How much water will it take to restore the Great Salt Lake and how to achieve it?

David Tarboton and the Great Salt Lake Strike Team

Presentation given to Utah State University Spring Runoff Conference

March 15, 2023

https://www.usu.edu/water/conference/2023-conference

Main Points

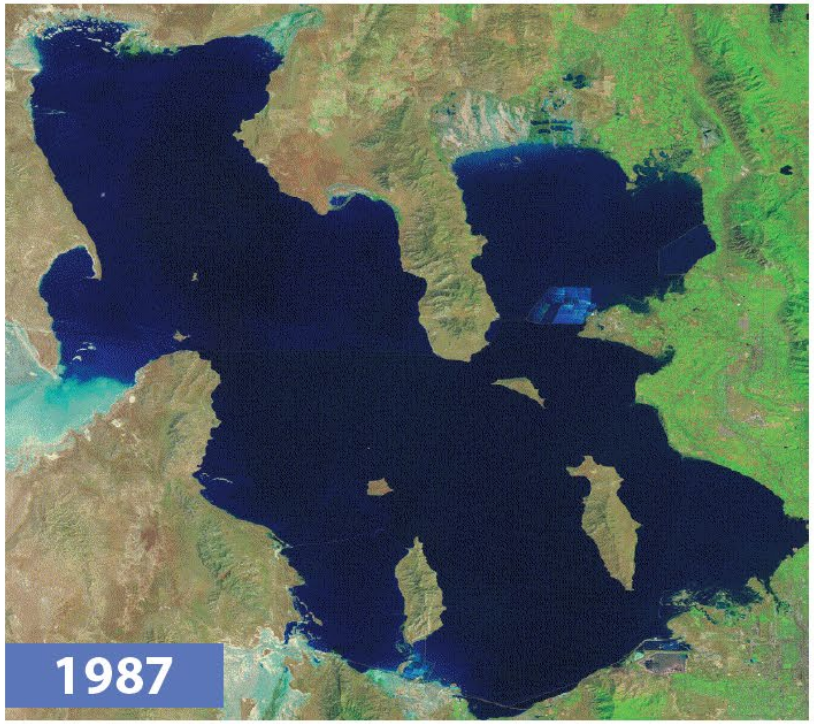
- To raise GSL one ft it takes ~150 KAF/yr of additional inflow
- The GSL is a dynamic system with considerable variability over time scales of decades, centuries and millennia
- Human inflow changes, both depletions and conservation, are superimposed on these dynamic fluctuations
- Given dynamics, if a goal is to be set, it may be better set as depletion limit rather than a specific lake level or range
- We can quantify use reduction trade offs and conservation options, but reductions are a societal and policy question where there are environmental, economic and cultural trade-offs
- Periodic high flow years (this year) are expected and should not lead to complacency

Importance of GSL

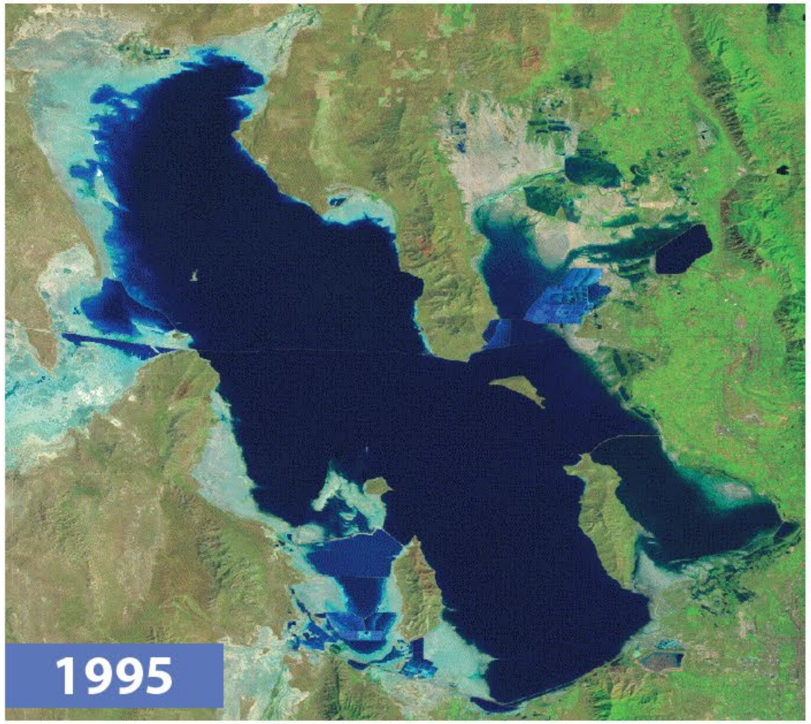
- Economy
  - Infrastructure along the shore
  - Brine Shrimp Industry
  - Mineral Industry
- Ecology
  - Western Hemisphere Shorebird Preserve
- Environment
  - Air quality
  - Dust
  - Moderates Temperature
  - Lake effect snow
- Recreation
- Spectacular Landscape
- Art
- It is in the name of Utah’s Capital

Problem: Declining Great Salt Lake (GSL) water levels threaten economic activity, local public health due to dust, and environmental ecosystems. Research can inform scientifically based decisions on management options.

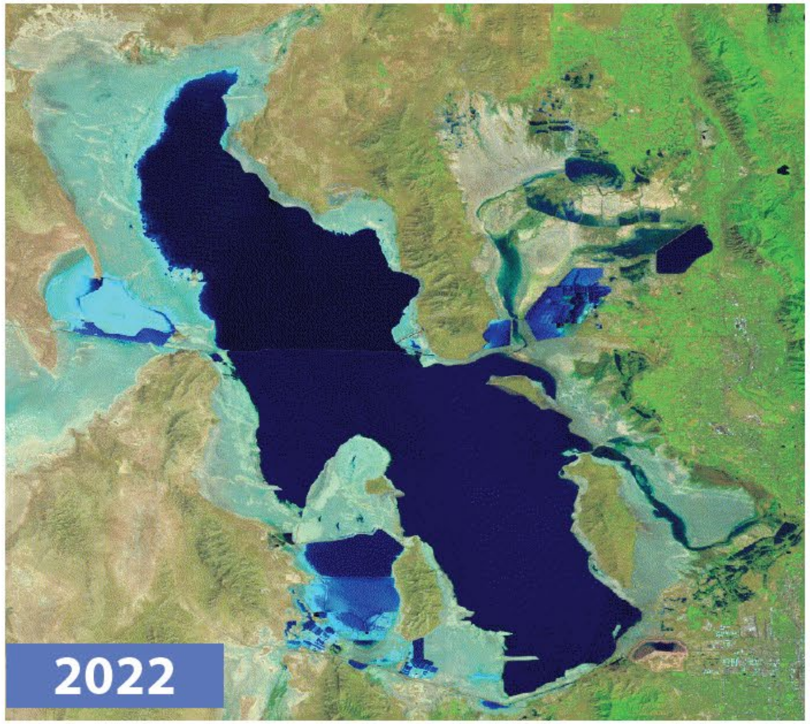
Contemporary Record High
4,210.4 feet



Average
4,198.6 feet



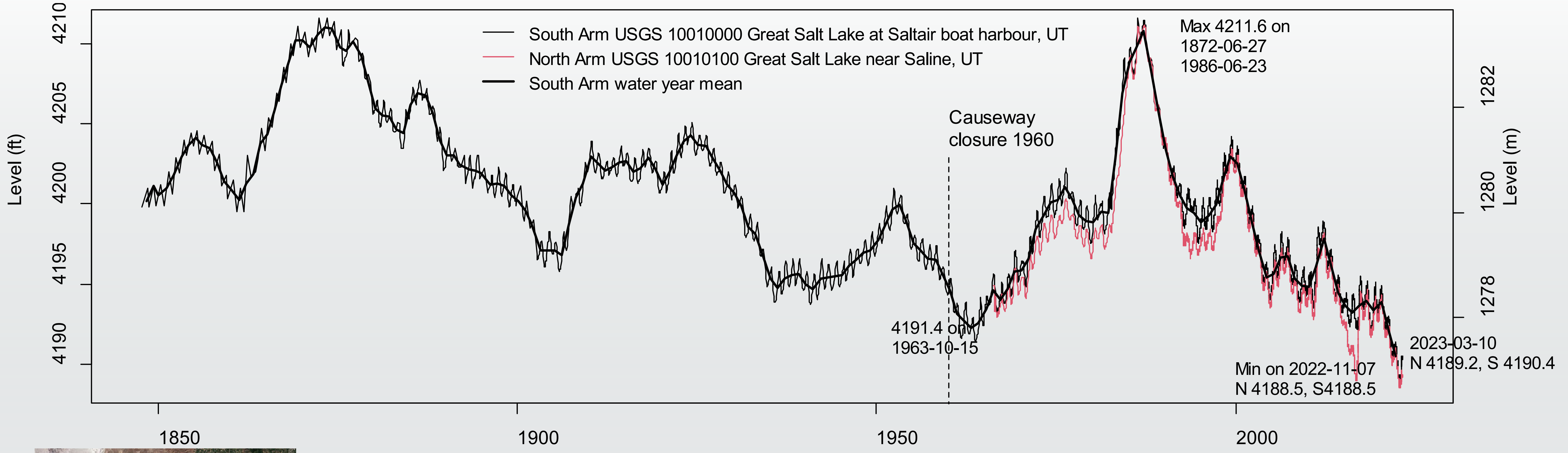
Record Low
4,190.1 feet

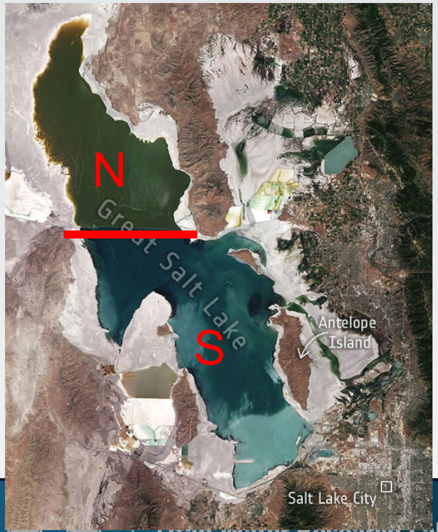


Source: Google Earth Engine

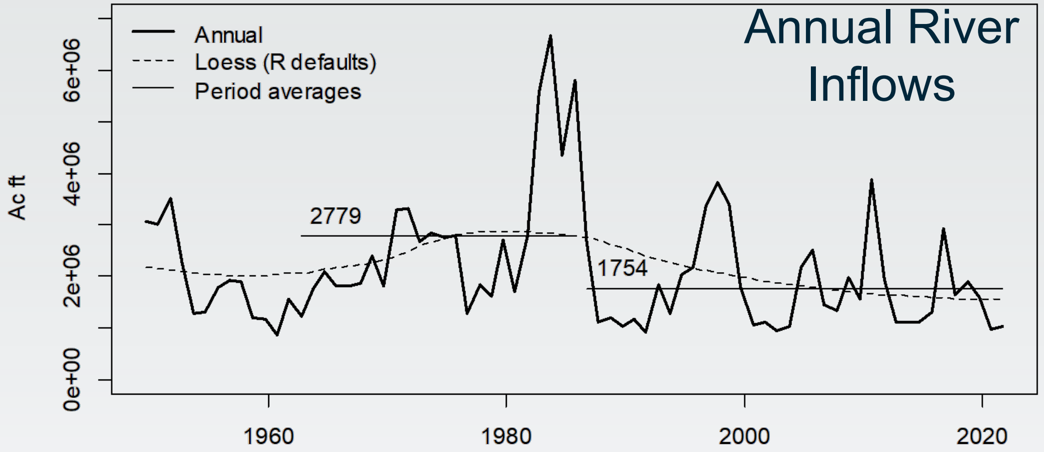
From Great Salt Lake Strike Team Policy Assessment
https://gardner.utah.edu/great-salt-lake-strike-team/

GSL Level Record

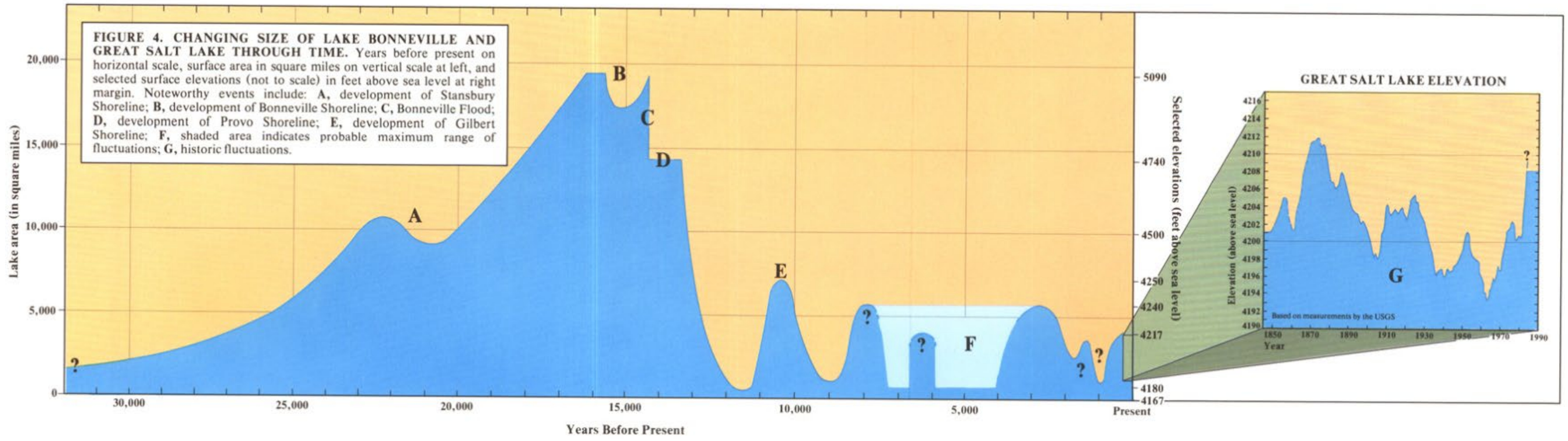


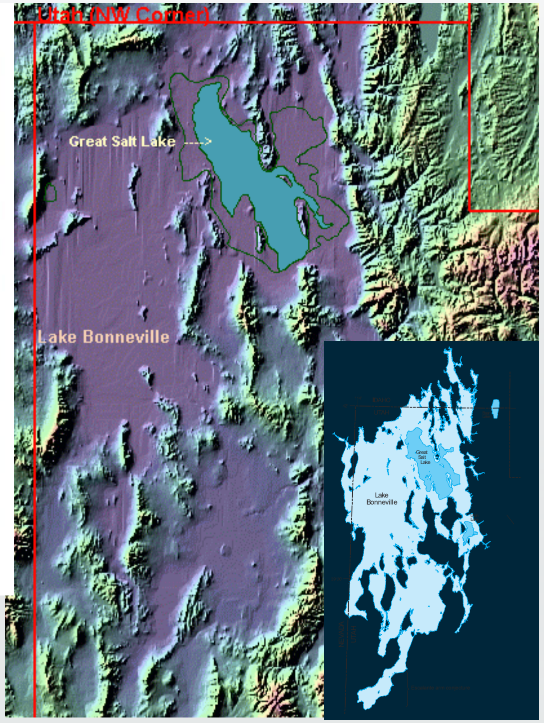


- Divided in 1960
- Critically high 1986 following wet period
- Presently up 1.9 ft from November 2022 record low



Geologic History: Pleistocene Lake Bonneville



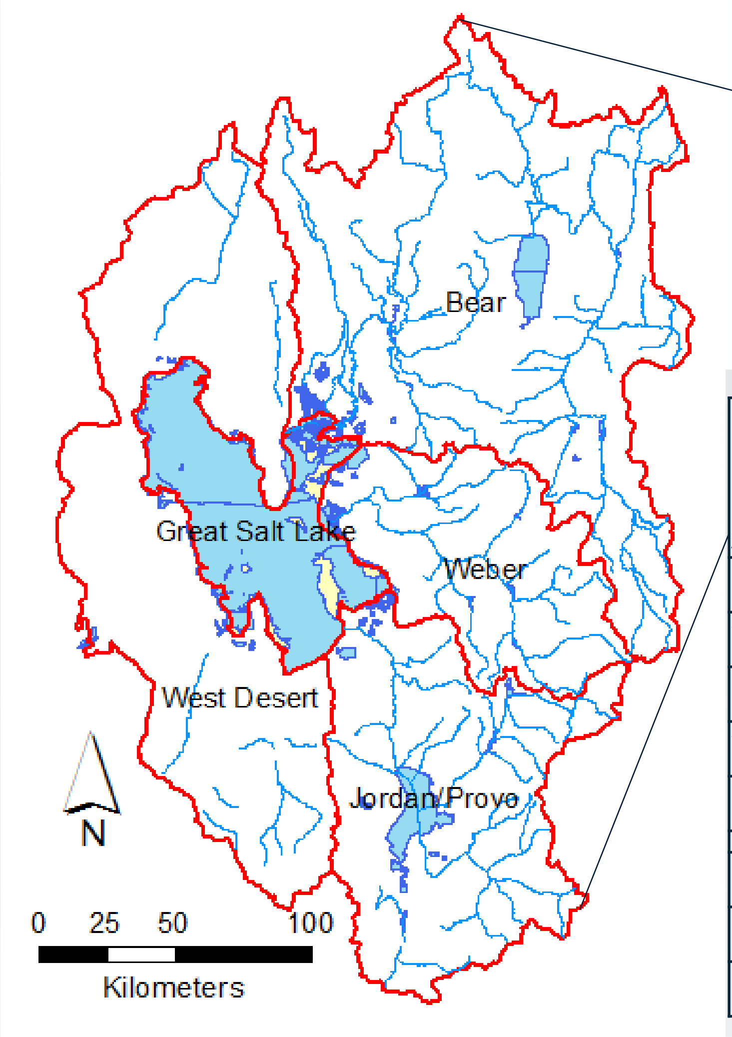


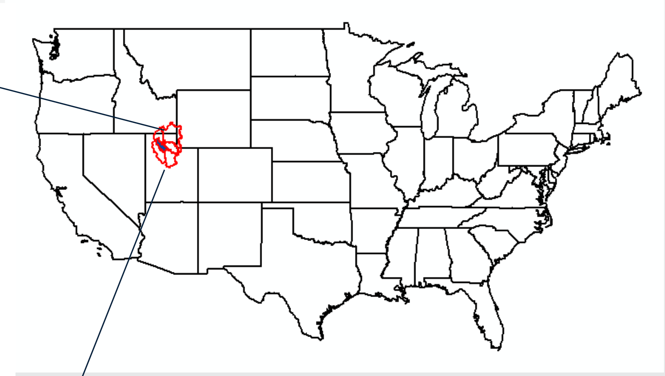
A. Stansbury Level
B. Lake Bonneville
C. Breach at Red Rock Pass
D. Provo Level
E. Gilbert Level
F. Pre-GSL Fluctuations
G. Historic Fluctuations

- Covered most of Northern Utah
- Extended into Idaho and Nevada
- Over 335 m deep 15,500 years ago
- 52,000 km^2 in area
- Overflowed at Red Rock Pass
- Lost 300m of water

Graphics from Rob Baskin, USGS

Great Salt Lake Inflow

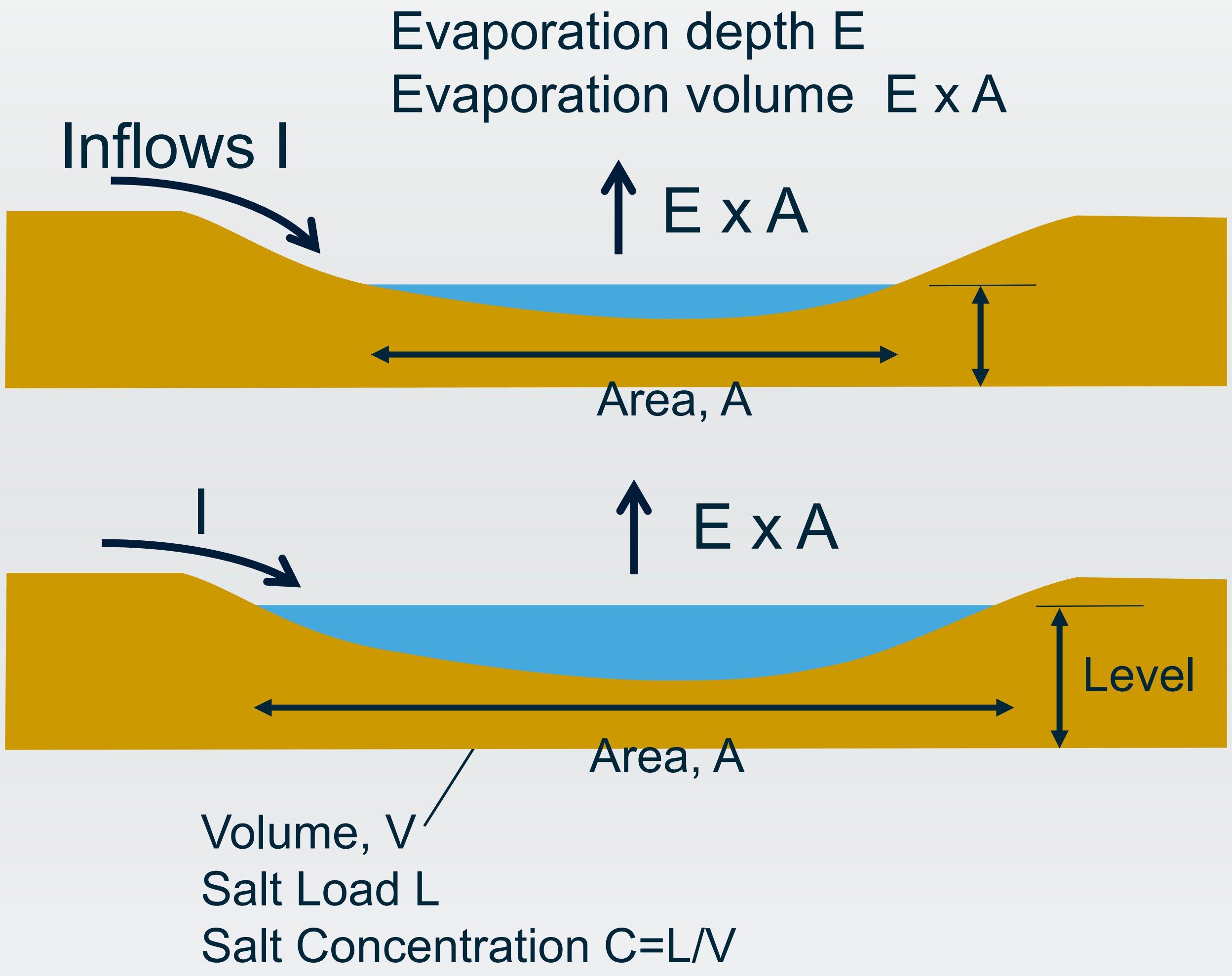




- Mean annual values 10/1/1949-9/30/2022
- Precipitation from aggregation of PRISM data over each area
- Streamflow from multiple USGS gages

Area	Area (km^2)	Precip. (mm)	Inflow (1000 acre-ft)	Stream-flow %	Overall %	Runoff (mm)	Runoff ratio
Bear	19262	535	1283	61%	39%	82	15%
Weber (inc. Davis)	6326	652	373	17%	12%	73	11%
Jordan/Provo	9963	559	462	22%	14%	57	10%
West Desert	14604	339	-			-	
Total Streamflow	50155	498	2118	100%	65%	56	12%
Lake Precipitation	3608	368	1077		33%		
Groundwater			75		2%		
Total	53763	486	3270		100%		

How a closed basin lake works



If I > E x A level rises
If I < E x A level falls
Level adjusts to fluctuating inputs so that on average
I = E x A

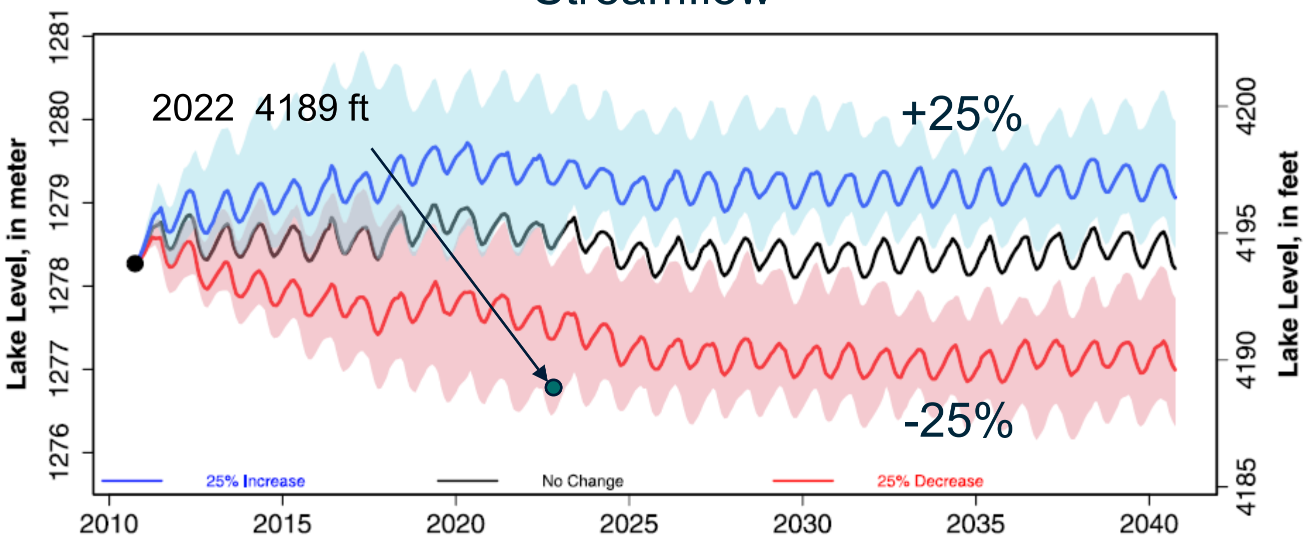
I includes inflows from streams and precipitation on the lake
I = Q + P x A
Subject to climate variability.

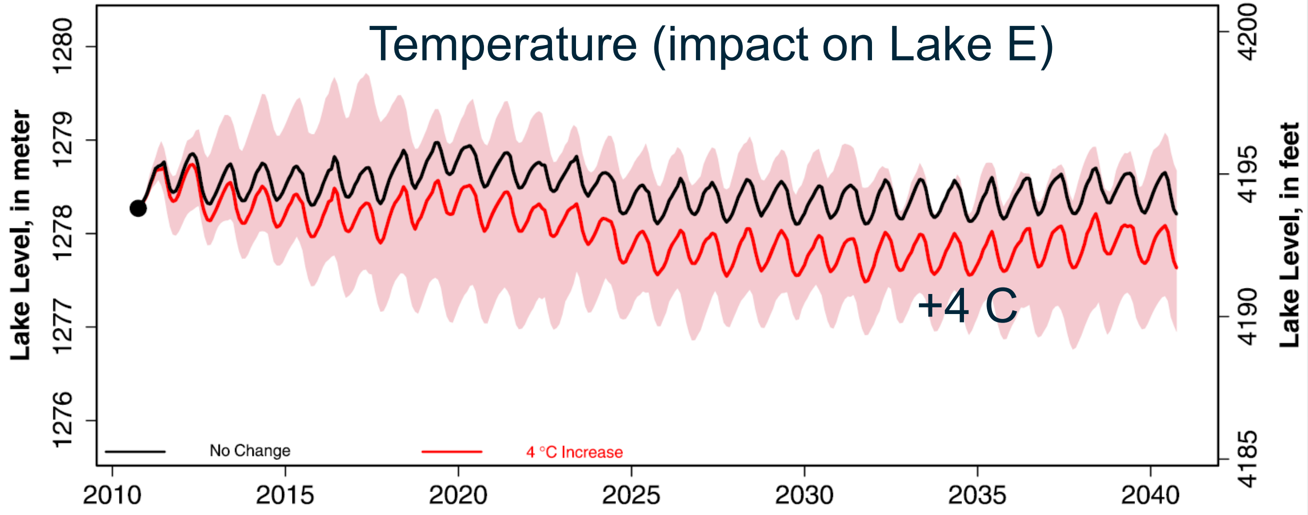
E is less variable, but also depends on climate and salinity, C.

As C increases E decreases

What is lake level most sensitive to?

Streamflow





Dimensionless volume change sensitivity to inputs

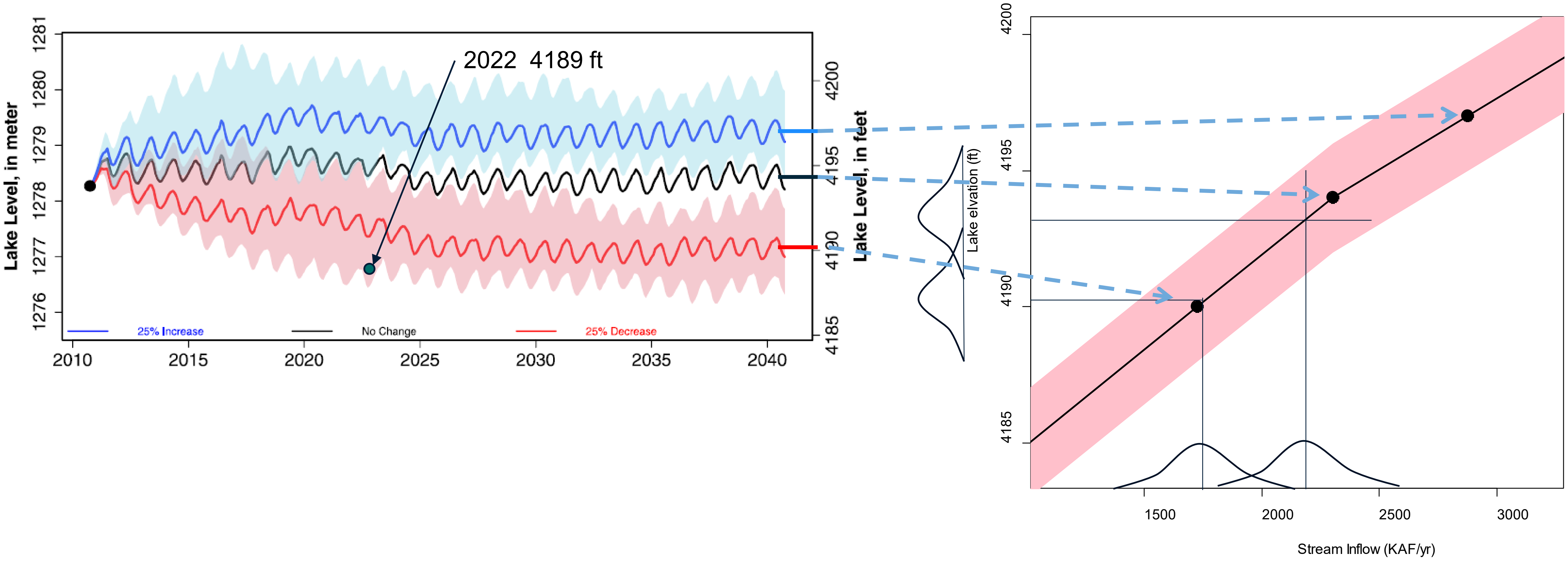
(Ratio of variable to volume change std deviation scaled to be dimensionless)

Streamflow	**0.83**
Precip on Lake	0.3
Evaporation (E) depth from lake	0.1
Salinity effect on E	0.09
Lake area control over E	0.49

Since variability is most sensitive to streamflow, holding other effects constant simplifies analysis for evaluation and explanation of options

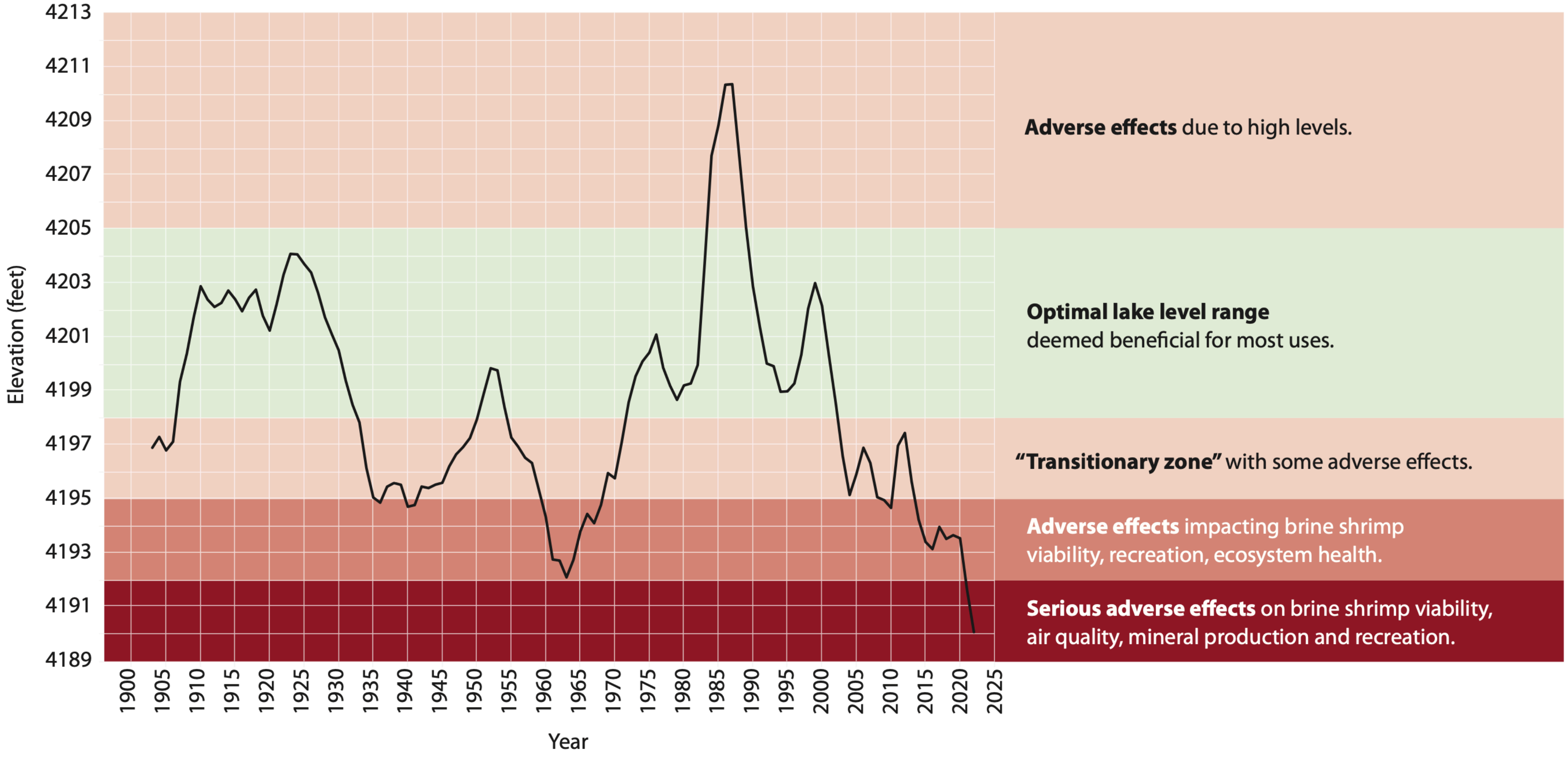
Mohammed, I. N. and D. G. Tarboton, (2012), "An examination of the sensitivity of the Great Salt Lake to changes in inputs," Water Resour. Res., 48(11): W11511, https://doi.org/10.1029/2012wr011908.

To raise the level an average of 3 ft will take an average additional 450 KAF/yr inflow



Based on Mohammed, I. N. and D. G. Tarboton, (2012), "An examination of the sensitivity of the Great Salt Lake to changes in inputs," Water Resour. Res., 48(11): W11511, https://doi.org/10.1029/2012wr011908.

What is a desirable level?



Sources: US Geological Survey Historical Elevation at Saltair Boat Harbor; Utah Division of Forestry, Fire and State Lands, GSL Lake Elevation Matrix, 2013

Inflows needed to get to target levels (KAF/yr)

Target Elevation (ft .)	Fill in 5 years	Maintain
4,189	1,327	1,327
4,192	1,759	1,463
4,195	2,272	1,738
4,198	2,975	2,137

- Starts from 4189 ft. October 2022
- Assumes average lake precipitation 1 ft/yr
- Assumes average lake evaporation 3.4 ft/yr

Streamflow scenarios

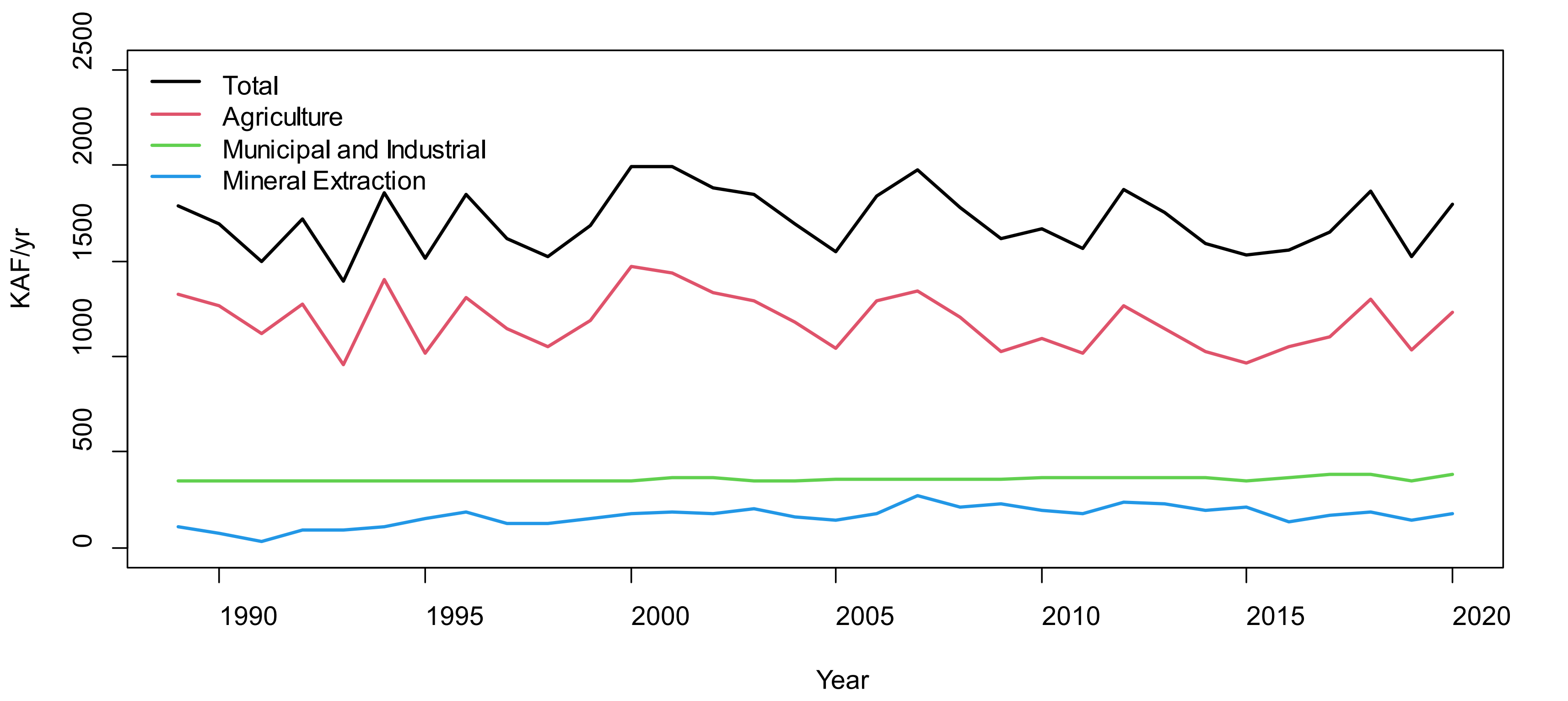
- Drought like 1988-1992 (lowest 5 years on record) 1059 KAF/yr
- Contemporary average 2000-2022) 1643 KAF/yr

Conservation required to fill

Target Elevation (ft .)	Drought	Contemporary
4,189	268	0
4,192	700	116
4,195	1,213	629
4,198	1,916	1,332

From Great Salt Lake Strike Team Policy Assessment
https://gardner.utah.edu/great-salt-lake-strike-team/

Manageable depletions 1989-2020



Depletion	Thousand Acre Ft
Agriculture	1188
Municipal and Industrial	358
GSL Mineral Extraction	165
Total	**1711**

Wetlands, Reservoirs and West Desert excluded as not viable options for getting water to the lake

Source: Great Salt Lake Water Budget, Utah Division of Water Resources, 2023 provided to Great Salt Lake Strike Team.

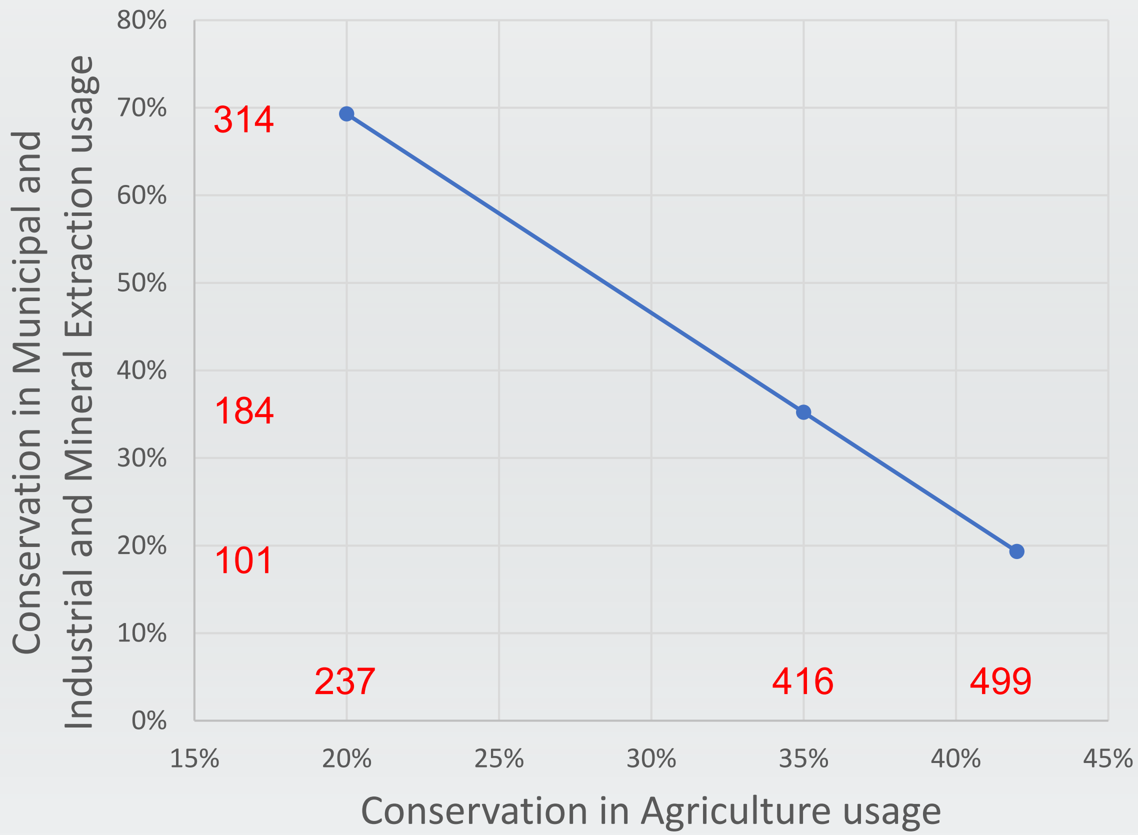
Trade off scenarios for increasing lake inflow

Basin Wide Manageable Consumptive water use

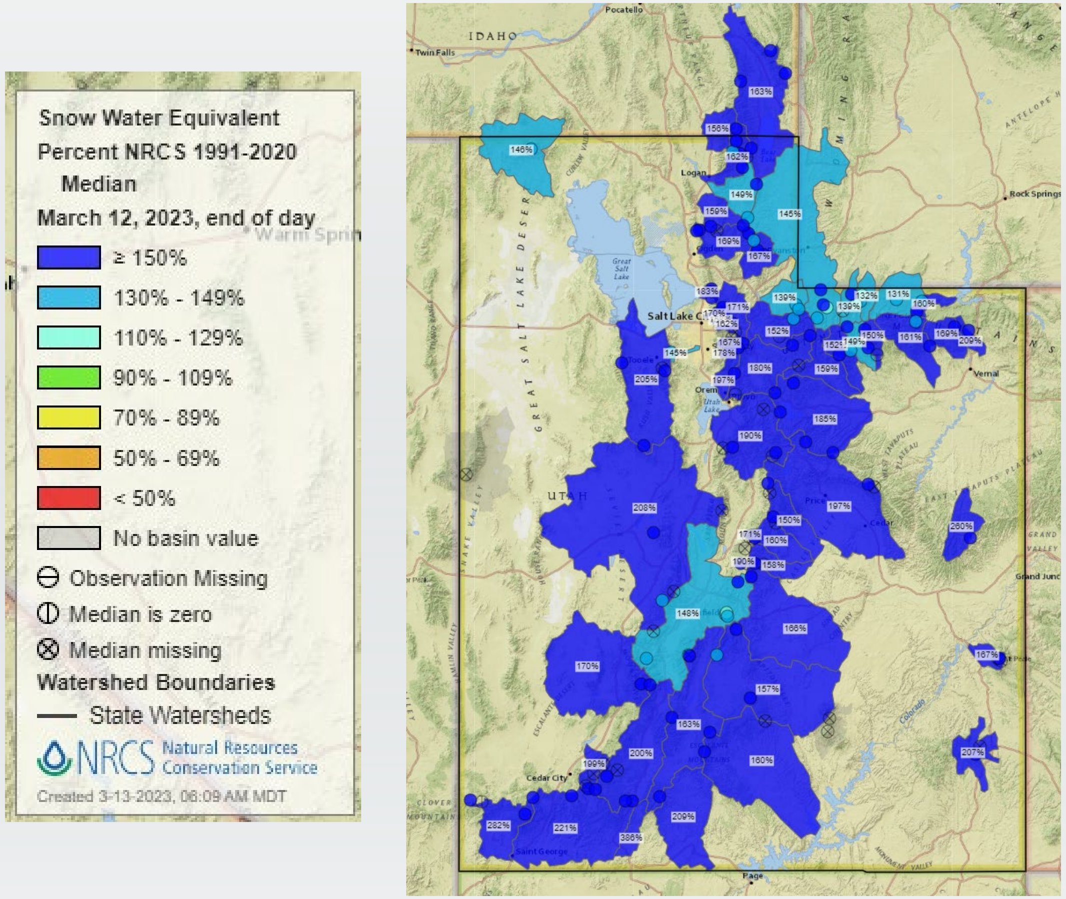
Depletion	Thousand Acre Ft	% of Total Depletion
Agriculture	1188	69%
Municipal and Industrial	358	21%
GSL Mineral Extraction	165	10%
Total	**1711**	

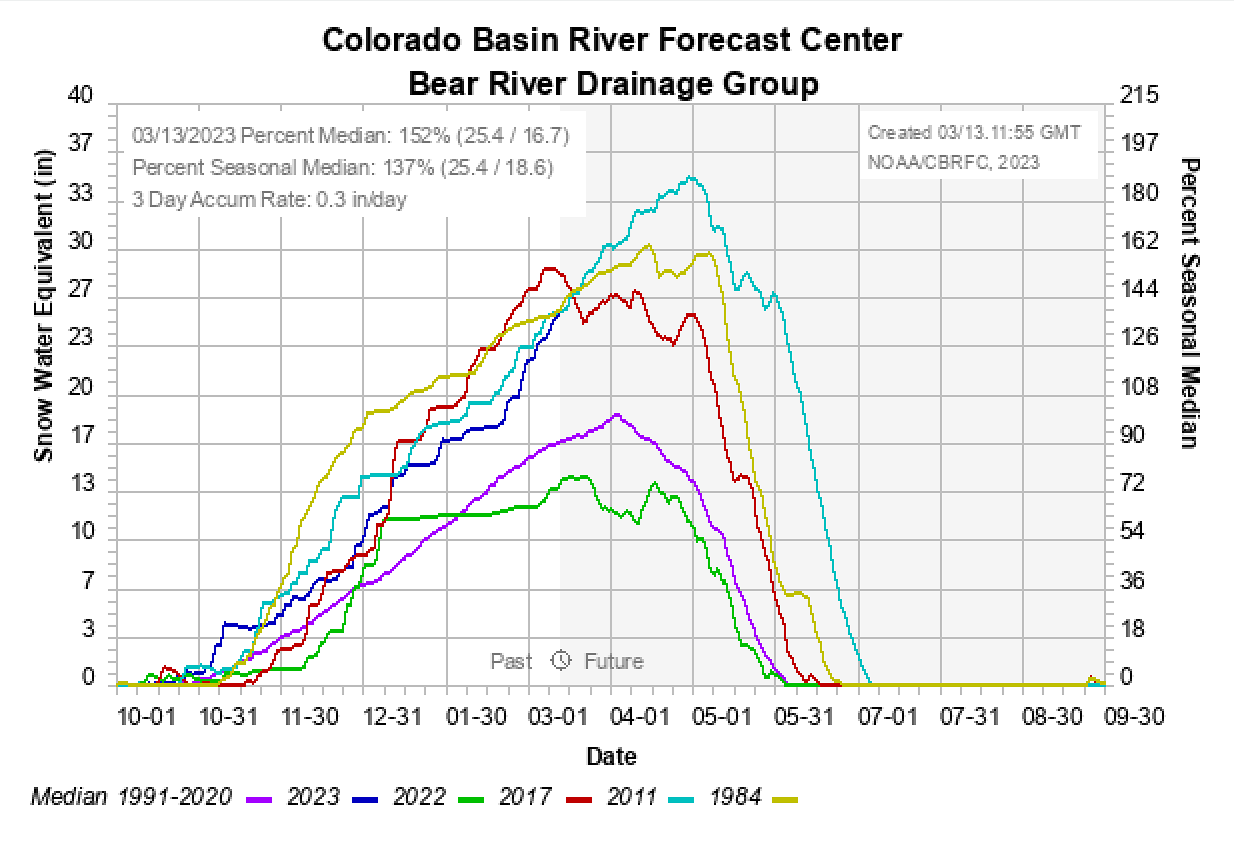
Depletion data from Utah Division of Water Resources, 1989-2020

Options to increase inflow 600 KAF/yr



But we are having a wet year





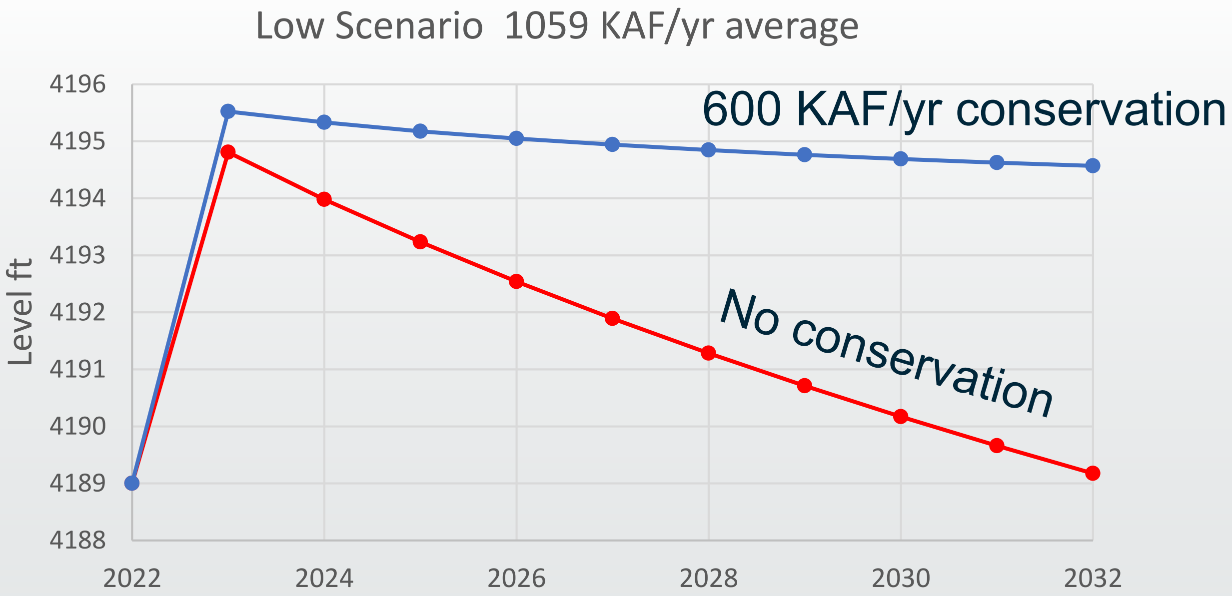
https://www.nrcs.usda.gov/wps/portal/wcc/home/

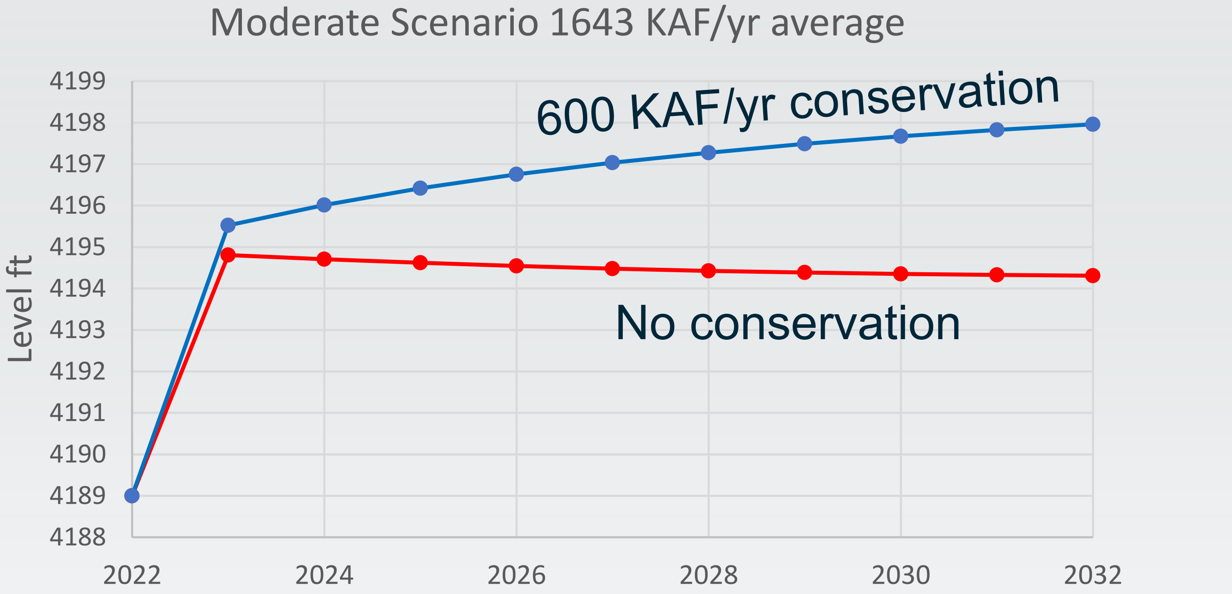
https://www.cbrfc.noaa.gov/station/sweplot/sweplot2.cgi

2023 Outlook

	Streamflow (KAF/yr)	Lake Precip (mm)
1984	6516	516
2011	4592	669
2017	3244	511
2013 (Oct-Feb)	427	261
2023 prediction	**4784**	**565**

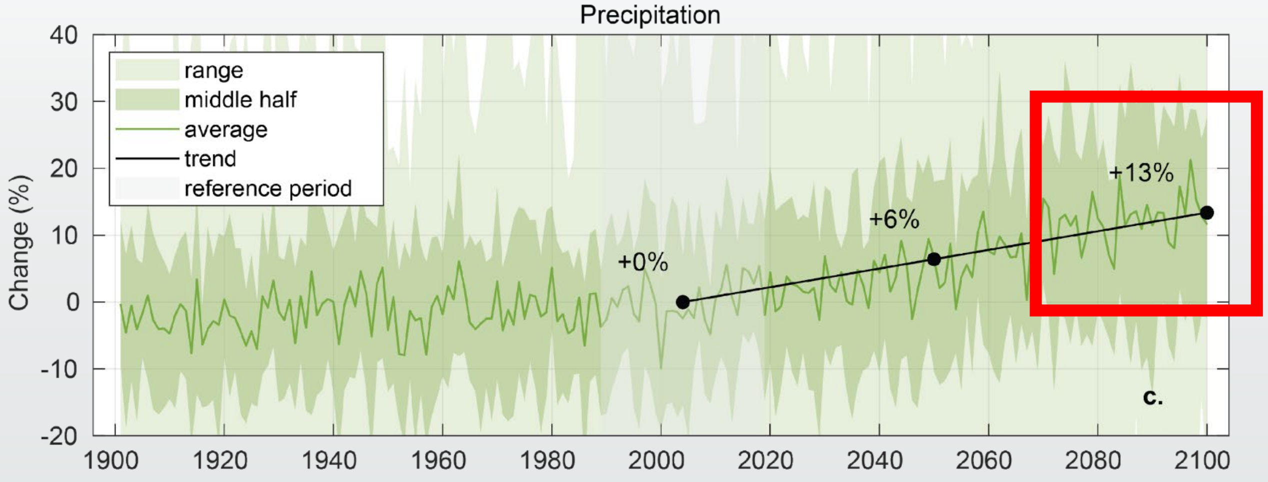
Low Outlook	1059	305
Moderate Outlook	1643	305

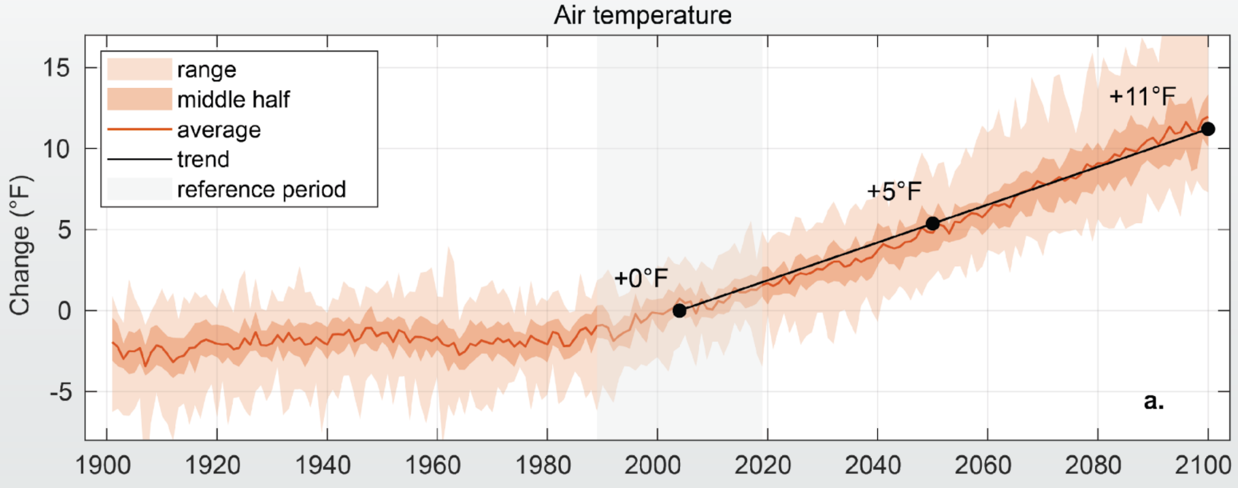


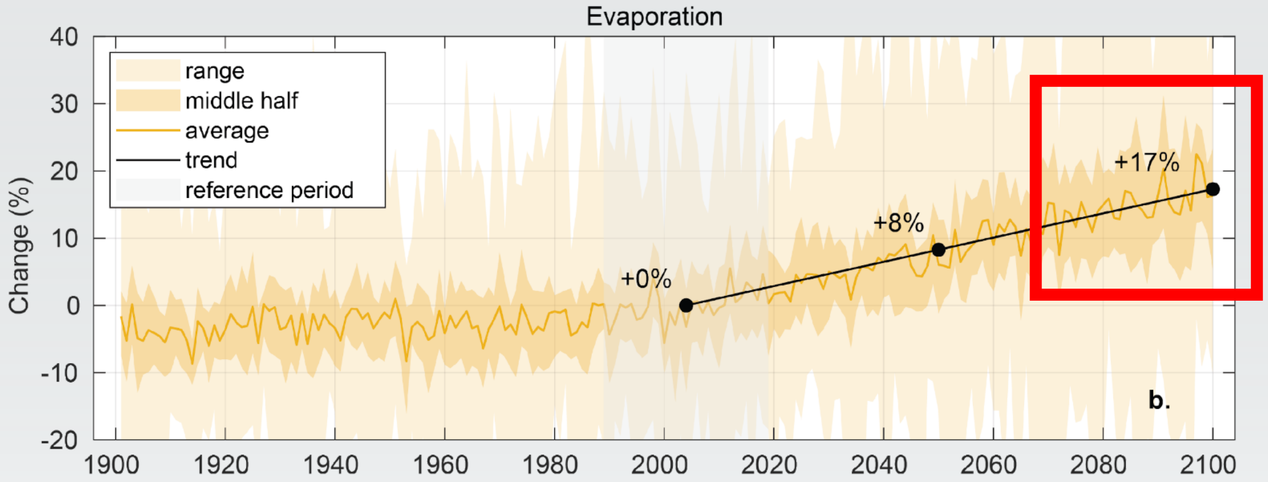


Projected Trends in the Great Salt Lake Basin, 2022-2100

Changes Relative to 1989–2019







Projections indicate that slight increases in precipitation (on average) will be more than offset by increases in temperature and evaporation, **creating further challenges for the lake .**

Note: The analysis is based on a high greenhouse gas emission scenario referred to as Shared Socioeconomic Pathway (SSP) 585, 30 global climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6).

Source: Data from CMIP6; Analysis by Courtenay Strong, 2022.

Conclusions

- To raise GSL one ft it takes ~150 KAF/yr of additional inflow
- The GSL is a dynamic system with considerable variability over time scales of decades, centuries and millennia
- Human inflow changes, both depletions and conservation, are superimposed on these dynamic fluctuations
- Given dynamics, if a goal is to be set, it may be better set as depletion limit rather than a specific lake level or range
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Thanks to collaborators on the Great Salt Lake Strike Team

Questions