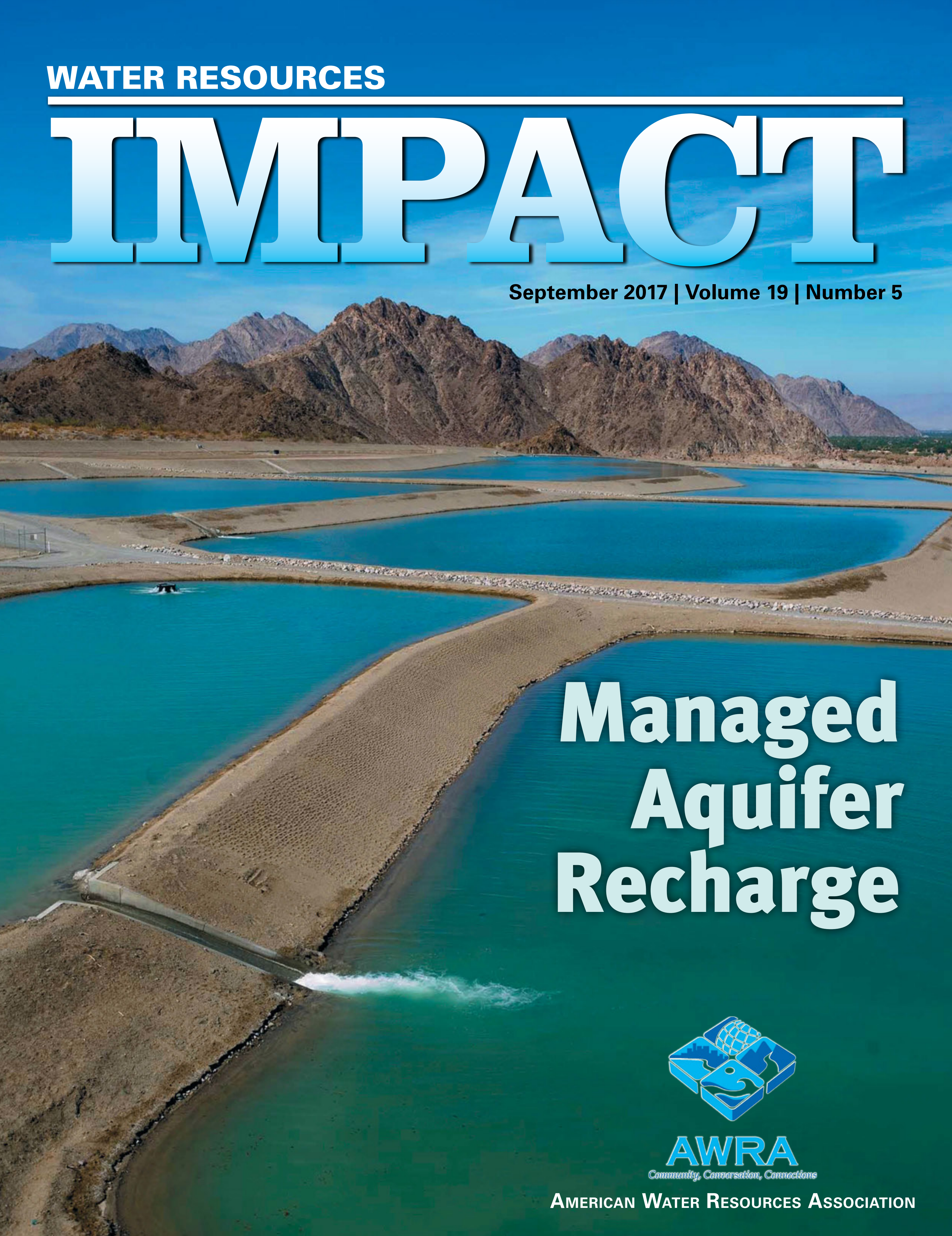
WATER RESOURCES

IMPACT

September 2017 | Volume 19 | Number 5



Managed Aquifer Recharge

AWRA

Community, Conversation, Connections

American Water Resources Association

FEATURE

Domestic Well Aquifer Storage and Recovery Using Seasonal Springs

Julianne Robinson, Todd Jarvis and Desirée Tullos

Rainwater, springwater, everywhere,
It doesn't matter how many wells we sink;
Rainwater, springwater, everywhere,
Nor any drop to drink.

Apologies to Coleridge's poem *The Rime of the Ancient Mariner*, but this stanza sums up the frustration of many a well owner trying to service their dream homes built on the tortured rocks and aquifers comprising the coastal range in Oregon. What's a homeowner to do after investing tens of thousands of dollars on their water well only to have it barely yield a pint a minute, or worse, salt water?

Figure 1: New well.

Figure 2: Natural spring.

To date, aquifer storage and recovery (ASR) projects have been predominantly implemented by large municipalities and industries with high seasonal water demands. However, ASR is also a promising tool for small-scale water management using exempt wells for domestic water use. For example, ASR has recently been successfully implemented as a subsurface storage technique for a small water utility district in Warren, Oregon (see Mansfield's article elsewhere in this issue). Researchers (Händel et al. 2016) have shown that small-diameter wells can be a cost-effective approach for managed aquifer recharge, and a pilot study conducted outside of Eugene, Oregon, demonstrated the applicability of ASR using low-yield exempt (domestic) wells and rainwater recharge (Embleton 2012).

Similar to the application of ASR with exempt wells and rainwater (Embleton 2012), spring-sourced ASR has the potential to be used by domestic well owners to provide a year-round supply of water where water sources are seasonal. In areas where the subsurface geology hinders well productivity, spring-sourced ASR poses a unique solution to seasonal water supply shortages. However, regulations surrounding the underground injection and storage of water were formulated in the context of large-scale projects, which can make the development process less accessible to private well owners. As a result, the feasibility of domestic-scale spring-sourced ASR is a result of both local geological conditions and regulations. In this article, we aim to outline a strategy for evaluating the feasibility of spring-sourced domestic-scale ASR, using a case study from Toledo, Oregon.

Why ASR?

In many places, artificial recharge is necessary because groundwater is being consumed faster than it is being replaced. Surface water is often already fully allocated, or insufficient to meet the demands of a growing population. ASR provides local control over the timing of water use, which is important in areas that have historically relied on a diminishing winter snowpack for surface water supply in the summer.

In locations characterized by marine sediments and fractured shale, such as the Oregon Coast Range, aquifers typically have a low permeability and are hydraulically compartmentalized, leading to low-yield wells and unhappy well owners. Opportunely, seasonal springs are abundant in the area and already serve as a local source of drinking water in the winter and spring. Aquifer storage and recovery could provide the storage necessary to use spring water throughout the entire year.

In this case study, a new well was drilled (see Figure 1) outside of Toledo for the purpose of providing drinking water for a single household. Previously, water was sourced from a natural spring (see Figure 2) on the property, which produces water throughout the winter and spring, but dries up in the summer, making it necessary to purchase and transport water from outside sources. The new well yielded only one pint/minute of flow, which was not enough to sustain household water demands.

In this situation, ASR could be used to store spring water in the well during the winter for use in the summer when the spring water is no longer available. However, key uncertainties were raised regarding the feasibility of implementing ASR at this location, including how quickly water could be injected and removed, how much water could be stored, what permits and regulations would apply, and cost. After formulating a conceptual model of the local hydrogeology, we conducted a series of aquifer tests to assess the technical feasibility of the site for ASR and evaluated the regulatory and economic feasibility for the case study in Oregon.

Feasibility of ASR for domestic well owners

Transmissivity and Storativity

The transmissivity (a measure of how well an aquifer transmits water throughout its entire thickness) of the aquifer is an important factor in consideration of an ASR project because it determines the rate at which water can be injected or recovered from the well. It is established primarily by geological characteristics of an area. In general, aquifers with low transmissivity are not suitable for ASR because the turnover rate (storage and recovery) is limited. Correspondingly, there is an upper limit for acceptable transmissivity because the aquifer must be capable of holding water over time. Previous studies (Woody 2007) have identified the ideal range of transmissivity for implementation of ASR to be between 5,000 and 25,000 square feet per day, based on Brown's site rating system for a large-scale project (Woody 2007). However, we speculate that transmissivities below this range could potentially be feasible for ASR projects with smaller storage and recovery objectives.

Storativity is a measure an aquifer's water storage properties. When the storativity is too low, much of the water injected into a well can spread out laterally and be unrecoverable. Woody (2007) identified an acceptable range of storativity to be between 0.0001 and 0.30.

ASR metric

An ASR metric incorporates aquifer transmissivity to estimate whether the aquifer's capacity to store water is adequate:

$$\text{ASR metric} = \frac{T max\triangle h}{5.6Q}$$

In this equation, T is transmissivity, $max\triangle h$ is the maximum feasible head change in the well, and Q is the well's pumping rate. An ASR metric equal to 1 indicates that the volume of water being injected is equal to the available space in the aquifer, so sites with an ASR metric greater than 1 will likely meet storativity requirements (Woody 2007).

In cases where existing hydrogeologic conditions are inadequate for storage and recovery needs, well owners may turn to artificial stimulation techniques, such as blasting with explosives, to improve well performance. Well design is another consideration. If unsuitable hydrogeologic characteristics are anticipated prior to well construction, the well can be designed to accommodate an ASR system through open borehole completion or highly perforated casings.

Regulations

In Oregon, ASR projects are typically regulated by the Water Resources Department and require a limited license for feasibility assessment under OAR 690-350. Under this process, acquisition of a long-term license and periodic water quality tests are required following the feasibility assessment. However, because this case study involves an exempt well, it is regulated under the Department of Environmental Quality's (DEQ) Underground Injection Control (UIC) program (OAR 340-044). Under the UIC program, the use of "dual-purpose wells" requires an application to the DEQ for authorization by rule (Embleton 2012). Water injected into wells must meet drinking water quality standards. Water rights must also be considered. In this case study, the spring was exempt from a water rights permit because it did not flow off the property where it originated (ORS 537.141). As a result, it could be used for domestic water supply as long as it met quality standards.

Source water quality

Spring-sourced ASR is unique in regards to water quality because the source water is presumably similar in composition to the groundwater in the well, and thus less of a concern than water from an external source. However, once above the ground, spring water is subject to contamination from surrounding elements. Under the UIC rule authorization, this water must be of drinking water quality.

Economics

Beyond regulations and geologic factors, the bottom line for most well owners considering ASR is whether the project is financially feasible. This factor must be considered on a case-by-case basis because of the variability of objectives for well owners. The ability of the system to provide adequate supply to meet demand is the foremost concern. This goes hand-in-hand with the cost and maintenance associated with operating the system. Trade-offs between alternatives should be assessed. For instance, in this case study, it was necessary to weigh the cost of more frequent pump operation against the cost of importing water from an outside source.

The successful implementation of ASR in the Oregon Coast Range could provide well owners with a year-round supply of water, depending upon feasibility, at a very local scale. ■

Julianne Robinson is an undergraduate student in ecological engineering at Oregon State University. As part of her honors thesis, she is conducting a feasibility study on aquifer storage and recovery using a domestic well outside of Toledo, Oregon. She expects to graduate from OSU in June 2018. Contact: robinsju@oregonstate.edu.

Co-authors:

Todd Jarvis, Oregon State University
Todd.Jarvis@oregonstate.edu
Desirée Tullos, Oregon State University
Desiree.Tullos@oregonstate.edu

References

Embleton, David, 2012. Use of Exempt Wells As Natural Underground Storage and Recovery Systems. Journal of Contemporary Water Research & Education, Vol.148(1), pp.44-54. doi: 10.1111/j.1936-704X.2012.03112.x

Händel, F., Liu G., Fank J., Friedl F., Liedl R., Dietrich, P, 2016. Assessment of small-diameter shallow wells for managed aquifer recharge at a site in southern Styria, Austria. Hydrogeol J (2016) 24: 2079. doi:10.1007/s10040-016-1442-7

Woody, Jennifer L., 2007. A preliminary assessment of hydrogeologic suitability for Aquifer Storage and Recovery (ASR) in Oregon. OSU Libraries Scholars Archive.