

Induced Seismicity Hazard Assessment in Northeast British Columbia

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Summary

Although it is considered a seismically quiet area with infrequent natural seismicity, the history of induced seismic activity across the oil and gas fields in northeast British Columbia (NE BC), Canada, goes back to more than 40 years (e.g., Horner et al., 1994). From high-pressure fluid injection to increase production in the Eagle and Eagle West fields in the 1980's to more recent activities since the turn of century, including wastewater disposal and multi-stage hydraulic fracturing along horizontal wells within the Horn River Basin and Montney resource play, significant anthropogenic activities have caused the seismicity rate to pick up considerably. As a result, regulatory agencies have established (in collaboration with academia and private sector) seismic monitoring networks to ensure public safety is achieved while economic development continues (e.g., Kao et al., 2016). Due to their shallow depths, small, induced earthquakes (M~2) can be felt by residents living near operations and a few moderate magnitude (M4+) earthquakes have occurred with peak ground motions close to damage thresholds (e.g., Babaie Mahani and Kao, 2018).

In this study, we analyze the variation in seismic hazard levels in NE BC over the years. Based on the seismic source zones described in the 6th generation of the Canadian National Seismic Hazard Map and an earthquake catalog prepared in this study, we define and characterize natural and induced seismicity sources within 300 km of the city of Fort St. John. The parameters used to characterize the seismic sources include minimum and maximum magnitudes, Gutenberg-Richter parameters (a-value and b-value), and earthquake focal depth. Using Monte Carlo sampling, we synthesize earthquake catalogs for different realizations of seismic sources over a total time span of 100,000 years. We then estimate ground motions (peak ground acceleration, PGA, and peak ground velocity, PGV) at the target location for each earthquake using a suite of ground motion prediction equations. Applying a logic tree to account for epistemic uncertainty in seismic sources and estimated ground motion, we generate hazard curves for the periods 1980-2002, 2003-2012, 2013-2024, and individual years between 2013 and 2024 (inclusive).

Our results indicate fluctuations in both PGA and PGV for the exceedance probability of 2% in 50 years, with PGA exhibiting a much larger variation than PGV. The peak in ground motion levels for the 2% in 50 years probability occurs during 2022-2023 (for both PGA and PGV), corresponding to a ~30% increase in PGA compared to the baseline value of 493 cm/sec². In contrast, the peak in PGV during 2022-2023 only reflects a ~10% increase compared to the baseline value of 30.5 cm/sec. These findings suggest that while the frequency of felt ground motions has increased significantly due to induced seismicity (as reflected in PGA values), the potential for structural damage from induced earthquakes does not exhibit the same degree of change (as indicated by PGV values).

Workflow

The methodology for probabilistic seismic hazard assessment (PSHA) includes (1) identification of seismic sources and evaluation of their activity rate, magnitude recurrences, and distribution of source-to-site distances, (2) selection of appropriate GMPEs, and (3) hazard calculation. We follow the Monte Carlo sampling to perform PSHA (Musson, 2000; Assatourians and Atkinson, 2013; Sianko et al., 2020). In this approach, hazard is calculated directly through simulation of seismicity data and calculation of ground motions at the target location from each earthquake.

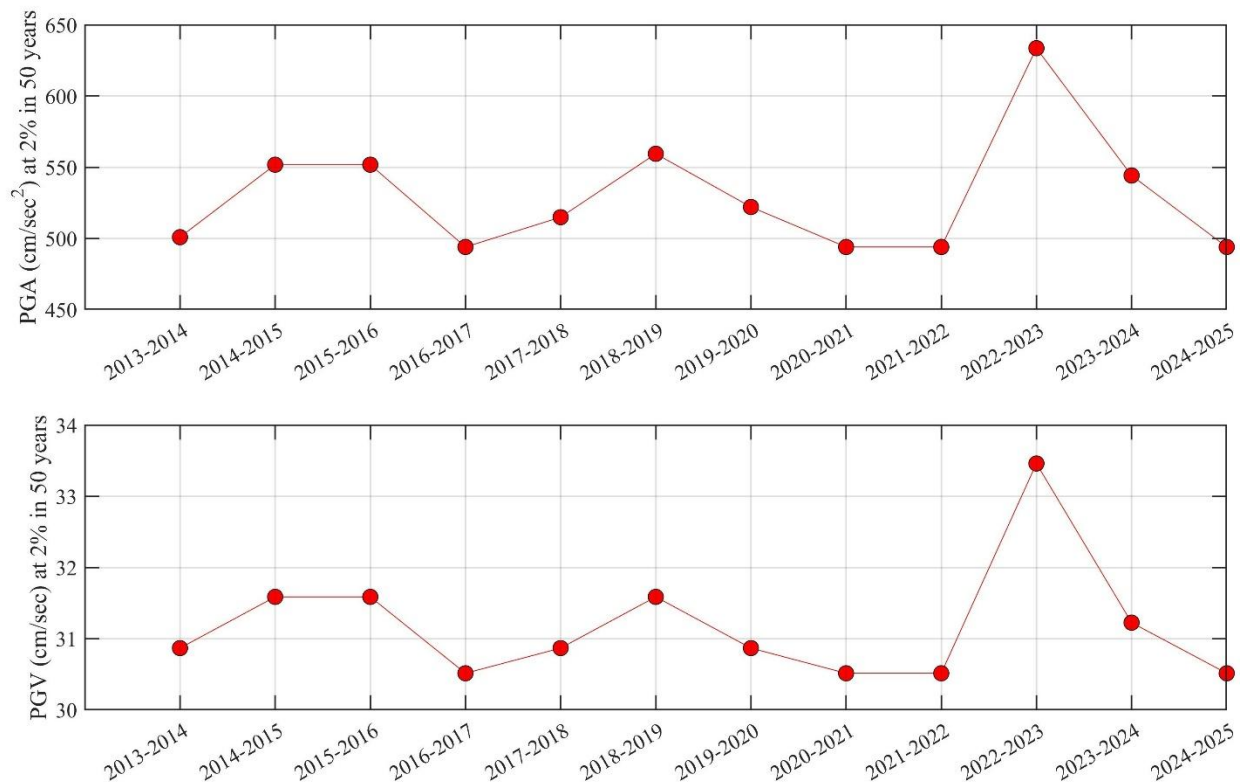


Figure 1. Peak ground acceleration (PGA) and peak ground velocity (PGV) at the target location for the probability of 2% in 50 years since 2013.

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