Interpretation and Application of Hydrogeological Concepts to Commercial-scale Brine Extraction Projects

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Why brines?

Why not???

No miners
No mining engineers
Low environmental impact
Byproduct potential
Low surface impact
Low OPEX
Schematic Brine Deposit

Source: A Preliminary Deposit Model for Lithium Brines. Bradley, D et al. USGS 2013
Intro to Brine Extraction Process

- Brine extraction from wellfield
- Pre-concentration Ponds
- Process Plant
- Reagents
  - Power
  - Water

Final Product
- $\text{Li}_2\text{CO}_3$
- $\text{LiOH}$
- $\text{KCl}$

Byproducts

Spent Brine

Salts - Sludge

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Mineral Resource and Reserve Reporting For Brine Deposits

Application of Hydrogeological Concepts
Brine Resources and Reserves

Increasing level of geological knowledge and confidence

Modifying Factors: consideration of mining, processing, economics, marketing, legal, environmental, social and governmental factors
Brine Exploration Methods

- **Brine Samples**
  Elemental analysis of brine samples collected from representative sampling depths

- **Hydraulic Conductivity**
  Estimated from in-situ testing (e.g., packer testing, short-term bore hole tests, pumping tests) or ex-situ laboratory testing (e.g., ASTM)

- **Specific yield (Sy) or Specific storage (Ss)**
  Approximated through in-situ testing (pumping tests) or ex-situ laboratory testing (e.g., RBRC - relative brine release capacity)
Matrix “Sampling” – In Situ
Brine Resource

What is the challenge?

- **Dynamic Resource** - Brine moves.....
- Resource Volume - Aquifer volume and specific yield
- Permeability governs rate of extraction
- Once the pump is on; the system is ON!
- Weather plays major role
- Sampling storage
- Spent brine disposal
Brine Resource: What are we looking for?

- **Brine Volume**
  - Lateral boundaries
  - Vertical distribution
  - Specific Yield (Sy) or specific storage (Ss) for confined zones
  - Effective porosity (he)
- **Transmissivity, Hydraulic Conductivity** (lateral and vertical)
- **Dispersivity** (longitudinal and transversal)
- **Assays** (Li, K, B, etc.)
- **Dilution** (e.g. presence of fresh water, brackish, low grade)
Factors that matter: Extractability

- In-situ recovery
- Brine aquifer characteristics
  - Characteristic porosity
  - Specific yield
  - Transmissivity
  - Heterogeneity of stratigraphy
  - Grade distribution
Extractability

Volume of brine resource = Storage (Sy/Ss) x Volume of host aquifer
Extractability

- Production well
- Initial brine elevation
- Specific retention loss, $S_r$
- Loss due to minimum well drawdown
- Brine elevation during exploitation
- Reserve base subject to an in-situ recovery factor
Numerical model is used for brine projects as “dynamic” resource model to support mineral reserve estimates.

- Brine movement is a 3D process.
- Numerical model combines geology, fresh water and brine flows, density driven flow, and optimal setting for production wells.
- Fresh water intrusion and dilution effect must be considered (aquifers, rivers, precipitation events)

Model predicts:
- Extracted brine volume over time
- Brine chemistry in time
Brine Concentration over Time

Initial Conditions (0 years)

20 years of production

100 years of production
Numerical Groundwater Model for Brine Projects

**Quantity**

**Quality**

- **a)** Predicted total pumping rate and average drawdown in brine extraction wells
- **b)** Predicted average concentration of Li, K, and B
Take Home Message

• Dynamic Resource
• Hydrogeologist is the new “mine engineer”
• Continuous update and calibration to the numerical dynamic model throughout the LoM