Colorado River Water-Supply Crisis: how we got here

John (Jack) C. Schmidt

Center for COLORADO RIVER Studies

Utah State University

https://qcnr.usu.edu/coloradoriver/

Photo credit: Freshwaters Illustrated

Climate change causes … → … decline in water supply, increase in duration of years of low runoff, increased variability in year-to-year runoff

that necessitate political response, including … → … renegotiation of 2007 Interim Guidelines and related Law of the River agreements that concern water allocation and use

that necessitate management response, including … → … changes in rules of reservoir operations and reservoir releases to meet water supply and environmental objectives

that cause changes in the drivers of regulated river ecosystems, such as … → … changes in flow regime, sediment supply, river temperature, and other water quality parameters of releases from reservoirs that are relatively full or relatively empty

that cause changes in the attributes of the novel aquatic ecosystems that presently exist in each part of the river system, such as … → … changes in aquatic food base and changes in non-native and native fish communities in regulated river segments

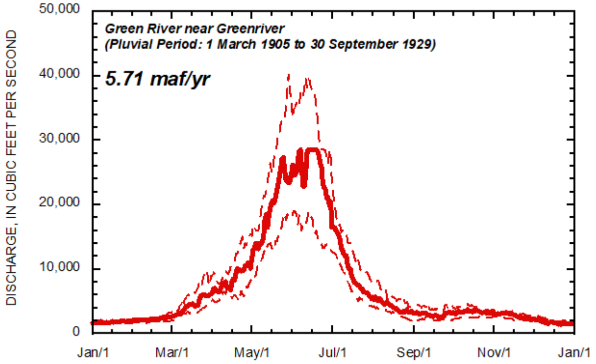
Climate change causes … → … **decline in water supply**, increase in duration of years of low runoff, and increased variability in year-to-year runoff

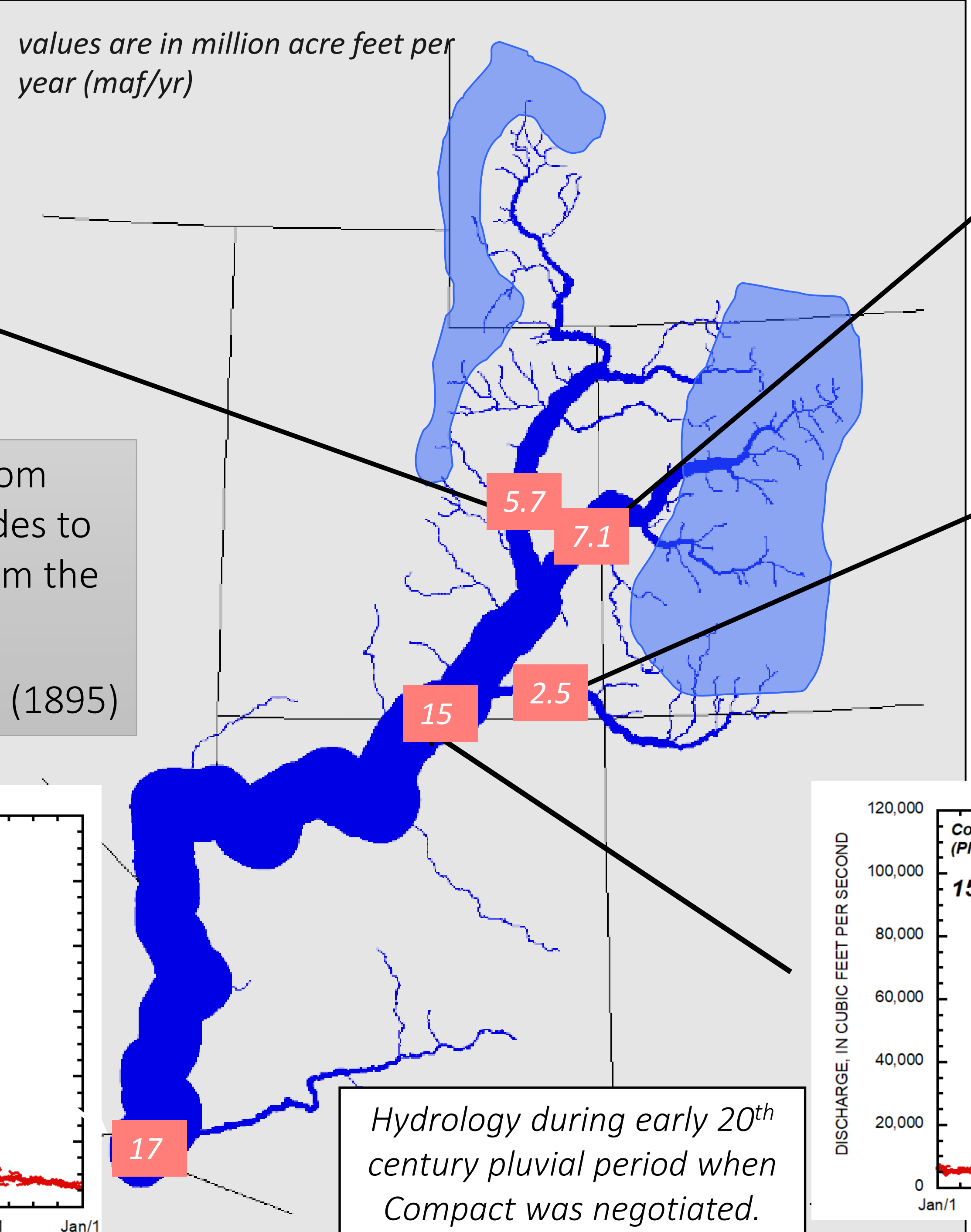
that necessitate political response, including … → … renegotiation of 2007 Interim Guidelines and related Law of the River agreements that concern **water allocation and use**

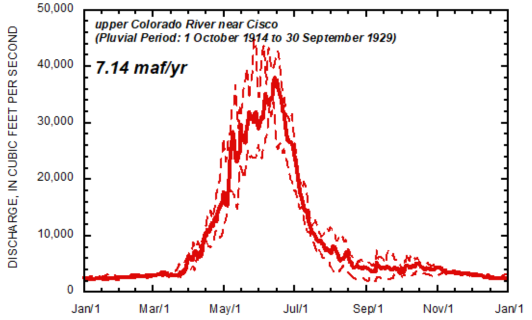
that necessitate management response, including … → … changes in rules of reservoir operations and reservoir releases to meet water supply and environmental objectives

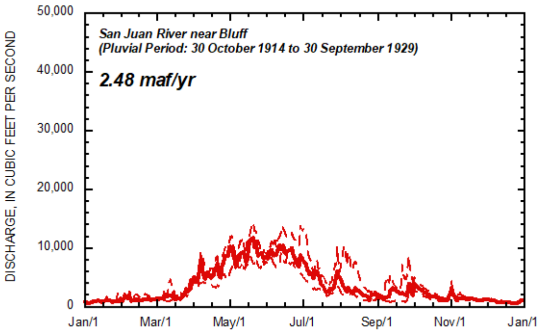
that cause changes in the drivers of regulated river ecosystems, such as … → … changes in flow regime, sediment supply, river temperature, and other water quality parameters of releases from reservoirs that are relatively full or relatively empty

that cause changes in the attributes of the novel aquatic ecosystems that presently exist in each part of the river system, such as … → … changes in aquatic food base and changes in non-native and native fish communities in regulated river segments



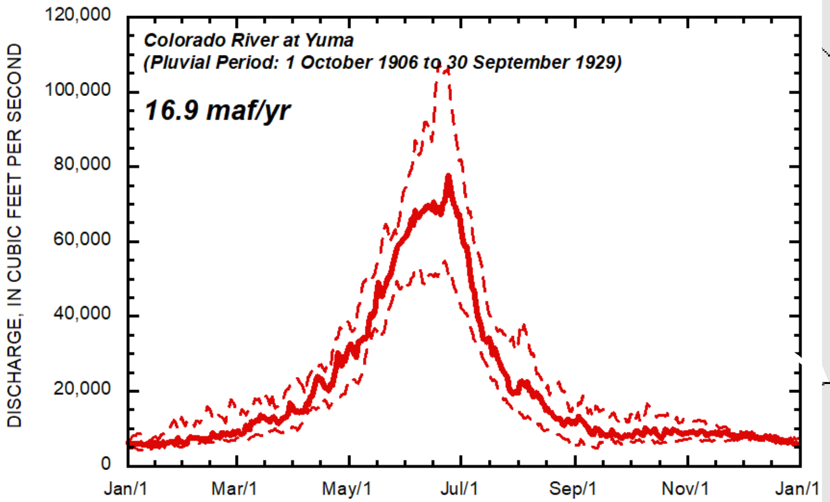




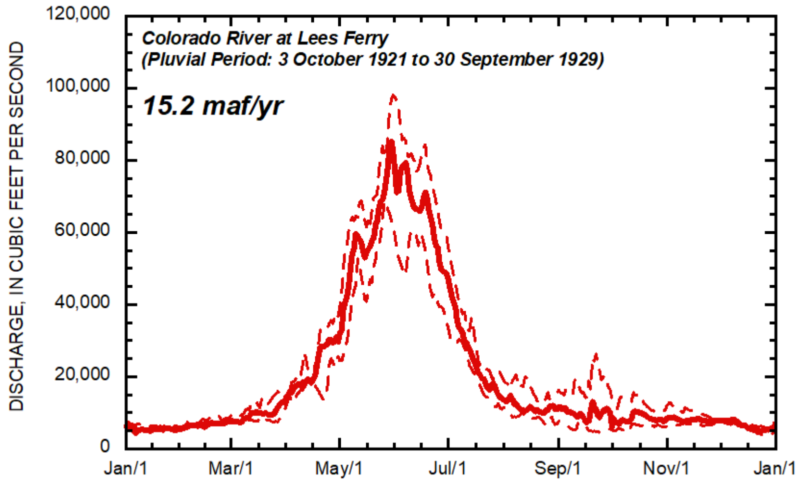


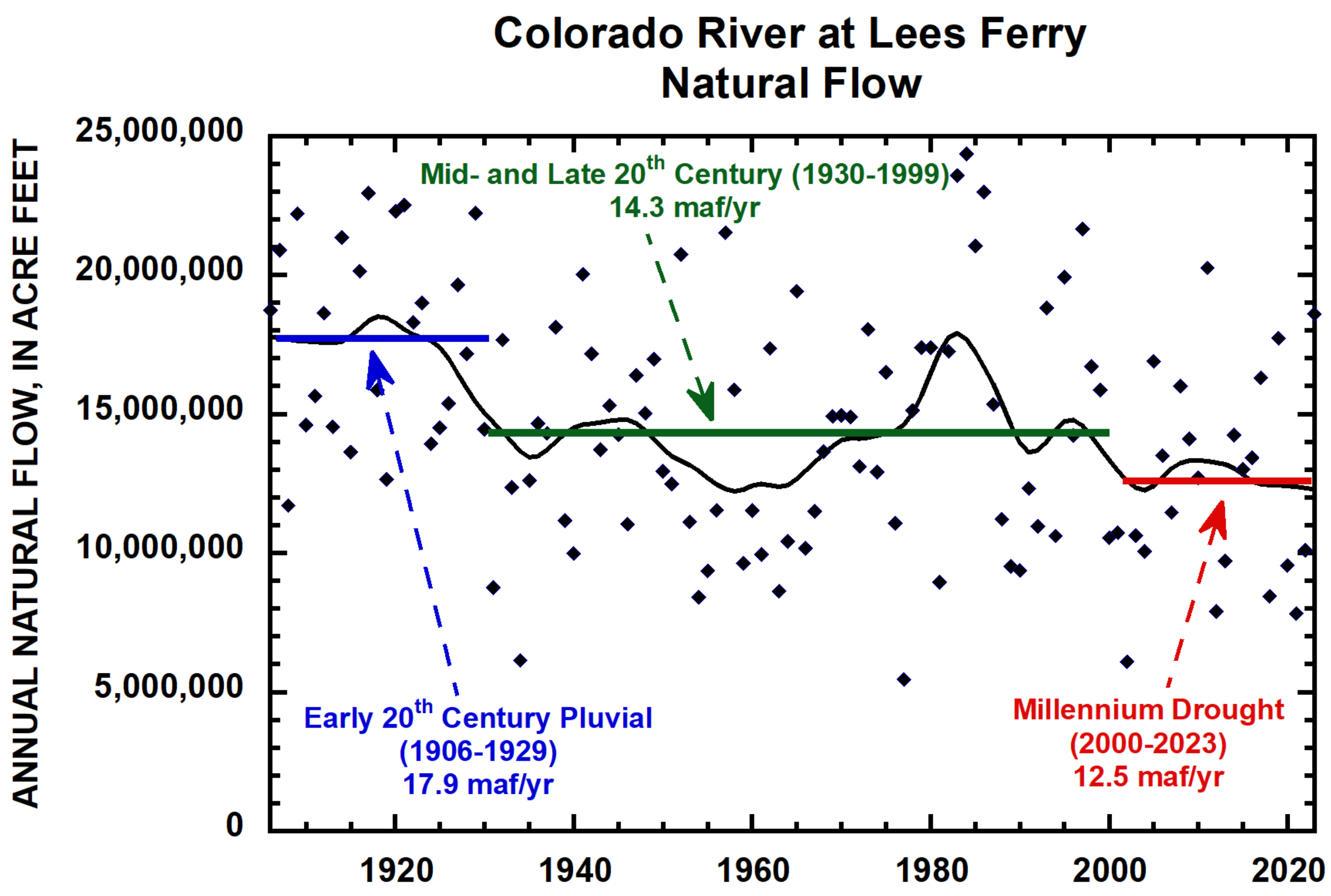
"The general course of the river is from north to south and from great altitudes to the level of the sea. Thus, it runs from the land of snow to the land of sun."

John Wesley Powell (1895)



Hydrology during early 20th century pluvial period when Compact was negotiated.





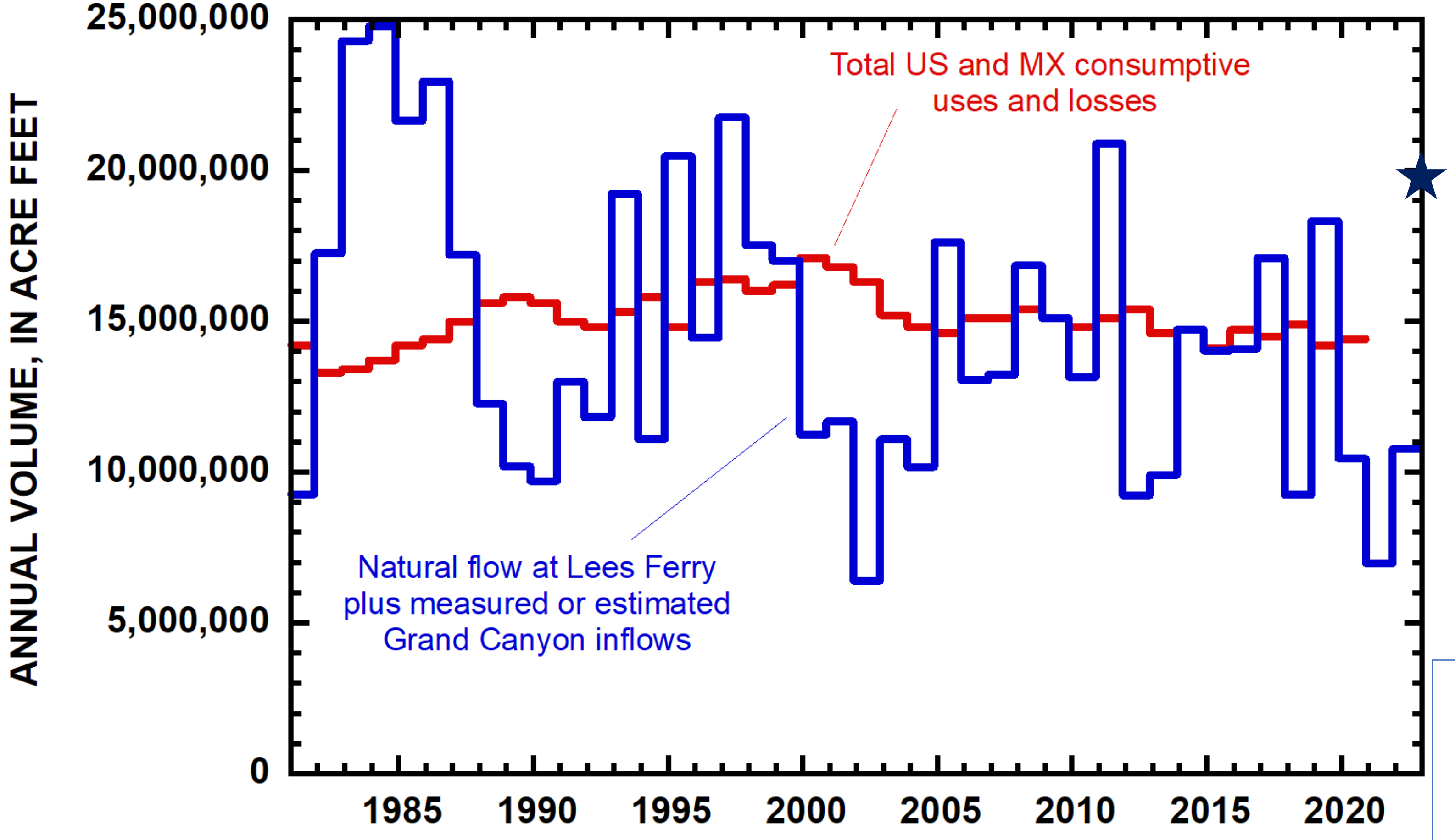
Natural flow of the Colorado River has declined during the past ~115 years

Today's natural flow at Lees Ferry is 13% less than the average flows of the mid- and late-20th century, and 30% less than the flows of the early 20th century when the Compact was negotiated.

recent natural flow
2018-2022: 10.7 maf/yr
2023: 18.6 maf

data are for calendar year;
Bureau of Reclamation
17 April 2023

Consumptive Uses and Losses in the United States and Mexico in Relation to the Natural Supply of Water from the Upper Basin and the Grand Canyon

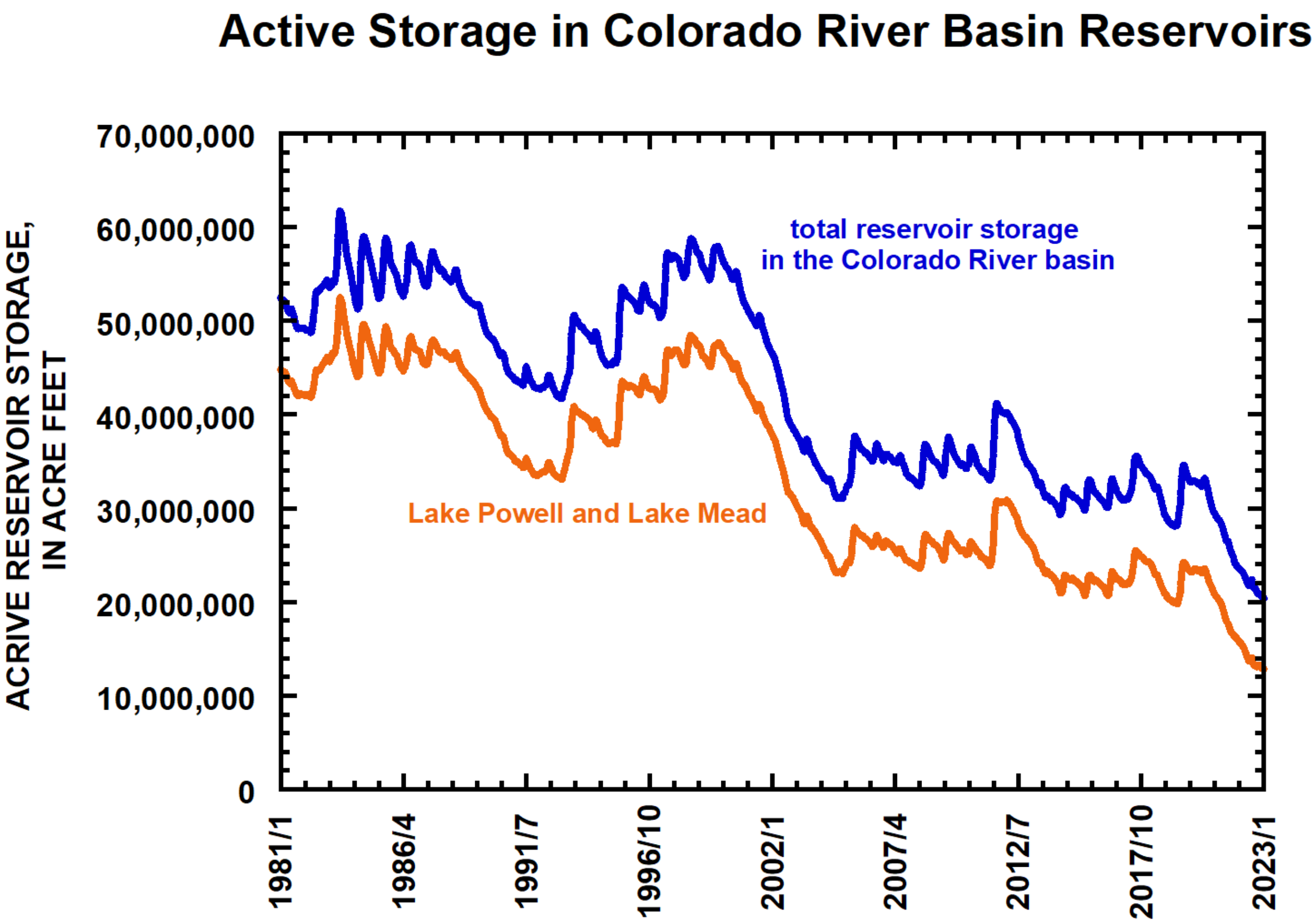


Year-to-year watershed runoff is more variable than are the fluctuations in basin-wide consumptive uses and losses.

Total natural supply (2000-2023) = 13.6 maf/yr
Total basin-wide consumptive uses and losses (2001-2020) = 15.0 maf/yr

Components of total natural supply (2000-2023)
Upper Basin natural runoff = 12.5 maf/yr
Grand Canyon actual inflows = 0.77 maf/yr
Estimated Hoover to Imperial inflows = 0.34 maf/yr

Recent average (2018-2022) = 11.5 maf/yr
(2023) = 19.7 maf



Reservoir Contents (1 May 2023, unless noted)

total system – (20.3 maf) (28 F 2023)

federal system – 34% of capacity (19.8 maf)

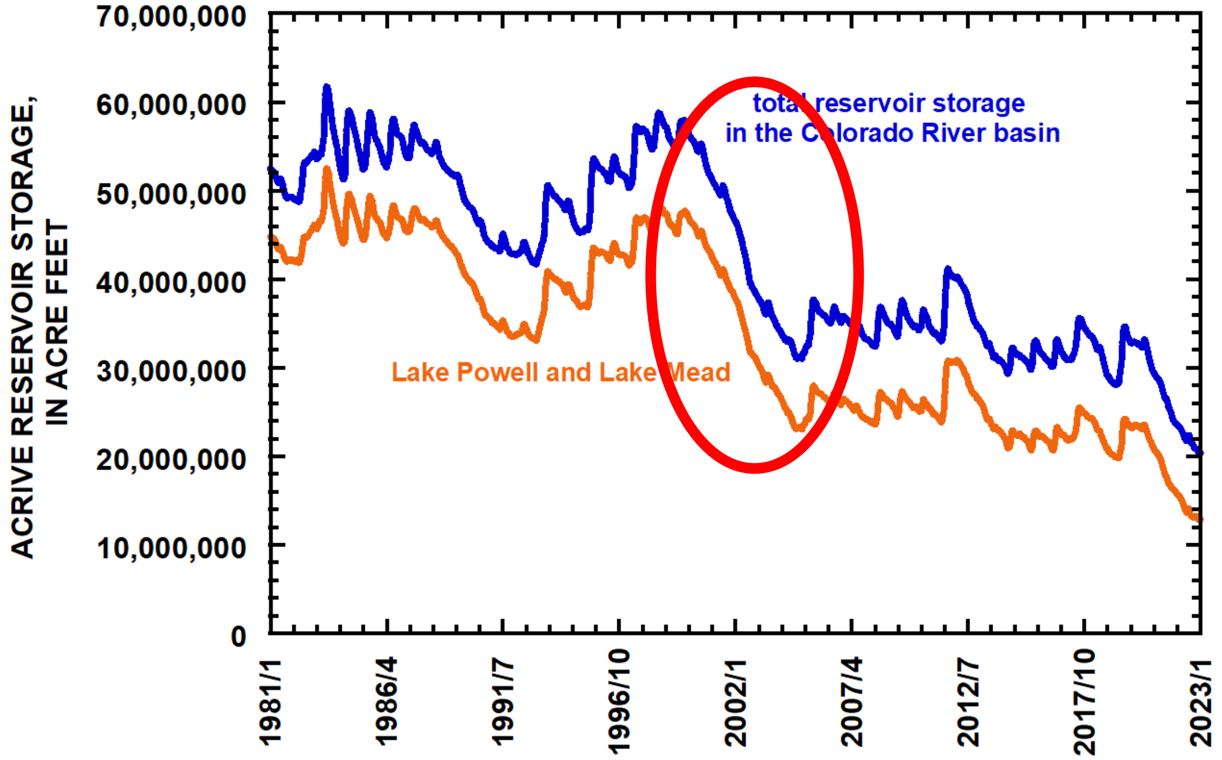
Lake Mead – 29% of capacity (7.7 maf)

Lake Powell – 24% of capacity (5.5 maf)

maximum storage

- *Total system = 61.7 maf (16 July 1983)*
- *Powell+Mead = 52.5 maf (19 July 1983)*

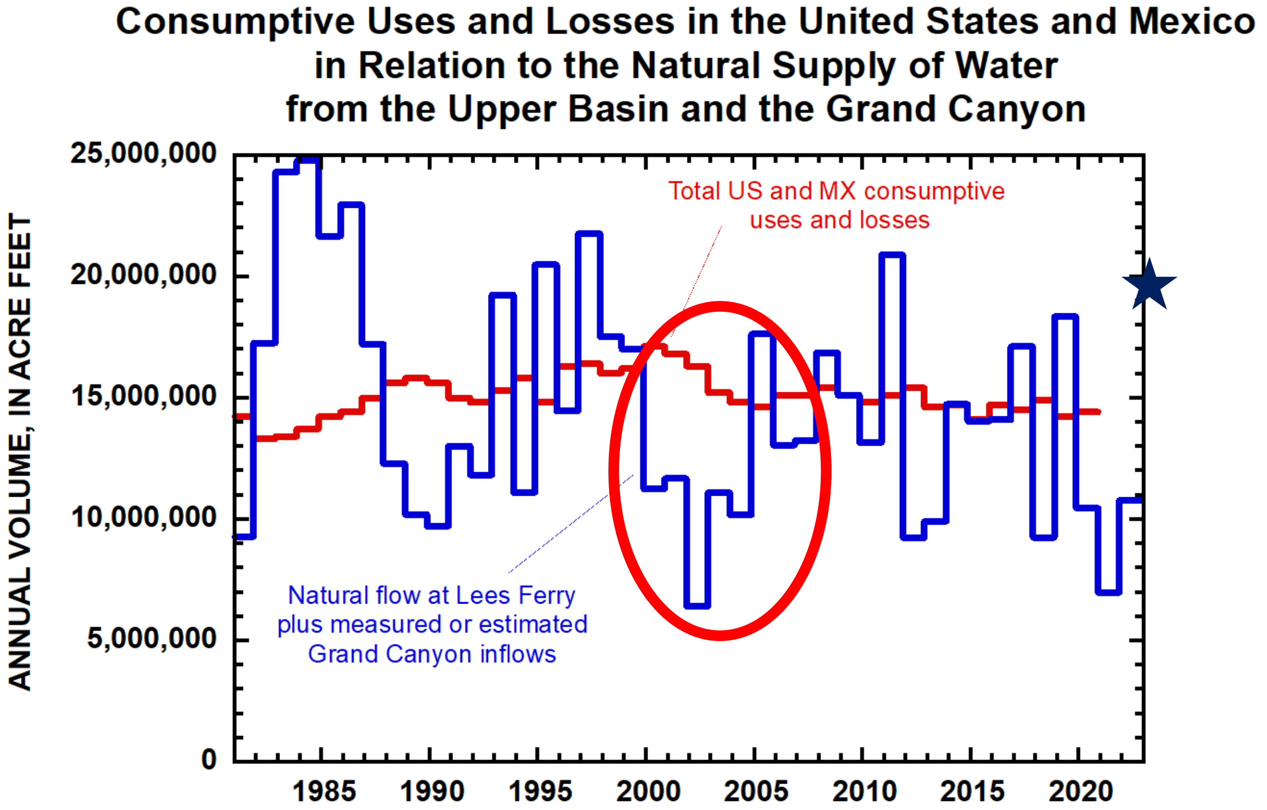
Most of the watershed's reservoir storage is in Mead and Powell

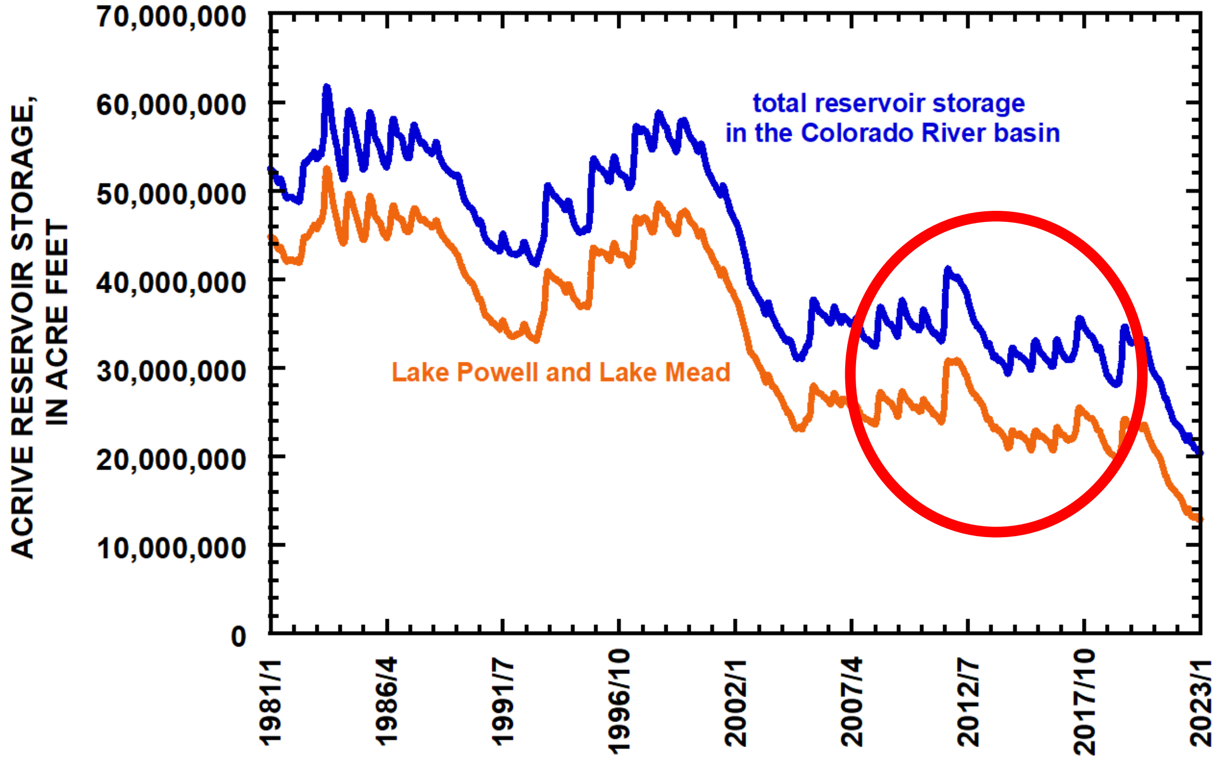


Observations

- 2000-2007 – supply > use in only 1 yr (2005) out of 8; storage declined by 22.5 maf

How did today's water crisis develop?



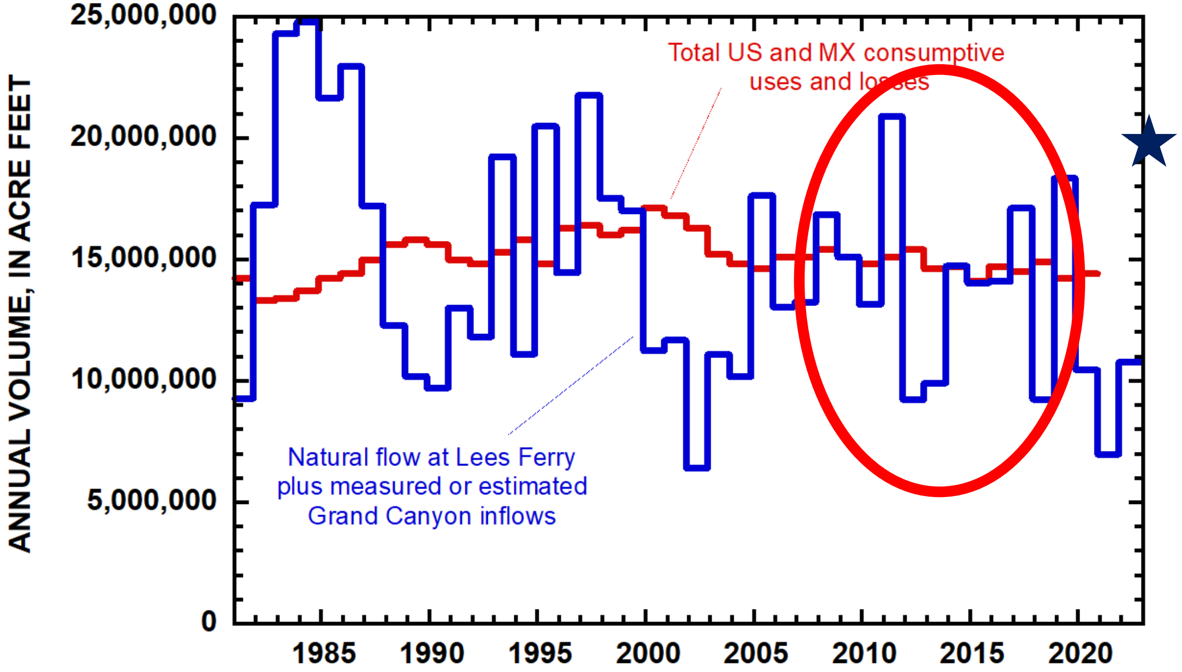


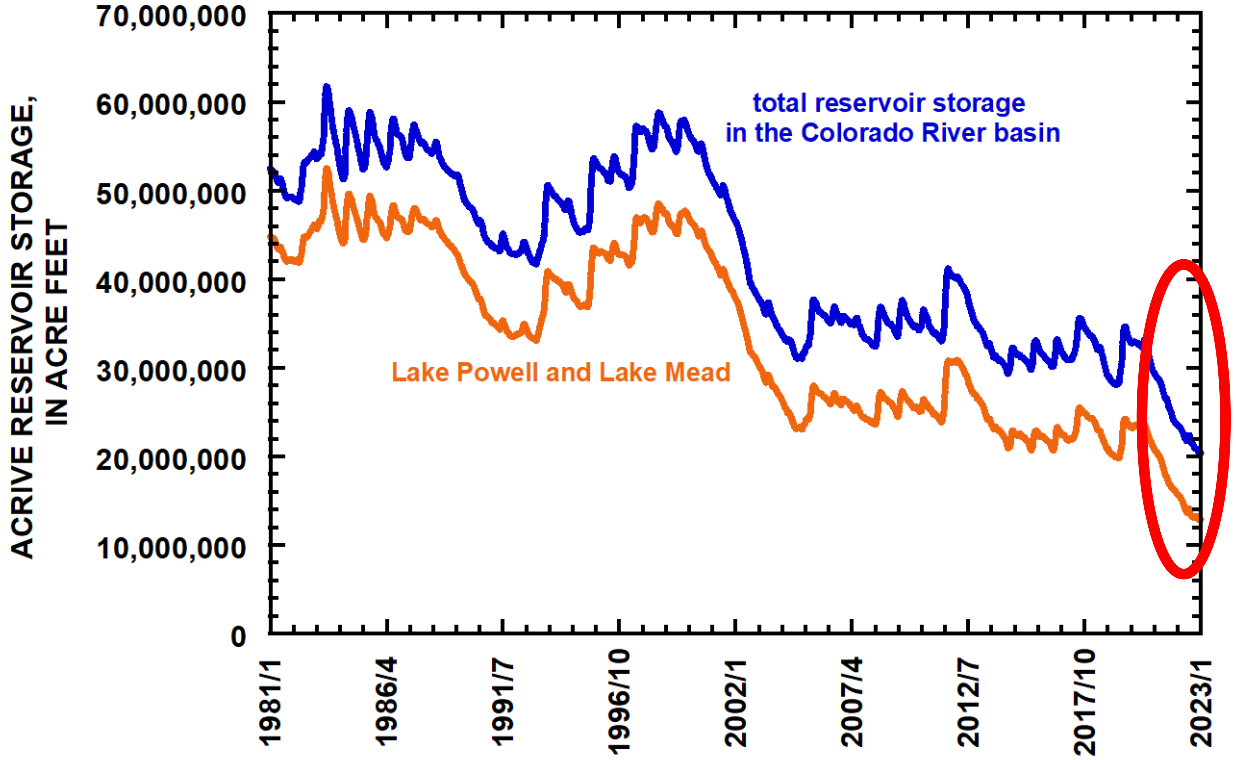
Observations

- 2000-2007 – supply > use in only 1 yr (2005) out of 8; storage declined by 22.5 maf
- 2008-2019: supply > use (2008, 2011, 2017, 2019); total storage ~same during 14-yr period

- Declining natural supply
- Inability to develop adaptive policies that sufficiently reduced use to match the declining supply

Consumptive Uses and Losses in the United States and Mexico in Relation to the Natural Supply of Water from the Upper Basin and the Grand Canyon

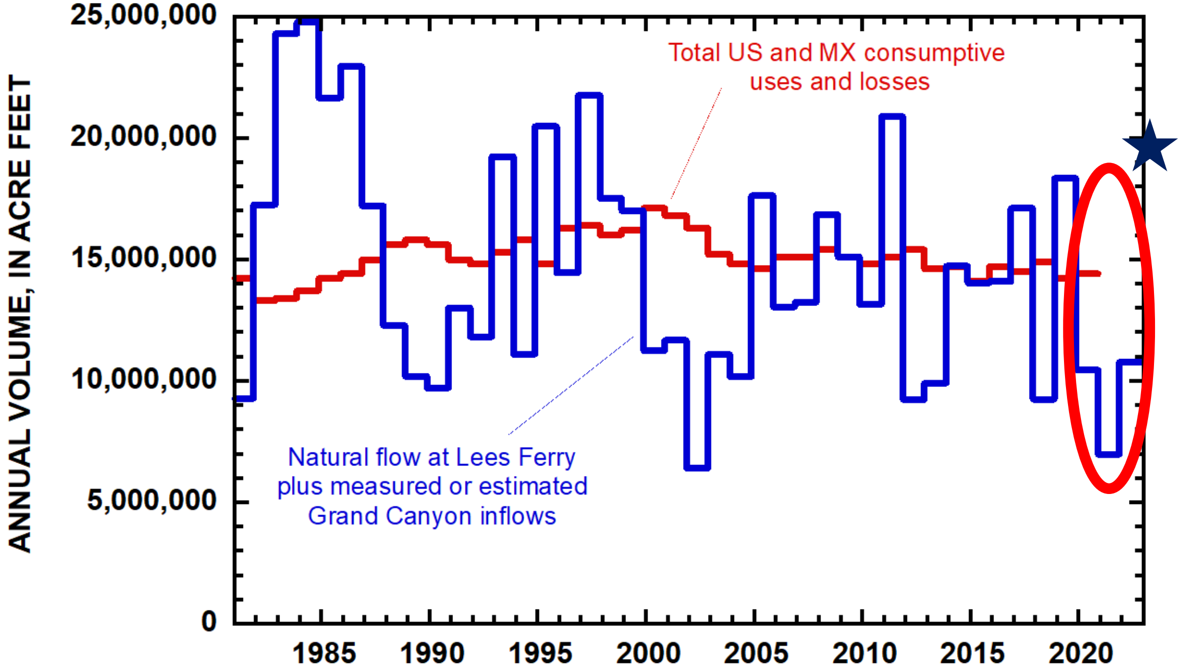




Observations

- 2000-2007 – supply > use in only 1 yr (2005) out of 8; storage declined by 22.5 maf
- 2008-2019: supply > use (2008, 2011, 2017, 2019); total storage ~same during 14-yr period
- 2020-2022: storage declines 11.6 maf in a 3-yr period

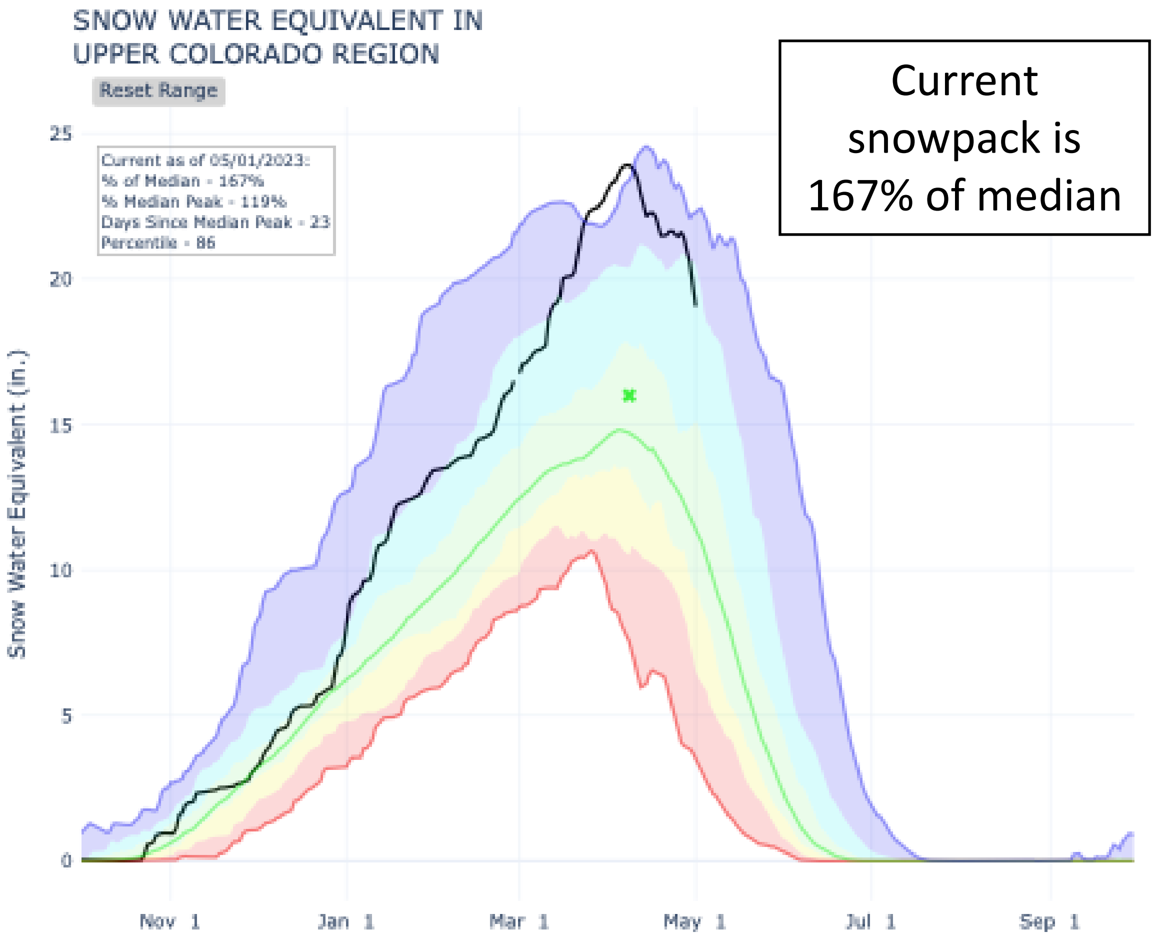
Consumptive Uses and Losses in the United States and Mexico in Relation to the Natural Supply of Water from the Upper Basin and the Grand Canyon



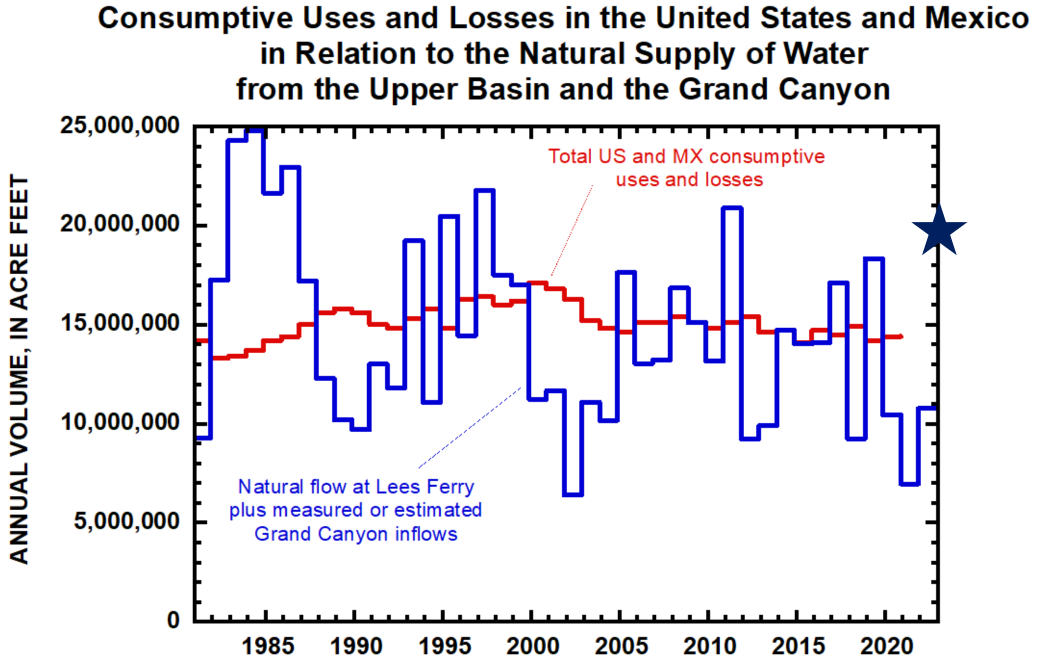
- During >20 years of low runoff, reservoir storage was never replenished
- Reservoir system remained in a vulnerable condition 2008-2020 and there was insufficient storage to maintain use during the next significant dry period (2020-2022)
- 2023 is a rare opportunity to recover reservoir storage

2023 snowmelt runoff will be unusually large

It would take ~4 additional years similar to WY2023 to refill Mead and Powell, assuming consumptive uses and losses are similar to the last 5 years



Current snowpack is 167% of median

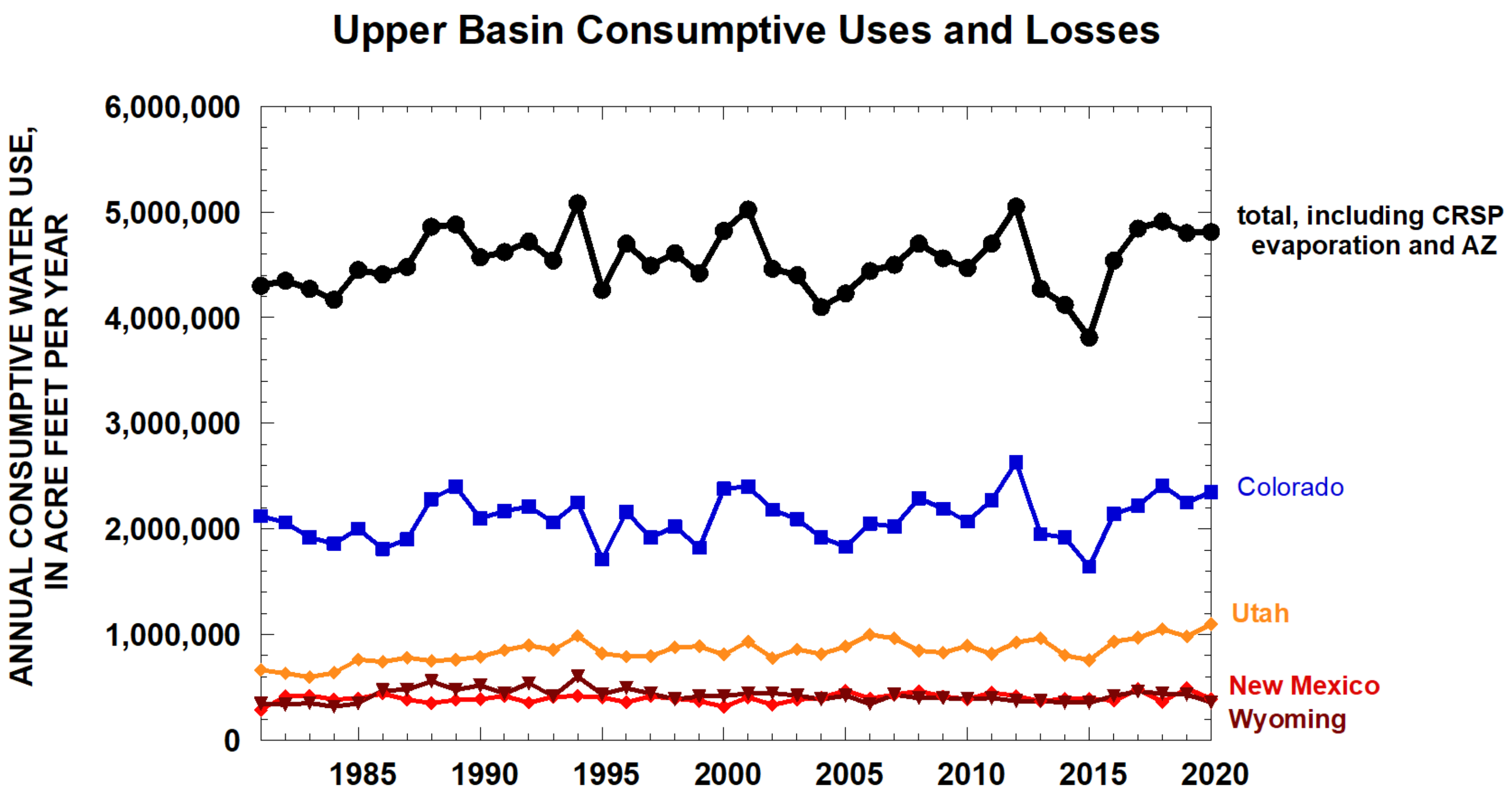


total supply in 2023
~20 maf

Average basin-wide CU&L
2016-2020 = (14.5 maf/yr)

Likely surplus in 2023
(~5 to 6 maf)

Number of wet years to refill
(~6 yrs)



Water use: Upper Basin

4.57 maf/yr
(2001-2020)

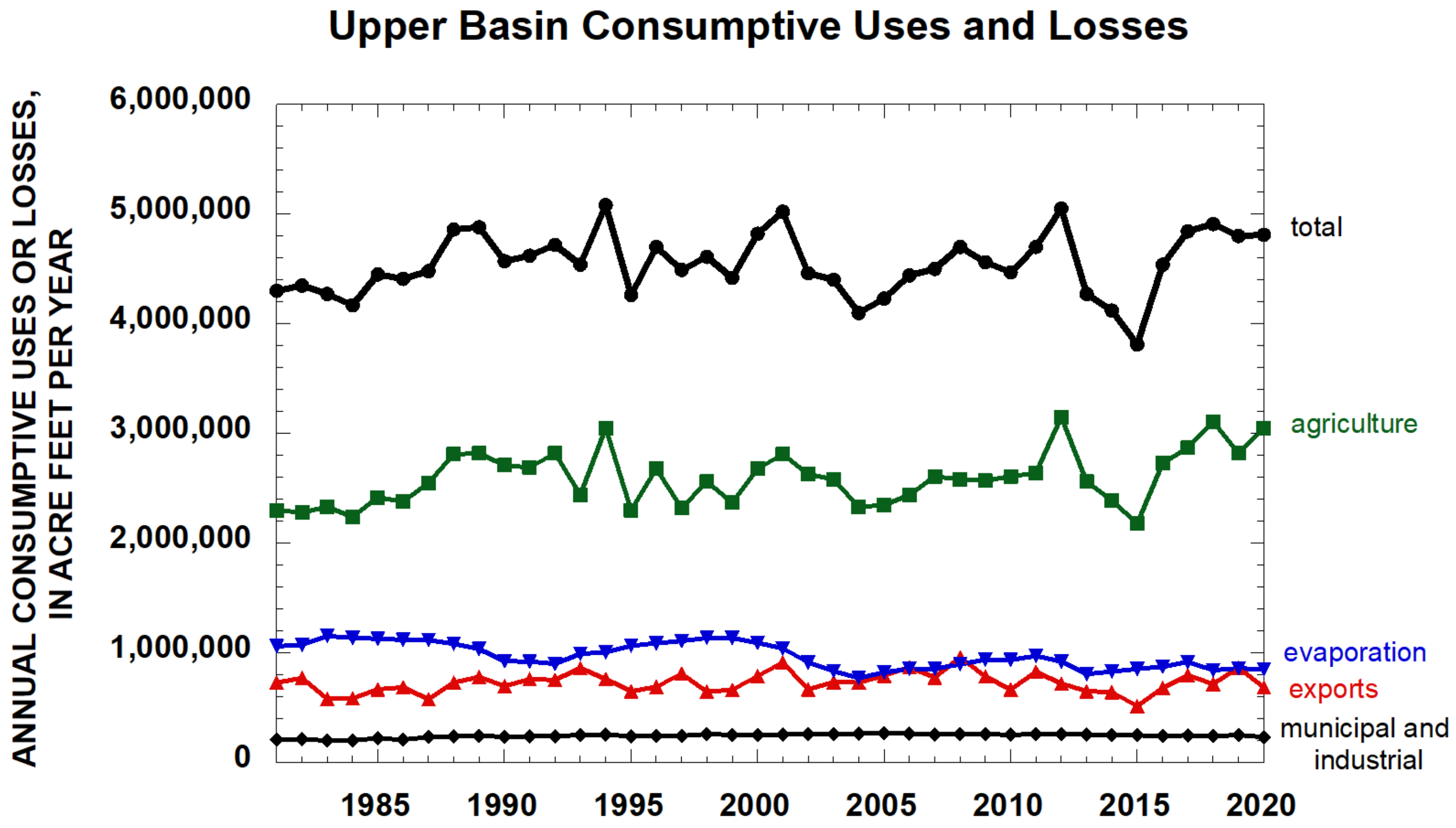
note: assumes Lake Powell gross evaporation

Range
2012: 5.05 maf/yr
2015: 3.81 maf/yr

Average consumptive uses, including state reservoirs (2001-2020):

- Colorado (2.14 maf/yr) (47%)
- Utah (0.904 maf/yr) (20%)
- New Mexico (0.410 maf/yr) (9%)
- Wyoming (0.402 maf/yr) (9%)
- Arizona (0.0332 maf/yr) (1%)
- CRSP gross evaporation (0.68 maf/yr) (14%)

state data includes state reservoir evaporation;
Sources: Reclamation Upper Basin CU&L Reports, updated with Reclamation .xlsx files



Water use: Upper Basin

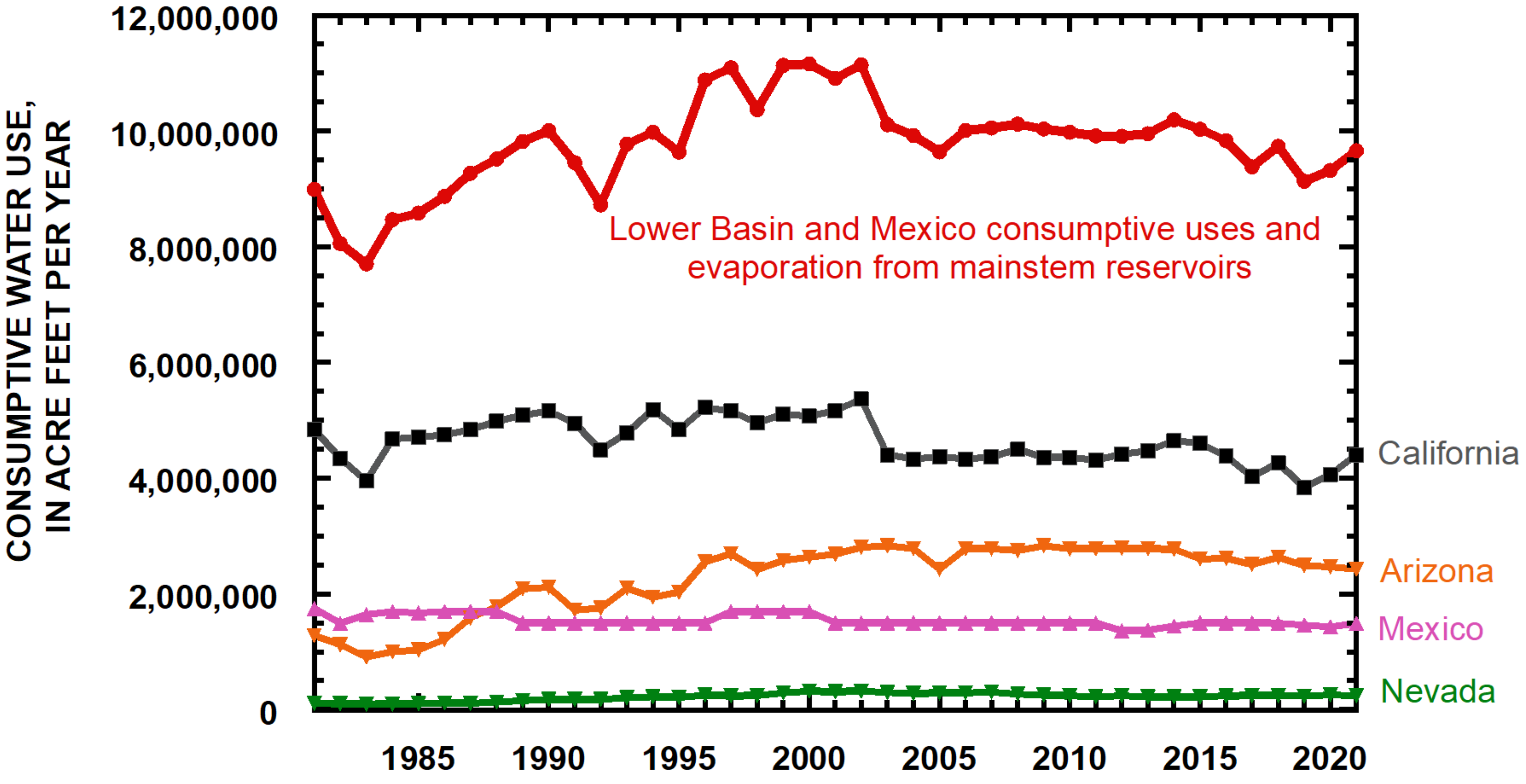
4.57 maf/yr (2001-2020)

note: assumes Lake Powell gross evaporation

Average consumptive water use and losses by economic sector (2001-2020)

- agriculture (2.65 maf/yr) (58%)
- evaporated from all reservoirs, including CRSP (0.910 maf/yr) (20%)
- export (0.750 maf/yr) (17%)
- industry (0.256 maf/yr) (6%)

all data: Reclamation Upper Basin CU&L Reports, updated with Reclamation .xlsx files; updated 21 S 2022



Total use in the Lower Basin (including Mexico) increased 1985-2003 with completion of the Central Arizona Project (CAP) Canal. California reduced its total use beginning in ~2003.

mainstem evaporation ~0.98 maf/yr (2001-2020)

Average consumptive uses in the Lower Basin (2001-2020): 7.39 maf/yr

- California (4.43 maf/yr)
- Arizona (2.70 maf/yr)
- Nevada (0.260 maf/yr)

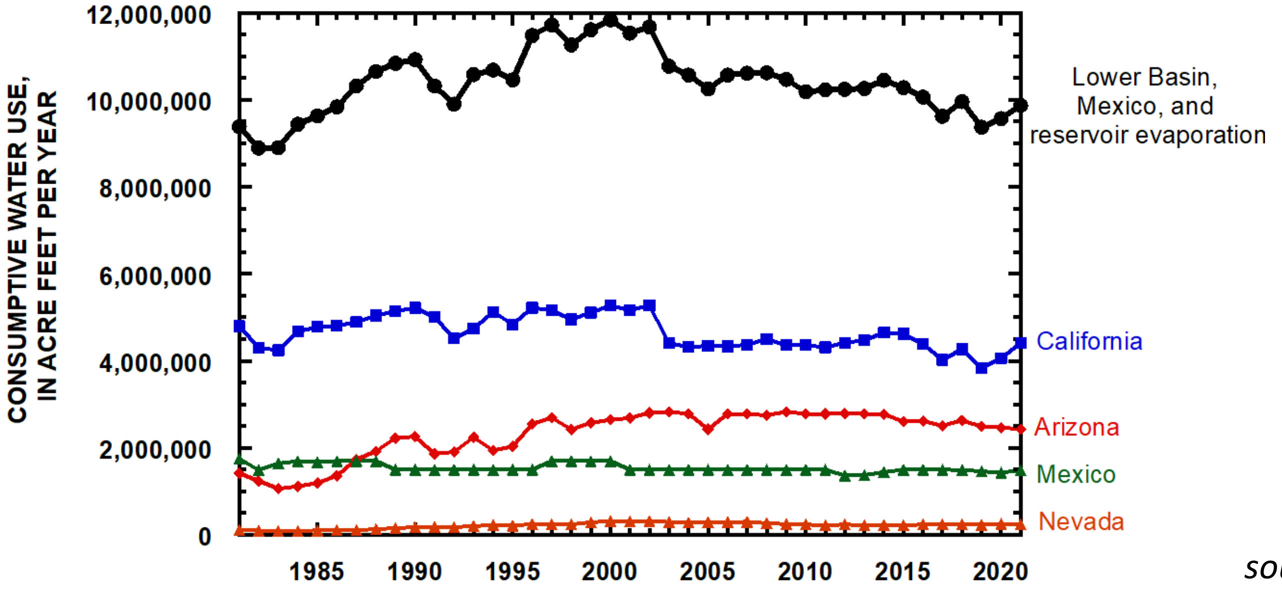
Average deliveries to Mexico (2001-2020): (1.55 maf/yr)

Total water use in Lower Basin and MX: 10.4 maf/yr

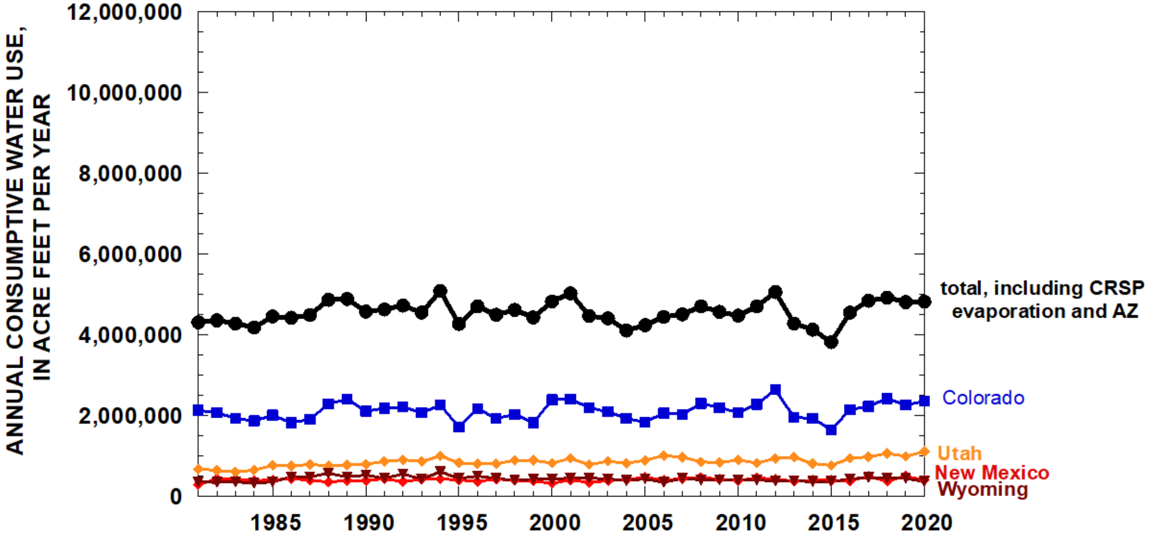
Lower Basin average (mainstem: 7.4 maf/yr) + Mexico (1.5 maf/yr) + evaporation (0.98 maf/yr)+ evapotranspiration (0.52 maf/yr)

CA– 4.4 maf/yr
AZ – 2.7 maf/yr
MX – 1.5 maf/yr
mainstem evaporation – ~0.98 maf/yr
mainstem riparian evapotranspiration = ~0.52 maf/yr
NV (mainstem) – 0.26 maf/yr

Lower Basin Consumptive Uses and Losses



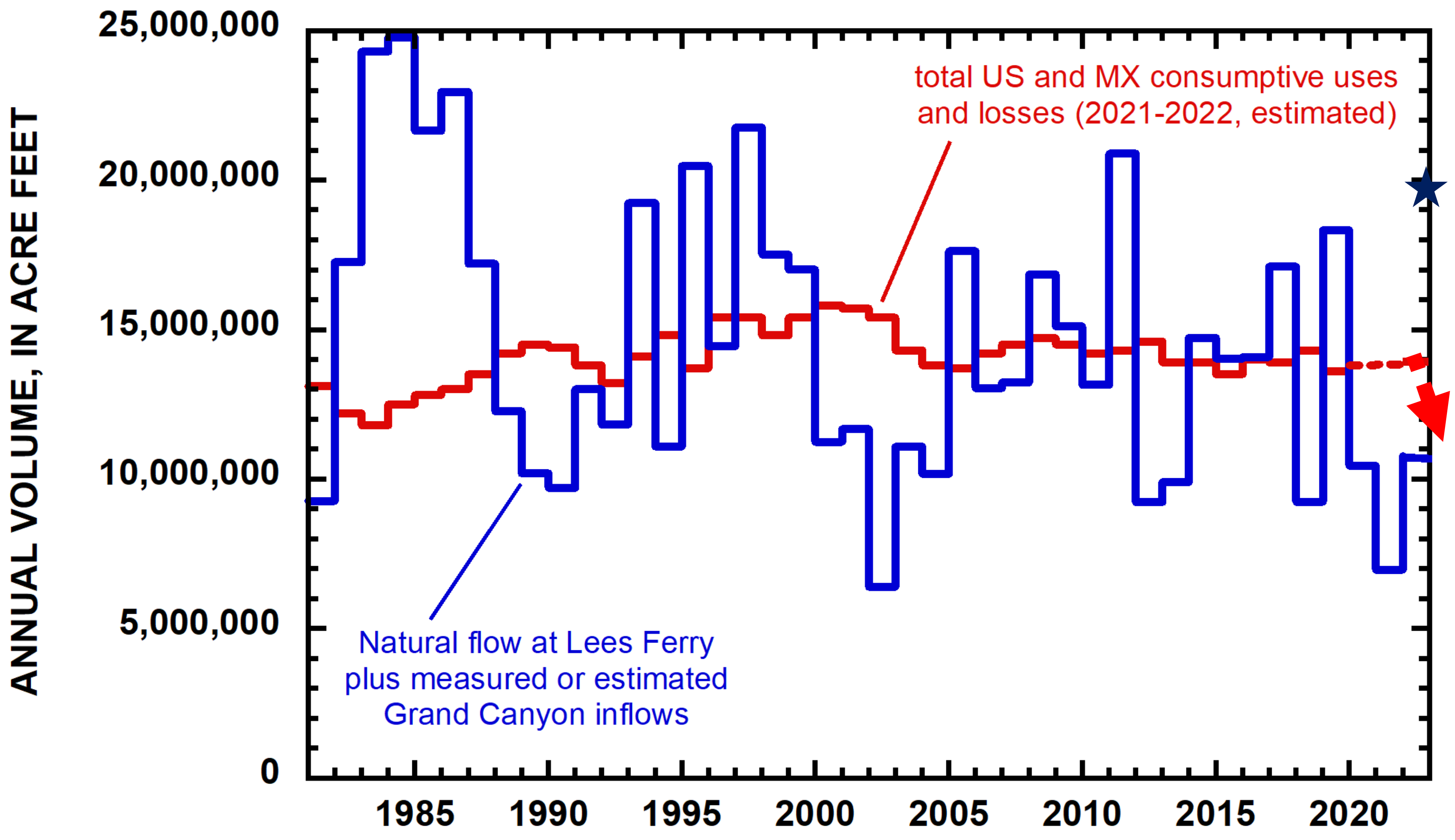
Upper Basin Consumptive Uses and Losses



Upper Basin consumptive uses = 4.6 maf/yr

CO – 2.1 maf/yr
UT– 0.82 maf/yr
reservoir evaporation – 0.91 maf/yr
NM – 0.38 maf/yr
WY – 0.37 maf/yr
AZ -- 0.030 maf/yr

state data do not include state reservoir evaporation; reservoir evaporation includes Powell gross evaporation
sources: Reclamation Upper Basin CU&L Reports, updated with Reclamation files
all data 2001-2020



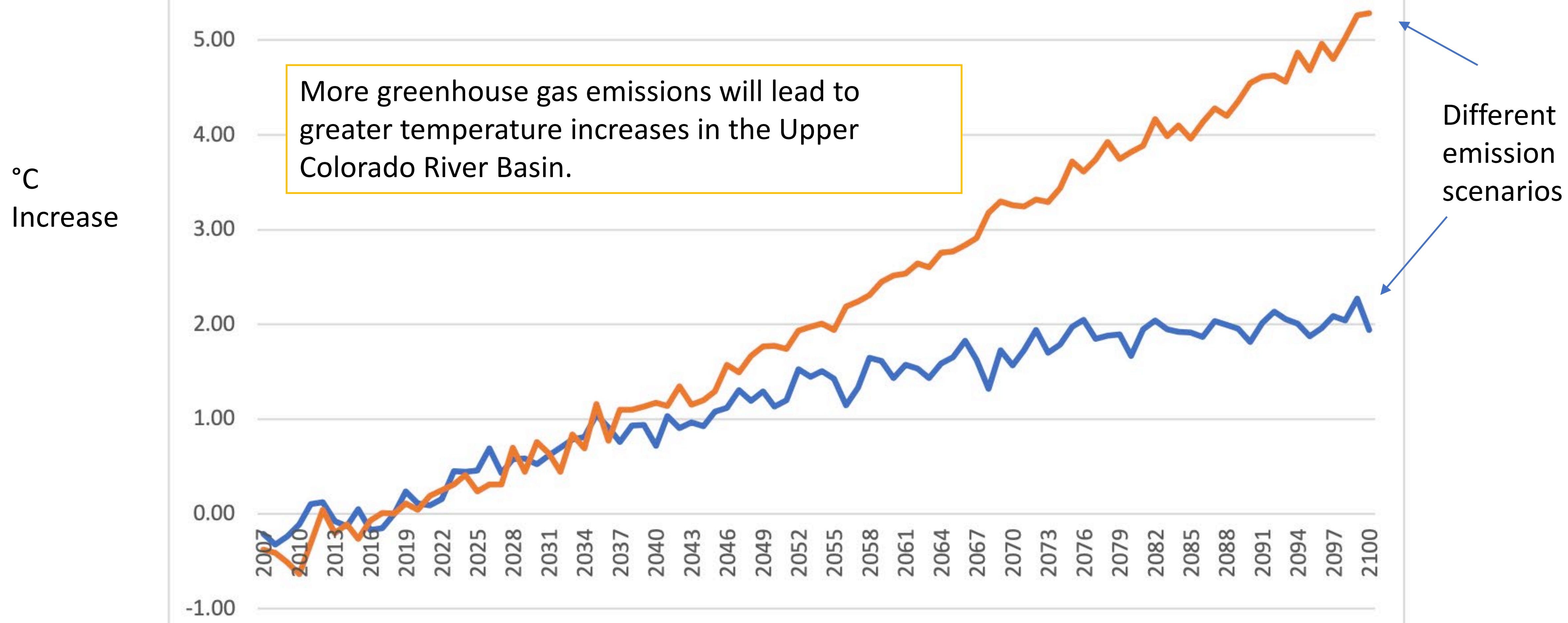
2-4 maf/yr reduction in CU&L is needed to be in balance with long-term average supply

2023 is a rare opportunity to recover significant reservoir storage

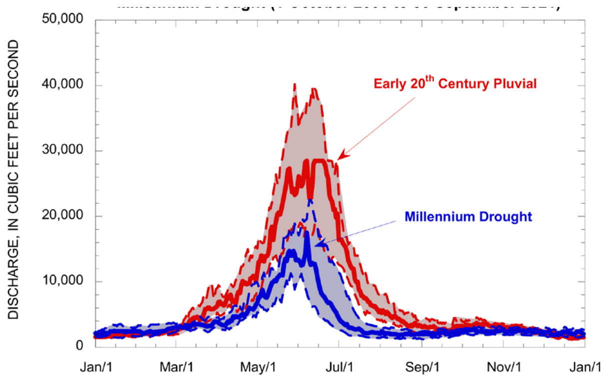
Long-term goal: reduce basin-wide CU&L to 11-12 maf/yr

Consumptive uses and losses should be significantly reduced

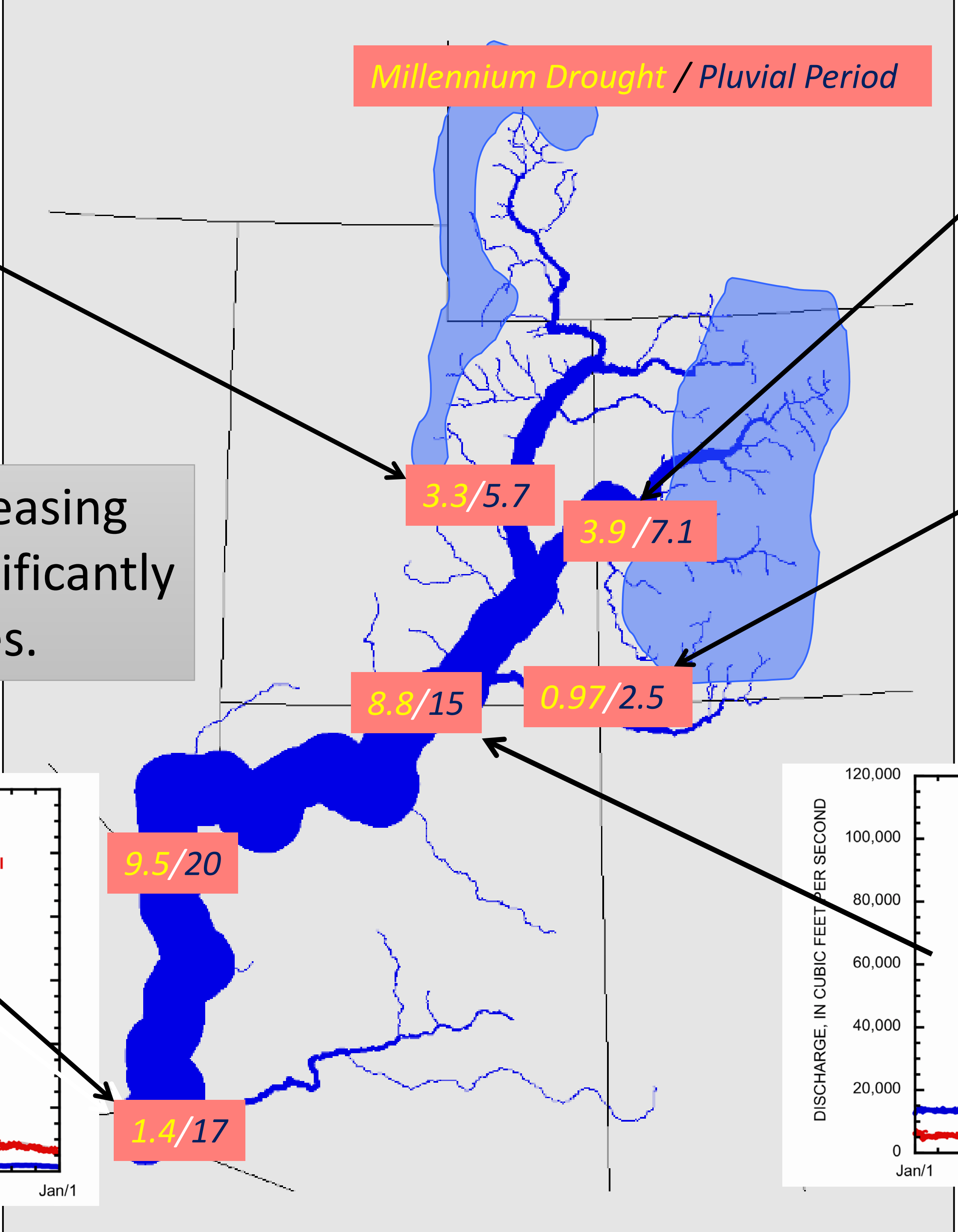
Progressive warming of the atmosphere is predicted to further reduce Colorado River natural runoff to 9.5 to 11.5 maf/yr (in 2050), necessitating further reductions in consumptive use and likelihood that Mead and Powell will never fill again

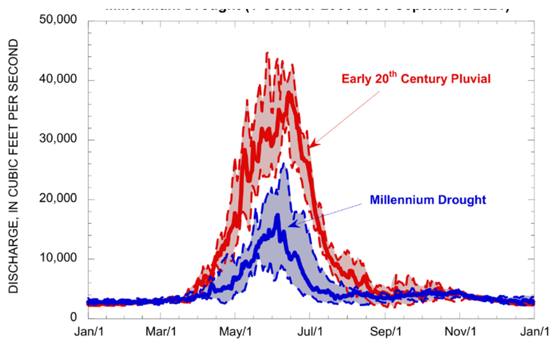


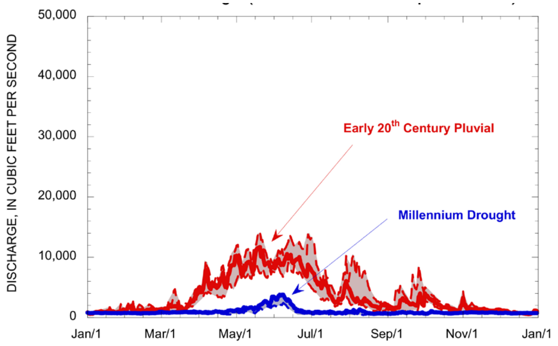
Multi-model ensemble CMIP5 upper Colorado River basin warming relative to 2018

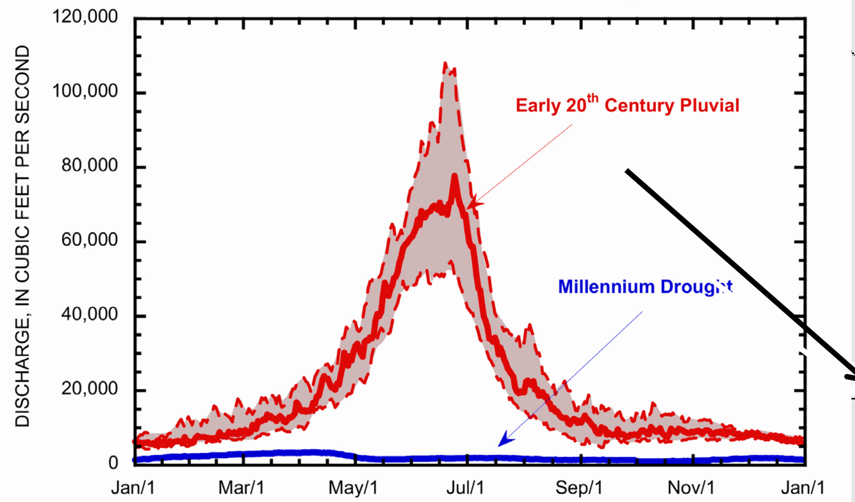


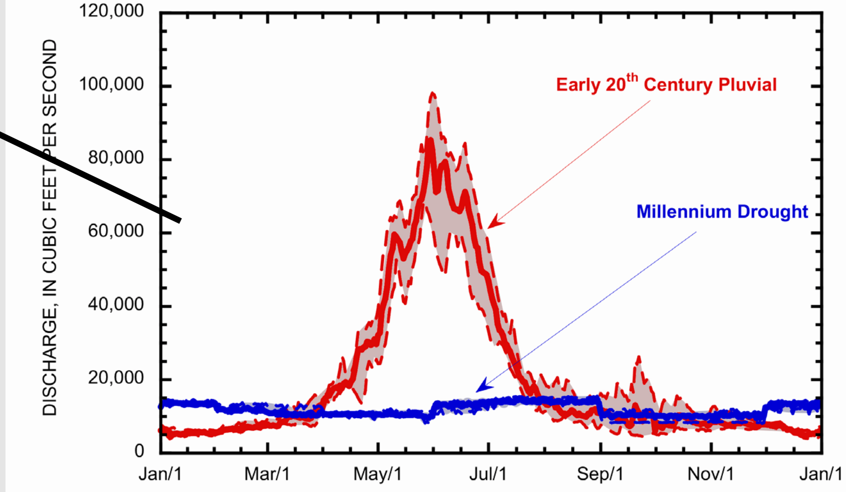
Climate change and increasing consumptive use have significantly reduced flow regimes.











Consumptive Uses from Lower River (2001-2021)

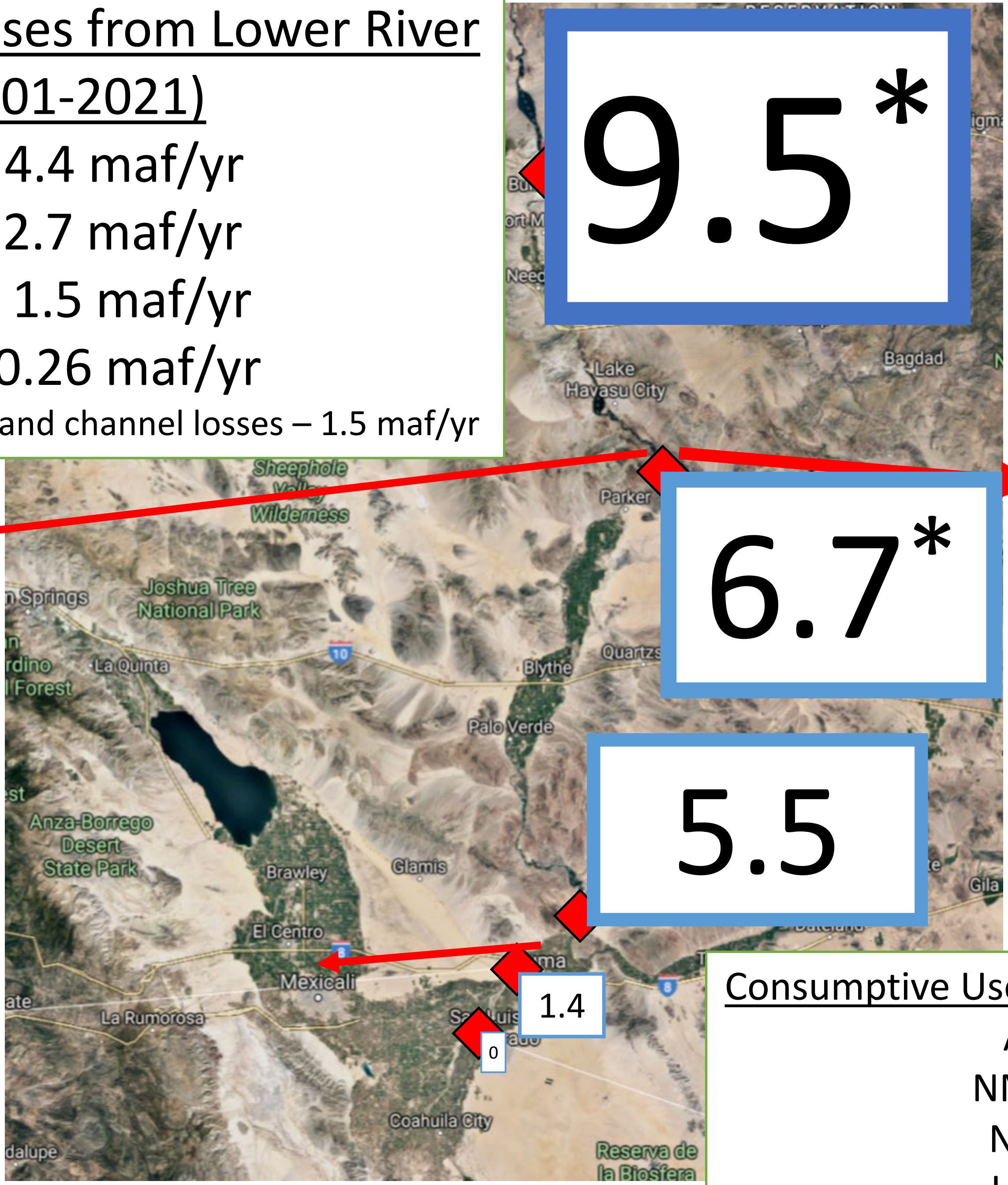
CA – 4.4 maf/yr

AZ – 2.7 maf/yr

MX – 1.5 maf/yr

NV – 0.26 maf/yr

Reservoir evaporation and channel losses – 1.5 maf/yr



gaging data 2001-2022, except as noted (*)

Consumptive Uses from Tributaries (2000-2005)

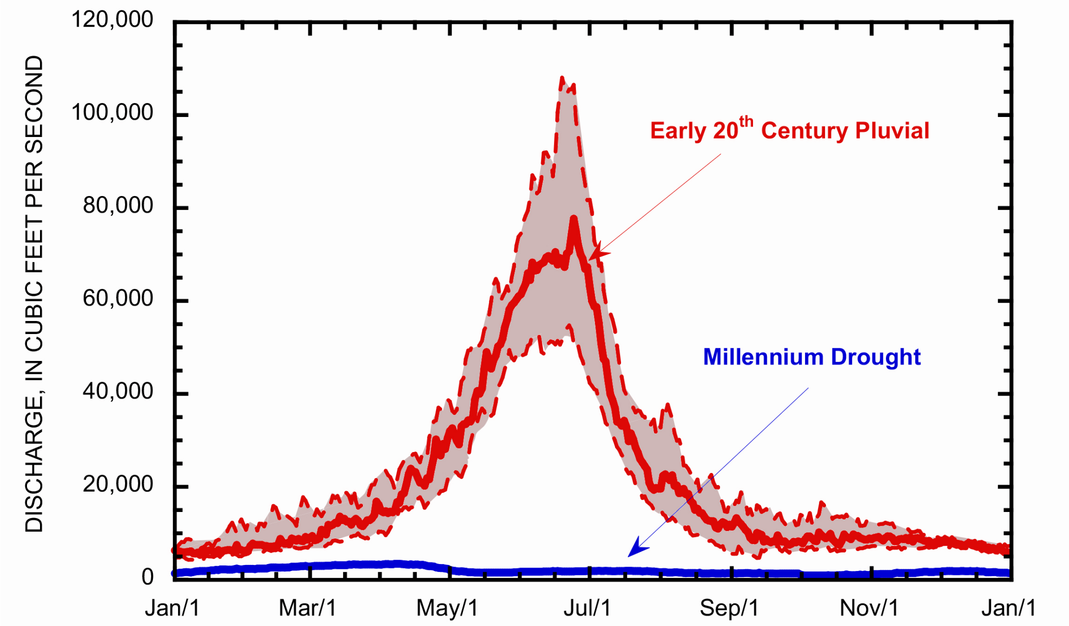
AZ – 2.0 maf/yr

NM – 0.028 maf/yr

NV – 0.11 maf/yr

UT – 0.12 maf/yr

The plight of the Delta reminds us that the most critical component of aquatic ecosystem restoration is water



America's Nile: in four parts

The Lower River:

~50% of river length is now reservoirs; elsewhere levees and channelization; 2-3 m of bed incision in parts; large reductions in stream flow

The Delta

Mostly confined in levees; no water

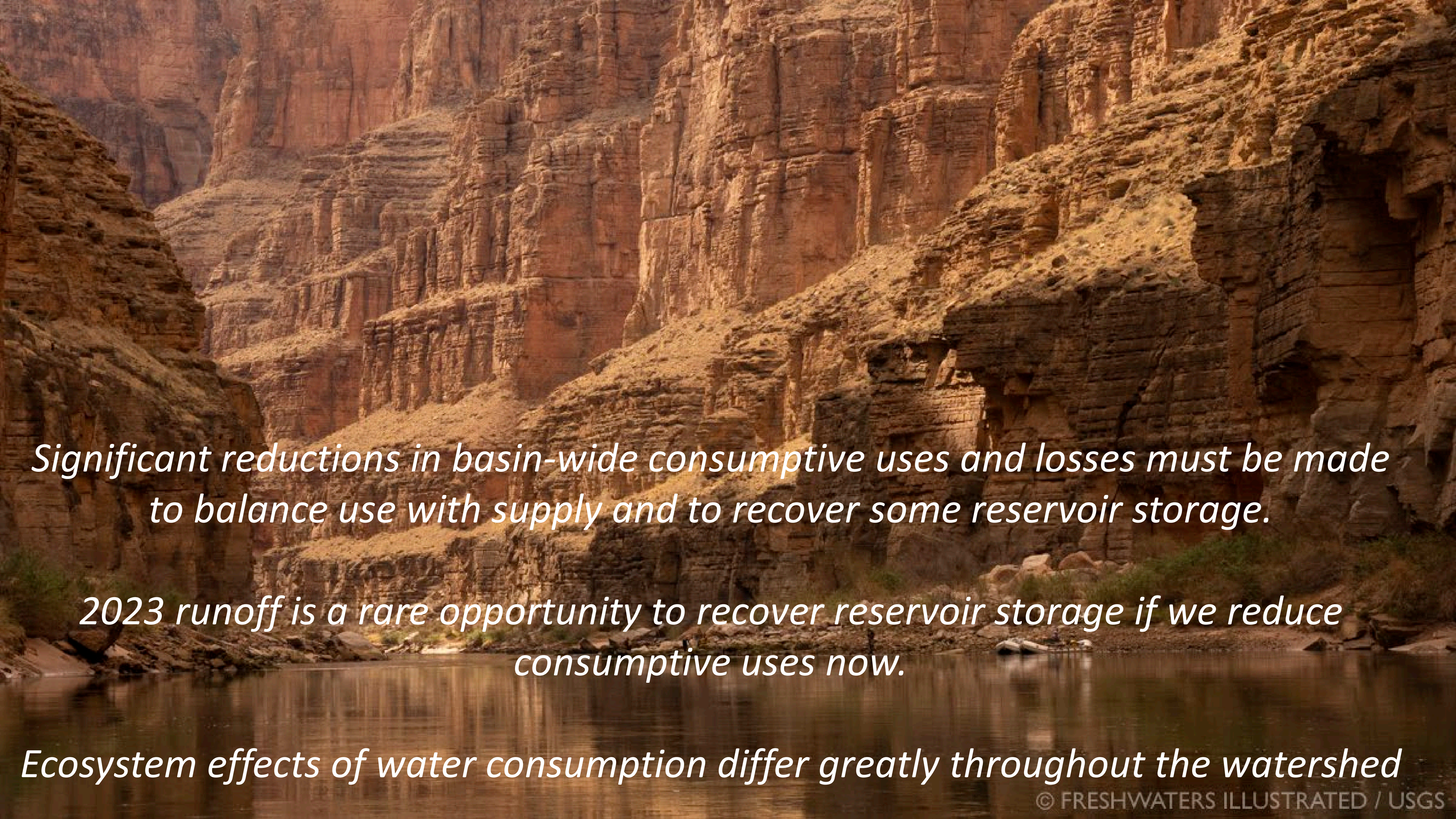
The Upper River:

Long segments of river remain; no levees or channelization; relatively natural hydrograph and sediment supply; fish assemblage of natives and non-natives

The Grand Canyon:

255-mile "wilderness" corridor with constrained flow regime, little sediment supply, and altered temperature regime

Schmidt, 2022


Significant reductions in basin-wide consumptive uses and losses must be made to balance use with supply and to recover some reservoir storage.
2023 runoff is a rare opportunity to recover reservoir storage if we reduce consumptive uses now.
Ecosystem effects of water consumption differ greatly throughout the watershed
© FRESHWATERS ILLUSTRATED / USGS