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A Numerical Modeling Methodology for Solution Mine Cavern Growth and Produced Brine Grade

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Abstract

A numerical model of solution mining production and cavern growth has been developed to evaluate production rates, brine concentrations, and geometric evolution of cavern shape over time. The modeled solution cavern shape and produced brine grade are influenced by many factors, including dissolution rate, pumping rate, soluble surface area, cavern volume, impurity concentrations, and temperature.

The model is composed of three linked components: 1) a chemistry model, 2) a cavern shape and surface area model, and 3) a time-dependent production model. The chemistry model describes the change in dissolution rate and solubility with changes in temperature, brine concentration, and impurity concentrations. Effective field-scale parameters are derived from production data with support from theoretical models. The cavern shape and surface area model describes the evolution in cavern shape and change in cavern soluble surface area. A novel application of implicit surface representation to describe solution cavern shape is discussed. The level-set method is used, which allows for complex geometries and cavern topology changes to be modeled. The time-dependent production model ties the chemistry and cavern models together to predict produced brine concentration over time. The model accounts for variable pumping rates, variable influent brine concentration, cavern growth, and variable soluble surface area.

Nine years of historical production data were matched with the model. The model was calibrated by adjusting the field-scale dissolution rate and provided good agreement with the production data and theoretical estimates of dissolution rates. The model was then used to make future production forecasts. This experience demonstrated that a simple zero-dimensional isothermal representation of a well-connected solution cavern can be sufficient to reproduce historical production data and make future predictions. However, uncertainty remains regarding the accuracy of the predicted cavern shape because the actual cavern geometry was not measured. The model is computationally efficient, requiring less than a minute to run. The model discussed here was found to be the simplest system that described the production data that were available for the mine and that also provided estimates of cavern shape through time. The model has been extended to include variable temperatures and complex interconnected flow paths. The model has been linked with geomechanical models of overburden response and cavern closure.

Key words: Cavern Dissolution Modeling, Computer Modeling, Cavern Hydraulics, Potash, Trona, and Brine Chemistry