Resource and Reserve Estimation of Salar-Type Lithium Brine Deposits

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Lithium brine mineral resources are fluid deposits of variable density and mobility, and resource and reserve estimations need to be conducted differently than for traditional hard rock deposits. These mineral-enriched brines are commonly hosted in porous- and fractured-rock aquifers, typically within closed hydrologic basins where lithium has been concentrated via evaporation over long periods of time. In these high altitude, arid basins, the conceptualization and exploration of brine mineral resources requires not only an understanding of the spatial and temporal variability of brine densities and lithium concentrations, but also the hydraulic parameters of the aquifer.

The approach for exploration, characterization, and estimation of lithium resources and reserves in salar-type aquifer systems is in many ways more similar to development of a fresh water supply than characterization of a mineral deposit. Similar to reservoir evaluation in the petroleum industry, key parameters such as brine volume and grade, aquifer geometry, hydrogeologic unit definition, effective porosity, specific yield, flow rate, recoverability, etc. are used in order to meet the definition of reasonable prospects of economic extraction and to define the mineral resource.

Evaluation of a lithium brine sometimes requires different methods and analytical tools for resource and reserve estimation. For example, a traditional resource categorization of an ore deposit is a function of the spacing between exploration boreholes, with decreasing distance between boreholes resulting in increasing confidence in the resource category. Although more boreholes or wells will also provide increased confidence in the understanding of a lithium brine resource in a salar-type environment, a robust understanding of the aquifer framework and its hydraulic parameters is more important than well spacing given that lithium brine chemistry tends to be less variable in an aquifer (except in zones where dilution with fresh water may occur). Therefore, in salar basins with a good understanding of the aquifer stratigraphy, hydraulic parameters, and lithium grade distribution, fewer exploration wells are typically required to achieve higher levels of resource and reserve categorization that than for typical hard rock deposits.

Unlike traditional hard rock methods, estimation of a resource (static) versus a reserve (dynamic) require different types of methods and numerical models. 3-D block models can be used to estimate the theoretically drainable percentage of the lithium contained in the brine for resource estimation, even though in practice, 100% of the computed resource brine cannot be practically removed from the aquifer due to pumping limitations. For reserve estimation, numerical groundwater flow and transport models are needed to understand the capacity of the aquifer to allow sustainable brine pumping during the life of mine, and to project the future lithium grade of brine that may be affected by dilution. That said, an understanding of the water balance for the basin, and fresh water aquifer zones is critical for understanding how fresh water may dilute the brine during operational pumping.

Practical methods have been developed to characterize and evaluate lithium brine resources and reserves in salar-type aquifer systems (see Figure 1). Although the same elements need to be evaluated for other types of mineral resources (types and methods of exploration and sampling, adequacy of the conceptual model, type and quality of the resource and reserve numerical models, and method and adequacy of the resource or reserve estimation), how these elements are evaluated often varies from traditional evaluation of hard rock deposits. A structured approach to evaluation of lithium brine deposits has been developed in order to be efficient and cost effective during the characterization process. Each phase of the characterization process (Initial evaluation of properties, Reconnaissance and initial conceptualization, Exploration and resource estimation, and Development of a reserve estimate), is structured to ensure that adequate, reliable information is available before advancing to the next phase.

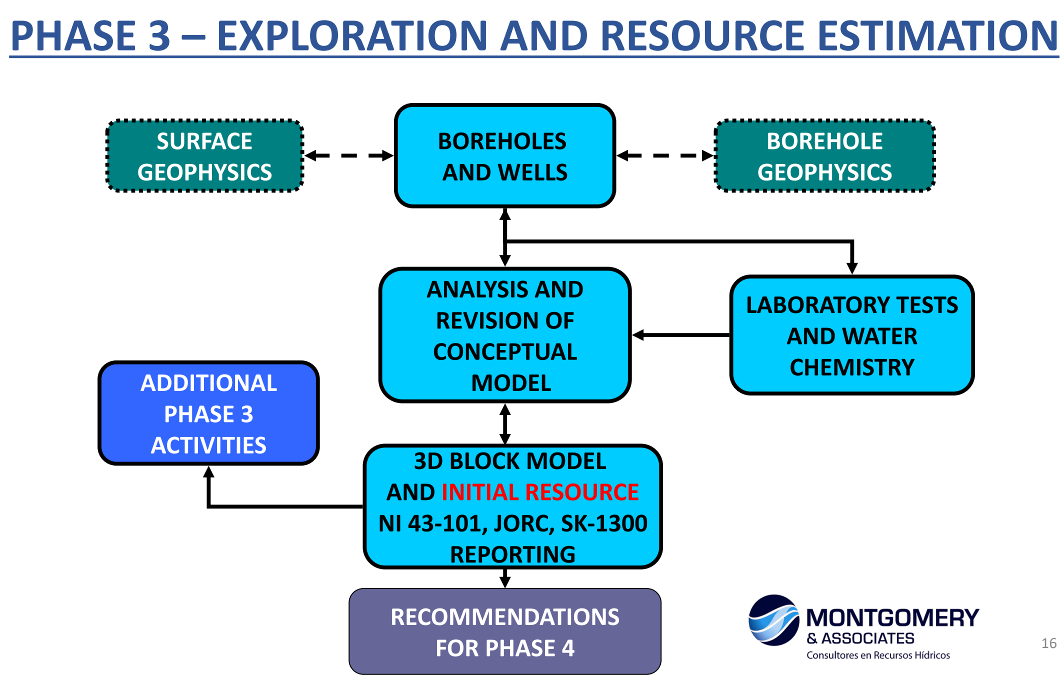

Figure 1. Example of Phase 3 Resource Estimation Flow Diagram