February 2014 No. 8

Water Matters

Published by the Nebraska Department of Natural Resources

A guide to integrated water management in Nebraska

Balancing Water Supplies Through Groundwater Recharge

Part One: A Component of the Conjunctive Management Toolbox

Key concept

Hydrologic processes in many areas of the state involve a cycle in which water diverted from streams seeps through the soil into a groundwater storage system called an aquifer. Completion of this cycle involves areas of hydrologic connection where water stored in an aquifer can discharge back into a stream or river. Through integrated water management techniques, this natural process can be enhanced and controlled, making water more readily available for human use with positive streamflow impacts.

Introduction

Since the turn of the century many western states, including Nebraska, have developed substantial surface water reservoir storage capacities to purposely retime streamflows. Retiming of streamflows is done by blocking a portion of a stream's flow, storing it in a reservoir, and then returning it to the stream at a later time. Reservoirs such as Lake McConaughy, Harlan County Reservoir, and Merritt Reservoir represent a few such storage facilities in Nebraska. The retiming of water supplies provided by surface water storage facilities allow for utilization of the water resources for benefits such as irrigation, power production, and recreation.

While the value of using surface water reservoirs is understood by most water users, many are unaware that water can also be purposely stored in underground reservoirs, also known as aquifers. In order to maximize water use and minimize negative impacts on streamflows and groundwater levels, conjunctive management uses the connection between surface water and groundwater aquifers to store water underground, thereby increasing the availability and reliability of the water supply in a region[1]. In other words, conjunctive management optimizes use of the whole water supply. Diverting stream water to allow it to seep into the aquifer during times of excess flow can help mitigate streamflow shortages that occur in subsequent periods. One way that excess flows can be stored in the aquifer is by diverting that water into existing canals and allowing seepage to occur via the canal bottom (figure 1). Under the authorities of an integrated management plan and the Ground Water Management and Protection Act (the Act), conjunctive management projects can be implemented that divert excess streamflows for the purpose of achieving and sustaining a balance between water uses and water supplies. To support the efforts of implementing conjunctive management projects, this edition of *Water Matters* provides a brief examination of the value of purposely storing water underground in order to increase groundwater discharge to streams and help achieve a sustainable water balance.

[1]California Department of Water Resources. (2009). Conjunctive management and groundwater. *California Water Plan Update 2009*, 1-25.

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.

Utilizing Excess Flows

A stream can experience reduced flow in part due to variability in precipitation, reservoir storage, and the effects of beneficial uses of surface water and groundwater. Because of the variability of flow, the supply may not meet the demands at any given time. At other times there may be more than enough water, or excess flow, to satisfy all the beneficial uses on a given stream. It can be advantageous to store and retime excess streamflows for occasions when the water supply is insufficient to meet the demands. Implementing conjunctive management projects to utilize aquifers as extensions of available storage increases the available storage capacity. These projects potentially require less capital investment than a new surface water reservoir while still providing long-term benefits to the future water supply.

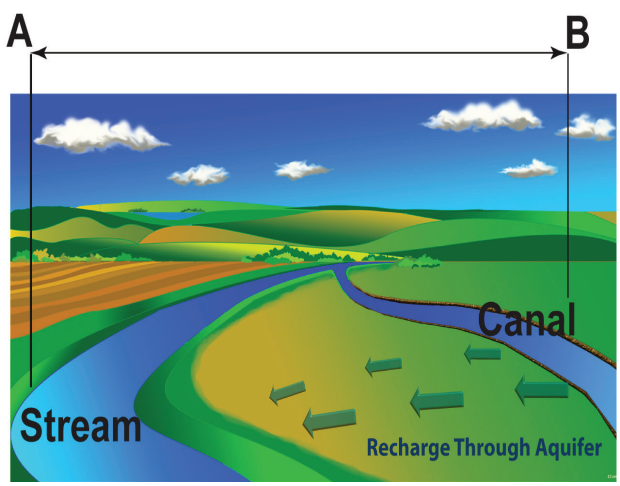

Figure 1: Schematic diagram illustrating the diversion of excess flow from the stream to the canal and the direction of groundwater recharge through the aquifer.

Retiming streamflows can be done using two different approaches: active or passive. The active approach includes mechanical methods such as pipes, tanks, pumps, and reservoirs for moving the water back to the stream. Mechanical methods for moving and storing water can be expensive, often requiring significant investment in infrastructure and continued operation and maintenance costs. Mechanical methods have the advantage of supplying more control over timing and amount of water; operationally, a pump can be utilized at the flip of a switch to supply water. The passive approach, such as the diversion of excess streamflows, minimizes the use of man-made structures and takes advantage of the natural hydrologic properties of near-stream aquifers. The passive approach gives the operator less control over when water is supplied to the stream than the mechanical method, but typically requires less cost.

A single groundwater recharge event continues to influence streamflows over a period of years or decades.

Nebraska is fortunate to have large aquifers adjacent to most of its streams that can be used for conjunctive management, serving as storage reservoirs for excess water and providing a conveyance mechanism for its return to the stream. Purposely storing water in an aquifer can be referred to as groundwater recharge, artificial recharge, or aquifer storage and recovery. These techniques have the potential to increase water storage levels in the aquifer and also increase groundwater discharge, or accretion, to streams.

Several techniques for groundwater recharge have been widely studied and implemented. In many cases, wells are used to inject and store water in a deep aquifer to be recovered later. In other situations, irrigation canals and drains can also be used to direct excess surface water flows into an aquifer. An open, unlined canal that is filled with excess streamflow can seep water into the aquifer below, and through time, that recharged water will gradually flow underground and find its way back to the stream as baseflow (see figure 1 and the cross-section of points A and B shown in figure 2). The concept that unlined canals provide water to groundwater aquifers through recharge has been well understood in Nebraska for over a century.

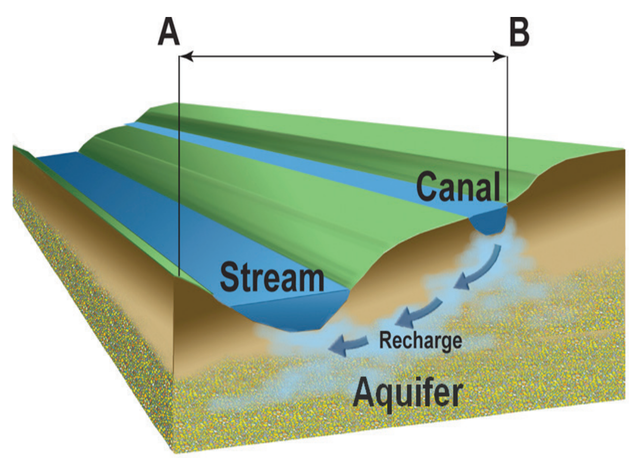

Figure 2: Schematic diagram illustrating the seepage of excess flow from the canal into the groundwater aquifer and subsequent return path of water to the stream.

Quantifying the Benefits

When excess water is diverted from the stream, a portion of it may return as runoff to the stream through surface return ditches, and a portion of it may recharge into the groundwater aquifer to return to the stream at a later point in time as baseflow. The rate at which recharged water returns to the stream as baseflow depends upon how easily the water can move through the soil and rocks of the aquifer and the distance from the canal to the stream. How fast the effects due to recharge occur throughout the aquifer is dependent upon characteristics such as the amount of connected pore space in the soil and the effective thickness of the aquifer. Many mathematical equations have been developed to estimate the quantity and timing of this returning water. One such mathematical function was described by Hunt[2] in 1999. The "Hunt Method" strives to calculate how much water will return to the stream over time, using aquifer characteristics, streambed characteristics, and distance from the stream. For a one-time diversion and recharge event (pulse), the accretion to the stream over time generally looks like the graph shown in figure 3.

Figure 3 illustrates that a single groundwater recharge event continues to influence streamflows over a period of years or decades. As an aquifer's ability to transmit water varies from location to location, and because canals lie at different distances from the stream, the response to the stream for each canal (or different sections of a single canal) will differ. Figure 4 illustrates a range of accretion rates to the stream, calculated for aquifers with varying ability to transmit water and located at varying distances from the stream. For a project with a fast response, most of the estimated accretion occurs rapidly. For moderate or slow responses, the maximum instantaneous accretion rate is lower, but persists at a higher level for much longer. Both figures 3 and 4 show that, for a single event, as water discharges to the stream the amount of accretion reaches a maximum instantaneous value at some point after the event, and then the effect gradually diminishes.

> *It can be advantageous to store and retime excess streamflows for occasions when the water supply is insufficient to meet the demands. Implementing conjunctive management projects to utilize aquifers as extensions of available storage increases the available storage capacity.*

Figures 3 and 4 depict the response of the stream to a single groundwater recharge event, or pulse. Increased benefits to the system can occur if the groundwater recharge events are repeated through time.

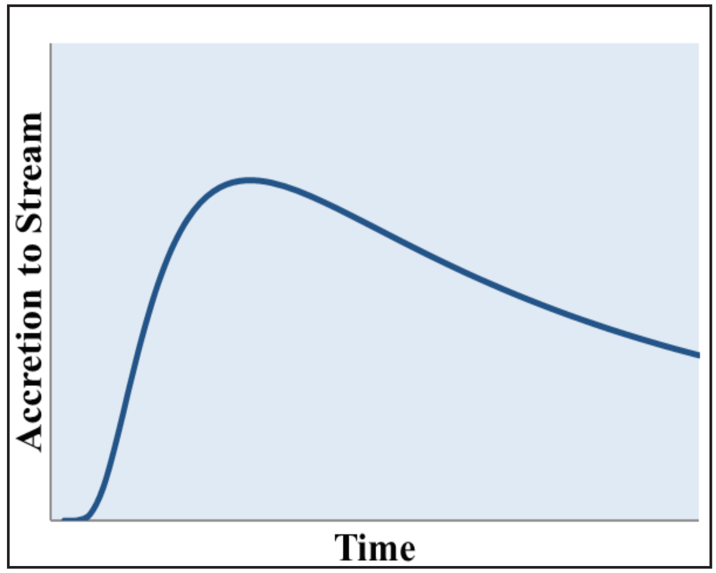

Figure 3: Illustration of typical accretion to streamflow from a single groundwater recharge event.

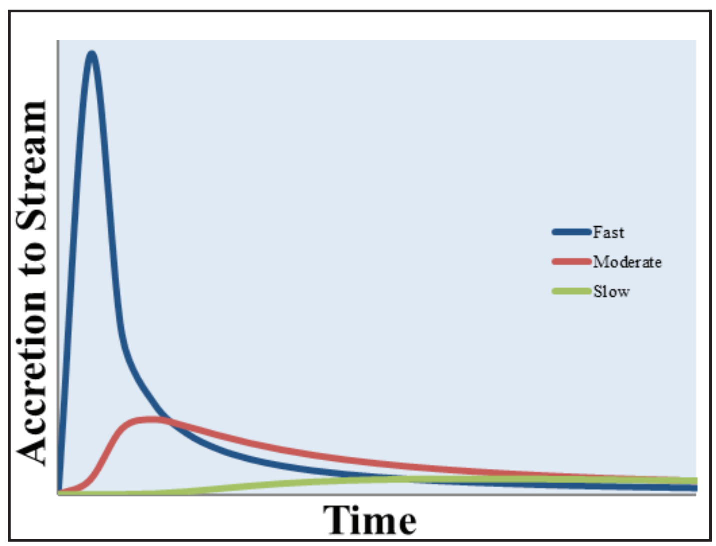

Figure 4: Graph illustrating fast, moderate, and slow response times and accretion rates.

[2]Hunt, B. (1999). Unsteady stream depletion from ground water pumping. *Ground Water*, *37*, 98-102.

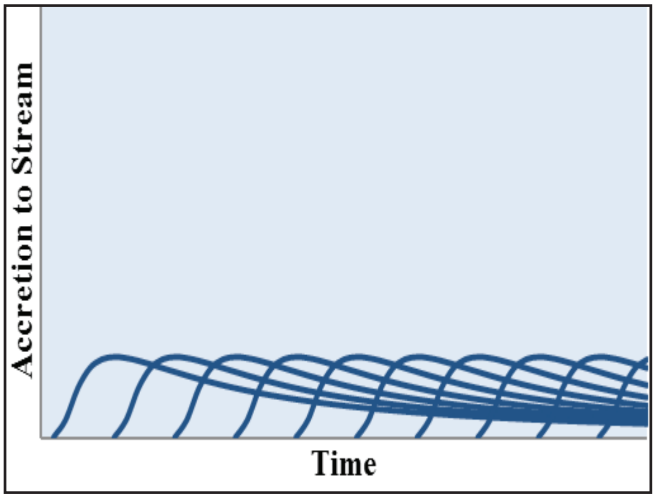

Figure 5: Multiple applications through time: each curve represents a single event, like that shown in figure 3. Calculating each accretion individually and plotting them on a single graph looks like a simple sequence of accretive events.

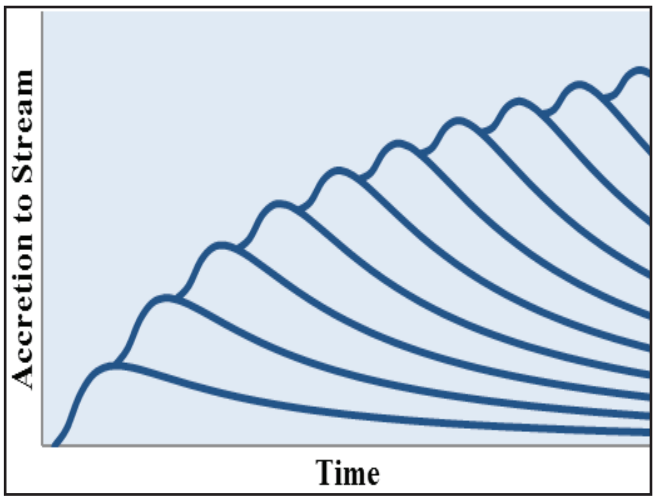

Figure 6: Multiple events accumulate flow: the true benefit of multiple events is not fully realized until the additive effects are shown as here, where each individual event from figure 5 is added to the previous event(s) to demonstrate the additive effect of using numerous opportunities to store excess flow in the aquifers under canals.

The State of Nebraska has the technical and administrative tools available to design, implement, and evaluate the benefits of a groundwater recharge project.

Figures 5 and 6 show how purposeful groundwater recharge events applied over time will create an aggregate, long-term accretion to the stream.

Conclusions

Conjunctive management actions aimed at developing groundwater recharge projects take advantage of excess streamflows and can retime those flows to be available to the stream in the future. If recharge events are implemented on a recurring basis, these projects have the potential to supply significant amounts of water to the stream. The State of Nebraska has the technical and administrative tools available to design, implement, and evaluate the benefits of a groundwater recharge project.

Conjunctive management strategies hold the potential to increase available storage capacity in order to mitigate flooding, protect rivers, and provide long-term benefits to future water supplies. Projects that employ methods of conjunctive management can have many positive outcomes, including minimal capital investment due to the use of existing infrastructure, and little, if any, negative effects. *Water Matters*, No. 9 describes such a project, outlining a groundwater recharge project undertaken cooperatively by the Department of Natural Resources with local natural resources districts and irrigation districts located along the Upper Platte River. Details of the project's implementation and lessons learned from the resulting data verify that conjunctive management of surface and groundwater resources can be a very adaptable and widely beneficial approach.

In *Water Matters*, No. 9, a pilot project is described in which the theoretical concepts outlined above are demonstrated in a real world setting.

Nebraska
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Please contact the Nebraska Department of Natural Resources with questions or concerns about this publication at (402) 471-2363.

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