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Uncertainty in the prediction of erosion on geologic time scales

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Abstract: Landscape Evolution Models (LEMs) compute the evolution of the topography through time. One application of LEMs is in assessing potential for erosional exposure and release of contaminants into the environment. Examples include mine tailings, which are often toxic, and buried radioactive waste. In some cases, regulations governing the safety of hazardous waste requires a demonstration of probable site stability extending hundreds to thousands of years or more into the future. We present a multi-model calibration, validation, and prediction-under-uncertainty case study in a post-glacial landscape in which a nuclear-fuel reprocessing facility left a legacy of buried radioactive waste. One challenge in using LEMs for the prediction of erosion lies in the simplifications to physical process representation necessary to implement a model over a geologic time scale. To assess this source of uncertainty, we consider 37 alternative LEMs built using the Landlab Earth Surface Dynamics Framework. Each of these models differs systematically from the others in its representation of processes, materials, or both. We first calibrate all alternative landscape evolution models for the time period 13 ka to present. Using the most successful ~10 calibrated models we make predictions from the present to 10,000 years in the future. We assess prediction uncertainty arising from model selection and calibration, geologic boundary conditions such as downstream river incision and stream capture, future climate scenarios, and human modification to the site surface. As in other studies, model error is a significant part of the overall uncertainty, accounting for as much as 90% of the uncertainty at the end of the prediction time period.

***Keywords**:* multi-model prediction, landscape evolution, erosion, uncertainty partitioning