Data Analysis Assignment #1 – Evaluating the effects of watershed land use on storm runoff

Assignment due: 21 February 2013, 5 pm

Objectives: After completing this assignment, you should be able to:

1) Calculate peak discharge for small urban watersheds using the graphical method of the NRCS (TR-55);
2) Evaluate sources of uncertainty and error in the TR-55 estimates;
3) Compare TR-55 prediction to USGS measurements of peak flow for the same watershed; and
4) Calculate selected hydrograph parameters from USGS discharge measurements.

Study Area:

You will be working with data from West Creek at Pleasant Valley Road, near Parma, OH. There is a USGS stream gage (#412141081) located at N 41°21'41", W 81°41'21". The drainage area at the stream gage is 1.10 mi^2. According to USDA soil survey maps[1], the Mahoning and Ellsworth silt loams are the dominant soil type in the watershed. They belong to the USDA Hydrologic Soils Group C. Two versions of USGS topographic maps of the watershed area are available. The 1953 topographic map is what we will use for our pre-development conditions, and the 1994 topographic map is what we will use for our urbanized conditions. You may also want to look at this area in Google Earth, where there is imagery ranging from 1994 to today.

In the 1994 map, West Creek is underneath the label Pleasant Valley Shopping Center, and the stream gage is where Pleasant Valley Road crosses the stream. The major road to the south of Pleasant Valley Road is Sprague Road. The major north-south road is Broadview Road. *It is 0.73 miles along Broadview Road from Pleasant Valley to Sprague Road.*

Note: Even though I prefer metric units, the TR-55 method and USGS data are reported in imperial units (feet, miles, etc.). Watch your units carefully, and stick with the units defined in the methods.

Part 1: Watershed delineation

Delineate the watershed of West Creek at Pleasant Valley Road on a topographic map. *Turn in a neatly outlined watershed on the 1953 or 1994 topographic map.* Make sure your name is on it.

[1] Soil survey maps accessed at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Part 2: Worksheet 2: Runoff curve number and runoff

Turn in two neatly completed Worksheet 2s from the TR-55 manual. One worksheet should indicate 1953 conditions, while the other indicates 1994 conditions.

1. Assume that your soils are uniformly hydrologic group C and write that information on worksheet 2.
2. Using the 1953 topo map, examine land use conditions in your watershed, considering cover type, treatment, and hydrologic condition, using Chapter 2 of the TR-55 manual for guidance.
3. Estimate the % of the watershed covered by each land use type and write those estimates in the "cover description" and "area" columns of Worksheet 2.
4. Use Table 2.2a to select the appropriate curve number for your watershed,
    a. Assume average antecedent runoff conditions
    b. Assume all impervious cover is directly connected to the drainage system
5. Calculate a weighted curve number for your watershed.
6. Using Table 2-1, calculate a runoff depth for different size rain storms, as follows:
    a. 2.5 inches (2 year, 24 hour event)
    b. 3 inches (5 year, 24 hour event)
    c. 5 inches (100 year, 24 hour event)
    d. Note that these rainfall amounts are derived from the maps in Appendix B of TR-55.

Congratulations! You've calculated the total runoff from each storm for the 1953 pre-development conditions.

7. Now repeat steps 1-6 using the watershed land use conditions as shown on the 1994 topographic map.

Part 3: Worksheet 3: Time of Concentration and Travel Time

Turn in two neatly completed Worksheet 3s from TR-55 (one for 1953 and one for 1994). On your watershed map from Part 1, indicate the segments you used in your calculations.

1. Time of concentration (Tc) is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest (i.e., the outlet). This is the method we will be using.
2. Identify the hydraulically most distant point on your watershed map. This should be someplace along the watershed divide. You'll probably want to sketch in a flowline connecting this point to the appropriate downslope channel.
3. Calculate travel time for sheet flow
    a. Select a surface description from Table 3.1 and record the appropriate Manning's roughness coefficient
    b. Measure the flow length of your hydraulically most distant point to the downslope channel. Follow the rules for flow routing (i.e., flowlines go downhill along steepest slope and perpendicular to contour lines.
    c. Reminder: You can scale your distance to feet using the distance from Pleasant Valley Road to Sprague Road along Broadview Road (hint: that distance is 0.73 miles).

d. If the distance to the channel is greater than 300 feet, record 300 feet and use the rest of the distance for the next section.
e. The two year 24 hour rainfall is 2.5 inches from Part 2.6
f. Using the contour lines, measure the land slope along your flowline.
g. Calculate the travel time using the equation given on Worksheet 3.

4. Calculate travel time for shallow concentrated flow (this would usually be within a crenulation on the topographic map but upslope of a stream channel).
    a. Is your surface paved or unpaved?
    b. Use the remainder of your flow length calculated in part 3.3b.
    c. Using the contour lines, measure the land slope along your flowline.
    d. From Figure 3.1, determine the average velocity.
    e. Calculate the travel time using the equation given on Worksheet 3.
5. Calculate travel time for channel flow.
    a. Since we don't have data for this stream, I've used some data on hydraulic geometry for streams in the North Carolina Piedmont.[2] In a real application of the TR-55 method, you would want to have field measurements of channel geometry or a regionally appropriate hydraulic geometry curve.
    b. Assume a cross-sectional area of 23 ft^2 and a wetted perimeter of 14.8 ft.
    c. Using the contour lines, measure your channel slope over the length of the channel.
    d. Assume a Manning's roughness coefficient of 0.045.[3]
    e. Compute velocity using the equation on Worksheet 3. This is the Manning's equation widely used to estimate velocity and discharge when direct measurements are not available.
    f. Measure the flow length in the stream channel. (You should have already had to do this in order to get slope.)
    g. Calculate the travel time using the equation given on Worksheet 3.
6. Compute the total Tc by summing the travel times calculated in steps 3-5.
7. Repeat steps 3-6 using 1994 land cover conditions. Some of your numbers may be the same.

Part 4: Worksheet 4: Graphical Peak Discharge method

Turn in two neatly completed Worksheet 4s from TR-55 (one for 1953 and one for 1994).

1. Record the drainage area (given above), runoff curve number, and time of concentration from previous parts of the assignment.
2. Ohio, and most of the US, has a Type II rainfall distribution.
3. Using the topo maps for guidance, decide if there are pond or swamp areas spread through the watershed.
4. Using the storms you used in Part 2, record the frequency and precipitation.
5. Use Table 4.1 to get the initial abstraction I_a and compute I_a/P.
6. Using Exhibit 4-II, find T_c and I_a/P to calculate unit peak discharge (csm/in = cubic feet per square mile per inch).

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[2] http://www.bae.ncsu.edu/programs/extension/wqg/srp/rural_pied_paper.html Is the assumption that channel geometries are similar in the Piedmont and northeastern Ohio justified? Is the assumption that channel geometry is the same between 1953 and 1994 justified?

[3] Based on calculated values for headwater streams in central Ohio: http://naldc.nal.usda.gov/download/35868/PDF

7. Record total runoff Q from worksheet 2.
8. Apply the pond and swamp correction factor if appropriate.
9. Calculate peak discharge using the equation provided on worksheet 4.
10. After you've filled out worksheet 4 for 1953 conditions and all 3 storms, repeat the process for 1994 conditions.

Part 5: Discuss your results

Write 1-2 pages answering the following questions:

1. *Based on your calculations in parts 1-4, how did urbanization affect the total runoff and peak flows in the West Creek watershed? (Be quantitative in your answers)*
2. *How do your calculations compare to real data on peak flows from a ~2.5" storm event?*
3. *What are the sources of uncertainty and/or error in your analyses? Which of these potential errors do you think is likely to be most important?*

During the passage of "Superstorm Sandy", the West Creek watershed received 2.38 inches of precipitation on October 30, 2012.[4] In order to see what the hydrologic result was, go to the USGS web page with current and historical observations for West Creek at Pleasant Valley Road (http://waterdata.usgs.gov/oh/nwis/uv/?site_no=412141081412100&PARAmeter_cd=00065,00060,00010). Select an appropriate date range and use the graphs and/or tables to identify the peak flow.

Part 6: Calculate hydrograph parameters from USGS discharge measurements

Turn in a printed hydrograph[5] of the November 12, 2012 storm event in West Creek, along with your calculations of the following parameters: (1) peak discharge; (2) lag time (=time of rise) from peak precipitation to peak discharge; (3) total storm flow; (4) total baseflow during the event; and (5) the hydrograph response factor for the event.

1. On November 12, 2012, Parma received 0.58" of precipitation[6]. Rain began at ~9:24 am, and ended at 7:55 pm. Half of the rainfall had occurred by 12:39 pm, and the most intense rainfall occurred at 1:24 pm.
2. Go to the USGS web page with current and historical observations for West Creek at Pleasant Valley Road (http://waterdata.usgs.gov/oh/nwis/uv/?site_no=412141081412100&PARAmeter_cd=00065,00060,00010) and download tab separated data from November 11th – 18th, 2012. Open tab separated file in Excel or another spreadsheet program of your choice.
3. Create a graph of discharge versus time. Use this hydrograph and/or the tabular data to identify the peak discharge and the lag time.

[4] http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KOHPARMA8&day=30&year=2012&month=10&graphspan=day
[5] One you created in a graphing program and labeled appropriately, and not one you downloaded directly from the USGS website.
[6] http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KOHPARMA8&graphspan=day&month=11&day=12&year=2012

4. In order to calculate the total storm flow and total baseflow during the event, you will need to compute a hydrograph separation. A hydrograph separation line is added to the hydrograph that divides stormflow from baseflow. The hydrograph separation line begins at the point of initial rise for the storm and extends upward at a slope of 0.05 $ft^3/sec/mi^2/hour$ until it intercepts the hydrograph. The volume of runoff between the hydrograph and the baseflow separation line is the stormflow (or quickflow). This is one arbitrary, but widely accepted, method to separate a storm hydrograph into streamflow that is directly associated with a storm versus streamflow that is baseflow.[7]
    a. Make sure you use the watershed area (1.1 mi^2) to adjust the slope of the separation line.
    b. The best way to do this separation is to create a formula in the spreadsheet to calculate baseflow at each timestep. Then subtract the baseflow from the measured discharge to get stormflow. Sum up each of those baseflow and stormflow numbers, multiply by the the number of seconds between each timestep, and you'll get the total volumes of baseflow and stormflow for the event.
    c. If you don't know how to do this in Excel, you should learn. But if you can't or don't have time to learn, you can carefully draw the correctly sloped line on your hydrograph by hand and then figure out how to calculate the area in each portion of the hydrograph.
5. Once stormflow is determined, a hydrograph response factor can be calculated for the storm. The hydrograph response factor is the total stormflow volume divided by the total rainfall for the storm, expressed as a percent. To convert the precipitation given above to a volume per time, multiply by the watershed area. [Note: You need to watch units!]

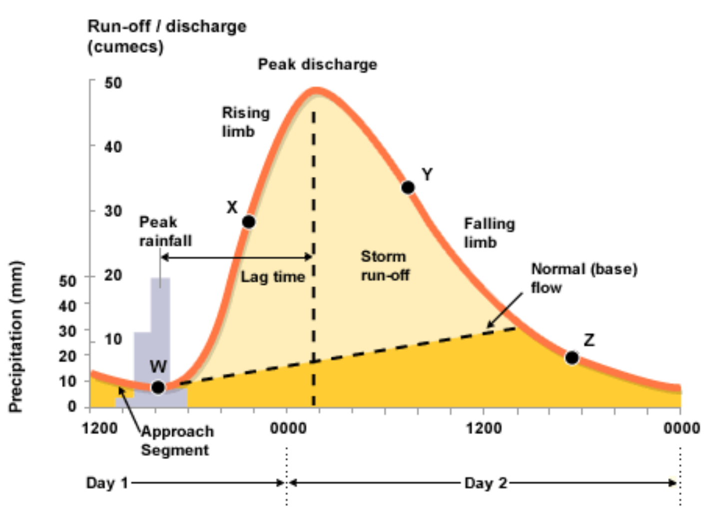

Image from http://www.bbc.co.uk/bitesize/higher/geography/physical/hydrosphere/revision/1/.

[7] Hewlett, J.D. and Hibbert, A.R. 1967: Factors affecting the response of small watersheds to precipitation in humid areas. In Sopper, W.E. and Lull, H.W., editors, Forest hydrology, New York: Pergamon Press, 275–90. Available at: http://soilandwater.bee.cornell.edu/research/VSA/papers/HewlettHibbert67.pdf