# UNIT IV
# HYDROLOGY OVERVIEW

## INTRODUCTION

Minimum Standard 19 of the Virginia Erosion and Sediment Control Law states that "properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity, and peak flow rate of stormwater runoff ." Fulfilling this requirement provides the basis for one of the most complex and detailed aspects of erosion and sediment control plan review. Understanding why and how development impacts runoff is vital to successfully reviewing plans.

## LEARNING OBJECTIVES

1. To understand the hydrologic cycle.
2. To become familiar with how land use changes affect the hydrologic cycle.
3. To learn how rainfall relates to runoff.
4. To understand how hydrographs are used to determine peak rates of runoff.

## INSTRUCTION ELEMENTS

### IV.1 THE HYDROLOGIC CYCLE

#### Understanding the Relationship Between Rainfall and Runoff

The relationship between rainfall and runoff is governed by the hydrologic cycle. Depicted in Figure 4.1, the hydrologic cycle depicts the different paths water can take on and above the earth's surface. When it rains, some of this rainfall is absorbed into the ground through infiltration, where it contributes to groundwater. Likewise, some of this rainfall creates stormwater runoff, which is captured by bodies of water such as lakes and streams. In both cases, there is an opportunity for this water to return to the atmosphere as precipitation. Water contained in moist soils is subject to being captured by plants, which convert water back into water vapor through a process known as transpiration. Similarly, large expanses of water provide the opportunity for evaporation.

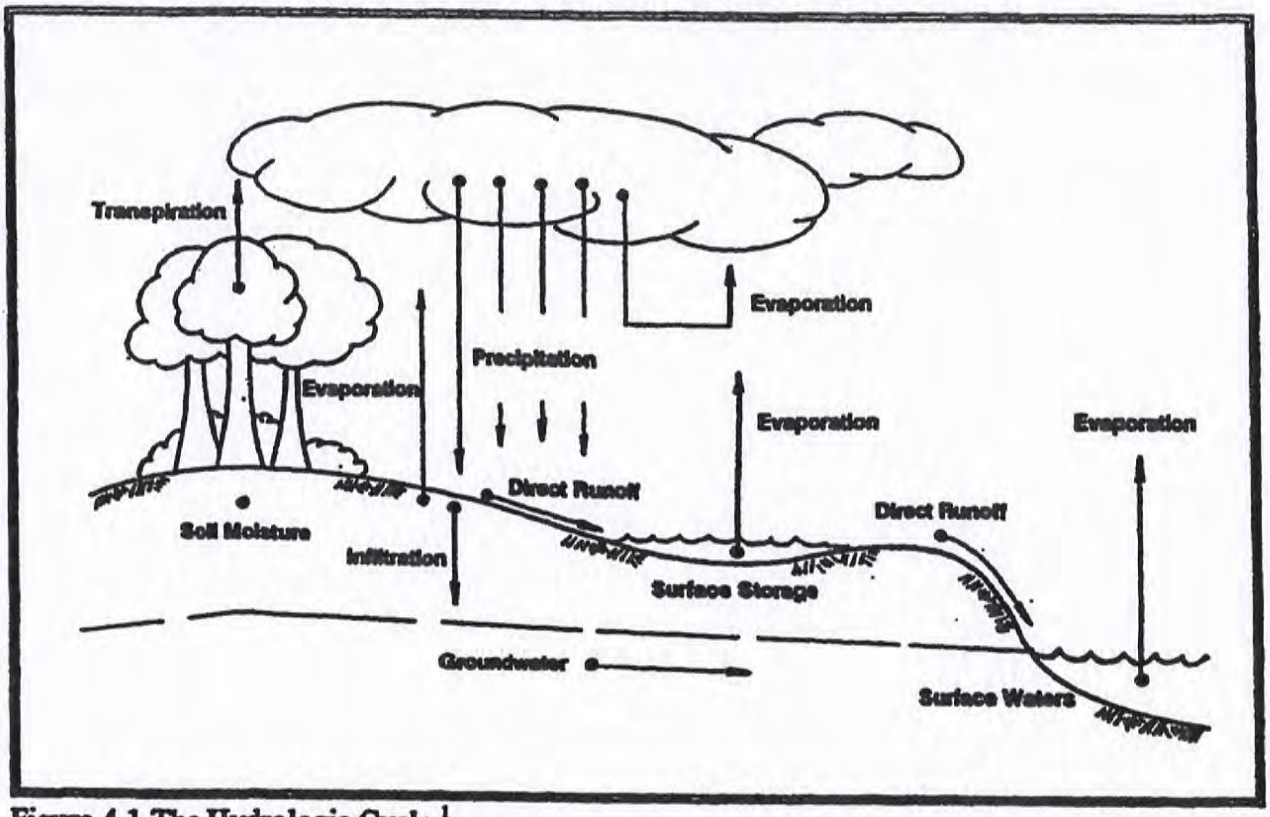


**Figure 4.1 The Hydrologic Cycle** [1]

## IV.2 HYDROLOGIC MODIFICATION

Understanding the Effects of Land Use Changes on the Hydrologic Cycle

While the movement of water between the earth's surface and in the atmosphere maintains a delicate balance (that's why skies aren't always cloudy and properties inland don't eventually become waterfront[1]), the movement of water on the earth's surface changes as development occurs. Figure 4.2 illustrates how increasing the amount of impervious area (e.g., asphalt and pavement) associated with development, decreases the amount of water that infiltrates into the soil, increasing the amount of runoff. This effect becomes more and more exaggerated as the amount of impervious area increases.

Hydrology is defined as the study of the properties, distribution, and effects of water on the earth's surface, and in the soils, underlying rocks, and atmosphere.[3] Changes in hydrology, such as those that result from development, are referred to as hydrologic modification. The principal hydrologic change associated with development is increased runoff, which if not addressed, can lead to erosion, sediment deposition, flooding, and property damage.

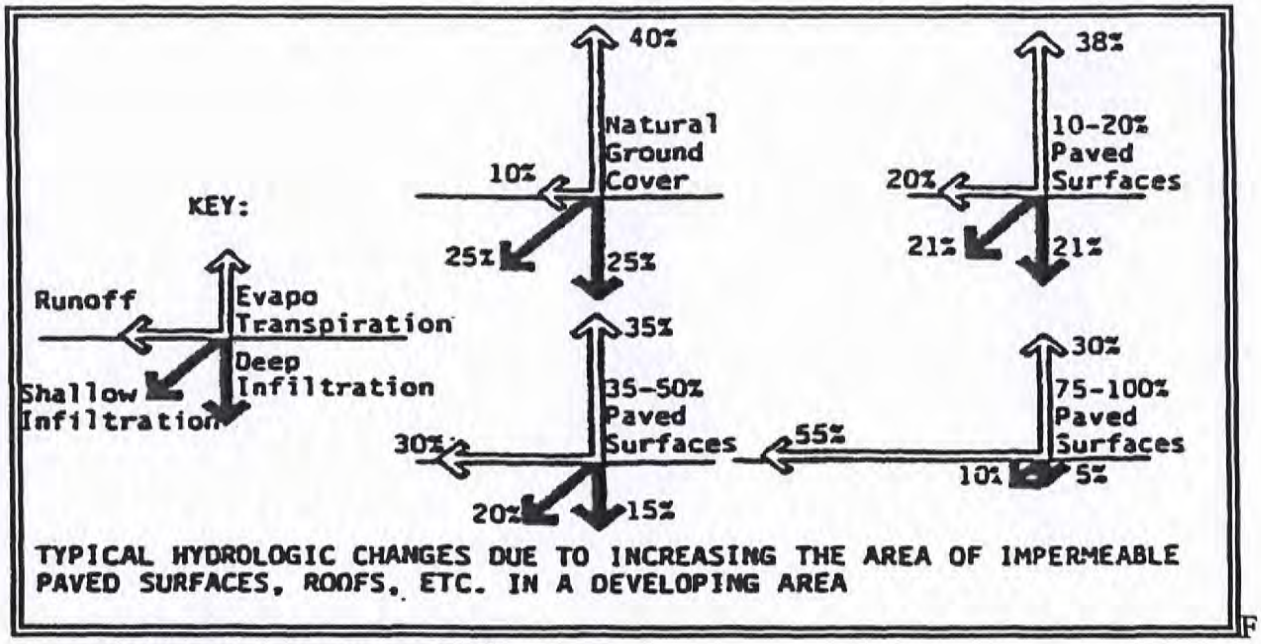


Figure 4.2 Infiltration Versus Runoff[2]

## IV.3 RELATING RAINFALL TO RUNOFF

Understanding Rainfall

Rainfall, because it is the driving force behind runoff, is a key component in determining the amount of runoff (known as "Q") produced by any given site. Rainfall has four distinct and independent characteristics:[3]

- ✔Duration — the length of time over which rainfall occurs (hours)
- ✔Volume — the amount of rainfall occurring throughout the storm duration (inches)
- ✔Frequency — the recurrence interval of events having the same duration and volume
- ✔Intensity — the volume divided by the duration (inches per hour)

Minimum Standard 19 specifies a 24-hour duration storm be used in runoff analysis. It also specifies the frequency (2-year or 10-year) of the storm to be used. Storm frequency is often misunderstood to mean that a 100-year storm will occur only once in 100 years. In actuality, a 100-year storm can occur in any given year, however, the probability of a storm with this duration and volume occurring is considerably less that the probability of a 2-year storm taking place in any given year. The relationship between the frequency of the storm and the probability of the storm occurring in a given period of time (typically one year) is known as the exceedance probability and is further explained in Table 4.1.[3]

Table 4.1 Exceedance Probability of Storms of a Given Frequency

| Year Storm | Probability | Percent Chance |
|---|---|---|
| 100-year | 1/100 | 1% |
| 50-year | 1/50 | 2% |
| 25-year | 1/25 | 4% |
| 10-Year | 1/10 | 10% |
| 5-year | 1/5 | 20% |
| 2-year | 1/2 | 50% |
| 1-year | 1/1 | 100% |

Other factors that influence runoff include cover, area, and soils. How these inputs affect runoff and how they are used in two different methods (rational method and TR-55 graphical peak discharge method) will be explored in later sections of this course book.

## IV.4 ESTIMATING RUNOFF

### Generating a Hydrograph

A hydrograph is a graph that relates runoff to time at a given point in a stream or watershed. Figure 4.3 depicts a hydrograph generated based on storm runoff data obtained at an actual stream gauge in the Chickahominy River Basin in Virginia. The hydrograph relates the storm discharge (or runoff) to time (in this case specific sampling dates) for an actual storm event. A hydrograph obtained from flow records recorded by a stream gauge is a natural hydrograph.

Oftentimes, in designing projects, stream gauge data is not available. More often, the predominant information available is rainfall data, collected using rain gauges. In these cases synthetic hydrographs must be used. A synthetic hydrograph combines watershed parameters with storm characteristics to simulate a natural hydrograph.[4]

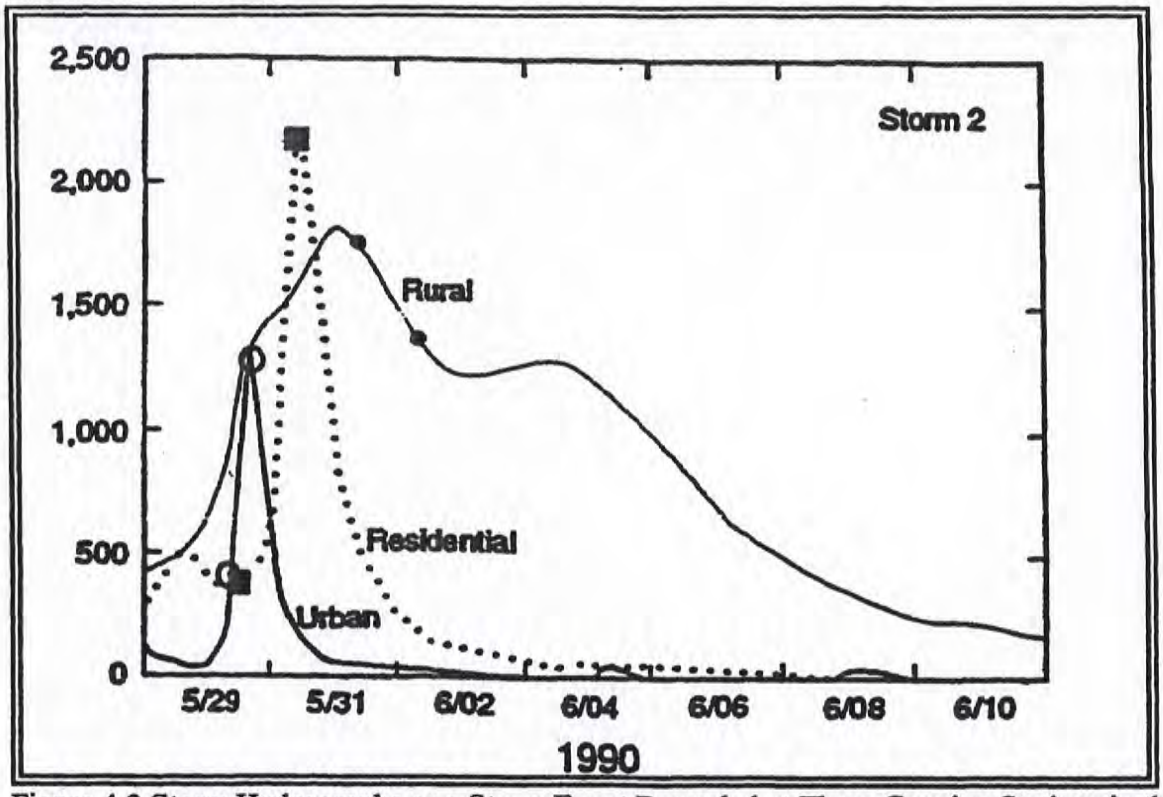


Figure 4.3 Storm Hydrographs or a Storm Event Recorded at Three Gauging Stations in the Chickahominy River Basin[5]

Figure 4.3 also reveals how different land uses affect runoff. The time to peak is much quicker in the urban and residential areas, as opposed to the rural areas, where the peak is more gradual and the hydrograph is spread over a longer period of time. The increased amount of impervious surfaces in urban areas tends to produce large volumes of runoff in a short period of time. In rural areas, the amount of runoff and the time to peak is impacted by infiltration and evapotranspiration.[5]

Both the time to peak and the peak runoff can be determined directly from the hydrograph. In addition, the area beneath the hydrograph represents the volume of runoff (usually expressed in cubic feet or cubic meters). The methods discussed in this course book produce hydrographs that have a peak discharge only. They do not "flesh out" the hydrograph to show runoff rates at individual times (e.g., those that occur on the ascending and descending limbs of the hydrograph). Two of these methods, the rational method and the TR-55 graphical peak discharge method are described later in the course book (in Unit VIII and Unit IX, respectively).