GREAT SALT LAKE DATA AND INSIGHTS SUMMARY

A synthesized resource document for the 2024 General Legislative Session

January 10, 2024

Version 1.0

In 2023, Great Salt Lake rose from the record-low elevation reached in 2022, aided by record-high winter snowfall and the adaptive management berm. Economic activity, public health, and the lake's ecosystems continue to be adversely impacted by low water levels. This summary synthesizes essential data and insights so decision-makers have the information they need to improve water management, increase water deliveries to the lake, mitigate adverse impacts, and recover the lake to a healthy range.

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

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

Great Salt Lake Timeline

2023: NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC — 2024: JAN

November 2022:
Gov. Spencer Cox issues proclamation closing Great Salt Lake Basin to new water right appropriations.

February:
Great Salt Lake Strike Team releases first policy assessment.

February:
State raises the adaptive management berm from an elevation of 4,187 feet to 4,192 feet.

March:
The Utah Legislature passes a number of policies and appropriations related to Great Salt Lake in the 2023 Legislative Session:

- $200 million for agricultural optimization
- Establishment of a Great Salt Lake Commissioner
- Requirement for mineral extractors to pay royalties for used lake water and limit use if salinity rises too high
- Limit wastewater reuse to ensure water delivery to the lake
- Requirements and incentives for waterwise landscaping

March:
The Church of Jesus Christ of Latter-day Saints donates 20,000 acre-feet of water shares to the Great Salt Lake, which significantly boosts the Great Salt Lake Watershed Enhancement Trust.

June:
The Utah Legislature confirms Brian Steed as Great Salt Lake Commissioner. The appointment is a dual role, with his existing position as executive director of the Janet Quinney Lawson Institute for Land, Water, and Air at Utah State University.

Run-off leads to rising water levels, allowing boats to re-enter Great Salt Lake Marina.

August:
Great Salt Lake Collaborative takes first prize for collaboration in the Online Journalism Awards.

September:
A consortium of environmental groups file a lawsuit to force the state to bring more water into Great Salt Lake.

October:
Utah's water year ends at 139% of average precipitation following a record-breaking winter. This precipitation, paired with the raising of the adaptive management berm, increased the south arm elevation by three feet from the end of the 2022 water year to the end of the 2023 water year.

November:
Great Salt Lake Trust announces $8.5 million for wetland protection.

Compass Minerals pauses planned lithium project.

January 2024:
Great Salt Lake Strike Team releases data and insights summary.

Great Salt Lake Strategic Plan to be released January 15th, 2024.

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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 the annual runoff amount to annual precipitation amount in a given basin. Higher temperatures and consecutive dry years reduce runoff efficiency by depleting groundwater storage.

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

Water year – A 12-month period that begins on October 1st of one calendar year and ends on September 30th of the following year. The period covering October 1, 2022 to September 30, 2023 is the 2023 water year.

Great Salt Lake Strike Team

The Great Salt Lake Strike Team includes researchers from Utah State University and the University of Utah working together with state leads from the Utah Departments of Natural Resources, Agriculture and Food, Environmental Quality, 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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January 2024

Dear friends,

The Great Salt Lake Strike Team serves Utah decision-makers by bringing together the technical expertise of Utah's state agencies, research universities, and policy experts. Our multidisciplinary, multi-agency, and multi-university approach provides state leaders with a comprehensive resource for the very latest data-informed insights about the lake.

The data and analyses generated last year set a new standard in our understanding of Great Salt Lake. This year's report again provides bedrock data for understanding lake levels, water flows, and conservation needs. Importantly, we collaborated closely with the Great Salt Lake Commissioner and Great Salt Lake Advisory Council, ensuring our findings and recommendations remain rooted in rigorous scientific evidence and applied policymaking.

Looking forward, we are mindful of how much progress has been made and how much work remains. Our work confirms that no single solution will cure the lake, data and modeling investments will make a significant difference, and "shepherding" conserved water to the lake are all critical to Utah's success. If Utahns continue to engage, collaborate, align, and act, we can set a new international standard for the healthy recovery of a terminal lake. This would be particularly timely as Utah welcomes the world for the 2034 Olympic and Paralympic Winter Games.

We extend our appreciation to Gov. Spencer Cox, the Utah Legislature, Presidents Taylor Randall and Elizabeth Cantwell, and other community leaders who support this important work. Together, we will continue to take the necessary steps to ensure the health and sustainability of Great Salt Lake, a natural treasure of immense value.

With appreciation,

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Executive Summary

The low water levels of Great Salt Lake threaten Utah's economic, ecological, and human health. The Great Salt Lake Strike Team, which brings together the technical expertise of Utah state government agencies and research universities, analyses and synthesizes essential information about the lake so Utah decision-makers can make informed decisions.

In this the second annual summary, the Strike Team offers nine major insights:

1 Impact of the 2023 water year

The 2023 water year contributed a significant amount of water to the Great Salt Lake Basin. Paired with emergency measures like raising the adaptive management berm, the daily elevation[1] of the south arm of the lake rose 5.5 feet. Evaporation reduced 2023 water gains by 2.0 feet, resulting in a net elevation increase of 3.5 feet. (Figure 1).

2 Reservoir storage and salinity

Utah reservoirs gained the highest volume ever recorded following the 2023 water year. Salinity levels in the south arm returned to a healthy range because of relatively high inflows and the raising of the berm that connects the north and south arms of the lake.

3 Runoff efficiency

A significant portion of the 2023 snowpack recharged groundwater storage. Utah enters 2024 with much higher groundwater levels and so runoff efficiency is expected to be much higher this year, which will benefit streamflow.

4 Human water use

Human water use, while variable in the past 30 years, has remained relatively constant. Agriculture depletes the most water, but has remained relatively constant since 1989. Municipal and industrial, managed wetlands, and mineral extraction have increased over the same period, while reservoir evaporation has remained constant. Warmer and drier years tend to increase depletions.

5 Mineral extraction

Water depletion from mineral extraction peaked in 2007 and has declined slightly since. Compass Minerals and U.S. Magnesium deplete the most water due to mineral extraction. In total, mineral extraction comprises 7.4% of total human depletion.

6 Future water availability

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

7 Water shepherding

Water conservation efforts will be ineffective for Great Salt Lake if conserved water fails to reach it. Water shepherding ensures that water conserved within the Great Salt Lake Basin flows to Great Salt Lake. The shepherding process requires accurate measurement, robust accounting models, and timely adjustments so depletions can be accurately quantified.

8 Conservation strategy

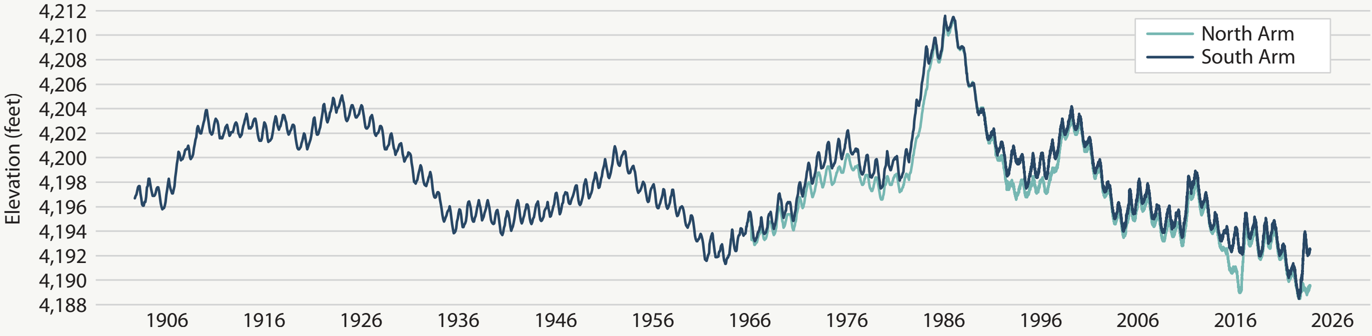
Restoring Great Salt Lake to a healthy range involves filling the lake to a healthy level and then maintaining that level. The Division of Forestry, Fire and State Lands has created an elevation matrix that shows healthy ranges for a variety of competing interests. The Strike Team has made estimates as an aid to decision-makers of the inflow volume required to fill and maintain the lake at an elevation of 4,198 over four different time periods (Figure 2).

9 Lessons learned

The Strike Team's work confirms that no single solution will cure the lake, data and modeling investments will make a significant difference, and shepherding conserved water to the lake are all critical to Utah's success. If Utahns continue to engage, collaborate, align, and act, Utah can set a new international standard for the healthy recovery of a terminal lake. This would be particularly timely as Utah welcomes the world for the 2034 Olympic and Paralympic Winter Games.

1. Lake elevation differs depending on the measure used: average daily, annual, or water-year-end elevation. The Strike Team publishes all three measures, but uses daily elevation as its standard measure.

Figure 1: Daily Elevation of Great Salt Lake North and South Arms, 1903-2023



Note: From 1903-1959, daily elevation was collected once a month. In 1960, the elevation was collected twice monthly. Starting in 1990, the data were collected daily. Recently, data are collected multiple times a day but averaged for a single daily average value.
Source: US Geological Survey Historical Elevation at Saltair Boat Harbor and Saline, UT.

Figure 2: Projected Elevation of Great Salt Lake for Varying Conservation Strategies

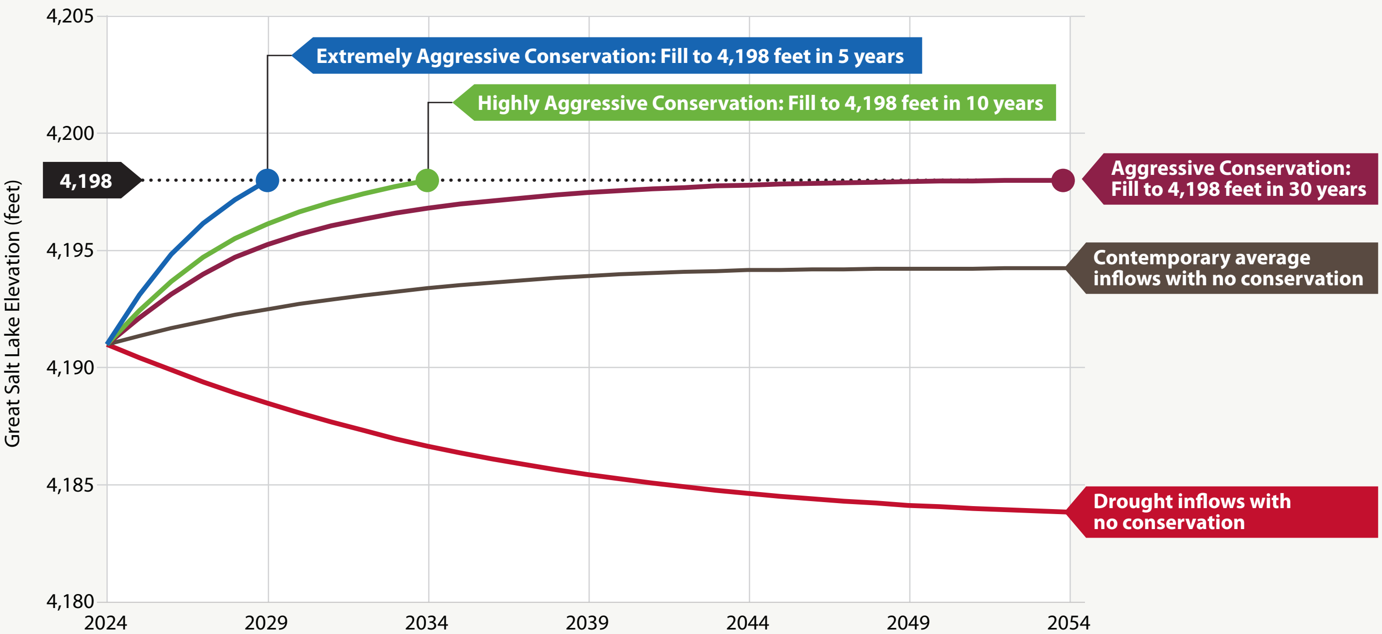


Table 1. Additional Conservation Inflow Needed to Fill the Lake in 5, 10, 20, and 30 Years (KAF/year)

Elevation (feet)	Extremely Aggressive Conservation: Five Years		Highly Aggressive Conservation: Ten Years		Aggressive Conservation: Thirty Years	
	Drought Streamflow	Average Streamflow	Drought Streamflow	Average Streamflow	Drought Streamflow	Average Streamflow
4,198	1,748	1,164	1,289	705	1,055	471

Note: This table assumes an initial lake elevation of 4,191 feet.
Source: Analysis by Great Salt Lake Strike Team, 2023

GREAT SALT LAKE:

Lessons learned in 2023

This data and insights summary results from thousands of hours of work, including the synthesis of existing research, identification of knowledge and data gaps, development of new analyses, and evaluation of policy alternatives by a multidisciplinary team. The Great Salt Lake Strike Team identified six lessons learned in their analysis.

- **No single solution is a cure for the lake**

  In all investigations and discussions, no policy was identified as the sole solution for the lake. Instead, the lake needs "silver buckshot," a wide suite of policies implemented concurrently to bring more water to the lake.

- **Tradeoffs**

  Great Salt Lake functions within a complex ecosystem and economy. Tradeoffs inevitably occur as decision-makers seek to balance human, ecological, and economic health. Decision-makers must grapple with these tradeoffs in making policy decisions.

- **Conserved water must make it to the lake**

  Water conservation efforts are ineffective for Great Salt Lake if that conserved water does not reach it. Established efforts must be augmented to make residential, business, and agricultural conservation meaningful solutions.

- **Investments in observational and modeling infrastructure are essential**

  Although the Strike Team continues to provide foundational data for lake levels, water flows, and conservation needs, a more extensive measuring network, more detailed models, and integrated data and modeling systems that advance knowledge, understanding, and collaboration are needed to support informed decision-making.

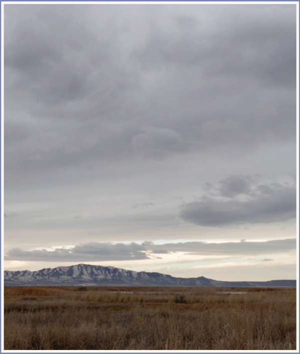
- **Short-, medium-, and long-term solutions**

  Options for addressing lake levels immediately are limited by existing infrastructure. However, long-term solutions need to be addressed immediately to return the lake to healthy levels over time.

- **State leadership**

  The governor, Legislature, and state decision-makers created the Great Salt Lake Commissioner's Office with broad support and alignment. Their ongoing support will be critical to bringing together once-disparate efforts to create cohesive and coordinated state policies that serve Utah's interests.

These lessons broadly apply to other water challenges in the West and a variety of other natural resource issues. In addressing the challenges associated with Great Salt Lake, Utah will become a leader in water resource management–regionally, nationally, and globally.

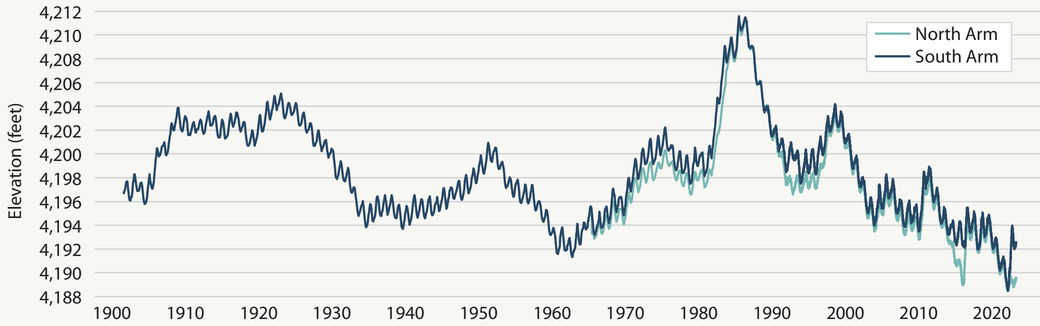


Impact of the 2023 Water Year

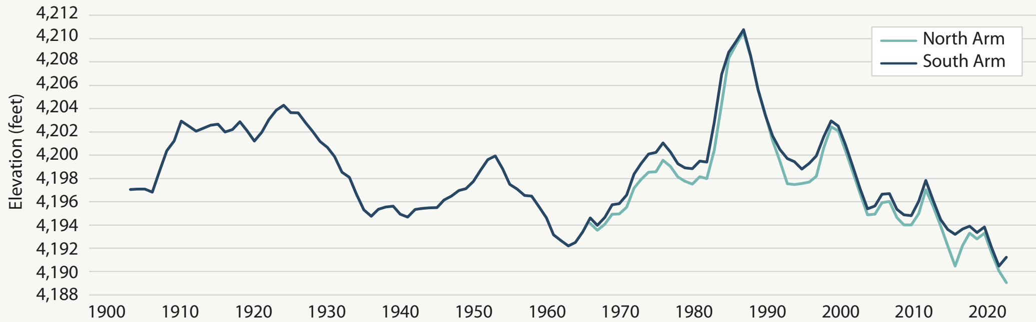
In 2022, the lake dropped to its lowest level in recorded history, salinity reached levels that pushed the Gilbert Bay ecosystem to the brink of collapse, and reservoir storage in the basin fell to the lowest level since 2005. The 2023 water year contributed a significant amount of water to the Great Salt Lake Basin. Paired with emergency measures like raising the adaptive management berm, the south arm of the lake rose from a record daily low of 4,188.5 feet to 4,194.0 feet, a 5.5 foot increase.

Figure 3: Elevation of Great Salt Lake North and South Arms, 1903-2023

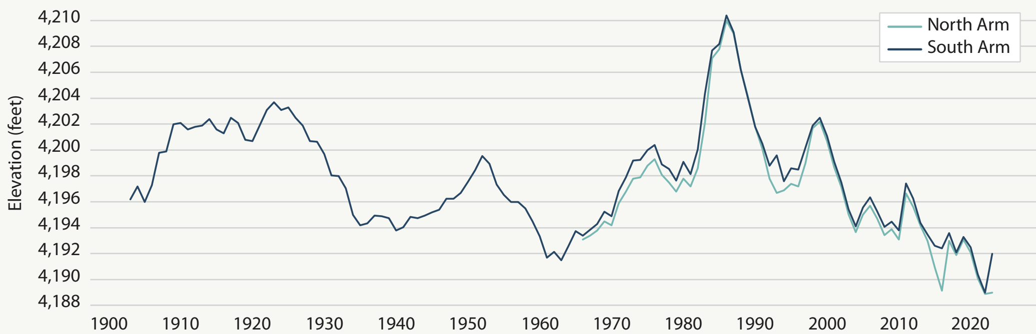
Daily Elevation



Average Annual Elevation



Water-Year-End Elevation



Note: From 1903-1959, daily elevation was collected once a month. In 1960, the elevation was collected twice monthly. Starting in 1990, the data were collected daily. Recently, data are collected multiple times a day but averaged for a single daily average value.
Source: US Geological Survey Historical Elevation at Saltair Boat Harbor and Saline, UT.

Insights

Daily insight - Daily elevations show the south arm of Great Salt Lake rising from a daily low of 4,188.5 feet in November 2022 to a daily high of 4,194.0 in June 2023. This 5.5-foot increase was followed by a 2.0-foot drop due to evaporation and some flow into the north arm for a net elevation gain of 3.5-feet.

Annual insight - When considering average annual elevation, the south arm rose from 4,190.0 in 2022 to 4,192.1 in 2023, a 2.1-foot increase. The north arm fell from 4,189.7 in 2022 to 4,189.3 in 2023, a 0.4-foot decrease.

Year-end insight - The water-year-end elevation shows the south arm rising from 4,189.0 in 2022 to 4,192.0 in 2023, a 3-foot increase. The north arm remained essentially unchanged, rising from 4,188.9 in 2022 to 4,189.0 in 2023.

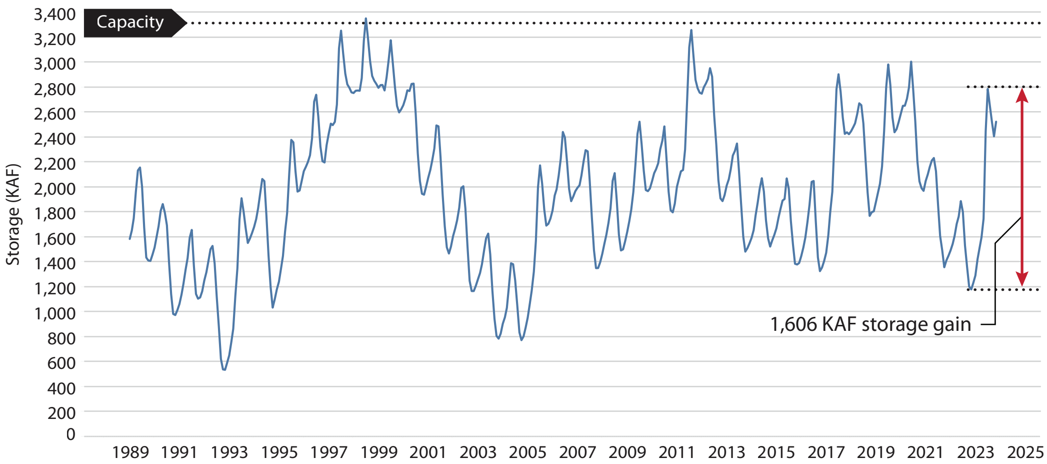
Data and Insights Summary

Reservoir storage, salinity, natural flow, stream flow, human water use, and future water availability convey additional critical information about Great Salt Lake.

RESERVOIR STORAGE AND SALINITY

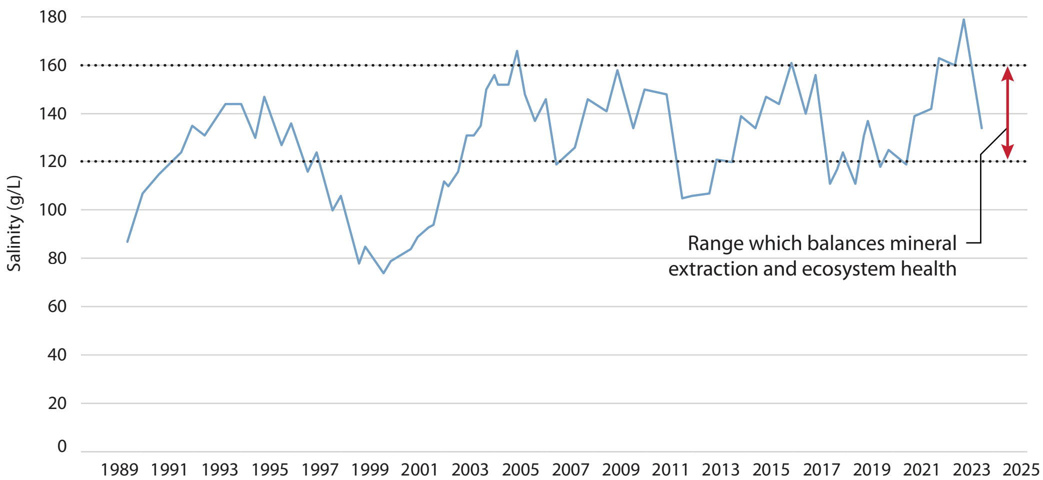
Reservoirs gained the highest volume ever recorded following the 2023 water year. After Great Salt Lake salinity reached a record high in 2022, spring snowmelt in 2023 brought salinity back to healthy levels.

Figure 4: Reservoir Storage in the Great Salt Lake Basin, 1989-2023



Source: Utah Division of Water Resources, 2023

Figure 5: Salinity of Great Salt Lake South Arm, 1989-2023



Note: Salinity varies by depth, location, and over time.
Source: UGS EOS south arm salinity measurements at site AS2, 10-foot depth; Utah Department of Natural Resources and Environmental Quality, Influence of Salinity on the Resources and Uses of Great Salt Lake, 2021

Insights

Reservoir storage - Reservoirs in the basin gained a record total of 1,606 KAF of storage, rising from 36% of total storage capacity to 84%. This water, effectively held back from flowing into the lake, contributed to smaller lake level increases but helped provide additional water security for municipalities, industry, and agriculture.

Salinity - Salinity varies by elevation and depth, but peaked at 179 grams per liter in September 2022 at this measurement site and depth. An extrapolation of data from other sites and depths resulted in a reported salinity of 185 grams per liter around the same time. These salinity concentrations rise above the healthy range, threatening the ecosystem of Gilbert Bay. Raising the adaptive management berm and relatively high inflows lowered salinity back to healthier levels.

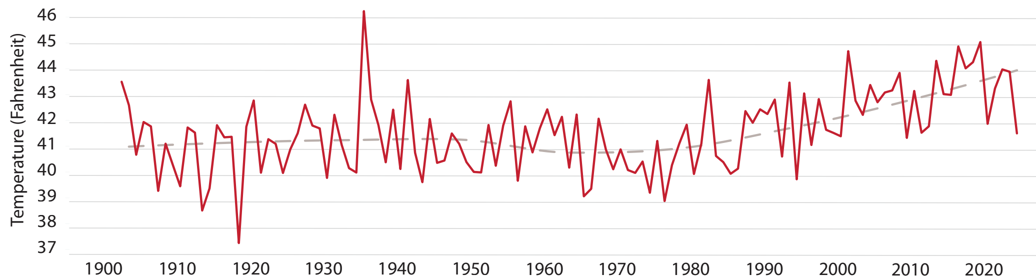
TEMPERATURE, PRECIPITATION, AND HEADWATER STREAMFLOW

Streamflow and groundwater originating in the mountains of northern Utah are the primary water sources for both human use and Great Salt Lake. Understanding how these sources respond to climate is key to predicting water supply for all uses.

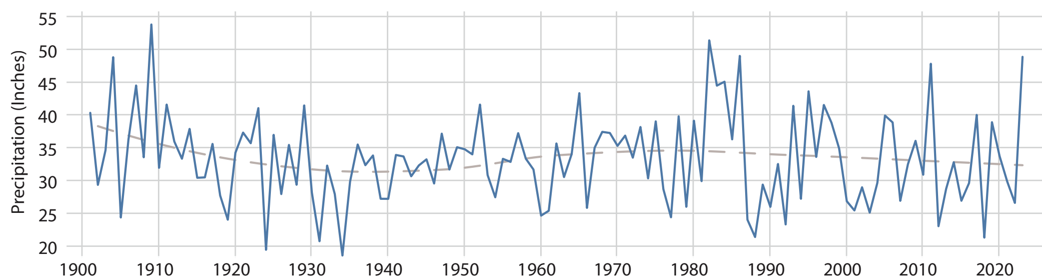
In northern Utah, air temperature has increased. Precipitation shows no long-term trend, but the number and frequency of consecutive dry years have increased. Warmer temperatures and consecutive dry years reduce groundwater storage and runoff efficiency.

Figure 6: Historical Temperature, Precipitation, Streamflow, and Groundwater Storage in Great Salt Lake Headwaters

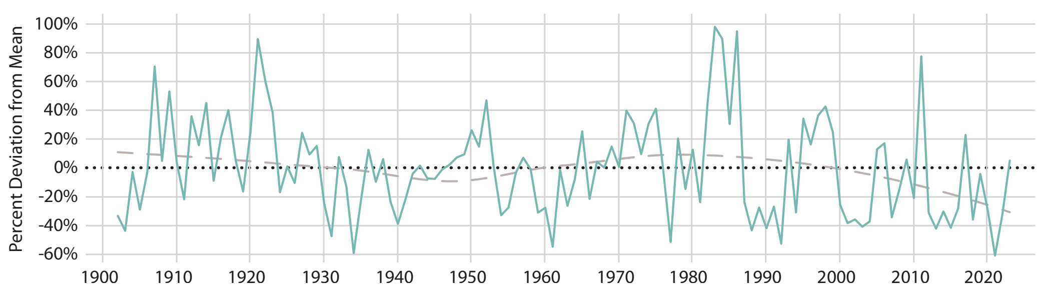
Air Temperature 1901-2023



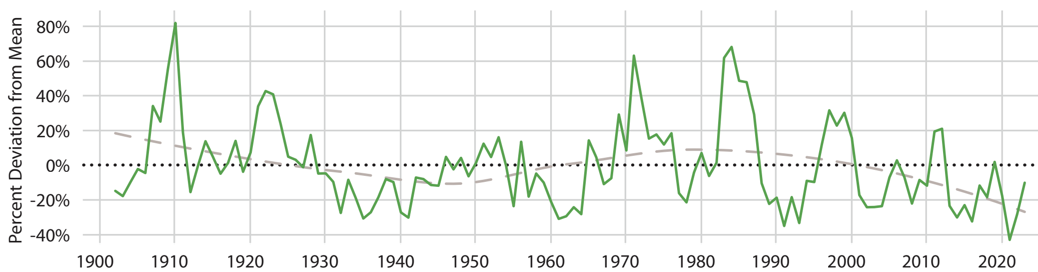
Precipitation, 1901-2023



Headwater Streamflow, 1902-2023



Groundwater Storage 1902-2023



Sources: 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;
Wolf, M. A. (2023). Quantifying spatial and temporal patterns in groundwater recharge and subsequent controls on runoff efficiency in snowmelt-dominated headwater streams of the western US. [Doctoral Dissertation, University of Utah].

Insights

Temperature - Mean annual air temperature in northern Utah has increased more than 3 degrees Fahrenheit since 1983.

Precipitation - There has been no change in mean annual precipitation in northern Utah. However, there has been an increase in the frequency of consecutive dry years (years with below-average precipitation) since the 1980s.

Evaporation - Higher air temperatures result in increased evaporation from reservoirs and Great Salt Lake, as well as higher evapotranspiration from watersheds.

Groundwater storage - Higher temperatures and consecutive dry years interact to reduce groundwater storage, which decreases runoff efficiency and streamflow in subsequent years (see “Understanding runoff efficiency” on the following page).

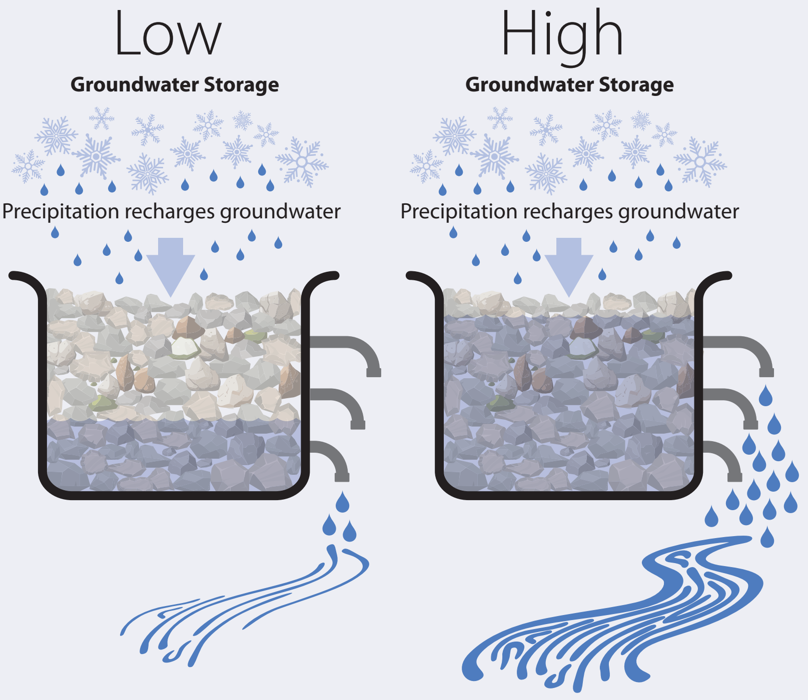
Understanding Runoff Efficiency

Runoff efficiency is the fraction of precipitation that becomes streamflow. In Great Salt Lake Basin, approximately one-third of the precipitation that falls contributes to streamflow. This value varies significantly from year to year, primarily due to changes in groundwater storage. Groundwater storage is related to precipitation, temperature, and melt dynamics during previous years.

The relationship between streamflow, precipitation, and groundwater storage is similar to a bucket with multiple outlets. When groundwater storage is low, only one outlet flows from the groundwater bucket to produce streamflow, and a larger amount of winter snowfall is used to refill the bucket. When groundwater storage is high, the bucket is full, and more outlets contribute water to streamflow.

In 2023, groundwater storage was low, and a significant portion of the 2023 snowpack recharged groundwater rather than showing up as streamflow. The groundwater storage going into 2024 will be higher, due to 2023 record precipitation. Higher groundwater storage resulting from 2023 snowmelt should increase runoff efficiency in 2024.

Streamflow Varies Because of Precipitation and Groundwater Storage



Consecutive dry years lead to low groundwater storage. When precipitation falls, a larger proportion recharges groundwater than flows to streams, compared to when groundwater storage is high.

Consecutive wet years lead to high groundwater storage. When precipitation falls, groundwater does not need to be recharged and a larger proportion of water results in streamflow, compared to when groundwater storage is low.

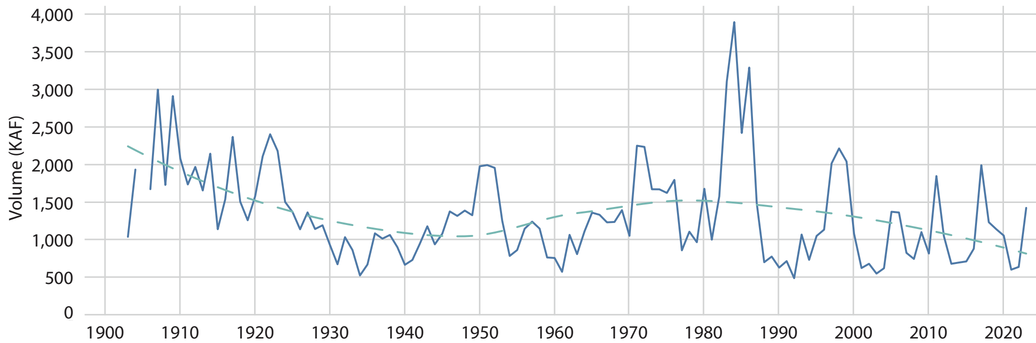
Source: Great Salt Lake Strike Team, 2023

STREAMFLOW INTO GREAT SALT LAKE

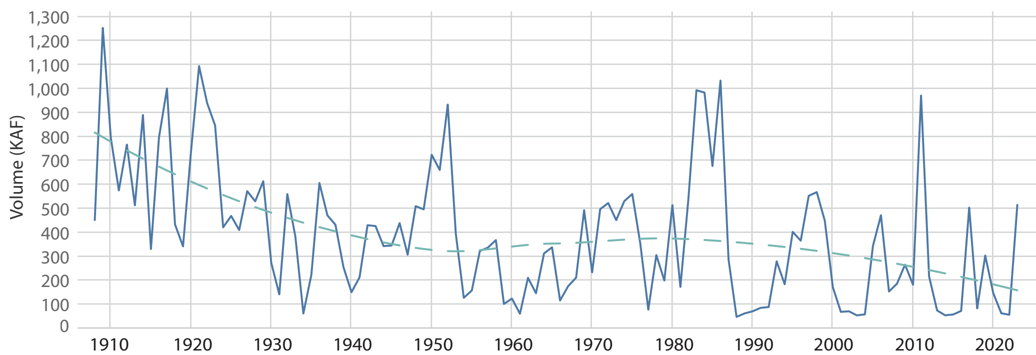
Streamflow into Great Salt Lake is highly variable but has declined since 1900.

Figure 7: Bear, Weber, and Jordan River Streamflow, 1903-2023

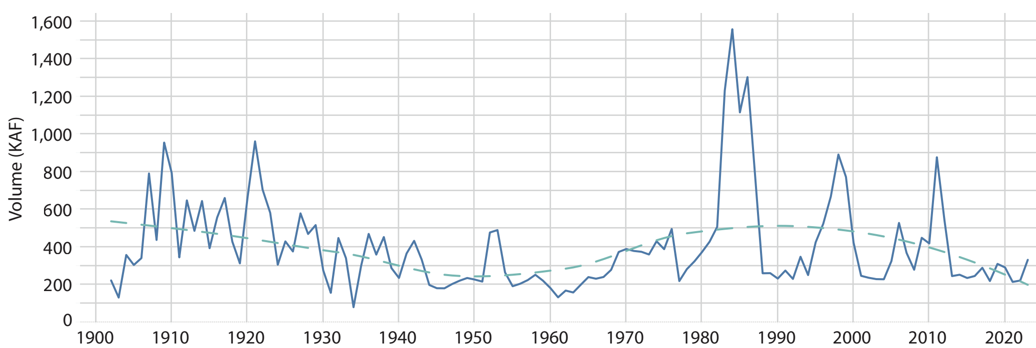
Bear River



Weber River



Jordan River



Note: Trend line generated using LOESS regression.
Source: Bear River 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); Weber River data from USGS gage 10141000 Weber River near Plain City, UT; Jordan River data from USGS gage 10170490 (1944-2022) with modeled data from 1902-1943 (Analysis by Margaret Wolf).

Insights

Diversions - Streamflow, measured at gages near the outlets of each major river draining into Great Salt Lake, is reduced due to diversions and water use upstream.

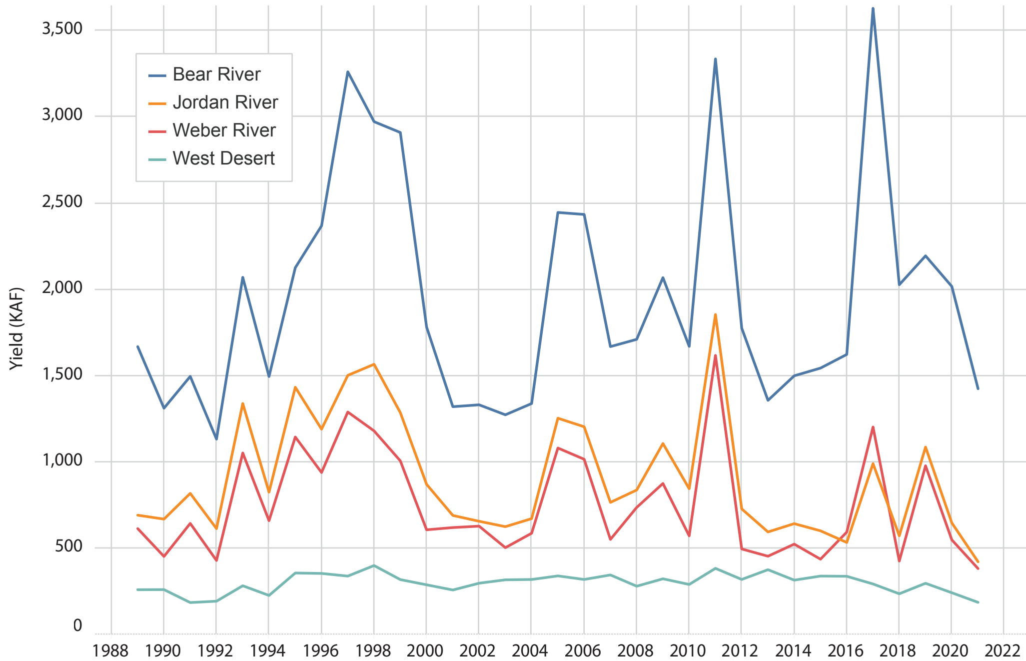
Runoff efficiency - Streamflow may also be reduced, due to decreases in runoff efficiency, related to increasing temperature and decreasing groundwater storage.

Combined effect - These effects combine to reduce inflows to the lake, leading to lower lake levels.

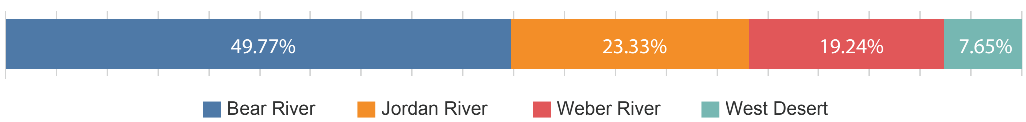
NATURAL FLOW

Distinguishing between natural flow (which varies due to climate) and actual flow (which varies due to climate and consumptive use) is critical for determining the effectiveness of conservation measures.

Figure 8: Natural Flow in the Great Salt Lake Basin, 1989-2021



Average Natural Flow by Basin, 1989-2021



Source: Great Salt Lake Water Budget, Utah Division of Water Resources, 2023
Note: Water Budget data from Division of Water resources are only available through 2021, so the impact of the 2023 water year is not shown here.

Insights

Variability - Natural flow is highly variable, primarily due to winter snowfall and changes in runoff efficiency.

No declining near-term trend - Natural flow from 1989-2021, the only years these data are available, show no declining trend. However, if a longer time span is considered, trends would be similar to those in streamflow (see Figure 7).

Bear River largest - The Bear River's natural flow is the largest of the Great Salt Lake sub-basins.

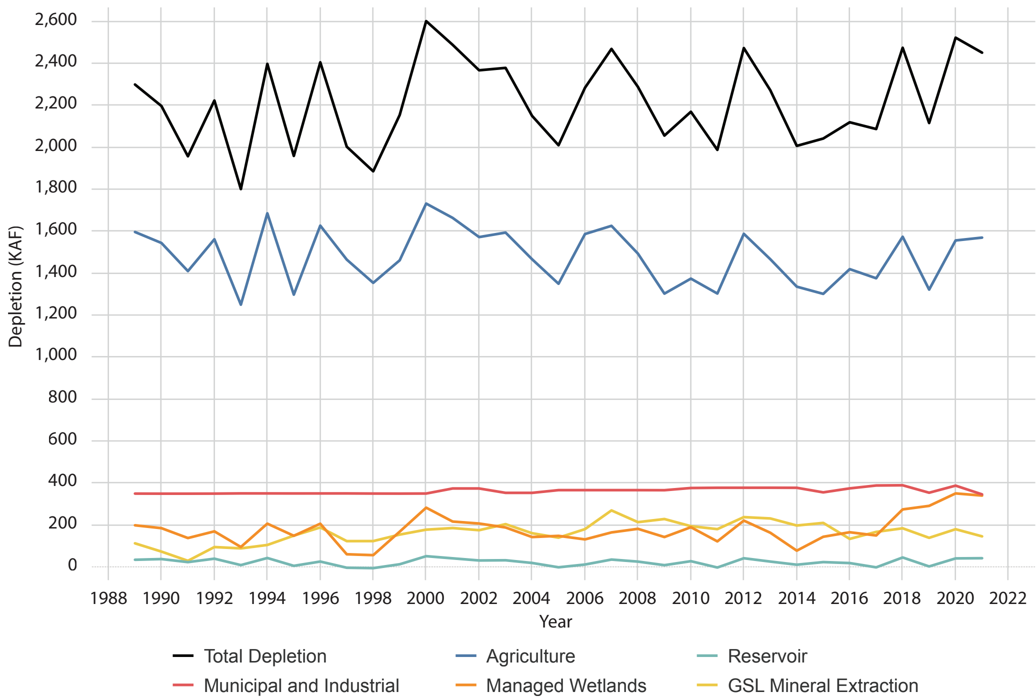
Natural flow

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

HUMAN WATER USE

Total depletions have been variable in the past 30 years but have remained relatively constant. They range from a low of 1,800 KAF to a high of 2,600 KAF, averaging 2,217 KAF per year.

Figure 9: Human Water Depletion by Type, 1989-2021



Average Depletion (KAF/year)

Depletion Type	1991-1996	1997-2001	2002-2006	2007-2011	2012-2016	2017-2021
Agriculture - Includes all agriculture water depletions.	1,474	1,537	1,515	1,421	1,424	1,481
Reservoir - Represents evaporation from reservoirs (does not include Bear or Utah Lakes).	26	21	20	21	26	28
Municipal and Industrial - Covers urban water depletions from commercial, industrial, institutional, and residential uses.	352	357	364	372	374	375
Managed Wetlands - Includes depletions associated with human-maintained riparian habitats and wetlands.	163	159	165	162	156	283
GSL Mineral Extraction - Incorporates depletions from all mineral extraction companies operating on GSL.	111	155	174	219	204	165
Total Depletion	**2,125**	**2,228**	**2,239**	**2,195**	**2,184**	**2,332**

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

Insights

Agriculture - Agriculture depletes the most water, and this use has remained relatively constant since 1989.

Evaporation and M&I - Reservoir evaporation has remained relatively constant, while municipal and industrial depletions have increased slightly over time.

Mangaged wetlands and mineral extraction - Depletions due to managed wetlands and mineral extraction have increased since 1989.

Warmer and drier years - Human water use and total depletion tend to be greater in warmer and drier years.

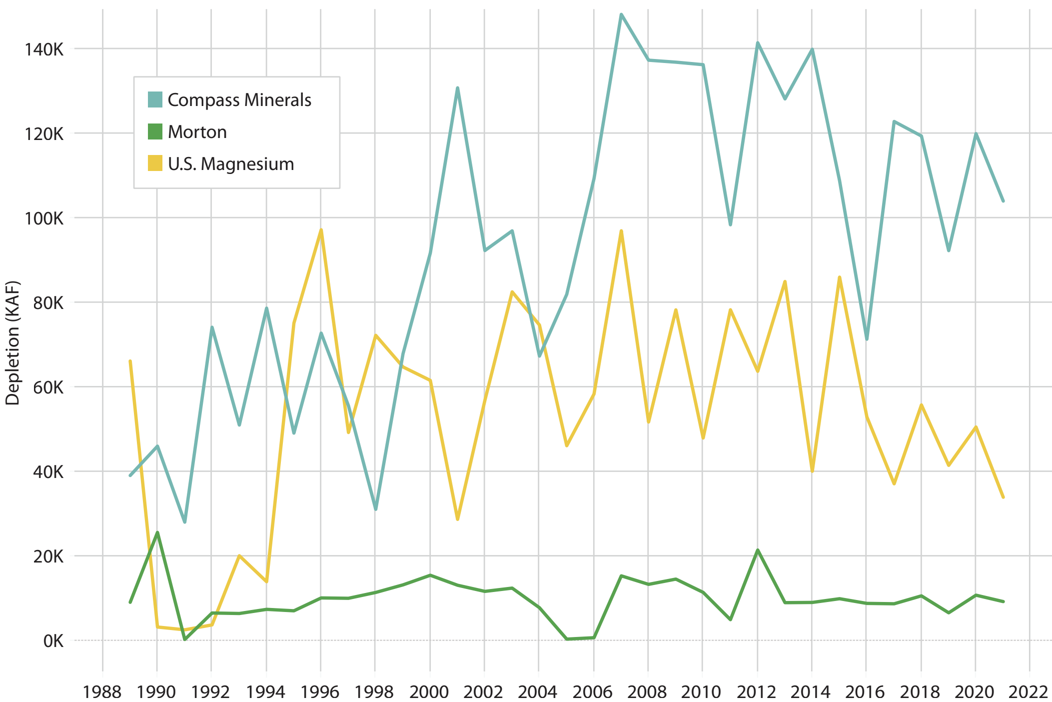
Managed wetlands

Managed wetlands should in many ways not be considered as distinct from the Great Salt Lake as a whole. Wetlands provide critical habitat and ecosystem services on the lake. The amount of water depleted in these wetlands is tracked because as the lake has diminished in size, much of the main body of the lake has receded from the wetlands. Accordingly, wetlands require more water to stay wet and healthy. Lake management plans involve providing sufficient water to the lake system to reconnect the wetlands with the main body of the lake.

MINERAL EXTRACTION

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 to mine three critical minerals: potash, lithium, and magnesium. Brines have become harder to reach due to low water levels.

Figure 10: Mineral Extraction Water Depletions on Great Salt Lake, 1989-2021



Average Depletion (KAF/year)

Company	1991-1996	1997-2001	2002-2006	2007-2011	2012-2016	2017-2021
Compass Minerals	59.0	75.4	89.6	131.4	118.0	111.7
Morton	6.3	12.7	6.6	11.9	11.7	9.2
U.S. Magnesium	35.5	55.3	63.7	70.7	65.6	43.8
Total	**100.7**	**143.4**	**159.9**	**214.0**	**195.2**	**164.7**

Source: Utah Division of Water Resources, 2023
Note: While Cargill operates on Great Salt Lake, it receives its brine from U.S. Magnesium. As a result, on-lake water uses from Cargill are incorporated into U.S. Magnesium's depletions.

Insights

Peaked in 2007 - Depletions due to mineral extraction peaked at 271.3 KAF in 2007, declining to 147.7 KAF in 2021.

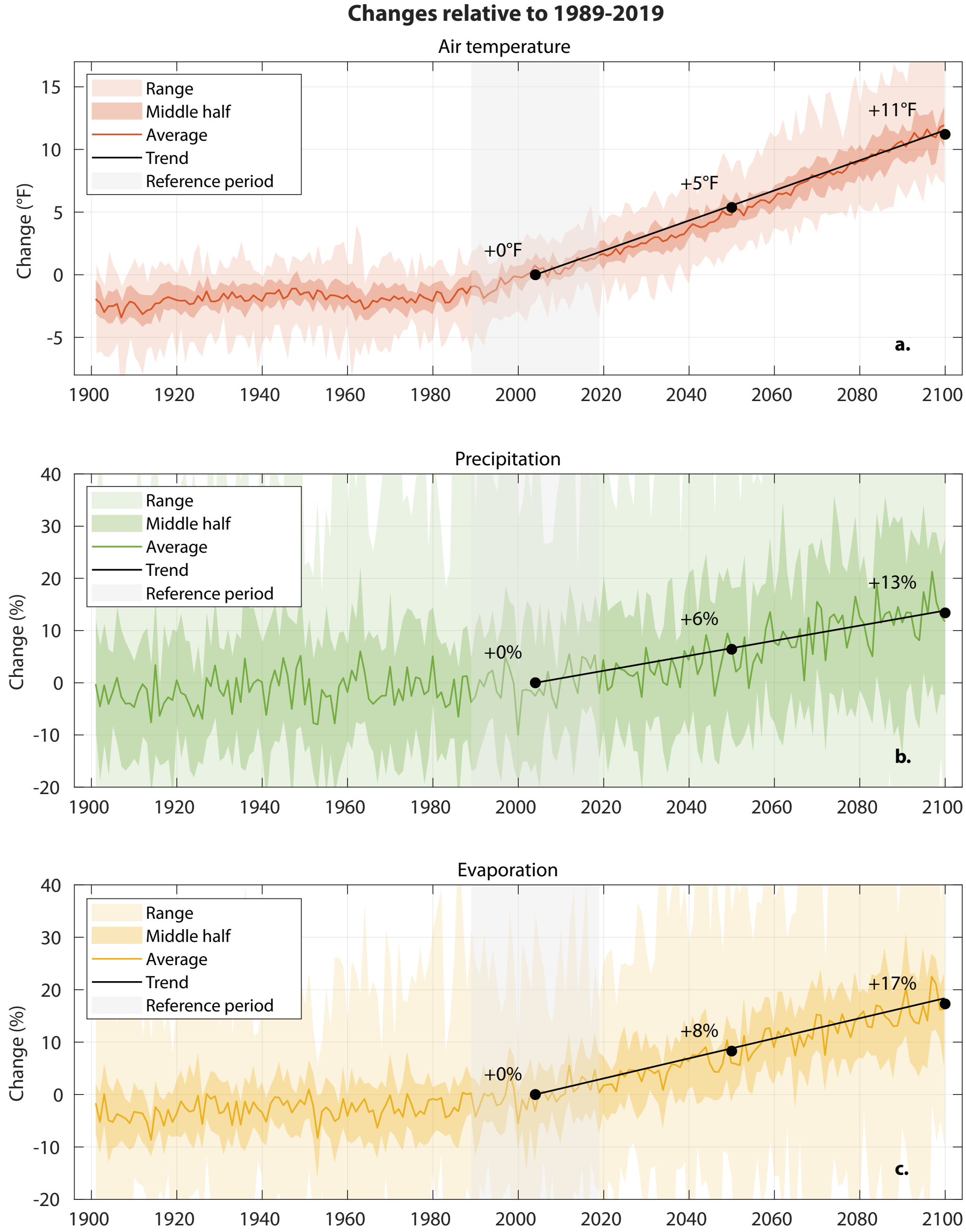
Largest users - Compass Minerals and U.S. Magnesium are the largest mineral depletion users.

Depletion percentage - Over this period, mineral extraction depletion accounted for 7.4% of total human depletion.

FUTURE WATER AVAILABILITY

Cutting-edge climate models project that over the long term, expected increases in precipitation will be overwhelmed by rising temperature and evaporation, creating further challenges for the lake.

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



Notes:

1. The analysis is based on a high greenhouse gas emission scenario referred to as Shared Socioeconomic Pathway (SSP) 585. Lower emission scenarios tend to produce similar changes but at smaller magnitudes.
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

Insights

High greenhouse scenarios - Under a high greenhouse gas emission scenario, 5°F of warming is projected by 2050, and 11°F is projected by 2100.

Increased precipitation - Warming is projected to increase precipitation because a warmer atmosphere can hold and deliver more water.

Increased evaporation - However, warming also increases evaporation, and that will tend to offset any water gains from precipitation.

Warmer temperatures - Warmer temperatures increase lake evaporation and human water needs.

Runoff efficiency and groundwater storage - If longer periods of consecutive dry years continue to occur in the future, runoff efficiency and groundwater storage will decline.

Conservation Planning Scenarios

Conservation planning requires a delineation of healthy lake levels, an understanding of the water needed to fill and maintain that level, and recognition of streamflow variability. The Great Salt Lake Strike Team has made estimates of inflow requirements to achieve alternative elevations.

Healthy lake level range

Lake elevation on Great Salt Lake serves as a valuable proxy for lake health and serves as a useful management tool. Adverse economic, human, and ecological health effects occur with both high and low lake levels. The Division of Forestry, Fire and State Lands created a Great Salt Lake Elevation Matrix to demonstrate to decision-makers the implications of different elevation zones (see Figure 12). The full matrix lists healthy ranges for over 90 competing interests.

Two phases: Filling and maintaining

Restoring Great Salt Lake to a healthy range involves first filling the lake to that level and then maintaining it. More inflow is needed in the filling phase. Table 2 summarizes the inflow volume required to fill and maintain Great Salt Lake at different elevations.

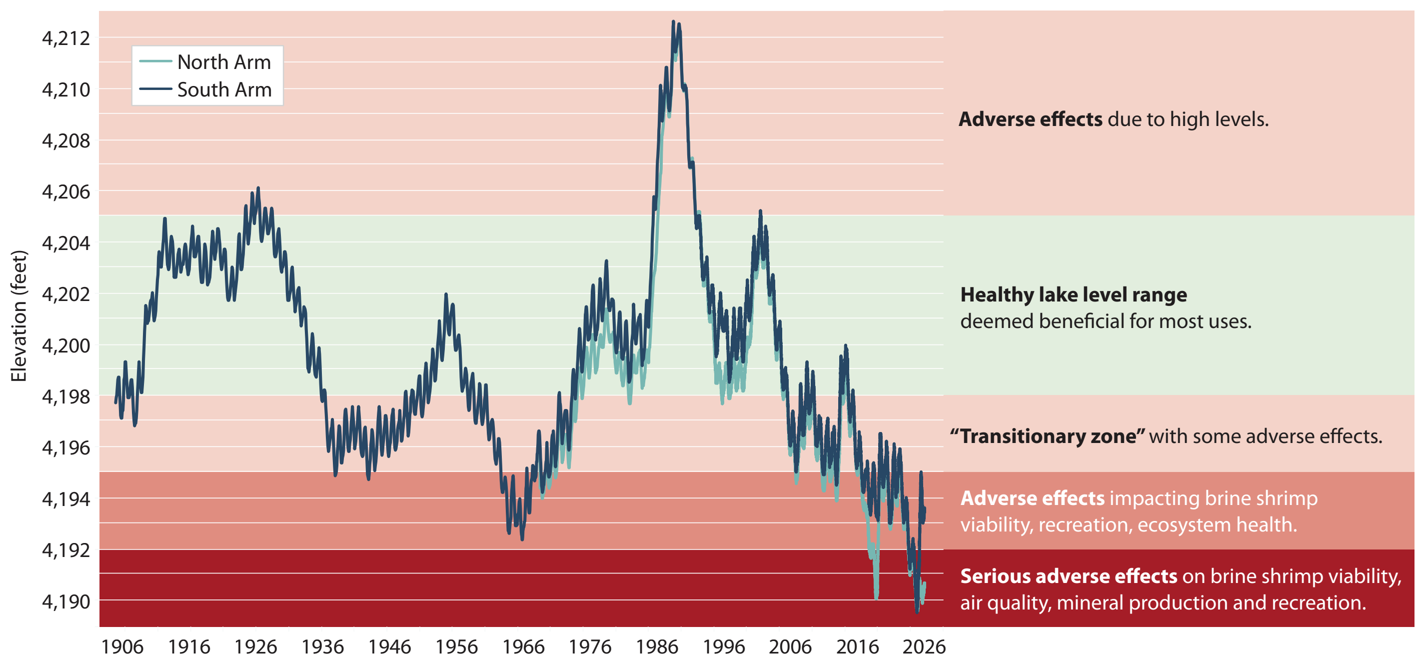
Plan for streamflow variability

Filling and maintaining Great Salt Lake within an elevation range is complicated due to the fluctuation of streamflow from year to year. Although they are infrequent, managers can capitalize on wet years to bring water to the lake. Below are two streamflow scenarios that can be used for planning.

Drought streamflow - The average of the lowest sequential five years on record: 1988 to 1992 (1,059 KAF/year).

Contemporary average streamflow - The contemporary average inflows between 2000 and 2022 (1,643 KAF/year).

Figure 12: Elevations of Great Salt Lake North and South Arms with Elevation Zones, 1903-2023



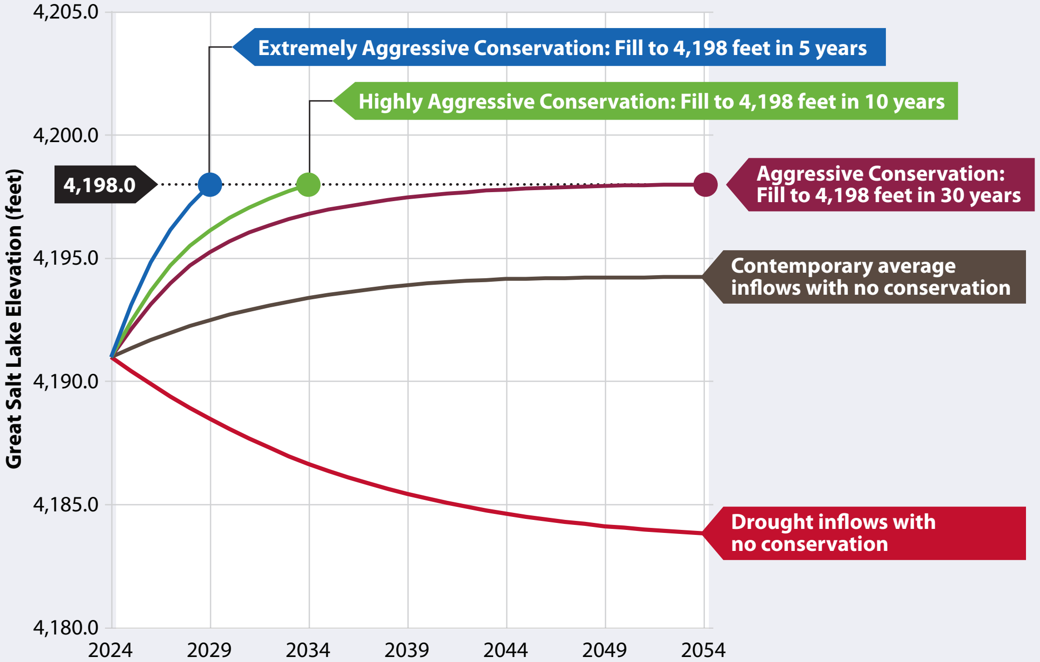
Sources: US Geological Survey Historical Elevation at Saltair Boat Harbor; Utah Division of Forestry, Fire and State Lands, GSL Lake Elevation Matrix, 2013

Conservation Scenarios

Achieving desired inflows requires conservation to reduce human water use. This conservation must come from municipal and industrial or agricultural water use.

Figure 13 shows the projected change in lake level given different conservation strategies over a 30-year planning period. The data are also displayed in Table 2 (Inflow Requirements for Alternative Elevations), which show the inflow required to reach selected target levels.

Figure 13: Projected Elevation of Great Salt Lake Given Different Conservation Strategies



Conservation needed to reach alternative elevations

The conservation required for each of the scenarios displayed in Figure 13 and Table 2 depends on streamflow. Table 3 displays the required conservation for drought and average streamflow across multiple filling time horizons. Each conservation strategy requires significant water use reductions.

Table 2: Inflow Requirements to Meet Alternative Elevations (KAF/year)

Elevation (feet)	Reach target in: 5 years	10 years	30 years	Maintain	Condition
4,191				1,414	Serious adverse effects
4,192	1,564	1,504	1,468	1,463	Adverse effects
4,195	2,091	1,849	1,743	1,738	Transitionary effects
4,198	2,807	2,348	2,145	2,137	Healthy range

Note: This table assumes an initial lake elevation of 4,191 feet.
Source: Analysis by Great Salt Lake Strike Team, 2023

Table 3. Additional Conservation Inflow Needed to Fill the Lake in 5, 10, 20, and 30 Years (KAF/year)

Elevation (feet)	Extremely Aggressive Conservation: Five Years		Highly Aggressive Conservation: Ten Years		Aggressive Conservation: Thirty Years	
	Drought Streamflow	Average Streamflow	Drought Streamflow	Average Streamflow	Drought Streamflow	Average Streamflow
4,191	355	0	355	0	355	0
4,192	505	0	445	0	409	0
4,195	1,032	448	790	206	684	100
4,198	1,748	1,164	1,289	705	1,055	471

Note: This table assumes an initial lake elevation of 4,191 feet.
Source: Analysis by Great Salt Lake Strike Team, 2023

Water Distribution and Shepherding

Water shepherding ensures that water conserved within the Great Salt Lake Basin flows to Great Salt Lake. Measurement infrastructure and distribution accounting models are needed to ensure that available water from the water rights change application process flows to the lake, without being depleted before it gets there.

Importance of water shepherding

- Without a way to "shepherd" water past intervening users, efforts intended to dedicate water to Great Salt Lake could be easily undermined. However, upon approval of an appropriate change application, the State Engineer can deliver the dedicated water to Great Salt Lake via river commissioners, accurate measurements, and distribution accounting models.
- Accurate quantification of depletions is critical to any change application that contemplates delivering water to Great Salt Lake.
- Delivering the dedicated water requires accurate measurement, robust accounting models, and timely adjustments.
- Enhanced measurement infrastructure within the Great Salt Lake watershed is imperative for the State Engineer to deliver the dedicated water. It is also critical for a shared understanding of water use and distribution among all stakeholders within the basin.

Progress on achieving water shepherding

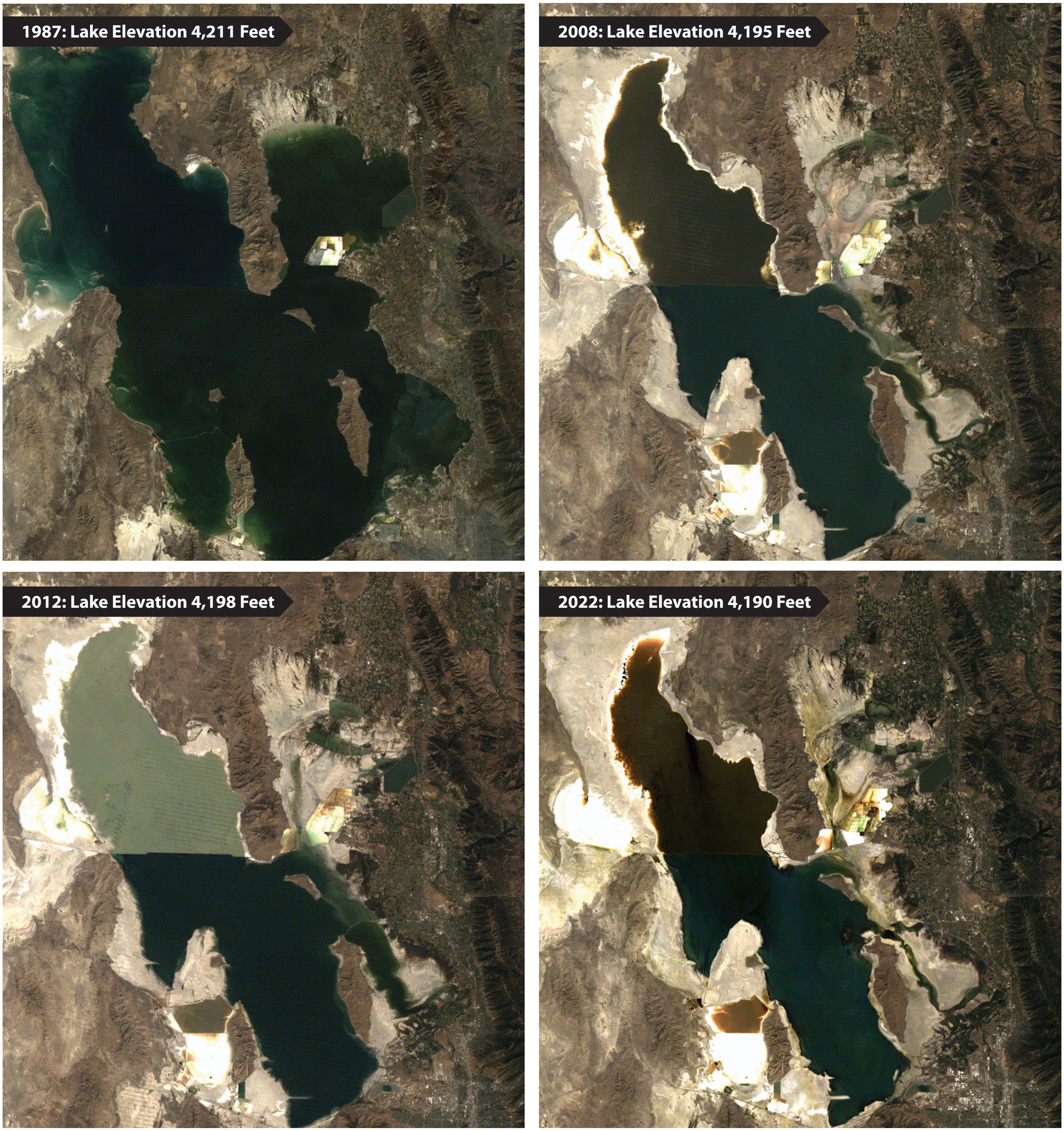
- **Saved water change application** - During the 2023 general session, the Legislature passed SB 277, allowing agricultural producers to file a change application on "saved water" resulting from an agricultural water optimization project.
- **Gap analysis** - The State Engineer has entered into a cooperative agreement with Utah State University to conduct a Measurement Infrastructure Gap Analysis within the Great Salt Lake watershed to identify areas where additional measurement and telemetry are needed to meet these requirements.
- **Measurement appropriation** - To address immediate needs, the Legislature appropriated $300,000 in 2022 to install additional measurement and telemetry infrastructure within the Great Salt Lake watershed.

What is needed

- **Distribution accounting models** - The State Engineer has developed distribution accounting models on select river systems to facilitate water delivery according to the respective water rights—including any prospective saved water under an optimization project. There is a need for further refinement of the existing models, including incorporating real-time data and developing additional models where none currently exist.
- **Measurement infrastructure** - Additional water measurement infrastructure is needed to improve and optimize the State Engineer's ability to deliver dedicated water and provide required data to the existing and prospective distribution accounting models. The current gap analysis undertaken by the State Engineer and Utah State University will identify areas where additional diversion measuring devices, river gages, and telemetry are needed to facilitate the accurate and transparent water distribution within the Great Salt Lake watershed.
- **Diversion measurement devices** - Pending the gap analysis results, the state would benefit from new funds for installing and maintaining diversion measurement devices, river gages, and telemetry infrastructure within the Great Salt Lake watershed.

Appendix

Figure 14: Satellite Imagery of Great Salt Lake



Source: U.S. Geological Survey

Notes:

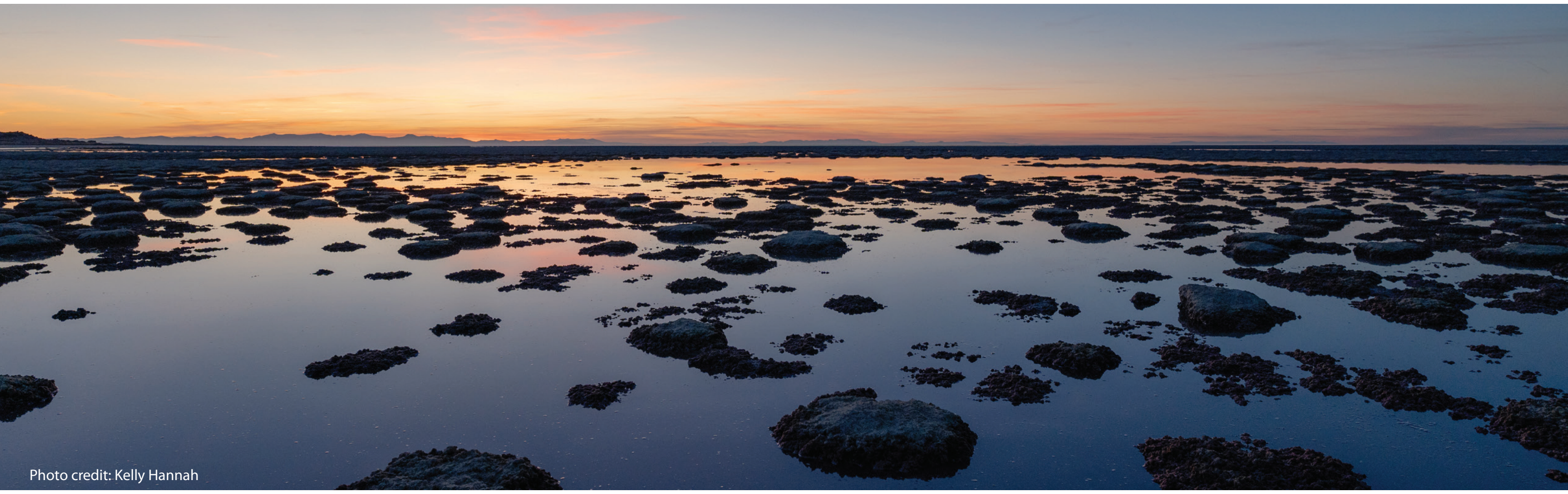


Photo credit: Kelly Hannah