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Water Matters

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A guide to integrated water management in Nebraska

Stream Depletion and Groundwater Pumping

Part One: The Groundwater Balance

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> While the information presented in this article is technical in nature, it has been generalized to appeal to a broader audience. This article provides an overview of a very complex topic.

The effect of groundwater pumping on streamflows has emerged as a major water issue and the source of many conflicts in several western states. In Nebraska, some conflicts have gone before the courts, including disputes over the Republican River Compact, the North Platte Decree, and between surface water appropriators and well owners in the Pumpkin Creek Basin, a North Platte River tributary in western Nebraska.

The Nebraska Legislature has passed substantial legislation attempting to resolve some of these conflicts twice in the past 15 years. In 1996, LB 108 encoded the hydrologic connection between aquifers and streams into state law and authorized natural resources districts (NRDs) and the Department of Natural Resources (DNR) to address conflicts. In 2004, LB 962 provided for proactive, integrated management of surface water and groundwater.

Successful management of the state's water resources requires an understanding of how groundwater supplies interact with surface water supplies. This edition of *Water Matters* is intended to provide a basic explanation of the way groundwater pumping can affect surface water, a key component at the heart of integrated management. Future editions will further explore this relationship and the complex effects (including the lag effect) of groundwater use.

Understanding the effects of groundwater use on streamflow

Though the individual relationships are varied and complex, groundwater aquifers in most of Nebraska are hydrologically connected to streams, and the two should be viewed as a single resource. The addition of water to either the aquifer or the stream will result in an overall increase to the hydrologically connected system over time. The removal of water from either the aquifer or the stream will result in a decrease over time (see figure 1).

As a general rule, the amount of water entering a system over the long term must equal the amount leaving the system, including any change in the amount stored in the system. In the shorter term, if inflows exceed outflows, the excess is stored and the water levels in the aquifer rise or the amount of water in the stream increases (or both). If the outflow is greater than the inflow to the system, water levels in the aquifer or stream decrease. If the amount of water entering the system stays relatively constant over the long term, as is typically expected, then any amount being removed (e.g., through groundwater pumping) will cause a reduction in storage or in the amount flowing out of the system.

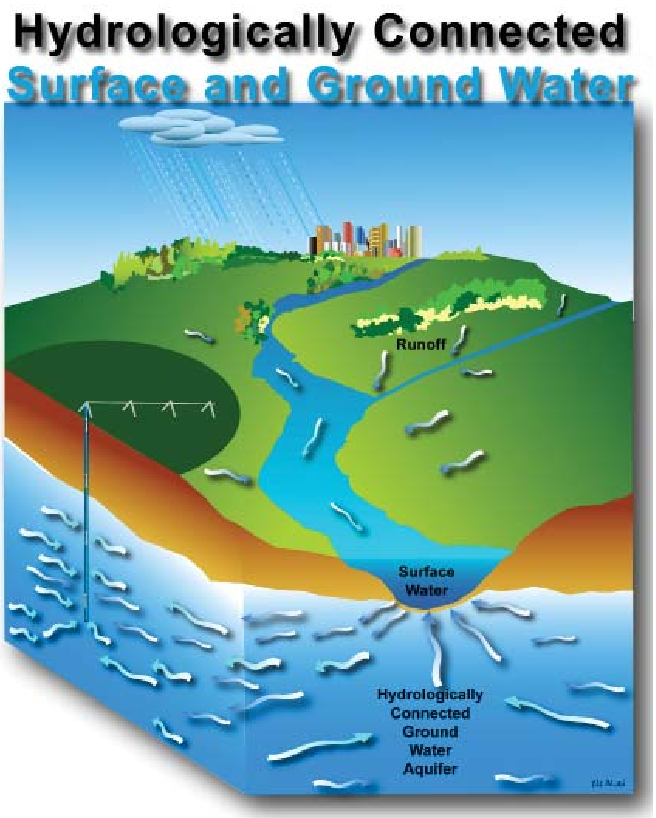

Figure 1: Hydrologically connected surface water and groundwater.

Prior beliefs that groundwater pumping can continue until the amount of groundwater withdrawn by pumping is balanced by the amount recharged to the aquifer by precipitation (also known as "safe yield") are not valid in hydrologically connected systems. This viewpoint assumes that a constant level of precipitation (recharge) will satisfy the groundwater withdrawals but fails to consider the necessity of the recharge to maintain or preserve streamflows.

Groundwater flow and the simple sandbox analogy

Unlike surface water flow, which is readily observed and measured, groundwater flow occurs below the land surface and is difficult to measure. This makes the effects of changes in groundwater flow more abstract and difficult to understand. Groundwater velocities are generally much slower than those of surface water. Groundwater often only moves a few feet per year, compared to typical flow rates of a few feet per second in rivers and streams. This slow movement of water occurs through the pore spaces between the rocks, sands, gravels, and other sub-surface materials. These sub-surface materials that store and transmit groundwater are called aquifers.

A simple way to think of an aquifer is as a sandbox filled with sand. When water is poured into the sandbox (addition of water to the system is called recharge), it fills the empty spaces between the grains of sand, much like groundwater in an aquifer. If there is a hole in the side of the sandbox, water will flow out of it until the water level in the box drops below the elevation of the hole. The hole in this case is like a river, and the flow out of the hole will depend on how full the sandbox is with water (or how quickly the sandbox is recharged with water to replace the water flowing out). In the absence of any other factors, the relationship between the amount of water being poured into the sandbox and the amount flowing through the hole will eventually come into equilibrium (see figure 2).

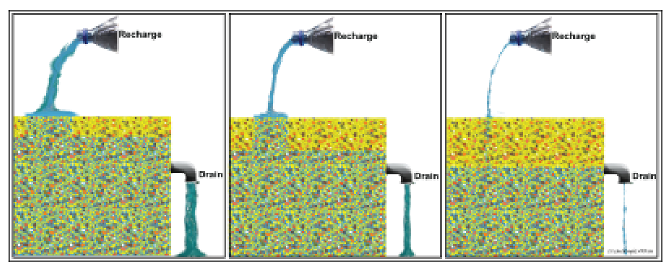

Figure 2: In a system with no additional factors (i.e. pumping), the amount of recharge will be equal to the change in storage plus the flow out the drain (or river)

If you dig a hole in the sand, you may see water fill in the hole (this is like many of the sandpit lakes and borrow pits along the Platte River and in other portions of the state). If you scoop water out of the hole with a cup, water will move into the hole from the surrounding sand. Scooping water out of the hole is like pumping a well. Like a well, it reduces the amount available to go out of the notch unless the amount of water being poured in (recharge) is increased (see figure 3).

Now, think of this type of system on a much larger scale. In a large system, the location of the hole

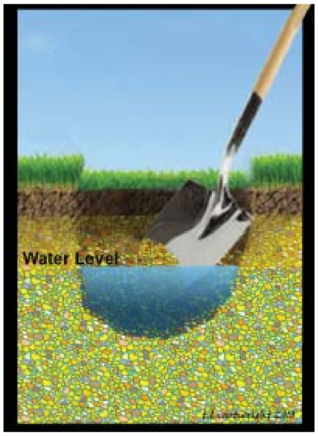

Figure 3: If you dig a hole in the sand, water will fill the hole. Scooping water out of the hole is like using a well. It decreases the amount of water in the system.

you dig in the sand box (i.e., well) to remove water relative to the drain (i.e., river) will affect how quickly flow of water out of the drain is reduced. Of course, increasing the flow into the sandbox (i.e., increased precipitation or recharge) will add water to the system, which may temporarily restore the amount of flow. However, this can't permanently mitigate the effects of the ongoing removal of water (i.e., groundwater pumping) unless the flow into the sandbox (recharge) continues to increase. Also, while the temporary increase in recharge may increase the water level in the aquifer (and consequently increase the amount of water flowing from the drain), it's important to remember that the effects of water withdrawn far away from the drain may not be fully realized at the location at which flow is being measured. Consider the complexity of a system like this as big as the High Plains Aquifer (also known as the Ogallala Aquifer), which covers roughly two-thirds of Nebraska (figure 4).

How does groundwater pumping affect the hydrologically connected system?

In a hydrologically connected surface water/groundwater system, depletions to streamflow due to groundwater pumping can occur either by wells that intercept water that otherwise would have flowed to the stream or by causing water to move from the stream to the well (see figure 5). In Nebraska, the first case is more common, though excessive levels of development and groundwater use can lead to the latter. So, as a typical well is pumped, water is initially removed from aquifer storage and over time this translates into less water reaching the stream. If pumping continues to the point that the water level in the aquifer is lower than the water level of the stream, water would flow from the stream into the aquifer to replenish aquifer storage and supply the well.

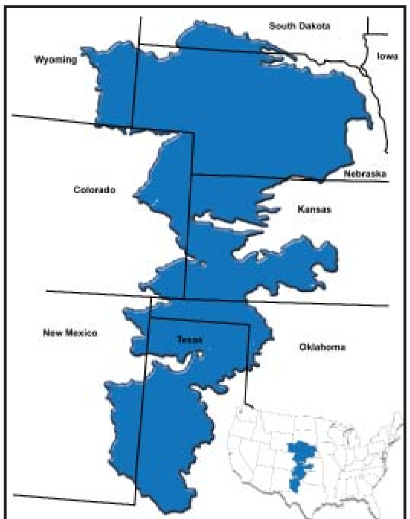

Figure 4: The High Plains Aquifer

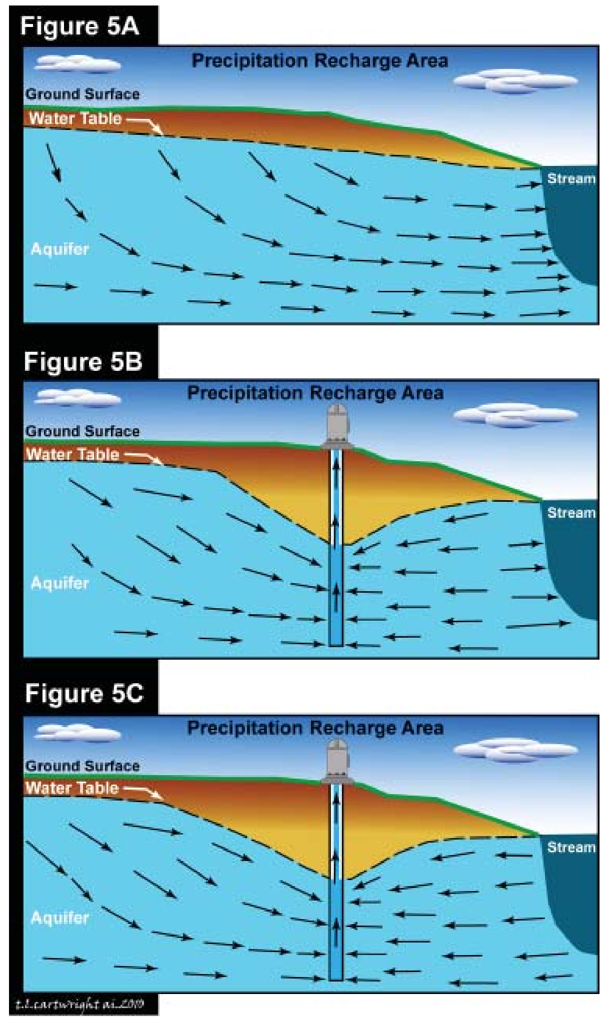

Figure 5: If a well starts removing water from the aquifer (5B), the well will intercept water that otherwise would have flown to the stream. As the well continues to pump, more water is removed from the system and less water reaches the stream. Eventually, if pumping continues, water will flow directly from the stream toward the well (5C).

Groundwater models (analytical and numerical) must be used to understand and predict streamflow depletions. Depletions are determined by calculating the difference between the streamflow that would have occurred if the well was not pumped and the streamflow that occurs when a well is pumped (figure 6). Many factors within a model can change the time it takes for a pumping well to affect water supply, such as the properties of the aquifer, intensity and duration of the pumping, the presence or absence of a clogging layer within the streambed, and distance to the stream. In many areas of Nebraska significant efforts have been and are being made to refine our understanding of these properties, which will help us to further understand the timing aspects of depletions. However, all pumping[1] in the hydrologically connected system must eventually result in a near 100% depletion. In other words, if one acre-foot of water is pumped, there will be one acre-foot less water in the system, even though the effect may not be realized instantaneously. The next issue of *Water Matters* will provide an in-depth discussion of the lag effect of groundwater pumping and other timing-related issues of stream depletions.

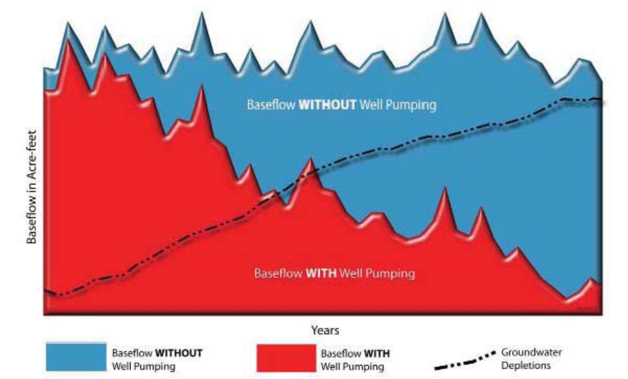

Figure 6: An example of how groundwater pumping may affect streamflow.

When does streamflow depletion become a concern?

There are many factors that may determine how much streamflow depletion due to groundwater use is acceptable in a given area, such as interstate compacts or decrees and the rate of past and predicted future development. For this reason, the definition of effective management can vary greatly by area. Not only are there different restrictions in various areas across the state; stakeholders also have different priorities. Therefore, the type of management utilized must be receptive to changes in circumstances and provide for monitoring of how those circumstances may change through time. That is why the integrated management process (read more about the integrated management process in *Water Matters*, No. 1) is so critical to successful preservation of Nebraska's water resources.

Through the integrated management process, Nebraska must ensure that it is able to meet its interstate obligations. The process should also be used to respond flexibly and responsibly to the area's needs and priorities. Conceptually, and by law, an integrated management plan is always a work in progress for either maintaining a balance of the hydrologic system or regaining a balance. As the affected area changes and more data become available, an IMP must be reassessed, evolving as needed to accommodate changing circumstances, which may include hydrology, economics, water demands, and stakeholder priorities.

[1]Groundwater pumping in this document is intended to represent water that is pumped and consumed. The remainder will either return to the aquifer as recharge, or run off and become streamflow.

This edition of *Water Matters* will be referenced and discussed in the July 2010 DNR newsletter.

NEBRASKA Department of Natural Resources

Please contact the Nebraska Department of Natural Resources with questions or concerns about this publication at 471-2363.

Visit the Integrated Water Management Division's website at http://www.dnr.ne.gov/IWM for up-to-date information. *Water Matters* is available at this website.