11.5 Hydrology

11.5.1 Introduction

The rational method is the most common method in use for the design of storm drains when the momentary peak flow rate is desired. Its use should be limited to systems with drainage areas of 81 ha (200 acres) or less. Drainage systems involving detention storage and pumping stations require the development of a runoff hydrograph. (See Chapters 6, 10 and 12 – Hydrology, Storage Facilities, and Pump Stations).

11.5.2 Rational Method

The Rational Equation is written as follows:

$$Q = 0.00278CIA = 0.00278\ (\sum CA)\ I \qquad (Q = CIA) \qquad \mathbf{(11.1)}$$

Where: Q = discharge, m^3/s (ft^3/s)
C = runoff coefficient
I = rainfall intensity, mm/h (in/h)
A = drainage area, ha (ac)

11.5.3 Runoff Coefficient

The runoff coefficients for various types of surfaces are discussed in Chapter 6, with tables of appropriate values. The weighted C value is to be based on a ratio of the drainage areas associated with each C value as follows:

$$\text{weighted } C = [A_1C_1 + A_2C_2 + A_3C_3] / [A_1 + A_2 + A_3] \qquad \mathbf{(11.2)}$$

11.5.4 Rainfall Intensity

Rainfall intensity (I): Rainfall intensity is the intensity of rainfall in millimeters (inches) per hour for a duration equal to the time of concentration. Intensity is a rate of rainfall over an interval of time such that intensity multiplied by duration equals amount of rain, i.e., an intensity of 130 mm/h for a duration of 5 min indicates a total rainfall amount of 130 X 5/60 = 10.8 mm. See Chapter 6 Hydrology for a more complete discussion and data to be used for determining the intensity of rainfall.

11.5.5 Time of Concentration

The time of concentration is defined as the period required for water to travel from the most hydraulically distant point of the watershed to the point of the storm drain system under consideration. The designer is usually concerned about two different times of concentration: one for inlet spacing and the other for pipe sizing. There is a major difference between the two times.

- **Inlet Spacing**

The time of concentration (t_c) for inlet spacing is the time for water to flow from the hydraulically most distant point of the drainage area to the inlet, which is known as the inlet time. Usually this is the sum of the time required for water to move across the pavement or overland back of the curb to the gutter, plus the time required for flow to move through the length of gutter to the inlet. **For pavement drainage, when the total time of concentration to the upstream inlet is less than 5 min, a minimum t_c of 5 min should be used to estimate the intensity of rainfall**. The time of concentration for the second downstream inlet and each succeeding inlet should be determined independently, the same as the first inlet. In the case of a constant roadway grade and relatively uniform contributing drainage area, the time of concentration for each succeeding inlet could also be constant.

- **Pipe Sizing**

The time of concentration for pipe sizing is defined as the time required for water to travel from the most hydraulically distant point of the watershed to the point of the storm drain system under consideration. It generally consists of two components: (1) the time to flow to the inlet which can consist of overland and channel or gutter flow and (2) the time to flow through the storm drain to the point under consideration.

Travel time within the storm drain pipes can be estimated by the relation:

$$t_t = L / 60V \quad \textbf{(11.3)}$$

Where: t_t = travel time, min
L = length of pipe in which runoff must travel, m (ft)
V = estimated or calculated normal velocity, m/s (ft/s)

Methods for determining time of concentration are further described in Chapter 6 Hydrology.

To summarize, the time of concentration for any point on a storm drain is the inlet time for the inlet at the upper end of the line plus the time of flow through the storm drain from the upper end of the storm drain to the point in question. In general, where there is more than one source of runoff to a given point in the storm drainage system, the longest t_c is used to estimate the intensity (I). There could be exceptions to this generality, for example where there is a large inflow area at some point along the system, the t_c for that area may produce a larger discharge than the t_c for the summed area with the longer t_c. The designer should be cognizant of this possibility when joining drainage areas and determine which drainage area governs. To determine which drainage area controls, compute the peak discharge for each t_c. Note that when computing the peak discharge with the shorter t_c, not all the area from the basin with the longest t_c will contribute runoff. One way to compute the contributing area, A_c, is as follows:

$$\mathbf{A_c = A\,[t_{c1} / t_{c2}]} \quad \textbf{(11.4)}$$

Where: $t_{c1} < t_{c2}$ and A is the area of the basin with the longest t_c.

In municipal areas, a minimum time of concentration of 5 min is recommended for calculation of runoff from paved areas and 10 min. for areas mostly grass. All other areas should be calculated on a case by case basis.

11.5.6 Detention Storage

Reduction of peak flows can be achieved by the storage of runoff in detention basins, storm drains, swales and channels, and other detention storage facilities. Stormwater is then released to the downstream conveyance facility at a reduced flow rate. The concept should be considered for use in highway drainage design where existing downstream conveyance facilities are inadequate to handle peak flow rates from highway storm drainage facilities, where the highway would contribute to increased peak flow rates and aggravate downstream flooding problems, and as a technique to reduce the right-of-way, construction, and operation costs of outfalls from highway storm drainage facilities. See Chapter 10, Storage Facilities.