EXAMPLES OF t_L – EQUATIONS
(Source: Wurbs & James, 2000)

8.3.2.1 NRCS lag equation. The NRCS developed the following equation for watersheds with areas of less than about 8 km^2 (2,000 ac) and CN between 50 and 95 (NRCS, 1985; Haan, Barfield, and Hayes, 1994; McCuen, 1998). Equations 8.3 and 8.4 are English (l in ft) and metric (l in m) versions of the NRCS lag formula.

$$t_L = \frac{l^{0.8}(1{,}000 - 9\text{CN})^{0.7}}{1{,}900\text{CN}^{0.7}Y^{0.5}} \tag{8.3}$$

$$t_L = \frac{l^{0.8}(2{,}540 - 22.86\text{CN})^{0.7}}{1{,}410\text{CN}^{0.7}Y^{0.5}} \tag{8.4}$$

The lag t_L is in hours. The hydraulic length l from the outlet to the most hydraulically remote point in the watershed is in feet (Eq. 8.3) or meters (Eq. 8.4). CN is discussed in Section 8.5.1. Y is the average land slope of the watershed in percent.

8.3.2.2 USGS lag equation. Jennings, Thomas, and Riggs (1994) summarize lag equations developed by the USGS for different rural and urban regions of the U.S. by applying regression analyses to data from gaged watersheds. Based on regression analyses for 170 gaged urban watersheds throughout the U.S., the USGS developed the following equation for estimating t_L for urban watersheds nationwide.

$$t_L = 0.003L^{0.71}\,(13 - BDF)^{0.34}\,(ST + 10)^{2.53}\,RI2^{-0.44}\,IA^{-0.20}\,SL^{-0.14} \tag{8.5}$$

Lag t_L is in hours. L in miles is the length from the outlet along the main channel and its extension to the watershed divide. Storage ST is the percentage of the watershed occupied by lakes, reservoirs, and wetlands. $RI2$ is the rainfall in inches for a duration of 2 hours and recurrence interval of 2 years. IA is the percentage of the watershed covered by impervious surfaces. SL is the slope of the main channel in feet per mile. The basin development factor (BDF) in Eq. 8.5 is also incorporated in Eqs. 7.39–7.45 and is defined in Section 7.8.2. BDF is an index of the prevalence of urban drainage improvements.

8.3.2.3 Snyder lag equation. As discussed in Section 8.6.5, Snyder (1938) developed a synthetic unit hydrograph based on a study of watersheds in the Appalachian Mountains region with drainage areas ranging from 26 to 26,000 km^2 (10 to 10,000 mi.^{2}). Snyder's unit hydrograph procedure includes the lag equation

$$t_L = C_t(LL_c)^{0.3} \tag{8.6}$$

where lag t_L is in hours, L is the length of the main stream from outlet to divide, and L_c is the length of the main stream from outlet to a point nearest the watershed centroid. C_t is a coefficient that accounts for the slope, land use, and associated storage characteristics of the river basin. With distances L and L_c in miles, Snyder found values of C_t to range from 1.8 to 2.2, with a mean of 2. With distances L and L_c in kilometers, the corresponding range of C_t is 1.35–1.65, with a mean of 1.5.

Example 8.1

Estimate the lag time for the watershed of Fig. 8.4. The soil and vegetative characteristics of the watershed are represented by a CN of 80.

Solution A hydraulic length of 15,000 ft (4,570 m) is scaled from Fig. 8.4. The map has a contour interval of 10 ft (3.05 m). Scaling horizontal distances between the contours provides estimates of land slope (vertical divided by horizontal distances) at various points throughout the watershed. Although the slope varies significantly at different locations, a Y of 2.3 percent is estimated to be a representative average for the watershed. Equations 8.3 and 8.4 are based alternatively on metric and English units, respectively.

$$t_L = \frac{l^{0.8}(2{,}540 - 22.86\text{CN})^{0.7}}{1{,}410\text{CN}^{0.7}Y^{0.5}} = \frac{(4{,}570)^{0.8}(2{,}540 - 22.86(80))^{0.7}}{1{,}410(80)^{0.7}(2.3)^{0.5}} = 1.83 \text{ hrs}$$

$$t_L = \frac{l^{0.8}(1{,}000 - 9\text{CN})^{0.7}}{1{,}900\text{CN}^{0.7}Y^{0.5}} = \frac{(15{,}000)^{0.8}(1{,}000 - 9(80))^{0.7}}{1{,}900(80)^{0.7}(2.3)^{0.5}} = 1.83 \text{ hrs}$$

The watershed lag time is estimated to be about 1.8 hours.

SOURCE: Wurbs & James, 2002

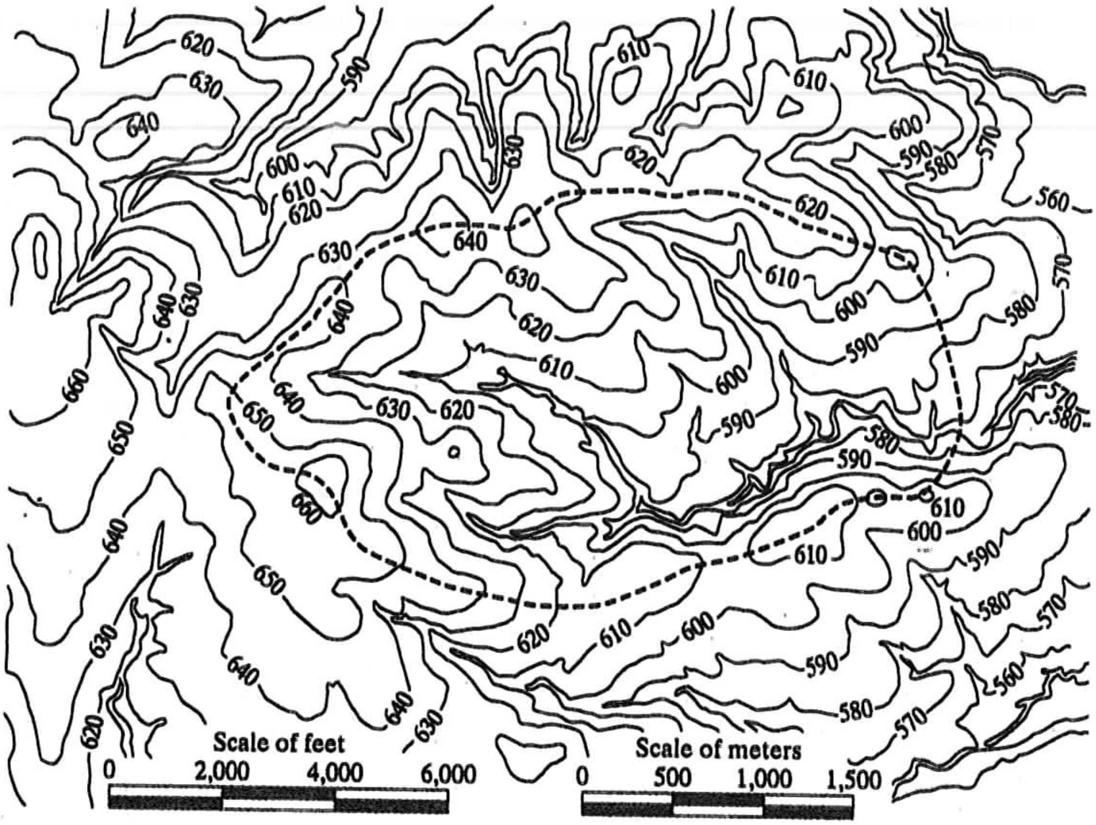

Figure 8.4 The watershed is delineated on a contour map (contour interval = 10 ft).