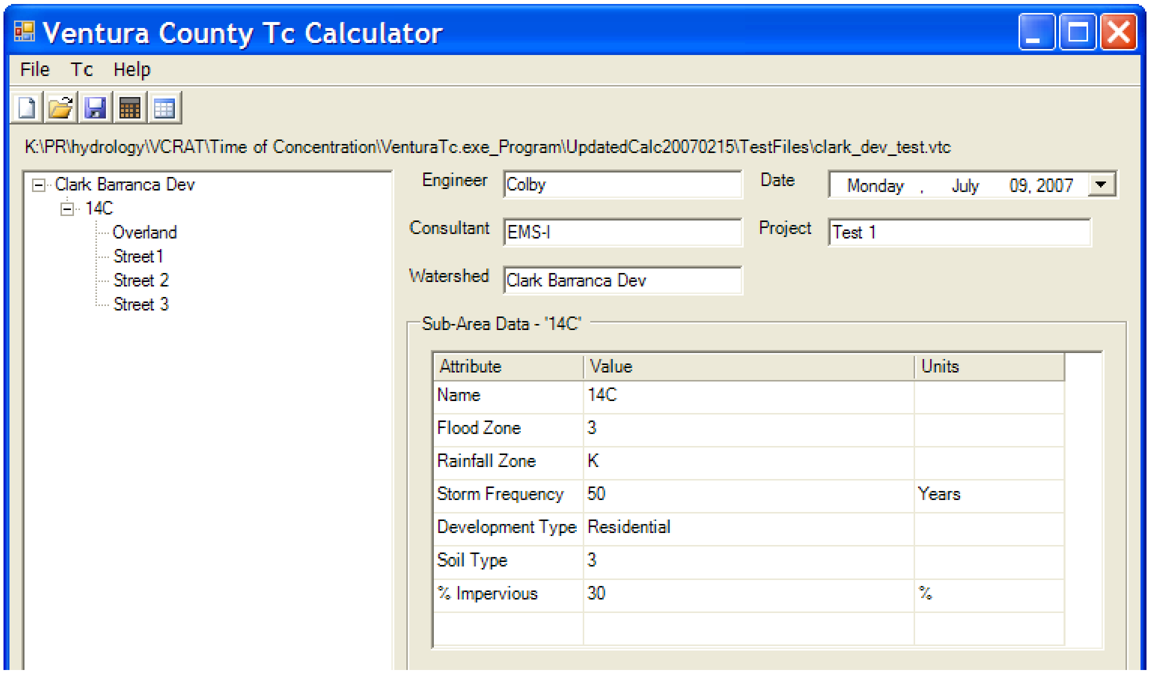


Figure 6-2: Sub-area data input

4. Flow path parameter assignment entry
5. Create a new flow-path by right-clicking on subarea "14C" in the project explorer and choosing *New Flow Path for Sub-area*. Repeat this step 3 more times to create a total of 4 flow-paths.

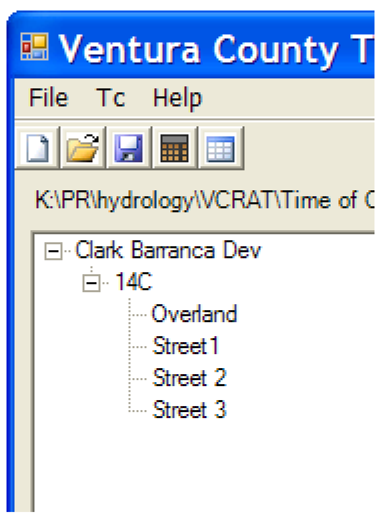


Figure 6-3: Flow-paths

6. Save your project before moving on to more data entry. Choose File | Save As and name your file "ClarkBarrancaDev.vtc" – put it in any folder convenient for you.

7. Select the first (top) flow-path in the project explorer window – note that the flow-path data fields become active.
    - Name – Overland
    - Type – Overland
    - Length – 200
    - Top Elevation – 110
    - Bottom Elevation – 95
    - Contributing Area - 4
    - Development Type – Residential

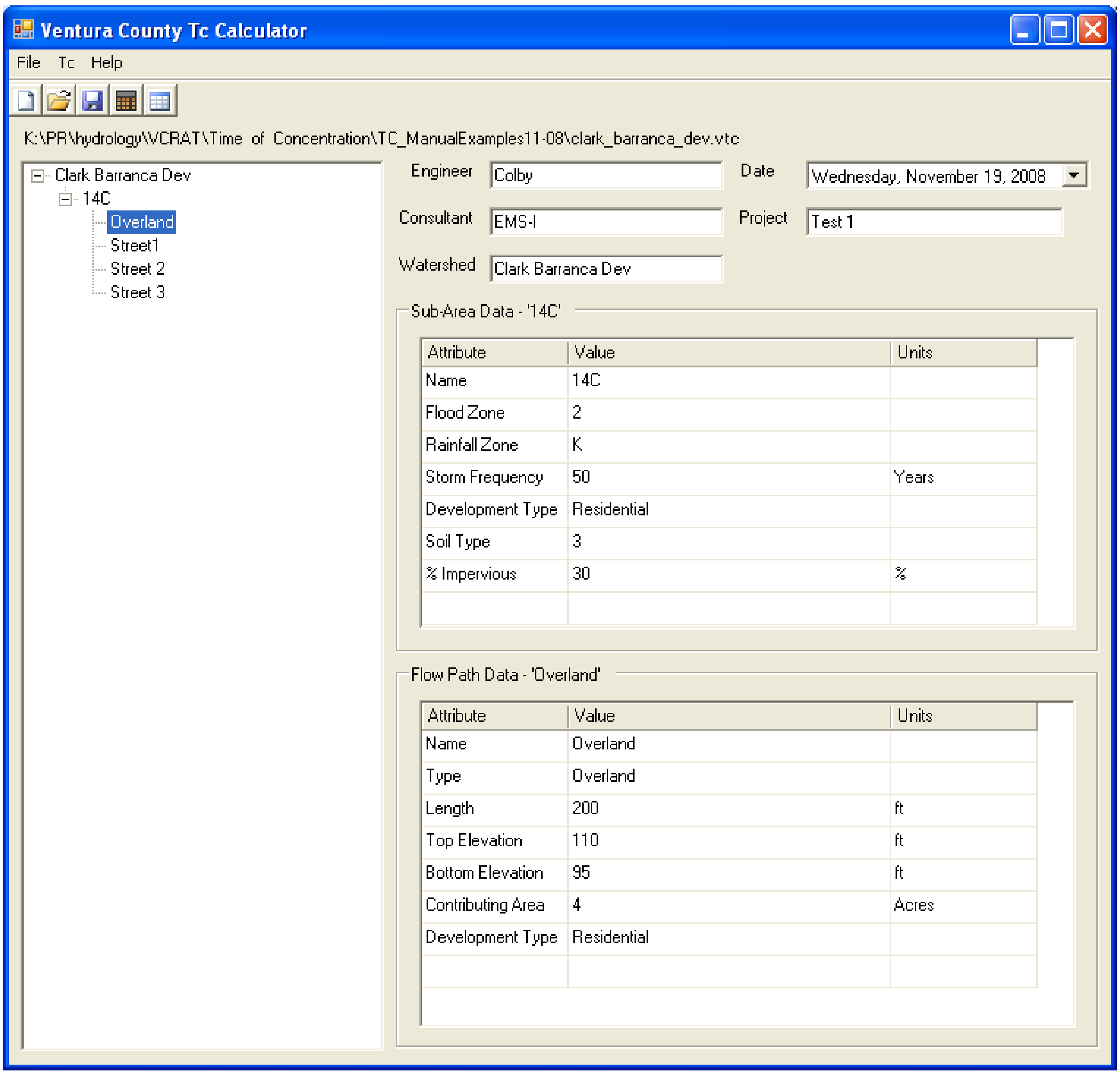


Figure 6-4: Flow-path data input

8. Repeat the previous data entry procedure and input the information shown below for the remaining 3 flow-paths:

Table 1: Flow-path input data

Name	Street 1	Street 2	Street 3
Type	Street	Street	Street
Length	400 ft	300 ft	1400 ft
Top Elevation	95.0 ft	85 ft	79.6 ft
Bottom Elevation	85 ft	79.6 ft	56.22 ft
Contributing Area	10	11	19
Street Width	32 ft	32 ft	32
Curb Height	6 in	6 in	6

9. Once finished, save your input before moving on. Choose File | Save to save all the changes to the Tc input file.

6.1.2 Calculate of Time of Concentration

Now that the data entry is complete, the Tc calculation can be performed. The calculator will check your input data to make sure it is complete and then run the calculations to find Tc.

1. Compute Tc
2. Click the *Compute* button on the toolbar
3. Calculator runs and creates an output file
4. The Results screen appears and shows the detailed results of the calculation.

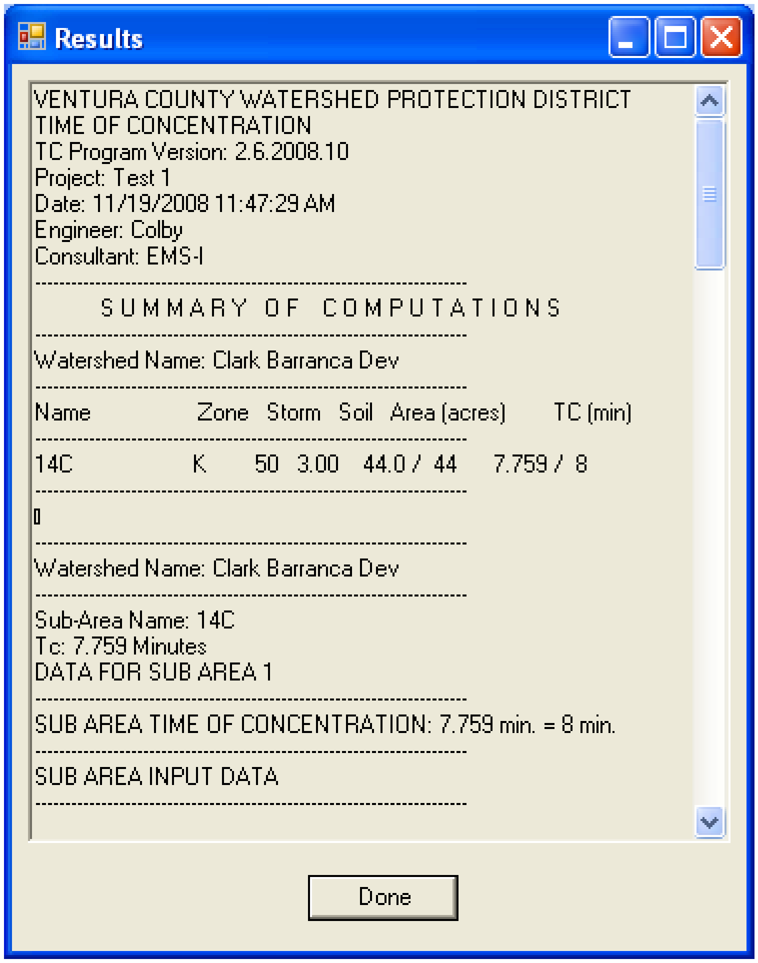


Figure 6-5: Tc Output

6.2 <u>Tutorial #2 – Pitas Point</u>

6.2.1 Watershed delineation and sub-area computations.

1. This example was developed from a Digital Elevation Model (DEM) of Pitas Point near Ventura, California.
2. Sub-area delineation was performed using the Watershed Modeling System (WMS). The watershed was delineated and sub-areas created that have areas in the recommended range of 40 to 80 acres.

6.2.2 Tc Calculator Input

1. Launch Tc calculator opening VenturaTc.exe.
2. Right click in the project explorer (the white box on the left hand side of the window) and select *New Watershed.* See Figure 6-6.

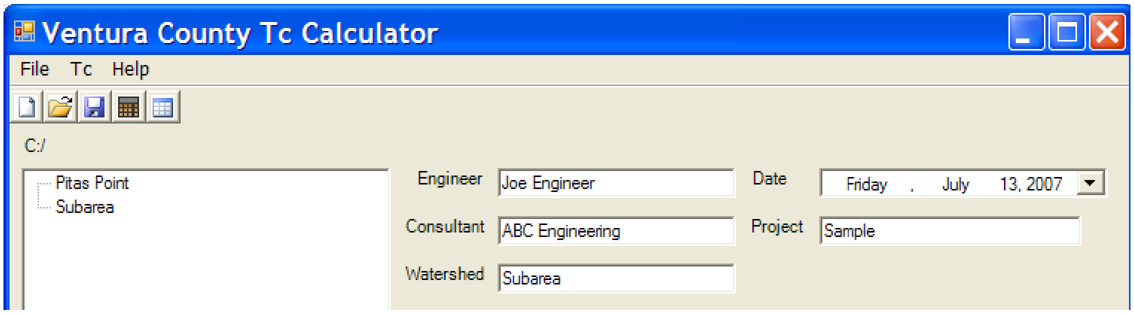


Figure 6-6: Watershed/Project information

3. Project parameters assignment
    - Engineer – Your name
    - Date – Assigned automatically to current date
    - Consultant – EMS-I
    - Project – Test 2
    - Select "Watershed" in the project explorer
    - Watershed – Pitas Point
4. Sub-area parameters assignment
5. Right click on the watershed name in the project explorer and select *New Sub-Area for Watershed*
6. Select the new Sub-Area in the project explorer – note that the sub-area fields become active.
7. Enter or choose the following information into the appropriate fields:
    - Name – Pitas Point
    - Flood Zone – 1
    - Rainfall Zone – K
    - Storm Frequency – 100
    - Development Type – Undeveloped
    - Soil Type 2.3 **Note: This is a weighted average of multiple soil numbers in the sub-area estimated from Plate B-14 of Pitas Point.
    - % Impervious – 20

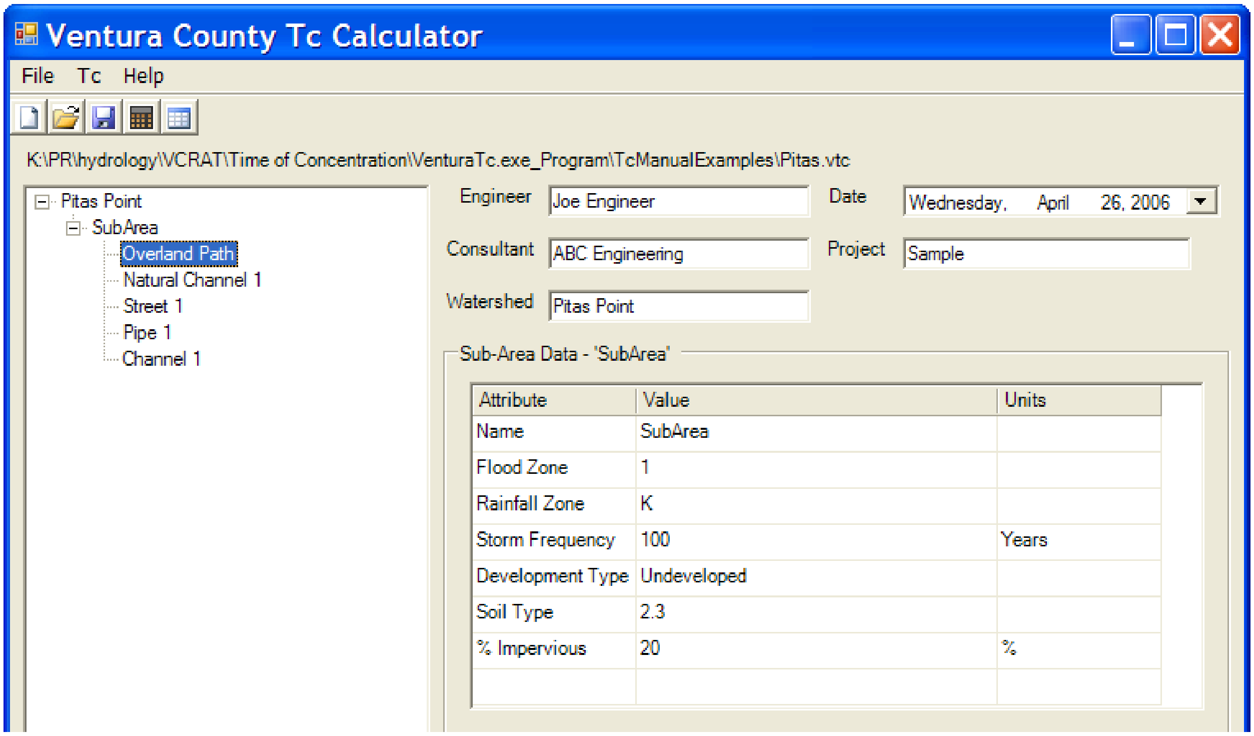


Figure 6-7: Sub-area parameters

8. Flow path sub-delineation
9. Flow-paths are decided upon and the flow-path types are designated. The following is a sample consisting of one flow-path of each type. WMS was used to sub-delineate the sub-area into areas contributing to each flow-path. The areas are computed by WMS and were converted into percentages. See Table 2.

Table 2: Flow-path percent areas

Flow-path	Type	Area (acres)	%
1	Overland	11.79	19%
2	Natural Channel	3.78	6%
3	Street	10.45	17%
4	Pipe	18.24	29%
5	Channel	18.01	29%
	Total	62.27	

10. Right click on the Sub-area name in the project explorer and select *New Flow-Path for Sub-Area.*
11. Select the new Flow-Path in the project explorer and the flow-path fields become active.
12. Enter or choose the following information into the appropriate fields:
    - Name – Overland Path
    - Type – Overland
    - Length – 1,000 ft
    - Top Elevation – 905

- Bottom Elevation – 814
- Area – 11.79
- Development Type - Undeveloped

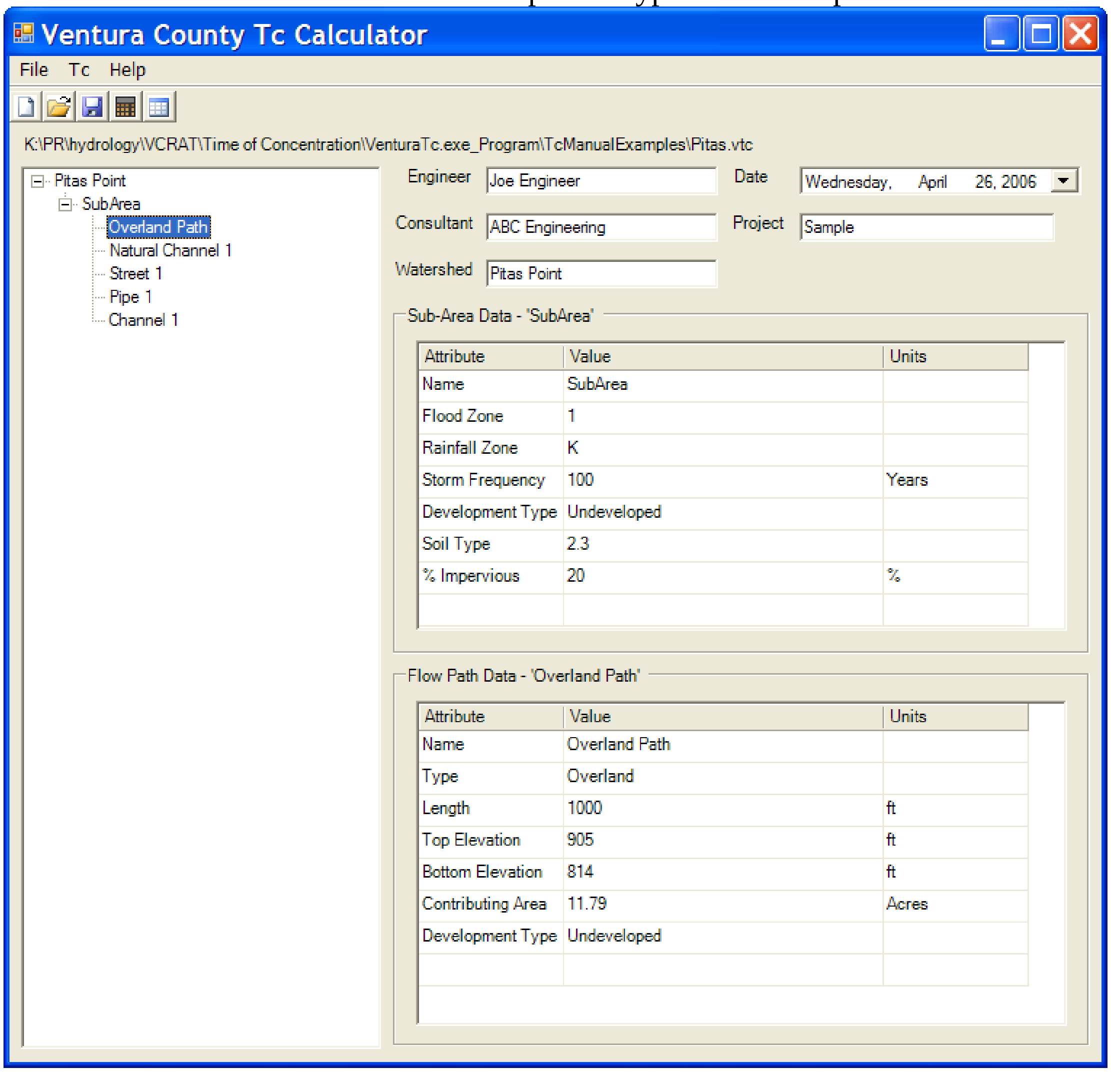


Figure 6-8: Flow-path data

13. Repeat the previous step and input the information found the table below for four new flow-paths.
14. Once finished, save your input before moving on. Choose File | Save As and enter pitas_point.vtc as the filename.

Table 3: Flow-path input data

Name	Natural Channel 1	Street 1	Pipe 1	Channel 1
Type	Natural Channel	Street	Pipe	Channel
Length	389’	460’	232’	408’
Top Elevation	814’	717’	562’	534’

Name	Natural Channel 1	Street 1	Pipe 1	Channel 1
Bottom Elevation	717’	562’	534’	473’
Area (ac)	3.78	10.45	18.24	18.01
Street Width	na	32’	na	na
Curb Height	na	6”	na	na
Diameter	na	na	24”	na
Manning’s n	na	na	0.013	0.02
Side Slope	na	na	na	1.5
Bottom Width	na	na	na	8’

Na= not applicable

6.2.3 Compute Tc

15. Click the *Compute* button on the toolbar
16. Calculator runs and creates an output file
17. The Report window will appear showing the output of the Time of Concentration

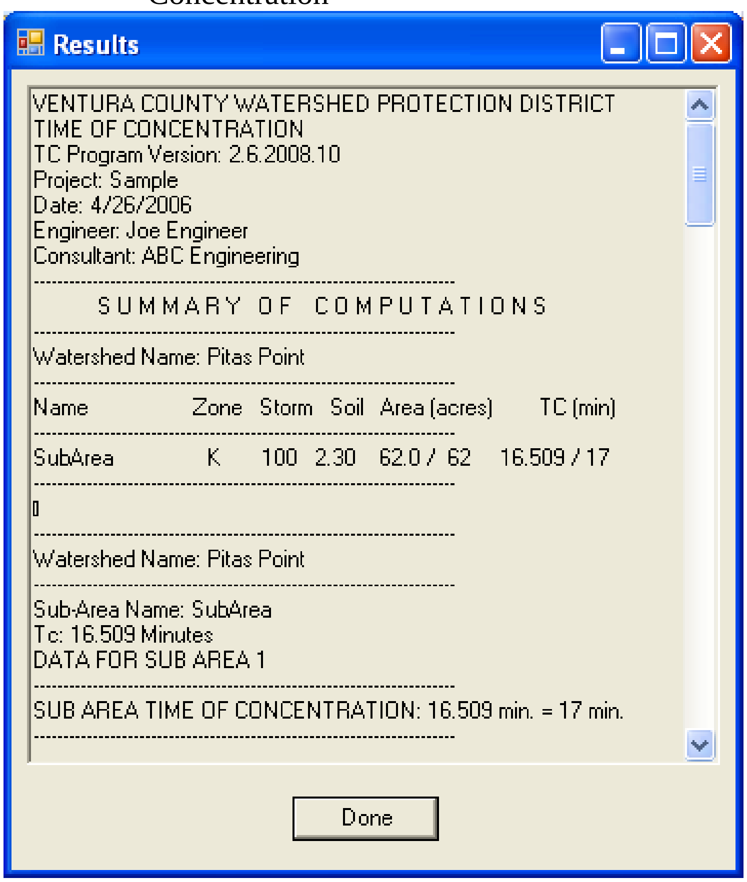


Figure 6-9: Tc Output