THE FUTURE OF THE COLORADO RIVER PROJECT

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USGS science for a changing world

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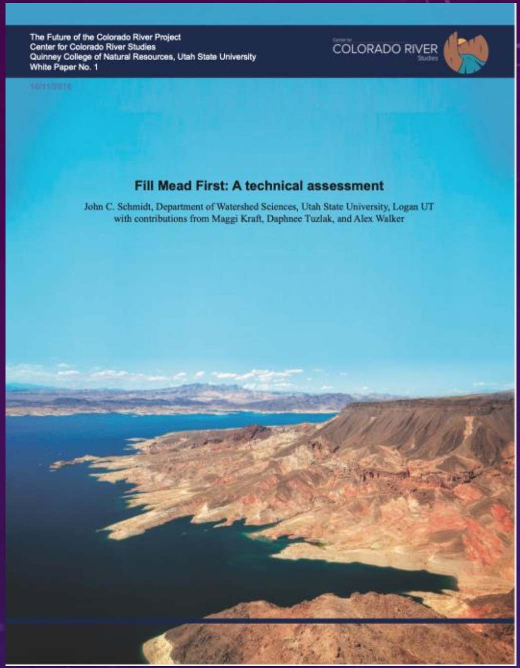
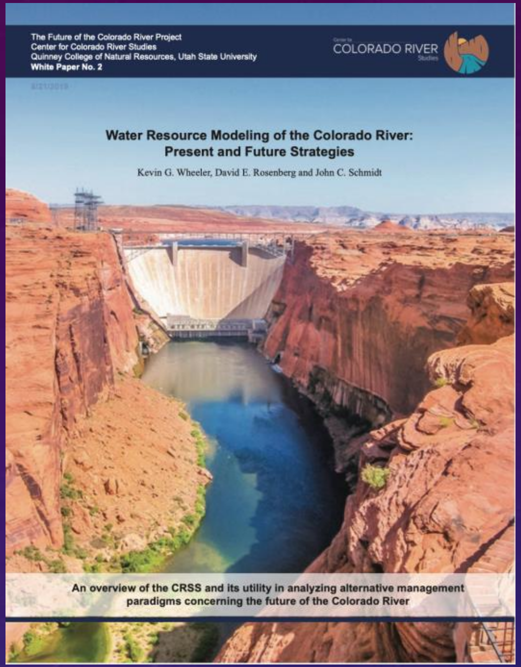
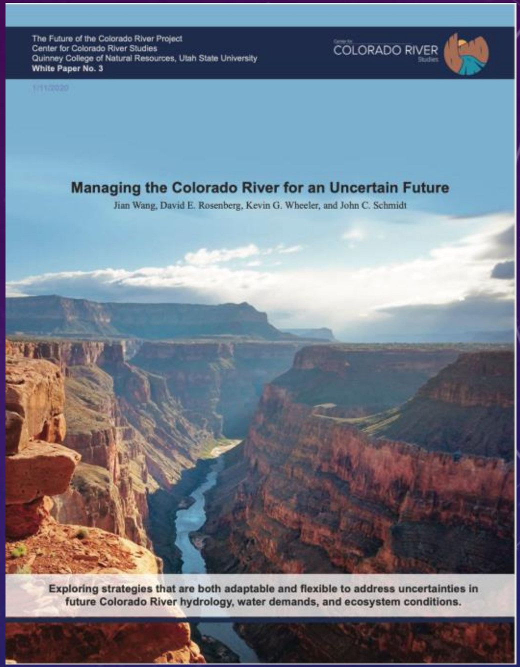
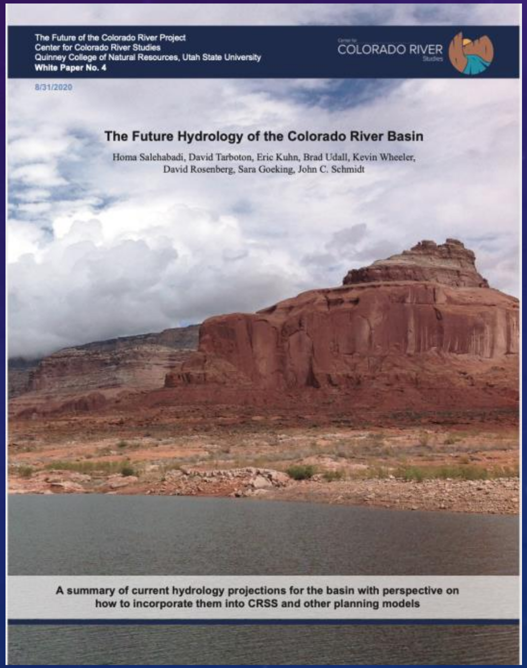
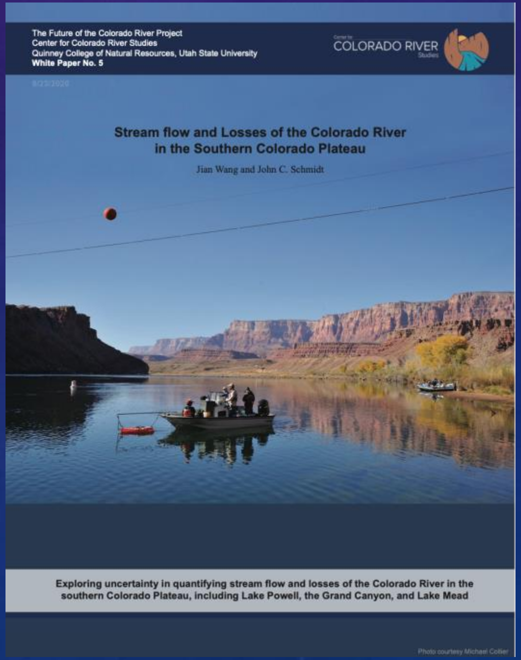


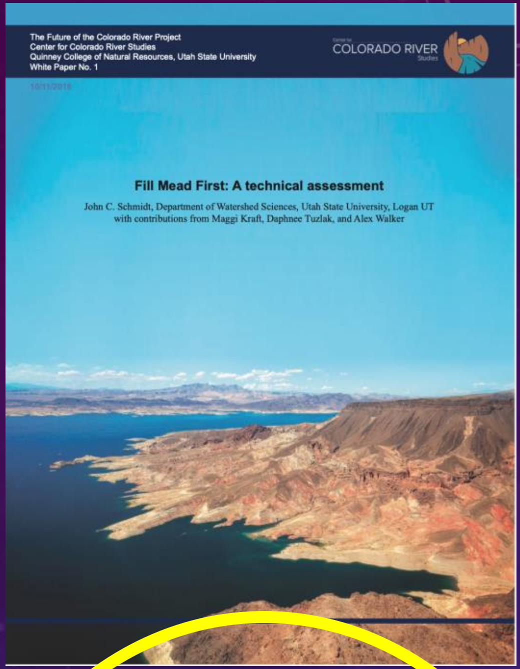


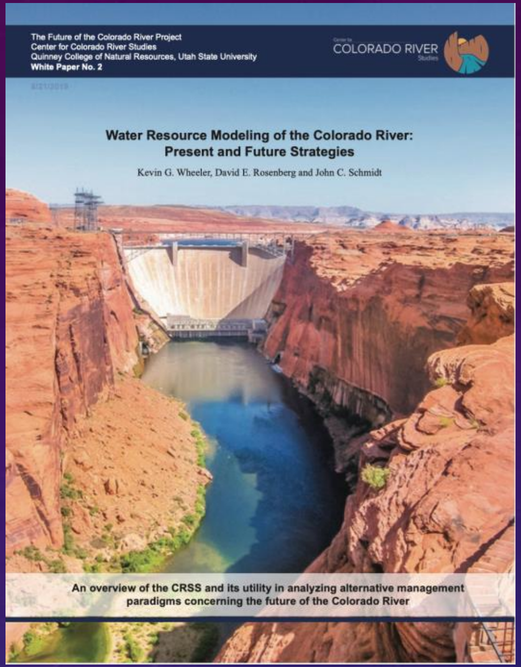


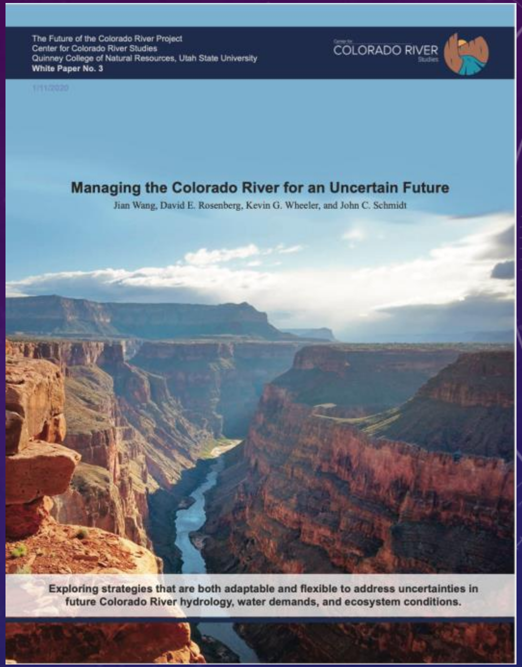


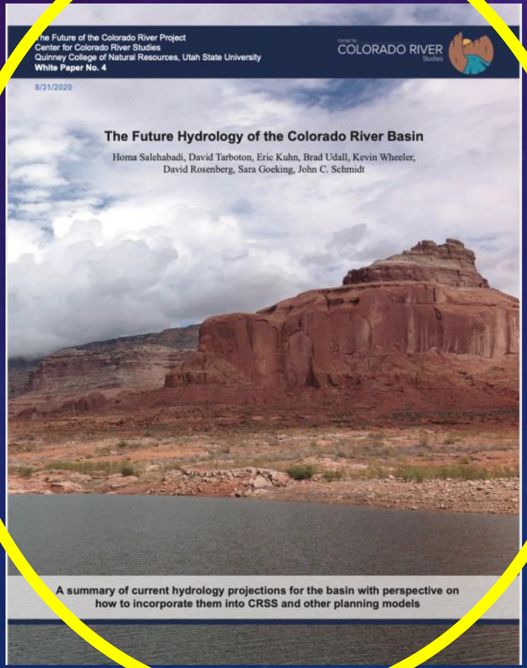


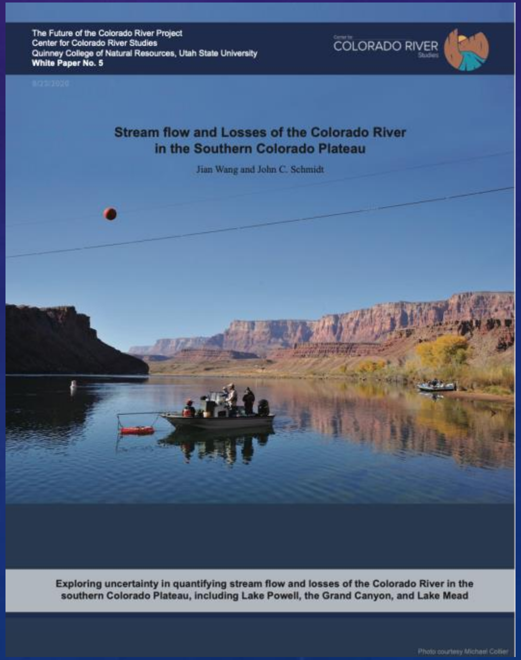
White Paper series





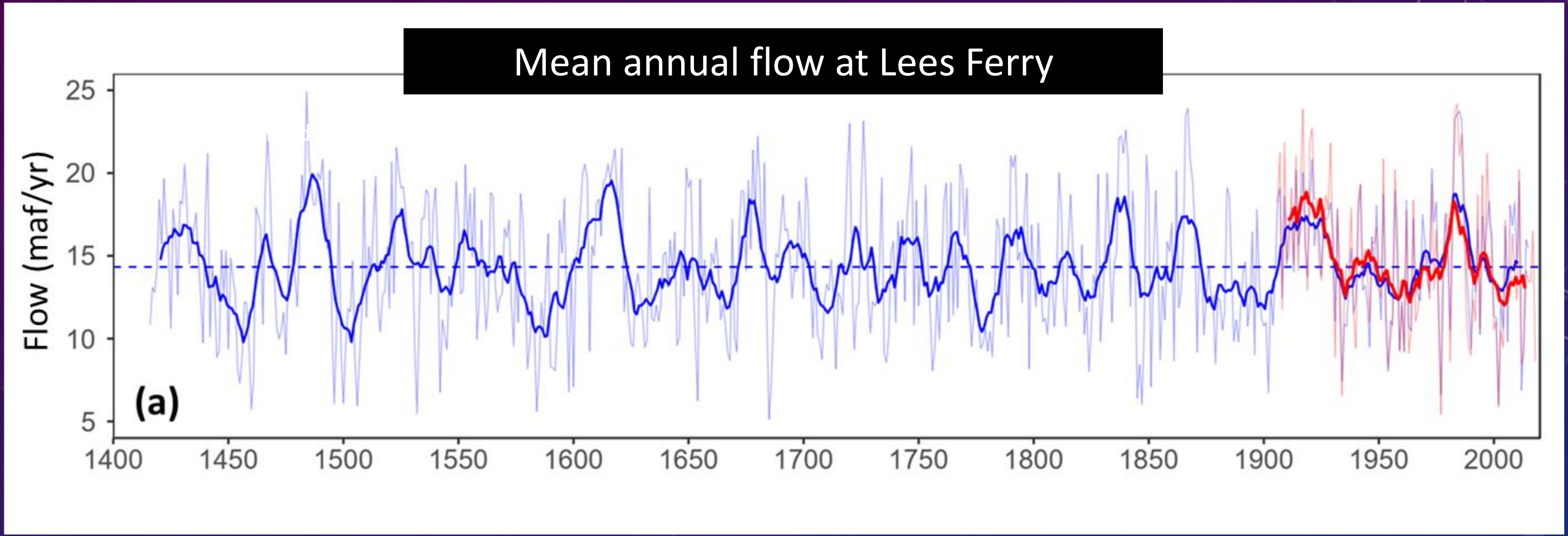






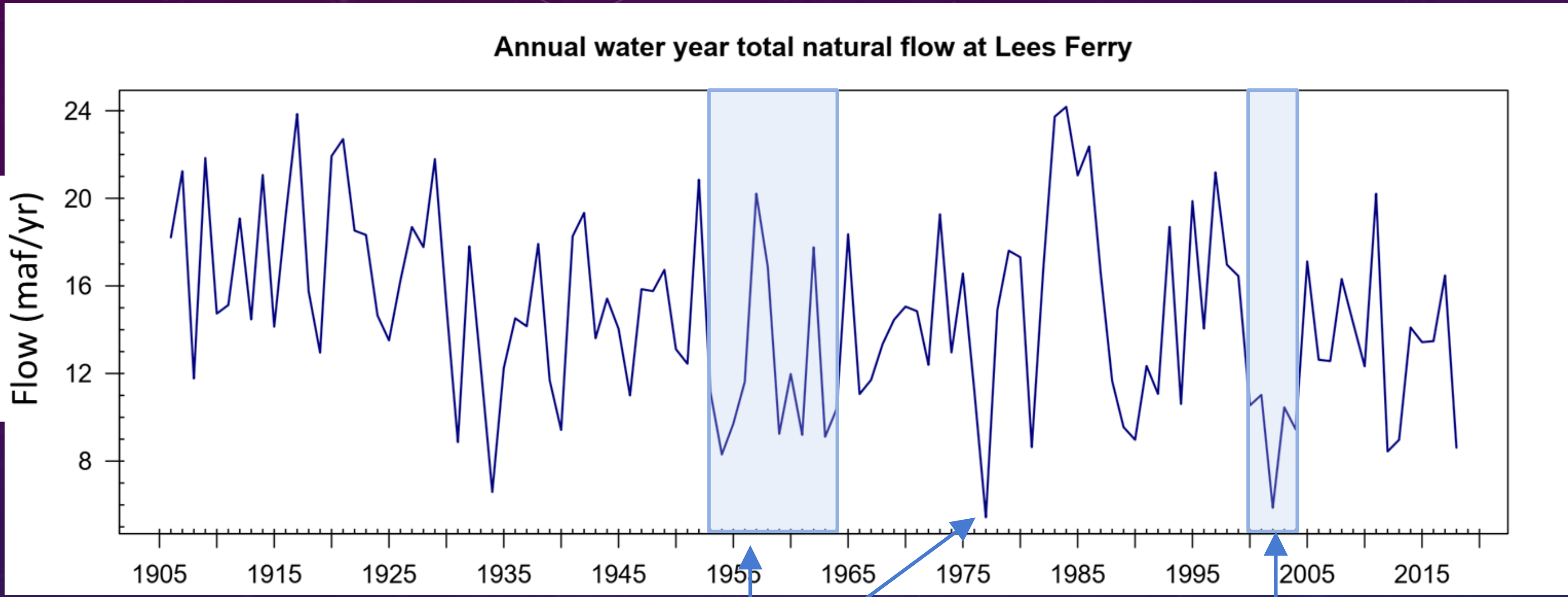
The Future Hydrology of the Colorado River

HOW DRY MIGHT FUTURE CONDITIONS IN THE COLORADO WATERSHED BECOME?

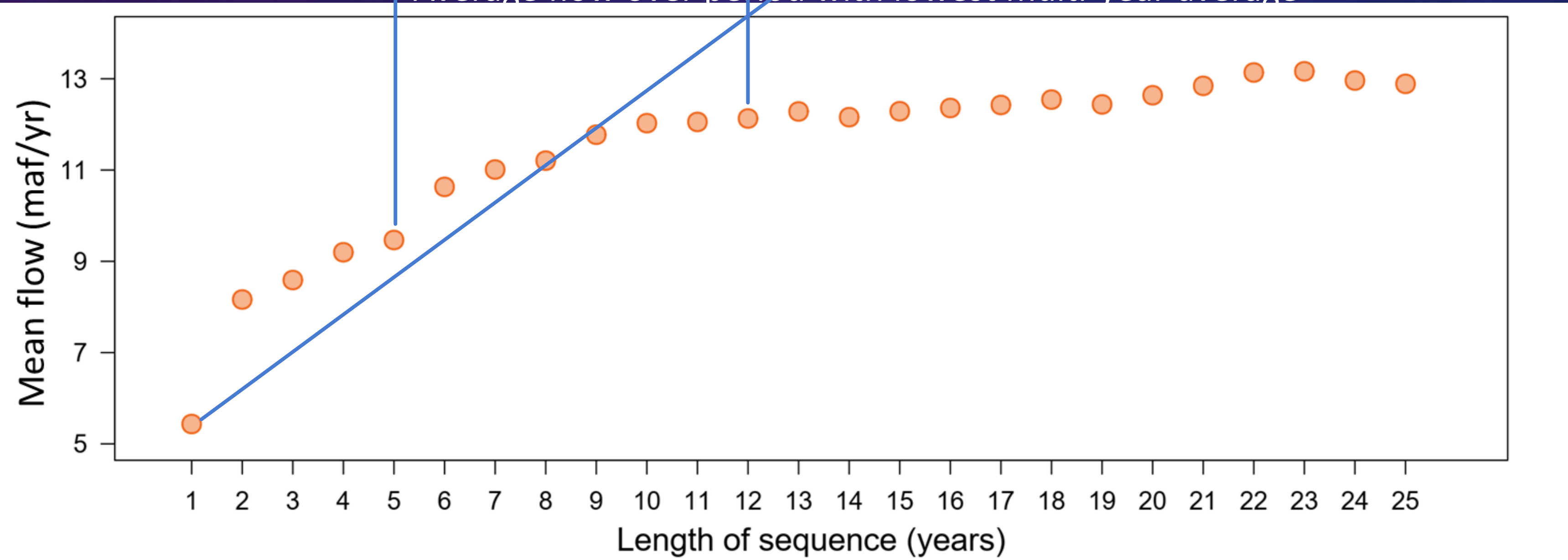


1906-2018 USBR Natural Flows	14.76 maf/yr
1906-1929 USBR Natural Flows (Early 20th century pluvial)	17.8 maf/yr
1930-2018 USBR Natural Flows (Post-pluvial period)	13.9 maf/yr
2000-2018 USBR Natural Flows	12.44 maf/yr
1576-1600 Tree Ring Drought	11.76 maf/yr

Using sequence average plots to characterize drought severity



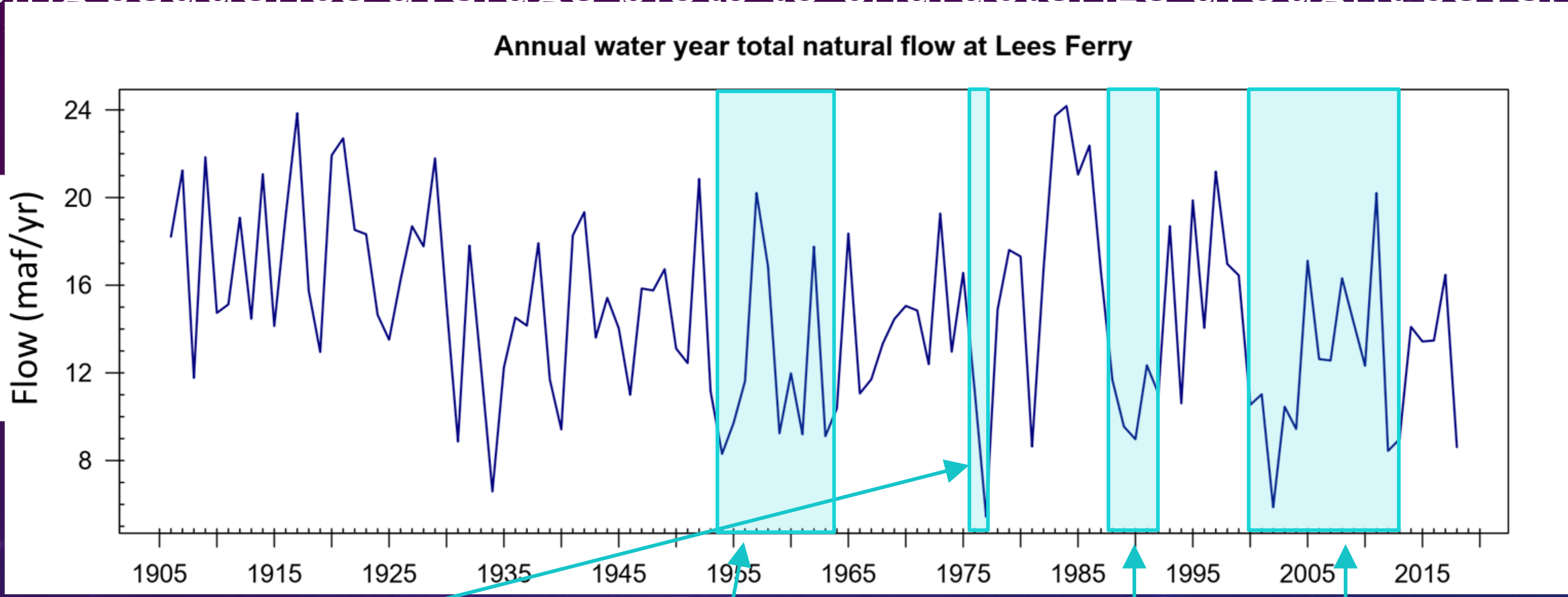
Average flow over period with lowest multi-year average



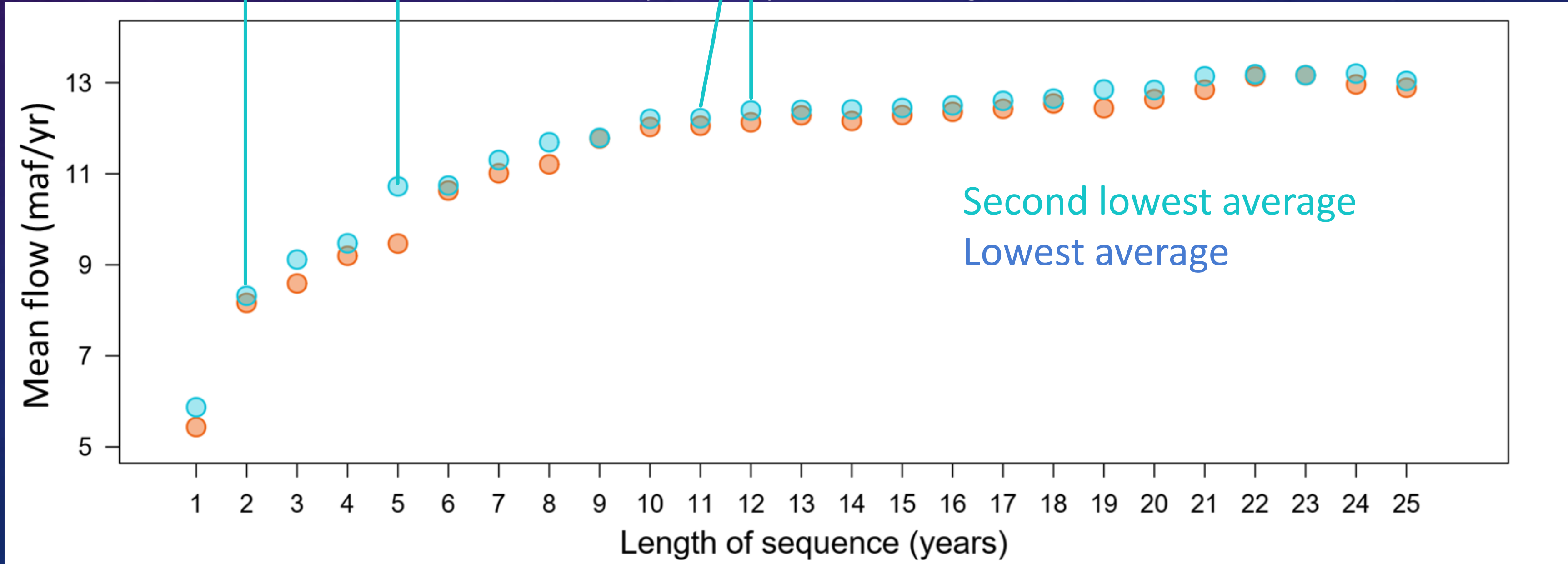
First year and average flow over period with lowest multi-year average

Length of sequence (years)	First year	Mean flow (maf/yr)
1	1977	5.44
2	2002	8.16
3	2002	8.59
4	2001	9.20
5	2000	9.47
6	1999	10.63
7	2000	11.01
8	2000	11.21
9	2000	11.77
10	2000	12.03
11	2000	12.05
12	1953	12.13
13	2001	12.28
14	2000	12.16
15	2000	12.29
16	2000	12.36
17	2000	12.43
18	2001	12.54
19	2000	12.44
20	1999	12.64
21	1998	12.84
22	1953	13.14
23	1955	13.16
24	1954	12.96
25	1953	12.89

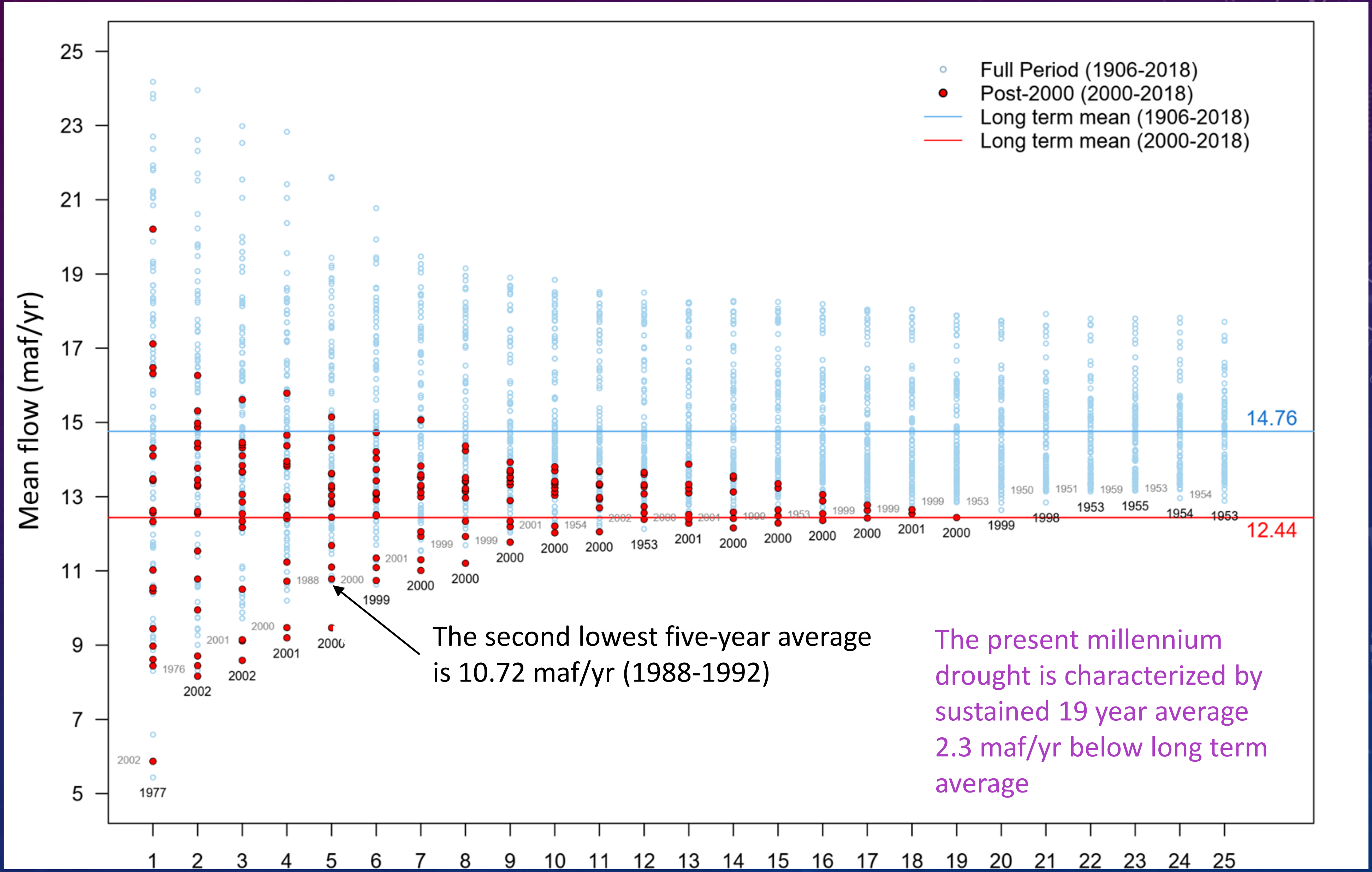
Using sequence average plots to characterize drought severity



Multi-year sequence average flows

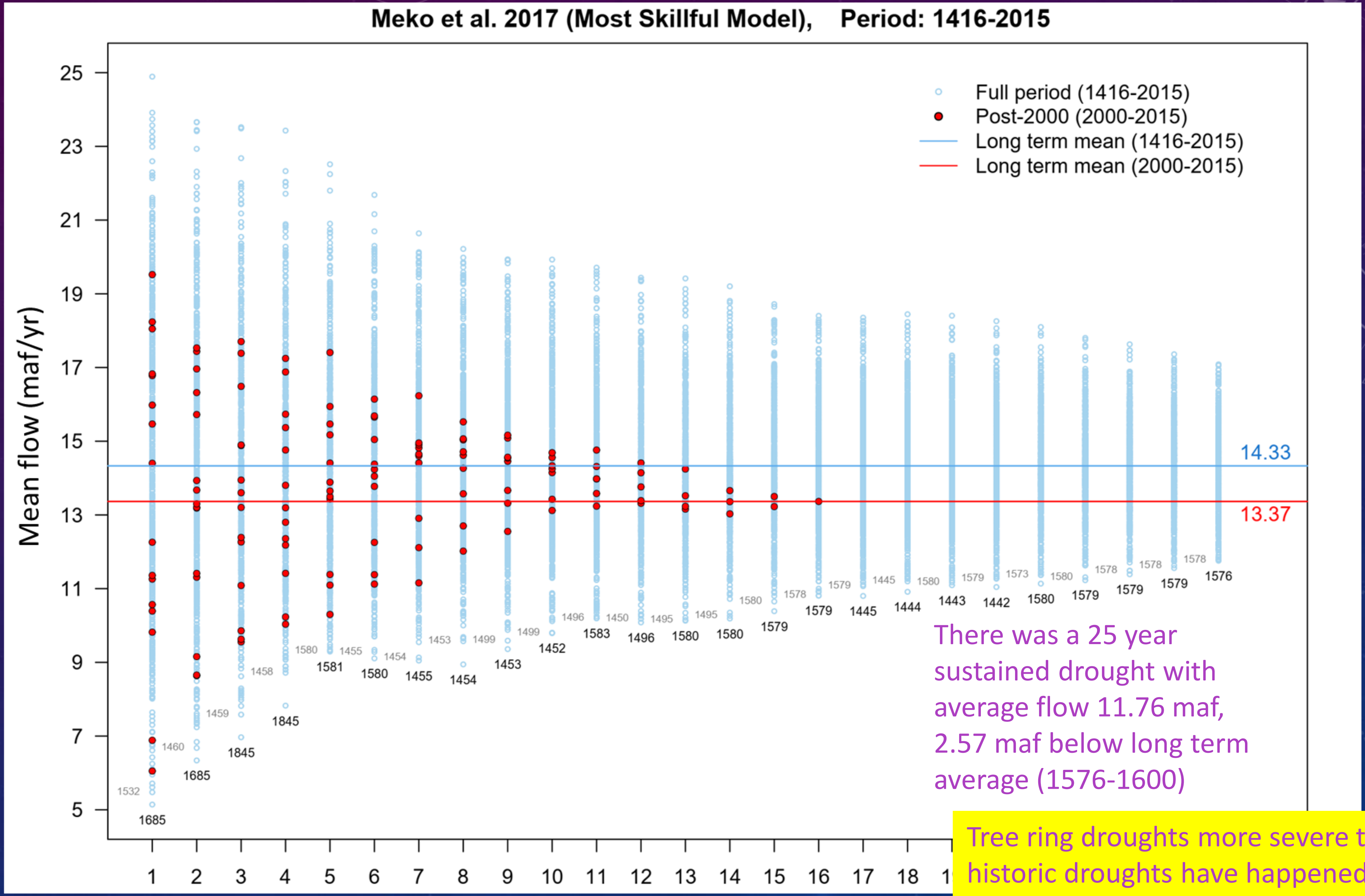


Sequence-Average plot of the natural flow of the Colorado River at Lees Ferry, 1906-2018



Length of sequence (yrs)

Sequence-Average plot of the tree-ring reconstructed flow of the Colorado River at Lees Ferry.



Length of sequence (yrs)

There was a 25 year sustained drought with average flow 11.76 maf, 2.57 maf below long term average (1576-1600)

Tree ring droughts more severe than historic droughts have happened before and may happen again

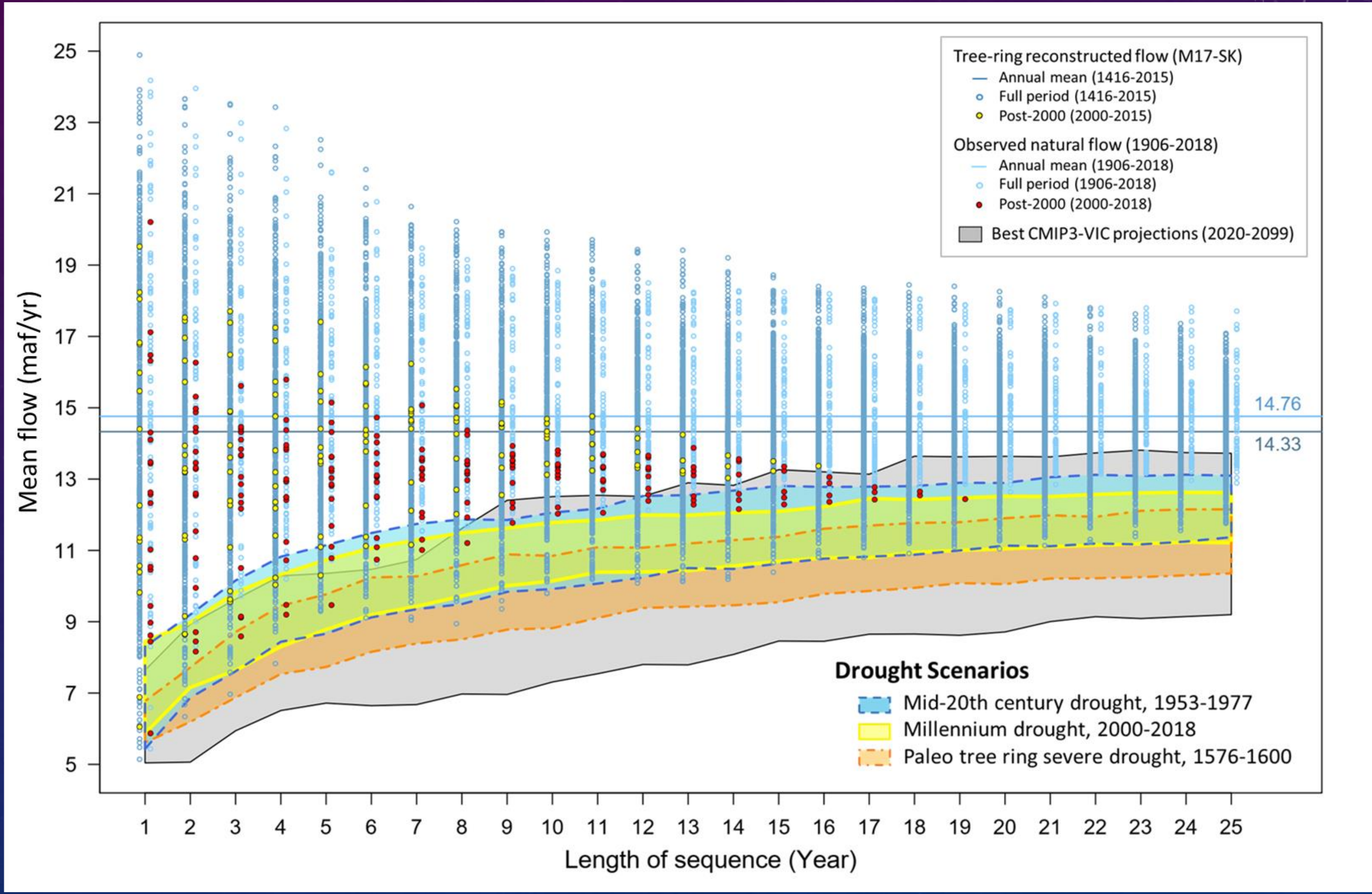
DROUGHT SCENARIOS

- Defined based on historic natural and tree ring reconstructed flows
- 100 traces 42 years long resampled from each scenario and disaggregated to each CRSS input node to be used for CRSS modeling of potential drought impacts

Scenario	Flow data	Period	Duration	Mean flow (maf/yr)	Cumulative decreases below average (maf)
Millennium drought	USBR natural flow	2000-2018	19 years	12.44	44.08
Mid-20th century drought	USBR natural flow	1953-1977	25 years	12.89	46.75
Paleo tree ring severe drought	Tree-ring reconstructed flow (Meko et al., 2017)	1576-1600	25 years	11.76	75

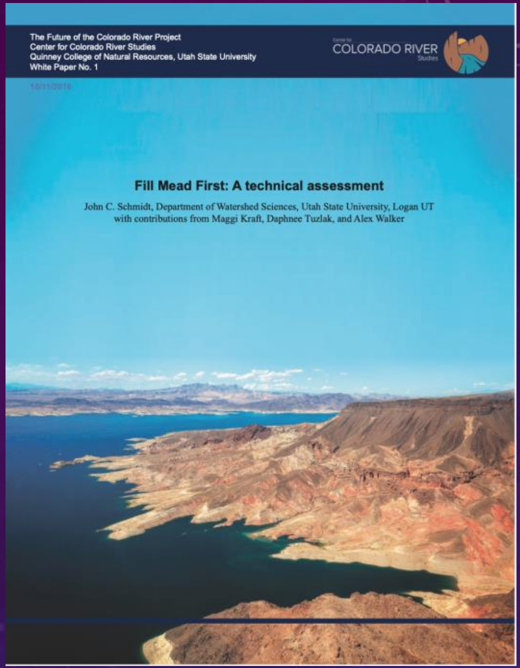
These are defined in terms of water year annual flow at Lees Ferry

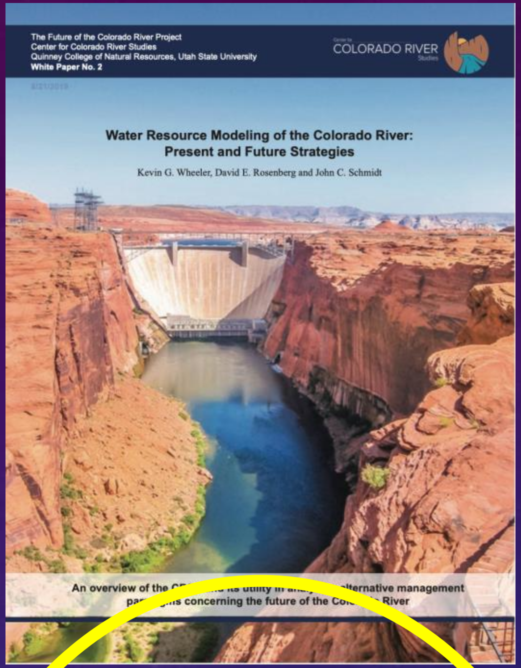
MINIMUM SEQUENCE AVERAGES FROM HISTORIC AND TREE RING DROUGHT AND CLIMATE SCENARIOS JUXTAPOSED ON HISTORIC AND TREE RING DATA

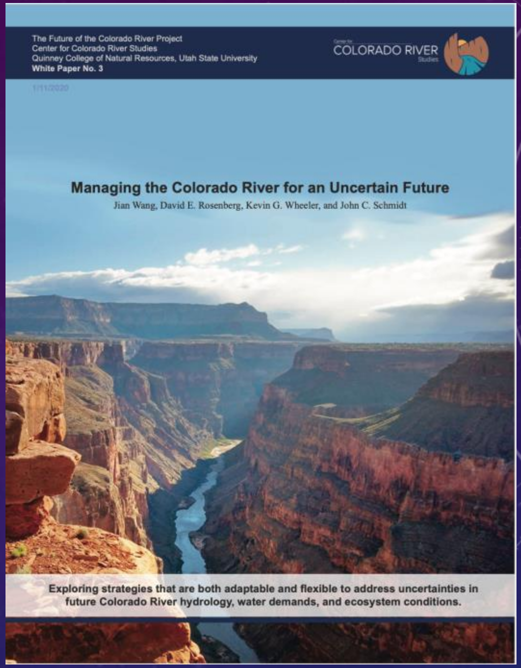


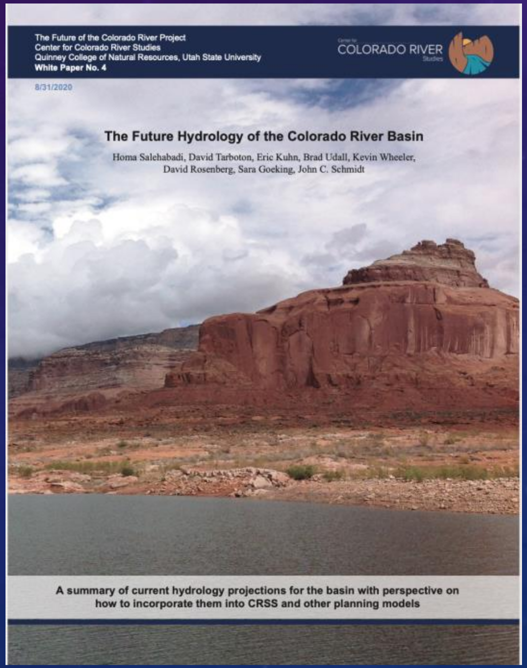
CONCLUSIONS

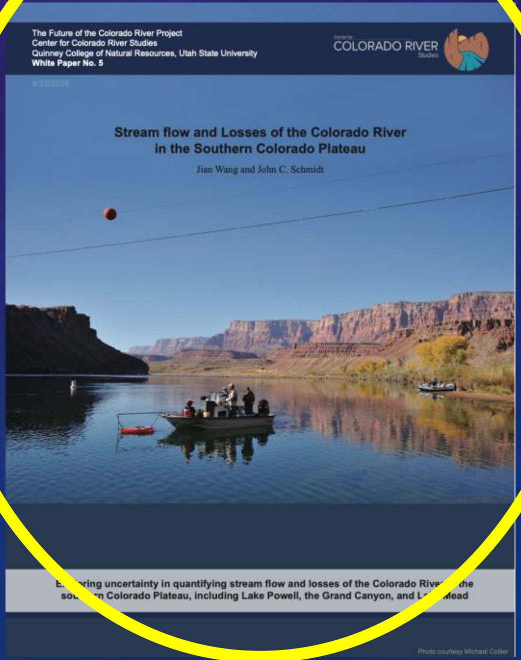
- Three severe and sustained drought scenarios were identified using the average of streamflow and cumulative decrease relative to the mean flow over varying sequence lengths.
- Drought scenario based resampling combined with block disaggregation partitions these throughout CRSS nodes to support modeling of water resources impacts.
- Scenarios are less extreme than some climate projections, and plausible because they are based on past flow estimates and what has happened in the past might happen again in the future
- Full white paper at https://qcnr.usu.edu/coloradoriver/news/WP4_Announce
- Data available at https://www.hydroshare.org/resource/6d351874f16947609eab585a81c3c60d







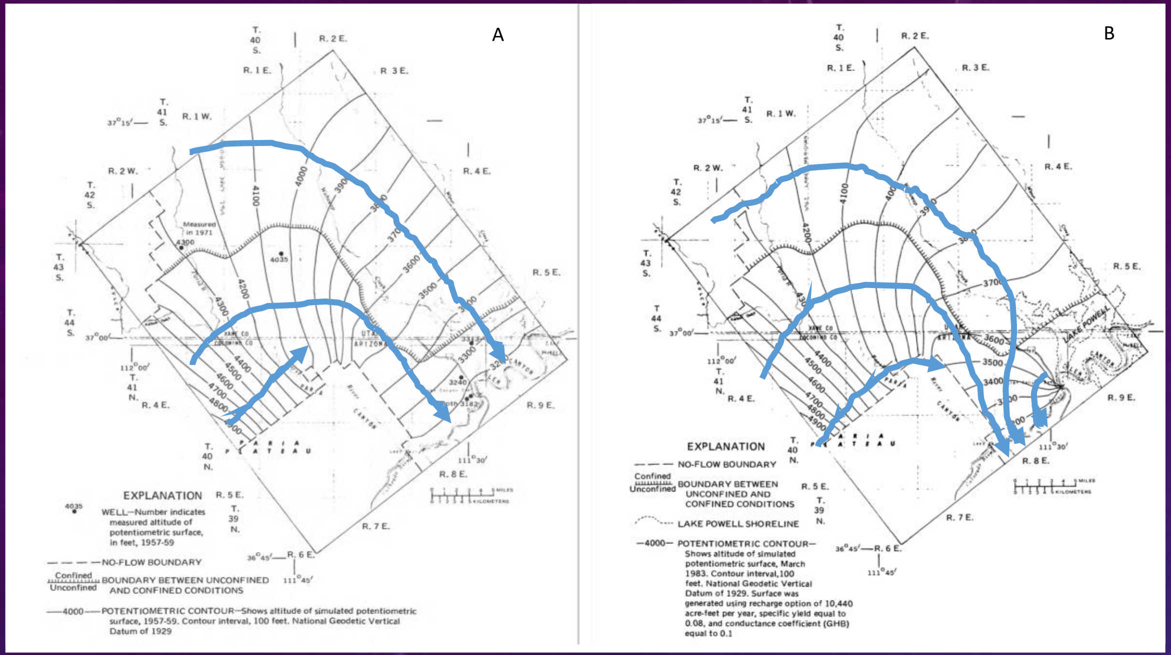




Stream flow and losses of the Colorado River in the southern Colorado Plateau

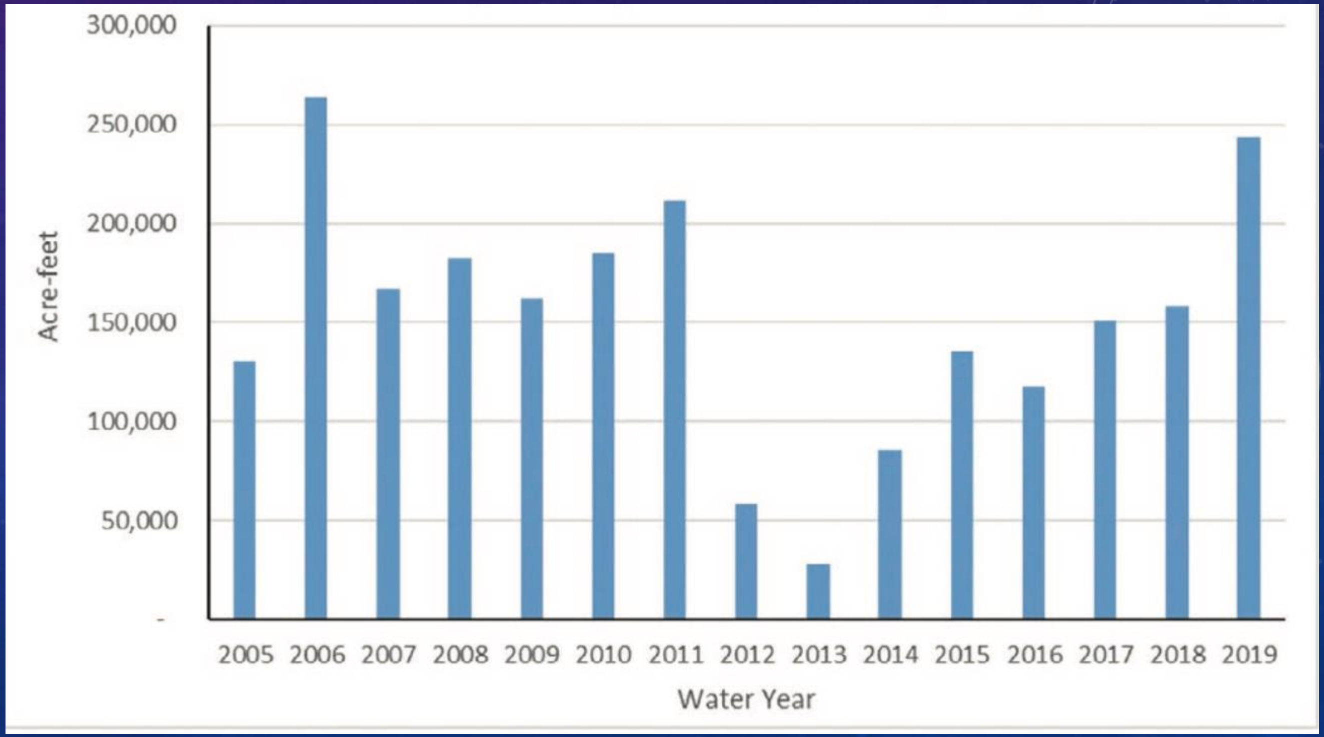
Estimated perturbations of ground-water flow near Glen Canyon Dam

Thomas, 1986



Increase in Colorado River flow between Glen Canyon Dam and Lees Ferry gage (~15 miles)

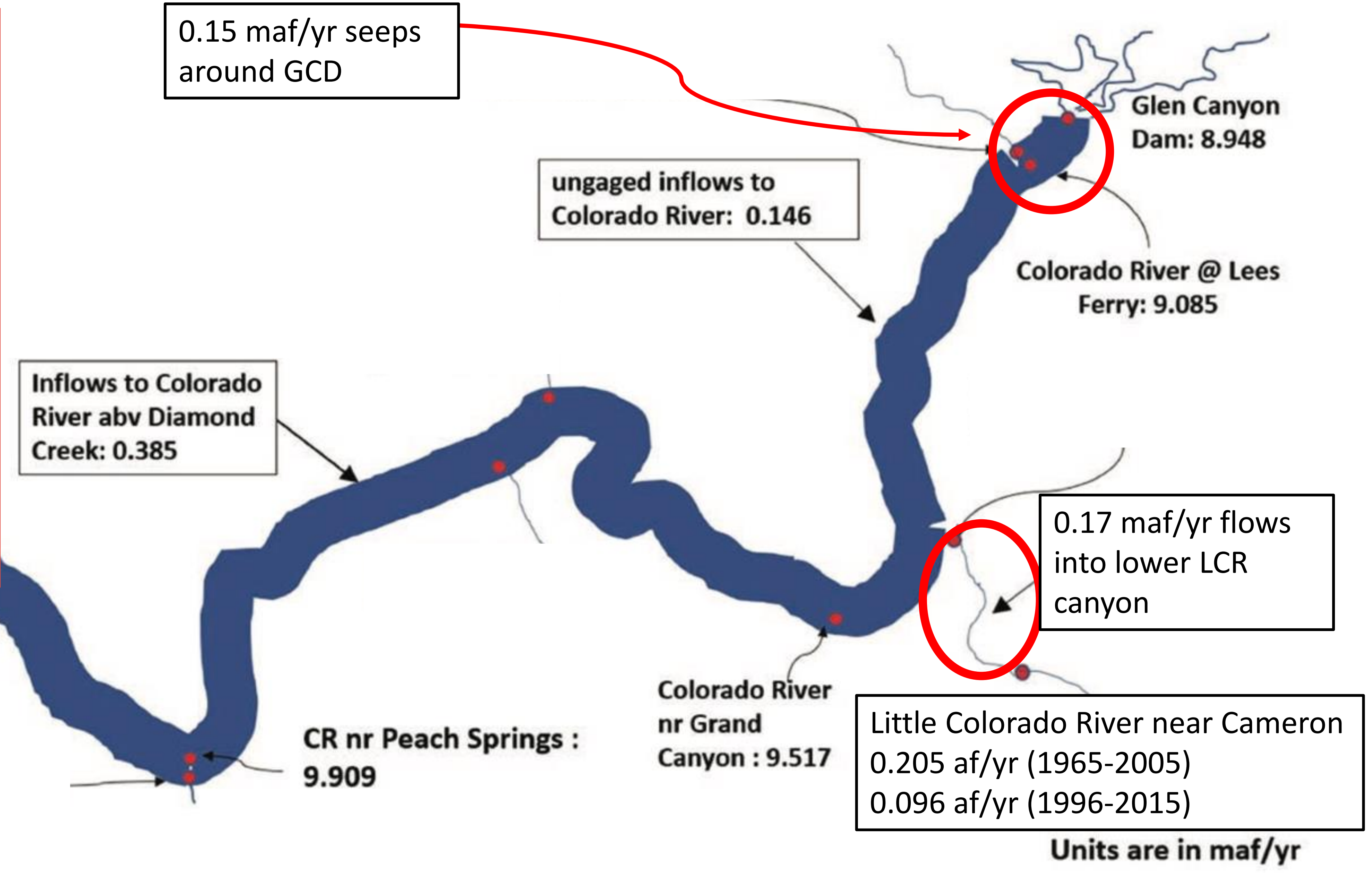
Average (WY2005 – WY2020) = 150,000 af/yr
28,000 (WY2013) – 260,000 (WY2006)
170,000 af in WY2020



<u>Increase in flow Lees Ferry to Diamond Creek (1990-2018): 0.768 maf/yr</u>

0.13 maf/yr from Paria and LCR abv Cameron

0.64 maf/yr ground water sources within Grand Canyon (47% Marble and eastern Grand Canyon); 53% in central Grand Canyon)



Lake Mead inflows and change in storage = 10.56 maf/yr

Colorado River (Diamond Creek) – 10.13 maf/yr (9.93-10.33) (2% uncertainty)

All other sources – 0.18 maf/yr

Change in Lake Mead storage – 0.25 maf/yr

Lake Mead outflows = 10.28 maf/yr

Hoover Dam releases – 9.49 maf/yr (9.40-9.58) (1% uncertainty)

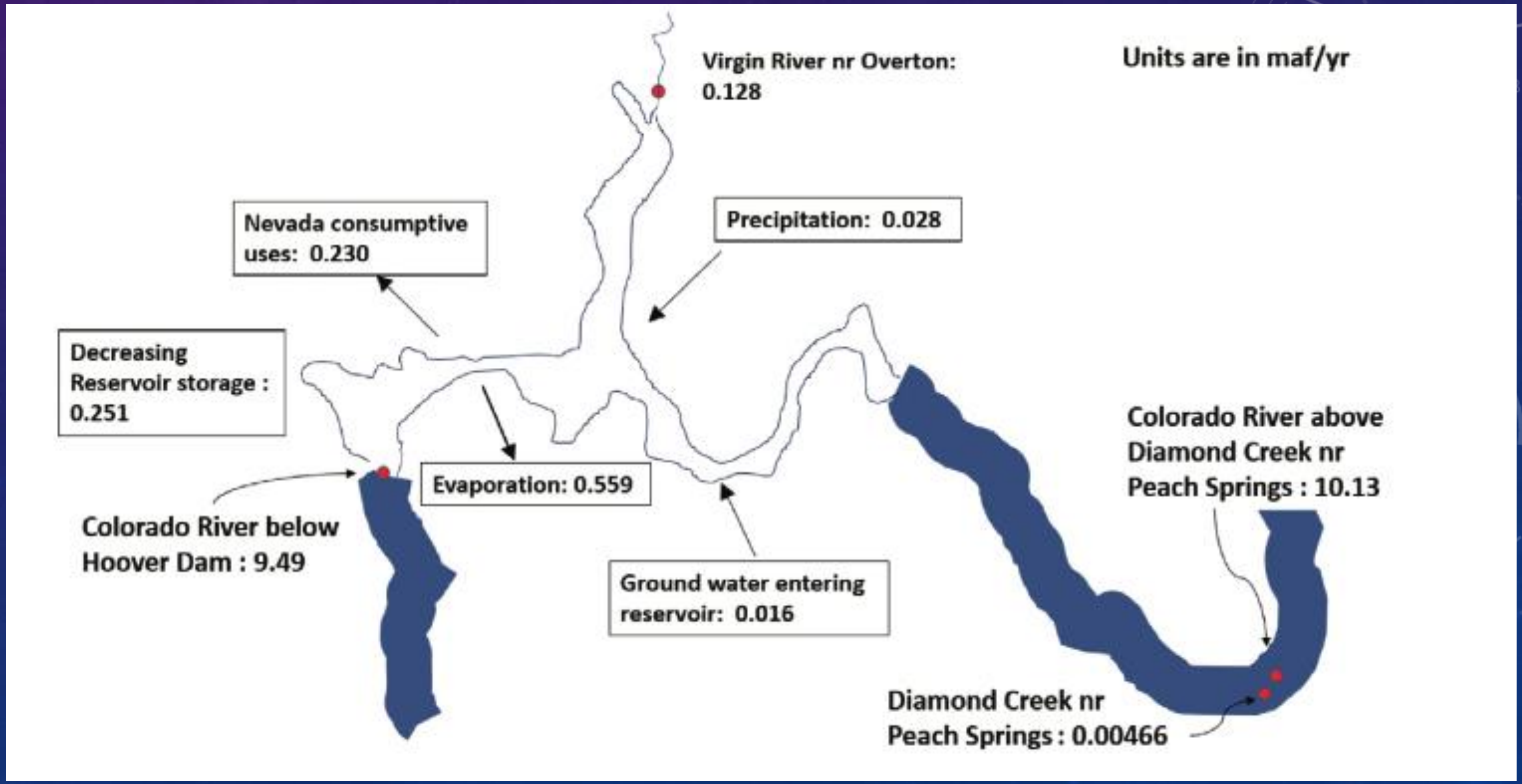
Evaporation – 0.56 maf/yr (0.54 – 0.58)

Nevada – 0.23 maf/yr (0.23 – 0.24)

March 2010 – February 2015

All d

Measurements of inflow at Diamond Creek are the most likely source of uncertainty and may be an overestimate by ~200,000 af/yr (2% uncertainty)



WY2016 – WY2019

<u>**Lake Powell inflows and change in storage = 9.80 maf/yr**</u>

Upper Colorado - 4.41 maf/yr (4.32-4.50)
Green - 4.11 maf/yr (4.03 – 4.19)
San Juan - 1.12 maf/yr (1.10 – 1.14 maf/yr)

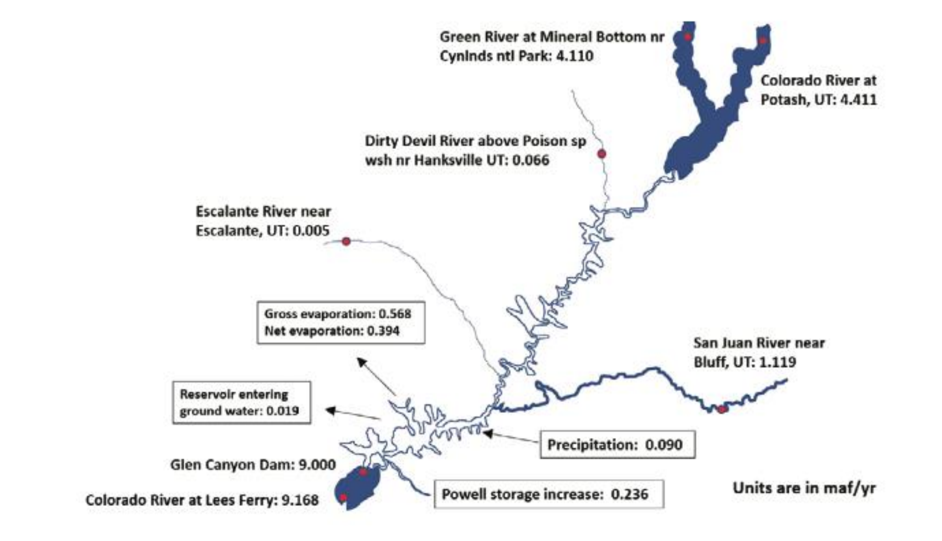
All data 2015-2019

<u>**Lake Powell outflows = 9.99 maf/yr**</u>

Colorado River at Lees Ferry – 9.17 maf/yr (9.08-9.26); note GCD releases – 9.00 maf/yr
Gross evaporation – 0.57 maf/yr (0.41 – 0.78)
Other losses into sandstone – 0.02 maf/yr
Increase in storage – 0.24 maf/yr

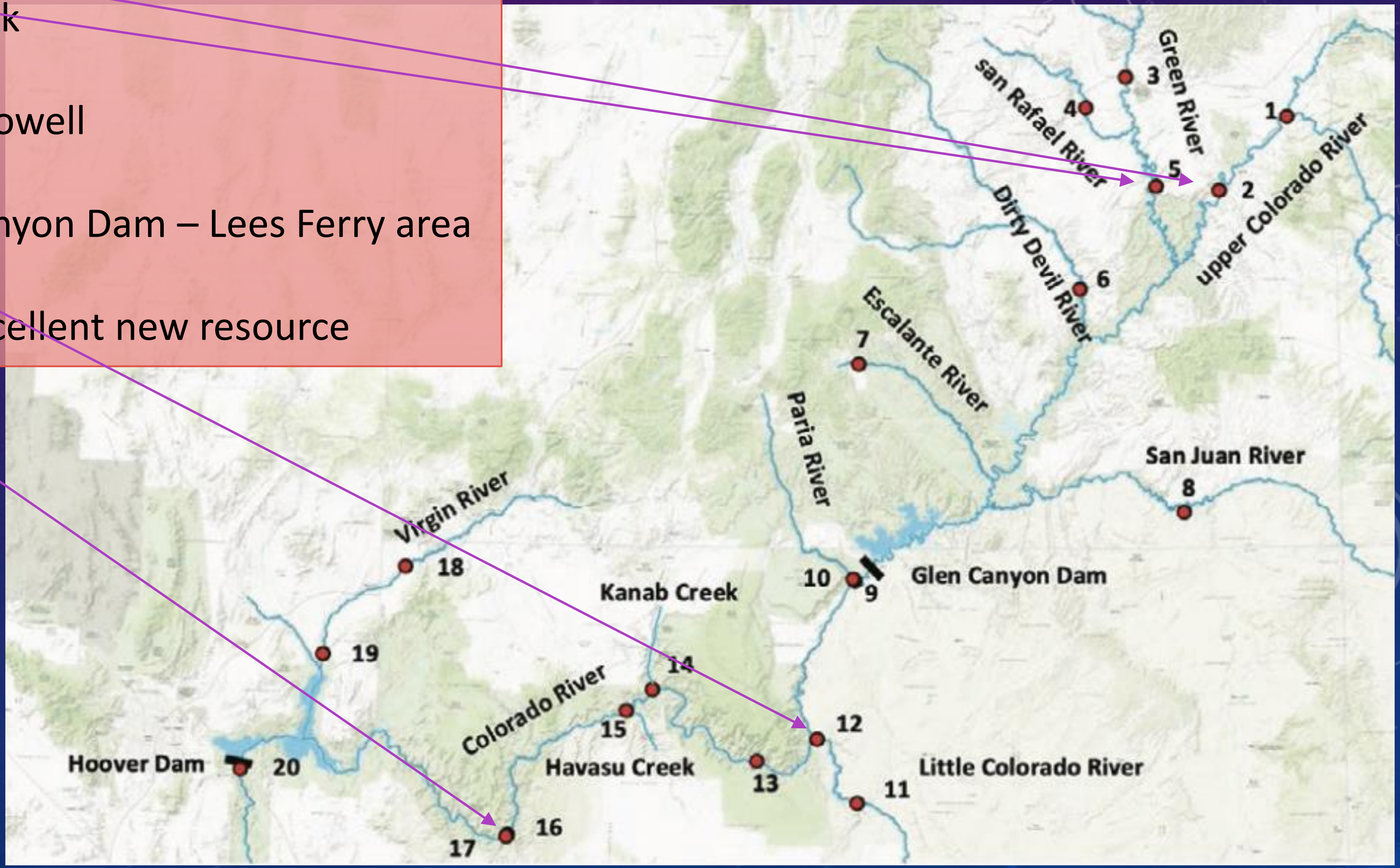
BUT –if one assumes net evaporation of 0.39 maf/yr (0.30-0.49), then water budget is balanced!!!

Total reservoir evaporation is the most likely source of uncertainty in the Lake Powell water budget. One should use measurements of outflow at the Lees Ferry gage, not reservoir releases



Some recommendations

- Fund key gages and incorporate data into river basin modeling
  - Colorado River at Potash
  - Green River at Mineral Bottom
  - Little Colorado River at mouth
  - Colorado River above Diamond Creek
- Resolve uncertainties in evaporation at Powell
- Renew studies of seepage in the Glen Canyon Dam – Lees Ferry area
- Reclamation Hydrologic database and excellent new resource



The Future of the Colorado River project
https://qcnr.usu.edu/coloradoriver/futures

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