

Referee #1

General comments

This is a very interesting and resourceful paper to read. Authors integrated climate data in hydro-geochemical modeling to investigate climate resilience at groundwater contamination sites under different scenarios. By simulating reactive transport in groundwater, they found what geochemical mechanism plays a major role in uranium transport. The results would help decision-makers to manage the site and prepare for potential risks from climate change. Since this paper overarches from the general concepts (e.g., resilience) to specific mechanisms in modeling (e.g., dilution and remobilization), I would like to ask some questions that help people to have a better understanding of this paper:

Response: Thanks for your feedback and comments. Please find the point-to-point answers below.

Specific comments

1) The definition of climate resilience authors made is clear. How would you connect the results to the climate resilience? Are you able to quantify the climate resilience as an environmental metric? e.g., contaminants' concentrations or pH at an environmentally sensitive location.

Response: The averaged concentrations or pH over time in the climate scenarios at environmentally sensitive locations (in this case, the two monitoring wells) are the environmental metrics for supporting quantifying climate resilience. Resilience is usually quantified as the capability to return back to the system's original condition, in this case the concentrations at monitoring wells or other sensitive locations at the end of the simulation in comparison to the background baseline concentrations.

2) What is the difference between enhanced and monitored natural attenuation for the target contamination site? Do you mean the construction and destruction of the funnel-and-gate system?

Response: Enhanced natural attenuation is more invasive and tends to be more energy intensive i.e. pump and treat. MNA is more passive, encourages attenuation and relies more on continuous monitoring. They completely stopped with the pump and treat method. This was mostly because it was very energetically demanding and costly/unsustainable.

We are mostly discussing the funnel-and-gate system and barriers, which were constructed and in operation since 2004. We revised this sentence to "The funnel-and-gate system is operating and requires the injection of base solution to increase pH and immobilize contaminants. Quantitative estimation from the modeling study will provide insights for site management when the site transitions to natural attenuation status without any treatments. "

3) I understand that the flow and transport model is well established to describe spatio-temporal evolution of the contaminants of concern. Nevertheless, I am wondering about the limitation of the model as well, e.g., is the sorption model able to capture all sorption mechanisms?

Response: We agree that all the models have some limitations. We would note that our model is built upon more than 10 years of site characterization, sorption experiments and reactive transport models (Dong et al., 2012; Bea et al., 2013; Sassen et al., 2013; Wainwright et al., 2019). Extensive studies have been done focused on sorption experiments and model development (Dong et al., 2012). Our sorption is based on Arora et al. (2018), which developed a non-electrostatic sorption model (NEM) and calibrated geochemical parameters at the SRS site. In the revised manuscript, we will emphasize the past developments contributing to our model, by the following text in Line 639: "The non-electrostatic sorption model (NEM) sorption model used in this study is based on Arora et al. (2018), which is calibrated with long-term monitoring datasets and considered competitive H⁺ and uranium sorption".

4) The flow and transport model assumed that hydrogeological properties are homogeneous within each unit, and there is no dispersion. However, dispersion could have some impacts when the flow rate is slow, e.g., decreasing recharge scenarios. What impact would you expect on the results if the model considers dispersion due to natural heterogeneity of subsurface (e.g., permeability)?

Response: This issue has been addressed by Bea et al (2013). To clarify, we will include the citation and the following texts: "The system was considered to be advection dominated, so that hydro-mechanical and diffusion transport processes were neglected".

5) Could you explain why there is the nonlinear relationship between recharge and uranium concentrations (around +20~30%?) with specific pH values? You already explained it clearly with specific mechanisms (pH buffering from kaolinite and goethite). However, in decreasing recharge cases, it is much easier to understand because I could compare the pH range of gibbsite formation (>5.4) with simulation results.

Response: We assume the referee is referring to the uranium breakthrough curves in Figure 6d. Due to the different scales of pH and uranium, the non-linear relationship between recharge and uranium is more evident, but pH oscillates as well. This was mentioned in Line 343 and revised to highlight in line 350: "The uranium concentrations (Figure 6d) are also similar to the breakthrough curves for the nitrate concentrations and show negative correlation with pH oscillation."

6) What do you mean by the uncertainty (in line 652)? Do you mean annual variability mentioned in line 543? Is the variability of net infiltration also the same across all climate scenarios?

Response: We mean the uncertainty of both precipitation and ET in CMIP5 projection, which is an ensemble average of multiple climate model outputs. The variabilities of those climate model outputs were not considered. The annual variability of precipitation and ET hence net infiltration are more significant in RCP8.5 than other scenarios.

We revised this sentence as “Our reactive transport modeling with CMIP5 projection recharge shows that the contaminant migration is sensitive to recharge rate. In our study, ET is prescribed from the ensemble average of CMIP5 datasets and is not computed by our Amanzi simulations. The annual variability of precipitation and ET hence net infiltration are more significant in RCP8.5 than other scenarios. The uncertainty of ET estimation as well as the annual variability in CMIP5 scenarios could significantly affect the assessment of waste disposal and contaminant transport.”

Miscellaneous comments

1) You might want to mention “total recharge” instead of “total runoff” in line 267

Response: Yes, we agree that “total runoff” here can be misleading, and will correct it as “total recharge” in the revision.

2) You can specify ET is evapotranspiration before first mentioning it in line 643

Response: Agree. We change it to “Evapotranspiration (ET)” in Line 643