PROCEEDINGS, 50th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 10-12, 2025
SGP-TR-229

The Lithium Valley Project

Eva Schill[1], Margaret M. Busse[2], William T. Stringfellow[1], John O'Sullivan[3], Margaret Slattery[4], Peter Nico[1], Michael A. McKibben[5], Maryjo Brounce[5], Patrick Dobson[1] and the Lithium Valley Team

[1]Lawrence Berkeley National Laboratory, Berkeley, California, [2]Pennsylvania State University, University Park, Pennsylvania, [3]University of Auckland, Auckland, New Zealand, [4]former: University of California, Davis, California, [5]University of California, Riverside, California

eschill@lbl.gov

Keywords: Direct lithium extraction (DLE), Salton Sea geothermal field, water consumption, reservoir management, solid waste

ABSTRACT

The Lithium Valley Project has pinpointed a significant domestic U.S. source of brine-hosted lithium located in the deep geothermal reservoir beneath the Salton Sea in Imperial County, California (Dobson et al., 2023). The project's first phase focused on assessing the key opportunities and challenges associated with developing this lithium resource.

The first demonstrators for direct lithium extraction (DLE) from geothermal brines are currently under development (e.g., Fleming et al., 2024). In a co-production scenario, lithium-depleted brine is reinjected back into the geothermal reservoir at depth. The primary mechanism for replenishing lithium is anticipated to be the upward flux of convecting, lithium-rich brine from below the producing reservoir, alongside unexploited brines within the reservoir itself (Sonnenthal et al., 2024). However, the replenishment rates from the host rocks may not be fast enough to achieve significant increases in lithium over several decades, which could pose a challenge for the long-term sustainability of the resource.

One objective of the current study is to further our understanding of fluid circulation and recharge dynamics, alongside the characteristics of deeper lithium-bearing minerals within the geothermal system, focusing on their chemical properties and reactivity. Additionally, our team has refined the reservoir model to assess the impact of different reinjection strategies on long-term lithium recovery (O'Sullivan et al., 2024).

Based on a previous impact analysis examining geothermal power production and lithium extraction's impact on regional water resources, we estimate that the water demand for the currently proposed geothermal and lithium extraction facilities will account for only about 4% of the region's historical water supply (Busse et al., 2024). More significant impacts on regional water allocation will likely stem from proposed reductions in the Colorado River's water allotments between now and 2050, rather than from the expansion of geothermal production and lithium extraction. To effectively plan for future water needs, more detailed information will be necessary regarding the water consumption associated with lithium extraction and refining processes.

Power plants in the Salton Sea geothermal field produce solid wastes as part of normal operations. Waste manifest information was used to evaluate quantities and types of wastes transported from Salton Sea power plants. Geothermal power plants in the Salton Sea geothermal field currently produce approximately 80,000 metric tons of solid waste per annum, representing approximately 30 kg of solid waste per MWh of electrical production. These solid wastes are predominantly composed of iron-silicate filter cake, brine-pond solids, and solids generated during plant maintenance.

1. INTRODUCTION

In the United States, critical minerals are defined by the Energy Act of 2020 as non-fuel minerals, elements, substances, or materials that are essential to energy technologies and have a high risk of supply chain disruption. These technologies include those for producing, transmitting, storing, and conserving energy. Geothermal brines contain several critical minerals, such as lithium, manganese, zinc, strontium, rubidium, and copper. The extraction of these additional mineral resources, alongside lithium, could become a significant contributor to the economic viability of geothermal brine production and potentially boost domestic production of these critical minerals. However, lithium extraction from geothermal brines is currently the most advanced area of research.

The Salton Sea geothermal field in Imperial County, California, has been identified as a promising domestic source due to the brine-hosted lithium in its deep subsurface geothermal reservoir. In their 2023 study, Dobson et al. provide a comprehensive overview of the opportunities and challenges associated with developing this lithium resource.

Geothermal brine production at the Salton Sea geothermal field has averaged just over 120 million metric tons per year since 2004. With an estimated lithium brine concentration of 198 ppm, this yields approximately 127,000 metric tons of lithium carbonate equivalent (LCE) annually. The total dissolved lithium in the well-characterized portion of the field is estimated at 4.1 million metric tons of LCE. However, by adjusting assumptions for porosity and total reservoir size based on geophysical data, which better reflect the probable extent of the resource (Kaspereit et al., 2016), the total estimated resource in the so-called Lithium Valley could rise to as much as 18 million metric tons of LCE (Dobson et al., 2023).

The primary sources of lithium are salt-rich pore fluids and clay-evaporite deposits, which formed during repeated cycles of infilling and desiccation following flooding of the Imperial Valley by the Colorado River during the Pleistocene epoch. This process is recorded in the lithium-rich surface mudstones found in the Durmid Hills (Humphreys et al., 2023). Over time, these lacustrine-evaporite sediments and pore fluids were buried, eventually becoming the primary source material for the geothermal brines found in the Salton Sea today (Williams and McKibben, 1989; McKibben et al., 1988). Humphreys et al. (2023) measured lithium concentrations in the reservoir rocks, which were shown to vary with depth and mineralogy. These data were used to help refine conceptual and numerical models of the reservoir; specifically, two complementary simulations of the reservoir were developed. One simulates the approximate 30-year history of geothermal power production in the area using historical production and reinjection data, which is then used to simulate a 30-year forecasting period. This forecast assumes continued production and reinjection rates at current levels but removes 95% of the lithium from the produced geothermal brine starting January 1, 2024. The model found that lithium recovery declines by more than half, from 0.8 to 0.3 kg/s. Forecast scenarios that are optimized to both recover lithium and harness geothermal energy are expected to sustain lithium production rates much more effectively.

The simulations of the movement of brine and chemical reactivity of lithium within the reservoir showed that the reactions of relatively stable lithium-bearing minerals are slow, and that the primary replenishment mechanism for lithium in the brines is the upward flux of convecting lithium-rich brine from below the producing reservoir. However, these replenishment rates are not fast enough to produce significant increases in lithium, which could limit the long-term sustainability of the lithium resource. It is important to note that these models are preliminary and are based on current understanding of fluid replenishment rates, the minerals present in the geothermal system, and their chemical properties and reactivity. Further work is being undertaken to improve them and the associated predictions.

The report highlights that lithium development is not likely to create significant negative environmental impacts on regional water resources, air quality, chemical use, and solid waste disposal needs, as well as on the seismic response associated with geothermal power production and lithium extraction activity. Specifically, expanding geothermal energy production and lithium extraction will have a modest impact on water availability in the region. Initial estimates suggested that ~3% of historically available water supply for the region would be needed for currently proposed geothermal energy and lithium recovery operations; most of the current water usage is for agriculture. It is not anticipated that expanding geothermal capacity or lithium production would impact the availability or quality of water used for human consumption and will not directly affect the water quality of the Salton Sea. However, the long-term drought conditions in the western United States may restrict future availability of water to the region, which is sourced from the Colorado River. In terms of regional air emissions of all pollutants identified in the analysis (particulate matter, hydrogen sulfide, ammonia, and benzene, expanding geothermal energy and adding lithium extraction overall have a small impact. Chemical use involved in geothermal power production and lithium extraction is consistent with chemical use in industrial settings, and the analysis did not identify any persistent organic pollutants or acutely toxic chemicals among those currently being used. Moving fluids within the subsurface can impact subsurface pressures and stresses, potentially triggering seismic activity. Early in geothermal energy production, increasing seismicity rates in the Salton Sea Geothermal Field correlated strongly with energy production activity; however, that correlation weakened after 1996. While the increased rate of seismicity in the geothermal field suggests increased seismic hazard, it is difficult to make accurate forecasts of future seismicity in this area (White and Nakata, 2025).

2. ADVANCES IN THE LITHIUM VALLEY PROJECT

Our new analyses are based on the planned increase of geothermal power production in the Salton Sea geothermal field. Currently, three new geothermal power plants are proposed in this field: Black Rock Geothermal Project, Elmore North Geothermal Project, and Morton Bay Geothermal Project. The proposed Elmore North and Morton Bay geothermal power plants are each designed to have a gross capacity of 157 MW and a net capacity of 140 MW, while the Black Rock geothermal power plant is designed with a lower gross capacity of 87 MW and a net capacity of 77 MW (California Energy Commission, 2024a, 2024c, 2024e). The combined capacity of the three proposed projects is 401 MW (gross) and 357 MW (net). The Elmore North and Morton Bay projects will each be capable of annual electricity production of 1,226,400 MWh. The Black Rock project will be able to produce 674,500 MWh annually. The three projects combined will be capable of producing 3,127,300 MWh of electricity annually.

2.1 Reservoir Management Simulation

Lithium extraction from geothermal brine alongside energy production presents a range of new challenges for effective reservoir management. Our previous analysis (Dobson et al., 2023) highlighted that reinjected dilute lithium geothermal brine is likely to return to the production zones relatively quickly, impacting the lithium yield. Follow-up studies (O'Sullivan et al., 2024) have shown that while the decline in lithium yield is inevitable over time, it can be mitigated without significantly hindering energy production by strategically targeting outfield reinjection zones. However, effective reservoir management will require more than just conceptual strategies—it will require more precise, detailed reservoir models that incorporate and account for the inherent uncertainties in model forecasts.

One of the primary goals of the current phase of this project is to enhance the reservoir model to improve our understanding of the dynamics of both lithium extraction and geothermal energy production in tandem. Accurate models will be essential for optimizing reinjection strategies and sustaining both lithium recovery and energy production over time. However, even with advanced modeling tools, managing the Salton Sea geothermal field effectively will necessitate collaboration between all key stakeholders.

A critical point to consider is that dilute lithium brine will likely have a more immediate impact on lithium production than the longer-term effects of enthalpy decline on energy output. Moreover, the movement of dilute lithium brine will not adhere to concession boundaries, and if not carefully managed, it could adversely affect neighboring production fields. This underscores the importance of cooperation across stakeholders to ensure that the resource is managed sustainably and equitably. Without such collaboration, individual producers may face challenges in managing the shared resource effectively.

Sustainable reservoir management will depend on several key factors, including robust monitoring, high-quality reservoir modeling tools, and transparent, cooperative management practices. These elements will be critical to ensure that lithium extraction and geothermal energy production can proceed in a manner that is both efficient and sustainable. Furthermore, technoeconomic analyses, grounded in the results of detailed reservoir modeling, will be essential to ensuring that the lithium resource develops in a way that provides a reliable return on the investment required to unlock its potential.

2.2 Water Consumption during Production

Due to the limited availability of data on water use for geothermal energy production and direct DLE facilities, our water use estimates to date have primarily relied on aggregate figures that represent total water consumption across multiple processes. While these lumped values provide an overall sense of water requirements, they fail to capture key details, such as the specific factors driving water demand, the distinction between water that is withdrawn versus water that is consumed, and the various variables that influence the overall impact of water use. This lack of granularity can hinder the accuracy of water impact assessments and limit our ability to make informed decisions regarding water resource management. To improve our evaluations, we aim to refine our approach by quantifying water use with more precision, and to better capture the uncertainties inherent in these estimates.

To achieve this, we are developing a bottom-up model of water use requirements for geothermal and lithium extraction operations within the Salton Sea geothermal field. This approach will break down water use by individual unit processes involved in geothermal power production and DLE. This level of detail will allow us to better understand the specific water demands at each stage of the operation, from geothermal energy production to the various steps of lithium extraction, including brine pretreatment and chemical dilution processes. The model will be constructed using a variety of sources, including past and updated Environmental Impact Reports, industry responses to data requests, scientific literature, fundamental engineering principles, and patents. This multi-source approach will ensure that the model is grounded in both current industry practices and sound technical principles, while also incorporating a degree of uncertainty to reflect the variability in the data.

Our current progress includes integrating newly available data from updated Environmental Impact Reports for planned geothermal and DLE operations in the region, such as those from Black Rock Geothermal LLC (2023), Elmore North Geothermal LLC (2023), and Morton Bay Geothermal LLC (2023). These reports have provided new insights into the potentially higher water use rates for geothermal operations than previously reported by existing facilities. Freshwater demand for the three proposed projects during plant operation is estimated to total approximately 16,238,788 m^3 with added demand during construction (Jacobs Engineering Inc., 2024a; 2024b; 2024c). The freshwater demand for operations is shown in Table 1. The demand will be met using Imperial Irrigation District (IID) canal water and proposed water recycling and recovery activities at the power plant.

Table 1: Annual freshwater demand for the operation of the new geothermal power plants Black Rock, Elmore North and Morton Bay (Jacobs Engineering Inc., 2024a; 2024b; 2024c).

Components of water demand (m^3/yr)	**Black Rock**	**Elmore North**	**Morton Bay**
Dust control	0	0	185,022
Brine water dilution	0	5,498,862	4,361,591
Cooling tower	978,151	1,408,636	1,383,967
Auxiliary systems (maintenance, fire system)	409,516	1,085,464	1,112,601
Totals	**1,387,667**	**7,992,962**	**7,043,181**

Our updated estimate suggests that water allocation for geothermal energy production in the region may need to be 1.3 times greater than earlier projections for the planned expansion over the next 3 to 4 years (Gupta and Busse, 2024). This increase is primarily driven by the anticipated growth in geothermal capacity and the associated rise in water requirements. We have also mapped out water needs for different stages of the lithium extraction process, including the dilution of chemicals on-site and brine pretreatment—critical stages that often require significant water inputs.

In addition to providing a clearer understanding of water demands, our model will be a key tool for future decision-making. It will support efforts to identify areas where water use can be reduced, help prioritize water-saving technologies and ultimately guide the development of geothermal and lithium extraction projects in the region. By refining our understanding of water needs at a granular level and incorporating uncertainties, we aim to provide stakeholders with a robust, data-driven tool for managing water resources more effectively in the face of growing demands for both energy and critical minerals.

2.3 Solid Waste during Production

As part of this study, we investigated the possible amount of solid waste from the development of new geothermal power plants in the region. Both nonhazardous and hazardous solid wastes will be generated during the anticipated life of the projects (Table 2). Nonhazardous operations phase solid waste will primarily consist of filter cake, a solid product from the crystallizer clarifiers used for power plant silica control. The projections for solid waste presented in the applications are based on filter cake that is 95% nonhazardous and 5% hazardous due to metals. Hazardous operations phase solid wastes will include used oil, brine pond solids, geothermal scale, cooling tower debris and sludge, aerosol containers, solvents, paint, adhesives, laboratory waste, batteries, and filter cake that does not pass standards to qualify as nonhazardous waste. The facility will also generate commercial trash typical of an industrial facility. Other solid wastes anticipated include metals, machine parts, electronic waste, and empty containers. It may be possible to recycle some of the nonhazardous waste.

Table 2: Solid wastes streams anticipated during operation of the new geothermal power plants (Black Rock Geothermal LLC, 2023; Elmore North Geothermal LLC, 2023; Morton Bay Geothermal LLC, 2023).

Wastes (10^3kg/yr)	Black Rock	Elmore North	Morton Bay
Non-hazardous process waste: non-hazardous geothermal filter cake	14,000	24,000	24,000
Hazardous process waste: Brine pond solids, geothermal scale, hazardous geothermal filter cake, cooling tower debris and sludge	11,000	12,600	12,600
Hazardous waste: Petroleum contaminated solids, oily sludge, and used oil	120	135	135
Nonhazardous: Commercial trash	75	120	120
Misc. hazardous and universal waste: Aerosol containers, solvents, paint, adhesives, laboratory analysis waste, lead acid batteries, alkaline batteries, fluorescent tubes, scrap metals, electronic waste	<2	<3	<3

3. CONCLUSION

In conclusion, the Lithium Valley Project represents a significant step forward in addressing both energy production and critical mineral extraction within the Salton Sea geothermal field. The proposed expansion of geothermal power capacity through the Black Rock, Elmore North, and Morton Bay geothermal power plants holds the potential to generate a combined total of 3,127,300 MWh annually, contributing substantially to California's renewable energy goals. However, this dual-purpose development also introduces new challenges, particularly in managing both geothermal energy production and lithium extraction simultaneously. As our analyses have shown, reinjected lithium-rich brine is likely to return to production zones quickly, which can impact lithium yield over time. While strategic reinjection can mitigate some of these challenges, the need for accurate and detailed reservoir models is crucial to optimizing both lithium and energy production.

Effective reservoir management will not only require advanced modeling tools but also collaboration among all stakeholders to ensure that the geothermal field's resources are managed sustainably. The movement of dilute lithium brine across concession boundaries underscores the necessity for shared responsibility and careful coordination among producers. Moreover, managing water resources efficiently remains a critical concern for the development of geothermal and lithium extraction projects. Our bottom-up approach to modeling water use at the unit process level is helping to refine water consumption estimates and account for uncertainties. This more granular understanding will be essential for guiding future decisions, identifying areas where water use can be minimized, and ensuring the sustainable management of water resources.

Solid waste management is another key area of concern. As geothermal and lithium extraction operations expand, the generation of both nonhazardous and hazardous solid waste will increase. Our findings suggest that while some nonhazardous waste can be recycled, careful management of hazardous waste streams will be necessary to minimize environmental impacts. The projected waste generation data for the new geothermal plants provide important insights into the scale of waste management required during their operational phases.

Ultimately, the successful development of geothermal power production and lithium extraction in the Salton Sea region will depend on a combination of advanced technologies, precise modeling, and collaborative efforts. By continuing to refine our understanding of water and waste management and by enhancing our reservoir models, we aim to ensure that these projects contribute to a sustainable and economically viable energy future while minimizing environmental impacts. As the projects move forward, ongoing monitoring and transparent management practices will be critical for ensuring the long-term sustainability of the lithium resource and the geothermal energy system. Through careful planning, innovation, and cooperation, the Lithium Valley Project has the potential to play a pivotal role in both renewable energy production and the responsible extraction of critical minerals for the clean energy transition.

ACKNOWLEDGMENTS

This work was supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Office of Technology Development, Geothermal Technologies Office (GTO), under Award Number DE-AC02-05CH11231 with Lawrence Berkeley National Laboratory.

REFERENCES

Black Rock Geothermal LLC: Black Rock Geothermal Project Application for Certification Volume 1. (2023) BHER.

Busse, M.M., McKibben, M.A., Stringfellow, W., Dobson, P. and Stokes-Draut, J.R.: Impact of geothermal expansion and lithium extraction in the Salton Sea known geothermal resource area (SS-KGRA) on local water resources. *Environmental Research Letters*, *19*(10), (2024), p.104011.

Dobson, P., Araya, N., Brounce, M., Busse, M., Camarillo, M.K., English, L., Humphreys, J., Kalderon-Asael, B., McKibben, M., Millstein, D., and Nakata, N.: *Characterizing the Geothermal Lithium Resource at the Salton Sea*. Lawrence Berkeley National Laboratory (LBNL), LBNL Report LBNL-2001557, Berkeley, CA (United States) (2023).

Elmore North Geothermal LLC: Elmore North Geothermal Project Application for Certification Volume 1. (2023), BHER.

Fleming, M., Kannan, S.G., and Eggert, R.: Long-run availability of mineral resources: The dynamic case of lithium. *Resources Policy*, v. 97, (2024), 105226.

Gupta, S., and Busse, M.M.: Quantifying the impact of water needs for lithium production from geothermal brines in the Salton Sea KGRA. GRC Transactions, 48, (2024), 2324–2336.

Humphreys, J., Brounce, M., McKibben, M.A., Dobson, P., Planavsky, N., and Kalderon-Asael, B.: Distribution and isotopic composition of Li in the Salton Sea Geothermal Field. GRC Transactions, 47, (2023), 225–240.

Kaspereit, D., Mann, M., Sanyal, S., Rickard, B., Osborn, W. and Hulen, J.: Updated conceptual model and reserve estimate for the Salton Sea geothermal field, Imperial Valley, California. Geotherm. Res. Council Trans, 40, (2016), 57–66.

McKibben, M. A., Williams, A. E., and Okubo, S.: Metamorphosed Plio-Pleistocene evaporites and the origins of hypersaline brines in the Salton Sea geothermal system, California: fluid inclusion evidence. *Geochimica et Cosmochimica Acta*, Vol. 52, (1988), 1047–1056.

Morton Bay Geothermal LLC: Morton Bay Geothermal Project Application for Certification Volume 1. (2023) BHER.

O'Sullivan, J., Araya, N., Popineau, J., Renaud, T., Riffault, J., and O'Sullivan, M.: Investigating reinjection strategies to optimize lithium production from the Salton Sea geothermal field. Proceedings, 49th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA (2024).

Sonnenthal, E., Spycher, N., Araya, N., O'Sullivan, J., Dobson, P., Humphreys, J., Brounce, M.J., and McKibben, M.: Lithium Evolution and Reservoir Sustainability in the Salton Sea Geothermal Reservoir from Reactive-Transport Modeling, PROCEEDINGS, 49th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA (2024).

White, M.C.A., and Nakata, N. Induced seismicity and geothermal energy production in the Salton Sea geothermal field, California. *Scientific Reports*, 15:1638 (2025).

Williams, A. E., and McKibben, M. A.: A brine interface in the Salton Sea geothermal system, California: fluid geochemical and isotopic characteristics. *Geochimica et Cosmochimica Acta*, vol. 53, (1989), 1905–1920.