UNIT VIII

RATIONAL METHOD

INTRODUCTION

The rational method is one of the methods commonly used to calculate runoff ("Q"). In order to evaluate the runoff determined in this method, reviewers must be familiar with the inputs to this method (cover, rainfall intensity, and area) and how they are affected by development. Reviewers must also know the limitations of this method to determine if it is the most appropriate method to use to approximate runoff given the conditions of the site.

LEARNING OBJECTIVES

1. To know the inputs used to determine runoff in the rational method.
2. To become familiar with how development impacts each of these inputs.
3. To learn the assumptions used in the rational method and the limitations of the rational method.

INSTRUCTION ELEMENTS

VIII.1 RATIONAL METHOD INPUTS

The rational formula is:

$$Q = CiA$$

where,

- Q = Peak rate of runoff in cubic feet per second (cfs)
- C = Runoff Coefficient (represents the relationship between rainfall and runoff)
- i = Average rainfall intensity for the time of concentration (Tc) for the selected design storm
- A = Drainage area in acres

Runoff Coefficient

The first input of the rational method is the runoff coefficient ("C"). The runoff coefficient relates the amount of rainfall to the amount of runoff. In general, as the amount of impervious surface increases, "C" increases. If there was no infiltration of water and the amount of rainfall was equal to the amount of runoff, "C" would be equal
to 1. Runoff from paved surfaces and rooftops most closely approximates this value with a "C" factor ranging up to 0.95. Table 5-2 on page V-29 of the VESCH provides a table of "C" values for various land uses. If more than one land use exists in the watershed, a weighted average of "C" values should be calculated. Step 2 under the Rational Method in the VESCH (page V-5) explains how to calculate the weighted "C."

Rainfall Intensity

The second input of the rational method is the rainfall intensity (*I*). In order to determine the rainfall intensity, the time of concentration must already be known (refer to Unit VII). In the rational method, the time of concentration is considered to be equal to the storm duration. Using storm duration and the frequency of the storm being used (2-year, 10-year), the intensity can be determined from the Intensity-Duration-Frequency (IDF) curves presented in the VESCH on pages V-14 through V-28 (find the Tc/duration on the horizontal axis, read up to the frequency curve, read left to the vertical axis to find intensity). The IDF curves vary from locality to locality, so care should be taken to use the IDF chart for the area closest in proximity to the project.

The intensity derived from the IDF charts represents the average rainfall intensity for a given frequency. Typically, the rainfall intensity will vary throughout the duration of the storm This relationship can be graphed as rainfall intensity of the vertical axis versus time on the horizontal axis. Known as a hyetograph, this graph shows the volume of precipitation as the area beneath the curve and indicates the time-variation of the intensity.[4] The rational method assumes that the peak discharge of a given frequency storm (2-year, 10-year) is produced by the average rainfall intensity. Furthermore, it also assumes that the duration of the average intensity is equal to the time of concentration. Figure 4.4 depicts how the duration (time) of the average rainfall intensity (shown at the top of the graph) is equal to the time of concentration, and that both are equal to the time to peak (shown at the bottom of the graph).

Area

The final input of the rational method is the area (A). The area is the drainage area to the analysis point in acres.

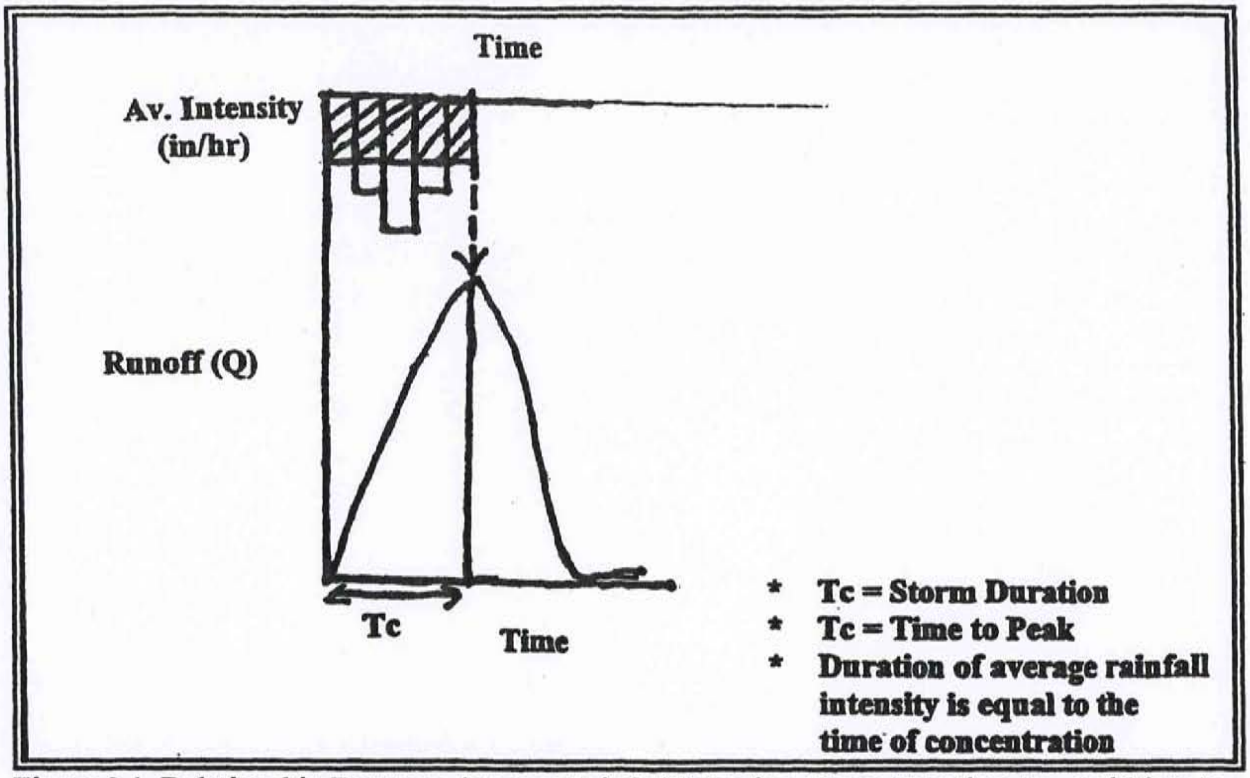

Figure 8.1. Relationship Between Average Rainfall Intensity, Storm Duration, Tc, and Time to Peak in the Rational Method

VIII.2 EFFECTS OF DEVELOPMENT

The key to verifying the runoff calculated by the rational method is to ensure that the inputs are accurate. In particular, those inputs that are more subjective and may be interpreted differently from one person to the next, should be checked. In the rational method, the key inputs to verify are the runoff coefficient ("C") and the time of concentration (Tc).

Runoff Coefficient

To ensure that the runoff coefficient ("C") is correct, the value selected for each type of land use needs to be checked against the Table 5-2 in the VESCH (page V-29). Where there is more than one land use present, the area corresponding to each land use and the weighted "C" also needs to be verified. Reviewers should pay close attention to the pre-developed condition to make sure that the proper land use has been used. For example, if a designer uses a "C" value for rangeland instead of turfgrass, the "C" factor, and the associated runoff, will be higher in the pre-developed condition.

Rainfall Intensity

Checking the intensity involves checking the time of concentration (Tc) (see Unit VII). It is more likely that an error was made in drawing the Tc flow path and calculating Tc, than in reading the intensity off of the IDF chart. Most often, the time of concentration will decrease from pre-development to post-development due to the increase in impervious surfaces and the addition of storm sewer (refer to Unit VII).

Area

If the final input, the area, does not appear correct, it can be verified using a scale or planimeter.

Once all of the inputs have been verified, the only item that remains to be checked is the actual calculation to ensure that a simple math error was not made.

VIII.3 ASSUMPTIONS AND LIMITATIONS

The rational method assumes that the time of concentration is equal to the time it takes runoff from the watershed to peak. Essentially, this means that the peak discharge (measured at the analysis point) does not take place until the entire drainage area is contributing to runoff. As watersheds become larger (and several subwatersheds become apparent) and time of concentration flow paths become longer, the actual peak may have already occurred before the entire watershed contributes to the analysis point. Therefore, the rational method should not be applied to large watersheds. The *Virginia Erosion and Sediment Control Handbook, 1992 Edition* specifies that the rational method can be used to determine peak discharge for drainage areas up to 200 acres. The *Virginia Stormwater Handbook* recently established a more restrictive limit of 20 acres for the rational method.

The rational method also assumes that the time of concentration is equal to the storm duration. Actually, it is more likely that the total storm duration will be longer than the time of concentration in most urbanizing watersheds.[3] However, the rational method assumes that the time to peak equals the time of concentration. It also assumes that the time of concentration equals the storm duration, therefore, this is the duration used in selecting a storm intensity from the IDF curves. If you consider that the time to peak is also equal to the storm duration in the rational method, it follows that this is the duration that is critical to determining runoff.

The rational method becomes more accurate as the amount of impervious area increases.[4] The amount of rainfall that becomes runoff in the rational method is represented only by the runoff coefficient ("C"). Factors that would reduce the amount of rainfall becoming runoff, such as soil type (soils have varied infiltration rates) or ponding (in natural areas or depressions), are not considered by the rational method. Largely impervious areas are less subject to these impacts. Likewise, homogeneous areas lend to better accuracy in determining the runoff coefficient and calculating the amount of runoff using the rational method.