GREAT SALT LAKE POLICY ASSESSMENT

A synthesized resource document for the 2023 General Legislative Session

February 9, 2023

Declining water levels threaten economic activity, public health, and ecosystems of Great Salt Lake and surrounding communities. This policy assessment provides a summary of data, insights, and policy options that will inform strategies to improve water management and increase deliveries to the lake.

UtahState University | The University of Utah | Utah DNR Natural Resources | UDAF | Utah Department of Environmental Quality

Version 3.1

Special thanks to Kelly Hannah
for allowing the use of his
Great Salt Lake photography.

February 2023

Dear friends,

Declining water levels of Great Salt Lake threaten economic activity, local public health, and ecosystems. The need for data-informed guidance is now. In response to this emergent statewide challenge, we have embarked on a new type of partnership to get answers to state policymakers faster. We call it the Great Salt Lake Strike Team.

The Strike Team quickly synthesizes cutting-edge research and delivers information to those who need it most. It includes top researchers from Utah's research universities who are experts in public policy, hydrology, water management, climatology, and dust. They join with experts from Utah state agencies, who are the "boots on the ground" in overseeing Great Salt Lake.

In just a few months, we've worked to create clear guidance and consensus on the most critical questions about the lake. How serious is it? How much water are we taking from the lake? How much more do we need? What are our options?

This approach aims to be impartial, data-informed, and solution-oriented. The peer-reviewed research prepared at Utah's research universities serves as the gold standard of scientific inquiry and provides the shoulders this Strike Team stands on.

The Strike Team offers six specific recommendations for gubernatorial and legislative support in the coming year: Leverage the wet years, set a lake elevation range goal, invest in conservation, invest in water monitoring and modeling, develop a holistic water management plan, and request an in-depth analysis of policy options. The Strike Team stands ready to support state leaders in this important work.

This policy assessment provides a first step. As responsible stewards we have many more steps to take.

With appreciation,

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Great Salt Lake Strike Team

The Great Salt Lake Strike Team includes researchers from the University of Utah and Utah State University working together with state leads from the Utah Department of Natural Resources and Utah Department of Agriculture and Food and additional experts from other entities. Together, these entities join in a model partnership to provide timely, relevant, and high-quality data and research that help decision-makers make informed decisions about Great Salt Lake.

The Strike Team fulfills a two-fold purpose: 1) Serve as the primary point of contact to tap into the expertise of Utah's research universities, and 2) Provide urgent research support and synthesis that will enhance and strengthen Utah's strategies to improve watershed management and increase water levels in Great Salt Lake.

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Glossary

Depletion – The amount of water consumed by a given use and not returned to the system.

GSL - Great Salt Lake

Municipal and Industrial (M&I) – Includes water use and depletion for commercial, industrial, institutional, and residential purposes.

Natural Flow – The amount of streamflow that would occur if there were no human depletions. It is estimated by adding calculations of depletions to measured streamflow.

Runoff Efficiency – The ratio of volume of runoff to volume of precipitation in a given basin is a measure of natural system water use. It can vary due to temperature, aquifer replenishment, and extended periods of drought.

Thousand Acre-feet (KAF) – An acre-foot is the amount of water it takes to fill one acre of land one foot deep in water, typically expressed in this report as thousand acre-feet (KAF) and occasionally referred to by million acre-feet (MAF).

GREAT SALT LAKE STRIKE TEAM

POLICY ASSESSMENT EXECUTIVE SUMMARY

Declining water levels of Great Salt Lake threaten economic activity, local public health, and ecosystems. The situation requires urgent action. Fortunately, science provides crucial perspective, understanding, and scenarios for policymakers to chart a path forward. Many policy levers can help return the lake to healthy levels.

Utah's research universities formed the Great Salt Lake Strike Team to provide a primary point of contact for policymakers as they address record-low elevations of Great Salt Lake. Together with state agency professionals, the Strike Team brings together experts in public policy, hydrology, water management, climatology, and dust to provide impartial, data-informed, and solution-oriented support for Utah decision-makers. The Strike Team does not advocate but rather functions in a scientific/ policy advisory role as a service to the state.

The Strike Team offers six major insights and recommendations

1 Explanation for record-low elevation

Human and natural consumptive water use explain over two-thirds of low lake levels. Other smaller contributing factors include natural precipitation variability and climate warming. Human use is a large contributing factor for Great Salt Lake's decline and the only factor that can be changed in the near term.

Estimated Contribution of Impacts on Current Record Low Elevation

Direct Evaporation from Climate Warming

Estimated Impact: 8–11%

Natural Variability (Precipitation and Runoff Efficiency)

Estimated Impact: 15–23%

Natural and Human Consumptive Use

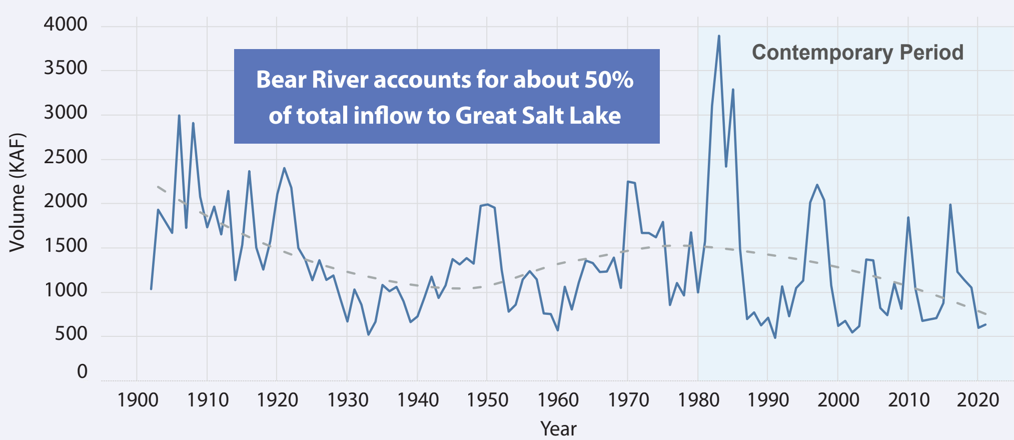
Estimated Impact: 67–73%

Source: Analysis from Great Salt Lake Strike Team, 2022; Mohammed, I., & Tarboton, D. (2012). An examination of the sensitivity of the Great Salt Lake to changes in inputs. Water Resources Research, Volume 48, Issue 11. https://doi.org/10.1029/2012WR011908

2 Decreasing inflow

Even though overall water supply from the mountains shows no long-term trend, inflow to the lake is decreasing. This decrease reflects greater depletion by natural and human systems at lower elevations.

Bear River Annual Streamflow, 1903-2022



Note: Trend line generated using LOESS regression.
Source: Data from USGS gage 10126000 Bear river Near Corrinne with missing data (1957-1963) and values prior to 1949 derived from USGS gage 10118000 Bear River near Collinston (Analysis by David Tarboton)

3 Policy options

A variety of policy options exist to increase water deliveries to Great Salt Lake. Interventions fall into three broad categories: conservation, new water, and engineering solutions. Policymakers will need to rapidly assess the benefits, costs, and speed of each policy lever to prioritize state actions. The Strike Team can help with more detailed analysis to support prioritization.

Conservation

- Commit conserved water to Great Salt Lake
- Optimize use of agricultural water
- Optimize municipal and industrial water pricing
- Limit municipal and industrial water use growth
- Utilize water banking and leasing
- Conduct active forest management in Great Salt Lake headwaters
- Optimize Great Salt Lake mineral extraction

New water

- Import water
- Increase winter precipitation with cloud seeding

Engineering solutions

- Raise and lower the causeway berm
- Mitigate dust transmission hotspots

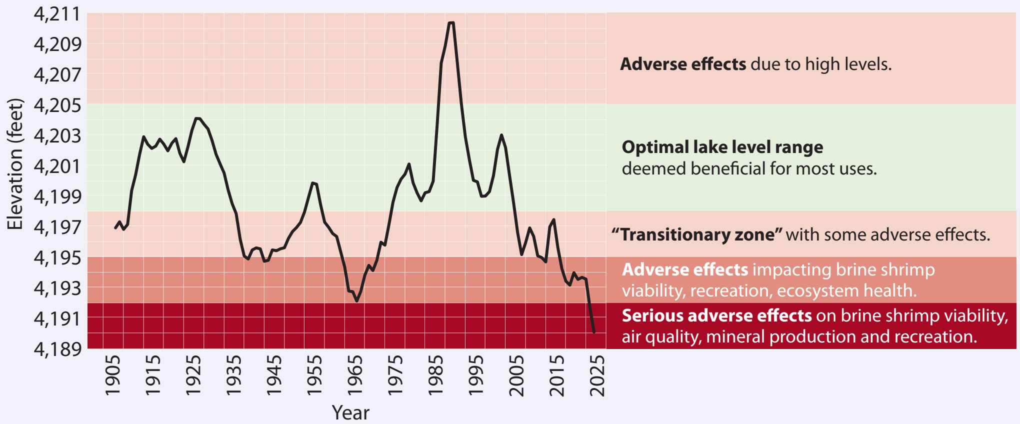
4 Commit conserved water

Commit conserved water Committing conserved water to the lake is a fundamental policy lever that is crucial for many other policies to function effectively. Upon approval of an appropriate change application, the state engineer can readily deliver conserved water to Great Salt Lake under a "distribution system."

5 Elevation range goal

Elevation range goal – The Strike Team recommends policymakers adopt a lake elevation target level range based on analysis prepared by the Utah Division of Forestry, Fire, and State Lands. Preliminary analysis suggests a transitional elevation range of 4,195–4,197 feet and an optimal elevation range of 4,198–4,205 feet. Meeting this goal requires policymakers to focus on inflows that both fill and maintain targeted elevation ranges.

Average Annual Elevation of Great Salt Lake with Elevation Zones, 1903–2022

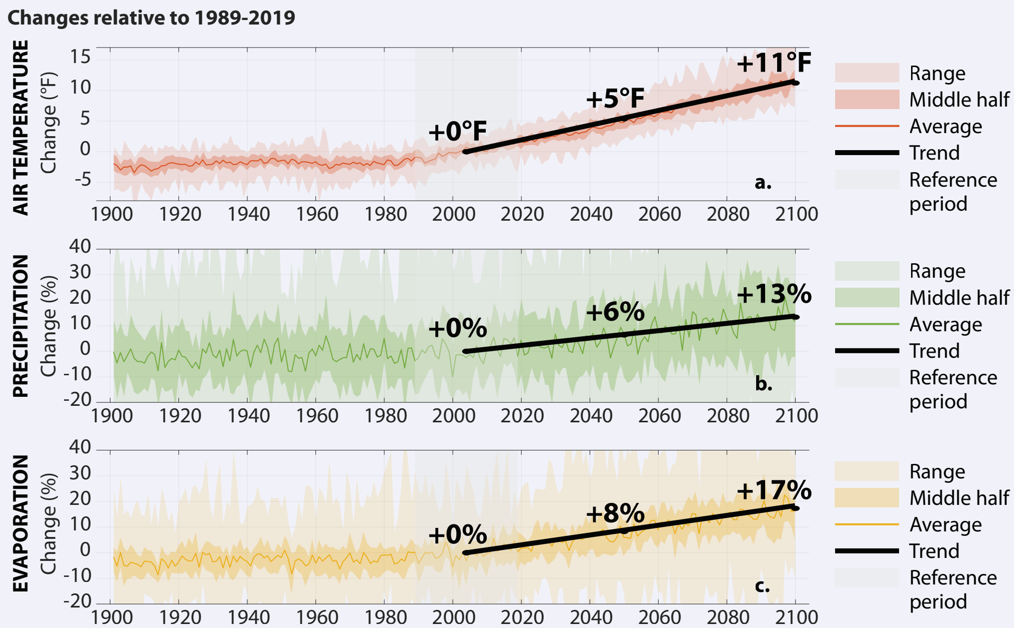


Sources: US Geological Survey Historical Elevation at Saltair Boat Harbor; Utah Division of Forestry, Fire and State Lands, GSL Lake Elevation Matrix, 2013

6 Future water availability

Future water availability – Over the long term, slight increases in expected precipitation will likely be overwhelmed by increases in temperature and evaporation, creating further challenges for the lake. These future challenges underscore the need for resolve. The state will benefit by filling the lake quickly and creating an adaptive process to monitor and maintain lake levels in coming decades.

Projected Trends in Temperature, Precipitation, and Evaporation in the Great Salt Lake Basin, 2004-2100



Notes:

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2. There are 30 global climate models included in this analysis, developed by leading modeling centers in countries including the United States. The simulations were coordinated by the Coupled Model Intercomparison Project Phase 6 (CMIP6) and were analyzed by Courtenay Strong at the University of Utah.
3. Great Salt Lake is not explicitly represented at the grid spacings used in these global climate models. The analysis uses the grid point nearest the central latitude and longitude of the lake in each model.

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

"As leaders of Utah's public research universities, we share a commitment to the research needs of this state. Together with our partners in state government, we have joined in a model partnership to share with state policymakers the best available data and research on Great Salt Lake's declining water levels and the policy options that exist to reverse this trend. This is Utah at its best – a state that collaborates, makes data-driven choices, and acts for the greater good."

Taylor R. Randall, President
University of Utah

Noelle E. Cockett, President
Utah State University

Data and Insights Summary

Understanding the recent record-low elevation of Great Salt Lake is foundational to charting a path forward. The following figures clarify how the lake reached its current level and explore how a changing climate will impact Great Salt Lake in the future.

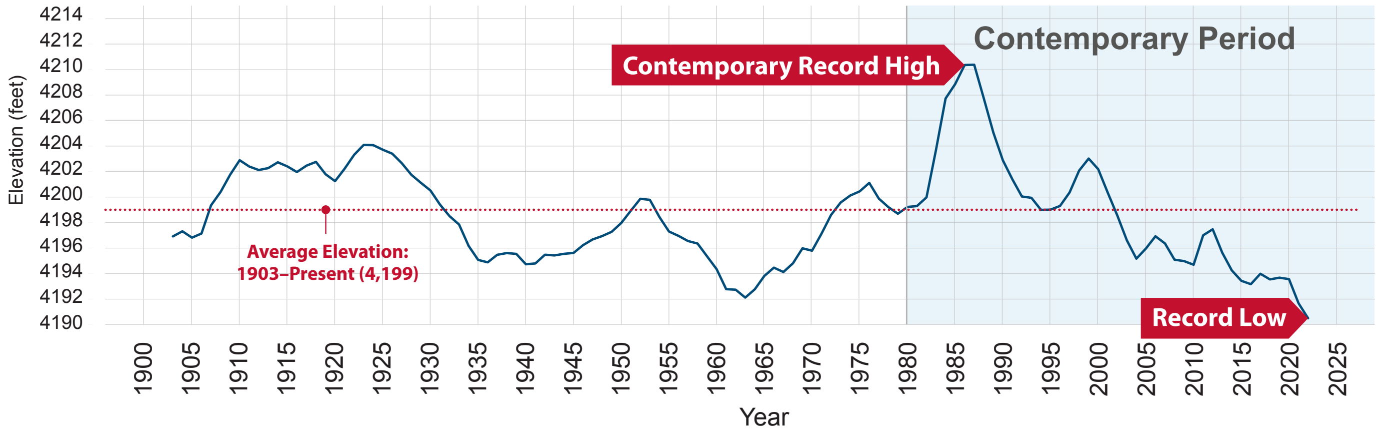
Lake Level

Great Salt Lake elevation is at a historical low.

INSIGHTS

1. In 2022, the annual average lake level dropped to the lowest level on record (4,190.1 ft).
2. On October 27, 2022, the lake reached a daily record low of 4,188.6 ft.
3. After a peak in 1987 (4,210.4 ft), there has been clear downward trend in lake elevation.

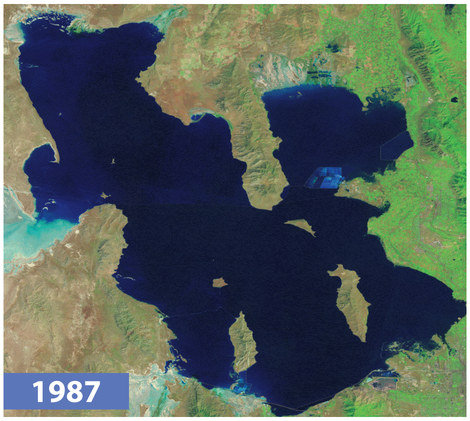
Figure 1: Average Annual Elevation of Great Salt Lake, 1903–2022



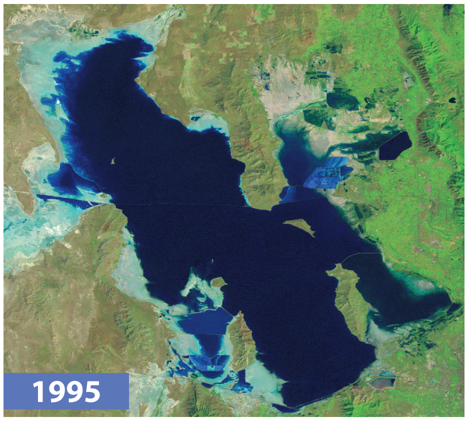
Sources: US Geological Survey Historical Elevation at Saltair Boat Harbor

Average Annual Elevation of Great Salt Lake: 1987, 1995, and 2022

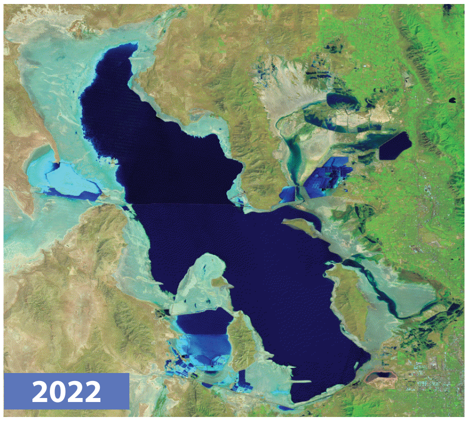
Contemporary Record High
4,210.4 feet



Average
4,198.6 feet



Record Low
4,190.1 feet



Source: Google Earth Engine

Temperature, Precipitation, and Runoff Efficiency

In northern Utah, temperature is rising, while precipitation and runoff efficiency show no consistent trend.

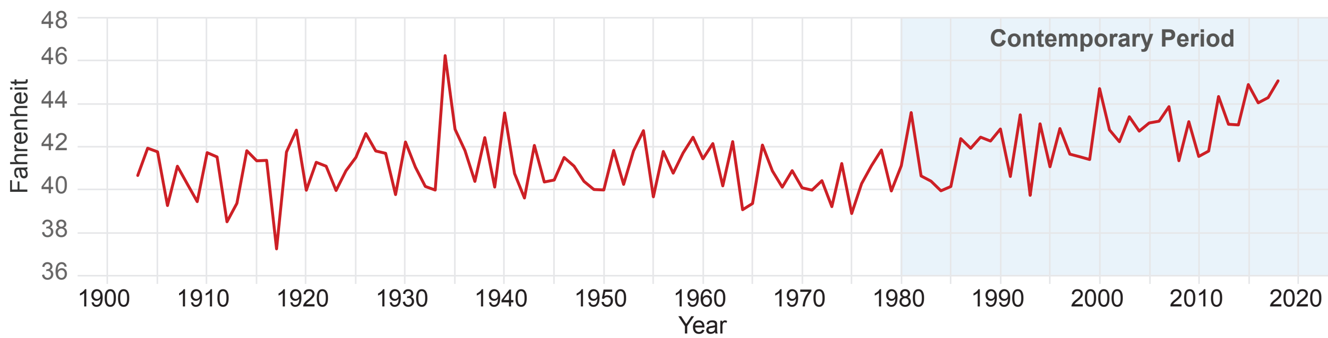
INSIGHTS

1. Mean annual air temperature in northern Utah increased more than 3 degrees Fahrenheit since 1983.
2. Higher air temperatures result in increased evaporation from reservoirs and GSL.
3. Annual precipitation is becoming more variable, with more dry periods.
4. Runoff efficiency increases for several years after one or more years with above average precipitation and decreases following years with below average precipitation.
5. Consecutive dry years and warmer temperatures interact to reduce runoff efficiency and streamflow more than would be expected based on precipitation alone.

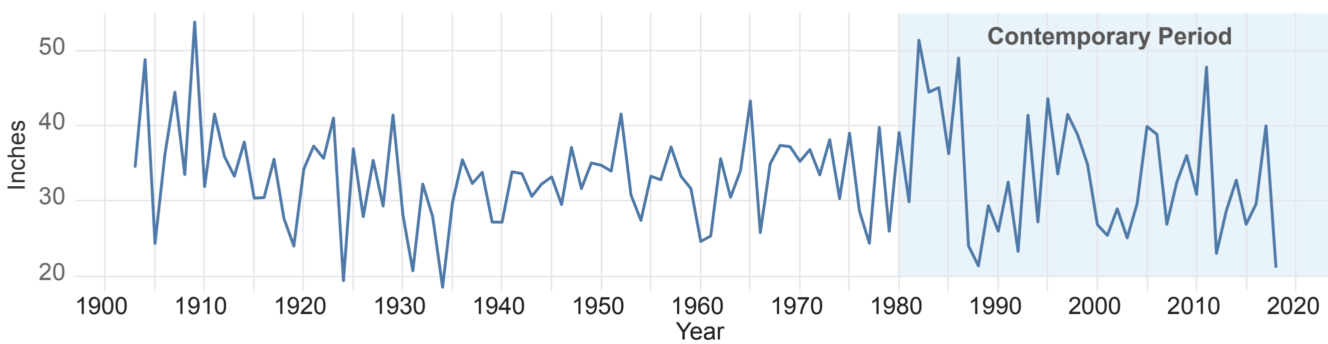
Runoff Efficiency is the ratio of volume of streamflow to volume of precipitation in a given basin. Approximately one-third of the precipitation that falls contributes to streamflow. This value is highly variable from year to year but has not changed appreciably over the last century.

Figure 2: Historical Observations: Northern Utah Mean Annual Temperature, Precipitation, and Runoff Efficiency, 1903-2020

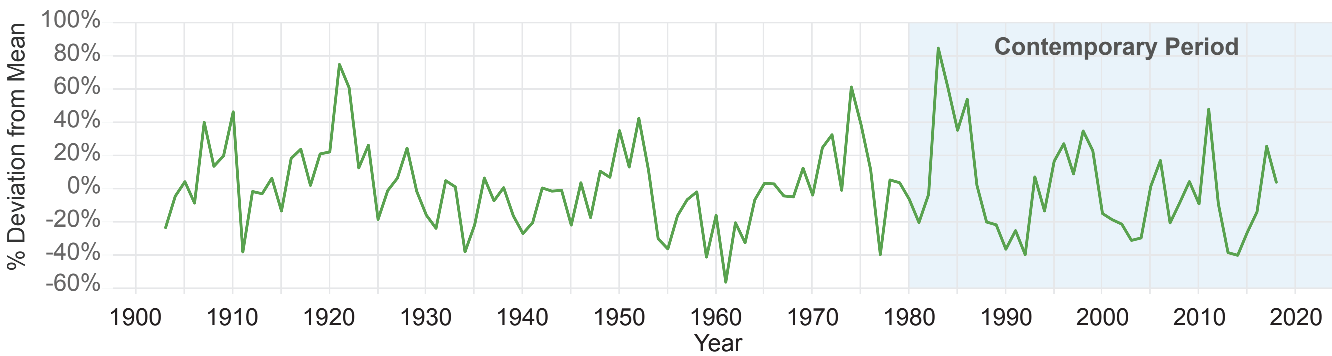
Mean Northern Utah Air Temperature



Mean Northern Utah Precipitation



Northern Utah Runoff Efficiency



Source: Brooks, P. et al. (2021). Groundwater-mediated memory of past climate controls water yield in snowmelt-dominated catchments. Water Resources Research, 57 e2021WR030605. https://doi.org/10.1029/2021WR030605

Natural Flow and Streamflow into Great Salt Lake

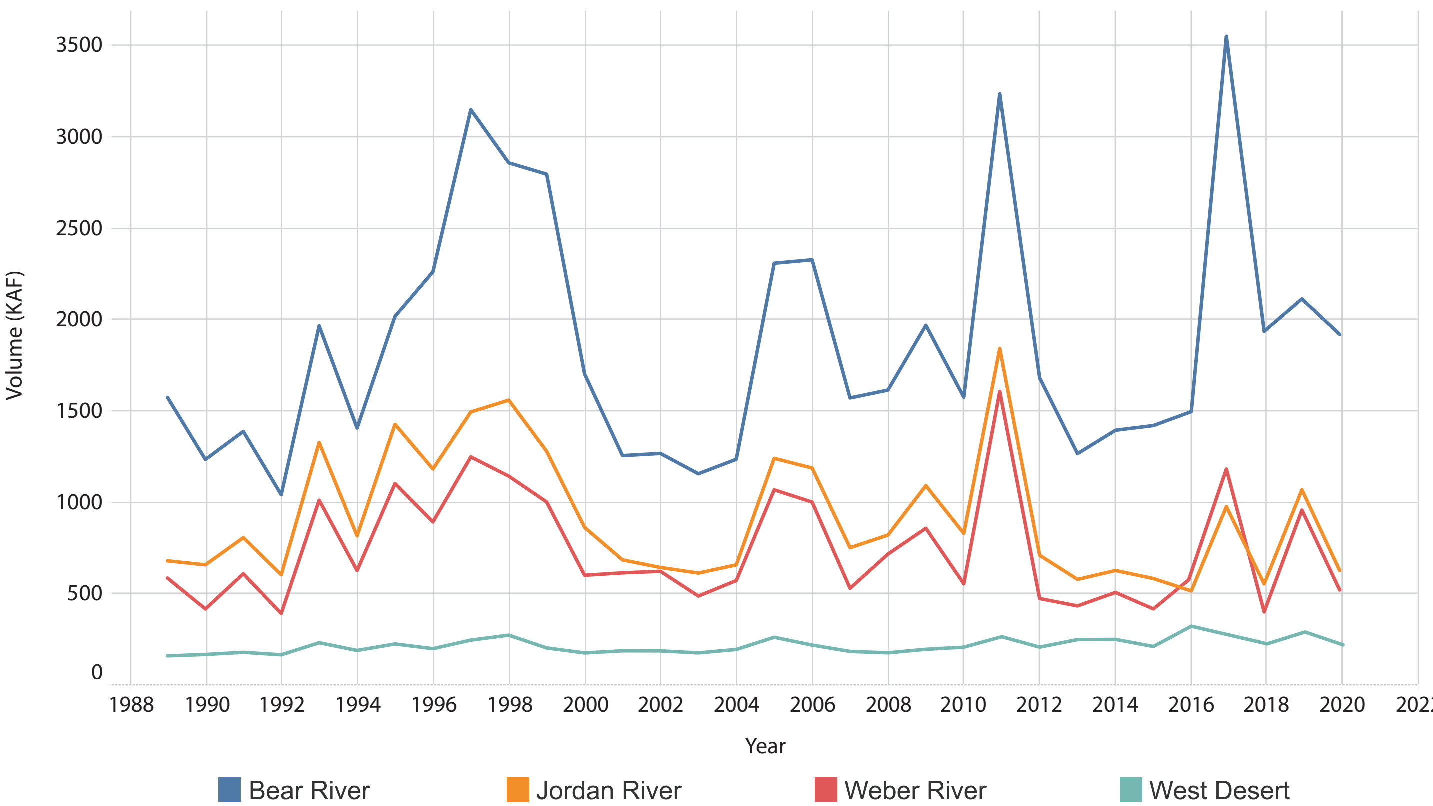
Natural flow and streamflow in the Great Salt Lake basin are highly variable. Natural flow in the contemporary period shows no trend, while streamflow into Great Salt Lake shows a declining trend.

INSIGHTS: NATURAL FLOW

1. Natural flow is highly variable due primarily to winter snowfall and runoff efficiency.
2. Natural flow in the basin does not show a declining trend over the last 30 years.
3. The Bear River's natural flow is the largest of the Great Salt Lake sub-basins.

Natural flow is the amount of streamflow that would occur if there were no human depletions. It is estimated by adding calculations of depletions to measured streamflow.

Figure 3: Natural Flow in the Contemporary Period, 1989-2020



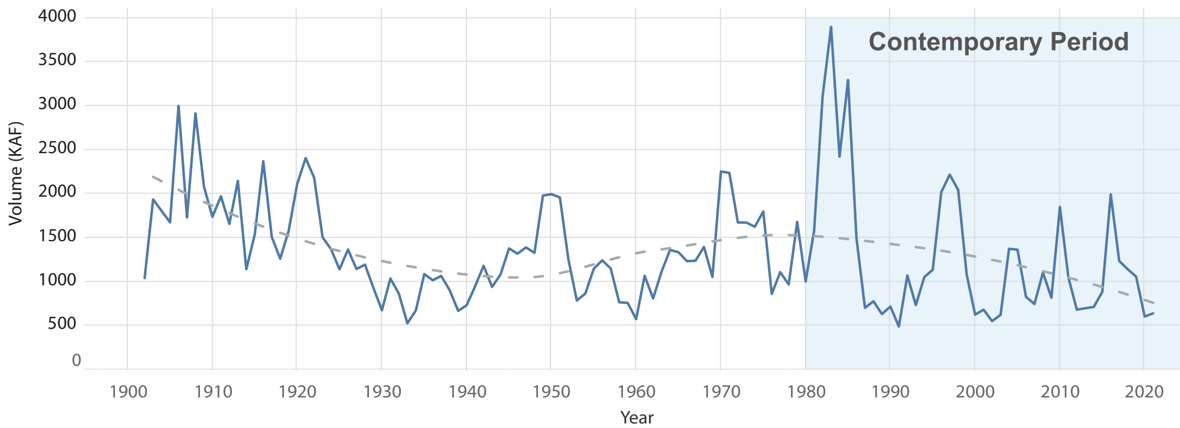
Average Natural Flow by Basin, 1989-2018

Source: Great Salt Lake Water Budget, Utah Division of Water Resources, 2023

INSIGHTS: STREAMFLOW INTO GREAT SALT LAKE

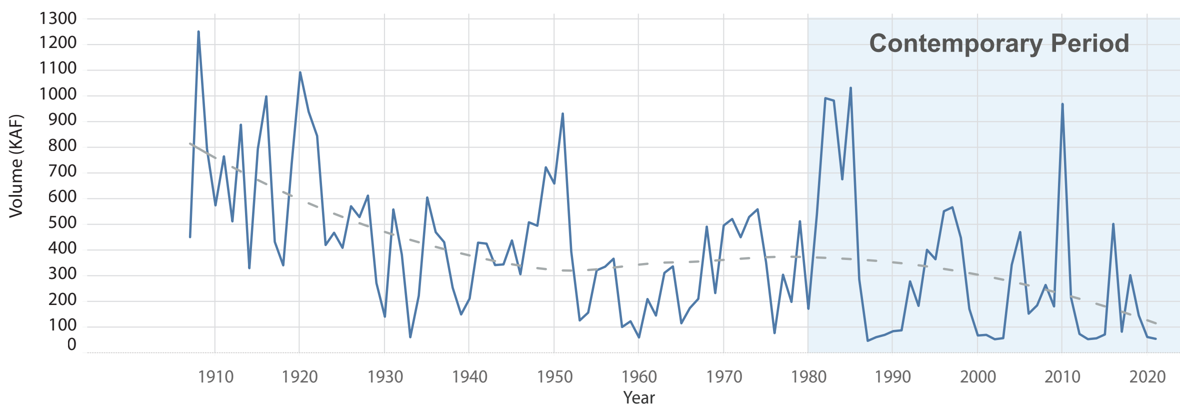
1. Even though natural flow shows no long-term trend, inflow to the lake is decreasing.
2. These decreases reflect greater depletion by natural and human systems.

Figure 4: Bear River Annual Streamflow, 1903-2022



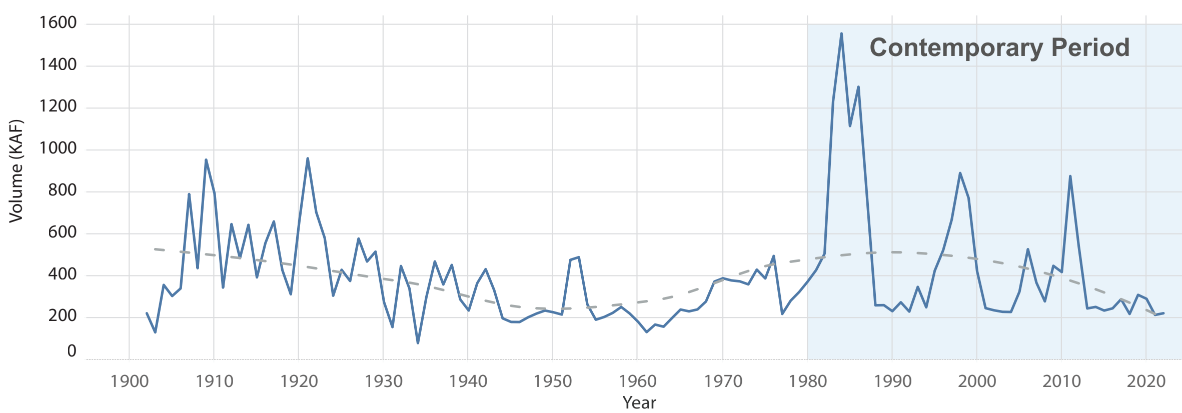
Note: Trend line generated using LOESS regression.
Source: Data from USGS gage 10126000 Bear river Near Corrinne with missing data (1957-1963) and values prior to 1949 derived from USGS gage 10118000 Bear River near Collinston (Analysis by David Tarboton)

Figure 5: Weber River Annual Streamflow, 1908-2022



Note: Trend line generated using LOESS regression.
Source: Data from USGS gage 10141000 Weber River near Plain City, UT

Figure 6: Jordan River Annual Streamflow, 1902-2022



Note: Trend line generated using LOESS regression.
Source: Data from USGS gage 10170490 (1944-2022) with modeled data from 1902-1943 (Analysis by Margaret Wolf)

Explanation for Record-low Elevation

Human and natural consumptive water use reduce Great Salt Lake elevations.
The Strike Team estimates human water use comprises 67-73%, natural variability 15-23%, and climate warming 8-11% of Great Salt Lake's low elevation.

INSIGHTS: CONTRIBUTING FACTORS

1. The nature and lack of data prevent greater precision in these estimates.
2. A changing climate further complicates the analysis, creating more variable precipitation, longer droughts, and higher temperatures.
3. A solution based on these estimates will not be sufficient, as these estimates capture the system as it currently is. Natural variability, climate warming, and direct evaporation are expected to increase with continued climate change.
4. Policy must focus on human water use, as it is the only component that can be changed in the near term.

Figure 7: Estimated Contribution of Impacts on Current Record Low Elevation

Direct Evaporation from Climate Warming
Estimated Impact: 8–11%

Natural Variability (Precipitation and Runoff Efficiency)
Estimated Impact: 15–23%

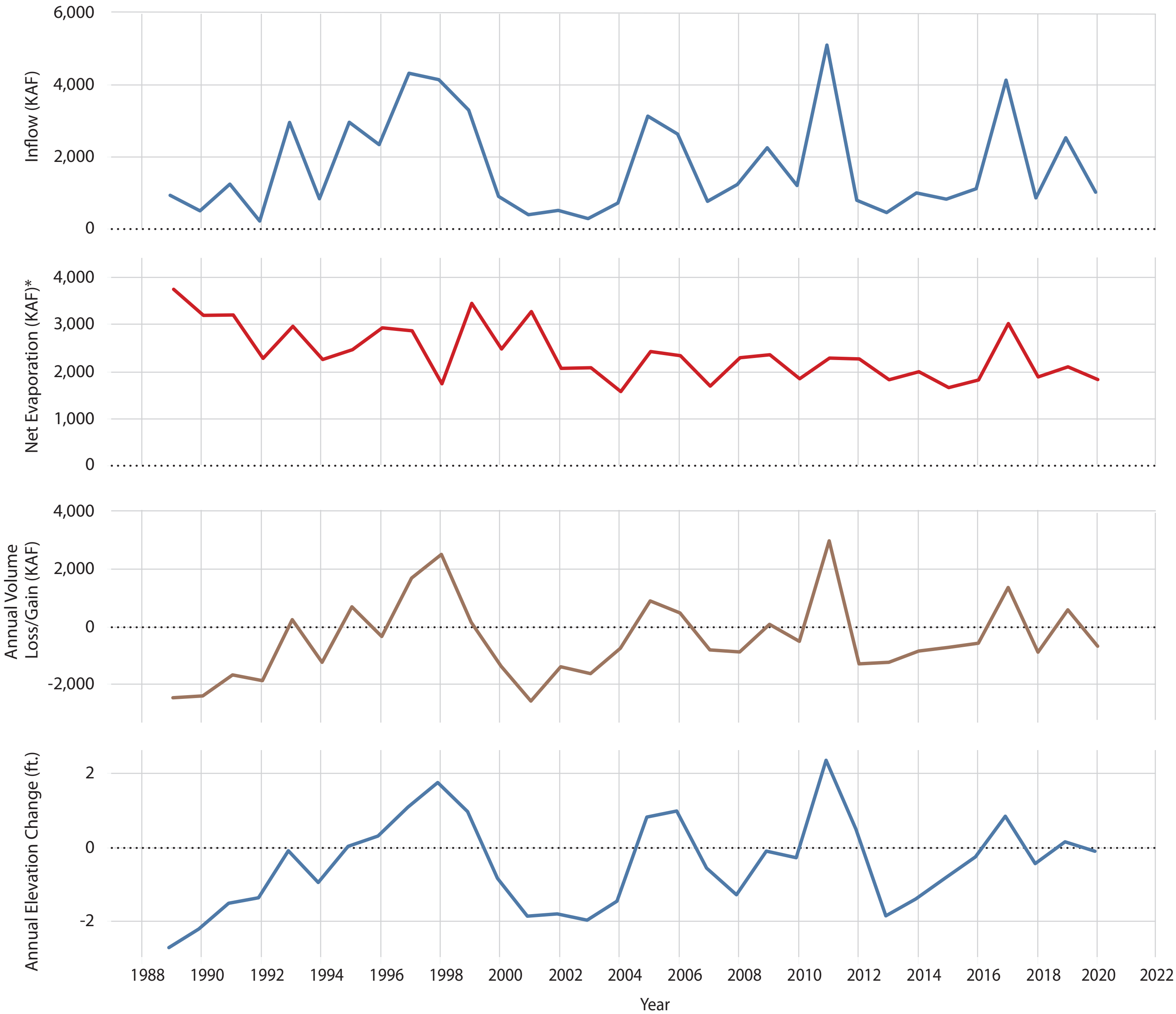
Policy Lever Natural and Human Consumptive Use
Estimated Impact: 67–73%

Source: Analysis from Great Salt Lake Strike Team, 2022; Mohammed, I., & Tarboton, D. (2012). An examination of the sensitivity of the Great Salt Lake to changes in inputs. Water Resources Research, Volume 48, Issue 11. https://doi.org/10.1029/2012WR011908

INSIGHTS: DETAIL

1. Inflows are greater during and following years with higher precipitation. High precipitation years have become less frequent over the last few decades.
2. Evaporation decreases as the surface area of the lake shrinks.
3. The contemporary period includes both years of water loss and gain, but has overall been a period of water loss.

Figure 8: Inflow, Evaporation, Loss/Gain, and Elevation Change on Great Salt Lake in the Contemporary Period, 1989–2020



*Note: Net evaporation is equal to evaporation minus precipitation over the lake surface.
Evaporation in 1989 includes water pumped to the West Pond.
Sources: Great Salt Lake Water Budget, Utah Division of Water Resources, 2023; US Geological Survey Historical Elevation at Saltair Boat Harbor

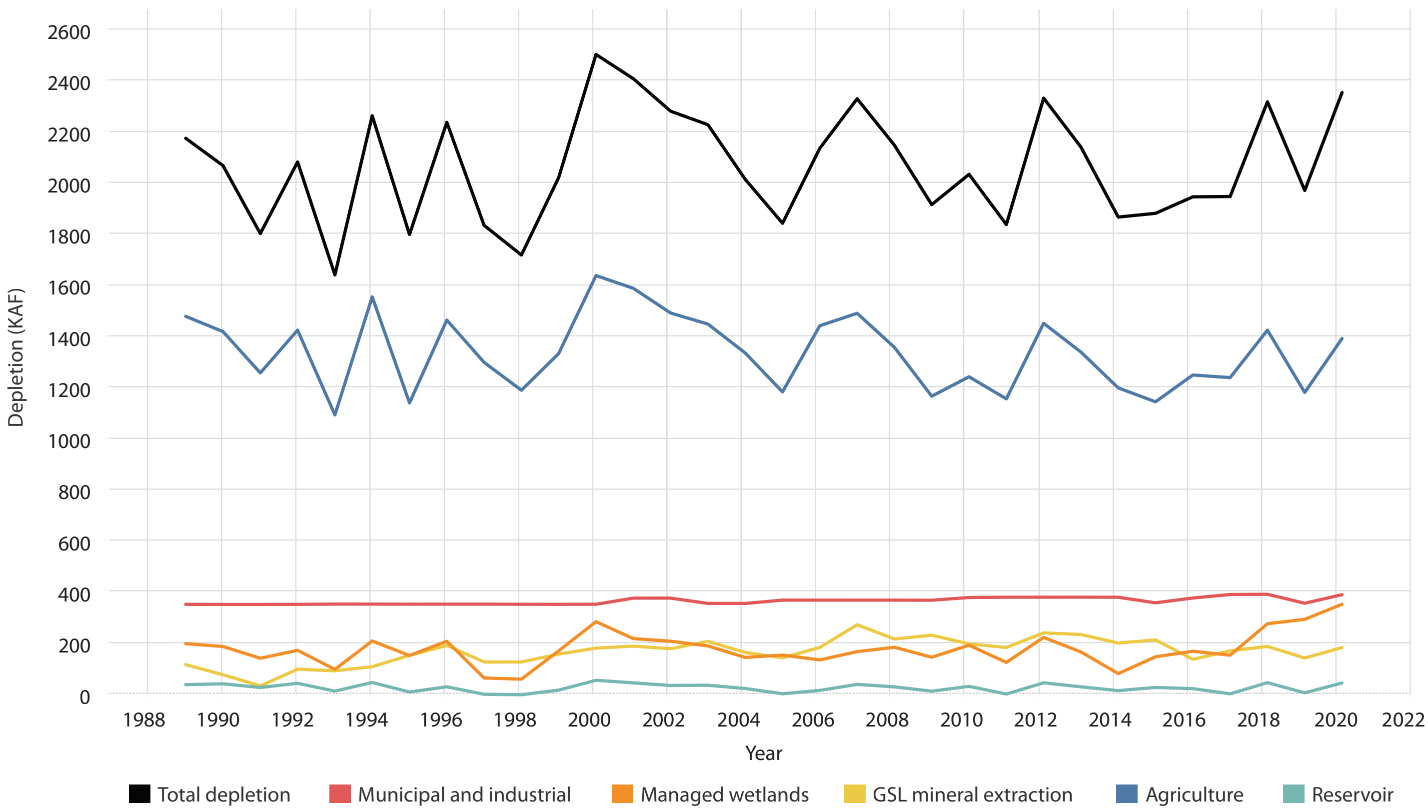
Human Water Use

Human water use varies by type.

INSIGHTS

1. Agriculture depletes the most water and this use has remained relatively constant in the contemporary period.
2. Reservoir evaporation has remained relatively constant, while municipal and industrial depletion has increased slightly over time.
3. Managed wetlands and mineral extraction have increased over the contemporary period.
4. Human water uses and total depletions tend to be larger in warmer and drier years.
5. Total depletions have been variable in the past 30 years, but the range has remained relatively constant, averaging 2,077 KAF per year.

Figure 9: Human Water Depletion by Type in the Contemporary Period, 1989-2020



Average Depletion (KAF/year)

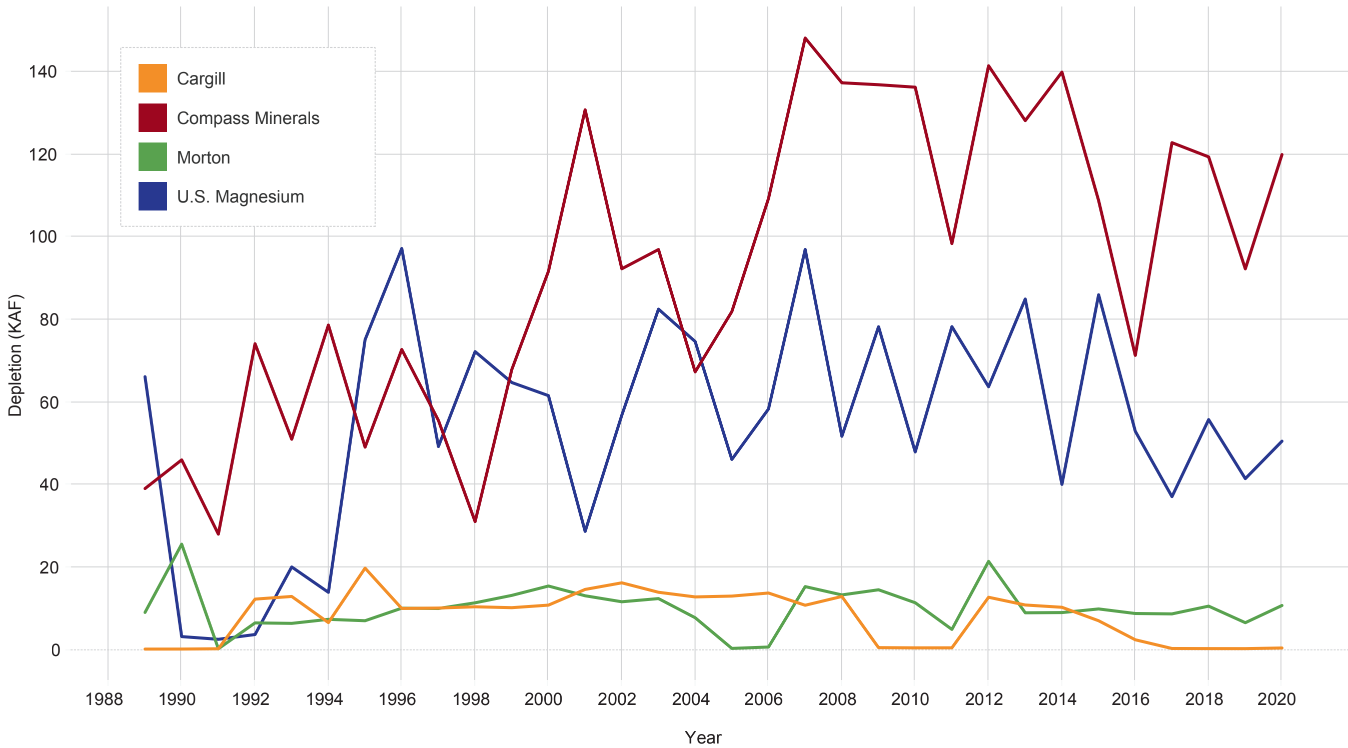
Depletion Type	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Agriculture – Includes all agriculture water depletions.	1,297	1,388	1,413	1,343	1,261	1,300
Reservoir – Represents evaporation from reservoirs (does not include Bear or Utah Lakes).	26	18	26	24	22	22
Municipal and Industrial – Covers urban water depletions from commercial, industrial, institutional, and residential uses.	352	352	366	370	375	381
Managed Wetlands – Includes depletions associated with man-made riparian areas and wetlands.	153	156	181	163	147	248
GSL Mineral Extraction – Incorporates depletions from all mineral extraction companies operating on GSL.	95	155	175	219	213	163
Total Depletion	**1,923**	**2,069**	**2,161**	**2,119**	**2,018**	**2,113**

Source: Great Salt Lake Water Budget, Utah Division of Water Resources, 2023

INSIGHTS: MINERAL EXTRACTION

1. Mineral extraction water depletion on Great Salt Lake grew to 181.8 KAF in 2020 with a peak in 2007 (271.3 KAF).
2. Compass Minerals and U.S. Magnesium drove the increase in depletion from 1989 to 2020.
3. Over this period, mineral extraction depletions account for 8.0% of total human depletion.

Figure 10: Mineral Extraction Water Depletions on Great Salt Lake in the Contemporary Period, 1989–2020



Average Depletion (KAF/year)

Company	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Cargill	10.4	10.4	14.2	7.7	8.3	0.8
Compass Minerals	56.2	63.8	93.9	133.6	123.4	105.2
Morton	5.6	12.1	9.1	11.1	10.9	9.1
U.S. Magnesium	23.1	69.0	57.8	66.7	70.6	47.6
Total	**95.3**	**155.2**	**174.9**	**219.1**	**213.2**	**162.7**

Source: Utah Division of Water Rights, 2023

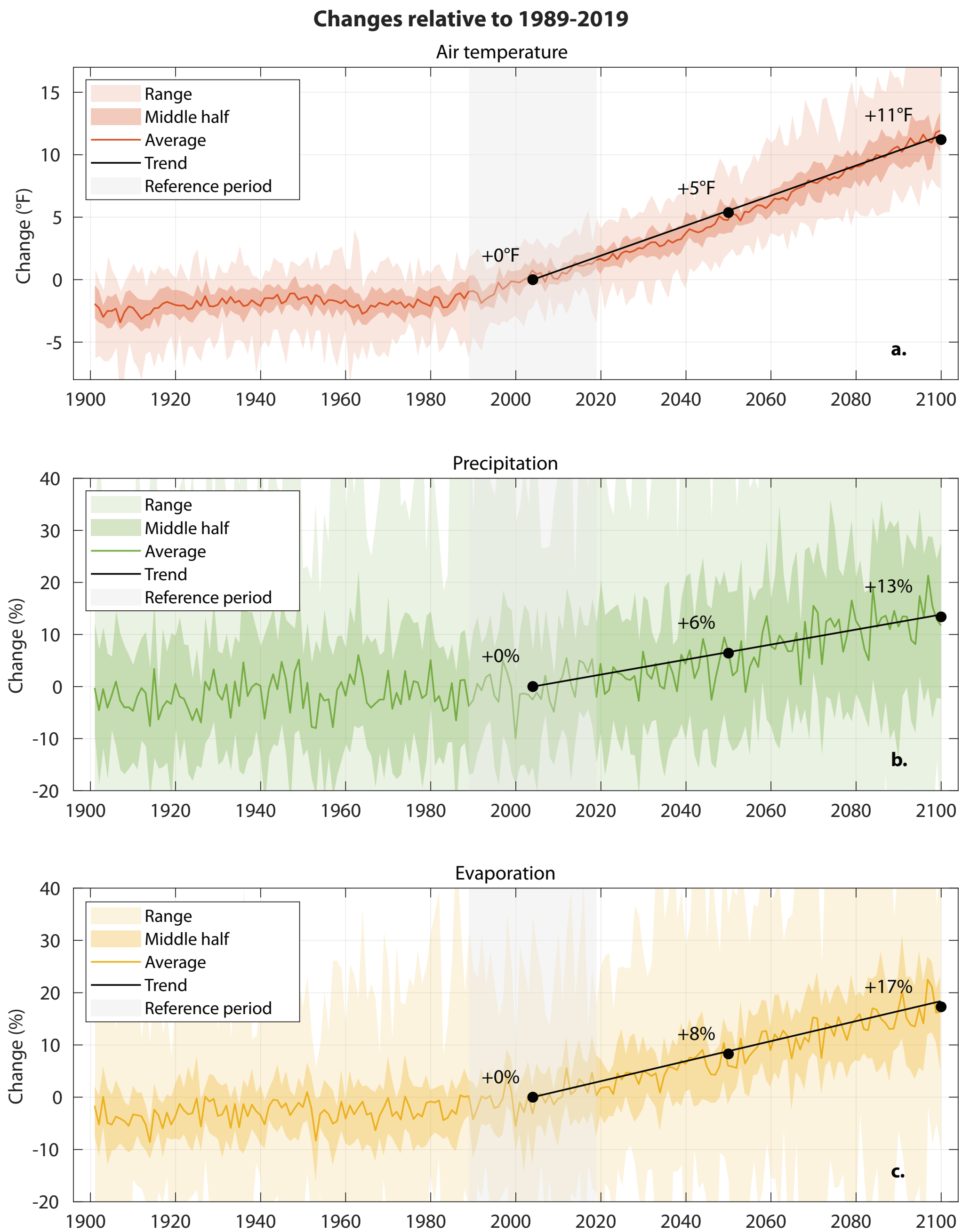
Future Water Availability

Experts predict that over the long term, expected increases in precipitation will be overwhelmed by rising temperature and evaporation, creating further challenges for the lake.

INSIGHTS

1. Under a high greenhouse gas emission scenario, 5°F of warming is projected by 2050 and 11°F by 2100.
2. Warming is projected to increase precipitation because a warmer atmosphere can hold and deliver more water.
3. However, warming also increases evaporation, and that will tend to offset any water gains from precipitation.
4. Warmer temperatures increase lake evaporation and human water needs.

Figure 11: Projected Trends in Temperature, Precipitation, and Evaporation in the Great Salt Lake Basin, 2004-2100



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3. Great Salt Lake is not explicitly represented at the grid spacings used in these global climate models. The analysis uses the grid point nearest the central latitude and longitude of the lake in each model.

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

Target Lake Elevation Range

The Strike Team recommends carefully selecting a target lake elevation range and using the following analysis to set conservation goals and plan for needed inflows to Great Salt Lake.

Adopt an elevation range goal. Select a range goal using the Division of Forestry, Fire and State Land's Great Salt Lake Elevation Matrix (See Figure 12).

Plan for a filling phase and a maintenance phase. Restoring Great Salt Lake to a target elevation range involves first filling the lake to that level and then maintaining it. More inflow is needed for the filling phase. Table 1 shows the inflow volume required to fill and maintain Great Salt Lake at different target elevations.

Plan for streamflow variability. Filling and maintaining Great Salt Lake within a target elevation range is complicated, due to the fluctuation of streamflows from year to year. Managers should capitalize on wet years, although they are infrequent. Below are two streamflow scenarios that can be used for planning.

- **Low streamflow** – The average of the lowest sequential five years on record: 1988 to 1992 (1,059 KAF/year).
- **Average Streamflow** – The contemporary average inflows between 2000 and 2022 (1,643 KAF/year).

Set conservation targets. Table 2 shows the range of additional water conservation needed per year to reach different target lake elevations for low and average streamflow conditions. If a target elevation range greater than 4,195 ft. is set to be reached in five years, conservation of at least 600 KAF/year would be required. Conservation of approximately 300 KAF/year is needed just to prevent further loss if five-year average flows remain low.

Table 1: Inflow Requirements for Target Elevations (KAF/year)

Target Elevation (ft.)	Fill in 5 years	Fill in 10 years	Fill in 20 years	Maintain
4,189 ft.	-	-	-	1,327
4,192 ft.	1,759	1,583	1,501	1,463
4,195 ft.	2,272	1,913	1,770	1,738
4,198 ft.	2,975	2,403	2,184	2,137

Note: This table assumes an initial lake elevation of 4,189 ft.
Source: Analysis by Great Salt Lake Strike Team, 2023

Table 2: Range of Conservation Needed (KAF/year)

Target Elevation (ft.)	Fill in 5 years	Fill in 10 years	Fill in 20 years	Maintain
4,189 ft.	-	-	-	0-268
4,192 ft.	116-700	0-524	0-442	0-404
4,195 ft.	629-1,213	270-854	127-711	95-679
4,198 ft.	1,332-1,916	760-1344	541-1,125	494-1,078

Note: This table assumes an initial lake elevation of 4,189 ft.
Source: Analysis by Great Salt Lake Strike Team, 2023

Determine conservation strategy. Table 3 explores different scenarios for achieving water conservation targets. Different water sectors could have similar or different conservation goals to begin to refill the lake to the target level (e.g. with 600 KAF per year)—or at least to prevent further losses to the lake (e.g. with 300 KAF per year).

In the first two scenarios in Table 3, conservation percentages are spread equally across each sector. In the third and fourth scenarios, potential tradeoffs are illustrated if the three sectors take on different conservation goals. These four scenarios are not exclusive, but provide a subset of examples for reaching needed inflows.

Significant conservation and commitment to deliver water to the lake is needed to reach desired elevations.

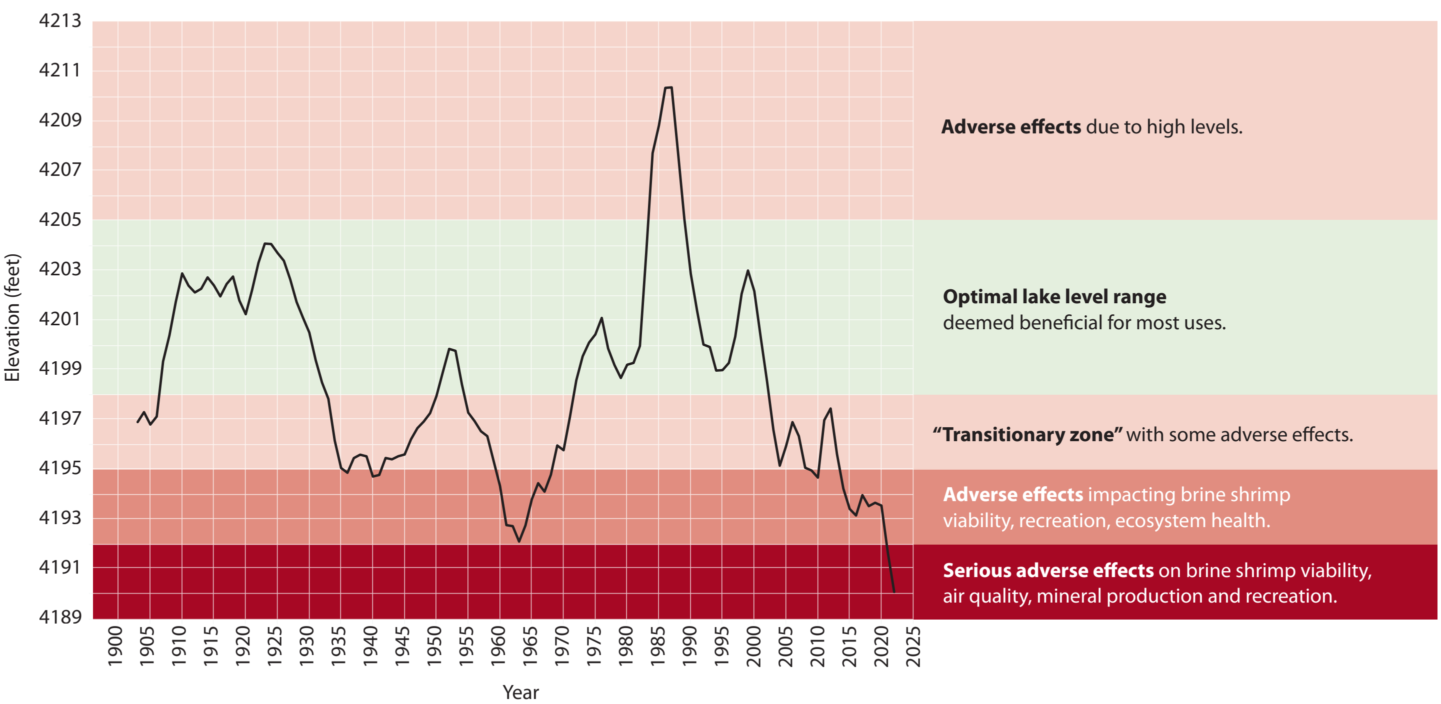
Filling the lake to the low end of the range that maximizes benefits on most dimensions per the Great Salt Lake Elevation matrix (4,198 ft.) in 20 years would require between 500,000 and 1,100,000 acre-feet per year of additional water delivered to the lake. Filling the lake to a level of 4,192 ft. (3 ft. higher than present) in five years would take between 100,000 and 700,000 acre-feet per year of additional conservation and water deliveries to the lake. Both ranges depend on streamflow.

Table 3: Scenarios for Reaching Conservation Targets

Sector	Average Depletion, 1989-2020	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
		Equal percentage reductions to prevent further decline		Equal percentage reductions		Primary reliance on municipal and industrial conservation to achieve desirable lake level in 20 years		Primary reliance on agricultural conservation to achieve desirable lake level in 20 years	
		Percent	Volume (KAF/year)	Percent	Volume (KAF/year)	Percent	Volume (KAF/year)	Percent	Volume (KAF/year)
Agriculture	1,188	17.5%	208	35%	416	20%	238	42%	499
Municipal and Industrial	358	17.5%	63	35%	125	69%	247	20%	72
GSL Mineral Extraction	165	17.5%	29	35%	58	69%	114	20%	33
Total	1,711		300		599		599		604

Note: Average depletion values in this table exclude the West Desert, as conservation in the West Desert is not deemed to be a viable option for getting water to the lake.
Source: Analysis by Great Salt Lake Strike Team, 2023

Figure 12: Average Annual Elevation of Great Salt Lake with Elevation Zones, 1903–2022



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

Policy Options

A variety of policy actions have been proposed to address declining levels of Great Salt Lake. Each suggested course of action comes with different benefits and costs.

The Great Salt Lake Strike Team selected 11 policy options that would help increase water deliveries to the lake. The options fall into three categories and include the following:

Conservation

- Commit conserved water to Great Salt Lake
- Optimize use of agricultural water
- Optimize municipal and industrial water pricing
- Limit municipal and industrial water use growth
- Utilize water banking and leasing
- Conduct active forest management in Great Salt Lake headwaters
- Optimize Great Salt Lake mineral extraction

New Water

- Import water
- Increase winter precipitation with cloud seeding

Engineering Solutions

- Raise and lower the causeway berm
- Mitigate dust transmission hotspots

The Strike Team developed an evaluation scorecard to create apples-to-apples comparisons of the most commonly proposed options to address Great Salt Lake decline. By briefly outlining these policies and providing necessary context, options, and tradeoffs, we give an overview of expected water gains, monetary costs, environmental impacts, and feasibility. Many options work in conjunction with others, particularly "Commit Conserved Water to Great Salt Lake" which is foundational to shepherding water conserved through other policy options to the lake.

Expert Assessment Scorecard Scale

Each policy option includes an expert scorecard with a five-point scale that evaluates the option on nine dimensions.

Benefits

Water brought to the lake:
1 = A little (100,000 acre-feet/year) — 5 = A lot (500,000 acre-feet/year)

Air quality improvements:
1 = No dust control — 5 = Significant dust control

Biological health:
1 = Ecological collapse — 5 =Ecological safety

Costs, Challenges, and Adaptations

Financial cost
1 = Less (~$1 million) — 5 = More ($10+ billion)

Agriculture changes
1 = Minimal change — 5 = Significant change

Extractive industry changes
1 = Minimal change — 5 = Significant change

Cultural shift
1 = No change — 5 = Significant changes

Feasibility

Speed of implementation
1 = Slow (5+ years) — 5 = Fast (1 year)

Legal/regulatory feasibility
1 = Low feasibility — 5 = High feasibility

Commit Conserved Water to Great Salt Lake

Coupled with accurate quantification, appropriate procedural mechanisms, and practicable means of delivery, stakeholders may be able to commit conserved water to Great Salt Lake.

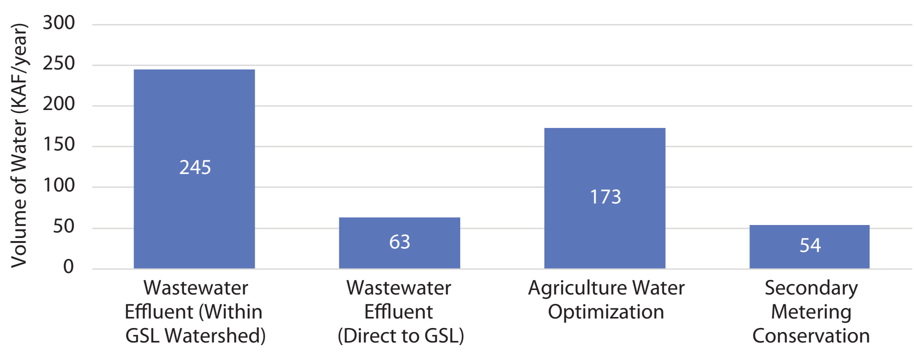
Summary

Conserving water for the benefit of Great Salt Lake is a fundamental strategy. However, water conservation alone may not benefit the lake since other uses often intercept water. If large-scale conservation efforts are combined with administrative actions on the underlying water rights (i.e., through a change application), the state engineer may help ensure that the conserved water makes it to the lake.

Key facts and insights

- **Water conservation doesn't mean increased lake elevation:** Although collective water conservation may help mitigate the effects of drought on Utah's water supply, it does not necessarily translate into additional water for Great Salt Lake.
- **Targeted Conservation:** Decision-makers may want to target large-scale water users with underlying water rights eligible for shepherding to the lake by the state engineer under a change application.
- **Quantification of Available Water:** Water available for conservation is likely limited to the amount of water depleted (or consumed) under previous use. Consequently, accurate quantification is critical to any change application committing conserved water to the lake. This quantification will prevent impairing use by downstream water users.
- **Shepherding Water:** Without a way to shepherd water past intervening users, conservation efforts could be easily frustrated. However, upon approval of an appropriate change application, the state engineer can readily deliver conserved water to Great Salt Lake under a "distribution system." All of the main tributaries to Great Salt Lake have distribution systems wherein water commissioners can shepherd water through the system.

Figure 15: Selected Water Sources Available for Committing to GSL



Note: Wastewater effluent in the GSL watershed is discharged into streams and is likely intercepted and diverted by downstream users. Currently, only 63 KAF is discharged directly to the lake.
Sources: Utah Division of Water Quality data using 5-year mean daily discharges from Publicly Owned Treatment Works (POTWs). Excludes discharges from POTWs utilizing evaporative lagoons; 2022 Ag Water Optimization Task Force Annual Report, https://water.utah.gov/wp-content/uploads/2022/11/2022-AWOTF-Annual-Report-Research-and-Policy.pdf; Utah Division of Water Resources website, https://water.utah.gov/wp-content/uploads/2022/03/Secondary-Meter-3rd-Round-of-Funding.jpg

Expert Assessment Scorecard Results

Criterion	Score (1 = Low, 5 = High)
Benefits	
Water brought to the lake	3
Air quality improvements	3
Biological health	3
Costs, Challenges, and Adaptations	
Financial cost	3
Agriculture changes	2
Extractive industry changes	1
Cultural shift	3
Feasibility	
Speed of implementation	5
Legal/regulatory feasibility	4

Source: Great Salt Lake Strike Team

Policy options and tradeoffs

Policy Options

- Conservancy districts benefiting from the water savings associated with subsidized secondary metering efforts could dedicate a portion of the saved water to the lake.
- Irrigation companies or large agricultural users could employ full-season or split-season fallowing to conserve water and commit it to the lake.
- Municipalities can conserve water to offset future demands and commit a commensurate amount of treated sewage effluent that would otherwise be available for reuse.

Tradeoffs

- Without enhanced conservation efforts elsewhere, conservancy districts would need to develop additional sources to satisfy growing demand.
- Agricultural users would require compensation from an interested stakeholder. The increased demand for the limited resource would result in cascading price increases.
- Forgoing the potential for reuse of sewage effluent may limit the extent of future municipal growth.

Agriculture Water Optimization

Agriculture water optimization provides immediate and improved resilience to producers and builds the foundation of flexibility, infrastructure, and methods required to make more water available for Great Salt Lake.

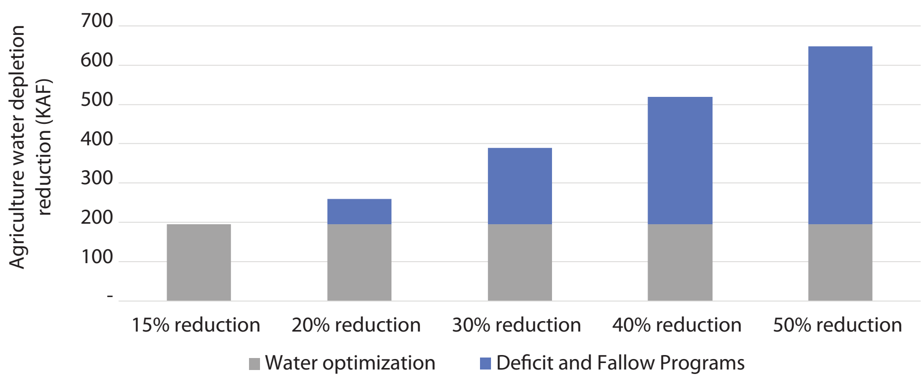
Summary

Reducing agriculture depletions annually by 10-15% through agriculture optimization makes farming more resilient to drought and could supply nearly 180,000 acre-feet of water annually to the lake without reducing crop production. It could be achieved through strategic agriculture water optimization that includes improving conveyance systems that deliver water to the farm, and a variety of on-farm improvements in water, crop, and soil management. Greater reductions in depletion are possible but would require compensated strategic deficit irrigation or fallowing. This optimization comes at various costs ranging from about $60-400 per acre-feet of water per year, based on which practices are implemented.

Key Facts and Insights

- **Begin with on-farm optimization** - Reductions of approximately 10-15% in water consumption could be achieved through on-farm optimization without reducing production.
- **Additional gains are possible** - Voluntary, temporary, and compensated short-term water banks and leases that may facilitate deficit irrigation/fallowing programs, which might be necessary to help gain additional water for the lake, depending on the degree of effectiveness of other options.
- **Difficult and costly task** - Reducing agriculture water depletion is difficult without reducing crop production. Most water used in agriculture is "beneficially used" through crop consumption or returns to natural systems. Agricultural optimization requires capital-intensive changes that often exceed producers' capacity to perform without assistance.
- **Other pieces required** – Quantification of water savings, as well as other legal mechanisms, including water leasing and/or banking, and shepherding will be required to ensure agricultural optimization delivers water to the lake.

Figure 16: Estimated Reductions in Agriculture Depletions through Optimization and Deficit/Fallow Programs



Note: Proposed water optimization would have minimal damage to food production
Source: Analysis by Matt Yost, 2022

Expert Assessment Scorecard Results

Scale: 1 (Low) – 5 (High)

Benefits	Score
Water brought to the lake	3
Air quality improvements	3
Biological health	3
Costs, Challenges, and Adaptations	
Financial cost	3
Agriculture changes	5
Extractive industry changes	1
Cultural shift	5
Feasibility	
Speed of implementation	4
Legal/regulatory feasibility	4

Source: Great Salt Lake Strike Team

Policy Options and Tradeoffs

On-farm optimization could save up to 180,000 acre-feet per year (assuming 15% reduction in total water use) with minimal crop losses. This assumes that farmers willingly participate and are compensated for loss.

Policy Options

- Increased financial and technical support for on-farm optimization
- M&I water conservation and other solutions could help offset agriculture reductions
- Investment in water measurement would aid in the refinement of what the possible and feasible reductions are for agriculture
- Enhanced capacity of Division of Water Rights to rapidly and accurately track and approve use changes

Tradeoffs

- Lost agriculture production and profit
- On-farm optimization or fallowing incurs high ongoing costs
- Reductions in Utah food security
- Damages rural communities and industries that rely on agriculture

Optimize Municipal and Industrial Water Pricing

By optimizing water pricing in Utah, policymakers can improve water management and increase water deliveries to Great Salt Lake.

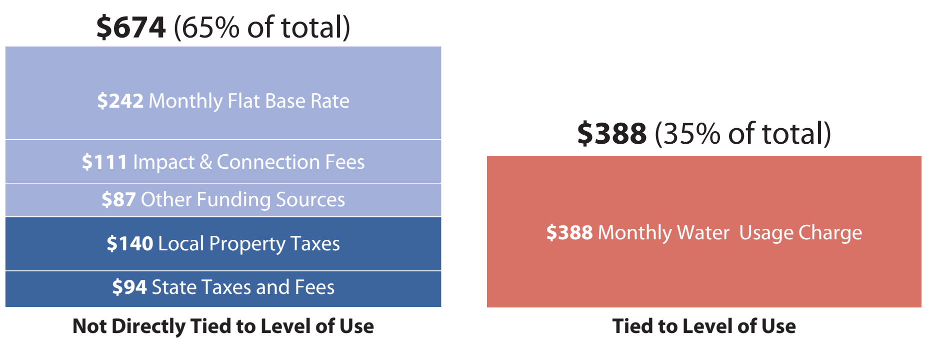
Summary

Water pricing impacts consumption. Economists estimate that for every 10% increase in water rates, water consumption declines by 2.5%-7.5%. By optimizing water pricing, policymakers can benefit from market forces and more closely align supply with demand. This will improve efficiency and fairness, while also reducing demand.

Key facts and insights

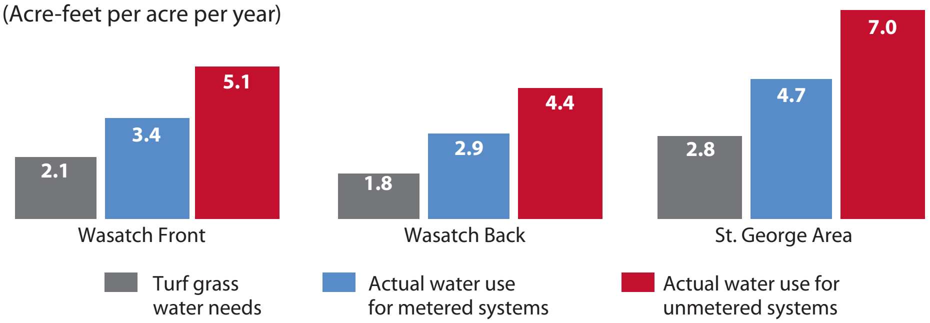
- **Metering –** An estimated 60% of municipal and industrial water in Utah is metered. The state's recent $265 million investment in secondary-metering infrastructure provides additional metering capabilities.
- **Water subsidies** – An estimated 65% ($674 million) of Utah's state and local water delivery costs in FY 2020 accrued from revenues <u>*unrelated*</u> to water use. The remaining 35% ($388 million) came from monthly water usage charges. Currently, more than 90% of Utahns pay subsidized water rates.
- **Property and sales taxes** – In FY2022 Utahns paid nearly $120 million in sales taxes for water and $160 million in local property taxes for water. Because water delivery in Utah is often metered, it does not require general tax financing, like many other government services.

Figure 13: Utah State and Local Water Revenues, FY 2020 (in millions)



Note: Does not include wholesale water sales to avoid double-counting revenues
Source: Office of the State Auditor, Division of Water Rights, and Governor's Office of Planning and Budget

Figure 14: Estimated Lawn Watering Use Compared to Plant Needs, 2018
(Acre-feet per acre per year)



Source: Utah Department of Natural Resources - State of Utah Water Use Data Collection Program Report

Note: Economists view water pricing as an area of public policy ripe for what is called *Pareto improvement* - a change in allocation that harms no one and benefits someone or society as a whole.

Expert Assessment Scorecard Results

	Score (Low 1 – High 5)
Benefits	
Water brought to the lake	1
Air quality improvements	1
Biological health	1
Costs, Challenges, and Adaptations	
Financial cost	1
Agriculture changes	1
Extractive industry changes	1
Cultural shift	1
Feasibility	
Speed of implementation	3
Legal/regulatory feasibility	3

Source: Great Salt Lake Strike Team

Policy options and tradeoffs

Water managers and policymakers can refine water pricing proposals to maximize the public good and minimize unintended consequences. Water pricing options and trade-offs include, but are not limited to, the following:

Policy Options

- Increased secondary water metering
- Tiered water pricing
- Revenue-neutral water user charge increases
- Refined analysis on price elasticity of water
- Tax credit for homeowners and mobile homeowners who meet certain income and resident qualifications
- Additional optimization of state water loan funds for conservation and potential private market capitalization

Tradeoffs

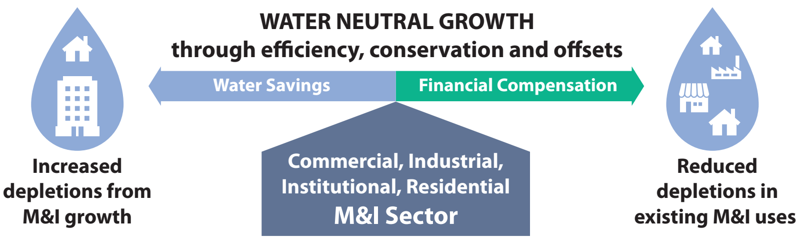
- Adjusting to new landscapes
- Increased transaction costs
- Higher financing costs for water districts
- Switching costs associated with more efficient water use (ex. landscaping)

Limiting Municipal and Industrial Water Use Growth

Efficiency and conservation in new and existing M&I water use creates savings for future growth and can also conserve water to be delivered to Great Salt Lake.

Summary

Policies for water-smart M&I growth financially incentivize high water-use efficiency in new development. Policies can require that conservation savings partially or fully offset new water demand in existing M&I uses. Offsets can be tailored to meet local community needs and facilitated by water providers. These efforts reduce market pressures for "buy-and-dry" agriculture-to-urban water transfers and increase the ability to lease or purchase agricultural water for Great Salt Lake. Water-smart growth implemented now helps deliver ongoing, long-term water use reductions and avoids future water conservation costs. More aggressive implementation of water-smart practices (up to considering water-neutral growth) could secure water demand offsets over the next 30-40 years.



Key facts and insights

- **Growth** – Utah is projected to grow by 2.2 million people between 2020 and 2060, exceeding the 1.8 million people it added between 1980 and 2020. About 85% of projected population and employment growth will occur in Great Salt Lake Watershed.
- **M&I water depletions** – Depletions will potentially increase 80,000 AF between 2020 and 2060 due to projected population growth, climate warming, and diminishing returns on conservation and efficiency gains.
- **Water demand offset policies** – Successfully implemented nationally, these policies create ways to estimate water demand in new developments, calculate savings of water efficiency measures, and verify conservation savings and return on investment from water use offsets. Offset ratios can be structured to accelerate savings and also secure some water for Great Salt Lake in the near term.
- **Programmatic investments** – Water efficiency and conservation are realized through educational, incentive, and regulatory approaches. Accelerating water demand management will require public and private investments in institutional programs to implement change across all M&I uses.

Policy options and tradeoffs

Effective and equitable water-smart M&I growth requires existing M&I users to create water conservation savings. It also needs new development to meet the highest water efficiency standards when using those savings offsets. Combinations of on-site and off-site efficiency measures ensure new and redeveloped construction uses less new water in overall developments. Policy options include those listed to the right.

Expert Assessment Scorecard Results

	Rating (1 = Low, 5 = High)
Benefits	
Water brought to the lake	1
Air quality improvements	1
Biological health	1
Costs, Challenges, and Adaptations	
Financial cost*	2, 3
Agriculture changes	1
Extractive industry changes	1
Cultural shift	4
Feasibility	
Speed of implementation	4
Legal/regulatory feasibility	5

Note: Water potential estimate results from avoiding 80,000 acre-feet/year of depletion from developing new water supplies to meet anticipated growth in demand.
Source: Great Salt Lake Strike Team

Policy options

- Water offset policies and tools in the M&I sector
- More aggressive state water conservation goals and limits on new large M&I uses in Great Salt Lake Watershed
- Integrated land use and water planning for water smart growth
- Highest current water efficiency standards for new and redeveloped construction
- Fixture/appliance replacements and landscape conversions for existing M&I users
- M&I rate increases
- Advanced metering infrastructure to support transparent billing and conservation tracking

Tradeoffs

- Adjusting expectations from drought adaptation to climate change resilience
- Acceptance of new urban forms (increased residential density, low water landscapes)
- Equity of implementation across communities (rationale for state-level policy action)
- Scaling up water smart growth policies for watershed-scale implementation
- Transaction costs
- Ability to secure water demand offsets declines over time

Water Banking and Leasing

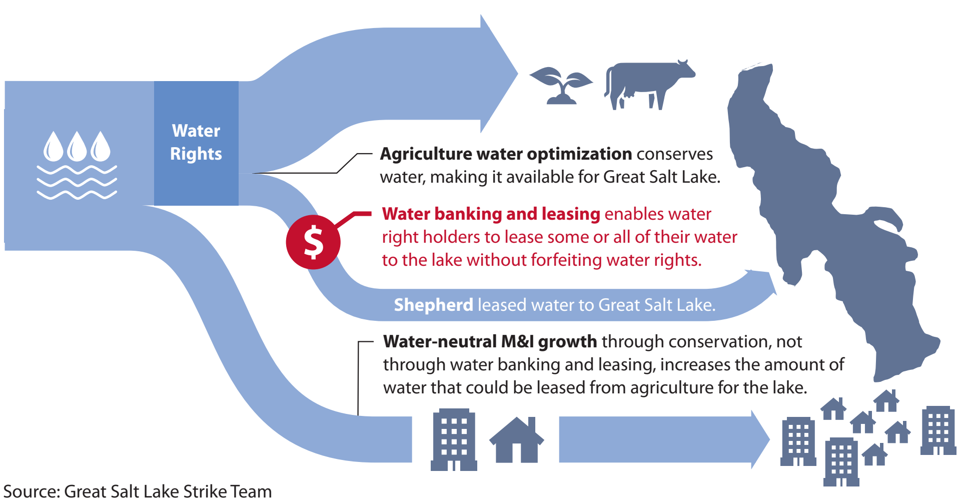
The State of Utah or the Great Salt Lake Trust could lease water for Great Salt Lake, reallocating water from willing sellers to willing buyers.

Summary

Water leasing enables water rights holders to voluntarily lease all or some of their water without forfeiting their water rights. Water banking is one mechanism to lease water, facilitated by Utah's 2020 Water Banking Act under Utah Code 73-31-101(20). Water banks can connect buyers and sellers through intermediaries and institutional processes. Potential exists to lease up to 200,000 - 300,000 acre-feet of water annually for Great Salt Lake. This solution should be paired with water shepherding, agriculture water optimization, and water-neutral M&I conservation to deliver water to the lake.

Key Facts and Insights

- **How it works**
  - Water leasing does not forfeit water rights.
  - Water right priority transfers to leases provided it does not impair other water rights.
  - Water leases may be restricted to the amount of water historically consumed.
  - Requires a change application to deliver water to Great Salt Lake.
- **Cost per acre-foot** – Existing water markets suggest the cost per acre-foot may range between $150 and $300. Prices will differ by priority date, location, and other factors, making them highly variable.
- **Relative cost** - Water banking is a relatively cheap option to deliver water to Great Salt Lake because infrastructure needs are small. New infrastructure includes additional streamflow gages for water shepherding. Transaction costs include legal and hydrologic expertise.
- **Part of a portfolio of solutions** – Agriculture water optimization reduces depletions so that a portion could be voluntarily leased to Great Salt Lake. Leased water must be shepherded to Great Salt Lake with improved streamflow gaging and monitoring. Water-neutral municipal and industrial (M&I) growth should focus on efficiency, conservation, and offsets to reduce competition for leased water.



Source: Great Salt Lake Strike Team

Expert Assessment Scorecard Results

Scale: 1 (Low) – 5 (High)

	Score
Benefits	
Water brought to the lake	3
Air quality improvements	3
Biological health	3
Costs, Challenges, and Adaptations	
Financial cost*	2, 3
Agriculture changes	3
Extractive industry changes	1
Cultural shift	5
Feasibility	
Speed of implementation	4
Legal/regulatory feasibility	4

*Leasing 200,000 acre-feet per year might cost between $30 and $60 million per year, depending on the market price to lease water.
Source: Great Salt Lake Strike Team

Policy Options and Tradeoffs

Water managers and policy-makers could regulate water leases to minimize unintended consequences. Water leasing and banking policy options and tradeoffs include, but are not limited to, the following:

Policy Options

- Increase water prices to incentivize leases.
- Exclude M&I buyers to facilitate urban conservation.
- Expect water leases to cost more in dry years and less in wet years.
- Irrigation companies or large agricultural users could lease water volumes large enough to be shepherded to the lake.

Tradeoffs

- Less water for agriculture.
- Transaction costs for legal and hydrologic expertise.
- Externalities, or side effects, of water leasing are common.
- Negligible effect on Great Salt Lake without water shepherding.

Active Forest Management in Great Salt Lake Headwaters

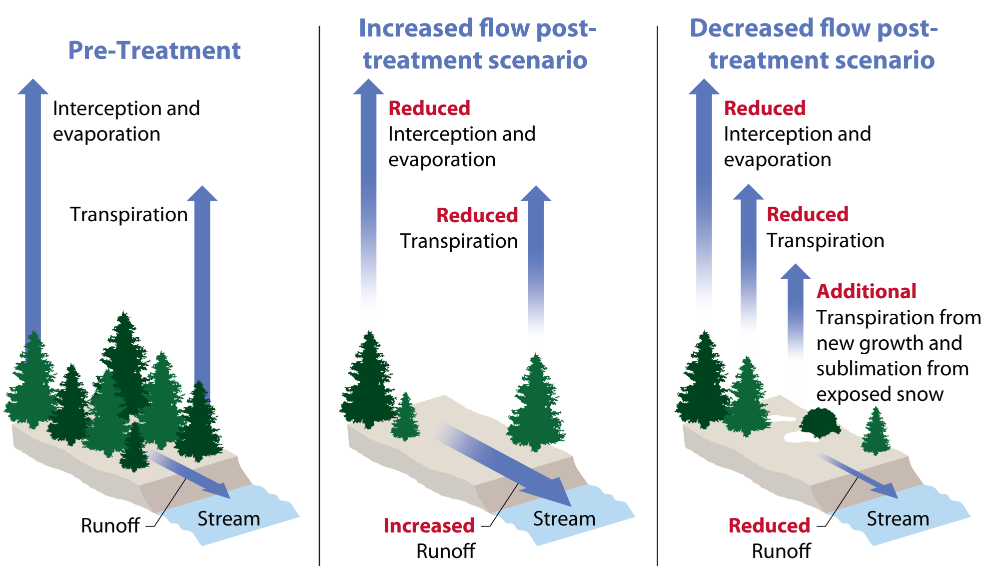
Thinning Utah's forests is not guaranteed to substantially increase the amount of water reaching the GSL. Although thinning can improve forest health and reduce the risk of severe wildfire, it does not always increase streamflow.

Summary

Watershed restoration through the thinning of overgrown forests may reduce water loss to evaporation and transpiration and thus increase streamflow. Research over the past century has shown that extensive timber harvest can and often does lead to increased water yield, especially in wetter areas and when the entire canopy is removed. However, this does not necessarily hold for forest thinning. In the past decade, a growing body of research has shown both increases and decreases in streamflow following canopy reduction. Mechanisms for reduced streamflow include increased water use by vegetation regrowth, increased sublimation and evaporation of exposed snowpack, and increased soil evaporation from removing canopy shade.

Key Facts and Insights

- **Forests in Utah are overgrown -** Like much of the west, Utah forests are overgrown with even-aged trees and extensive ground cover which together increase the risks of high intensity fires and widespread forest mortality due to warming climate.
- **Streamflow may increase or decrease –** In the past decade or so a growing body of research has shown both increases and decreases in streamflow following canopy reduction.
- **Beetle-Kill Mimics Forest Treatment –** Extensive tree mortality events driven by pine beetle infestations mimic forest thinning treatments in terms of runoff. Research on these events shows no large-scale increases in streamflow.
- **Uncertain Effects –** There are many reasons to improve forest management, but the impact of tree thinning on Great Salt Lake inflows is unclear and likely to be minimal. Concerningly, there is a potential to decrease flows.



Expert Assessment Scorecard Results

	Rating (Low 1 – 5 High)
Benefits	
Water brought to the lake	1
Air quality improvements	1
Biological health	4
Costs, Challenges, and Adaptations	
Financial cost	3
Agriculture changes	1
Extractive industry changes	1
Cultural shift	3
Feasibility	
Speed of implementation	2
Legal/regulatory feasibility	3

Source: Great Salt Lake Strike Team

Policy Options and Tradeoffs

Forest management and thinning of over-stocked forests are likely to reduce the risk of severe wildfire and improve forest heath bringing important non-water benefits. However, whether active management, such as thinning, delivers runoff increases is complicated and varies by slope angles, aspect, elevation, and species. These treatments may contribute modest additional runoff but also have the potential to backfire and decrease streamflow.

Policy options

- Removal of invasive species in riparian areas
- Mechanical thinning of dense forests
- Prescribed fire to remove understory fuels

Tradeoffs

- These treatments do not make sense in all Utah forests
- Fuels or thinning treatments have more positive influences when returning forests to a pre-1800 density and fire regime
- Removal of riparian vegetation adversely affects water temperature and aquatic ecosystems

Great Salt Lake Mineral Extraction Optimization

Mineral extractors working on Great Salt Lake collectively hold over 600,000 acre-feet of water rights. The state is currently working with these companies to encourage innovative processes for new mineral development.

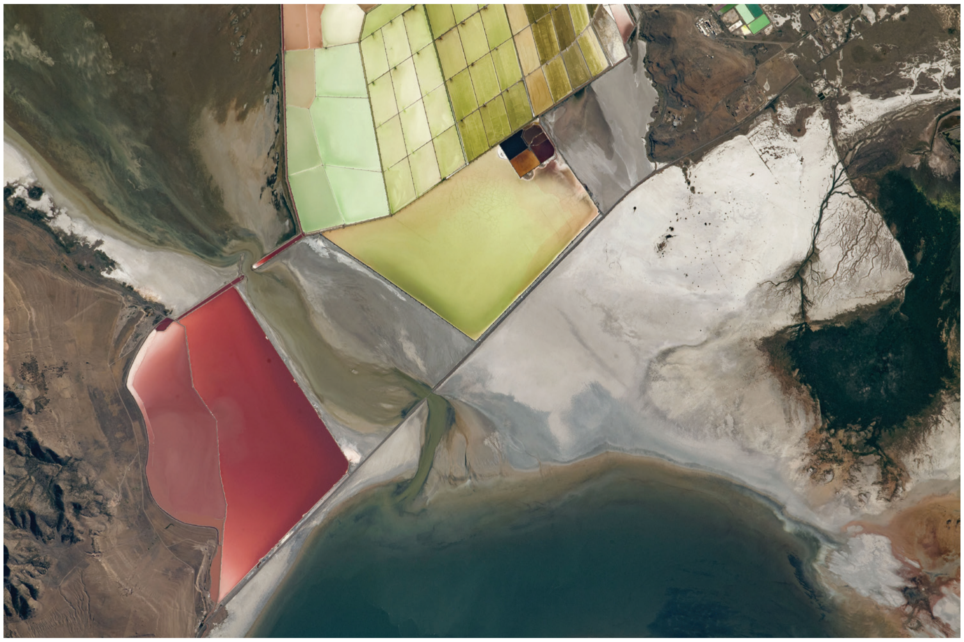
Summary

In 2020, mineral extraction companies working on Great Salt Lake depleted a total of 182,000 acre-feet of water. These companies rely upon the evaporation of lake brines in their extractive processes. However, brines have become harder to reach due to low water levels. The Utah Division of Forestry, Fire and State Lands (FFSL) is currently working with industry to encourage technologies that are not reliant on evaporation and those that reduce water depletions.

Key Facts and Insights

- **Economic Contribution** – A study was conducted in 2010 by the Great Salt Lake Advisory Council that reported approximately $1.13 billion in economic output from the Great Salt Lake mineral industry.*
- **Critical Minerals** – Three critical minerals of the state, Potash, Lithium, and Magnesium, are currently found in Great Salt Lake in marketable quantities and currently in production.

Evaporation Ponds on Great Salt Lake



Source: Aerial Image from Earth Science and Remote Sensing Unit, Johnson Space Center, 2022.

Expert Assessment Scorecard Results

	Score (1 = Low, 5 = High)
Benefits	
Water brought to the lake	1
Air quality improvements	1
Biological health	1
Costs, Challenges, and Adaptations	
Financial cost	2
Agriculture changes	1
Extractive industry changes	5
Cultural shift	1
Feasibility	
Speed of implementation	3
Legal/regulatory feasibility	4

Source: Great Salt Lake Strike Team

Policy Options and Tradeoffs

Eliminating mineral production on GSL has economic consequences and threatens a key source of three of the state's critical minerals. However, Great Salt Lake cannot sustain continued water diversions and depletions at the rate seen in previous decades. The state is encouraging innovation and sustainability in the development of Lithium on the lake.

* Great Salt Lake Advisory Council. (2012). Economic Significance of the Great Salt Lake to the State of Utah. Retrieved from: http://deq.utah.gov.

Import Water

Importing water to Great Salt Lake from the Pacific Ocean (or other sources) is feasible but would be expensive, slow, and controversial.

Summary

Delivery of 500,000 acre-feet per year could be achieved through a 13.3-foot diameter pipeline stretching 700 to 800 miles from the Pacific Ocean, depending on the route. Without the construction of tunnels to bypass higher elevations, the pipeline would need to pump water over the Sierra Nevada mountains (6,500 to 7,000 feet). Figure 17 shows one possible route and the elevation profile along the way. However, nearly unlimited route options exist including from the Gulf of California, or importing freshwater from the Missouri/Mississippi drainage or the Snake River drainage. The latter two options are less likely due to current demands on those sources.

Key Facts and Insights

- **Interstate Project** – The pipeline would be an interstate project crossing California, Nevada, and possibly a portion of Arizona, depending on the route selected. Construction across states and installing an intake structure in the Pacific Ocean would likely require federal involvement. This large pipeline would probably traverse highly developed urban areas.
- **High Cost** – Based on similar completed projects, the total cost could exceed $100 billion for the studies, design, and construction of a pipeline, depending on the route chosen.
- **Intermittent Use** – During wetter years, the pipeline would likely not be used because natural inflows could supply the demands for Great Salt Lake.
- **Unknown Impacts** – Importing salt water to Great Salt Lake may impact the lake in unanticipated ways. Understanding impacts requires further study of potential treatments for imported water, which would further increase project costs.
- **Long Process** – Project completion would likely take decades. In addition to significant construction time, completion would depend on environmental, cultural, and economic impact studies.

Expert Assessment Scorecard Results

Benefits	Low (1) – High (5)
Water brought to the lake	5
Air quality improvements	5
Biological health	5

Costs, Challenges, and Adaptations	Low (1) – High (5)
Financial cost	5
Agriculture changes	1
Extractive industry changes	3
Cultural shift	1

Feasibility	Low (1) – High (5)
Speed of implementation	1
Legal/regulatory feasibility	1

Source: Great Salt Lake Strike Team

Policy Options and Tradeoffs

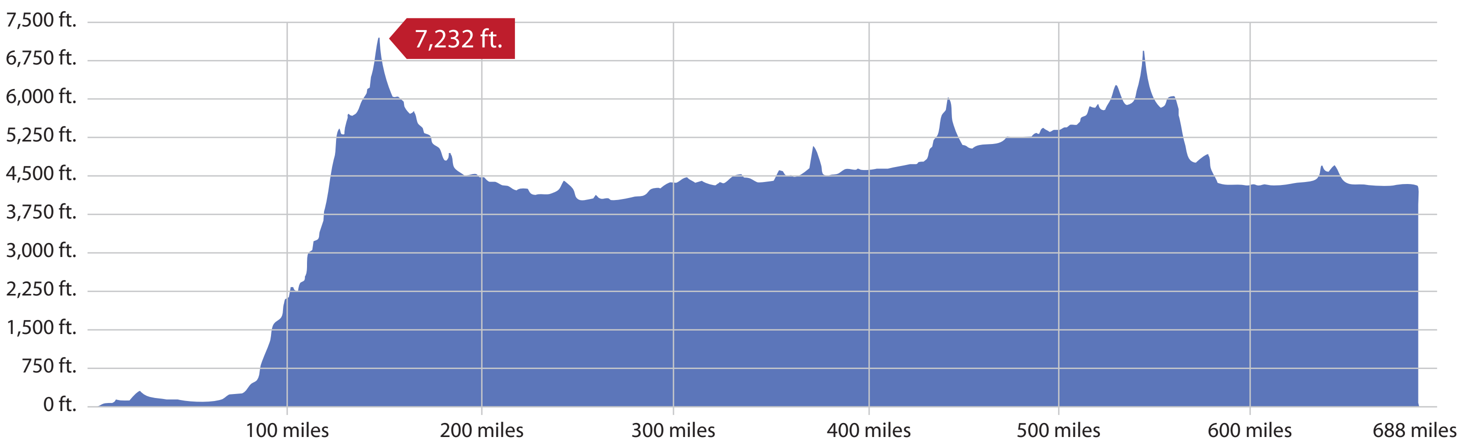
Intake Location Options

- Coast of California
- Gulf of California
- Missouri/Mississippi River basin
- Snake River basin

Tradeoffs

- High costs and complications
- Inter-state (potentially international) project
- Unknown ecological impacts
- Water likely unavailable in river basins because of current demands

Figure 17: Elevation Profile for Importing Water from the Pacific Ocean to Great Salt Lake



Distance: 688 miles • Elevation Gain/Loss: 20,135 ft. /15,931 ft.

Source: Google Earth elevation profile of potential pipeline route from California coast to Great Salt Lake.

Increase Winter Precipitation with Cloud Seeding

Cloud seeding can marginally enhance the amount of snowfall in mountainous regions of primary water sources.

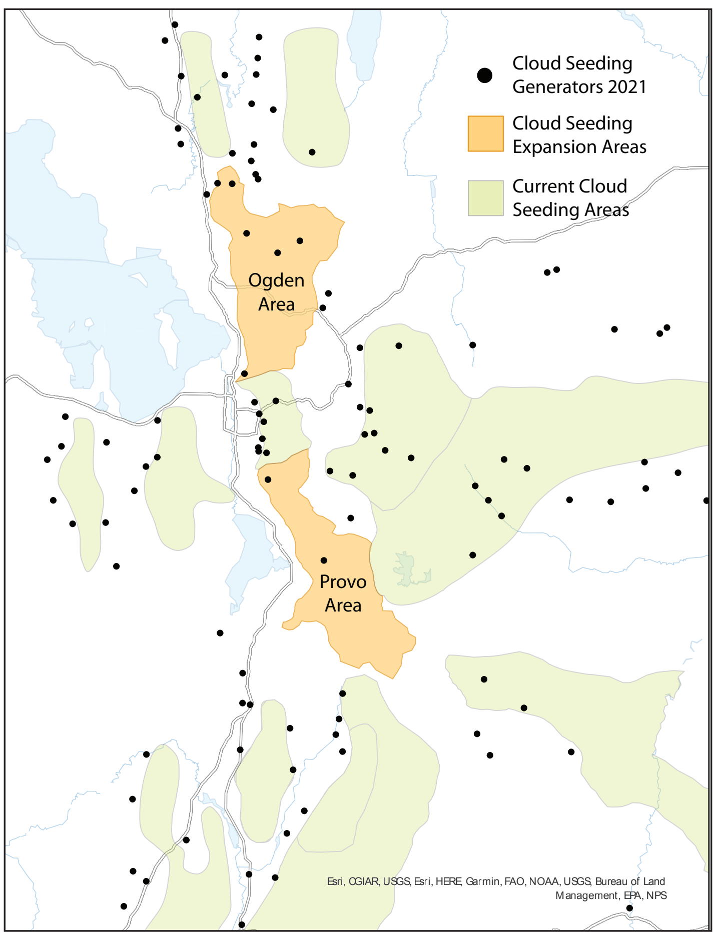
Summary

Under certain weather conditions, it is possible to intentionally modify snowstorms using existing cloud seeding methodologies. However, the amount of additional snowpack is uncertain and can vary between project types and locations. The amount of runoff produced is also uncertain. Program evaluations in Utah suggest cloud seeding could produce an average annual increase in snowfall between 4% and 13%, though more research is needed to improve these estimates. Peer reviewed research documenting increased snowfall or runoff from cloud seeding is minimal.

Key Facts and Insights

- **Ongoing Research** – Several experiments have shown cloud seeding increases precipitation in wintertime storm systems. However, the ability to measure runoff resulting from cloud seeding is low and objective evaluations on non-randomized operational projects continue to be challenging.
- **Ground and aircraft-based Seeding** – Wintertime cloud seeding projects use aircraft and ground-based systems that disperse silver iodide to seed clouds.
- **Low State Investment –** Utah's budget for cloud seeding remains relatively low compared to other Mountain West states. Local entities typically pay operational costs (most often water conservation districts).

Figure 18: Cloud Seeding Generators and Program Areas



Expert Assessment Scorecard Results

Category	Low (1) – High (5)
Benefits	
Water brought to the lake	1
Air quality improvements	1
Biological health	1
Costs, Challenges, and Adaptations	
Financial cost	1
Agriculture changes	1
Extractive industry changes	1
Cultural shift	1
Feasibility	
Speed of implementation	4
Legal/regulatory feasibility	5

Source: Great Salt Lake Strike Team

Policy Options and Tradeoffs

The primary limitation to expanding cloud seeding in Utah is budgetary constraints and program evaluation. With additional funding, the state could consider the following options.

Policy Options

- Sponsor cloud seeding programs directly
- Target new mountain ranges
- Expand cloud seeding beyond what local entities can support
- Improve methods for evaluation of cloud seeding programs

Tradeoffs

- Expenditure of public funds on a policy which yields an indefinite water quantity.
- Public perception of cloud seeding
- Public concerns of safety

For relevant research on cloud seeding, please see the following:

• Rauber, M. et al. (2019). Wintertime Orographic Cloud Seeding – A Review. Journal of Applied Meteorology and Climatology, 58 (2117-2140). https://doi.org/10.1175/JAMC-D-18-0341.1

• Friedrich, K. et al. (2019). Quantifying snowfall from orographic cloud seeding. Proceedings of the National Academy of Sciences, 117(5190-5195). https://doi.org/10.1073/pnas.1917204117

Raise and Lower the Causeway Berm

Raising the adaptive management berm at the Union Pacific Railroad causeway breach between the North and South Arms of Great Salt Lake would effectively act as a dam. This would keep freshwater inflows of the major tributaries in the South Arm where salinity levels are reaching a critical threshold.

Summary

The Union Pacific Railroad causeway bisects GSL into the North and South arms. A breach in the causeway allows water interchange between the two arms and can be altered by the adaptive management berm that slows flows between the arms. Raising the elevation of the adaptive management berm above the current surface elevation of GSL will effectively act as a dam between the two arms. By restricting flows between the two arms, the elevation of the South Arm rise and salinity will be reduced. This solution will amplify the benefits of conservation efforts, water purchases, and other methods for the South Arm.

Key Facts and Insights

- **Modifying the Berm** – Current work is underway to develop a decision-tree to assess the timing of raising and lowering the berm. Raising the berm addresses critical salinity concerns in the South Arm and is intended to be a short-term solution.
- **Funding** – An appropriation made in 2021 allows immediate implementation of the project.
- **Salinity Advisory Committee** – On January 19th, 2023, the Salinity Advisory Committee recommended adaptive action, including raising the top level of the control berm, be taken to reduce the trajectory of salinity in the South Arm while lake levels are low (below 4,192 feet). It was recommended that this action is taken as soon as practicable with consideration of lake dynamics.
- **All major inflows are in the South Arm** – Freshwater inflows from major tributaries flow into the South Arm, creating a major salinity difference between the two arms.
- **North Arm considerations** – The North Arm of GSL does not support an ecosystem dependent on specific salinity levels. The North Arm also has a thick salt crust that is not as prone to erosion and is less likely to contribute to poor air quality than exposed lakebed in the South Arm.

Expert Assessment Scorecard Results

Benefits	Low (1) – High (5)
Water brought to the lake	1
Air quality improvements	3
Biological health	3

Costs, Challenges, and Adaptations	Low (1) – High (5)
Financial cost	1
Agriculture changes	1
Extractive industry changes	4
Cultural shift	1

Feasibility	Low (1) – High (5)
Speed of implementation	5
Legal/regulatory feasibility	5

Source: Great Salt Lake Strike Team

Lake Level Modelling

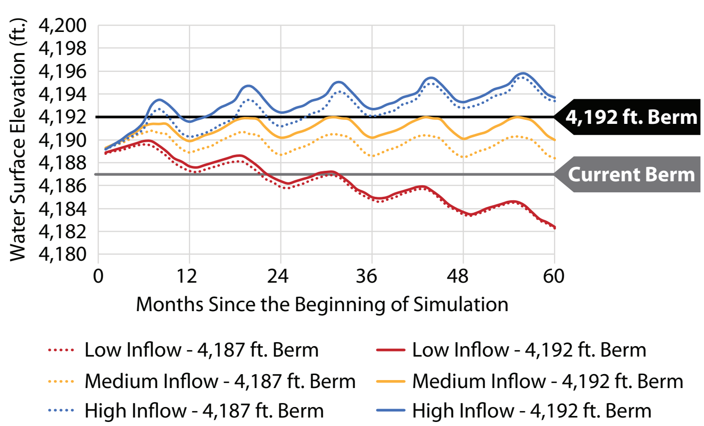
The Great Salt Lake Integrated Model used by the Utah Division of Water Resources allows for simulation of berm scenarios. Different berm elevations (4,187 ft. and 4,192 ft.) were analyzed along with three different lake inflow scenarios (low, medium, and high). For the lowest inflows simulated, the impacts of berm closure are minimal, indicating the importance of other options for increasing inflows to the lake in conjunction with raising the berm.

Table 5: Lake Elevation (ft.) Given Different Inflow and Berm Elevation Scenarios

Water Surface Elevation (ft.)		Berm Elevation 4,187 ft.		Berm Elevation 4,192 ft.	
		South Arm	North Arm	South Arm	North Arm
1 Year	High Inflow	4,190.3	4,189.7	4,191.6	4,187.5
1 Year	Medium Inflow	4,188.9	4,188.3	4,189.9	4,186.7
1 Year	Low Inflow	4,187.3	4,186.8	4,187.7	4,186.1
2 Years	High Inflow	4,191.2	4,190.8	4,192.4	4,188.9
2 Years	Medium Inflow	4,188.7	4,188.0	4,190.2	4,185.7
2 Years	Low Inflow	4,185.9	4,184.7	4,186.4	4,184.0
3 Years	High Inflow	4,192.1	4,191.6	4,192.7	4,190.7
3 Years	Medium Inflow	4,188.6	4,187.8	4,190.2	4,185.2
3 Years	Low Inflow	4,184.8	4,182.5	4,185.0	4,182.2

Note: Inflow scenarios in this table are different from the Lake Elevation Target section.
Low Inflow = 800 KAF, Medium Inflow = 1,800 KAF, and High Inflow = 2,700 KAF.
Source: Great Salt Lake Integrated Model simulations, Utah Division of Water Resources, 2023

Figure 19: South Arm Water Surface Elevation with Berm Raised to 4,192 ft.



Source: Great Salt Lake Integrated Model simulations, Utah Division of Water Resources, 2023

Mitigate Dust Emission Hotspots

Implementing dust control measures on exposed portions of the Great Salt Lake lakebed would reduce the impacts of dust on human health.

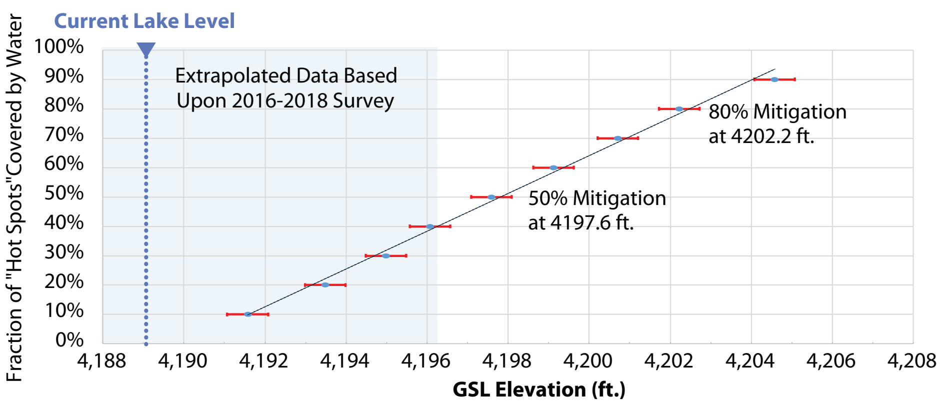
Summary

Dust plumes from the Great Salt Lake lakebed have increased in frequency and severity as the lake has receded. These dust episodes pose an immediate health risk to all residents along the Wasatch Front due to inhalation of particulate matter (i.e., PM_{10}) and high concentrations of arsenic, which could increase the risk of certain cancers. Dust hotspots exist in all four quadrants of the lake and represent about 9% of the exposed lakebed. Over time, the fraction of the lakebed capable of producing dust will increase as the protective surface crust that formed as the lake receded gradually erodes.

Key Facts and Insights

- **Dust Hotspots** – The number of dust hotspots is linearly related to lake elevation and will decrease by approximately 6.4% per foot of lake-level rise. 50% of the dust hotspots occur at elevations below 4,198 feet. 80% occur at elevations below 4,202 ft.
- **Air Quality Linkages** – Dust from GSL will likely lead to violations of the National Ambient Air Quality Standards (NAAQS) established by the U.S. EPA. Designation as non-attainment for PM_{10} will trigger a mandatory and costly State Implementation Plan (SIP).
- **Human Health Linkages** – Dust from GSL can adversely impact human health due to high PM_{10} concentrations (acute exposure risk) and high arsenic concentrations in the dust (chronic exposure risk).
- **Snowpack Linkages** – A shrinking GSL produces less lake-effect snow and increases the dust deposited on the snowpack. The dust significantly darkens the snow, increasing the spring melt rate of the snowpack by several weeks.
- **Implementing Dust Control Measures is Expensive** - The Los Angeles Department of Water and Power has spent more than $2.5 billion on federally-mandated dust mitigation efforts at Owens (Dry) Lake due to violations of the NAAQS for PM_{10}. Great Salt Lake is 15 times larger than Owens lake.

Figure 20: Great Salt Lake Dust "Hot Spot" Elevation Survey Extrapolated for Current Lake Level



Note: Utilizing DCMs other than water requires capital costs of $20 - $30M per mi^2 with additional ongoing maintenance costs of $0.2 - $0.5M per mi^2 per year. The surface area of current dust hotspots exceeds 75 mi^2 but could increase to 200 mi^2 in a decade as the protective surface crusts begin to erode.
Source: Analysis by Kevin Perry, 2022

Expert Assessment Scorecard Results

Benefits	Low (1) – High (5)
Water brought to the lake	1
Air quality improvements	5
Biological health	3
Costs, Challenges, and Adaptations	
Financial cost*	2, 3
Agriculture changes	2
Extractive industry changes	2
Cultural shift	1
Feasibility	
Speed of implementation	1
Legal/regulatory feasibility	5

*Cost is dependent upon chosen dust mitigation technique
Source: Great Salt Lake Strike Team

Policy Options

Dust control measures (DCMs) have been studied extensively at Owens (Dry) Lake. DCMs mitigate dust by 1) physically covering the dust hotspots with water or gravel, 2) treating the surface to strengthen the protective surface crust, and 3) installing vegetation or structures to reduce wind speeds near the surface of the lakebed. Specific DCMs that could be applied to GSL include, but are not limited to:

- Raising the water levels for the lake as a whole
- Strategically raising the water levels in Farmington and Bear River Bays using berms
- Levelized flooding of the worst dust emission areas
- Applying crushed gravel to the worst dust emission areas
- Strategic seasonal flooding to reform surface crusts
- Applying a surface crust-generating solution using aircraft on a seasonal basis
- Installing managed vegetation systems (e.g., drip irrigation systems)
- Installing physical barriers such as snow fences
- Ongoing mitigation costs
- No improvements for Great Salt Lake ecosystems, brine shrimp, or mineral extraction.

Recommendations

The Great Salt Lake Strike Team supports the data and research needs of state decision-makers. The Strike Team does not advocate for specific policy positions but does respond to requests to share technical expertise and evidence-based assessment.

The governor and Legislature have requested recommendations from the Strike Team to inform state actions in the near term. Consistent with this approach, the Strike Team offers six specific recommendations for gubernatorial and legislative support in the coming year.

1. **Leverage wet years.** The current wet year offers a significant opportunity to make progress on the lake elevation. Do not miss this opportunity.
2. **Set a lake elevation range goal.** Adopt a lake elevation target level range based on analysis prepared by the Utah Division of Forestry, Fire, and State Lands. Preliminary analysis suggests a range in the 4,198-4,205-feet elevation level will maximize benefits across many factors. Meeting this goal requires policymakers to focus on inflows that both fill and maintain targeted elevation ranges.
3. **Invest in conservation.** Conservation to increase the inflows to, or decrease withdrawals from, Great Salt Lake should be implemented to stop the decline in lake levels and initiate restoration.
4. **Invest in water monitoring and modeling.** Additional investment in water intelligence will allow the state to be more responsive and effective to challenges. The Strike Team suggests a more than doubling of current state investments in accurate and timely measurements and forecasts that will help inform and guide state decisions.
5. **Develop a holistic long-term water resource plan for the watershed.** The Utah Department of Natural Resources is currently developing the Great Salt Lake Basin Integrated Plan in partnership with water users, universities, environmental groups and government agencies. When finished, it will provide actions to ensure a resilient water supply for all water users in the basin, including Great Salt Lake. Resources should be allocated to the effort and all should be encouraged to participate.
6. **Request in-depth analyses on policy options.** The governor and Legislature can direct the Great Salt Lake Strike Team to further model specific policy options and parameters to identify the most water-efficient, cost-effective, and high-return options. Analyses can be completed and delivered by September 30, 2023, to allow for policy development proposals before the 2024 General Legislative Session.

In addition to addressing the health of Great Salt Lake, these strategies and investments will increase Utah's capacity to address other statewide water challenges. The Strike Team's model partnership of Utah' research universities and state agencies stands ready to support state leaders in this important work.

Notes:


Photo credit: Kelly Hannah