United States
Department of
Agriculture

Soil
Conservation
Service

Hydrology Training Series

Module 101 - Introduction to Hydrology

Study Guide

Engineering
Hydrology Training Series
Module 101

Introduction to Hydrology

National Employee Development Staff
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Preface

This module consists of a study guide that contains a brief introduction to hydrology. It is suitable for all SCS employees. The module's purpose is to present the subject in such a way that you will understand the hydrologic terms and units most commonly used in SCS activities.

Proceed through the module at your own pace. Be sure you completely understand each section before moving on. If you have questions or need help, please request assistance from your supervisor. If your supervisor cannot clear up your problems, he/she will contact the state-appointed resource person. The resource person is familiar with the material and should be able to answer any questions you may have.

Be sure to write out your answers to the included activities. This will help to reinforce your learning. After completing each activity, compare your answers with the included solution.

Acknowledgment

The design and development of this training module is the result of a concentrated effort by practicing engineers in the Soil Conservation Service. The contributions from many technical and procedural reviews have helped make this module one that will provide needed knowledge of hydrology and hydraulics to SCS employees.

Module Description

Objectives

Upon completion of this module, the participant will be able to:

1. Define, in simple terms, hydrology and hydraulics.
2. Describe the physical processes that together make up the hydrologic cycle.
3. Identify and derive, with notes, the terms or units commonly used in hydrology.
4. Identify and locate common SCS references used in hydrology.

The participant should be able to perform at ASK Level 3 (Perform with Supervision) after completing this module.

Prerequisites

None

Length

Participant should take as long as necessary to complete the module. Training time for this module is approximately one hour.

Who May Take The Module

This module is intended for all SCS personnel who use hydrology in their work.

Method of Completion

This module is self-study, but the state or NTC should select a resource person to answer any questions that the participant's supervisor cannot handle.

Content

Information on hydrology and the hydrologic cycle, and their relationships with SCS program activities, is presented. Common units used in hydrology references are discussed and used in practice problems.

Contents

Preface iii
Acknowledgement iii
Module Description v
Introduction 1
Definitions 1
Hydrologic Cycle 2
Activity 1 5
Activity 1 - Solution 6
Common Terms and Units 7
Common Hydrology References 11
Activity 2 12
Activity 2 - Solution 14
Summary 17
Appendix A - Useful Information A1
Glossary of Terms A3
Definitions of Symbols A9
Metric Conversions A10
Conversions A10
Certification of Completion ..... Last Page

Introduction

The purpose of this module is to present an introduction to hydrology so that you will understand the hydrologic terms and units most commonly used in SCS activities.

Hydrology and hydraulics are involved in most conservation activities and in every SCS program. Some aspects are used in planning and design ranging from a field diversion or terrace to a large complex dam or system of dams in a watershed project.

Definitions

Hydrology is the science that deals with the occurrence and behavior of water in the atmosphere, on the earth's surface, and below its surface. Hydrology is the science that relates to water.

Present SCS procedures are based on a considerable background of practical experience. The SCS developments in hydrologic application are recognized and used by many other Federal and State agencies, universities, and engineering consultants worldwide.

Hydraulics is the branch of engineering science dealing primarily with the flow of water or other liquids.

In the broadest sense, hydrology deals with the computation of how much water we could expect, and hydraulics deals with the level or elevation this water will attain.

The **hydrologic cycle** is a descriptive term applied to the general circulation of water from the atmosphere to the ground, to the seas, and back to the atmosphere through various stages or processes such as precipitation, interception, runoff infiltration, percolation, storage, evaporation, and transpiration.

Hydrologic Cycle

The three main phases of the hydrologic cycle are precipitation, runoff and evaporation. Following are definitions of the stages and processes in the hydrologic cycle.

1. **Precipitation** is all forms of moisture falling to the ground, i.e., rainfall, snow, hail, etc.

2. **Runoff** is that part of precipitation that appears as stream flow. Three types of runoff are:

   a. **Surface runoff** is water that reaches the stream by traveling over the soil surface.

   b. **Interflow or quick return flow** is water that moves through upper soil layers and returns to the surface or appears in streams promptly, i.e. does not become ground water.

   c. **Base flow** is water that flows into the stream from natural storage. In most streams, base flow comes largely from groundwater.

   Direct runoff is a term you will hear quite often. This is runoff that enters a stream promptly (contributes to a flood) and consists chiefly of surface runoff and interflow.

3. **Evaporation** is a process by which precipitation is returned to the atmosphere as vapor.

4. **Transpiration** is a process by which plants dissipate water into the atmosphere from leaves and other surfaces.

5. **Evapotranspiration** is the combination of evaporation of water from wet plant and soil surfaces and the transpiration of water in plants.

6. **Interception** is that part of precipitation at the beginning of a storm that is stored in vegetal cover and does not contribute torunoff.

7. **Infiltration** is the movement of water through the soil surface into the soil profile.

8. **Percolation** is the movement of water through the soil profile.

There really is no beginning or end to the hydrologic cycle. For the purpose of discussion, we can visualize the cycle as beginning with evaporation from the oceans. The resulting vapor is transported by air masses, and under proper conditions the vapor is condensed to form clouds, which may result in precipitation to the earth, either on land or on the oceans.

A portion of the precipitation falling on land is retained temporarily in the soil, in surface depressions, and on vegetation or other objects, until it is returned to the atmosphere by evapotranspiration.

The remainder may run over the ground surface into streams, infiltrate and appear promptly in streams as interflow, or infiltrate into the soil and percolate to deeper zones to be stored as ground water. That portion that reaches the ground water will later appear in streams.

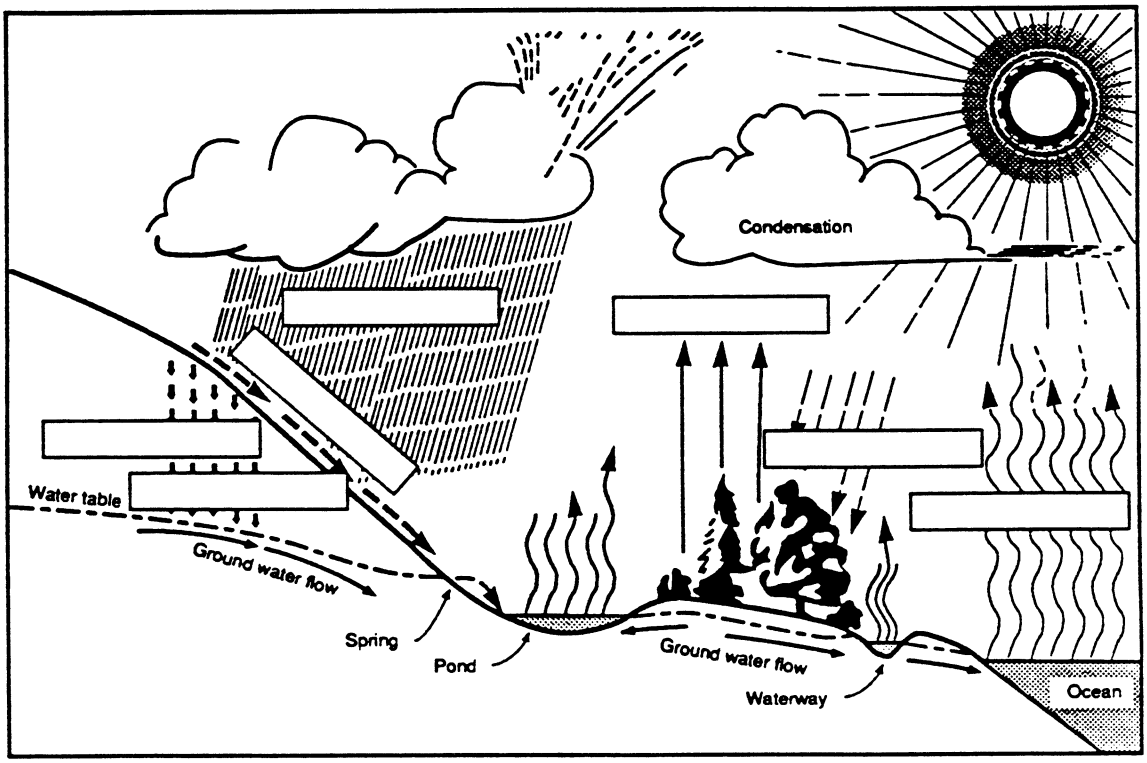
Activity 1

At this time, complete Activity 1 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 1

1. In your own words, define hydrology and hydraulics.

2. In the blank spaces below (marked with small black boxes), enter the stages or processes in the hydrologic cycle.



3. Runoff is that part of precipitation which appears as streamflow. There are three types of runoff. In most streams, _____comes largely from groundwater. Water that reaches the stream by traveling over the soil surface is referred to as _____ Water that moves through upper soil layers and returns to the surface or appears in streams promptly, but does not enter the water table is _____ or _____.

4. What is direct runoff?

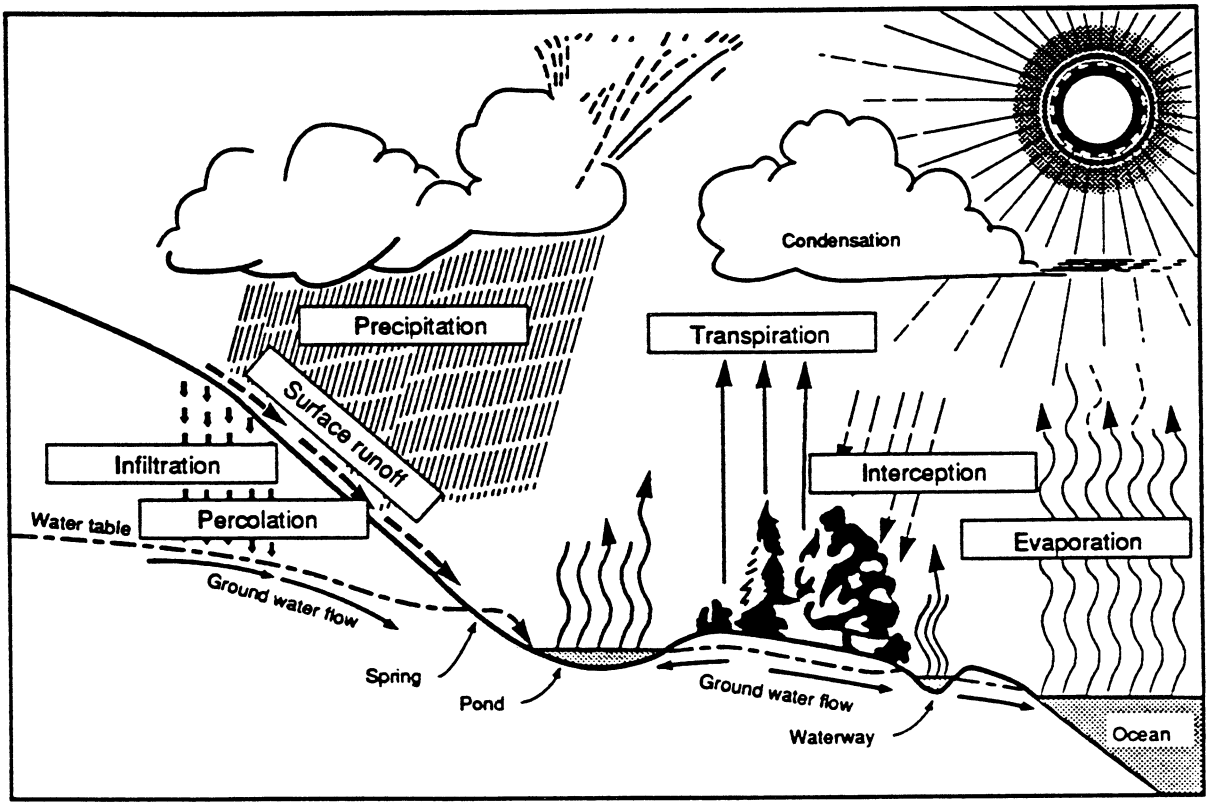
Activity 1 – Solution

1. In your own words, define hydrology and hydraulics.

Hydrology is the science that deals with the occurrence and behavior of water in the atmosphere, on the earth's surface, and below its surface. Hydrology is the science that relates to water.

Hydraulics is the branch of engineering science dealing primarily with the flow of water or other liquids.

2. In the blank spaces below (marked with small black boxes), enter the processes in the hydrologic cycle.



3. Runoff is that part of precipitation which appears as streamflow. There are three types of runoff. In most streams, base flow comes largely from groundwater. Water that reaches the stream by traveling over the soil surface is referred to as surface runoff. Water that moves through upper soil layers and returns to the surface or appears in streams promptly, but does not enter the water table is interflow or quick return flow.

4. What is direct runoff?

Direct runoff is runoff that enters a stream promptly (contributes to a flood) and consists chiefly of surface runoff and interflow.

Common Terms and Units

Some common units and conversions used in field office activities are:

1. Volume units

   a. Gallon (gal) — The United States gallon is the standard unit of liquid measure. Gallons are commonly used to express storage and flow capacity of water supply facilities.

   b. Cubic feet (ft^3) — The cubic foot is generally the most convenient volume unit for expressing the capacity of small tanks or holding ponds.

   c. Acre-feet (ac-ft) — An acre-foot is the quantity of water required to cover 1 acre to a depth of 1 foot. Acre-feet is the unit of volume most convenient for expressing the storage in SCS reservoirs.

   d. Inches per area (in/ac) — Inches per area is usually used in connection with drainage areas, but frequently the area is omitted resulting in simply inches of depth to represent volume. For example, runoff volume is often expressed as so many inches. This really means watershed inches.

      Inches per area per time is often used in irrigation to express an application rate (ac-in/hour) or to express large volumes of runoff (inches per month or inches per year).

2. Volume per time or rate units.

   a. Gallons per time — This unit is usually used in expressing the consumption rate of water and is generally stated in gallons per day (gpd) or millions of gallons per day (mgd). The capacity of pumps is generally expressed as gallons per minute (gpm).

   b. Cubic feet per second (cfs) — Cubic feet per second, sometimes called second-feet, is the most common unit used to express flow of water. It is the rate of discharge representing a volume of one cubic foot passing a given point during one second.

   c. Cubic feet per second-day (cfs-day) or second-foot-day — This is is a volume of water represented by a flow of one cubic foot per second for 24 hours. Cfs-day is used in storage computations when converting cfs to acre-feet or inches per area.

   d. Miner's inch — This unit was formerly used in hydraulic mining and irrigation in the West and is still often encountered in reference to water rights. It has been

defined by statute in most western states. It is the quantity of water that will flow through an orifice one inch square under a head which varies from four to six and one half inches, depending on location. 1 cfs = 40 - 50 miner's inches.

3. Common hydrologic units

a. Precipitation — inches (in)

b. Precipitation rate or intensity — inches per hour (in/hr)

c. Runoff — inches (in)

d. Runoff volume — watershed inches (in); acre-feet (ac-ft); cubic feet (ft^3)

e. Runoff rate — cubic feet per second (cfs)

f. Evaporation — inches (in)

g. Interception —inches (in)

h. Infiltration — inches/hour (in/hr)

i. Percolation — inches/hour (in/hr)

j. Storage — cubic feet (ft^3); acre feet (ac-ft); watershed inches

4. Common definitions

a. Time of concentration (T_c) — The time it takes water to move from the hydraulically most distant point in a watershed to a watershed outlet, usually expressed in hours. It is used to estimate peak discharge or to develop a hydrograph.

b. Hydrograph — A graph showing the discharge, velocity, or other property of water with respect to time. Usually we work with discharge hydrographs, where the points on the hydrograph are expressed in cfs.

c. Peak discharge (q_p) — The maximum discharge rate for a given hydrograph or flood event, usually expressed in cfs.

d. Runoff (Q) — That portion of precipitation which appears as streamflow, usually expressed in inches.

e. Velocity (V) — The distance traveled divided by the time required to travel that distance, usually expressed in feet per second (ft/s).

f. Flood routing — Determining the changes in a hydrograph as it moves downstream through a valley or through a reservoir (then sometimes called reservoir routing).

g. Initial abstraction (I_a) — The portion of precipitation occurring before surface runoff begins, usually expressed in inches. It consists mainly of interception, infiltration, and depression storage.

h. Runoff curve number (CN) — An index of the runoff potential from a specific combination of cover, land use, and soil.

i. Watershed (w/s)— The area contained within a divide above a specified point on a stream. It can also be called drainage area, subarea, basin or catchment area.

j. Frequency — An expression or measure of how often a hydrologic event of given size or magnitude should, on the average, be equaled or exceeded. It is usually expressed in years. For example, a 50-year frequency flood will be equaled or exceeded in size, on the average, once in 50 years.

k. Travel time — The average time for water to flow through a portion of a stream, usually expressed as hours.

5. Common conversions

a. **1 cfs-day** = 1.9835 or approximately **2 acre-feet**

(2 ac-ft = 1 cfs-day)

$$1\frac{ft^3}{s}(\text{day}) \times \frac{86{,}400\ s}{1\ \text{day}} \times \frac{1\ ac}{43{,}560\ ft^2} = 1.9835\ ac\text{-}ft$$

b. **1 acre-foot = 12.1 cfs-hour** (12.1 cfs-hr = 1 ac-ft)

$$1\ ac\text{-}ft \times \frac{1\ cfs\text{-}day}{1.9835\ ac\text{-}ft} \times \frac{24\ hr}{1\ day} = 12.0998\ cfs\text{-}hr$$

c. **1 acre-inch per hour** = 1.0083 or approximately **1 cfs**

(1 cfs = 1 ac-in/hr)

$$1\frac{ac\text{-}in}{hr} \times \frac{12.1\ cfs\text{-}hr}{1\ ac\text{-}ft} \times \frac{1\ ft}{12\ in} = 1.0083\ cfs$$

d. **1 cfs = 448.8 gallons per minute**

(448.8 gpm = 1 cfs)

$$1\frac{ft^3}{s} \times \frac{60\ s}{1\ min} \times \frac{7.48\ gal}{1\ ft^3} = 448.8\ gpm$$

e. **1 inch per hour = 1.008 cfs per acre**

(1 cfs/ac=1 in/hr)

$$1\frac{in}{hr} \times \frac{1\ ft}{12\ in} \times \frac{1\ hr}{3600\ s} \times \frac{43{,}560\ ft^2}{1\ ac} = 1.008\ cfs/ac$$

f. **1 ft³ = 7.48 gallons**

Summary:

1) 2 ac-ft = 1 cfs-day

2) 12.1 cfs-hr = 1 ac-ft

3) 1 cfs = 1 ac-in/hr

4) 448.8 gpm = 1 cfs

5) 1 in/hr = 1 cfs/ac

6) 1 ft³ = 7.48 gallons

Common Hydrology References

The following are some of the more commonly used references in SCS:

1. Engineering Field Manual For Conservation Practices (EFM) is in every field office.
2. Urban Hydrology For Small Watersheds, Technical Release 55 (TR-55) is in most field offices and every area office.
3. National Engineering Manual (NEM) is in all area offices.
4. Engineering Practice Standards (Section 4, Technical Guide) is in every field office.
5. National Engineering Handbook, Section 4, Hydrology (NEH-4) is in most area offices.

Activity 2

At this time, complete Activity 2 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 2

1. Circle the four typical volume units used in field office activities?

   gal ft^3

   in^3 liters

   ac-ft milliliters

   watershed inches

2 What are four rate units (volume per time) used in field office activities?

   cfs

   gpm or gpd

   cfs-day

   miner's inch

   ft/s

   in/hr

3. Define the following common hydrologic terms.

   a. Time of concentration (T_c)

   b. Hydrograph

   c. Peak discharge (q_p)

   d. Velocity (V)

e. Flood routing

f. Initial abstraction

g. Runoff curve number

h. Watershed

i. Frequency

4. Convert 4 cfs-day to acre-feet.

5. How many acre-feet are there in 37.5 cfs-hours?

6. Convert 3.4 acre-inch per hour to cubic feet per second.

7. Convert 100 gal to cubic feet.

Activity 2 – Solution

1. Circle the four typical volume units used in field office activities?

gal ft²

in² liters

ac-ft milliters

watershed inches

2. What are four rate units (volume per time) used in field office activities?

cfs

gpm or gpd

cfs-day

miner's inch

ft/s

in/hr

3. Define the following common hydrologic terms.

a. Time of concentration (T_c) — The time it takes water to move from the hydraulically most distant point in a watershed to a watershed outlet, usually expressed in hours. It is used to estimate peak discharge or to develop a hydrograph.

b. Hydrograph — A graph showing the discharge, stage, velocity or other property of water with respect to time. Usually we work with discharge hydrographs, where the points on the hydrograph are expressed in cfs.

c. Peak discharge (q_p) — The maximum discharge rate for a given hydrograph or flood event, usually expressed in cfs.

d. Velocity (V) — The distance traveled divided by the time required to travel that distance, usually expressed in ft/s.

e. Flood routing — Determining the changes in a hydrograph as it moves downstream through a valley or through a reservoir (then sometimes called reservoir routing).

f. Initial abstraction (I_a) — The portion of precipitation occurring before surface runoff begins, usually expressed in inches. It consists mainly of interception, infiltration, and depression storage.

g. Runoff curve number (CN) — A measure of the runoff potential from a specific combination of cover, land use, and soil type.

h. Watershed (w/s) — The area contained within a divide above a specified point on a stream. It can also be called drainage area, subarea, basin, or catchment area.

i. Frequency — An expression or measure of how often a hydrologic event of given size or magnitude should, on the average, be equaled or exceeded, usually expressed in years. For example a 50-year frequency flood will be equaled or exceeded in size, on the average, only once in 50 years.

4 Convert 4 cfs-days to acre-feet.

1 cfs-day = 1.9835 ac-ft

4 cfs-day = 4 (1.9835 ac-ft) = 7.9 ac-ft

OR

$$4\,\frac{ft^3}{s}\left(day\right)\times\frac{86{,}400\,s}{1day}\times\frac{1ac}{43{,}560\,ft^2}\;=\;7.9\,ac\text{-}ft$$

5. How many acre-feet are there in 37.5 cfs-hour?

12.1 cfs-hour = 1 ac-ft

$$1cfs\text{-}hr\;=\;\frac{1}{12.1}\,ac\text{-}ft$$

$$37.5\,cfs\text{-}hr\;=\;\frac{37.5\left(1\,ac\text{-}ft\right)}{12.1}\;=\;3.1ac\text{-}ft$$

OR

$$37.5\,\frac{ft^3}{s}\left(hr\right)\times\frac{1\,ac}{43{,}560\,ft^2}\times\frac{3600\,s}{hr}\;=\;3.1\,ac\text{-}ft$$

6. Convert 3.4 acre-inch per hour to cubic feet per second.

1 ac-in/hr = 1.0083 cfs

3.4 ac-in/hr = (3.4)(1.0083 cfs) = 3.4 cfs

OR

$$3.4\,\frac{\text{ac-in}}{\text{hr}} \times \frac{1\text{ft}}{12\text{ in}} \times \frac{43{,}560\,\text{ft}^2}{1\text{ac}} \times \frac{1\text{hr}}{3600\,\text{s}} = 3.4\ \text{cfs}$$

7. Convert 100 gallons to cubic feet.

$$100\ \text{gal} \times \frac{1\ \text{ft}^3}{7.48\ \text{gal}} = 13.4\ \text{ft}^3$$

Summary

This completes Module 101 - Introduction to Hydrology. You should have learned to define hydrology and hydraulics, and to list the various components of the hydrologic cycle. You should be able to use common conversion factors.

Retain this Study Guide as a reference until you are satisfied that you have successfully mastered all the methods covered. It will provide an easy review at any time if you should encounter a problem.

If you have had problems understanding the module or if you would like to take additional, related modules, contact your supervisor.

When you are satisfied that you have completed this module, remove the Certification of Completion sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your State or NTC Training Officer.

Appendix A
Useful Information

Glossary of Terms
(Taken from NEH-4, Hydrology)

Italicized words and terms in a definition are defined elsewhere in the list.

Acre-foot. The amount of water that will cover one acre to a depth of one foot. Equals 43,560 cubic feet. Abbreviated ac-ft (formerly AF).

Ac-ft or AF. Abbreviation for acre-foot or acre-feet.

Annual flood. The highest peak discharge in a water year.

Annual runoff. The total natural discharge of a stream for a year, usually expressed in inches depth or ac-ft. See *water yield.*

Annual series. A *frequency series* in which only the largest value in each year is used, such as the *annual floods.*

Annual yield. The total amount of water obtained in a year from a stream, spring, artesian well, etc. Usually expressed in inches depth, ac-ft, millions of gallons, or cubic feet.

Antecedent Moisture Condition (AMC). The degree of wetness of a watershed at the beginning of a storm.

Area rainfall. The average rainfall over an area, usually as derived from, or discussed in contrast with, *point rainfall.*

Base flow. Stream discharge derived from ground water sources. Sometimes considered to include flows from regulated lakes or reservoirs. Fluctuates much less than storm runoff.

cfs. Abbreviation for cubic feet per second. A unit of water flow. Sometimes called "second-feet."

cfs-day. Often called a *second-foot-day.* The volume of water represented by a flow of one cubic foot per second for a period of one day.

Consumptive use. A term used mainly by irrigation engineers to mean the amount of water used in crop growth plus evaporation from the soil. See evapotranspiration.

Cover. The vegetation, or vegetational debris such as mulch, that exists on the soil surface. In some classification schemes, fallow or bare soil is taken as the minimum cover class.

Cross section (stream or valley). The shape of a channel, stream, or valley, viewed across the axis. In watershed investigations, it is determined by a line approximately perpendicular to the main path of water flow, along which measurements of distance and elevation are taken to define the cross-sectional area.

Damage reach. A length of flood plain or valley selected for damage evaluation.

Degree-day. As used in snowmelt studies, a day with an average temperature one degree above 32° F. The average is usually obtained by averaging the maximum and minimum for the day. A day with an average of 40° F gives 8 degree-days.

Depth-area curve. A graph showing the change in average rainfall depth as size of area changes.

Design storm. A given rainfall amount, areal distribution, and time distribution, used to estimate runoff. The rainfall amount is either a given frequency (25-year, 50-year, etc.).

Direct runoff. The water that enters the stream channels during a storm or soon after, forming a runoff hydrograph. May consist of rainfall on the stream surface, surface runoff, and seepage of infiltrated water.

Double-mass curve. A graph in which accumulated amounts of item X are plotted versus accumulated amounts of item Y, the amounts for given times being used.

Drainage area. The area draining into a stream at a given point. The area may be of different sizes for *surface runoff, subsurface flow*, and *base flow*, but generally the surface runoff area is used as the drainage area. See *watershed*.

Effective duration. The time in a storm during which the water supply for *direct runoff* is produced. Also used to mean the duration of *excess rainfall*.

Effective rainfall. Another term for *direct runoff*. Usually not the same quantity on upland streams as on downstream rivers because of variability of seepage flows.

Emergency spillway. A rock or vegetated earth waterway around a dam, built with its crest above the normally used *principal spillway*. Used to assist the principal spillway in conveying extreme amounts of runoff safely past the dam.

ET. Abbreviation for *evapotranspiration*.

Evaluation series. A list of floods or storms that produced floods during a representative period, and used in water project evaluation to obtain estimates of flood damages.

Evapotranspiration. Plant transpiration plus evaporation from the soil. Difficult to determine separately, therefore used as a unit for study. See *consumptive use*.

Excess rainfall. *Direct runoff* at the place where it originates.

Fallow. Cropland kept free of vegetation during the growing season. May be a normal part of the cropping system for weed control, water conservation, soil conditioning, etc.

f_c. Symbol for the low, almost uniform, infiltration rate obtained after prolonged wetting of the soil.

Flood. In common usage, an event where a stream overflows its normal banks. In frequency analysis it means an *annual flood* that may not overflow the banks.

Flood routing. Determining the changes in a *flood wave* as it moves downstream through a valley or through a reservoir (then sometimes called *reservoir routing*). Graphical or numerical methods are used.

Flood pool. Floodwater storage in a reservoir. In a floodwater retarding reservoir, the temporary storage between the crests of the *principal* and *emergency spillways*.

Floodwater retarding structure. A dam, usually with an earth fill, having a *flood pool* where incoming flood water is temporarily stored and slowly released downstream through a *principal spillway*. The reservoir contains a *sediment pool* and sometimes storage for irrigation or other purposes.

Flood wave. The rise and fall in stream flow during and after a storm.

Frequency. An expression or measure of how often a hydrologic event of given size or magnitude should, on the average, be equaled or exceeded. For example, a 50-year frequency flood should be equaled or exceeded in size, on the average, only once in 50 years. In drought or deficiency studies it usually defines how many years will, on the average, be equal to or less than a given size or magnitude.

Frequency line. The line on probability paper that represents a series of events and their frequencies.

Frequency series. A sequence or array of actual events (floods, etc.) suitable for use in frequency analysis; or, a sequence or array of hypothetical events obtained from a frequency analysis.

Ground water. The water in the saturated zone beneath the *water table*. A source of *base flow* in streams.

Hazen method. It consists of using the Hazen equation and *log-normal paper* (or Hazen paper) to obtain frequencies. More generally, it consists also of skewness computations described by Allen Hazen in his book, "Flood Flows," published in 1930 by John Wiley and Sons, Inc., New York, N.Y.

Historical series. A list of all actual storms (or floods) that caused flood damage in a watershed, in a given period of years, with the date of each storm or flood being known.

Hydrograph. A graph showing, for a given point on a stream or for a given point in any drainage system, the discharge, stage, velocity or other property of water with respect to time.

Hydrologic soil cover complex. A combination of a *hydrologic soil group* and a type of *cover*.

Hydrologic soil group. A group of soils having the same runoff potential under similar storm and cover conditions.

Hydrology. The science that deals with the occurrence and behavior of water in the atmosphere, on the ground, and under the ground. Rainfall intensities, rainfall interception by trees, effects of crop rotations on runoff, floods, droughts, and the flow of springs and wells, are some of the topics studied by a hydrologist.

Initial abstraction (I_a). When considering *surface runoff*, I_a is all the rainfall before runoff begins. When considering *direct runoff*, Ia consists of interception, evaporation, and the soil-water storage that must be exhausted before direct runoff may begin. Sometimes called "initial loss," about which see *loss*.

Infiltration. Rainfall minus interception, evaporation, and surface runoff. The part of rainfall that enters the soil.

Interception. Precipitation retained on plant or plant residue surfaces and finally absorbed, evaporated, or sublimated. That which flows down the plant to the ground is called "steamflow" and not counted as true interception.

Irrigation pool. Reservoir storage used to store water for release as needed in irrigation.

Isohyet. A line of a map, connecting points of equal rainfall amounts.

Lay (or lag time). The time from the centroid of rainfall to the peak of the hydrograph. It can be estimated from *time of concentration* as 0.6 T_c.

Land treatment measure. A tillage practice, a pattern of tillage or land use, or any land improvement, with a substantial effect of reducing runoff and sediment production or of improving use of drainage and irrigation facilities. Examples included are contouring, improved crop rotations, controlled grazing, land leveling, and field drainage. In hydrologic computations, nonbeneficial measures (such as straight-row, poor-rotation corn) are included for convenience in evaluation. In general conservation work, "land treatment measure" has a broader meaning that includes measures to improve the soil, control sheet erosion, and increase soil fertility.

Land use. A land classification. *Cover*, such as row crops or pasture, indicates a kind of land use. Roads may also be classified as a separate land use.

Log paper. Short for "full-logarithmic graph paper," which is a graph paper (available commercially) that has logarithmic scales on both horizontal and vertical axes. Sometimes called "log-log paper." The scales may be any number of cycles, but are usually in combinations like 1x1, 2x2, 3x3, 3x5, 4x7, etc.

Log-normal. Short for "logarithmic-normal probability distribution."

Log-normal paper. Graph paper used in estimating frequencies of floods, etc. Has a logarithmic scale for the flood (or other) amounts, and a cumulative distribution scale (also called frequency or percent chance scale) for the probability plotting positions.

Loss. In hydrology, a loss for one purpose is usually a gain for another, so that the net effect may be more important than the loss. At various times, *evapotranspiration, initial abstraction, infiltration, surface storage, direct runoff*, seepage, etc. have been called losses according to the aims of a water user. See *water loss*.

Manning's n. A coefficient of roughness, used in a formula for estimating the capacity of a channel to convey water. Generally, "n" values are determined by inspection of the channel.

Mean daily. The average or mean discharge of a stream for one day. Usually given in cfs.

NEH-4. National Engineering Handbook, Section 4, Hydrology.

NEH-5. National Engineering Handbook, Section 5, Hydraulics.

Partial-duration series. A list of all events, such as floods, occurring above a selected base, without regard to the number, within a given period. In the case of floods, the selected base is usually equal to the smallest annual flood, in order to include at least one flood in each year.

Percent chance. A name often given to the probability scale on *log-normal paper*. A 2-percent chance flood is a 50-year frequency flood (see *frequency*) since 100÷ percent chance = frequency in years

Plotting position. The point computed by an equation and used to locate given data on *probability paper*.

Point rainfall. Rainfall at a single rain gage.

Principal spillway. A concrete or metal pipe or conduit used with a drop inlet dam or floodwater retarding structure. It conveys, in a safe and nonerosive manner, all ordinary discharges coming into a reservoir and all of an extreme amount that does not pass through the *emergency spillway*.

Probability paper. Any graph paper prepared especially for plotting magnitudes of events versus their frequencies or probabilities. See *log-normal paper*.

Reach. A length of stream or valley, selected for convenience in a study. See *damage reach, stream reach*.

Recession curve. The receding portion of a hydrograph, occurring after *excess rainfall* has stopped.

Recurrence interval. The average number of years within which a given event will be equaled or exceeded. A 50-year *frequency* flood has a 50-year recurrence interval and so on.

Regional analysis. Flood frequency lines for gaged watersheds in a similar area or region are used to develop a flood frequency line for an ungaged watershed in that region. Also used with other types of hydrologic data. Method is a simple (usually graphical and freehand) form of "regression analysis" used by statisticians.

Reservoir routing. *Flood routing* through a reservoir.

s.d. Abbreviation for *standard deviation*.

Second-foot. See *cfs*.

Second-foot-day. The volume of water represented by a flow of one cubic foot per second for a period of one day.

Sediment pool. Reservoir storage provided for sediment, thus prolonging the usefulness of floodwater or irrigation pools.

Semilog paper. Short for "semilogarithmic graph paper," which is graph paper having a arithmetic scale along one axis and a logarithmic scale along the other. Either scale is used for the independent variable, as the data require. Commercially available paper has various divisions (5, 6, 7, 10 to the inch) for the arithmetic scale, and various cycles (1, 2, 3, 4, 5) for the logarithmic scale.

Small grains. Wheat, oats, barley, flax, rice, and other close-drilled or broadcast grain crops.

Soil cover complex. See *hydrologic soil cover complex*.

Soil water storage. The amount of water the soils (including geologic formations) of a watershed will store at a given time. Amounts vary from watershed to watershed. The amount for a given watershed is continually varying as rainfall or ET takes place.

Spillway. See *principal spillway* and *emergency spillway*.

Standard deviation. Statisticians' name for an important measure of dispersion, abbreviated s.d. Data grouped closely about their mean have a small s.d.; grouped less closely, they have a larger s.d.

Standard rain gage. Also "standard gage." The *USNWS* nonrecording rain gage, having an opening 8 inches in diameter, and a holding capacity of 24 inches of rainfall. The gage is usually examined once daily at a regular time, and the catch (if any) measured by depth in inches and hundredths of an inch.

Storage-indication method. Name often given to a flood-routing method also called the Puls method (after Louis G. Puls) though it is actually a variation of the method devised by Puls.

Stream reach. A length of stream channel selected for use in hydraulic or other computations.

Structural measure. Any form of earthwork (dam, ditch, levee, etc.) or installation of concrete, masonry, metal or other material (drop spillway, jetties, riprap, etc.).

Subsurface runoff. Water that infiltrates the soil and reappears as seepage or spring flow, and forms part of the flood hydrograph for that storm. Difficult to determine in practice and seldom worked with separately. See *direct runoff.*

Subwatershed. A watershed that is part of a larger watershed. It is worked on separately when necessary in order to improve computational accuracy for results on a whole watershed basis, or to get results for that area only.

Surface runoff. Total rainfall minus *interception*, evaporation, *infiltration, and surface storage*, and that water which moves across the ground surface to a stream or depression.

Surface storage. Natural or man-made roughness of a land surface, which stores some or all of the surface runoff of a storm. Natural depressions, contour furrows, and terraces are usually considered as producing surface storage, but stock ponds, reservoirs, stream channel storage, etc. are generally excluded.

Synthetic series. A storm or flood series obtained by taking selected values from a frequency line based on historical data.

Time of concentration (T_c). The time it takes water from the most distant point (hydraulically) to reach a watershed outlet. T_c varies, but often is used as constant.

Transmission loss. A reduction in volume of flow in a stream, canal, or other waterway, due to infiltration or seepage into the channel bed and banks. Evaporation is also a transmission loss, but it is ordinarily neglected under the assumption that it is small.

Travel time. The average time for water to flow through a reach or other stream or valley length that is less than the total length. A travel time is part of a T_c but never the whole T_c.

Unit hydrograph. A discharge hydrograph coming from one inch of *direct runoff* distributed uniformly over the watershed, with the direct runoff generated at a uniform rate during the given storm duration. A watershed may have 1-hour, 2-hour, etc. unit hydrographs.

USGS. United States Department of the Interior, Geological Survey.

USNWS. United States Department of Commerce, National Weather Service.

Water equivalent. The depth of water, in inches, that results from melting a given depth of snow.

Water loss. Variable meaning, depending on personal interest of water user. Farmers and ranchers usually think of flood runoff as a water loss; many river engineers think of infiltration as a water loss. See *loss.*

Watershed. The area contributing *direct runoff* to a stream. Usually it is assumed that *base flow* in the stream also comes from the same area. However, the ground water watershed may be larger or smaller.

Watershed measures. Any vegetative or structural means (including earthwork) of directly improving or conserving the soil and water resources of a watershed. See *land treatment measure* and *structural measure.*

Water table. The upper surface of *ground water*.

Water year. The year taken as beginning October 1. Often used for convenience in stream flow work, since in many areas stream flow is at its lowest at that time. Used by *USGS* in their *WSP*.

Water yield. The actual stream flow, at a given place, from a watershed. This is natural *annual runoff* that may be affected by irrigation uses, reservoir losses, diversions into or out of the watershed, etc.

WSP. Water-Supply Paper. An annual publication of the *USGS*, in which stream flow for the *water year* is given for all gaged streams in a subdivision of the United States or in Hawaii.

Definitions of Symbols

Symbol	Unit	Definition
a	ft^2	Cross sectional flow area
A_m	mi^2	Drainage area
CN		Runoff curve number
CN_c		Composite runoff curve number
CN_p		Pervious runoff curve number
E_{max}		Maximum stage
F_p		Pond and swamp adjustment factor
H_w	ft	Head over weir crest
I_a	in	Initial abstraction
L	ft	Flow length
L_w	ft	Weir crest length
m		Number of flow segments
n		Manning's roughness coefficient
P	in	Rainfall
P_{imp}		Percent imperviousness
P_2	in	Two-year frequency, 24-hour rainfall
p_w	ft	Wetted perimeter
q	cfs	Hydrograph coordinate
q_i	cfs	Peak inflow discharge
q_o	cfs	Peak outflow discharge
q_p	cfs	Peak discharge
q_t	csm/in	Tabular hydrograph unit discharge
q_u	csm/in	Unit peak discharge
Q	in	Runoff
r	ft	Hydraulic radius
R		Ratio of unconnected impervious area to total impervious area
s	ft/ft	Slope of hydraulic grade line
S	in	Potential maximum retention after runoff begins
t	hr	Hydrograph time
T_c	hr	Time of concentration
T_p	hr	Time to peak
T_t	hr	Travel time
V	ft/s	Average velocity
V_r	acre-ft, ft, or watershed inch	Runoff volume
V_s	acre-ft, ft, or watershed inch	Storage volume

Metric Conversions

To convert to the International system of units (metric) from English units, use the following factors:

From English unit	To metric unit	Multiply by
Acre	Hectare	0.405
Square mile	Square kilometer	2.59
Cubic feet per second	Cubic meters per second	0.0283
Inch	Millimeter	25.4
Feet per second	Meters per second	0.3048
Acre-foot	Cubic meter	1233.489
Cubic foot	Cubic meter	0.0283

Perform rounding operations as appropriate to indicate the same level of precision as that of the original measurement. For example:

1. A stream discharge is recorded in cubic feet per second with three significant digits.
2. Convert stream discharge to cubic meters per second by multiplying by 0.0283.
3. Round to enough significant digits so that, when converting back to cubic feet per second, you obtain the original value (step 1) with three significant digits.

Conversions

This:Times	This:	Gives You This:
cfs-day	1.983	ac-ft
cfs-day	0.03719	inches depth on 1 square mile
cfs-day per square mile	0.03719	inches depth
cfs-hour	0.08264	ac-ft
cfs-hour per square mile	0.001550	inches depth
cfs	1.983	ac-ft per day
cfs	724.0	ac-ft per year (365 days)
cfs	448.8	U.S. gallons per minute
cfs	0.6463	million U.S. gallons per day
csm	0.03719	inches depth per day
csm	13.57	inches depth per year (365 days)
inches per hour	645.3	csm
inches per hour	1.008	cfs per acre
inches depth	53.33	ac-ft per square mile

This:	Times	This:	Gives You This:
inches depth on 1 m^2	53.33		ac-ft
ac-ft	0.5042		cfs per day
ac-ft	12.10		cfs per hour
ac-ft	0.01875		inches depth on 1 square mile
ac-ft	0.3258		million U.S. gallons
ac-ft per day	0.5042		cfs
ac-ft per square mile	0.01875		inches depth
U.S. gallons per minute	0.002228		cfs
million U.S. gallons per day	1.547		cfs
million U.S. gallons per day	3.069		ac-ft
feet per second	0.6818		miles per hour
centimeters	0.3937		inches
hectares	2.471		acres
liters	0.2642		U.S. gallons
kilograms	2.205		pounds
cubic feet	7.480		U.S. gallons
imperial gallons	1.200		U.S. gallons

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