Public Health Impacts of a Drying Saline Lake

HOPKINS JUDICIAL HEALTH NOTE:

UTAH PHYSICIANS FOR A HEALTHY ENVIRONMENT V. UTAH DEPARTMENT OF NATURAL RESOURCES

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Synopsis

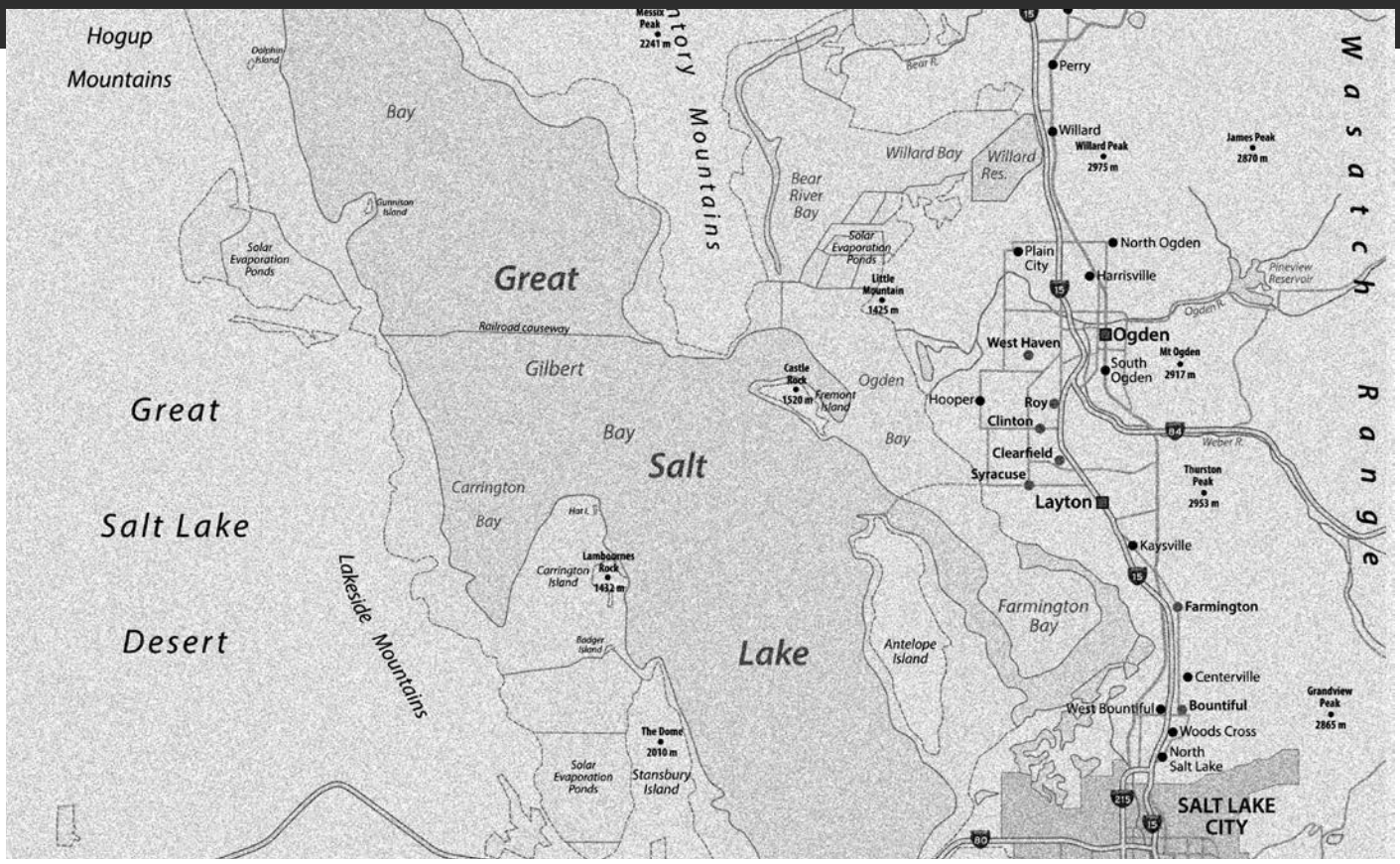
In 2023, a coalition of environmental and community groups filed suit against several Utah state agencies for failing to protect the Great Salt Lake from ecological decline. Strong evidence shows that shrinking saline lakes contribute to more frequent dust storms and deteriorating air quality as exposed lakebed, or "playa," soil dries and becomes airborne. The resulting particulate matter and saline lakebed dust pose serious health risks, including respiratory illnesses, lung inflammation, and hypertension.

This analysis also found substantial evidence that dust from the Great Salt Lake contains heavy metals and neurotoxins, which can be carried by wind to nearby metropolitan areas. Additionally, new research indicates that the lake's shrinking is exacerbating climate change and threatening nearby natural resources. For example, dust from the lakebed deposited on nearby mountain ranges accelerates snowpack melt, a critical source of fresh water for Salt Lake City. Emerging evidence also links the lake's desiccation to increased ozone and greenhouse gas emissions, which contribute to rising temperatures and extreme weather events.

The communities most affected by these changes include low-income, under-resourced, and marginalized groups, as well as racial and ethnic minority or minoritized populations. Alongside the health impacts for the 1.8 million people living downwind of the exposed playa, the lake's desiccation may jeopardize a vital source of employment and revenue for Utah.

Should the Third Judicial District Court of Utah rule in favor of the plaintiffs, and if significant policies are implemented to reduce upstream water diversions from the Great Salt Lake, many of these harms to human and environmental health could be avoided or mitigated. Such actions could also reduce exposure inequities. Restoration efforts must prioritize inclusive planning by involving communities, particularly Tribal Nations and low-income and racial and ethnic minoritized residents along the Wasatch Front, in both restoration plans and advocacy efforts.

ABOUT THE CASE:
PRESERVING THE GREAT SALT LAKE FROM ECOLOGICAL COLLAPSE



In 2023, conservation and community groups represented by Earthjustice filed suit against the state of Utah for failing to "ensure that enough water reaches the Great Salt Lake to prevent ecological collapse."[1] A group of plaintiffs argue that the Great Salt Lake is a natural resource owned by the public, and that the state of Utah has failed to uphold its obligations under the public trust doctrine to protect it for the public's benefit and use. Most of the negative health effects stemming from the desiccation of the Great Salt Lake are caused by the exposed lakebed. The plaintiffs are asking the court to compel the state's resource managers to halt upstream water diversions until the lake is restored to 4,198 feet above sea level, about six feet above the lake's elevation at the time of this note's writing, which state experts determined to be the minimum healthy lake level.[2] Raising the lake's elevation 6 feet would inundate about 420 square miles of exposed lakebed.[3] Over 800 square miles of the lakebed are currently exposed, and it is unclear if the relief requested by plaintiffs will be sufficient to reverse the ecological and public health harms underway.[4] Defendants argue that the Great Salt Lake and its tributaries are not subject to the public trust doctrine, and that the state is already working to restore the lake. This judicial health note examines the potential public health implications of this lawsuit. This health note does not provide a legal argument or strategy.

[1] Earthjustice, "Lawsuit Targets State of Utah for Failing to Protect the Great Salt Lake," news release, 2023, https://earthjustice.org/press/2023/lawsuit-targets-state-of-utah-for-failing-to-protect-the-great-salt-lake.

[2] "Current Conditions," State of Utah, updated November 4, 2024, accessed November 4, 2024, 2024, https://greatsaltlake.utah.gov/current-conditions; Earthjustice v. Utah, No. 230906637 (Third Judicial District Court).

[3] "Commonly Asked Questions About Utah's Great Salt Lake & Lake Bonneville," Popular Geology, accessed November 4, 2024, 2024, https://geology.utah.gov/popular/great-salt-lake/commonly-asked-questions/#toggle-id-7.

[4] "About," accessed November 7, 2024, https://greatsaltlake.utah.gov/about.

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Methods Summary

The Health in All Policies Initiative research team at the Johns Hopkins Bloomberg School of Public Health developed this health note to identify the health and equity impacts of preventing further desiccation of the Great Salt Lake. To do so, the team hypothesized pathways between the complaint, health determinants, and health outcomes. They then conducted an expedited literature review using a systematic approach to minimize bias and identify recently published and peer-reviewed studies to answer each of the identified research questions. A subject matter expert and advisory committee reviewed the draft note and provided feedback. A detailed description of the methodology is available in the appendix on page 6.

Summary of Hopkins Judicial Health Note Findings: Drying Saline Lakes Can Have a Variety of Health and Economic Impacts

Saline lakes around the world are drying up because of human activity, such as water diversion, and climate change, which reduces precipitation in arid regions and can accelerate water evaporation.[5] Increasing surface temperatures can accelerate water evaporation. The surface area of the Great Salt Lake has reduced dramatically over the past four decades—by approximately 71%.[6] The lake is shrinking due to upstream diversion of freshwater feeder streams, increasing ambient temperatures, and persistent drought, which is likely to worsen with the progression of climate change. The reduction in volume of the lake is associated with an increase in salinity that threatens the lake's ecosystem, key features of which are reductions in brine shrimp and migratory birds.[7] Shrinking lakes contribute to salt-dust storms, aerosol emissions, and deteriorating soil quality, with implications for human and environmental health through their effects on air quality, quality of groundwater, greenhouse gas emissions, and agriculture.

This judicial health note identified peer-reviewed evidence pertaining to the effects of shrinking saline lakes, sometimes referred to as inland seas, on air quality and subsequent health effects for nearby communities; effects of dust from drying lakebeds on nearby snowpacks, air quality and health risks for surrounding neighborhoods, and climate; and effects of a declining aquatic ecosystem on local economic wellbeing. The review includes studies pertaining to the Great Salt Lake specifically, in addition to other saline lakes around the world that are comparable in terms of climate or rates of decline. Below is a summary of key findings[8]:

- **There is strong evidence that shrinking saline lakes contribute to the frequency of dust storms and harm air quality as exposed lakebed or playa soil dries and becomes airborne.** This is important because of the impacts of particulate matter (PM) that can cause serious health problems.[9]
- **There is a fair amount of evidence that Great Salt Lake playa dust contains heavy metals and neurotoxins that can be carried by wind to nearby metropolitan areas.**
- **A fair amount of evidence indicates a link between exposure to playa dust and hypertension near a drying lake with salinity levels comparable to those of the Great Salt Lake.** Emerging research shows a link between exposure to Great Salt Lake dust and lung inflammation.

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[5] Muhammad Subtain Abbas et al., "Salt Lake Aerosol Overview: Emissions, Chemical Composition and Health Impacts under the Changing Climate," *Atmosphere* 15, no. 2 (2024), https://www.mdpi.com/2073-4433/15/2/212.

[6] J. S. Metcalf, S. A. Banack, and P. A. Cox, "Cyanotoxin Analysis of Air Samples from the Great Salt Lake," *Toxins (Basel)* 15, no. 11 (Nov 15 2023), https://doi.org/10.3390/toxins15110659.

[7] Nate Seltenrich, "A Terminal Case? Shrinking Inland Seas Expose Salty Particulates and More," *Environmental Health Perspectives* 131, no. 6 (2023), https://doi.org/doi:10.1289/EHP12835, https://ehp.niehs.nih.gov/doi/abs/10.1289/EHP12835.

[8] For an explanation of the strength of evidence ratings used below, please see page 7.

[9] "Particulate Matter (PM) Basics," updated June 20, 2024, https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

- **There is a fair amount of evidence that increased dust from the Great Salt Lake playa pollutes nearby snowpacks**, accelerating snow melt and impacting a crucial source of freshwater for nearby communities.[10]
- **Although not well researched, there is emerging evidence that the shrinking Great Salt Lake is contributing to ozone and greenhouse gas emissions levels.**[11] Greenhouse gas emissions have known impacts on the environment including rising temperatures and extreme weather events, which have public health implications.

What are the potential health effects of a ruling in favor of plaintiffs in Utah Physicians for a Healthy Environment v. Utah Department of Natural Resources? Harms to health, environment, and local economy could be reduced.

Should the Third Judicial District Court of Utah find in favor of the plaintiffs, and to the extent that policies are implemented to significantly reduce upstream water diversions from the Great Salt Lake, harms to human and environmental health documented around other saline lakes in a more advanced state of desiccation and those being studied in communities near the Great Salt Lake could be avoided or mitigated.

Effects of shrinking saline lakes on air quality and subsequent health effects due to dust

- **As lakes decrease in surface area, more lakebed is exposed. Dust particles from dried lakebeds, or playas, contribute to air pollution and are easily inhaled due to their small size.**[12] Restoration efforts that reduce or eventually help to reverse the lake's decline would protect communities vulnerable to airborne playa dust and salt dust storms, which also increase as lake levels drop.
  - » Based on composition analysis, a study found that regional playa dust accounted for 90% of dust deposited along the Wasatch Front, including urban and mountain areas.[13] Furthermore, the authors found that many of the chemicals in this dust—including cadmium and selenium—were environmentally available, or easily leached into surrounding soil, snow, or water.[14] This highlighted the importance of the growing Great Salt Lake playa as a dust source in the area.
  - » One study that compared Great Salt Lake playa dust to that of other regional lakebeds and dust from the Arizona desert found that its oxidative potential—believed to be an indicator of the dust's toxicity and a predictor of health harms of particulate matter—was higher than that of other regional playa dust.[15] Testing also found arsenic and lithium at levels that exceed EPA residential regional screening

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[10] Michael M. Goodman et al., "Trace element chemistry of atmospheric deposition along the Wasatch Front (Utah, USA) reflects regional playa dust and local urban aerosols," *Chemical Geology* 530 (2019/12/30/ 2019), https://doi.org/https://doi.org/10.1016/j.chemgeo.2019.119317, https://www.sciencedirect.com/science/article/pii/S0009254119304243; S. McKenzie Skiles et al., "Implications of a shrinking Great Salt Lake for dust on snow deposition in the Wasatch Mountains, UT, as informed by a source to sink case study from the 13–14 April 2017 dust event," *Environmental Research Letters* 13, no. 12 (2018/12/21 2018), https://doi.org/10.1088/1748-9326/aaefd8, https://dx.doi.org/10.1088/1748-9326/aaefd8.

[11] Dhruv Mitroo et al., "ClNO2 Production from N2O5 Uptake on Saline Playa Dusts: New Insights into Potential Inland Sources of ClNO2," *Environmental Science & Technology* 53, no. 13 (2019/07/02 2019), https://doi.org/10.1021/acs.est.9b01112, https://doi.org/10.1021/acs.est.9b01112; Melissa Cobo, Tobias Goldhammer, and Soren Brothers, "A desiccating saline lake bed is a significant source of anthropogenic greenhouse gas emissions," *One Earth 7*, no. 8 (2024/08/16/ 2024), https://doi.org/https://doi.org/10.1016/j.oneear.2024.07.001, https://www.sciencedirect.com/science/article/pii/S2590332224003269.

[12] S. F. Farzan et al., "Assessment of Respiratory Health Symptoms and Asthma in Children near a Drying Saline Lake," *Int J Environ Res Public Health* 16, no. 20 (Oct 11 2019), https://doi.org/10.3390/ijerph16203828.

[13] Goodman et al., "Trace element chemistry of atmospheric deposition along the Wasatch Front (Utah, USA) reflects regional playa dust and local urban aerosols."

[14] Ibid.

[15] Reuben Attah et al., "Assessing the oxidative potential of dust from great salt Lake," *Atmospheric Environment* 336 (2024/11/01/ 2024), https://doi.org/10.1016/j.atmosenv.2024.120728.

levels at most sites.[16] The study found higher levels of certain metals in Great Salt Lake dust that may contribute to or exacerbate lung inflammation caused by PM, including manganese, iron, and copper.[17]Another study found that Great Salt Lake sediment and dust PM2.5 contained metals, including toxic metals such as arsenic and lead; pathogenic bacteria, such as Streptococcus pyogenes; and other chemicals and bacteria.[18]

» While reports of the presence of arsenic in the Great Salt Lake's playa dust have raised concerns about the shrinking lake's health impacts on surrounding communities, the concentration may not be as problematic as the increase in particulate matter itself, which is harmful regardless of its composition.[19] A review of decades of research on efforts to restore the drying hyper-saline Lake Urmia in Iran identified several studies investigating health effects of exposure to aerosols from the lakebed. It found that rising PM10 was associated with increased relative mortality risk.[20]

» If the lake's reduction is left unchecked, current and increased levels of air pollution will likely exacerbate chronic conditions, such as hypertension and asthma. Researchers used air quality monitoring and sensors to establish patterns of dust exposure around the lake and studied mice and human cells to determine potential harms.[21] When exposed to Great Salt Lake Dust $PM_{2.5}$, mice showed symptoms of lung inflammation.[22] Studies done with human airway basal cells indicated that the airways may become inflamed or secrete more mucus when exposed to the dust, which can exacerbate asthma and other respiratory conditions.[23] These effects were larger for cells exposed to Great Salt Lake dust than for those exposed to another common pollutant, coal dust.[24] These studies show that the health risks of dust from the Great Salt Lake may be severe and warrant further testing and monitoring.

» Another study examined the relationship between lake shrinkage, air pollution, and mortality from respiratory diseases such as bronchitis, respiratory tract infections, COPD, asthma, and lung disease, analyzing the shrinking of the Salton Sea in California from 1998 and 2014.[25] The authors demonstrated that lake shrinkage led to increased respiratory mortality, with a foot drop in lake levels associated with 0.68 per 100,000 additional respiratory deaths, or an additional nearly 6 deaths per year, in the population surrounding the Salton Sea.[26] The authors estimated the economic impact of these deaths is roughly $151.5 million per each one-foot drop in lake elevation in the areas around Salton Sea.

[16] Attah et al., "Assessing the oxidative potential of dust from great salt Lake."

[17] Ibid.

[18] J. M. Cowley et al., "Pro-Inflammatory Effects of Inhaled Great Salt Lake Dust Particles," Res Sq (Jul 26 2024), https://doi.org/10.21203/rs.3.rs-4650606/v1.

[19] Seltenrich, "A Terminal Case? Shrinking Inland Seas Expose Salty Particulates and More."

[20] Masoud Parsinejad et al., "40-years of Lake Urmia restoration research: Review, synthesis and next steps," Science of The Total Environment 832 (2022/08/01/ 2022), https://doi.org/10.1016/j.scitotenv.2022.155055, https://www.sciencedirect.com/science/article/pii/S0048969722021489.

[21] Cowley et al., "Pro-Inflammatory Effects of Inhaled Great Salt Lake Dust Particles."

[22] Ibid.

[23] Ibid.

[24] Ibid.

[25] B. A. Jones and J. Fleck, "Shrinking lakes, air pollution, and human health: Evidence from California's Salton Sea," Sci Total Environ 712 (Apr 10 2020), https://doi.org/10.1016/j.scitotenv.2019.136490.

[26] Jones and Fleck, "Shrinking lakes, air pollution, and human health: Evidence from California's Salton Sea."

- **The release of toxins into the air is likely to increase as the Great Salt Lake's surface area recedes.**
  - » Cyanobacteria are naturally occurring in the Great Salt Lake and form an important part of the food chain, feeding brine shrimp, who in turn feed migratory birds. These cyanobacteria also produce cyanotoxins, including neurotoxins, which can become airborne as more lakebed becomes exposed. Winds can further diffuse these airborne toxins to nearby metropolitan areas in the Wasatch Front.[27]
    - A study that examined exposed Great Salt Lake lakebed soil and airborne dust samples found cyanotoxins suspended in the air that can easily be inhaled by populations living to the east of the lake.[28] Three of those cyanotoxins studied have been found to have dangerous neurological effects, including the neurotoxin BMAA—chronic exposure to which can cause ALS, also known as Lou Gehrig's disease.[29] While the airborne levels measured were not high enough to cause acute toxicity, long-term exposure could lead to chronic toxicity.[30] Furthermore, authors mention the possibility of synergistic neurotoxicity, or the combination of multiple toxins increasing each other's toxic effects.[31]
  - » Harmful algal blooms in saline lakes can aerosolize toxins that are dangerous to human health, especially when dispersed by wind.[32]
- **Gas emissions from drying saline lakes can also affect air quality, human health, and climate.**
  - » In addition to harming air quality through releasing particulate matter (PM), drying saline lakebeds can threaten respiratory and environmental health by contributing to greenhouse gas and ground-level ozone gas.
    - A 2019 study showed through laboratory studies that dust from dried salt lakes, including the Great Salt Lake, can produce nitryl chloride. When exposed to sunlight, nitryl chloride breaks down into compounds that can contribute to ground-level ozone formation.[33]
    - One study compared emissions from the Great Salt Lake's drying to estimates of the lake's aquatic emissions and concluded that the drying lake contributes a new source of greenhouse gasses to the atmosphere. Although not the focus of this note, there is very strong evidence of the impacts of greenhouse gas emissions, especially rising temperatures and extreme weather events.[34]
  - » A qualitative study of Latinx and Indigenous Mexican caregivers' perceptions of the shrinking Salton Sea's effects on their children's health revealed two themes that are relevant to the receding Great Salt Lake: sulfuric smells from hydrogen sulfide—a toxic gas emitted by both lakes— and dust storms exacerbate children's respiratory issues.[35]

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[27] Metcalf, Banack, and Cox, "Cyanotoxin Analysis of Air Samples from the Great Salt Lake."

[28] Ibid.

[29] Ibid.

[30] Ibid.

[31] Ibid.

[32] Abbas et al., "Salt Lake Aerosol Overview: Emissions, Chemical Composition and Health Impacts under the Changing Climate."

[33] Mitroo et al., "ClNO2 Production from N2O5 Uptake on Saline Playa Dusts: New Insights into Potential Inland Sources of ClNO2."

[34] Cobo, Goldhammer, and Brothers, "A desiccating saline lake bed is a significant source of anthropogenic greenhouse gas emissions."; Engineering National Academies of Sciences and Medicine, *Greenhouse Gas Emissions Information for Decision Making: A Framework Going Forward* (Washington, DC: The National Academies Press, 2022). https://nap.nationalacademies.org/catalog/26641/greenhouse-gas-emissions-information-for-decision-making-a-framework-going.

[35] A. M. Cheney et al., "Latinx and Indigenous Mexican Caregivers' Perspectives of the Salton Sea Environment on Children's Asthma, Respiratory Health, and Co-Presenting Health Conditions," *Int J Environ Res Public Health* 20, no. 11 (Jun 1 2023), https://doi.org/10.3390/ijerph20116023.

- **Scientists have observed mixed health effects from the salt dust scatter of saline lakes at a more advanced stage of desiccation than the Great Salt Lake, offering a potential glimpse into future air quality issues for communities along the Wasatch Front.**
  - » A study of a drying hyper-saline lake in Iran, Lake Urmia, whose salinity is comparable to that of the GSL's north arm, found that the salt dust scatter in residential areas near the lake were associated with increases in hypertension, with the greatest effects seen in adults ages 50-70 and females.[36] In one county, there was a significant correlation between decreasing lake area and increasing levels of prevalence with the number of hypertensive patients.[37] A review of studies investigating Lake Urmia restoration efforts found links between exposure to hypersaline particles and markers for inflammation and cardiovascular disease.[38]
  - » One study noted that aerosolized salt water can benefit lung health, especially in children, and can be used as therapy for patients with chronic obstructive pulmonary disease and pneumoconiosis.[39]

Efforts to increase lake levels have the potential to reduce these harms.

One study modeled how air pollution exposure would change based on differing water-level scenarios in the Great Salt Lake in the counties downwind of the lake.[40] They find that dust exposure for those living in affected counties is reduced under scenarios where lake level is restored. Racial and ethnic minority and minoritized residents and those without a high school diploma have higher exposure across all scenarios. However, these disparities in exposure narrow under scenarios where lake level is higher. Specifically, comparing a dried lake to a restored lake level, the gap in exposure between Pacific Islanders or Hispanics and Whites shrinks by over 50%, and between those with and without a high school diploma by 60%.[41] Therefore, restoring the Great Salt Lake has implications for health equity, as well as population health improvement.

Playa dust on nearby snowpacks affects snowfall, snowmelt, and climate

The health of snowpacks in mountain ranges near the Great Salt Lake is crucial to the economic wellbeing of the region, as a driver of recreation and related jobs, but it is also a critical natural resource to urban communities. The snowpack in the Wasatch Mountains near the Great Salt Lake is the largest natural source of surface water for Salt Lake City, supplying an estimated 80% of surface water to the Department of Public Utilities.[42] To the extent that Great Salt Lake restoration efforts reduce rates of dust storms and particulate matter from the drying lakebed, they could ensure the viability of the mountains' snowpacks as a vital water source and recreation attraction for future decades.

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[36] B. Feizizadeh et al., "Health effects of shrinking hyper-saline lakes: spatiotemporal modeling of the Lake Urmia drought on the local population, case study of the Shabestar County," *Sci Rep* 13, no. 1 (Jan 28 2023), https://doi.org/10.1038/s41598-023-28332-6; Wayne A. Wurtsbaugh and Somayeh Sima, "Contrasting Management and Fates of Two Sister Lakes: Great Salt Lake (USA) and Lake Urmia (Iran)," *Water* 14, no. 19 (2022), https://www.mdpi.com/2073-4441/14/19/3005.

[37] Ibid.

[38] Parsinejad et al., "40-years of Lake Urmia restoration research: Review, synthesis and next steps."

[39] Abbas et al., "Salt Lake Aerosol Overview: Emissions, Chemical Composition and Health Impacts under the Changing Climate."

[40] Sara E. Grineski et al., "Harmful dust from drying lakes: Preserving Great Salt Lake (USA) water levels decreases ambient dust and racial disparities in population exposure," *One Earth* 7, no. 6 (2024), https://doi.org/10.1016/j.oneear.2024.05.006, https://doi.org/10.1016/j.oneear.2024.05.006.

[41] Grineski et al., "Harmful dust from drying lakes: Preserving Great Salt Lake (USA) water levels decreases ambient dust and racial disparities in population exposure."

[42] Tim Bardsley et al., "Planning for an Uncertain Future: Climate Change Sensitivity Assessment toward Adaptation Planning for Public Water Supply," *Earth Interactions* 17, no. 23 (01 Oct. 2013 2013), https://doi.org/https://doi.org/10.1175/2012EI000501.1, https://journals.ametsoc.org/view/journals/eint/17/23/2012ei000501.1.xml.

- One study examined the effects of a dust event in April 2017 on the snowmelt in the Wasatch Mountains, which increased dust concentration from 4 parts per million (ppm) to 55 ppm.[43] The authors found that dust from the Great Salk Lake Desert was the greatest source of dust deposited on the snowpack at the study site.[44] The dust darkens the snow, increasing its ability to absorb heat from the sun and accelerating snowmelt. The dust deposit from this event accounted for 30% of snowmelt in the five days following the event and sped up the melting process by approximately 5 days, although the authors note that the impact was likely greater due to several factors the study did not account for.[45] When multiple dust layers combined in May, the dust's contribution to snowmelt increased.[46] Although the study site was too far south to receive a significant deposit of dust from the Great Salt Lake lakebed due to wind direction, the study's models demonstrated the effects of significant dry dust deposits on the mountains' snowpack. The growing exposed Great Salt Lake playa is likely to accelerate snow melt in the Wasatch Mountains.[47]
- A study found that declining snowfall and earlier snowmelt in the Wasatch and Uinta mountain ranges lead to decreased water flowing into the Great Salt Lake via feeder rivers.[48] Therefore, the snowpack melt caused by dust storms from the shrinking Great Salt Lake lakebed and reduced snowpack due to snowfall reinforce each other and are likely to further accelerate the desiccation of the Lake, if upstream water diversions continue at their current pace.

Shrinking Great Salt Lake effects climate, agriculture, and local ecosystem

- Alarming results from a recent study found that the shrinking Great Salt Lake may contribute to climate change and the region's habitability through reduced precipitation over the lake and downwind. The study used models to predict the effects of the lake's disappearance altogether, which could result in a 50% decrease in precipitation compared to rates measured at the lake's 2004 levels.[49] This trend illustrates a negative feedback loop in which decreased precipitation expedites declining lake levels through increased need for upstream diversion and reduced local snowpacks, and the declining lake levels cause a further reduction in local precipitation.
- Heavy metals found in the Great Salt Lake lakebed can exacerbate the toxicity of cyanotoxins.[50] BMAA and mercury, for example, can both accumulate in water-based ecosystems. Those who hunt and eat birds near the lake are therefore at potential risk of ingesting both, which increase each other's toxicity when combined.[51]

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[43] Skiles et al., "Implications of a shrinking Great Salt Lake for dust on snow deposition in the Wasatch Mountains, UT, as informed by a source to sink case study from the 13–14 April 2017 dust event."

[44] Ibid.

[45] Ibid.

[46] Ibid.

[47] Ibid.

[48] Dorothy K. Hall et al., "The role of declining snow cover in the desiccation of the Great Salt Lake, Utah, using MODIS data," *Remote Sensing of Environment* 252 (2021/01/01/ 2021), https://doi.org/https://doi.org/10.1016/j.rse.2020.112106, https://www.sciencedirect.com/science/article/pii/S003442572030479X.

[49] Hongping Gu, Wei Zhang, and Robert Gillies, "The Shrinking Great Salt Lake May Exacerbate Droughts by Reducing Local Precipitation: A Case Study," *Journal of Hydrometeorology* 25, no. 7 (01 Jul. 2024 2024), https://doi.org/https://doi.org/10.1175/JHM-D-23-0189.1, https://journals.ametsoc.org/view/journals/hydr/25/7/JHM-D-23-0189.1.xml.

[50] Ibid.

[51] Ibid.

- Extrapolating from studies of Iran's Lake Urmia, which is in a more advanced state of desiccation than the Great Salt Lake and may offer a forecast of potential effects on the environment surrounding the latter, the shrinking lake may harm the local agricultural industry and affect the quality of foods grown nearby. Studies of Lake Urmia have shown that the shrinking lake has affected nearby agricultural production through increasing soil and groundwater salinization, which restrict plant growth, quality, and production.[52]
- A study that assessed lakes in Asia with varying salinity found that increased lake salinity inhibits natural nitrogen removal processes while enhancing nitrogen retention, leading to nitrogen accumulation in lake waters. Excess nitrogen can harm the lake's ecosystem and plant life. [53]

Minoritized Communities most likely to be affected by a ruling in Utah Physicians for a Healthy Environment v. Utah Department of Natural Resources

Across the United States, low-income and under-resourced communities and racial and ethnic minority or minoritized communities are disproportionately exposed to environmental hazards and toxins.[54] There are roughly 1.8 million people living downwind of the lake along the Wasatch Front who are particularly vulnerable to potential dust exposures. Notably, while the Wasatch Front is predominantly White, communities of color are the most vulnerable to dust exposure.[55] White settlement and subsequent redlining pushed communities of color to less desirable areas closer to the lake.[56] This historical marginalization has led to present-day structural inequities, with racially diverse and low-income neighborhoods concentrated on the north and west side of Wasatch Front. These communities, particularly Pacific Islander, Black, Hispanic, and Native American communities, are therefore more exposed to dust storms.[57] Restoring the Great Salt Lake to a healthy level could significantly reduce the disparities in dust exposure.[58]

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[52] R. Ghasempour et al., "Assessing the soil salinity vulnerability and groundwater quality variations due to drying up of the lake," *Environmental Science and Pollution Research* 30, no. 54 (Nov 2023), https://doi.org/10.1007/s11356-023-30394-y; Bakhtiar Feizizadeh et al., "Scenario-based analysis of the impacts of lake drying on food production in the Lake Urmia Basin of Northern Iran," *Scientific Reports* 12, no. 1 (2022/04/14 2022), https://doi.org/10.1038/s41598-022-10159-2, https://doi.org/10.1038/s41598-022-10159-2.

[53] Xingyu Jiang et al., "Climate-induced salinization may lead to increased lake nitrogen retention," *Water Research* 228 (2023/01/01/ 2023), https://doi.org/10.1016/j.watres.2022.119354, https://www.sciencedirect.com/science/article/pii/S0043135422012994.

[54] Cheney et al., "Latinx and Indigenous Mexican Caregivers' Perspectives of the Salton Sea Environment on Children's Asthma, Respiratory Health, and Co-Presenting Health Conditions."; Paul Mohai, David Pellow, and J. Timmons Roberts, "Environmental Justice," *Annual Review of Environment and Resources* 34, no. Volume 34, 2009 (2009), https://doi.org/10.1146/annurev-environ-082508-094348, https://www.annualreviews.org/content/journals/10.1146/annurev-environ-082508-094348; J. Liu et al., "Disparities in Air Pollution Exposure in the United States by Race/Ethnicity and Income, 1990-2010," Environ Health Perspect 129, no. 12 (Dec 2021), https://doi.org/10.1289/ehp8584.

[55] U.S. Census Bureau, "Selected Characteristics of the Total and Native Populations in the United States," in *American Community Survey, ACS 1-Year Estimates Subject Tables, Table* S0101 (2023). https://data.census.gov/table/ACSST1Y2023.S0601?g=050XX00US49003,49011,49035,49045,49057. Grineski et al., "Harmful dust from drying lakes: Preserving Great Salt Lake (USA) water levels decreases ambient dust and racial disparities in population exposure."

[56] Grineski et al., "Harmful dust from drying lakes: Preserving Great Salt Lake (USA) water levels decreases ambient dust and racial disparities in population exposure."; Shane Burke, "See the maps: Where redlining happened in Utah," *The Salt Lake Tribune*, December 1, 2021 2021, https://local.sltrib.com/redline-utah/.

[57] Ibid.

[58] Ibid.

The Great Salt Lake also holds significance to many Tribal Nations. As of 2020, there were approximately 2,602 Ute, 1,043 Shoshone, 765 Paiute, and 329 Goshute people in Utah representing nations who have been stewards of the lake for centuries.[59] The lake has been and remains an important food source, a site of burial grounds, and a sacred landmark.[60] Including and in addition to the Ute, Shoshone, Paiute, and Goshute people, there are over 19,000 Native Americans living in areas directly surrounding the Great Salt Lake.[61]

Children are particularly susceptible to environmental factors that harm lungs and contribute to respiratory conditions, and studies of a shrinking hyper-saline lake in Iran found that women are most likely to develop hypertension as a result of exposure to salt dust.[62]

The health of the Great Salt Lake is critical to local employment and Utah's economy

Great Salt Lake restoration would bolster the livelihood of those that rely on the lake for employment. Roughly 2.8 million people live in the broader Great Lake Economic Region.[63] Over 7,700 people are employed in industries directly related to the Great Salt Lake, in recreation, brine shrimp fishing, and mineral extraction. Great Salt Lake also indirectly supports an additional 22,511 jobs as of 2023 related to the ski industry and related tourism, as lake effect snow contributes 5-10% to Utah's snow and extends the ski season 5-7 weeks.[64] The ski industry is critical to the local economy, generating over one billion dollars annually and $2.64 billion in the winter of 2022-2023, with this recent increase tied to record snowfall. Winter recreation employed 22,511 individuals in the first quarter of 2023.[65]

Implementation considerations for Great Salt Lake restoration

Although several tribal nations' ancestral homelands border the Great Salt Lake, and their cultural wellbeing is linked to that of the Lake, Great Salt Lake preservation movements such as the Great Salt Lake Advisory Council have excluded Tribal leaders' voices.[66] Preserving the Great Salt Lake and elevating the voices of Native Americans while doing so would protect and honor a long and rich history of the region's Indigenous peoples.

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[59] Kem C. Gardner Policy Institute, *Exploring Utah's Racial and Ethnic Groups: A Detailed Analysis*, The University of Utah (July 2024), https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/2024/07/C2020-FS-July2024.pdf; University of Utah Environmental Humanities, "Great Salt Lake and the Great Basin Tribes: Ancestral Connection and Pathways to Repair," September 30, 2022 2022, https://www.youtube.com/watch?v=OMQRDFB8f8Q; Leia Larsen, "Tribes still not consulted as state tries to save Great Salt Lake," *The Salt Lake Tribune* 2023, https://www.sltrib.com/news/politics/2023/02/07/stakeholders-gather-save-great/.

[60] Larsen, "Tribes still not consulted as state tries to save Great Salt Lake."; ALASTAIR LEE BITSÓÍ, *Salt of the Earth: Preserving the Great Salt Lake* (Atmos, March 15, 2023 2023), https://atmos.earth/great-salt-lake-utah-indigenous/; University of Utah Environmental Humanities, "Great Salt Lake and the Great Basin Tribes: Ancestral Connection and Pathways to Repair."

[61] U.S. Census Bureau, "Selected Characteristics of the Total and Native Populations in the United States."

[62] Farzan et al., "Assessment of Respiratory Health Symptoms and Asthma in Children near a Drying Saline Lake." Feizizadeh et al., "Health effects of shrinking hyper-saline lakes: spatiotemporal modeling of the Lake Urmia drought on the local population, case study of the Shabestar County."

[63] Kem C. Gardner Policy Institute, *Mean Centers of Population and Employment in Utah's Economic Regions*, The University of Utah (June 2024), https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/2024/06/Mean-Pop-Center-FS-Jun2024.pdf.

[64] Inc. Bioeconomics, *Economic Significance of the Great Salt Lake to the State of Utah*, Great Salt Lake Advisory Board (State of Utah, 2012), https://lf-public.deq.utah.gov/WebLink/DocView.aspx?id=392799&repo=Public&searchid=16c394eb-83ba-43ac-b0a1-fc0a149774d0&cr=1; "Industry & Recreation," accessed September 23, 2024, 2024, https://greatsaltlake.utah.gov/industry-recreation.

[65] Jennifer Leaver, *The State of Utah's Travel and Tourism Industry, 2024*, Kem C. Gardner Policy Institute, The University of Utah (Salt Lake City, Utah, February 2024 2024), https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/2024/02/TT-Report-Feb2024.pdf.

[66] Larsen, "Tribes still not consulted as state tries to save Great Salt Lake."

Appendix: Methodology

How and why was this case selected?

The Health in All Policies Initiative selected *Utah Physicians for a Healthy Environment v. Utah Department of Natural Resources* for judicial health note analysis due to its timeliness and compliance with the judicial health note screening criteria. The case meets the selection criteria because of the body of evidence regarding the environmental and human health impacts of the Great Salt Lake's declining surface area, the potential for public health and equity-focused data to add value to the case's legal arguments, and its relevance to the environmental challenges focus area of the Bloomberg American Health Initiative.

Research methodology

Once the case was selected for analysis, a research team from the Health in All Policies Initiative hypothesized connections, or pathways, between the ruling, health determinants, and health outcomes. These hypothesized pathways were developed using research team expertise and a preliminary review of the literature. The ruling was mapped to steps on these pathways and the team developed research questions and a list of keywords to search. The research team reached consensus on the final conceptual model, research questions, contextual background questions, keywords, and keyword combinations. The conceptual model, research questions, search terms, list of literature sources, and draft health note were peer-reviewed by one external subject matter expert. The expert also reviewed a draft of the health note. A copy of the conceptual model is available upon request.

The Health in All Policies Initiative developed and prioritized four research questions:

- How and to what extent do shrinking saline lakes affect air quality, e.g. through dust storms and release of toxins or chemicals into the air?
- To what extent does lakebed dust affect snowpacks?
- To what extent do exposed lakebeds affect climate change?
- To what extent do melting snowpacks affect climate change?

The research team next conducted an expedited literature review using a systematic approach to minimize bias and answer each of the identified research questions.[67] The team limited the search to systematic reviews and meta-analyses of studies first, since they provide analyses of multiple studies or address multiple research questions. If no appropriate systematic reviews or meta-analyses were found for a specific question, the team searched for nonsystematic research reviews, original articles, and research reports from U.S. agencies and nonpartisan organizations. The team limited the search to electronically available sources published between 2019 and 2024. The research team searched PubMed and EBSCO databases along with the following leading journals in public health, as well as sector-specific journals suggested by subject matter experts for this analysis to explore each research question: American Journal of Public Health; Social Science & Medicine; Health Affairs; Science; Journal of Environmental and Public Health; Environmental Health Perspectives; and Toxins.[68] For all searches, the team used the following search terms: lake drying, drought, air quality, saline lake, extreme

[67] Expedited reviews streamline traditional literature review methods to synthesize evidence within a shortened timeframe. Prior research has demonstrated that conclusions of a rapid review versus a full systematic review did not vary greatly. M.M . Haby et al , "What Are the Best Methodologies for Rapid Reviews of the Research Evidence for Evidence-Informed Decision Making in Health Policy and Practice. A Rapid Review," Health Research Policy and Systems 14, no. 1 (2016): 83, https://doi.org/10.1186/s12961-016-0155-7.

[68] American Journal of Public Health, Social Science & Medicine, and Health Affairs were selected using results from a statistical analysis completed to determine the leading health research journals between 1990 and 2014 and in consultation with policing and criminal justice experts. Merigó, José M/, and Alicia Núñez/ "Influential Journals in Health Research. A Bibliometric Study/" Globalization and Health 12.1 (2016), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4994291/.

heat, snowpack, saline lakebed, airborne toxins and chemicals, inland sea decline, and playa dust. The team also searched the U.S. Geological Survey for additional resources outside of the peer-reviewed literature. After following the above protocol, the team screened 93 titles and abstracts,[69] identified 20 abstracts for potential inclusion, and reviewed the full text corresponding to each of these abstracts. After applying the inclusion criteria, 7 articles were excluded. Eleven additional sources were identified upon review of the included articles. A final sample of 24 articles, including one review article, was used to create the health note. In addition, the team used 17 references to provide contextual information.

Of the studies included, the Health in All Policies Initiative qualitatively described and categorized the strength of the evidence as: not well researched, mixed evidence, a fair amount of evidence, strong evidence, or very strong evidence. The evidence categories were adapted from a similar approach from Washington State.[70]

Very strong evidence: the literature review yielded robust evidence supporting a causal relationship with few if any contradictory findings. The evidence indicates that the scientific community largely accepts the existence of the relationship.

Strong evidence: the literature review yielded a large body of evidence on the association, but the body of evidence contained some contradictory findings or studies that did not incorporate the most robust study designs or execution or had a higher-than-average risk of bias; or some combination of those factors.

A fair amount of evidence: the literature review yielded several studies supporting the association, but a large body of evidence was not established; or the review yielded a large body of evidence, but findings were inconsistent with only a slightly larger percent of the studies supporting the association; or the research did not incorporate the most robust study designs or execution or had a higher-than-average risk of bias.

Mixed evidence: the literature review yielded several studies with contradictory findings regarding the association.

Not well researched: the literature review yielded few if any studies, or yielded studies that were poorly designed or executed or had high risk of bias.

Expert Reviewer

This document benefited from the insights and expertise of Paul Locke, DrPH, JD, MPH, Professor of Environmental Health and Engineering at the Johns Hopkins Bloomberg School of Public Health. Although he reviewed the materials and found the approach to be sound, neither Dr. Locke nor his institution necessarily endorse its findings or conclusions.

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[69] Many of the searches produced duplicate articles. The number of sources screened does not account for duplication across searches in different databases.

[70] Washington State Board of Health, "Executive Summary. Health Impact Review of HB 2969," http://sboh.wa.gov/Portals/7/Doc/HealthImpactReviews/HIR-2016-05-HB2969.pdf.

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