# Saltwater intrusion in fractured rock – a study of the proposed high-level nuclear waste repository at Forsmark, Sweden

**Clifford I. Voss**[1], Georg A. Lindgren[2] and Joel Geier[3]
[1] US Geological Survey, Menlo Park, CA, USA
[2] Swedish Radiation Safety Authority, Solna, Sweden
[3] Clearwater Hardrock Consulting, Corvallis, OR, USA

## ABSTRACT

Intrusion of highly saline formation brines through fractures may adversely impact the isolation ability of Sweden's high-level nuclear waste repository. The repository should isolate copper-steel canisters containing used nuclear fuel rods from groundwater flow and should prevent any leakage of radioactive nuclear waste from reaching the human ecosystem. Canisters will be placed in cylindrical deposition holes on the bottom of tunnels excavated at about 500 m depth in the fractured granitic bedrock. Each canister should be wrapped in a 'buffer' of relatively-impermeable bentonite clay, completely filling the deposition hole. Upon completing emplacement of all canisters, the tunnels will be backfilled and closed with a bentonite-rock mixture. Initially, bentonite is placed in deposition holes in dry form and it does not fill the entire hole volume around the canister. After repository closure, the bentonite will absorb groundwater that naturally leaks into deposition holes and must swell until it completely fills each deposition hole, providing the intended waste isolation. However, bentonite swelling requires absorption of relatively fresh groundwater but the repository is underlain by highly saline groundwater (brine). Should saline groundwater enter the repository during swelling, it would reduce swelling, possibly leaving gaps around canisters through which groundwater can reach the canister and through which groundwater can transport any leaking radionuclides out of the repository, reducing its isolation ability.

Numerical simulation analysis of variable-density groundwater flow through fracture zones that intersect repository tunnels at the proposed repository site at Forsmark, Sweden, is carried out. Results reveal the main controls on brine intrusion (upconing) to the repository and on brine flushing ('downconing'), and provide a range of time delays before brine reaches the open repository and an understanding of how long brine may remain in the repository rock surrounding the canisters. Simulations indicate that upconing is driven primarily by the pressure gradient created by open tunnels at 500 m depth, but downconing is driven exclusively by fluid density differences. This is similar to the behavior of seawater intrusion in coastal water-supply wells. Upconing is strongly affected by the ratio of permeability to porosity in each fracture zone, quantities that are not well known in fractured rock. Within the full range of parameter values that may describe the Forsmark site, simulations yield either no significant upconing at all during the canister emplacement period or rapid intrusion of brines within a few decades. After initial intrusion, brine remains in the repository while the pressure is low (until it resaturates with groundwater, perhaps 1000's of years after closure). This is a case in which saltwater intrusion may adversely affect the performance of a nuclear waste repository.

Complete reference:
*Lindgren GA, Voss CI, Geier J (2013) Brine intrusion by upconing for a high-level nuclear waste repository at Forsmark, Sweden: Scoping calculations. Swedish Radiation Safety Authority (SSM) Report 2013:28, ISSN: 2000-0456, 47p (available at www.stralsakerhetsmyndigheten.se)*

**Contact Information**: Clifford I. Voss, U.S. Geological Survey, 345 Middlefield Rd, Menlo Park, CA 94025 USA, Phone: 650-329-5885
Email: cvoss@usgs.gov