

Recommended Practices for Addressing Induced Seismicity Associated With Subsurface Injection

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Introduction

Large-scale deployment of geologic carbon storage may be accompanied by induced seismicity (IS). Best practice recommendations are needed to address **technical and non-technical stakeholder issues** related to IS associated with geological storage of CO₂.

We present a set of 7 steps to serve as general guidelines to proactively deal with IS issues, setting expectations for operators, regulators, and the general public. While each underground reservoir will be unique and will require a custom approach, these general science-based actionable best practice recommendations can be used as a starting point for any site-specific plan on how to evaluate, communicate about, and mitigate IS at a particular reservoir.

Our recommended practices are similar to the overall scope of the Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems (Majer et al., 2012), but with added insights from recent general scientific and technical developments and a specific focus on geological storage of CO₂.

The goal is to provide a clear set of guidelines and practices focused on IS that would facilitate the development and permitting of carbon storage projects.

Specifically, the recommended best practices steps are:

- Step 1** Preliminary Seismic Risk Screening Evaluation
- Step 2** Outreach and Communication
- Step 3** Criteria for Damage, Vibration, and Noise
- Step 4** Collection of Seismicity Data
- Step 5** Hazard Evaluation of Natural and Induced Seismic Events
- Step 6** Risk Informed Decision Analysis
- Step 7** Risk Informed Mitigation Plan

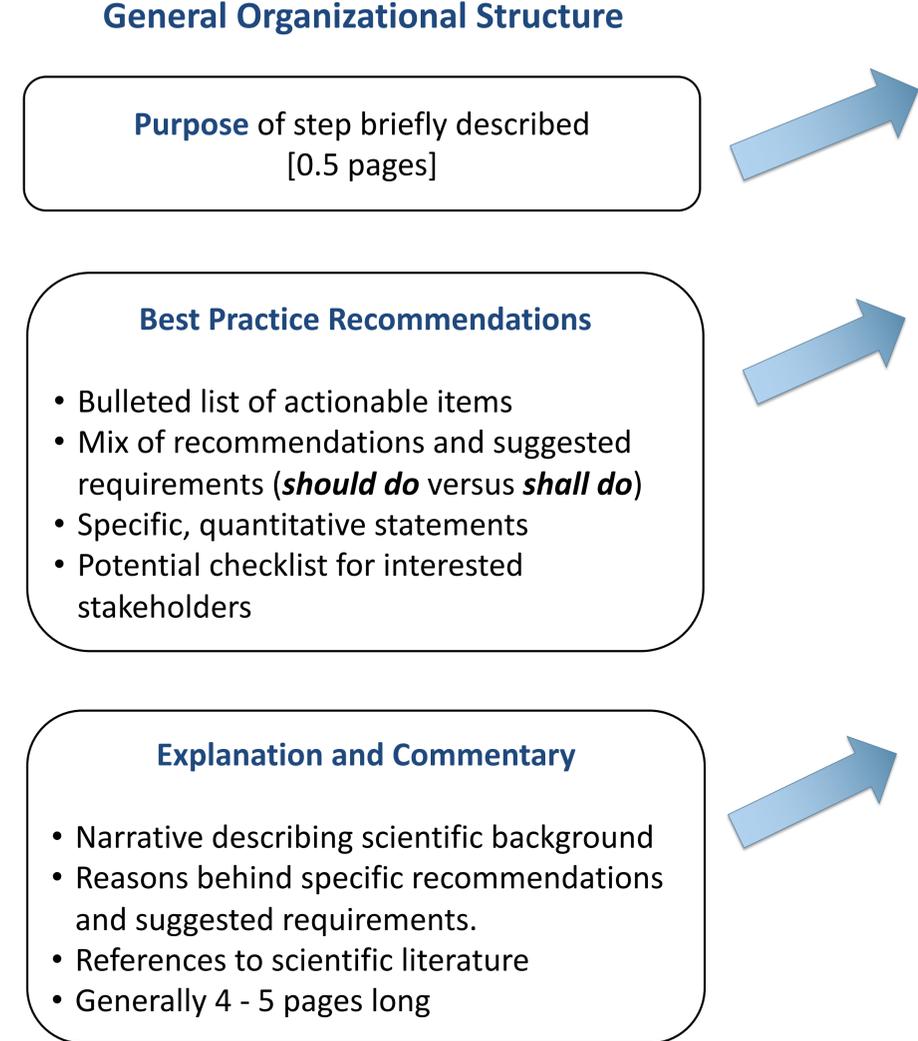
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The Take Away

- Creating an easy to understand and follow **list of actionable items** to proactively deal with any potential induced seismicity associated with geologic carbon storage reservoirs.
- Describes in detail the technical reasons **why** the actions are being recommended.
- Easy to update format.

The Now and The Future

- Document is currently under **internal** review within the NRAP Induced Seismicity Working Group.
- Want to get involved: We are creating a list of potential **external** reviewers, send us your name to be included.

Step 1: Preliminary Seismic Risk Screening Evaluation

Purpose
The purpose of this step is to broadly assess the probability of success of candidate site locations before investing substantial resources into the planning and construction of a project. The preliminary seismic risk screening evaluation is based on simple bounding methods and acceptability criteria with the goal of determining go/no-go decision points for future planning. [...]

Best Practice Recommendations
1.1 Classification of Preliminary Site-Specific Seismic Risk
1.1.1 A preliminary site-specific seismic risk assessment shall be completed which qualitatively classifies seismic risk into one of four general categories. This assessment shall include, but is not limited to:

- a) A review of local, state, and federal laws and regulations;
- b) An initial estimation of the Radius of Influence of potential seismic events;
- c) A listing of the potential impacts to the local community within the Radius of Influence;
- d) Lower and upper bound estimates of the potential impacts;
- e) An assessment of local stakeholder risk tolerance; and
- f) A final assessment of the overall seismic risk, based on factors (a) – (e).

I. Very Low:	II. Low:	III. Medium:	IV. High:
Proceed with planning.	Can proceed with planning, but may require additional analysis to confirm.	Probably should not proceed at this site, but additional analysis might support proceeding.	Do not proceed.

Explanation and Commentary
[4 – 5 pages of technical content, including References]

Step 4: Collection of Seismicity Data

Purpose
The purpose of this step is to gather data on seismicity that will be used for three related but different needs. The first need is to accurately assess and periodically re-assess the natural and induced seismic hazard/risk associated with the project. The second is to aid in the successful and rapid characterization of induced seismicity occurring in the Perturbed Stress Zone. The last need is to provide accurate data for input into induced seismicity mitigation plans (e.g., traditional or adaptive traffic-light systems). [...]

Best Practice Recommendations
4.1 Seismic Activity Before Operations
4.1.1 Previous seismic activity shall be characterized within a region of at least 100 km radius around planned injection operations. Elements of a seismic characterization analysis should include, but are not limited to, collecting existing information from:

- a) Earthquake catalogs from national, state, or regional entities;
- b) Historical records of earthquakes, including by not limited to newspaper records;
- c) Fault maps;
- d) Paleoseismic records from known faults, including but not limited to, trenching studies; and
- 3) Previous induced earthquake activity reports, including but not limited to, scientific publications.

4.1.2 A seismic monitoring network shall operate for at least six months but preferably for one year or longer before injection operations commence.

4.2 Seismic Monitoring Network Design
[Recommendations and requirements for sensor types, location accuracy, minimum recordable ground motions, and velocity model calibration.]

4.3 Seismic Monitoring Network Operation
[Recommendations and requirements for earthquake products, archiving, and duration of monitoring.]

Explanation and Commentary
[4 – 5 pages of technical content, including References]