Protocol and Best Practices for Addressing Induced Seismicity Associated With Enhanced Geothermal Systems (EGS)

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Introduction

- The implementation of EGS affects subsurface conditions and thus there exists the potential to cause induced seismicity.

- Although induced seismicity has occurred in the development and production of several conventional hydrothermal resources, there has never been a case of significant damage in any of these geothermal applications.
There have been a few instances of public concern where induced seismicity has hindered and/or stopped EGS projects, e.g., Basel.

To help gain acceptance from the general public for geothermal in general and EGS specifically, the DOE seeks to better understand the issues associated with EGS induced seismicity.

These issues are both positive (since seismicity is a diagnostic tool for EGS development) and negative (since the public may be concerned about seismicity).
The overall goal of the Protocol is to help facilitate the successful development of EGS projects.

A Protocol and an associated Best Practices document, which expands on the Protocol, were prepared at the direction of the DOE’s Geothermal Technologies Program.

The Protocol is an advisory document intended to identify important issues and parameters that may be necessary for the evaluation and mitigation of adverse effects of induced seismicity.
Background

- Induced seismicity has occurred in many different energy and industrial applications (reservoir impoundment, mining, construction, waste disposal, oil and gas production).

- Although certain projects have been stopped because of induced seismicity issues, proper study and engineering controls have always been applied to enable the safe and economic implementation of these technologies.

- Recent publicity surrounding induced seismicity at several geothermal sites, e.g., Basel, points out the need to address and mitigate any potential problems that induced seismicity may cause in geothermal projects.
Maximum Induced Earthquakes from Global Geothermal Activities
Seismicity ($M_L \geq 2.0$) at The Geysers and Surrounding Region, 1970 to 2012

- 1172 $M \geq 1.5$ events since 2004
- 30 $M 4.0$ to 4.7 events since 1972
- There are two main communities within 5 km of the induced seismicity: Cobb and Anderson Springs

Orange triangles – seismic stations
Intended Use

- The Protocol and Best Practices are intended to be living documents for the public and regulators, and geothermal operators.

- It also recognizes that “one size” does not fit every geothermal project, and not everything presented should be required for every EGS project. Local conditions at each site will call for different types of action.

- Local conditions include the population density around the project, past seismicity in the area, the size of the project, the depth and amount of injection and its relation to any faults, etc.
Step 1: Perform a Preliminary Screening Evaluation

- Evaluate risks with simple bounding methods
  - Local, state and Fed governments’ acceptance criteria
  - Impact on local community
  - Natural seismicity and associated long term seismic risk
  - Associated risk of worst case induced earthquake

- Assess the overall risk of the planned EGS

- Identify the potential risks to completing project
Step 2: Implement an Outreach and Communication Program

- Goal is to increase the level of acceptance of the project by regulators and the public.
- Support for the project by local community is an important milestone that is ideally achieved before any significant EGS and/or expenditure proceeds.
- Identify the stakeholders: project proponents, community members, regulators, public safety officials and experts, and politicians.
- Evaluate outreach needs.
- Develop plans to approach community, stakeholders, regulators and public safety officials.
Step 3: Identify Criteria for Ground Vibration and Noise

- Building damage criteria
  - Threshold cracking
  - Structural damage

- Civil structures – dams, pipelines, bridges, highways, and railroads

- Landslide and rockslide

- Research institutions

- Human response
  - Vibration
  - Ground-borne noise
Step 4: Establish Seismic Monitoring

- Data collection for characterizing background seismicity levels
- Local seismic monitoring
  - Design
    - Instrumentation
    - Calibration
    - Aperture
    - Temporal coverage
    - Sensitivity/location accuracy
    - Data processing and analysis
- Data availability/archival
Step 5: Quantify the Hazard From Natural and Induced Seismic Events

- Estimate the baseline hazard from natural seismicity
- Estimate the hazard from induced seismicity
- Compare probabilistic hazard from natural and induced seismicity
Step 6: Characterize the Risk From Induced Seismic Events

- Identify the assets that could be adversely affected and that could contribute to the total risk.

- Three classes of impacts:
  - Physical damage to buildings and infrastructure
  - Human activity interference
  - Socio economic impact

- Characterize the damage potential (vulnerability).

- Estimate the risk.
Step 7: Develop Risk-Based Mitigation Plans

- Direct
  - Injection modification
  - Manmade and environmental modifications

- Indirect
  - Insurance
  - Bonding
  - Financial compensation (private and public)
  - Other compensation/subsidies
  - Jobs program
  - Community outreach
  - Other Benefits
Summary

- Provide a flexible Protocol and Best Practices that ensure the safety of EGS activities while allowing geothermal technology to move forward in a cost effective fashion.

- The Protocol and Best Practices provide a set of general procedures that detail *useful steps that geothermal project proponents can take to deal with induced seismicity issues.*

- The procedures are not prescriptive, but suggest an approach to engage public officials, industry, regulators, and the public at large, facilitating the approval process, helping to avoid project delays and promoting safety.
The Protocol is currently available on DOE’s Geothermal Technologies Program website: www1.eere.energy.gov/geothermal/plans/comments.cfm?doc=egs
Induced Seismicity Issues

- Factors influencing induced seismicity.
- Uncertainties in characterizing induced seismicity.
- Strategies to control induced seismicity.
- Methods to characterize the earthquake hazards associated with fluid injection.
Annual Steam Production, Water Injection, and Seismicity at The Geysers
Seismicity ($M_L \geq 2.0$) at The Geysers and Surrounding Region, 1970 to 2012

- 30 $M \geq 4.0$ to 4.7 events since 1972
Number of Reported Felt Events/Month Jan 2004 to Aug 2010