The Oxbow

FROM THE NORTH DAKOTA STATE WATER COMMISSION

Aquifer Recharge and Recovery

The Forest River Project ARR sites.

Agricultural water, which is primarily used for irrigation, remains the single greatest consumptive water use, by volume, in North Dakota. While irrigation can enhance yields in crop production and allows agriculture in areas that would not receive sufficient precipitation in "normal" years, it can face serious challenges in terms of water availability.

Groundwater supplies are less prone than surface water to extreme variations in quantity from short-term changes in climate, which is why it is often used as a source for irrigation. However, even aquifers are eventually affected by long-term climate trends, where extended droughts can reduce available groundwater.

Aquifer
A deposit of materials such as sand, gravel, etc…, able to yield significant amounts of subsurface water through wells or springs.

Confined Aquifer
An aquifer confined between two impermeable layers.

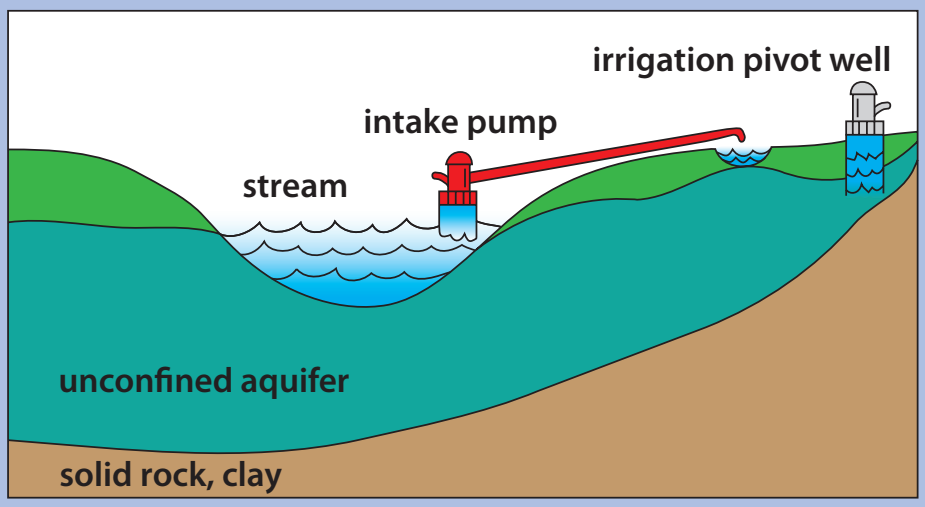
Another challenge to developing new irrigation is that, in many areas of the state, available surface and groundwater supplies are already highly appropriated, making it very challenging to find sufficient water for new or expanded projects.

A technology that has shown potential for mitigating the challenges to existing and available water supplies is Aquifer Recharge and Recovery (ARR).

ARR generally involves the capture of waters from rivers and streams during periods of high flow (often in the spring), and then the storing of that water in an aquifer for later recovery and use. Water is placed in aquifers by surface infiltration through excavated basins. In areas that have soils with low permeability, or where the aquifer is especially deep, injection wells may be used.

Unconfined Aquifer
An aquifer where the upper boundary is the water table.

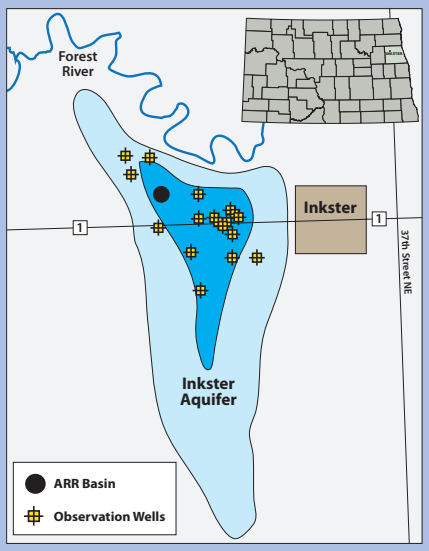
ARR has been used periodically in North Dakota over the past 80 years. In 1932, Valley City was using Sheyenne River water to recharge local groundwater during



high river flows for later municipal use. During the 1950s, Minot used ARR to supplement water in a local aquifer with water pumped from the Mouse [Souris] River. In the late 1980s and 1990s, the U.S. Bureau of Reclamation and the Garrison Conservancy District supplemented groundwater in the Oakes aquifer using spring infiltration of water pumped from the James River. Also in the late 1980s, the North Dakota State Water Commission worked with the U.S. Bureau of Reclamation to conduct studies on a pilot recharge basin, infiltrating water from the James River into the Oakes aquifer in Dickey County. Possible use of ARR to augment groundwater in the Englevale Aquifer (Ransom and Sargent Counties) was also examined in the early 1990s. In recent years, the Bureau considered ARR as part of an integrated plan for stabilizing water supplies in the Red River Valley.

Forest River Project

In 1992, the Forest River Hutterite Community, near Fordville, ND in eastern North Dakota, began the planning, testing, and operation of an ARR basin and well field facility. The project, which is still being operated today, was developed in close consultation with the State Water Commission. Water Commission hydrologists provided assistance to ensure that all of the necessary scientific instrumentation was put into place to measure the effectiveness of the process, to confirm that all of the appropriate Water Commission permits were acquired and that the project would not impact prior water permits, and to ensure that groundwater was adequately protected from contamination. The project examined the feasibility of taking Forest River water during higher spring flows for injection into an aquifer for irrigation when needed.



A map of the Forest River ARR site and observation wells that were used to track the impacts of injection and pumping.

The Forest River Community ARR project, includes two infiltration basins, each about 3.5 acres in area. Topsoil was removed from both basins to two feet below grade, with that removed soil being used to build a berm around the infiltration basins. The excavated topsoil, which was high in the less water-permeable clay, exposed a bed material of fine and medium sand, which is more permeable to water.

This project takes water from the Forest River during high flows in the spring and early summer, flows that would otherwise have been unavailable to beneficial use, for storage in a shallow aquifer. The water is pumped from the river into the two basins, allowing gravity to move that water into an aquifer through infiltration. That aquifer then serves as a water "bank" where the water can be saved from a part of the year when it was not needed, to be used later, when the presence of that water will benefit the crops being grown.

In order to quantify the amount of water that could be reliably withdrawn from the Forest River for aquifer injection, an analysis based upon two climate scenarios, a "dry" and a "wet" cycle was developed by the Water Commission. The dry cycle allowed for 200 acre-feet of aquifer recharge annually, and the wet cycle allowed 600 acre-feet of aquifer recharge annually. For the period of operation of the project, the region has been in an extended wet cycle.

Results

The project has operated for 21 years, and over that relatively long period of time, a much better understanding of ARR has been gained. Between 1992 and the most recently published report in 2009, the following things have been learned.

FACTS

- Approximately 80% of the water injected into the aquifer was recovered for irrigation.
- Approximately 17% of the water injected was lost through various natural processes (evaporation, plant use, seepage from the aquifer to adjacent springs, etc…).
- ARR injection raised the aquifer elevation at the basin sites, creating a "mound" on the water table closer to the surface.
- The ability of water to infiltrate the sand at the bottom of the ARR basins was limited by the buildup of "filter cake," or a layer of sediment and organic materials that plugged the highly permeable sand, lowering the ability of water to pass through the sand.
- After the basins are allowed to dry out, the filter cake can be removed using a grader that removes less than 1" of material.
- Annual use of a scraper to remove filter cake allowed the Forest River Project to operate effectively for the entire 21 years of the project study period, without a rebuild of the infiltration basins. No major renovation of the basin floors have been required at the current rate of surface removal, although it is expected that replacement of bottom sands with nearby materials will be needed at some time in the future.
- No adverse impacts to groundwater quality were detected as a result of the Forest River Project.
- The average long-term estimated cost of recharging the aquifer, including amortized construction costs, maintenance costs and pumping costs was about $100 to $130 per acre-foot. Pumping from the aquifer for irrigation would be additional.
- Water stored in an aquifer via ARR is short-term storage, meaning that water cannot be "banked" for more than a year under local conditions. Losses to evaporation and seepage increase each year.
- ARR will work best in unconfined aquifers with relatively deep (greater than 20') water tables.
- Aquifers with shallow water tables (less than 20') will not work as well due to higher evaporation and plant use and a lack of storage volume in the aquifer.
- An alternative to storing spring water for later use would be to lower the water table through pumping, followed by ARR replacement in the following year.
- Increased crop yields due to ARR at the Forest River Site ranged from 40-60 bushels/acre of corn during "normal" precipitation years, to as many as 100 bushels per acre during dry years.
- Stable sources of irrigation water allowed the Forest River Site to expand into the production of high value, water intensive crops, such as potatoes.

The intake in the Forest River for the ARR.

Future Work

The valuable information gathered by the Water Commission through the Forest River Aquifer Recharge Project sets the stage, and provides a good guide for how to design an ARR system in the future, and in other locations in North Dakota. Research such as this exemplifies the commitment of Water Commitment staff in conducting and supporting investigations promoting the development of water-use technologies to optimize the use of state water resources.

Information on ARR can be downloaded as pdf files from the North Dakota State Water Commission web site, under Reports and Publications/Water Resource Research (WRI No. 47 and WRI No. 48.) Oakes pilot ARR projects are documented in WRI Nos. 5-8. The evaluation of potential ARR use for the Englevale Aquifer is in WRI No. 23, http://swc.nd.gov/4dlink9/4dcgi/GetSubCategoryRecord/Reports%20and%20Publications/Water%20Resource%20Investigations

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