

# Why drought risk is underestimated when demand and long-term variability are ignored

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## Key Messages

- Water demand dominates reservoir drought risk. Supply-only-based drought indices can misstate true system vulnerability.
- Increasing water demand strongly amplifies extreme drought risk. Even modest demand increases substantially worsen drought severity and duration.
- Instrumental records underestimate drought extremes. Multi-century paleo-reconstructed streamflow reveals more severe and persistent droughts than those observed in the historical record.
- System-aware drought indicators can improve drought planning and negotiation. Reservoir-specific metrics provide a clearer basis for operational decisions, demand management, and long-term water security planning.

Builds on: Kim, S.-H., Gangopadhyay, S., McGuire, M., Lall, U., & Devineni, N. (2025). <https://doi.org/10.1029/2025WR040096>

## Policy Context

Reservoirs underpin water security across the western United States. They supply cities and irrigation districts while supporting hydropower production and environmental flows. These systems are under increasing pressure from rising water demand and hydroclimate variability, while opportunities for new storage are limited. Recent multi-year droughts have also intensified this pressure. During droughts, managers must decide when to adjust releases, negotiate shortages, and implement demand reductions. These decisions are typically based on drought indicators established on precipitation or streamflow anomalies and do not reflect system water demand (Fig. 1a). Moreover, limited water demand and hydroclimate records further hinder the ability to capture drought risks experienced by water resources systems. More system-relevant drought risk metrics, together with improved data availability, can improve preparedness, transparency, and long-term adaptation planning.

## Main Results

This study introduces a Normalized Reservoir Drought Index (NRDI) that links water supply and demand, and reservoir storage to assess drought risk at the system level (Fig. 1a). Unlike traditional drought indices, NRDI tracks how cumulative deficits develop over time and how they are buffered (or not) by available storage. Moreover, data-driven method and paleo reconstructed data were applied to fill data gaps (Fig. 1a).

Applied to seven major reservoirs in the western United States, the analysis shows that reservoir drought risk is path-dependent – identical hydroclimatic conditions can produce very different outcomes depending on water demand. The results also demonstrate that drought risk is highly sensitive to demand, especially during extreme events. As demand increases, drought severity and duration rise sharply even when reservoir storage is explicitly accounted for (Fig. 1b).

More importantly, the study shows that instrumental records alone do not capture the full range of plausible drought risk. When multi-century paleo-reconstructed streamflow is integrated into the same framework, more severe and longer-lasting drought events emerge. These events exceed those seen in the historical period, providing a broader and more realistic basis for assessing long-term vulnerability.

## Implications

Current drought policies often rely on indicators that are well-suited for climate monitoring but poorly aligned with reservoir demands and operations. This can lead to inefficient demand management and contentious inter-agency negotiations over releases and shortages.

By explicitly linking water demand, system-aware metrics like NRDI clarify when reservoirs are approaching critical stress. This improves transparency around trade-offs, supports more targeted interventions, and reduces reliance on ad hoc judgment during crises.

The findings also highlight the importance of demand-side policy as a drought adaptation tool. Because extreme drought risk is disproportionately sensitive to demand, policies that manage or reduce demand can meaningfully alter outcomes if risk is assessed using indicators that reflect this sensitivity.

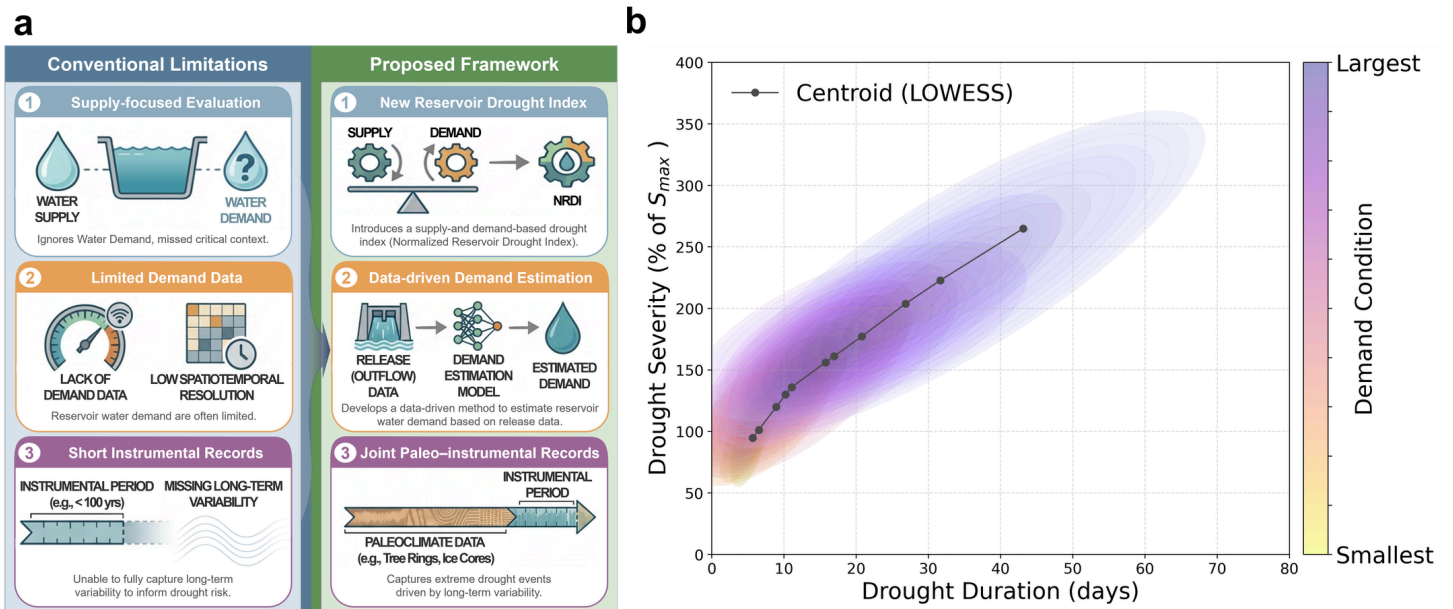
Finally, the results suggest that long-term planning based solely on the instrumental record may underestimate risk. Incorporating paleo-informed drought scenarios can help stress-test infrastructure, operating rules, and contingency plans against conditions outside our lived experience.

## Policy Recommendations

**Adopt reservoir-relevant drought indicators in planning and operations.** Water agencies should complement traditional drought indices with system-aware metrics that include demands & track cumulative deficits relative to storage capacity.

**Explicitly integrate demand into drought risk assessments.** Drought planning frameworks should evaluate how changes in demand affect risk, particularly for extreme events, and use this information to guide demand management policies.

**Use paleo-informed scenarios for long-term drought preparedness.** Infrastructure planning, reservoir operating rule efficacy tests, and drought contingency plans should be evaluated under drought conditions extending beyond the instrumental record.



**Fig. 1. Summary of achievements and key findings of this study.**

**a** Limitations and achievements in reservoir drought management. **b** Changes in extreme drought events at American Falls Reservoir under varying demand conditions. Each colored distribution represents metrics of extreme drought events under different demand conditions, and the LOWESS curve indicates the centroids of the distributions

## References and Further Reading

- Kim, S.-H., Gangopadhyay, S., McGuire, M., Lall, U., & Devineni, N. (2025). The role of water demand and paleo streamflow in advancing reservoir drought risk analysis. *Water Resources Research*, 61, e2025WR040096. <https://doi.org/10.1029/2025WR040096>
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## Competing Interests

The authors declare no competing interests.

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