RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Research Update

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Bottom Line
This research project quantified projected changes in Upper Colorado River Basin groundwater recharge from recent historical (1950–2015) through future (2016–2099) time periods.

Better, Faster, Cheaper
Investigating groundwater recharge under climate change in the Upper Colorado River Basin provides vital information to help manage water in this complex and challenging region.

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Quantifying Projected Changes in Groundwater Recharge in the Upper Colorado River Basin

Groundwater recharge in the Upper Colorado River Basin may hold steady under climate change

Problem

The Colorado River traverses more than 2,200 kilometers from its Rocky Mountain headwaters through seven states and Mexico to discharge into the Gulf of California. The Colorado River and its tributaries are vital to the United States and to Mexico, generating billions of dollars a year in agricultural and economic benefits and providing habitat for a wide range of species.

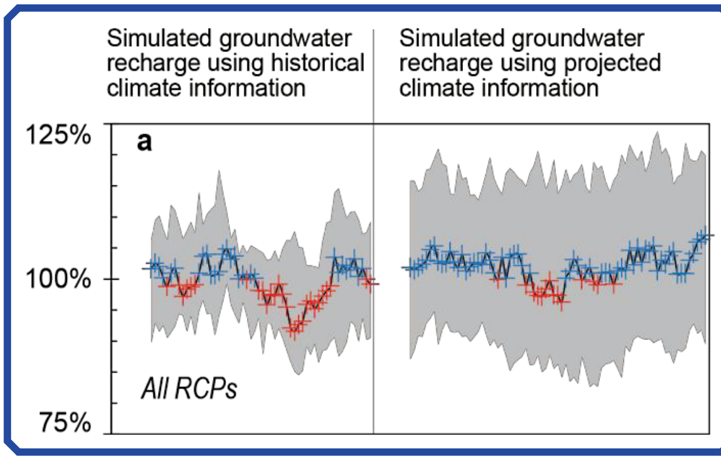
The Upper Colorado River Basin drains an area of 293,721 square kilometers upstream of Lees Ferry, Arizona. Groundwater contributes an estimated 21 to 58 percent (%) of the streamflow to the rivers and streams in the Upper Colorado River Basin, with higher percentages during low-flow conditions.

Understanding groundwater budget components, particularly groundwater recharge, is important to sustainably manage both groundwater and surface water supplies in the Colorado River basin now and in the future. Recently, simulations of future hydrologic conditions using downscaled climate data from one or more general circulation models and multiple emission scenarios have become an important tool for evaluating potential changes in hydrologic systems.

Solution

This Reclamation Science and Technology Program research project quantified projected changes in groundwater recharge from recent historical (1950–2015) through future (2016–2099) time periods in the Upper Colorado River Basin. To simulate recharge in historical and future time periods, the study used a soil-water balance distributed-parameter groundwater recharge model. The soil-water balance groundwater recharge model estimates groundwater recharge by direct infiltration by calculating water balance components at daily time steps for each model cell.

The model used climate data, including daily precipitation, maximum daily temperature, and minimum daily temperature. The model used downscaled climate data from 97 Coupled Model Intercomparison Project Phase 5 (CMIP5) climate projections. Each of these projections were derived from a general circulation model run using a given future emission scenario, known as a representative concentration pathway (RCP).

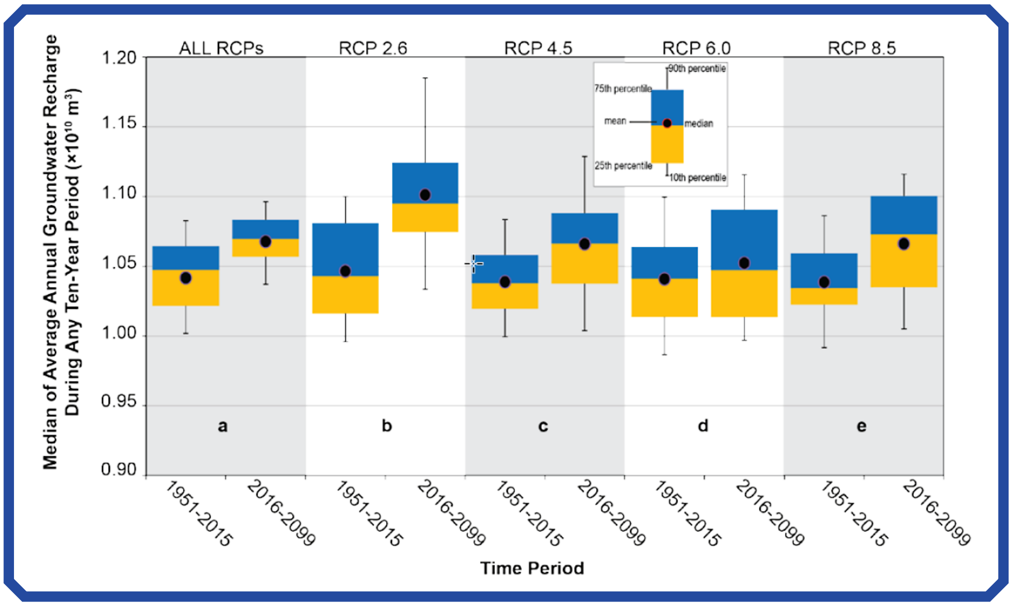


Model results for 10-year moving averages (gray shows the interquartile range of 10-year moving averages, blue shows median of 10-year moving averages greater than the median for the historical climate period, and red shows less than the median).

Application and Results

Given the current understanding of projected climate in the Upper Colorado River Basin and the mechanics of the soil-water balance model, study results indicate that groundwater recharge in future climates may in fact be somewhat greater than what has been experienced in the recent past and is not expected to be less. Median simulated groundwater recharge in future 10-year moving annual averages is projected to be greater than the median of historical averages in 81% of combined RCP simulations, and 88%, 73%, 56%, and 75% of RCP2.6, RCP4.5, RCP6.0, and RCP8.5 simulations, respectively.

Mean daily temperature and precipitation are both projected to increase in the Colorado River basin. Increases in groundwater recharge in the Upper Colorado River Basin are thus a consequence of projected increases in precipitation, offsetting reductions in recharge that would result from projected increased temperatures.



Boxplots showing distribution of median of 10-year moving averages of simulated annual groundwater recharge in the Upper Colorado River Basin from past (1951–2015) and future (2016–2099) time periods. Results presented for combined RCP simulations (a) and for separate RCP simulations (b through e).

Future Plans

This research method and results will help to inform future research activities with Reclamation, the U.S. Geological Survey, and other partners and stakeholders in the Upper Colorado River Basin. Improvements in climate modeling and downscaling techniques could help reduce uncertainty and refine projections for groundwater recharge.

Further investigations of temporal subbasin results would help elucidate the relationship between magnitude and timing of changing climate parameters. For example, increasing temperatures during already dry times of the year would not reduce groundwater recharge further in the soil-water balance model. Location also is important. Increasing temperatures in already dry areas of the basin, coupled with increasing precipitation in areas that are not expected to experience higher temperatures, would result in an overall increase in basin recharge.

Further investigations would help reduce uncertainty stemming from the substantial variability in projected impacts of climate change on groundwater systems and are also recommended. Substantial variability is evident in the 97 CMIP5 climate data projections—mostly in projected precipitation, but also somewhat in projected temperature. This variability in input data is compounded in recharge simulation results.

"These results are the first step in understanding the quantity of groundwater we can expect in the Upper Colorado River Basin; however, further studies are needed to help more accurately forecast future groundwater availability."

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Collaborators

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More Information

www.usbr.gov/research/projects/detail.cfm?id=2005

www.usbr.gov/research/projects/researcher.cfm?id=1962

Tillman, F. D., S. Gangopadhyay, and T. Pruitt. 2016. "Changes in groundwater recharge under projected climate in the upper Colorado River basin." *Geophysical Research Letters*, 43, 6968–6974, doi:10.1002/2016GL069714.

Modeling results are available on the U.S. Geological Survey's ScienceBase-Catalog website at:

http://dx.doi.org/10.5066/F7ST7MX7