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Induced seismicity risk assessment for the 2006 Basel, Switzerland, Enhanced Geothermal System (EGS) project: Role of parameter uncertainty

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A project to exploit the geothermal potential of the crystalline rocks below the city of Basel, Switzerland, was abandoned in recent years due to unacceptable risk associated to increased seismic activity during and following hydraulic stimulation. The largest induced earthquake (Mw = 3.2, 8 December 2006) was widely felt by the local population and provoked slight non-structural damage to buildings. Here we present a probabilistic risk assessment analysis for the 2006 Basel EGS project, including uncertainty linked to the following parameters: induced seismicity forecast model, maximum magnitude, intensity prediction equation, site amplification or not, vulnerability index and cost function. Uncertainty is implemented using a logic tree composed of a total of 324 branches. Exposure is defined from the Basel area building stock of Baisch et al. (2009) (SERIANEX study). We first generate deterministic loss curves, defined as the insured value loss (IVL) as a function of earthquake magnitude. We calibrate the vulnerability curves for low EMS-98 intensities (using the input parameters fixed in the SERIANEX study) such that we match the real loss value, which has been estimated to 3 million CHF (lower than the paid value) for the Mw = 3.2 event. Coupling the deterministic loss curves with seismic hazard curves using the short-term earthquake risk (STEER) method, we obtain site-specific probabilistic loss curves (PLC, i.e. probability of exceeding a given IVL) for the 79 settlements considered. We then integrate over the different PLCs to calculate the most probable IVL. Based on the proposed logic tree, we find considerable variations in the most probable IVL, with lower values for the 6-day injection period than for the first 6 days of the post-injection period. This difference is due to a b-value significantly lower in the second period than in the first one, yielding a higher likelihood of larger earthquakes in the post-injection phase. Based on tornado diagrams, we show that the variability in the most probable IVL is mostly due to the choice of the vulnerability index, followed by the choice of including or not site amplification. The choice of the cost function comes in third place. Based on these results, we finally provide guidelines for decision-making. To the best of our knowledge, this study is the first one to consider uncertainties at the hazard and risk level in a systematic way in the scope of induced seismicity regimes. The proposed method is transferable to other EGS projects as well as to earthquake sequences triggered by wastewater disposal, carbon capture and sequestration.