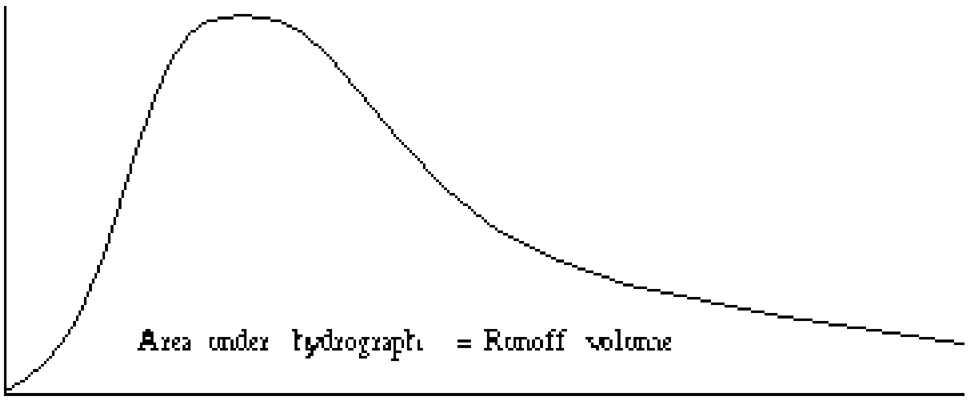
Storm Runoff Prediction



Runoff Hydrograph

Credits:

These materials were adapted from ASM 521 course materials developed by Dean Larry Huggins.

Goal:

To learn quantitative methods to predict surface runoff rates and amounts, *i.e.* simple mathematical models, with known probabilities of occurrence.

Scope:

Runoff is the most basic and important factor needed when planning water control strategies/practices such as waterways, storage facilities or erosion control structures. This module will cover the simpler models; more comprehensive, distributed-parameter models giving complete hydrographs and water chemistry will be covered in section III of this course.

Terms:

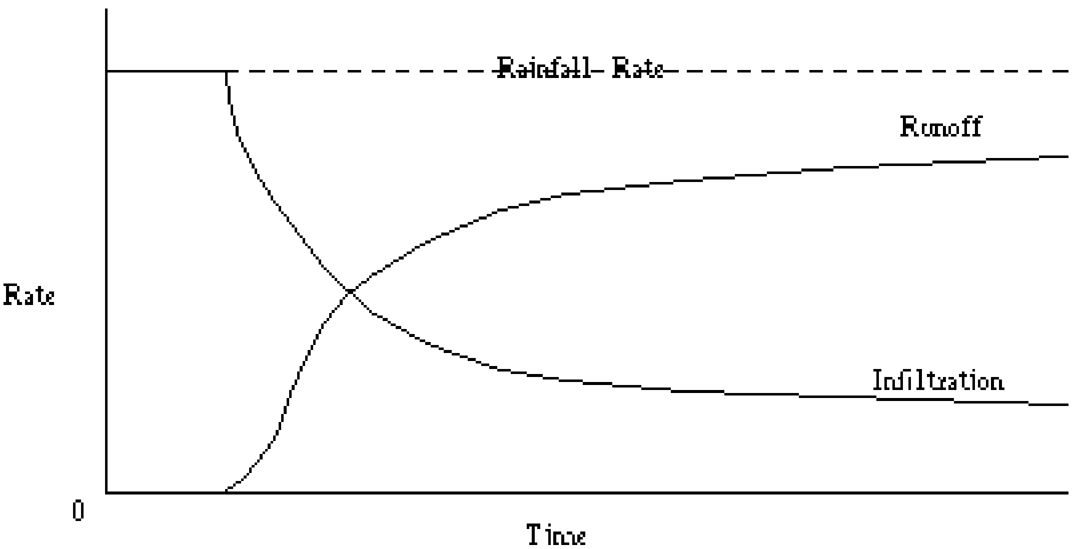
Technical terminology used within this lesson includes: drainage area, hydrograph, interception, return period and/or recurrence interval, runoff, surface storage, surface detention, and time of concentration.

Topic:

Runoff is that portion of precipitation that flows over land surfaces toward larger bodies of water. Before runoff can occur, rainfall must satisfy the immediate demands of infiltration, evaporation, interception, surface storage, surface detention and/or channel detention. Some are very minor losses, *e.g.*, interception by a corn crop is only about 0.02 inches. However, in a forested area interception may not be minor, accounting for up to 25 percent of the rainfall. For short time periods (storms) on agricultural lands:

$$\textbf{rainfall} - \textbf{runoff} \approx \textbf{infiltration}$$

This can be illustrated by a hydrograph with a steady rainfall input:



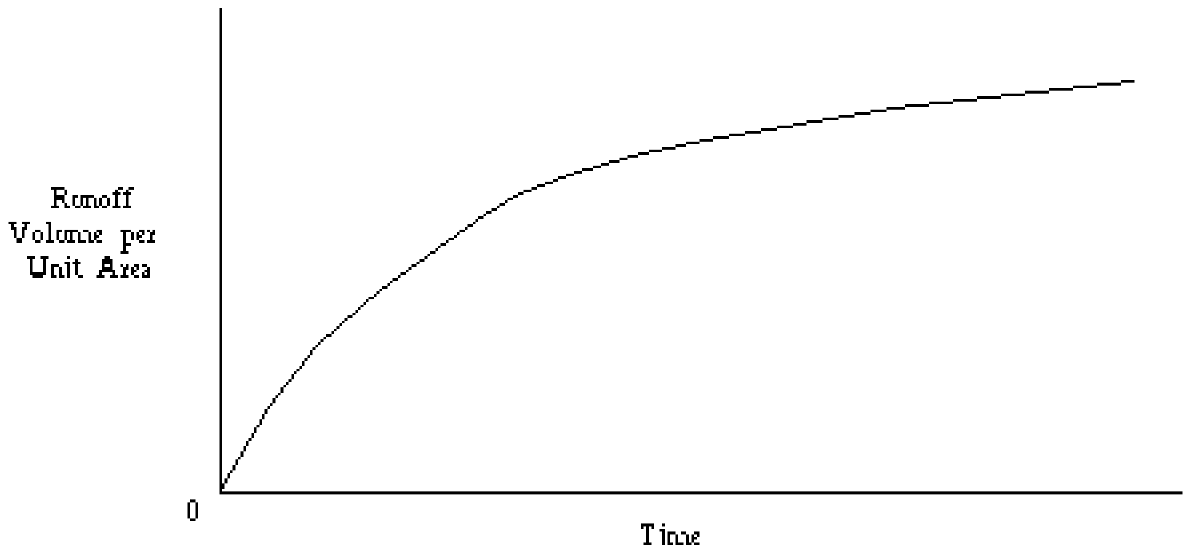
Notice that runoff is an approximate mirror image of infiltration (with some additional time-lag for overland flow travel lag).

Factors Affecting Runoff:

There are two broad categories of factors that control runoff: rainfall (storm) characteristics and watershed physical conditions. Important rainfall characteristics include duration, amount, intensity and distribution. Key watershed factors are:

Size.

> For a fixed return interval, as watershed size increases, the runoff per unit area decreases. This occurs primarily because **average** rainfall amount decreases with increasing area; secondarily, increased travel time for runoff allows more infiltration and other losses.



Shape.

For equal sized watersheds, runoff decreases as overland flow length increases. This results from the increased time of concentration. Longer duration storms, needed to produce runoff from all points in watershed, have lower average intensities.

Topography.

Surface slopes and roughness greatly influence runoff. Seep slopes reduce time of concentration and detention volume. Roughness increases surface storage and promotes greater infiltration, both of which decrease runoff.

Soils.

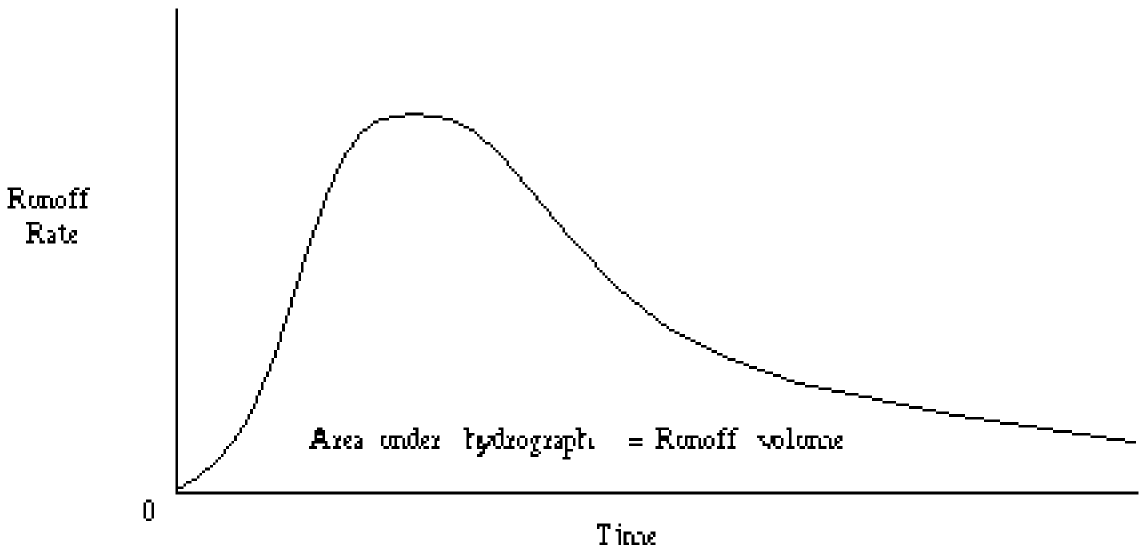
Watershed soils influence infiltration and deep seepage rates. Infiltration must be satisfied before runoff begins.

Surface culture.

Modern agricultural practices promote infiltration, slow runoff and reduce the antecedent water content of soils prior to a storm event.

Runoff hydrograph:

A graph of runoff rate vs. time is called a runoff hydrograph. The shape of a hydrograph depends on the time distribution of rainfall and upon watershed flow characteristics. However, most hydrographs bear some resemblance to the "typical shape" shown below:



The receding limb of a hydrograph usually extends over a longer period of time than the rising limb. The area under the curve gives the volume runoff (volume/time x time = volume). In this course, we will primarily use the peak runoff rate in our problems. Since hydrographs of previous storm events are seldom available for small watersheds, estimates of peak rates and/or volume must be made using computational models rather than from statistical analyses of past records.

Predicting Runoff:

Many methods for estimating peak runoff rates exist. The ones we will use (until later in the semester when full-featured watershed models are introduced) are known as: (1) the rational method and (2) the curve number method. Do not expect close agreement between these very different estimation-type methods.

Rational formula.

This rather simple "model" estimates peak runoff rates by the formula:

$$q = C\, i\, A$$

where:

- q = peak runoff rate, cfs;
- C = runoff coefficient;
- i = rainfall intensity, in/hr; and
- A = area, acres.

The "rationale" of this method is: (1) Units agree: 1 cfs = 1 in/hr x 1 acre, and (2) C (a dimensionless quantity) varies from 0 to 1 and can be thought of as the percent of rainfall that becomes runoff.

Assumptions for the rational formula are related to the intensity term and to quantifying C. They include:

- Rainfall occurs uniformly over the entire watershed.
- Rainfall occurs with a uniform intensity for a duration equal to the time of concentration for the watershed.
- The runoff coefficient, C, is dependent upon physical characteristics of the watershed, *e.g.* soil type.

The formula is usable for watersheds or drainage areas smaller than 2000 acres.

A table with limited C values is accessible here.

Predicting Runoff Volume by Curve Number:

Water conveyance measures are sized by peak runoff **rates**. Water supply systems for irrigation or other water consumptive use are sized on the basis of runoff **volume**. The Natural Resources Conservation Service* Curve Number Method can predict a complete runoff hydrograph, but it will not be so used in this course. It predicts runoff volume, **Q**, by the formula:

$$Q = \frac{(I - .2\ S)^2}{(I + .8\ S)}$$

where:

Q = direct runoff volume, in.
I = storm rainfall depth, in. (ave. intensity x duration)
S = (1000/CN) - 10
CN = runoff curve number

Curve number is based on the soils and land uses in the watershed (see CN-table). For nonuniform watersheds, an area-weighted average is used. Rainfall depth, I, is estimated for a given recurrence interval and duration for the location in question.

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*NRCS was formerly called the Soil Conservation Service, SCS.

How can this presentation be improved?