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Artesian (Confined) Aquifers and Effect of Pumping

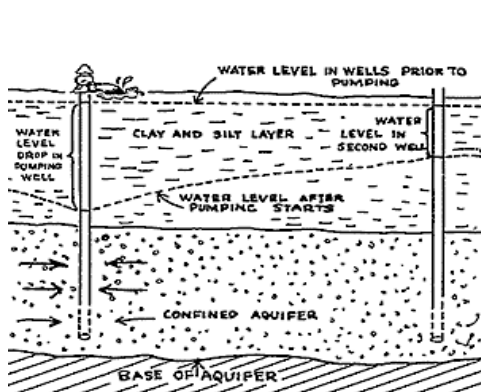
Nebraskans are concerned about declining water levels in some domestic and stock wells.

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Nebraskans are concerned about declining water levels in some domestic and stock wells. Drought and irrigation well development have been major factors. Water level declines have been especially pronounced during the pumping season in places where the aquifer is artesian or confined (a confined aquifer is also referred to as an artesian aquifer). Many domestic and livestock pumps may have to be set deeper in order to yield water. In nearly all cases water levels recover rapidly when the pumping season ends. Large water-level fluctuations are normal in confined aquifers.

What is a Confined Aquifer?



A confined aquifer, in contrast to an unconfined aquifer, is separated from other aquifers and the land surface by a confining layer (*Figure 1*). This confining layer is usually a clay or silt-sized sediment, a tightly cemented rock, or a mixture of sediment sizes such as found in glacial till. The confining layer inhibits the vertical movement of water into or out of the aquifer. The degree to which that water movement is slowed depends on the thickness and composition of the confining layer. A complete range of confining conditions ranging from totally confined to only minimally confined can be found in Nebraska.

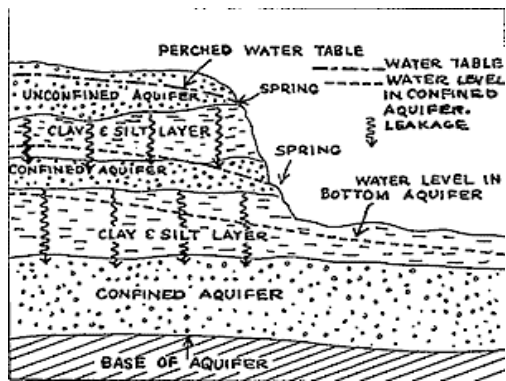
Figure 1.

Confined aquifers are also distinguished from unconfined aquifers, water table aquifers, by a "pressure head." Pressure head is a measure of the elevation to which water levels will rise above the top of the aquifer. If the pressure head is greater than the elevation of the ground surface, the well will flow without pumping. This is sometimes referred to as artesian flow from an artesian well.

Source of Pressure Head

This pressure head is generated in a number of ways. With time the slow downward movement of water through the upper confining layer can cause a pressure head in the aquifer equal to the thickness of the saturated region above the aquifer. With certain shapes of confining layers the pressure head may be caused by adjacent aquifers with higher water tables or higher pressure heads.

Where Does Water Come From When a Confined Aquifer is Pumped?



Water pumped from a confined aquifer moves by three principal processes. These are leakage into the aquifer, expansion of water within the aquifer because of pressure head reduction, and compaction of the aquifer much like squeezing a sponge. The amount of water yielded by each process depends on the degree to which the aquifer is confined and the compressibility of the aquifer. Voids or pore spaces in confined aquifers remain saturated. If they are dewatered the aquifer becomes unconfined (*Figure 2*).

Figure 2.

Leakage

The rate of leakage into the confined aquifer is determined by the composition, thickness, fracturing, and geometry of the confining material. If there is fair hydraulic interconnection with other aquifers, leakage will soon equal water being pumped and additional lowering of the well level will stop. The degree of hydraulic interconnection will vary throughout Nebraska. The original source of leakage is infiltrating precipitation.

Expansion

Pumping lowers the pressure head in an aquifer. Since water in a confined aquifer may be slightly compressed, a reduction of pressure head means the water will expand. This increase in volume then replaces the water that was removed by pumping. It should again be noted that no pore spaces (voids) are dewatered. A large pressure head drop is needed to create significant expansion of water. As a result, the drawdowns in confined aquifers are much greater than in unconfined aquifers. Neighboring wells experience significant drops in water level because this pressure head drop spreads over large areas. (*Figure 1*).

Compaction

A drop in pressure head means less hydraulic pressure is exerted against the confining layer overlying the aquifer. This means more of the weight of the earth above the aquifer must be borne by the solid material of the aquifer. Under these conditions the aquifer itself may compact, leaving less pore space for water storage (much like squeezing a sponge). The degree of compaction would depend on the strength and composition of the materials in the aquifer. Water yield would be determined by the degree to which pore spaces are closed up. The restoration of the aquifer to its original shape with higher pressure heads would depend on how elastic the compacted material was. A rubber ball, which is very elastic, will return to its original form after being squeezed, while a chunk of putty will not. A confined aquifer would be somewhere in between these extremes.

Recharge of Confined Aquifers

Regional precipitation is the source of water recharging confined aquifers. A small portion of this precipitation infiltrates the surface of the ground and is pulled downward by gravity. Downward movement continues until a point called the water table is reached. Below the water table all pore spaces are filled with water. If the surface of this saturated zone is at an elevation greater than the pressure head in a lower confined aquifer, leakage of water into the confined aquifer will continue until the two are in equilibrium. This saturated zone could be an adjacent aquifer, a region in the overlying confining layer, an aquifer above the confined aquifer or a combination of the above.

Recharge could also come from an adjacent confined aquifer with a higher pressure head.

Recognizing Confined Aquifers

Here are a few ways you can identify a confined aquifer. (1) Water levels in wells are higher than the top of the aquifer. (2) Water levels drop rapidly when pumping starts and recover as rapidly when pumping stops. (3) Geologic well logs show confining layers above the aquifer. (4) Water levels in nearby wells drop within a short time after pumping starts.

Note: It is possible to have a number of confined aquifers at different levels. Nearby wells could be completed in a higher or lower aquifer and show no reaction to pumping in a given well.

Confined Aquifers in Nebraska

One of the major confining layers in Nebraska is glacial till. Extensive glacial till deposits are found in the eastern part of Nebraska (*Map 1*). Confining layers of clay and silt are found throughout Nebraska. Some confining layers are found where the bedrock has been tightly cemented, such as in the Ogallala formation. Confining layers may be encountered in many areas of Nebraska.



Map 1. Some known areas of confined aquifer in Nebraska.

Potential Pump Damage Can Be Averted

Pump damage can occur when the water level declines and stays below the pump inlet. Many domestic wells have submersible electric pumps. Some pump motor bearings are water lubricated. When the pump runs without being submerged in water, the bearings are not lubricated and, consequently, get hot and seize. Some pump motors are oil lubricated, but when pump motors are deprived of the cooling effect of the water, they rapidly overheat and are damaged.

Sensing switches are available from suppliers which will turn off the pump when air problems are encountered. These should be installed where practical.

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