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Managing risks of anomalous induced seismicity: An evidence-based approach

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Summary

In the past few years, public concerns in western Canada have been raised about anomalous induced seismicity (AIS) from fluid injection, largely in response to felt events of local magnitude up to M_L 4.6. The occurrence of AIS requires: a) a source of elevated pore pressure; b) a pre-existing slip surface (geological fault) that is close to a critically state and with sufficient contiguous surface area (order of 0.1 km^2 or more) to produce a felt event; c) a diffusion pathway from the injection site to the fault.

Currently, the most widely used approach for management of risk from AIS is magnitude-based traffic-light protocols (TLPs). In general, a TLP is a site-specific, real-time, risk management system with multiple discrete risk levels. Each TLP level is determined using observable criteria and invokes specific actions designed to mitigate risk.

It is important to recognize that earthquake magnitude is not the only possible TLP metric; other considerations include: ground-motion levels such as peak ground velocity, which is linked to damage potential; seismicity rate parameter, including (but not limited to) the *b*-parameter that stems from the Gutenberg-Richter magnituce-recurrence relation; and observed spatiotemporal alignment of epicentres during and after treatment. In addition, reference ground motions from other domains where ground vibration measurements are a concern, such as blasting, pile driving, and traffic studies, can provide useful but often overlooked practical guidance for TLP response metrics.

In both Canada and the U.S., well established methods for probabilistic seismic hazard assessment (PSHA) are used to develop maps and site-specific uniform hazard curves that provide a basis for seismic provisions of building codes. Although details vary, the general procedure used for PSHA analysis involves: 1) identification of source regions; 2) determination of magnitude-frequency distributions; 3) estimation of distance relationships between the source region and the site or map point; 4) application of ground-motion prediction equations to estimate ground shaking intensity as a function of distance; 5) combination of contributions from different source regions within a frequency-dependent probabilistic framework. Induced events are generally excluded from PSHA analysis, although the USGS is developing short-term hazard forecasting models designed for induced seismicity. Such short-term forecasts are intended to inform capital spending plans (e.g. investment in more resilient infrastructure) rather than for building codes. The adaptation of probabilistic approaches for time-dependent hazard estimation for incorporation into TLPs warrants further considration.