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Rangeland Watershed Program

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Precipitation and Rangeland Watershed Management

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A hydrologist might view precipitation solely as it relates to stream flow and water yield. An ecologist might view precipitation as a factor determining soil and vegetation types. A rancher might view precipitation in terms of forage production and stock water. A watershed manager must view precipitation in all these lights and in many more. Precipitation is the major factor determining the hydrology of a watershed, and thus determines in large part how a watershed will respond to management. Watershed response includes everything from forage production to nonpoint source pollution generation. Precipitation is a result of meteorological factors and is largely outside of a manager's control. Yet, a watershed manager must always plan with the weather in mind.

How Does Precipitation Occur?

Warm air will hold more water, as vapor, than cool air. Most precipitation occurs when warm/moist air is lifted to high altitudes, cools, and water vapor condenses into water drops or freezes as ice crystals. How the air mass is uplifted determines the type of storm which will result. Three main uplifting mechanisms, and thus storm types, exist (Figure 1, Brooks et al. 1991). All three of these storm types occur on California's rangelands.

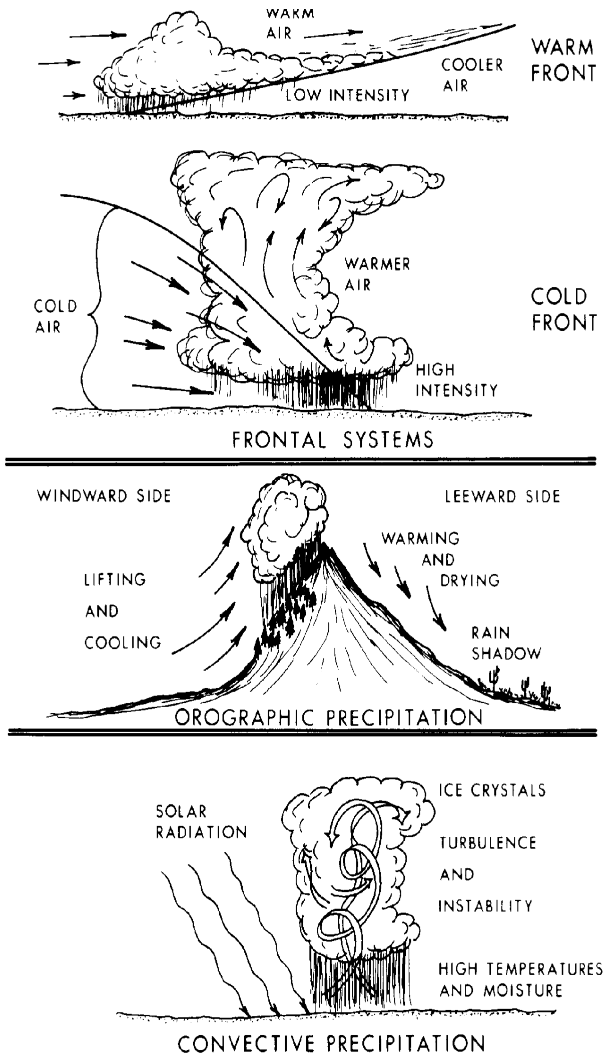

Figure 1. Storm Type

Frontal precipitation results when a warm air mass meets a cold air mass and the warm air mass is lifted above the cold air mass. *Warm fronts* occur at the leading edge of warm air invading cooler air and produce low precipitation intensities over large land areas. *Cold fronts* occur when the leading edge of cold air invades warm air and the warm air is forced up over the advancing cold air. Cold fronts produce high intensity rainfalls in a narrow advancing band.

Orographic precipitation results when an air mass rises as it crosses 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 ft rise in elevation can result in a 10 inch increase in annual precipitation. Even more dramatic is the 25 inch increase per 1,000 ft of elevation found along the Pacific Northwest coastline. A rain shadow often exists on the leeward side of the mountain range. The Great Basin and the western Great Plains are perfect examples of rain shadow effected areas.

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

Storm Characteristics

We often report or discuss precipitation as long-term averages. **When considering nonpoint source pollution, the watershed manager should be interested in individual storm flow events and thus individual precipitation events.** Storm flow, which can generate and transport nonpoint source pollution, is in part a result of various storm characteristics. For instance, a storm that produces 3 inches of rain in one hour will generate different storm flow than a storm that produces 3 inches of rain in 24 hours.

Despite the strong relationship between storm characteristics and storm flow, it is often very difficult to predict the timing and amount of storm flow based solely upon precipitation characteristics. There are two reasons for this. First, storm flow is dependent upon complex *interactions* between *storm characteristics* (rainfall amount, rainfall intensity, timing of precipitation, storm direction, etc.) and *watershed characteristics* (soil type, geology, topography, vegetation type, watershed shape, land use, etc.) Second, precipitation is a ***stochastic*** process. This means that there is a *random component* to rainfall. Regardless of the fact that we cannot predict watershed response solely upon storm characteristics, the watershed manager must understand these characteristics because they still play a major role in determining storm flow and nonpoint source pollution generation.

Precipitation Type. *Rain* is formed when condensation droplets become too large to remain suspended in air. The falling drops grow by collision and condensation up to about 5 mm in diameter before breaking apart into smaller droplets (0.1 - 3 mm). *Drizzle* is a form of rain with droplets less than about 0.5 mm in diameter. Drizzle occurs at low intensities in cool and maritime climates. *Fog Drip* occurs in coastal climates when fog collects on vegetative surfaces, forms into drops, and falls to the ground. Fog drip may contribute substantially to the water balance of watersheds along the Pacific Northwest coast and in high mountain areas. Although measured amounts are small, the presence of fog and moisture helps to reduce transpiration and maintain higher soil moisture content. *Snow* forms when water vapor is cooled below the frost point. Up to 75% of the water in the western US comes from snow. Three characteristics distinguish snow from liquid forms of precipitation:

1. Large quantities of water may be stored in a watershed as snow pack.
2. The water is not available for runoff until the snow pack melts, often months after it was deposited.
3. Wind may move snow from one location to another after it has been deposited.

Sleet is ice pellets formed at higher levels that fall through a cold layer of air near the surface. *Hail* is ice balls formed by ice crystals that grow in size as they are transported up and down inside of convectional storms.

Precipitation amount, intensity, and duration are important storm characteristics which determine how a watershed will respond hydrologically to individual storm events. *Amount* is simply the depth (in) of rainwater which falls on a watershed during a specific time period. *Intensity* is the rate of rainfall (in/hr). **Runoff and erosion tend to increase as rainfall intensity increases.** *Duration* is the time period (hr) over which a storm event occurred.

Temporal distribution (timing of storms) of precipitation over a watershed is a factor influencing antecedent soil moisture (moisture stored in the soil from previous storms) which has a large impact on

watershed response. Two exact storms occurring on the same watershed will generate different runoff volumes and peak flows under different antecedent soil moisture conditions. More runoff volume and higher peak flows are generated from a watershed under saturated than dry soil conditions.

Spatial distribution (patterns of precipitation across a watershed) of precipitation on a watershed effects runoff. Precipitation which is uniformly distributed over a watershed generally produces less runoff per unit watershed area than intense storms that cover a small portion of a watershed. The direction which a storm moves over a watershed affects runoff. Lower peak runoff is realized if the storm moves towards the head versus towards the bottom of the watershed.

Implications for Rangeland Watershed Management

The random nature of precipitation, and our inability to control or predict it, has profound implications for rangeland watershed management. Because precipitation is a stochastic process, watershed response (peak flow, sediment generation, forage production, etc.) is also a random or uncertain phenomena. We as managers continually try to predict *exactly* what effect our management will have on water quality and quantity. In our attempts do so, we often *over simplify* a very complex system. In fact, we can never hope to predict watershed response with 100% certainty, and in some instances with no where near 100% certainty.

Yet, we as managers often do not recognize this fact. We tend to plan for absolutes. **We often fail to incorporate contingency plans either to take advantage of "favorable" weather or to survive "unfavorable" weather.** We also tend to evaluate the failure or success of watershed management plans or practices without accounting for the weather experienced during the time period of interest. For instance, a watershed management plan implemented the first year of a seven year drought would have very different effects than if it were implemented the first year of a seven year wet period. **Also, it is important during project evaluation to do our best to separate the impacts of management from the impacts of naturally occurring, extreme weather events.** This is not an easy task, but it must be attempted. Be it flood or famine, weather extremes can mask the benefits of good management or exasperate the problems of poor management.

There are ways to account for the impact of uncertain weather on management and watershed response. Whether that be a rancher storing extra hay, a restoration project being prepared to implement emergency erosion control practices, or a hydrologist examining long-term weather records and assessing the probability of the occurrence of an intense storm coinciding with the implementation of a particular management practice. Hydrologists, ranchers, ecologists, and watershed managers all realize that precipitation impacts the system we manage; we just do not always try to account for this in our management of these systems.

Monitoring Precipitation on Rangeland Watersheds

Most ranchers have one or more rain gauges out and are actively monitoring rainfall. Some are even monitoring at different locations across the ranch. A record of precipitation can be very important to a watershed manager. Either to help determine the reason for the success or failure of a practice, to determine the probability of a certain event (such as a drought or flood) occurring, or simply to gain a better understanding of the system being managed.

Rainfall at a Point is measured at a site or location with a ***gauge***. There are nonrecording and recording rain gauges (Figure 2, Hewlett 1982). A nonrecording gauge is a container which must be manually monitored and emptied at regular or irregular time intervals (i.e., every 24 hours, after each storm, or seasonally). If a non-recording rain gauge is to be monitored infrequently, a very small amount of oil can be added to the gauge to reduce evaporation. Nonrecording gauges provide an estimate of rainfall amount. Recording rain gauges provide rainfall intensity. Two common

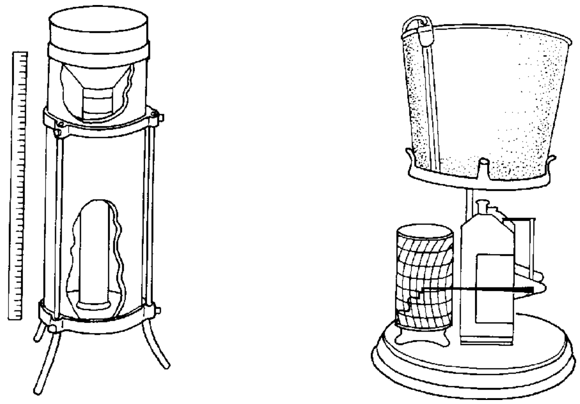

Figure 2. Rain gauges

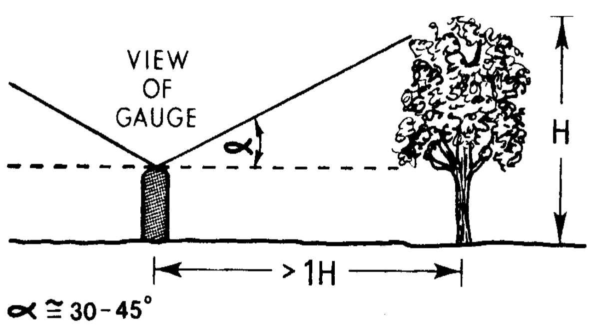

Figure 3. Placement of a rain gauge.

recording gauges are the weighing bucket and the tipping bucket rain gauge. These gauges are automated and are much more expensive than nonrecording gauges.

Simple, nonrecording gauges are adequate for most management purposes. Rain gauges should be placed on relatively flat ground, in an open area, about 3.28 ft (1 m) off the ground. Objects such as trees and barns can influence gauge accuracy. Figure 3 (Brooks et al. 1991) illustrates the distance a rain gauge should be placed away from an obstacle. High winds can also effect the accuracy of gauges, and specially designed wind shields can be used if necessary.

Rainfall on a Watershed — It takes more than a single gauge to estimate the rainfall amount and distribution over a watershed. The number of gauges required usually increases with watershed size and topography. A network of several gauges, placed to account for topographic effect, can provide an accurate estimate of rainfall. The procedure would be to establish the gauging stations, monitor on a common time interval, and compute the average rainfall amount based upon all gauges.

The sources of error associated with precipitation measurements are *instrument error* and *sampling error*. Instrument error occurs when the gauge is not established correctly (Figure 3). Sampling error occurs when the arrangement of gauging stations on the watershed do not represent the distribution of rainfall on the watershed (perhaps all stations are at the same elevation). Accurate precipitation monitoring requires that both types of error be minimized. If a network of gauging stations is not feasible, then a gauge at the top and bottom of the watershed may be a valuable compromise. Practical considerations such as time, access, and cost often limit the location and number of gauges on a watershed. The point is to do the best possible job with the resources available. Dedication and consistency in monitoring and maintaining the stations are crucial.

References

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