

# Understanding the Great Salt Lake Shrinkage: Stakeholders, Current Efforts, and Research Gaps

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## 1. Introduction

The Great Salt Lake (GSL) has been a part of Utah for thousands of years and has been a reliable staple as the state has transformed into a thriving system with development covering the Wasatch Front. Great Salt Lake is the capital city’s namesake, the center of an important ecosystem, and a contributor to Utah’s fast-growing economy; it embodies the unique essence of Utah. However, this lake that was once seen as an immutable constant is now at risk. In November 2022, Great Salt Lake reached its lowest measured elevation of 4188.5 feet<sup>i</sup>.

Saving the Great Salt Lake is a large responsibility and a difficult task. It will first require a deep understanding of the problem and the stakeholders involved. The hope of this paper is to address this step to pave the way for future decision-making, protecting both the lake and all the life it supports.

## 2. The Great Salt Lake System and History

### 2.1 Lake Bonneville

Long before Great Salt Lake formed, Lake Bonneville, its gigantic predecessor, dominated nearly a quarter of present-day Utah<sup>ii</sup>. Lake Bonneville was a freshwater lake that existed roughly 30-13 thousand years ago<sup>iii</sup>. A sandstone wall at the top of the lake, now Red Rock Pass in Idaho, acted as a natural dam. That wall ruptured about 14,500 years ago, causing the lake to drain rapidly in one of the biggest flash floods in Earth’s history<sup>iv</sup>. The escaping water traveled northwest through Idaho to the Pacific Ocean, with the remaining water of Lake Bonneville slowly evaporating from droughts for over 500 years. 11,000 years ago, the Great Salt Lake that exists today was officially formed<sup>v</sup>.

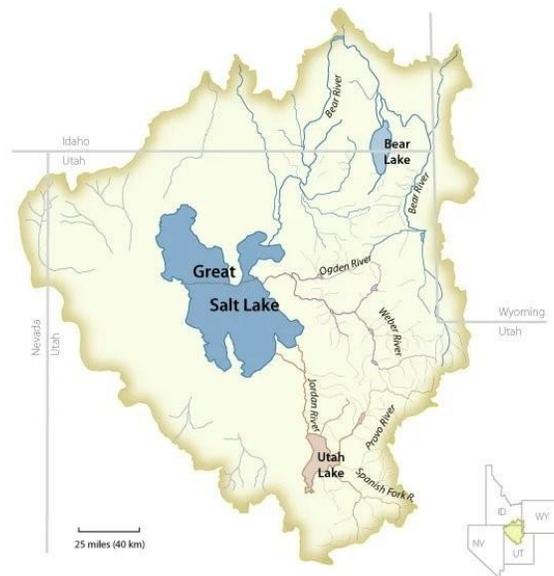
## 2.2 A Terminal Lake

Great Salt Lake is a terminal lake, meaning that there are no rivers or outlets that drain out of the lake. The only way water can leave is through evaporation. As tributary rivers flow toward the lake, they pick up and carry minerals, such as salt, to the lake. As the lake evaporates, these minerals are left behind and become increasingly concentrated. This concentration of deposited salt is what gives Great Salt Lake its trademark high salinity<sup>vi</sup>.

On average, Great Salt Lake's annual water input is between 1 million and 3.6 million acre-feet of water, originating from the Bear, Weber, and Jordan Rivers and direct precipitation (Figure 1). In contrast, an average of 3 million acre-feet of water evaporates off the lake annually<sup>vii</sup>. This creates a delicate balance of water flowing in and out of the lake; just a few years of drought and low precipitation can cause the lake to shrink significantly<sup>viii</sup>. During these periods, there are only two ways to ensure that any water is making it to GSL: either generate additional water (augmentation) or use less water (conservation).

Because water inflow and outflow are so important to GSL, it is necessary to be able to measure and track where and how much water from upper tributaries is diverted before making it to the GSL. The ability to measure water is known as telemetry, and the ability to track water is known as water shepherding<sup>ix</sup>.

Figure 1: Map of Great Salt Lake Basin



Source: *Great Salt Lake, an overview of change*, p. 304; map compiled by Daniel Smith from the Utah Division of Oil, Gas and Mining, 2002.

## 2.3 History of Water Rights

The culture of water use in Utah that impacts GSL today originates from water law created by pioneers in the 19<sup>th</sup> century<sup>x</sup>.

In early America, many people deemed the West uninhabitable because of its arid land. When the pioneers arrived, they created water diversions and dams to keep water from snowmelt for the dry summer. The Mormon settlers used irrigation systems to transport water artificially. This differed significantly from the Eastern United States, where farmers relied solely on precipitation to water

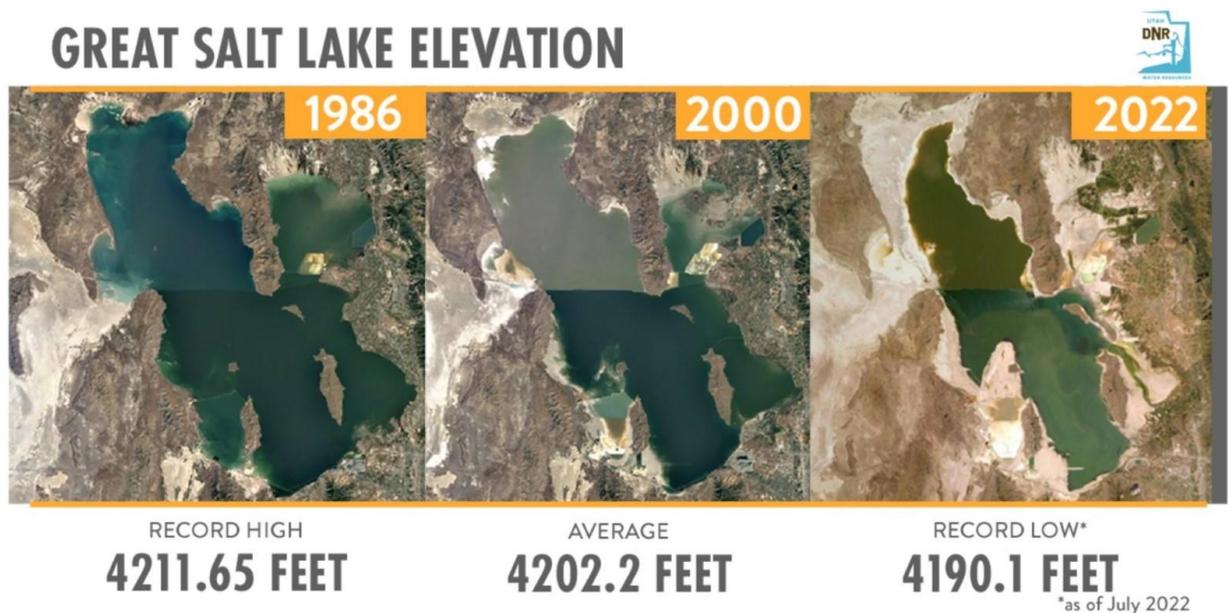
their crops. The pioneers' system relied on collaboration and creativity, and the lack of established laws in Utah allowed the Latter-day Saints to establish new precedents that differed from Eastern norms<sup>xi</sup>.

Two key parts of their success were their irrigation techniques and the creation of the "first in time, first in right" precedent. This precedent is formally called "prior appropriation." Prior appropriation is a system of managing water as a limited resource<sup>xii</sup>. This system centers on the idea that water rights are given chronologically, with the first people to beneficially use water receiving "senior" water rights. These senior appropriators can use all their allocated water for the same use every year, regardless of the year's precipitation levels. In a year with less precipitation and thus less inflowing water, senior water users can still use their full water right, while more junior water users may only be able to partially use their water right. An important element of prior appropriation is that one's water right must be used, or it can be taken away. This element is sometimes referenced as "use it or lose it" to describe the pressure for an appropriator to use their entire water right<sup>xiii</sup>. This competitive water system allows successful development in a more arid climate because it creates order for water use where water is limited. Prior appropriation is the foundation of Utah water law today<sup>xiv</sup>.

### 3. Great Salt Lake's Decline

Due to climate change and increased water consumption, Great Salt Lake is shrinking. November 2022 saw Great Salt Lake hit a record low elevation of 4,188.5 ft<sup>xv</sup>. Though only 12 ft below GSL's average elevation, this loss shrunk the lake's surface area from an average 1,700 square miles to almost 800<sup>xvi</sup>. This aridification now puts the state of Utah and its citizens at risk. Figure 2 shows satellite images taken of Great Salt Lake at different elevations<sup>xvii</sup>. The 2022 record low depicted in the figure of 4,190.1 feet was taken in July 2022, before the lake reached its ultimate low of 4,188.5ft in November of that year.

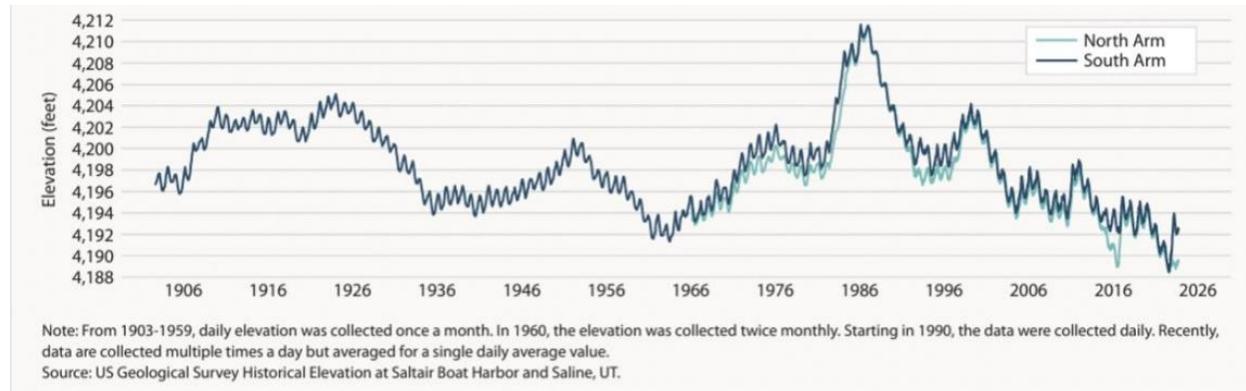
Figure 2: Elevation and Surface Area of GSL



Source: Utah Division of Water Resources, July 7 2022<sup>xviii</sup>.

Elevation data collected from the United States Geological Survey in the figure below depict the variable elevation of GSL throughout history. As shown, the elevation of GSL has fluctuated over time, even reaching over 4,210ft in 1986. However, since that year, there has been a declining trend that caused the lake to reach its historic low<sup>xix</sup>.

Figure 3: Elevation of GSL

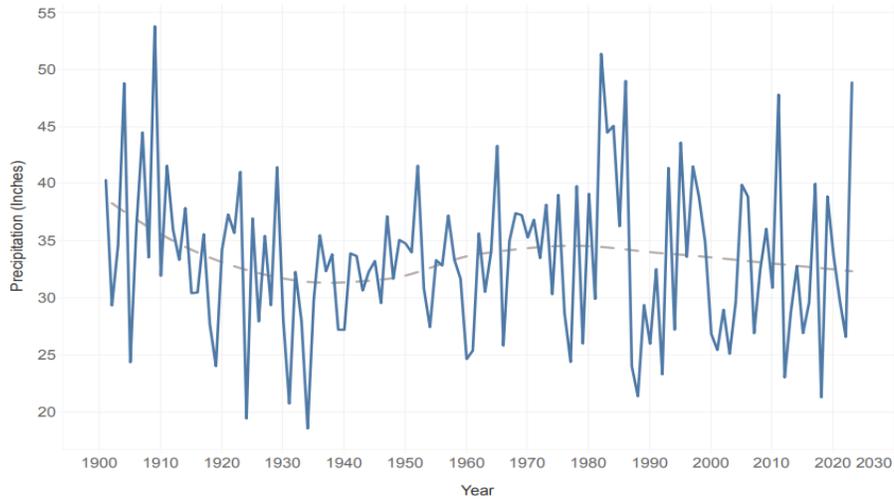


Multiple issues contribute to the contemporary decline of the Great Salt Lake. Some come from a larger, global scale, while others are directly related to Utahns.

### 3.1 Climate Change

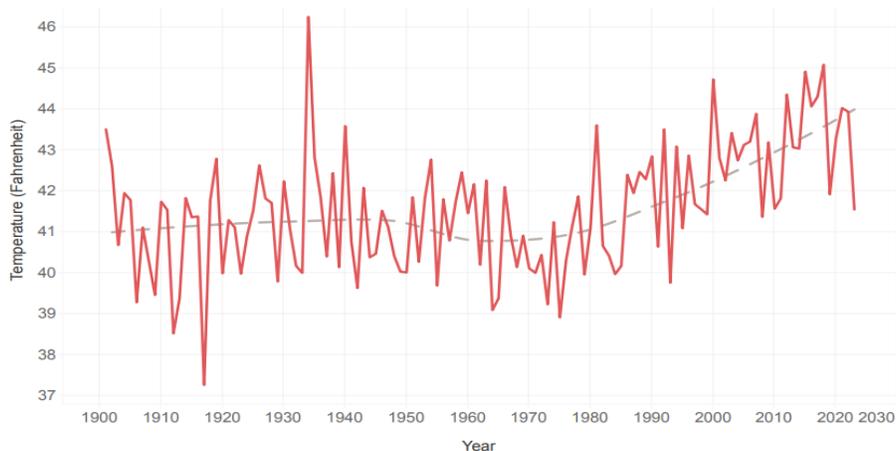
In a 2023 study, Ben Abbott, a professor of Environmental Science and Sustainability at Brigham Young University, claims that 9% of GSL's decline can be attributed to climate change, and that as temperatures increase, climate change poses a long-term threat to the health of the lake<sup>xx</sup>. Data collection beginning in 1901 shows that precipitation has not increased or decreased in a statistically significant trend (Figure 4). Figure 5, however, shows the increase in air temperature over the last 40 years in particular<sup>xxi</sup>.

Figure 4: Mean Northern Utah Precipitation (1901-2023)



Sources: Great Salt Lake Strategic Plan

Figure 5: Mean Northern Utah Temperature (1901-2023)

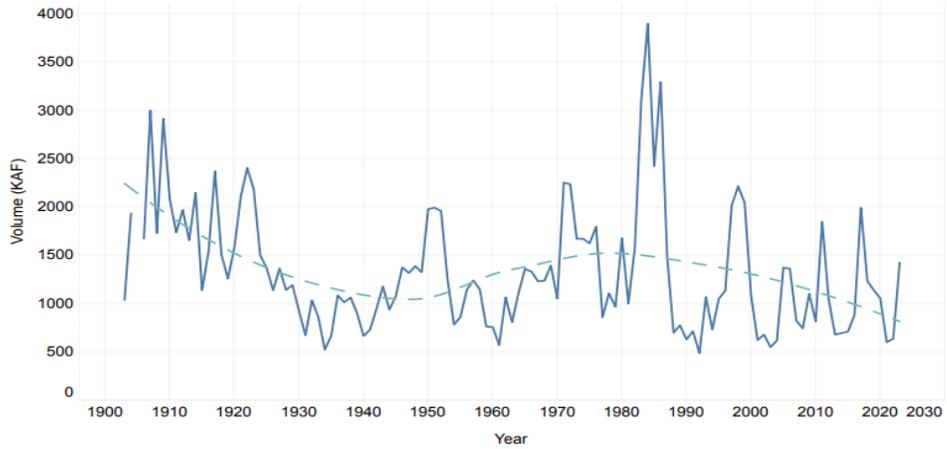


Sources: Great Salt Lake Strategic Plan

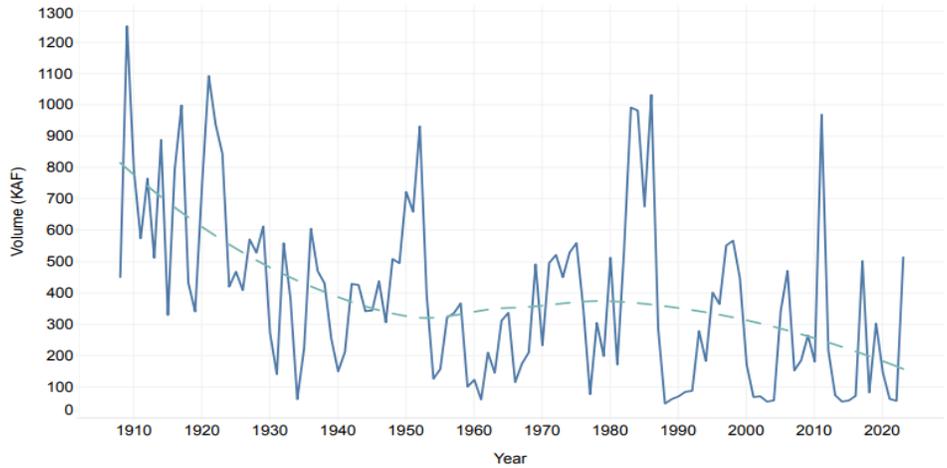
According to the GSL strike team, the mean annual air temperature in Utah has increased by more than 3 degrees Fahrenheit since 1983, which has led to an increase in evaporation of GSL and a decrease in the efficiency of groundwater recharge in the GSL Basin<sup>xxii</sup>. The GSL Strike Team’s 2024 Data and Insights Summary explains the relationship between groundwater recharge, precipitation, and temperature; When precipitation events occur, that water either seeps into the ground to recharge groundwater levels, or it runs off the ground directly into streams. The Strike Team states that “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.” Thus, as Utah’s temperature increases and the state experiences consecutive dry years, more precipitation will flow to depleted groundwater aquifers than to stream flows that lead to Great Salt Lake (Figure 6)<sup>xxiii</sup>.

Figure 6: Bear, Weber, and Jordan River Annual Streamflow (1900-2023)

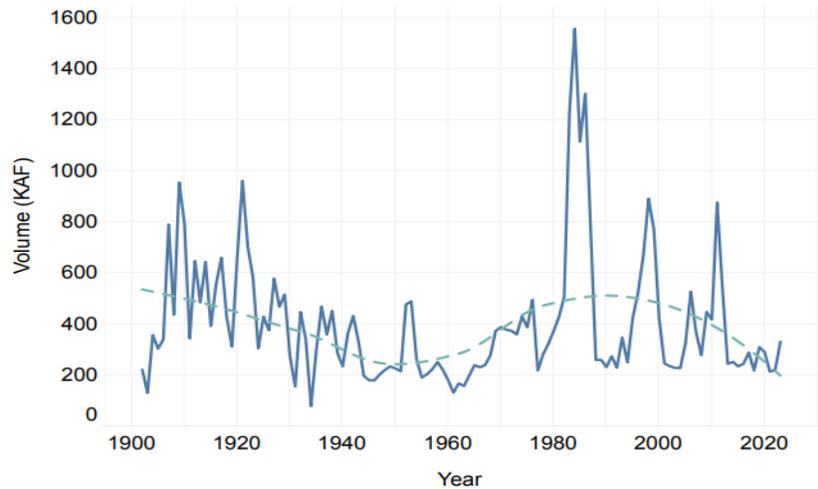
Bear River



Weber River



Jordan River



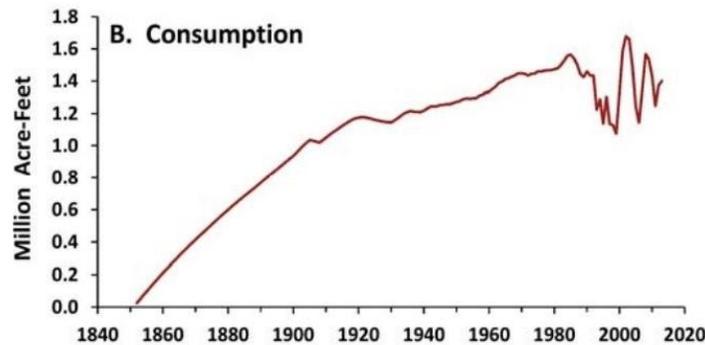
Sources: Great Salt Lake Strategic Plan

In opposition to the claim that Great Salt Lake’s aridification is largely impacted by climate change and rising temperatures, a group of scientists in 2019 determined that a 1.4 degrees Celsius increase in temperature would have only lowered the lake by 0.12 m— yet the lake fell by 0.81 m. As such, they conclude that while increased evaporation causing lake drying is impacted by climate change, it is not enough to explain the total elevation decrease of GSL. Instead, increasing water development and water consumption in Utah explains much more of the lake’s decline<sup>xxiv</sup>.

### 3.2 Consumption of Water Resources

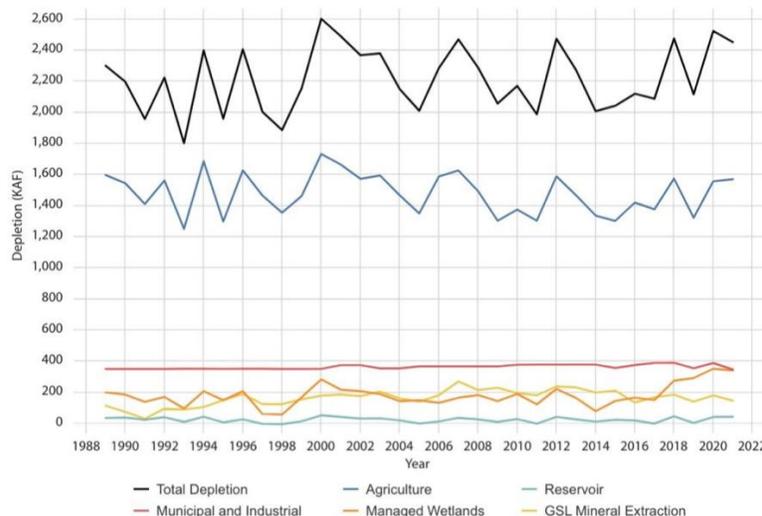
A recent measurement of human water consumption in Utah from the Great Salt Lake Strike Team has revealed that Utah’s total water use has remained relatively constant since 1989 (Figure 7)<sup>xxv</sup>. However, a separate study completed by researchers from Utah State University, Salt Lake Community College, the Division of Water Resources, and the Division of Wildlife Resources concluded that the long-term trend of water use in Utah displays a large increase<sup>xxvi</sup>.

Figure 7: Estimated Water Consumption in Utah Since the 1840’s



Source: Impacts of Water Development on Great Salt Lake and the Wasatch Front, USU, 2016.

Figure 8: Utah Human Water Depletion Since 1989

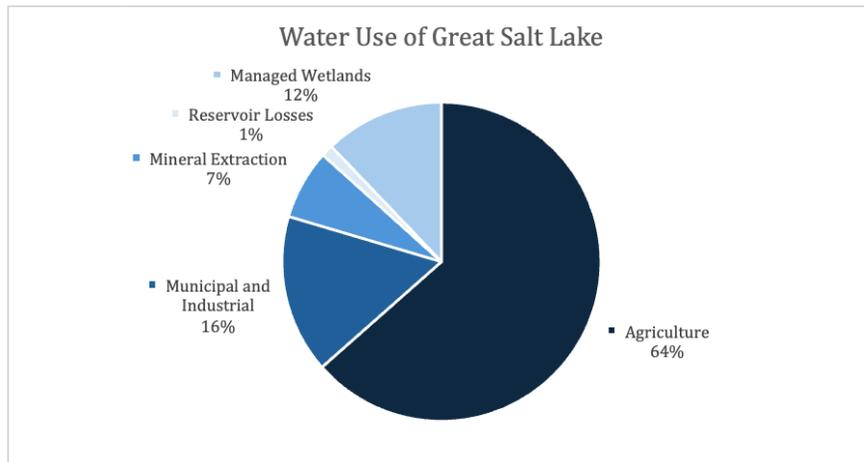


Source: Great Salt Lake Water Budget, Utah Division of Water Resources, 2023

This total water consumption can be further broken down into its specific uses (Figure 8). Agriculture is the largest water user in the state at 1.48 million acre-feet of water annually. In total, this makes up 64% of all Utah’s consumption. Municipal and Industrial residents and providers use 375,000 acre-feet annually, and mineral extraction uses 165,000 acre-feet per year. Other water losses are not caused directly by human activity. This includes the estimated 28,000 acre-feet that evaporates off reservoirs every year and 283,000 acre-feet used to preserve GSL’s wetlands. These wetlands provide crucial wildlife habitat, manage floods, improve water quality, and allow for recreation, so the state sees them as essential to maintain. Additionally, when the lake’s water levels are normal, it does not require as much additional water to manage these areas as when the lake’s water levels are low<sup>xxvii</sup>.

It is worth noting, however, that not all consumptive water use has the same impact on GSL. When water is just diverted from its source for human use, it can be returned to the system. In contrast, water depletion refers to water that is diverted and then fully consumed so that it does not return to GSL. These water depletions measurements are essential for understanding how human water uses impact Great Salt Lake and its watershed<sup>xxviii</sup>.

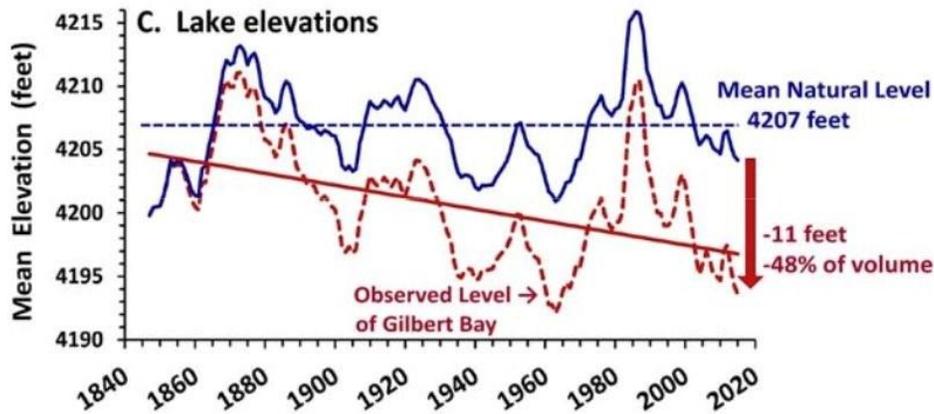
Figure 9: Water Consumption in Utah by Use



Source: Great Salt Lake Strategic Plan, 2024.

In 2016, researchers from Utah State University, Salt Lake Community College, the Division of Water Resources, and the Division of Wildlife Resources determined that overconsumption of water was responsible for a 39% reduction in inflow to the lake. The study claims that “without consumptive water use, the long-term trend in the lake level since 1847 would have been flat with a natural mean elevation of 4,207 feet. Put another way, the lake is now 11 feet lower than it would have been if not for the existence of human consumptive use since the settlement of Utah in 1847” (Figure 10)<sup>xxix</sup>. This estimated natural mean elevation of 4,207 feet is 7 feet higher than the state’s estimated mean of 4,200 feet. However, despite discrepancies in specific estimates, our team believes this study still demonstrates the overall conclusion that the lake’s level is lower now than it otherwise would be without the effects of human water consumption<sup>xxx</sup>.

Figure 10: Estimated Impact of Water Development on Great Salt Lake Elevation



Source: *Impacts of Water Development on Great Salt Lake and the Wasatch Front*, USU, 2016.

However, due to a lack of telemetry devices deployed on the lake and its tributaries, it is difficult to accurately measure how much water is directly making its way into the lake and how much is being diverted away for other uses. Additionally, it is difficult to determine if “saved” water is entering the lake or being diverted elsewhere later<sup>xxxxxxxii</sup>.

## 4. Consequences

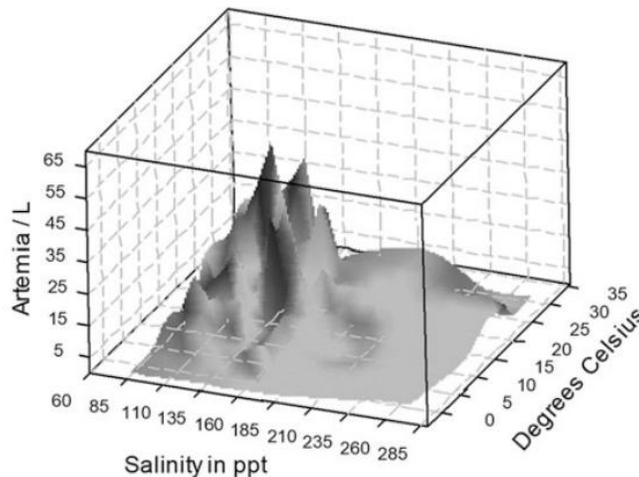
Because Great Salt Lake has not dried up before, the negative consequences of such an event are not well established. However, researchers and examples of other saline lake declines can provide some realistic expectations.

### 4.1 Ecological Collapse

With no lake, there is no place for the living organisms that inhabit it to survive. This specifically includes brine shrimp and migratory birds.

Brine shrimp (artemia) are crustaceans that inhabit the Great Salt Lake and serve as a primary food source for migratory birds. Brine shrimp thrive in saltwater conditions but only between certain salinity thresholds. Salinity levels below 120g/L create a risk of predation by other species able to survive the saline conditions, increased competition with other species, and changes in phytoplankton populations that harm brine shrimp populations. Salinity levels greater than 160g/L lead to decreased metabolism rates, oxygen stress, and reduced reproductive rates of the shrimp, preventing the population from expanding. Figure 11, depicted below, demonstrates how brine shrimp populations fluctuate given different salinity and water temperature conditions in Great Salt Lake<sup>xxxxxiii</sup>.

Figure 11: GSL Artemia Population Densities Across Salinity and Temperature from GSLBSC Monitoring of the South and North Arms



Source: Great Salt Lake Salinity Advisory Committee. "Influence of Salinity on the Resources and Uses of Great Salt Lake." Utah.gov, 2021.<sup>xxxiv</sup>

As Great Salt Lake continues to dry, the salt left behind increases salinity levels of the lake overall, leading to decreased brine shrimp populations. Salinity levels at both Gilbert Bay and the Saltair Boat Harbor reached 183g/L in September of 2022 when the lake level dropped to 4,189 feet of elevation, demonstrating that the reality of a lake with salinity levels beyond the brine shrimp's healthy capacity is a very real issue<sup>xxxv</sup>.

Great Salt Lake also acts as an important stop in the migration patterns of 338 bird species, totaling over 10 million birds per year. This number includes up to 5 million eared grebes, 20,000 white pelicans, and 600,000 Wilson's phalaropes<sup>xxxvi</sup>. These birds stop to rest in Great Salt Lake and feed on brine shrimp before continuing their migratory journeys from Canada to South America. Some birds, like the Wilson's phalarope, will double their weight through their brine shrimp consumption in Great Salt Lake before continuing their journey. If the brine shrimp population in the lake dies, these birds will lose one of the biggest food sources of their migrations, making those journeys nearly impossible and potentially leading to large declines in their populations. These birds do not only affect Utah's ecosystem but the entire North American continent, as Utah is only a stop on the birds' journeys<sup>xxxvii</sup>.

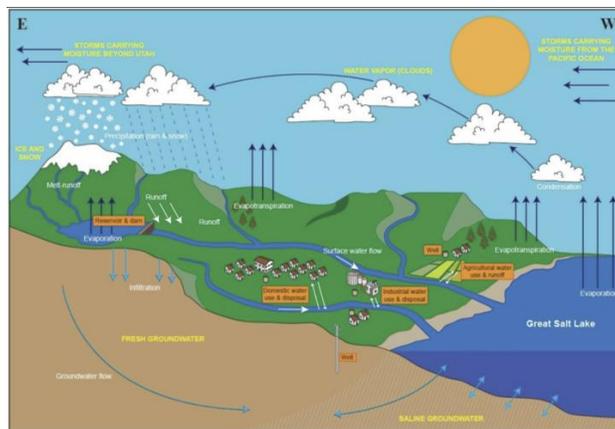
## 4.2 Economic Damage

The growing economy of Utah has been a major part of putting our state on the map. The drying of the Great Salt Lake would affect Utah's economy, both in industries directly related to the lake and those indirectly impacted. Business activity directly impacted by Great Salt Lake includes brine shrimp farming and mineral extraction. These industries, along with recreational uses, contribute \$1.9 billion each year to Utah's economy and provide over 7,700 jobs<sup>xxxviii</sup>. Brine shrimp are the basis of a \$10-60 million harvesting industry in Utah<sup>xxxix</sup>. Brine shrimp cysts harvested from Great Salt Lake are used to feed other shrimp and fish in commercial fisheries and comprise up to 45% of the world's supply<sup>xl</sup>. Mineral extraction of materials such as salt, lithium, and magnesium not only

contribute to Utah's economy, bringing in around \$300 million every year, but also are an important part of making batteries that are key for modern and sustainable technology<sup>xli</sup>.

Utah's ski industry is also closely related to Great Salt Lake. In 2023, Milligan showed that Utah's "greatest snow on Earth" is 5%-10% dependent on lake effect snow (Figure 12)<sup>xlii</sup>. Lake effects are common in areas where the temperature of a large lake differs from the air temperature above it. In the Great Salt Lake basin, winter air blowing in from the Pacific Ocean carries moisture over the lake. As these cold air temperatures combine with the lake water's slightly warmer temperature, the moisture in the air between the two condenses into clouds. These clouds move past the lake towards the mountains, where their size is augmented along the way through evaporation from the lake itself and evapotranspiration from the land between the lake and the mountains. When these clouds finally reach the mountains, they precipitate as snow and become part of the Utah winter snowpack<sup>xliii</sup>. It is estimated that this effect extends Utah's ski season by 5-7 weeks<sup>xliv</sup>.

Figure 12: Great Salt Lake's Lake Effect Snow



Source: Utah Geological Survey, Mark Milligan, 1999.

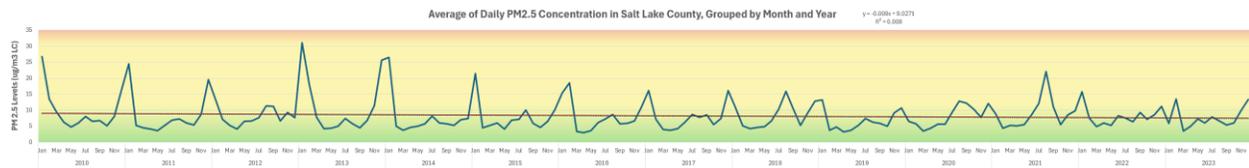
### 4.3 Public Health Crisis

Perhaps the most frightening and elusive consequence of the drying of the Great Salt Lake is its impact on public health. The Salt Lake Valley has notoriously bad air quality, particularly in the winter, because of air pollution and the surrounding geography that creates an inversion<sup>xlv</sup>. Studies show that Utah's air quality currently negatively affects children and other vulnerable populations<sup>xlvi</sup>. A study of the Wasatch Front found that for every 10 micrograms of PM<sub>2.5</sub> (particulate matter) added to the air, there was a 15-32% increase in the odds of a child getting an acute lower respiratory infection<sup>xlvii</sup>. Additionally, a study of third graders in Salt Lake County found that more students performed below their grade level when the air quality was worse<sup>xlviii</sup>. With more of the lakebed exposed, the crust that was once underneath the water can blow dust east into the valley. The lakebed crust has already been proven to have toxic elements in high quantities such as copper, cobalt, and arsenic<sup>xlix</sup>. Along with children's health, new studies are beginning to observe the correlation between air pollution and neonatal mortality, low birth weight, and preterm birth<sup>l</sup>. While these vulnerable populations are the most at risk of poor air pollution, all Utahns experiencing high levels of particulate matter can experience respiratory complications<sup>li</sup>.

Raw data of particulate matter of less than 2.5 micrometers in diameter (PM 2.5) in Salt Lake County indicates that air pollution has not drastically changed in the last few years. (Figure 13)<sup>lii</sup>.

However, a study of Owens Lake, a saline lake in California that dried up in 1926, can shed light on the potential for serious air pollution as Great Salt Lake shrinks.

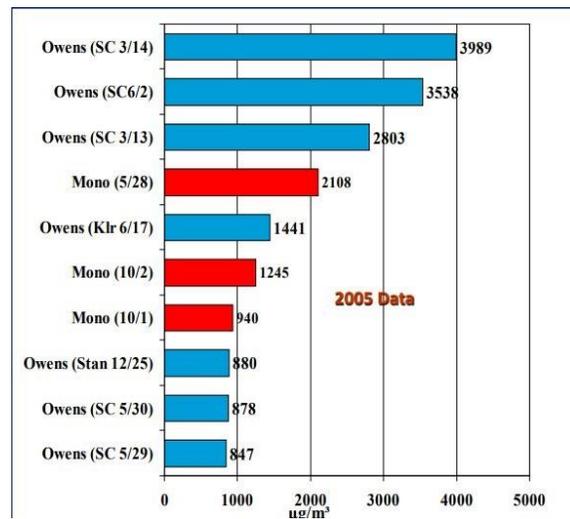
Figure 13: Salt Lake County PM 2.5 Levels



Source: Utah Air Monitoring Program, Utah Department of Environmental Quality – Air Quality<sup>liii</sup>

According to the EPA, Owens Lake produced some of the worst PM 10 pollution in the United States after it dried up in the 1920's<sup>liv</sup>. Figure 14 depicts EPA data from 2005 of the top 10 areas in the US with the highest PM 10 levels. Of those 10 locations, 7 come from areas surrounding Owens Lake. The federal standard for PM 10 is 150 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). At Owens Lake, those levels were near 4000  $\mu\text{g}/\text{m}^3$ <sup>lv</sup>. As the Great Salt Lake is nearly 12 times larger than Owens Lake, concerns for air pollution are even greater<sup>lvi</sup>.

Figure 14: Greatest Levels of PM 10 in the United States (2005)



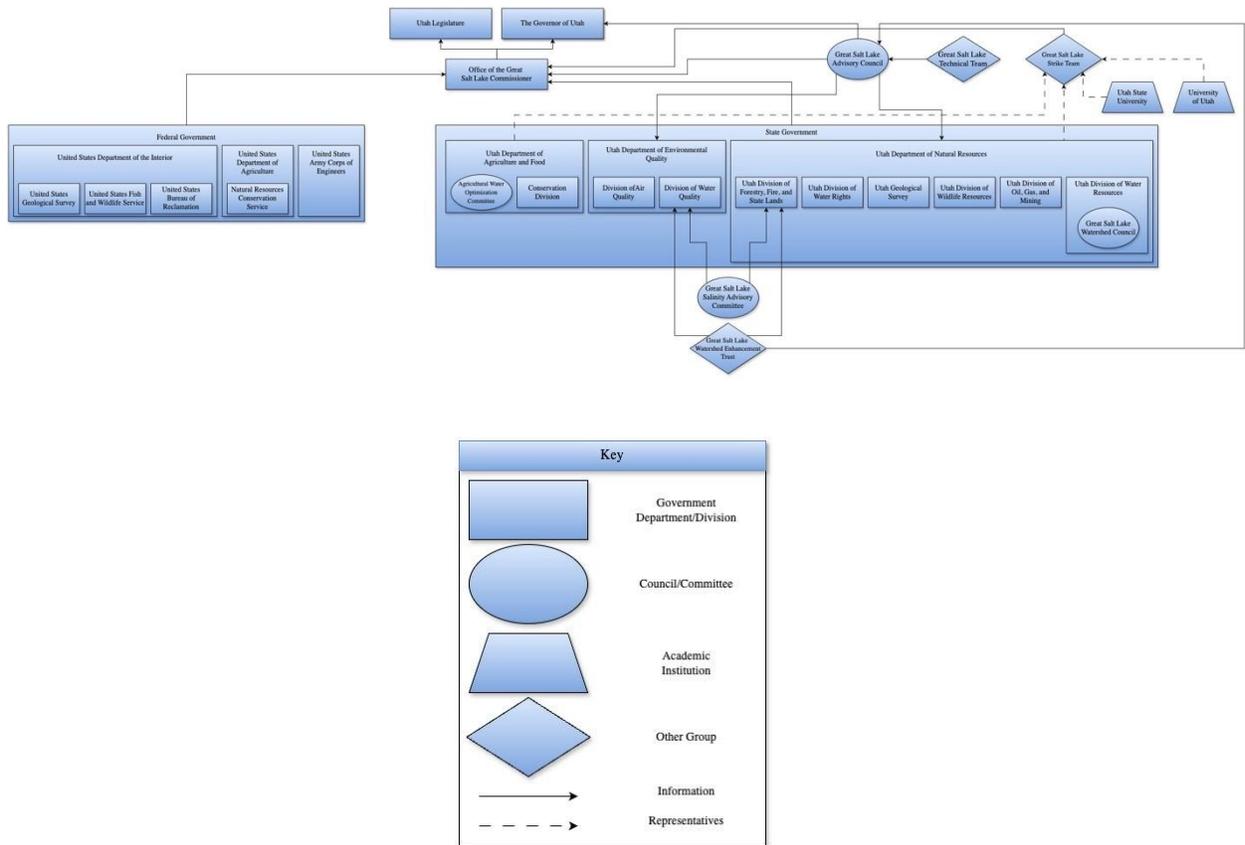
Source: Schade, Ted. *It All Starts With You- Air Quality Data Collection. It\_All\_Starts\_With\_You.pdf* (csus.edu). 2005.

## 5. Great Salt Lake Stakeholders

The following organization map illustrates important stakeholders and explains what value they provide to the lake, helping us better understand what is currently being done to protect Great Salt Lake (GSL) and where potential gaps in solutions exist.

### 5.1 Government Entities

As a large body of water with a broad range of effects on Utah as a whole, management efforts to save GSL fall largely under the authority of governmental organizations.



### 5.1.1 Office of the Great Salt Lake Commissioner <sup>lvii</sup>

Created in 2023 by the Utah legislature, the Great Salt Lake Commissioner’s role is to coordinate collaboration between the various agencies and organizations working on GSL and to create and maintain a strategic plan for saving GSL<sup>lviii</sup>. Additionally, the Commissioner has the power to set requirements for state agencies. Brian Steed currently sits as the Great Salt Lake Commissioner. According to the GSL Strike Team’s 2025 Data and Insights Summary Report, GSL needs a minimum of 770,000 AF of additional water annually to bring the lake to a healthy level in 30 years, assuming normal weather conditions<sup>lix</sup>.

### 5.1.2 State Agencies under the Department of Natural Resources

#### 5.1.2.1 Utah Division of Forestry, Fire, and State Lands <sup>lx</sup>

FFSL has direct jurisdiction over Fremont Island and lands below the GSL meander line. The officially surveyed meander line encompasses the extent of the lake when its elevation is between 4,202 and 4,212 feet above sea level<sup>lxi</sup>. Recognizing the importance of GSL, FFSL developed a Comprehensive Management Plan and Mineral Leasing Plan in 2013 for itself and its partners, which defines management goals, objectives, and implementation strategies for the resource management of GSL<sup>lxii</sup>.

#### 5.1.2.2 Utah Geological Survey <sup>lxiii lxiv</sup>

The UGS has performed research and created many technical publications on the history of GSL and Lake Bonneville. It monitors the salinity and geochemistry of the lake and conducts studies on groundwater, information used by other government departments such as the FFSL. Additionally, UGS keeps records of all mineral production on the lake.

### 5.1.2.3 *Utah Division of Water Resources*

The DWRe models the lake and its tributaries. It is involved in all the state's water conservation projects, awarding grants and rebates for initiatives such as water-efficient landscaping, secondary metering, and smart controllers. The DWRe also manages the state's cloud seeding program and, with the FFSL, modified the Union Pacific Railroad Causeway to improve salinity conditions in the lake. The DWRe has also been tasked with creating an integrated plan, known as the Great Salt Lake Basin Integrated Plan (GSLBIP), to determine current and future water supply and demand and to use that information to make management decisions. Finally, this Division currently has control over the Great Salt Lake Integrated Model (GSLIM), which models how different conditions affect the lake<sup>lxv lxxvi lxxvii</sup>.

### 5.1.2.4 *Utah Division of Wildlife Resources* <sup>lxxviii</sup>

Through the DWR, the Great Salt Lake Ecosystem Program seeks to protect and conserve the resources necessary for avian and aquatic life. It manages the commercial harvesting of brine shrimp cysts, surveys waterfowl and shorebird populations, treats for invasive phragmites, and collects other environmental data from the lake and its surrounding areas as it pertains to wildlife.

### 5.1.2.5 *Utah Division of Water Rights* <sup>lxxix</sup>

The DWRI, also known as the Office of the State Engineer, manages all of Utah's water and how it is appropriated, measured, and distributed. As such, it is involved with the installation of measuring/telemetry devices, the development of regional water plans, and collaboration with the Utah legislature to update old and current water laws.

### 5.1.2.6 *Utah Division of Oil, Gas, and Mining* <sup>lxxx</sup>

This Division is responsible for overseeing mineral operations that work along GSL. It ensures that companies are following applicable permits and protecting the safety of the public and the environment.

## 5.1.3 *State Agencies under the Department of Environmental Quality*

### 5.1.3.1 *Utah Division of Water Quality* <sup>lxxxi</sup>

To protect GSL, the DWQ sets numeric and narrative standards that protect the lake from chemicals and activities that threaten its water quality. It enforces and monitors these standards by granting discharge permit limits, performing antidegradation reviews, and monitoring water quality, brine shrimp, and bird eggs. The DWQ has created a Strategy Plan on how it will specifically manage and maintain the water quality of the lake.

### 5.1.3.2 *Utah Division of Air Quality* <sup>lxxxii</sup>

The DAQ is responsible for managing and monitoring air quality among major cities in Utah<sup>lxxxiii</sup>. Specifically, DAQ gives permits to polluting entities, develops plans to reduce air pollution, and ensures that residents and industries are complying with federal and state regulations. Currently, DAQ is not doing anything specifically related to GSL. However, this may change if Utah faces severe air pollution as GSL dries and loses its surface area.

## 5.1.4 *State Agencies under the Department of Agriculture and Food*

### 5.1.4.1 *Conservation Division* <sup>lxxxiv</sup>

Various conservation projects exist within the Conservation Division to protect Utah's agricultural lands and preserve its natural resources. Such projects include management of salinity and groundwater and agricultural loans. The project with the biggest impact on GSL is the Agricultural

Water Optimization Program (see 7.2), which helps farmers maximize water use and improve irrigation efficiency<sup>lxxv</sup>.

### *5.1.5 Federal Agencies under the Department of the Interior*

#### *5.1.5.1 United States Geological Survey<sup>lxxvi</sup>*

The Utah Water Science Center of the USGS actively monitors and researches various water resources of GSL. Compiled together as the Great Salt Lake Hydro mapper, the USGS provides real-time data on salinity and surface water inflows and information on lakes, streams, and groundwater within the GSL Basin<sup>lxxvii</sup>.

#### *5.1.5.2 United States Fish and Wildlife Service<sup>lxxviii</sup>*

As manager of the Bear River Migratory Bird Refuge, the USFWS is responsible for the marshes that make up a large component of the freshwater in GSL's ecosystem and the wildlife it supports. It is currently developing a Comprehensive Conservation Plan to create long-term goals and guide management for the next 15 years<sup>lxxix</sup>. Within this plan, USFWS maps out the conditions that currently threaten the Refuge's resources and hopes to guide actions that will benefit wildlife, habitat, and public use of the land.

#### *5.1.5.3 Bureau of Reclamation<sup>lxxx</sup>*

The Bureau of Reclamation provides funds for studying current and future water supply and demand for US water basins. These funds, called WaterSMART grants, resulted in the DWRe receiving over \$3 million to initiate a GSL Basin study. This money has gone towards the creation of the Great Salt Lake Basin Integrated Plan.

### *5.1.6 Federal Agencies under the Department of Agriculture*

#### *5.1.6.1 Natural Resources Conservation Service<sup>lxxxi</sup>*

The NRCS is designed to aid in reducing soil erosion, enhancing water supplies, improving water quality, increasing wildlife habitat, and reducing flood damage. It additionally has various data on GSL, including precipitation levels, snow water equivalent (SWE) levels, temperature measurements, soil moisture content, and water inflows into the GSL Basin.

### *5.1.7 Federal Agencies under the Department of Defense*

#### *5.1.7.1 United States Army Corps of Engineers<sup>lxxxii</sup>*

Passed in 2022, the Great Salt Lake Recovery Act authorized and provided funds for the USACE to study drought conditions affecting GSL, including possible technological solutions (such as pipelines, canals, and desalination plants). The USACE was also authorized to monitor and assess the conditions of saline lakes across the Great Basin, including GSL.

## **5.2 Councils and Committees**

### *5.2.1 Great Salt Lake Advisory Council<sup>lxxxiii</sup>*

Created in 2010 by H.B. 343, the GSL Advisory Council advises the Governor, DNR, and DEQ on how to develop, protect, and sustainably use the resources of GSL. Members from different industries, counties, and backgrounds are appointed by the Governor. This council has created various reports related to GSL, addressing the consequences of declining lake levels, strategies for saving the lake, and the impact of those strategies<sup>lxxxiv</sup>.

### 5.2.2 *Great Salt Lake Salinity Advisory Committee* <sup>lxxxv</sup>

The Salinity Advisory Committee conducts frequent studies on GSL's salinity to provide management recommendations to the Division of Forestry, Fire, and State Lands and the Division of Water Quality, especially concerning the Union Pacific Causeway/Berm.

### 5.2.3 *Agricultural Water Optimization Committee* <sup>lxxxvi</sup>

Agricultural Water Optimization has been a critical issue for lawmakers since 2018, when H.B. 381 formed an initial task force to research how agricultural water could be quantified and saved. Later, in 2023, the Utah legislature passed SB 277, which appropriated \$200 million for agricultural optimization. It also created the Agricultural Water Optimization Committee within the Utah Department of Agriculture and Food. This Committee continues to help producers receive grants and report on their water usage so that they can optimize their water use and agricultural production.

## 5.3 Nonprofit Organizations

### 5.3.1 *The Nature Conservancy* <sup>lxxxvii</sup>

The Nature Conservancy (TNC) is an environmental nonprofit organization that promotes and initiates conservation projects across the globe. In Utah, TNC oversees the Great Salt Lake Shorelands Preserve – 4,400 acres of wetland and upland habitat along the Eastern shoreline of GSL, home to millions of migratory birds. To assist in the protection of GSL, TNC has established partnerships with numerous agencies, groups, and committees to acquire land, promote balanced growth, and create numeric water quality standards. It is also heavily involved with community outreach and education programs. Finally, in coordination with Audubon, TNC manages the Great Salt Lake Watershed Trust (see 5.6.3).

### 5.3.2 *National Audubon Society* <sup>lxxxviii</sup>

The National Audubon Society works to protect the decline of bird species across the Americas. Audubon has invested in efforts to support GSL as a notable bird habitat, such as enhancing water flows to the lake, protecting its wetland habitat, leveraging funding, improving water distribution, and improving management planning. Audubon is involved throughout the Western US, with teams dedicated to bridging the gaps between water use, bird habitat, and protecting saline lakes. Audubon also manages the Gillmore Sanctuary along the Southeastern shore of GSL and co-manages the GSL Watershed Trust with The Nature Conservancy (see 5.6.3).

### 5.3.3 *Friends of Great Salt Lake* <sup>lxxxix</sup>

Friends of Great Salt Lake is an organization founded in 1994 and currently led by Lynn de Freitas that uses education, research, advocacy, and art to protect GSL and increase public awareness of what is happening to the lake. It has multiple educational resources, such as field trips and summer camps. Friends of Great Salt Lake also gives scholarships to university students completing research on the lake and holds an annual arts competition related to GSL. It additionally holds a GSL forum every two years to encourage conversation and dialogue from various players, stakeholders, and the public.

### 5.3.4 *Great Salt Lake Collaborative* <sup>xc</sup>

The Great Salt Lake Collaborative is a group of over 19 different media, education, and civic organizations that want to keep the public better informed on the news surrounding GSL. Its website has compiled information and facts about the lake and consistently posts news articles

from its partnered media groups in a free-to-access space. Published stories cover a variety of topics, including challenges that face the lake, GSL's cultural significance, summaries of research being performed at the lake, and efforts that different state and nonprofit agencies are contributing towards GSL. Great Salt Lake Collaborative also uses solutions journalism to better understand possible solutions to utilize for the lake. This involves looking at similar issues and seeing what other organizations have done to curb these problems in other places. For example, Great Salt Lake Collaborative news covers solutions from Owens and Mono Lakes, Las Vegas, and Israel to provide readers with a well-rounded view of the problem. It also has an extension of its main website called Colorado River Collaborative to talk about the issues facing the Colorado River. Finally, GSL Collaborative also hosts creative works contests and sends a weekly newsletter to encourage people to get involved.

### *5.3.5 Grow the Flow<sup>xci</sup>*

Started by Executive Director Ben Abbott in conjunction with Conserve Utah Valley, Grow the Flow is focused on supporting initiatives that already exist and pushing for new efforts to save GSL. It has 4 different coordinating programs to achieve this: the Water Policy Accelerator to improve policy, the Public Action Network to empower the public, the Research Coordination Network to innovate solutions, and the Philanthropic Council to grow support. Grow the Flow has held and participated in many public events to promote awareness of GSL, such as a Town Hall in August 2024, inviting Utah Valley residents and representatives to learn and express concerns about Utah's water usage<sup>xcii</sup>.

### *5.3.6 Utah Farm Bureau Federation*

The Utah Farm Bureau is a nonprofit organization of thousands of voluntary Utah agricultural producers. Specifically, the Farm Bureau focuses on working with Utah's state legislature to promote public policy that benefits its members and Utah's farms and ranches<sup>xciiii</sup>. Regarding GSL, the Farm Bureau addresses related legislation they support and oppose in their annual Policy Book<sup>xciiv</sup>. Additionally, the Utah Farm Bureau holds an Annual Convention (UFBF), which has been going on for 108 years. This year, one of the discussion forums plans to cover agricultural water usage. The purpose of this meeting is to help farmers address water management challenges and find long-term solutions for managing their water rights and optimizing their water usage<sup>xciv</sup>.

### *5.3.7 Additional Nonprofits<sup>xcvi</sup>*

Various other nonprofit organizations, such as Earthjustice, Utah Rivers Council, American Bird Conservancy, Center for Biological Diversity, The Sierra Club, and Utah Physicians for a Healthy Environment, have expertise in areas such as environmental law, conservation, public health, and stewardship. In a combined effort, these groups are currently suing the state of Utah for their inaction and failure to protect GSL.

Additionally, many of these nonprofits, in addition to some previously mentioned, join together to hold the GSL People's Summit every year. This convention invites residents from around Utah and the GSL Basin to learn about the status of GSL, current solutions and efforts, and how they can get involved<sup>xcvii</sup>.

## 5.4 For-profit Organizations

### 5.4.1 *Great Salt Lake Artemia* <sup>xcviii</sup>

GSLA is a collection of member companies that harvest and distribute artemia (more commonly known as brine shrimp). It is focused on delivering quality products and preserving resources. It has been sustainably certified, implements a science-based management system, and works with other stakeholders to improve conservation efforts.

### 5.4.2 *Compass Minerals* <sup>xcix</sup>

Compass Minerals is a mineral extraction company with a location in Ogden, Utah. This location extracts sodium chloride, sulfate of potash (SOP), and magnesium chloride from GSL through evaporation ponds. This company has a goal of sustainable environmental development, and since 2021, it has reduced freshwater consumption by 33%. At the Ogden location specifically, Compass Minerals states that it works with community stakeholders to improve its current infrastructure to help GSL<sup>c</sup>. In 2023, Compass Minerals abandoned a lithium extraction project on the lake due to heightened regulatory risks posed by newly passed legislation<sup>ci</sup>.

### 5.4.3 *U.S. Magnesium* <sup>cii</sup>

U.S. Magnesium, located on the Southwest shore of GSL, is North America's largest producer of primary magnesium. It has donated land to a wildlife center and states that it works with other stakeholders (such as the Great Salt Lake Water Bird Survey) to be a better steward and improve conservation<sup>ciii</sup>.

### 5.4.4 *Clyde Snow Attorneys* <sup>civ</sup>

Clyde Snow is a law firm in the Western United States. It has a location in Salt Lake City and attorneys who focus on natural resources and water law. One of its attorneys hosts a podcast about water law, and it recently gave policy recommendations for GSL in the GSLBIP<sup>cv</sup> <sup>cvi</sup>.

## 5.5 Academic Institutions

### 5.5.1 *Utah State University* <sup>cvii</sup>

Utah State University's Institute for Land, Water, and Air is directly involved with Great Salt Lake and the many organizations working to save it. Partnered with the GSL Strike Team, USU has numerous researchers studying the lake and authoring scientific reports used to inform legislative and agency decisions.

### 5.5.2 *University of Utah* <sup>cviii</sup>

The University of Utah's Center for Climate Science and Policy is involved with GSL as researchers work on the GSL Strike Team along with USU. Its center is focused on studying climate change around the globe and locally in Utah to assist with the drying of GSL.

### 5.5.3 *Westminster College* <sup>cix</sup>

Established in 2008, Westminster College's Great Salt Lake Institute holds community field trips, develops high school and college curricula about GSL, and hosts a summer undergraduate research program. Faculty and students from Westminster have also authored a children's book about GSL and a book about the lake's biology.

## 5.6 Other Groups

### 5.6.1 Great Salt Lake Technical Team <sup>cx</sup>

The GSL Technical Team is comprised of representatives from academic, federal, state, political, and special interest groups. It assists the Advisory Council (see 2.1) with its efforts in monitoring, managing, and researching GSL. It meets multiple times a year, makes all its data public, and provides guidance and recommendations. Additionally, the Technical Team awards yearly grants to those researching the lake. These grants are financed by the DNR through legislative funds.

### 5.6.2 Great Salt Lake Strike Team <sup>cx</sup>

The GSL Strike Team is comprised of researchers from the University of Utah, Utah State University, the DNR, and UDAF. It provides data and research to help decision-makers manage the lake, specifically reporting to the GSL Commissioner. It has created a yearly report since 2023 that summarizes key data and findings and provides recommendations.

### 5.6.3 Great Salt Lake Watershed Enhancement Trust <sup>cxii</sup>

In 2022, the Utah Legislature created the Great Salt Lake Watershed Enhancement Program, establishing a water trust for GSL. Water trusts are private, nonprofit organizations that acquire water rights to enhance instream flow for conservation purposes<sup>cxiii</sup>. The GSLWET's primary goals include retaining and enhancing water flows, conserving and restoring habitat, engaging stakeholders and leveraging funding, and improving the distribution and management of water. It recently formed an advisory council representing various interests to help guide the Trust's strategic direction and provide input for major projects. This trust reports to FFSL, DWQ, the GSLAC, and the legislature's Natural Resources, Agriculture, and Environmental Quality Appropriations Subcommittee<sup>cxiv</sup>.

### 5.6.4 Utah Native Tribes <sup>cxv</sup>

The Northwestern Band of Shoshone and the Goshute Tribes populated the Great Salt Lake Area and used its plentiful resources for hundreds of years. As the first people to make GSL their home, these indigenous peoples affirm a spiritual connection to the land surrounding it<sup>cxvi</sup>. Today, members of these tribes still call it their home and have been involved in preserving and conserving water in Utah<sup>cxvii</sup>. For example, in 2022, the U.S. Bureau of Reclamation rewarded the Shoshone with a \$2 million grant to restore Battle Creek, a section of the Bear River that feeds into GSL<sup>cxviii</sup>. While some nonprofits have made an effort to include Native voices, the committees and councils created by the government to represent all interests do not have any Indigenous people on them<sup>cxix</sup>.

## 6. Current Efforts to Save Great Salt Lake

### 6.1 Cloud Seeding

Cloud seeding is a weather modification technique that aims to enhance existing precipitation events in the form of rain, snow, or hail<sup>cx</sup>. Clouds are made of water molecules and other particles like dust. Some of these dust particles are hygroscopic, meaning that they attract and easily bond with water molecules. Other particles are hydrophobic, meaning that they do not naturally bond with water. In a perfect world, a cloud's water molecules collect around each particle of dust in enough quantity to form water drops that precipitate rain or snow. However, if the dust particles are made up of hydrophobic materials, those water drops cannot form. These clouds are referred to by the Utah Division of Water Resources as "sick" clouds because they either do not contain the

chemical properties necessary to facilitate precipitation events or the amount of water that does precipitate from them is small relative to what it could be if the cloud were full of hygroscopic materials<sup>cxxi</sup>.

Utah's cloud seeding efforts began in 1974 and have consistently evolved over the past 50 years<sup>cxxii</sup>. In Utah, the Division of Water Resources primarily seeds clouds with silver iodide to help facilitate water droplet formation in clouds. The chemical structure of silver iodide closely resembles that of hygroscopic natural ice crystals, making it possible for the small, supercooled liquid particles in clouds to bond with the silver iodide and artificially create water droplets. However, this bonding process can only occur under certain conditions. First, the ice nucleation process required to form water droplets through silver iodide seeding only occurs when a cloud's temperature is between -5°C and -20°C<sup>cxxiii</sup>. Additionally, the seeded clouds must naturally contain favorable liquid water content and surface wind conditions. Thus far, the DWRe has not observed any negative environmental effects as a result of cloud seeding with silver iodide, but it will continue to monitor the health of soils and water systems to ensure that no harmful effects occur or persist<sup>cxxiv</sup>.

Utah is also working with Idaho to explore the feasibility of using liquid propane as a cloud seeding substance. Liquid propane creates a "burst of evaporative cooling," which instantly freezes supercooled liquid particles in clouds from -40°C to 0°C, thereby effectively removing the cloud temperature limitations seen in silver iodide seeding. However, liquid propane seeding has its disadvantages. The seeding must be directly applied to clouds by aerial means, which increases human safety risks for pilots flying into the storm clouds. The Idaho Division of Water Resources will conduct a study during the winter of 2025 to determine the effectiveness of cloud seeding using liquid propane<sup>cxxv</sup>.

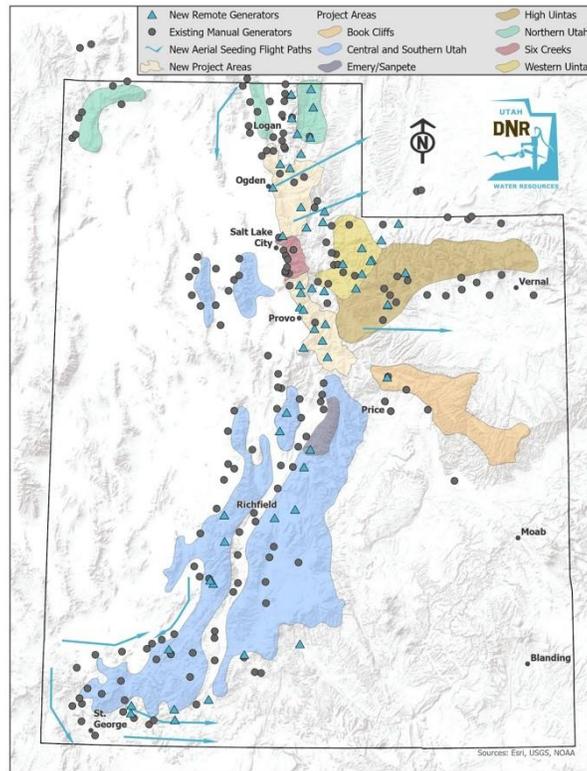
Currently, the Division of Water Resources employs two methods – ground generators and aerial programs – to seed clouds. Ground generators are placed in favorable locations where the clouds passing over them naturally experience some kind of instability, such as the organic airlift that occurs as clouds move up along a mountain face. This instability helps facilitate the ice nucleation process to produce water droplets in the clouds. The generators release silver iodide particles into the air to rise with the passing air and bond with water molecules in clouds overhead<sup>cxxvi</sup>.

Aerial cloud seeding involves attaching silver iodide or liquid propane applicators to the wings of planes and then flying those planes directly into storms experiencing precipitation events<sup>cxxvii</sup>. For aerial seeding to be effective, pilots can only apply the materials to clouds with an appropriate level of liquid water content. For safety reasons, pilots also cannot fly into clouds where icing conditions threaten the plane's functionality.

Finally, it is important to note that cloud seeding is an artificial water *augmentation* process, not an artificial water *creation* process. It can only be applied to existing clouds to help them release more water through precipitation than they otherwise would. Thus, cloud seeding is most effective during wet years when clouds naturally form more frequently<sup>cxxviii</sup>.

Presently, Utah's cloud seeding efforts contribute to an additional 200,000 AF of streamflow across the state per year at \$2-5 per acre-foot. This cost includes capital, operating, and maintenance costs but does not include the cost of any planes. Jonathan Jennings, the Utah DWRe's Cloud Seeding Coordinator, estimates that the state's efforts create a 6-11% increase in precipitation per seeded cloud event. Figure 15 maps where Utah's current cloud seeding projects are happening<sup>cxxix</sup>.

Figure 15: Cloud Seeding Projects in Utah



Source: Utah Division of Water Resources Cloud Seeding FAQ, 2024

Despite the success that the DWRe has seen so far, its expansion opportunities are limited because of the set number of locations that house favorable seeding conditions. However, the DWRe has begun work with Idaho to place generators along the Bear River in southern Idaho to help increase the river basin’s water supply in both Idaho and Utah. This collaboration exemplifies how there may be more options for water augmentation moving forward as states work together to bring more water to the western United States<sup>cxxx cxxxi</sup>.

## 6.2 Agricultural Optimization

### 6.2.1 Program Overview

The Agricultural Optimization program incentivizes farmers and canal managers to upgrade their irrigation and water delivery systems to be more water efficient. Efficient irrigation and canal systems use less water overall and lose less water to evaporation, leakage, and runoff compared to other traditional systems. The Agricultural Optimization Program provides these water users with partial reimbursements for the cost of upgrading these systems. Consequently, the Agricultural Optimization Program creates a symbiotic relationship between producers and the state that ultimately results in more favorable outcomes for all involved<sup>cxxxii cxxxiii</sup>.

Program participants can apply to receive funding from the state for projects to upgrade their farms’ irrigation systems or their canals’ infrastructural designs. An applicant whose project is approved shares the costs of that project 50/50 with the Program<sup>cxxxiv</sup>. 20% of the state’s funding for each project is withheld until the project has been completed, inspected, and approved, with a

final report issued<sup>cxxxv</sup>. Upon completion, the water use resulting from the project must be metered at all times, and farmers must provide an annual water usage and crop production report to the Program for 3 years<sup>cxxxvi</sup>. The maximum amount that can be granted to irrigation and canal companies is \$1 million, and the Program hosts a 10% minimum in-kind match for implementation costs<sup>cxxxvii</sup>.

Producers cannot apply to participate in the Program unless they can prove that their optimization projects will reduce their water usage. Thus, the application process for the Program begins with a pre-consultation meeting with a member of the State Water Engineer's team. If the producer can effectively reduce water depletion levels, they are approved to file for a change application to their water rights based on the engineer's recommendation<sup>cxxxviii</sup>. Changing the point of diversion, place of use, type of use, or period of use for a water right allows farmers to adapt their water rights to meet their specific needs. This personalized process allows for a reduction in rates of unnecessarily used water.

Applications for optimization projects beyond a change in water rights are evaluated and approved based on a list of criteria. Factors such as the project type, whether a water change application has already been filed, what kind of water will be saved, the location of the project, whether the project has already been designed, etc., are considered and weighted to determine to which projects the Program's funding should be allocated<sup>cxxxix</sup>. According to Hannah Freeze, the Agricultural Water Optimization Program Director, projects located within the Great Salt Lake watershed are weighted more heavily in the selection process, but that is not a requirement for a project to be approved<sup>cxl</sup>.

During the December 2023 to February 2024 project application season, 389 applications were received, totaling a request for funding of \$65 million. 209 of these projects were selected for funding and \$48 million in funding was granted for them. As of October 10, 2024, many projects have been started and \$6.1 million had already been paid out for these selected projects<sup>cxli</sup>. Most projects approved involved the installation of pivot sprinklers, wheel lines, sub-surface drip irrigation, pipe and riser, telemetry, micro-irrigation systems, and canal improvements<sup>cxlii</sup>.

### *6.2.2 Irrigation Infrastructure Projects*

Clay Carter, a farmer and engineer from Logan, Utah, received a grant from the Program in 2021 to fund the implementation of a surge irrigation system in place of a historical flood irrigation system on his farm<sup>cxliii</sup>. Carter used surge valves, telemetry, and software that he had designed to automate a system that incrementally pushed water down his fields with "rest periods" in between surges. This method of incremental watering prevented the water from leaching into deep percolation zones while also reducing the amount of water needed for his fields<sup>cxliv</sup>. In total, Carter reduced his annual diverted water usage by 37.5% from 4 acre-feet per year under his previous flood irrigation system to only 2.5 acre-feet per year under the surge irrigation system<sup>cxlv</sup>. The new system also led to a 20% increase in his alfalfa yield from 2020 to 2021<sup>cxlvi</sup>. Currently, Clay Carter's surge irrigation system is one example of the many projects contracted through the Agricultural Water Optimization Program. His project represents the potential that this Program has to create lasting change in the world of Utah irrigation. In an interview with Hannah Freeze, the Program Director, Freeze described the relationship between farmers and the state Legislature as "cautiously optimistic." Freeze stated that farmers have previously been very protective of their water rights out of fear that their most "precious resource" will be lost to uses other than agriculture. She described the Program as a way to help farmers tailor their projects to help them meet both their own goals

(infrastructure improvement and cost reduction) and the goals of the state (water conservation) simultaneously<sup>cxlvii</sup>.

### 6.2.3 Canal Optimization Projects

In addition to farming infrastructure improvements, the Program also funds canal and irrigation company optimization projects such as funneling canal water through pipes or covering canals<sup>cxlviii</sup>. These projects enable canal companies to move water quicker and reduce water losses from evaporation and seepage.

A study performed by Utah State University created a simulation of water loss levels for uncovered, lined, and piped irrigation canals<sup>cxlix</sup>. Each simulation estimated water loss along a 1-mile and 6-foot-wide canal sourced from a reservoir in central Utah. “Conveyance losses” in the study refers to water loss due to seepage, absorption by canal bank vegetation, operational spill, and evaporation. The simulation of the unlined canal resulted in a 40% conveyance loss, the simulation of the lined earthen canal yielded a 15% conveyance loss, and the simulation of the piped canal resulted in no conveyance loss. While this simulation is not a representation of all real-world factors that potentially affect conveyance losses in canals (outside temperature, time of day of diversion, etc.), it does represent how piped canals lead to reduced water loss compared to uncovered or unlined canals<sup>cl</sup>.

The Uintah Water Conservancy District owns and operates the Steinaker Service Canal, located in Utah’s Ashley Valley. In 2022, the district received funding from the Program, alongside other grants, to fully enclose 2.82 miles of its 12-mile canal system at an estimated total cost of \$27 million and total water savings of around 1,000 acre-feet per year<sup>cli</sup>. The company also received a grant from the Program to aid its automation of two of its turnouts in 2023<sup>clii</sup>. These projects are steps forward in the Steinaker Canal Service’s overarching project to enclose all 12 miles of its canals leading up to Steinaker Reservoir and to then convert its water outlet system from a gravity flow system to a pressurized one that will move water to its intended destinations more reliably<sup>cliii</sup>.

### 6.2.4 Land Fallowing

The final facet of the Agricultural Water Optimization Program involves compensating farmers for fallowing their land altogether. The Fallow Land Amendments (H.B. 520) were signed by Governor Cox on March 12, 2024, and took effect May 1, 2024<sup>cliv</sup>. These amendments state that fallowed agricultural land may qualify for the agricultural and urban farming assessment (the greenbelt assessment) which assesses farms’ tax liabilities based on the land’s productive capacity instead of its market value<sup>clv</sup>. Because fallowed land is essentially unproductive, this bill provides a tax incentive for farmers to fallow their land either temporarily or permanently.

Farmers must also provide assurance that the fallowed land will be returned to strictly agricultural use following the fallowing period. Once a county assessor approves the project, that assessor then enforces the farmers’ management plans to ensure that the producer remains eligible for the tax break over the fallowing period<sup>clvi</sup>.

The goal of this bill is to incentivize farmers to conserve water that can then be channeled to Great Salt Lake. Because the bill was just recently enacted, little data exists to ascertain its immediate effect.

### 6.2.5 Program Effects Summary

The Agricultural Optimization Program has some limitations that prevent it from growing as a major force toward water conservation. Some farmers who are skeptical of the Program still worry that using less water through optimized systems will result in their losing those rights. Other farmers who are enthusiastic about the Program lack the wealth needed to provide 50% of the funding needed for their optimization projects<sup>clvii</sup>. Finally, uncertainty remains regarding whether any water conserved through the Program is being properly shepherded to Great Salt Lake<sup>clviii</sup>.

As of January 15, 2024, the Office of the Great Salt Lake Commissioner estimates that projects funded by the Program through the 2024 irrigation season will result in annual water savings of about 234,000 acre-feet of diverted water<sup>clix</sup>. However, in interviews with both the Program Director, Hannah Freeze, and Rep. Casey Snider, who helped pass the legislation to create the program, it was admitted that they don't know how much water saved through the Program is reaching Great Salt Lake. Freeze stated, "Our program is very young in terms of the data we have of how much water we've saved.... We're just barely having projects that are finished. So, we don't have solid numbers"<sup>clx</sup>. This lack of data does not mean that no water is making it to the Great Salt Lake due to the Program, but that amount of water has not yet been quantified or tracked.

However, SB 277 (2023) represents a step toward amending that data gap. SB 277 allocated \$200 million to the Program and established new rules and oversights regarding reports of the amount of water saved through the Program and its allocation. The bill also established the Agricultural Water Optimization Committee, a blend of directors and contributors from the Agricultural Optimization Program, the Division of Water Rights, and the Division of Natural Resources<sup>clxi</sup>. This committee will meet monthly to oversee the funding of current projects, prioritize new water-saving projects, and review instream flow applications<sup>clxii</sup>. Additionally, the committee is responsible for publishing annual reports on completed optimization projects, the amount of water saved from those projects, and the effectiveness of the optimization program overall<sup>clxiii</sup>. Hannah Freeze expressed her excitement for the new committee, stating, "We have the great opportunity to work now with the Division of Water Rights. Every project that we install has to have a meter on it so we can work with the Division of Water Rights to read those meters and get real accurate numbers of what ag[riculture] is using, which has kind of been a data gap that we've had"<sup>clxiv</sup>.

## 6.3 Municipal Conservation

Municipal and industrial water includes residential, commercial, and institutional uses. It excludes water used for agriculture, mining, and power generation<sup>clxv</sup>. 80% of Utah's citizens live in and around the Salt Lake Valley, where most of the state's municipal water is used<sup>clxvi</sup>. This section will review the current solution space for municipal and industrial (M&I) conservation to establish a framework for how water can be saved effectively.

### 6.3.1 Smart Technology

Smart controllers are adaptive sprinkler systems that are more efficient than standard outdoor watering equipment. Instead of a sprinkler's watering schedule being set to a timer, smart controllers take local weather data and evapotranspiration rates to adjust how much water is needed automatically<sup>clxvii</sup>. Other smart technology used in Utah includes smart toilets. These toilets detect water levels to determine the appropriate amount of water needed to flush. These toilets can adjust to use as little as 1/3 the amount of water that a standard model would<sup>clxviii</sup>.

From 2018-2023, the EPA estimates that the Utah DWRe helped consumers save a total of 1,050 acre-feet using smart controllers and smart toilets<sup>clxxix</sup>. Beyond this statistic, it is difficult to determine how much water Utah is and could be saving due to a lack of information on how many residents are implementing these technologies. WaterSense, an EPA partnership program, estimates potential home savings of up to 0.05 acre-feet annually for smart controllers and 0.04 acre-feet annually for smart toilets<sup>clxx clxxi</sup>. A separate BYU study of 2,000 homes in Spanish Fork found a 17% reduction in water use for homes with smart controllers<sup>clxxii</sup>. Regarding smart technology on larger properties, Davis County, the second largest school district in Utah, switched to smart controllers for all its irrigation needs in 2022. It saw a 35% reduction in water use in the first 90 days and has experienced annual savings of nearly five acre-feet<sup>clxxiii</sup>.

In Utah, citizens can receive rebates if they choose to replace their sprinklers with smart controllers or their toilets with smart toilets. This rebate is currently \$100 for any smart controller sprinkler installed and \$150 for any toilet<sup>clxxiv clxxv</sup>. Today, smart controllers especially are becoming very affordable, with costs as low as \$59<sup>clxxvi</sup>. With a \$100 rebate program, this allows Utahns to purchase and switch to a smart controller at no personal cost. Smart controllers can also cut water bills by up to one-half, allowing homeowners to receive additional money savings through lowered utility costs<sup>clxxvii</sup>.

In 2017, the Utah legislature established \$750,000 in ongoing funding for water efficiency rebates. That funding was later reduced to \$700,000 in 2020<sup>clxxviii</sup>. In 2022, the DWRe helped customers receive rebates on 900 toilets and 3500 sprinklers<sup>clxxix</sup>. Under the current rates, this comes out to a max of \$352,500 in rebates. With an annual budget of \$700,000, this leaves more room for additional smart technology installations. However, the state does not currently enforce the use of these smart technologies. Switching to these systems and applying for a rebate is a voluntary process that homeowners must be personally motivated to do.

### *6.3.2 Waterwise Landscaping*

Another technique suggested by the state for residential and commercial areas is waterwise landscaping. Instead of simply reducing the amount of water used to save secondary water, waterwise landscaping looks to change an outdoor environment to not require as much water in the first place. Often referred to as xeriscaping or localscaping, this method of groundskeeping incorporates native, drought-resistant plants and organizes them in a way that promotes greater water efficiency<sup>clxxx</sup>. In May 2023, Utah launched a new rebate program to encourage homeowners to use waterwise landscaping. This program pays residents \$3 per square foot of turf grass that is replaced with water-efficient landscaping<sup>clxxxi</sup>.

As of 2024, 5,447 applications for waterwise landscaping rebates have been filed. This has resulted in over 3.5 million square feet of grass being replaced at a cost of over \$5 million. It is estimated that 320 additional acre-feet of water are being saved annually<sup>clxxxii</sup>.

Nonetheless, waterwise landscaping requires a great upfront cost for homeowners. Installation prices can vary greatly, depending on the desired style, the location and climate, the selection of rocks and plants, and the quality of the soil. With nationwide xeriscaping specifically, installation costs range from as low as \$5 to as high as \$20 per square foot<sup>clxxxiii</sup>. As such, even at the lower end of the price range, with only a \$3 rebate, Utah residents are going to be expected to pay for a lot of their changed yard out of pocket. With the nationwide average at a total of \$17,000, this is no cheap project<sup>clxxxiv</sup>.

In addition to individuals who want to utilize waterwise landscaping, there is a great cost from the state level. \$5 million state dollars for 320 acre-feet of water savings breaks out to a cost of \$15,625 per acre-foot<sup>clxxxv</sup>. However, assuming the \$5 million is a one-time, upfront cost, continued yearly water savings could bring down the cost per acre-foot.

Like Smart Technology, the factor that limits the full-scale implementation of waterwise landscaping is that homeowners must voluntarily participate in this program. And despite the benefits of landscaping in this way, many are drawn away because of perceived negative consequences. Waterwise landscaping is a large project to undertake, and there is a common belief and misconception among residents that waterwise landscaping looks “ugly” and barren, which further diminishes the appeal of this program<sup>clxxxvi</sup>.

### *6.3.3 Secondary metering*

Another method seeking to reduce secondary water use is secondary metering. Although it doesn't directly save water, secondary metering helps citizens track their water usage and reduce it without the implementation of restrictions. In 2022, H.B. 242 established a state requirement to have all secondary connections metered by 2030<sup>clxxxvii</sup>. At the time, the state only had 15% of 260,000 secondary connections metered<sup>clxxxviii</sup>. To aid implementation of these meters, the state used \$250 million in American Rescue Plan Act grant funds but estimates that complete installation will cost between \$450 and \$670 million<sup>clxxxix</sup>. One contractor, Utah Water Metering, is currently installing meters in Davis and Weber counties and plans to install 200,000 more connections by January 2030<sup>cxc</sup>.

Secondary metering is an accountability-based solution that holds all citizens of Utah to a higher standard, making them aware of their water use and their potential to save. Districts with secondary meters installed have seen a 20-30% reduction in water use by residents<sup>cxcii</sup>.

### *6.3.4 Mineral Extraction Standards*

To reduce industrial water use, the state is making efforts to implement mineral extraction standards. Mineral extraction companies that work on the lake have over 600,000 acre-feet of water rights in GSL. In 2020, these companies depleted 182,000 acre-feet, making up 8% of human-driven lake depletion<sup>cxcii</sup>. To lower these depletions, and under H.B. 513 (2023), the Commissioner's Office and the Division of Forestry, Fire, and State Land work with mineral extraction companies to increase optimization and conservation<sup>cxciii</sup>. According to H.B. 453 (2024), a severance tax is implemented on mineral extraction operators unless they use non-evaporative technology or are part of a water mitigation agreement. It also gives the state engineer further authority and responsibility to necessitate prior appropriation of the water and provides a tax incentive for extraction companies that do not deplete water or try to reduce their water use<sup>cxciv</sup>.

## **7. Gap Analysis**

To adequately represent the current crisis facing GSL and what work involved stakeholders are already performing, it is crucial to look at what amount of water is being saved and then recognize gaps that need to be addressed. As previously stated, the GSL Strike Team modeled that in 45% of scenarios, an additional 770,000 AF of water annually will bring GSL to a healthy elevation by 2054<sup>cxcv</sup>. Unfortunately, there are no clear figures on how much water the state's current programs and initiatives are saving. Based on 2023 program reporting, it is estimated that a combined total of 292,167 AF of water is being saved every year, coming from cloud seeding (50,000 AF), Agricultural

Optimization (172,847 AF), waterwise landscaping initiatives (320 AF), and the Watershed Enhancement Trust (69,000 AF)<sup>cxvii</sup>. However, as previously mentioned, these numbers are just estimates, and even then, it is not certain whether this saved water is traveling and making it to the Great Salt Lake. Additionally, regardless of the validity of this amount, it is still around 477,833 AF under the minimum input need of the lake. This analysis reveals that gaps remain in acquiring water for GSL<sup>cxviii</sup>.

This section will explore the gaps we have identified that create barriers against the implementation and expansion of solution efforts. The largest gap spanning all areas of water use and conservation in Utah is water shepherding, or tracking the movement of water throughout Utah's river systems and reservoirs. The second and third gaps – coordination of efforts and widespread cultural change – represent gaps in the logistical application and social adoption of existing solutions. The technology to provide a massive amount of water to the Great Salt Lake exists. However, until the right organizations and people start working together to scale those efforts effectively, they will remain only as “drops” in a crowded ocean of uncoordinated projects. And, until the general population of the Great Salt Lake basin fully understands the urgency and consequences of the lake's shrinkage, those projects and efforts will be hemmed at every corner by a culture that does not appreciate the importance of continuous and intentional water management and conservation practices.

## 7.1 Water Shepherding

Water shepherding involves placing monitoring systems along streams and rivers as well as at diversion points where streams diverge to track and account for the movement of water throughout the river system. These monitoring systems consist of either stream gages that measure the total inflow of water from tributary streams in mainstem rivers or diversion measurement stations that monitor how much water is diverted away from the tributary streams or mainstem rivers<sup>cx</sup>.

The importance of measuring water as it moves throughout the Great Salt Lake Basin is critical when considered from the perspective of water conservation. As agricultural producers, municipalities, and businesses work to conserve water and as researchers and companies work to augment Utah's water supply, the water saved or created through those efforts must be accurately accounted for to quantify and measure their efficacy. As our team has interviewed stakeholders in agricultural, municipal, and legislative capacities, the issue of water shepherding and skepticism about whether conserved water is making it to Great Salt Lake has been brought up often. This skepticism arises mainly from the general belief that there is not enough water measurement infrastructure in place to accurately track water movement at the level required to measure the impact of these stakeholders' efforts in Utah.

### *7.1.1 Measurement Infrastructure Gap Analysis in Utah's Great Salt Lake Basin*

To better understand the existing gaps in the Great Salt Lake Basin's water measurement system, the Utah Division of Water Rights (DWRi) and Utah State University partnered together to conduct a comprehensive inventory and analysis of the current state of water measurement systems in the basin. The study identified and evaluated 586 stream and diversion measurement devices within 19 primary river and stream systems within the GSL basin<sup>cci</sup>.

The results of the study indicated that “approximately 33% of existing diversion measurement devices were flagged as having an insufficient device type gap.” This means that either the measurement device itself or the metadata to describe the device was insufficient for a high-quality

understanding of diversion quantities. Additionally, approximately 33% of diversion and 10% of stream measurement devices are not telemetered at all<sup>ccii</sup>. The absence of automated or remotely monitored systems constitutes a gap because it hampers the ability to efficiently monitor water use and stream flow in remote areas. Additionally, when a device is not telemetered, it must be read and monitored manually, thereby increasing the risk of human error as well as delays in manual reporting.

Public data records from approximately 45% of existing diversion and 12% of existing stream measurement infrastructure have a timestep at a daily or greater interval, impacting real-time water management capabilities<sup>cciii</sup>. Large time-step intervals inhibit water managers' ability to capture short-term variability in water movement due to sudden hydrological events (rainfall, snowmelt, etc.) or fluctuations in water use by consumers due to temperature or weather changes that occur throughout the day. This real-time measurement ensures that water rights are respected, water quality conditions are met, and that water is used as efficiently as possible<sup>cciv</sup>.

These results indicate that there is a considerable amount of work yet to be done to ensure that the water measurement infrastructure surrounding Great Salt Lake is as robust and effective as it can be.

## 7.2 Coordination of Efforts

Organizing coordination efforts for the Great Salt Lake is no small feat. The variety of interests and voices involved has created a complicated space filled with a mix of perspectives. The state has taken steps to foster collaboration and open communication among the various sectors involved with the Great Salt Lake. However, it remains unclear how much of this dialogue is translating into meaningful action.

We see encouraging trends in relations, especially between the different state government agencies. These agencies meet together often in councils, committees, teams, and commissions. At the helm of these coordination efforts is the Office of the Great Salt Lake Commissioner, tasked with gathering progress reports and plans from the different entities to ensure little overlap in efforts or funds<sup>ccv</sup>. Different councils, committees, and commissions work to establish well-rounded boards of experts. For example, the Legislative Water Development Committee includes not only state legislators but also land developers, environmental lawyers, and conservancy district managers, creating diverse seats at the table of discussion<sup>ccvi</sup>. More specialized groups like the Agricultural Optimization Committee consist of carefully selected members who focus on specific sector-related concerns<sup>ccvii</sup>.

Other key players include nonprofits organizations, irrigation and canal companies, Utah residents, industries, researchers, municipalities, and water conservancy districts. The main operations of these interest groups generally don't overlap, other than through the fact that they are all water users or advocates in Utah. As the issue of water conservation is a statewide issue, all interest groups need to be on the same page about each other's efforts. This way, the different groups can provide support but also know where they best fit in with the solution.

Our team conducted 40 separate interviews with stakeholders from a wide range of interests—legislators, state agency members, water conservancy district leaders, agricultural producers, real estate developers, nonprofit organization leaders, and university professors—to learn more about their efforts regarding this issue. We asked these experts if they collaborated with other stakeholders, and what those efforts looked like. Overall, we found that many of these parties

coordinate with certain legislators to advocate for the passage of various water-related bills and funding. There is also a fair amount of communication between universities and state agencies relating to studies of Great Salt Lake. Finally, we found that there appears to be regular communication between parties that exist within the same sector, such as among different nonprofit organizations or state agencies.

However, we also found areas where collaboration or coordination between interest groups has proven to be less successful. A major point of contention in the water conservation dialogue has existed between farmers and nonprofits. Farmers and nonprofit advocacy groups seem to have mutual disapproval of each other, causing tension and gridlock that the instilled coordination efforts have not been able to solve. Many nonprofits have expressed concern over agricultural practices, particularly the excessive use of water, claiming that farmers use a surplus of water and do little to instill conservation efforts for the state. Farmers, on the other hand, have expressed that they feel misunderstood, viewing themselves as the original conservationists, strategically managing their water allocation each year to sustain their operations. Hesitant relations are seen from farmers to members of industries and municipalities as well. Farmers feel that they often get the short end of the stick and are expected to go above and beyond when other areas might “slide under the radar.” This point-the-finger model Utah has developed has created a divide between farmers and others in the water industry. These perceptions have poisoned the relationship between the two groups, creating a space of distrust.

A similar relationship can also be seen between the state government and nonprofits. The state government and nonprofits tend to have more interaction than nonprofits and farmers, yet even within this relationship, there’s often a disconnect in the understanding of each sector’s efforts. Even though collaboration exists between nonprofits and certain legislators, many nonprofits openly express general, overarching dissatisfaction with the legislature's efforts for not meeting their expectations. While state agencies have a more positive view of nonprofits, actionable collaboration with those nonprofits, such as with the Great Salt Lake Watershed Enhancement Trust, is limited to only several organizations, creating a weak connection between the two parties overall.

Other areas of high disagreement are found between water districts, Utah residents, and the applicable industries. Tension exists between some water districts and Utah residents as those water districts work hard to implement procedures that encourage water conservation on a smaller scale. Utah residents who do not see water conservation as a priority often push back against these water districts’ campaigns. Industries with an interest in the state of water usage in Utah appear to disagree with the water districts on what steps should be taken. A trend of the two interest groups moving in different directions can often be observed, especially with the land development industry in Utah. When the two groups have different ideas on programs and operations, there can be tension between the two, leading to a lack of comradery that hinders coordination efforts.

### 7.3 Widespread Cultural Change

Cultural change regarding water conservation in the state of Utah is crucial to support lake growth efforts. Water scarcity is not only a problem for Great Salt Lake but all industries and households that utilize water in the state. In the 2020 U.S. Census Report, Utah was labeled as the fastest-growing state and with more industries and individuals moving to Utah, water resources are being spread thinner<sup>ccviii</sup>. Additionally, as the climate of Utah continues to get hotter, the rate of

evaporation from above-ground water sources is going to increase<sup>ccix</sup>. While water use among sectors is not equivalent, all water users in Utah must be accountable for their water usage and find ways to conserve. The lake belongs to all Utahns; it is everyone's responsibility to find solutions for this environmental crisis and to change Utah's water culture. Current efforts include educating the public about different conservation methods and why these are important to implement as Utah grows.

Endeavors to increase the education of various stakeholders surrounding the Great Salt Lake have proven to be both successful and limited. Public surveys have shown that Utah residents are aware of and care about the lake, and record funding in the state government since 2022 signals the same conclusion of lawmakers and state agencies. However, these surveys tend to have low response percentages, causing one to question whether these results are representative of the feelings of all Utahns. Additionally, after interviewing over 40 experts and stakeholders heavily involved in the decision-making around Great Salt Lake, half mentioned the need for a cultural change in Utah through more public education. Naturally, public education is a very broad need, and these stakeholders often refer to different types of education based on their insight. For example, some stakeholders mentioned the importance of educating government entities, while others emphasized the education of citizens. There are multiple ways to go about educating the public, including media awareness and events. However, it is once again hard to gauge whether these events are making a significant impact on the public because most who engage with these sources are already invested in the lake.

## 8. Conclusion

Though the Great Salt Lake has experienced periods of high and low elevation in the past, recent trends indicate that the Lake is drying due to climate change and the overconsumption of water by users in the Great Salt Lake Basin. Losing the lake would bring devastating consequences to Utah in the form of ecological collapse, economic damage, and a public health crisis. It would also signal a loss of part of Utah's identity and history.

Saving the Great Salt Lake will require extensive collaborative efforts from willing stakeholders who deeply understand the problem. This paper hopes to have addressed this step, helping future decision-makers protect the lake and all the life it supports.

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<sup>i</sup> n.d. Utah Division of Water Resources: Great Salt Lake. Accessed May 21, 2024. <https://water.utah.gov/great-salt-lake/#:~:text=Record%20Low%20Lake%20Levels,South%20Arm%20Causeway%20gauge%20location>.

<sup>ii</sup> 2022. GSLEP. January 3. <https://wildlife.utah.gov/gslep/about/history.html>

<sup>iii</sup> n.d. Great Salt Lake and Lake Bonneville. <https://geology.utah.gov/popular/great-salt-lake/>.

<sup>iv</sup> O'Connor, J. 2016. *The Bonneville Flood - A Veritable Debacle*. Vol. 20. Portland, Oregon: Elsevier. [https://www.sciencedirect.com/science/article/pii/B9780444635907000068?casa\\_token=qT6EKyOM-ToAAAAA:UZi4S3eutiOHb-EKk5qXxyU0QvkKbkS\\_f0EqsNVQqXI2jeQD24NwcDITlBayP9aY3ylTvmuDeOM](https://www.sciencedirect.com/science/article/pii/B9780444635907000068?casa_token=qT6EKyOM-ToAAAAA:UZi4S3eutiOHb-EKk5qXxyU0QvkKbkS_f0EqsNVQqXI2jeQD24NwcDITlBayP9aY3ylTvmuDeOM).

<sup>v</sup> Bjornstad, Bruce. 2021. "Lake Bonneville Flood." Springer Link 159-165. [https://link.springer.com/chapter/10.1007/978-3-030-53043-3\\_5](https://link.springer.com/chapter/10.1007/978-3-030-53043-3_5).

<sup>vi</sup> Wallace, Gwynn J., Jim Davis, and Andrew Rupke. 2022. Commonly Asked Questions about Utah's Great Salt Lake and Lake Bonneville. <https://geology.utah.gov/popular/great-salt-lake/commonly-asked-questions/#toggle-id-11>.

<sup>vii</sup> Wallace, Gwynn J., Jim Davis, and Andrew Rupke. 2022. Commonly Asked Questions about Utah's Great Salt Lake and Lake Bonneville. <https://geology.utah.gov/popular/great-salt-lake/commonly-asked-questions/#toggle-id-11>.

<sup>viii</sup> n.d. Great Salt Lake and Lake Bonneville. <https://geology.utah.gov/popular/great-salt-lake/>.

- 
- ix Null, Sarah, and Bethany Neilson. 2023. Water Shepherding: USU Experts Discuss How to Ensure Conserved Water Gets to the Great Salt Lake. Utah State University. February 2. <https://www.usu.edu/today/story/water-shepherding-usu-experts-discuss-how-to-ensure-conserved-water-gets-to-the-great-salt-lake>.
- x n.d. Water Right Information. Accessed April 2, 2025. <https://waterrights.utah.gov/wrinfo/#:~:text=The%20Utah%20pioneers%2C%20in%20the,chief%20water%20rights%20administrative%20officer>.
- xi Garner, Carley. n.d. Utah's Water Management: Growing a Populous State in the Desert. Accessed April 2, 2025. <https://history.byu.edu/water-management>.
- xii 2021. "Overview of Prior Appropriation Water Rights." National Sea Grant Law Center. May 2. <https://nsglc.olemiss.edu/projects/waterresources/files/overview-of-prior-appropriation-water-rights.pdf>.
- xiii n.d. Water Right Information. Accessed April 2, 2025. <https://waterrights.utah.gov/wrinfo/#:~:text=The%20Utah%20pioneers%2C%20in%20the,chief%20water%20rights%20administrative%20officer>.
- xiv 2021. "Overview of Prior Appropriation Water Rights." National Sea Grant Law Center. May 2. <https://nsglc.olemiss.edu/projects/waterresources/files/overview-of-prior-appropriation-water-rights.pdf>.
- xv 2024. Great Salt Lake. May 2. <https://water.utah.gov/great-salt-lake/>.
- xvi n.d. Great Salt Lake Hydro Mapper. Accessed May 2, 2024. <https://webapps.usgs.gov/gsl/>.
- xvii 2022. Great Salt Lake Elevation - July 2022. July 7. Accessed April 2, 2025. <https://water.utah.gov/on-july-3-the-level-of-great-salt-lake-dropped-below-the-october-2021-historic-low-elevation/>.
- xviii 2022. Great Salt Lake Elevation - July 2022. July 7. Accessed April 2, 2025. <https://water.utah.gov/on-july-3-the-level-of-great-salt-lake-dropped-below-the-october-2021-historic-low-elevation/>.
- xix Great Salt Lake Strike Team. 2024. Great Salt Lake Data And Insights Summary. January 10. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.
- xx Abbott, Benjamin W. 2023. "Emergency measures needed to rescue Great Salt Lake from Ongoing Collapse." BYU Plant and Wildlife Sciences. January 4. <https://pws.byu.edu/GSL%20report%202023>.
- xxi Great Salt Lake Strike Team. 2024. Great Salt Lake Data And Insights Summary. January 10. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.
- xxii Great Salt Lake Strike Team. 2024. Great Salt Lake Data And Insights Summary. January 10. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.
- xxiii Great Salt Lake Strike Team. 2024. Great Salt Lake Data And Insights Summary. January 10. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.
- xxiv Wine, Michael L., Sarah E. Null, R. Justin DeRose, and Wayne A. Wurtsbaugh. 2019. "Climatization—Negligent Attribution of Great Salt Lake Desiccation: A Comment on Meng (2019)" *Climate* 7, no. 5: 67. <https://doi.org/10.3390/cli7050067>
- xxv Great Salt Lake Strike Team. 2024. Great Salt Lake Data And Insights Summary. January 10. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.
- xxvi Wurtsbaugh, Wayne, Craig Miller, Peter Wilcock, Maura Hahnenberger, and Frank Howe. 2016. "Impacts of Water Development on Great Salt Lake and the Wasatch Front." USU Digital Commons. February 24. [https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1891&context=wats\\_facpub](https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1891&context=wats_facpub).
- xxvii Steed, Brian. 2024. "The Great Salt Lake Strategic Plan." Office of the Great Salt Lake Commissioner. January 15. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.
- xxviii Great Salt Lake Strike Team. Great Salt Lake Data and insights summary, January 10, 2024. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.
- xxix Wurtsbaugh, Wayne, Craig Miller, Peter Wilcock, Maura Hahnenberger, and Frank Howe. 2016. "Impacts of Water Development on Great Salt Lake and the Wasatch Front." USU Digital Commons. February 24. [https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1891&context=wats\\_facpub](https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1891&context=wats_facpub).
- xxx Wurtsbaugh, Wayne, Craig Miller, Peter Wilcock, Maura Hahnenberger, and Frank Howe. 2016. "Impacts of Water Development on Great Salt Lake and the Wasatch Front." USU Digital Commons. February 24. [https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1891&context=wats\\_facpub](https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1891&context=wats_facpub).
- xxxi n.d. USGS: Map Viewer. Accessed June 25, 2024. <https://webapps.usgs.gov/gsl/viewer/index.html>.
- xxxii Miller, Saige. 2022. Utah can't save or stretch its precious water if it can't super accurately measure it. August 22. <https://www.kuer.org/politics-government/2022-08-22/utah-cant-save-or-stretch-its-precious-water-if-it-cant-super-accurately-measure-it>.
- xxxiii Great Salt Lake Salinity Advisory Committee. 2021. "Influence of Salinity on the Resources and Uses of Great Salt Lake." Utah.gov. [https://ugspub.nr.utah.gov/publications/open\\_file\\_reports/ofr-736.pdf](https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-736.pdf).
- xxxiv Great Salt Lake Salinity Advisory Committee. "Influence of Salinity on the Resources and Uses of Great Salt Lake." Utah.gov, 2021. [https://ugspub.nr.utah.gov/publications/open\\_file\\_reports/ofr-736.pdf](https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-736.pdf)
- xxxv 2024. Environment & Ecology. April 1. <https://greatsaltlake.utah.gov/environment-ecology>.

- 
- xxxvi 2023. "Birds: An Avian Oasis." June 22. <https://wildlife.utah.gov/gslep/wildlife/birds.html>.
- xxxvii 2023. "Birds: An Avian Oasis." June 22. <https://wildlife.utah.gov/gslep/wildlife/birds.html>.
- xxxviii 2024. "Protecting and Preserving Great Salt Lake." April 29. <https://greatsaltlake.utah.gov/#:~:text=The%20lake%20contributes%20%241.9%20billion,refuel%20during%20migration%20each%20year>.
- xxxix 2023. "Brine Shrimp Harvests." March 20. <https://wildlife.utah.gov/gslep/harvests.html>.
- xl DahDah, Jeff. 2023. Great Salt Lake Preservation Key for Global Food Security. December 8. <https://ksltv.com/606630/great-salt-lake-preservation-key-for-global-food-security/>.
- xli "Minerals." Utah Division of Wildlife Resources, September 1, 2021. [https://wildlife.utah.gov/gslep/industries/minerals.html#:~:text=The%20Great%20Salt%20Lake%20boasts.to%20\\$300%20million%20per%20year!](https://wildlife.utah.gov/gslep/industries/minerals.html#:~:text=The%20Great%20Salt%20Lake%20boasts.to%20$300%20million%20per%20year!)
- xlii Milligan, Mark. 2023. Glad You Asked: Utah's Hydrologic Cycle. August 10. <https://geology.utah.gov/map-pub/survey-notes/glad-you-asked/utahs-hydrologic-cycle/#:~:text=A%20Wasatch%20Front%20hydrologic%20sub.resorts%20in%20the%20Cottonwood%20Canyons>.
- xliii Milligan, Mark. 2023. Glad You Asked: Utah's Hydrologic Cycle. August 10. <https://geology.utah.gov/map-pub/survey-notes/glad-you-asked/utahs-hydrologic-cycle/#:~:text=A%20Wasatch%20Front%20hydrologic%20sub.resorts%20in%20the%20Cottonwood%20Canyons>.
- xliv 2021. "Great Salt Lake." Great Salt Lake Advisory Council. <https://documents.deq.utah.gov/water-quality/standards-technical-services/gsl-website-docs/DWQ-2021-013131.pdf>.
- xlv Dunphey, Kyle. 2023. Report: Northern Utah Has Some of the Country's Worst Ozone, Particulate Pollution. April 19. <https://www.deseret.com/utah/2023/4/19/23690368/states-with-worst-air-pollution-how-bad-is-air-in-utah/>.
- xlvi Kulkarni, Neeta, and Jonathan Grigg. 2008. "Effect of Air Pollution on Children." *Paediatrics and Child Health* 18 (5): 238-243. <https://www.sciencedirect.com/science/article/abs/pii/S1751722208000280>.
- xlvii Horne, Benjamin D, Elizabeth A Joy, Michelle G Hofmann, Per H Gesteland, John B Cannon, Jacob S Lefler, Denitza P Blagev, et al. "Short-Term Elevation of Fine Particulate Matter Air Pollution and Acute Lower Respiratory Infection." *American Thoracic Society*, September 18, 2017. <https://www.atsjournals.org/doi/10.1164/rccm.201709-1883OC>.
- xlviii Mullen, Casey, Sara E. Grineski, Timothy W. Collins, and Daniel L. Mendoza. 2020. "Effects of PM2.5 on Third Grade Students' Proficiency in Math and English Language Arts." MDPI. <https://www.mdpi.com/1660-4601/17/18/6931>.
- xlix Perry, Kevin D., Erik T. Crosman, and Sebastian W. Hoch. 2019. Results of the Great Salt Lake dust Plume Study. The University of Utah. [https://d1bbnjcm4wttri.cloudfront.net/wp-content/uploads/2019/12/10101816/GSL\\_Dust\\_Plumes\\_Final\\_Report\\_Complete\\_Document.pdf](https://d1bbnjcm4wttri.cloudfront.net/wp-content/uploads/2019/12/10101816/GSL_Dust_Plumes_Final_Report_Complete_Document.pdf).
- l Veras, Mariana Matera, Elia Garcia Caldini, Marisa Dolhnikoff, and Paulo Hilário Nascimento Saldiva. 2010. "Air Pollution and Effects on Reproductive-System Functions Globally with Particular Emphasis on the Brazilian Population." *Journal of Toxicology and Environmental Health, Part B* 13 (1): 1-15. doi:10.1080/10937401003673800.
- li n.d. Air Quality and Health. Accessed October 13, 2023. <https://www.pca.state.mn.us/air-water-land-climate/air-quality-and-health#:~:text=Populations%20most%20at%20risk%20of,who%20work%20or%20exercise%20outdoors>.
- lii n.d. Utah Air Monitoring Program. Accessed May 28, 2024. <https://air.utah.gov/dataarchive/index.htm>.
- liii *Utah Air Monitoring Program, Utah Department of Environmental Quality – Air Quality*. <https://air.utah.gov/dataarchive/archpm25.htm>.
- liv n.d. "Owens Valley Particulate Matter Plan." Accessed June 25, 2024. <https://19january2017snapshot.epa.gov/www3/region9/air/owens/index.html>.
- lv Schade, Ted. n.d. "Air Quality Data Collection." Great Basin UAPCD. Accessed June 25, 2024. [https://apps.cce.csus.edu/sites/arb/pqao/docs/presDay2/It All Starts With You.pdf](https://apps.cce.csus.edu/sites/arb/pqao/docs/presDay2/It%20All%20Starts%20With%20You.pdf).
- lvi O'Donoghue, Amy Joi. 2022. Five Things to Know About Owens Lake. October 10. <https://greatsaltlakenews.org/latest-news/deseret-news/what-makes-the-great-salt-lake-experience-different-but-alike-to-californias-owens-lake#:~:text=The%20Great%20Salt%20Lake%20C%20the,than%20Owens%20Lake%20in%20California>.
- lvii n.d. Office of the Commissioner. Accessed April 1, 2024. <https://greatsaltlake.utah.gov/commissioner>.
- lviii Steed, Brian. 2024. "The Great Salt Lake Strategic Plan." Office of the Great Salt Lake Commissioner. January 15. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.
- lix 2025. Great Salt Lake Data and Insights Summary. The Great Salt Lake Strike Team. Accessed March 31, 2025. <https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/2025/01/GSL-Jan2025.pdf>.
- lx n.d. Great Salt Lake. Accessed May 2. <https://ffsl.utah.gov/state-lands/great-salt-lake/>.
- lxi Wallace, Gwynn J., Jim Davis, and Andrew Rupke. 2022. Commonly Asked Questions about Utah's Great Salt Lake and Lake Bonneville. <https://geology.utah.gov/popular/great-salt-lake/commonly-asked-questions/#toggle-id-11>.
- lxii 2013. Great Salt Lake Plans. March. <https://ffsl.utah.gov/state-lands/great-salt-lake/great-salt-lake-plans/>.
- lxiii 2023. Great Salt Lake & Lake Bonneville. October 17. <https://geology.utah.gov/popular/great-salt-lake/>.
- lxiv 2024. Great Salt Lake. May 2. <https://water.utah.gov/great-salt-lake/>.

- 
- lxv DenBleyker, Jeff. n.d. Great Salt Lake Integrated Model. Accessed May 28, 2024. <https://www.goldsim.com/Web/Applications/ExampleApplications/EnvironmentalExamples/GSLIM/>.
- lxvi Jacobs Engineering Group. 2019. Great Salt Lake Integrated Model (GSLIM) An Integrated Water Resources Management Tool for the Great Salt Lake Watershed. September 26. <https://documents.deq.utah.gov/water-quality/standards-technical-services/great-salt-lake-advisory-council/DWQ-2022-028692.pdf>.
- lxvii Great Salt Lake Advisory Council, Utah Department of Natural Resources, and Utah Department of Environmental Quality. 2018. Great Salt Lake Integrated Model, v1.10: An Integrated Water Resource Management Tool for the Great Salt Lake Watershed. January.
- lxviii n.d. Great Salt Lake Ecosystem Program. Accessed May 2, 2024. <https://wildlife.utah.gov/gsllep.html>.
- lxix 2023. Great Salt Lake Actions. November. <https://ffsl.utah.gov/state-lands/great-salt-lake/great-salt-lake-plans/>.
- lxx n.d. Minerals Program. Accessed May 2, 2024. <https://ogm.utah.gov/minerals-program/>.
- lxxi 2024. Great Salt Lake. May 2. <https://water.utah.gov/great-salt-lake/>.
- lxxii 2024. About the Division of Air Quality. May 21. <https://deq.utah.gov/air-quality/about-the-division-of-air-quality>.
- lxxiii n.d. Utah Air Monitoring Program. Accessed May 28, 2024. <https://air.utah.gov/dataarchive/index.htm>.
- lxxiv 2024. Conservation Division. March 28. <https://ag.utah.gov/farmers/conservation-division/>.
- lxxv 2023. Agricultural Water Optimization Program. March 13. <https://ag.utah.gov/ag-water-optimization/>.
- lxxvi 2024. Utah Water Science Center. May 2. <https://www.usgs.gov/centers/utah-water-science-center>.
- lxxvii n.d. Great Salt Lake Hydro Mapper. Accessed May 2, 2024. <https://webapps.usgs.gov/gsl/>.
- lxxviii 2023. Bear River Migratory Bird Refuge. January 12. <https://www.fws.gov/refuge/bear-river-migratory-bird>.
- lxxix 2023. Planning for the Future. September 1. <https://www.fws.gov/story/2023-09/planning-future>.
- lxxx 2024. WaterSMART Basin Studies. April 5. <https://www.usbr.gov/watersmart/bsp/>.
- lxxxi 2024. The Great Salt Lake. May 2. <https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/utah/the-great-salt-lake>.
- lxxxii 2022. Senate Passes Romney, Stewart, Owens, Curtis Bill to Save Utah's Great Salt Lake. July 28. <https://www.romney.senate.gov/senate-passes-romney-stewart-owens-curtis-bill-to-save-utahs-great-salt-lake/>.
- lxxxiii 2024. Great Salt Lake Advisory Council. January 3. <https://deq.utah.gov/great-salt-lake-advisory-council/great-salt-lake-advisory-council>.
- lxxxiv 2024. Water: Great Salt Lake Resolution Steering Group. May 2. [https://fogsl.org/advocacy-issues/water#:~:text=Great%20Salt%20Lake%20Resolution%20\(HCR%2D10\)%20Steering%20Group&text=HCR%2D10%20recommended%20that%20a.flows%20to%20Great%20Salt%20Lake](https://fogsl.org/advocacy-issues/water#:~:text=Great%20Salt%20Lake%20Resolution%20(HCR%2D10)%20Steering%20Group&text=HCR%2D10%20recommended%20that%20a.flows%20to%20Great%20Salt%20Lake).
- lxxxv n.d. Great Salt Lake Salinity Advisory Committee. Accessed May 2, 2024. <https://ffsl.utah.gov/state-lands/great-salt-lake/great-salt-lake-salinity-advisory-committee/>.
- lxxxvi 2023. Agricultural Water Optimization Program. March 13. <https://ag.utah.gov/ag-water-optimization/>.
- lxxxvii n.d. Great Salt Lake Shoreland Preserve. Accessed May 2, 2024. <https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/the-great-salt-lake-shorelands-preserve/>.
- lxxxviii 2024. Great Salt Lake. January 24. <https://www.audubon.org/content/great-salt-lake>.
- lxxxix 2024. Our Purpose and History. January 19. <https://www.fogsl.org/about>.
- xc n.d. Latest News. Accessed May 2, 2024. <https://greatsaltlakenews.org/latest-news>.
- lxi n.d. Grow the Flow. Accessed May 2, 2024. <https://growtheflowutah.org/>.
- lxii Graham, Addison. 2023. Town Hall with Rachel Whipple and Tyler Clancy. December 4. <https://growtheflowutah.org/2023/12/04/town-hall-with-rachel-whipple-and-tyler-clancy/>.
- lxiii 2024. About Us. <https://www.utahfarmbureau.org/About-Us>.
- lxiv 2024. Policy and Action. <https://www.utahfarmbureau.org/Policy-Action>.
- lxv n.d. "UFBF Annual Convention 2024." The Balance of Progress. Accessed November 26, 2024. <https://www.eventleaf.com/e/ufbfannualconvention24#!>.
- lxvi 2023. Lawsuit Targets Utah State Government for Failing to Protect the Great Salt Lake. September 6. <https://abcbirds.org/news/great-salt-lake-lawsuit/>.
- lxvii n.d. People's Great Salt Lake Summit. Accessed August 28, 2024. <https://www.greatsaltlakesummit.org/program>.
- lxviii n.d. Resource Sustainability. <https://gsla.us/sustainability/>.
- lxix 2024. Solar Evaporation Pond: Ogden, Utah. March 25. <https://www.compassminerals.com/who-we-are/locations/ogden-utah/>.
- c 2024. Fiscal 2023 ESG Report. April 3. [https://www.compassminerals.com/wp-content/uploads/2024/04/CompassMinerals\\_Fiscal2023ESGReport-1.pdf?x14299](https://www.compassminerals.com/wp-content/uploads/2024/04/CompassMinerals_Fiscal2023ESGReport-1.pdf?x14299).
- ci Patterson, Scott. 2024. The Great Salt Lake Is Full of Lithium. A Startup Wants to Harvest It. February 12. <https://www.wsj.com/science/environment/great-salt-lake-lithium-startup-lilac-d84c9f76>.
- cii n.d. Home. Accessed May 2, 2024. <https://usmagnesium.com/>.
- ciii n.d. Conservation. Accessed May 2, 2024. <https://usmagnesium.com/environment/conservation/>.
- civ n.d. Serious About Solutions. Accessed May 2, 2024. <https://www.clydesnow.com/>.

- 
- cv Lewis, Emily E. 2024. Podcasts. May 2. <https://www.clydesnow.com/category/media/blogs/podcasts/>.
- cvi Lewis, Emily E. 2022. Keeping Current: Clyde Snow Policy Recommendations Featured Prominently at the Utah Legislature's Great Salt Lake Summit. January 5. <https://www.clydesnow.com/firm-news/in-current-clyde-snow-policy-recommendations-featured-prominently-at-the-utah-legislatures-great-salt-lake-summit/>.
- cvii n.d. Partnerships for Research and Policy Regarding Our Great Salt Lake. Accessed May 2, 2024. <https://www.usu.edu/ilwa/projects/great-salt-lake/>.
- cviii n.d. The Wilkes Center for Climate Science & Policy. Accessed May 2, 2024. <https://wilkescenter.utah.edu/>.
- cix n.d. Great Salt Lake Institute. Accessed May 2, 2024. <https://westminsteru.edu/student-life/great-salt-lake-institute/index.html>.
- cx n.d. Great Salt Lake Technical Team. Accessed May 2, 2024. <https://ffsl.utah.gov/state-lands/great-salt-lake/great-salt-lake-technical-team/>.
- cxii n.d. Great Salt Lake Strike Team. Accessed May 2, 2024. <https://wilkescenter.utah.edu/home/great-salt-lake-strike-team/>.
- cxiii n.d. Great Salt Lake Watershed Enhancement Trust. Accessed May 2, 2024. <https://www.gslwatertrust.org/>.
- cxiii King, Mary Ann. n.d. Getting Our Feet Wet: An Introduction to Water Trusts. Accessed May 2, 2024. <https://journals.law.harvard.edu/elr/wp-content/uploads/sites/79/2019/07/35.1-Kuh.pdf>.
- cxiv Shoop, Marcelle. 2022. Great Salt Lake Watershed Enhancement Trust Grant Agreement. December 21. <https://ffsl.utah.gov/wp-content/uploads/Final-GSLWET-Agmt-FFSL-NAS-TNC-signed.pdf>.
- cxv n.d. The People of the Great Salt Lake. Accessed May 2, 2024. <https://nhmu.utah.edu/sites/default/files/attachments/The%20People%20of%20the%20Great%20Salt%20Lake%20.pdf>.
- cxvi Harman, Teri. 2023. Native American History Month and Great Salt Lake. November 20. <https://growtheflowutah.org/2023/11/20/indigenous/>.
- cxvii n.d. Washakie Water Project. Accessed May 2, 2024. <https://www.nwbshoshone.com/washakie-water-project/>.
- cxviii Larsen, Leia. 2022. The Great Salt Lake's Most Important Source of Water Has a Troubled History. But There Is Hope Its Future May Be Better. December 6. <https://greatsaltlakenews.org/latest-news/salt-lake-tribune/the-great-salt-lakes-most-important-source-of-water-has-a-troubled-history-but-there-is-hope-its-future-may-be-better>.
- cxix Larsen, Leia. 2023. Tribes Still Not Consulted as State Tries to Save Great Salt Lake. February 7. <https://www.sltrib.com/news/politics/2023/02/07/stakeholders-gather-save-great/>.
- cxix n.d. Cloud Seeding: Enhancing our water supply. Accessed April 1, 2025. <https://water.utah.gov/cloudseeding/>.
- cxxi Utah Division of Water Resources. n.d. "A Comprehensive Look at Cloud Seeding in Utah." Accessed April 1, 2025. <https://byu.sharepoint.com/sites/BallardLabs-GSLLab/Shared%20Documents/GSL%20Lab/Information%20Archive/Interviews/Interview%20Material/CloudSeedingBYUBallard.pptx.pdf?CT=1743524252198&OR=ItemsView&wdOrigin=TEAMSFILE.FILEBROWSER.DOCUMENTLIBRARY>.
- cxvii n.d. Cloud Seeding: Enhancing our water supply. Accessed April 1, 2025. <https://water.utah.gov/cloudseeding/>.
- cxviii n.d. Cloud Seeding Frequently Asked Questions. Utah Division of Water Resources. Accessed April 3, 2025. <https://water.utah.gov/wp-content/uploads/2024/02/Cloud-Seeding-FAQ-1.pdf>.
- cxviii Utah Division of Water Resources. n.d. "A Comprehensive Look at Cloud Seeding in Utah." Accessed April 1, 2025. <https://byu.sharepoint.com/sites/BallardLabs-GSLLab/Shared%20Documents/GSL%20Lab/Information%20Archive/Interviews/Interview%20Material/CloudSeedingBYUBallard.pptx.pdf?CT=1743524252198&OR=ItemsView&wdOrigin=TEAMSFILE.FILEBROWSER.DOCUMENTLIBRARY>.
- cxv Utah Division of Water Resources. n.d. "A Comprehensive Look at Cloud Seeding in Utah." Accessed April 1, 2025. <https://byu.sharepoint.com/sites/BallardLabs-GSLLab/Shared%20Documents/GSL%20Lab/Information%20Archive/Interviews/Interview%20Material/CloudSeedingBYUBallard.pptx.pdf?CT=1743524252198&OR=ItemsView&wdOrigin=TEAMSFILE.FILEBROWSER.DOCUMENTLIBRARY>.
- cxvii n.d. Cloud Seeding Frequently Asked Questions. Utah Division of Water Resources. Accessed April 1, 2025. <https://water.utah.gov/wp-content/uploads/2024/02/Cloud-Seeding-FAQ-1.pdf>.
- cxvii n.d. Cloud Seeding Frequently Asked Questions. Utah Division of Water Resources. Accessed April 1, 2025. <https://water.utah.gov/wp-content/uploads/2024/02/Cloud-Seeding-FAQ-1.pdf>.
- cxviii Utah Division of Water Resources. n.d. "A Comprehensive Look at Cloud Seeding in Utah." Accessed April 1, 2025. <https://byu.sharepoint.com/sites/BallardLabs-GSLLab/Shared%20Documents/GSL%20Lab/Information%20Archive/Interviews/Interview%20Material/CloudSeedingBYUBallard.pptx.pdf?CT=1743524252198&OR=ItemsView&wdOrigin=TEAMSFILE.FILEBROWSER.DOCUMENTLIBRARY>.
- cxviii Utah Division of Water Resources. n.d. "A Comprehensive Look at Cloud Seeding in Utah." Accessed April 1, 2025. <https://byu.sharepoint.com/sites/BallardLabs-GSLLab/Shared%20Documents/GSL%20Lab/Information%20Archive/Interviews/Interview%20Material/CloudSeedingBYUBallard.pptx.pdf?CT=1743524252198&OR=ItemsView&wdOrigin=TEAMSFILE.FILEBROWSER.DOCUMENTLIBRARY>.
- cxviii Utah Division of Water Resources. n.d. "A Comprehensive Look at Cloud Seeding in Utah." Accessed April 1, 2025. <https://byu.sharepoint.com/sites/BallardLabs-GSLLab/Shared%20Documents/GSL%20Lab/Information%20Archive/Interviews/Interview%20Material/CloudSeedingBYUBallard.pptx.pdf?CT=1743524252198&OR=ItemsView&wdOrigin=TEAMSFILE.FILEBROWSER.DOCUMENTLIBRARY>.
- cxviii "Cloud Seeding." Utah Division of Water Resources. Accessed October 31, 2024. <https://water.utah.gov/cloudseeding/>.

- 
- <sup>cxxx</sup> Jennings, Jonathan A. "A Comprehensive Look at Cloud Seeding in Utah." Utah Division of Water Resources, August 26, 2024.
- <sup>cxxxii</sup> Utah Department of Agriculture and Food. "Understanding Utah Water Rights." AG Talk with UDAF, September 11, 2023. <https://podcast.ag.utah.gov/understanding-utah-water-rights>.
- <sup>cxxxiii</sup> Utah Department of Agriculture and Food. "Agricultural Water Optimization." AG Talk with UDAF, August 28, 2023. <https://podcast.ag.utah.gov/agricultural-water-optimization>.
- <sup>cxxxiv</sup> Utah Department of Agriculture and Food, May 7, 2024. <https://ag.utah.gov/ag-water-optimization/>.
- <sup>cxxxv</sup> Utah Department of Agriculture and Food, May 7, 2024. <https://ag.utah.gov/ag-water-optimization/>.
- <sup>cxxxvi</sup> Utah Department of Agriculture and Food, May 7, 2024. <https://ag.utah.gov/ag-water-optimization/>.
- <sup>cxxxvii</sup> Utah Department of Agriculture and Food, May 7, 2024. <https://ag.utah.gov/ag-water-optimization/>.
- <sup>cxxxviii</sup> Utah Department of Agriculture and Food. "Understanding Utah Water Rights." AG Talk with UDAF, September 11, 2023. <https://podcast.ag.utah.gov/understanding-utah-water-rights>.
- <sup>cxxxix</sup> "Ranking Matrix for On Farm Projects." Utah Department of Agriculture and Food, May 7, 2024. <https://ag.utah.gov/ag-water-optimization/>.
- <sup>cxl</sup> Utah Department of Agriculture and Food. "Agricultural Water Optimization." AG Talk with UDAF, August 28, 2023. <https://podcast.ag.utah.gov/agricultural-water-optimization>.
- <sup>cxli</sup> 2024. Agricultural Water Optimization Program 2024 Annual Report. Utah Division of Water Resources, Department of Agriculture and Food, Division of Water Rights. <https://water.utah.gov/wp-content/uploads/2024/11/2024-Agricultural-Water-Optimization-Report.pdf>.
- <sup>cxlii</sup> Freeze, Hannah. "Presentation Slides from the 2024 Uintah Basin Water Summit - Agricultural Water Optimization Program." Uintah Water, January 22, 2024. <https://www.uintahwater.org/home/news/presentation-slides-2024-uintah-basin-water-summit>.
- <sup>cxliiii</sup> DenBleyker, Jeff. "Agricultural Water Optimization Meeting Summary Task Force." Utah.gov, September 9, 2022. <https://www.utah.gov/pmnm/files/889457.pdf>.
- <sup>cxliv</sup> DenBleyker, Jeff. "Agricultural Water Optimization Meeting Summary Task Force." Utah.gov, September 9, 2022. <https://www.utah.gov/pmnm/files/889457.pdf>.
- <sup>cxlv</sup> DenBleyker, Jeff. "Agricultural Water Optimization Meeting Summary Task Force." Utah.gov, September 9, 2022. <https://www.utah.gov/pmnm/files/889457.pdf>.
- <sup>cxlvi</sup> DenBleyker, Jeff. "Agricultural Water Optimization Meeting Summary Task Force." Utah.gov, September 9, 2022. <https://www.utah.gov/pmnm/files/889457.pdf>.
- <sup>cxlvii</sup> Utah Department of Agriculture and Food. "Agricultural Water Optimization." AG Talk with UDAF, August 28, 2023. <https://podcast.ag.utah.gov/agricultural-water-optimization>.
- <sup>cxlviii</sup> Utah Department of Agriculture and Food. "Agricultural Water Optimization." AG Talk with UDAF, August 28, 2023. <https://podcast.ag.utah.gov/agricultural-water-optimization>.
- <sup>cxlix</sup> Barker, Burdette, Matt Yost, Jody Gale, and Mark Nelson. "Understanding Irrigation Water Optimization." DigitalCommons@USU, May 30, 2023. [https://digitalcommons.usu.edu/extension\\_curall/2343/](https://digitalcommons.usu.edu/extension_curall/2343/).
- <sup>cl</sup> Barker, Burdette, Matt Yost, Jody Gale, and Mark Nelson. "Understanding Irrigation Water Optimization." DigitalCommons@USU, May 30, 2023. [https://digitalcommons.usu.edu/extension\\_curall/2343/](https://digitalcommons.usu.edu/extension_curall/2343/).
- <sup>cli</sup> "Steinaker Service Canal Enclosure Project." Uintah Water Conservancy District. Accessed May 15, 2024. <https://www.uintahwater.org/project-updates/pages/steinaker-service-canal-enclosure-project>.
- <sup>clii</sup> 2023 Board of Trustees Meeting Minutes." Uintah Water Conservancy District, December 18, 2023. <https://www.uintahwater.org/node/52/minutes/2023>.
- <sup>cliii</sup> "Piping the Steinaker Service Canal." Bureau of Reclamation, November 10, 2022. [https://www.usbr.gov/newsroom/news-release/4376?field\\_story=1](https://www.usbr.gov/newsroom/news-release/4376?field_story=1)
- <sup>cliv</sup> "H.B. 520 Fallow Land Amendments." Utah State Legislature, March 12, 2024. <https://le.utah.gov/~2024/bills/static/HB0520.html>.
- <sup>clv</sup> H.B. 520 Fallow Land Amendments." Utah State Legislature, March 12, 2024. <https://le.utah.gov/~2024/bills/static/HB0520.html>.
- <sup>clvi</sup> H.B. 520 Fallow Land Amendments." Utah State Legislature, March 12, 2024. <https://le.utah.gov/~2024/bills/static/HB0520.html>.
- <sup>clvii</sup> Williams, Carter. "Why Utah Is Amending Its AG Water Optimization Program before Spending next \$200M." KSL.com, November 9, 2023. <https://www.ksl.com/article/50783199/why-utah-is-amending-its-ag-water-optimization-program-before-spending-next-200m>.
- <sup>clviii</sup> "The Great Salt Lake Strategic Plan - Utah.Gov." greatsaltlake.utah.gov, January 15, 2024. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.
- <sup>clix</sup> "The Great Salt Lake Strategic Plan - Utah.Gov." greatsaltlake.utah.gov, January 15, 2024. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.

---

clx Williams, Carter. "Why Utah Is Amending Its AG Water Optimization Program before Spending next \$200M." KSL.com, November 9, 2023. <https://www.ksl.com/article/50783199/why-utah-is-amending-its-ag-water-optimization-program-before-spending-next-200m>.

clxi "SB0277 Water Conservation and Augmentation Amendments." Utah State Legislature, March 14, 2023. <https://le.utah.gov/~2023/bills/static/SB0277.html#73-10g-205>.

clxii Williams, Carter. "Why Utah Is Amending Its AG Water Optimization Program before Spending next \$200M." KSL.com, November 9, 2023. <https://www.ksl.com/article/50783199/why-utah-is-amending-its-ag-water-optimization-program-before-spending-next-200m>.

clxiii "SB0277 Water Conservation and Augmentation Amendments." Utah State Legislature, March 14, 2023. <https://le.utah.gov/~2023/bills/static/SB0277.html#73-10g-205>.

clxiv Williams, Carter. "Why Utah Is Amending Its AG Water Optimization Program before Spending next \$200M." KSL.com, November 9, 2023. <https://www.ksl.com/article/50783199/why-utah-is-amending-its-ag-water-optimization-program-before-spending-next-200m>.

clxv Utah DNR. Regional Water Conservation Goals. [Regional Water Conservation Goals – Conserve Water Utah](https://www.water.utah.gov/conservation-goals).

clxvi "Utah Population 2024". <https://worldpopulationreview.com/states/utah-population>.

clxvii "Smart Controllers." Regional Water Providers Consortium, June 5, 2024. <https://www.regionalh2o.org/water-conservation/outdoor-water-conservation/smart-controllers#:~:text=It%20adjusts%20how%20long%20and%20how%20much%20your%20system%20waters>.

clxviii "Smart Toilet Benefits." Signature Hardware, December 29, 2023. <https://www.signaturehardware.com/ideas-buying-guide-smart-toilet-benefits.html#:~:text=Smart%20toilets%20sense%20water%20levels,and%20helps%20the%20environment.%E2%80%8C>.

clxix "Utah Division of Water Resources Wins 2023 WaterSense® Excellence Award." Utah Division of Water Resources, October 10, 2023. <https://water.utah.gov/utah-division-of-water-resources-wins-2023-watersense-excellence-award/>.

clxx "Smart Controller Program." Utah Water Savers. Accessed October 29, 2024. <https://www.utahwatersavers.com/smartcontrollerprogram>.

clxxi "Residential Toilets." EPA, June 3, 2024. <https://www.epa.gov/watersense/residential-toilets>.

clxxii Paxton, Josephine, Angie McGraw, and Whitney Robison. "Spanish Fork Irrigation-Water Conservation Study." BYU Civil and Environmental Engineering, April 12, 2019. <https://www.spanishfork.org/>.

clxxiii "Utah's 2nd Largest School District Chooses Smart Irrigation to Cut Water Use." HydroPoint, April 7, 2023. <https://www.hydropoint.com/case-studies/davis-utah-school-district-case-study/>.

clxxiv "Secondary Meter Grants." Utah Division of Water Resources. Accessed October 29, 2024. <https://water.utah.gov/secondarymetergrants/>.

clxxv n.d. Utah Water Savers: Home. Accessed April 1, 2025. <https://www.utahwatersavers.com/>.

clxxvi "Changes Coming to Smart Irrigation Controller Rebate Program." Utah Division of Water Resources, September 15, 2020. <https://water.utah.gov/changes-coming-to-smart-irrigation-controller-rebate-program/>.

clxxvii "Is a Smart Sprinkler Controller Worth It?" Irrigreen, November 28, 2023. <https://irrigreen.com/blogs/sprinkler-systems/smart-sprinkler-controller-benefits>.

clxxviii "Changes Coming to Smart Irrigation Controller Rebate Program." Utah Division of Water Resources, September 15, 2020. <https://water.utah.gov/changes-coming-to-smart-irrigation-controller-rebate-program/>.

clxxix "Utah Division of Water Resources Wins 2023 WaterSense® Excellence Award." Utah Division of Water Resources, October 10, 2023. <https://water.utah.gov/utah-division-of-water-resources-wins-2023-watersense-excellence-award/>.

clxxx "Water-Wise Landscapes." Sandy Public Utilities, n.d. Accessed October 29, 2024. <https://sandy.utah.gov/413/Water-wise-Landscapes>

clxxxi "Utah Launches Statewide Water-Wise Landscaping Incentive Program." Utah Division of Water Resources, May 1, 2023. <https://water.utah.gov/utah-launches-nations-first-water-wise-landscaping-incentive-program/>.

clxxxii Steed, Brian. "The Great Salt Lake Strategic Plan." Utah.gov, January 15, 2024. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.

clxxxiii Caayao, Janine. "How Much Does Xeriscaping Cost in 2024?" Lawnstarter, April 8, 2024. [https://www.lawnstarter.com/blog/cost/xeriscaping-price/#:~:text=Xeriscaping%20Cost%20per%20Square%20Foot,to%20\\$20%20per%20square%20foot](https://www.lawnstarter.com/blog/cost/xeriscaping-price/#:~:text=Xeriscaping%20Cost%20per%20Square%20Foot,to%20$20%20per%20square%20foot).

clxxxiv Caayao, Janine. "How Much Does Xeriscaping Cost in 2024?" Lawnstarter, April 8, 2024. [https://www.lawnstarter.com/blog/cost/xeriscaping-price/#:~:text=Xeriscaping%20Cost%20per%20Square%20Foot,to%20\\$20%20per%20square%20foot](https://www.lawnstarter.com/blog/cost/xeriscaping-price/#:~:text=Xeriscaping%20Cost%20per%20Square%20Foot,to%20$20%20per%20square%20foot).

clxxxv Steed, Brian. 2024. "The Great Salt Lake Strategic Plan." Office of the Great Salt Lake Commissioner. January 15. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.

---

clxxxvi Ikeda, Kathy. "Overcoming the Fear of Water-Wise Landscaping." The Stockton Record, March 12, 2018. <https://www.recordnet.com/story/lifestyle/columns/2018/03/12/overcoming-fear-water-wise-landscaping/13006885007/>.

clxxxvii Rep. Peterson, Val L. H.B. 242 Secondary Water Metering Amendments. 4 May 2022. <https://le.utah.gov/~2022/bills/static/HB0242.html>

clxxxviii 2022. \$250 Million for the Installation of Secondary Meters Will Fast-Track Water Conservation Efforts. April 5. <https://water.utah.gov/250-million-for-the-installation-of-secondary-meters-will-fast-track-water-conservation-efforts/>.

clxxxix Sanchez, Michael. "\$250 Million for the Installation of Secondary Meters Will Fast-Track Water Conservation Efforts." Division of Water Resources, April 5, 2022. <https://water.utah.gov/250-million-for-the-installation-of-secondary-meters-will-fast-track-water-conservation-efforts/>.

cxci Utah Secondary Water Metering: FAQs". <https://utahwatermetering.com/>

cxci "Third Round of Grant Funding Applications for the Purchase and Installation of Secondary Meters Announced." Utah Division of Water Resources, November 30, 2022. <https://water.utah.gov/third-round-of-grant-funding-applications-for-the-purchase-and-installation-of-secondary-meters-announced/>.

cxcii Great Salt Lake Advisory Council. Economic Significance of the Great Salt Lake to the State of Utah. [GSL-Options-Minerals.pdf \(d36oiwf74r1rap.cloudfront.net\)](https://gslwatertrust.org/our-impact), 8 February 2023.

cxciiii Steed, Brian. Great Salt Lake Strategic Plan. 15 January 2024. <file:///C:/Users/13177/Downloads/Great-Salt-Lake-Strategic-Plan-1.pdf>.

cxciiv Snider, Casey. H.B. 453 Great Salt Lake Revisions. [HB0453 \(utah.gov\)](https://legis.utah.gov/bills/2024/HB0453) .14 March 2024.

cxciiv 2025. Great Salt Lake Data and Insights Summary. The Great Salt Lake Strike Team. Accessed March 31, 2025. <https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/2025/01/GSL-Jan2025.pdf>.

cxciiv Steed, Brian. 2024. "The Great Salt Lake Strategic Plan." Office of the Great Salt Lake Commissioner. January 15. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.

cxciiv n.d. GSLWET: Our Impact. Accessed April 1, 2025. <https://www.gslwatertrust.org/our-impact>.

cxciiv Steed, Brian. "The Great Salt Lake Strategic Plan." Utah.gov, January 15, 2024. <https://greatsaltlake.utah.gov/wp-content/uploads/Great-Salt-Lake-Strategic-Plan-1.pdf>.

cxciiv n.d. GSLWET: Our Impact. Accessed April 1, 2025. <https://www.gslwatertrust.org/our-impact>.

cc Emerson, T. (2023, February 2). Water Shepherding: USU Experts Discuss How to Ensure Conserved Water Gets to the Great Salt Lake. Utah State TODAY. <https://www.usu.edu/today/story/water-shepherding-usu-experts-discusshow-to-ensure-conserved-water-gets-tothe-great-salt-lake>

ccci Lukens, E., E. K. Turney, S. Null, B. Neilson (2024). Measurement and Infrastructure Gap Analysis in Utah's Great Salt Lake Basin, HydroShare, <https://doi.org/10.4211/hs.8bf055dbe78b46d184cc7a4bb53931c7>.

ccci Lukens, E., E. K. Turney, S. Null, B. Neilson (2024). Measurement and Infrastructure Gap Analysis in Utah's Great Salt Lake Basin, HydroShare, <https://doi.org/10.4211/hs.8bf055dbe78b46d184cc7a4bb53931c7>.

ccci Lukens, E., E. K. Turney, S. Null, B. Neilson (2024). Measurement and Infrastructure Gap Analysis in Utah's Great Salt Lake Basin, HydroShare, <https://doi.org/10.4211/hs.8bf055dbe78b46d184cc7a4bb53931c7>.

ccci Lukens, E., E. K. Turney, S. Null, B. Neilson (2024). Measurement and Infrastructure Gap Analysis in Utah's Great Salt Lake Basin, HydroShare, <https://doi.org/10.4211/hs.8bf055dbe78b46d184cc7a4bb53931c7>.

ccci n.d. Office of the Commissioner. Accessed April 1, 2024. <https://greatsaltlake.utah.gov/commissioner>.

ccci n.d. Legislative Water Development Commission 2023. Access April 4, 2025. <https://le.utah.gov/committee/committee.jsp?com=speswd&year=2023>.

ccci 2024. Agricultural Water Optimization Program 2024 Annual Report. Utah Division of Water Resources, Department of Agriculture and Food, Division of Water Rights. <https://water.utah.gov/wp-content/uploads/2024/11/2024-Agricultural-Water-Optimization-Report.pdf>.

ccci Small, Adam. "Utah's Population Is Growing, Even Booming." KSLNewsRadio, December 6, 2023. <https://kslnnewsradio.com/2063700/utah-population-growth-booms-still/#:~:text=Utah%20has%20maintained%20a%201.6.nearly%20a%20half%20million%20people>.

ccci Great Salt Lake Strike Team. Great Salt Lake Data and insights summary, January 10, 2024. <https://www.usu.edu/today/pdf/great-salt-lake-strike-tream-report-2024.pdf>.