Conceptual and Numerical Modeling to Close Ranger Mine Pits in Australia's Northern Territory

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Located in Australia's Top End, Ranger Mine has produced more than 120,000 metric tons of U_3O_8 between 1981 and the present, one of three mines in the world to do so. Mine reclamation is scheduled to be completed by 2026, but Ranger remains a high-profile project because it is surrounded by the Kakadu National Park, is upstream of world heritage RAMSAR wetlands, and is regulated by an agency created for this mining area. Energy Resources of Australia (ERA) contracted INTERA over the last 5 years to provide a defensible understanding of the risks from groundwater constituents of potential concern (COPCs) during decommissioning and after closure.

Ranger's governing agreement calls for placing all tailings in the two pits, Pit 1 and Pit 3, and to ensure the tailings and associated mine wastes cause no detrimental environmental impact for 10,000 years. After developing site-specific conceptual models, INTERA constructed and calibrated a three-dimensional groundwater flow model that was used to create a flow and solute transport model for simulating COPC migration from tailings backfilled in the pits to the surrounding groundwater and nearby seasonal creeks. The potential impact assessment modeling also included variable-density simulations of the high-density brine currently being injected into Pit 3 waste rock underfill beneath the tailings.

At ERA's request, INTERA developed the Ranger Conceptual Model, which examines the features, events, and processes most important to understanding groundwater flow and solute migration for closure of Ranger mine at three different scales: regional, sitewide, and source areas. Our findings revealed that the differences in groundwater and surface water chemistry also indicate that groundwater discharge contributes a small fraction of the water and solutes carried in creek flows. Solute concentrations are much larger in groundwater than creek surface water, even at times of low creek flow. Upstream of the Ranger Mine, the average annual natural magnesium (Mg) load in Magela Creek surface water is about 137,000 kilograms, equating to an average surface water concentration of 0.6 milligrams per liter. Magnesium is one of the key COPCs at Ranger.

During the post-closure period, COPCs in the Pit 3 waste rock backfill, tailings, and brine will likely migrate toward Magela Creek, but loading from the brine will be negligible. Peak loading from tailings and brine occur near the end and at the end, respectively, of the 10,000-year evaluation period. Peak Mg loading from Pit 3 tailings and brine are about 3% and 0.05%, respectively, of the historical average annual Mg load in Magela Creek upstream of Ranger mine.

COPCs in the Pit 1 waste rock backfill, tailings, and pit tailings flux will likely migrate toward the Corridor Creek tributary. Loading from pit tailings flux into the overlying waste rock backfill is expected only to persist for several decades and then decline steeply to negligible levels. Peak loading from tailings occurs at the end of the 10,000-year evaluation period for tailings. Peak Mg loadings from Pit 1 tailings and from pit tailings flux are less than 2 and 4%, respectively, of the historical average annual Mg loading in Magela Creek upstream of Ranger mine.

INTERA's combination of conceptual and numerical modeling provides ERA with a defensible context for understanding and assessing future solute loadings from mine wastes after closure.