Hydrology Training Series

Module 102 – Precipitation

Study Guide

Module Description

Objectives

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

1. List the various forms of precipitation.
2. Describe the physical processes that generate precipitation.
3. List and explain the various methods for measuring precipitation.
4. Obtain the precipitation values for commonly used conservation practices from available data sources.
5. List where precipitation values are used.

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

Prerequisites

Module 101 - Introduction to Hydrology

Who may take the module

This module is intended for all SCS Personnel who need precipitation values to calculate runoff, determine peak discharge, or develop hydrographs.

Content

This module presents the forms of precipitation and how precipitation is generated, measured, and used in the Soil Conservation Service.

Introduction

Precipitation is the general term for all forms of moisture originating from clouds and falling to the ground. It is that portion of the hydrologic cycle in which atmospheric water vapor is condensed, forming water droplets sufficiently large that gravity causes them to fall to earth.

Physical Processes Generating Precipitation

A complete discussion of the meteorological theory of precipitation and its formation is beyond the scope of this module. However, a brief review is presented here to provide an awareness of the processes. Figure 1 shows a sketch of the hydrologic cycle in a simple pictorial form.

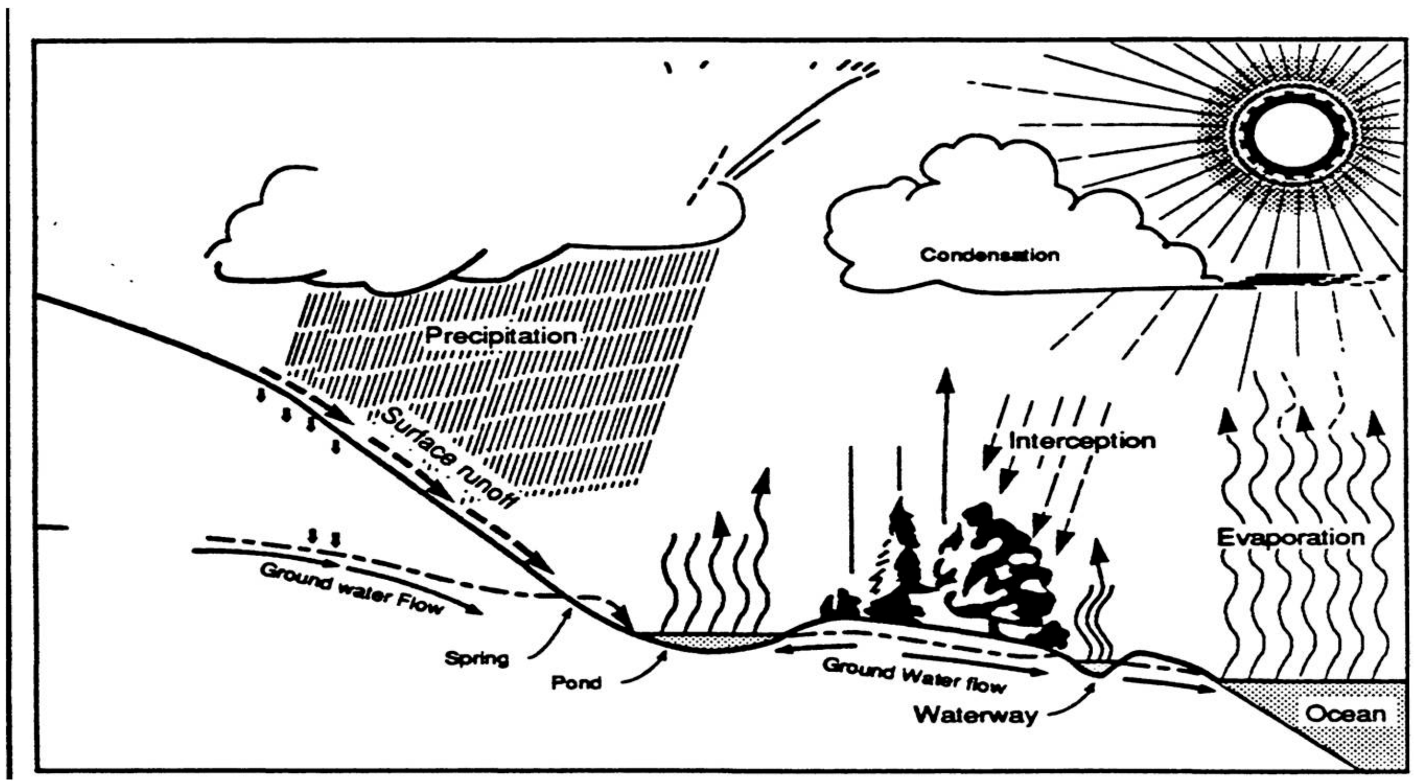


Figure 1. *Hydrologic cycle*

Although water vapor in the atmosphere is a necessary factor in the formation of precipitation, it is by no means the only requirement. The air mass containing the water vapor must be cooled to condense the vapor into water droplets. The large-scale cooling needed for sufficient amounts of precipitation is achieved by lifting the air. Lifting can occur in three ways that also classify the type of precipitation.

Cyclonic Precipitation

Cyclonic precipitation results from the lifting of air converging into a low pressure area, or cyclone (figure 2). A cyclone is defined as an area of low pressure with a counter-clockwise (Northern Hemisphere) circulation of the air around it, usually inward, towards the center. This type of precipitation can also be classified into non-frontal and frontal. Non-frontal precipitation can occur in any kind of barometric depression or barometric low. The lifting of the air is caused by horizontal convergence of air flowing from an area of higher pressure into the low pressure area. Frontal precipitation is the result of lifting of lighter warm moist air over more dense cold air. Generally, most storms in the Great Plains states are cyclonic.

Convection Precipitation

Convective precipitation results from the lifting or upward movement of air that is warmer and lighter than its colder denser surroundings (figure 3). Typically, on a hot day the ground surface becomes heated, as does the air in contact with it. This causes the air to rise, expand, and cool dynamically, causing condensation and precipitation.

Orographic Precipitation

The third method of1ifting an air mass occurs when air flows up and over a topographic feature such as a mountain barrier (figure 4). Orographic barriers often supply the lift to set off precipitation. For this reason, precipitation is heavier on windward slopes, with rain shadows (areas of lighter precipitation) on leeward slopes. Orographic precipitation not associated with cyclonic or convective action tends to be of low intensity with relatively long durations

Forms of Precipitation

The many forms of precipitation depend on existing meteorological conditions. Because we are concerned only with the precipitation that falls to the ground, the forms of precipitation not included here are damp haze, fog, ice fog, drifting snow, blowing snow, and frost. Forms of precipitation that fall to the ground include the following:

1. Drizzle is a fine sprinkle of small and rather uniform water drops that have a diameter less than 0.02 inch (0.5 mm). The drops are so small that they seem to float in the air and fo11ow the irregularities of the air motion. To qualify as a drizzle, the drops must not only be small, but they must also be numerous. It usually falls from stratiform clouds, and its intensity is generally less than 0.04 inch per hour.

2. Rain is precipitation of liquid water in which the drops, as a rule, are larger than in drizzle. On occasion, the drops may be of drizzle size, but they are then few and far between. This distinguishes them from drizzle. It is usua11y reported in three intensities, light for rates offa11 from a trace to 0.10, moderate from 0.11 to 0.30, and heavy over 0.30 in/hr.

3. Snow is precipitation of solid water, mainly in the form of branched hexagona1 crystals (or stars) resulting from condensation of water vapor directly to ice. Single ice crystals can reach the ground, but usually a number of them coalesce and fall as snowflakes. Even at temperatures well below 10˚ freezing, the crystals carry a thin coating of liquid water, and when they collide, they stick together, becoming large flakes.

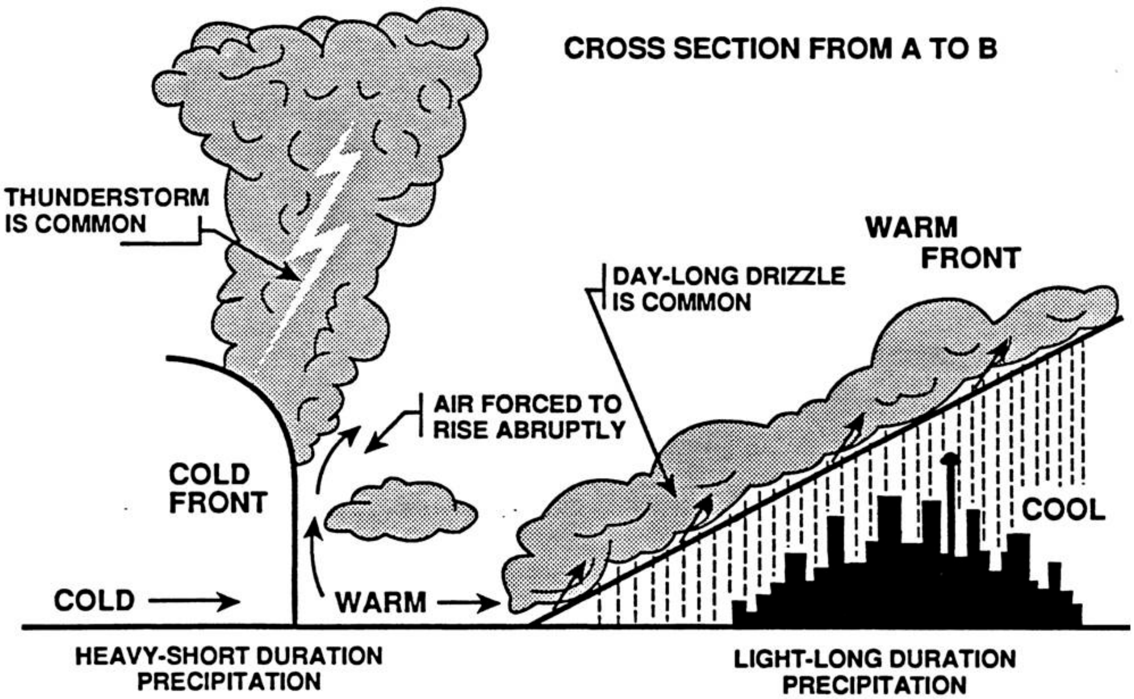


Figure 2. *Cyclonic storm*

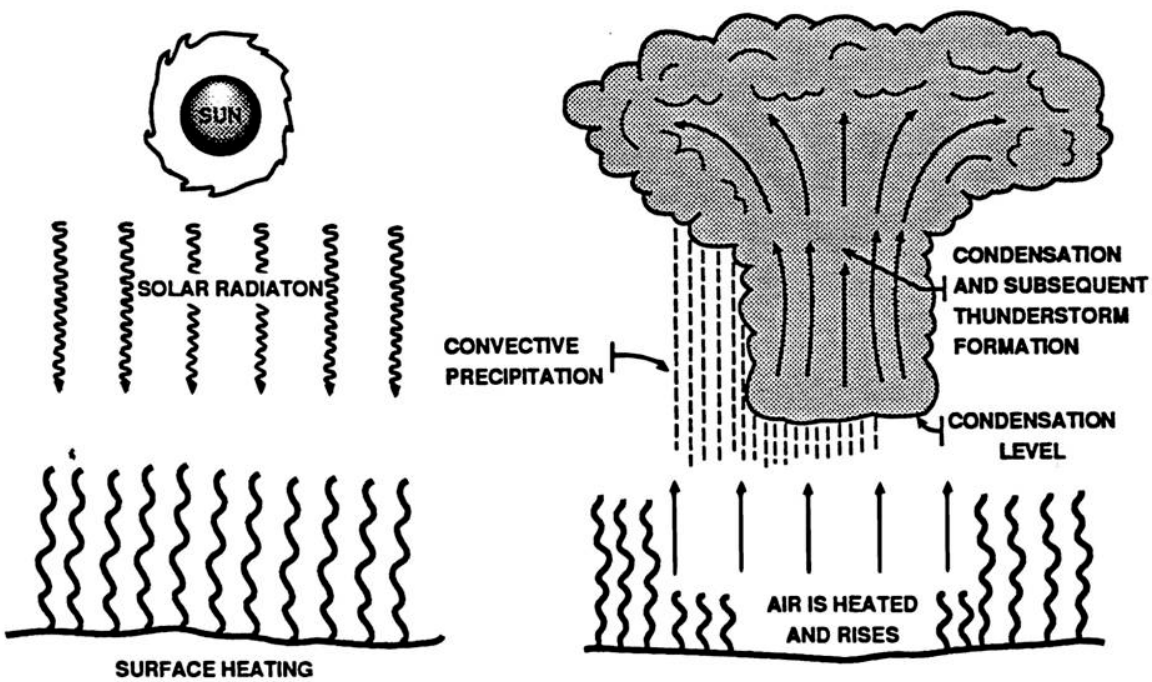


Figure 3. *Concective storm*

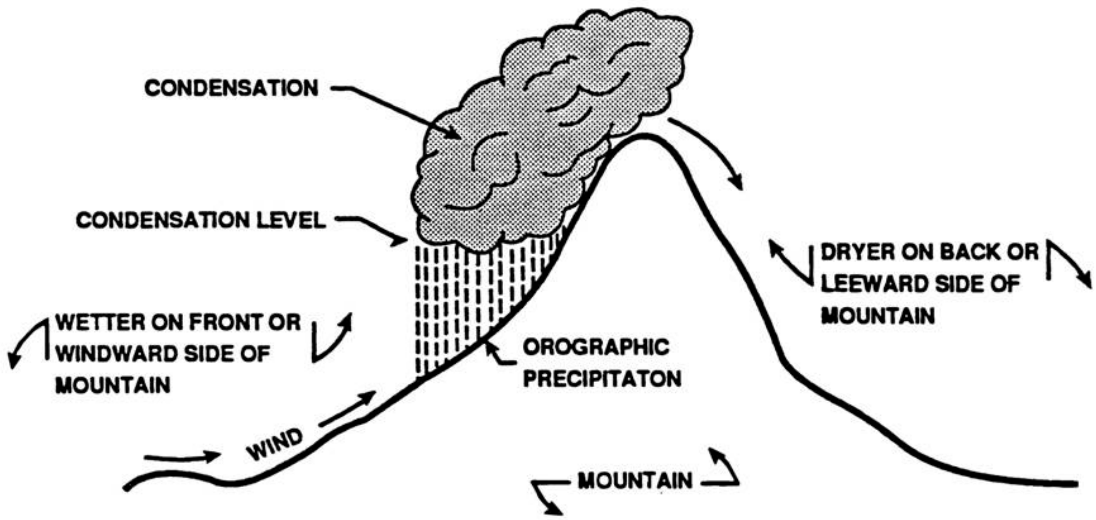


Figure 4. ***Orographic storm***

4. Granular snow is opaque small grains falling from stratus clouds. It is the frozen counterpart of drizzle.

5. Hail is precipitation in the form of balls or lumps of ice over 0.2 inch in diameter, formed by alternately freezing and melting as it is carried up and down in highly turbulent air currents of violent storms.

6. Sleet is rain that freezes to pellets of ice when falling through a layer of cold air.

7. Glaze or freezing rain is rain that falls into a cold layer of air and freezes when it strikes objects on the ground.

Precipitation Measurement

A variety of instruments and techniques have been developed for gathering information on various phases of precipitation. Instruments for measuring amount and intensity of precipitation are the most important. Other instruments include devices for measuring raindrop-size distribution and for determining the time of beginning and ending of precipitation.

Precipitation Gages

Any open receptacle that has vertical sides is a convenient rain gage, but because of varying wind and splash effects, the measurements would not be comparable unless the receptacles were of the same size and shape and similarly exposed.

1. The National Weather Service standard gage has an 8-inch diameter collector. Rain water passes from the collector into a cylindrical measuring tube inside the overflow can. The measuring tube has a cross-sectional area one-tenth that of the collector so that a 0.1 inch rainfall will fill the tube to a depth of 1 inch.

2. Three types of recording gages in common use are:

a. The *universal weighing-type gage* consists of a collecting bucket resting on a weighing platform and frame, which are suspended from a spring. This gage was designed to obtain a continuous record not only of rain but also snow, hail, and sleet. Precipitation collected in the bucket increases the load on the spring, which lowers the platform and frame. This deflection is proportional to the amount of precipitation collected. The movement of the frame is transmitted through a system of links and levers to the pen, which marks a graduated revolving chart. The record thus shows the accumulation of precipitation.

b. The *tipping bucket gage* consists of a collector orifice, 12 inches in diameter that funnels rain water into a small outlet directly over a tipping bucket mechanism. The tipping bucket is divided into two equal compartments, each holding exactly 0.01 inch of rainfall. When one compartment fills, the bucket tips and empties into the overflow reservoir. Simultaneously, the opposite compartment is positioned below the nozzle to receive the incoming rainfall. Electrical impulses are transmitted to a recorder or indicator, each impulse representing 0.01 inch of rainfall.

c. A *float-type gage* measures rainfall in a chamber that has a light weight float into which the rainwater is funneled. The vertical movement of the float as the level of the water rises is then transmitted, by a suitable mechanism, into the movement of the pen on the chart. By adjusting the dimensions of the receiving funnel, float, and float chamber, any desired scale value on the chart can be obtained.

Precipitation Gage Network

A network for the collection of hydrologic data is not always designed as a. result of scientific planning. The number of gages necessary to determine the depth of precipitation on an area depends on (1) size of the area, (2) prevailing storm type, (3) form of precipitation, (4) topography, (5) aspect, (6) season, and (7) the uses for which the precipitation data are intended. Where prevailing storms are cyclonic, a sparse network may be adequate. A denser network will be required where storms are predominately convective and characterized by thunderstorms that have high intensities and uneven distribution. Mountainous areas that create orographic-type storms may require more gages. Generally, more gages are needed where precipitation is variable

The objectives of the study are important in determining the number of gages required. A relatively sparse network of stations would suffice for studies of large general storms or for determining annual averages over large areas of level terrain. A dense network is required to determine the rainfall pattern in thunderstorms. Because of a large number of factors involved, the range of adequate network requirements is broad. Specifying the required density of hydrology stations on a unit-area basis is particularly difficult

Bucket Surveys

Analysis of specific storms will likely show that the density of standard or recording precipitation gages does not adequately define the storm rainfall patterns. Either maximum depths or areal distribution may be inadequately defined. In such cases, the use of bucket surveys may be the only way missing data can be estimated. Residents in the study area are interviewed as soon as possible after the storm event, measurement made of any open container that caught rainfall and exposure evaluated to fill in the data. Large errors and inconsistent data may occur but, if the work is done carefully, useful data can be obtained.

Snow Courses

The accumulation of snow in a basin may be the major source of the water supply in some areas. At the same time, a rapidly melting snowpack may result in costly flooding. Forecasting of flows from snowmelt for water supply and flood control is important to farmers, ranchers, and users and providers of irrigation water. Operation of flood control reservoirs in many parts of the country depends on such forecasts.

A snow course is a permanently marked area where snow surveys are taken each year. The snow courses should provide an estimate of the snowpack conditions within the basin. Some requirements for selecting snow course sites are:

1. The site should be open and large enough so that it is not affected by interception.
2. The site should be protected from high winds.
3. The site should be on a well-drained soil.
4. The site should be accessible so that continuous measurements can be made throughout the season.
5. The site should represent the snow conditions at a given exposure, cover, and elevation complex.

The number of snow courses will depend on the diversity of topographical and meteorological conditions and local topographic features, such as aspect and ground slope. Planned use and required accuracy of the data also should be considered in determining the number of snow courses.

SNOTEL

SCS has implemented a data collection, transmission, and processing system, designated SNOTEL (Snow Telemetry). The SNOTEL system collects snow and other hydrometerological data from remote data sites throughout 10 western states and transmits the data to a central computer where they are stored and validated. The data are provided to a variety of cooperating users. The system has five main components:

1. Presently, each of 500 remote stations collects up to 16 data parameters and transmits them on command. Each station consists of data collection equipment and communication electronics. A special type of precipitation gage is used at each site in which the depth of precipitation collected is measured by a pressure sensor. Accumulated precipitation contained within the snowpack is called snow water equivalent (SWE). Other data collected are temperature and, as needed, soil temperature, soil moisture, relative humidity, wind speed and direction, and solar radiation. The sensors are connected to transducers, which convert the data into electrical impulses that can be stored or transmitted.

2. Two master polling stations command the remote stations and gather data from them.

3. A central computer facility at the West National Technical Center (WNTC) coordinates communication throughout the SNOTEL network and disseminates data to its users.
4. Remote computer terminals can access the system, obtain data, and control the polling of remote stations.
5. Several portable communication field test units are available.

Data Sources

Several sources are available for precipitation values used in the design of various conservation practices.

Engineering Field Manual, Chapter 2

EFM, Chapter 2 gives 24-hour rainfall data maps for 2-year, 5-year, 10-year, 25-year, 50-year and 100-year frequencies for the central and eastern United States (including Alaska and Hawaii), Puerto Rico, and the Virgin Islands.

A copy of the maps for 10-year, 24-hour rainfall are in Appendix A (A-3 through A-6).

Example

Given: Using the 10-yr, 24-hr rainfall map in chapter2, EFM or in Appendix A of this Study Guide (A3), determine the rainfall for Columbus, Ohio.

Solution:

Locate Columbus on the rainfall map. It is slightly south of the center of the state (county boundaries are drawn, but not named). Columbus is about halfway between the 3.5 in and 4.0 in rainfall lines.

tC40-3.5) = 0.25in

10-yr, 24-hr rainfall for Columbus, Ohio = 3.5 + 0.25 = 3.75; round to 3.8 in.

Technical Release No. 55

TR-55, Appendix B contains 24-hour rainfall data maps for 2-year, 5-year, 10year, 25-year, 50-year and 100-year frequencies for the central and eastern United States. Alaska, Hawaii, and the Virgin Islands are not included. TR-55 references detailed maps for the 11 western states. A copy of the map for a 10-year, 24-hour rainfall is in Appendix A (A3).

Technical Paper No. 40

TP-40, Rainfall Frequency Atlas of the United States, prepared in 1961 by the U.S. Department of Commerce, Weather Bureau, for SCS, gives rainfall data for durations from 30 minutes to 24 hours and return periods from 1 year to 100 years. Data on the western states are included, but no information is available for Alaska, Hawaii, Puerto Rico or the Virgin Islands. A copy of the 10-year, 24-hour rainfall is included in Appendix A (A 7). . SCS does not use the precipitation data for the western states from TP-40

NOAA Atlas 2

NOAA Atlas 2, Precipitation -- Frequency Atlas of the Western United States, developed in 1973 by the U.S. Department of Commerce, National Oceanic and Atmospheric Administrational National Weather Service, for the SCS, gives rainfall data for 6- and 24-hour durations for return periods of 2, 5, 10, 25, 50 and 100 years. This atlas contains a volume for each of the 11 western states. A copy of10-year, 24-hour rainfall for New Mexico is included as sheet A8.

Use of Precipitation Values

Precipitation values play a key role in determining peak discharges and runoff, as well as in hydrograph development. SCS uses a rainfall-runoff model to compute runoff volumes, peak discharge, and hydrographs. These rainfall values are converted to values used in the design of conservation practices. The importance of these values is evident when you consider that the following runoff and hydrograph computation procedures would be useless without precipitation data:

1. Engineering Field Manual, Chapter 2
2. TR-55
3. TR-20 watershed model computer program
4. DAMS 2 computer program
5. EGEM & WEPP computer program
6. CREAMS, SPUR and other continuous simulation computer models

In addition, without the precipitation value, you could not determine the "R" factor in the Universal Soil Loss Equation.

Summary

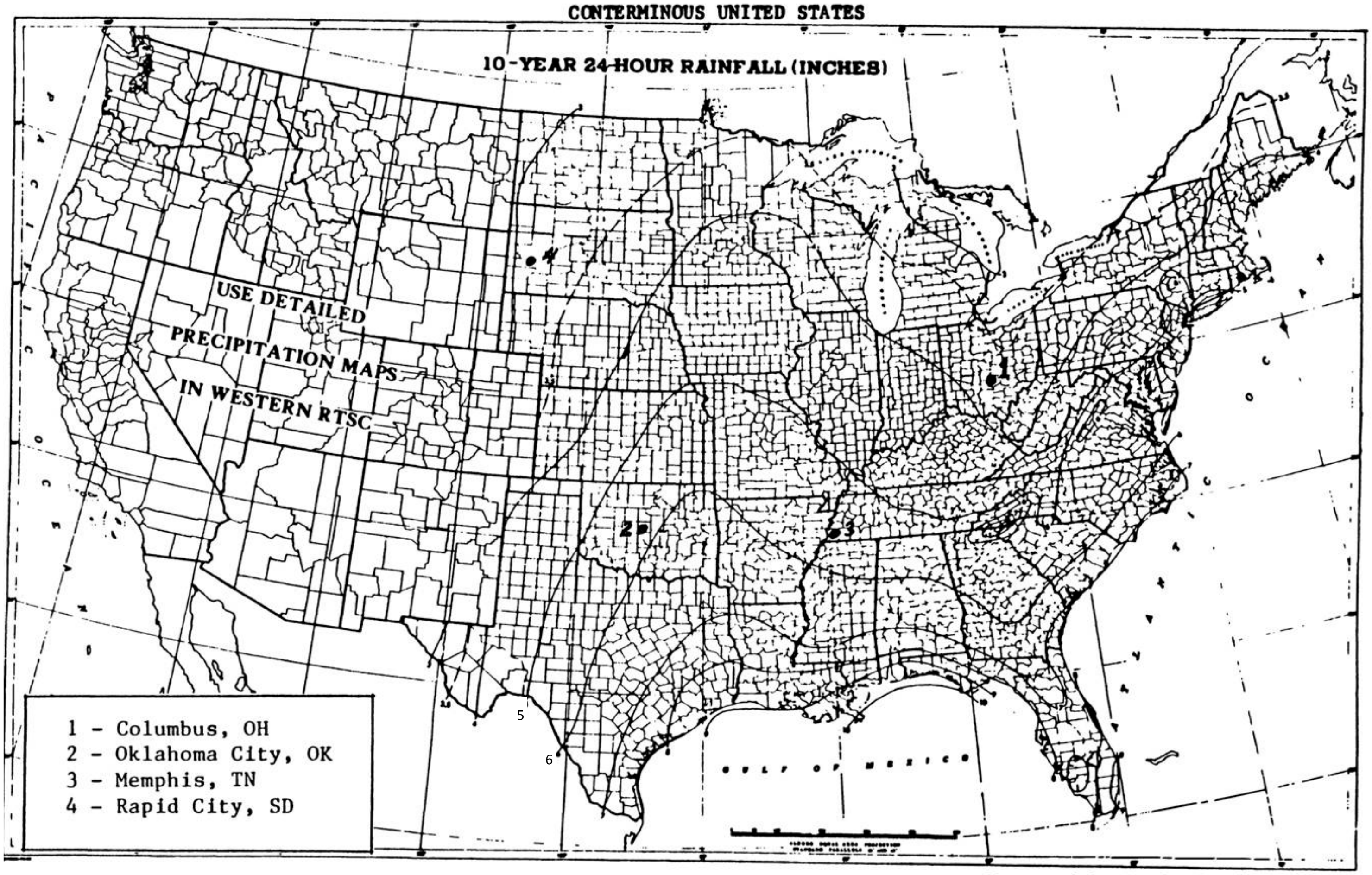
This completes Module 102 - Precipitation. By now, you should have learned to describe the seven forms of precipitation, list and describe the physical processes that generate precipitation, list and explain the three major types of recording gages, tell where to get precipitation values and list where the precipitation values are used. You have completed a couple of activities on the review of key points and on how to use a precipitation map. Selection of the proper precipitation map for various conservation practices will be discussed in other modules. 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 additional 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

Precipitation Maps

CONTERMINOUS UNITED STATES

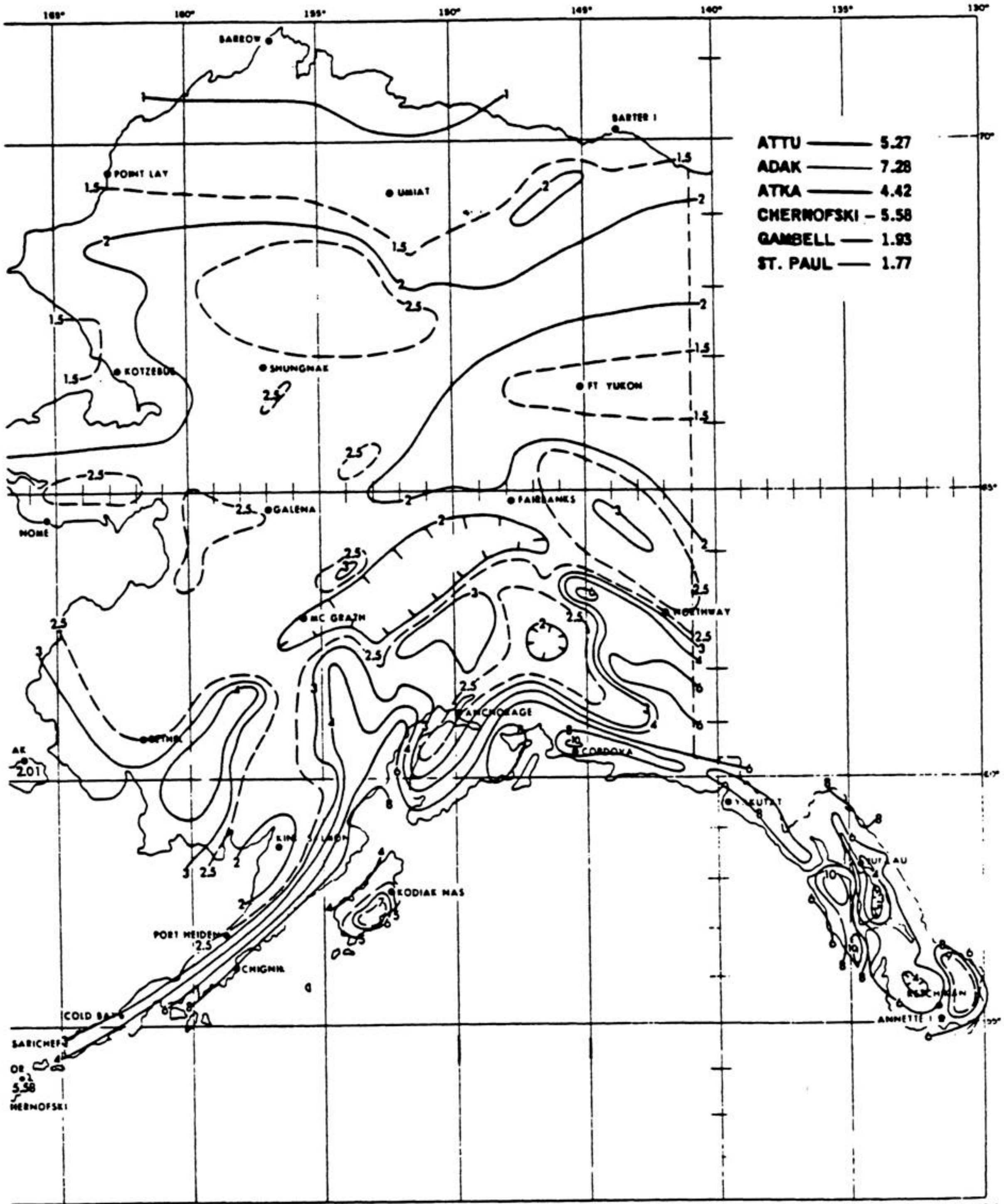


Prepared by U. S. Weather Bureau

Source - Chapter 2,EFM and TR-55

ALASKA

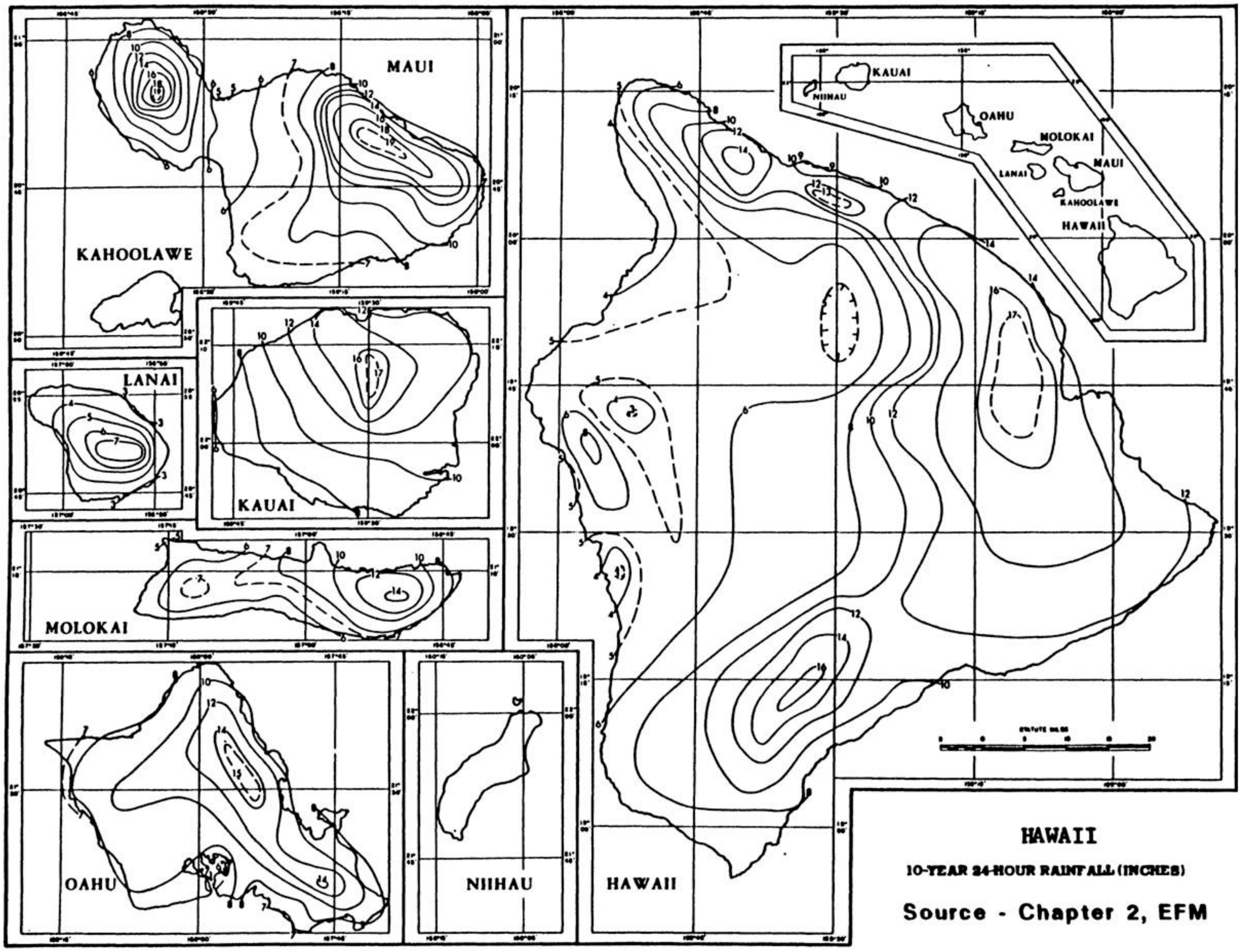
10-YEAR 24-HOUR RAINFALL (INCHES)



Source - Chapter 2, EFM

Prepared from U. S. Weather Bureau Maps

Prepared by U. S. Weather Bureau



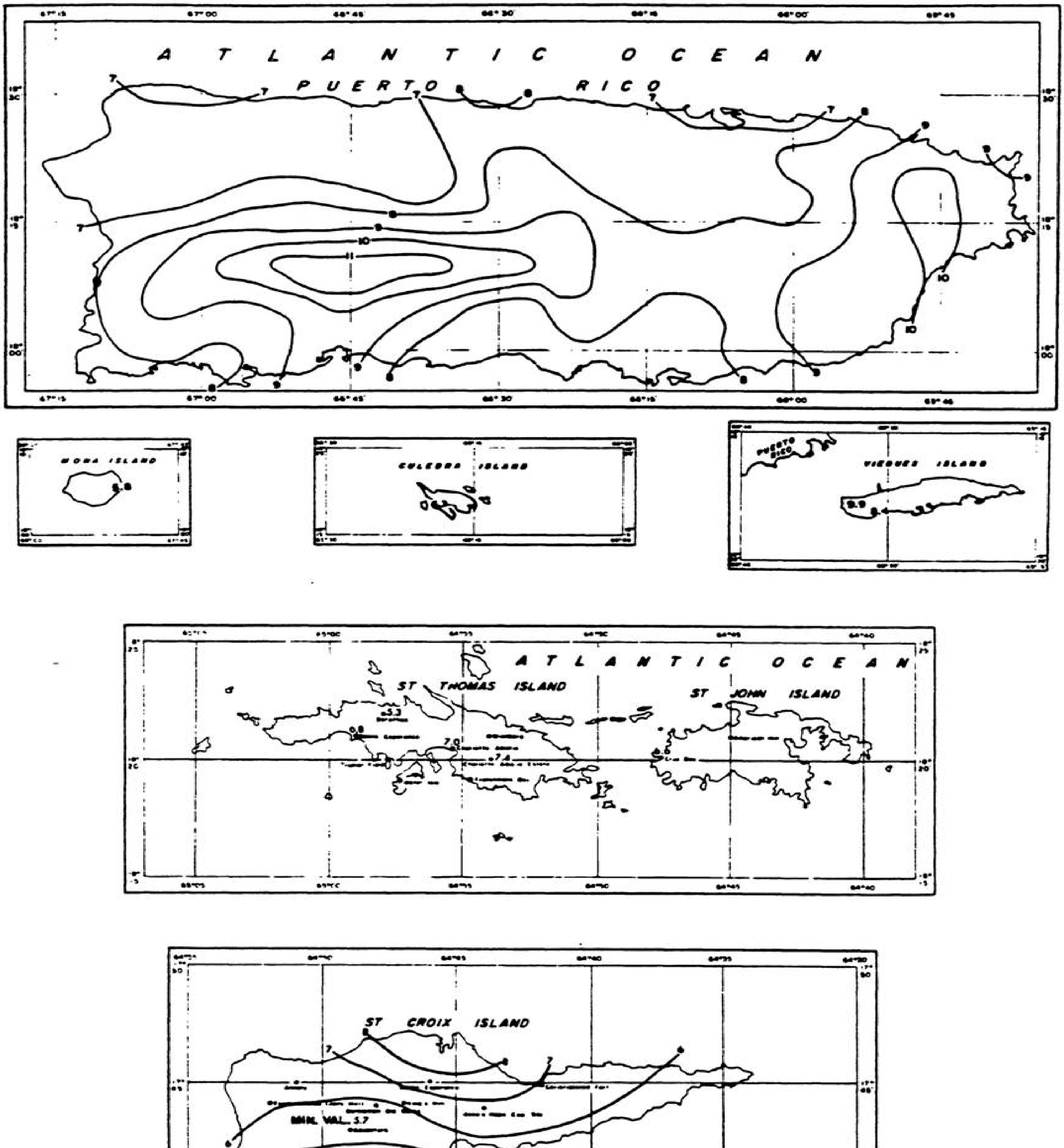
HAWAII

10-YEAR 24-HOUR RAINFALL (INCHES)

Source - Chapter 2, EFM

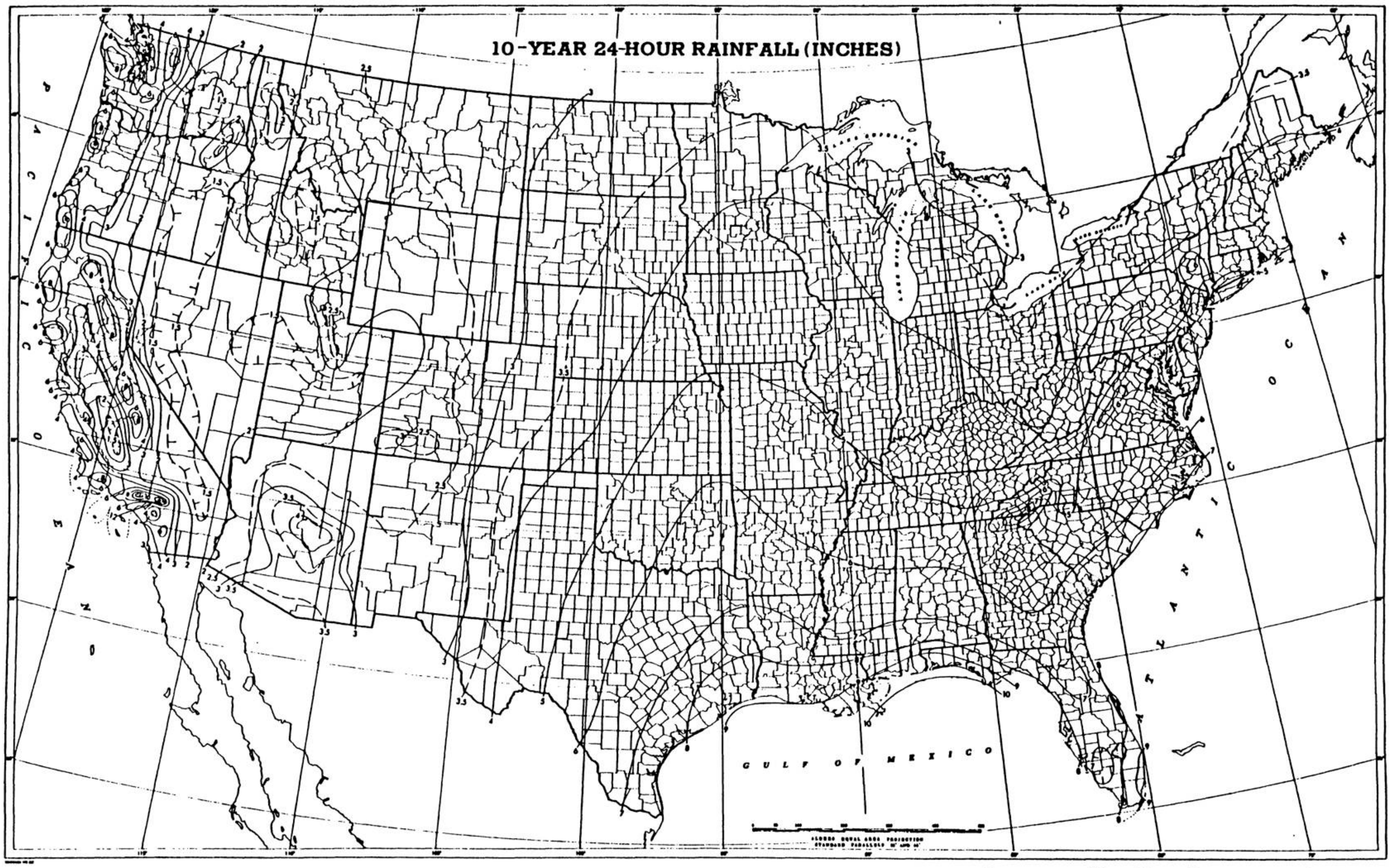
PUERTO RICO AND VIRGIN ISLANDS

10-YEAR 24-HOUR RAINFALL (INCHES)

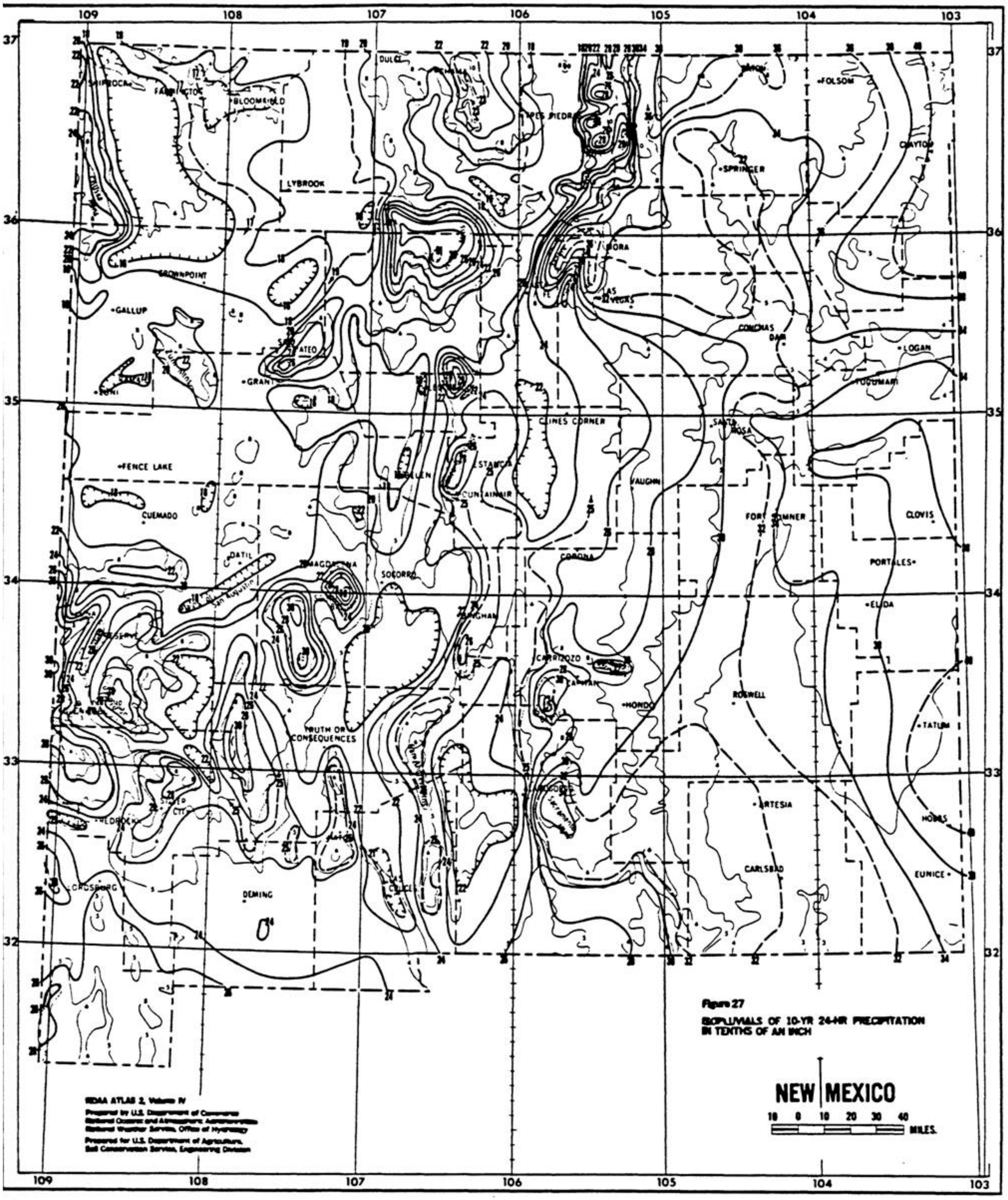


Source - Chapter 2, EFM

Prepared from U. S. Weather Bureau Maps



Source - Weather Bureau and



Source - NOAA Atlas 2, Volume IV

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 solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

1. List the seven forms of precipitation
    a.
    b.
    c.
    d.
    e.
    f.
    g.
2. What are three types of recording gages used to measure precipitation?
    a.
    b.
    c.
3. What does the acronym SNOTEL mean?

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.

1. List four of the most common sources for precipitation values.

   a.

   b.

   c.

   d.

2. Using the 10-year 24-hour rainfall map in the Engineering Field Manual, Chapter 2 or in Appendix A of your Study Guide (A3), determine the rainfall for the locations listed below. Note: You may need to interpolate between rainfall lines

   a. Oklahoma City, Oklahoma

   b. Memphis, Tennessee

Activity 1 - Solution

1. List the seven forms of precipitation

   a. Drizzle

   b Rain

   c. Snow

   d. granular snow

   e. hail

   f. sleet

   g. glaze or freezing rain

2. What are three types of recording gages used to measure precipitation?
   a. Universal weighing-type gage
   b. Tipping bucket gage
   c. Float-type gage
3. What does the acronym SNOTEL mean?

   Snow telemetry

Activity 2 - Solution

1. List four of the most common sources for precipitation values.

    a. Engineering Field Manual, Chapter 2

    b. TR-55 (except for the 11 western states)

    c. TP-40 (except Alaska, Hawaii, Puerto Rico, and the Virgin Islands).

    d. NOAA Atlas 2 (Available only for 11 western states, one volume for each state).

2. Using the 1 O-year 24-hour rainfall map in the Engineering Field Manual, Chapter 2 or in Appendix A of your Study Guide (A3), determine the rainfall for the locations listed below. Note: You may need to interpolate between rainfall lines

    a. Oklahoma City, Oklahoma

    Approximately 3/4 the difference between 5- and 6-inch rainfall 3/4 (6 - 5) = 0.75 in
    Rainfall = 5.0 + 0.75 in, round to 5.8

    b. Memphis, Tennessee

    Approximately 2/3 the difference between 5- and 6-inch rainfall 213 (6 - 5) = 0.67 in
    Rainfall = 5.0 + 0.67 in, round to 5.7

    c. Rapid City, South Dakota

    Approximately 1/5 the difference between 3.0- and 3.5-inch rainfall 1/5 (63.5 - 3.0) = 0.1 in
    Rainfall = 3.0 + 0.1 in, round to 3.1