# Field Evaluation of the Restorative Capacity of the Aquifer Downgradient of a Uranium In-Situ Recovery Mining Site

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## Executive Summary

A two-part field study was conducted to evaluate the restorative capacity of the aquifer downgradient (i.e., hydrologically downstream) of a Uranium in-situ recovery (ISR) mining site with respect to the transport of uranium and other potential contaminants in groundwater after mining has ceased. The study was conducted at the Smith Ranch-Highland ISR facility near Douglas, WY, operated by Cameco Resources. Because it was not possible to conduct field experiments involving elevated concentrations of uranium or other potential contaminants in an aquifer downgradient of an ore zone (by definition this would constitute an 'excursion' requiring corrective action), the tests were conducted in ore zone wells in two different mining units.

The first part of the study involved conducting cross-well tracer tests in two five-spot well patterns in Smith Ranch mining unit 4 (MU-4), which was mined by ISR from 1999 to 2005 and is currently in the process of being restored by groundwater sweep and reverse osmosis treatment. The tracer tests were conducted to evaluate hydrologic sweep in the two five-spot patterns, which was then used to predict the hydrologic dispersion of a residual contaminant 'plume' as it migrates from an ore zone into the aquifer downgradient of an ore zone. It was assumed that the flow heterogeneity in the two patterns was representative of the flow heterogeneity existing downgradient of an ore zone. The results of the tests indicated that the flow heterogeneity in the aquifer is not extreme and that dispersion downgradient of the ore zone can be represented using a Peclet number (travel distance divided by longitudinal dispersivity) of about 8. The results of the cross-well tracer tests were also useful for the planning of a pilot bioremediation field test that was subsequently conducted in one of the two five-spot patterns by the University of Wyoming in collaboration with Cameco Resources.

The second part of the study involved injecting waters withdrawn from two different wells in MU-4A (previously mined) at Smith Ranch into three different wells in the ore zone of MU-7 (unmined), and then pumping the wells back after allowing the injected waters to sit in the ore zone for different periods of time. These tests are referred to as 'push-pull' tests. The two MU-4A wells differed in that one had not undergone any restoration and its water had a uranium concentration of about 40 mg/L and an alkalinity of about 550 mg/L $CaCO_3$, while the other had undergone groundwater sweep and reverse osmosis treatment and its water had a uranium concentration of about 5 mg/L and an alkalinity of about 275 mg/L $CaCO_3$. The water from the unrestored MU-4A well was injected into two different MU-7 wells, and 'wait periods' of approximately 2 weeks and 3 months, respectively, were implemented before the wells were pumped back. The water from the partially-restored MU-4A well was injected into a third MU-7 well and allowed to sit for approximately 3 months before being pumped back. All of the injected



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waters were spiked with non-reactive tracers so that the return of the injected water could compared to the return of uranium and other constituents in the injected water. It was assumed that the geochemical conditions in the unmined ore zone were representative of the geochemical conditions downgradient of the ore zone. Available data suggest that this is a reasonable assumption.

The push-pull tests indicated that uranium from the MU-4A waters was strongly attenuated in the ore zone aquifer, with only 13-23% of the uranium being recovered when the MU-7 wells were pumped back and the uranium concentrations declining to near background levels before pumping ceased in all three wells. Recoveries of the nonreactive tracers suggested high recoveries of the injected waters in all the wells. Uranium isotope analyses indicated that there was not a significant shift in $^{238}U$ to $^{235}U$ ratios in the water pumped back from the push-pull tests, which suggests that biotic reduction (from U(VI) to U(IV)) was not a significant uranium attenuation process. However, uranium reduction by abiotic processes cannot be ruled out. $^{234}U$ to $^{238}U$ ratios were used to distinguish between injected uranium and uranium mobilized from the ore zone during the tests, and a significant amount of mobilized uranium was observed in all three push-pull tests. Other constituents, such as vanadium and selenium, were also clearly mobilized during the push-pull tests, which precluded an evaluation of the ability of the downgradient aquifer to attenuate the transport of these constituents.

A non-mechanistic multi-site, multi-rate adsorption/desorption transport model was used to interpret that uranium concentration-vs.-time histories in each of the push-pull tests, and the resulting model parameters were used to predict uranium transport in the aquifer downgradient of an ore zone over much longer time and distance scales than were interrogated in the tests. A conservative approach was taken in which it was assumed that there was only reversible adsorption of uranium and no irreversible attenuation (i.e., reduction) of uranium. The dispersion parameters deduced from the cross-well tracer tests were used in the predictive model. The results of the modeling indicate that the downgradient aquifer should significantly attenuate the transport of uranium, even without taking credit for any irreversible uranium immobilization, and if uranium reduction or some other irreversible immobilization process occurs, the attenuation should only be greater than predicted.