What About the "R" in ASR?

Betsy Woodhouse – Southwest Hydrology, University of Arizona

Southern Nevada Water Authority ASR well

Getting water into the ground is fairly straightforward: water drains down from a basin or goes down a well. But then what happens to it? Will the water really be there when it's needed? Does it matter if the exact same water is there to recover? Was water actually stored? The answers depend on the goals of the project and the local regulatory framework.

When fresh water is stored in saline or brackish aquifers, common in the Southeast, mixing of the waters is undesirable: the goal is to recover essentially the same water that was recharged. When fresh water is stored in fresh-water aquifers, as is typical in the Southwest, recovering the same water is less critical. The goal of such projects may be to reverse water level declines in the aquifer or to store water long-term for future drought or development.

What Storage Means

From a physical standpoint, water must remain in a location that is definable and accessible for recovery in order to be considered "stored." Rising water levels in wells demonstrate that the volume of water stored in an aquifer is increasing. The Vidler Water Company has been recharging about 30,000 acre-feet per year of Central Arizona Project water in its spreading basin facility in western Arizona since 2000; nearly a 200-foot rise in water levels has been observed. The Southern Nevada Water Authority stores water in a highly transmissive confined aquifer that also is used by other entities. It operates on a seasonal cycle, storing water during the wet months when demand is low (and natural recharge also replenishes the aquifer) and pumping it during dry months. Water levels fluctuate 35 to 40 feet between the two seasons, of which 13 to 18 feet are attributed to artificial recharge.

> *Sometimes recovery of an equivalent mass matters more than getting the same molecules back.*

Permeability tests, tracer experiments (primarily using chloride), and flow and transport models have been used to study the behavior of recharged water in an aquifer. In general, recharged water usually stays in a somewhat coherent mass in the subsurface for a period of time after some initial mixing at the entry zone. How much and how quickly the recharged water mixes with native groundwater depends on parameters such as regional groundwater flow velocity and the dispersivity, transmissivity, and heterogeneities of the aquifer.

If water is stored only briefly or the aquifer is not highly transmissive, the recharged water mass will likely maintain its integrity, permitting recovery of most of the stored water. If the water is stored longer, its mass may eventually dissipate throughout the aquifer, but if the aquifer is well-constrained, storage will still be evident through elevated water levels. If the aquifer is very large or highly transmissive, however, physical storage may be measurable only briefly if at all.

Another Kind of Storage

From a regulatory perspective, storage can simply mean credit for recharging a certain quantity of water which provides the storing entity a right to withdraw water in the future. The water need not stay in any particular location, although ideally it should stay within the groundwater basin. In some states or regions, a storing entity receives an equal amount of credits for withdrawal as was recharged. In other cases, a "tax" may be levied. The Arizona Water Banking Authority takes a five percent "cut to the aquifer" for recharge of Central Arizona Project water in recognition that some amount of water is lost in the aquifer. However, that five percent does not have a scientific basis.

Robert Maliva of Schlumberger Water Services points out that socalled “regulatory storage” can cause problems. Where groundwater use of an aquifer is being limited because of local hydrogeologic concerns such as water levels in wetlands or spring flows during dry periods, the additional pumping during recovery from an ASR system could actually make matters worse. If the aquifer is not sufficiently constrained and recharged, water spreads over a very large area and no long-term local rise in aquifer water level or pressure occurs to compensate for subsequent withdrawals.

Getting It Back

When fresh water is recharged into brackish or saline aquifers, an initial “investment” of unrecoverable water is often necessary to, in effect, clean out space in the aquifer. Recovery ceases when water quality deteriorates. When fresh water is recharged into a fresh-water aquifer, recovery of an equivalent mass matters more than getting the same molecules back—and storage may only be of the regulatory kind.

Recovery can take place on a regular cycle, such as during the annual dry season, or it may simply be part of the long-term plan, such as for future development or drought protection. Many long-term projects in the Southwest have no specific recovery plans yet. In an ASR project under development, the City of Phoenix plans to recharge and recover on an annual cycle, but will only recover slightly more than 50 percent of the 1,900 acre-feet per year that will be recharged, with the remainder used to maintain the aquifer for future needs. For the privately-owned Vidler Recharge Facility, recovery will be initiated at an undetermined time in the future dictated by either sale of some or all of the water credits or Vidler’s decision to build a development itself. Project goals also influence placement of the recovery system relative to the recharge facilities (see sidebar).

On Recovery Efficiency

Recovery efficiency is strictly defined as the amount of useable water that is recovered compared to the volume that was recharged, for a single recharge/recovery cycle in a dual-purpose well. This calculation is typically used where fresh water is stored in a brackish-water aquifer for seasonal use; water is recovered until concentrations exceed a drinking water standard, such as for chloride or total dissolved solids. For fresh-water systems having a well-defined aquifer, a quantity-based recovery efficiency can be estimated using a mass-balance approach and changes in water level elevations.

According to Maliva, too much emphasis is placed on achieving high recovery efficiency, with the implication that a project is wasting water otherwise. But if water is being stored that would have been lost, that in itself is a benefit. As an example, the township of Clayton, Australia, is storing fresh water in a saline aquifer. The recovery efficiency of the project is less than 10 percent, but the system is providing much-needed fresh water at lower cost than other options and is viewed as a success. The system stores excess lake water during wet periods that would otherwise not be put to beneficial use. The water that is recovered comprises a critical component of the town’s water supply during dry periods.

Water Is Lost

No large-scale water storage system is loss-proof. Just as reservoirs lose some amount of water to evaporation, artificially recharged water is undoubtedly not entirely recoverable, although one could argue that at least it remains in its liquid form and goes *somewhere*. Loss to fresh-water aquifers generally is not monitored or calculated. It may not be a problem now when more recharge than recovery is occurring, but when storing entities start cashing in their credits, the importance of knowing where that water went will likely increase.

Is Downgradient Recovery Better Than Upgradient Recovery?

Mark Cross – Errol L. Montgomery & Associates Inc.

Placement of recovery wells relative to recharge facilities varies widely in practice due to differences in recharge and recovery objectives, legal and regulatory constraints, hydrogeologic conditions, and other factors. If the intent is to recover the same water that was used for recharge, recovery wells should be located at or down-hydraulic-gradient from the recharge site. However, if the objective of recharge is simply to increase the amount of water in storage, recovering the same water may not be important and recovery wells need not be located at or downgradient from the recharge site.

The physical benefits of recharge include increased water storage and water-level rise, or at least reduced water-level decline. A common misconception is that these benefits are greater downgradient from a recharge site than upgradient. However, both theory and practice indicate that the benefits of increased storage radiate outward in all directions from a recharge site, depending only on aquifer hydraulic properties (transmissivity, storage coefficient). The magnitude of the water-level rise (or reduced water-level decline) diminishes dramatically with distance from the recharge site. The magnitude of water-level rise does *not* depend on the rate or direction of groundwater movement, only on aquifer hydraulic properties and distance from the recharge site. Thus, if recovering the same water is not important, no advantage is gained by locating recovery wells downgradient from the recharge facility.

Contact Mark Cross at mcross@elmontgomery.com.