



Fact Sheet 19-10

### Managed Aquifer Recharge in Snow-Fed River Basins: What, Why and How?

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#### Water for the Seasons is a

collaborative modeling research program that partners researchers with water managers representing the diverse water-use communities in the Truckee-Carson River System in California and Nevada. Through systematic and iterative engagement, key water managers and researchers work together to assess climate resiliency and examine local strategies to adapt to climate-induced water supply variability. Fact sheets generated as part of this research program are intended to educate readers about ongoing research activities and share findings from interactions among researchers and local water managers. The intent is not to provide recommendations for water

management, but rather generate science information useful to managers' climate adaptation planning. This fiveyear (2014-2019) research program is funded by the National Science Foundation (#1360506) and the U.S. Department of Agriculture (#2014-67003-22105) through the Water Sustainability and Climate program.

## What does climate change mean for snow-fed river basins?

Climate change poses unique challenges in snow-fed river basins across the western United States because the majority of water supply originates as snow (Dettinger, Udall, & Georgakakos, 2015). In the Sierra Nevada, recent observations include changes in snow accumulation and snowmelt, and shifts in peak streamflow timing (Barnhart et al., 2016; Hatchett et al., 2017; Kim & Jain, 2010; McCabe, Wolock, & Valentin, 2018; Mote, Li, Lettenmaier, Xiao, & Engel, 2018). Such changes upstream alter surface water deliveries downstream, as well as groundwater recharge utilized as both primary and supplemental water supply (Godsey et al., 2014; Harpold, 2016; Jasechko et al., 2014).

The Carson River Basin typifies such a basin where snowmelt runoff produces substantial water supply to meet diverse

Carson Valley, a rich agricultural region (40,000 acres) that grows primarily alfalfa hay. The majority of irrigators rely on surface water delivered through a network of earthen ditches constructed in the mid-19th and early 20th centuries. Flow through these earthen networks and the practice of flood irrigation contribute significantly to groundwater recharge.

Because no upstream surface water reservoirs exist, snowpack that accumulates through winter and melts slowly through spring has acted as a "natural" reservoir, providing ample supply through the summer irrigation



Figure 1. The Truckee-Carson River System, including boundaries for the hydrologic models used in the Water for the Seasons research program. Graphic design by Kelley Sterle and Ron Oden.

agricultural, environmental and urban water demand (Figure 1). The East and West Forks join at the confluence of the Carson River near the north end of the season. Some irrigators have permitted access to supplemental groundwater that is useful during periods of drought for augmenting shortfalls in surface water delivery. Groundwater is the primary source of municipal and industrial water supply for surrounding communities (e.g., Carson City, Minden, Gardnerville, Dayton).

Across the basin, water use is highly regulated through federal, tribal, state and local water-sharing agreements based on prior appropriation doctrine (Wilds, 2014). Carson River surface water allocations follow the Alpine Decree, initiated by the United States Department of Interior in 1925 and signed into law in 1980, following 55 years of litigation, to adjudicate surface water rights to individual parties (NDWP, 1999). The Alpine Decree acknowledges return flows to lower river segments, and thus each river segment is distributed autonomously. This means that the most junior water right on an upper segment can be fulfilled before considering the most senior water right on a lower segment. Ultimately, the ruling is at the discretion of the Federal Water Master to satisfy the needs of each water right.

Downstream of Carson Valley, surface water flows are stored in Lahontan Reservoir, the nation's first desert reclamation project (est. 1906), where releases are managed to meet the Newland's Project irrigation water demand and for environmental use on the Stillwater National Wildlife Refuge. Flows from the Carson River are supplemented through diversions from the Truckee River via the Truckee Canal, resulting in a trans-basin water supply system.

#### <sup>1</sup> For further details on this research program, see Extension publication, *Assessing the Climate Resiliency and Adaptive Capacity of the*

# How is the *Water for the Seasons* research program informing snow-fed river basin communities?

In the Truckee-Carson River System, researchers and local water managers are working together to assess climate change impacts to water supply and explore how model simulations can produce useful information to support local climate adaptation. Twelve key water managers represent agricultural, environmental, urban and regulatory water-use communities, and bring to the table diverse input and perspectives on how to adapt to climate change. <sup>1</sup>

Hydrologists use this input to craft scenarios and simulations that meet the information needs of local water managers. Biannual workshops provide an opportunity for information exchange, where researchers and key water managers generate new knowledge of river system function. That is, researchers share results of models that examine the physical potential, and managers validate the on-the-ground potential, further informing the research process.

Coincident to this research program, the region faced a prolonged drought period (2012-2016) with historically low snowpack, followed by a historic wet year (2017) that brought winter and spring flooding as a result of atmospheric river storm events (Sterle et al., 2019). For the Carson River, an important observation made by managers was that peak streamflow that had traditionally coincided with peak irrigation demands, had shifted to earlier in the spring, with summer baseflow also

*Truckee-Carson River System: Results of a Survey of Local Organizations (SP-16-03)* (Singletary, Sterle, & Simpson, 2016).

decreasing (Sterle & Singletary, 2017). Managers shared with researchers concerns over potential future impacts that changing snowpack will have on surface water deliveries and reliance on groundwater, as the region's population and economy continue to grow.

During workshops that occurred over this period, local water managers and researchers discussed ways to evaluate water distribution and use that honors the existing legal framework and accounts for changing snowpack regimes (amount, rain versus snow, timing). In response to managers growing interest, researchers introduced the concept of *managed aquifer recharge* as one potential strategy to adapt and enhance regional water sustainability.

#### What is managed aquifer recharge?

Simply stated, managed aquifer recharge is the intentional recharge of

structures to spread water over agricultural lands, allowing water to naturally infiltrate into the groundwater system (Bouwer, 1999; Niswonger et al., 2017). The latter may occur during the irrigation season by applying excess water, or during the nonirrigation season when evapotranspiration losses are low.

Figure 2 illustrates managed aquifer recharge in a snow-fed river basin, where streamflow generated from snowmelt runoff is diverted to agricultural lands to recharge the aquifer. Such flood irrigation practices, including water delivery through earthen ditch networks, provide incidental but significant aquifer recharge through seepage and deep drainage beneath fields (Niswonger, Allander, & Jeton, 2014).

The effects of managed aquifer recharge can vary depending on the location and intensity of practice. For example, implementing managed aquifer recharge



**Figure 2.** Managed aquifer recharge on agricultural lands in a snow-fed river basin. Graphic design by Kelley Sterle and Ron Oden.

water into the groundwater system (Dillon, 2009). This differs from the incidental recharge that may occur as part of normal irrigation practices. Managed recharge may occur by injection into the aquifer through existing wells, or by using existing conveyance adjacent to/along the river's floodplain has the potential to enhance late-season instream flows due to increased return flows, resulting in greater downstream deliveries as well as improving ecological conditions (Niswonger et al., 2017). Implementing managed aquifer recharge away from the river's floodplain has the potential to enhance groundwater supply which is increasingly relied upon during surface water shortage (Green et al., 2011), by storing water in available aquifer space in the deep aquifer. At the basin scale, managed aquifer recharge may lead to regional groundwater sustainability.

While in theory the process may seem straightforward, in practice several challenges exist. For example, in most snow-fed river basins in the western United States and in the case of the Carson River Basin, surface and groundwater resources are fully appropriated. This includes floodwaters resulting from high water years and rain on snow events. Currently all surface water in Nevada is allocated for beneficial use, resulting in no "excess water." Thus, diverting additional surface flows away from downstream users to irrigate agricultural lands is currently prohibited. In addition, diverting water before the start of the irrigation season (approximately April 1) would require permission from the Federal Water Master. Additional challenges include identifying areas suitable for deep aquifer storage and quantifying longterm benefits at the basin scale

### Is the Carson River Basin a candidate for managed aquifer recharge?

The physical limitations to implementing managed aquifer recharge in the Carson River Basin hinges on three key factors. The first factor relates to the physical connectivity between rivers and streams, and the irrigation delivery network of canals and ditches that divert water to agricultural lands (Niswonger et al., 2017). In the Carson River Basin the mechanisms for getting water to fields is already in place. Thus, intentionally routing high flows that occur in wet years through this system during the nonirrigation season would mimic what occurs naturally during the irrigation season.

The second factor relates to the occurrence of atmospheric river storm events that deliver large amounts of precipitation to the region, much greater than average (Dettinger et al., 2015). With increased frequency and intensity projected under a warmer climate, such events have the potential to produce excess water over short periods of time that could be stored through mechanisms such as managed aquifer recharge (Niswonger et al., 2017).

The third factor relates to the change in snowpack accumulation and shifts in snowmelt timing observed elsewhere in the Sierra Nevada (e.g., Godsey et al., 2014; Mote et al., 2018). Having a mechanism in place to maximize use of earlier snowmelt and shifts in streamflow timing could be advantageous and enhance regional groundwater sustainability.

As part of the Water for the Seasons study, a hypothetical scenario was developed to determine the feasibility of managed aguifer recharge in the Carson River Basin, assuming no legal constraints. During "wet" or aboveaverage water years, irrigators in the Upper Carson Valley would divert high flows and spread water over agricultural lands during the nonirrigation season. Assuming flows are abundant and "early," diversions would begin prior to the growing season, when water would otherwise flow downstream to the Lahontan Reservoir. During "dry" years or drought periods, when surface water

availability is less, irrigators in the Upper Carson Valley could augment surface water shortages with groundwater, allowing available surface water flows to flow downstream. Researchers hypothesize the amount of water has the potential to boost baseflow to support environmental instream flows, for example.

### What concerns have local water managers expressed?

The hypothetical managed aquifer recharge scenario was presented to water managers in a workshop setting. Presentations included an overview of the hydrologic and operations modeling tools used to evaluate managed aguifer recharge by simulating the timing and distribution of water in the upper watershed. Specifically, in the Upper Carson Valley, a hydrologic model (GSFLOW) simulates streamflow driven by snowmelt, and surface and groundwater interactions, while a river basin operations model (MODSIM) allocates water according to the prior appropriation doctrine in the basin (see Figure 1) (Morway, Niswonger, & Triana, 2016; Niswonger et al., 2017). Integrating these two modeling tools advances the evaluation of climate impacts on water availability in agricultural communities and the resulting impacts of alternative management strategies (Morway et al.,  $2016).^{2}$ 

When asked about the viability of managed aquifer recharge, the perspectives of 11 managers varied (Figure 3). Regardless of rating, all managers questioned, "How would this really work?" Several managers questioned whether models could simulate the connectivity between surface and groundwater to accurately quantify changes to instream flow. Others raised concerns that managed aquifer recharge violates the Alpine Decree and Nevada Water Law. Still others requested researchers consider alternatives that could work within the confines of current (2019) water law.



Figure 3. Water managers' responses when asked "How viable is managed aquifer recharge in the Upper Carson Valley?

Managers posed specific questions that should be considered when evaluating the potential for managed aquifer recharge. For example:

- What triggers implementation of managed aquifer recharge? How "high" or "low" must annual flows be to initiate managed aquifer recharge? When in the water year is this determined?
- Where exactly in the Carson Valley is managed aquifer recharge possible? For example, what areas away from

Modeling Water Resources in the Truckee-Carson River System (SP-17-04) (Sterle, Singletary, & Pohll, 2017).

<sup>&</sup>lt;sup>2</sup> For a more detailed description of the models, see Extension publication *Collaboratively* 

the floodplain could ensure longterm storage?

• Can model simulations quantify potential benefits and consequences system-wide? Would this information support decision-making, such as permitting of additional supplemental groundwater rights?

### How are researchers going to address managers' research questions?

Managers' perspectives help to validate the on-the-ground potential of particular strategies and further refine alternative management scenarios. For example, understanding that managers are concerned with oversaturated fields helps researchers to define conditions in the model, such as what defines a wet versus "too" wet type of year and where to focus irrigation for managed aquifer recharge. Incorporating these nuances provides more accurate quantification of the potential benefits and consequences for users across the basin.

Modeling is underway to simulate managed aquifer recharge scenarios and explore basin-wide implications. Researchers and local water managers will convene to collaboratively review results and further assess whether this or other strategies could work under the confines of existing water law. Subsequent fact sheets will present these findings.

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