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# Hydrology and Uncertainty in the Colorado River Basin

Colorado River Symposium  
September 23, 2021

James Prairie, PhD, Upper Colorado Basin Region

# Reclamation announces 2022 operating conditions for Lake Powell and Lake Mead

August 16, 2021



KNAU Arizona Public Radio Lake Mead at 1071.61 feet

Colorado River, Lifeline Of The West, Sees Historic Water Shortage Declaration

August 22, 2021 NPR all things considered

***In a First, U.S. Declares Shortage on Colorado River, Forcing Water Cuts***

*August 16, 2021 New York Times*

**First-ever federal water shortage declaration for the Colorado River**

August 16, 2021 KTNV Las Vegas

**US declares first water shortage on Colorado River amid historic drought; cuts expected for Arizona farmers**

August 16, 2021 USA Today

**Colorado River Water Shortage Forces First-Ever Cutback to Southwest States**

August 16, 2021 The Wall Street Journal

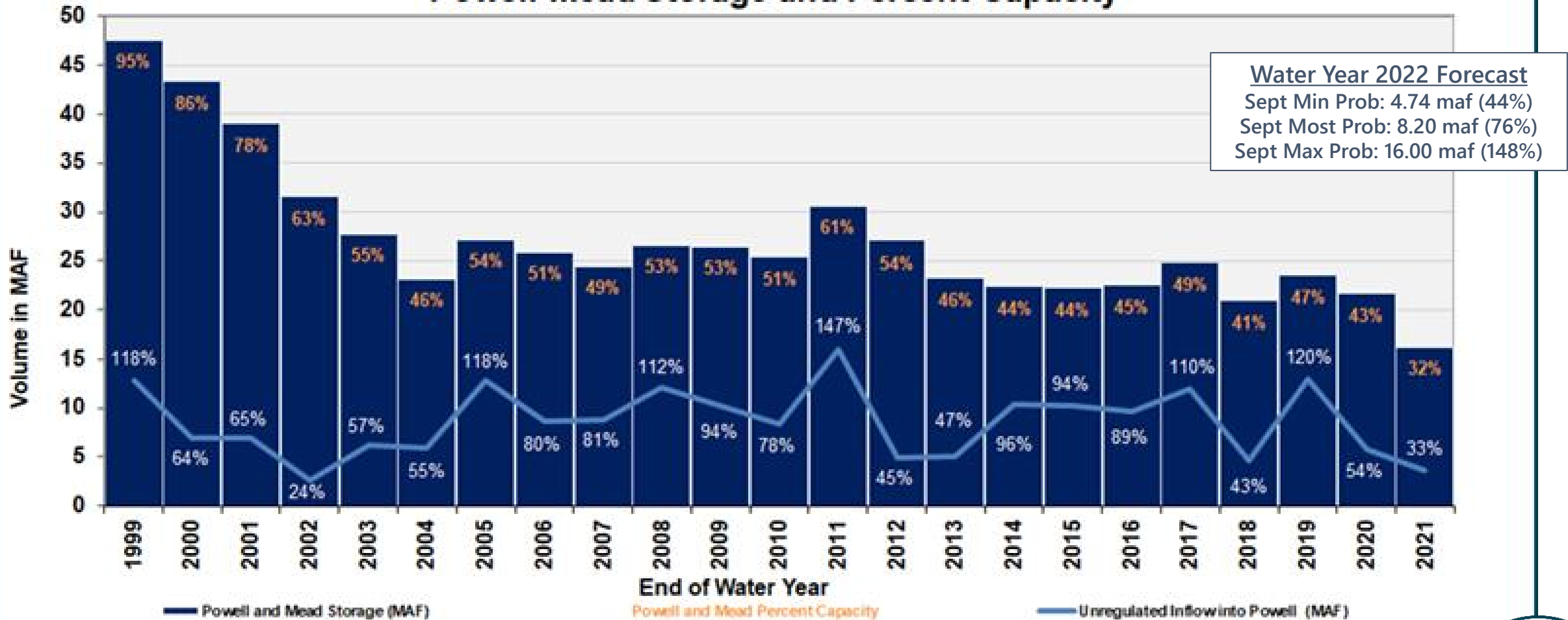
**U.S. declares first-ever water shortage for Colorado river, triggering cuts in Western states**

August 16, 2021 Los Angeles Times



# State of the System (Water Years 1999-2021)<sup>1,2</sup>

## Unregulated Inflow into Lake Powell Powell-Mead Storage and Percent Capacity



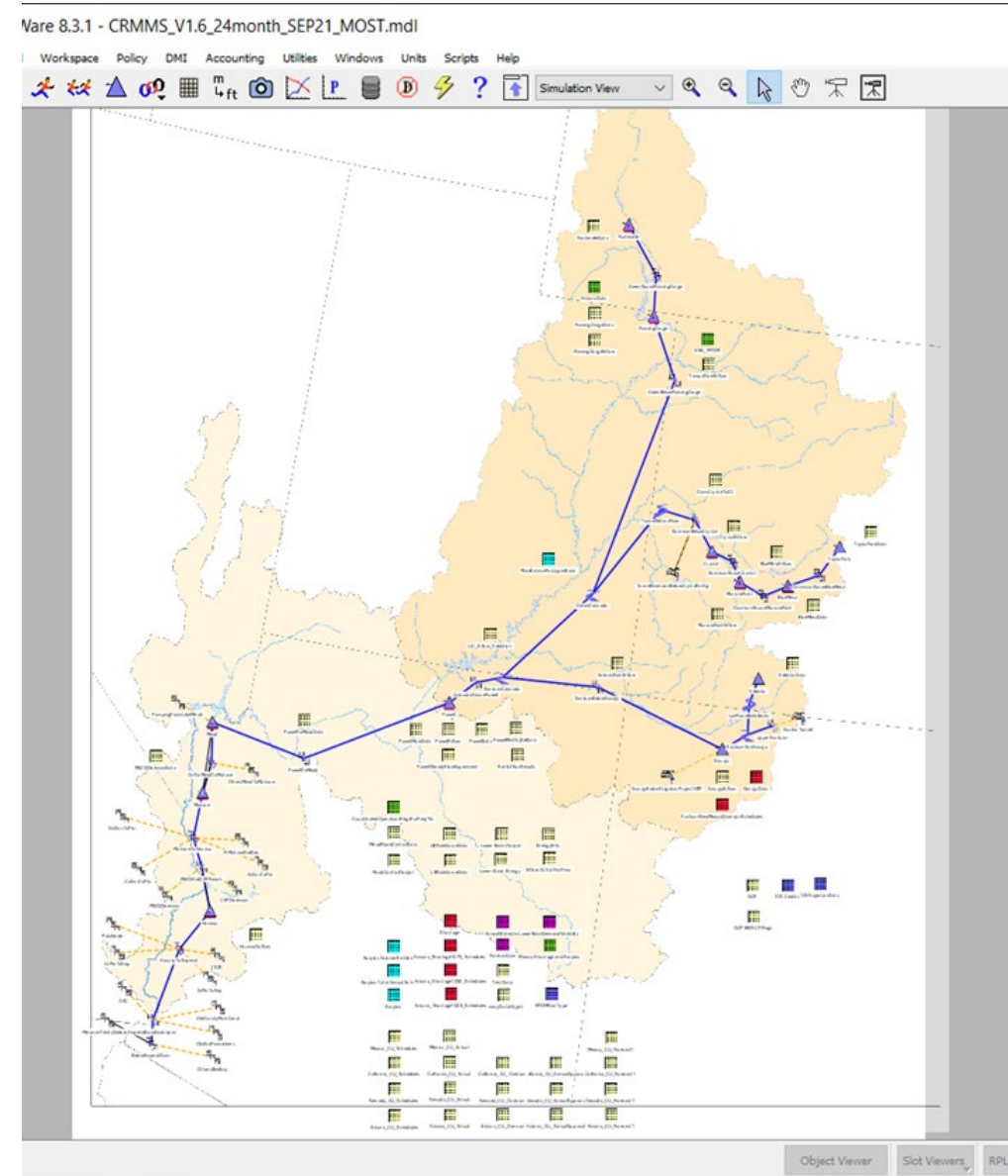
<sup>1</sup> Values for Water Year 2021 are projected. Unregulated inflow is based on the latest CBRFC forecast dated September 16, 2021. Storage and percent capacity are based on the September 2021 24-Month Study.

<sup>2</sup> Percentages on the light blue line represent percent of average unregulated inflow into Lake Powell for a given water year. The percent of average is based on the period of record from 1981-2010.



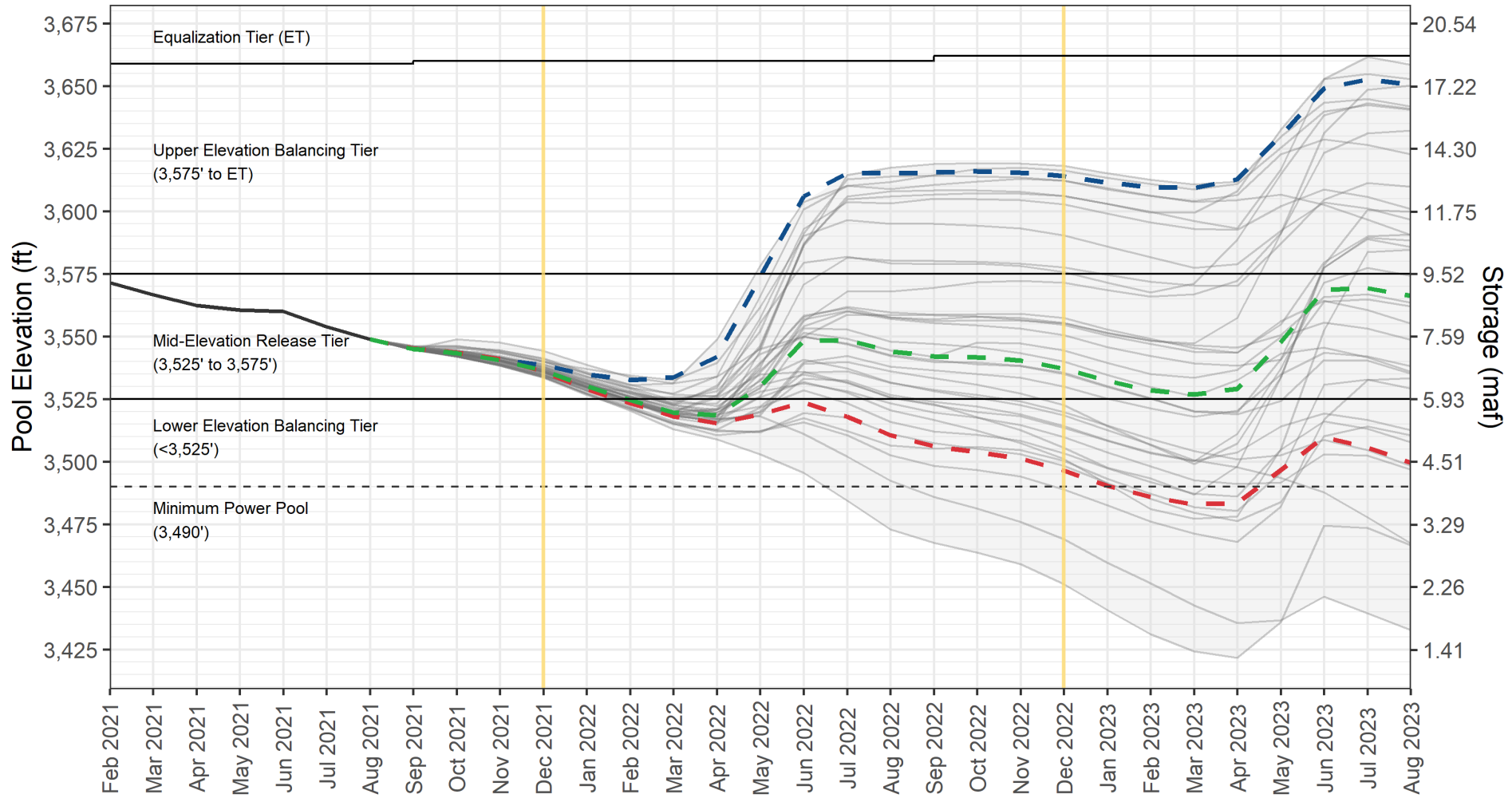
# 2-Year Probabilistic Projections

- Colorado River Mid-Term Modeling System (CRMMS)
- 35 Ensemble Streamflow Prediction inflow traces
  - Begin with current conditions
  - Sample Precipitation and Temperature from 1981-2015
  - Generate unregulated inflow forecasts



# Lake Powell End-of-Month Elevations

Projections from the September 2021 Colorado River Mid-Term Modeling System (CRMMS)



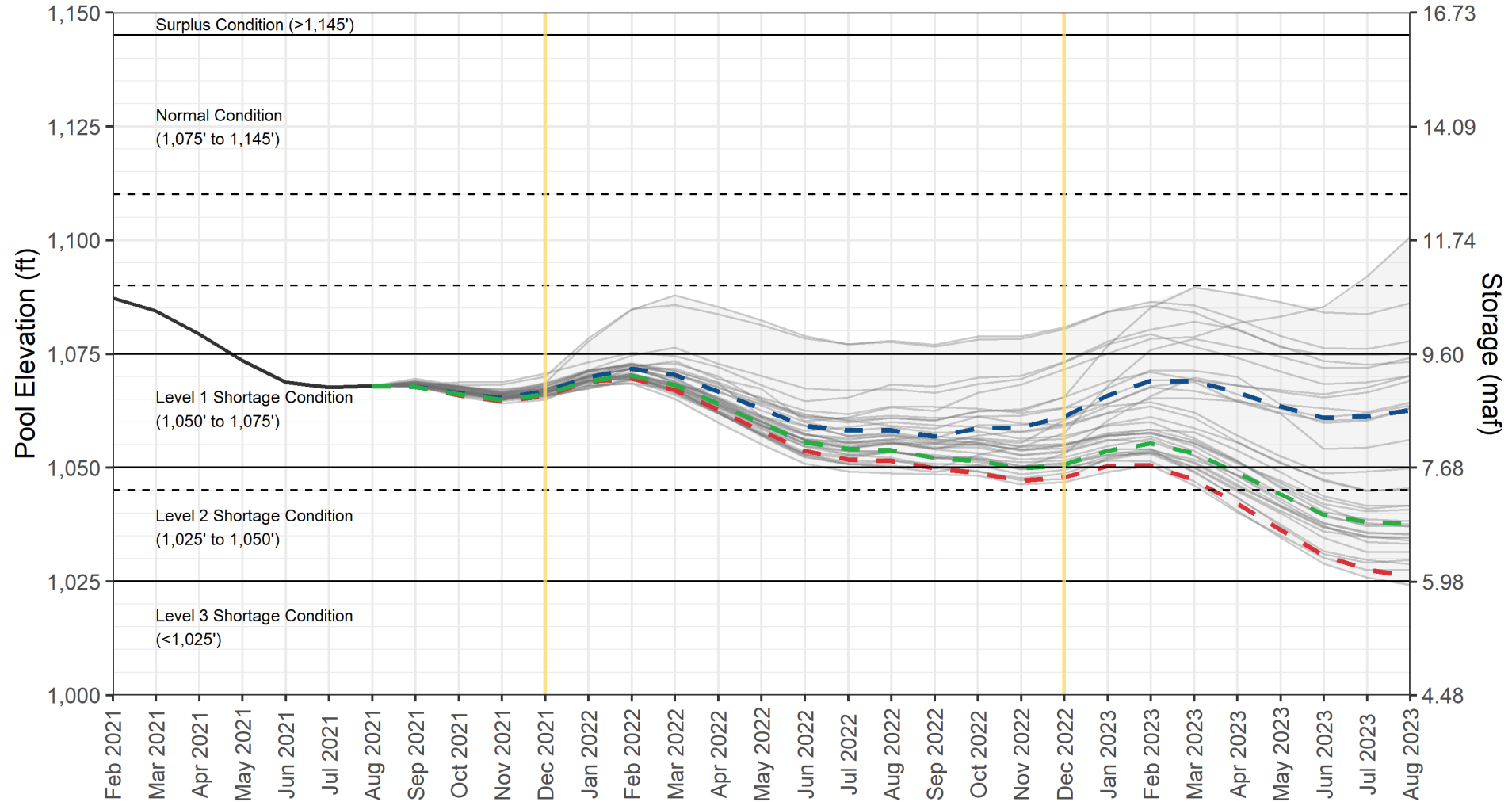
- 24-Month Study Minimum Probable
- 24-Month Study Maximum Probable
- 24-Month Study Most Probable
- Historical
- CRMMS-ESP Projections (35 projections)
- CRMMS-ESP Projections Range

Now available at <https://www.usbr.gov/lc/region/g4000/riverops/crmms-2year-projections.html>



# Lake Mead End-of-Month Elevations

Projections from the September 2021 Colorado River Mid-Term Modeling System (CRMMS)



- - - 24-Month Study Minimum Probable
- - - 24-Month Study Maximum Probable
- - - 24-Month Study Most Probable
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# 5-Year Probabilistic Projections and Beyond



# Precipitation Variability

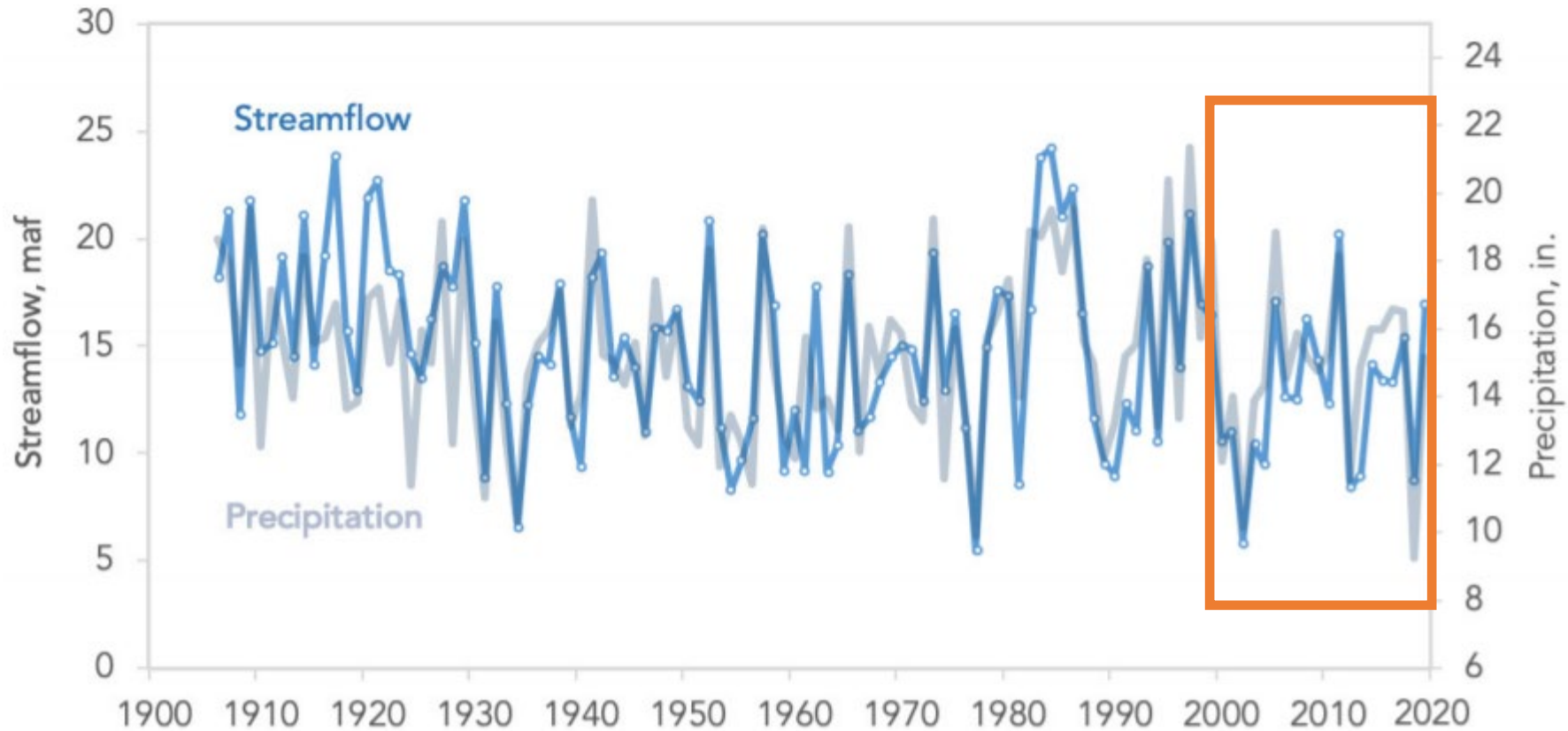


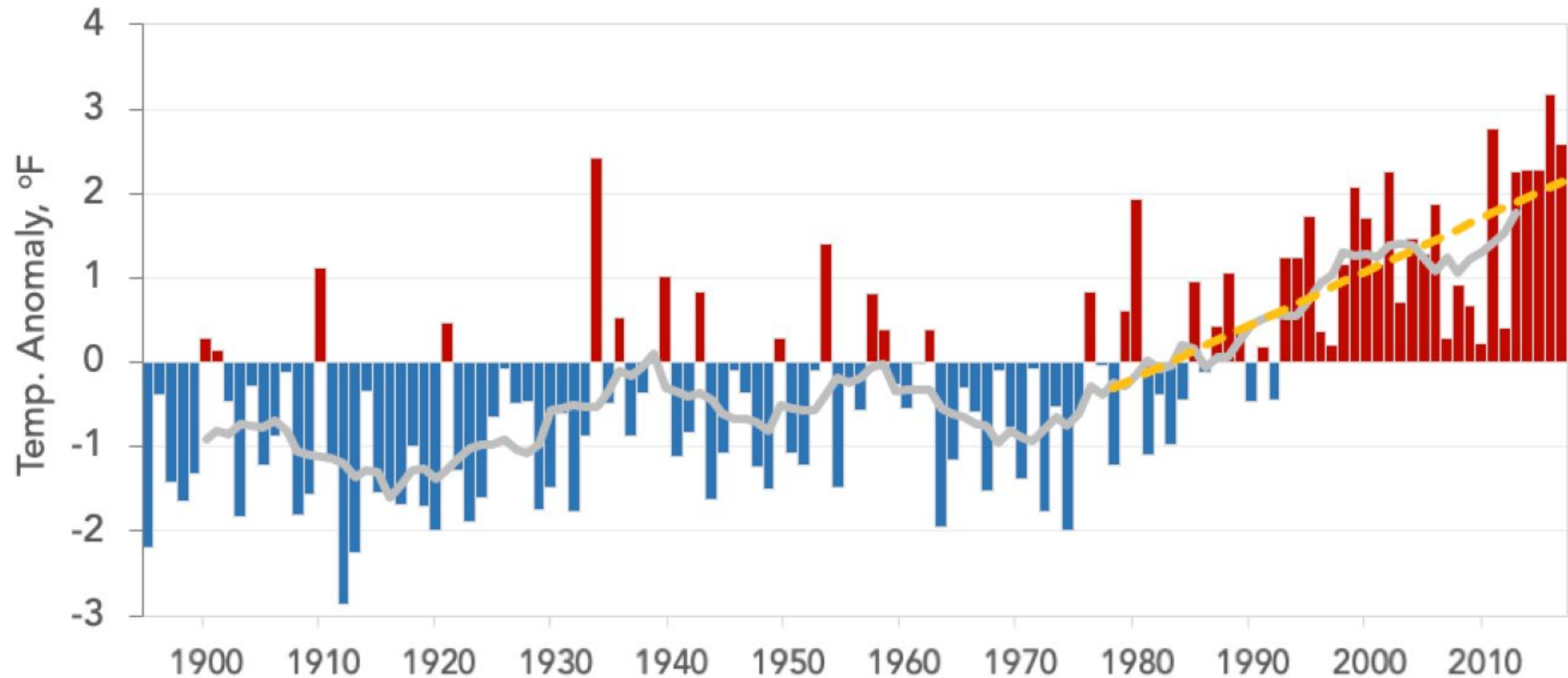
Figure 2.6: Upper Basin water-year precipitation compared with Colorado River at Lees Ferry water-year natural streamflow, 1906–2019. The correlation between the two time-series is 0.77 ( $R^2 = 0.61$ ) over the entire record, with higher correlations over more recent periods. (Data: precipitation, NOAA NCEI; streamflow, Reclamation)

“... the average annual precipitation over the past 20 years (2000–2019) does not stand out relative to periods of the same length earlier in the observed record.” Ch.2 p.75 SoS Report





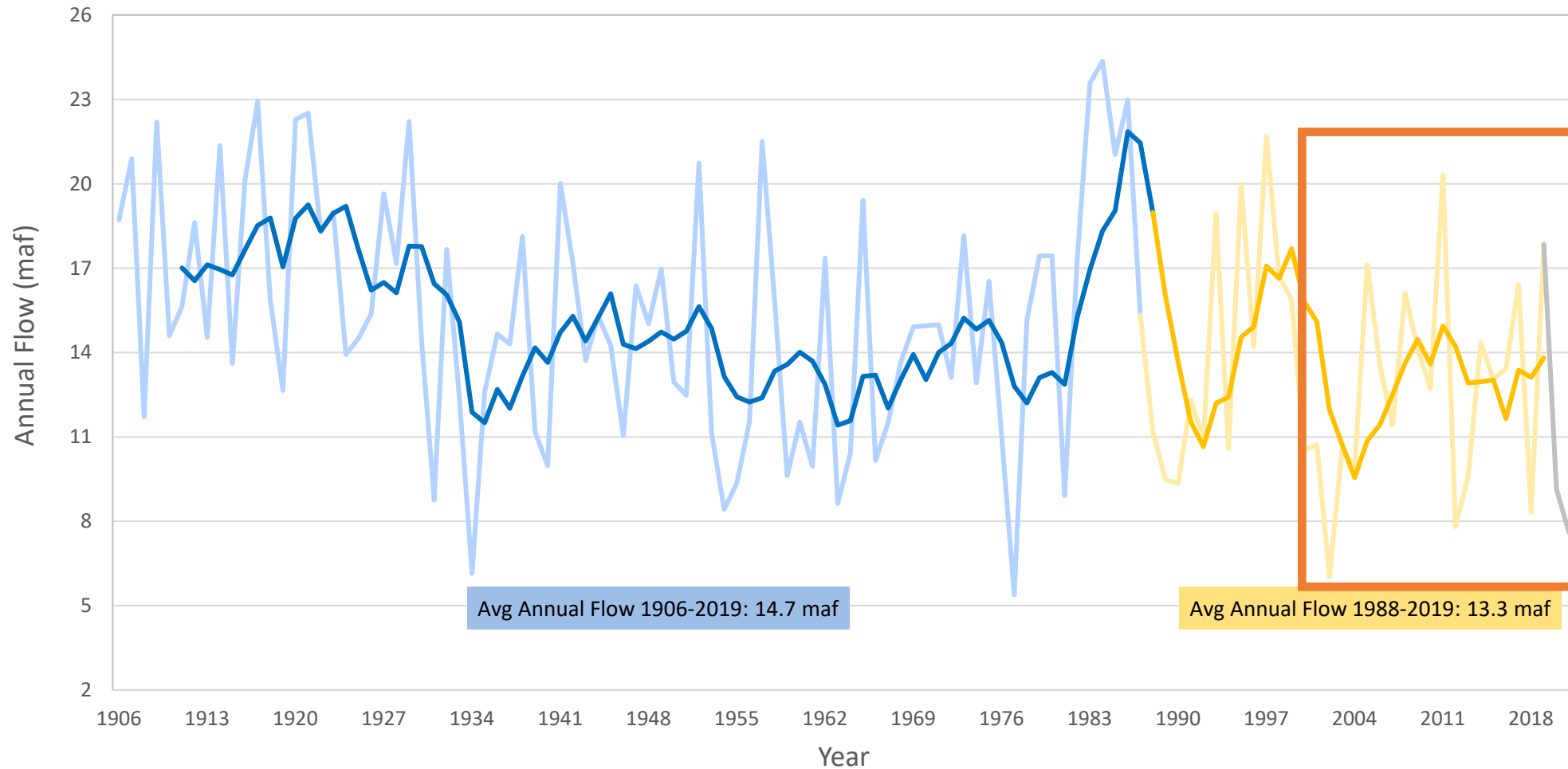
# Increasing Temperature Trend



Annually-averaged temperature for the Colorado River Basin, 1895–2018, shown as departures from a 1970–1999 average. The gray line is a 10-year running average plotted on the 6th year. A 40-year linear trend (dashed yellow line) shows 2.4°F of warming from 1979–2018. Figure taken from forthcoming **Colorado River Basin Climate and Hydrology—State of the Science Report**: [https://www.usbr.gov/lc/region/programs/research-reports-etc/Final\\_CRB\\_SoS\\_Project\\_Overview.pdf](https://www.usbr.gov/lc/region/programs/research-reports-etc/Final_CRB_SoS_Project_Overview.pdf)



# Lees Ferry Observed Natural Flow Record (1906-2021)



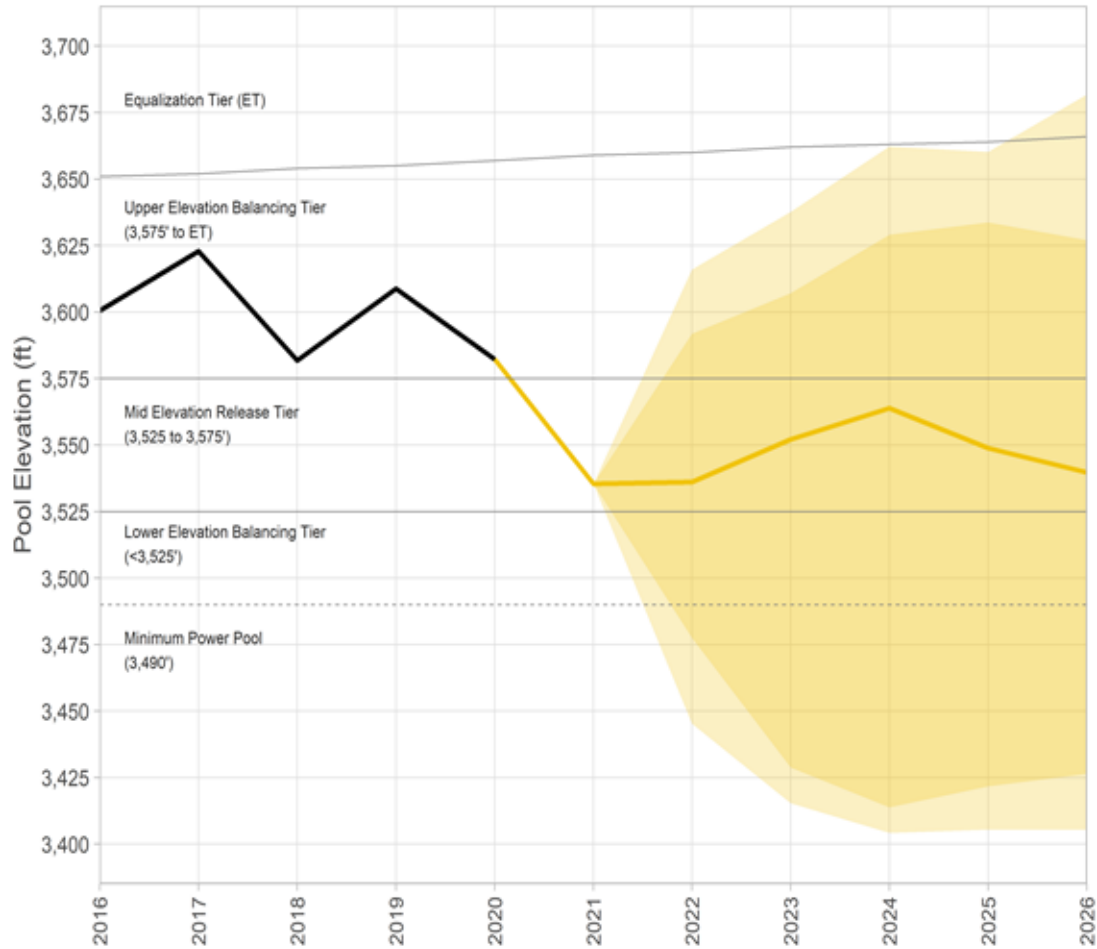
— Observed 1906-1987    — Stress Test 1988-2019    — Provisional 2020-2021    — 5-Year Avg    — 5-Year Avg



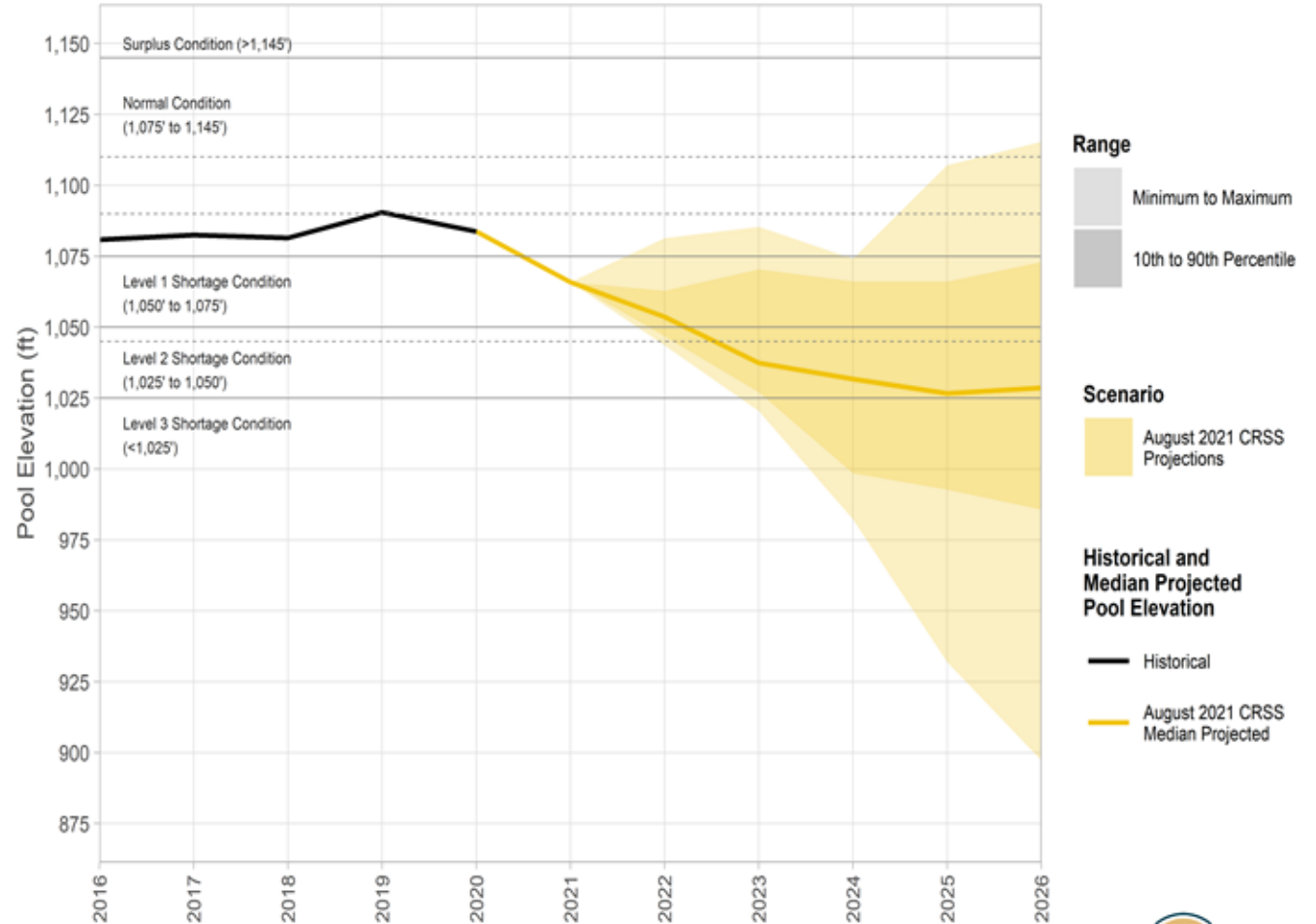
# Lake Powell and Lake Mead End-of-December Elevation

## August 2021 CRSS Projections with 1988 – 2019 Resampled Hydrology

Powell End-of-December Elevation



Mead End-of-December Elevation



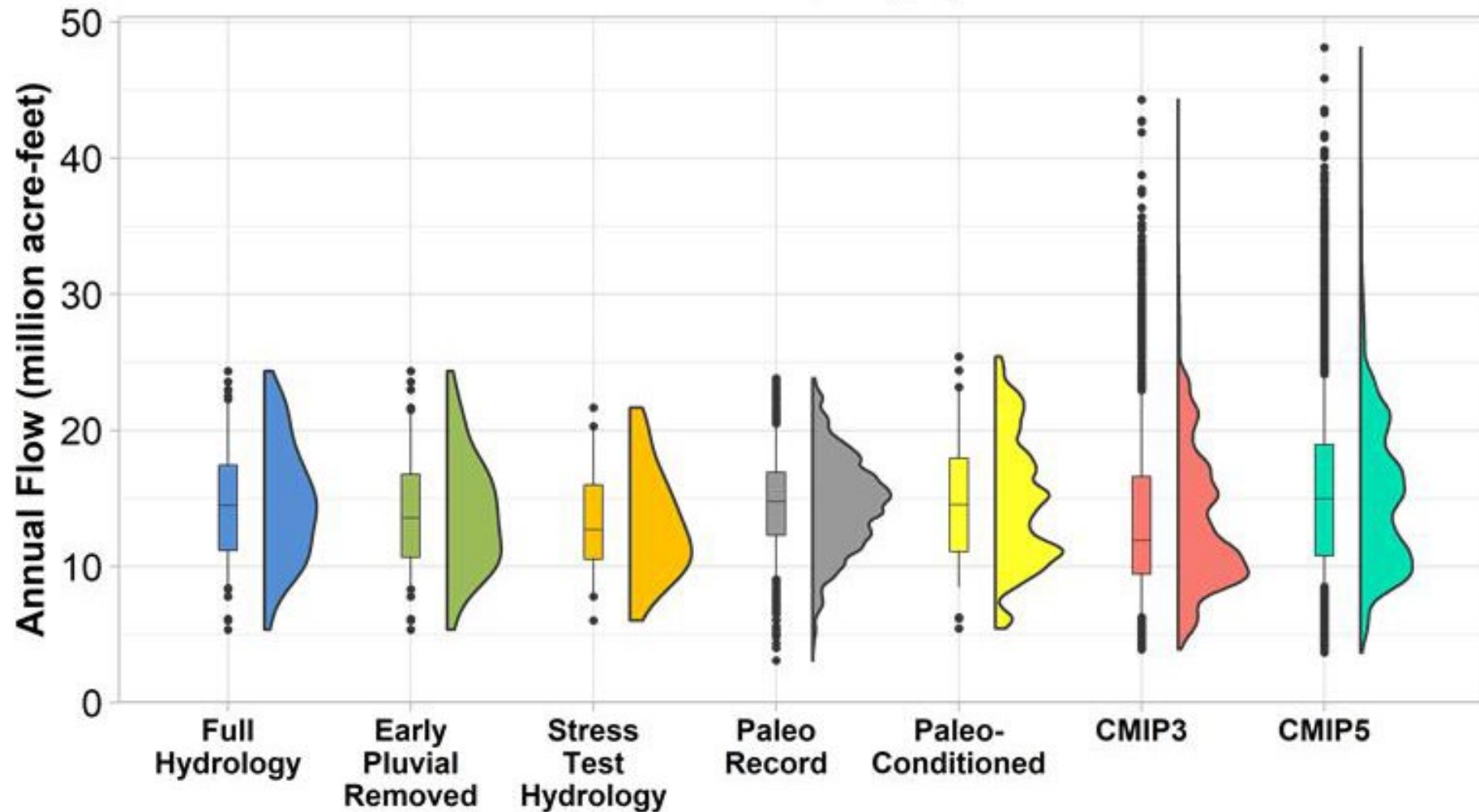
\*Projections assume 1988-2019 resampled natural flows (Stress Test Hydrology). In contrast to the June 2021 projections, these results do not include Upper Basin Drought Response Operations beyond 2021. The range shown in this figure may not be representative of the full range of possible conditions that could occur with different modeling assumptions.

Now available at <https://www.usbr.gov/lc/region/g4000/riverops/crss-5year-projections.html>



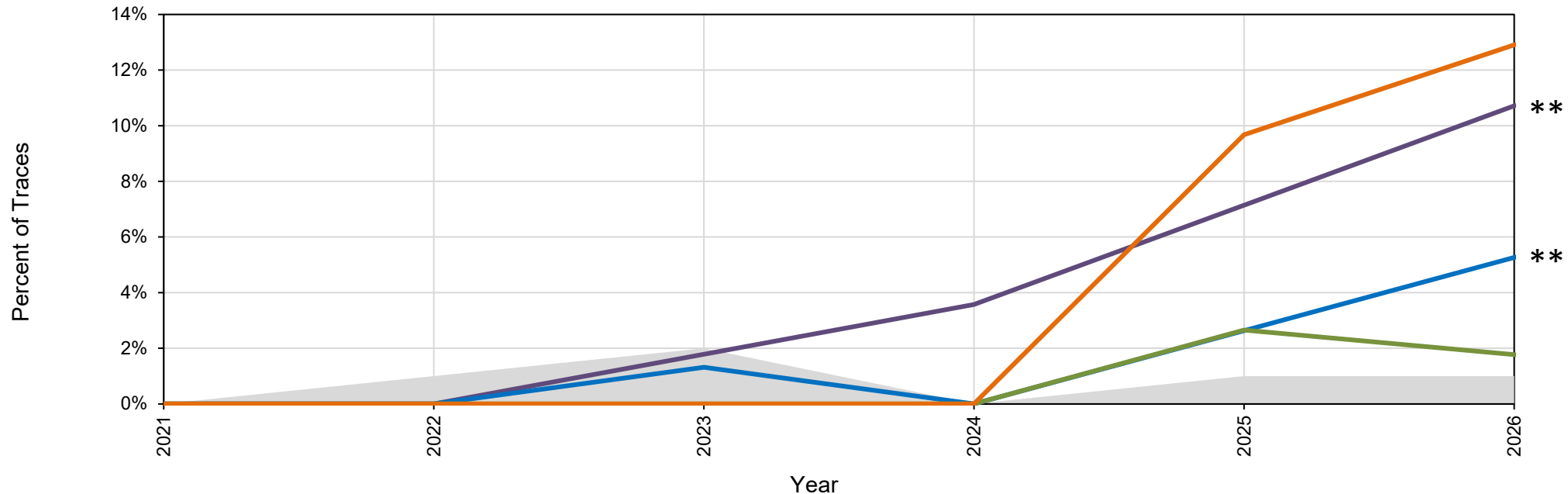
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# Distributions of Alternative Hydrology Scenarios Colorado River natural Flow at Lees Ferry Gaging Station



# Shifting Risk\*

## Risk of Lake Powell dropping below 3,490 feet in any month



- Scenario
- 2007 Projections (1905-2005 Hydrology, 1999 Demands; 2007 Interim Guidelines)
  - CMIP3 Hydrology; 2016 Demands; Current Policies Continue
  - CMIP5 Hydrology; 2016 Demands; Current Policies Continue
  - Full Hydrology; 2016 Demands; Current Policies Continue
  - Stress Test Hydrology; 2016 Demands; Current Policies Continue

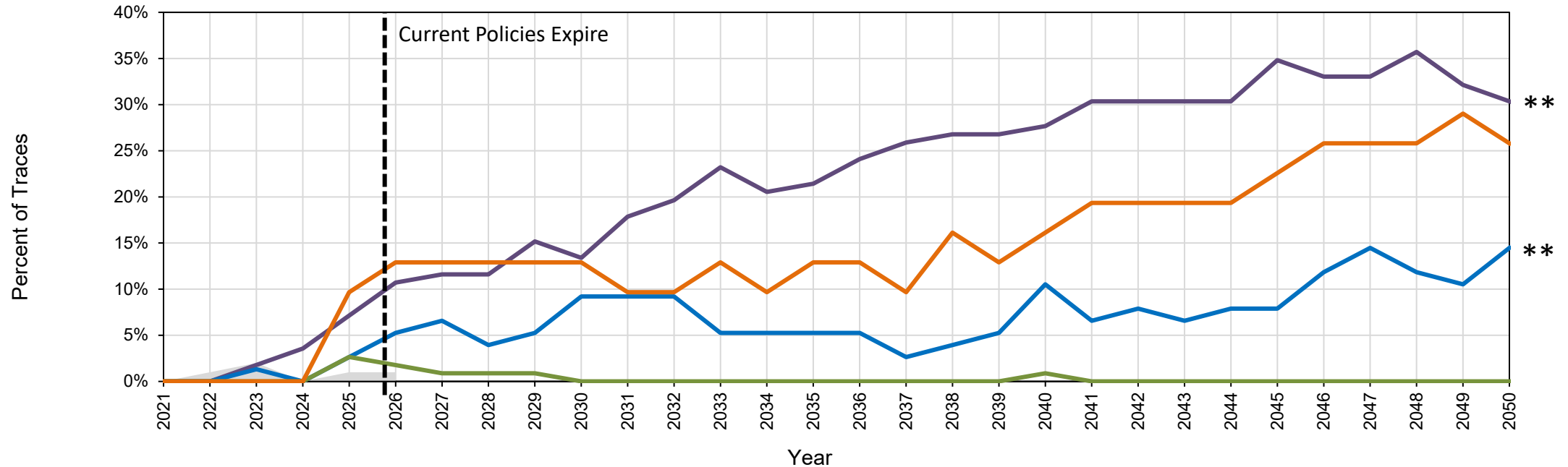
\* Not official Projections, based on August 2020 CRSS modeling with Lake Powell initial elevation of 3,592 feet. Lake Powell's 9/21/21 elevation is 3,547 feet

\*\* CMIP3 and CMIP5 ensembles span 3 different emissions futures and were downscaled using Bias Correction Spatial Downscaling (BCSD)



# Shifting Risk\*

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# Concerns with Planning under Deep Uncertainty

- Deep uncertainty occurs when probabilities of any given set of future conditions cannot be estimated with confidence
  - Translation: it is impossible to determine the most appropriate planning assumptions
- Choices of hydrologic ensemble and other assumptions about the future are likely to be controversial
- Statistics-based analysis may be unreliable as the sole basis for understanding system or planning for future
  - Risk = percent of traces; *completely dependent on the composition of the chosen ensemble of traces*
  - “acceptable” level of risk, risk reduction, etc. are common planning metrics but the implications of the underlying calculations are not well understood by stakeholders



# Decision Making under Deep Uncertainty

- Decision Making under Deep Uncertainty (**DMDU**) methods incorporate concepts and techniques that help address the challenges of planning under climate change
- Shift away from statistics-based risk analysis
- Focus on **robustness**- performance is *good enough* in a wide range of futures
- Fundamental concepts
  - Wide range of futures, all equally likely
  - Vulnerability analysis based on observable conditions
  - Adaptation based on observable signposts as conditions evolve (and uncertainty decreases)





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# Current Drought in a Historical Context

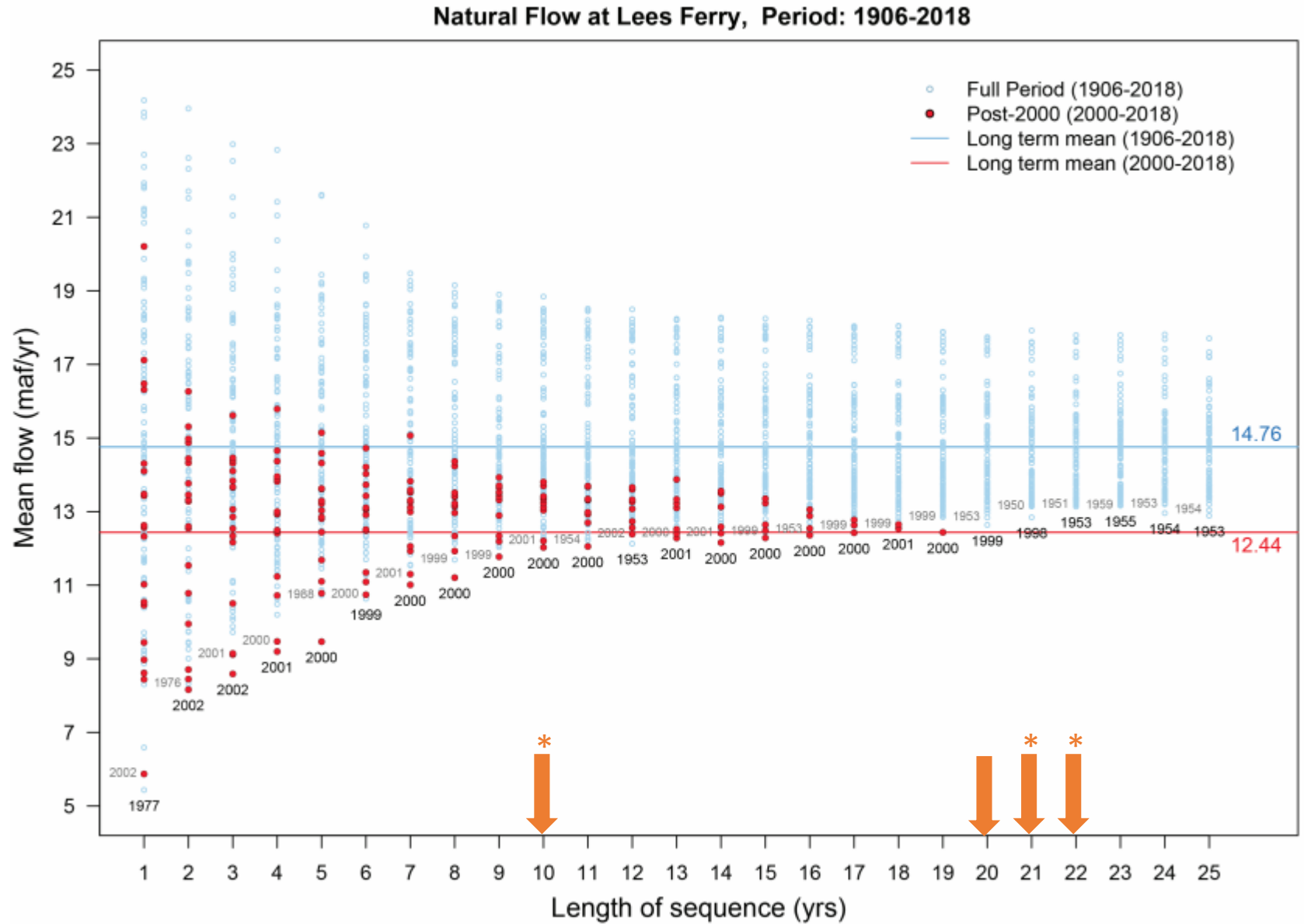


Figure 12 Sequence Average plot from Salehabadi, et al (2020) "The Future Hydrology of the Colorado River Basin" <https://qcnr.usu.edu/coloradoriver/files/WhitePaper4.pdf>

\*based on August 2021 provisional natural flow calculations for 2020 & 2021 <https://www.usbr.gov/lc/region/g4000/NaturalFlow/provisional.html>

