1993

G93-1128 Understanding Groundwater

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G93-1128-A

NebGuide
Published by Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln

Understanding Groundwater

This NebGuide provides information on how groundwater exists, where it exists, and how it moves. Key definitions are highlighted.

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Water is the life blood of every living creature on earth. Approximately 70 percent of the earth's surface is covered with water. Through the wonders of nature, water can take on many different forms, from the water we drink, to the ice we use to chill a glass of lemonade, to the water vapor used to steam clean equipment. It is easy to understand the significance water plays in our lives, but it may be much more difficult to understand the water that exists below the earth's surface, called groundwater.

Groundwater provides approximately 85 percent of the water used for human consumption in Nebraska, yet by its very location it tends to be somewhat mysterious. Despite much available information, groundwater's existence, movement, quantity and quality remain a mystery to many.

For example, some individuals think groundwater is stored in a vast underground lake; others believe Nebraska's groundwater comes from the Rocky Mountains -- flowing in underground rivers. These notions are incorrect descriptions of groundwater in Nebraska.

Hydrologic Cycle

The hydrologic cycle describes the constant movement of water above, on and below the earth's surface. Water changes states between liquid, solid and gas during the cycle. Condensation, evaporation and freezing of water occur in the cycle in response to the earth's climatic conditions. *Figure 1* presents components of the hydrologic cycle that directly affect Nebraska.

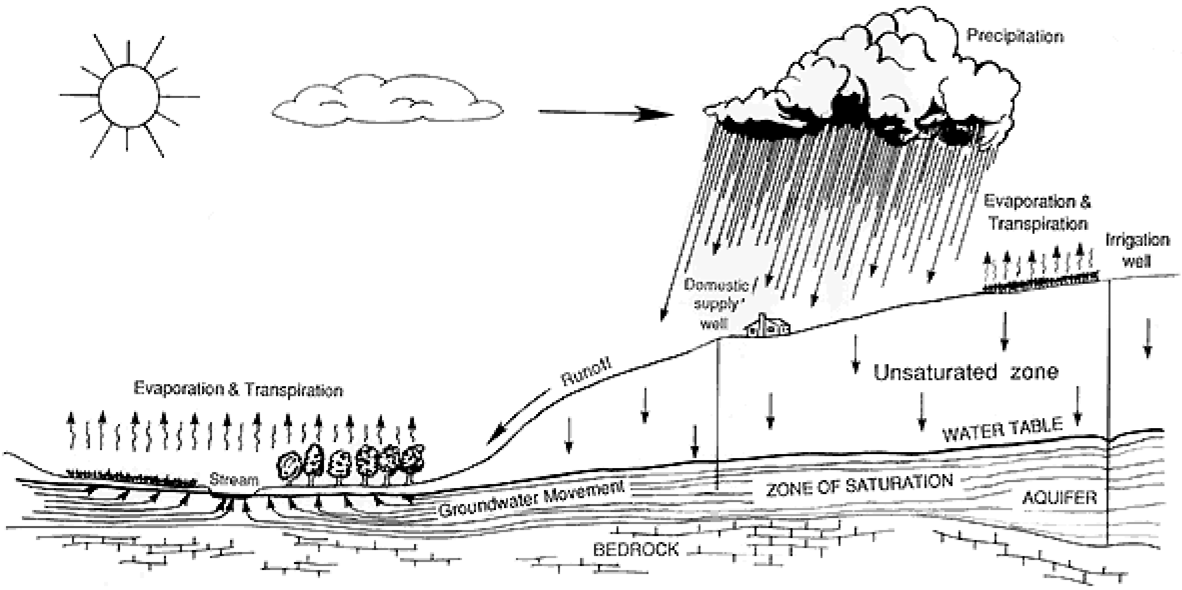

Figure 1. Components of the hydrologic cycle.

The hydrologic cycle begins with water evaporation from the earth's soil, plant and water surfaces to form water vapor. The energy required to evaporate water is supplied by the sun. The vast majority of evaporation occurs from the oceans. It is estimated that 39 inches of water annually evaporate from each acre of ocean (*Water of the World, US Geological Survey*).

Water vapor is drawn into the atmosphere by temperature gradients and can be transported over hundreds of miles by large air masses. When water vapor cools, it condenses to form clouds. As water condenses within clouds, water droplets increase in size until they fall to the earth's surface as precipitation such as rainfall, hail, sleet or snow.

Precipitation amounts vary from east to west across Nebraska. Long term average annual precipitation varies from 14 inches near Scottsbluff in western Nebraska to nearly 35 inches near Falls City in southeast Nebraska. The statewide average annual precipitation is 20 inches.

Approximately 70 to 90 percent of the water that falls to the earth's surface enters the soil (in Nebraska, 17 to 19 inches annually). This water can become groundwater but most of it evaporates from the soil surface or is used by vegetation (12 to 17 inches annually, in Nebraska).

Water that passes through the root zone (in Nebraska, 0.5 to 2 inches annually) may continue to move downward to reach the groundwater. The distance water has to travel to reach groundwater can range from a few feet to hundreds of feet. Water movement toward groundwater may take hours or years, depending on the depth to the aquifer and the characteristics of the unsaturated zone.

Once in the groundwater, water may move into surface waters such as lakes or streams. For example, groundwater flow from springs is a primary source of water for rivers originating in the Sandhills. Groundwater moves slowly within the groundwater aquifer, often remaining in storage for long periods of time.

Typically, 10 to 30 percent of Nebraska's rainfall becomes surface runoff (2 to 6 inches annually, in

Nebraska). This water typically flows into Nebraska streams and rivers. Some surface water evaporates directly into the atmosphere, and some recharges groundwater supplies. Variation in surface runoff is attributed to differences in surface slopes, soils, vegetation, and rainfall intensity and duration. In general, eastern Nebraska produces more runoff than western Nebraska.

Occurrence of Groundwater

Groundwater is stored in the voids, spaces and cracks between particles of soil, sand, gravel, rock or other materials. These materials form what is sometimes called the groundwater aquifer or reservoir. In most areas of the world, and specifically in Nebraska, water does not flow in and is not stored in large underground lakes or rivers.

Nebraska has a vast supply of excellent quality groundwater. The UNL Conservation and Survey Division has estimated Nebraska has 2 billion acre-feet of groundwater in storage, or approximately 25 times the state's average annual precipitation. If all the water stored as groundwater in Nebraska were removed, it would cover the state with approximately 40 feet of water.

More information on Nebraska's groundwater resources is presented in *The Groundwater Atlas of Nebraska*, published by the University of Nebraska Conservation and Survey Division. Additional information may be obtained from your Natural Resources District.

How Groundwater Moves

To understand how we can remove groundwater using wells, we must understand how groundwater moves. Some people attempt to associate the flow of water on the earth's surface with groundwater movement. However, one major difference between groundwater and surface water movement is the average water flow velocity.

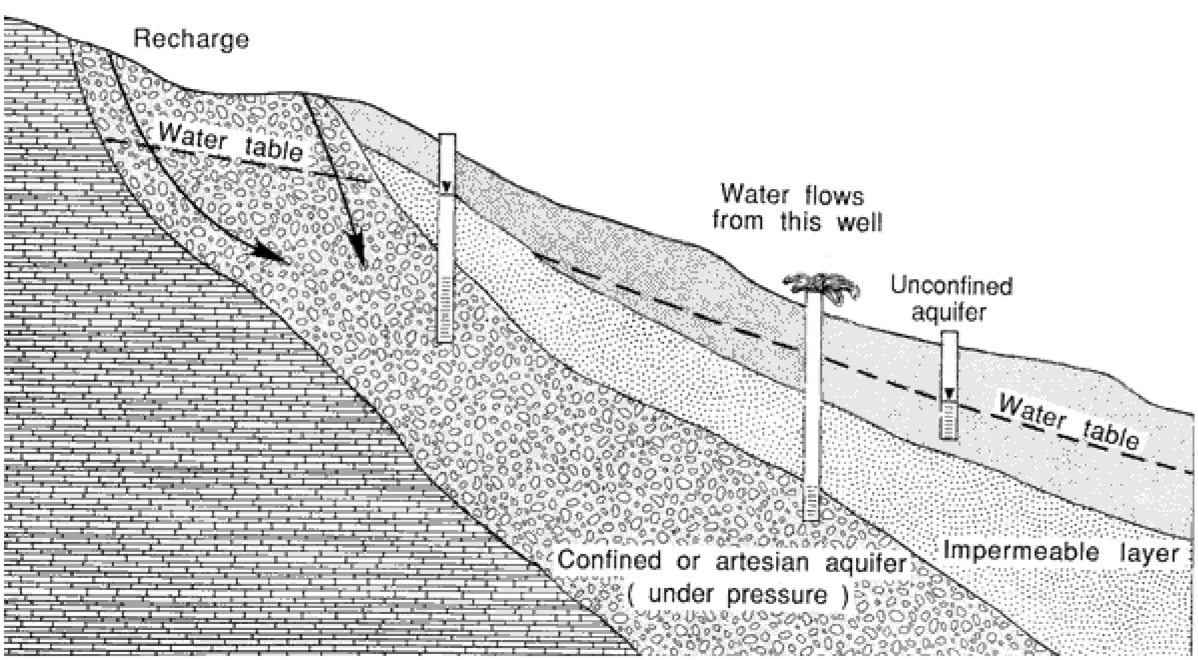

Figure 2. Confined and unconfined aquifers and related water tables.

Surface water flows in rivers or streams at velocities of 2-8 miles per hour. Nebraska's groundwater moves through the spaces between particles of a saturated material at rates between 0.1 foot per day to 3 feet per day. That translates into movement of 35 to 1,100 feet per year.

Groundwater moves only if sufficient pressure, or head, is available to force water through the spaces between porous aquifer materials. Rate of movement is determined by the hydraulic gradient, and how well pores are interconnected. The hydraulic gradient, or slope of the water surface between two points in an aquifer, and the aquifer material determines how rapidly water moves from one location to another.

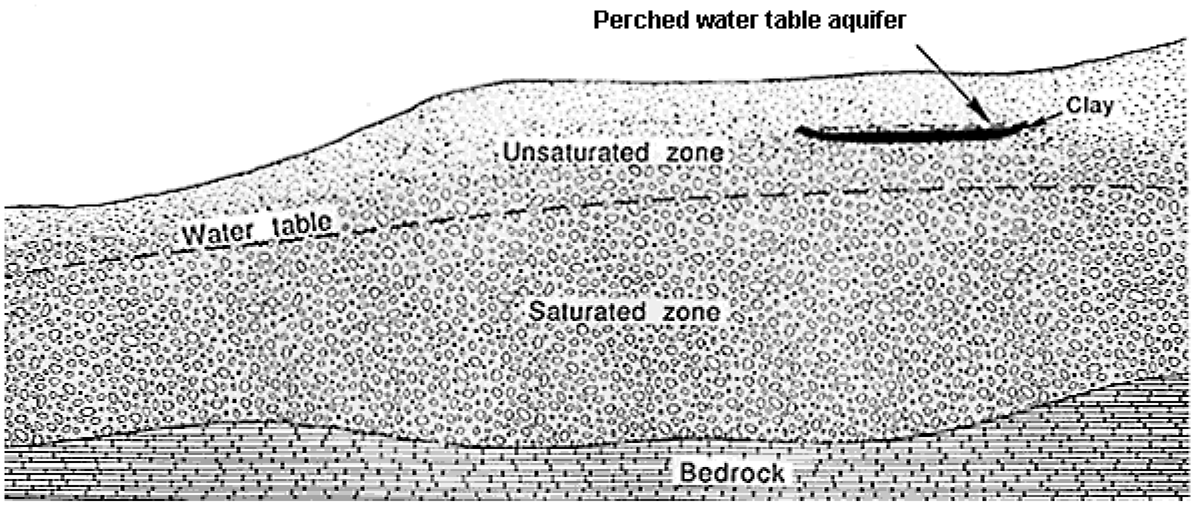

Figure 3. Unconfined and perched water table aquifers.

Groundwater moves from high water surface elevations (high pressure or head) to low water surface elevations (low pressure or head). Water flows more rapidly where large differences exist in water surface elevations (steep hydraulic gradients). Groundwater may move toward or away from streams or lakes, depending on the hydraulic gradient. As groundwater moves it may be removed by a pumping well, or it may be discharged to the earth's surface as a spring, a lake or stream.

Groundwater supplies are recharged by precipitation or from rivers and lakes. Groundwater removed by wells or discharged by springs may have been stored for thousands of years, or may have entered the aquifer quite recently.

How Do Wells Work?

Wells are drilled into a variety of different aquifer formations to supply water for many different uses. Specialized equipment is required to meet the construction standards for drilling a well, installing the well casing and screen, back filling the well hole, and test pumping the well for its intended purpose. Without proper well drilling and construction techniques, the reliability of the well and protection provided to the aquifer may be questionable.

Water is removed from an aquifer using pumps. Pumps use mechanical energy supplied by a drive motor or engine to force water toward the land surface. Removing water lowers the water level in the well. The difference between the initial water level, or static water level, and the pumping water level causes water to move within the aquifer (*Figure 4*). Since the water level always is lowest in the well, water from the surrounding aquifer flows toward the well to replace the water being removed.

When pumping starts in an unconfined aquifer, most of the water is removed from very near the well. With continued pumping, water is removed further from the well, lowering the water level at a greater distance from the well.

Drawdown decreases with the distance from the well until at some distance, the water level remains relatively unaffected by pumping. Drawdown in the well continues to increase slightly with pumping. After many hours of pumping the pumping water level nearly stabilizes. The resulting cone-like shape of the water surface is referred to as a cone of depression (*Figure 4*).

The size and shape of the cone of depression is determined by the aquifer materials and the amount of water being removed from the aquifer. For example, domestic wells generally pump for short periods of time at rates of 5 to 20 gallons per minute. This results in small, poorly defined cones of depression. Even low-yield aquifers often can be developed for domestic uses.

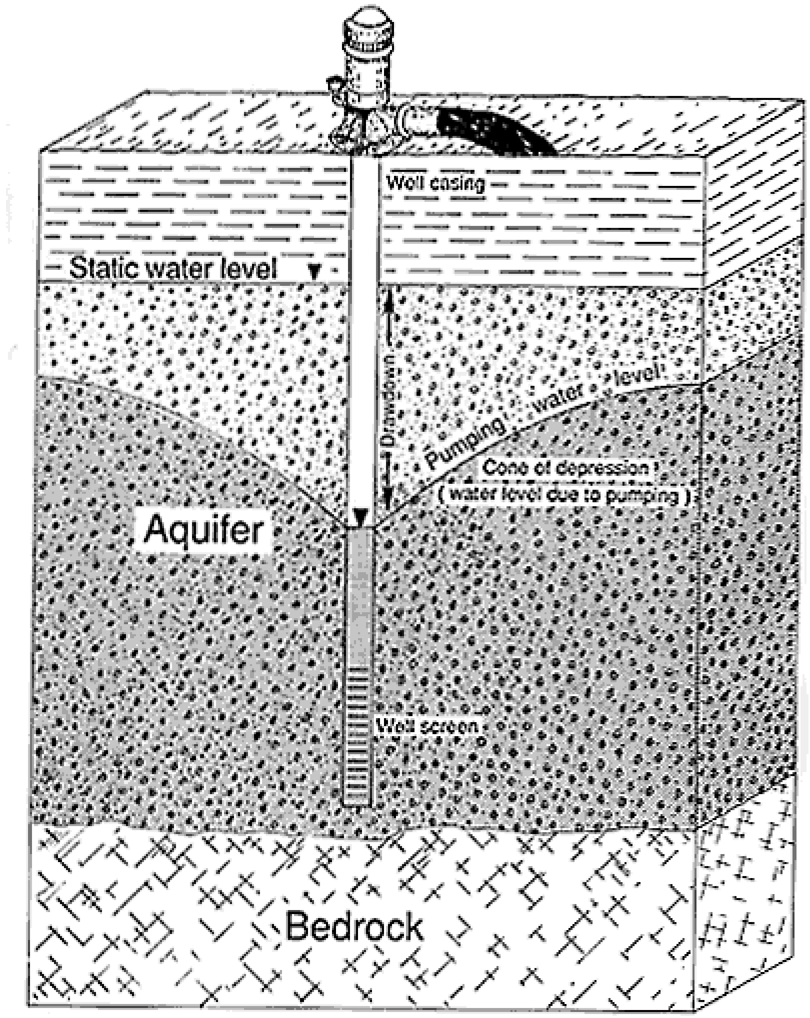

Figure 4. Water level changes associated with groundwater pumping.

Irrigation and municipal wells typically have pumping rates that range from 100 to more than 1,500 gallons per minute, and operate for long periods. Aquifers must yield large volumes of water, and much larger and deeper cones of depression result. In some cases, the cone of depression may extend several hundred feet from the well and be up to 100 feet deep. Where there are many wells, like in the Platte River Valley, cones of depression for adjacent wells can overlap, increasing the depth and size of each well's cone of depression.

Factors Affecting Groundwater Declines

Under natural conditions, a balance existed between the volume of water entering an aquifer and the volume of water being discharged from an aquifer. With the development of water wells, the natural balance between recharge rates and discharge rates was disrupted. The overall groundwater supply has been depleted due to increased discharge.

Groundwater supplies also can be altered due to natural causes. Years of below-normal precipitation can alter the amount of water entering the aquifer. Likewise, seasonal and year-to-year differences in regional stream flow can cause fluctuation in localized groundwater levels.

In Nebraska, the major cause of groundwater level declines is intensive groundwater pumping. Since nearly 90 percent of the groundwater pumped each year is used for irrigation purposes, most declines are attributed to irrigation pumping. In some areas, irrigation pumping has lowered groundwater levels by nearly 30 feet.

The combination of intensive pumping and several years of below-normal precipitation can accelerate the downward trend in water levels. This is true because below normal precipitation often results in decreased groundwater recharge. More important, below normal precipitation generally results in increased groundwater pumping.

Overview of Groundwater Quality

Much effort is being placed on managing Nebraska's groundwater supplies and reducing the potentially negative impact of human activities. Challenges remain if an adequate supply of high quality groundwater is to be available for domestic, municipal, industrial and irrigation purposes.

Natural groundwater quality varies greatly from location to location in Nebraska. Water's natural quality is affected by the materials it must pass through on its way to and within the groundwater reservoir. In some areas, groundwater contains minerals in concentrations high enough to warrant treatment for domestic uses, but generally, Nebraska has excellent quality groundwater.

Some of the naturally occurring minerals found in groundwater are: calcium, magnesium, potassium, iron, sodium, chlorine, sulfate and bicarbonate. The most common pollutant found in excess of U.S. Environmental Protection Agency public water standards is nitrate-nitrogen. Other chemicals occur naturally in localized areas of the state. While these chemicals reduce the quality of the water, health impacts generally are minor.

There are localized areas where human activities have caused water quality degradation. Some are serious enough to prevent the use of the water for human consumption. Industrial solvents, manufacturing chemicals, ammunition wastes, agricultural pesticides, fumigants used at large grain storage facilities and livestock wastes have been detected in groundwater at some Nebraska locations. Detection of pollutants indicates current practices may need modifications to reduce or eliminate groundwater pollution potential.

Nebraska's water quality cannot be covered adequately here. More information is available in the publications *Groundwater Quality Atlas of Nebraska*, available through the UNL Conservation and Survey Division, *Occurrence of pesticides and Nitrate in Nebraska's Ground Water*, available from the UNL Water Center.

For more information on the water quality and quantity in your area, contact one of the many local, state and federal water resources agencies. The following Extension publications also may be helpful:

- G89-907, *Water Testing Laboratories*
- G90-989, *Testing for Bacterial Safety of Drinking Water*
- EC91-735, *The Impact of Nitrogen and Irrigation Management and Vadose Zone Conditions on Ground Water Contamination by Nitrate-Nitrogen*
- EC90-2502, *Perspectives on Nitrates*

Definitions

- **Aquifers** are saturated underground formations that will yield water to a well or spring. The water in an aquifer is called groundwater and the two terms often are used interchangeably. A saturated formation that will not yield water in usable quantities is not considered an aquifer. *Figure 2* shows various types of aquifers discussed here.
- **Cone of depression** is a depression in groundwater levels around a well or group of wells in response to groundwater withdrawal.
- **Confined aquifers,** or artesian aquifers, are saturated formations between low permeability materials that restrict movement of water into or out of the saturated zone. In some areas of the state, confined aquifers supply water for flowing wells (*Figure 2*). When pumping from confined aquifers, water levels often change rapidly over large areas. Water levels generally will recover to normal when pumping ceases.
- **Drawdown** is the difference between the level of water standing in a well under non-pumping and pumping conditions. It is the difference between the static water level and the pumping water level.
- **Groundwater,** sometimes written as "ground water," is water that occupies voids, cracks or other spaces between particles of clay, silt, sand, gravel or rock within the saturated zone of a geologic formation.
- **Groundwater recharge** is water that enters the soil and eventually reaches the saturated zone. In Nebraska, approximately 1 to 10 percent of the annual precipitation received typically reaches the groundwater (0.5 to 2 inches annually). Recharge varies considerably, depending on the total amount of water available (precipitation, lakes, streams, or irrigation), the type and amount of vegetation (grasses, trees, or row crops), the rate at which water enters the soil, and the permeability and depth of the unsaturated zone.
- **Hydraulic conductivity** is a term used to describe the rate (distance traveled per unit of time) water will move through soil or a saturated geologic formation. The rate groundwater travels is controlled by the type of material comprising an aquifer, the porosity of the material, the slope of the water table, and the degree to which existing pores are interconnected.
- **Hydraulic gradient** is the slope of the water surface. The hydraulic gradient indicates which direction groundwater will flow, and how rapidly. Water always will flow from higher water surface elevations to lower water surface elevations (*Figure 1*).
- **Perched water tables** occur when a low permeability material, located above the water table, blocks or intercepts the downward flow of water from the land surface. Water mounds up over the impermeable material creating a water table (*Figure 3*).
- **Permeability** is a property of porous soils indicating how rapidly water will be transmitted through soils toward the groundwater. Sand and gravel have high permeabilities while clay has low permeability.
- **Porosity** refers to the percentage of the formation that consists of open spaces or voids that could contain air or water. Porosity determines the amount of water that can be stored in a saturated zone. For example, a saturated zone 100 feet thick with a porosity of 20 percent could store an equivalent water depth of approximately 20 feet.
- **Pumping water level** is the water level in a well when the pump is operating and water is being removed.
- Saturated zones are the portions of a soil profile or geologic formation where all voids, spaces or cracks are filled with water. No air is present. *Figure 3* locates the saturated zone within a typical geologic formation.
- **Static water level** is the water level in a well located in an unconfined aquifer when the pump is not operating and no water has been discharged from the well for several days.
- **Unconfined aquifers** often are called water table aquifers because they have no layers that restrict water movement into the saturated zone from above. The upper water surface of an unconfined aquifer is called the water table (*Figure 3*).
- **Unsaturated zones** are the soil and geologic materials located between the land surface and the

saturated zone. The voids, spaces or cracks are filled with a combination of air and water. *Figure 3* locates the unsaturated zone within a typical geologic formation.

- **Water table** is the level in the geologic formation below which all voids or cracks are saturated. The water table also can be thought of as the upper surface of the groundwater and top of the saturated zone for an unconfined aquifer.

File G1128 under: WATER RESOURCES MANAGEMENT
A-11, Water Quality
Issued January 1993; 7,000 printed.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Elbert C. Dickey, Director of Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources.