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WaterSMART BULLETIN

RECLAMATION
Managing Water in the West

BASIN STUDY PROGRAM

RESERVOIR OPERATIONS PILOT STUDY
Washita Basin Project, Oklahoma

Using Paleohydrology from Tree Rings to Inform Long-Term Planning and Reservoir Operations During Drought

OVERVIEW

PURPOSE AND NEED

In 2011, parts of western Oklahoma experienced the most severe drought in the past 100 years ("drought of record") and reservoir levels reached record lows. The drought revealed risks to the system that could be mitigated through new approaches to better understand how long-term variations in climate can affect reservoir yield. In the Washita Reservoir Operations Pilot Study (pilot study), Reclamation used tree-ring data to expand the period for analyzing water availability from the 100-year historical record to a period of over 600 years.

LOCATION

Foss and Fort Cobb Reservoirs, located within the Washita Basin Project in Oklahoma, supply 90 percent of the surface water in the area, providing municipal water for about 40,000 people.

STUDY QUESTION

How much water can a reservoir provide to the cities that depend on it during different critical drought scenarios?

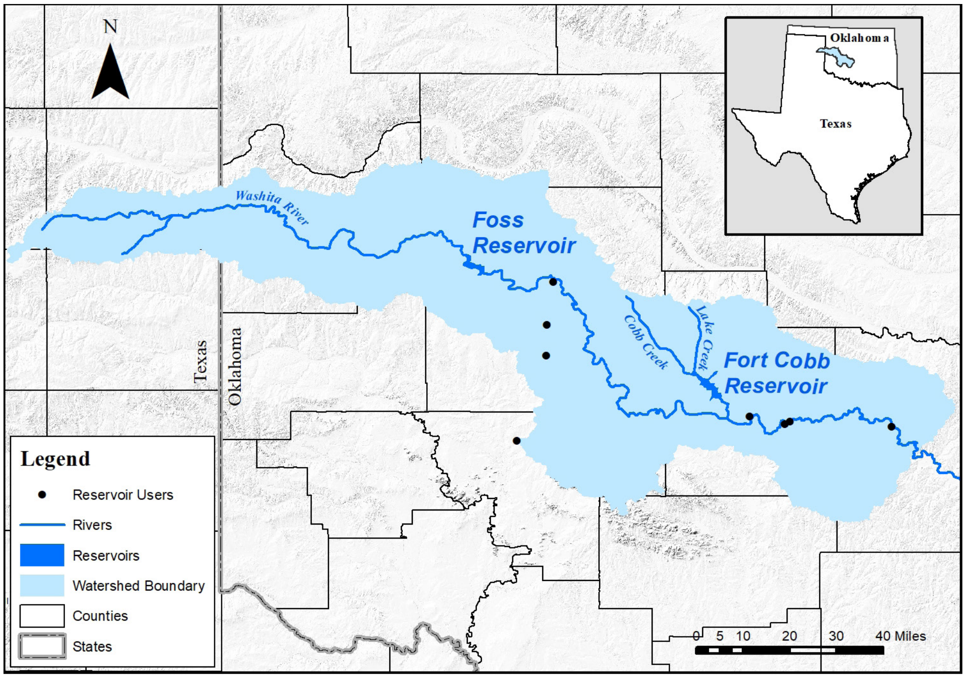

Figure 1. Reservoir Operations Pilot Study Area, Great Plains Region

TAKEAWAYS

This pilot study provides a successful example of the methodology for developing paleohydrology drought scenarios (i.e. estimates of past streamflow) using the Palmer Drought Severity Index (PDSI) and using those scenarios to evaluate firm yield in a reservoir.

The study demonstrated that using paleohydrology scenarios can help water managers reduce the risk of water shortages.

This study also includes details on how this information may be used to inform real-time operational decisions using a broader range of historical data than had been considered before.

Tree ring data is available for most of North America, so these developed methods may be applied in other Reclamation basins

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Figure 2. Foss Reservoir, Great Plains Region

BACKGROUND

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

Reclamation's Great Plains Region conducted the Washita Reservoir Operations Pilot Study to improve management during drought conditions at the Foss and Fort Cobb Reservoirs within the Washita Basin Project in Oklahoma (Figure 1). This reservoir system predominantly serves municipal and industrial (M&I) needs, including needs for domestic and residential purposes—i.e., water for human consumption—public health and sanitation, and commercial and industrial processes. Managing water during times of drought is particularly challenging in the Washita Basin because an interruption in water supply has detrimental impacts on critical water uses, such as public health and sanitation.

Reservoirs in this system depend mostly on rainfall and streamflow for their supply and are, therefore, vulnerable to drought. Droughts vary in intensity, duration, and severity, which means that water managers face different water supply issues from one drought to the next. Given these uncertainties, preparing for drought requires identifying an acceptable level of risk for water shortages.

In managing Foss and Fort Cobb Reservoirs, risk is often quantified in terms of a reservoir's "firm yield," which is the amount of water each reservoir could reliably supply (in this case for M&I uses) during a repeat of the worst drought on record. Operating reservoirs based on firm yield gives managers an assumed level of certainty that a minimum water supply will be available to customers.

However, a disadvantage of the firm yield approach is that record keeping for these reservoirs encompasses only 90 years of historical data on which to base assumptions about future hydrologic conditions, and the drought of record may not be the worst drought that could be experienced in the basin. Indeed, the 2011 drought exceeded the previous drought on record for much of the area.

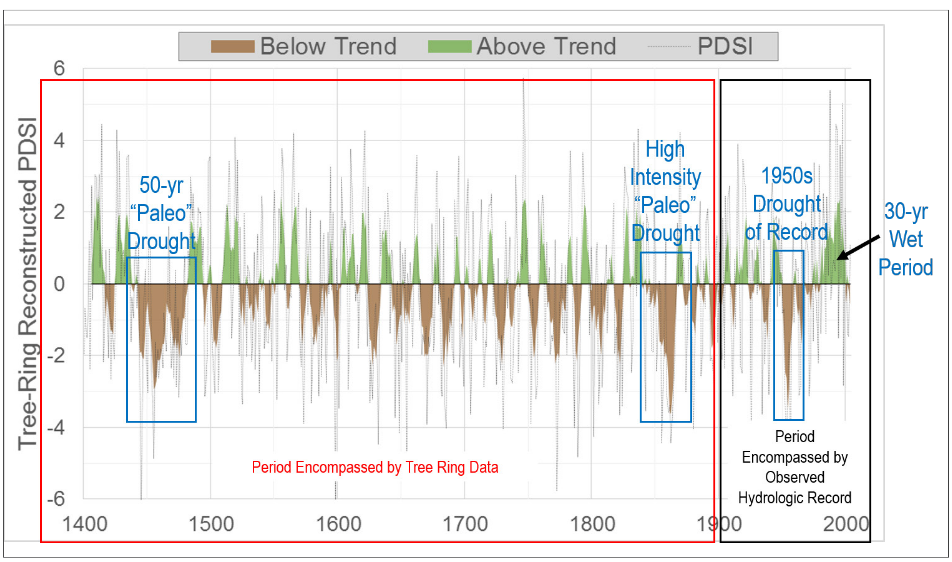

Figure 3. Reconstructed Palmer Drought Severity Index (PDSI) using tree ring data in western Oklahoma from years 1400 through 2000.

> They say that necessity is the mother of all invention. The 2011 drought proved that in western Oklahoma. With this new tool, we can feel more confident that when the next drought comes, we will be better prepared.
>
> Shawn Dewees, *General Manager, Foss Reservoir Master Conservancy District*

USING TOOLS DRIVEN BY PALEOHYDROLOGY

In the Washita Pilot Study, Reclamation used reconstructions of the Palmer Drought Severity Index (PDSI) based on tree rings, to develop reservoir inflow sequences (paleohydrology) that encompass about 600 years of past wet and dry cycles, including "mega droughts" (Figure 3) for Foss and Fort Cobb Reservoirs. Reclamation then generated over 1,000 paleohydrology drought scenarios using statistical resampling approaches and evaluated their impacts on reservoir firm yield. Figure 3 illustrates wet and dry periods over approximately the past 600 years, reconstructed from tree rings. Green regions represent wet periods, and brown regions represent droughts. Figure 3 shows drought periods (where PDSI is less than zero) that exceed the 1950's drought of record for Foss Reservoir in magnitude (High Intensity Paleo Drought) and length (50- year Paleo Drought).

Using paleohydrology drought scenarios, Reclamation also developed a tool that can be used to plan for and respond to drought scenarios in real-time: the Enhanced Drought Response Reservoir Operations (EDRRO) Model. With stakeholder input, Reclamation selected several scenarios of drought to provide benchmarks for real-time delivery of M&I water supplies. With this range of scenarios, the model can be used to quantify the needed percentages of curtailment to avoid emergency drought response.

KEY RESULTS AND FINDINGS

The tools and approaches developed in this pilot study can help inform long-range planning decisions or real-time drought response.

Figure 4 illustrates the firm yield at each reservoir based on the drought of record (black line) and paleohydrology drought scenarios (shaded bar). As expected, the analysis for long-range planning showed that the drought scenarios based on tree-ring reconstructions of the PDSI result in reservoir firm yield much lower than that based on the observed droughts of record. In other words, under a risk management approach, the actual risks of drought were greater than previously understood.

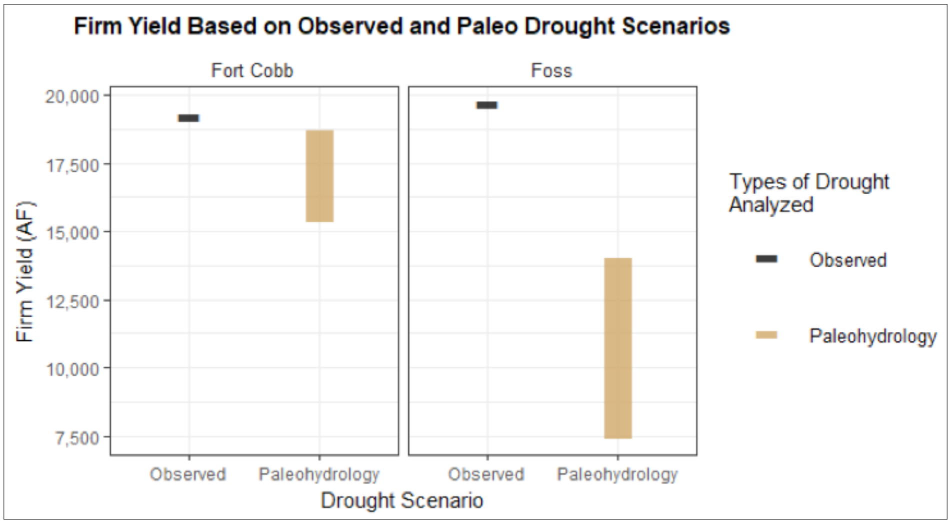

Figure 4. Firm Yield in acre-feet (AF) based on the drought of record (DOR) and the range of droughts under paleohydrology scenarios (based on Table 4 and Table 5 of Pilot Study Final Report).

Using a 600-year paleohydrology record helps develop robust statistics to understand the likelihood of each reservoir going dry under different drought scenarios, along with the demand curtailments necessary to prevent the reservoir from going dry. As shown in Table 1, if maximum demands are placed on Foss Reservoir, they would need to be curtailed by 32 to 66 percent to prevent water shortages. However, the same conditions under observed droughts at Foss Reservoir would not have required any curtailment to prevent shortages— providing a false sense of security.

Similarly, at Fort Cobb Reservoir, maximum demands would need to be curtailed by 34 to 53 percent to prevent water shortages under the most severe paleo droughts modeled, compared to

Percent Curtailment Needed Under Maximum Demand	
Foss Reservoir Selected Drought Scenarios	Percent
Observed 2011-2015 Drought (61st Percentile)	0
Observed 1970s Drought of Record (72nd Percentile)	0
95th Percentile Paleo Droughts (High Intensity/Short Duration)	32
95th Percentile Paleo Droughts (Low Intensity/Long Duration)	33
99.9th Percentile Paleo Droughts (High Intensity/Short Duration)	66
99.9th Percentile Paleo Droughts (Low Intensity/Long Duration)	52
Most Severe Paleo Drought Scenario	65
Fort Cobb Reservoir Selected Drought Scenarios	Percent
Observed 2011-2015 Drought (21st Percentile)	4
Observed 1950s Drought of Record (92nd Percentile)	29
95th Percentile Paleo Droughts (Low Intensity/Long Duration)	34
95th Percentile Paleo Droughts (Low Intensity/Long Duration)	36
99.9th Percentile Paleo Droughts (High Intensity/Short Duration)	52
99.9th Percentile Paleo Droughts (Low Intensity/Long Duration)	48
Most Severe Paleo Drought Scenario	53

Table 1: Percent demand curtailments needed under Maximum Demand scenarios to prevent water shortages at Foss and Fort Cobb Reservoirs under seven drought scenarios simulated using the EDRRO model.

the observed 1950s and 2010s droughts that only required curtailment between 4 and 29 percent. When a wider range of demand curtailments are expected, steps may be taken earlier to identify demand management strategies to prepare for the next drought.

Incorporating paleohydrology information captures more variation in wet and dry cycles (both in severity and length), which results in a range of firm yield values and provides information on risk exposure. Accounting for real-time water demand allows for a more informed calculation of available reservoir storage. This allows for a more robust assessment of risks to the system to better inform near and long-term water management decisions.

ADDITIONAL **INFORMATION**

USEFUL LINKS

Site Specific Pilots
https://www.usbr.gov/watersmart/pilots/

Pilot Study Final Report Press Release
https://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=63583

STUDY LEAD

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