Induced Seismicity Consortium
Frequently Asked Questions about
Induced Seismicity Consortium and Area of Study

1. What is the Induced Seismicity Consortium?

The Induced Seismicity Consortium (ISC) is a collaborative effort of scientists from the University of Southern California (USC) based Southern California Earthquake Center (SCEC). The SCEC includes representatives from the USC Department of Civil and Environmental Engineering, USC Petroleum Engineering program, as well as representatives from industry, national laboratories, regulatory agencies, non-governmental organizations, and community groups interested in developint science-based understanding of the causes and risks of induced seismicity.

2. What is induced seismicity?

Induced seismicity is seismic activity that occurs as a result of human activity (anthropogenic). Seismic activity refers to the frequency, type and size of earthquakes. The vast majority of earthquakes are natural, caused by stresses that cause fracturing of rock in the earth's crust. Examples of processes that might cause induced seismicity include subsurface wastewater injection, geothermal energy generation, and surface-water reservoir impoundment. Most seismic events related to induced seismicity cannot be felt by humans, because they have very low magnitudes (less than 2 on the Richter scale) that can only detected by specialized instruments.

3. What causes induced seismicity?

The main cause of induced seismicity is increased fluid pressure in rock pores that reduces that natural friction and allows slippage of rocks along a fault.[1] Researchers investigating causes of induced seismicity have documeted that fluid pressures have a role in seismicity.[2] As explained by the U.S. Department of Energy (DOE), "pore pressures act against the weight of rock and forces holding the rock together; if the pore pressures are low, then only the imbalance of natural *in situ* earth stresses will cause an

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[1] http://www.gwpc.org/sites/default/files/events/white%20paper%20-%20final_0.pdf

[2] U.S. Department of Energy, 'Induced Seismicity Primer': http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

occasional earthquake. If, however, pore pressures increase, then it would take less of an imbalance to cause an earthquake."[3]

Cases have recently been observed in Oklahoma and Ohio, were seismic activity has been associated with the disposal of large volumes of wastewater into deep geologic formations.[4] Such injection can disrupt the balance of stress within rock, especially when not paired with corresponding fluid withdrawl. Other potential sources of induced seismicity include underground mining, and chemical interaction of fluids with rock materials.[5]

4. Can hydraulic fracturing cause induced seismicity?

Hydraulic fracturing is a well stimulation practice that uses the injection of fluid to open flow channels in tight formations to produce the hydrocarbons locked within them[6]. The practice has been in use for over sixty years.

A report published in 2013 by the National Academies of Science concluded that hydraulic fracturing does not pose a high risk for inducing seismic events that could be felt by humans. The U.S. Geological Survey (USGS) has also found that hydraulic fracturing is not a substantial cause of induced seismicity, and that "only very rarely" is hydraulic fracturing the cause of any earthquakes that can be felt by humans. The "microearthquakes" that hydraulic fracturing creates are too small to be felt or cause structural damage.[7] Hydraulic fracturing has been associated with only minor sesmic events at two U.S. locations, neither in California.

Accordingly the U.S. Department of Energy has also concluded that hydraulic fracturing is "rarely, if ever, a hazard when used to enhance permeability in oil and gas or other types of fluid-extraction activities."[8] Furthermore, the USGS finds that "although the disposal process has the potential to trigger earthquakes…very few of the more than 30,000 wells designed for this purpose appear to cause earthquakes."[9]

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[3] U.S. Department of Energy, 'Induced Seismicity Primer': http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

[4] Ozarks Public Radio, 'USGS: Oka Fracking Has Increased Chance of 'Damage Quake'': http://ksmu.org/npr/usgs-okla-fracking-has-increased-chance-damaging-quake

[5] U.S. Department of Energy, 'Induced Seismicity Primer': http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

[6] U.S. Department of Energy, 'Induced Seismicity Primer': http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

[7] USGS 'Man-Made Earthquakes Update' http://www.usgs.gov/blogs/features/usgs_top_story/man-made-earthquakes/

[8] U.S. Department of Energy, 'Induced Seismicity Primer': http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

[9] USGS 'Man-Made Earthquakes Update' http://www.usgs.gov/blogs/features/usgs_top_story/man-made-earthquakes/

5. How can one determine whether a seismic event is natural or induced?

In their 1993 paper[10], Davis and Frohlich set forth a simple set of yes or no questions that could be used as a rubric in determining whether a seismic event was likely induced. The questions were as follows:

1. Are these events the first known earthquakes of this character in the region?
2. Is there a clear correlation between injection and seismicity?
3. Are the epicenters near wells (within five kilometers)?
4. Do some earthquakes occur at or near injection depths?
5. If not, are there known geologic structures that may channel flow to sites of earthquakes?
6. Are changes in fluid pressure at well bottoms sufficient to encourage seismicity?
7. Are changes in fluid pressure at hypocentral locations sufficient to encourage seismicity?

From these, an even may be scored, with more "yes" answers indicating an increased likelihood of an event having been induced.

6. Has hydraulic fracturing caused earthquakes in California?

A recent study by the USC Induced Seismicity Consortium (ISC) found no correlation between hydraulic fracturing and induced seismic activity in California[11]. This study evaluated 30 years of seismic data in areas of oil production where hydraulic fracturing has been used in California and found little or no correlation between oil field activities in general and seismic activity.

The ISC study compared seismic activity from 1980 to 2013 with oil field activity, including hydraulic fracturing, at locations throughout California. Oil field activities and well locations were obtained from the California Division of Oil, Gas, and Geothermal Resources (DOGGR) and the FracFocus website. Seismic activity data were compiled from the Northern and Southern California Earthquake Centers, and included epicenter locations of seismic activity and the magnitudes and depths of seismic events. Database maps were prepared to display oil and gas well locations, well type (e.g. oil or gas producer, water flood injector, steam flood injector, water disposal), type of activity (drilling, producing, injecting, completing, stimulating, or abandoning), and the depth of the activity.

Composite maps were prepared comparing locations of seismic events and known geologic faults with oil and gas well locations and oil field activities. Statistical analyses were conducted to determine whether there was any correlation between seismic

[10] Davis, S.D. and C. Frohlich, 1993, did (or will) Fluid Injections Cause Earthquakes? – Criteria for a Rational Assessment, Seismological Research Letters, 64(3-4), p. 207-224.
[11] "Application of Induced Seismicity Mapping (ISM) Software - in Wilmington Oil Field," Chen et. al.

events and oil field activities. Little or no correlation was found. For example, in northern California, a total of 303,609 seismic events recorded from 1980-2013. The main area of northern California where oil and gas activities have occurred is in the Sacramento area, far from known fault zones, where oil is produced from shallow depths (less than 6 kilometers). Of the total 303,609 seismic events in northern California, only 210 event were in the Sacramento area, only 3 seismic events had magnitudes greater than 3, and none was greater than 4.

7. Does induced seismicity from wastewater injection by the oil industry differ in California than in other states?

The practice of deep wastewater injection is commonly used in states throughout the U.S. and is strictly regulated by state and federal laws. California has strict regulations governing subsurface wastewater injection. Injection wells used by the oil industry in California are different from the injection disposal wells linked to earthquakes in other states, like Ohio Oklahoma, Texas, and Arkansas.[12] In California oil fields, wastewater is reinjected back into the formation after the oil is removed.[13] In California, the water is injected into porous sandstone reservoirs, from which water and oil was originally removed. In other areas of the U.S., wastewater is often injected into rocks with little porosity and storage capacity. Pore pressures in the rock increases dramatically as the limited available pore space is filled and, additional injected water causes the rock to break, causing an induced seismic event. As a result, a University of California Santa Barbara geophysicist, Craig Nicholson, concluded that "very little of the state's [California] earthquake activity can be tied in any way to reinjection…there's not a connection like there is in the central and eastern United States."

8. How do we know if an earthquake was caused by induced seismicity?

Seismologists conduct extensive analysis of earthquake data and potential anthropogenic factors to determine whether an earthquake is natural, triggered or induced. More information is needed to improve researchers' understanding of the "triggering" mechanisms of injection and production-related induced seismicity as well as any irregularities that naturally occurring earthquakes may have.[14]

Recent studies by USC and the California Institute of Technology indicate that there is not a significant correlation between earthquakes and oil and gas field operations. A

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[12] Energy in Depth California, 'Earthworks Study Makes Shaky Assumptions on California Earthquakes,"http://energyindepth.org/california/earthworks-study-shaky-assumptions-california-earthquakes/

[13] Energy in Depth California, 'Earthworks Study Makes Shaky Assumptions on California Earthquakes,"http://energyindepth.org/california/earthworks-study-shaky-assumptions-california-earthquakes/

[14] U.S. Department of Energy, 'Induced Seismicity Primer': http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

major reason for this is that natural earthquake epicenters are typically at depths below five kilometers, while oil field operations are conducted at depths shallower than two kilometers, typically less than one kilometer.

9. Are there any documented cases of injuries or property damage caused by induced seismicity?

There have been no documented cases in California where injuries or property damage been have caused by induced seismicity. However, property damage has been documented from shaking thought to be a result of wastewater injection into rock formations adjacent to known faults.

According to the National Research Council's Committee on the Induced Seismicity Potential in Energy Technologies Report[15], virtually all induced seismicity attributed to energy development has been small in magnitude, and unable to be felt. The same committee also concluded that hydraulic fracturing does not pose a high risk triggering noticeable seismic activity.

10. Where can I find information about induced seismicity?

http://earthquake.usgs.gov/research/induced/

http://esd.lbl.gov/research/projects/induced_seismicity/

Induced Seismicity FAQ EOS Draft 5 5 14.docxhttp://www.nap.edu/openbook.php?record_id=13355&page=37

11. What are the relevant federal, state, non-governmental organizations, and trade associations that have information about induced seismicity and how can they be contacted?

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- United States Geological Survey
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  Web Information: energy.usgs.gov

- National Research Council
  Induced Seismicity ad hoc Study Committee

[15] http://www.nap.edu/catalog.php?record_id=13355

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CALIFORNIA

- Southern California Earthquake Consortium (SCEC)
  http://www.scec.org/
  Thomas Jordan

- California Department of Conservation
  quake.gov, DOGGR, DOGGR and State Water Resources Control Board

OKLAHOMA

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