Water for Great Salt Lake

Prepared for

Great Salt Lake Advisory Council

Compiled by

SWCA Environmental Consultants

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SWCA Environmental Consultants
257 East 200 South, Suite 200
Salt Lake City, Utah 84111
801-322-4307
www.swca.com

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INTRODUCTION

This document is intended to facilitate a discussion of potential strategies to maintain and/or increase the surface elevation (that is, the water levels) of Great Salt Lake (GSL). The Great Salt Lake Advisory Council commissioned this report because GSL water levels are in a long-term decline.

The strategies presented here consist of wide-range coordination, environmental, legal, operational, policy, and structural practices that, if implemented, could possibly deliver greater quantities of water to GSL or maintain water in it. Each strategy includes a title, category, description, applicability to GSL, and potential limitations.

The strategies included in this document comprise submissions from a wide range of individuals and organizations, including water suppliers, water users, conservation interests, state and local governments, industry and commercial interests, non-governmental organizations, and members of the general public. Strategies were solicited and submitted anonymously or without attribution. Although the list of strategies is by no means exhaustive, it reflects an attempt to compile a wide range of strategic options.

No ranking or prioritization was completed as part of the compilation process. **Inclusion in this document does not constitute an endorsement of any individual strategy by the Great Salt Lake Advisory Council or its members.**

To provide hydrological context for these strategies and to identify where implementation of specific strategies might be most effective spatially, the following two sections provide an overview of GSL Basin hydrology and water budgets for major tributaries to GSL.

GREAT SALT LAKE BASIN HYDROLOGY

Despite years with high snowpack and/or high spring precipitation (e.g., 2011 and 2017), GSL water levels are in a long-term decline, with serious effects to wildlife habitat, recreation, public health, industry, aquaculture, and ecosystem services. This trend is not unique to GSL. Climate as well as anthropogenic practices such as irrigation diversions have left the Aral Sea (Kazakhstan and Uzbekistan) and Lake Chad (Cameroon, Nigeria, Niger, and Chad) a fraction of their original size. The hydrograph in Figure 1 illustrates historical GSL elevation based on estimates and actual monitoring data as well as the overall declining trend, which appears more pronounced since 1986 (SWCA Environmental Consultants [SWCA] 2013).

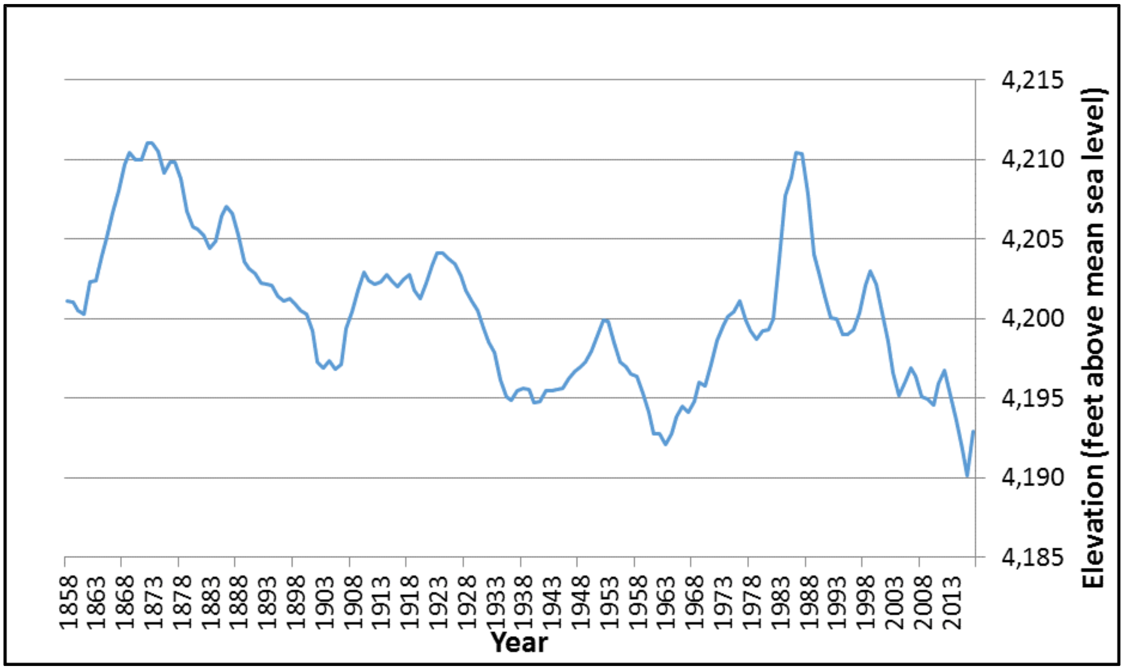

Figure 1. Average annual level of Great Salt Lake, from 1858 to 2017, as measured at Saltair (SWCA 2013)[1].

GSL is a shallow waterbody and is approximately 33 feet at its deepest point (BIO-WEST 2011). Consequently, the surface elevation of GSL has a profound effect not only on lake depth but also on surface area and volume, as shown in Figure 2. The average elevation to date in 2017 of approximately 4,193 feet above mean sea level (U.S. Geological Survey 2017) equates to a volume of 9,573,000 acre-feet covering approximately 656,000 acres. Compared to a very common lake elevation of 4,200 feet above mean sea level, which occurred in recent memory from the mid-1970s to the early 2000s, a lake elevation increase in 7 feet equates to a volume of 15,435,000 acre-feet covering a surface area of 1,030,000 acres. Changes in volume and area affect many aspects of lake ecology and physical processes,

[1] Figure 1 is from the Utah Division of Forestry, Fire & State Lands *Final Great Salt Lake Comprehensive Management Plan and Record of Decision* (SWCA 2017). The data in this figure are from a series of lake gages since 1875 and from lake level estimates for the period before 1875. As the plan states, "These estimates are based largely on interviews with stockmen who moved livestock to and from Antelope and Stansbury Islands from 1847 to 1875. The annual variations shown for this early period are the average of those measured since 1875. Although the major features of the pre-1875 hydrograph are real, the details are uncertain. For the period since 1875, a small but significant uncertainty exists in the elevation of the various gages used and thus an uncertainty of several tenths of a foot exists in the absolute elevation of the lake level shown on the hydrograph for certain periods. Any analysis of the hydrograph should consider the uncertainties in the data upon which it is based." (SWCA 2013).

e.g., salinity concentrations and acreage of exposed mudflats, respectively. Changes in these parameters can have a measurable impact on the overall ecosystem, including avian and brine shrimp populations, as well as air quality when wind mobilizes dust and other particulates.

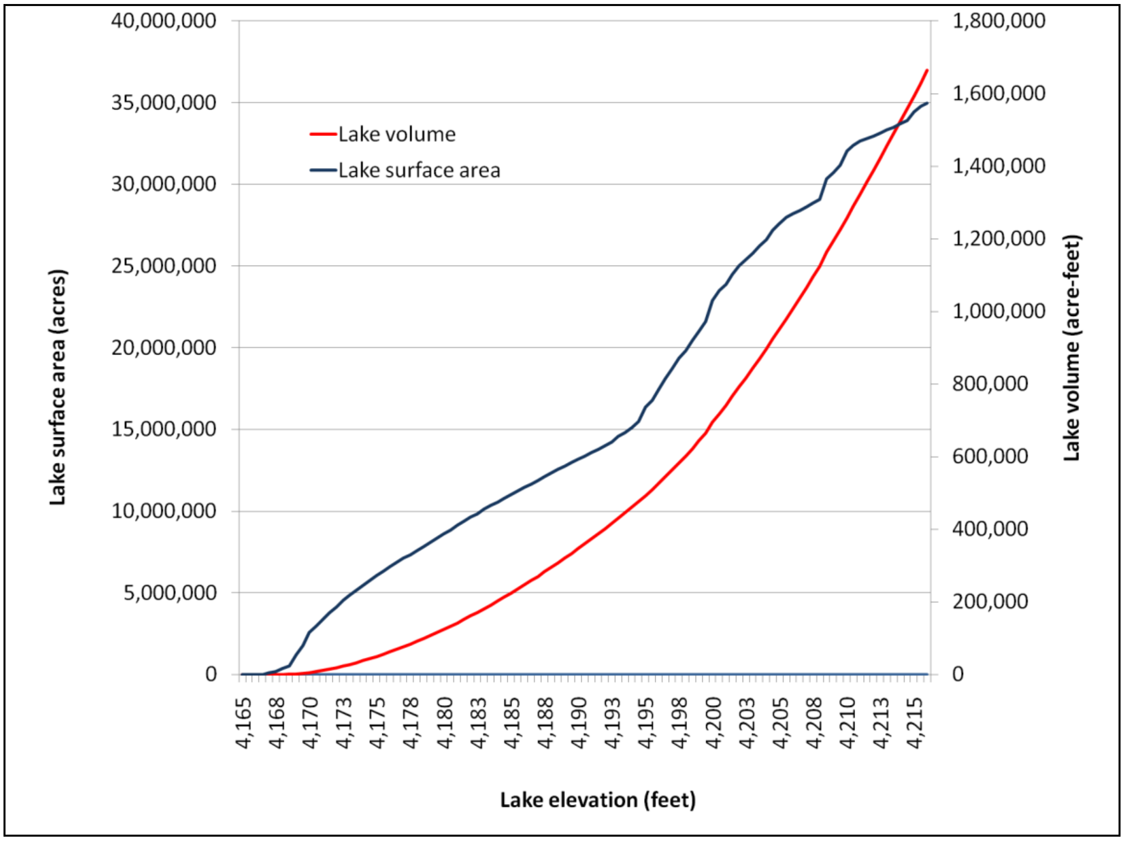

Figure 2. Great Salt Lake elevation compared with lake area and volume (BIO-WEST 2011).

GREAT SALT LAKE BASIN WATER BUDGET

A water budget accounts for all water that flows into and out of a specific region or waterbody. The water budget for GSL includes inflows from major basins and direct precipitation, as illustrated in Figure 3. Recent information from the Utah Division of Water Resources (DWRe) compiled in Table 1 estimates that each year, on average, slightly more than one-third of the water entering GSL comes from direct precipitation, approximately one-third from the Bear River Basin, and slightly less than one-third from the Weber River, Jordan River, and West Desert Basins combined. Annual inputs are approximately 2.4 million acre-feet, which is roughly one-quarter of the 2017 average elevation (4,193 feet mean sea level) volume. The Utah Geological Society estimates that, on average, approximately 2.9 million acre-feet of water evaporates from the lake annually with the actual amount a function of surface area, temperature, humidity, and wind (Utah Geological Survey 2010).

Table 1. Summary of Water Inflow to Great Salt Lake

Basin	Drainage Area (square miles)	Average Annual Precipitation (inches per year)	Average Annual Flow to Great Salt Lake (acre-feet per year)	Total (%)	Discharge Location in Great Salt Lake
Bear River	7,118	21	794,075	32.6%	7% to Bear River Migratory Bird Refuge; 93% to Bear River Bay
Weber River	2,476	26	324,200	13.3%	Ogden Bay Waterfowl Management Area, other waterfowl management areas, and Willard Bay
Jordan River	805*	23	383,000	15.7%	Farmington Bay, Gilbert Bay, various duck clubs, and the Inland Sea Shorebird Reserve
West Desert	18,281	10	45,700	1.9%	Gilbert Bay and Gunnison Bay
Direct precipitation	1,500	12.3	889,300	36.5%	Entire lake and surrounding exposed lake bed
Total	**30,180†**	**–**	**2,436,300**	**100%**	**–**

Source: DWRe (2017a)

* 4,651 square miles if including Utah Lake Basin

† 34,026 square miles if including Utah Lake Basin

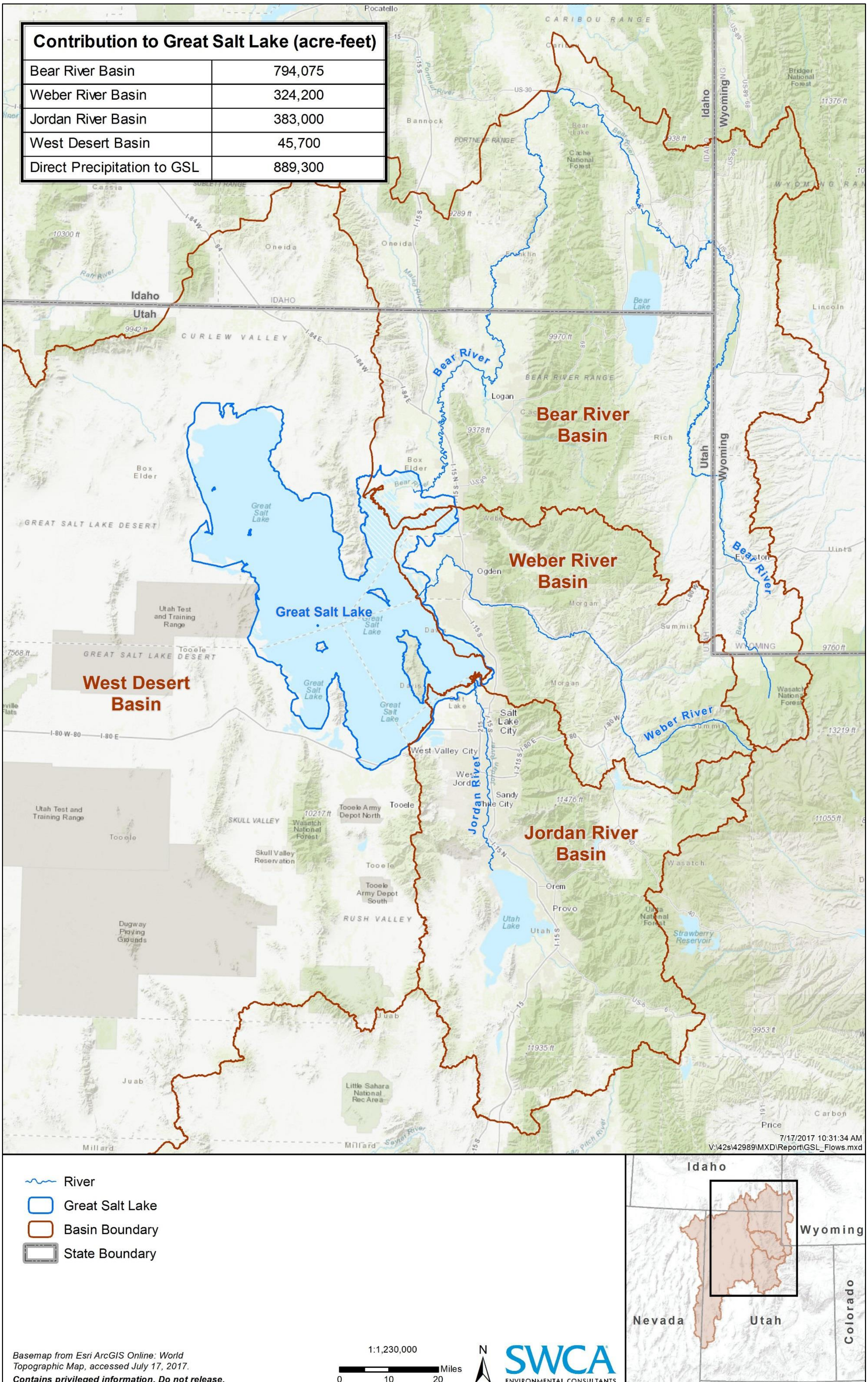

Figure 3. Great Salt Lake Basin.

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Summaries of past water budgets for the major GSL basins are provided in Tables 2 through 4. These tables include estimates of total precipitation, water use by vegetation and natural systems, agricultural, municipal and industrial depletions, and evaporation. These estimates illustrate where potential water savings might occur that could be delivered to GSL.

Table 2. Estimated Water Budget for the Utah Portion of the Bear River Basin

Category	Water Supply (acre-feet)
Total precipitation	3,726,571
Used by vegetation and natural systems	1,929,744
Basin yield	**1,796,828**
Agricultural depletions	763,645
Municipal and industrial depletions	13,774
Exports out of the basin	16,221
Wetland/riparian depletion and reservoir evaporation	209,113
Flow to GSL	**794,075**

Source: DWRe (2017a)

Table 3. Estimated Water Budget of the Weber River Basin

Category	Water Supply (acre-feet)
Total precipitation	3,373,465
Used by vegetation and natural systems	2,672,239
Basin yield	**701,226**
Inflow to basin	2,110
Exports out of basin	34,574
Agricultural depletions	187,140
Municipal and industrial depletions	37,035
Other depletions	230,000
Wetland/riparian depletion and reservoir evaporation	116,167
Flow to GSL	**324,200**

Source: DWRe (2017a)

Table 4. Estimated Water Budget of the Jordan River Basin

Category	Water Supply (acre-feet)
Total precipitation	4,258,234
Used by vegetation and natural systems	3,619,104
Basin yield	**639,130**
Imports to the basin	234,502
Agricultural depletions	287,859
Municipal and industrial depletions	128,338
Other depletions	68,191
Flow to GSL	**383,000**

Source: DWRe (2017a)

WATER SUPPLY STRATEGIES

This section presents 72 strategies with potential to maintain and/or increase the surface elevation (that is, the water levels) of GSL. The strategies consist of coordination, environmental, legal, operational, policy, and structural practices that, if implemented, could deliver greater quantities of water to GSL or conserve water within GSL itself. Each strategy, grouped by category, includes a title, description, applicability to GSL, and potential limitations. A primary limitation associated with many strategies would be ensuring that water conserved, allocated, or otherwise directed to GSL actually makes it to this destination. Other overarching limitations, although not always specified under each strategy, could include cost, communication, inclusion of all stakeholder voices, reluctance, litigation, time, leadership, and development of new processes or procedures. No ranking or prioritization was completed as part of the compilation process.

Coordination

1. *Determine Consumptive-Use Coefficients for Various Water Applications*

Category: Coordination

Description: Determine consumptive-use coefficients for various water applications and use the data to rank efficiency of water use. These coefficients indicate "the percentage of water removed from the immediate environment by evaporation, transpiration, incorporation into products or crops, or consumption by humans or livestock" (Shaffer and Runkle 2007).

Applicability to Great Salt Lake: The rankings could be used to prioritize water uses that could be modified or altered to improve efficiency of use thereby returning more water back into the hydrological cycle, which, pending other changes, e.g., water rights beneficial uses, could result in more water reaching GSL.

Potential limitations: Water rights may restrict the possibilities to modify or improve water use efficiency.

2. *Update Economic Analysis of Great Salt Lake Uses to Determine Economic Impact of Low Lake Levels*

Category: Coordination

Description: The major industries that rely on GSL include brine shrimping, mineral extraction, snow sports (skiing and snowboarding), lake tourism, and waterfowl hunting. Although current studies, such as the economic analysis previously completed for the Great Salt Lake Advisory Council (Bioeconomics 2012), indicate that GSL contributes $1.3 billion annually to the Utah economy, no attempt has been made to quantify the economic cost associated with low lake levels. Low lake levels have a negative effect on each of these industries, and a quantitative analysis could illustrate the economic losses in the immediate future if lake levels continue to decline.

Applicability to Great Salt Lake: Quantifying the economic delta between a healthy lake level and low lake levels would be valuable to understanding and discussing the cost of failing to ensure that sufficient water levels exist in GSL.

Potential limitations: Implementing this strategy would be difficult and expensive, and there may be a reluctance to modify the current $1.3 billion figure.

3. *Continue to Support and Provide Resources for Ensuring the Effective, Ongoing Use and Benefit of the Integrated Water Resource Model*

Category: Coordination

Description: Ensure effective and ongoing use of the GSL Integrated Water Resource Model (IWRM) and quality modeling results. This includes resourcing (financial and other) for adequate staffing and updating and improving data to provide modeling results of sufficient reliability and insight to inform planning and decision-making.

This strategy should include running key model scenarios with differing variables (lake levels, inflow changes, potential upstream water diversions, changes to salinity, climate data, etc.), and as underlying data are updated.

For example, modeling scenarios could assess lake levels using current average water flows, diversions, precipitation, temperature and evaporation variables, etc. This could improve understanding of possible future lake levels and salinities based on current average conditions. Additional modeling scenarios could assess changes to lake levels resulting from decreased inflows and increased diversions (e.g., ranging from 10% to 40%), increased temperatures, increased evaporation rates, etc. Water modeling scenarios could be combined with an assessment of benefits and impacts to various uses of the GSL ecosystem, such as those identified in the GSL Lake Level Matrix for the 2013 *Final Great Salt Lake Comprehensive Management Plan and Record of Decision* (SWCA 2013).

Applicability to Great Salt Lake: Effective and ongoing use and improvement of the model can allow the model to inform decision-making, planning, and policy development that support efforts to ensure adequate water resources are provided at appropriate times (hydrologic cycle) for GSL and its important wetlands ecosystem. The model could estimate or help predict the quantity of annual water supply needed in GSL to meet specific management objectives.

Potential limitations: Limitations on obtaining adequate resources for this strategy, including financial support for staffing to run and manage the model and incorporate improvements and updates, will limit the effectiveness and benefit of the model and the investment made to date.

Limitations inherent to the model will need to be understood and factored into the interpretation of model outputs used to guide or inform decision-making.

4. *Complete an Analysis on the Public Health Effects of the Exposed Sediments around Great Salt Lake at Low Levels*

Category: Coordination

Description: Complete a thorough, credible scientific analysis on the public health effects of both the particulate/dust and the chemical makeup (heavy metals, etc.) of the exposed sediments around the lake at low lake levels. Use science to drive policy. Conduct scientific research to determine the lake level necessary to “cover” or prevent particulate and any pollutant components of exposed lake bed from migrating by wind to the densely populated Wasatch Front where it might be a public health hazard. Use these data to determine how much water is needed in GSL to reduce risk from health hazards.

Applicability to Great Salt Lake: Any exposed lake bed caused by the drying of GSL poses a risk to the air and water quality along the Wasatch Front. The fine particulate matter of the dry lake bed could worsen the already poor air quality of the Salt Lake Valley as it is swept in the air by winds. Additionally, the sediments of the lake bed contain high concentrations of metals. These pose a risk not only to air quality but to water quality as dust settles on snow or water.

An analysis of the potential public health effects of the exposed lake bed sediment could raise public interest and involvement in increasing the delivery of water to GSL and thereby increasing the water levels of GSL.

Potential limitations: An analysis of this scale would require significant time and money. There is no guarantee that this would increase public interest and it is unknown whether it would have any effect on getting water to the lake.

5. *Incorporate Best Management Practices for Watershed Planning into Policy Making Decisions*

Category: Coordination

Description: Codify or incorporate best management practices for watershed planning into policy making decisions. Include a consistently updated GSL IWRM for scenario planning. Budget for research to fill data gaps in model. Systematically fill data gaps by priority to better predict impacts to GSL from changes in water use or climate. Model the effects of best management practices on the levels of GSL.

Applicability to Great Salt Lake: To approach and understand GSL's decreasing water levels, solutions should be approached at a watershed level. Best management practices would be implemented at the watershed level to address water conservation. Incorporating these practices into policy could cause a dramatic increase in water use efficiency throughout the watershed, which would ultimately lead to more water entering GSL.

Potential limitations: Water uses may push back on the implementation of these practices. No data are available to accurately predict the impact that these best management practices would have on the overall lake levels of GSL.

6. *Conduct a County by County Assessment of Conveyance Water Loss*

Category: Coordination

Description: Conduct a thorough county by county assessment of conveyance water loss and develop an infrastructure plan to replace faulty pipelines to minimize conveyance water losses.

Applicability to Great Salt Lake: Researchers estimate that approximately 2.1 trillion gallons of purified drinking water is lost each year through leaky infrastructure in the United States (Schaper 2014). A 2013 review of Utah's infrastructure concludes that "most Utah municipal water systems do not accurately account for water use and that most do not have an "active" leak detection program" (DWRe 2013).

A thorough analysis of water loss would allow the public and government officials to gain an understanding of the magnitude of conveyance water loss in their area. This understanding could lead to increased budgets for replacing faulty infrastructure. Ultimately this could decrease conveyance water loss and as a result reduce needs for water and increase flow of water to GSL.

Potential limitations: This strategy would be expensive and time-consuming. There is no guarantee it would lead to infrastructure being replaced. Infrastructure replacement is expensive, and there may be budgetary restrictions to infrastructure projects. In addition, studies would need to be done to better understand where conveyance losses go and where water conserved through better conveyance efficiencies would go.

7. *Mandate Municipalities within the Great Salt Lake Watershed to Submit Water Conservation Plans*

Category: Coordination

Description: Water conservation plans can be used to implement best management practices, develop conservation education strategies, enact municipal polices to implement during droughts, set landscaping and water use standards for new developments, and set targets to reduce water use by a certain time period.

Applicability to Great Salt Lake: Municipal and industrial water use is approximately 18% of the total water use in the State of Utah (DWRe 2010a). According to modelled water budget information for the three major basins to GSL, i.e., Bear River, Weber River, and Jordan River, this could be as much as 179,000 acre-feet of water (see Tables 2–4; DWRe 2017a). A reduction in municipal and industrial water use, although small relative to other sectors, is measurable.

Potential limitations: Municipal conservation plans, although written with good intent, might not realize actual water conservation without incentives or other structural changes such as increases in water pricing.

8. *Facilitate Communication Between State Organizations, Legislators, Canal Companies, Farmers, Brine Shrimpers, and all Other Invested Stakeholders*

Category: Coordination

Description: Invite stakeholders, e.g., legislators, lobbyists, canal/ditch companies, farmers, brine shrimpers, etc. to the table to discuss the realities of GSL Basin hydrology, water use, and water rights.

Applicability to Great Salt Lake: Preliminary discussions such as these could identify opportunities and concerns to actually delivering more water to GSL.

Potential limitations: Complexity of the legal subtleties and fear there will be a gap in the equity of voices at the table.

9. *Create and Empower Basin Councils*

Category: Coordination

Description: Creating basin councils—groups of stakeholders in a particular watershed—can help to manage competing demands for water, particularly in times of water scarcity. Often, such groups operate on a less formal level and adopt measures that do not have the legal and regulatory costs and impediments associated with formal change applications, etc. filed with the State Engineer. The goal in creating basin councils is to optimize and balance competing demands across an entire watershed.

Applicability to Great Salt Lake: Utah tends to embrace more collaborative approaches to problem solving, and creating basin councils represents just such an effort. If replicated in multiple watersheds that feed into GSL, basin councils with the goal of augmenting inflows to the GSL could result in an increase in total lake inflows.

Potential limitations: Basin councils could take time and money to set up and maintain, although they could work in a more informal manner with time volunteered by stakeholders. Nevertheless, councils would need some authority to manage water without subjecting rights to forfeiture, etc. and to mediate conflicts between water users and competing demands.

10. *Improve Coordination between State Agencies*

Category: Coordination

Description: Several state agencies, including DWRe, Utah Division of Water Rights (DWRi), Utah Division of Wildlife Resources (DWR), and Utah Division of Forestry, Fire & State Lands (FFSL), have responsibility either for GSL directly or over decisions that affect the lake and lake levels. Improved coordination between those agencies and improved legal or regulatory mechanisms that, for example, allow DWRi to take into account information and advice provided by DWR or FFSL could improve decision-making and help to better protect the resource, including inflows.

Applicability to Great Salt Lake: Because these agencies all have the authority to make decisions affecting the lake, it makes sense to better coordinate those decision-making processes so as to better protect the lake and lake levels. In particular, DWRi could better evaluate change applications and new appropriations if it has access to sound science regarding the potential public interest impacts of those water rights applications.

Potential limitations: Agencies can be complex and can answer to different mandates and responsibilities. In some instances, legal and regulatory mechanisms simply do not exist and would have to be created in ways that foster rather than frustrate informed decision-making.

11. *Develop a Public Education Campaign*

Category: Coordination

Description: Develop an public education campaign with an outreach component similar to the Utah Governor's Water Conservation Team's "Slow the Flow," but with a broader message that includes not only the benefits of water conservation but how specific water use decisions can benefit GSL. Include information about the economic, public health, and environmental effects of low GSL elevation. Develop a video or series of short videos that explore the challenges behind water levels in GSL and what people can do to help. Make the connection between people's water use habits and the water supply to GSL.

Applicability to Great Salt Lake: This strategy would help raise awareness of how individuals' actions affect water levels in GSL, and hopefully it would also provide tractable strategies for people to apply.

Potential Limitations: A campaign raises awareness and would hopefully provide strategies for individuals. However, it would need to be backed up with a framework and social infrastructure to take the individual strategies of the public and translate them to real water. Like many other similar campaigns, its impact may be short lived.

12. *Facilitate Voluntary Contributions to Pay for Instream Flow Needs*

Category: Coordination

Description: Allow water users or homeowners to voluntarily pay a little more on their yearly assessments and sign a contract with the conservancy districts to use less secondary water. Use the money raised by the voluntary signups to pay for instream flow needs, e.g., purchasing water for instream flows, agricultural efficiency improvements, and shepherding agreements. The key to this voluntary initiative is bringing it up to scale. If a large enough sector of the community can be engaged to participate, real changes are possible. The success of this strategy could provide a self-funding framework to allow water managers to develop the necessary tools for transporting water to GSL.

Applicability to Great Salt Lake: This strategy is not unlike voluntary payments that people make on tax forms or when people purchase special group license plates that generate funds for a specific purpose.

Potential Limitations: Funds would have to go to entities capable of holding instream flow rights. This kind of program depends on willing sellers of water rights and a market for instream flows.

Environmental

13. *Reduce Lawn and Turf Grass Use and Promote Xeriscaping*

Category: Environmental

Description: Reduce lawn and turf grass use and promote xeriscaping to conserve water. A 2015 National Aeronautics and Space Administration study (Milesi et al. 2015) estimates that residential lawns now cover more than 63,000 square miles in America—an area about the size of Texas—making it by surface area the single biggest "crop" in the United States. Utah is little different than the rest of the country in terms of its use of lawns, though the environmental price paid for this use is much higher in an arid state like Utah.

Applicability to Great Salt Lake: Any water consumed by lawns or evaporated in the process of watering lawns reduces inflows to GSL, and reducing that use, particularly on a broad scale, could significantly increase water supply to the lake, though studies are needed to better understand the water volumes involved.

Potential limitations: Social resistance is high, particularly where the cost to water lawns remains relatively low. In addition, xeriscaping remains relatively expensive, particularly upfront, limiting its appeal for people of modest means. In addition, some city landscape ordinances require the use of turf, particularly in park strips, and discourage xeriscaping. Such ordinances would need to be modified to better promote xeriscaping and other forms of water conservation.

14. *Reduce Water Use by Golf Courses*

Category: Environmental

Description: Reduce water use by golf courses to achieve greater water conservation. Some golf courses in some arid states only water the greens and xeriscape any remaining land on the courses, meaning that such golf courses consume less water than a typical golf course in the GSL watershed.

Applicability to Great Salt Lake: If golf courses in the GSL Basin chose to water only their greens (and xeriscape the rest), it would reduce their water demands significantly, potentially freeing up more water for GSL.

Potential limitations: The current cost of water may leave little economic incentive to take this step. Mandating it could generate political and/or legal backlash. The volumes in question may not be sufficient to make a measurable impact on lake levels.

15. *Conduct Cloud Seeding to Increase Water Supply*

Category: Environmental

Description: Efforts to address increased demand for water generally focus on maximizing the existing surface water supply. However, local demand for water often exceeds the supply that is locally available. Cloud seeding (weather modification) is considered by some as to be a viable way to augment the natural water supply by increasing precipitation. The practice originated at the General Electric Research Laboratories in Schenectady, New York, in 1946, and since then, cloud seeding projects have been carried out in over 20 different countries (DWRe 2017b). Cloud seeding encourages the formation of precipitation within clouds by providing the appropriate types and numbers of nuclei at the proper times and places. Some clouds may retain up to 90% of their moisture during a precipitation event, and cloud seeding aims to improve this efficiency by increasing the amount of moisture that is formed into precipitation. Therefore, cloud seeding cannot be done at any location at any time, but under the right conditions, it can increase the precipitation efficiency of clouds. A variety of cloud seeding agents are used; however, silver iodide, which can be released from both ground-based devices and devices on airplanes, is the most common. Although cloud seeding has been conducted in Utah since the 1950s, the 1973 Utah Cloud Seeding Act, which provided for the licensing of cloud seeding operators and the permitting of cloud seeding projects by DWRe, has resulted in frequent use of cloud seeding in parts of Utah (DWRe 2017b).

Applicability to Great Salt Lake: Given that cloud seeding has the potential to increase winter precipitation by approximately 14% (DWRe 2017b), cloud seeding could be effective in increasing water supply for the GSL watershed. However, cloud seeding efforts have been implemented within Box Elder and Cache Counties since 1989, and therefore the technology is already being used within the watershed and may not result in increased water available to GSL.

Potential limitations: Cloud seeding is only appropriate in certain locations and situations and therefore has limited applicability. Cloud seeding can be effective in increasing the precipitation efficiency of certain clouds; however, a large proportion of this precipitation is lost (by evaporation, seepage, natural use, etc.) before it is available for diversion from surface water. Additionally, the additional water that does end up in surface waters may not equate to increased deliveries to GSL. Without proper regulation (legislation) and enforcement, increased runoff may be diverted before it ever reaches GSL.

16. *Mine Groundwater*

Category: Environmental

Description: In many parts of the world where surface water is in short supply, water is pumped to the surface from subsurface aquifers for a variety of uses. Depending on the water use application, the volume required, and the hydrology of the area, groundwater mining is an option for increasing surface water supply. From small scales (e.g., single family lots) to large scales (e.g., industrial agriculture), groundwater mining has the potential to support the water needs of many individuals and/or organizations in the short term. The depth and quality of groundwater influence the ease at which it can be extracted and used in various applications. However, environmental issues associated with over-drafting of groundwater supplies have elucidated the interconnectedness of the water cycle (i.e., surface and groundwater) and the concept of a groundwater budget. For groundwater supplies to recharge, the total amount of water entering, leaving, and being stored within the groundwater system must be conserved. When the withdrawal portion of a specific groundwater budget cannot be supported by recharge, environmental consequences such as subsidence may occur. Over-drafting of groundwater in Utah's Iron County resulted in a 114-foot drop in the water table in addition to subsidence and deep fissures in the ground surface (Lund et al. 2017). Similar consequences from groundwater mining in other parts of Utah have resulted in subsidence and surface stability issues along with restrictions on building new homes and groundwater pumping.

Applicability to Great Salt Lake: Groundwater mining harvests subsurface water for use aboveground. The diversion of GSL tributaries is reducing the volume of GSL. Groundwater mining could be considered as an alternative to water diversions from GSL tributaries or as a way to supplement water inflows to the lake.

Potential limitations: Although groundwater mining on a small scale may be an appropriate solution for certain applications, there may be severe environmental consequences to over drafting subsurface aquifers. As mentioned above, groundwater and surface water systems are interconnected, and switching from surface to groundwater sources for agricultural or environmental (e.g., GSL) may not actually represent a net gain in water supply.

17. *Protect Groundwater Levels beneath Great Salt Lake and the Broader Great Salt Lake Basin*

Category: Environmental

Description: Analyses completed by the U.S. Geological Survey estimate that upward of 10,000 acre-feet per year of groundwater flow into GSL from the Snake Valley, a valley on the Utah-Nevada border in the central Great Basin. Loss of this groundwater flow would have some effect (however minimal) on GSL levels, but could have a significant impact on the surrounding basin and the West Desert. Hydraulic pressure from this subsurface flow prevents the brackish groundwater beneath the lake and surrounding basin from pushing south (upgradient and potentially lowering GSL levels) into Snake Valley, therefore protecting the seeps, springs, and aquifers that provide critical water for wildlife and human consumption, farming, and ranching. The proposed Southern Nevada Water Authority Groundwater Development Project could intercept and interrupt this subsurface flow, causing the brackish groundwater to the north to gradually flow south and essentially "salt the wells" of north Snake Valley. There is also an unknown amount of groundwater flow from Tule Valley and Fish Springs to the GSL Basin from the south. From the north, into Clyman Bay, groundwater flows from Locomotive Springs have been threatened by agricultural pumping on the Idaho side of the border.

Applicability to Great Salt Lake: Given the interconnectedness of groundwaters and surface waters in general and in the GSL Basin, wise conjunctive management of surface waters and groundwaters should be the basis for policies that protect groundwater flows to GSL, including prohibiting groundwater mining (currently illegal) and opposing diversions or inter-basin groundwater transfers that will adversely affect GSL levels and adversely impact the GSL Basin and adjoining aquifers and the environment.

Potential limitations: There are large uncertainties associated with estimates of interstate groundwater flows, groundwater quantities, and exactly how groundwater affects the levels and ecology of GSL. Groundwater rights and decisions on when a basin should be considered "closed" to further appropriations are made at the state level. Utah has no authority to determine how groundwater is used in adjacent states.

18. *Decrease Reservoir Evaporation*

Category: Environmental

Description: Evaporation from reservoirs represents a measurable (and potentially significant) loss of water from the local water budget. Variability in the rate of evaporation from reservoirs is the result of fluctuations in wind, temperature, humidity, and solar radiation. The rate of evaporation is greatest on hot, windy, dry, and sunny days. Researchers have estimated that evaporation in the Colorado River Basin, including Lake Mead and Lake Powell, is approximately 500 billion gallons of water annually (University of Colorado Boulder 2015). Some proposed strategies to reduce reservoir evaporation include covering the surface with thin films of organic compounds, reflective plastics, or lightweight shades. Relocating and developing storage in underground areas, aquifers, or higher elevations where less evaporation occurs are other possible strategies that have been proposed.

Applicability to Great Salt Lake: The Bear River Commission's 2009 Depletions Update, published in 2014, identifies evaporative loss (or depletions) associated with new or expanded reservoirs (Bear River Commission 2014). Although individually these figures are relatively small, e.g., 1,013 acre-feet of evaporation from Woodruff Narrows Reservoir, the total annual evaporative loss from all existing reservoirs (e.g., Cutler, Pineview, and Jordanelle) on tributaries that feed GSL could be more significant. An estimation of total annual evaporation from all major reservoirs within the GSL Basin could be calculated, and water saved through implementation of evaporation reduction strategies could be allocated to the GSL.

Potential limitations: Evaporation reduction strategies may be economically unfeasible relative to the amount of water saved or conflict with other uses of Utah's reservoirs. Water saved from evaporation would still need to be delivered to GSL. Additionally, there would likely be ecological consequences to this option, which could result in conflict with environmental regulations and natural resource management.

19. *Decrease Gunnison Bay Evaporation*

Category: Environmental

Description: An estimated 2.9 million acre-feet of water evaporate from GSL annually (U.S. Geological Survey 2007). Although there are no proven ways to limit or reduce evaporation at that scale, floating solar panels, membranes used to cultivate algae, thin films of organic compounds, reflective plastics, lightweight shades, or other means could be devised to limit evaporation, particularly on the Gunnison Bay, where there are less likely to be adverse effects on lake biota.

Applicability to Great Salt Lake: Decreasing evaporation keeps more water in the lake, and if accomplished at this scale, the resulting water savings could be substantial.

Potential limitations: Suitable technologies to reduce evaporation do not currently exist, and deploying such a technology at a sufficient scale to make a difference in the near term is unrealistic. In addition, the harsh environment of GSL makes an already challenging engineering problem even more difficult.

20. *Implement Vegetation Control around Great Salt Lake*

Category: Environmental

Description: Transpiration is the process by which water moves from plant roots to pores on leaves where it is released as vapor into the atmosphere. Although all plants transpire, some transpire at lower rates (e.g., cacti and succulents in arid regions), and some transpire at higher rates (e.g., invasive *Phragmites*). Transpiration rates in plants are also a function of size, leaf surface area, and environmental conditions. Because transpiration can effectively drawdown the water table, removal of vegetation or replacing a high transpiring plant with a lower transpiring one can have a mitigating effect by reducing water loss to transpiration.

Applicability to Great Salt Lake: As much as 2.6 million acre-feet of water is estimated to evapotranspire from GSL annually. Removal of vegetation around the fringes of the lake could reduce this amount.

Potential limitations: Vegetation in and around the GSL may actually help to reduce evaporation directly from the lake. It is not known whether more water is lost via evaporation vs. transpiration. Removing vegetation, especially native species, may degrade wildlife habitat.

21. *Eliminate Non-Native Phreatophytes and Other High Water Use Plants from Natural and Artificial Channels*

Category: Environmental

Description: Phreatophytes are any plant (but typically woody species in a stream or riparian context) that obtains water from a long tap root that reaches down to the water table. These plants are effective pumps and are able to transpire measurable quantities of water on a daily basis. In a study by the Tamarisk Coalition (2009), management of two phreatophytes—tamarisk (*Tamarix* sp.) and Russian olive (*Elaeagnus angustifolia*)—has the potential to save water within the Colorado River system at a reasonable cost per acre-foot. Researchers estimate that the average rate of evapotranspiration by tamarisk can range from 2.3 to 4.6 acre-feet per acre per year within the Colorado River Basin (Tamarisk Coalition 2009).

Applicability to Great Salt Lake: Russian olive and tamarisk, both non-native species, are found on the GSL shoreline and in and along its tributaries. Integrated management of these species has been successful at reducing populations of these species in some areas. Removal of these species from the system in significant quantities could leave more water in the system and deliver more water to GSL.

Potential limitations: The total acreage of tamarisk and Russian olive infestation within the GSL Basin is not known, and is it therefore difficult to calculate the potential water that would be saved from reduced evapotranspiration. Treatment and removal of these species is time intensive and expensive. In areas where these species provide bank stabilization and wildlife habitat, native or desirable species would need to be replanted and the evapotranspiration rates of the replacement plants would need to be calculated. Moreover, ensuring that the water saved by eliminating phreatophytes reaches GSL is problematic if there is potential for this water to be diverted before it reaches GSL.

22. *Implement Vegetation Control in Headwater Systems*

Category: Environmental

Description: Numerous studies confirm that vegetation management can increase or decrease water yields. For example, shifting from a dense coniferous forest to a thinner coniferous forest or a deciduous forest (e.g., aspen) can increase water yields. Although estimates vary, landscape-scale management to promote water yields can theoretically generate large increases. For example, a 1979 U.S. Department of Agriculture report estimates that a combination of vegetation shifts and snow management (using snow fences to promote drifts) could augment flows in the Colorado River watershed by as much as 6 million acre-feet annually. Although more recent studies have not confirmed that scale of potential new supply, small-scale studies continue to show potential increases in yield depending on vegetation type and management.

Applicability to Great Salt Lake: Because GSL drains such a wide area, forest thinning or other changes in vegetation type in upstream watersheds hold the potential to increase supplies to the lake.

Potential limitations: Better research is needed to understand the long-term and short-term tradeoffs between various vegetation management strategies. In addition, such strategies can be costly to implement and difficult on account of topography and federal regulations.

Legal

23. *Implement a State-Mandated Conservation Pool using Public Trust Doctrine*

Category: Legal

Description: Utah Courts or the State Legislature could define Public Trust Doctrine responsibilities to protect instream flow uses, such as a conservation pool, that would help sustain a minimum GSL lake level. In 1983, the California Supreme Court ruled that the State of California has an obligation to protect places such as Mono Lake “as far as feasible” even if it means reconsidering past water allocation decisions (National Audubon Society v. Superior Court, 658 P.2d 709 (Cal. 1983)). Currently, as a result of the California Supreme Court ruling, the quantity of diversions out of the Mono Lake Basin depend on the elevation of the lake. In addition, the Water Resource Control Board has ordered minimum and maintenance flows for all diverted streams in the Mono Lake Basin.

Applicability to Great Salt Lake: GSL is a resource of international importance, and for this reason, there is arguably a need to establish a conservation pool requiring a minimum GSL surface elevation that might also be associated with minimum and maintenance flows in major tributaries such as the Bear, Weber, Ogden, and Jordan Rivers. Theoretically, a suit filed by stakeholders could argue that the depletion of water from tributaries, although not a trans-basin diversion, is a violation of the Public Trust Doctrine.

Potential limitations: Outside of the Mono Lake Decision, it appears that the Public Trust Doctrine has rarely been a determining factor in legal decisions regarding water rights and instream flows. Instead, in legal decisions in California and other states, it has been viewed merely as a tool to help supplement various statutes and regulations. Beyond that, most Utah legislators remain opposed to applications of Public Trust that may interfere with private rights, and significant uncertainty exists as to how the issue would be addressed in the Utah Courts.

24. *Deny Water Rights Applications to Protect the Public Interest*

Category: Legal

Description: The Utah State Engineer can deny water rights applications if these applications would prove detrimental to the public interest, such as interfering with a more beneficial use of the water or the natural stream environment (Utah Code Annotated 73-3-8(1)(b)).

Applicability to Great Salt Lake: It would be detrimental to the public interest to approve water rights that prevent adequate instream flows in major tributaries to GSL, such as the Bear, Weber, Ogden, and Jordan Rivers, which are vital to the functions of the greater GSL ecosystem.

Potential limitations: The extent of the public interest power of a State Engineer is largely untested, and it could be politically difficult to exercise these public interest powers in Utah. A major limitation on the State Engineer's ability to affect GSL water supply by using the public interest powers to deny applications is that most of Utah's water is already appropriated.

25. *Expand State Agencies Acquisition of Water with Appropriated Funds, or Acquisition of Water Rights by Gift, Donation, Lease, or Other Arrangements*

Category: Legal

Description: DWR and the Utah Division of State Parks and Recreation (DSPR) can purchase water rights with appropriated funds, or can acquire water rights by gift, donation, lease, or other arrangements (Utah Code Annotated 73-3-30(2)). Water rights can be purchased from any willing seller, but cannot be acquired through eminent domain.

Applicability to Great Salt Lake: Acquiring water rights within major GSL tributaries such as the Bear, Weber, Ogden, and Jordan Rivers and managing them for minimum and maintenance instream flow purposes would allow more water to reach GSL and would protect its critical ecosystem functions. This could include leasing early or late year senior water rights to allow water to reach GSL at times when lake levels are typically at their lowest.

Potential limitations: This strategy would require willing sellers, lessees, or donators of water or water rights, and would also require adequate funding for what would be a substantial amount of water.

26. *Expand the Ability to Purchase or otherwise Acquire Water for Instream Flow Uses to Entities other than State Agencies*

Category: Legal

Description: Currently, DWR and DSPR can purchase water rights with appropriated funds, or can acquire water rights by gift, donation, lease, or other arrangements. The Utah State Legislature could pass legislation that allows other groups (non-profits, private individuals, etc.) to do the same.

Applicability to Great Salt Lake: Acquiring water and water rights within major GSL tributaries such as the Bear, Weber, Ogden, and Jordan Rivers and managing them for minimum and maintenance instream flow purposes would allow more water to reach GSL and protect its critical ecosystem functions. Allowing entities other than state agencies to acquire water and water rights for instream flow uses would increase opportunities for increasing water delivery to GSL.

Potential limitations: Passing new legislation could be politically difficult and time-consuming. This strategy would also require willing sellers, lessees, or donators of water or water rights.

27. *Pass Legislation to Set Minimum Instream Flow or Lake Level*

Category: Legal

Description: The Utah State Legislature could pass legislation that sets minimum or maintenance instream flow in major tributaries to GSL, such as the Bear, Weber, Ogden, and Jordan Rivers, or sets minimum lake level requirements for GSL. This could include clarifying the legal definition of "beneficial use" to include conservation and instream flow uses on an equal legal footing with other recognized beneficial uses.

Applicability to Great Salt Lake: Setting minimum instream flow or lake level requirements within GSL tributaries and within GSL would allow more water to remain in GSL tributaries, thus increasing water delivery to GSL and helping protect its critical ecosystem functions.

Potential limitations: Passing new legislation could be both politically and legally difficult to accomplish because it would affect many existing water rights holders, who would likely challenge such a move in both the legislature and in the courts.

28. *Authorize Pooled Leases*

Category: Legal

Description: The Utah State Legislature could modify the instream flow statute (Utah Code Annotated 73-3-30) to allow shared usage of water. Pooled leases are one example of a shared water use. For example, an irrigation district or water company could pool available water storage and lease the pooled water to agencies such as DWR for instream flows (Clyde 2016).

Applicability to Great Salt Lake: Water in pooled leases could be released at optimum times to augment stream flows in major GSL tributaries, such as the Bear, Weber, Ogden, and Jordan Rivers, and could increase GSL lake levels.

Potential limitations: This strategy would require the Utah State Legislature to make modifications to existing law, which may be politically difficult.

29. *Authorize Water Banks*

Category: Legal

Description: The Utah State Legislature could modify the instream flow statute (Utah Code Annotated 73-3-30) to allow shared usage of water. Water banks are one example of a shared water use. Water banks have been successful in Idaho and other states. In Utah, there are still Central Utah Project waters that are not currently being used. There may be Central Utah Project water that could be used for broader instream flow purposes without impairing long-term project operations and carry-over storage needs for the project (see Clyde 2016).

Applicability to Great Salt Lake: Increasing instream flows in major GSL tributaries, such as the Bear, Weber, Ogden, and Jordan Rivers, would help increase GSL lake levels.

Potential limitations: This strategy would require the Utah State Legislature to make modifications to existing law to allow for shared uses and to shepherd water downstream to the lake, both of which may prove politically difficult.

30. *Authorize Split-Season Leases*

Category: Legal

Description: The Utah State Legislature could modify the instream flow statute (Utah Code Annotated 73-3-30) to allow shared usage of water. Split-season leases are one example of a shared water use. Oregon law (Oregon Revised Statues 537.348) authorizes split-season leases where a portion of the water right is used for irrigation for part of the irrigation season, and then the remainder of the water right is made available for instream use during the same calendar year. For example, land could be irrigated during a 3-month growing season, and then the remaining water available under the water right in priority could be used for instream flows subject to adequate monitoring and reporting to the water agencies (Clyde 2016).

Applicability to Great Salt Lake: Increasing instream flows in major GSL tributaries, such as the Bear, Weber, Ogden, and Jordan Rivers, would help increase GSL lake levels.

Potential limitations: This strategy would require the Utah State Legislature to make modifications to existing law, which may be politically difficult.

31. *Allocate Reservoir Storage for the Benefit of Great Salt Lake*

Category: Legal

Description: Currently, all reservoir storage in the GSL Basin is either allocated to consumptive uses or, in some cases, a conservation pool dedicated to protecting that particular waterbody. Only in rare cases can part of that conservation pool be used to benefit downstream resources. If the law were changed, however, a portion of new or existing storage could be set aside for release to benefit GSL and help maintain lake levels. In addition, water resource managers currently manage to maintain reservoir levels and deliver water to consumptive uses downstream. If storage rights are earmarked for GSL, water managers could optimize the storage system to deliver multi-sector benefits, including increasing the levels of GSL.

Applicability to Great Salt Lake: Currently, all water stored upstream operates to the detriment of GSL. Allowing stored water to be earmarked for GSL and delivered downstream when needed changes that dynamic and could operate to help mitigate adverse impacts of other water use and to deliver water to GSL in times of scarcity.

Potential limitations: Most of the water in existing reservoirs is already allocated, creating conflicts with any new designation for GSL. Moreover, many water users will likely view water delivered to GSL as "wasted." Current law lacks both a recognition of the economic and environmental benefits of GSL levels and the necessary legal tools to shepherd conserved water downstream.

32. *Allow Contractual Arrangements to Limit Water Withdrawals*

Category: Legal

Description: Water users could enter into contractual agreements to limit withdrawals from GSL or its tributaries as lake levels decrease. For example, PacifiCorp and irrigation users entered into an agreement with Bear Lake recreational and environmental groups to limit withdrawals of water from Bear Lake as the lake levels decrease.

Applicability to Great Salt Lake: A contractual agreement could be negotiated with large irrigation users on all the major tributary rivers to allow water that might otherwise be diverted to reach GSL during dry cycles when lake levels are low. Industries and lake users that benefit from a higher maintained lake level (i.e., mineral extraction, brine shrimp harvesting, boating) might be induced to provide economic assistance to irrigators to offset their lost crops and/or their need to buy alternative feed (Clyde 2016).

Potential limitations: Some industries that rely on higher lake levels are also withdrawing water from GSL to support their industries (i.e., mineral extraction from lake brines). Therefore, contractual agreements to allow more water to reach the lake, only to withdraw that water once it reaches the lake, may not result in a net increase in lake level.

33. *Allow Statutory Reservation of Unappropriated Waters*

Category: Legal

Description: Under Utah Code Annotated 73-6-1, the governor can, by proclamation, reserve unappropriated waters in any source from appropriation and can hold water for future uses.

Applicability to Great Salt Lake: This authority could be used to reserve unappropriated waters in major tributaries to GSL, such as the Bear, Weber, Ogden, and Jordan Rivers, allowing more water to reach the lake.

Potential limitations: The vast majority of Utah’s water is already appropriated.

34. *End Statutory Prohibition on Condemnation (use of eminent domain)*

Category: Legal

Description: Currently, DWR and DSPR have authority to acquire water rights for instream flow purposes, but they are barred by statute from acquiring them by condemnation (Utah Code Annotated 73-3-30(2)(d)). However, condemnation requires payment of fair market value for the water rights and for severance damages for related economic loss caused by the loss of water rights, which may make it preferable to the reallocation of water under the Public Trust Doctrine, because reallocation using the Public Trust Doctrine provides no method of compensation.

Applicability to Great Salt Lake: Increasing instream flows in major GSL tributaries, such as the Bear, Weber, Ogden, and Jordan Rivers, would help increase GSL lake levels.

Potential limitations: It would be politically difficult for the Utah State Legislature to revise the applicable statute to allow for condemnation of existing water rights.

35. *Employ Migratory Bird Protection*

Category: Legal

Description: The Migratory Bird Treaty Act of 1918 (MBTA) (16 United States Code 703–712) makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to federal regulations. DWR's sensitive species list includes three migratory bird species that rely on GSL as habitat: American white pelican (*Pelecanus erythrorhynchos*), long-billed curlew (*Numenius americanus*), and bald eagle (*Haliaeetus leucocephalus*) (DWR 2015). The sensitive species list identifies these three species as wildlife species of concern, which are those species for which there is credible scientific evidence to substantiate a threat to continued population viability. According to DWR, wildlife species of concern designations "identify species for which conservation actions are needed, and that timely and appropriate conservation actions implemented on their behalf will preclude the need to list these species under the provisions of the federal Endangered Species Act" (DWR 2015). The statutory protections provided to migratory bird species could provide a rationale for the State Engineer to use his or her public interest powers to deny water rights applications in GSL tributaries to protect, maintain, and/or enhance migratory bird habitat. In theory, there would more habitat of high quality as GSL lake levels rise. These statutory protections may also provide a rationale for the Utah State Legislature to establish minimum instream flow levels in GSL tributaries and/or minimum lake level requirements for the lake.

Applicability to Great Salt Lake: Many bird species protected under the MBTA rely on GSL for seasonal habitat in the spring and fall during the migration period.

Potential limitations: The MBTA and DWR's sensitive species list do not include measures that would make it possible to enforce minimum instream flow or minimum lake levels to protect wildlife species. The Utah State Legislature would need to create minimum instream flow and minimum lake level requirements through legislation, relying on the MBTA and DWR's sensitive species list as rationales. Theoretically, the Utah State Engineer could use his or her public interest powers to deny water rights applications based on a migratory bird species protection rationale. However, the State Engineer's public interest powers are largely untested, and most water in Utah is already appropriated.

36. *Change Beneficial Use Designation of Farmington Bay*

Category: Legal

Description: Change the beneficial use designation of Farmington Bay under Utah Administrative Code R317-2-13 (*Classification of Waters of the State*) Section 6.5 Class 5D as shown below.

> Changed from:
>
> Beneficial Uses -- Protected for infrequent primary and secondary contact recreation, waterfowl, shorebirds, and other water-oriented wildlife including their necessary food chain.
>
> Changed to:
>
> Beneficial Uses -- Protected for waterfowl, shorebirds, and other water-oriented wildlife including their necessary food chain and for infrequent secondary contact recreation.

Applicability to Great Salt Lake: Such changes would reduce pressure on regulators to move toward dual nutrient reductions into Farmington Bay, which in turn would result in publically owned treatment works (POTWs) reducing loads to a level where water has greater value and will be sold for secondary use.

Potential limitations: A change in beneficial use designation would require regulatory or legislative action. The order in which beneficial uses are listed in the Utah Administrative Code does not prioritize one use over another. Therefore, the applicable water quality standards are those that protect the most sensitive of the beneficial uses. Any downgrade of the infrequent primary contact recreational use designation for Farmington Bay would require a use attainability analysis that demonstrates that attaining the designated use is not feasible because of one of the six factors described in 40 Code of Federal Regulations 131.10(g). The use attainability analysis must be approved by the Utah Water Quality Board and the U.S. Environmental Protection Agency.

The effluent discharged from all POTWs in the GSL watershed, by some estimates, represents approximately 6.5% of the total annual inflow into GSL (Wayment 2012). The effluent from POTWs that discharge directly into GSL, by some estimates, represents approximately 1.8% of the total annual inflow into GSL (Wayment 2012).

37. *Make Great Salt Lake One Regulatory Unit*

Category: Legal

Description: Currently, water quality decisions regarding GSL are made for each bay (i.e., Willard Bay, Bear River Bay, Farmington Bay, Gilbert Bay, and Gunnison Bay) as separate regulatory units. GSL in its entirety should be the regulatory unit used when making water quality decisions, with the separate bays being geographically distinct regions of one interconnected lake.

Applicability to Great Salt Lake: Managing GSL's interconnected bays as separate regulatory units results in identifying beneficial processes as harmful and consequent nutrient regulations, which may result in unintentional water loss to GSL because of reuse of POTW water.

Potential limitations: Regulatory changes are time-consuming, and as new regulations are created, new frameworks for decision-making regarding GSL would also need to be created. Water quality management currently considers connected waterbodies and protection of downstream beneficial uses. For GSL, this would include flow between interconnected bays. Combining GSL bays into a single regulatory unit would likely not alter water quality management decisions, which already take into account the flow between interconnected bays. However, combining GSL bays into a single regulatory unit would mean that all geographic regions of GSL would share the same beneficial uses, water quality criteria, and use attainment assessment methods, which may not be appropriate.

38. *Use the Antidegradation Statute to Protect Great Salt Lake Tributaries*

Category: Legal

Description: The water quality criteria in Utah Administrative Code R317-2-3 (*Antidegradation Policy*) are the water quality "floor" for Utah's waterbodies. The Utah Division of Water Quality antidegradation policy is applicable to both new and existing discharges to waters of the state. If the water quality standards in GSL tributaries are below the floor, as determined by the state, the state is required to improve it. This could be used to help increase water delivery to GSL.

Applicability to Great Salt Lake: The water quality of GSL tributaries could directly impact the water quality of GSL by carrying pollutants to GSL. If water levels in GSL tributaries decrease to a point that pollutants become concentrated, and water quality falls to meet the statutory standards, the state could require an increase in water levels to help decrease pollutant concentrations and improve the water quality in these surface waters. Increasing water levels in these surface waters would allow more water to reach GSL.

Potential limitations: Political and practical limitations exist. Politically, if this strategy negatively impacts existing water rights holders, pressure could be applied to the Utah State Legislature to change the statute. Practically, this strategy may result in only a minor increase in water reaching GSL.

The antidegradation policy is intended to maintain water quality in waterbodies whose existing quality is better than the established standards for its designated uses. Regardless of the antidegradation classification, the Utah Division of Water Quality does not have the authority to mandate increases in water quantity under antidegradation.

39. *Allow Irrigators or Other Water Users to Send Unneeded Water Downstream Without Being Penalized or at Risk of Losing Water Rights*

Category: Legal

Description: Existing law requires that water rights holders put water to a beneficial use in order to retain the right. Otherwise, the water right could be reduced or lost entirely (Utah Code Annotated 73-1-4).

Applicability to Great Salt Lake: Allowing water not needed by irrigators to remain in GSL tributaries could allow more water to reach GSL.

Potential limitations: This would represent a major shift in Utah water rights law, which would require new legislation that would likely be time-consuming and politically difficult to accomplish.

40. *Develop and Implement Other Measures to Supply Water to Great Salt Lake*

Category: Legal

Description: Utah law may not provide adequate mechanisms to either 1) incentivize conservation, or 2) move conserved water to GSL. The law could be changed to allow water conserved at any point in the watershed for the express purpose of benefitting GSL to actually make it to the lake without risk of forfeiture or re-diversion.

Applicability to Great Salt Lake: Many of the potential strategies that could supply water for GSL face a similar challenge: there is no guarantee that the water in question will actually make it to the lake without being diverted for other purposes. Absent those guarantees, it is hard to secure the support and resources necessary to implement the strategies.

Potential limitations: Moving conserved water downstream below the last existing diversion poses difficult practical (measurement) and legal challenges. Solutions for those challenges would likely meet with resistance and could complicate the administration of water rights.

41. *Lease Early/Late Year Senior Water Rights*

Category: Legal

Description: Prior appropriation of water rights is a legal doctrine that can be summarized as "first in time, first in right." This doctrine allocates water to senior water rights users before subsequent users can take the remaining water and put it to their own beneficial use. In addition to the date of allocation, water rights might also be associated with a time of the year. Specifically, early or late season refers to the growing season and the probability of increasing economic yield of a field while offsetting additional costs. Typically, there is less economic return on early and late season crops, unless one is growing crops specifically suited to this time of year.

Applicability to Great Salt Lake: Diverting senior water rights used for growing early or late season crops that might not provide significant economic return could generate water for GSL.

Potential limitations: Water rights not put to beneficial use can be considered abandoned and allocated to other users. To secure these water rights for the owner, a system of temporary leases or transfers would be needed.

42. *Change Zoning Laws to Encourage Higher Density Development*

Category: Legal

Description: High-density developments like apartments, condominiums, and townhomes typical consume less water overall because they devote less water to landscaping. Indoor water, by contrast, remains fairly consistent between types of homes and generally enters the lake as treated effluent in any event. Although recent studies confirm that Utah is moving naturally toward smaller average lot sizes (i.e., higher densities), in many areas, local zoning regulations actively discourage higher density housing and promote sprawl in the form of larger homes on larger lots, all of which consume a lot of water to put in and maintain outdoor landscapes, particularly turf.

Applicability to Great Salt Lake: If the trend toward higher density developments persists, it may lessen the overall impact on water supplies of an increased population.

Potential limitations: The effect of converting agriculture land to urban development on overall water budgets needs to be better understood. In addition, there would likely be political and cultural resistance to making zoning laws less restrictive, and many communities rely on zoning to preserve a certain look or quality of life.

43. *Implement a Dry Year Contract*

Category: Legal

Description: Water users can implement legal mechanisms that allocate water differently in dry years. For example, Bear Lake water users entered into an agreement with recreational and environmental groups to limit withdrawals of water from Bear Lake as the lake level decreases. Bear Lake water users are subject to minor reductions in water allocation based on the projected level of Bear Lake.

Applicability to Great Salt Lake: Projected dry years that could result in less flow to GSL would trigger a uniform reduction in water allocation to users. Such a dry year contract could be implemented on a watershed by watershed basis since variation in snowpack exists at this scale.

Potential limitations: This strategy could result in junior water rights holders not receiving their water share or could arguably result in harm to agricultural producers. There is no guarantee that water left in a stream or river would reach GSL.

Operational

44. *Meter All Secondary Water*

Category: Operational

Description: In many areas of Utah, including the GSL watershed, secondary water remains unmetered and charged based on a fixed fee regardless of the amount of water used. For example, a residential user who waters a lawn every day for an hour in the middle of the day pays the same rate as a user who xeriscapes a yard and uses only minimal drip irrigation. In short, there is no financial incentive to conserve secondary water for many water users. Experiments conducted by the Weber Basin Water Conservancy District show dramatic reductions in water use by simply installing a secondary meter and reporting water use to the consumer relative to his/her own use and in comparison to other users, even if the pricing structure is not changed (Office of the Legislative Auditor General State of Utah 2015).

Applicability to Great Salt Lake: Secondary water use in the GSL watershed is substantial, and much of the water diverted from natural systems for that secondary use either does not return to the lake (because it is taken up by plants in yards and gardens) or returns to the lake in a different form (e.g., by storm drains). Reducing that upstream consumption would both lessen the demand for new supply projects that could impair the lake and reduce current consumption, leaving more water in streams and rivers that feed into the lake.

Potential limitations: The biggest limitation to metering secondary water is cost, with a reliable secondary meter costing roughly $1,000 per hook-up. Technological innovations and increasing demand for such technologies will likely reduce that cost over time.

45. *Reduce Evaporative Mining*

Category: Operational

Description: A reduction in evaporative mining of GSL would help alleviate the diversion and consumption of the lake's water volume. Mineral extraction from GSL is a $1 billion industry (Larson 2016). By diverting mineral-rich water into shallow evaporation ponds along the shores of the lake, companies are able to harvest salts such as sodium, chloride, sulfate, magnesium, and potassium by evaporating lake water. In general, evaporative mining relies on the same process of evaporation that occurs naturally on GSL; however, by diverting water into shallow areas, the water surface area, temperature, and therefore rate of evaporation all increase. Five different evaporative mining companies are located along the shores of GSL. These companies depend on specific minimum surface water elevations that allow their diversion infrastructure to divert the lake water. One of these companies is responsible for evaporating 40 billion gallons of water each year. This figure only represents approximately 4% of the estimated natural evaporation from GSL; however, the cumulative evaporation from the operations of the five mining companies represents a significant amount of water that could benefit the lake if it were not diverted. Since settlers arrived along the Wasatch Front and began diverting and damming water, it is estimated that GSL water levels have dropped 11 feet (Wurtsbaugh et al. 2016). Scientists at Utah State University estimate that water diversions from mineral industries account for 1.4 feet (approximately 13%) of the 11-foot decline in lake level (Wurtsbaugh et al. 2016). Although the evaporative mining industry depletes GSL water, it is an advocate of increased tributary flow into the lake to ensure its ability to divert and evaporate water, particularly when agricultural diversions have been responsible for 7.0 feet (63%) of the 11-foot decline in lake level (Wurtsbaugh et al. 2016).

Applicability to Great Salt Lake: The evaporative mining industry represents both an economic driver for protecting GSL and a consumptive use of the lake water, which has resulted in lowering the surface water elevation of the lake. The evaporative mining industry supports increased inflows to GSL and other methods of increasing the surface elevation. If the mining industry were to stop diverting GSL water, theoretically it would result in an increase of approximately 1.4 feet surface elevation (Wurtsbaugh et al. 2016).

Potential limitations: The evaporative mining industry has been a stakeholder in the management of GSL for many years (since ca. 1969) and helps to demonstrate the economic value of the lake to the Utah economy. Forcing the industry to reduce its diversion or evaporation of lake water could prove politically difficult and raise serious legal challenges. The industry could voluntarily agree to reduce evaporation in times of shortage. Future methodological or technological advancements might allow the industry to operate with less evaporative losses.

46. *Restrict Great Salt Lake Industries in Dry Years or Based on Elevation*

Category: Operational

Description: A restriction of existing diversions and/or new diversions during dry years or at certain elevations could leave more water in the main bays of GSL. The need for GSL water in the evaporative mining industry is well documented. Through a system of canals, pumps, and diversions, the mining industry diverts water from the main bays of the GSL and through the process of solar evaporation mines minerals and other products. Recent low water years have caused some operators to request permits from the State of Utah to extend diversion structures farther into the lake to access brine for evaporation.

Applicability to Great Salt Lake: GSL evaporative mining provides significant economic benefits for Utah. It also represents a consumptive use of the lake water, which has resulted in lowering the surface water elevation of the lake. If the evaporative mining industry were to stop diverting GSL water at certain times, this could result in an increase in surface elevation.

Potential limitations: There is no legal precedent (or clear authority) to restrict a diverted right where water is available to satisfy that right. Moreover, restricting mining and other operations could have an effect on the local economy by eliminating employment opportunities and income generated by mineral sales.

47. *Increase the Water Use Efficiency of Agriculture*

Category: Operational

Description: Most of the water diversions in the state of Utah are for agricultural uses (82%) (Edwards, et al. 2017). Given the importance of agriculture to Utah's economy, surface water diversions are a vital and precious resource. The methods used for irrigation water transport and delivery to agricultural lands have implications for overall water use, water losses, and efficiency. Most of the water diverted is transported by un-lined irrigational canals that connect surface waters to agricultural lands. Seepage through these canals represents a loss of water, and an investment in canal lining could save more than 459,000 acre-feet per year of water for the state of Utah (Edwards et al. 2017). Ironically, only approximately half of Utah agricultural land users currently use high-efficiency irrigation systems, with the other half relying on flood-irrigation systems. Although flood irrigation may be approximately 70% efficient, pivot sprinklers are approximately 80% efficient and may represent an opportunity for water savings. The state of Utah recognizes the value in upgrading to more efficient systems and has started to offer incentives to farmers such as low-, or even no-interest loans for system upgrades. Seventy agricultural efficiency projects across the state are taking advantage of these state incentives (O'Donoghue 2015). Conversion to sprinklers may cost between $63 and $228 per acre-foot of water saved and a total savings of over 349,000 acre-feet per year for the state. A third main area where water savings may be found is in the scheduling of irrigation. Crops are often irrigated on a standard schedule that is not adjusted for weather, soil conditions, or the growth stage of the crop. Irrigation scheduling provides a means to evaluate and apply the appropriate amount of water to meet crop requirements at the right time (Cooley et al. 2009). Following conversion to sprinkler technology, improvements in scheduling throughout the state could generate savings of 247,000 acre-feet per year. Dramatic advances in scheduling have been achieved in the country's most valuable croplands where soil moisture and weather station sensors provide real-time information that can determine irrigation scheduling. However, the cost of automated systems may currently be prohibitive for many Utah farmers. Other agriculture efficiency methods should also be considered, including crop rotation, crop cover, and soil improvements.

Applicability to Great Salt Lake: Increased efficiency of irrigation systems could leave more surface water in the streams for possible delivery to GSL. All of the major tributary watersheds to GSL have agricultural land use, and increased efficiency could result in fewer diversions and greater water deliveries to GSL.

Potential limitations: Seepage from flood irrigation and from unlined irrigation canals helps maintain groundwater reserves. A reduction in seepage could deplete groundwater levels in certain areas and reduce the size of wetland and riparian areas. In addition, more efficient irrigation methods such as sprinkler systems could increase both evaporative losses and water consumption through increased transpiration by plants, potentially reducing downstream supply, particularly at the watershed scale. Reducing irrigation diversions does not ensure that additional water would be delivered to GSL because it might just be appropriated further downstream by another user. There is still uncertainty about the quantity of water that could be made available to GSL through improvements in agriculture water use efficiency; however, agriculture is such a significant water user that efficiency measures should be seriously considered. Greater efficiencies in water use may come with additional costs. For example, changing from flood irrigation to sprinklers requires additional energy costs for pumping and could result in an economic impact on an agricultural producer.

48. *Reuse Residential Gray Water*

Category: Operational

Description: Gray water includes all wastewater (except toilet, kitchen sink, and dishwasher water) generated in the home that can be reused in various applications such as landscape irrigation. Gray water harvesting is the practice of collecting gray water from the home for reuse instead of directing it to the wastewater system. The most common application of gray water is in landscape irrigation where plants and microorganisms in the soil consume and filter the organic nutrients and bacteria found in gray water, treating it naturally and returning clean water to the water cycle. Though not suitable as drinking water, gray water can be used for irrigation and even within the household for uses such as flushing toilets. However, gray water reused in the home requires additional treatment. Utah is the second driest state and the second highest per capita domestic water consumer in the nation (DWRe 2010a); therefore, gray water systems may help address water scarcity issues. In arid environments such as Utah, outdoor household-related water use including landscape irrigation represents more than half of the total household water use, and the implementation of gray water systems could help cut residential water use by more than half (Brain et al. 2015).

Applicability to Great Salt Lake: A decrease in residential water use would theoretically result in greater surface water flows and deliveries to GSL. Although residential water use is dwarfed by agricultural water use in Utah, a reduction in residential use could nonetheless be beneficial.

Potential limitations: As previously stated, residential water use represents a small fraction of all surface water diversions in Utah. A reduction in residential water use by using gray water systems may not result in significant increased surface water flows to GSL, particularly as treated wastewater often ends up in GSL. Additionally, an increase in surface water flow would not necessarily result in increased water for GSL because it may be diverted before it reaches the lake.

49. *Limit Water Reuse*

Category: Operational

Description: Proposals to treat POTW discharges to higher water quality standards threaten to create a new market and new demand for water that currently flows into GSL and that currently provides a meaningful amount of overall supply to the lake. Strategies should be pursued that either discourage reuse projects or insist that any reuse project incorporates a one-to-one tradeoff, i.e., as water reuse increases, the losses are offset by reduced diversions from natural systems so that the lake is held harmless by such a shift in use.

Applicability to Great Salt Lake: Treated POTW discharges make up an increasingly important amount of lake inflow, an amount likely to increase as the population in the GSL Basin grows. If that water is reused and increases upstream consumptive use, water supplies to the lake will decline further.

Potential limitations: There is no clear mechanism in place to prohibit or limit reuse projects, and those with an interest in treating to higher standards (for whatever reason) could resist limitations.

The effluent discharged from all POTWs in the GSL watershed, by some estimates, represents approximately 6.5% of the total annual inflow into GSL (Wayment 2012). The effluent from POTWs that discharge directly into GSL, by some estimates, represents approximately 1.8% of the total annual inflow into GSL (Wayment 2012).

50. *Employ Water Conservation Measures (General)*

Category: Operational

Description: Water conservation measures exist for all categories of water use. Even though Utah is one of the driest states in the country, water conservation measures are not applied consistently throughout the state’s various water use categories (e.g., agricultural, municipal [for example, residential indoor and residential outdoor], and industrial). Residential water use conservation is generally done through conversion of shower heads, toilets, and washing machines to low-flow, high-efficiency units. Conversion to more water-efficient technology has been either mandated or encouraged on a national scale by legislation and U.S. Environmental Protection Agency programs such as Energy Star. The State of Utah adopted the Energy Policy Act mandate for toilets not to exceed 1.6 gallons per flush; however, data on conversion to low-flow shower heads and high-efficiency washing machines are less clear. Replacement of toilets, shower heads, and washing machines to high-efficiency models has the potential to save roughly 52,000 acre-feet of water per year in Utah. Water savings in residential outdoor, commercial, and institutional use categories largely consist of improving the landscape irrigation schedule and irrigating during nighttime hours. Commercial users are assumed to use 20% of water for landscaping, and institutional users are assumed to use 37% for landscaping. This improved conservation could result in a savings of 14,700 acre-feet of water per year (Edwards et al. 2017). However, approximately 82% of water use in the State of Utah is used in agricultural applications (Edwards et al. 2017), and therefore improved efficiencies in agricultural water use have the greatest potential for water savings. Additionally, there are many different strategies for improving agricultural water use efficiency from lining irrigation canals to improving the irrigation scheduling and the actual method of crop irrigation, therefore providing significant opportunities for water savings.

Applicability to Great Salt Lake: Increased efficiency of residential, commercial, institutional, and agricultural systems would result in more surface water in the streams for delivery to GSL. All of the major tributary watersheds provide water for these various uses, and increased efficiency would result in fewer diversions and greater water deliveries to GSL.

Potential limitations: Water conservation would theoretically result in a reduction in water diversions and therefore an increase in the flows of GSL tributaries. However, there is no guarantee that the water left in the tributaries would reach GSL. An overhaul of the regulation of water rights in addition to increased enforcement would be necessary to help increase water deliveries to GSL. Calculations of water saved must take into account that some of the water diverted already reaches the lake (e.g., residential indoor through treated wastewater and residential outdoor through storm drains).

51. *Agriculture Conversion in the Bear, Weber, and Jordan River Basins Combined with Municipal Water Conservation Measures*

Category: Operational

Description: Much of Utah's urban growth is occurring on irrigated agricultural lands, which use 82% of Utah's total water. On average, Utah loses more than 30 acres of farmland each day (American Farmland Trust 2017) to urban development as the state's urban population grows. Paving irrigated farmland creates a surplus of water because most urban land uses less water than agricultural land, per acre. During an average summer, a farm might use 10 to 15 vertical feet of water on its irrigated fields, whereas domestic grass might use more than 2.5 to 3.0 feet of water. Because a typical ¼-acre home lot might have a lawn of roughly ⅛ acre or less, the water used per acre is dramatically less than when it was an irrigated field. Furthermore, unlike the vast acreage of irrigated farmland that was previously flood-irrigated or that used large sprinkler systems, a large portion of the new municipal acreage is not watered at all. Although some of this surplus agricultural water will be used to meet increasing municipal water demand along the Wasatch Front, the rest could be left instream. This is studied in great detail in Chapter IV of the 2015 *A Performance Audit of Projections of Utah's Water Needs*, titled "Growth in Utah's Water Supply Should Be Reported to Decision Makers" (Office of the Legislative Auditor General State of Utah 2015).

According to the U.S. Geological Survey, Utah has the highest per-person water use in America (Nuñez 2014). Municipal water users can implement a number of conservation measures to use less water. One notable conservation measure is in the unmetered secondary water sector. Because 23% of Utah's municipal water use is from secondary water and because this use is generally unmetered, installing meters has the potential to greatly reduce Utah's water use (Office of the Legislative Auditor General State of Utah 2015). Recent DWRe studies indicate that some secondary customers in Davis and Weber Counties overwater their landscapes by more than 100% (DWRe 2010a). Simply installing meters to let these water users know how much water they use saves large quantities of water, according to a lengthy research project conducted by Dr. Joanna Endter-Wada at Utah State University. Her research focused on installing 2,000 meters on secondary water users in the Weber Basin Water Conservancy District (Endter-Wada 2013). Three years after the meters were installed, water use declined by approximately 25% on the metered connections (Endter-Wada 2013; Office of the Legislative Auditor General State of Utah 2015). Universal metering of secondary connections could help save tens of thousands of acre-feet per year along the Wasatch Front.

Additional water conservation measures could include switching to tiered block water pricing and reducing or eliminating property tax subsidies for water use. Utah's current water pricing structures increase demand for water and encourage waste by keeping the price of water artificially low.

Applicability to Great Salt Lake: Reducing the amount of water Utah uses involves diverting less water from the state's streams and rivers before it can reach GSL. Increasing the amount of water left instream in the Bear, Jordan, and Weber Rivers could augment seasonal flows into GSL.

Potential limitations: Agricultural water use can be overestimated, which might not result in the gains expected by conversion to residential or industrial uses.

Utah's existing water rights structure requires rights holders to use their entire water right, or risk forfeiture. Therefore, Utah's instream flow law would need to be amended to allow for surplus agriculture water from willing sellers to be converted to instream flows. Currently, two Utah state departments can hold instream water rights: DWR and DSPR.

With regard to universal metering of secondary water connections, the primary limitation is cost of implementation. For example, cost estimates vary between $50 and $100 million to meter all the water users in the Weber Basin Water Conservancy District system.

52. *Employ Water Conservation Measures (Municipal and Industrial)*

Category: Operational

Description: Water conservation measures exist for all categories of water use. However, the application of water conservation measures generally happens out of necessity and not from advanced planning. Even though Utah is one of the driest states in the country, water conservation measures are relatively uncommon throughout the state's various water use categories. General water use categories include agricultural, municipal, and industrial. In all, 82% of water use in Utah is used for agricultural purposes with the remaining 18% going to municipal and industrial purposes. Of that 18%, approximately three-quarters of the water is used residentially and the remaining one-quarter is split among various industrial purposes (DWRe 2010a).

Residential indoor water use conservation is generally done through conversion of shower heads, toilets, and washing machines to low-flow, high-efficiency units. Conversion to more water-efficient technology has been either mandated or encouraged on a national scale by legislation and U.S. Environmental Protection Agency programs such as Energy Star. The State of Utah adopted the Energy Policy Act mandate for toilets not to exceed 1.6 gallons per flush; however, data on conversion to low-flow shower heads and high-efficiency washing machines are less clear. Replacement of toilets, shower heads, and washing machines to high-efficiency models has the potential to save roughly 52,000 acre-feet of water per year in Utah.

Applicability to Great Salt Lake: Increased efficiency of municipal and industrial systems would result in more surface water in the streams for delivery to GSL. All of the major tributary watersheds provide water for these various uses, and increased efficiency would result in fewer diversions and greater water deliveries to GSL.

Potential limitations: Water conservation would theoretically result in a reduction in water diversions and therefore an increase in the flows to GSL from its tributaries. However, there is no guarantee that the water left in the tributaries would reach GSL. An overhaul of the regulation of water rights in addition to increased enforcement would be necessary to help increase water deliveries to GSL. Calculations of water saved must take into account that some of the water diverted already reaches the lake (e.g., residential indoor through treated wastewater and residential outdoor through storm drains).

53. *Buy and Dry Farmland in the Great Salt Lake Basin*

Category: Operational

Description: Buying farmland equates to taking agricultural water rights out of use with the assumption that they can be reallocated to other beneficial uses such as instream flows or a GSL conservation pool that will ultimately reach GSL.

Applicability to Great Salt Lake: Agricultural uses are a primary allocation of water rights within the GSL Basin. In theory, farmland in any location in the basin could be removed from production—if for example it is uneconomic to deliver the current crop to market—and those water rights could be diverted to GSL.

Potential limitations: This strategy might result in junior water rights holders not receiving their water share or could harm other agricultural producers who rely on a specific crop or crops. So-called “buy and dry” strategies can have unintended social and environmental impacts (e.g., harm to rural economies and social structure and degradation of air quality through soil desiccation and dust storms), as exemplified by initial efforts to augment flows into Walker Lake, Nevada. Lastly, there is no guarantee that water left in a stream or river will reach GSL.

54. *Move More Water to Great Salt Lake in High Water Years*

Category: Operational

Description: The amount of water reaching GSL is not only a function of depletions but is also dependent on the amount of precipitation falling in the basin in any given year. High water years provide an opportunity to deliver excess water to GSL.

Applicability to Great Salt Lake: There is measurable variation in the amount of water within the GSL Basin from one year to the next. The high snow pack and runoff in 2017 saw an upturn in the GSL hydrograph. An agreement to maintain or increase GSL elevations could include a provision that delivers varying amounts of water relative to the percentage of which the snowpack is above normal.

Potential limitations: Junior water right holders are dependent on high water years, and this may be the only time they receive their water rights. In addition, current legal mechanisms would have to be modified to allow for this kind of systemic delivery of water downstream past diverters with valid, existing rights.

55. *Increase Capacity of Existing Reservoirs*

Category: Operational

Description: Increase capacity of existing reservoirs to provide periodic release of flows. Additional storage capacity would allow for greater flexibility in water supply management, as high flows in a given year could be stored and slowly released during other parts of the year.

Applicability to Great Salt Lake: Additional reservoir storage would allow for greater flexibility in the delivery of water to the GSL. Excess water could be stored in reservoirs and released to the GSL as it is needed to maintain critical surface elevations. Releases to the GSL could be separated from agricultural demands.

Potential limitations: The expansion of certain reservoirs may not be feasible because of logistical challenges surrounding land uses or because of public outcry. Moreover, increased upstream storage can both increase evaporative losses and potentially increase upstream consumption by making more water available to existing users. Beyond that, increasing storage capacity could encourage population growth and housing development, which would increase water demands and reduce the water available to the GSL.

56. *Store Water in Bear Lake for Prolonged Release to Great Salt Lake*

Category: Operational

Description: Water storage is a commonly used solution to mitigate for the effects of drought and to manage release of water consistently throughout the year as opposed to springtime snowmelt-driven runoff. The Bear River watershed is a significant contributor of water to GSL relative to other tributaries in the basin and Bear Lake and therefore has the greatest capacity for storage.

Applicability to Great Salt Lake: Bear Lake could function as a natural storage reservoir for water that could be released under certain conditions to GSL.

Potential limitations: The current legal structure would not ensure that water released from Bear Lake would reach GSL. Better science is needed (e.g., Integrated Watershed Management Model) to understand how much water could be stored in Bear Lake, how that additional storage could be generated, as well as appropriate release times and storage amounts needed to affect GSL elevations.

57. *Plant Alternative Crops with Lower Crop Water Need*

Category: Operational

Description: The crop water need refers to the amount of water needed to meet the water loss through evapotranspiration. Shifting from a crop with a high water need to a low water need represents a potential waters savings if less water is diverted from a surface waterbody.

Applicability to Great Salt Lake: High water need crops grown in the basins of major tributaries to GSL could be converted to lower water need crops.

Potential limitations: Current crop selection has occurred for specific reasons and is likely driven by local needs and regional markets. Expecting farmers to switch from alfalfa, for example, to a less water intensive crop could undermine other agricultural sectors and might not be financially feasible. Ensuring that the water saved by shifting to low water need crops reaches GSL is problematic if there is potential for this water to be diverted before it reaches GSL.

Policy

58. *Increase Treatment and Effluent Standards at Public Sewage Treatment Plants*

Category: Policy

Description: Currently, public sewage treatment plants in Utah are required to meet Type I or Type II standards for wastewater effluent. Type I effluent is required for municipal irrigation purposes and other uses where human contact is likely. Type II effluent is acceptable mainly for agricultural irrigation purposes where it is not likely to come in direct contact with the edible parts of crops or with humans. If wastewater is to be reused for applications such as environmental reuse, groundwater recharge, or indirect potable reuse, additional regulations may be necessary.

Applicability to Great Salt Lake: If additional filtration requirements are applied to wastewater, this wastewater could be discharged into GSL or its tributaries rather than used for agricultural or municipal irrigation.

Potential limitations: Additional filtration requirements would increase the costs of treatment, and these costs would likely result in increased rates for consumers. If wastewater effluent is discharged into GSL or its tributaries, rather than used for irrigation, irrigators would likely use other sources of water from within the watershed. Therefore, this strategy may result in the same amount of water being diverted from GSL and its tributaries.

The effluent discharged from all POTWs in the GSL watershed, by some estimates, represents approximately 6.5% of the total annual inflow into GSL (Wayment 2012). The effluent from POTWs that discharge directly into GSL, by some estimates, represents approximately 1.8% of the total annual inflow into GSL (Wayment 2012).

59. *Permanently Abandon the Bear River Project*

Category: Policy

Description: Permanently abandon the Bear River Project. The Bear River Project proposes to construct a dam (or dams) and reservoir (or reservoirs) that would divert 20% of GSL's primary water source (i.e., the Bear River) in an effort to provide more municipal water to the Wasatch Front.

Applicability to Great Salt Lake: Abandoning the Bear River Project would prevent 20% of GSL's input from the Bear River from being diverted and stored in a reservoir (or reservoirs). Although it may not be currently needed, DWRe anticipates that the project will not be necessary until 2040 (Utah Division of Natural Resources 2017).

Potential limitations: As the population along the Wasatch Front grows, along with the need for more municipal water, pressure to pursue the Bear River Project at some point may increase. The Bear River Project would reduce flows in the Bear River and therefore would reduce potential diversions and water deliveries to GSL.

60. *Implement Tiered Water Rates*

Category: Policy

Description: Implement tiered water rates for residential-commercial use, where larger water users are charged more per gallon than smaller water users, with significant increases in costs for water use that goes above typical indoor water use. Increases in rates would encourage users to reduce consumptive use.

Applicability to Great Salt Lake: Reduction in consumptive use would result in increased water flowing back into GSL.

Potential limitations: Tiered rates could result in consumer resistance and potentially inequities for low-income households that need large quantities of water but cannot afford to pay the increased rates.

61. *Change Subsidized Value of Water to Private/Public Sectors to Reflect Real Costs*

Category: Policy

Description: State and federal funding programs help pay for projects that build and improve municipal and industrial water systems throughout the state (DWRe 2010b). This funding often occurs with grants and/or low- or no-interest loans. These projects have helped to keep the cost of water low.

Applicability to Great Salt Lake: Removing the economic benefits of the state and federally funded programs, and passing those costs on to water users would encourage water users to reduce their consumptive use, allowing more water to reach GSL.

Potential limitations: The low cost of water in the state is a result of many different factors (climate, geography, water delivery systems, conversion of agricultural water to municipal and industrial uses, etc.) (DWRe 2010b); therefore, changes in the way water costs are subsidized may not have a substantial impact on water use.

62. *Phase Out Property Tax Subsidies for Water*

Category: Policy

Description: Utah’s water conservancy districts collect property taxes on homes and businesses. These property tax revenues are used to artificially lower the price of water and help explain why Utah’s water rates are among the lowest in the United Sates while Utah’s per-capita water use is the highest. According to basic market economics, without a clear pricing signal, consumers will not use a given resource efficiently. Cheap water encourages waste and necessitates greater withdrawals from rivers that flow into GSL (e.g., Bear, Jordan, and Weber Rivers). Additionally, state and federal government, churches, and nonprofits pay no property taxes, which means they do not pay their fair share for the water they use. Phasing out property taxes for water in urban areas would mean that Utah taxpayers would pay only for the water they use, and no individual or institution would be subsidized. Phasing out these taxes would use the free market to extend Utah’s municipal water supply while eliminating the need for unnecessary government spending. Proponents of property taxes for water often argue that municipal bond ratings would be negatively affected if property taxes were abandoned; however, research shows this claim to be unsubstantiated. Proponents further argue that property taxes are not a subsidy because homeowners and businesses “split” payment through their property taxes and water bills. However, because government and nonprofit institutions pay no property tax, their water use is therefore heavily subsidized by the tax paying public. This is significant when considering that 11 out of the top 20 water users—over 50%—in Salt Lake City are non-taxed government institutions.

Applicability to Great Salt Lake: Reducing urban water demand by eliminating property tax subsidies along the Wasatch Front can help reduce river diversions and increase the amount of water that makes its way to GSL. It also reduces the need for costly new infrastructure projects such as the Bear River Development.

Potential Limitations: Reducing water use and leaving more water instream do not guarantee that this water will actually make it to GSL. Measures to create new and more robust instream flow protections are needed in concert with property tax removal to ensure that water saved from reduced demand in urban areas along the Wasatch Front makes it to GSL.

63. *Deny Permits (or have applicant show net neutral or net gain in water to Great Salt Lake) for Projects that Require New Withdrawals of Water*

Category: Policy

Description: Regulators at the Utah Department of Environmental Resources (or other departments and divisions) could deny permits for projects with large water consumption needs that would be a drain on the freshwater or saline supplies in GSL and the larger GSL Basin.

Applicability to Great Salt Lake: GSL is close to areas with economic development potential. Many new projects whether commercial or industrial, e.g., landfills, high-tech manufacturing, or data storage, require water as part of their operation.

Potential Limitations: In urban and rural areas surrounding GSL, economic development is one of many proprieties to support citizens and local governments. If water rights are available, it is unlikely that they would be withheld by the State of Utah to ensure that water supply to GSL is maintained.

Structural

64. *Remove Cutler Dam*

Category: Structural

Description: Most major rivers across the United States have been dammed for hydropower, irrigation, and/or flood control over the past 150 years. This damming has dramatically altered the hydrology of the nation’s watersheds and estuarine environments. In recent years, the country has entered into a phase of dam decommissioning and removal. The license for a given dam must be renewed every 30 to 50 years with the Federal Energy Regulatory Commission (FERC) and in many cases the relicensing process demonstrates the ecological, social, and/or economic rationale for dam removal. Cutler Dam and Reservoir on the Bear River at the border of Cache and Box Elder Counties are owned and operated by PacifiCorp and will be up for renewal in 2024. One main purpose of Cutler Dam is water storage (for agriculture) and diversion into two different irrigation canals from the east and west sides of the dam. In conjunction with PacifiCorp’s Bear Lake Irrigation Project, the Cutler Reservoir stores Bear River water to ensure sufficient irrigation water during the summer months. By storing Bear River water and diverting it to irrigation canals in the summer, Cutler Dam results in less water released into the Bear River downstream of the dam.

Applicability to Great Salt Lake: The Bear River is the largest contributor of freshwater to GSL, and water deliveries from Bear River to GSL are regulated by Cutler Dam, which is managed for irrigation and hydropower. The removal of Cutler Dam would result in a more natural hydrograph for the Bear River, resulting in a more natural hydrograph of inflows to the lake and an increase in the amount of sediment delivered to the lake. Depending on how agricultural diversions are managed, the removal of the dam may result in a greater volume of annual water deliveries to GSL.

Potential limitations: Although the removal of Cutler Dam would eliminate storage of Bear River water, it would not prevent diversions of Bear River water before it reaches GSL. Additional strategies to guarantee that water stays within the Bear River and is delivered to GSL would be needed in tandem with the removal of Cutler Dam. Bear River's flows would be more subject to natural variability such as low summer flows in dry years without storage potential in dry years.

65. *Extend the Lake Powell Pipeline*

Category: Structural

Description: The Lake Powell Pipeline is a State of Utah project that would allow for the transfer of Colorado River water from Lake Powell to Sand Hollow Reservoir through a 140-mile, 69-inch buried pipeline. The State of Utah has rights (based on the Colorado River Compact) to more Colorado River water than it is currently using, and the pipeline transfer would distribute more of this allocated water right. Similar pipeline projects already exist in Utah and in the western United States, such as the Bureau of Reclamation Strawberry Valley Project, which transfers water from the Colorado River Basin to the Bonneville Basin. Although the initial plan for the Lake Powell Pipeline would provide water to Washington and Kane Counties, a modification of the original plan could increase the water transfer and extend the pipeline north to GSL. Transferring Colorado River water to GSL would allow the State of Utah to use more of its share of the Colorado River Compact and offset the depletion of GSL. This transfer of water would provide a dependable source of inflow to GSL because the natural inputs to GSL (Bear, Provo, and Weber Rivers) are being depleted by agricultural and other diversions.

Applicability to Great Salt Lake: A modification of the original plan for the Lake Powell Pipeline could extend the pipeline north to GSL, transferring Colorado River water to GSL to maintain or raise lake water levels. The surface water elevation of GSL is in a continual decline, and the Lake Powell Pipeline represents an alternative to help reverse this trend.

Potential limitations: There are many ecological concerns regarding trans-basin water diversions. In addition, trans-basin pipelines represent extremely costly, logistically challenging endeavors. The project would involve an array of pipelines, pumping stations, and generators to move water, in some cases uphill. Additionally, the need for the project is somewhat questionable, given the opportunities for water savings from conservation and other efforts that could help solve Utah's water supply issues. Finally, the claim that Utah is not using all of its allocated Colorado River Compact water may not be valid, given that the Colorado River Compact was based on hydrologic data that do not represent current conditions. Based on the Colorado River Compact, the State of Utah may be entitled to divert additional flows; however, the total volume available to the state based on the Colorado River Compact is not actually available because of overuse by other users.

66. *Increase Diversions from the Colorado River System*

Category: Structural

Description: Utah has not yet fully developed the share of water from the Colorado River allocated to it under the Colorado River Compact. A pipeline constructed from Flaming Gorge or elsewhere in the upper Colorado River Basin, e.g., Strawberry River, could in theory bring more water to the Wasatch Front and GSL.

Applicability to Great Salt Lake: The biggest challenge to augmenting flows into GSL is finding new supply when so many of Utah's water resources are already over-allocated. Providing water from the Colorado River would represent a genuine new supply for the GSL Basin that could help maintain or even raise lake levels.

Potential limitations: There are many ecological concerns regarding trans-basin water diversions. In addition, trans-basin pipelines represent extremely costly, logistically challenging endeavors. Diverting more water from the Colorado River system to supply water to GSL would involve an array of pipelines, pumping stations, and generators to move water, in some cases uphill. Additionally, the need for this is somewhat questionable given the opportunities for water savings from conservation and other efforts that could help solve Utah's water supply issues. Finally, the claim that Utah is not using all of its allocated Colorado River Compact water may not be valid, given that the Colorado River Compact was based on hydrologic data that do not represent current conditions. Based on the Colorado River Compact, the State of Utah may be entitled to divert additional flows; however, the total volume available to the state based on the Colorado River Compact is not actually available because of overuse by other users.

67. *Construct a Trans-Basin Diversion from the Columbia River System*

Category: Structural

Description: One of the largest river systems in North America, the Columbia River, flows on average at 265,000 cubic feet per second when it enters the Pacific Ocean. By comparison, the Colorado River in pre-settlement days was estimated to deliver, on average, 22,500 cubic feet per second into the Gulf of Mexico. The Snake River is tributary to the Columbia River, and water from that system could theoretically be diverted and delivered to the GSL Basin by a pipeline and pumping system at significant volumes.

Applicability to Great Salt Lake: The biggest challenge to augmenting flows into GSL is finding new supply when so many of Utah's water resources are already over-allocated. Providing water from the Columbia River-Snake River system would represent a genuine new supply of water for the GSL Basin that could help maintain or even raise lake levels.

Potential limitations: Utah has no legal right to water in the Columbia River Basin because only a smallest part of the basin (the north edge of the Raft River Range) falls into Utah. As a result, Utah would have to contract for the water in substantial enough volumes to have any effect on GSL levels. The logistics and expense of water purchase and delivery and the complicated nature of such a transaction pose significant hurdles. In addition, there are many ecological concerns regarding trans-basin water diversions, though those concerns are somewhat mitigated in the case of the Columbia River-Snake River system given that limited flows rarely (if ever) pose an ecological problem in those systems.

68. *Engineer Stream Flows*

Category: Structural

Description: Although tributaries to GSL theoretically deliver their flows to the lake, the flows often do not make it to the lake for a variety of reasons. Pipelines, lined canals, channel modifications, and regulated stream flows are used in many capacities, e.g., trans-basin diversions, water conservation, and flood control, respectively, to minimize water loss or maximize water delivery from one point to another.

Applicability to Great Salt Lake: Many strategies presented in this document suggest methods for keeping more water in tributaries with the hope that it will eventually reach GSL. Engineering flows directly from the point of conservation or large storage facility to the GSL would provide more control over management of water resources.

Potential limitations: The engineering, environmental, and construction costs of building a large system of pipelines or other structures to deliver water to GSL may be prohibitive. Also, the ecological cost of diverting water out of or modifying natural channels verses the ecological benefits these flows provide should be considered.

69. *Reduce Evaporation by Diking Areas of Great Salt Lake*

Category: Structural

Description: Impounding areas of GSL could create conditions that are less susceptible to evaporation, e.g., exposure to wind and decreased surface area. A series of diked cells or impoundments could also create deeper waterbodies that could be managed for specific water quality conditions such as salinity.

Applicability to Great Salt Lake: Willard Bay, existing mining operations, and proposed options for Bear River water development and storage on GSL are examples of diked areas and impoundments demonstrating that such an operation is feasible.

Potential limitations: GSL stakeholders may be opposed to further segmentation of the lake, which could also result in larger areas of exposed lake bed and mudflat. Compliance with Section 404 of the Clean Water Act would be required to discharge fill into GSL, which is a water of the U.S. Mitigation requirements would increase the cost and could limit the utility of this strategy.

70. *Create an "In-Lake Storage Reservoir" to Assist Maintaining Lake Elevation*

Category: Structural

Description: Site future water storage within GSL or construct a reservoir system so that in times of low or declining GSL elevation, depth and coverage of this portion of the lake bed can be managed.

Applicability to Great Salt Lake: The GSL is shallow, with areas of low-angle shoreline that can result in substantial lake bed exposure (or lake bed shielding) by relatively small changes in lake elevation. The rate of evaporation is highly influenced by the concentration of dissolved solids—higher concentrations evaporate much slower than dilute concentrations. This strategy suggests that a dike system be constructed on the western or southern side of the lake. In times of declining lake elevation, the gates could be closed, which would cut off the (in-lake reservoir) area to maintain more depth and surface elevation in the balance of the lake. This would tend to preserve more of the lake's eastside shoreline ecosystem. With the gates closed, the water would saturate, and minerals would be precipitated on the pond floors. Those salt floors would prevent any dust from blowing off of the exposed lake bed if those sections became dry. In periods of continual low input, some concentrated lake water could occasionally be bled or pumped into the in-lake reservoir to assist in controlling salinity in Gilbert Bay. The state could use the precipitated minerals as a source of revenue. The end result might not result in greater water supply to the lake, but could allow for management and distribution of water to where it is needed.

Potential limitations: The cost of constructing a lake-dike structure or reservoir would be expensive. Environmental regulations might prohibit implementation of this strategy. In periods of high GSL elevation, the diking structure would be subject to wave erosion.

71. *Use Groundwater Aquifers along the Wasatch Front*

Category: Structural

Description: Consider using groundwater aquifers along the Wasatch Front to store water as a means of counteracting the negative impacts of evaporation in existing and proposed reservoirs.

Applicability to Great Salt Lake: There is a direct hydrological connection between the aquifers along the Wasatch Front and GSL. As these aquifers are drawn down to provide drinking water to Wasatch Front communities, the amount of water that flows to GSL from the aquifers is diminished. Recognizing this connection and the advantages of storing water underground, an effort should be made to quantify the advantages and disadvantages of either injecting water underground for the purposes of storage and later retrieval or recharging the aquifers through a series of percolation ponds.

Potential limitations: Given the substantial investment that the State of Utah has in its current storage system, there may be a reluctance to transition to underground storage. There is also a scientific question of how much underground storage is available. Lastly, in the overall water budget, putting more water underground will not increase supply, but simply reduce the supply elsewhere (in reservoirs, streams, GSL, etc.).

72. *Research Existing Diversions and Consider Reducing Them*

Category: Structural

Description: There is concern that water managers do not adequately consider impacts to the environment (e.g., instream flows for fish and GSL health) when planning for and installing water diversions. In the past, agricultural and human needs overwhelmed the environmental needs in decision-making and policy making and have typically been short term (less than 25 years). Ensuring there is a direct link between the health of the environment and health of humans and food production usually takes precedent over many lake level scenarios. This direct link is often overlooked when managing water for established beneficial uses. Water managers should consider the effects that existing and proposed diversions will have on GSL health at various lake levels over 100 years. Specific attention should go to those diversions with the greatest threat to the watershed and to cross-watershed health, and the greatest potential for mitigating those impacts should be identified. Diversions should address adequate water supply for the environment within watershed. Decision-makers should also consider reducing the total number of diversions.

Applicability to Great Salt Lake: Since settlers arrived to the Wasatch Front and began diverting and damming water, it is estimated that GSL water levels have dropped 11 feet. This is approximately a 48% reduction in water volume (Wurtsbaugh et al. 2016). Water diversions are the largest factor affecting GSL water levels. A careful analysis of each diversion and proposed future diversion could help determine which are really necessary. Even a small reduction in the total number of diversions could have a large impact on GSL levels.

Potential limitations: Every storage system in use today has a system of water users that have come to rely on that source of supply, and those users will predictably resist efforts to reduce or eliminate those supplies and the legal rights and investments associated with them. Reducing supply also limits the state's ability to respond to drought.

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