Assessment of Potential Costs of Declining Water Levels in Great Salt Lake

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Prepared for:

Great Salt Lake Advisory Council

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Executive Summary

The purpose of this report is to assess the potential costs of declining water levels in Great Salt Lake and its wetlands. A multitude of people, systems, and wildlife rely on Great Salt Lake and value the services it provides. Declines in lake levels threaten current uses, imposing risks to livelihoods and lake ecosystems. This report synthesizes information from scientific literature, agency reports, informational interviews, and other sources to detail how and to what extent costs could occur at sustained lower lake levels.

Water diversions from the rivers that feed Great Salt Lake have driven historical declines in lake levels. Current and future water stressors, without intervention to protect or enhance water flows to Great Salt Lake, have the potential to deplete water levels even further. Declines in lake levels threaten the business, environmental, and social benefits that Great Salt Lake provides and could result in substantial costs to surrounding local communities and the State of Utah.

This report traces the pathways and resulting costs that could arise due to declines in water levels in Great Salt Lake. The potential costs evaluated in this report include those caused by reduced lake effect, increased dust, reduced lake access, increased salinity, habitat loss, new island bridges, and the spread of invasive species.

Summary of Costs

Each of the effects and resulting costs of declining water levels in Great Salt Lake are described in detail in this report. Some resulting costs have sufficient information that the magnitude of the effect can be measured and quantified. Where possible, costs are also monetized. The costs evaluated in this report fall into three categories:

1. **Monetized Costs**: These estimates should be used to inform the magnitude of the potential cost that could result from a drying Great Salt Lake, rather than the specific dollar amount. Each type of monetized cost occurs at a different lake elevation. The extent of the cost could vary depending on water management and policy decisions.
2. **Quantified Costs**: Unlike the costs that could be monetized, quantified costs lack sufficient information about either the change that could occur or the costs that could arise from declining water levels at Great Salt Lake. These non-monetary values represent opportunities for further study and should be applied with caution.
3. **Non-Quantified Costs**: Costs that resist quantification either because of a lack of available information or because the value is not something that should be quantified are included in this category.

The monetized potential costs of a drying Great Salt Lake could be as much as ***$1.69 billion to $2.17 billion per year and over 6,500 job losses.*** Over twenty years these costs could be as high as $25.4 billion to $32.6 billion (discounted using a three percent discount rate). These values do not include coordination, planning, or legal costs that could arise due to declines in water levels at Great Salt Lake.

Monetized Costs of Declines in Water Levels at Great Salt Lake

Type of Cost	Potential Annual Cost	Potential 20-Year Costs	Potential Job Losses
Loss of Mineral Extraction Output	$1.3 billion	$19.3 billion	5,368
Landscape Mitigation Costs	$191.5 million to $610.4 million	$2.8 billion to $9.1 billion	N/A
Loss of Lake Recreation Output	$81.1 million	$1.2 billion	615
Loss of Brine Shrimp Industry Output	$67 million	$1.3 billion	574
Loss of Recreation Economic Value	$33.8 million to $81.9 million	$502 million to $1.2 billion	N/A
Health Costs	$6.6 million to $22.3 million	$98.2 million to $331.8 million	N/A
Loss of Ski Resort Spending	$5.8 million to $9.6 million	$86.3 million to $142.8 million	>0

Note: The potential 20-year cost estimates use a 3 percent discount rate and assume output for industries has constant capital and labor ratios throughout the time period. ECONorthwest recognizes that projecting economic contribution output in the future using IMPLAN, rather than a dynamic input-output model, is not a best practice and provides this estimate for illustrative purposes only.

The monetized costs describe only a portion of the consequences of declining water levels at Great Salt Lake. Other important information to consider is how the costs arise, at what water level they could arise, and what conditions could reduce or magnify their effect. The table below describes and summarizes the monetized, quantified, and non-quantified potential costs that could result from declining water levels at Great Salt Lake.

Description and Summary of Costs

Type of Cost	Description
Monetized Costs	
Loss of Mineral Extraction Output	Declines in water levels could result in costs to adjust operations for the mineral extraction industry at Great Salt Lake. Uncertainty and large fluctuations in water levels from year to year could also impose costs to this industry. If water levels are not sufficient to meet the water rights held by these companies, the industry at Great Salt Lake could be jeopardized. The potential loss of the mineral extraction industry at Great Salt Lake could result in an annual loss of $810 million in direct output, $1.3 billion in total output, $365 million in total labor income, as well as a loss of 5,368 total jobs.
Landscape Mitigation Costs	Other terminal lakes that have experienced water level declines have incurred significant costs for mitigation to prevent the adverse effects of a drying lake, including habitat loss and increased dust. The potential costs to mitigate future dust loads could rise to $191.5 million to $610.4 million per year, including mitigation for the acres currently exposed by the dry lakebed at Great Salt Lake. Costs will vary based on the area of land mitigated and mitigation treatment implemented. Responsibility to pay mitigation costs is unknown.
Loss of Lake Recreation Output	Recreation to Great Salt Lake could be reduced by over 50 percent due to declines in water levels. This decline in recreational use represents a loss of spending by recreationists on a variety of activities, including bird watching, hunting, sightseeing, boating, and sailing. If these recreation visits are lost the potential costs could be $44.5 million in direct spending, $81.1 million in total output, $15.4 million in total labor income, and 615 total jobs.

Type of Cost	Description
Loss of Brine Shrimp Industry Output	Brine shrimp harvesting is a valuable industry at Great Salt Lake, and it could be reduced or completely eliminated if brine shrimp populations decline. The potential loss of the brine shrimp industry would result in an annual loss of $40.1 million in direct output, $67.0 million in total output, $23.9 million in total labor income, as well as a loss of 574 total jobs supported by the industry.
Loss of Recreation Economic Value	In addition to the spending and job losses that could occur with declining water levels at Great Salt Lake, lower visitation also reduces the recreational-use value for recreationists. This value is equal to what recreationists would be willing to pay minus what they actually paid. The potential loss of recreational-use value from declining water levels at Great Salt Lake is $33.8 million to $81.9 million per year. This value range includes only monetized recreation for birding, duck hunting, boating and sailing, and ski resorts. Sightseeing, hiking, picnicking, and other recreation are not quantified but also anticipated to experience losses.
Health Costs	Increased dust and the resulting poor air quality are associated with a suite of adverse health effects that often affect sensitive populations the most, such as children, the elderly, and people with existing health conditions. Great Salt Lake is already contributing to dust loads, the cost of which is estimated as $3.2 million to $13.6 million per year based on values from the literature on the cost of particulate matter pollution. With further declines in lake levels, the potential health costs from dust from Great Salt Lake could rise to between $6.6 million to $22.3 million per year.
Loss of Ski Resort Spending	If Great Salt Lake no longer contributes to lake effect snow, average annual snowpack could decline approximately 5.1 to 8.4 percent. Snowmelt could melt by approximately 1 week sooner due to increased dust. From these changes, ski resort visits in Northern Utah could decline by 18,000 to 30,000 user days per year. As a result of the visitation decline, the potential lost spending at ski resorts could result in $5.8 million to $9.6 million per year in reduced recreation revenue. This value does not include costs to snowmobilers, backcountry skiers, and other snow-related recreationalists, suggesting that the true potential costs to the industry and recreationists is likely even higher.
Quantified Costs	
Water Management Costs and Impacts to Water Rights	Due to declines in the surface area and water level of Great Salt Lake, snowpack could be affected by both lower amounts of snow from reduced lake effect and earlier snowmelt from decreased albedo. In addition to the ski industry, water managers and water users along the Wasatch Front that rely on snowpack could be impacted.
Property Value Reductions	The homes near Great Salt Lake could experience a reduction in property value from the increased dust, reduced recreational opportunities, and other costs from declines in water levels at Great Salt Lake. Studies suggest increases in particulate matter air pollution can reduce property values by 0.2 to 1.1 percent. These reductions in property value would also impact property tax revenue for local taxing authorities.
Impacts to Bird Populations	As water levels decline in Great Salt Lake we expect negative impacts to populations of many bird species due to the potential reduction in brine shrimp, brine flies, and other macroinvertebrates. Land bridges can increase predation at island nesting sites and loss of both quantity and quality of habitat could also adversely affect bird populations. Based on survey values from other locations, the willingness to pay by people in Utah for migratory bird protections could be as high as $27.8 million per year.
Invasive Species Costs	Phragmites, a state-listed noxious weed, has populated large areas of Great Salt Lake. Declines in water levels at Great Salt Lake could increase the spread of this invasive species in some areas and decrease its presence in others. Costs to mitigate for phragmites are approximately $500–$1,000 per acre for three years. The Utah Department of Natural Resources currently budgets approximately $500,000 per year to control phragmites.
Loss of Non-Use Value	People value Great Salt Lake even if they do not visit or obtain value from it directly. The amount people are willing to pay to preserve an environmental resource like Great

Type of Cost	Description
	Salt Lake is known as a non-use value or passive use value. Based on estimates for Mono Lake, the potential loss of non-use value for Great Salt Lake could be as high as $328 million to $746 million per year for all households in Utah.
Non-Quantified Costs	
Increased Costs for Agriculture	Increased dust from a dry lakebed could create costs to agriculture by reducing yields and crop productivity due to interference with rates of transpiration and photosynthesis, as well as changes to soil composition.
Airport Operation Disruptions	Dust storms have delayed and cancelled flights at SLC International Airport. Increases in dust levels from a dry Great Salt Lake could increase the frequency of these disruptions, creating costs to the airline industries and reducing the attractiveness of the airport to travelers.
Increased Wildlife Management Costs	The land bridges to islands created by declines in water levels at Great Salt Lake could increase management costs for the terrestrial species of Antelope Island and costs for predation management at other islands. Fencing or predator control costs could be incurred for wildlife management.
Outmigration and Reduction in Business Attraction and Retention	Quality of life could be reduced due to water level declines at Great Salt Lake, primarily due to impaired air quality, reduced recreation opportunities, and the degraded environment. As a result, businesses and residents might leave Utah, or decide not to locate in the state.
Loss of Cultural and Spiritual Values	Great Salt Lake is a cultural resource to Utah and part of the state's identity. Water level declines at Great Salt Lake would change the landscape and aesthetics of Northern Utah. Current and future Utahns would be impacted by the cultural and spiritual losses resulting from a declining Great Salt Lake.

Policy Implications

Policy solutions and investments in water for Great Salt Lake now can prevent future costs to the region. The magnitude of potential consequences, $25.4 billion to $32.6 billion over twenty years, suggests that major interventions are likely warranted. The science review and economic analyses in this study indicate that reduced lake levels at Great Salt Lake are already imposing adverse conditions and economic costs on the regional community and economy. The continued trajectory of declining lake levels will likely only increase the magnitude and expand the categories of costs imposed on Utahns.

The experience of other terminal lake systems suggests that proactive approaches to water management and investments to protect a lake and its wetlands can be at least an order of magnitude less in costs than eventual restoration or mitigation after conditions are allowed to significantly deteriorate. Maintaining the full array of benefits that Great Salt Lake provides to the region will directly or indirectly return value to both residents and visitors.

This study did not find that conditions are beyond salvage or repair. The variety of costs and incremental nature of their relationship to lake conditions suggest that any policy solutions and improvements in lake level from current lows that ensure continued water flows can provide benefits for the region. Similarly, any incremental declines that can be avoided will have benefits. Reversing the current trend by allocating sufficient efforts and resources now to prevent declining lake levels could provide tens of billions of dollars in benefits over the coming decades and protect the quality of life in Northern Utah.

Acknowledgments

For over 40 years ECONorthwest has helped its clients make sound decisions based on rigorous economic, planning, and financial analysis. For more information about ECONorthwest: www.econw.com.

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ECONorthwest staff that contributed to this study include Mark Buckley, Laura Marshall, Justin Sherrill, and others. Martin & Nicholson staff that contributed to this study include Brian Nicholson and Susan Martin. The staff at ECONorthwest and Martin & Nicholson prepared this report based on their general knowledge of natural resources and scarcity, and on information derived from government agencies, private statistical services, the reports of others, interviews of individuals, or other sources believed to be reliable. ECONorthwest has not independently verified the accuracy of all such information and makes no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute the authors' current opinions, which may change as more information becomes available.

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1 Introduction

1.1 Background and Purpose of Report

Great Salt Lake is the largest natural lake west of the Mississippi River[1] and the largest saline lake in the Western Hemisphere. It is a shallow, terminal lake with no outlet and can fluctuate greatly in size depending on natural and human-influenced water inflows. Because of its extensive wetlands, Great Salt Lake is an important destination for millions of migratory birds that use the lake to feed, rest, and nest. The birds support recreation and tourism from hunting and bird watching. Other recreational uses of Great Salt Lake include sailing, hiking, swimming, and sightseeing. Industries also use the lake, including brine shrimp harvesting and mineral extraction operations. Culturally, Great Salt Lake is the namesake for Salt Lake City and represents a source of heritage, inspiration, and identity for many Utahns.

With the exception of flooding that occurred in the 1980s, Great Salt Lake has been in a period of sustained declining lake levels since record keeping began in the late 1800s. Over the past 150 years, inflows to the lake have been reduced over 39 percent leading to roughly an 11-foot drop in water elevation due to human diversions upstream.[2] The Bear River Development Act calls for the development of 220,000 acre-feet from Bear River or 20 percent of the average inflow to the Lake.[3]

Although Great Salt Lake covers a large area, it is a shallow lake, meaning that small changes in lake levels can change the surface area of the lake dramatically. The declining lake levels and the resulting surface area loss, increased salinity, and hazards to air quality jeopardize many of the uses of the lake and impose costs to the community. Lake level declines would make Great Salt Lake more saline due to less dilution from freshwater inputs. Dust created by exposed lakebed can also impact air quality, which is associated with adverse health effects.

Across the world, other terminal lakes of similar importance have been drying at alarming rates as water is diverted upstream and from the lake system. These declines have come with sizeable economic, social, and environmental costs. Utah has a narrow window of opportunity to prevent similar severe impacts to the agriculture, aquaculture, environment, recreational industry, public health, and economic vitality of the region.[4]

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[1] Utah Travel Industry Website. (No Date). *Great Salt Lake*. Retrieved from https://utah.com/great-salt-lake-state-park/facts

[2] Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., Hahnenberger, M., & Howe, F. (2016). Impacts of water development on Great Salt Lake and the Wasatch Front. *Watershed Sciences Faculty Publications*. Paper 875.

[3] Utah Code Sections 73-26-101 – 73-26-507.

[4] AECOM. (2019). *Consequences of Drying Lake Systems around the World*. Prepared for Great Salt Lake Ecosystem Program. February 19.

Recognizing the importance of Great Salt Lake, in 2010 House Bill 343 created the Great Salt Lake Advisory Council ("Advisory Council") to advise on the sustainable use, protection, and development of the Great Salt Lake. In 2019, the Utah Legislature and Governor Gary Herbert adopted Concurrent Resolution to Address Declining Water Levels of the Great Salt Lake (HCR010). The Resolution recognized a *"need for an overall policy that supports effective administration of water flow to Great Salt Lake to maintain or increase lake levels, while appropriately balancing economic, social, and environmental needs, including the need to sustain working agricultural land."*[5]

A 2012 report by Bioeconomics, commissioned by the Advisory Council, estimated the economic contributions of Great Salt Lake to the State of Utah as $1.32 billion in total annual economic output from recreation, industry, and aquaculture (2010 dollars).[6] This 2012 report considered the perspective of a sustained lake and its economic value, but not the costs from a drying Great Salt Lake and how those costs could impact quality of life in Utah. To answer those questions, the Advisory Council asked ECONorthwest and Martin & Nicholson Environmental to identify and quantify the economic impacts of a drying Great Salt Lake, including costs that could be avoided if the lake is preserved and maintained. Assembling this information will help resource managers, water users, and other stakeholders identify and prioritize actions intended to improve the quantity, quality, and distribution of water-related goods and services in Great Salt Lake.

There are tradeoffs between using water that would otherwise flow to Great Salt Lake for upstream consumptive uses and maintaining lake levels. Each of these actions has a multitude of associated benefits and costs. This report characterizes the costs of a declining Great Salt Lake. As such, the report provides information that decisionmakers can use to assess tradeoffs and costs of water management processes, or other actions that would impact volume, timing or quality of flows to Great Salt Lake and its wetlands.

1.2 Methodology

Cost analysis typically progresses from identification of costs to estimation of their monetary value. While there are many direct costs of a declining lake, other costs are more difficult to quantify in dollar values. This report presents the monetary value of quantifiable costs when possible. However, sufficient information is available to assign a dollar value to only a subset of the total costs incurred from declines in lake levels. Other costs resist quantification in physical and monetary terms. These costs, such as uncertain future costs, are theorized to exist but cannot be identified and verified. Figure 1 provides a visual aid describing the set of costs. These costs range from those with precise information that can be quantified and valued ("Monetized") to costs with limited information or that we don't even yet recognize ("Known &

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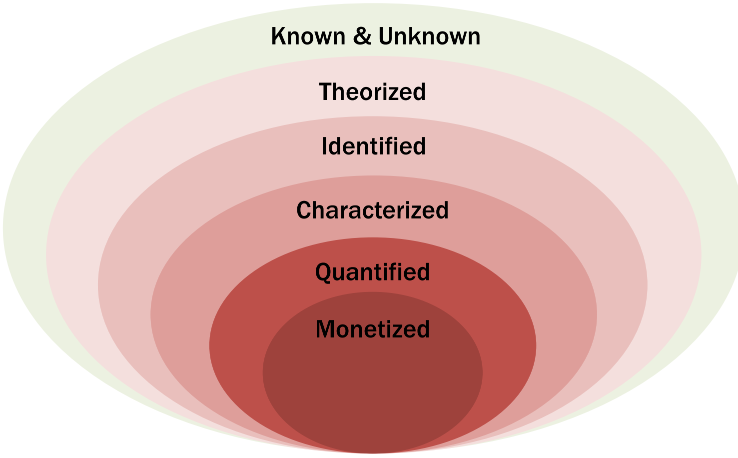
[5] Utah State Legislature. (2019). *H.C.R. 10 Concurrent Resolution to Address Declining Water Levels of the Great Salt Lake.* Enacted March 27, 2019. Retrieved from https://le.utah.gov/~2019/bills/static/HCR010.html.

[6] Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.

Unknown"). Many of the costs discussed herein cannot be represented at the quantified or monetized levels but can still be characterized and identified with scientific methods.

Figure 1. Hierarchy of Cost Analysis



Source: Created by ECONorthwest

The impacts of a drying Great Salt Lake are a result of complex ecological and hydrological processes that have other factors influencing their magnitude. While this report makes every effort to disentangle the factors that are only attributable to declines in water flows to Great Salt Lake and its associated wetlands, we recognize the potential for confounding factors.

To understand the costs of lake level declines of Great Salt Lake we relied on informational interviews, literature, and secondary data sources. The "Great Salt Lake Level Matrix" that was completed as part of the *Great Salt Lake Comprehensive Management Plan* by Utah Division of Forestry, Fire, and State Lands in 2013 describes how elevation influences the various locations and activities that occur at Great Salt Lake.[7]

1.3 Organization of this Report

This report begins in **Section 2** which describes the past, present, and future conditions of Great Salt Lake. This discussion includes a summary of Great Salt Lake's physical characteristics, socioeconomic setting (land use, political jurisdictions, demographics), and the regulatory/policy landscape as it applies to water resources. This information provides context for the rest of the report.

[7] Utah Department of Natural Resources, Utah Division of Forestry, Fire & State Lands. (2013). *Final Great Salt Lake Comprehensive Management Plan*. Retrieved from https://ffsl.utah.gov/index.php/state-lands/great-salt-lake/great-salt-lake-plans

Section 3 describes the costs of a declining Great Salt Lake based on the impact and estimated economic value associated with each use. This section also includes a review of past efforts to quantify the value of Great Salt Lake. The costs analyzed include:

- Wildlife and Habitat Costs
- Business Costs
- Recreation Costs
- Health Costs
- Mitigation Costs
- Reduction of Quality of Life

The **Summary** at the end of this document synthesizes the major findings of the report, including the total costs and implications of a declining Great Salt Lake.

2 Description of Great Salt Lake

In this section, we describe the characteristics of Great Salt Lake that are relevant to understanding how costs accrue with declines in lake levels. This includes physical characteristics that both support and limit the economic productivity of Great Salt Lake and the socioeconomic systems that interact with and depend on the resources produced by Great Salt Lake. Key points from this section include:

1. Although Great Salt Lake water levels and volume fluctuate over time, overall, there is a long-term downward trend in lake level.
2. Even small reductions in water levels would cause large declines in surface area, exposing portions of the lakebed, creating the potential for increased dust and decreasing lake effect snow.
3. Declining lake volume is correlated with increased salinity, which would impact industry and ecosystems at Great Salt Lake.
4. Increasing water consumption driven by population growth and rising incomes could contribute to future declines in water levels at Great Salt Lake.
5. Upstream water use, including the Bear River Development, Bear River Appropriations, and municipal water reuse, have the potential to decrease water levels of Great Salt Lake to levels that would trigger the most extreme effects characterized by this report.

2.1 Historical Trends in Lake Level

Great Salt Lake is a remnant of Lake Bonneville, which existed between 30,000 and 16,000 years ago.[8] Lake Bonneville discharged through the Snake River in a massive flood, leaving behind the lakebed that shapes much of Northern Utah's geography. Great Salt Lake formed approximately 11,000 years ago in the footprint of Lake Bonneville. Native Americans, including the Timpangotzis, Shoshone, and Fremont tribes, lived near Great Salt Lake for centuries.[9] In 1843 the first scientific measurements of the lake were taken by John C. Fremont – at that time the recorded elevation was 4,200 feet.

The lake level (also known as water elevation) of Great Salt Lake has been in decline since the early 1900s. Aside from flooding that occurred in the 1980s, lake levels are on a sustained downward trend (Figure 2). The lake was at approximately 4,192 feet in elevation in the fall of 2018, which is the second lowest it has been in recorded history. As of May 2019, Great Salt Lake was at 4,194.5 feet.[10] Models and early recordings of lake elevation suggest that 49 percent

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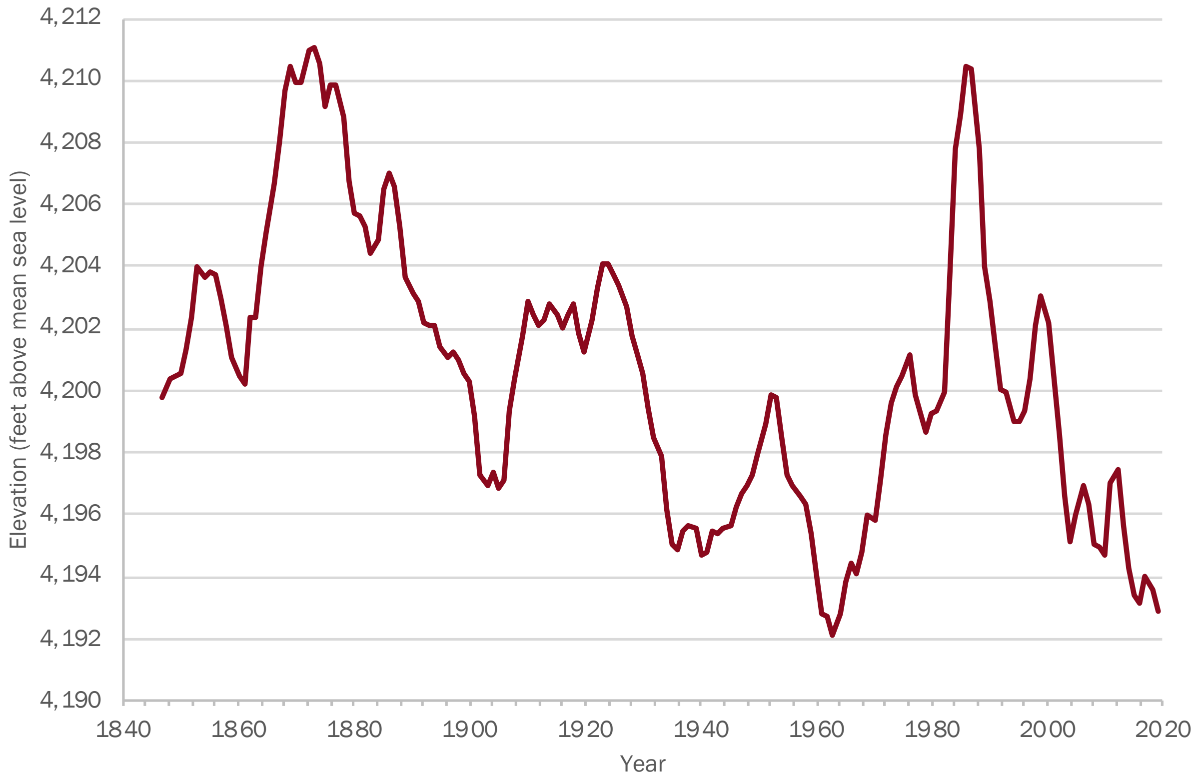
[8] U.S. Geological Society. (1999). *Great Salt Lake*, Utah. Retrieved from https://pubs.usgs.gov/wri/wri994189/PDF/WRI99-4189.pdf

[9] Great Salt Lake Ecosystem Program. (No Date). *History*. Retrieved from https://wildlife.utah.gov/gsl/history/index.php

[10] U.S. Geological Survey Gage 10010000 Great Salt Lake at Saltair Boat Harbor, Utah calculated in May 2019.

of the surface area and 11 feet of the depth of the lake that would otherwise be there today have been lost due to human consumptive use.[11]

Figure 2. Great Salt Lake Depth Over Time (Saltair Gage – South Arm)



Source: Created by Martin & Nicholson Environmental Consultants with data from USGS gage 10010000 Great Salt Lake at Saltair Boat Harbor, Utah. Available at https://waterdata.usgs.gov/nwis/uv?cb_62614=on&format=gif_default&site_no=10010000&period=&begin_date=2019-05-01&end_date=2019-05-08
Note: There is a portion of time before the year 1900 when elevation is modelled and not based on actual gage observations.

Scientists characterize Great Salt Lake elevations that are able to provide important aquatic and wetland habitats and their significant species as between 4,198 feet and 4,203 feet above sea level. [12] Great Salt Lake is currently at a ten-year median elevation ranging between 4,193.2 feet minimum and 4,197.5 feet maximum, below the defined elevation range.[13] Because the lake can fluctuate from year to year, long-term trends in lake level are appropriate for characterizing trends in lake level.

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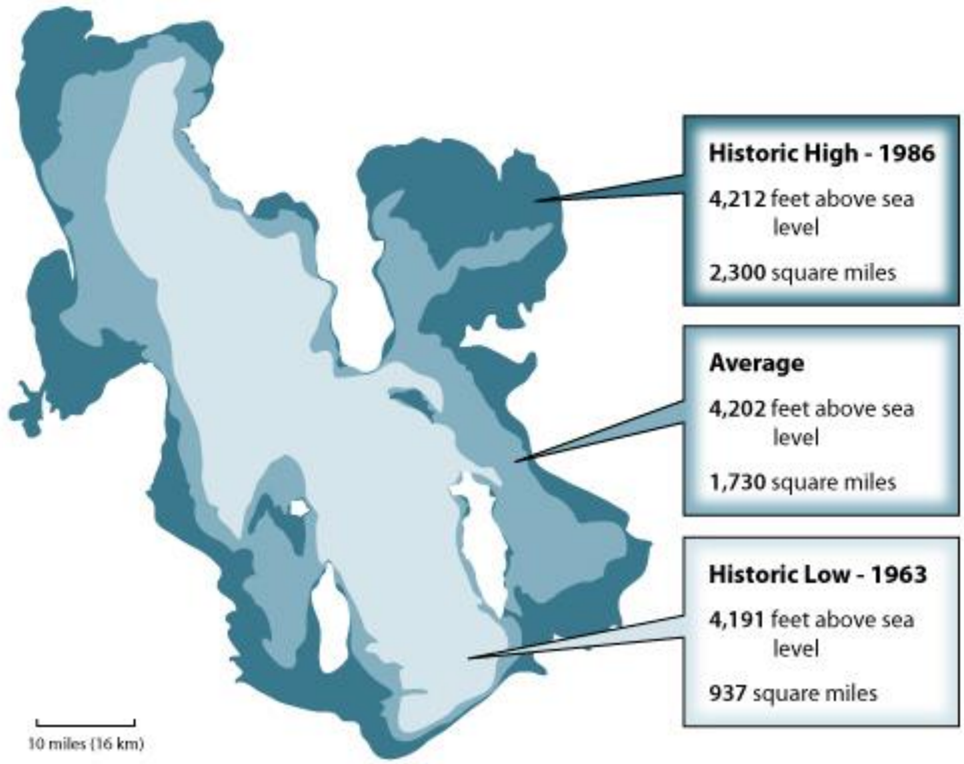
[11] Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., Hahnenberger, M., & Howe, F. (2016). *Impacts of water development on Great Salt Lake and the Wasatch Front*.

[12] SWCA Environmental Consultants. (2012). *Definition and Assessment of Great Salt Lake Health*. Prepared for Great Salt Lake Advisory Council. January.

[13] Calculations by Martin & Nicholson Environmental Consultants based on data from U.S. Geological Survey Gage 10010000 Great Salt Lake at Saltair Boat Harbor, Utah calculated in May 2018.

The relationship between lake level and surface area is represented visually in Figure 3 which shows the decline from the historic high of 4,212 feet in 1986 to the historic low of 4,191 feet in 1963. The historic low is approximately 3.5 feet below current lake levels, as of May 2019.

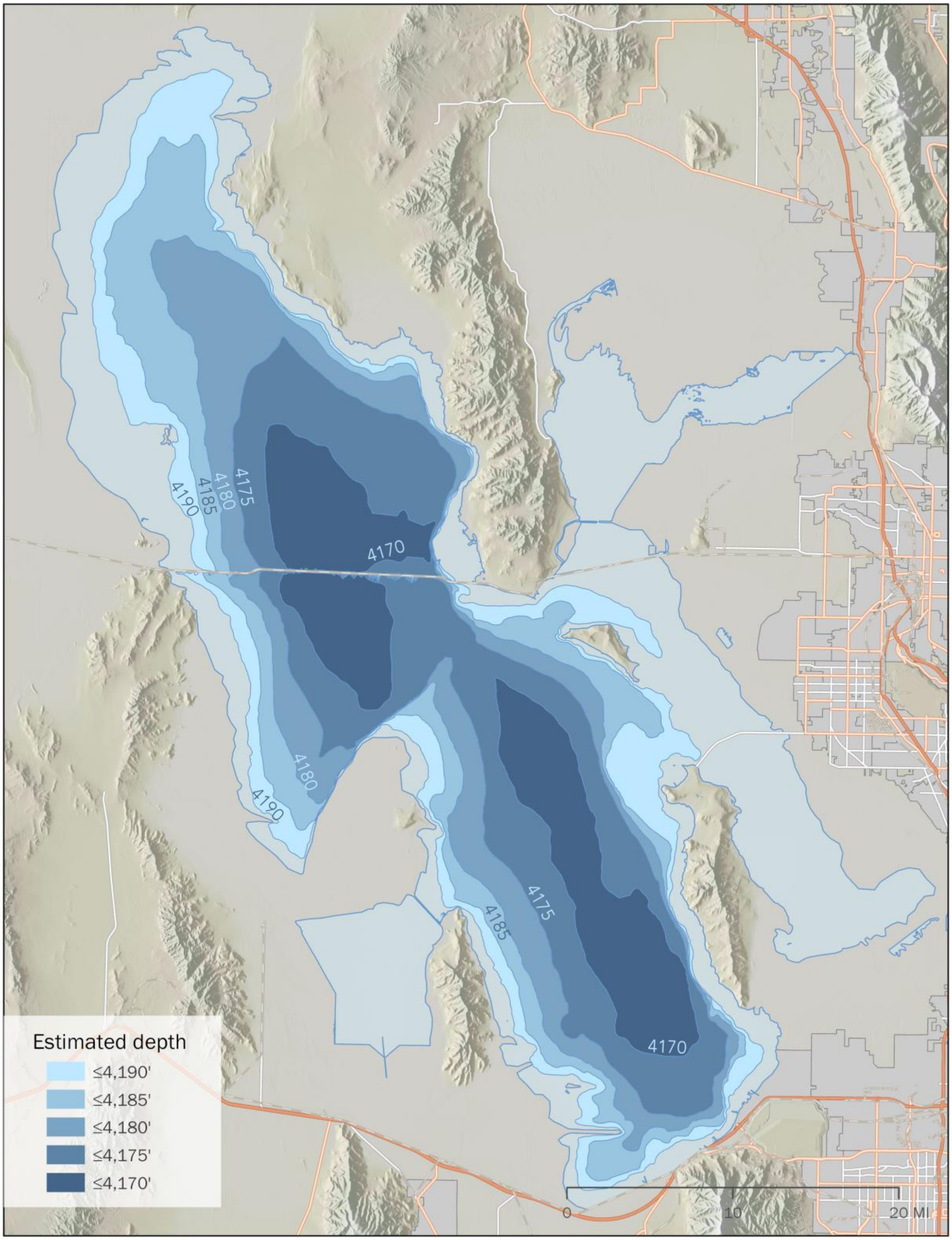
Figure 3. Surface Area Decline from Loss of Lake Level Elevation



Source: University of Utah, Genetic Science Learning Center. (No Date). "Illustration based on Major Levels of Great Salt Lake and Lake Bonneville, published by the Utah Geological and Mineral Survey". Retrieved from https://learn.genetics.utah.edu/content/gsl/physical_char/.

Future water level declines at Great Salt Lake would decrease the surface area of the lake and expose large portions of the lake bed. At 4,170 feet in elevation, approximately 24.5 feet below May 2019 levels, Great Salt Lake would likely split into two waterbodies separating the north and south arms (Figure 4).

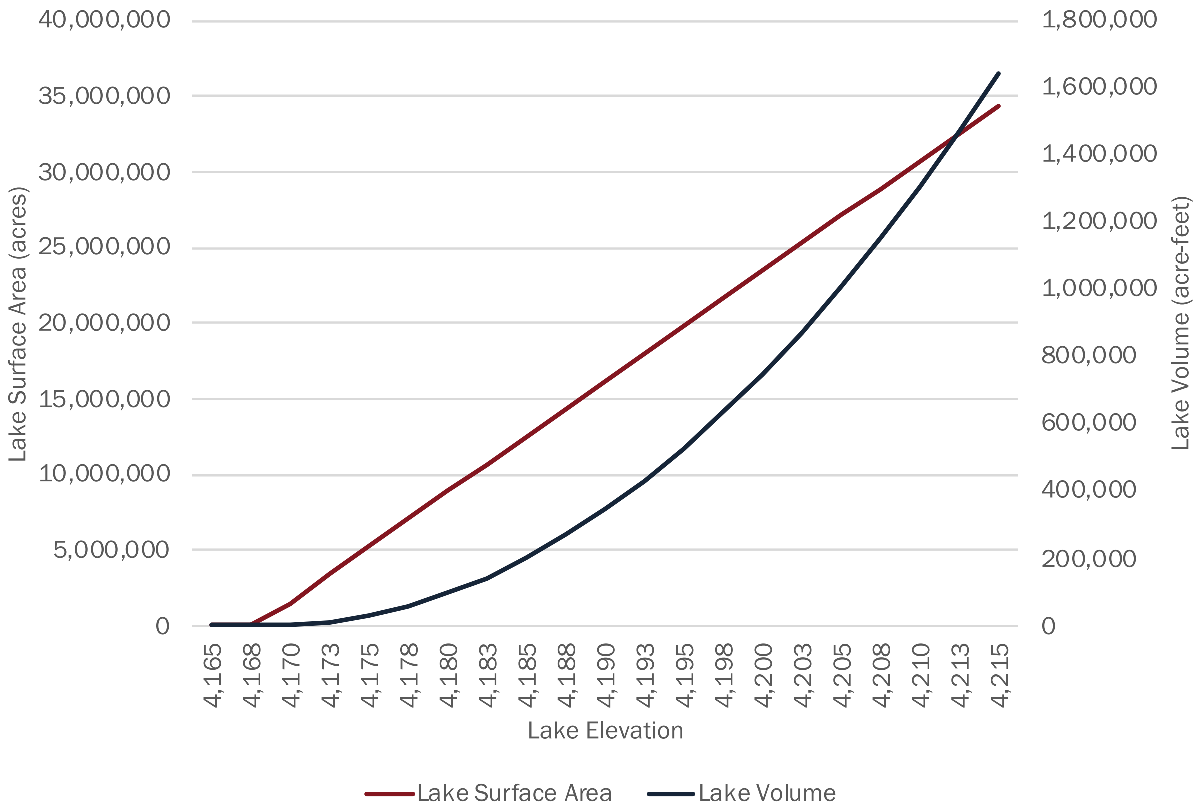
Figure 4. Surface Area of Great Salt Lake at Various Elevations



Source: Created by ECONorthwest with data from Tarboton, D. (2017). *Great Salt Lake Bathymetry*, HydroShare, http://www.hydroshare.org/resource/582060f00f6b443bb26e896426d9f62a

The relationship between lake elevation, volume, and surface area is demonstrated in Figure 5. An elevation of around 4,167 feet would represent a loss of approximately 400,000 acre-feet in volume of water compared to current conditions. The gray bar of Figure 5 represents the 10-year elevation range for Great Salt Lake.

Figure 5. Great Salt Lake Elevation, Surface Area, and Volume



Source: Created by ECONorthwest with information from SWCA. (2017). *Water for Great Salt Lake*. Figure 2. Data from Blaise Chanson to (BIO-WEST) to Laura Vernon (SWCA) on April 18, 2011.
Note: The gray bar represents the 10-year lake level range (4,193.2 feet to 4,197.5 feet) as of May 2019. The trends of lake surface area and lake volume have been smoothed because original data was not obtained to show the general trajectory.

2.2 Causes of Lake Level Declines

Saline lakes around the world have been drying at increasing rates during the last century. Saline lakes are generally terminal lakes, meaning they have no outlet other than evaporation, which allows for the pooled water to increase the concentration of salts and minerals. Globally, the decline in water levels and volume in saline lakes is often a result of human consumption of freshwater that otherwise flows into the lakes, such as for agricultural irrigation and urban demand.[14] Climate change and the resulting decline in precipitation and increase in evaporation can also accelerate water loss for terminal lakes.[15]

For Great Salt Lake, the declining lake levels over recent decades and resulting lake bed exposure are primarily driven by human actions. Great Salt Lake is fed by three major river basins in addition to precipitation and groundwater, the Jordan River, the Bear River, and Weber River. There are also other freshwater and groundwater sources of flow into the lake, including from the West Desert Basin.

The increase in consumptive water used has reduced the inflows to Great Salt Lake by an estimated 39 percent over the last 150 years.[16] As a result, consumptive uses have reduced the lake level by 11 feet, decreased its volume by 48 percent, increased lake salinity, and exposed approximately 50 percent of the lake bed.[17] Meanwhile, precipitation trends on average have been relatively stable (Figure 10, discussed later). Floods and droughts do have carryover effects, impacting lake elevations for years afterwards.

The percent of consumptive uses of water by type that would otherwise flow to Great Salt Lake is presented in Table 1. Agricultural uses are the largest share of consumptive uses, accounting for approximately 63 percent of the total.

Table 1. Estimated Water Consumption Impacts on Great Salt Lake Levels

Source	Percent of Use	Median Decrease in Lake Level (feet)
Agriculture	63%	7.0
Mineral extraction – salt ponds	13%	1.4
Municipal & industrial	11%	1.3
Impounded wetlands	10%	1.1
Reservoir evaporation	3%	0.3
Total	**100%**	**11.1**

Source: Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., Hahnenberger, M., & Howe, F. (2016). Impacts of water development on Great Salt Lake and the Wasatch Front. *Watershed Sciences Faculty Publications*. Paper 875.

Naturally, water is also lost from evaporation on the surface of the lake and from climate fluctuations. On average, approximately 2.9 million acre-feet of water evaporates from the lake annually, depending on lake conditions such as surface area, temperature, humidity, and wind.[18] However, climate change is believed to have increased aridity in the Great Salt Lake Basin and across the US Southwest due to increased temperatures that increase

[14] Wurtsbaugh, W. A., Miller, C., Null, S. E., DeRose, R. J., Wilcock, P., Hahnenberger, M., ... & Moore, J. (2017). Decline of the world's saline lakes. *Nature Geoscience*, 10(11), 816.

[15] Oren, A. (2018). *Salt Lakes, Climate Change, and Human Impact: A Microbiologist's Perspective*. Department of Plant and Environmental Sciences, The Institute of Life Sciences, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel.

[16] Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., Hahnenberger, M., & Howe, F. (2016). Impacts of water development on Great Salt Lake and the Wasatch Front. *Watershed Sciences Faculty Publications*. Paper 875.

[17] Ibid.

[18] SWCA Environmental Consultants. (2017). *Water for Great Salt Lake*. Prepared for Great Salt Lake Advisory Council. September.

evapotranspiration and snowmelt. [19] These changes have magnified the demand for upstream freshwater water diversions and likely impacted Great Salt Lake water levels.

2.3 Current Lake Conditions

Great Salt Lake is currently at a ten-year median elevation ranging between 4,193.2 feet minimum and to 4,197.5 feet maximum.[20] Figure 6 presents an image of the current Great Salt Lake water level as of September 2018 when elevation was approximately 4,192.4 feet. Farmington Bay and Bear River Bay were not inundated by the lake at this elevation and both have exposed acres of mud and salt flats.[21] Trenches of water travel across these flats to reach the main body of Great Salt Lake.

Figure 6. Satellite Image of Great Salt Lake as of September 2018

Source: Google Earth, accessed May 2019
Note: Left image is all of Great Salt Lake, upper right image is Bear River Bay, bottom right image is Farmington Bay.

The Great Salt Lake Basin is comprised of four smaller basins, three of which contain the major rivers that provide inflow: Bear River, Weber River, and Jordan River (including Utah Lake).

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[19] Gonzalez, P. eds. (2018). Southwest. *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, *Volume II*. U.S. Global Change Research Program. Retrieved from https://nca2018.globalchange.gov/chapter/25/

[20] Calculations by Martin & Nicholson Environmental Consultants based on data from U.S. Geological Survey Gage 10010000 Great Salt Lake at Saltair Boat Harbor, Utah calculated in May 2018.

[21] Elevations below 4,200 feet are when Bear River Bay and Farmington Bay lose connection to Great Salt Lake.

The West Desert basin contributes little surface water to Great Salt Lake, but the groundwater located there does contribute to lake levels.[22] Together, the watersheds of these river basins make up the larger Great Salt Lake Basin (Figure 7). Precipitation that collects and drains through the three river basins (excluding diverted water) largely determines the inflows to Great Salt Lake, and therefore the lake level, exposed shoreline, and mineral concentrations.

Figure 7. Great Salt Lake Basin

Source: Salt Lake County. (No Date). *Amazing Great Salt Lake*. Retrieved from https://slco.org/watershed/know-your-local-waters/amazing-great-salt-lake/

2.3.1 Water Supply

Great Salt Lake receives over 30 percent of its water from direct precipitation onto the lake and approximately 3 percent from groundwater inflow.[23] The other two-thirds of inflows are from the three river basins and West Desert basin. The largest of the contributing water basins is Bear River Basin, which contributes one-third of the total inflow. Table 2 provides a summary of the sources of inflow, including discharge location and Figure 8 shows geographically where each of the three rivers flows into Great Salt Lake.

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[22] Utah Department of Natural Resources: Forestry, Fire & State Lands. (No Date). *Great Salt Lake Basin Watershed Description*. Retrieved from http://www.greatsaltlakeinfo.org/Background/Description

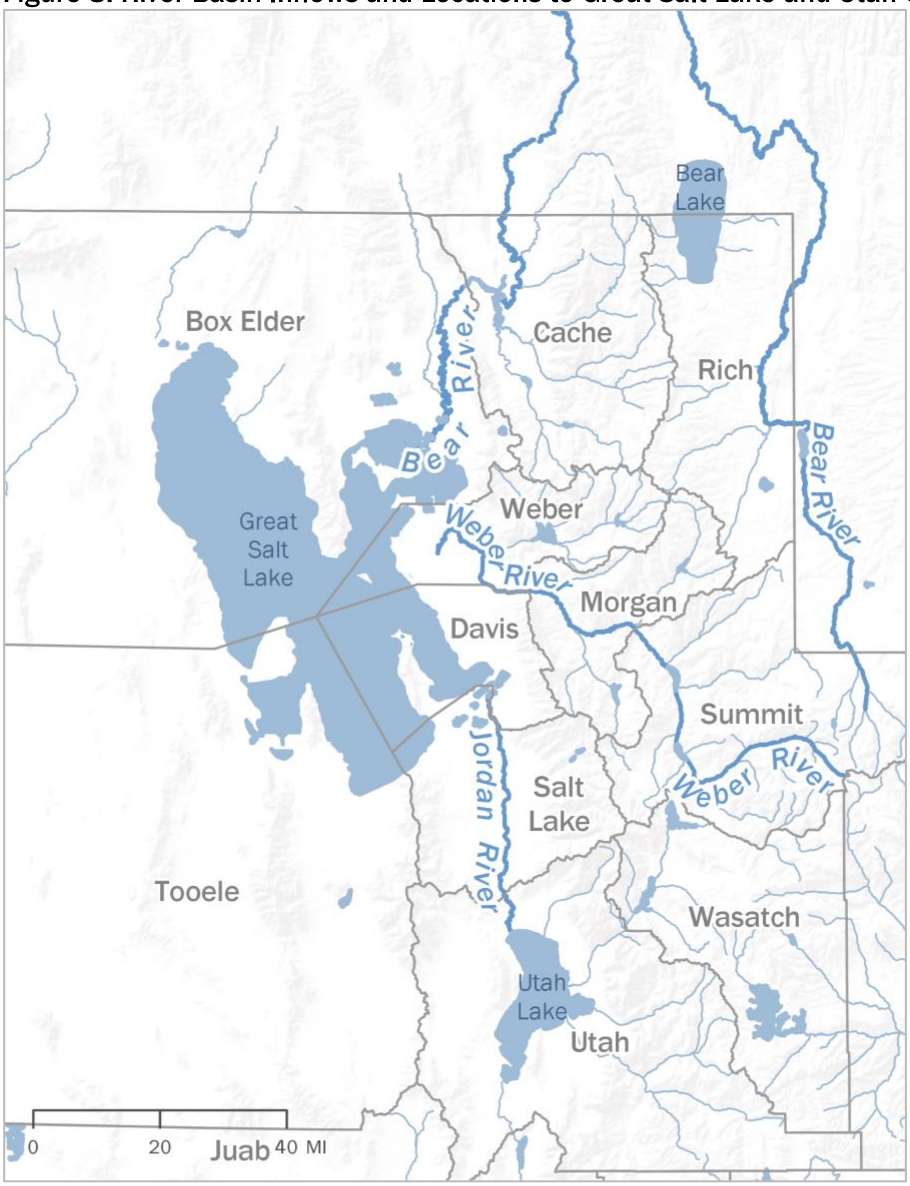
[23] U.S. Geological Society. (1999). Great Salt Lake, Utah. Retrieved from https://pubs.usgs.gov/wri/wri994189/PDF/WRI99-4189.pdf

Table 2. Inflows to Great Salt Lake by Source (2017)

Basin	Avg. Annual Flow (acre-feet per year)	Percentage	Discharge Location
Bear River	794,075	32.6%	Bear River Bay and Bear River Migratory Bird Refuge
Weber River	324,200	13.3%	Ogden Bay Waterfowl Management Area, other waterfowl management areas, and Willard Bay
Jordan River	383,000	15.7%	Farmington Bay, Gilbert Bay, various duck clubs, and the Inland Sea Shorebird Reserve
West Desert	45,700	1.9%	Gilbert Bay and Gunnison Bay
Direct Precipitation	889,300	36.5%	Lake and exposed lake bed
Total	**2,436,300**	**100%**	

Source: SWCA Environmental Consultants. (2017). *Water for Great Salt Lake*. Prepared for Great Salt Lake Advisory Council. September.

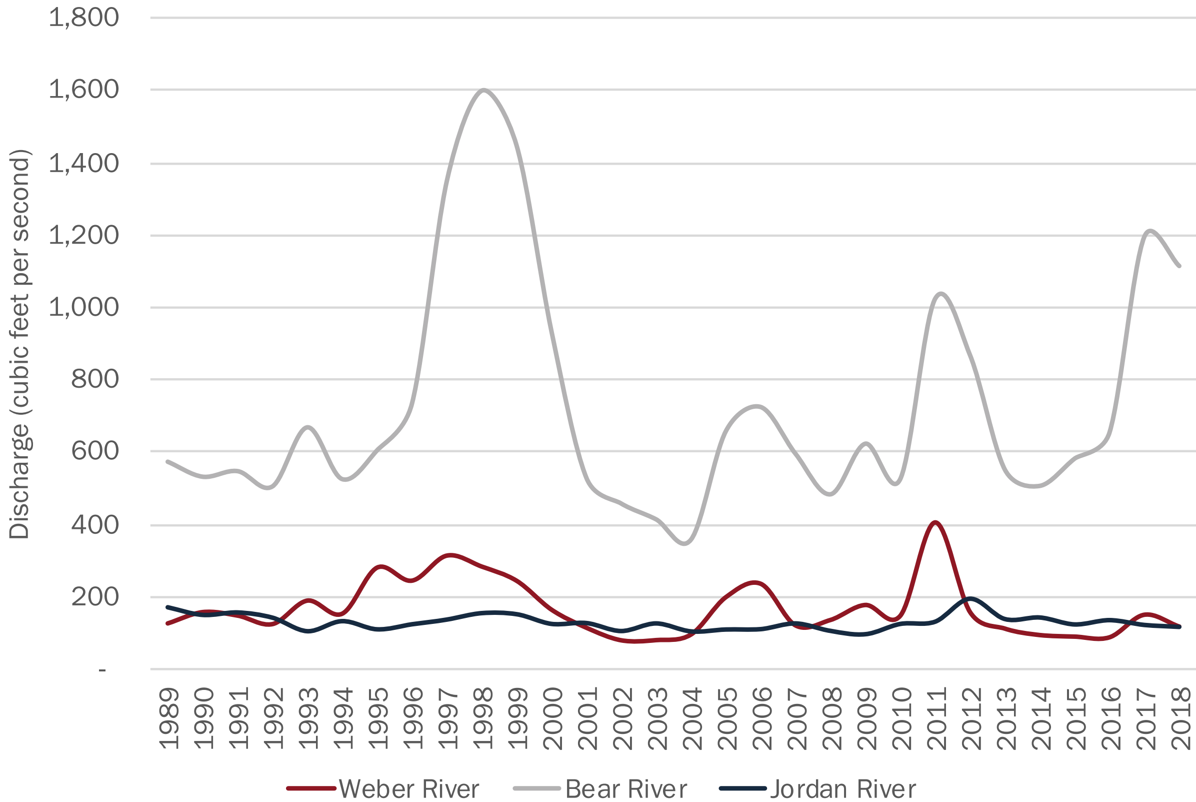
Figure 8. River Basin Inflows and Locations to Great Salt Lake and Utah Counties



Source: Created by ECONorthwest

Because three river basins contribute approximately 60 percent of the water into Great Salt Lake, fluctuations in streamflow can greatly affect the size of Great Salt Lake. Streamflow in these three river basins can vary each year depending on climate, precipitation, and snowpack fluctuations (Figure 9). Hydrology modeling suggests that if there was a 25 percent decrease in streamflow to the lake that lake elevation would decline by approximately 2.2 feet.[24]

Figure 9. Discharge Rates for the Weber River, Bear River, and Jordan River (1989-2018)

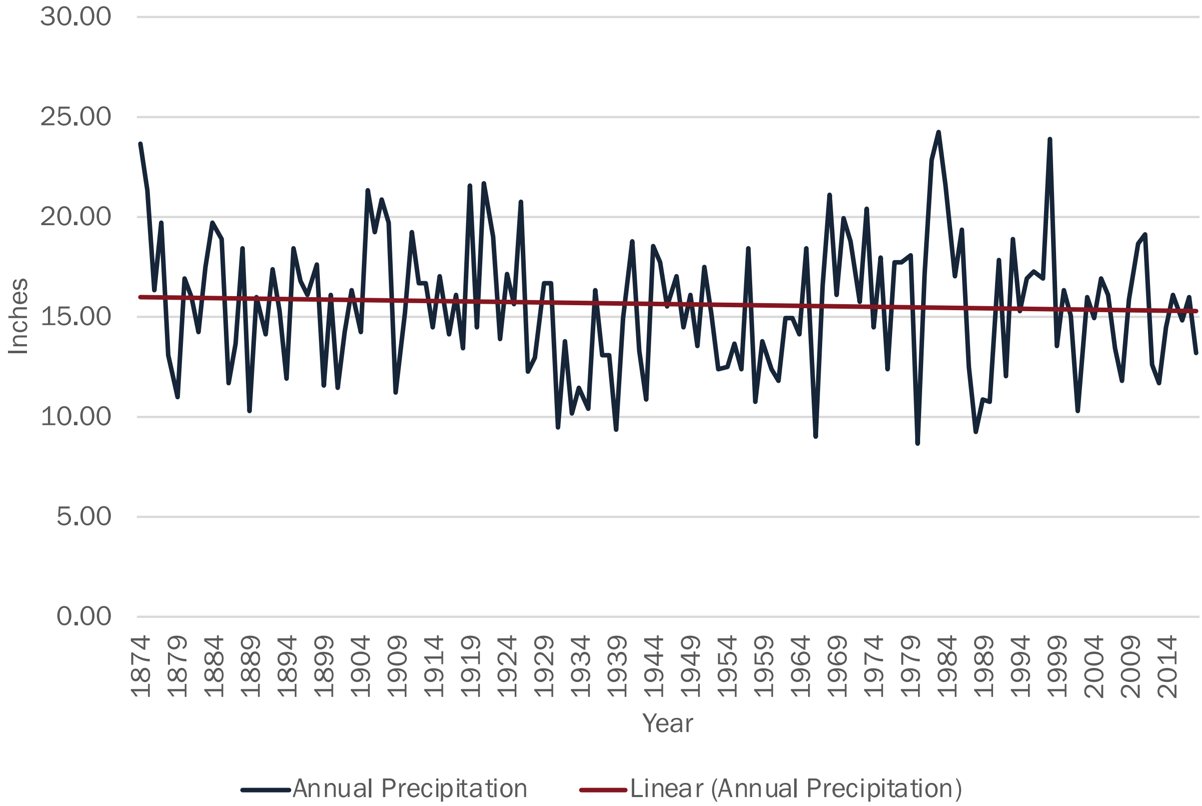


Source: Created by ECONorthwest with data from U.S. Geological Society National Water Information System (Weber River is gage # USGS 10129500 WEBER RIVER NEAR WANSHIP, UT, Bear River is gage # USGS 10092700 BEAR RIVER AT IDAHO-UTAH STATE LINE, and Jordan River is gage # USGS 10171000 JORDAN RIVER @ 1700 SOUTH @ SALT LAKE)

Precipitation into Great Salt Lake has been relatively constant over time, varying between a minimum of 8.70 annual inches in 1979 to the maximum of 24.26 inches in 1983. The average annual precipitation is 15.62 inches. Since recordings have been made, there has been a negligible change in precipitation directly onto the lake (Figure 10).

[24] Mohammed, I.N., & Tarboton, D.G. (2012). An examination of the sensitivity of the Great Salt Lake to changes in inputs. *Water Resources Research*, 48. 1-17, doi: 10.1029/2012wr011908.

Figure 10. Annual Precipitation for Salt Lake City, Utah (1874-2018)



Source: Created by ECONorthwest with data from National Oceanic and Atmospheric Administration, NOAA Online Weather Data, Salt Lake City, Utah: https://w2.weather.gov/climate/xmacis.php?wfo=slc

In addition to snowpack and precipitation, water management practices largely dictate the amount of water that reaches the lake. Management of the Bear River is conducted through the Bear River Compact between Utah, Wyoming, and Idaho. A 20-year compact review is currently in progress for the Bear River Compact.[25]

2.3.2 Salinity

Freshwater inflows occur on the east side of Great Salt Lake. There is also a railroad causeway that splits the lake into north and south arms. As a result, the salinity in bays on the eastern side of the lake is lower than in the central, west, and parts of the lake north of the railroad causeway. Salinity represents the concentration of all dissolved salts in Great Salt Lake. Salts in Great Salt Lake include sodium chloride as well as other compounds such as magnesium chloride and potassium chloride.

In 1959, Union Pacific Railroad constructed the railroad causeway, separating Great Salt Lake into two arms, north (Gunnison Bay) and south (Gilbert Bay), which has affected salinity for over 50 years. As a result, there is a visible difference in the water composition of the two lake arms (Figure 6). Although there is mixing between the two arms, the causeway is enough of a

[25] More information about the Bear River Compact can be found at: http://bearrivercommission.org/compact-review.php

barrier that the salinity differs by 12 percent on average between the two arms, approximately 25 percent in the north arm and 13 percent in the south arm. Table 3 illustrates average salinities at a depth of 10 feet and salinity ranges for the two regions of the lake. Because Bear River Bay and Farmington Bay receive freshwater inflows they are less saline and are able to support a greater diversity of insects, crustaceans, and fish which are also important prey for the bird community.[26]

Table 3. Salinity North and South of Railroad Causeway

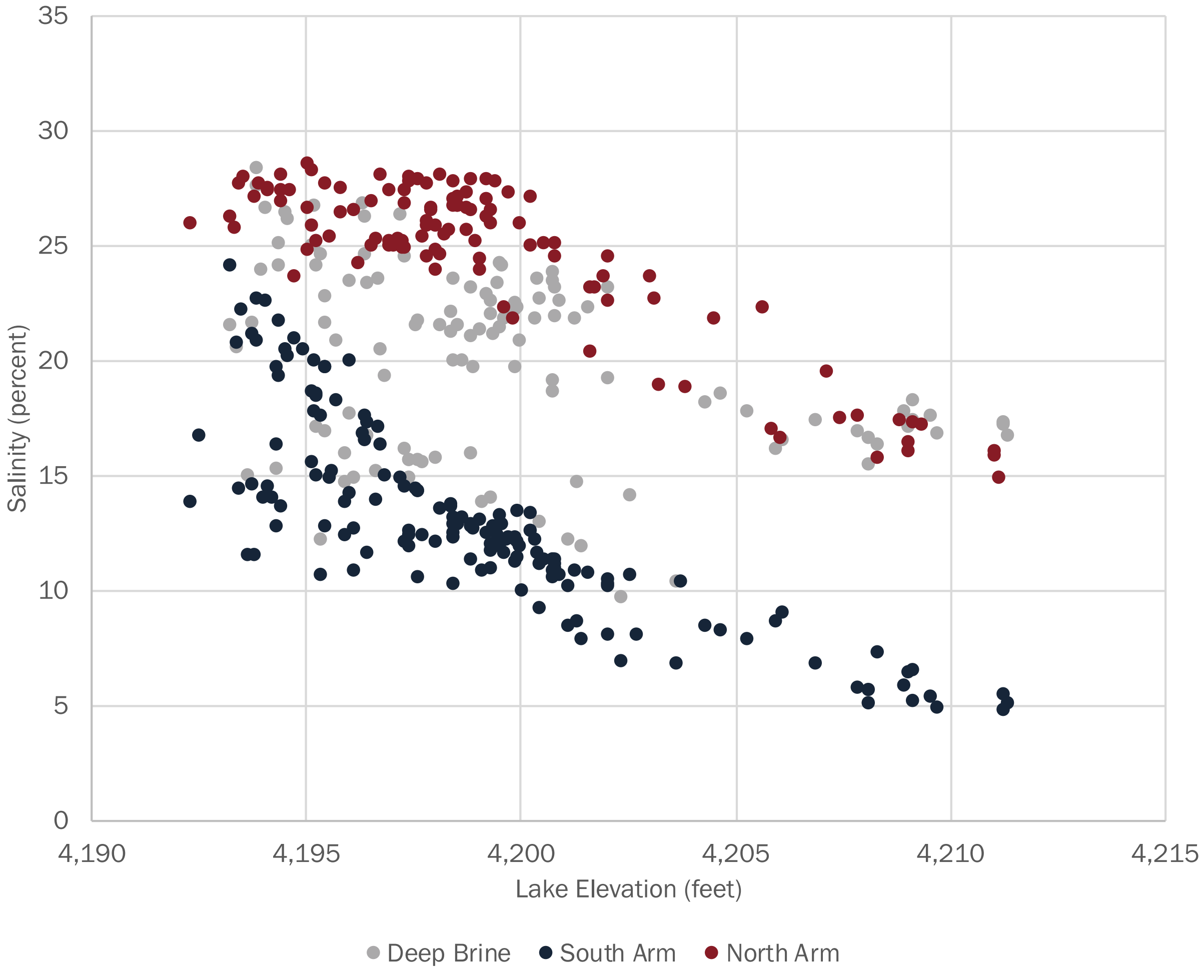
Arm	Average	Range
North Arm	25%	15% - 29%
South Arm (excluding deep brine)	13%	10% - 24%

Source: Created by ECONorthwest with data from UGS 2018 (measurements from 1966 to 2017)

Salinity is inversely related to volume for Great Salt Lake, and volume is directly related to elevation. Salinity of Great Salt Lake changes seasonally with inflows and evaporation and over longer temporal periods as a result of climate variation. Salinity of Great Salt Lake is also dependent on location – sites near freshwater tributaries have lower salinity. Depth also impacts salinity. High salinity water is denser than freshwater, so salinity can increase with depth. In the deepest part of Great Salt Lake there is a "deep brine layer". The relationship between salinity and elevation for the north arm, south arm, and the deep brine layer are plotted in Figure 11 in years using data from 1966 to 2017, generally showing higher salinity at lower elevation.

[26] Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., Hahnenberger, M., & Howe, F. (2016). Impacts of water development on Great Salt Lake and the Wasatch Front. *Watershed Sciences Faculty Publications*. Paper 875. https://digitalcommons.usu.edu/wats_facpub/875

Figure 11. Correlation of Salinity with Elevation (1966-2017)



Source: Created by Martin & Nicholson Environmental Consultants with data from Utah Department of Natural Resources, Utah Geological Survey

Evaporative mining is a major industry at Great Salt Lake because of the high concentration of minerals in the water. Large salt evaporation ponds are used by mineral extractors in Stansbury Bay and Bear River Bay. These ponds spread salt water at thin depths to evaporate it using solar heat. Great Salt Lake is the largest source of solar-evaporated salt in North America. The annual inflow from the freshwater inputs carries about 2.2 million tons of salt, which is similar in magnitude to the commercial removal of 1.6 to 2.5 million tons per year. Great Salt Lake contains approximately 4.3 billion tons of salt.[27]

For the species living in Great Salt Lake, optimal salinity levels vary by species depending on osmoregulation capacity, food availability, and suitable habitat. Salinity of Great Salt Lake does affect brine shrimp, a cornerstone species of the lake. While brine shrimp can tolerate salinities between 5 percent and 26 percent, ideal salinities for brine shrimp reproduction are between 12

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[27] U.S. Geological Society. (1999). *Great Salt Lake, Utah*. Retrieved from https://pubs.usgs.gov/wri/wri994189/PDF/WRI99-4189.pdf

percent and 16 percent.[28] Brine shrimp are not present in most of the north arm of Great Salt Lake, which has significantly higher salinity, because of these salinity thresholds. Brine flies (an important food source for birds using the open salt water of the lake) may tolerate salinities of up to 26 percent, yet microbialites, a common vegetative habitat for fly larvae, have optimal salinities of less than 17 percent.[29] Generally, higher salinities equate to increased ecosystem stressors and decrease in biomass throughout the food web. Reductions in brine shrimp due to high salinities would likely impact bird populations at Great Salt Lake, such as Eared Grebes, that depend on brine shrimp as a primary food source, as well as Wilson's Phalaropes that rely on brine shrimp as part of their diet.

2.4 Projected Future Condition of Great Salt Lake

The future condition of Great Salt Lake depends on the extent of future consumptive uses of water as well as the impacts of climate change. Increased populations in the counties in the Great Salt Lake Basin would likely increase the consumptive use of water that would otherwise flow to the lake, assuming no major water policy changes or conservation efforts. A planned development on the Bear River, which contributes one-third of the annual inflows to Great Salt Lake, could impact the amount of water delivered to the lake. This section describes the factors that could shape the future of Great Salt Lake.

2.4.1 Population Changes

There are eleven Utah counties located primarily in the Great Salt Lake Basin. Of these, Salt Lake County has the largest population at approximately 1.1 million people – it also contains the state's capitol and largest city. Utah County has the second highest population. The populations of all eleven of the counties (Box Elder, Cache, Rich, Weber, Davis, Morgan, Summit, Salt Lake, Wasatch, Utah, and Toole counties) are projected to increase over the next 45 years (Figure 12). The average annual population increase is approximately 1.2 percent, which is expected to decline over time from a high of 1.8 percent in 2021 to a low of 0.9 percent in 2065. As the populations of these counties increase, demands for freshwater for both municipal and industrial use would also increase, assuming constant per capita water consumption rates. The magnitude of the future demand for water that would otherwise flow to Great Salt Lake will vary depending on future conditions and where water is moved for new or different users.

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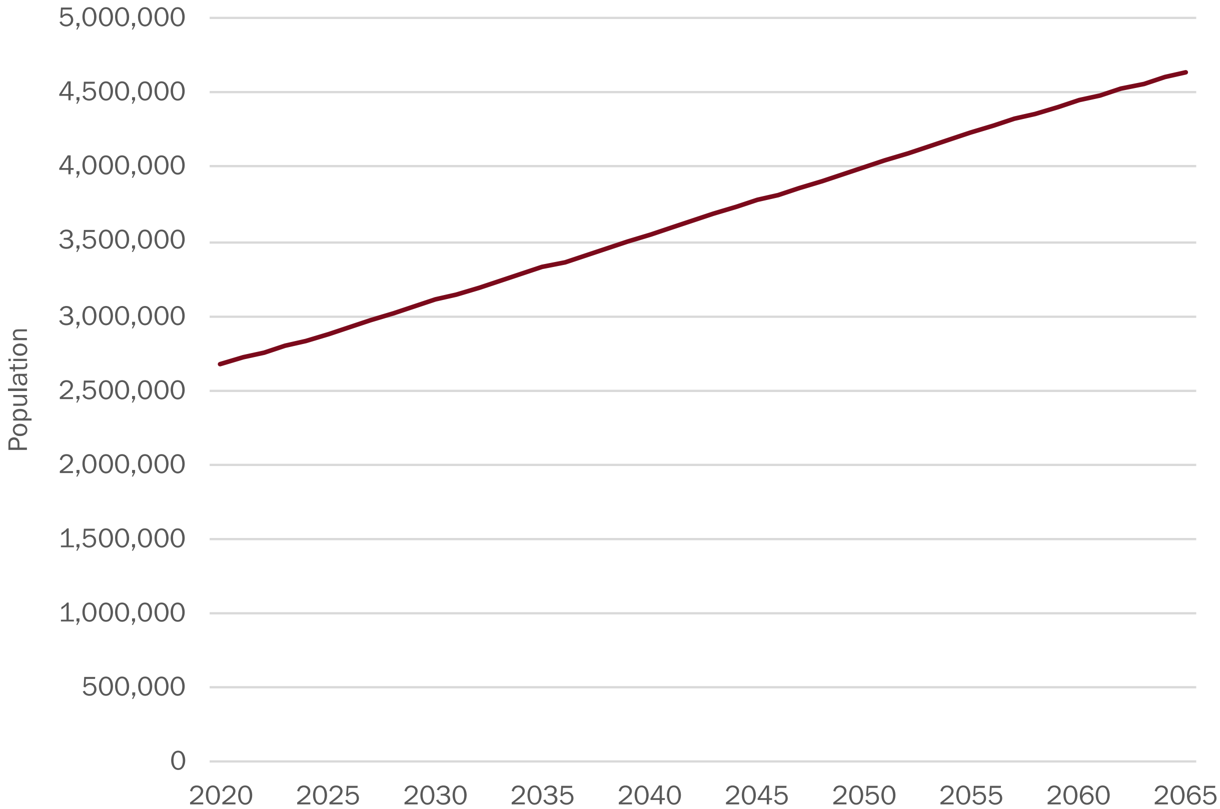
[28] Bosteel, T. (2018). *Salinity Effect on Great Salt Lake Brine Shrimp: General Overview*. Presentation at the Great Salt Lake Issues Forum, Salt Lake City, Utah. May.

[29] Bonnie Baxter, Great Salt Lake Institute, Westminster College, personal communication on February 25, 2019.

Figure 12. Population Projection for Counties in the Great Salt Lake Basin (2020–2065)



Source: Created by ECONorthwest with data from University of Utah, Kem C. Gardner Policy Institute 2015-2065 State and County Projections
Note: The counties included in the Great Salt Lake Basin are Box Elder, Cache, Rich, Weber, Davis, Morgan, Summit, Salt Lake, Wasatch, Utah, and Toole counties.

Upstream Water Diversions

Any large upstream diversion could potentially deplete water levels in Great Salt Lake. There are two planned upstream diversions on the Bear River which would likely have that effect. Other potential large diversions of water in any of the watersheds, such as wastewater reuse, could also reduce water flows to Great Salt Lake.

Bear River Development

In 1991, the Utah State Legislature authorized the Bear River Development Act to use the Bear River and its tributaries to meet the future water needs of the Wasatch Front by increasing the storage potential above Great Salt Lake through a new reservoir. The planning process for the Bear River Development has been ongoing ever since 1991. Recent estimates by the Utah Department of Natural Resources suggest that the Bear River Development will not be needed until 2040, rather than the original estimate of 2015.[30]

[30] Utah Department of Natural Resources. (No Date). *Bear River Development Can Likely be Delayed Further*. Retrieved from https://naturalresources.utah.gov/dnr-newsfeed/bear-river-development-can-likely-be-delayed-further

If and when the Bear River Development occurs, it is projected to divert up to 20 percent of the water that would otherwise have flowed to Great Salt Lake.[31] Because the Bear River supplies approximately one-third of the water to Great Salt Lake, this withdrawal would decrease the level of Great Salt Lake approximately 8.5–14 inches and expose about another 30–45 square miles of lake bed.[32] At this time, 220,000 acre-feet annually of water rights have been secured for the project.[33]

Bear River Appropriations

In 2018, Idaho and Utah filed joint applications to appropriate and store up to 400,000 acre-feet in Bear Lake.[34] Approvals for the applications are pending and analyses of the potential impacts on Great Salt Lake water levels are not readily available.

Municipal Water Reuse

In order to discharge into Great Salt Lake, wastewater treatment plants have to meet water quality standards – although these standards are lower than if the discharge was occurring into an upstream freshwater system. Calculations by Bioeconomics (2012) based on information from the "Statewide Nutrient Removal Cost Impact Study"[35] are that the costs of meeting higher water quality standards for the 12 publicly owned treatment works (POTWs) that discharge into the lake would be $169 million to $964 million over 20 years (2010 dollars). Unless a new standard was implemented that required more stringent treatment, declines in lake levels at Great Salt Lake are not expected to impose these costs to the POTWs.[36]

Although POTWs rely on Great Salt Lake as a discharge point, Great Salt Lake also relies on the POTWs for water flow. Average annual discharges to Great Salt Lake by the POTWs are approximately 250,000 to 275,000 acre-feet per year,[37] approximately 10 percent of average annual inflows based on the total in Table 2.

Water conservation and water reuse are beginning to be implemented in many of the cities and towns that discharge into Great Salt Lake. If more of these conservation measures are implemented in the future, less water would flow to Great Salt Lake. Farmington Bay would be

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[31] SWCA Environmental Consultants. (2017). *Water for Great Salt Lake*. Prepared for Great Salt Lake Advisory Council. September.

[32] Wurtsbaugh, W., Miller, C., Null, S., Wilcock, P., Hahnenberger, M., & Howe, F. (2016). Impacts of water development on Great Salt Lake and the Wasatch Front. *Watershed Sciences Faculty Publications*. Paper 875.

[33] Utah Department of Natural Resources, Water Resources. (2014). *Bear River Development Project*. Retrieved from https://deq.utah.gov/legacy/great-salt-lake-advisory-council/docs/2014/10Oct/BearRiverPipelineProject.pdf

[34] Utah Water Right Application 23-3972 https://www.waterrights.utah.gov/asp_apps/wrprint/wrprint.asp?wrnum=23-3972

[35] CH2MHILL. (2010). *Statewide Nutrient Removal Cost Impact Study*. Report for the Utah Division of Water Quality. SLC, Utah.

[36] Leland Myers, Central Davis Sewer District (retired), personal communication on May 15, 2019.

[37] Leland Myers, Central Davis Sewer District (retired), personal communication on May 15, 2019.

most impacted from the loss of inflows, since this is where the highest population centers are, and thus this area receives a larger amount of municipal discharge. This change would also reduce overall lake levels.

2.4.2 Climate Change

Climatic fluctuations have historically influenced the level of Great Salt Lake, including the flooding in the mid-1980s and recent drought conditions – however, climate change has not been identified as a major contributor to past declines in water levels.[38] Research by the U.S. Forest Service investigating how climate change could affect the Wasatch Mountain Range in the future projects that "there is a high degree of confidence that temperatures in all seasons will continue to increase, there is less confidence with projected changes in precipitation"(p.14).[39]

Estimates for the Wasatch Front, along with other Southwestern U.S. mountain ranges, is that snowmelt could occur 20 to 40 days earlier under future climate scenarios.[40] Some scientific projections suggest increases in precipitation at lower elevations with climate change,[41] but these increases may not offset the losses in water to Great Salt Lake from the reduced snowpack and increased evaporation from increased temperatures. Research projecting the exact magnitude of water level declines due to climate change have not yet been finalized, although some are in progress, so the extent of water loss to Great Salt Lake under future climate conditions is unknown.

2.5 Water Rights

There is currently no formally implemented policy to maintain Great Salt Lake water levels at any particular elevation range. The lake itself has 13 perfected water rights to divert water, all owned by mineral extraction companies.[42] These thirteen rights entitle the holders to divert 416,776 acre-feet of water per year, but due to economic limitations, climatic conditions, and the available evaporative surface, only 77,600 to 338,000 acre-feet per year are believed to be

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[38] Wine, M. L., Null, S., DeRose, R. J., & Wurtsbaugh, W. A. (2019). Climatization—negligent attribution of Great Salt Lake desiccation: A comment on Meng. *Climate*.

[39] Rice, J., Bardsley, T., Gomben, P., Bambrough, D., Weems, S., Leahy, S., ... & Joyce, L. A. (2017). *Assessment of watershed vulnerability to climate change for the Uinta-Wasatch-Cache and Ashley National Forests, Utah*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[40] Rauscher, S. A., Pal, J. S., Diffenbaugh, N. S., & Benedetti, M. M. (2008). Future changes in snowmelt-driven runoff timing over the western US. *Geophysical Research Letters*, 35(16).

[41] Rice, J., Bardsley, T., Gomben, P., Bambrough, D., Weems, S., Leahy, S., ... & Joyce, L. A. (2017). *Assessment of watershed vulnerability to climate change for the Uinta-Wasatch-Cache and Ashley National Forests, Utah*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[42] Utah Department of Natural Resources, Utah Division of Forestry, Fire & State Lands. (2013). *Final Great Salt Lake Comprehensive Management Plan*. Retrieved from https://ffsl.utah.gov/index.php/state-lands/great-salt-lake/great-salt-lake-plans

diverted.[43] As of 2013, an additional eight water rights were approved but not yet developed by mineral extractors, amounting to an additional 456,000 to 787,000 acre-feet of water per year if fully developed for extraction purposes.[44] Most of the water diverted from Great Salt Lake by the mineral extractors is consumed by evaporation. Due to the nature and makeup of Utah's water rights policy areas, the water rights held by the extraction industries for Great Salt Lake generally have not been allowed to make a call on upstream water rights, even if they have an earlier priority date.[45]

Many other surface water rights exist within the Great Salt Lake Basin, on the three major rivers, and their tributaries. With the exception of the Bear River Basin and the West Desert, all other surface water is considered fully appropriated.[46] Adjacent to the fresher east side bays of the Great Salt Lake, some of the duck clubs have surface water rights to freshwater to create hunting ponds. Utah Division of Wildlife Resources also holds water rights in conjunction with the operation of some of its waterfowl management areas around the lake.

Surface water rights in the Wasatch Front are fed primarily from snowmelt, with snow essentially acting as storage for the region.[47] Another impact of water level declines of Great Salt Lake on water rights is declines in snowpack and earlier snowmelt, since snowpack provides a large portion of water to the Wasatch Front. Changing in the amount and timing of water stored in snowpack would impact water rights along the Wasatch Front.

2.6 Land Ownership and Land Use

Many different entities own land in and around Great Salt Lake. Figure 13 displays the land ownership by type around the lake. The distribution of land ownership provides information on how different landowners would be affected if the lakeshore retreats. Federally, the U.S. Fish and Wildlife Service operates and manages the Bear River Migratory Bird Refuge. The Bureau of Land Management (BLM) owns large portions of land on the western side of Great Salt Lake. Additionally, the Department of Defense operates the Hill Air Force Range located on the western side of Great Salt Lake.

At the state level, the Utah Division of State Parks and Recreation (DSPR) manages Antelope Island, Willard Bay, and Great Salt Lake Marina. DSPR also coordinates search-and-rescue and boating enforcement on the lake. Other state agencies are involved with the management of the lake, including the Division of Water Rights (DWRi) which regulates water rights, the Division

[43] Utah Department of Natural Resources, Utah Division of Forestry, Fire & State Lands. (2013). Final Great Salt Lake Comprehensive Management Plan. Retrieved from https://ffsl.utah.gov/index.php/state-lands/great-salt-lake/great-salt-lake-plans

[44] Ibid.

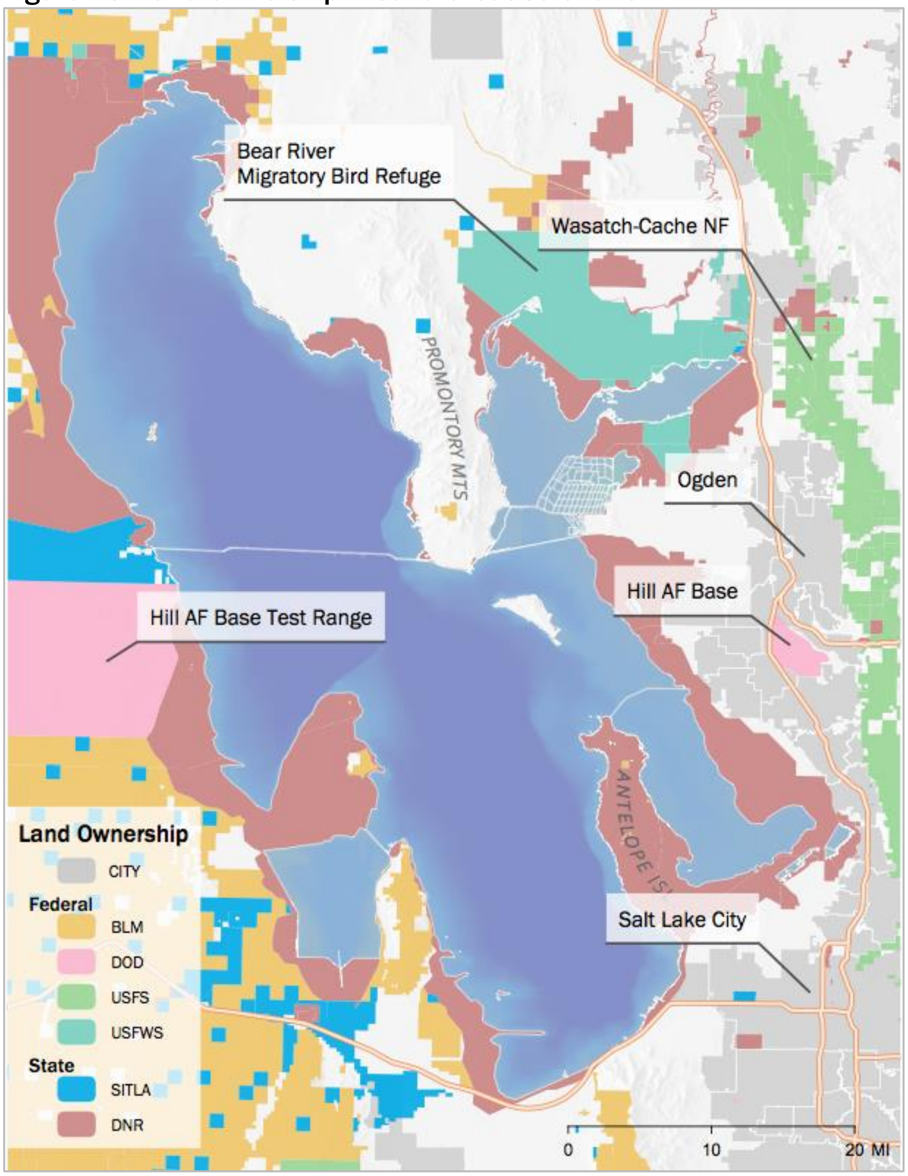
[45] Joe Havasi, Compass Minerals, personal communication on May 17, 2019.

[46] Utah Department of Natural Resources, Utah Division of Forestry, Fire & State Lands. (2013). *Final Great Salt Lake Comprehensive Management Plan*. Retrieved from https://ffsl.utah.gov/index.php/state-lands/great-salt-lake/great-salt-lake-plans

[47] Tom Ward, Director of Public Utilities for the City of Sandy, personal communication on June 19, 2019.

of Wildlife Resources (DWR) which manages wildlife and six state waterfowl management areas around Great Salt Lake, and Utah Division of Forestry, Fire & State Lands which manages activities on sovereign lands and regulates mineral extraction activities on state sovereign lands. The majority of the land surrounding the lake is private, including mineral extraction operations, duck clubs, and privately held reserves, such as The Nature Conservancy's Great Salt Lake Shorelands Preserve and Audubon Gillmor Sanctuary.

Figure 13. Land Ownership Around Great Salt Lake



Source: Created by ECONorthwest

2.7 Regional Economic Characteristics

The regional economic characteristics for the counties in the Great Salt Lake Basin informs the characteristics of the people who would be affected by declines in water levels at Great Salt Lake. The counties included in the Great Salt Lake Basin for this analysis are Box Elder, Cache, Rich, Weber, Davis, Morgan, Summit, Salt Lake, Wasatch, Utah, and Toole counties. The population within the Great Salt Lake Basin has increased in the past two decades by an average of 77.4 percent since 1990. Table 4 displays the change in population from 1990 to 2017.

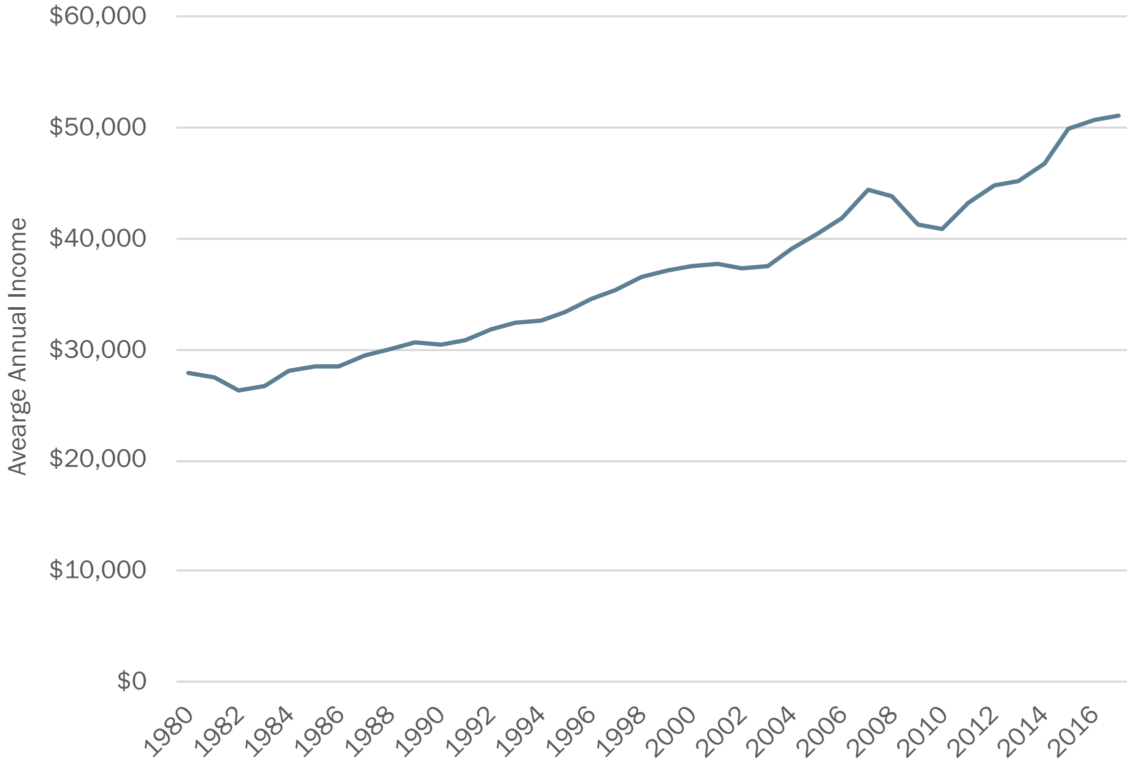
Table 4. Population of Communities Around Great Salt Lake (1990, 2000, 2010, and 2017)

Community	1990	2000	2010	2017	Change 2010-2017	Change 1990-2017
Box Elder	36,509	42,863	50,147	54,079	7.8%	48.1%
Cache	70,560	91,849	113,365	124,438	9.8%	76.4%
Davis	188,471	240,162	307,978	347,637	12.9%	84.5%
Salt Lake	728,298	902,843	1,033,172	1,135,649	9.9%	55.9%
Tooele	26,581	41,548	58,517	67,456	15.3%	153.8%
Weber	158,673	197,591	232,214	251,769	8.4%	58.7%
Rich	1,728	1,953	2,251	2,391	6.2%	38.4%
Morgan	5,561	7,171	9,527	11,873	24.6%	113.5%
Summit	15,690	30,012	36,465	41,106	12.7%	162.0%
Wasatch	10,134	15,427	23,629	32,106	35.9%	216.8%
Utah County	265,766	371,798	520,118	606,425	16.6%	128.2%
Total	**1,507,971**	**1,943,217**	**2,387,383**	**2,674,929**	**12.0%**	**77.4%**

Source: Created by ECONorthwest with data from Utah Department of Workforce Services. (2019). Available at https://jobs.utah.gov/wi/data/library/firm/index.html

Per capita incomes have been on the rise in the counties in the Great Salt Lake Basin since 1980 (Figure 14). The Great Recession that began in 2008 reduced the average real per capita income for all the counties surrounding Great Salt Lake, but recent economic growth has put the real per capita income level back at the trendline trajectory. This increased real per capita income trend suggests that there will be future increases in demand from higher income levels that may create scarcity for goods and services in the area, including those requiring water as an input.

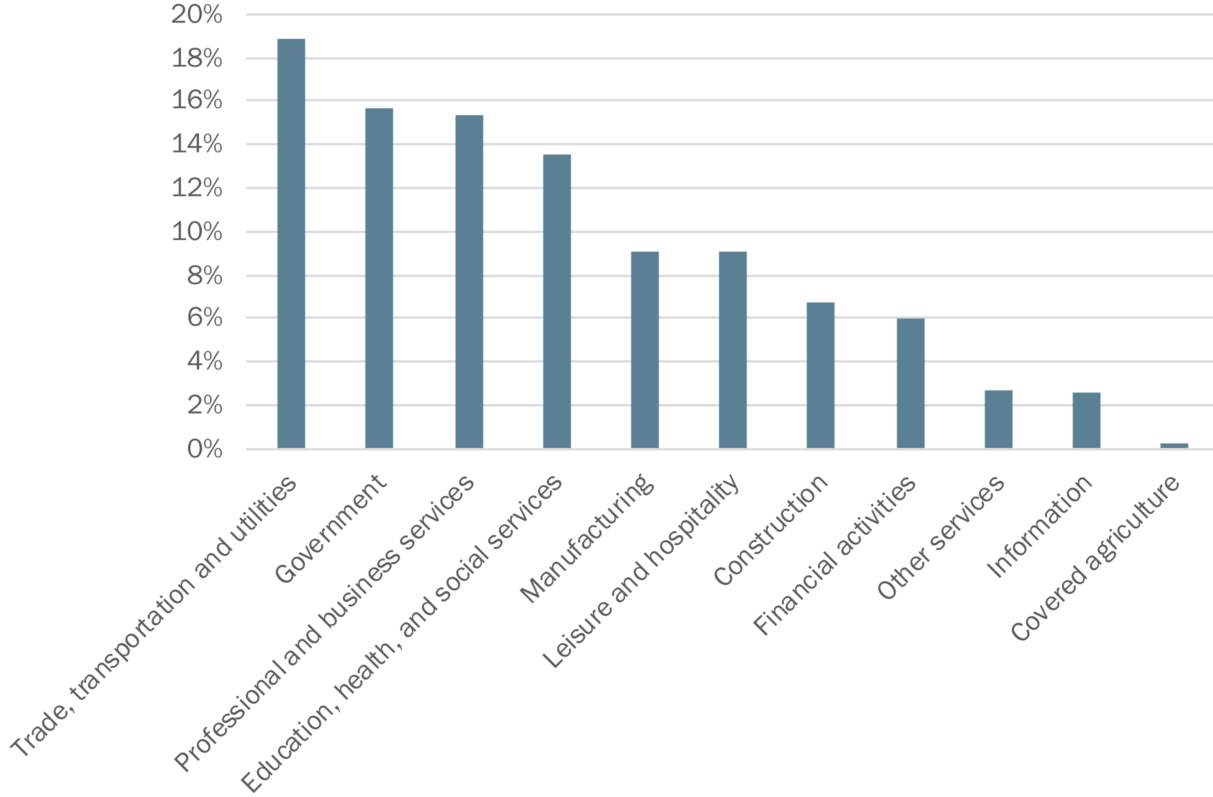
Figure 14. Average Real Per Capita Personal Income of Counties Near Great Salt Lake (1980-2017)



Source: Created by ECONorthwest, with data from Bureau of Economic Analysis (2019)
Note: All dollar estimates are in thousands of dollars, adjusted for inflation as of May 2019. The counties included in the Great Salt Lake Basin are Box Elder, Cache, Rich, Weber, Davis, Morgan, Summit, Salt Lake, Wasatch, Utah, and Toole counties.

There are similar employment trends by industry in the counties around Great Salt Lake. The highest share of employment in these counties is in the trade, transportation and utilities, and government sectors. Table 5 displays the proportion of non-farm employment for the counties within the Great Salt Lake Basin.

Table 5. Proportion of Total Non-Farm Employment by Industry for Counties in Great Salt Lake Basin (2018)

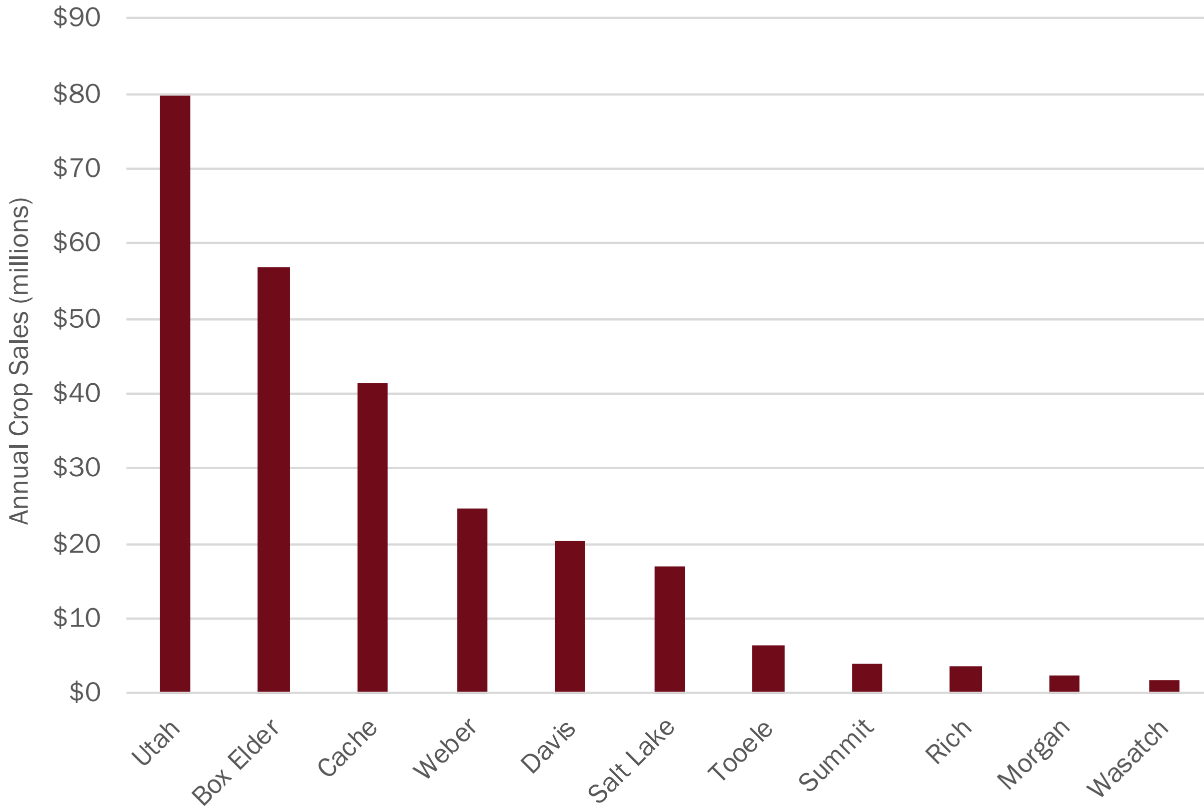


Source: Created by ECONorthwest, with data from Utah Department of Workforce Services. (2019). Available at https://jobs.utah.gov/wi/data/library/firm/index.html
Note: The counties included in the Great Salt Lake Basin include Box Elder, Cache, Rich, Weber, Davis, Morgan, Summit, Salt Lake, Wasatch, Utah, and Toole counties.

In the Great Salt Lake Basin, agricultural sales as a percent of the state total are largest for Utah and Box Elder counties (Figure 15). Hay to support Utah's large cattle and dairy industries is the primary agricultural product grown on farms, followed by barley. The rental value of irrigated cropland in Box Elder County is $115 per acre compared with only $39.50 for non-irrigated cropland (as of 2016).[48] This difference illustrates the value of water for crop production in Utah.

[48] Utah Department of Agriculture and Food. (2017). *Utah Agriculture Statistics and Utah Department of Agriculture and Food Annual Report.*

Figure 15. Agricultural Sales as Percent of State Total (2017)

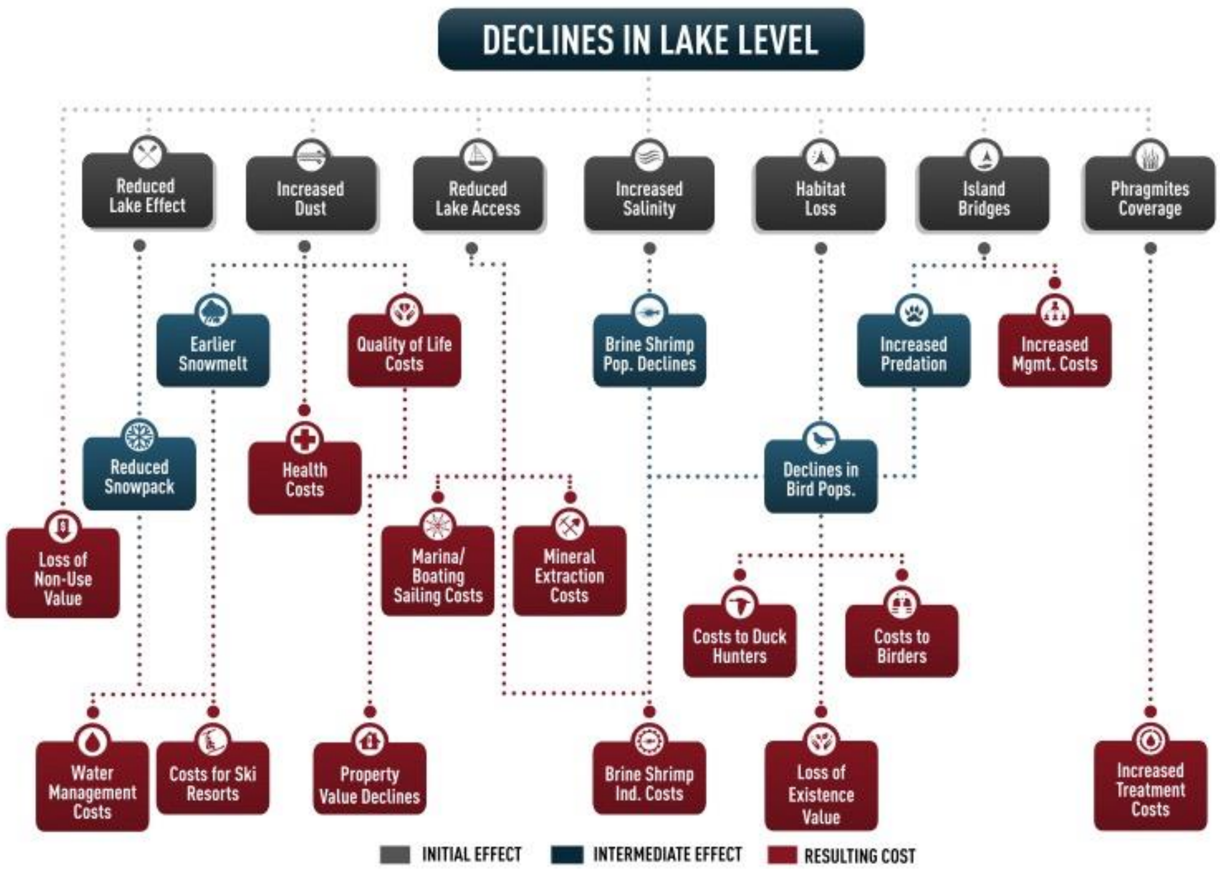


Source: Created by ECONorthwest with data from U.S. Department of Agriculture, National Agricultural Statistics Service, Quick Stats: https://quickstats.nass.usda.gov/

3 Costs of a Declining Great Salt Lake

The consequences of water level declines in Great Salt Lake may arise via multiple pathways, many of which have compounding effects that create other costs. Based on the review conducted for this report, the costs expected to occur with declines in water levels at Great Salt Lake are summarized in Figure 16. The magnitude of effects depends on the additional consumptive uses of water in the upstream three river basins, particularly from water diversions on the Bear River. Future climate change may also contribute to future lake level declines. Potential loss of municipal wastewater discharge due to reuse and conservation programs is another potential driver of declining Great Salt Lake water levels. The water elevation at Great Salt Lake can fluctuate seasonally and significantly year to year. Major wet and dry periods can have lingering impacts for years, meaning that costs of declining lake levels may not correspond directly with annual inflows.

Figure 16. Pathways of Cost Creation from Declines in Water Level at Great Salt Lake



Source: Created by ECONorthwest

As presented in Figure 16 there are seven primary detrimental changes resulting from the lost surface area, volume, and elevation of Great Salt Lake. These changes and their mechanisms are:

1. **Habitat Loss**: As Great Salt Lake dries and the surface area declines, the available habitat for water birds would diminish in quantity and degrade in quality. Additionally, the main body of Great Salt Lake will become more disconnected from the freshwater inputs where freshwater wetlands provide food, shelter, and drinking water for birds and other wildlife. If lake levels are reduced, groundwater recharge in shallow areas may decrease, a phenomenon that may lead to decreased habitat functions, increased invasive plant species, and a drier lake bed over a sustained period.
2. **Increased Salinity/Changes to Water Quality**: As surface area and lake volume decline there is an increase in salinity levels (see Figure 11 for the relationship between elevation and salinity). Salinity affects the ecosystem of Great Salt Lake, including brine shrimp. Increased salinity also reduces the amount of lake effect precipitation and snow.
3. **Loss of Access**: The infrastructure in and around Great Salt Lake is built to accommodate historic lake levels. As water levels of Great Salt Lake decline, sites and activities that were previously accessible at higher water levels may become more difficult to access or inaccessible by means of watercraft.
4. **Increased Dust**: The drying of lakes systems has resulted in large increases in particulate matter (PM) and other air pollutants. For example, the site of the former Owens Lake in California is the largest source of PM_{10} pollution in the United States. Increased dust also affects the rate of snow melt in nearby mountains (albedo effect).
5. **Islands Accessible by Mainland (Island Bridges)**: Lake level declines could allow land bridges to form to the islands at Great Salt Lake. This increased access could increase predation and create opportunities for people and other wildlife to cross between the shore and the island.
6. **Phragmites Coverage**: The invasive, noxious weed known as phragmites outcompetes most native species in uncovered mudflats. These types of habitats could be exposed at lower lake levels. Phragmites also consumes large amounts of water, perpetuating water level losses.
7. **Reduction of Lake Effect:** Lake effect occurs when cold air moves across warmer lake bodies and the air collects water vapor which is later deposited as rain or snow. Reduction of lake effect and reduced snowpack would likely impact the ski industry and water managers in the Great Salt Lake Basin, including water right holders along the Wasatch Front.
8. **Loss of Non-Use Value**: People who do not directly use Great Salt Lake still value the resource's existence, and this value could be lost with declines in water levels. Non-use value can be measured by the amount people would be willing to pay to preserve Great Salt Lake.

If and when these changes occur due to water declines in Great Salt Lake they would create costs affecting businesses, health, recreation, ecosystem services, mitigation expenditures, as well as broader community and cultural values. We discuss, characterize, and quantify where possible each of these resulting costs in this section of the report. The magnitude of the costs depends on the extent of water level declines, so obtaining costs is sensitive to the future condition of Great Salt Lake. The goal of this report is to inform the potential costs of declines in water levels at Great Salt Lake, so to capture the full potential costs we assume declines in lake levels representing the largest potential costs. Past research on the value created by Great Salt Lake informs the potential loss from a drying Great Salt Lake, so this section begins with a summary of those values.

3.1 Past Efforts to Quantify the Value of Great Salt Lake

Multiple efforts over the past decade have been undertaken to understand more about the impacts of a drying Great Salt Lake. The economic contribution to Utah's economy that the lake supports partially determines the economic value of the lake. In 2002, the Utah Department of Natural Resources released a special publication "The Great Salt Lake: An Overview of Change" which included an economics chapter discussing the industrial and recreational economic activity at Great Salt Lake.[49] In 2012, the Great Salt Lake Advisory Council commissioned a report to estimate the economic significance of Great Salt Lake.[50] Our report expands on the findings of the 2012 report by inverting the scenario to instead consider the potential losses that would be created with a drying Great Salt Lake. This section summarizes the findings of the 2012 report, then presents our analysis and findings of the costs of a drying Great Salt Lake.

3.1.1 Bioeconomics 2012 Report

The 2012 report by Bioeconomics, "Economic Significance of the Great Salt Lake to the State of Utah", calculates the regional economic significance of business activities associated with Great Salt Lake as $1.32 billion in total annual economic output (2010 dollars).[51] This value is for only industry (minerals), aquaculture, and recreational expenditures associated with Great Salt Lake. In addition, this report estimated the "net economic value" of Great Salt Lake in 2010 dollars for general recreation ($26.3 million), waterfowl hunting ($9.6 million), publicly-owned treatment works discharges ($10.3 to $58.9 million), and other industrial/municipal discharges (dollar amount not estimated). Table 6 describes the uses of Great Salt Lake included in the $1.32 billion estimate of the economic significance.

[49] Isaacson, A., Hachman, F., and Robson, R. (2002). "The Economics of the Great Salt Lake" in Great Salt Lake: an Overview of Change J.W. Gwynn ed. DNR Special Publication, Utah Geological Survey.

[50] Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.

[51] Updated to 2019 values this figure is equivalent to $1.56 billion as of March 2019, using the BLS CPI Inflation Calculator, available at https://data.bls.gov/cgi-bin/cpicalc.pl.

Table 6: Uses of Great Salt Lake Used to Calculate Economic Significance

Lake Harvest	Minerals	Recreation	Waste Assimilation	Adjacent Ecosystem Services
Brine Shrimp Eggs	Magnesium	Birdwatching	Public Sewage Treatment Effluent	Government (military, county)
	Titanium	Waterfowl Hunting	Industrial Effluent Dilution	Grazing Leases
	Salt	Boating		Oil & Gas Drilling
	Potash	Swimming		Utility Right of Way

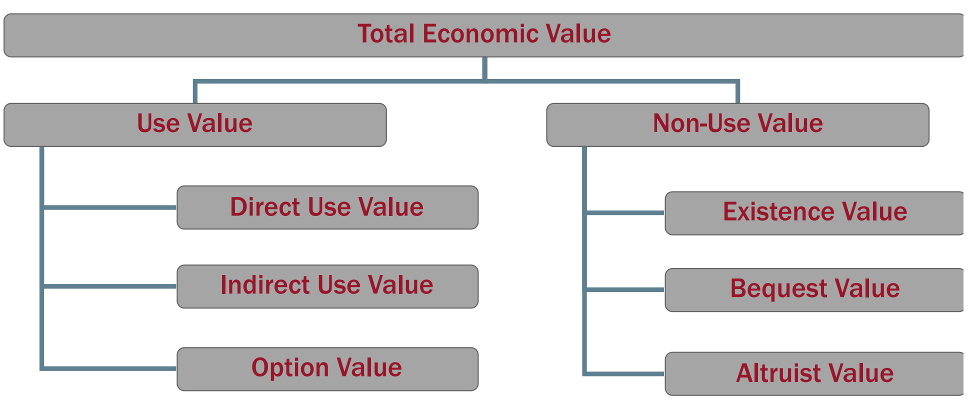
Source: Created by ECONorthwest with information from Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.

The Bioeconomics report estimates the economic significance of Great Salt Lake. This report is different because it instead estimates the cost of future water level declines at Great Salt Lake. Therefore, the two reports focus on different research questions, and do not have directly comparable results. However, the results are complementary and elements of the Bioeconomics report are applied in this report where appropriate.

3.2 Total Economic Value of Great Salt Lake

The total economic value provided by Great Salt Lake consists of both use values and non-use values (Figure 17). Losses of total economic value inform the potential costs of declining water levels at Great Salt Lake. Therefore, understanding the components of total economic value and how the values may change with lower lake levels is needed to discern the potential costs of a drying Great Salt Lake.

Figure 17. Components of Total Economic Value



Source: ECONorthwest

Total economic value for environmental resources can be further divided into two categories, use value and non-use value. The definitions of these sub-categories are as follows:

- **Use Value**: This value is derived from actual use of Great Salt Lake. It can be calculated and monetized by estimating the extent of use and corresponding value of the use.
    - Direct Use Value: These values include both consumptive and non-consumptive uses of Great Salt Lake, including mineral extraction, brine shrimp industry,

recreation, education, habitat provisioning, and other functions that occur from use of Great Salt Lake.

  - Indirect Use Value: Values from activities that do not directly occur at Great Salt Lake are included in this category, for example, lake effect, albedo, dust, and other regulating and provisioning services that the lake provides.
  - Option Value: The value of future use of Great Salt Lake.

- **Non-use Value**: These values are generally defined and measured as a dollar amount that individuals are willing to pay to protect or enhance an environmental resource, regardless of whether they ever plan on visiting or directly utilizing that resource. These values are sometimes referred to as passive use values.
  - Existence Value: The value derived from knowing that a species or ecosystem exists.
  - Bequest Value: The value derived from knowing that future generations will have access to nature's benefits.
  - Altruist Value: The value derived from knowing that other people (current generation) have access to nature's benefits.

Use values are discussed in the proceeding sections of this report, representing the value that is derived from actual use of Great Salt Lake. Non-use values for Great Salt Lake apply to both the lake itself, as well as the species the lake supports, including migratory birds. Non-use values are discussed in Section 3.3 for migratory birds and Section 3.10 more generally.

3.3 Wildlife and Habitat Costs

Approximately 85 percent of Utah's existing wetlands are located around Great Salt Lake.[52] A comprehensive meta-analysis by De Groot et al. (2012) of 168 studies valuing ecosystem services by habitat type found a median value for inland wetlands of $20,874 per hectare per year or $8,447 per acre per year (2019 dollars).[53] The minimum value per acre for wetlands from this study is $1,545 per acre per year. The median annual value of services from this study for lakes is $2,016 per acre per year, and the minimum value for lakes is $740 per acre per year.

Although all of Great Salt Lake may not be considered a wetland, the lake serves similar functions as a wetland, so a wetland value elucidates the total value of the ecosystem. The median wetland value applied to the full 1,700 square miles of the lake (1.09 million acres) equates to $9.2 billion per year. Given the vegetation composition, proximity, and use by people and wildlife it is appropriate to consider these values as an upper bound. The minimum

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[52] Frank, M., Marty, J., Rohal, C., Downard, R., Endter-Wada, J., Kettenring, K., Larese-Casanova, M. (2016). Water Rights for Wetlands in the Bear River Delta. Utah State University. Retrieved from https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1806&context=extension_curall

[53] De Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., ... & Hussain, S. (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services*, 1(1), 50-61.

wetland value would equate to $1.7 billion annually, and the lake values correspond to $800 million to $2.2 billion annually.

Based on these estimates that were developed at other sites, we expect a range of annual ecosystem service values from Great Salt Lake of between $800 million to $9.2 billion per year. These ranges are provided as context for the total value of the lake ecosystem, based on prior studies. As the lake continues to decline in size, increasing scarcity likely drives the value of Great Salt Lake from a habitat and ecosystem service perspective closer to the higher value.

To understand if this range of $800 million to $9.2 billion in average annual value of ecosystem services is appropriate for Great Salt Lake as a measure of valuing the cost of lake level declines we investigate each of the components of the ecosystem services. The ecosystem services provided by the lake are the ecological functions the lake provides that people obtain value from. Relevant ecosystem services potentially provided by Great Salt Lake in the context of this potential valuation are provided in Table 7 based on the framework by The Economics of Ecosystems and Biodiversity (TEEB). To calculate the potential costs of water level declines in Great Salt Lake we perform a similar assessment to determine how these ecosystem services may change and the resulting costs.

Table 7. Ecosystem Services Provided by Great Salt Lake

Provisioning Services	Regulating Services	Habitat Services	Cultural Services
Food	Climate Regulation	Habitats	Recreation and mental and physical health
Raw Materials	Regulation of Water Flows	Maintenance of Genetic Diversity	Tourism
Medicinal Resources	Wastewater Treatment		Aesthetic appreciation and inspiration for culture, art, and design
	Pollination & Pest Predation		Spiritual experience and sense of place

Source: Created by ECONorthwest with information from The Economics of Ecosystems and Biodiversity available at: http://www.teebweb.org/resources/ecosystem-services/

Provisioning services provided by Great Salt Lake are primarily reflected in the values of industrial activity at Great Salt Lake, including the brine shrimp and mineral extraction industries. The climate regulation from the lake includes the lake effect precipitation. Cultural services are discussed based on potential recreation costs and community costs. Great Salt Lake also provides valuable regulating services and habitat services, as defined in Table 7.

3.3.1 Loss of Habitat Services

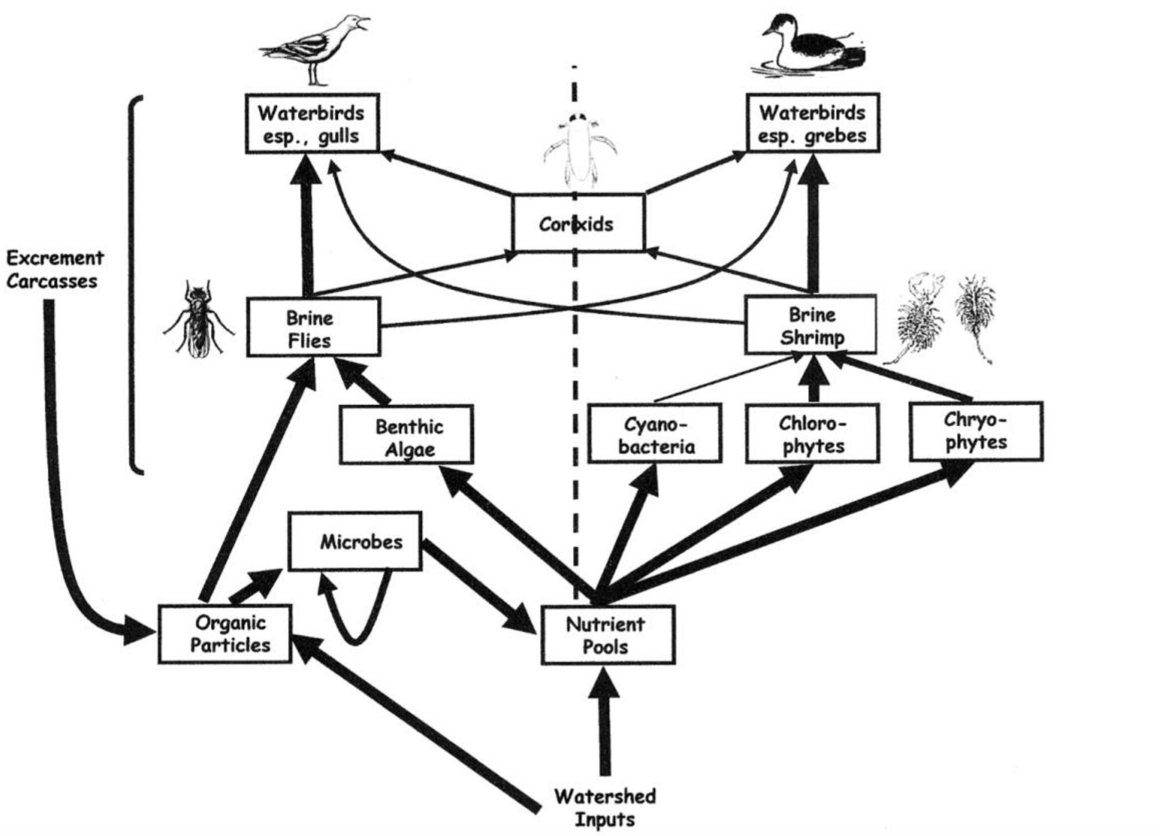
Primary Great Salt Lake aquatic habitats consist of open fresh water, brackish water, saline water, mudflats, playas, fresh marsh, and brackish marsh, including wet meadows and Great Salt Lake islands.[54] A decline in lake levels could lead to a reduction in some habitats, though

[54] Utah Department of Natural Resources. (2002). *Great Salt Lake Waterbird Survey Five-Year Report (1997-2001)*. Retrieved from https://wildlife.utah.gov/gsl/gsl_ws_report/gsl_ws_report.pdf

mudflats may increase, and there may be a disconnection to other habitat types. These factors can make remaining habitat less appealing to various species.

Within the Great Salt Lake open water habitat, there are relationships between nutrient levels that suggest the ecosystem is more complex than previously understood and major changes toward increased salinity would challenge its balance. The basic ecosystem energy flow depicted in the ecosystem food web highlights the importance of phytoplankton, that are eaten by brine shrimp, that are then eaten by birds and insects (Figure 18). More recent research has identified microbialites as the key to primary production and energy transfer in the lake, which sets the foundation of the food web.[55]

Figure 18. Ecosystem Feedbacks within Great Salt Lake



Source: Belovsky, G. E., Stephens, D., Perschon, C., Birdsey, P., Paul, D., Naftz, D., ... Allen, D. v. (2011). The Great Salt Lake Ecosystem (Utah, USA): Long term data and a structural equation approach. *Ecosphere*, 2(3).

Brine Shrimp: Brine shrimp are an essential food source for millions of birds that use Great Salt Lake as a staging or stopover site while molting and are important species in the food ecosystem. Brine shrimp populations are generally driven by salinity and nutrient availability.

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[55] Baxter, B.K. and Zalar, P. (2019). The Extremophiles of Great Salt Lake: Complex Microbiology in a Dynamic Hypersaline Ecosystem. *Ecosystems in Extreme Environments*. Seckbach J, and Rampelotto P.H. (eds).Elsevier, Netherlands.

Salinity affects population growth and long-term population health. Salinities lower than 10 percent allow for shifts in macroinvertebrate communities, whereby predators, such as rotifers, exert grazing pressure that controls and decreases the brine shrimp population. Nitrogen availability determines the abundance of phytoplankton, the food source for brine shrimp.[56] While brine shrimp can tolerate salinities between 5 percent and 26 percent,[57] salinities greater than 16 percent are physiologically stressful for brine shrimp, resulting in declines in reproductive success.[58]

As Great Salt Lake water levels decline, salinity will increase (Figure 11), reaching above the 16 percent threshold in the majority of the lake. This change could disrupt or even shut-down the brine shrimp industry. The resulting high salinity force the brine shrimp population into diapause (a dormant life stage when development ceases).[59] Loss of a robust brine shrimp population also would disrupt the food web of Great Salt Lake for some bird species, and possibly pose serious population risk to species such as Eared Grebes.[60]

Brine Flies: Brine flies are another important food source for migratory birds. One of the brine fly species at Great Salt Lake tolerate salinities of up to 26 percent.[61] Brine fly larvae are found primarily on microbialites and mud surfaces of Great Salt Lake.[62] Microbialites locations appear to correlate with Great Salt Lake faults on the south side of Great Salt Lake, west of Antelope Island, west of Promontory Point, and north of Carrington Island. Muddy substrates are typically found on the eastern side of Great Salt Lake where tributaries discharge into brackish bays. Microbialites generally occur between 1 meter and 2.5 meters of water depth.

Changes in salinity affect the microbial communities of microbialites. The optimal salinity for these communities is greater than 17 percent.[63] Once the lake levels drop low enough to expose them to air, the microbial community cannot survive and would no longer contribute to the food web. Exposure and death of microbialites communities would also reduce habitat for the larval stage of brine flies, although they may be able to partially shift to more salt tolerant

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[56] Belovsky, G. E., Stephens, D., Perschon, C., Birdsey, P., Paul, D., Naftz, D., … Allen, D. v. (2011). The Great Salt Lake Ecosystem (Utah, USA): Long term data and a structural equation approach. *Ecosphere*, 2(3).

[57] Ibid.

[58] Bosteel, T. (2018). *Salinity Effect on Great Salt Lake Brine Shrimp: General Overview*. Presentation at the Great Salt Lake Issues Forum, Salt Lake City, Utah. May. Retrieved from https://www.fogsl.org/images/Thomas_Bosteels_Salinity_Effect_on_Great_Salt_Lake_Brine_Shrimp.pdf.

[59] Podrabsky, J. E., & Hand, S. C. (2015). Physiological strategies during animal diapause: lessons from brine shrimp and annual killifish. *Journal of Experimental Biology*, 218(12), 1897-1906.

[60] Caudell, J. N., & Conover, M. R. (2006). Energy content and digestibility of brine shrimp (Artemia franciscana) and other prey items of eared grebes (Podiceps nigricollis) on the Great Salt Lake, Utah. *Biological Conservation*, 130(2), 251-254.

[61] Brown, P. (2018). *Salinity tolerance of Artemia and Ephydra: uncertainty and discrepancies*. Presentation at the Great Salt Lake Issues Forum, Salt Lake City, Utah. May.

[62] Roberts, A. J. (2013). Avian diets in a saline ecosystem: Great Salt Lake, Utah, USA. *Human-Wildlife Interactions*, 7(1).

[63] Bonnie Baxter, Great Salt Lake Institute, Westminster College, personal communication on February 25, 2019.

species. Habitat is already affected by lower lake levels in bays on east side of Great Salt Lake where some of the microbialites are exposed.

Macroinvertebrates of Associated Wetlands: The associated wetlands of Great Salt Lake are vast and diverse, providing a variety of habitat and forage for waterbirds (including shorebirds, wading birds and waterfowl). In addition to providing shelter and resting habitat, there is a diverse and robust macroinvertebrate community that provide an important food base for waterbirds. Not only are there brine shrimp and brine flies in the more saline wetlands, chironomid and corixid species are very common in wetlands of varying salinity and are favored by shorebirds although there are many other species from which to forage, since shorebirds tend to be opportunistic in their feeding behavior.[64]

Birds: Great Salt Lake is a critical refuge point for millions of migratory birds on the Pacific Flyway coming from as far north as the Arctic tundra and as far south as Chile. Approximately 7.5 million to 10 million birds from over 300 species visit Great Salt Lake each year to feed and/or reproduce. This estimate does not include non-waterbird species, that can be quite prolific around Great Salt Lake, such as swallows, blackbirds, starlings, wrens, sparrows, and rails.[65] These migratory birds that rely on Great Salt Lake include:

- nearly 4.7 million Eared grebes, which represents approximately 80 percent of the North American population,
- over 500,000 Wilson's Phalaropes, approximately one-third of the global population,[66]
- over 250,000 American Avocets,[67] estimated as 50 percent of the global population,[68] and
- over 23,000 breeding White-faced Ibis using Great Salt Lake wetlands, which is one of the largest breeding population.[69]

Great Salt Lake offers unique amenities that support the large quantity and diversity of species which feed, rest, breed, and nest in and along Great Salt Lake. Great Salt Lake has been designated as a Hemispheric Reserve in the Western Hemisphere Shorebird Reserve Network. Figure 19 illustrates distances traveled between Great Salt Lake and other habitat locations by

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[64] Cavitt, J.F. (2006). Productivity and foraging ecology of two co-existing shorebird species breeding at Great Salt Lake, UT: 2005 – 2006 Report. *Avian Ecology Laboratory Technical Report*. AEL 06-03. Weber State University.

[65] John Neill, Utah Division of Wildlife Resources, Great Salt Lake Ecosystem Program, personal communication June 17, 2019.

[66] Jehl, J. R., Jr. (1988). Biology of the Eared Grebe and Wilson's Phalarope in the nonbreeding season: a study of adaptations to saline lakes. *Studies in Avian Biology* No. 12, 74 pp.

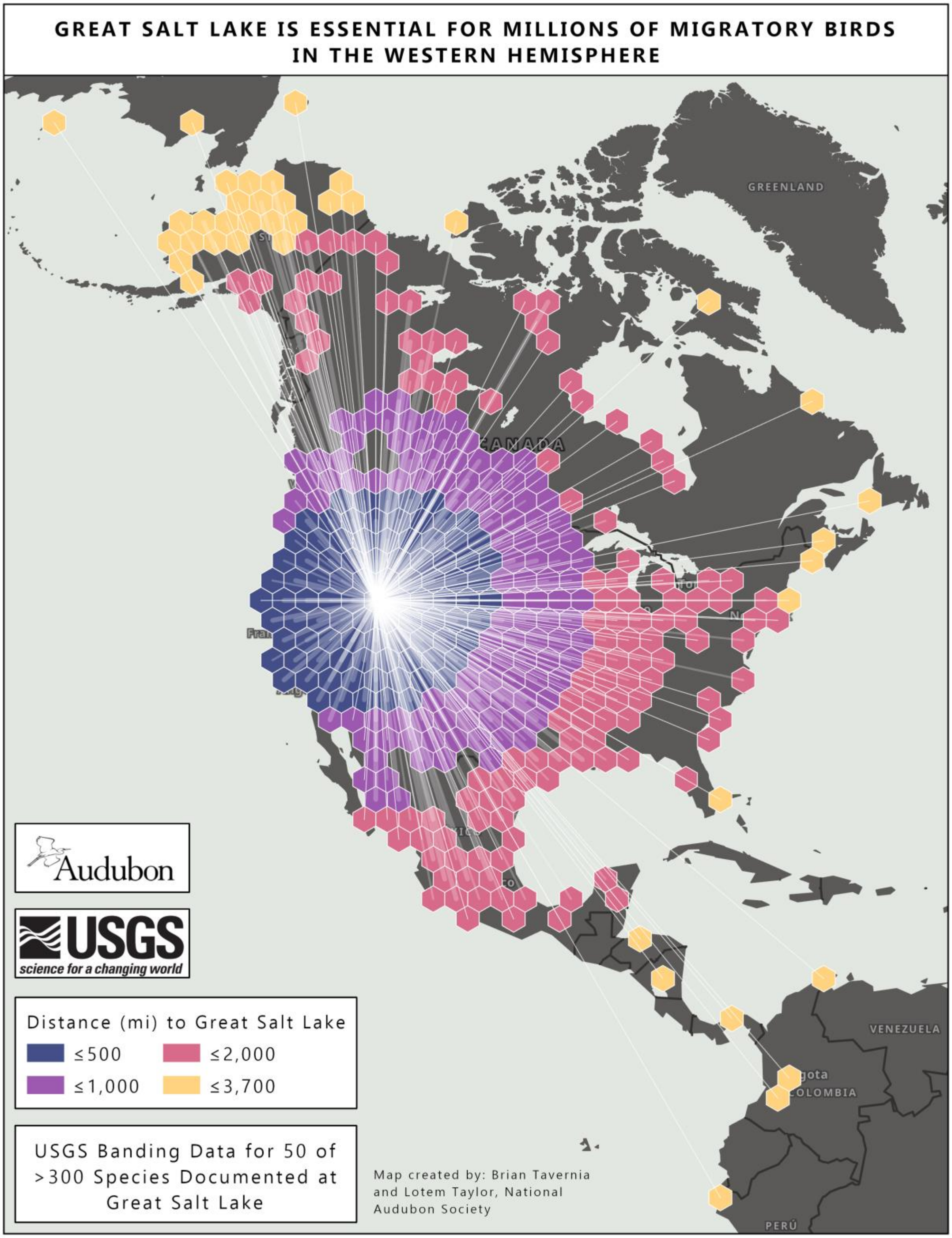
[67] Shuford, W. D., Roy, V. L., Page, G. W., and Paul, D. S. (1994). *A comprehensive survey of shorebirds in wetlands at Great Salt Lake, Utah, 10-11 August 1994*. Contribution No. 655 of Point Reyes Bird Observatory.

[68] Weber State University. (2014). *WSU Students, Professor First to Track Bird Species*. Retrieved from https://www.weber.edu/WSUToday/061714_ProfessorFirsttoTrackBird.html

[69] Cavitt, J. F., Jones, S. L., Wilson, N. M., Dieni, J. S, Zimmerman, T. S., Doster, R. H., and Howe, W. H.. (2014). *Atlas of breeding colonial waterbirds in the interior western United States.* Research Report, U.S. Department of the Interior, Fish and Wildlife Service, Denver, Colorado.

50 of more than 300 banded migratory bird species, including ducks, geese, swans shorebirds and other waterbirds.

Figure 19. Bird Species Migration Patterns that Include Great Salt Lake



Source: National Audubon Society. (2019). Provided by request.

The impacts of a shrinking Great Salt Lake on bird populations has broad implications. Globally, bird populations are declining, and loss of habitat is often the primary driver. Wetlands in particular have been reduced by approximately half due to human causes in the United States, primarily from land conversion activities.[70] Great Salt Lake is one of several of saline lake systems in the West that act as an interconnected network of habitats for millions of migratory birds.[71] Migratory birds rely heavily on these lakes for breeding and also stopover habitats like Great Salt Lake where they can rest and build fat reserves for their long journeys. Great Salt Lake is also not alone as a drying lake in the Great Basin region – other drying lakes compound the risk to migratory birds and increase the costs of water level declines at Great Salt Lake because there are limited substitute habitats available. Given the significant role that Great Salt Lake plays within a network of saline lake systems throughout the West, a significant decline in bird habitat at Great Salt Lake potentially could have negative ramifications for bird populations across the region.[72]

Types of birds that could be impacted by water level declines at Great Salt Lake include:

- **Waterfowl**: Approximately 3 million to 5 million waterfowl that use Great Salt Lake and its wetlands. From December to February, approximately 300,000 ducks use the open waters of Great Salt Lake.[73] These ducks are known to have a diet consisting of more than 75 percent brine fly larvae and brine shrimp cysts.[74] Common feeding locations occur over mud substrates near freshwater inflow sites in lower salinity bays such as Bear River Bay, Ogden Bay, and Farmington Bay. These species move back to freshwater marshes as ice melts in the spring.
- **Eared Grebes:** Populations of eared grebes at Great Salt Lake represent one of two of the largest staging populations in North America.[75] This species feeds primarily on brine shrimp in the open salt water of the lake but they also feed on brine fly larvae as well as plant seeds and other invertebrates that are more prevalent along and in wetland habitats of the lake.[76] Approximately 80 percent of the global population of eared grebes

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[70] U.S. Department of the Interior. (2008). *Bird Populations Decline - 7/10/08*. House Testimony by Paul Schmidt, Assistant Director Migratory Birds Program. Retrieved from https://www.doi.gov/ocl/hearings/110/birdpopulationsdecline_071008

[71] Wilsey, C.B., Lotem T., Michel, N., and Stockdale, K. (2017). Water and Birds in the Arid West: Habitats in Decline. *National Audubon Society*.

[72] Wilsey, Chad B., Lotem Taylor, Nicole Michel, and Karyn Stockdale. 2017. Water and Birds in the Arid West: Habitats in Decline. National Audubon Society, New York, New York, USA.

[73] Roberts, A. J. (2013). Avian diets in a saline ecosystem: Great Salt Lake, Utah, USA. *Human-Wildlife Interactions*, *7*(1).

[74] Vest, J. L., & Conover, M. R. (2011). Food habits of wintering waterfowl on the Great Salt Lake, Utah. Waterbirds, 34(1), 40-51.

[75] Neill, J.C., Luft, J.T. and W.C. Perschon. (2006). *2006 Great Salt Lake eared grebe aerial photo survey*.

[76] Roberts, A. J., Conover, M. R., & Vest, J. L. (2016). Environmental Influences on Wintering Duck Abundance at Great Salt Lake, Utah. *Western North American Naturalist*, 76(1). https://doi.org/10.3398/064.076.0104

depends on Great Salt Lake.[77] Other habitat for the birds, such as Mono Lake and the Salton Sea in California, has been reduced, so although populations of the birds have increased at Great Salt Lake it may be because they have been pushed out of habitat elsewhere.[78]

- **Shorebirds:** Shorebirds using Great Salt Lake rely on the multiplicity of habitats available around Great Salt Lake, from the salty shoreline to freshwater wetlands and shallow ponds to forage on a variety of macroinvertebrate species.[79] While it is not known exactly how many birds would stop using the Great Salt Lake with lower lake levels, it is likely that there would be a decrease as a result of the decrease in food supply and reduction in available foraging and breeding habitat.[80]
- **Colonial Nesters:** Islands within Great Salt Lake function as breeding and nesting locations for multiple bird species and offer critical habitat.[81] There are over 160,000 breeding California Gulls on Great Salt Lake, which is the world's largest breeding population in North America.[82] At Gunnison Island in Great Salt Lake, there are approximately 20,000 breeding adult American White Pelicans, which is one of the three largest colonies in the western United States.[83] Ibis use the wetland interface between the lake and inputs to nest. There are over 23,000 breeding White-faced Ibis using Great Salt Lake wetlands, which is the world's largest breeding population.[84] Declining lake levels result in development of land bridges connecting the Great Salt Lake shoreline to islands and exposing nesting birds to increased predation.

3.3.2 Value of Migratory Birds

There has been only one study that has estimated the willingness-to-pay for migratory bird protections using direct surveys. Brouwer et al. (2008) found that approximately half of the Netherlands' residents surveyed were willing to pay for migratory bird protections and the average willingness-to-pay was approximately 10.6 Euros or 13.1 dollars (2005 prices). The survey question asked respondents their willingness to pay to cease reductions in migratory bird populations. Caution should be taken to apply this value to Great Salt Lake, since this

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[77] John Neill, Utah Division of Wildlife Resources, Great Salt Lake Ecosystem Program, personal communication June 17, 2019.

[78] John Luft, Utah Department of Natural Resources, personal communication, February 4, 2019.

[79] Cavitt, J.F. (2006). Productivity and foraging ecology of two co-existing shorebird species breeding at Great Salt Lake, UT: 2005 – 2006 Report. Avian Ecology Laboratory Technical Report. AEL 06-03. Weber State University, Ogden UT. 38pp.

[80] John Luft, Utah Department of Natural Resources, personal communication on February 4, 2019.

[81] Utah Department of Natural Resources. (2002). *Great Salt Lake Waterbird Survey Five-Year Report (1997-2001).* Retrieved from https://wildlife.utah.gov/gsl/gsl_ws_report/gsl_ws_report.pdf

[82] Robinette, K.W., White, P.A., F.P. Howe. (1993). *1993 Great Salt Lake California Gull survey*. Utah Division of Wildlife Resources unpublished report.

[83] Paul, D. S., & Manning, A. E. (2002). *Great Salt Lake waterbird survey five-year report* (1997-2001).

[84] Cavitt, J. F., Jones, S. L., Wilson, N. M., Dieni, J. S, Zimmerman, T. S., Doster, R. H., and Howe, W. H.. (2014). *Atlas of breeding colonial waterbirds in the interior western United States.* Research Report, U.S. Department of the Interior, Fish and Wildlife Service, Denver, Colorado.

value was not a value per bird, it is difficult to scale to the size and conditions of Great Salt Lake. **If we assume that 50 percent of the population of Utah, 1.58 million people, would also be willing to pay $17.59 (inflated to 2019 dollars), the resulting one-time willingness to pay by people in Utah for migratory bird protections would be $27.8 million.**

3.4 Business Costs

Businesses rely on Great Salt Lake both directly through brine shrimp harvesters and mineral extraction companies as well as indirectly from tourism and avoided expenditures. Declines in water levels at Great Salt Lake could create large costs for businesses such as the brine shrimp industry and tourism-dependent firms. Other industries like mineral extraction could also experience costs, depending on the magnitude of Great Salt Lake water level declines.

3.4.1 Brine Shrimp Industry

Commercial harvesting and processing of brine shrimp eggs (also known as cysts) has occurred at Great Salt Lake since 1952. The brine shrimp eggs are sold to commercial aquaculture breeders across the world and used as feed for shrimp, fish, and crustaceans which are then consumed by humans. Approximately 35 to 45 percent of the world's supply of brine shrimp eggs are from Great Salt Lake. The brine shrimp egg-harvesting season runs from October 1 to January 31 or once the threshold of 21 eggs per liter of water is met.

The 2012 Bioeconomics report estimates that annual sales by the 17 companies comprising the brine shrimp industry at Great Salt Lake are approximately $40.1 million per year and employs 373 full-time and part-time workers for $14.5 million in annual labor income.[85] Additionally, state and local taxes from the industry amount to $4.25 million per year. From supply chain (indirect) and consumption (induced impacts), the brine shrimp industry at Great Salt Lake contributes the following to Utah's economy (2019 dollars):

- Total Output of $67.0 million,
- Total Labor Income of $23.9 million, and
- Total Employment (full-time and part-time jobs) of 574 people.

Although brine shrimp are resilient enough to live in high salinity environments that many other creatures cannot tolerate, reproduction becomes limited in salinities above 16 percent.[86] Because of this upward limit, brine shrimp are not generally found in the north arm of Great Salt Lake which is well above the 16 percent threshold at approximately 26 percent salinity (the average from 1966 to 2017).[87] Increasing salinities at Great Salt Lake could cause the density of eggs per liter of water to decline to an extent that the harvest is severely limited or cancelled

[85] All values have been converted to 2019 values using the BLS CPI Inflation Calculator.

[86] Bosteel, T. (2018). *Salinity Effect on Great Salt Lake Brine Shrimp: General Overview*. Presentation at the Great Salt Lake Issues Forum, Salt Lake City, Utah. May

[87] Andrew Rupke, Utah Geologic Survey, personal communication, January 3, 2018.

altogether. The brine shrimp harvest is managed by Utah's Department of Natural Resources, Division of Wildlife Resources, Great Salt Lake Ecosystem Program

If the brine shrimp industry is impacted by lake level declines at Great Salt Lake, the entire value of the brine shrimp industry could be lost for that year or a number of years. Table 8 summarizes the potential costs based on the annual economic contribution by the brine shrimp industry. **The potential costs from water level declines at Great Salt Lake for the brine shrimp industry includes $67 million in total economic output and loss of 574 jobs.**

Table 8. Potential Costs to Brine Shrimp Industry from Water Level Declines at Great Salt Lake (2019 dollars)

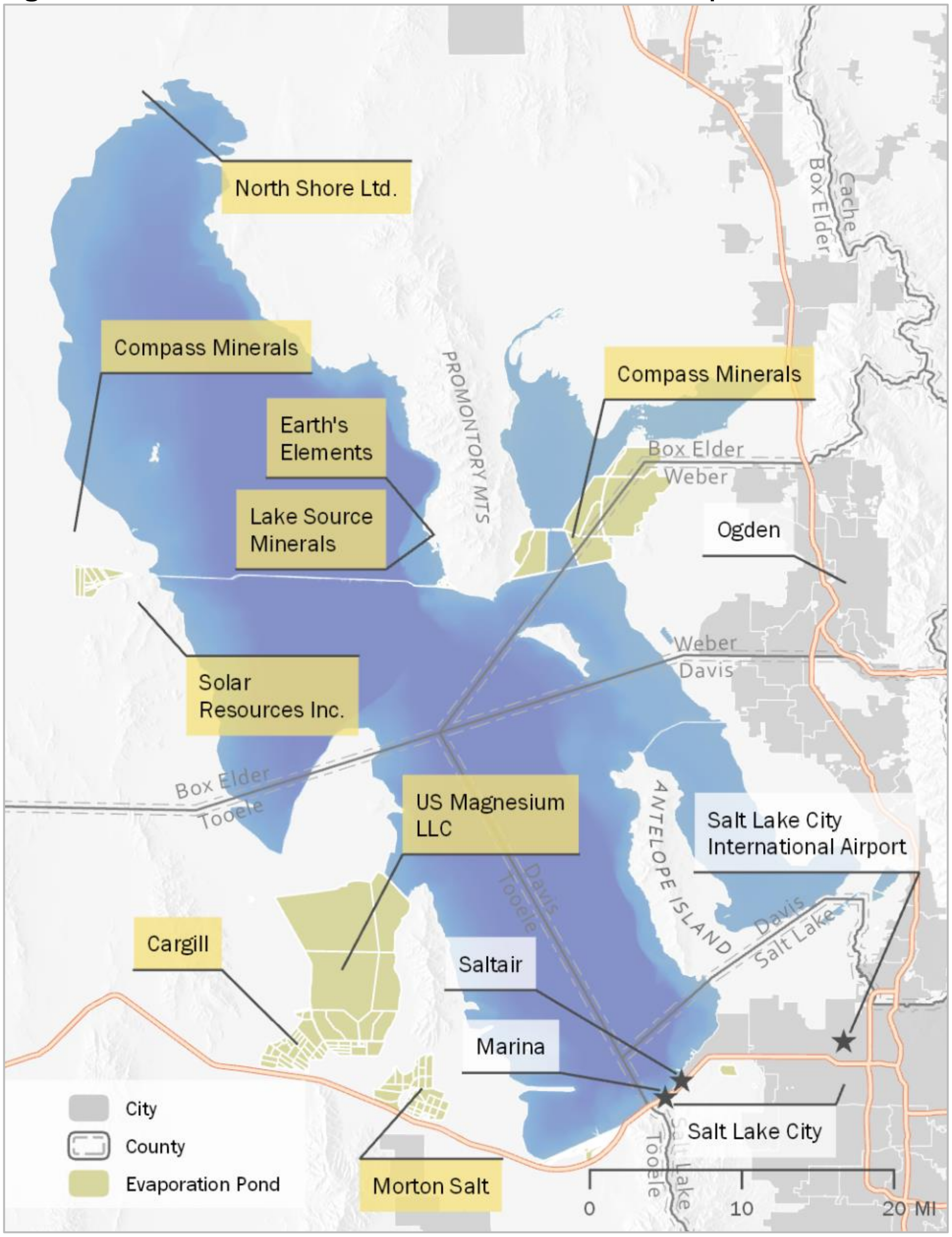
	Direct Effect	Total Effect
Output	$40.1 million	$67 million
Labor Income	$14.5 million	$23.9 million
Employment	373 jobs	574 jobs

Source: Created by ECONorthwest with information from Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.
Note: All dollar values have been inflated to 2019 values using the BLS CPI Inflation Calculator

3.4.2 Mineral and Metal Extraction

In addition to sodium chloride (table salt), other minerals extracted from Great Salt Lake include magnesium chloride, and potash (potassium sulfate), chlorine, calcium chloride (brine), magnesium chloride (brine), ferrous chloride, and ferric chloride. U.S. Magnesium also mines the mineral magnesium from Great Salt Lake. The location of these operations is shown in Figure 20.

Figure 20. Locations of Mineral and Metal Extraction Companies as of 2011



Source: Created by ECONorthwest

U.S. Magnesium is the largest producer of magnesium in the United States and magnesium is a necessary component of automotive and aircraft parts, so access to the resource is also a matter of national security and international trade.

The sulfate of potash produced by companies like Compass Minerals (Great Salt Lake Minerals Corporation) is an essential nutrient for crops sensitive to chloride, such as fruit and nut trees in California and Florida. Compass Minerals is the only North American producer of sulfate of potash and extracts it using solar power which has significantly lower greenhouse gas emissions that the synthetic forms of the substance. Lithium, another valuable metal that is present at Great Salt Lake, is critical to battery manufacture and other applications. Viable extraction efforts of lithium are currently being pursued by U.S. Magnesium. There are multiple mineral and metal operation companies operating in Great Salt Lake.

The 2012 Bioeconomics report estimate that the annual direct sales from these companies is $810 million and these businesses employ 1,967 full and part-time employees for $199 million in annual labor income.[88] From supply chain (indirect) and consumption (induced impacts), the mineral extraction industry at Great Salt Lake contributes the following to Utah's economy (2019 dollars):

- Total Output of $1.3 billion,
- Total Labor Income of $365.4 million, and
- Total Employment (full-time and part-time jobs) of 5,368 people.

For these extraction industries, the optimal lake elevation range for operations is above 4,193 feet and below 4,203 feet. Below 4,193 feet pumping of water to the evaporation ponds becomes limited and the companies could incur millions of dollars of costs to dredge and extend pipes, relocate pumps, or regrade intake canals.[89,90,91] In addition to the direct cost to these industries of implementing these changes, business would also be disrupted and potentially stop for a period of time, resulting in revenue losses and loss of confidence in the Great Salt Lake industries.

The changing chemical composition of Great Salt Lake with water level declines can also create costs for the mineral extraction industries. As the lake recedes outside of the normal ranges, between 4,193 feet to 4,203 feet in elevation, ponds need to be reconfigured.[92] This reconfiguration can create substantial costs to the mineral extraction industries in both time, money, and business disruptions.

The water rights held by the mineral extraction industries on Great Salt Lake and in general the extraction companies have not been able to make a call on upstream rights to ensure their water rights are met, even if they have an earlier priority date. In an extreme scenario where the Great Salt Lake experiences water level reductions that essentially leave the lake dry, the entire value of the mineral extraction industry at the lake could be lost. Table 9 summarizes the potential costs resulting from the loss of the mineral extraction industry at Great Salt Lake. **The potential costs from water level declines at Great Salt Lake for the mineral extraction industry includes $1.3 billion in total economic output and loss of 5,368 jobs.**

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[88] Values have been inflated to 2019 dollars using the BLS CPI inflation calculator.

[89] Joe Havasi, Compass Minerals, personal communication on May 17, 2019.

[90] Rob Hartman and Tom Tripp, U.S. Magnesium, personal communication on February 4, 2019.

[91] Utah Department of Natural Resources, Utah Division of Forestry, Fire & State Lands. (2013). *Final Great Salt Lake Comprehensive Management Plan*. Retrieved from https://ffsl.utah.gov/index.php/state-lands/great-salt-lake/great-salt-lake-plans

[92] Joe Havasi, Compass Minerals, personal communication on May 17, 2019.

Table 9. Potential Costs to Mineral Extraction Industry from Water Level Declines at Great Salt Lake (2019 dollars)

	Direct Effect	Total Effect
Output	$810 million	$1.3 billion
Labor Income	$199 million	$365 million
Employment	1,967 jobs	5,368 jobs

Source: Created by ECONorthwest with information from Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.
Note: All dollar values have been inflated to 2019 values using the BLS CPI Inflation Calculator

3.4.3 Costs to Other Industries

In addition to costs to the brine shrimp and mineral extraction industries, other businesses could be impacted by the decline of lake levels and associated impacts. The other industries that rely on Great Salt Lake are anticipated to experience costs, including agriculture, the airport, the real estate industry, as well as recreation and tourism industries. We address recreation and tourism in later sections of this report.

Agricultural Dust

When more dust is created from the exposed lakebed of Great Salt Lake the dust and associated salinity would likely impact crops and other agricultural products. Dust from the dried lakebed of the Aral Sea, located in Uzbekistan and Kazakhstan, settles on crops and substantially decreases their yield due to changes in rates of transpiration and photosynthesis.[93] The saline dust from the Aral Sea lake bed is also incorporated into the soils, which can decrease the regional long-term crop yield.[94] There is also qualitative evidence from the Salton Sea in California that saline dust from dried lake beds contributes to a decrease in crop productivity.[95]

The heavy metals present in some saline lake dust can damage the cells of plants and decrease their function and productivity.[96,97] All eleven of the counties within the Great Salt Lake Basin have agricultural land, but the most significant agricultural presence is in Box Elder County and Utah County. Agriculture is already limited in these areas due to soil conditions and aridity, so the impact of increased dust could further reduce the productivity and create more costs for the agricultural industry.

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[93] Micklin, P. (2006). The Aral Sea Disaster. *Annual Review of Earth and Planetary Sciences*, 35(1), 47–72. https://doi.org/10.1146/annurev.earth.35.031306.140120

[94] Abuduwaili, J., LIU, D., & WU, G. (2010). Saline dust storms and their ecological impacts in arid regions. *Journal of Arid Land*, 2(2), 144–150. https://doi.org/10.3724/sp.j.1227.2010.00144

[95] Cohen, M. J., & Hyun, K. H. (2006). *Hazard: The Future of the Salton Sea With No Restoration Project*. Oakland California: Pacific Institute.

[96] Farmer, A. M. (1993). The effects of dust on vegetation—a review. *Environmental Pollution*, 79(1), 63–75. https://doi.org/10.1016/0269-7491(93)90179-R

[97] Zenk, M. H. (1996). Heavy metal detoxification in higher plants-a review. *Gene*, 179(1), 21-30.

Airport Operations

Dust can also create significant problems for the Salt Lake City International Airport, located on the south shore of Great Salt Lake, as well as smaller regional airports. There has been an average of 5 large dust events per year in the Salt Lake Valley from 1930 to 2011.[98] The dust from these events impact visibility and can disrupt airport operations and pose safety risks. In April 2015 a wind-blown dust event resulted in the cancellations of flights at the SLC International Airport.[99]

The exact magnitude of current and future costs for the airport due to dust is difficult to estimate, however there are significant economic costs to flight delays and cancellations. The additional expenses involved with flight changes and reimbursing travelers costs the airline industry billions of dollars per year, as well as nonmonetized costs in the form of lost productivity, wages, and goodwill. The Federal Airline Aviation administration estimates the national annual costs of delays based on the combination of these direct and indirect costs as $26.6 billion as of 2017.[100]

Property Values and Development Potential

The property tax values of the counties adjacent to the eastern shore of Great Salt Lake may experience reductions in property levels due to dust and aesthetic loss from lake level declines. Previous research suggests that a 10 percent increase in local particulate matter air pollution can reduce property values by up to 1.1 percent.[101] Overall, studies have found that individuals value clean air and are willing to pay more to live farther away from air pollution.[102] A 2004 study estimated that a reduction of 1-μg/m3 in total suspended air particles increases mean housing values by 0.2–0.35 percent.[103] This finding exemplifies the general decrease in desirability and market value of households in highly air polluted areas. The National Ambient Air Quality Standard set by the EPA is a 3-year average of annual mean of $PM_{2.5}$ of 12 μg/m3.[104]

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98 Steenburgh, W. J., Massey, J. D., & Painter, T. H. (2012). Episodic Dust Events of Utah ' s Wasatch Front and Adjoining Region. *Journal of Applied Meteorology and Climatology*, 51, 1654–1669. https://doi.org/10.1175/JAMC-D-12-07.1

99 Mallia, D. V., Kochanski, A., Wu, D., Pennell, C., Oswald, W., & Lin, J. C. (2017). Wind-blown dust modeling using a backward-Lagrangian particle dispersion model. *Journal of Applied Meteorology and Climatology*, *56*(10), 2845-2867.

100 Airlines for America. (No Date). U.*S. Passenger Carrier Delay Costs*. Retrieved from http://airlines.org/dataset/per-minute-cost-of-delays-to-u-s-airlines/

101 Berkman, M. P., Hubbard, K. J., & Savage, T. H. (2012). The Adverse Impact of Particulate Matter on Property Values. *International Real Estate Review*, 15(2), 215-230.

102 Sullivan, D. M. (2016). *The true cost of air pollution: Evidence from house prices and migration*. Harvard University.

103 Chay, K. Y., & Greenstone, M. (2005). Does air quality matter? Evidence from the housing market. *Journal of political Econ*omy, 113(2), 376-424.

104 U.S. Environmental Protection Agency. (No Date). *What are the Air Quality Standards for PM?*. Retrieved from https://www3.epa.gov/region1/airquality/pm-aq-standards.html

Air pollution regularly exceeds EPA standards for $PM_{2.5}$ in Salt Lake City during the spring and fall (Figure 21, page 48).

Air pollution is not the only potential source of property value loss resulting from declining water levels of Great Salt Lake. Other changes resulting from declining lake levels such as job losses in the brine shrimp industry, reduced recreational opportunities, and the aesthetic loss at the lake could also result in property value decreases. A 2015 study on the impacts of lake levels on property values found that declining lake levels are positively correlated to property values – as lake levels decline, property values near the lake also decline.[105]

The average home price in the three counties west of Great Salt Lake (Salt Lake, Davis, and Weber counties) is $333,833 as of May 31, 2019.[106] There were 32,237 home sales in these three counties from May 2018 to April 2019, so the average value of home sales in a year is approximately $10.7 billion. Applying the 1.1 percent decline in property value from Berkman et al. 2012, over $118 million in property sales revenue to homeowners could be lost each year if air pollution levels increase by 10 percent. This value is illustrative since the study was not in the same context as Northern Utah, which has higher baseline air pollution levels. From this example we can surmise that declines in lake levels at Great Salt Lake that further degrade air pollution could have costs to local homeowners in the millions of dollars. Increase in housing prices is also a gain for homeowner sellers but a loss for home buyers, so this effect is not clearly a cost, other than for relators.

Reduction in property values affects both property owners and realtors, as well as local governments due to reductions in property taxes. The minimum, maximum, and average property tax rates for counties in the Great Salt Lake Basin are displayed in Table 10. There are 607,292 housing units in the three counties.[107] Based on these values, if costs of declining lake levels lead to the 1.1 percent decline in property values, we would expect property tax collection to decrease by approximately $29 million per year in total for Salt Lake, Weber, and Davis Counties.[108]

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[105] Dickes, L., & Crouch, E. (2015). The Impact of Changing Lake Levels on Property Values: A Hedonic Model of Lake Thurmond. *Review of Regional Studies*, 45(3).

[106] Zillow Home Value Index. Available at https://www.zillow.com/research/data/

[107] U.S. Census Bureau, QuickFacts. Available at https://www.census.gov/quickfacts/fact/table/daviscountyutah,webercountyutah,saltlakecountyutah,UT/PST045218

[108] This value is calculated by multiplying the 1.1 percent property value loss for the average home by the average property rate for the three counties of 1.33 percent and then applying that potential loss value to the 607,292 housing units.

Table 10. Property Tax Rate for Counties in Great Salt Lake Basin

County	Minimum Tax Rate	Maximum Tax Rate	Average Tax Rate
Weber	1.07%	1.65%	1.36%
Davis	1.01%	1.41%	1.21%
Salt Lake	1.09%	1.76%	1.43%
Average	**1.06%**	**1.61%**	**1.33%**

Source: Created by ECONorthwest with information from Utah State Tax Commission. (2018). *2018 Tax Rates by Tax Area.* Retrieved from https://propertytax.utah.gov/tax-rates/area-rates/taxarearates2018.pdf

3.5 Health Costs

The health costs incurred from declining lake levels at Great Salt Lake are due to the increased lakebed exposure and the resulting increase in airborne dust (i.e. particulate matter). As a result of historical declines in lake surface area, there is already some dust from Great Salt Lake that is contributing to regional dust loads. Further declines in water levels and surface area at Great Salt Lake would likely increase the health costs from dust exposure in Northern Utah.

3.5.1 Background on Air Quality in the Wasatch Front

Air quality along the Wasatch Mountain front near Great Salt Lake consistently ranks as some of the poorest in the country due to levels of ozone (smog) and short-term particle pollution.[109] The entire area between Great Salt Lake and the Wasatch front is classified as a nonattainment area for fine particle pollution ($PM_{2.5}$) by the EPA, meaning that it exceeds national air pollution standards.[110] Salt Lake County and Utah County are also in nonattainment for larger particulate pollution (PM_{10}).[111] There are multiple reasons for the high level of air pollution in this area near Great Salt Lake. In the winter, pollution (e.g. from cars, wood fires, or wildfires) are trapped in the valley by a layer of warmer air, holding the colder, more polluted air near the ground. The mountains exacerbate inversions by trapping the air to the west.

Dust storms most commonly occur in the spring and fall, and often in the late afternoon.[112] In 2012, the EPA updated the National Ambient Air Quality Standard for the annual average $PM_{2.5}$ from 15 μg/m3 to 12 μg/m3.[113] Air pollution regularly exceeds EPA standards for $PM_{2.5}$ in Salt Lake City during the spring and fall (Figure 21).

[109] American Lung Association. (2019). *State of the Air Report*. Retrieved from https://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2019-full.pdf

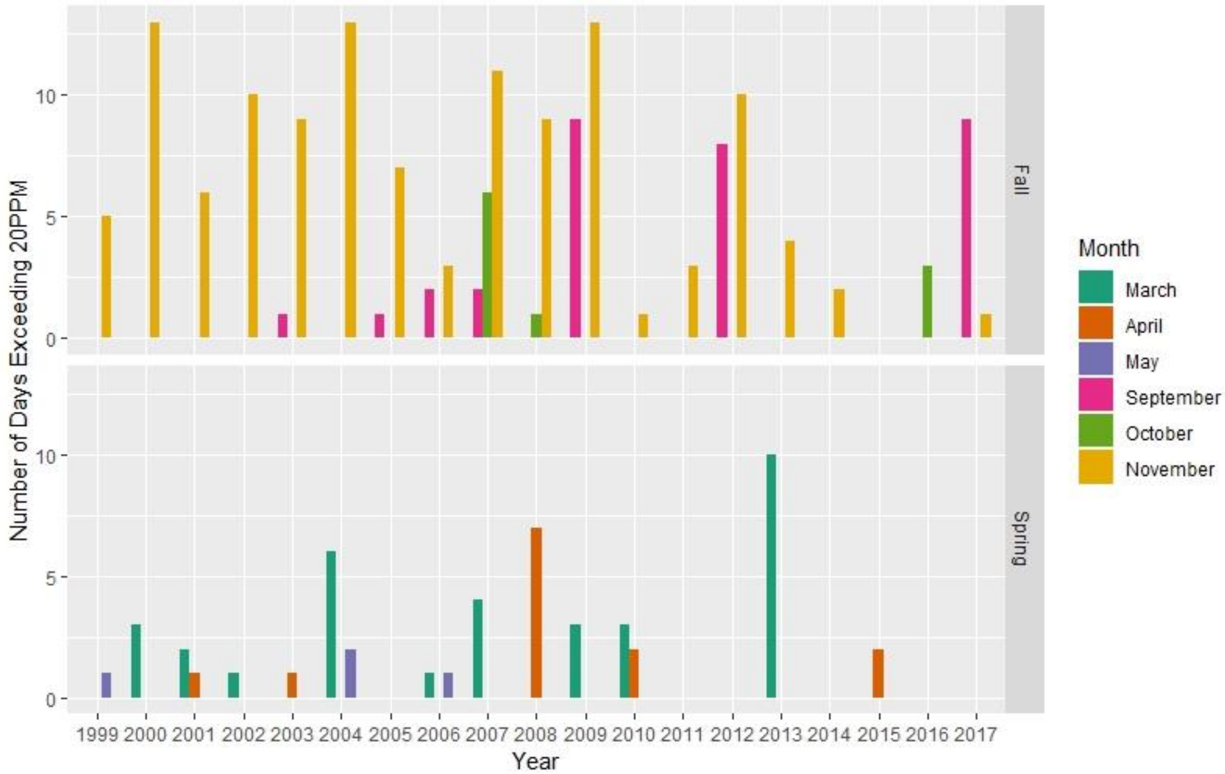
[110] U.S. Environmental Protection Agency. (No Date). *Nonattainment Areas for the 2006 Daily Fine Particle Standards*. Available at https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=726f1f1c59ab41c4ae65ea1f8dc743ca&webmap=2cec12bef377476cadd38af48918c5a3

[111] U.S. Environmental Protection Agency. (No Date). *PM-10 (1987) Designated Area State/Area/County Report*. Retrieved from https://www3.epa.gov/airquality/greenbook/pbcs.html#UT

[112] Steenburgh, W. J., Massey, J. D., & Painter, T. H. (2012). Episodic dust events of Utah's Wasatch Front and adjoining region. *Journal of Applied Meteorology and Climatology*, 51(9), 1654-1669.

[113] U.S. Environmental Protection Agency. (No Date). *What are the Air Quality Standards for PM?*. Retrieved from https://www3.epa.gov/region1/airquality/pm-aq-standards.html

Figure 21. Number of Days Exceeding 20 μg/m2 of $PM_{2.5}$ by Month and Season (1999-2017)



Source: Created by Martin & Nicholson Environmental Consultants with data from Hawthorne Gage (700 E 1700 S, Salt Lake City)

Particulate air pollution is associated with a variety of adverse health effects. Generally, the smaller the particulate matter the worse potential health outcomes. $PM_{2.5}$ is a smaller particle than PM_{10}. According to the U.S Environmental Protection Agency, the potential adverse health and environmental effect of particulate matter pollution include:[114]

- premature death in people with heart or lung disease,
- nonfatal heart attacks,
- irregular heartbeat,
- aggravated asthma,
- decreased lung function, and
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.

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[114] U.S. Environmental Protection Agency. (No Date). *Health and Environmental Effects of Particulate Matter (PM)*. Retrieved from https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

Dust can also severely impact visibility and result in injuries and fatalities from traffic accidents. A wind-blown dust event over Salt Lake City in April 2015 led to 25 injuries and 1 fatality, as well as the closure of major highways.[115]

In Utah, studies have found correlations between adverse health outcomes from dust and increased rates of hospitalization,[116] school absences,[117] and higher rates of death, particularly from respiratory and cardiovascular diseases.[118] A study in Utah County found that the increased incidences of death were 4 to 5 percent higher with an increase of PM_{10} of 50 μg/m² and 16 percent higher if PM_{10} reached levels above 100 μg/m².[119]

3.5.2 Current Costs of Air Pollution Attributable to Great Salt Lake

Based on a survey from 2014 from Envision Utah, residents ranked air quality as the third most important issue to Utah's future, but air quality ranks as the issue that the state of Utah is performing the worse at addressing.[120] The impact of worsening air pollution with a drying Great Salt Lake would undermine efforts by the state to improve air quality. Increases in dust pollution also have the potential to create liability for the state of Utah for failing to adhere to Clean Air Act requirements to improve air quality. In January 2019 a notice of intent to sue the Environmental Protection Agency was filed by Utah Physicians for a Healthy Environment and others to require air pollution clean-up occur for counties in Utah, including Salt Lake, Davis, Weber, Box Elder, and Tooele counties.[121]

The addition of high levels of particulate matter during Great Salt Lake dust events contributes to the already often poor air quality of the Wasatch Front and could further exacerbate existing pollution-related health problems. A 2016 study prepared for the Utah Division of Forestry, Fire, and State Lands used chemical ratios in dust samples to estimate the portion of dust coming from Great Salt Lake affecting Provo, Salt Lake City, Ogden, and Logan.[122] This research found that major dust events in Fall 2015 Great Salt Lake contributed approximately 40 percent

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[115] Mallia, D. V., Kochanski, A., Wu, D., Pennell, C., Oswald, W., & Lin, J. C. (2017). Wind-blown dust modeling using a backward-Lagrangian particle dispersion model. *Journal of Applied Meteorology and Climatology*, *56*(10), 2845-2867.

[116] Pope III, C. A. (1991). Respiratory hospital admissions associated with PM10 pollution in Utah, Salt Lake, and Cache Valleys. *Archives of Environmental Health: An International Journal*, 46(2), 90-97.

[117] Ransom, M. R., & Pope III, C. A. (1992). Elementary school absences and PM10 pollution in Utah Valley. *Environmental research*, *58*(1-2), 204-219.

[118] Archer, V. E. (1990). Air pollution and fatal lung disease in three Utah counties. *Archives of Environmental Health: An International Journal*, *45*(6), 325-334.

[119] Pope, C. A., Schwartz, J., & Ransom, M. R. (1992). Daily Mortality and PM10 Pollution in Utah Valley. *Archives of Environmental Health: An International Journal*, *47*(3), 211–217. https://doi.org/10.1080/00039896.1992.9938351

[120] Envision Utah. (2014). 2014 Values Study Results.

[121] Center for Biological Diversity. (2019). *Lawsuit Launched Against Trump's EPA for Failing to Protect More Than a Million People in Utah, Arizona From Particulate Pollution*. January 3. Retrieved from https://www.biologicaldiversity.org/news/press_releases/2019/arizona-utah-clean-air-01-03-2019.php

[122] Carling, G. and Fernandez, D. (2016). *Characterizing harmful effects of dust emissions from the dry lakebed of Great Salt Lake relative to other regional dust sources.* Prepared for Utah Division of Forestry, Fire, and State Lands. November

of the dust in Ogden and Logan, 20 percent in Salt Lake City, and zero in Provo. Spring 2016 dust events had significantly lower contributions to dust from Great Salt Lake, less than 10 percent of dust that reached Salt Lake City and Logan was from Great Salt Lake. Another study in the spring of 2017 found that 7 percent of the dust deposited during a storm event in the Wasatch Mountains was from Great Salt Lake.[123]

To calculate the cost of the dust coming from Great Salt Lake we obtained estimates from the Utah Division of Air Quality on the annual amount of dust (PM_{10} and $PM_{2.5}$) for four counties east of Great Salt Lake, as of 2017. Table 11 displays the annual emissions in tons per year for each county and particulate matter type. For the four counties, the total amount of PM_{10} in 2017 was 43,152 tons and the total amount of $PM_{2.5}$ was 9,767 tons.

Table 11. Annual PM_{10} and $PM_{2.5}$ Emissions for Counties Near Great Salt Lake

County	PM_{10} (tons/year)	$PM_{2.5}$ (tons/year)
Cache	11,538	1,717
Davis	5,167	1,320
Salt Lake	18,965	5,315
Weber	7,482	1,414
Total	**43,152**	**9,767**

Source: Created by ECONorthwest with information from Utah Department of Environmental Quality. (2017). *Utah Division of Air Quality 2017 Annual Report*. Retrieved from https://documents.deq.utah.gov/air-quality/annual-reports/DAQ-2018-001005.pdf

Based on these levels of emissions we can attribute the portion of that dust coming from Great Salt Lake based on a low end of 7 percent (based on Skiles et al. 2018[124] and the less than 10 percent from Carling and Fernandez 2016[125]) and a high end of 30 percent (based on the Fall 2015 averages for the counties from Carling and Fernandez 2016). The particulates associated with Great Salt Lake dust events are mostly in the PM_{10} category although $PM_{2.5}$ also occurs.[126] Approximately 80 percent of the dust sampled by Skiles et al. (2018) was larger than PM_2 (a smaller diameter than $PM_{2.5}$), so we are assuming that dust from Great Salt Lake contributes 80 percent to PM_{10} and 20 percent to $PM_{2.5}$. Based on those assumptions, the range of tons per year of dust within the four counties directly east of Great Salt Lake is a low of 3,000 tons/year of PM_{10} and 700 tons/year of $PM_{2.5}$ and a high of 12,700 tons/year of PM_{10} and 3,200 tons/year of $PM_{2.5}$ based on the amount of particulate matter air pollution from 2017 (Table 12). The costs from a declining lake are presented in the next section of this report.

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[123] Skiles, S. M., Mallia, D. V., Hallar, A. G., Lin, J. C., Lambert, A., Petersen, R., & Clark, S. (2018). Implications of a shrinking Great Salt Lake for dust on snow deposition in the Wasatch Mountains, UT, as informed by a source to sink case study from the 13–14 April 2017 dust event. *Environmental Research Letters*, 13(12), 124031.

[124] Ibid.

[125] Carling, G. and Fernandez, D. (2016). *Characterizing harmful effects of dust emissions from the dry lakebed of Great Salt Lake relative to other regional dust sources.* Prepared for Utah Division of Forestry, Fire, and State Lands. November

[126] Mallia, D. V., Kochanski, A., Wu, D., Pennell, C., Oswald, W., & Lin, J. C. (2017). Wind-blown dust modeling using a backward-Lagrangian particle dispersion model. *Journal of Applied Meteorology and Climatology*, *56*(10), 2845-2867.

Table 12. Estimates of Dust Levels Attributable to Great Salt Lake in Nearby Counties (2017)

Estimate	PM_{10} (tons/year)	$PM_{2.5}$ (tons/year)
Low-End Estimate: 7 percent attributable to Great Salt Lake	3,000	700
High-End Estimate: 30 percent attributable to Great Salt Lake	12,700	3,200

Source: Created by ECONorthwest

Various economic techniques are available to value the reduction in morbidity and premature mortality caused by air pollution. For purposes of this report, morbidity refers to a range of health impacts including acute asthma to chronic diseases like cancer. Because air pollution can create health costs in a variety of ways, the specific costs to individual residents based on incidence of disease relative to a baseline of little to no air pollution cannot be accessed without extensive primary data collection. However, the impacts of air pollution have been estimated in the literature based on pollutant concentrations and health costs more broadly, and it is these costs we can apply to pollutant loads from Great Salt Lake to understand the magnitude.

Using an integrated assessment model known as the "Air Pollution Emissions Experiments and Policy analysis model" (APEEP), Muller and Mendelsohn (2007)[127] have estimated the per-ton health damages from an additional ton of pollutant for six common air pollutants, including PM_{10} and $PM_{2.5}$. The health damages are based on the increased mortality and morbidity and are estimated using value of statistical life and cost of illness estimates.

Table 13. Health Damages from PM10 and PM2.5 (2019 Dollars)

Source Location	PM_{10} (tons/year)	$PM_{2.5}$ (tons/year)
Urban	$593	$3,916
Rural	$237	$1,305
Average	$415	$2,610

Source: Created by ECONorthwest using data from Muller, N. Z., & Mendelsohn, R. (2007). Measuring the damages of air pollution in the United States. *Journal of Environmental Economics and Management*, 54(1), 1-14.
Note: Values have been inflated to 2019 dollars using the BLS CPI inflation calculator. Damages are from Muller and Mendelsohn Table 3 applying the 94 percent for health costs (excluding the 6 percent of costs attributable to visibility loss, reduced agricultural yields, reduced timber yields, accelerated depreciation of man-made materials, and lost recreation usage).

Based on these dollars per ton per year costs of PM_{10} and $PM_{2.5}$ in Table 10, we estimate the annual costs of air pollution from dust created by Great Salt Lake based on 2017 air particulate matter levels by multiplying these costs by the low and high range estimates of the level of pollutants from Great Salt Lake described in Table 11. This analysis results in an estimate of the annual costs of air pollution of between $3.2 million to $13.6 million. These values represent estimates of current costs only based on the amount of dust Great Salt Lake is contributing to regional loads, the costs of water level declines in Great Salt Lake would be even higher due to more exposed lake bed and higher amounts of particulate pollution.

[127] Muller, N. Z., & Mendelsohn, R. (2007). Measuring the damages of air pollution in the United States. *Journal of Environmental Economics and Management*, 54(1), 1-14.

Table 14. Estimates of Current Annual Costs from Air Pollution Attributable to Great Salt Lake (2019 dollars)

Estimate	PM_{10} Costs	$PM_{2.5}$ Costs	Total Costs from Great Salt Lake
Low-End Estimate: 7% attributable to Great Salt Lake	$1,230,000	$1,930,000	$3,160,000
High-End Estimate: 30% attributable to Great Salt Lake	$5,270,000	$8,290,000	$13,560,000

Source: Created by ECONorthwest

3.5.3 Health Costs of a Declining Great Salt Lake

As water levels at Great Salt Lake decline, more of the lakebed would be exposed. This increased surface area that can create dust would result in higher levels of air pollution attributable to the Great Salt Lake area. As of 2018, approximately 750 square miles of dry lakebed are exposed and of that approximately 11 percent or 83 square miles is blowing dust.[128] The total area of Great Salt Lake is approximately 1,700 square miles. If the entire main body of Great Salt Lake was exposed and 11 percent continues to blow dust, we would expect dust from Great Salt Lake to increase by 227 percent to approximately 187 square miles, assuming a linear relationship for dust concentrations. We are also assuming that dust loads presented in Table 11 for 2017 are similar to dust loads in 2018 and that the 750 square miles of exposed lakebed in 2018 is similar to the amount of lakebed exposed in 2017.

Based on the 227 percent increase in dust if the entire lakebed of Great Salt Lake is exposed, the future levels of PM_{10} and $PM_{2.5}$ are modeled as also increasing by that amount. Future levels of dust are then calculated based on the scenarios described previously estimating that between 7 percent (low end) and 30 percent (high end) of the dust in the six counties near Great Salt Lake is from the dry lakebed. Table 15 demonstrates these calculations which show that if the entire Great Salt Lake lakebed is exposed in the future that the levels of dust from Great Salt Lake would increase by 227 percent and then percent of the total dust from all sources coming from Great Salt Lake would increase from 7 to 14.6 percent at the low end and from 30 to 49.3 percent at the high end.

Table 15. Estimates of Dust (PM_{10} and $PM_{2.5}$) from a Dry Great Salt Lake for Western Counties

	Low End (tons/year)		High End (tons/year)	
	Current, 2017 (7 percent)	**Dry Future** (14.6 percent)	**Current, 2017** (30 percent)	**Dry Future** (49.3 percent)
PM_{10}	3,000	6,200	12,700	20,800
$PM_{2.5}$	700	1,500	3,200	5,200

Source: Created by ECONorthwest

Note: Western Counties includes Cache, Davis, Salt Lake, and Weber counties.

[128] Perry, K. D., Crosman, E. T., & Hoch, S. W. (2019). *Results of the Great Salt Lake Dust Plume Study (2016-2018).* Prepared for Utah Department of Natural Resources.

The increase in costs resulting from this added dust pollution is calculated based on the per ton costs per pollutant from Muller and Mendelsohn.[129] The average cost per ton per year for PM_{10} is $415 and for $PM_{2.5}$ is $2,610 (2019 dollars). **Applying these average costs to the tons per year of each pollutant resulting from a dry lake scenario, the range total costs in the future from dust attributable to a dry Great Salt Lake lakebed could be up to $6.6 million to $22.3 million per year** (Table 16). This value range represents an increase in health costs beyond the current health costs from air pollution of approximately $3.4 million to $8.7 million per year.

Table 16. Estimates of Total Future Annual Costs from Air Pollution Attributable to Great Salt Lake (Dry Lake Levels, 2019 dollars)

Estimate	PM_{10} Costs	$PM_{2.5}$ Costs	Total Costs from Great Salt Lake
Low-End Estimate 14.6% attributable to Great Salt Lake	$2,560,000	$4,030,000	**$6,590,000**
High-End Estimate 49.3% attributable to Great Salt Lake	$8,660,000	$13,620,000	**$22,290,000**

Source: Created by ECONorthwest

The chemicals in the dust from Great Salt Lake can add to the potential costs that might increase in a dry Great Salt Lake scenario. Additionally, industrial and organic pollutants can adhere to airborne dust particles as they are transported through the air, potentially increasing the exposure of Utahns to these contaminants.[130,131] Soil samples of dust "hot spots" in the Great Salt Lake dry lakebed collected by researchers with the University of Utah in 2017 contained arsenic, lithium, copper, vanadium, and antimony levels above the EPA regional screening level residential limits.[132] These soil samples also contain measurable levels of chromium, lead, selenium, and thallium, decayed plant material, salts, gypsum, and calcium carbonate. All these components of the soil can potentially enter the atmosphere as dust. Approximately 11 percent of currently exposed lakebed at Great Salt Lake, approximately 83 acres, are dust hot spots.[133] This area would likely increase with decreased lake level and increased erosion of exposed lakebed surface over time.

3.6 Recreation Costs

Water level declines in Great Salt Lake are expected to impact the level of tourism and recreational opportunities for residents. All of the activities that occur at the lake are expected to

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[129] Muller, N. Z., & Mendelsohn, R. (2007). Measuring the damages of air pollution in the United States. *Journal of Environmental Economics and Management*, 54(1), 1-14.

[130] Marx, S. K., B. S. Kamber, and H. A. McGowan. 2008. Scavenging of atmospheric trace metal pollutants by mineral dusts: Inter-regional transport of Australian trace metal pollution to New Zealand. *Atmospheric Environment* 42:2460–2478.

[131] A study on dust chemical transport is ongoing for Great Salt Lake, "Quantifying Farmington Bay dust composition from source to sink", by Dr. Janice Brahney at Utah State University.

[132] Perry, K. D., Crosman, E. T., & Hoch, S. W. (2019). Results of the Great Salt Lake Dust Plume Study (2016-2018). Prepared for Utah Department of Natural Resources.

[133] Ibid.

be impacted, including the loss of bird watching, duck hunting, boating, sailing, swimming, and hiking. Bioeconomics (2012) estimates that hunting, bird watching, boating, swimming, and general recreation at Great Salt Lake directly contributes $88.2 million annually to Utah's economy, pays $30.4 million in labor income, and supports the direct employment of 1,217 people.[134] Additionally, the impact of additional dust from Great Salt Lake is anticipated to impact the quality and length of the season for ski resorts.

At low enough lake levels, boating, sailing, and swimming opportunities would be completely eliminated. Changes to bird watching and duck hunting recreation would depend on the amount of freshwater that can sustain bird populations in the surface water inlets to the lake. To the extent that state waterfowl management areas or private duck clubs are able to maintain habitat to some degree because of existing water rights, some recreation might be able to continue. Because brine shrimp populations could be negatively impacted from declines in lake levels and increases in salinities, some bird species could experience a reduction in their primary food source. Reduced habitat would also limit bird populations and contribute to the spread of disease.[135] The combination of these factors will determine the magnitude of the impact to bird watching and duck hunting activities. Hiking and picnicking would still be available with declines in water levels at Great Salt Lake, but the quality of the activity is likely to diminish without nearby water. Figure 22 shows the locations of recreational areas around Great Salt Lake.

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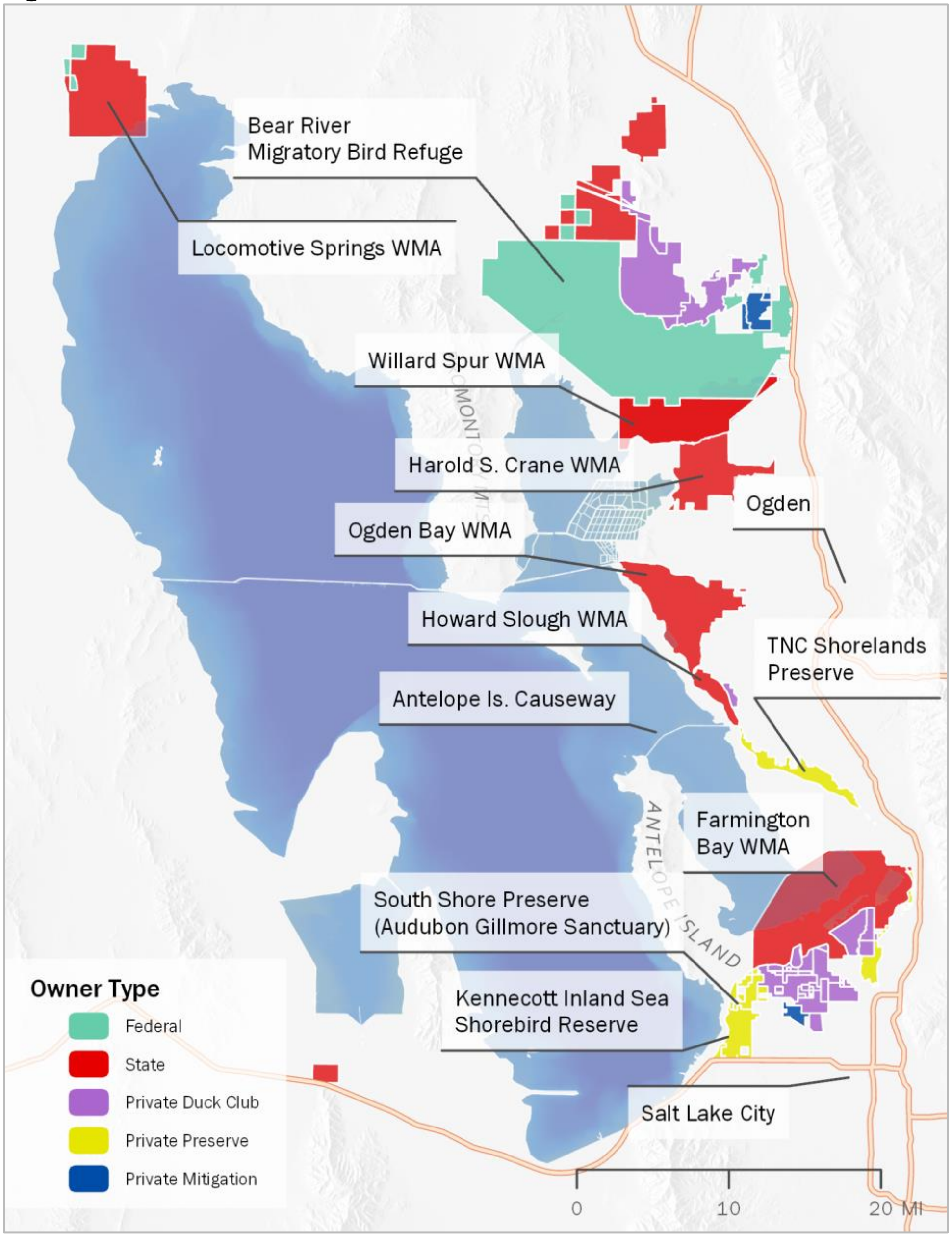
[134] Values have been inflated to 2019 dollars from 2010 dollars using the BLS CPI inflation calculator.

[135] Colwell, M. A., & Taft, O. W. (2000). Waterbird communities in managed wetlands of varying water depth. *Waterbirds*, *23*(1), 45-55.

Figure 22. Recreation Sites Around Great Salt Lake

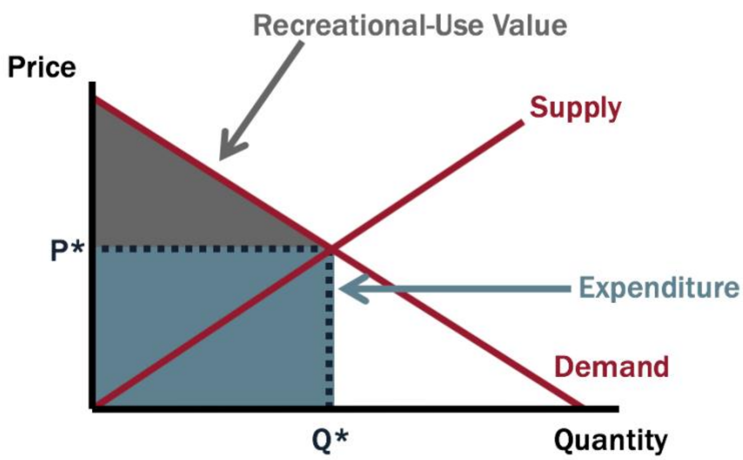


Source: Created by ECONorthwest

The values that people and businesses obtain from recreation include the spending associated with the activity as well as recreational-use value, also known as consumer surplus. The contribution that recreation makes to the regional economy was calculated by Bioeconomics (2012), but not all of that spending will be lost with declines in water level at Great Salt Lake. Recreational-use value is a measure of the value a person realizes from participating in a recreational activity beyond the expenditures they paid to do so. For example, if someone spends $100 dollars on gas, food, equipment, and other items to go birding for a day but that person would have been willing to spend $150 dollars on the activity, the $50 difference is the value of the recreational-use value because the participant is able to keep that value. Figure 23 provides a visual representation for how recreational-use value is calculated from the demand

and supply curves. Both the lost expenditures and lost recreational-use value values represent potential costs resulting from a declining Great Salt Lake.

Figure 23. Recreational-Use Value based on Supply and Demand



Source: Created by ECONorthwest

The per-day and per-person value of recreational-use value has been estimated by the U.S. Forest Service by activity for each of the ten forest service regions. Table 17 provides a summary of each of these values for activities that occur in and around Great Salt Lake. These values are for Region 4, the Intermountain Region, which includes Utah, Nevada, Southern Idaho, and Western Wyoming. We apply these values to the number of visits lost with declines in water levels at Great Salt Lake to estimate the lost value to consumers, as well as calculate the lost spending values that are based on the estimates from Bioeconomics (2012).

Table 17. Average Recreational-Use Value per Person per Primary Activity Day (Intermountain Region)

Activity	2019 Rounded Dollars
Hunting	$94
Nature Related	$75
Motorized Boating	$73
Nonmotorized Boating	$128
Hiking	$102
Downhill Skiing	$99
Picnicking	$63

Source: Created by ECONorthwest with information from Rosenberger, R.S.; White, E.M.; Kline, J.D.; Cvitanovich, C. (2017). Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. Rep. PNW- GTR-957. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

3.6.1 Bird Watching and Bird Related Tourism

Great Salt Lake is a location of hemispheric and global importance for the millions of migratory birds. It is designated as a Western Hemispheric Shorebird Reserve Network site (WHSRN)[136] and includes five globally Important Bird Areas around the lake.[137] Millions of birds use Great Salt Lake and its wetlands for feeding and resting during migration and some bird species also use the lake ecosystem for nesting and raising their young. Bird species include both shorebirds (e.g. avocets and sandpipers), and other waterbirds such as Eared Grebes and White-faced Ibis, as well as waterfowl (e.g. ducks, geese, and swans). Great Salt Lake provides important habitat for these species because of its wide variety of wetlands, and available food sources, including brine shrimp, brine flies, and other macroinvertebrates. The diversity of species and number of birds at Great Salt Lake attracts both local and non-local visitors.

Birding at Great Salt Lake can occur at a variety of locations, many of which are located on the eastern near freshwater inlets and the smaller bays, at Antelope Island, and along the causeway to Antelope Island. Although birding can occur throughout Great Salt Lake, one of the primary locations where it occurs is at the Bear River Migratory Bird Refuge, managed by the U.S. Fish and Wildlife Service, which has approximately 50,000 visits per year.[138] Other locations that are both public and private include Utah State Parks, State Waterfowl Management Areas, State Wildlife Management Areas, The Nature Conservancy's Shoreline Preserve, and Audubon's Gillmor Sanctuary and Lee Creek Area.

The Great Salt Lake Bird Festival has been occurring annually in Davis County every May since 1999. In 2018 over 1,000 events tickets were sold with over 2,000 people attending free festival events over the course of the 5-day festival.[139] Visitors came from twenty states of which Utah accounted for 804 of the ticket purchasers. In total the economic impact to the area is estimated at $150,000 from the festival event annually.[140]

Declining Great Salt Lake water levels could result in degradation of migratory bird habitat and reduction in overall populations. This decline in populations could reduce the appeal of birding locally and the ability to draw out-of-state visitors. The extent to which birding at Great Salt Lake would be impacted will vary by location.

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[136] More information about the Western Hemisphere Shorebird Reserve Network is available at https://whsrn.org/

[137] Audubon. (No Date). *Important Bird Areas: Utah*. Retrieved from https://www.audubon.org/important-bird-areas/state/utah

[138] Dietsch, A.M., Sexton, N.R., Koontz, L., and Conk, S.J. (2012). *National Wildlife Refuge Visitor Survey 2012: Individual Refuge Results for Bear River Migratory Bird Refuge*. Prepared for U.S. Fish and Wildlife Service Division of Visitor Services and Communications.

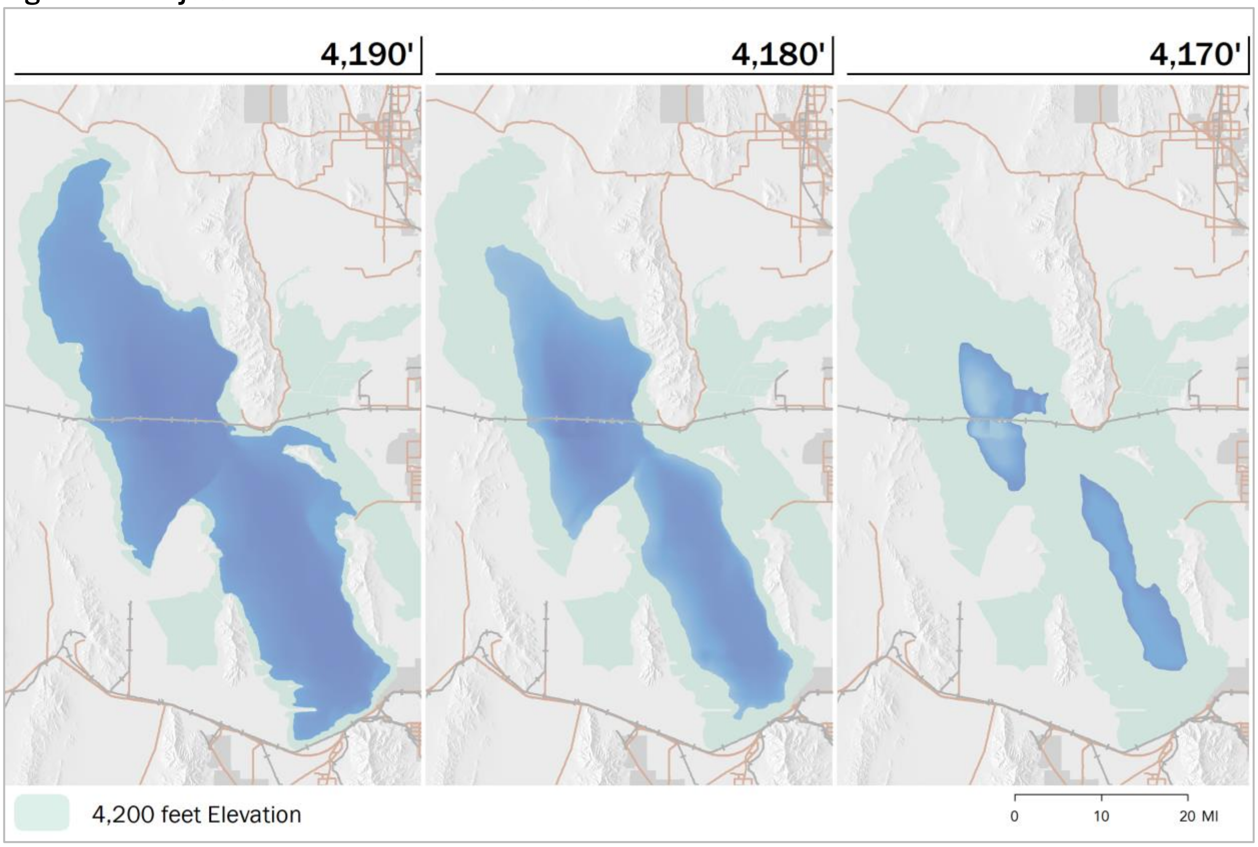
[139] Neka Roundy and Wendy Wilson personal communication on March 5, 2019.

[140] Great Salt Lake Bird Festival. (No Date). *20th Annual Great Salt Lake Bird Festival May 17-21, 2018*.

The Bear River Migratory Bird Refuge ("the Refuge") has a primary direct flow water right on the lower Bear River in the amount of 425,771 acre-ft per year.[141] The Refuge is also dependent on return flow from agriculture, which could be reduced in the future if agricultural lands are converted to municipal use. Although some water would be maintained in the Refuge, that water would only reach Great Salt Lake when there is excess flow, which could be limited during drought years. Duck clubs on the eastern and southern shores of the lake also have water rights and some water flows through the duck clubs can contribute to the lake.[142]

As the water level in Great Salt Lake is reduced, the main body of the lake would decrease in surface area and the inflows from the freshwater sources would be channelized. These changes would leave minimal open-water habitat for waterbirds and make the open-water or mudflat habitat inaccessible to birders based on current shore infrastructure. Figure 24 shows how lake elevation would change based on elevation. Lake elevation as of May 2019 was 4,194.5 feet.

Figure 24. Projected Surface Area of Great Salt Lake at Lower Lake Levels



Source: Created by ECONorthwest with data from Tarboton, D. (2017). Great Salt Lake Bathymetry. HydroShare. Retrieved from http://www.hydroshare.org/resource/582060f00f6b443bb26e896426d9f62a"

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[141] Frank, M., Marty, J., Rohal,C., Downard, R., Endter-Wada, J., Kettenring, K., Larese-Casanova, M. (2016). *Water Rights for Wetlands in the Bear River Delta.* Utah State University. Retrieved from https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1806&context=extension_curall

[142] Jack Ray, Utah Waterfowl Association, personal communication on February 25, 2019.

The declining open water habitat would also have other impacts which have the potential to severely reduce bird populations. The exact magnitude of the loss of birds is unknown, but there are many reasons to expect that bird populations would experience mortality or be forced to find new suitable areas, if possible, because of the increased stress including:

- High water salinity that would likely reach the threshold that it is unable to support brine shrimp and phytoplankton, which some bird species rely on as a food source.[143]
- Habitat decline could increase the risk of the spread of disease would increase substantially with the potential of severely impacting populations of some species.
- Predation of eggs could increase as lake levels decline and land bridges are formed to islands that were previously inaccessible.

The recreation and tourism from birders could be impacted from the decline in bird populations and the reduced opportunities to see the birds. To estimate the costs of the declines in water level at Great Salt Lake from these changes we apply the magnitude of the loss in visitation to estimate the lost spending and lost recreational-use value. Because birding occurs at a variety of locations that also offer hunting, hiking, and other recreational opportunities there is a potential for double counting and erroneous assignment for the reason for the visit.

Approximately 410,000 people birded in Utah in 2011 at least one mile away from their home.[144] Of those, an estimated 69 percent were state residents and the other 31 percent were from out of state. Total visitation estimates for all birding that only occurs in and around Great Salt Lake is not available. Birding does occur in other areas of Utah, such as Lytle Ranch and Fish Springs National Wildlife Refuge, so not all of the 410,000 birders in Utah went to a Great Salt Lake location for birding. The Audubon Society lists 22 Important Bird Areas in Utah, including areas in and around Great Salt Lake.[145] Using an estimate of 30 percent of the state total based on opportunities for birding in the state, approximately 112,000 of the birders would have gone to Great Salt Lake. This value is likely an underestimate given the quality of birding opportunities in Great Salt Lake. We know that Bear River Migratory Bird Refuge alone has between 50,000 and 85,000 visitors per year, of which approximately 80 percent are there for birding.[146,147] Based on those ranges and the birding activity that occurs at other locations, the 112,000 estimate of birders to Great Salt Lake is likely reasonable.

The number of birders is not the same as the total number of trips. Nationally, away from home birders take 13 trips per year. However, not every trip is likely to be to Great Salt Lake. The 2012

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[143] Belovsky, G. E., Stephens, D., Perschon, C., Birdsey, P., Paul, D., Naftz, D., ... & Mosley, R. (2011). The Great Salt Lake Ecosystem (Utah, USA): long term data and a structural equation approach. *Ecosphere*, 2(3), 1-40.

[144] U.S. Fish & Wildlife Service. (2013). *Birding in the United States: A Demographic and Economic Analysis*.

[145] Website is available at https://www.audubon.org/important-bird-areas/state/utah

[146] Dietsch, A.M., Sexton, N.R., Koontz, L., and Conk, S.J. (2012). *National Wildlife Refuge Visitor Survey 2012: Individual Refuge Results for Bear River Migratory Bird Refuge*. Prepared for U.S. Fish and Wildlife Service Division of Visitor Services and Communications.

[147] Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.

visitor survey at Bear River Migratory Bird Refuge found that, on average, people visited the refuge five times per year, suggesting that a minimum of 200,000 trips and potentially up to 560,000 trips per year to Great Salt Lake are for birding (based on the 40,000 number of visitors to Bear River Migratory Bird Refuge and 112,000 estimate, respectively). Applying the recreational-use value of $75 dollars per person per day for nature-related recreation from Table 17 results in a total annual recreational-use value attributable to birds is between $8.4 million and $41.4 million per year, based on the values from Table 17.

The recreational-use value that could be lost with declines in water levels at Great Salt Lake would depend on the birding opportunities still available. In a complete lake level loss scenario, water would be available at Bear River Migratory Bird Refuge and other eastern freshwater inlets, but bird populations are expected decrease at low lake levels based on reductions in habitat and food resources, and the potential for the spread of disease. Assuming bird populations or access is sufficiently reduced so that birding is essentially eliminated, **a declining Great Salt Lake could result in the loss of $8.4 million to $41.4 million per year in recreational-use value from birding**.

Recreational spending was estimated by Bioeconomics (2012) for combined recreational visits for hunting, bird watching, boating, swimming, and general recreation. The lost spending is summarized at the end of the recreation section for all recreation types, so we present the potential costs of those combined recreation values in terms of lost spending in the summary in section 3.5.5.

3.6.2 Hunting

The primary type of hunting relevant to aquatic resources of the Great Salt Lake is waterfowl hunting. Waterfowl include ducks, geese, swans, and other smaller waterbirds. Hunting on and around Great Salt Lake occurs on private land, including duck clubs, as well as federal land, state sovereign lands of the Great Salt Lake, and state lands managed for waterfowl production known as waterfowl or wildlife management areas (WMAs). Information from WMA managers suggests that waterfowl often use open water and bays of Great Salt Lake during the day to avoid disturbance and predation and return to freshwater/impounded marshes to feed at night. WMAs manage these freshwater impounded marshes for hunting and also provide hunter access to open water areas of Great Salt Lake by motorboat and airboat.

Declining lake levels can result in overall degradation of shorebird and other water bird and waterfowl habitat through a decrease in size and connectivity, and food sources. Lake surface area declines would also increase the distance between different aquatic habitat types. For example, the freshwater marshes of Ogden Bay WMA are currently over 4 miles from the present edge of Great Salt Lake. The majority of duck hunting occurs near the marshes and vegetation so the hunters can find cover, and not in open water portions of Great Salt Lake. Anecdotal evidence from WMAs and duck club managers suggests that lack of connectivity between Great Salt Lake and WMAs make the freshwater wetland habitat less appealing to avian resources. Consequently, there could be fewer birds during migration.[148] Anecdotal evidence supported by bird banding studies confirm that many birds use the California Central Valley where there are duck clubs and flooded agricultural fields in lieu of substandard conditions around Great Salt Lake.

The ten-year data on the number of duck and goose hunting days in Utah from 2008 to 2017 was 158,000 per year, which equates to approximately 6.3 days of hunting per hunter.[149] This value is lower than the 210,000 statewide hunting days used by Bioeconomics – however, hunting use days have been decreasing since the estimate in 2010. The lower value also does not include swan hunting or other less common species because information was not available. Not all of these hunting days are occurring at Great Salt Lake. Approximately 57 percent of the state hunting days occur at Great Salt Lake.[150] Based on these estimates, we believe approximately 90,000 to 120,000 hunting day trips occur in and around Great Salt Lake per year.

Applying the estimate of recreational-use value for hunting of $94 per trip from Table 17 to this number of annual visits, the total annual recreational-use value from hunting at Great Salt Lake is approximately $8.5 million to $11.0 million per year. **It is possible all of this $8.5 million to $11.0 million per year recreational-use value could be lost if duck and geese populations decline enough due to decreasing water levels.** Private duck clubs, the Bear River Migratory Bird Refuge, and WMAs would likely continue to have sufficient water to support some populations since many have water rights, but some loss of hunting days would likely occur as the quality of the experience diminishes.

In addition to the value hunters receive and the associated economic impacts from their spending, hunting permits and fishing licenses are also an important funding source for the Utah Division of Wildlife Resources making up approximately 39 percent or $38.7 million of its 2018 budget. Decreases in permits purchased would reduce the amount of money the Division has to pay staff and operate programs.

3.6.3 Boating, Sailing, and Water-Based Recreation

There are two primary boating access points on Great Salt Lake. On the southern shore of the lake is Great Salt Lake State Park and Great Salt Lake Marina. The Great Salt Lake Yacht Club is located here and has slips for 320 boats – however, 20 slips are already inaccessible due to insufficient depth and already a large number of sailors have relocated their boats elsewhere.[151] The Great Salt Lake Yacht Club was founded in 1877, so it also represents a cultural and historical value of the lake. Other clubs located at Great Salt Lake State Park/Marina include Great Salt Lake Row and the Hawaiian Canoe Club. Motor boats accessing the lake at Great Salt Lake State Park/Marina are used for brine shrimp harvest, hunting, sightseeing tours, search

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[148] Rich Hansen, Ogden Bay Waterfowl Management Area, personal communication on February 27, 2019.

[149] Olson, S. M. (2018). *Pacific Flyway Data Book 2018*. Vancouver, Washington: U.S. Fish and Wildlife Service.

[150] Bioeconomics. (2012). *Economic Significance of the Great Salt Lake to the State of Utah*. Prepared for Great Salt Lake Advisory Council.

[151] Dave Shearer, Great Salt Lake Marina, personal communication on February 3, 2019.

and rescue, and scientific research. There is one boat rental concession at Great Salt Lake State Park/Marina that offers dinner cruises, jet boat tours, and sailing lessons. Other boating uses of Great Salt Lake at this location include non-motorized boats such as canoes, kayaks, and sailboats. Kayaks, paddle boards, and other non-motorized rentals by the same concessionaire were suspended at this location and on Antelope Island.

The other primary access point is on the east side of Great Salt Lake, which is popular with the airboat community. Among other locations, air boaters use state-managed WMAs for hunting, service projects, and other recreation. However, lack of water adjacent to these areas and phragmites infestation resulting from low lake levels has resulted in decreased airboat use at these locations. Anecdotal comments suggest that airboat access is better in Willard Spur and the Bear River Migratory Bird Refuge. Brine shrimp operations also have access points for the boats the industry uses for operation.

Boating and sailing at Great Salt Lake could be severely impacted with declining lake levels if access is reduced. Two primary sources of costs would occur with declining water levels. The first is that expenditures would need to be made to maintain access to the lake. Current conditions allow for access to and from the marina. However, once GLS elevations reach 4,191 feet the Harbor Master of Great Salt Lake Marina expects to begin pulling boats out of the facility.[152] Utah State Parks recently dredged the access channel to the marina and northwest basin due to low lake elevation and sedimentation – the cost of this dredging was $1.5 million.[153] If dredging is not enough to provide access it will cost $10 million to $20 million to adapt the Great Salt Lake marina channel through the reef.[154] At low enough lake levels, no boating access will be feasible. In addition to recreational access at the Great Salt Lake Marina, search and rescue boats respond to between 40 and 100 distress calls annually and a plane crash approximately every 1.5 years.[155]

The second source of costs to boating and sailing at Great Salt Lake is the decline in recreational use and enjoyment, reflected in the lost recreational-use value values. From 2009 to 2018, Great Salt Lake State Park/Marina experienced an average of 207,000 visits per year. Not all of these visits were for boating or sailing, since there are other activities like sightseeing and picnicking that occur at the park. However, sightseeing and picnicking have similar recreational use values to motorized boating, thus even if this is an overestimate of sailors and boaters, it is likely a correct estimate of users who would cease visiting Great Salt Lake State Park/Marina. Although this value may be high, we assume visitors to the state park are going for lake access. We use this number of visitors to reflect all recreational boating at the lake that might decline with losses in Great Salt Lake. We apply the recreational-use value of $73 for motorized boating (a similar value to the $75 for nature related recreation) and $128 for nonmotorized boating from Table 17. Applying the average of these values to the 207,000 average annual visitors, the

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[152] Dave Shearer, Great Salt Lake Marina Harbormaster, personal communication on February 3, 2019.

[153] Ibid.

[154] Ibid.

[155] Ibid.

recreational-use value from boating at Great Salt Lake is estimated as $15.1 million to $26.5 million per year. This value does not reflect substitution effects from Great Salt Lake drying, meaning the preservation of some recreational-use value if boating occurs at a lake other than Great Salt Lake is not considered. **All of this $15.1 million to $26.5 million per year recreational-use value could potentially be lost if Great Salt Lake dries enough to limit the boating and sailing opportunities.** These values for boating and sailing potential costs represent the entire visitation to Great Salt Lake State Park/Marina, and thus likely include recreational-use value for sightseeing, picnicking, and other activity that is occurring at the park. These other activities are not excluded from the estimate because they have similar recreational-use values and are also likely to be reduced with declining lake levels.

The expenditures by boaters is also an important cost. While some people will move their boats to other lakes, others will not. Because the expenditures for boating are included with other recreational counts, these are summarized at the end of this recreation section.

3.6.4 General Recreation

Approximately 1.1 million visits occurred in 2018 to state parks around Great Salt Lake, including 496,000 visits to Antelope Island State Park, 122,000 visits to Great Salt Lake Marina State Park, and 523,000 visits to Willard Bay State Park. Many of these visits are included in our estimates of birding, hunting, sailing, and boating, but other visits are likely for sightseeing and general recreation and could also be reduced with water level declines at Great Salt Lake that diminish the quality of the experience.

3.6.5 Snow-Based Recreation

Earlier snow melt and reduced lake effect snow is anticipated to negatively impact the ski industry and snow recreation industries in Utah. Ski resorts in Utah have an economic impact valued at $1.43 billion for the 2016-2017 season.[156] During the 2016-2017 season there were an estimated 4.58 million skier days and average per person per visit spending (on-mountain and off-mountain) was $296.[157] Snowmobiling in Utah also has a considerable economic impact – in 2017 the activity contributed $88.4 million in value added to Utah's economy.[158] Backcountry skiing and other snow-related tourism also add economic value to Utah's economy.

Spending on snow recreation by visitors is anticipated to decline throughout the year and end earlier than in the past with a declining Great Salt Lake. The impact from reduced snowpack and accelerated snowmelt from water level declines at Great Salt Lake will compound with the growing impacts from climate change that are could also adversely affect Utah's snow recreation industries.

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[156] Leaver, J. (2018). *The State of Utah's Travel and Tourism Industry*. Kem C. Gardner Policy Institute. May.

[157] Ibid.

[158] Smith, J.W., and Lamborn, C.C. (2018). *The economic impact of snowmobiling in Utah*. Prepared for Utah Snowmobile Association.

Albedo and Snow Melt

Research in the Wasatch Mountains of Utah and the San Juan Mountains of Colorado has shown that dust on the snowpack results in decreased albedo (the proportion of light or radiation that is reflected by a surface) which causes faster and earlier peak snowmelt. The loss of snow cover is linearly related to the total dust concentration in the snowpack.[159,160] In the Wasatch mountains, there were five dust events observed during the spring of 2017. Data show that the dust from just one of these events caused the snowpack to melt five days earlier than it would have otherwise in the Wasatch Mountains.[161] Approximately 7 percent of the dust deposited during this event was from the dried lake bed of Great Salt Lake.[162]

In the future, the effect of dust is expected to increase. Based on research by Dr. Kevin Perry from University of Utah, dust "hot spots" increase by 7.26 to 13.83 percent for each 1-foot decrease in lake elevation, depending on the location.[163] Approximately 11 percent of the 750 square miles of exposed lake bed are currently blowing dust.[164] The total area of Great Salt Lake is approximately 1,700 square miles. If the entire main body of Great Salt Lake was exposed and 11 percent continues to blow dust, we would expect dust from Great Salt Lake to increase 227 percent. This means that the total dust load affecting snow melt would increase proportionately, accelerating the rate at which the snow melts. Skiles et al. (2018), who estimated the amount of snowmelt attributable to Great Salt Lake, conclude their paper by saying "these simulations indicate that a shrinking Great Salt Lake could impact the Wasatch Mountain's snowpack in the future".

Lake Effect Precipitation/Snow

Reduction of lake effect would also impact snowpack in the Wasatch Mountains. Lake effect occurs when cold air passes over relatively warmer water causing heat and moisture to create clouds that precipitate heavy snow downwind of the waterbody. The amount of lake effect that occurs in a given year is largely determined by the meteorology of air and moisture in the Great Salt Lake area, rather than the exact size of the lake.[165] As a large waterbody, recent declines in

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[159] Painter, T. H., Deems, J. S., Belnap, J., Hamlet, A. F., Landry, C. C., & Udall, B. (2010). Response of Colorado River runoff to dust radiative forcing in snow. *Proceedings of the National Academy of Sciences*, 107(40), 17125-17130.

[160] Skiles, S. M., Mallia, D. V., Hallar, A. G., Lin, J. C., Lambert, A., Petersen, R., & Clark, S. (2018). Implications of a shrinking Great Salt Lake for dust on snow deposition in the Wasatch Mountains, UT, as informed by a source to sink case study from the 13–14 April 2017 dust event. *Environmental Research Letters*, 13(12), 124031.

[161] Ibid.

[162] Ibid.

[163] Perry, K.D., Crosman, E.T., and Hoch, S.W. (2019). *Results of the Great Salt Lake Dust Plume Study (2016-2018)*. Prepared for Utah Department of Natural Resources Division of Forestry, Fire, and State Lands and Utah Division of Facilities Construction and Management. April.

[164] Ibid.

[165] Steenburgh, J. (2018) *2018 Great Salt Lake Issues Forum*. May 10. Retrieved from www.fogsl.org/programsgreat-salt-lake-issues-forum

lake elevation have heightened interest in determining how great of a lake effect exists for Great Salt Lake.[166]

Lake effect snow in the Salt Lake Valley can range from a few inches to over a foot of snow per event and an average of 10 events per year have occurred from 1998 to 2012.[167,168] Although falling primarily in the valley, [169] the Wasatch Mountains also receive snow attributable to lake effect.[170] To contextualize that scale, from 2004 to 2018 Alta Ski Resort received an average of 537.8 inches of snow per year.[171] Lake effect precipitation (primarily snow) accounts for approximately 5.1 to 8.4 percent of the cool-season (September 16 to May 15) precipitation and occurs predominately to the south and east of Great Salt Lake.[172,173] Assuming that this percentage also holds for snowpack, the 5.1 to 8.4 percent snowpack corresponds to approximately 27 to 45 inches of snow per year based on the annual average from 2004 to 2018 at Alta Ski Resort.[174] Higher elevation ski resorts are likely to be less affected than lower elevation ski resorts since they would maintain more snow and people would substitute to them.[175] In addition to ski resorts, snowmobilers and other backcountry snow recreationists would also be affected by reductions in snowpack. The result of decline in snowpack from lost lake effect with water level declines at Great Salt Lake would be a reduction in large storm days and a decrease in snow-related tourism. An increase in lake salinity could also produce smaller

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[166] Yeager, K. N., Steenburgh, J.W., & Alcott, T. I. (2013). Contributions of lake-effect periods to the cool-season hydroclimate of the Great Salt Lake Basin. *Journal of Applied Meteorology and Climatology*, *52*(2). https://doi.org/10.1175/JAMC-D-12-077.1

[167] Steenburgh, W. J., Halvorson, S. F., & Onton, D. J. (2000). Climatology of Lake-Effect Snowstorms of the Great Salt Lake. *Monthly Weather Review*, 128(3). https://doi.org/10.1175/1520-0493(2000)128<0709:coleso>2.0.co;2

[168] Alcott, T. I., Steenburgh, W. J., & Laird, N. F. (2012). Great Salt Lake–Effect Precipitation: Observed Frequency, Characteristics, and Associated Environmental Factors. *Weather and Forecasting*, 27(4). https://doi.org/10.1175/waf-d-12-00016.1

[169] Carpenter, D. M. (1993). The Lake Effect of the Great Salt Lake: Overview and Forecast Problems. *Weather and Forecasting*, 8(2). https://doi.org/10.1175/1520-0434(1993)008<0181:tleotg>2.0.co;2

[170] Alcott, T. I., & Steenburgh, W. J. (2013). Orographic influences on a Great Salt Lake–effect snowstorm. *Monthly Weather Review*, *141*(7), 2432-2450.

[171] Alta Ski Resort, Snowfall History. Available at https://www.alta.com/conditions/weather-observations/snowfall-history

[172] Yeager, K. N., James Steenburgh, W., & Alcott, T. I. (2013). Contributions of lake-effect periods to the cool-season hydroclimate of the Great Salt Lake Basin. *Journal of Applied Meteorology and Climatology*, *52*(2). https://doi.org/10.1175/JAMC-D-12-077.1

[173] Steenburgh, J. (2018). *The Great Salt Lake Effect: Mechanisms and Contributions to Wasatch Snow*. Presentation at Great Salt Lake Issues Forum. May 10. Retrieved from https://www.fogsl.org/images/Jim_Steenburgh_The_Great_Salt_Lake_Effect_.pdf

[174] Alta Ski Resort, Snowfall History. Available at https://www.alta.com/conditions/weather-observations/snowfall-history

[175] Steiger, R., Scott, D., Abegg, B., Pons, M., & Aall, C. (2017). A critical review of climate change risk for ski tourism. *Current Issues in Tourism*, 1-37.

lake effects,[176] so increases in Great Salt Lake salinity at lower lake volumes could exacerbate the lake effect loss.

In general, visitation to ski resorts has become less dependent on natural snow due to snowmaking technologies becoming more common. However, even at high elevations the depth of snow impacts the number of visits to ski resorts and associated spending. Falk and Vieru (2016) found that a 10 percent reduction in average snow depth relative to the previous season causes a 1.6 to 3.2 percent decline in skier visits.[177,178] Limited analysis has been conducted in the United States to estimate how visitation to ski resorts is impacted by snowpack depth. The Wasatch ski industry is largely driven by its reputation for the "Greatest Snow on Earth," with large storms of light, dry snow. Loss of extreme snowfall events could affect the overall reputation and attraction of the region to tourists, residents and potential residents alike.

If Great Salt Lake no longer contributes or contributes less to lake effect snow, average annual snowpack could decline up to 5.1 to 8.4 percent.[179] This snowpack decline could then lead to a 0.8 to 1.3 percent decline in visitors using the low-end estimates from Falk and Vieru (2016). Geographically, these snowpack declines are expected to impact primarily snow recreation areas southeast of Great Salt Lake, but also areas directly east of Great Salt Lake. Assuming 50 percent of the 4.58 million skier days statewide[180] are in the impacted area, there would be an estimated **18,000 to 30,000 fewer visitor days to Utah ski resorts alone (not including snowmobiling, backcountry skiing, and other snow activities)**. Average per person per visit spending (on-mountain and off-mountain) is $312.15 (2019 dollars).[181] **Combing this visitor spending with the reduced visitation estimate due to snowpack declines suggests that between $5.8 million to $9.6 million per year could be lost in statewide spending due to declines in water levels at Great Salt Lake.** This estimate does not include effects from early ski resort closures anticipated from the increased rate of snow melting caused by the dust from Great Salt Lake. We believe this is a conservative estimate of the costs to the snow recreation industries because it also does not include all snow recreation activities.

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[176] Onton, D. J., & Steenburgh, W. J. (2001). Diagnostic and sensitivity studies of the 7 December 1998 Great Salt Lake–effect snowstorm. *Monthly weather review*, 129(6), 1318-1338.

[177] Falk, M., & Vieru, M. (2017). Demand for downhill skiing in subarctic climates. *Scandinavian Journal of Hospitality and Tourism*, 17(4), 388-405.

[178] Steenburgh, J. (2018). *The Great Salt Lake Effect: Mechanisms and Contributions to Wasatch Snow*. Presentation at Great Salt Lake Issues Forum. May 10. Retrieved from https://www.fogsl.org/images/Jim_Steenburgh_The_Great_Salt_Lake_Effect_.pdf

[179] Yeager, K. N., Steenburgh, J.W., & Alcott, T. I. (2013). Contributions of lake-effect periods to the cool-season hydroclimate of the Great Salt Lake Basin. *Journal of Applied Meteorology and Climatology*, *52*(2). https://doi.org/10.1175/JAMC-D-12-077

[180] Leaver, J. (2018). *The State of Utah's Travel and Tourism Industry*. Kem C. Gardner Policy Institute. May.

[181] Inflated from $296 from Leaver (2018) using the BLS CPI Inflation Calculator

Recreational-use value (the measure of value equal to the amount recreationists are willing to pay beyond what they actually pay) would also decline if snow recreation is reduced due to declines in Great Salt Lake. Based on the per person per day value for downhill skiing from Table 17 of $99, the 18,000 to 30,000-annual loss in visitation results in a **$1.8 million to $3.0 million annual loss of recreational-use value from ski resort visits.**

Lower lake levels at Great Salt Lake could impact the marketability of Northern Utah as a skiing destination relative to other locations in Colorado and Wyoming. The *Ski Utah* website states that: "The Great Salt Lake does not freeze, so lake effect is a possibility all ski season long. Resorts within proximity to the lake enjoy lake-effect periods which produce about five percent of the average precipitation from September to May."[182] Even if lake effect losses are minimal, the inability to use lake effect as a marketing mechanism also represents an important potential costs to the ski industry in Utah.

3.6.6 Summary of Costs to Recreation

Declines in water levels at Great Salt Lake would affect birding and duck hunting, the magnitude of which will depend on the extent of the population declines. The current recreational-use value from these activities is estimated to be between $4.7 million per year for birding and $8.5 million per year for hunting. Boating would also be severely impacted by declines in Great Salt Lake because access could be reduced, requiring costs to maintain access of $10 million to $20 million and potentially resulting in total access loss if lake levels decline sufficiently.

We estimate that $21 million per year in recreational-use value at Great Salt Lake could be lost from boating relative to current levels. Ski resort recreation would also be impacted from earlier season closures and reduced snowpack. These impacts would result in an estimated $3.0 million annual loss of recreational-use value. Other recreational activities at Great Salt Lake would also be impacted, particularly swimming and sightseeing of the lake. Because of the aesthetic loss of water, hiking and picnicking are also expected to decline in quality. Projections for the decline in visitation due to these changes is unknown, so we did not monetize the recreational-use value loss. A summary of these recreational-use value losses is presented in Table 18.

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[182] Ski Utah. (No Date). *10 Things You Didn't Know About Utah Snow*. Retrieved from https://www.skiutah.com/explore/snow.

Table 18. Recreational-Use Value Loss from Declining Recreation/Visitation at Great Salt Lake (2019 dollars)

Activity	Estimated Reduction in Visitation	Annual Recreational-Use Value Loss
Birding	200,000 to 560,000 visits	$8.4 million to $41.4 million
Duck Hunting	90,000 to 120,000 visits	$8.5 million to $11.0 million
Boating, Sailing, and Other Water-Based Recreation	200,000 visits	$15.1 million to $26.5 million
Ski Resorts	18,000 to 30,000 visits	$1.8 million to $3.0 million
Sightseeing, hiking, picnicking, other general recreation	N/A	Unknown value, partial loss possible
Total	**508,000 to 910,000 visits**	**$33.8 million to $81.9 million**

Source: Created by ECONorthwest

Bioeconomics (2012) estimates that hunting, bird watching, boating, swimming, and general recreation at Great Salt Lake directly contributes $88.2 million annually to Utah's economy, increases total economic output by $160.5 million, pays $30.4 million in labor income, and employs 1,217 people.[183] These values are based upon visitation to recreational areas at Great Salt Lake to obtain the 990,000 visits per year estimate of total annual visitor days. To the extent that visitors cease going to Great Salt Lake recreation locations this spending would be lost. Based on the estimates discussed in each section that preceded this, bird watching, hunting, boating and sailing contribute a minimum of 500,000 annual visits per year, or approximately 50 percent of total visitation. **If these recreation visits are lost due to a declines in water levels at Great Salt Lake the costs of the spending loss would be $44.5 million in direct spending, $81.1 million in total output, $15.4 million in labor income, and 615 jobs** (Table 19). We believe this estimate is conservative because it uses the lower-bound visitation estimate for the reduction in recreational activities at Great Salt Lake.

Table 19. Estimated Recreation Spending Losses at Great Salt Lake from Water Level Declines (2019 dollars)

	Direct Output	Total Output	Labor Income	Jobs
Current Visitation: 990,000	$88.2 million	$160.5 million	$30.4 million	1,217
Future Visitation: 490,000	$43.7 million	$79.4 million	$15.0 million	602
Difference (Potential Loss)	**$44.5 million**	**$81.1 million**	**$15.4 million**	**615**

Source: Created by ECONorthwest with information from Bioeconomics (2012)
Note: These recreation estimates include only the following activities that occur at Great Salt Lake: hunting, bird watching, boating, swimming, and general recreation

Additionally, we estimate that another $5.8 million to $9.6 million per year could be lost in ski resort spending based on reduction in visitation. Including the ski resort spending reductions suggest that the **potential direct spending loss due to declines in water levels at Great Salt Lake is at least $50.3 million per year**.

[183] Values have been inflated to 2019 dollars from 2010 dollars using the BLS CPI inflation calculator.

3.7 Water Management Costs

Declining water levels at Great Salt Lake would likely impact snowpack through both the lake effect, which affects the amount of snow that falls, and decreased albedo, which affects the timing of snow melt. Between 5 to 8 percent of annual snowpack in the Wasatch Range is believed to be attributable to lake effect.[184,185] The albedo effect from recent dust events has contributed to accelerated snowmelt of approximately five day earlier.[186] Approximately 7 percent of the dust deposited during this event was from the dried lake bed of Great Salt Lake.[187]

3.7.1 Costs to Water Managers

The snowpack in the Wasatch Mountain Range functions as storage for the cities along the Wasatch Front that rely on spring snowmelt. The U.S. Forest Service characterizes the Wasatch Mountain Range as having high watershed vulnerability, partially due to the reliance on snowpack. [188] Decreases in the amount of water stored and earlier snowmelt timing would affect water management in the region and create uncertainty and vulnerabilities among water right holders.

Declines in water levels at Great Salt Lake could result in the reduction or loss of the lake effect, meaning that less snowpack would fall in the mountains.[189] Less snowpack would also mean there is less water in the Bear, Jordan, and Weber river basins, so less water will be available from those sources to flow into Great Salt Lake. Declines in water levels at Great Salt Lake would also expose more dry-lakebed, increasing the airborne dust load attributable to the lake. Increased dust will decrease the albedo, a measure of reflectiveness, of snow, especially in the spring when major dust storms occur. When the snow is less reflective from the dust it absorbs more light and heat, resulting in faster snowmelt. Water managers such as the U.S. Army Corps of Engineers and municipal water providers are accustomed to the current timing of snowmelt, and changes in snowmelt timing could result in costs from process or infrastructure changes.

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[184] Yeager, K. N., Steenburgh, J., & Alcott, T. I. (2013). Contributions of lake-effect periods to the cool-season hydroclimate of the Great Salt Lake Basin. *Journal of Applied Meteorology and Climatology*, *52*(2). https://doi.org/10.1175/JAMC-D-12-077.1

[185] Alcott, T. I., & Steenburgh, W. J. (2013). Orographic influences on a Great Salt Lake–effect snowstorm. *Monthly Weather Review*, *141*(7), 2432-2450.

[186] Ibid.

[187] Ibid.

[188] Rice, J., Bardsley, T., Gomben, P., Bambrough, D., Weems, S., Leahy, S., Plunkett, C., Condrat, C., Joyce, L.A. (2017). *Assessment of watershed vulnerability to climate change for the Uinta-Wasatch-Cache and Ashley National Forests, Utah.* U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[189] We recognize that lake effect likely does not have a linear relationship with surface area of the waterbody. However, we are assuming that if the surface area of Great Salt Lake declined enough the entire lake effect could be lost.

Earlier snowmelt would also result in earlier lower stream flows when water is needed in the late-summer.

3.8 Mitigation & Management Costs

Mitigation and management costs at Great Salt Lake could be incurred to minimize the adverse impacts discussed thus far in the report, including dust, habitat loss, invasive species, and others. Through the "Watershed Restoration Initiative", Utah Department of Natural Resources annually spends between $12 and $15 million in public and private funds to implement ecosystem management and restoration projects on 85,000 to 100,000 acres.[190] When considered in terms of cost per acre, this amounts to between $120 to $176 per acre and could include vegetation treatments, water system development, and instream habitat structures among other restoration strategies. Mitigation projects around Great Salt Lake provide an example of what the per-acre costs of mitigation and restoration might be. Other locations where mitigation for dust has occurred are discussed in the following sections to estimate the potential cost of mitigation at Great Salt Lake.

3.8.1 Dust and Habitat Mitigation

Restoration of terminal lakes at the scale required to renew large areas of wildlife habitat and mitigate environmental impacts can have high per acre costs, especially after severe degradation has occurred. Examples where large restoration projects have occurred in habitats similar to Great Salt Lake include Owens Lake and Salton Sea, both in California. Both Owens Lake and Salton Sea include avian habitat restoration and dust suppression as the primary goals to offset impacts to ecosystem services and mitigate poor air quality from historic dewatering.

Owens Lake: In 1913, Owens Lake, located east of the Sierra Nevada Mountain range, began to experience water diversions from the Los Angeles Department of Water and Power (LADWP). LADWP violated the Clean Air Act as a result of these water diversions because of the high concentrations of airborne dust from the dry lakebed. LADWP now has to pay for court ordered mitigation at Owens Lake. Mitigation measures include purchasing replacement water, large sprinkler systems, gravel cover, brine flooding, ridges, and tillage.[191] LADWP has spent approximately $2.1 billion from 1995 to June 2018 on dust suppression and habitat creation measures at Owens Lake,[192] including over $300 million in purchased water to replace the water

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[190] Utah Wildlife Action Plan Joint Team. (2015*). Utah Wildlife Action Plan*. Retrieved from https://wildlife.utah.gov/wap/Utah_WAP.pdf

[191] Los Angeles Department of Water and Power. (2013). *Owens Lake Master Project*. Retrieved from https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-losangelesaqueduct/a-w-laa-owenslake?_adf.ctrl-state=deealfjwb_21&_afrLoop=295337138500000

[192] Taghavi, M. (2015). "Subject: Los Angeles Department of Water and Power's Expenditures for Mitigation Dust Emissions from Owens Lake". Email to Phill Kiddoo. December 28. *2016 SIP References: (LADWP, 2015b)_Owens Lake Expenditures.* Retrieved from https://www.gbuapcd.org/District/AirQualityPlans/OwensValley/

diverted by the utility since 2002.[193] Moving forward, LADWP is projected to spend $3.65 billion through 2025 on dust mitigation and habitat restoration, with annualized costs $145.8 million per year (2016 dollars).[194] In 2018 alone, LADWP budgeted $112 million[195,196] for mitigation measures on approximately 31,100 acres at Owens Lake,[197] a cost of approximately $3,600 per acre for 2018.

Based on these values the real annual cost range is between $111.4 million to $157.6 million per year for mitigation costs at Owen's Lake (Table 20). Annual per acre costs for the approximately 31,000 acres being treated ranges between a real cost of $3,500 to $5,100 per acre.

Table 20. Owen's Lake Mitigation Cost Ranges

Time Period	Total Cost (Nominal)	Annual Cost (Nominal)	Annual Cost (2019 Dollars)	Approx. Per Acre Cost (2019 Dollars)
1995 to 2018	$2.1 billion	$91.3 million	$111.4 million	$3,500
2018	$112 million	$112 million	$115.7 million	$3,700
Annual for 25 Years	$3.65 billion	$145.8 million	$157.6 million	$5,100

Source: Created by ECONorthwest
Note: All dollar values have been inflated to 2019 values using the BLS CPI Inflation Calculator

***Salton Sea**:* The Salton Sea is a saline lake located southeast of Palm Springs in California. Water transfers and subsequent reductions in inflows have led to declines in lake levels and increases in salinity at the lake. Since 2001 lake elevation has decreased approximately 8.7 feet and is modeled to decline another 11 feet by 2030 based on expected conditions.[198] A 2003 Quantification Settlement Agreement included provisions for water transfers from the Imperial Irrigation District to the Salton Sea to make up for anticipated water losses that would likely adversely impact health and ecosystems.[199] In 2017, the California Natural Resources Agency released a ten-year plan for restoring the Salton Sea from 2018 to 2028.[200] Under this plan, 30,410

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[193] Los Angeles Department of Water & Power. (2015). *Water System Rate Action Report, Chapter 3: Rate Drivers*. July. Page 54. Retrieved from http://clkrep.lacity.org/onlinedocs/2015/15-1543_misc_13_12-23-2015.pdf

[194] Ramboll Environ. (2016). *2016 Owens Valley Planning Area PM_{10} State Implementation Plan.* Prepared for Great Basin Unified Air Pollution District. April. Retrieved from https://www.gbuapcd.org/District/AirQualityPlans/OwensValley/

[195] Los Angeles Department of Water & Power. (2015). *Water System Rate Action Report, Chapter 3: Rate Drivers*. July. Page 54. Retrieved from http://clkrep.lacity.org/onlinedocs/2015/15-1543_misc_13_12-23-2015.pdf

[196] Costs have been inflated to 2019 values using the BLS CPI Inflation Calculator

[197] Kiddoo, P. (2018). *Owens Valley Planning Area Reasonable Further Progress*. Great Basin Unified Air Pollution Control District. April. Retrieved from https://www.gbuapcd.org/Docs/District/AirQualityPlans/OwensValley/2018%20OVPA%20RFP.pdf

[198] Pacific Institute. (2019). *Current Information on the Salton Sea*. Retrieved from https://pacinst.org/current-information-salton-sea/

[199] San Diego County Water Authority. (No Date). *Quantification Settlement Agreement*. Retrieved from https://www.sdcwa.org/quantification-settlement-agreement

[200] California Natural Resources Agency. (2017). *Salton Sea Management Program Phase I: 10-Year Plan*. March. Retrieved from http://resources.ca.gov/docs/salton_sea/ssmp-10-year-plan/SSMP-Phase-I-10-YR-Plan-with-appendices.pdf

acres would be treated for an estimated capital cost over the ten years of $420 million (2017 dollars), not including operations and maintenance costs, or monitoring and adaptive management costs, which could reach 10 percent of total capital costs at full build-out. Applying a conservative 10 percent additional cost to the $420 million results in $462 million in project costs for 10 years.

A 2006 Bureau of Reclamation report for Salton Sea estimated that from 2006 to 2024 even the No Action Alterative would cost $1.4 billion based on costs of $7,000 to $14,000 per acre over multiple years (2006 dollars).[201] Assuming these values would hold for the 30,410 acres that were treated, the per acre cost for 18 years is approximately $2,600 (2006 dollars). Table 21 summarizes the mitigation costs ranges for Salton Sea.

Table 21. Salton Sea Mitigation Cost Ranges

Time Period	Total Cost (Nominal)	Annual Cost (Nominal)	Annual Cost (2019 Dollars)	Approx. Per Acre Cost (2019 Dollars)
2018 to 2028	$462 million	$46.2 million	$48.7 million	$1,600
2006 to 2024	$1.4 billion	$77.8 million	$100.44 million	$3,300

Note: All dollar values have been inflated to 2019 values using the BLS CPI Inflation Calculator

Great Salt Lake: The cost of mitigation at Great Salt Lake would be determined by the number of acres mitigated and the technique implemented. Caution is needed when applying per acre cost estimates from Owens Lake and Salton Sea because costs are unique to each location and will vary depending on the treatment needed, the regulatory and legal process, and other factors. Estimating an annual mitigation treatment cost is similarly difficult because the lifespan of projects could be 30 to 50 years with variation of orders of magnitude during that time. For example, dust control projects might require new treatments every 4 to 7 years. In order to estimate the potential costs of mitigation for dust and creation of habitat at Great Salt Lake we use per acre per year ranges from Owens Lake and Salton Sea that represent average per year project costs during the lifetime of the mitigation project.

A completely dry Great Salt Lake would expose at most 1,700 square miles of dry lake bed. It is unlikely that mitigation or land management would occur throughout this entire area, and precipitation and groundwater would ensure a small amount of water remained in Great Salt Lake at least seasonally even if the riverine inflows ceased completely.

Based on work by Dr. Kevin Perry et al. (2019) approximately 11 percent of the lake blows dust and contributes to regional airborne particulate matter levels.[202] As of 2018, there are approximately 750 square miles of lakebed exposed at Great Salt Lake at an elevation of approximately 4,192 feet. Therefore, the 11 percent of dry lakebed that is currently blowing dust is approximately 82.5 square miles. This area is likely an underestimate because it does not include any area that would be mitigated for habitat loss.

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[201] U.S. Department of the Interior, Bureau of Reclamation. (2007). *Restoration of the Salton Sea*. September. Retrieved from https://www.usbr.gov/lc/region/saltnsea/FinalSummaryRpt.pdf

[202] Dr. Kevin Perry personal communication on February 5, 2019.

The summary of costs for both Owens Lake and Salton Sea are in Table 22. Based on both these locations the cost per square mile ranges from $1,600 to $5,100 per acre per year ($1.0 million to $3.3 million per square mile).

Table 22. Summary of Example Annual Mitigation Costs (2019 dollars)

Location	Approx. Annual Cost per Acre	Approx. Cost per Square Mile
Owens Lake, California	$3,500 - $5,100	$2.2 million - $3.3 million
Salton Sea, California	$1,600 - $3,300	$1.0 million – $2.1 million

Source: Created by ECONorthwest

Based on the average treatment costs in Table 22, costs for mitigating the acres currently blowing dust would be between $84.5 million and $184.8 million per year. For each additional square mile of treatment, the cost would be $1.0 million to $3.3 million per year. **Assuming that 11 percent of exposed lakebed blows dust in a future drier lake scenario, approximately 187 square miles of dust would blow. If mitigation occurs on all of these 187 square miles, the cost to mitigate would be a total of $191.5 million to $610.4 million per year.**[203]

Responsibility to pay for this mitigation is unknown. In the case of Owens Lake, the Los Angeles Department of Water and Power was found liable because the diversion of water and resulting dust caused Clean Air Act violations. As a result, Los Angeles water users are paying higher water bills to fund the costs of mitigation. LADWP's *2015 System Rate Action Plan* noted that, "It has been estimated that nearly two months out of every Los Angeles ratepayer's annual water bill is spent on Owens Lake dust mitigation."[204] Responsibility for mitigation and related costs if Great Salt Lake declines significantly due to diversions, such as those predicted on the Bear River, could fall on the State of Utah and possibly other entities. There is also a potential Endangered Species Act liability which could require habitat mitigation if species become listed or harmed due to declines in water levels at Great Salt Lake.

3.8.2 Invasive Species Removal

The dominant invasive species present in and around Great Salt Lake is common reed grass, also known as phragmites (scientific name *Phragmites australis*). In 2012, there were approximately 36 square miles (over 23,000 acres) of phragmites around Great Salt Lake with an additional area of approximately 3.86 square miles of highly suitable, uninvaded habitat identified.[205] This species is known to greatly reduce the habitat quality for native bird species including waterfowl.[206] Phragmites crowds out native species and changes the shoreline habitat

[203] These annual costs represent average annual costs during the lifetime of the mitigation project, and not costs in perpetuity.

[204] Los Angeles Department of Water & Power. (2015). *Water System Rate Action Report, Chapter 3: Rate Drivers*. July. Page 54. Retrieved from http://clkrep.lacity.org/onlinedocs/2015/15-1543_misc_13_12-23-2015.pdf

[205] Long, A. L., Kettenring, K. M., Hawkins, C. P., & Neale, C. M. U. (2017). Distribution and Drivers of a Widespread, Invasive Wetland Grass, Phragmites australis, in Wetlands of the Great Salt Lake, Utah, USA. *Wetlands*, 37(1), 45–57. https://doi.org/10.1007/s13157-016-0838-4

[206] Kettenring, K. M., Garvie, K., Hazelton, E. L., Hough-Snee, N., & Ma, Z. (2012). *Final Report to the Utah Department of Natural Resources, Division of Forestry, Fire, & State Lands Part II Land Manager Survey*. Salt Lake City.

around Great Salt Lake.[207] Phragmites also has high levels of consumptive water use – phragmites in the wetlands within Great Salt Lake consume over 81,000 acre-feet of water from March to October, representing approximately 3 percent of annual inflows to Great Salt Lake.

While it is not known exactly how a continuing decrease in Great Salt Lake level would affect the distribution of phragmites, it is likely that the population would expand in some areas and contract in others. Phragmites around Great Salt Lake are most likely to occur in areas near nutrient pollution point sources, at lower elevations (with prolonged periods of inundation), and in waters with salinities less than 20 percent.[208] With this information, we can surmise that areas that currently support phragmites would continue to do so if lake levels declined, and possibly expand along canals and other inflows, but phragmites could disappear in areas where water dries up at lower lake levels.

Areas that are currently open water could see an increase in phragmites cover as the water level declines, but the soils remain continuously wet.[209] Personnel from the waterfowl management areas and other wetland managers have observed an increase in phragmites cover along canals as the Great Salt Lake water level has declined.[210] Salt encrusted dry lake bed cannot support most plant species due to the high soil salinity.[211] Therefore, the most saline areas of exposed dry lake bed would b1,000e absent of all vegetation, including any weed species.

Figure 25 shows phragmites on the eastern shore of Great Salt Lake, where the acres of phragmites in 2014 show the areas that had no phragmites before 2006, indicating the extent and magnitude of the spread of the species. The left map (pre-2006) is data from 2005 (the northern three-quarters) and 1998 (the southern one-quarter). In 2014 (left map), a year with lower lake levels than either 2005 or 1998, there is a spread of phragmites into areas that previously were mudflats or water. Approximately 36,357 acres that were classified as waterbody or mudflat, playa in the pre-2006 mapping data are classified as one of the three phragmites coverage categories in the 2014 National Wetland Inventory (NWI) dataset. The fact that open water and mudflat (a prime bird feeding habitat) are replaced with an invasive plant when the lake level drops is a significant source of both economic and ecological costs.

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[207] Kulmatiski, A., Beard, K. H., Meyerson, L. A., Gibson, J. R., & Mock, K. E. (2011). Nonnative Phragmites australis invasion into Utah wetlands. *Western North American Naturalist*, 70(4), 541-553.

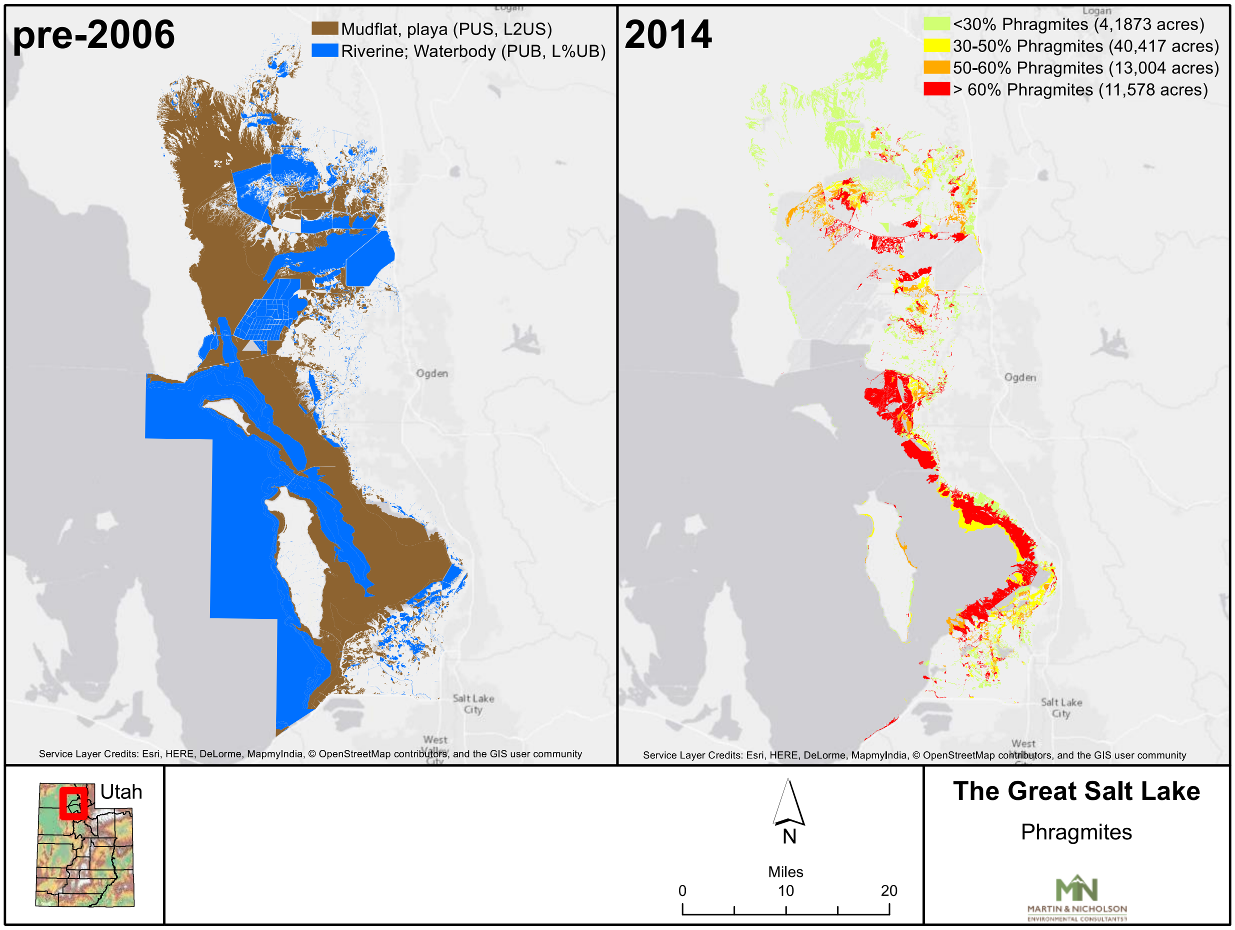
[208] Long, A. L., Kettenring, K. M., Hawkins, C. P., & Neale, C. M. U. (2017). Distribution and Drivers of a Widespread, Invasive Wetland Grass, Phragmites australis, in Wetlands of the Great Salt Lake, Utah, USA. *Wetlands*, 37(1), 45–57. https://doi.org/10.1007/s13157-016-0838-4

[209] Vanderlinder, M. S., Neale, C. M. U., Rosenberg, D. E., & Kettenring, K. M. (2014). Use of Remote Sensing to Assess Changes in Wetland Plant Communities Over An 18-Year Period: A Case Study from the Bear River Migratory Bird Refuge, Great Salt Lake, Utah. Western *North American Naturalist*, 74(1), 33–46. https://doi.org/10.3398/064.074.0104

[210] Rich Hansen, Utah Division of Wildlife, personal communication, February 27, 2019

[211] Downard, R., Frank, M., Perkins, J., Kettenring, K., & Larese-Casanova, M. (2018). *Wetland Plants of Great Salt Lake*. Logan: Utah State University Extension.

Figure 25. Phragmites Before and After 2006 at Great Salt Lake



The estimated cost to effectively control phragmites over the course of 3 years is $500/acre. This includes herbicide spraying and then mowing. If revegetation is required, this number would likely be closer to $1,000/acre.[212] Utah Division of Forestry, Fire and State Lands spends approximately $500,000 per year and Utah Division of Wildlife Resources spends approximately $300,000 per year on phragmites control treatments.[213] Other private entities around Great Salt Lake also incur costs for phragmites control.

The other major invasive species present around Great Salt Lake is cattail (*Typha* spp.). This cattail species provides habitat for some species such are Red-winged and Yellow-head Black Birds, Marsh Wrens, Yellowthroat, Sora, and Virginai Rails but, is considered poor quality habitat for some bird species, including shorebirds and waterfowl.[214] These species require

[212] Keith Hambrecht, Utah Division of Forestry, Fire & State Lands personal communication on April 22, 2019

[213] Laura Vernon, Utah Division of Forestry, Fire and State Lands, personal communication on June 11, 2019.

[214] Downard, R., Frank, M., Perkins, J., Kettenring, K., & Larese-Casanova, M. (2018). *Wetland Plants of Great Salt Lake.* Logan: Utah State University Extension.

continuous inundation of freshwater and are likely to follow the same distribution patterns discussed for phragmites.[215]

3.8.3 Wildlife Management

Antelope Island is managed by Utah Department of Natural Resources and is home to many large mammals. Free-ranging bison, mule deer, bighorn sheep, pronghorn (antelope), and other desert animals inhabit the island. As Great Salt Lake dries it creates a land bridge that has already connected Antelope Island to the mainland, which creates a pathway for these large mammals to leave the island. The land bridges could increase wildlife management costs for the state and potentially result in fences or other mechanisms that could also impact the aesthetics of the island. These land bridges could also allow predators that impact ground nesting birds such as Long-billed Curlew. The Utah Department of Natural Resources could incur additional management costs for fencing and cattle guards to mitigate the effects of land bridges.

3.8.4 Water Quality Management Costs

Water quality at Great Salt Lake would change with declining lake levels because the minerals would be less diluted and there would be lower volumes of water to accept wastewater discharge. If Great Salt Lake retreats from the mixing zone area used for wastewater discharge, the discharge would not be mixing with water, so there could be potential pipeline or water conveyance costs to ensure permit requirements are met. Boat maintenance costs would increase as the water becomes more corrosive. Changes in water composition would also influence wastewater discharge and potential for hazardous algae blooms in the wetlands near freshwater inputs.

3.9 Quality of Life Reductions

While many of the specific costs discussed so far in this report are changes to livelihoods, recreation, and other effects that influence the quality of life, there are additional potential costs posed by water level declines at Great Salt Lake that have more general impacts. These community costs include the marketability and attractiveness of Northern Utah as a place to live and grow a business, as well as the loss of the cultural and spiritual values that the lake provides.

3.9.1 Loss of Businesses & Workforce

Declines in water levels at Great Salt Lake would impact the quality of life due to increased dust, decreased recreational opportunities like bird watching and duck hunting, and reductions in the quality of recreation from the aesthetic loss of the lake. Drought conditions could also become more common with the loss of lake effect from Great Salt Lake. Lakefront property is

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[215] Belovsky, G. E., Stephens, D., Perschon, C., Birdsey, P., Paul, D., Naftz, D., … Allen, D. V. (2011). The Great Salt Lake Ecosystem (Utah, USA): Long term data and a structural equation approach. *Ecosphere*, 2(3). https://doi.org/10.1890/ES10-00091.1

not common at Great Salt Lake, so views would not be lost, but quality of life would nonetheless be impacted. Approximately 10 percent of substantial breezes from April-October are Great Salt Lake front breezes.[216] Declining lake levels could result in less frequent and intense breezes, increasing summer cooling costs for local residents. Increased dust and mineral content with declines in water levels at Great Salt Lake could also corrode and damage property as deck and lawn furniture degrades more quickly.

These changes would affect the desirability to live and work in Northern Utah. They would also reduce the ability of cities and counties in Northern Utah to compete for new businesses. All of the costs discussed in this report, especially health costs and recreation costs, could be factors that new and existing residents and companies would consider which could contribute to their decision to leave the region.

Quality of life has been found to play a supporting role in business site-location decisions.[217] Technology companies, research and development facilities, corporate headquarters, finance, and professional services have been found to prioritize quality of life in location decisions more than manufacturing operations.[218] Labor-dependent industries that are knowledge and technology-focused are especially likely to consider residential preferences.[219]

Environmental quality has also been found to rank as the highest reason for location decisions for high-tech firms.[220] Businesses and workers both benefit from the "second paycheck", the increase in quality of life, obtained from living and working in an attractive location. With a "second paycheck" in the form of quality of life improvements, workers enjoy the benefits, but businesses do not need to pay for those benefits, so overall welfare of the workforce and perceived compensation increases at no impact to a firm's expenses.

The eleven counties within the Great Salt Lake Basin have experienced a decline in net migration since 2009 (Figure 26). Although the population of these counties is expected to increase in the future, it is expected to do so at a decreasing rate (Figure 12). Declines in water levels at Great Salt Lake and the reduced attractiveness of Northern Utah as a place to live and work could result in further reductions in net migration and potentially cause negative net population migration – meaning more people would leave Northern Utah than would stay in the area.

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[216] Zumpfe, D. E., & Horel, J. D. (2007). Lake-Breeze Fronts in the Salt Lake Valley. *Journal of Applied Meteorology and Climatology*, *46*, pp. 196-211. doi: 10.1175/JAM2449.1

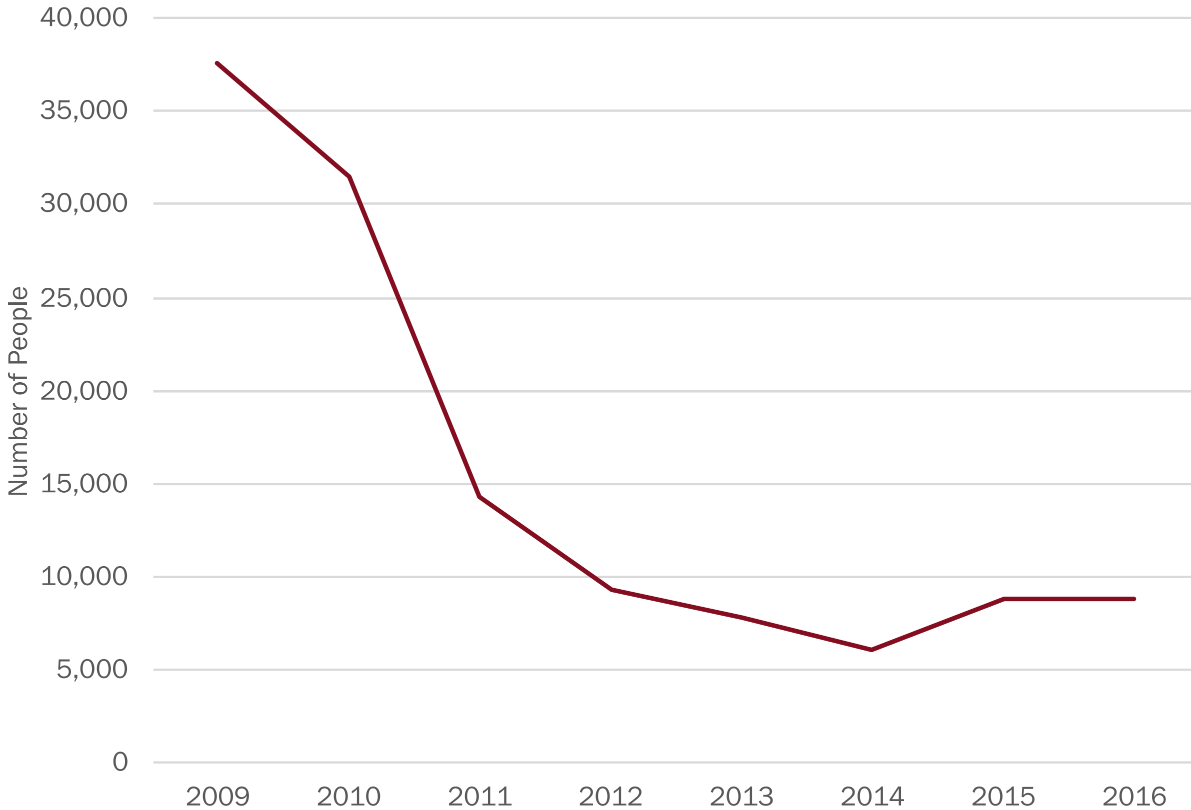
[217] George Mason University Center for Regional Analysis. (2018). Promoting Parks and Recreation's Role in Economic Development. *National Recreation and Park Association.*

[218] Reilly, C.J. and Renski, H. (2008). Place and Prosperity: Quality of Place as an Economic Driver. *Maine Policy Review*, 17(1),12-25.

[219] Ibid.

[220] Gottlieb, P. D. (1995). Residential amenities, firm location and economic development. *Urban Studies*, *32*(9), 1413-1436.

Figure 26. Net Migration for Counties within Great Salt Lake Basin



Source: Created by ECONorthwest with information from Federal Reserve Bank of St. Louis, Net Migration Flow for counties in Utah. Available at https://fred.stlouisfed.org/categories/30154
Note: The counties included in the Great Salt Lake Basin are Box Elder, Cache, Rich, Weber, Davis, Morgan, Summit, Salt Lake, Wasatch, Utah, and Toole counties.

While the exact magnitude of the consequences of a drying Great Salt Lake on business and talent attraction and retention is difficult to project, the negative environmental consequences that a drying Great Salt Lake would produce could cause future economic growth in Northern Utah to be lower than it would be absent a drying Great Salt Lake.

As a result of the undesirability to live in Northern Utah that could occur with increased dust resulting from water level declines at Great Salt Lake, home prices are also expected to go down. Economic literature suggests that increased air pollution decreases housing prices. A 1995 meta-review found that median willingness to pay, as measured by the difference in home prices for areas with and without pollution, is $56.18[221] to 373.67[222] (2019 dollars) for a one-unit

[221] Smith, V. K., & Huang, J. C. (1995). Can markets value air quality? A meta-analysis of hedonic property value models. *Journal of Political Economy*, 103(1), 209-227.

[222] Bayer, P., Keohane, N., & Timmins, C. (2009). Migration and hedonic valuation: The case of air quality. *Journal of Environmental Economics and Management*, 58(1), 1-14.

(micrograms per cubic meter, $\mu g/m_2$) reduction in particulate air pollution. Another study found that housing prices increase by 0.7 to 1.5 percent for a one-unit reduction in PM_{10}.[223]

3.9.2 Cultural and Spiritual Values

In addition to the ecological and environmental costs that have been described thus far, Great Salt Lake represents an important community resource and likely has significant cultural and spiritual value. Great Salt Lake is the namesake of the state's capital and is a definitive feature in the narrative of the origin of Utah's community and culture.

Declines in water levels at Great Salt Lake could change many of the identities currently associated with Northern Utah. The skiing industry is expected to be impacted when they can no longer claim the lake effect provides superior snow to other resorts. The Great Salt Lake Bird Festival could cease to be in Davis County. First nation tribes that attach cultural and spiritual value to Great Salt Lake would lose that heritage. Local birders would lose the opportunities to see species right out their backdoor. The comradery and community provided by organizations like the Duck Clubs and the Great Salt Lake Yacht Club would be lost and for many people are irreplaceable. The Yacht Club has been in existence since 1877 – but now in the 21st century that existence is threatened.

Locations like the Great Saltair demonstrate the potential for tourism and economic activity at Great Salt Lake when infrastructure and lake levels are maintained. Non-recreational tourism, such as sightseeing at the Spiral Jetty, is not expected to decrease as much as recreational tourism at Great Salt Lake since opportunities would still be available with a declining lake. However, as the lake retreats further from the shore it becomes more difficult for people to see the lake from existing vantage points.

In addition to the aesthetic loss, a drying Great Salt Lake could also lead to real and perceived cultural loss in Northern Utah. Other locations that have experienced saline lake declines are marred by the reputations of being locations unable to sustain their natural resources, and many of the economic activity around these lakes evaporates with the water. If the lake is used less, the perception of it being a wasteland could increase, and vandalism and illegal dumping, along with other illegal activities would likely increase. Littering is already a problem at Great Salt Lake and includes millions of bullet casing, discarded electronics, and other items. Friends of Great Salt Lake picked up 12,000 pounds of trash in 1 day alone at Antelope Island. Volunteers spend approximately 2,300 hours per year with Friends of Great Salt Lake.[224]

Although the magnitude and extent of loss cultural and spiritual values from declines in water levels at Great Salt Lake is unknown until it occurs, there are many reasons to believe it would be a significant loss that would create ripple effects throughout the communities of Northern Utah.

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[223] Chay, K. Y., & Greenstone, M. (2005). Does air quality matter? Evidence from the housing market. *Journal of political Economy,* 113(2), 376-424.

[224] Lynn de Freitas, Friends of Great Salt Lake, personal communication on February 14, 2019.

3.10 Loss of Non-Use Value

Non-use values are the dollar amount that individuals are willing to pay to protect or enhance an environmental resource, regardless of whether they ever plan on visiting or directly utilizing that resource. These values are sometimes referred to as passive use values and include the value from knowing that a species or ecosystem exists (existence value), the value derived from knowing that future generations will have access to nature's benefits (bequest value), and the value derived from knowing that other people in the current generation have access to nature's benefits (altruist value).

The non-use value for Great Salt Lake itself has not been evaluated, but non-use values have been established for similar lake ecosystems. The economic literature highlights the importance of using non-use values when evaluating lake ecosystems.[225,226] A study of Mono Lake investigated California utility customer's willingness to pay for protections of the lake and ecosystem[227] – this study is the most similar evaluation of non-use value to Great Salt Lake, but directly applying the non-use value is not necessarily appropriate. This study found an annual willingness to pay for preservation of Mono Lake, including option, existence, and bequest, as well as recreation use and dust suppression[228], of between $374 and $850 per year (representing the amount water customers would be willing to pay for increases in their water bill).[229] Assuming the values for Mono Lake from 1985 are similar to values for Great Salt Lake now, then the willingness to pay for preservation of Great Salt Lake would be between $328 million to $746 million per year for all households in Utah (877,692 households based on the 2010 Census).

The non-use value calculated for the State of Utah is presented for illustrative purposes only. Because this value includes recreational use (a direct use value) and dust suppression (an indirect use value) it is not purely a non-use value and would be double counting with the estimates we have for recreation and dust suppression values in this report. The existence value calculation we have conducted in Section 3.3 for migratory birds is also a component of non-use value, so reporting both would also be double counting. However, the $328 million to $746 million per year in potential benefits illustrates the magnitude of how much Utahns could value preservation of Great Salt Lake.

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[225] Loomis, J. (2006). Importance of including use and passive use values of river and lake restoration. *Journal of Contemporary Water Research & Education*, 134(1), 4-8.

[226] Wilson, M. A., & Carpenter, S. R. (1999). Economic valuation of freshwater ecosystem services in the United States: 1971–1997. *Ecological applications*, 9(3), 772-783.

[227] Loomis, J. B. (1987). Balancing public trust resources of Mono Lake and Los Angeles' water right: An economic approach. *Water Resources Research*, 23(8), 1449-1456.

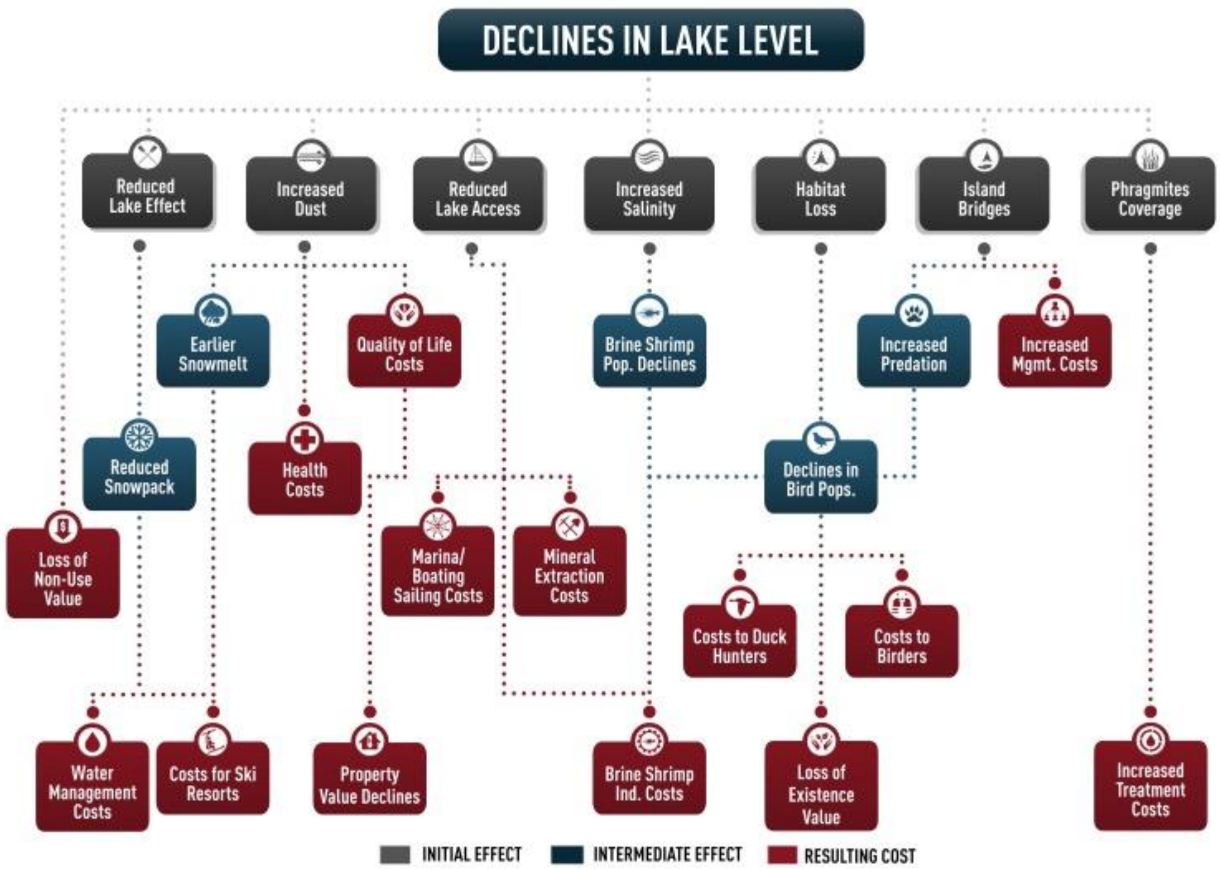
[228] Note that recreational use and dust suppression are not non-use values.

[229] Values have been inflated from 1985 dollars to 2019 dollars using the Bureau of Labor Statistics CPI Inflation Calculator

4 Summary of Costs

Great Salt Lake is experiencing water level declines that are causing numerous negative environmental and economic consequences. These costs to Northern Utah would continue to increase and more costs would be created with further declines in lake levels. Reductions in water levels at Great Salt Lake levels reduce surface area, increase salinity, and increase the amount of dry lake bed exposed. These effects then lead to other feedback effects which create costs to residents, companies, and visitors in Northern Utah. Figure 27 summarizes the feedback effects and the resulting costs evaluated in this report.

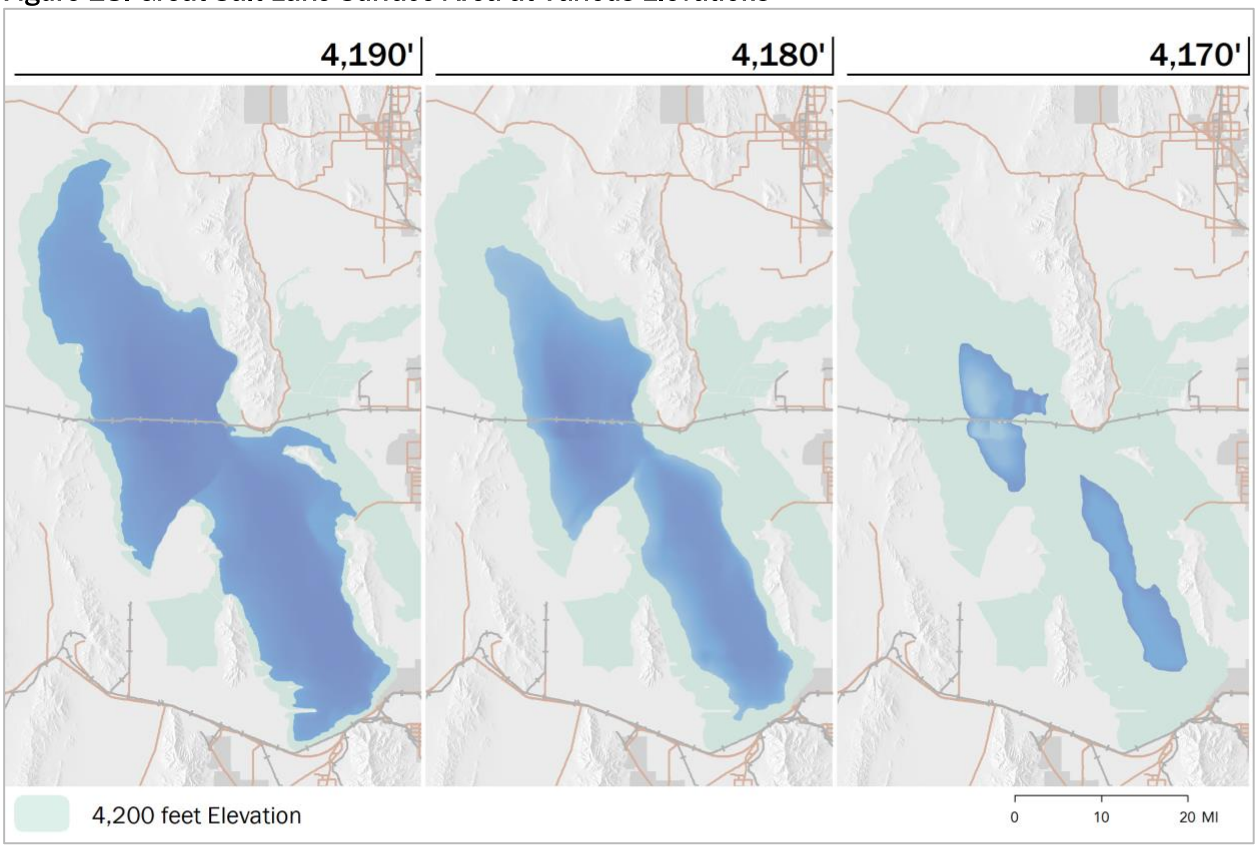
Figure 27. Costs Created by Declines in Water Levels at Great Salt Lake



Source: Created by ECONorthwest

The extent of these costs depends on the magnitude and timeframe of lake level declines. The Great Salt Lake elevation matrix indicates that lake levels between 4,198 feet and 4,203 feet above mean sea level provide important aquatic and wetland habitats and their significant species.[230, 231] The Lake still provides benefits outside those elevations, including the significant values it sustains at present, but the extent and nature vary, and certain benefits cannot be sustained below certain thresholds, particularly if low elevations persist for long periods of time.[232] The 10-year average annual elevation of Great Salt Lake from 2009 to 2018 has ranged from 4,193.2 feet to 4,197.5 feet,[233] below the threshold needed for many habitats. Further declines in Great Salt Lake elevation would expose large amounts of lakebed. Compared to a footprint of 4,200 feet in elevation, Figure 28 shows the surface area of Great Salt Lake at elevations that are 10 feet, 20 feet, and 30 feet lower.

Figure 28. Great Salt Lake Surface Area at Various Elevations



Source: Created by ECONorthwest using data from Tarboton, D. (2017). Great Salt Lake Bathymetry, HydroShare, http://www.hydroshare.org/resource/582060f00f6b443bb26e896426d9f62a

In many cases the effects of declining levels of Great Salt Lake are exacerbating other issues in Northern Utah, so the marginal impact of lake levels is more costly. For example, poor air quality caused by inversions is already creating health costs in Northern Utah and dust

230 SWCA Environmental Consultants. (2012). *Definition and Assessment of Great Salt Lake Health*. Prepared for Great Salt Lake Advisory Council. January.

231 Utah Department of Natural Resources, Utah Division of Forestry, Fire & State Lands. (2013). *Final Great Salt Lake Comprehensive Management Plan*. Retrieved from https://ffsl.utah.gov/index.php/state-lands/great-salt-lake/great-salt-lake-plans

232 Ibid.

233 U.S. Geological Survey Gage 10010000 Great Salt Lake at Saltair Boat Harbor, Utah calculated in May 2018.

contributed by additional exposed lakebed would worsen the already high particulate matter levels. Similarly, declines in snowpack and earlier snowmelts could worsen the potential effects of climate change for Utah's ski industry.

For other costs resulting from a declining Great Salt Lake there are possibilities for complete losses, such as the devastation that the brine shrimp industry would experience if salinities are sufficiently high to reduce brine shrimp populations to levels that prevent harvest from occurring. The decline in brine shrimp, a crucial regional food source for some migratory birds, could disrupt the Great Salt Lake ecosystem and impact current habitat conditions, as well as the brine shrimp harvesting industry. Many of the costs evaluated in this report would likely negatively impact the quality of life in Northern Utah – decreasing the attractiveness of the area as a place to live, work, and recreate.

This report analyzes and/or summarizes literature on costs imposed on the regional community with declining lake levels. The costs evaluated in this report fall into three categories, those that can be monetized, those that can be quantified, and those which cannot be quantified or monetized. In all cases, the estimates represent the general scale of value associated with each use of water, rather than precise estimates since the extent of future declines in water levels at Great Salt Lake is unknown. Wherever possible, we used assumptions that likely yield conservative estimates of value and describe factors that could indicate the likelihood of additional, unquantified value. We provide these values to illustrate the magnitude of the range of potential costs resulting from a declining Great Salt Lake.

Monetized Costs

Not all costs are able to be monetized because of a lack of information about the value of the loss or due to uncertainty that the effect would occur with declining lake levels. Considering only the costs which can be monetized, we estimate the potential annual costs of declines in water levels at Great Salt Lake as $1.69 billion to $2.17 billion per year and over 6,500 job losses (Table 23). Over twenty years these costs could be as high as $25.4 billion to $32.6 billion (discounted using a three percent discount rate,). These values do not include coordination, planning, or legal costs that could arise due to declines in water levels at Great Salt Lake.

Table 23. **Monetized Costs from Water Level Declines in Great Salt Lake (2019 dollars)**

Type of Cost	Potential Annual Cost	Potential 20-Year Costs	Potential Job Losses
Loss of Mineral Extraction Output	$1.3 billion	$19.3 billion	5,368
Landscape Mitigation Costs	$191.5 million to $610.4 million	$2.8 billion to $9.1 billion	N/A
Loss of Lake Recreation Output	$81.1 million	$1.2 billion	615
Loss of Brine Shrimp Industry Output	$67 million	$1.3 billion	574
Loss of Recreation Economic Value	$33.8 million to $81.9 million	$502 million to $1.2 billion	N/A
Health Costs	$6.6 million to $22.3 million	$98.2 million to $331.8 million	N/A
Loss of Ski Resort Spending	$5.8 million to $9.6 million	$86.3 million to $142.8 million	>0

Source: Created by ECONorthwest

Note: 20-year cost estimates use a 3 percent discount rate. The potential 20-year costs assumes output for industries has constant capital and labor ratios throughout the time period – ECONorthwest recognizes that projecting economic contribution output into the future using IMPLAN is not a best practice and provides this estimate for illustrative purposes only.

Spending on mitigation is included in the total costs, but it should be noted that mitigation could potentially offset some of the other costs, such as water delivery, habitat restoration, or dust suppression mitigation measures, resulting in a lower total cost. Another note about our calculation in Table 23 is that the economic contribution of the mineral extraction industry, brine shrimp industry, and lake recreation output assumes constant capital and labor ratios, as well as similar market conditions for the entire 20-year cost projection.

The types of costs comprising the potential annual costs of $1.69 billion to $2.17 billion would arise at different lake elevation levels, so the magnitude of the effect could vary at different points in time. Temporal considerations are also important because the longer that water elevations remain at low levels, the more difficult it could be to reverse the impacts and costs. Figure 29 provides a summary of the lake elevations and the relative magnitude of the costs that might be incurred. This figure demonstrates how costs are expected to be larger at lower lake elevations.

Figure 29. Illustrative Example of Monetized Costs Changes with Lake Levels

Lake Elevation (Feet)	Lake Elevation	Mineral Extraction	Mitigation Costs	Lake Recreation (Output, Recreation Economic Value)	Brine Shrimp	Health Costs	Ski Resort Spending
4,215	Matrix Green Range[1]						
4,195	At Current Levels	$$$$$$$$$$	$$	$$$		$	$
4,185	Below Historic Low	$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$	$$$$$	$$$$$	$	$$	$
4,175	Far Below Historic Low	$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$	$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$ $$$$$$	$$$$$$$$$$$$ $$$$$	$$$$$$$	$$$	$
4,165	Near-Dry	$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$	$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$ $$$$$$$	$$$$$$$$$$$ $$$$$$$$$$$ $$$$	$$$$$$$	$$$$	$$

Source: Created by ECONorthwest
Note: Each dollar sign represents approximately $10 million, although costs below 4,165 feet in lake elevation are speculative based on believed patterns of costs qualitatively described in this report. Elevations are not cumulative, and each elevation should be considered separately.

Quantified Costs

For some of the costs, information to monetize the cost exists, but there is uncertainty about the extent to which they would occur with declining lake levels or uncertainty about the value of the loss. These quantified costs represent opportunities for further research. These costs could be monetized through studies conducted at Great Salt Lake to obtain more, location-specific information about the effects and/or values.

- **Water Management Costs and Impacts to Water Rights:** Due to declines in the surface area and water level of Great Salt Lake, snowpack could be affected by both lower amounts of snow from reduced lake effect and earlier snowmelt from decreased albedo.

In addition to impacting the ski industry, water managers and water users along the Wasatch Front that rely on snowpack could be impacted.

- **Property Value Reductions:** The homes near Great Salt Lake could experience a reduction in property value from the increased dust, reduced recreational opportunities, and other costs from declines in water levels at Great Salt Lake. Studies suggest increases in particulate matter air pollution can reduce property values by 0.2 to 1.1 percent. These reductions in property value would also impact property tax revenue for local taxing authorities.
- **Impacts to Bird Populations**: As water levels decline in Great Salt Lake we expect negative impacts to populations of many bird species due to the potential reduction in brine shrimp, brine flies, and other macroinvertebrates. Land bridges can increase predation at island nesting sites and loss of both quantity and quality of habitat could also adversely affect bird populations. Based on survey values from other locations, the willingness to pay by people in Utah for migratory bird protections could be as high as $27.8 million per year.
- **Invasive Species Costs:** Phragmites, a state-listed noxious weed, has populated large areas of Great Salt Lake. Declines in water levels at Great Salt Lake could increase the spread of this invasive species in some areas and decrease its presence in others. Costs to mitigate for phragmites are approximately $500–$1,000 per acre for three years. The Utah Department of Natural Resources currently budgets approximately $500,000 per year to control phragmites.
- **Loss of Non-Use Value:** People value Great Salt Lake even if they do not visit or obtain value from it directly. The amount people are willing to pay to preserve an environmental resource like Great Salt Lake is known as a non-use value or passive use value. Based on estimates for Mono Lake, the potential loss of non-use value for Great Salt Lake could be as high as $328 million to $746 million per year for all households in Utah.

Non-Quantified Costs

The remaining category of costs evaluated in this report includes those which resist quantification but are expected to occur due to water level declines at Great Salt Lake. Although these costs are not quantified or monetized, they could have profound impacts to the economy and culture of Northern Utah.

- **Increased Costs for Agriculture:** Increased dust from a dry lakebed could create costs to agriculture by reducing yields and crop productivity due to interference with rates of transpiration and photosynthesis, as well as changes to soil composition.
- **Airport Operation Disruptions:** Dust storms have delayed and cancelled flights at SLC International Airport – increases in dust from a dry Great Salt Lake could increase the frequency of these disruptions, creating costs to the airline industries and reducing the attractiveness of the airport to travelers.

- **Increased Wildlife Management Costs**: The land bridges to islands created by declines in water levels at Great Salt Lake could increase management costs for the terrestrial species of Antelope Island and costs for predation management at other islands. Fencing or predator control costs could be incurred for wildlife management.
- **Outmigration and Reduction in Business Attraction and Retention**: Quality of life is expected to be reduced due to water level declines at Great Salt Lake, primarily due to the worsening air quality, reduced recreation opportunities, and the degraded environment. As a result, businesses and residents might leave Utah, or decide not to locate in the state.
- **Loss of Cultural and Spiritual Values:** Great Salt Lake is a cultural resource to Utah and part of the state's identity. Water level declines at Great Salt Lake would change the landscape and aesthetics of Northern Utah. Current and future Utahns would be impacted by the cultural and spiritual losses resulting from a declining Great Salt Lake.

Policy Implications

The science review and economic analyses in this study suggest that reduced lake levels at Great Salt Lake are already imposing adverse conditions and economic costs on the regional community and economy. The continued trajectory of declining lake levels will likely only increase the magnitude and expand the categories of costs imposed on Utahns. These costs can rise to over $1 billion annually for the monetized costs, and lead to numerous other effects as well. Some costs, particularly related to health effects via air pollution from volatized particulate matter air and reduced snowpack due to reduced lake effect and increased dust-induced albedo effect, have the potential to threaten the core quality-of-life and environmental quality characteristics of the region that make it attractive to residents and businesses. The full consequences of radical lake level decline or even loss of Great Salt Lake could have compounding effects that can be difficult to fully predict.

But there is good news. This study did not find that conditions are beyond salvage or repair. The lake conditions have not reached thresholds where they cannot be restored, and they are unlikely to do so for many years. However, the variety of costs and incremental nature of their relationship to lake conditions suggest that any improvements in lake level from current lows and ensuring continued water flows can provide benefits for the region, and similarly any incremental declines that can be avoided will have benefits.

Investments in water for Great Salt Lake now can prevent future costs to the region. The magnitude of potential consequences suggests that major interventions are likely warranted. The experience of other terminal lake systems suggests that proactively making investments to protect a lake and its wetlands can be at least an order of magnitude less in costs than eventual restoration or mitigation after conditions are allowed to significantly deteriorate. Maintaining the full suite of benefits Great Salt Lake provides to the region will directly or indirectly return value to both residents and visitors. Allocating sufficient resources now to prevent declining lake levels, reversing this current trend, can provide tens of billions of dollars in benefits over the coming decades, and protect the quality of life in Northern Utah.