CHAPTER 2

HYDROLOGY

2.4 Rational Method

2.4.1 Introduction

When using the rational method some precautions should be considered.

- In determining the C value (land use) for the drainage area, hydrologic analysis should take into account any changes in land use.
- Since the rational method uses a composite C value for the entire drainage area, if the distribution of land uses within the drainage basin will affect the results of hydrologic analysis, then the basin should be divided into two or more sub-drainage basins for analysis.
- The charts, graphs, and tables included in this section are given to assist the engineer in applying the rational methods. The engineer should use good engineering judgment in applying these design aids and should make appropriate adjustments when specific site characteristics dictate that these adjustments are appropriate.

2.4.2 Equation

The rational formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration (the time required for water to flow from the most remote point of the basin to the location being analyzed). The rational formula is expressed as follows:

$$Q = CIA \qquad \textbf{(Eq. 2.4.2-1)}$$

Where: Q = maximum rate of runoff (cfs)
C = runoff coefficient representing a ratio of runoff to rainfall
I = average rainfall intensity for a duration equal to the time of concentration (in./hr)
A = drainage area contributing to the design location (acres)

2.4.3 Infrequent Storms

The coefficients given in Table 2.5-1 are applicable for storms of 5-yr to 10-yr frequencies. Less frequent, higher intensity storms will require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on runoff (Wright-McLaughlin 1969). The adjustment of the rational method for use with major storms can be made by multiplying the right side of the rational formula by a frequency factor C_f. The rational formula now becomes:

$$Q = CC_fIA \qquad \textbf{(Eq. 2.4.3-1)}$$

The C_f values that can be used are listed below in Table 2.4.3-1. The product of C_f times C shall not exceed 1.0.

Table 2.4.3-1
Frequency Factors for Rational Formula

Recurrence Interval (Years)	C_f
25	1.1
50	1.2
100	1.25

2.4.4 Time of Concentration

Use of the rational formula requires the time of concentration (t_c) for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I) from Table 2.3-1. The time of concentration consists of an overland flow time to the point where the runoff enters a defined drainage feature (i.e., open channel) plus the time of flow in a closed conduit or open channel to the design point.

Figure 2.4.6-1 can be used to estimate overland flow time. For each drainage area, the distance is determined from the inlet to the most remote point in the tributary area. From a topographic map, the average slope is determined for the same distance. The runoff coefficient (C) is determined by the procedure described in a subsequent section of this chapter. Other methods and charts may be used to calculate overland flow time if approved by the City of Lawrenceville.

To obtain the total time of concentration, the pipe or open channel flow time must be calculated and added to the inlet time. After first determining the average flow velocity in the pipe or channel, the travel time is obtained by dividing velocity into the pipe or channel length. Velocity can be estimated by using the nomograph shown on Figure 2.4.6-2. Note: time of concentration cannot be less than 5 minutes.

Two common errors should be avoided when calculating time of concentration – t_c. First, in some cases runoff from a portion of the drainage area which is highly impervious may result in a greater peak discharge than would occur if the entire area were considered. In these cases, adjustments can be made to the drainage area by disregarding those areas where flow time is too slow to add to the peak discharge. Second, when designing a drainage system, the overland flow path is not necessarily the same before and after development and grading operations have been completed. Selecting overland flow paths in excess of 100 feet in urban areas and 300 feet in rural areas should be done only after careful consideration. The estimate of overland flow time should not dominate the total time of concentration.

2.4.5 Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in in./hr for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for a design, a time of concentration is calculated for the drainage area, the rainfall intensity can be determined from Rainfall-Intensity-Duration data. Table 2.3-1 gives the data for the City of Lawrenceville. Straight-line interpolation can be used to obtain rainfall intensity values for storm durations between the values given in Table 2.3-1.

2.4.6 Runoff Coefficient

The runoff coefficient (C) is the variable of the rational method least susceptible to precise determination and requires judgment and understanding on the part of the design engineer. While engineering judgment will be required in the selection of runoff coefficients, typical coefficients represent the integrated effects of many drainage basin parameters. Table 2.5-1 gives the recommended runoff coefficients for the Rational Method.

Figure 2.4.6-1 Rational formula – Overland Time of Flow - Nomograph

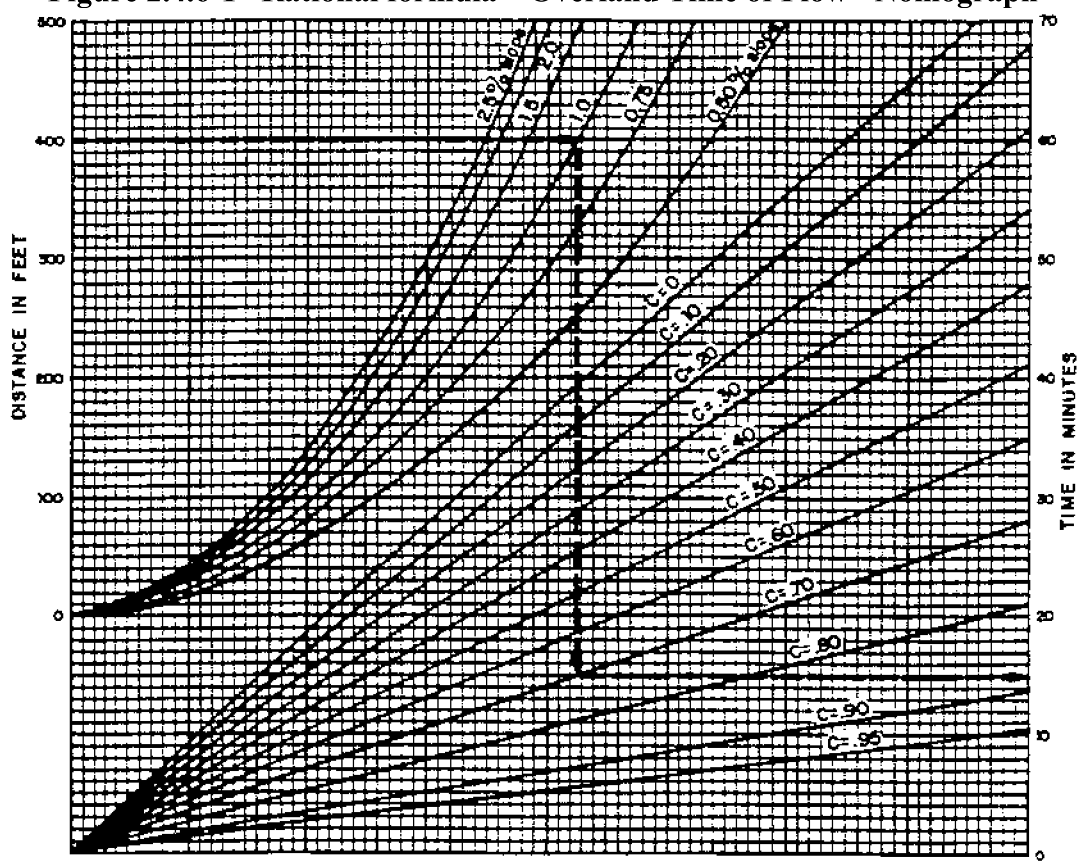
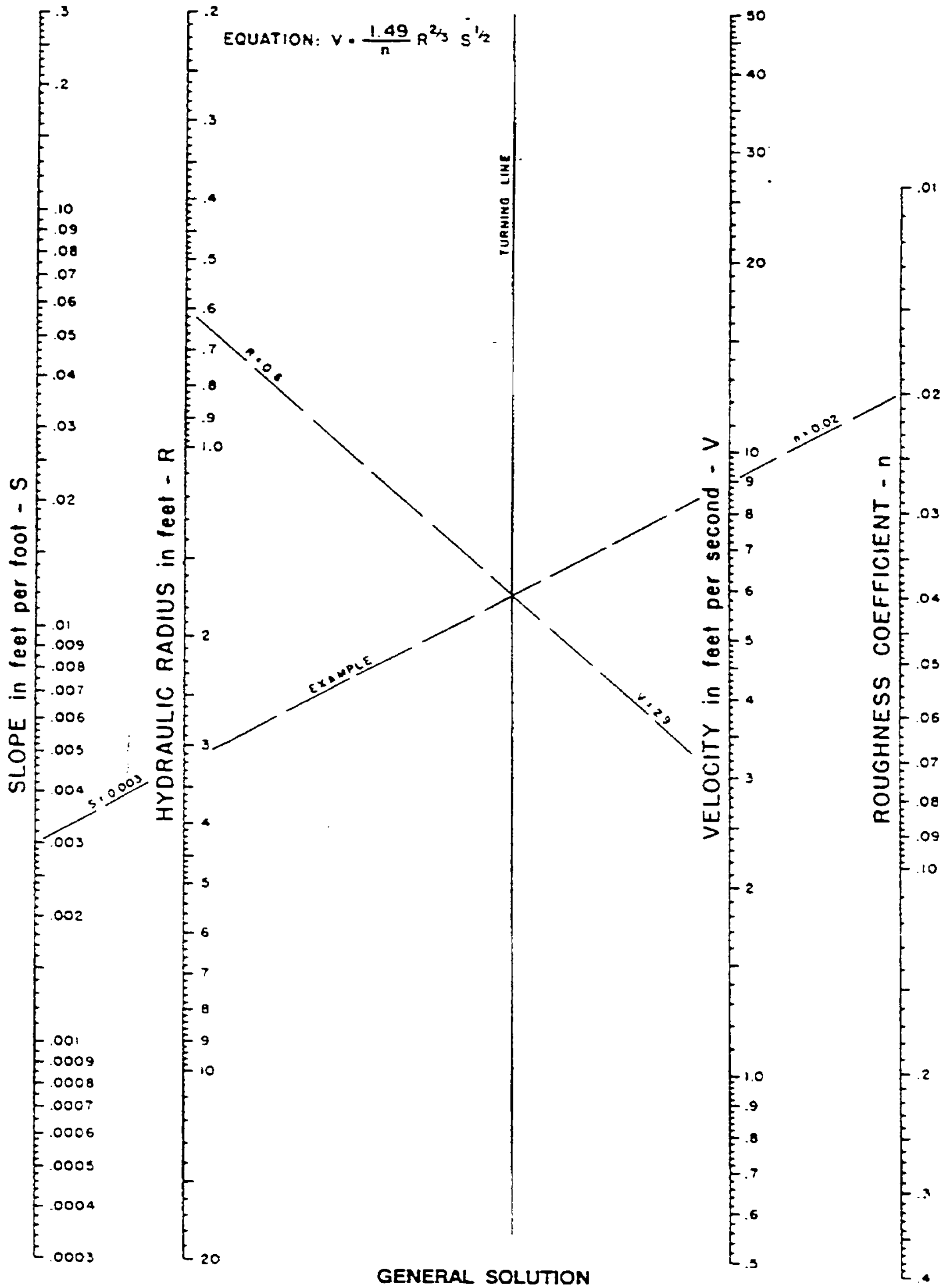


Figure 2.4.6-2
Manning's Equation Nomograph



Reference: USDOT. FHWA. HDS-3 (1961).

2.4.7 Composite Coefficients

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surfaces in the drainage areas. Composites can be made with the values from Table 2.5-1 by using percentages of different land uses. In addition, more detailed composites can be made with coefficients for different surface types such as roofs, asphalt, and concrete street, drives and walks. The composite procedure can be applied to an entire drainage areas or to typical "sample" blocks as a guide to the selection of reasonable values of the coefficient for an entire area.

It should be remembered that the rational method assumes that all land uses within a drainage area are uniformly distributed throughout the area. If it is important to locate a specific land use within the drainage area then another hydrologic method should be used where hydrographs can be generated and routed through the drainage system.

END OF SECTION 2.4