

# Future Water Policy in the Western US: The Colorado River

**Drought, Water, Wildfires and Climate Change in the Western U.S.:**

**Historical Context and the Road Ahead**

**American Meteorological Society's Environmental Science Seminar Series**

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*Western Water Assessment*

**Colorado**  
University of Colorado at Boulder



# Colorado River Basin Overview

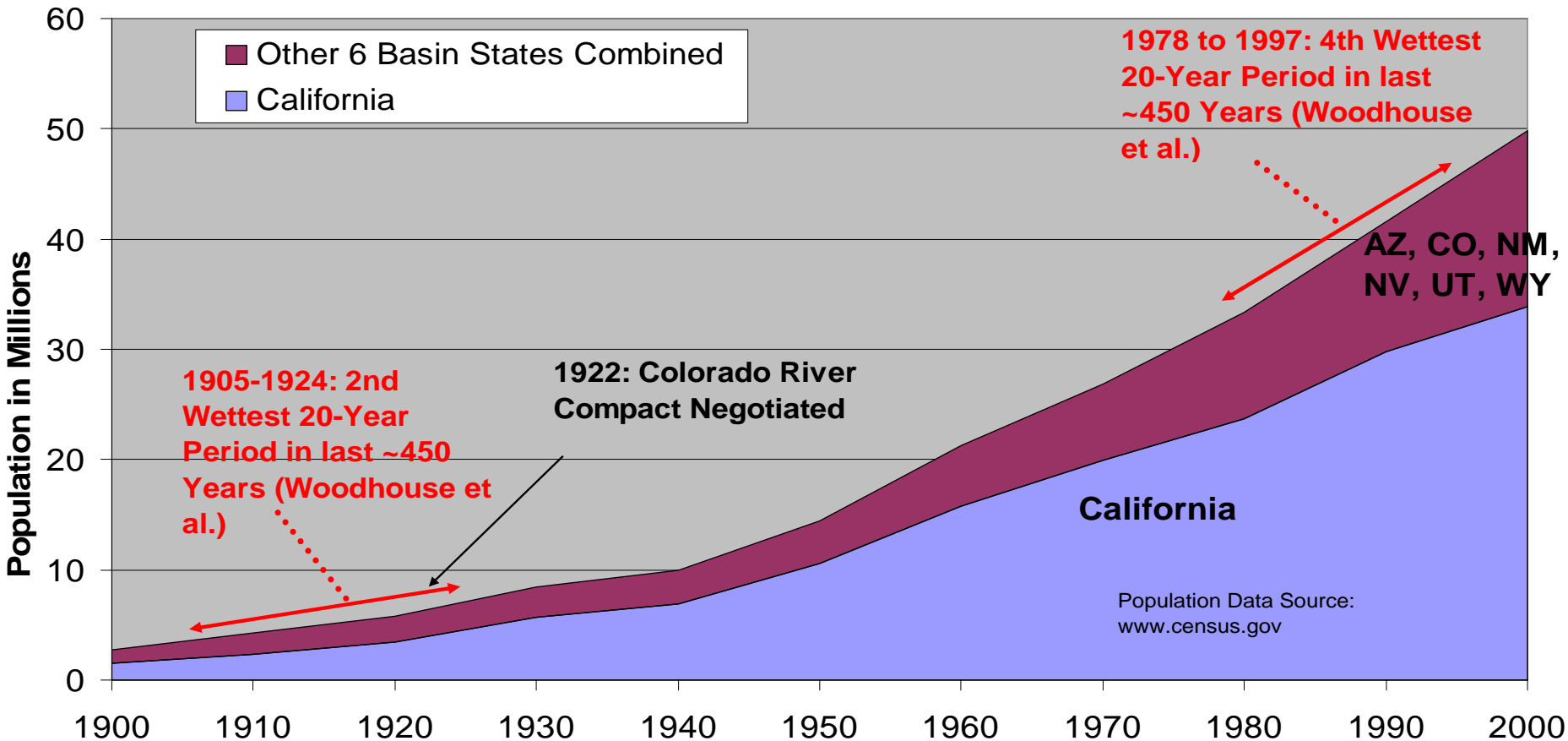


- Over 1,450 miles in length
- Basin makes up about 8% of total U.S. lands
- 60 MAF of total storage
- Average “natural” annual inflow of 15 MAF
- Irrigates 3.5 million acres
- Serves 30 million people
- Generates 10 billion KWh of electricity
- Provides more than 30 million visitor-days of recreation

Source: Reclamation

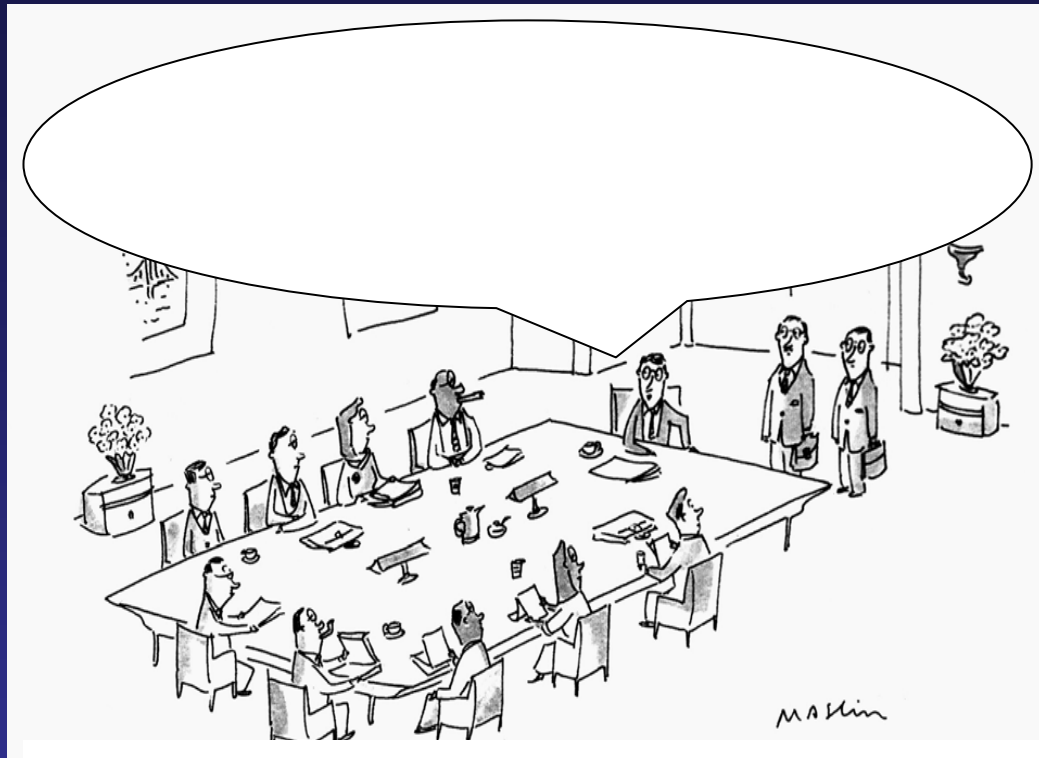


# Population Growth of Colorado River Basin 1900-2000



# Key Elements of Law of the River

- Allocation rules:
  - Two interstate compacts (1922, 1948)
  - Treaty with Mexico (1944)
  - Decades-long Supreme Court case (*Arizona v. California*, 1963)
- Several major water development acts (e.g., 1928, 1956, 1968)
- Sophisticated reservoir operations rules

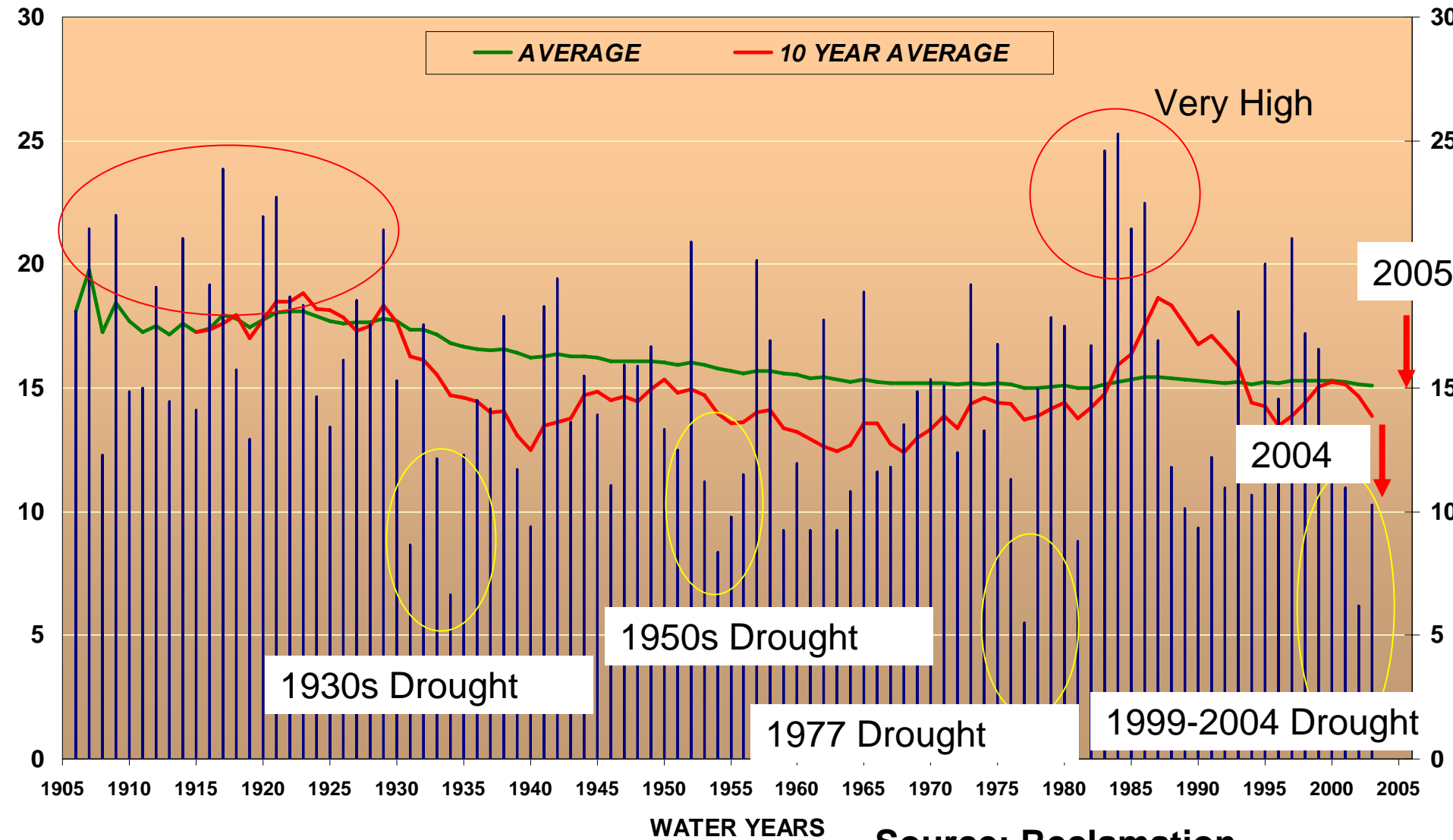


Basin States Negotiating Teams

# NATURAL FLOW

## Colorado River at Lees Ferry, AZ

### Water Year 1906-2003



Current data as of 9/23/2005 (subject to change)  
check <http://www.usbr.gov/lc/riverops.html> for periodic updates

Source: Reclamation

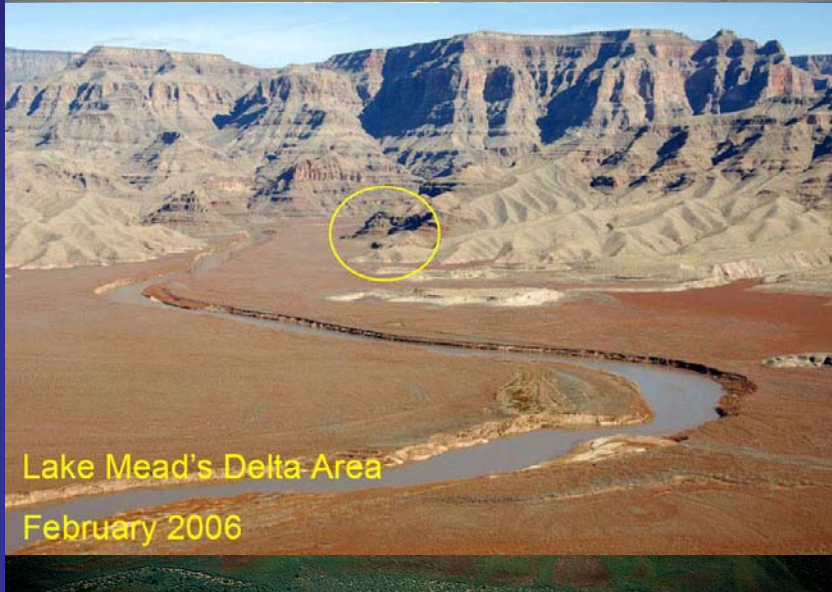


Lake Mead's  
Delta Circa 1999



A.

Lake Powell – June 29, 2002



Lake Mead's Delta Area  
February 2006



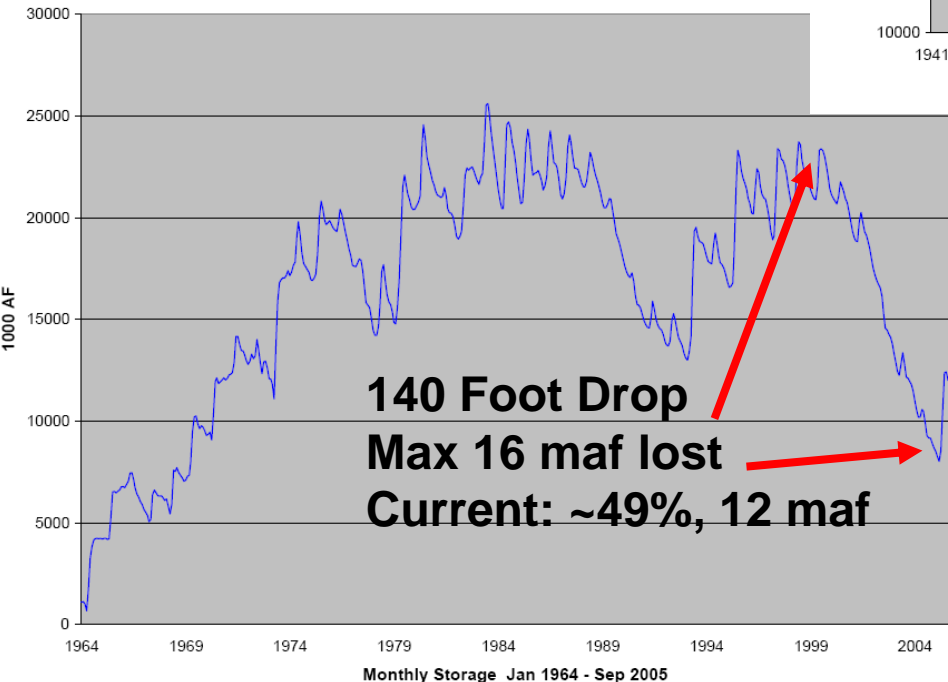
B.

Lake Powell – December 23, 2003

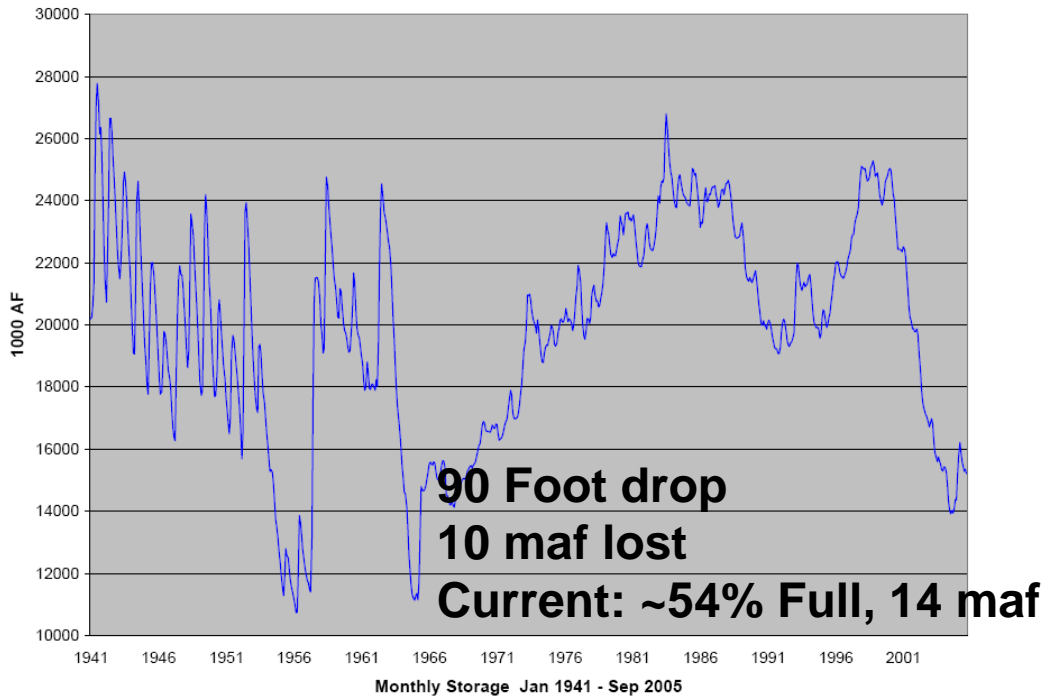


# Declining Lakes Mead and Powell

Lake Powell



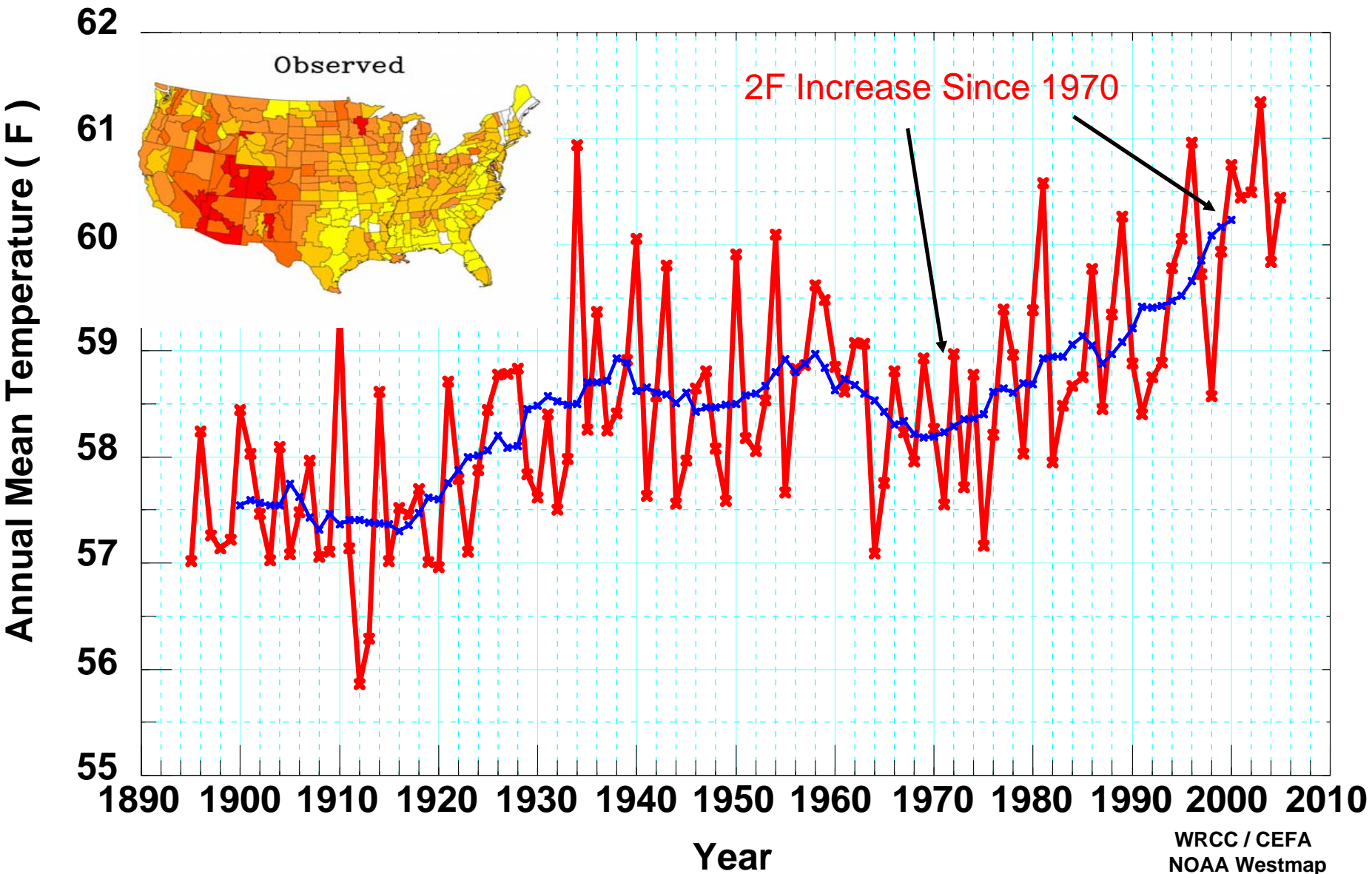
Lake Mead



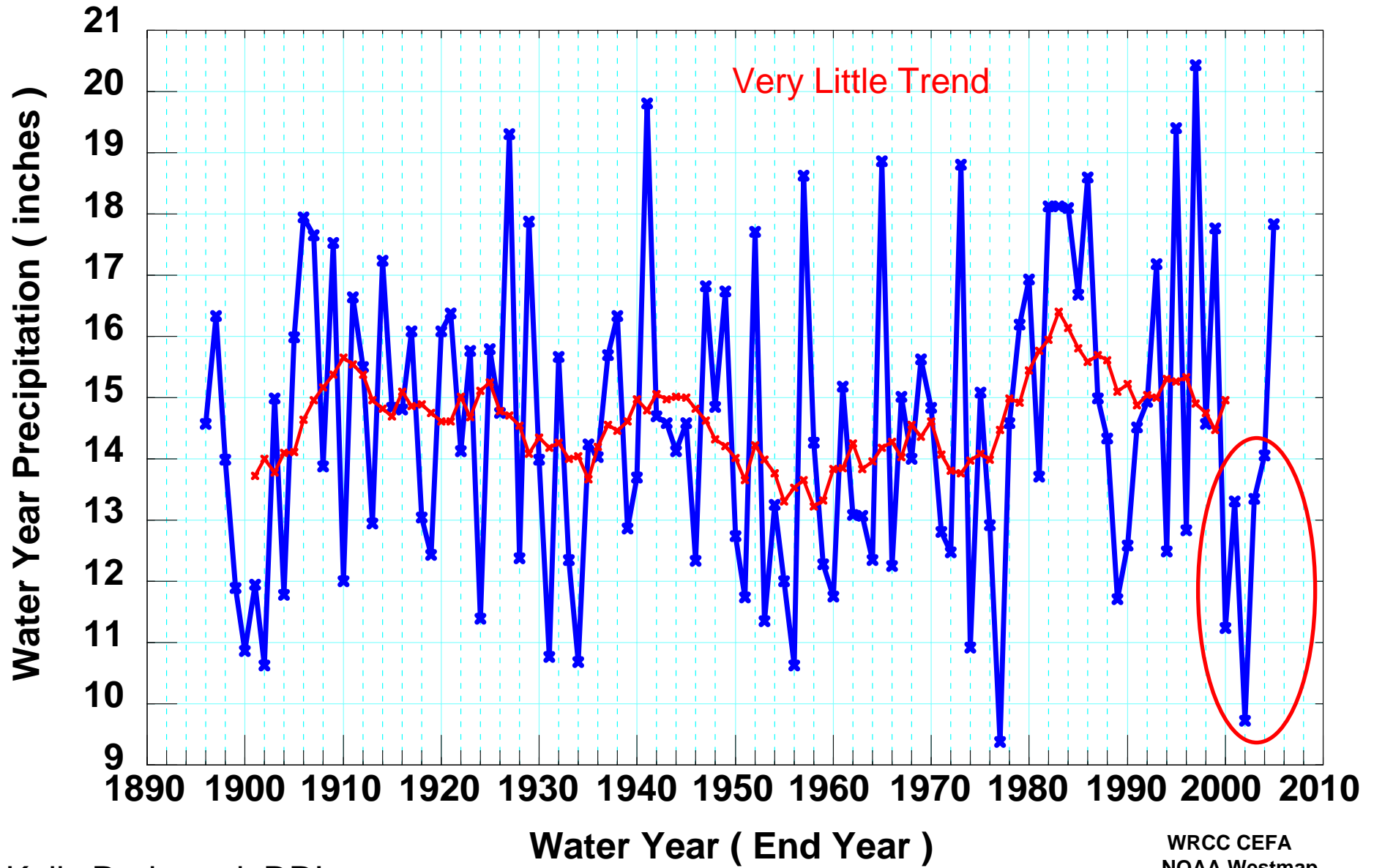
# Lower Colorado Basin Mean Annual Temperature.

Units: Degrees F. Annual: red. 11-year running mean: blue

Data from PRISM: 1895-2005.



**Upper Colorado River Water Year Precipitation.**  
**October through September. Units: Inches.**  
**Data from PRISM. Blue: annual. Red: 11-yr mean.**

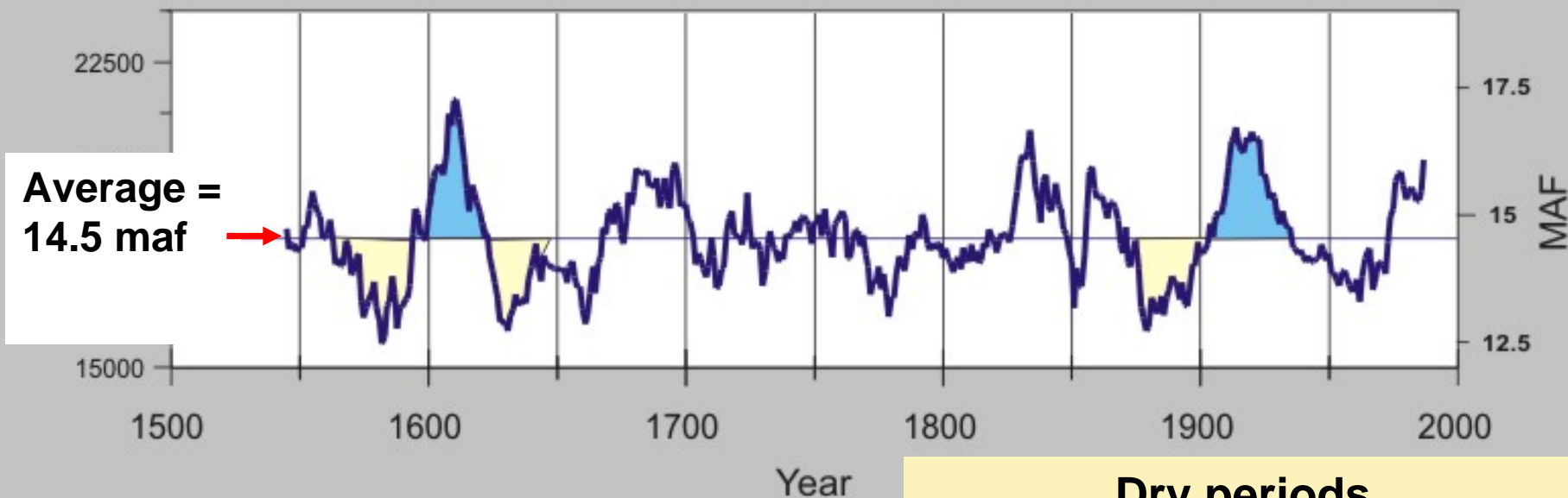


WRCC CEFA  
NOAA Westmap

Kelly Redmond, DRI

# Woodhouse, Meko, Gray New Reconstruction of Lees Ferry Streamflow, 20-year moving average, 1536-1997

Source: Woodhouse



Note that 20<sup>th</sup> Century Dry Periods are not especially dry....

## Dry periods

Lowest 20-yr avg.	Lowest 25-yr avg
1573-1592 (1)	1622-1646 (1)
1622-1641 (3)	1623-1647 (2)
1870-1889 (4)	1878-1902 (3)
1953-1972 (35)	1953-1977 (28)



# Current Thinking

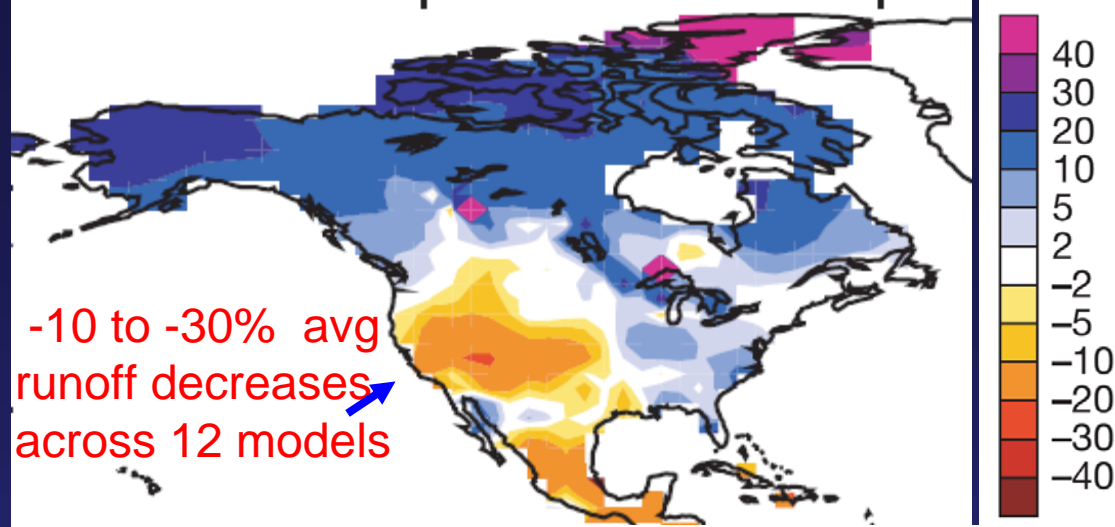
- PRELIMINARY Results -- lots of additional analysis required. Models are not predictions.

- 10 to 30% Less Runoff

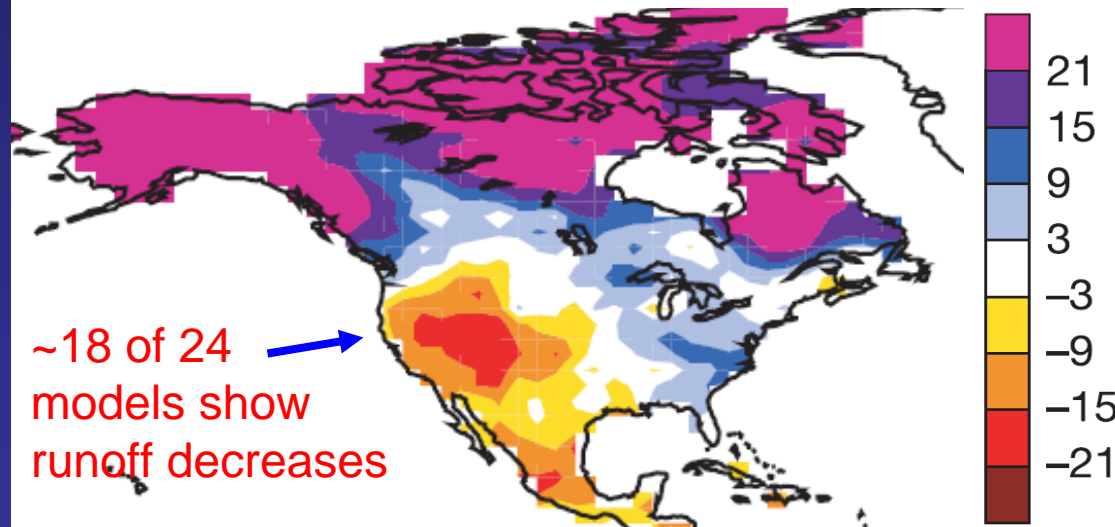
- About ¾ of Models Agree

- Decreases in runoff due to temperature increases, perhaps small precipitation declines

- Dryness consistent with world-wide poleward movement of deserts from ~30 N/S Latitude



Relative Change in Runoff 2041 to 2060 relative to 1900-1970 Runoff from 12 Models



Number of Models Runs showing a positive change minus number showing negative change. ("-" = dry agreement)

Milly, et al, Nature 2005



# A Big Problem in the Lower Basin

- Avg Lake Mead Inflows = 9.0 maf
  - 8.23 maf from Powell
  - 0.77 maf tributaries below Powell
- Avg Lake Mead Outflows = 10.4 maf
  - 7.5 maf LB States (4.4 CA, 2.8 AZ, 0.3 NV maf)
  - 1.5 maf Mexico
  - 1.4 maf Evap + Delivery Losses
- Net Balance = **-1.4 maf/year (Mead at 14 maf now)**

# A Lurking Problem in the Upper Basin

- How Much Water Left to Develop?
  - Current uses: ~4.7maf
  - At 13.5 maf, ~0.5 maf left to develop
  - At 15.0 maf, ~ 1.5 maf left to develop
- ‘Hydrologic Leftovers’ Creates Uncertainty
- Upper Basin Compact has significant penalties for overusing water, but overuse can only be determined after the fact

# Shortage and Reservoir Operations EIS Status

- Begun 2005, DEIS 12/06, Finish 2007
- Feb '06 Innovative Basin State's Proposal
  - Credit for imported water into basin
  - Leasing from Farmers in other states via water banking
  - NV to build an overflow reservoir to capture wasted water
  - Agreement about what shortages at what reservoir levels
  - New Rules for Operating Mead and Powell
- Environmental Community wants to let Mexico participate in some of the water banking

# Long Term Policy Issues

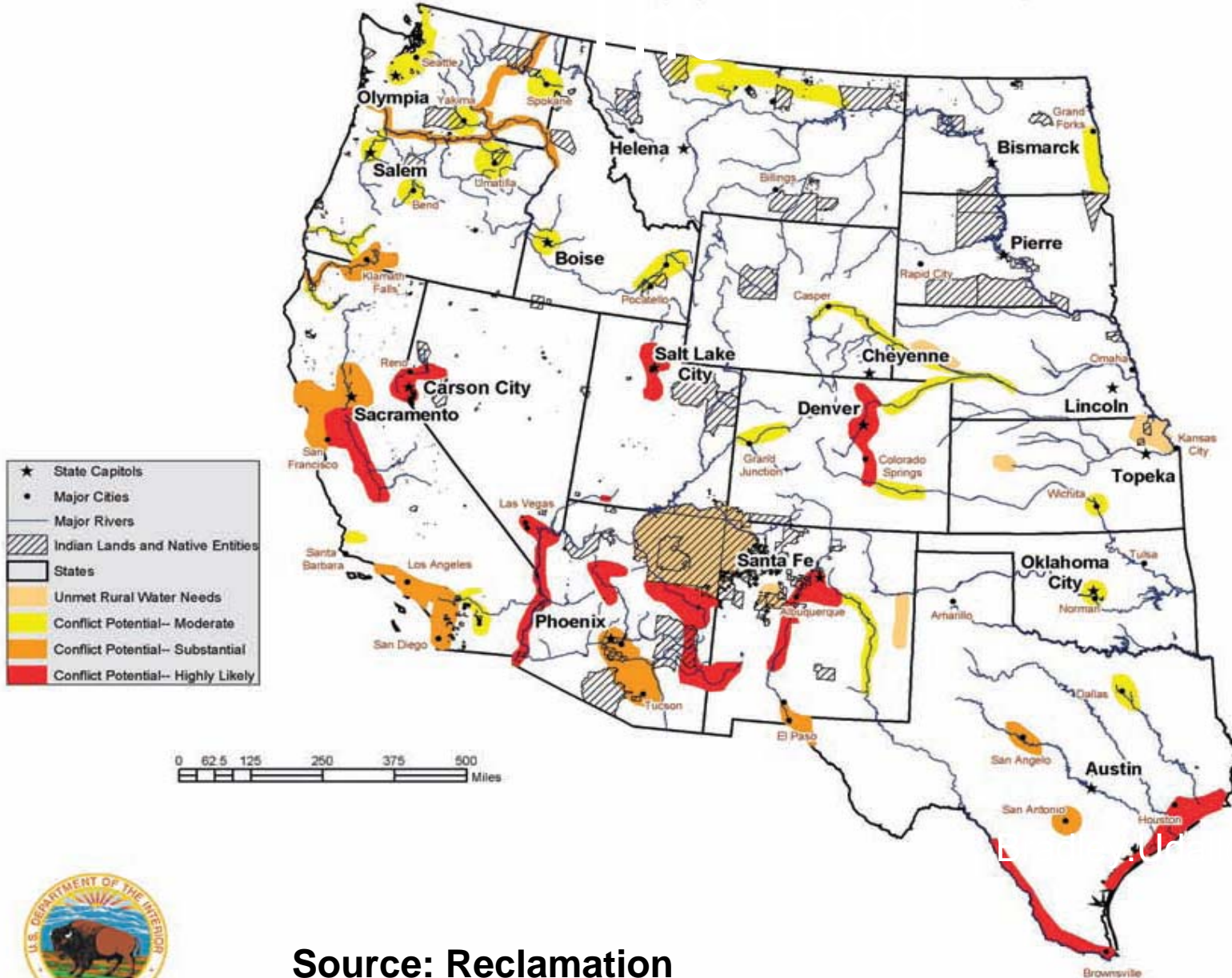
- Basin-wide Issues
  - Power Revenues from Powell and Mead
  - Interest in Weather Modification and Other Flow Augmentation
- Lower Basin Shortages
  - Arizona first to receive reductions – 1968 Act Agreement
  - AZ strong push for Augmentation
  - Arizona remaining Native American Reserved Rights Settlements
  - Nevada very little capacity to absorb shortage
  - S. California depends less than half on CR water
- Upper Basin Shortages
  - Tremendous uncertainty re future hydrology and LB deliveries
  - Colorado Front Range Municipalities 30+% Dependent on CR
  - UB growth depends on using additional water
- Colorado River Delta
  - No flow in most years and none likely for years to come



# The End

## Potential Water Supply Crises by 2025

(Areas where existing supplies are not adequate to meet water demands for people, for farms and for the environment)



Source: Reclamation



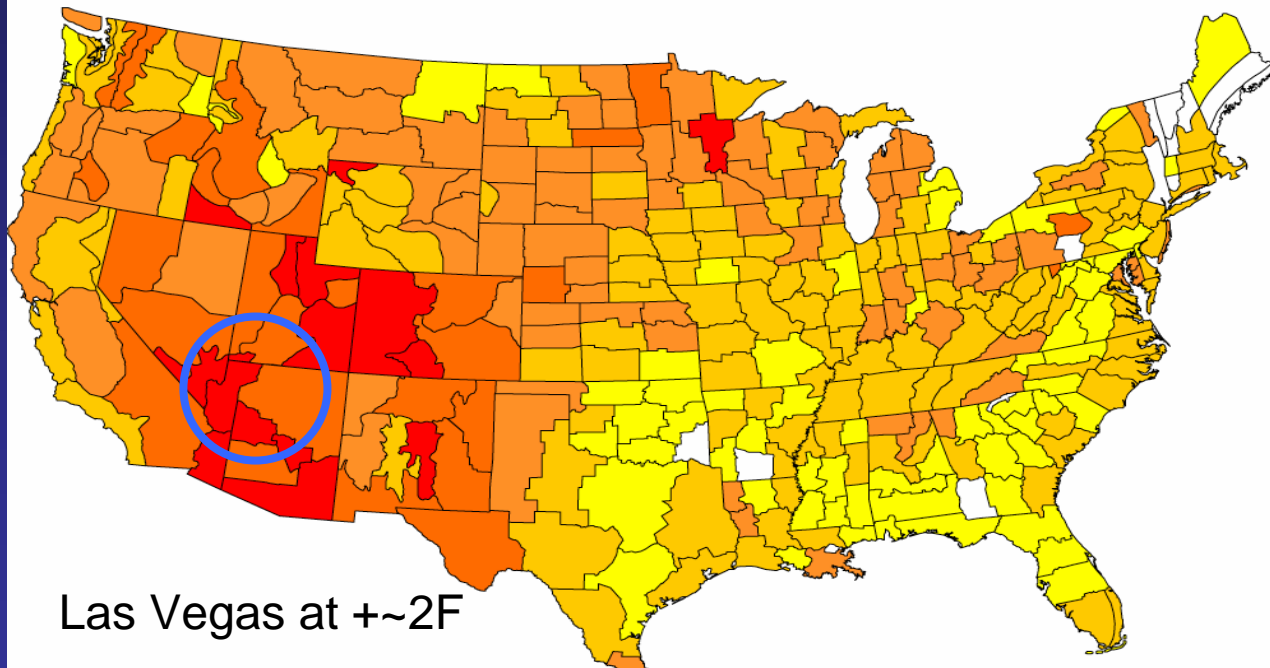
# Extra Slides



# Last 4 Years Were Warm !

U.S. Annual Temperature Departure  
(2000-04) minus (1961-90)

## Observed

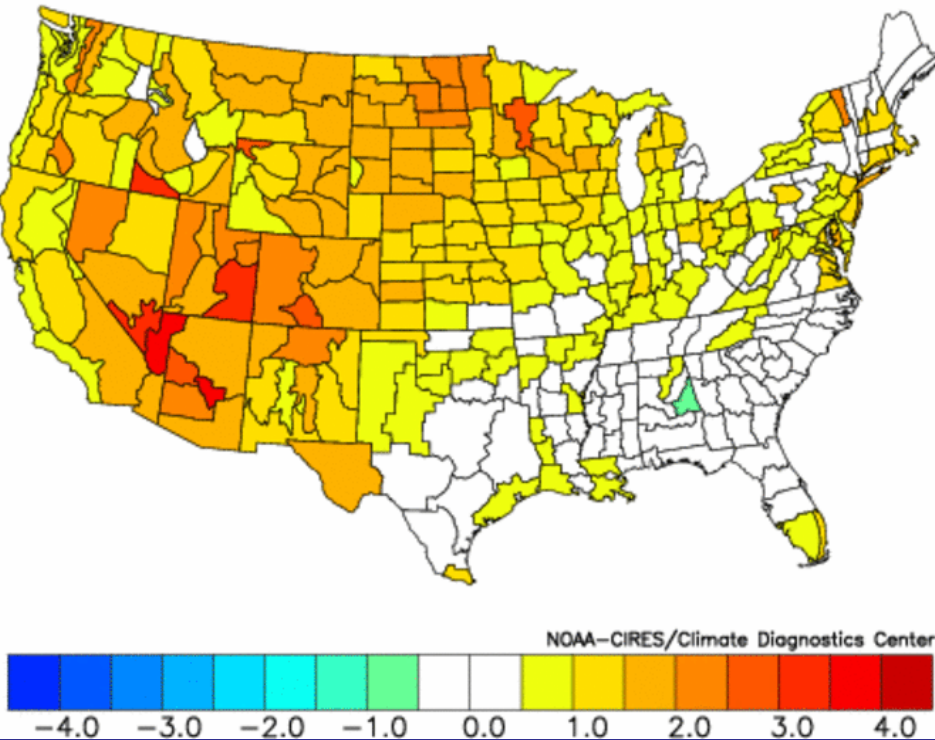


Degrees Celsius

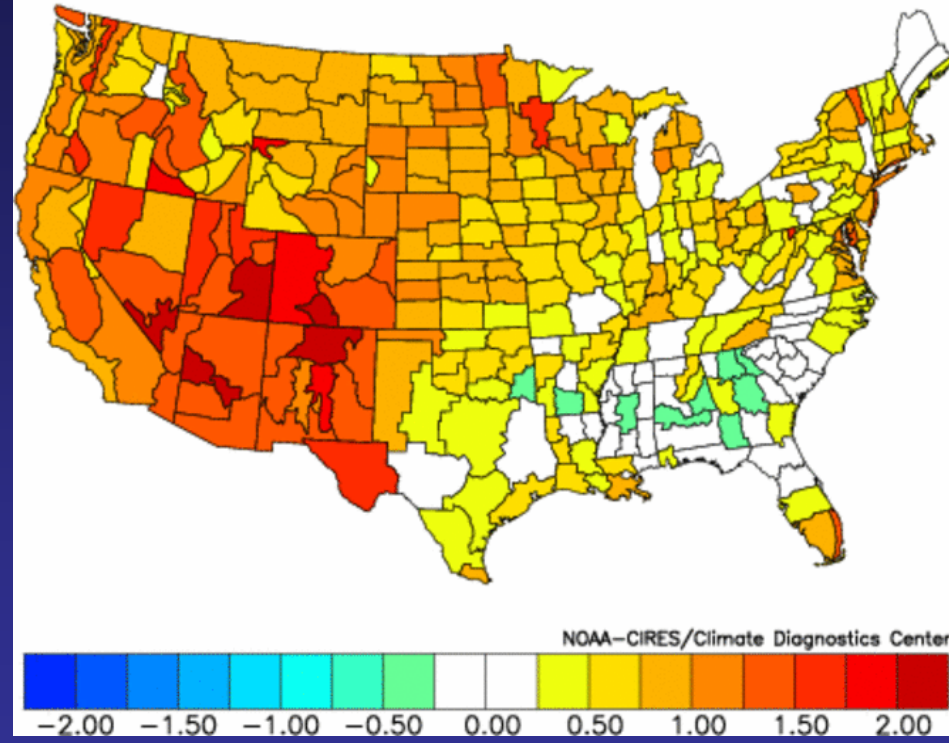


# Annual Mean Temperatures, 2000-2005. Departures from 1895-2000 Mean.

Composite Temperature Anomalies (F)  
Jan to Dec 2000 to 2005  
Versus 1895-2000 Longterm Average



Composite Standardized Temperature Anomalies  
Jan to Dec 2000 to 2005  
Versus 1895-2000 Longterm Average

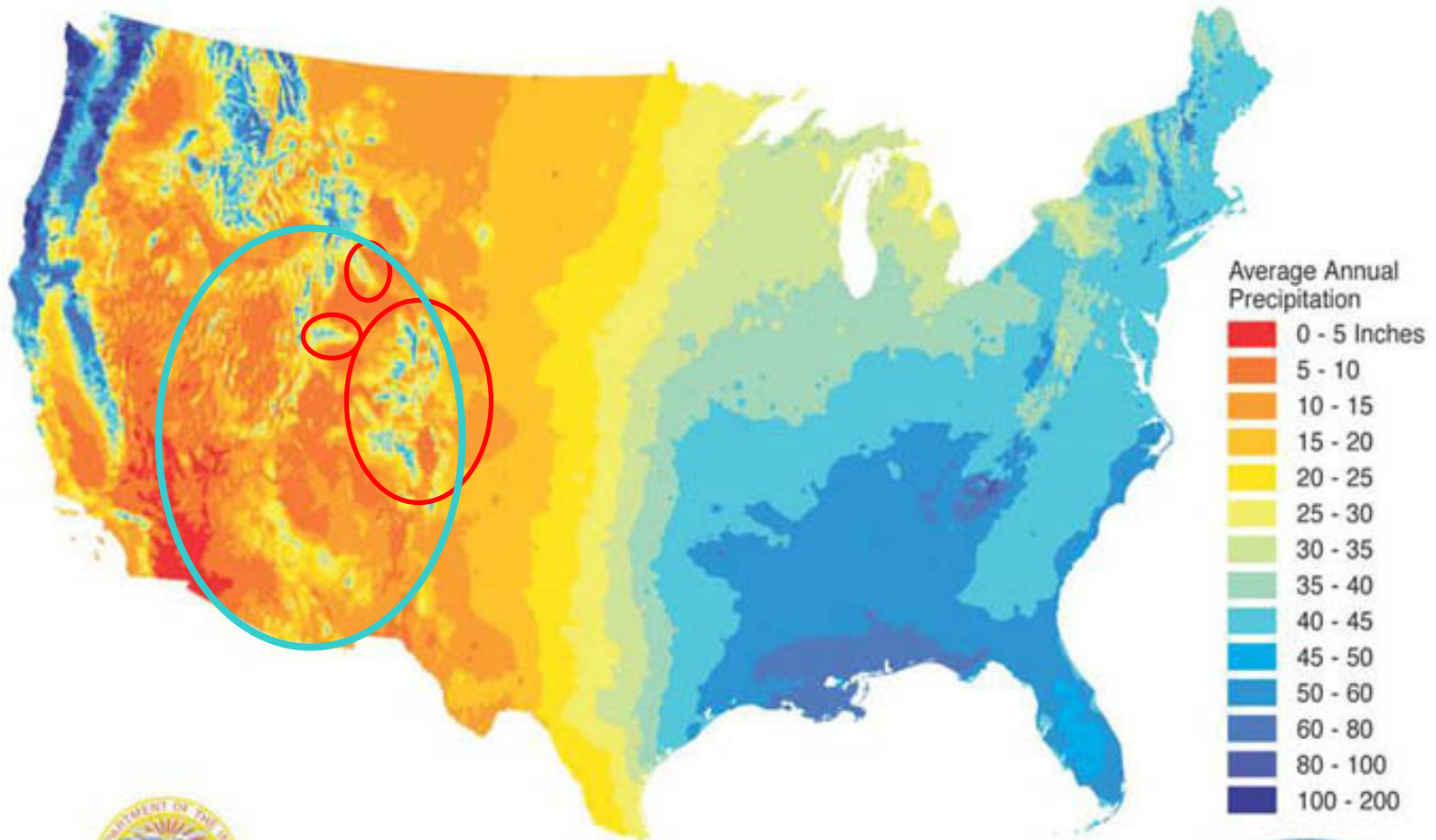


**Non-standardized. Units: Degrees F.      Normalized (standard deviations).**



**The West dominates recent U.S. warming.**

# Average Inches of Annual Precipitation in the United States 1961-1990

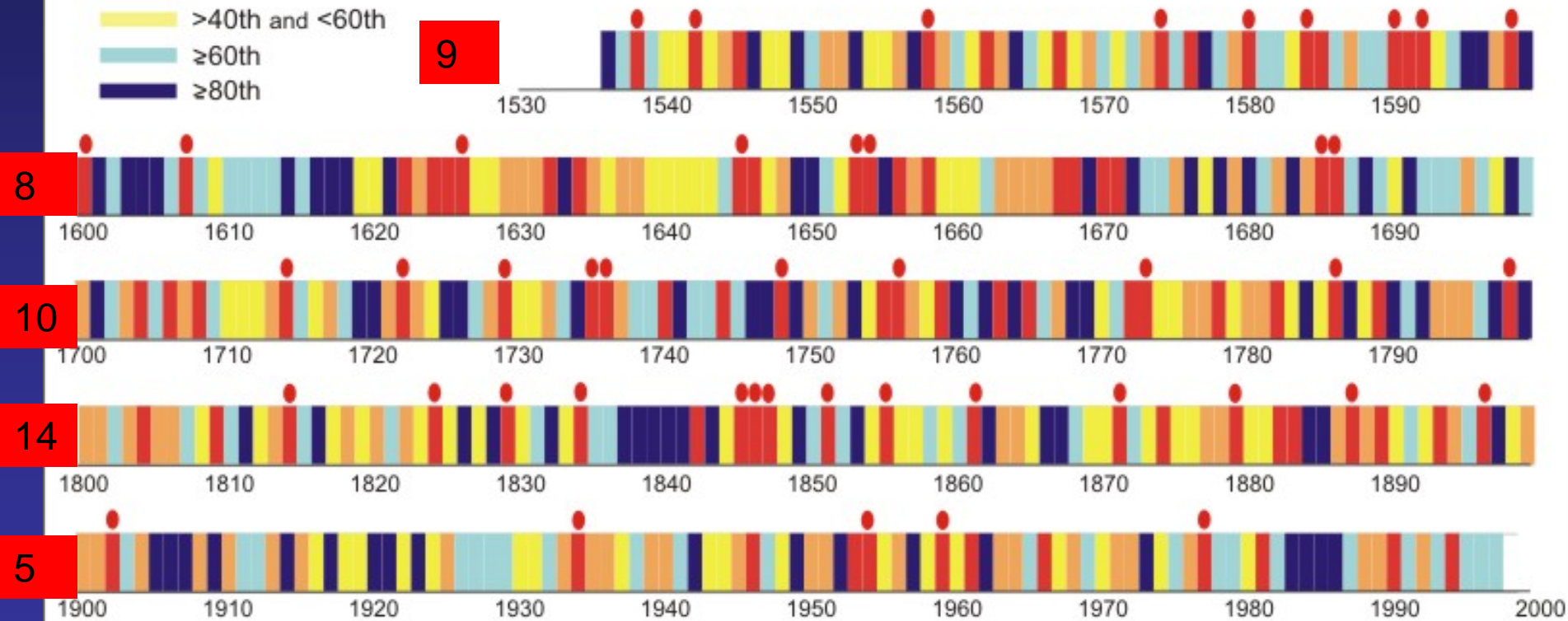
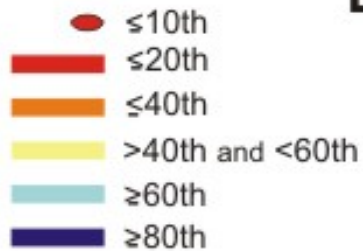


Source: USDA-NRCS: <http://www.ftw.nrcs.usda.gov/prism.html>



# There are other ways to examine features of the Lees Ferry streamflow reconstruction

## Lees Ferry flow years categorized by percentile, 1536-1997



**Extreme events are not evenly distributed over time**



# Lees Ferry Reconstruction, 1536-1997

## 5-Year Running Mean

Assessing the 1999-2004 drought in a multi-century context

