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Title

Watershed Response to Storm Events

Permalink

<https://escholarship.org/uc/item/1sr9k2bf>

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Publication Date

2003

DOI

10.3733/ucanr.8081

Peer reviewed



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Farm Water Quality Planning

A Water Quality and
Technical Assistance Program
for California Agriculture

<http://waterquality.ucanr.org>

This REFERENCE SHEET is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.



Reference:

Watershed Response to Storm Events

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If you know how your watershed is likely to respond to storm events, you as a land manager can do a better job of formulating a land management plan that will account for the potentially destructive effects and unpredictable nature of storms. Under natural conditions, precipitation is the main source of water input for a watershed. Precipitation water infiltrates the soil surface to recharge ground water and is essential for vegetative growth. There is a down side, however: storm water can transport pesticides, nutrients, and other pollutants to ground and surface waters. Sediment pollution is generated when storm water dislodges precious topsoil and carries it off-site.

HOW PRECIPITATION FORMS

Water enters the atmosphere as water vapor. As this vapor ascends through the atmosphere, air pressure decreases with increasing altitude, allowing the air to expand, and as it expands the air cools. Most precipitation occurs when warm, moist air rises to a high altitude, expands, and cools, and the water vapor condenses into water drops or freezes as ice crystals.

Rain forms when condensation droplets become too large and heavy to remain suspended in air. The falling drops grow through collision and condensation, reaching about 5 mm in diameter before they break apart into smaller droplets of 0.1 to 3 mm. *Drizzle* is a form of rain with droplets of less than about 0.5 mm in diameter. Drizzle occurs at low intensities in cool and maritime climates.

Snow forms when water vapor cools to below the frost point. Up to 75 percent of the precipitation in the western United States falls as snow. In most places along California's Central Coast region, however, less than 10 percent of the precipitation falls as snow.

Fog drip is not actually a type of precipitation, but the result of *interception*. Fog drip occurs in coastal climates when fog collects on vegetation, forms into drops, and falls to the ground. Fog drip may contribute a substantial amount of water to watersheds along California's Pacific Northwest coast and in high mountain areas. Although measured amounts are small, the presence of fog helps to reduce transpiration and increase soil moisture.

There are many other types of precipitation, including hail, sleet, and frost. Rain accounts for over 90 percent of the precipitation in most places along California's Central Coast, though, so this fact sheet focuses on rain when discussing precipitation in the context of storm events, storm characteristics, watershed response, and implications for land management.

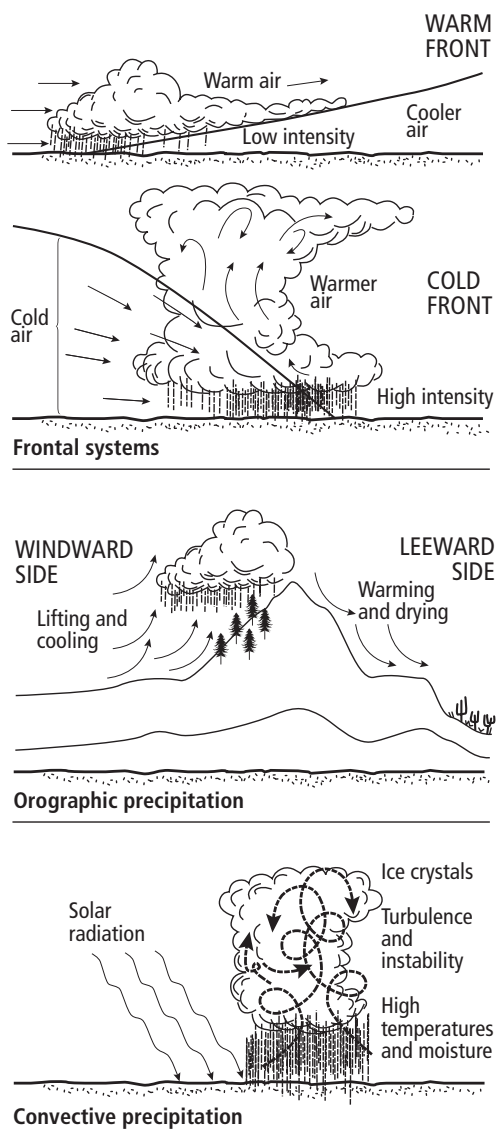


Figure 1. Storm types. (from *Hydrology and the Management of Watersheds*, Brooks et. al., 1997, Iowa State Press; used by permission)

STORM TYPES

A storm's type is determined by how its air mass is uplifted. Three main uplifting mechanisms generate the three main storm types (Figure 1). All three types occur on California's agricultural lands.

Frontal (or convergence) systems result when a warm, moist air mass and a cold, dry air mass meet. A warm front occurs when the warm air displaces cool air. This generally produces gentle rain over a large land area. A cold front occurs when cool air displaces warm air. Cold fronts produce high-intensity rainfalls over a short time period in a relatively small area.

Orographic precipitation results when an air mass is forced over a mountain range. There is often a marked increase in precipitation with elevation on the windward side of the mountain range. For example, a 1,000-foot rise in elevation can result in a 10-inch increase in annual precipitation. Even more dramatic is the 25-inch increase per 1,000 feet of elevation found along the coastline of the Pacific Northwest.

A rain shadow, where little precipitation occurs, often exists on the leeward side of a mountain range. The Great Basin and the western Great Plains are perfect examples of areas affected by rain shadows.

Convective precipitation results from the localized heating of an air mass at the Earth's surface causing the air mass to rise. Convective storms can occur within frontal storms. They tend to be small storms, but they produce intense rain showers, hail, or tornadoes, and they tend to be scattered across the landscape.

STORM CHARACTERISTICS

Precipitation amount, duration, and intensity are important storm characteristics that determine how a watershed will respond hydrologically to an individual storm event. The

precipitation amount is simply the depth (in inches) of rainwater that falls on a watershed. *Duration* is the time period (in hours) over which a storm event occurs. *Intensity* is the amount of rainfall that occurs over a given duration (inches per hour, or *in/hr*). Runoff and erosion tend to increase with the rainfall intensity.

The timing of storms over a watershed has a large impact on the watershed's response. Two similar storms that occur on the same watershed will generate different runoff volumes and peak flows depending on the antecedent soil moisture conditions (how much moisture was already stored in the soil from previous storms). Greater runoff volumes and higher peak flows are generated in a watershed under saturated soil conditions than in a watershed with dry soil conditions. The evapotranspiration (ET) rate for the time between precipitation events will also affect soil moisture conditions and hence runoff volume. For information on estimating ET, contact the California Department of Water Resources CIMIS program (<http://www.cimis.water.ca.gov>).

Spatial distribution, the pattern of precipitation across a watershed, also affects runoff. Precipitation that is distributed uniformly over a watershed generally produces less runoff per acre of watershed than an intense storm that covers a small portion of the watershed. The direction that a storm moves over a watershed also affects runoff rates. If a storm moves from lower elevations to higher elevations within the watershed, lower peak runoff levels will result than if it were to move the opposite way, from higher to lower elevations.

WATERSHED RESPONSE

Several things can happen to precipitation when it falls on a watershed. It may land directly on bare soil or it may be intercepted by a canopy of trees, vines, shrubs, forbs, grasses, or the litter layer of mulch that covers the soil surface. Precipitation that is intercepted can either be returned to the atmosphere as evaporation (*interception loss*) or it may reach the soil surface through the following processes:

- *Throughfall* — Precipitation falls directly to the ground through gaps in the canopy.
- *Stemflow* — Precipitation is directed to trunks and stems and then flows to the ground at the base of the plant.
- *Canopy drip* — Precipitation is directed to the edge of the canopy where it forms droplets and falls to the ground.
- *Leaf drip* — Precipitation collects in the leaves, where it forms droplets that fall to the ground.

Most intercepted precipitation reaches the soil surface where it may infiltrate the soil, flow downhill, or puddle to eventually evaporate or infiltrate.

The various terms for *storm flow* describe the combination of routes that precipitation falling in a watershed can take to reach or form a stream channel:

- *Channel interception* — Precipitation falls directly into a stream channel.
- *Overland flow* — Precipitation falls to the ground and flows into or forms an aboveground waterway or water body.
- *Subsurface flow* — Precipitation infiltrates the soil surface where it flows belowground to reach a waterway or water body.

Storm flow, which can account for much of the generation and transport of non-point source pollution, is influenced by storm characteristics such as rainfall amount, rainfall intensity, and timing of precipitation. For instance, a storm that produces 3 inches of rain in just one hour will generate higher storm flows than a storm that produces 3 inches of rain in 24 hours.

Storm flow is also influenced by watershed characteristics such as soil type, geology, topography, vegetation, watershed shape, and land use. Vegetation absorbs the impact of water droplets that could otherwise dislodge soil. Rain infiltrates porous soil more readily than soil that has been compacted. Vegetative cover, well-aggregated soils, and flat or gently sloped land serve to impede storm flow and therefore reduce the offsite movement of sediment.

Precipitation that falls on a watershed can also evaporate or percolate down to the ground water (see Reference Sheets related to ground water [UC ANR Publications 8083, 8084, 8085, and 8086]). Precipitation that enters the ground water may eventually recharge a stream, but since ground water moves slowly, its influence is not noticeable in immediate response to a storm.

100-YEAR EVENTS

In discussions of hydrologic events such as rainfall or floods, one hears terms such as *hydrologic frequency analysis*, the 20-, 50-, or 100-year event, *return period*, and *probability*. People often use these terms loosely, not fully understanding their meanings.

Hydrologic frequency analysis is the evaluation of hydrologic records, such as rainfall or stream flow, to estimate how frequently events of a given magnitude will occur. A 100-year event is an event of such magnitude that, over a very long period of hydrologic record, the time between events of equal or greater magnitude is on average 100 years. *Return period* is the period of time that one can expect will elapse between occurrences of events at a certain site: the return period for a 100-year event is 100 years. A 100-year event has a *probability* of 0.01 (1 percent) of being equaled or exceeded in any one year ($\text{probability} = 1/\text{return period} = 1/100$).

The magnitude of a 100-year event is different for each watershed and depends upon the climate and watershed characteristics. For instance, the 100-year 24-hour rainfall at Elko, Nevada, is approximately 2.5", while the 100-year 24-hour rainfall at Eureka, California, is approximately 8".

Return period is often misinterpreted as a statistical guarantee that hydrologic events of a given size will occur on a predictable, fixed time schedule. The return period and probability can be used to estimate how likely an event is, but they tell us nothing about *when* it will occur. The statement, "Well, we just had another 100-year flood, so we are safe for another 100 years" is a complete misrepresentation of the definition of a 100-year event. The statement, "Well, we just had an *estimated* 100-year flood, so statistically we would not expect to have another such flood for 100 years" would be more correct. In a given person's lifetime, a 100-year event might happen once, twice, or several times, or it might not happen at all.

IMPLICATIONS FOR LAND MANAGEMENT

Since storm events and watershed responses are largely unpredictable, a successful land management plan such as a Farm Water Quality Plan needs to include contingencies that take advantage of "favorable" weather or prepare for "unfavorable" weather.

Weather extremes can mask the benefits of good management or exacerbate the problems of poor management. A watershed management plan implemented in the first year of a seven-year drought could have a very different outcome than if it were implemented in the first year of a seven-year wet period. Whenever you evaluate the success or failure of watershed management plans or practices, make sure that you include good weather records.

MEASURING PRECIPITATION

Land managers can monitor rainfall and use that information in making irrigation scheduling and pest management decisions. Precipitation records can also help to determine the reason for the success or failure of a practice.

You can measure rainfall at a particular location *can be measured* by using a rain gauge. There are non-recording and recording rain gauges. Simple, non-recording gauges are adequate for many monitoring purposes. Recording rain gauges and automated weather monitors are much more expensive.

A non-recording rain gauge is a container that must be manually monitored and emptied. A rain gauge should be placed on relatively flat ground, in an open area,

about 39 inches (1 m) off the ground. Objects such as trees and barns can influence gauge accuracy. Figure 2 shows how far from an obstacle you should place a rain gauge. High winds can also affect a gauge's accuracy. If you have a non-recording rain gauge that you monitor infrequently, you can add a very small amount of mineral oil to the gauge's reservoir to reduce evaporation.

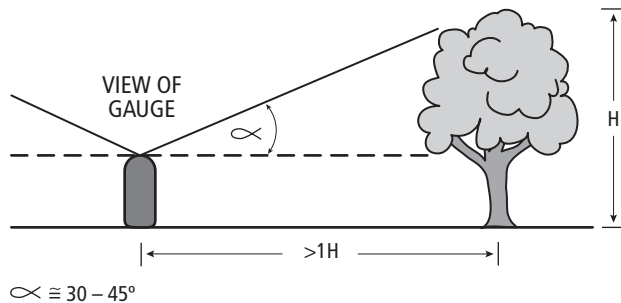


Figure 2. Rain gauge placement. (from *Hydrology and the Management of Watersheds*, Brooks et. al., 1997, Iowa State Press; used by permission).

It takes more than a single gauge to estimate the rainfall amount and its distribution over a watershed. The number of gauges required usually increases with the size and topographical complexity of a watershed. A network of several gauges placed to account for topographic effect can provide an accurate estimate of rainfall. The standard procedure is to establish gauging stations, monitor them on a common time interval, and compute the average rainfall amount based upon the readings from all gauges.

The errors you may encounter with precipitation measurements can be instrument errors or sampling errors. Instrument errors occur when the rain gauge is not correctly set up. Sampling errors occur when the arrangement of gauging stations on the watershed does not accurately represent the distribution of rainfall on the watershed (for instance, all of the stations in a hilly watershed may be at the same elevation). Accurate precipitation monitoring requires that both types of error be minimized. If a network of gauging stations is not feasible, one gauge at the top of the watershed and another at the bottom of the watershed may be a viable alternative. Practical considerations such as time, ease of access, and cost often limit the location and number of gauges on a given watershed. The point is to do the best job possible with the resources available. Dedication and consistency in monitoring and maintaining of the stations are crucial to successful monitoring.

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ACKNOWLEDGMENTS

The authors wish to thank Stuart Pettygrove, UCCE Soils Specialist, UC Davis, and Richard Snyder, UCCE Bioclimatologist, UC Davis, for their help in the preparation of this publication.

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Publication 8081

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pr-1/03-WJC/CR



This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Natural Resources.