



# WaterSMART Bulletin

## Basin Study Program

# Reservoir Operations Pilot Study Salt and Verde River Reservoir System, Arizona

Using Observed and Projected Climate Information to Inform Operational Decisions

### Overview

#### Purpose and Need

Highly variable climate conditions experienced in the Salt-Verde watershed over the past century have made it difficult to assess the long-term reliability of water supplies and infrastructure. In particular, recent droughts, such as those from 1999 to 2004 and 2011 to 2016, have caused water managers at the Salt River Project (SRP) to ask whether their traditional approaches to water management will meet their needs into the future.

#### Location

The Salt-Verde watershed stretches over about 12,500 square miles in central Arizona. These rivers and their systems of reservoirs, operated by the SRP, supply water for multiple uses in the Phoenix metropolitan area (Figure 1). The combined storage capacity of the Salt and Verde River Reservoir System is approximately 2.3 million acre-feet (AF) of water. The SRP supplies about 800,000 AF of water annually and serves more than one million customers with electricity.

#### Study Question

Are current operational strategies for the SRP reservoir system adequate to address future water supply reliability? To what extent does the SRP need to prioritize additional sources of supply outside the reservoir system, make changes to the current reservoir operations, or increase storage capacity within the SRP reservoir system? How can observed and projected climate information be used to understand future changes in climate and hydrology and improve the reservoir system operations?

#### Takeaways

Results from the detailed analysis in this planning study indicate that projected future changes in streamflow are within the range of conditions considered under the SRP's current worst-case scenario planning approach. In other words, the SRP's current operating approach was tested against potential future conditions and found to be robust. This determination allows the SRP to respond to customer inquiries regarding the reliability of water supplies, system design, and capacity.

*Knowing that the system is reliable against a range of future conditions gives SRP confidence that operating the reservoir system under its current procedures will ensure a sustainable water supply for its shareholders.*

Bruce L. Hallin,  
Director of Water Supply

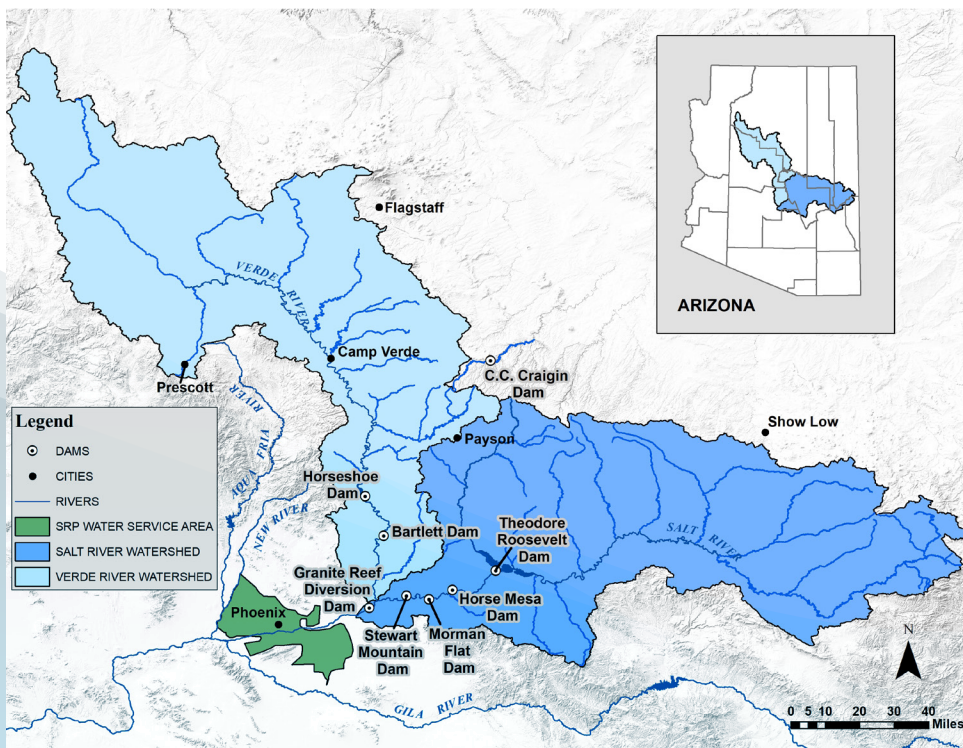


Figure 1. Reservoir Operations Pilot Study Area, Lower Colorado Basin.

## Background

Reservoir Operations Pilot Studies identify approaches to improve reservoir operations in response to variability in water supplies, floods, and droughts.

Reclamation's Lower Colorado Region conducted the Salt and Verde River Reservoir System Reservoir Operations Pilot Study to understand the implications of projected future hydrologic conditions to operations, including whether or not projected flood events exceed the Probable Maximum Flood (PMF).

Most of the water supply for the SRP comes from winter precipitation and snowpack in the headwaters of the Salt-Verde watershed. Precipitation over the region primarily falls within two seasons: the winter precipitation season from December through March, and the monsoon season from July through September (Figure 3).

Just one set of winter storms can produce one-third to one-half of the total inflow from January through May. Also, because large inflows from highly variable winter storms create the greatest high-flow risk at the reservoirs, the SRP currently plans for the worst-case water supply scenarios.

The SRP relies on groundwater supplies to supplement surface water supply when needed, and to meet demands in the part of the SRP service area that cannot be served by existing infrastructure. Historically, minimum annual pumping is about 50,000 AF. The conjunctive management of surface and groundwater resources at the SRP has resulted in a reliable and steady supply of water for its shareholders and customers. However, the variability of inflow into the reservoirs and how future conditions may be different from the past had not been fully explored.

## Using Water Supply Scenarios to Assess Future Risk

This study evaluated the reliability of the SRP reservoir system under different water supply scenarios, including scenarios based on paleohydrology (streamflow reconstructions based on tree rings), future climate, statistical analysis, and scenarios using a combination of these approaches.

The study team employed two approaches to incorporate future climate projections. A period change approach was used to develop future scenarios of seasonal water supply availability, and a transient approach was used to explore potential changes in flood events. The period change approach examined historical conditions with a 3.1°C increase in temperature (roughly the average of climate model projections using both higher and lower future emission scenarios). The transient analysis uses future climate projections more directly and allows us to understand the variability and frequency of future hydrologic events, including extreme conditions like floods and droughts.

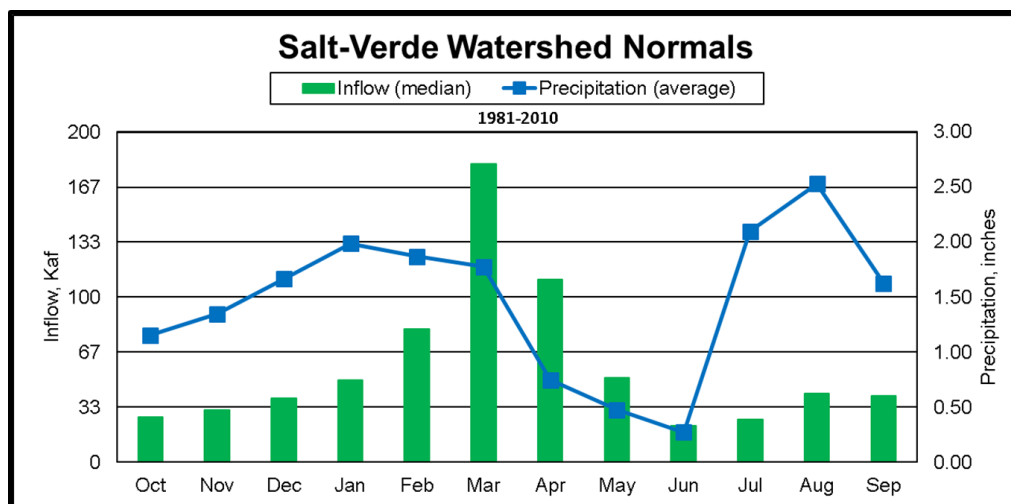
The study team also developed paleohydrology scenarios to evaluate streamflow over the last approximately 650 years.



Figure 2. Theodore Roosevelt Dam, Arizona.

*This study confirmed that SRP can address any future shortfalls through conservation and our existing system design. These findings can inform other water managers of the importance of looking ahead to identify potential changes in hydrology, and incorporating that information into decisions regarding system design and conservation efforts.*

Charles E. Ester III,  
Manager of Surface Water Resources



### WINTER:

Precip. (Dec-Mar): 7.6 in  
Inflow (Jan-May): 534 Kaf

### SUMMER:

Precip. (Jul-Sep): 6.4 in  
Inflow (Jul-Sep): 111 Kaf

Figure 3. Average Precipitation and Median Inflow (1981-2010) in the Salt-Verde Watershed. Notes: in = inches; Kaf = thousand AF.



## Paleohydrology Scenarios

These scenarios are based on statistical relationships between observed annual streamflow and width of tree rings, where years of higher flow indicate more tree growth and wider tree rings. These relationships, when many trees are considered together across a watershed, can be used to estimate streamflow in the distant past.

Paleohydrology can inform water managers about the severity and duration of droughts, for example, going back many hundreds of years before hydrologic records were kept. The severity and duration of droughts over time can provide useful context for determining a worst-case scenario of drought.

To evaluate seasonal water availability under different future scenarios, the study team focused on impacts to Net Basin Supply (NBS), defined as the difference between total inflow and losses for the SRP reservoir system. NBS is a measure that the SRP uses to determine water allocations and groundwater pumping for its users over the irrigation season. If NBS is not sufficient to meet projected water demands, then reductions to allocations or increases in groundwater pumping may be warranted.

NBS was quantified based on scenarios that incorporate paleohydrology, future climate, statistical analysis, and combinations of these. Scenarios of NBS from these methods, coupled with scenarios of water demand, were passed through a reservoir operations simulation model that uses current operating rules to assess the expected response of the reservoir system (e.g., changes in storage, refill frequency, groundwater pumping, and spill). Results from these scenarios demonstrate how the current operating policies might perform in the future.

## Additional Information

### Useful Links

#### Site Specific Pilots

<https://www.usbr.gov/watersmart/pilots/>

#### WaterSMART Website

<https://www.usbr.gov/watersmart>

To evaluate operations in the context of projected future extreme events, the study team modeled daily streamflows from 1950 to 2099. Modeled streamflow was input into a monthly reservoir planning model to evaluate projected future reservoir system storage, spill, and groundwater pumping. The simulations were also used to determine if any projections of precipitation produced floods exceeding the PMF.

### Key Results and Findings

The study team found that, at recent levels of demand (800,000 AF/year to 900,000 AF/year), analysis based on a scenario approach suggested that no specific actions are required at this time in response to projected future changes.

Investigations of future NBS using the period change approach, assumes higher levels of demand (e.g., 900,000 AF/year) along with a 3.1°C temperature increase, show that reduced allocations (i.e., total reservoir storage below 600,000 AF) may be expected in fewer than 10 years over a century, or less than 10% of the time. The warming scenario resulted in a greater percentage of years with reduced allocation due to the sensitivity of NBS to increased temperatures and seasonal precipitation levels. For example, if winter precipitation is much lower than normal in a given year, then NBS is more sensitive to increased temperatures. In order to offset reduced allocations under this future scenario, demands would need to decrease from 900,000 AF/year to 800,000 AF/year.

Results based on the transient analysis, which focused on the most extreme wet and dry future scenarios, indicate that inflows from the wet simulations fell well short of the PMF as illustrated in Table 1. There were greater reservoir

water spills in these wet simulations, however, and more spill would mean less groundwater pumping less overall stress on the SRP system. Additional spill volume does not pose problems to the operation of the SRP system, but may present issues with flooding in the Phoenix Metropolitan Area. Less groundwater pumping in a wetter future may also be more challenging for the downstream users affected by high water tables.

Taken together, the approaches discussed above for evaluating system reliability under statistically generated scenarios, paleohydrology scenarios, future climate scenarios, and combinations thereof, provide confidence to water managers that operations are robust under a broad range of possible conditions.

As a lesson learned, the study team found that historical summer precipitation from the downscaled global climate models does not capture localized summer monsoon rain events common in the Southwest. The team suggests further exploration into modeling localized summer storm events and how they may change in the future.

Horseshoe Reservoir (Verde River)			
	Year	10-day Volume (AF)	Peak Inflow (cfs)
Historical PMF	--	2,410,000	562,000
CESM1-BGC_1_RCP45	2071	943,000	220,000
CSIRO-MK3-6-0_1RCP85	2099	823,000	192,000
MRI-CGCM3_1_RCP85	2071	484,000	113,000
Roosevelt Lake (Salt River + Tonto River)			
	Year	16-day Volume (AF)	Peak Inflow (cfs)
Historical PMF	--	3,020,000 AF	531,000
CESM1-BGC_1_RCP45	2071	2,410,000	531,000
CSIRO-MK3-6-0_1RCP85	2057	1,790,000	394,000
MRI-CGCM3_1_RCP85	2083	1,940,000	427,000

Table 1. Estimated largest flood events for the three wet transient climate simulations

### Study Lead

Marcia Nesby  
Phoenix Area Office  
623-773-6226  
mnesby@usbr.gov

James Walter  
Salt River Project  
602-236-5189  
James.Walter@srpnet.com

### WaterSMART Contact

Avra Morgan  
303-445-2906  
aomorgan@usbr.gov