FACT SHEET **No. 33**

Rangeland Watershed Program

U.C. Cooperative Extension and USDA Natural Resources Conservation Service

Basic Concepts: Hydrology, the Hydrologic Cycle, Watershed, Watershed Management, and Watershed Water Balance

Kenneth W. Tate, Department of Agronomy & Range Science, University of California, Davis, CA 95616-8515

The purpose of this fact sheet is to establish some working definitions and to present several concepts pertaining to the management of watersheds. At first glance, these concepts appear to be easily understood and not worth a lot of thought. However, it is important to realize that basic concepts become complex as we try to *apply* them to *understand* and *predict* what is occurring on a watershed. Understanding these basic concepts allows us to realize what we can manage for, what we cannot control, and where best to allocate limited resources to achieve clearly defined environmental, social, and economic goals. Future fact sheets will examine each concept with respect to rangeland watershed management.

Hydrology

Hydrology might simply be defined as the science of water. Technically, *hydrology* is defined as the science that treats the waters of the Earth; their occurrence, circulation and distribution; their chemical and physical properties; and their reaction to their environment, including their relation to living things. A good working definition of *hydrology* is the study of the interrelationships and interactions between water and its environment in the hydrologic cycle.

Hydrologic Cycle

The *hydrologic cycle* is the most fundamental principle of hydrology. The *hydrologic cycle* represents the circulation of the Earth's waters from ocean to atmosphere to land and back to ocean. The cycle can be thought of as a huge water pump that is powered by *solar radiation* (energy from the sun) and by *gravity.* The *hydrologic cycle* is a global system, and every molecule of water on Earth is a part of the cycle. Figure 1 illustrates the compartments and processes of the hydrologic cycle. The cycle is continuous and modification of one compartment or process will influence the entire cycle. The hydrologic cycle continues endlessly in the presence or absence of human activity, but human activity can and does modify the cycle.

The sun provides the energy to transfer water

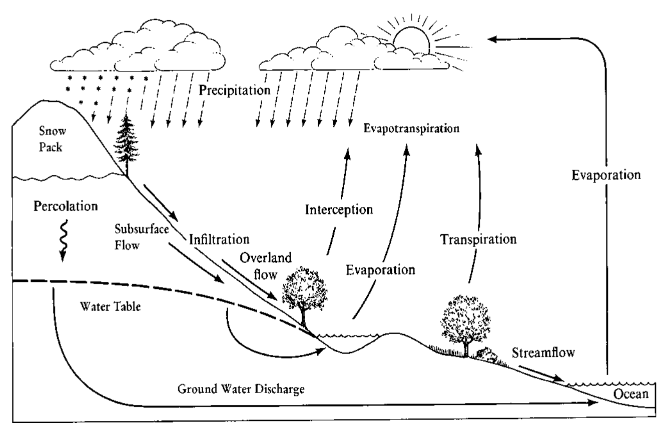

Figure 1. Hydrologic cycle.

from oceans, lakes, rivers, wetlands, bare soil, and vegetation to the atmosphere as a water vapor (oceans, rivers, etc., are *compartments* of the cycle, the transfer of water from one compartment to another occurs due to *processes*). Transfer of water from oceans, lakes, rivers, wetlands, bare soil, and plant surfaces to the atmosphere is called *evaporation* (a process). The transfer of soil water through living plants to the atmosphere is called *transpiration*. The processes of *evaporation* and *transpiration* are referred to together as *evapotranspiration.*

Due to gravity, water vapor in the atmosphere falls to Earth as *precipitation*. Rain and snow are the two dominant forms of precipitation. For this discussion we will only consider rainfall. Snow will be discussed in future fact sheets. Before reaching the Earth's surface, most rainfall is caught by vegetation (trees, grass, litter, etc.). This catching of rainfall is called *interception*. Most intercepted rainfall drips to the soil surface (*through fall*) or runs down the plant to the soil surface (*stem flow*). A portion of intercepted rainfall is evaporated back to the atmosphere. That rainfall which reaches the soil surface is referred to as *net rainfall*.

Once rainfall reaches the soil surface, a portion passes across the soil surface and enters the soil profile. The process of rainfall crossing the soil surface is known as *infiltration*. Rainfall that is not infiltrated runs down slope as *overland flow.* Rainfall carried as overland flow may infiltrate further down slope, or it may enter a stream channel. Infiltrated rainfall is initially stored in the soil profile as soil moisture.

As the amount of water in the soil (*soil moisture content*) increases during a storm, soil water may move vertically to ground water aquifers due to *percolation* or laterally to stream channels as *lateral subsurface flow*. Ground water may enter streams, lakes, oceans, or it may be stored for long time periods in aquifers. Not all soil water will be lost to percolation or lateral subsurface flow. Soils can hold a certain amount of water against gravity. Soil water held against gravity is eventually lost as *evapotranspiration*. It is the ability of the soil to hold water against gravity which makes plant life possible.

Rainfall which enters a stream channel becomes *stream flow. Stream flow* can be attributed to either *storm flow* or *base flow*. During, as well as shortly after a storm event, stream flow is dominated by storm flow resulting from overland flow and lateral subsurface flow. Between rainfall events, stream flow is dominated by base flow resulting from *ground water discharge. Runoff* is that portion of rainfall that leaves a land area as stream flow. *Water yield* is the sum of stream flow and ground water discharge from a contributing land area.

Because the sediment, chemicals, heat, and biota in water is an important component of the hydrologic cycle, the hydrologist must be concerned with *water quality*. *Water quality* refers to the physical, chemical, and biological characteristics of water. *Erosion* and *nutrient cycling* are natural processes which are linked to the hydrologic cycle. Soil generation and landscape development are in part products of weathering and the movement of sediment through the hydrologic cycle. Nutrients are naturally added and removed from land areas as water cycles thought the land area. As water flows through a land area it exchanges heat energy with the surrounding environment. The natural levels of erosion, sediment transport, nutrient transport, etc., are referred to as *background levels*.

The following estimates of the Earth's water supplies provide a feel for the relative size of the compartments of the *global* hydrologic cycle. There are roughly 287,131,678 cubic miles of water on Earth, 96.5 % of which is salt water contained in oceans. Only 2.5 % of the water on Earth is fresh water. Table 1 shows where the fresh water on Earth is located. It is important to note that only an estimated 0.336 % of the Earth's fresh waters are in a liquid form as surface water (lakes, marshes, rivers, etc.). Our fresh waters are indeed a valuable resource.

Table 1. Distribution of the Earth's fresh water reserves.

Fresh Water Compartment	Volume (mi^3)	Percent of Fresh Water
Polar Ice	4,976,900	68.6
Ground Water	2,181,479	30.1
Snow Pack	70,561	0.98
Lakes	18,852	0.25
Atmosphere	2,672	0.035
Marshes/Wetlands	2,376	0.026
Rivers/Streams	439	0.006
Living Organisms	232	0.003
TOTAL	7,253,511	100

Watershed

There is often confusion concerning *watershed* vs. *drainage basin* vs. *catchment*. The confusion arises from differences in usage within and outside the United States. Technically, a *drainage basin* or *catchment* is the area of land that drains water, sediment, dissolved materials, and biota to a common outlet at some point along a stream channel. If the area is large (hundreds of square miles) it is a *drainage basin*, if it is small (acres to square miles) it is a *catchment*. *Watershed* is technically defined as the topographical divide (*drainage divide*) that separates catchments. In the United States, we use watershed to mean catchment and drainage divide to mean watershed. The point is academic, but should be kept in mind when talking to someone from outside the United States, or when interpreting international work.

We will define a watershed as the area of land that drains water, sediment, dissolved materials, heat, biota, etc., to a common outlet at some point along a stream channel (watershed outlet). A watershed is a naturally delineated unit of land. Watersheds are the basic land unit of the hydrologic cycle, just as pastures are the basic land unit of a ranch. All of the land on Earth is in a watershed.

Watershed Management

Watershed Management is the management of land and other resources on a watershed to achieve well-defined environmental, social, and economic goals. Unique to the concept of watershed management is recognition of the relationship between land use, soil loss and productivity, water quantity and quality, wildlife populations and habitat, social factors, and economic factors. Up stream and down stream land areas and entities are linked on a watershed through the hydrologic cycle.

Watershed management practices are those non-structural and structural activities employed on a watershed to achieve clearly defined management goals. *Watershed management practices* are in fact *natural resources management practices.* The difference is in how and at what scale the practices are used and evaluated.

Watershed management focuses on water and its interrelationship with everything else on the watershed. Natural resources management may be occurring within a watershed, but that does not imply that watershed management is being practiced. The unique environmental, social, economic, and political scene of a watershed must be combined with traditional natural resources science to successfully manage a watershed.

A one-size-fits-all watershed management plan does not exist. *Dissociated management practices, restoration projects, or conservation projects applied within a watershed do not constitute watershed management*. A major challenge to watershed management is that ownership and political boundaries do not follow drainage divides.

Watershed Water Balance

From a hydrologic viewpoint, the first step of watershed management is to evaluate past, present, and proposed management practices on a watershed with respect to the watershed water balance. W*atershed water balance* refers to the balance between the inflow of water to a watershed as precipitation and the outflow of water from the watershed as evapotranspiration, ground water discharge, and stream flow. Basically, *watershed water balance* is an accounting tool to keep track of the hydrologic cycle of a watershed over time. When the watershed water balance concept is used in conjunction with probability analysis one can evaluate the hydrologic, economic, and ecological feasibility of past, present, and potential activities on a watershed.

Watershed water balance is best illustrated as an equation. The *water balance equation* is the single most recognized equation in hydrology. A basic water balance equation for a watershed follows:

$$P = ET + SF + GWD \pm SMC \pm GWS$$

P = Precipitation (gain)

ET = Evapotranspiration (loss)
SF = Stream flow (loss)
GWD = Ground water discharge (loss)
SMC = Soil moisture content (gain or loss)
GWS = Ground water storage (gain or loss)

The difficulty lies in the *accuracy* and the *precision* at which we can measure and or predict the components of the equation. Accuracy refers to how close a measurement or estimate is to the "true" value. Precision refers to how exact or fine our measuring device might be (i.e., inches versus feet). Always keep in mind that one can precisely measure. Unfortunately, hydrology is plagued by precisely, yet inaccurately measured components.