VCWPD Tc Calculation Procedure
<u>Developed for 2007 Training Classes</u>

1 Study Area Delineation

Develop workmaps using provided GIS files or pdf maps in 2006 Hydrology Manual Appendix E (available in provided Hydrology Manual CD or from website). Workmaps should show study area, rainfall zone information, soil type, topography, and 100-yr 1-Day rainfall depth contours (if watershed yield adjustment will be done). Record the following information in the Tc Calculator:

1. County Zone, which is equivalent to Flood Zone in the program (1 through 4) (see Hydrology Manual),
2. Rainfall Zone (J, J', K, or L) (use GIS shapefile or Appendix E of Manual),
3. Soil Type (Number from 1 through 7. If area has several soil types, calculate a weighted soil number based on percent area and enter a number from 1.0 through 7.0 with increments of 0.1.
4. Rainfall frequency (i.e. 50-yr, 100-yr.);
5. Type of development (i.e. undeveloped, residential, commercial, industrial);
6. Percent of impervious area (recommended percentages are provided in the Hydrology Manual, Exhibits 14a-b).

2 Flow-Path Delineation

Identify flow-path for runoff from the hydraulically most distant point of the subarea to its outlet or concentration point. Divide flow-path into segments and calculate areas associated with each segment based on overland flow, natural channel segments with uniform slope and flow, and concentrated flow in streets, pipes and stream channels as follows:

1. Overland flow-path. This is the portion of the subarea where runoff occurs as uniform shallow overland flow. The flow-path lengths are limited to 1,000-ft for undeveloped areas (natural or parks) or 200-ft for developed land uses (residential, commercial, or industrial). For undeveloped overland flow-paths, the downstream end of the flow-path should conclude at the 1,000 ft limit or the v-shaped contour line that shows the presence of a channel. Delineate the area that contributes flow to this concentration point based on your contours.
2. In undeveloped subareas, create additional segments along the runoff flow-line to account for changes in slope or inflow from tributary areas that will affect velocity calculations in the channel.
3. In developed subareas, create additional segments along the runoff flow-line to account for changes in slope, inflow from tributary areas, or changes in conveyance type.
4. Measure and record the length of the flow-path and upstream and downstream elevations of each flow-path.
5. Calculate the map slope for each flow-path: [(upper elevation) – (lower elevation)] / (flow length).

6. If initial overland flow area is undeveloped, use Exhibit 7 to determine effective slope from the map slope. This step accounts for the formation of natural drop structures in unimproved channels in areas of steep slope. Effective slope will be used to check for scour velocity as described in section 4.5. Note: if the map slope is less than 0.1 ft/ft, the map slope is equal to the effective slope.
7. Delineate the area associated with each segment according to the runoff that concentrates along the flow-path based on your contour lines or tributary areas.
8. Calculate the area associated with each flow-path. Determine each sub-area's percentage of the total area.

3 Initial Tc Assumption and Flow-Path Area Q's

1. Make an assumption as to what the total Tc (min.) will be for your area. Urban areas frequently have small Tc's, and undeveloped areas with low slopes can have long Tc's. The limits are from 5-30-min.
2. Find maximum rainfall intensity for your rainfall zone, design storm, and Tc from Exhibit 2 of the Hydrology Manual. Record it as your intensity (I).
3. Using the intensity from step 2, soil type, and percent effective imperviousness of your subarea, find your runoff coefficient from exhibits 6a-g from the Hydrology Manual. Use linear interpolation if you have an areally-weighted soil type or percent impervious value not shown in the exhibits.
4. Calculate the QTotal with the equation Q = CIA
5. Calculate the Q for each flow-path area: Qsubarea = CIAsubarea or Qtotal x Sub-Area Percent

4 Overland Flow Velocity and Scour Check

1. For overland areas with undeveloped or residential land uses, use Exhibit 8 and your calculated map slope to find the overland flow velocity for the appropriate recurrence interval (10, 25, 50, 100).
2. Calculate the overland flow travel time from this velocity and the flowpath length in the initial overland flow-path area.
3. For commercial or industrial areas, use Exhibit 8 and map slope to calculate the overland flow velocity. The overland flow velocity is further limited to a minimum of 1.0 fps for 100- and 50-yr storms, and a minimum velocity of 0.5 fps for 25- and 10-yr storms. In areas of extremely flat slopes such as the Oxnard floodplain, if the street flow velocity provided by Exhibits 11a-d is less than these minimum values, the hydrologist has the choice of reducing the minimum velocity for the 100- and 50-yr storms to 0.5 fps. The Tc calculator does not currently have this capability, so in order to use this minimum velocity the Tc calculation must be done by hand.
4. For maps slopes greater than 0.35, the overland flow velocity is limited to the overland flow velocity calculated for a slope of 0.35 due to the complex dynamics of overland flow for steep slopes.
5. If the overland flow –path area is undeveloped, perform a velocity check to make sure the flow has not reached the velocity that will lead to scouring and development of a channel, thus invalidating your overland flow assumption. From Exhibit 9 or 10, use the flow

calculated for the flow-path area and the effective slope to find the channel velocity in the area. If the effective slope for the overland flow-path is greater than or equal to 5 percent, use Exhibit 9 for Natural Mountain channels. If the effective slope is less than 5 percent, use Exhibit 10 for Natural Valley channels. If the velocity is not less than 6 fps, you will need to go back to Section 2 and decrease your initial overland flow-path length and re-delineate your flow-path areas to reduce the overland flow-path channel velocity until it is less than 6 fps.

5 Channelized Flow-Path Area Travel Times

1. Record the Q's at the upstream and downstream end of each flow-path segment reach. Q_{top} is generally equal to the sum of all the previous $Q_{flow\text{-}pathareas}$. Q_{bottom} is generally equal to the sum of all the previous $Q_{flow\text{-}pathareas}$ plus $Q_{immediateflow\text{-}patharea}$.
2. For natural channels, use Exhibit 9 or 10 (depending on slope) and effective slope to determine the velocity at the top and bottom of the reach. Find the average of the two velocity values. Determine wave velocity for mountain and valley channels with unknown geometry or streets by multiplying average velocity by 1.5.
3. For streets, use Exhibits 11a-d and map slope to find the velocities and average the results. Determine wave velocity as above.
4. If one of the reaches has an improved rectangular or trapezoidal open channel, find reach top and bottom elevation, length, sideslope (H:V) and map slope. Calculate velocity at the top and bottom of the reach using Manning's equation with n assumed to be 0.015 for formed or wood-floated finish of a Reinforced Concrete Channel. Average the velocities and calculate wave velocity from Exhibits 12a-b.
5. For pipe flow, size the pipe and find the wave velocity with the following:
   - Calculate the approximate diameter of the pipe with Manning's Equation and the Q at the downstream end of the reach. Increase the calculated pipe size to the standard pipe size which is the next size up from the calculation result (standard pipe sizes go up by 3 inches from 3" to a diameter of 42", and by 6" up to a diameter of 8-ft. 8-ft is the maximum pipe size used in the VCRat program).
   - Calculate the Qfull of the standard size pipe using Manning's equation
   - Calculate Qaverage of the flows at the upstream and downstream ends of the pipe reach.
   - Calculate the velocity of the Qfull flow in the pipe (Vfull).
   - Check to make sure Qfull is greater than subarea flow.
   - Calculate Qave/Qfull to find %Q
   - From Exhibit 12c look up %Vw (pipe wave velocity) corresponding to %Q.
   - Multiply Vfull by %Vw to find Vw and calculate travel time in minutes.
6. Calculate channel travel time in minutes for each subarea reach: ((subarea flow length)/ [(60)(wave velocity)])

6 Sum Travel Times for Tc and Iterate if Necessary

1. Obtain total Tc from the sum of the overland flow and downstream flow-paths for the subarea.

2. If the total calculated Tc does not equal the initial assumed Tc, you will have to make another Tc assumption and repeat the calculations. If the total calculated Tc is greater than your estimated Tc, increase your estimated Tc value. If the total calculated Tc is less than your estimated Tc, decrease your estimate. Repeat until your calculated Tc is less than 0.50-min different from your initial estimate.
3. Tc cannot be any less than 5 min or any more than 30 min. Adjust your subarea size to produce a Tc in the desired range.
4. Currently Tc's can only be entered into the VCRat program in whole minutes.
5. If you are using the Tc Calculator program, the program will perform the iterations for you.

7 Land Development Review Submittal Materials

1. Tc calculations for 75% of your developed subareas and 25% of your undeveloped subareas.
2. Workmaps with scale showing subareas, topo, flow-paths, flow-path area delineation and names, calculations for flow-path areas and percents, and hand calculation forms or Tc Calculator program output