

PREPARED FOR:

Chair Senator Michael Dembrow, Vice-Chair Alan Olsen, Senator Herman Baertschiger Jr., Senator Flyod Prozanski, Senator Arnie Roblan

SENATE COMMITTEE ON ENVIRONMENT & NATURAL RESOURCES



POTENTIAL THREAT OF INJECTION INDUCED SEISMIC ACTIVITY

&

SELECTED ASSOCIATED HYDRAULIC FRACTURING TORT LITIGATION

TESTIMONY SUPPLEMENT:

HB 2711 A

17 May (2017)

The increased frequency of injection induced earthquakes was initially observed in 2009 by the scientific community. An overwhelming amount of this abnormal seismic activity was credibly confirmed to be a result of sending abundant amounts of produced fracturing fluid (wastewater injection) into class II injection wells. The potential ability for wastewater injection to cause human induced seismic activity has been common knowledge, and universally accepted, by US and international geologists and geophysicists since the mid 1960's (USGS 1968; 1981; 2013; 2013b; 2014; 2014b; 2014c; 2015; 2015b; 2015c; 2015d; 2015e; 2016; 2016b; 2016c; NRC 2013).

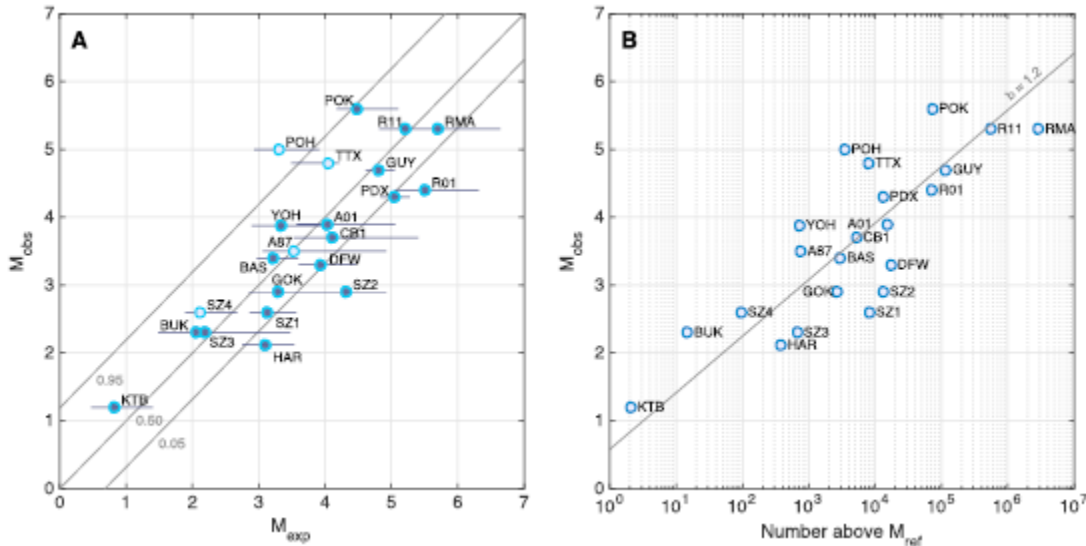
Until 2011, the most intense injection induced seismic activity occurred during the Rocky Mountain Arsenal earthquake, which transpired in 1967 (USGS 1968; 2015e). In 2011, after the vast rise of unconventional directional and horizontal hydraulic fracturing, substantial unintended seismic activity was recorded in Prague Oklahoma (M=5.6), Trinidad Colorado (M=5.3), Timpson Texas (M=4.8), and Guy Arkansas (M=4.7). These specific earthquakes prompted the scientific community to reassess the unforeseen dangers initiated by the mass injection of hydraulic fracturing fluids. Surprisingly, in all of these site-specific regions, fracturing fluid injection wells were located in extreme close proximity of the seismic activity, and the USGS also confirmed a valid connection between the actual timing of the immense fluid injection procedure, and the unnatural human induced earthquakes (Won-Young Kim 2013; USGS 2015e).

During a study conducted by the USGS in 2016, which researched 19 different regions where humanmade injection induced earthquakes transpired, geophysicists were actually able to successfully predict the future frequency of human induced seismic activity. Data collected from all of the 19 sites passed all of the statistical tests, and revealed that the fluid injection process “controlled earthquake nucleation”, but “tectonics controlled the earthquake magnitude”, and that the actual “injected volume (of fracturing fluids) controls the total number of earthquakes”, and also that “induced earthquakes should be treated with the same maximum magnitude bound that is currently used to treat seismic hazard from tectonic earthquakes” (USGS 2016).

USGS geophysicists were highly successful when predicting the actual magnitude and occurrence rate of seismic activity, in relationship to the overall amount of class II injection wells in operation, combined with the overall quantity (volume) of fracturing fluid associated with the wastewater injection process (Equation A-USGS 2016b).

$$f_{\Delta M_{\max}}(\Delta m|N_{\text{tot}}) = b \ln(10) \cdot 10^{-b\Delta m} \sum_{N=N_{\min}}^{N_{\text{tot}}} \frac{1}{N} \left[1 - \frac{1}{N} 10^{-b\Delta m} \right]^{N_{\text{tot}}-1},$$

(Equation A)



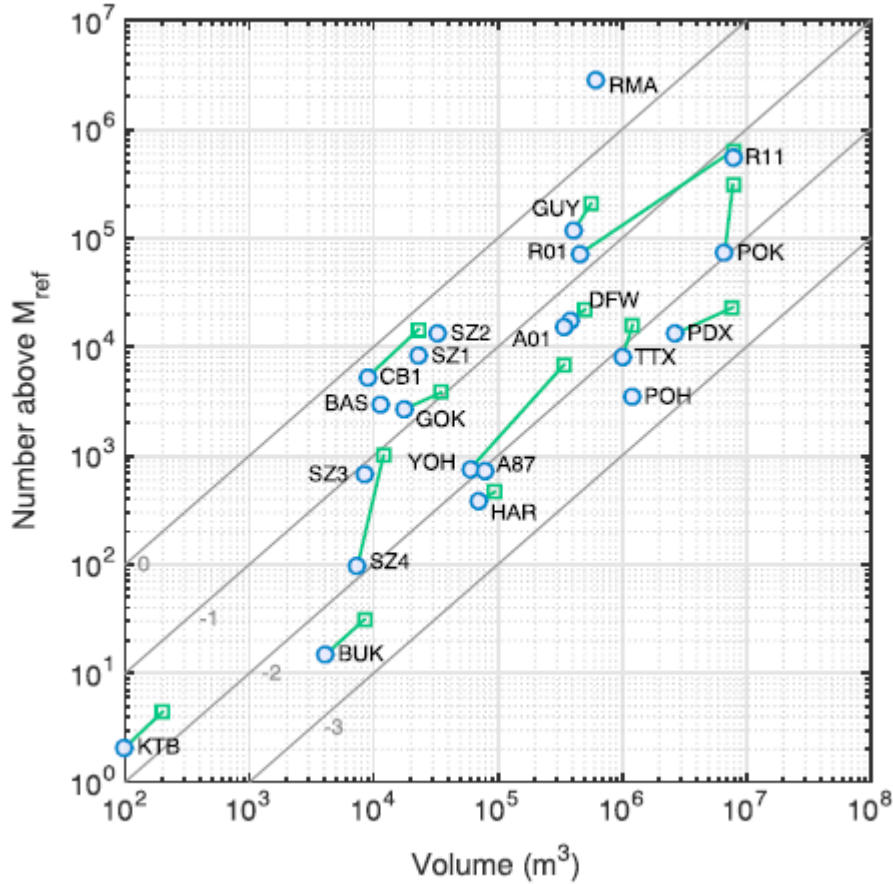
(USGS 2016b)

Figure 1(a): “Observed versus expected maximum magnitude M_{\max} . Diagonal lines are probability contours for the expected maximum (Equation A) assuming $b = 1.2$. Thin horizontal lines show 95% confidence ranges associated with b value uncertainty at each site.

Figure 1(b): “Observed M_{\max} as a function of the number of prior events above a reference magnitude $M_{\text{ref}} = 0$, assuming $b = 1.2$ ”

Equation A: “The number of events N prior to the largest event is thus a discrete uniform variable on the interval $[1, N_{\text{tot}}]$. The deviation ΔM_{\max} between the true sample maximum (assuming N is uniform) and the naïve estimate (i.e., assuming $N = N_{\text{tot}}$) has the distribution.”

TOTAL VOLUME OF INJECTION WELLS IS PROPORTIONAL TO INDUCED SEISMIC ACTIVITY



(USGS 2016b)

Figure 2: “Number of induced earthquakes versus volume, scaled to $M_{ref} = 0$, assuming $b = 1.2$. Blue circles give values at the time of the largest induced earthquakes; connected green squares give final values for that site. Thin gray lines show expected scaling for a range of seismicogenic indexes” (Equation B).

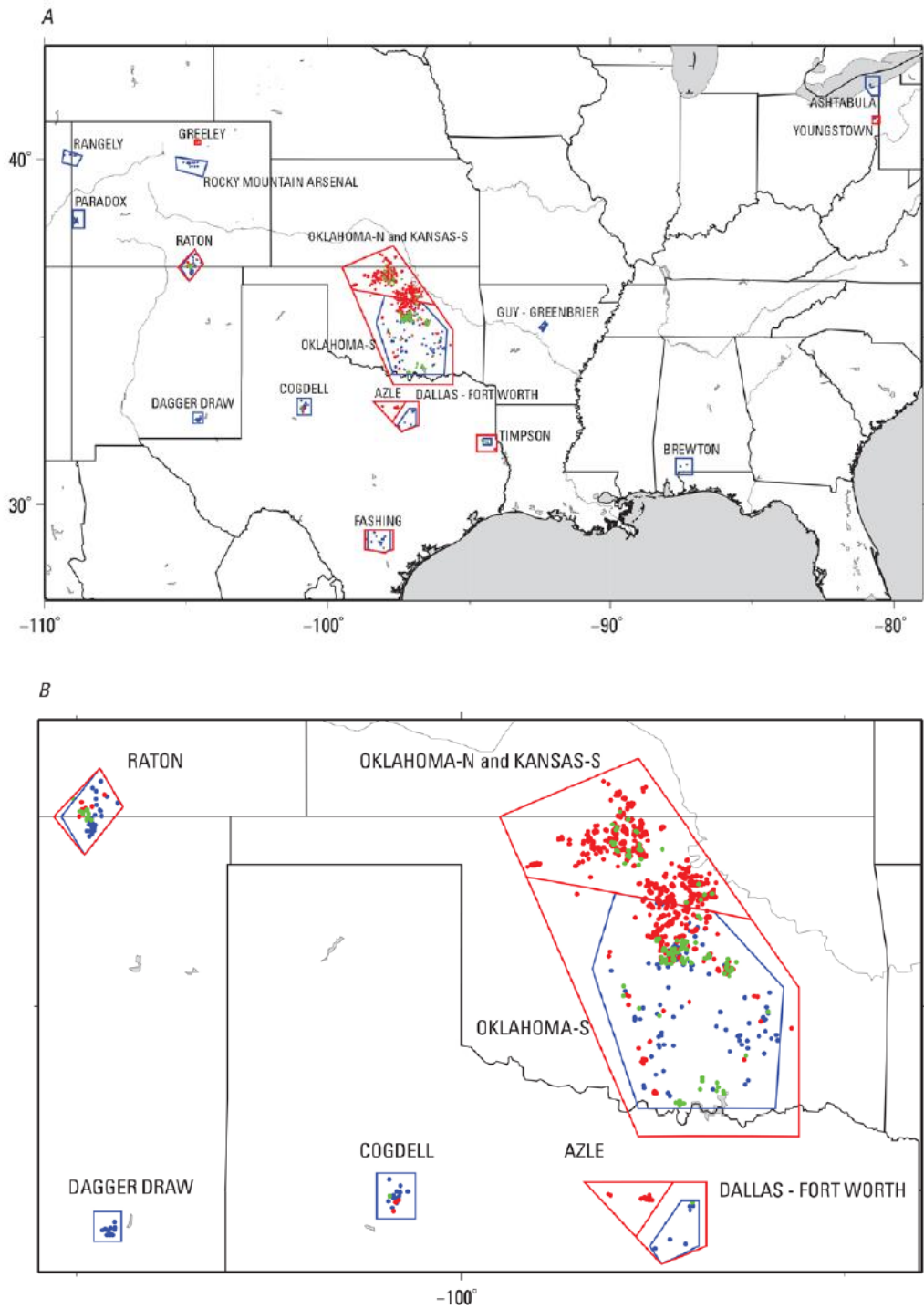
$$\log_{10}(N) = \Sigma + \log_{10} V - bM_c,$$

(Equation B)

Equation B: “Connects the number of triggered events to total injected volume. The number of earthquakes triggered by fluid injection is commonly parameterized in terms of the seismicogenic index Σ , where V is the volume injected. This formula is common in geothermal applications, where the seismicogenic index is found to be relatively constant over the lifetime of the reservoir (Shapiro et al. 2010; 2011) and is supported by studies of injection-induced seismicity (Shapiro et al. 2007; Rubinstein et al. 2014; Asanuma et al. 2005)” (USGS 2016b).

USGS 2016b. Induced earthquake magnitudes are as large as (statistically) expected. Journal of Geophysical Research: Solid Earth 121 (6), pp. 4575–4590. <http://www.its.caltech.edu/~pagem/InducedMmax.pdf>

MINIMUM M=2.5 INDUCED SEISMIC ACTIVITY FOR 17 DIFFERENT GEOGRAPHICAL ZONES

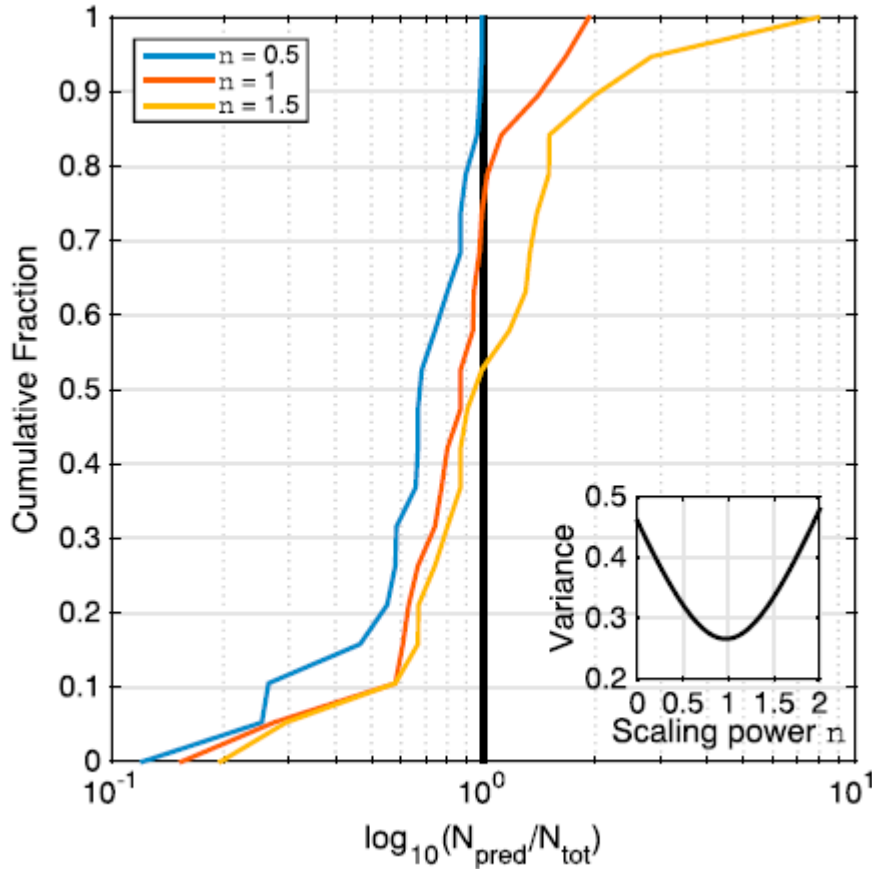


(USGS 2015)

Figures 3 & 4: “Polygons showing where potential induced earthquakes have been extracted for the following: A. Central and Eastern United States. B. Induced seismicity showing area near Oklahoma. For 3A and 3B Red = 2014 nondeclustered catalog, Green = 2013 nondeclustered catalog, Blue = 2012 and previous using a declustered catalog (2015).

ACCURATE USGS FORECAST FOR FUTURE PREDICTIONS OF INDUCED SEISMIC ACTIVITY

(ALL RESEARCHED SITES)



(USGS 2016b)

Figure 5: “The distribution of the ratio of predicted to observed number of induced earthquakes, using the formula $N_{pred} = N(V_{tot}/V)^n$. N and V are the number of earthquakes and injected volume at the time of the main shock; V_{tot} is the final volume injected at the end of the sequence. Variance of $\log(N_{pred}/N_{tot})$ as a function of the scaling power n , where N_{tot} is the observed final number of earthquakes. Maximum variance reduction is obtained for an exponent $n = 0.96$ ” (USGS 2016b).

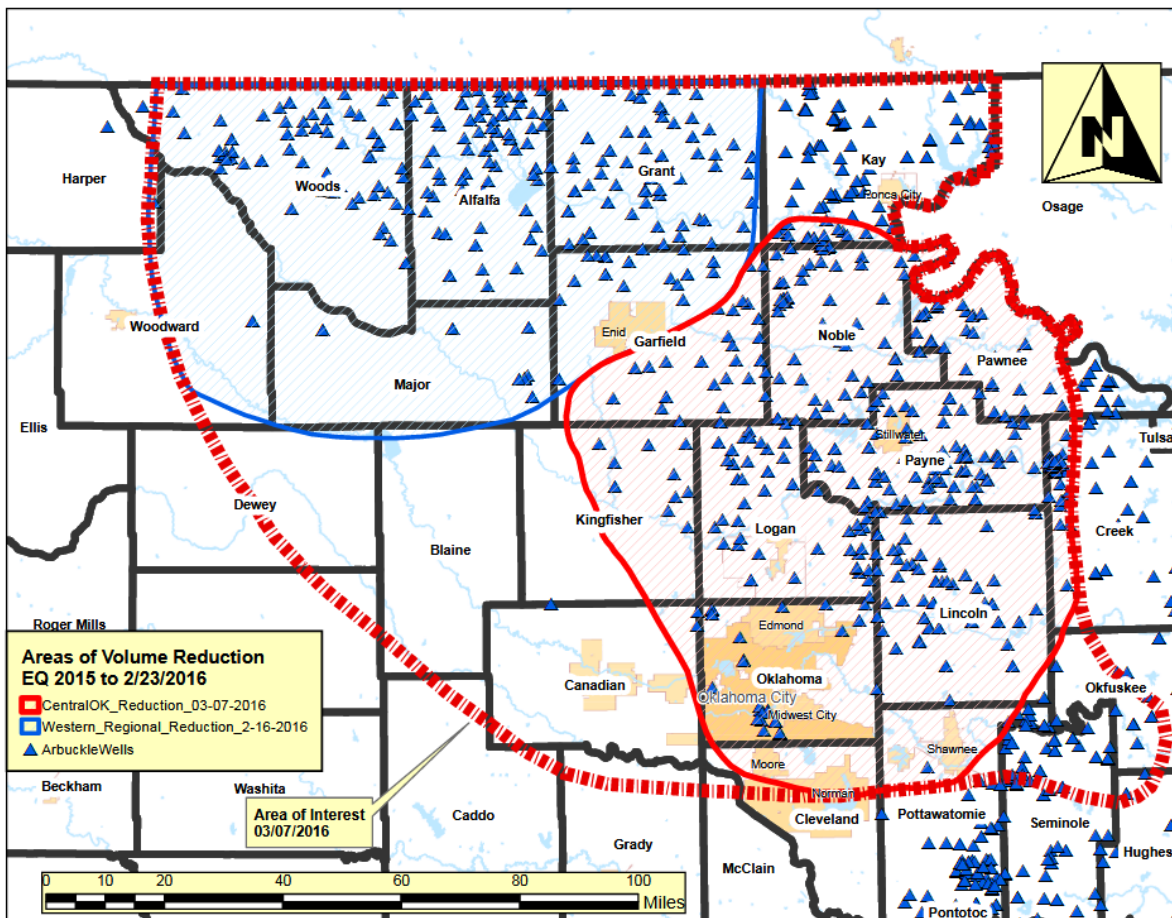
Earthquakes historically have not been associated within the scope of civil litigation regarding substantial property damage, along with personal injuries, until recently. Essentially, seismic activity has been directly related to “acts of God”, or as unforeseen and unpredictable catastrophic events. Currently, there is a plethora of litigation transpiring, solely linked to induced (humanmade) earthquakes, which are seen as a byproduct of the rapid development of hydraulic fracturing produced water injection wells. (McGarvey-Rosendahl 2016).

These now plausible cases pose as an immense threat to the “oil and gas industry, the insurance industry, and other sections of the economy”, and also to substantial realms of “existing law”, which could potentially have “profound consequences” for all of these industries (McGarvey-Rosendahl 2016). The Oklahoma Geological Survey (OGS) has concluded that the recent vast rise in seismic activity

experienced in their state was *“very unlikely to represent a naturally occurring process”*, due that the earthquakes transpired in the exact geographical location where there was an equal increase of hydraulic fracturing produced water disposal wells.

On March 7, 2016, the Oklahoma Corporations Commission (OCC) required fracturing well operators located in central Oklahoma to *“reduce by 40% the amount of oil and gas wastes being injected”* into disposal wells (McGarvey-Rosendahl 2016; OCC Oil & Gas Division 2016), which included over 400 wells. The OCC had already implemented a similar measure just one month earlier, that was successfully enforced in northwest Oklahoma, which also demanded that 400+ injection wells significantly reduce fracturing wastewater disposal. The OCC has affirmed that they will be forced to litigate against any company that refuses to comply with their ordered reductions in fracturing produced water injection.

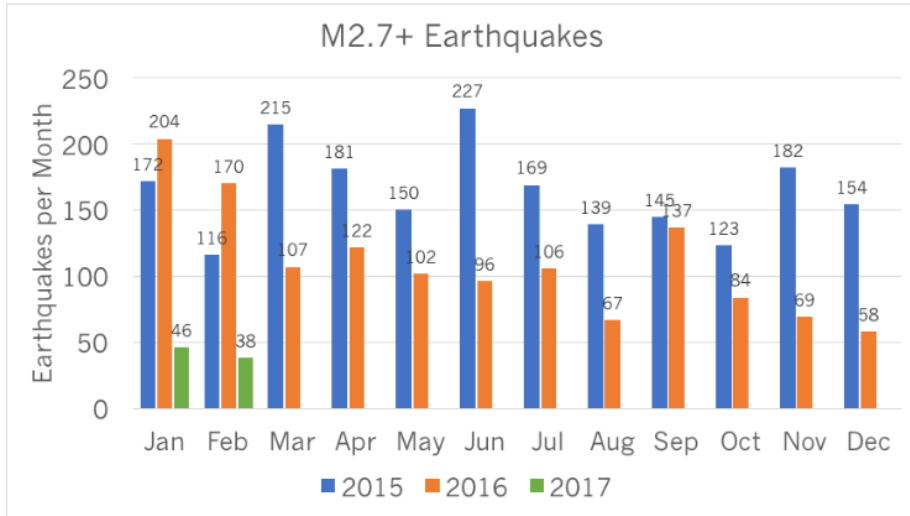
OCC: 2016 INJECTION INDUCED SEISMIC ACTIVITY RESPONSE PLAN



(Oklahoma Corporations Commission 2017)

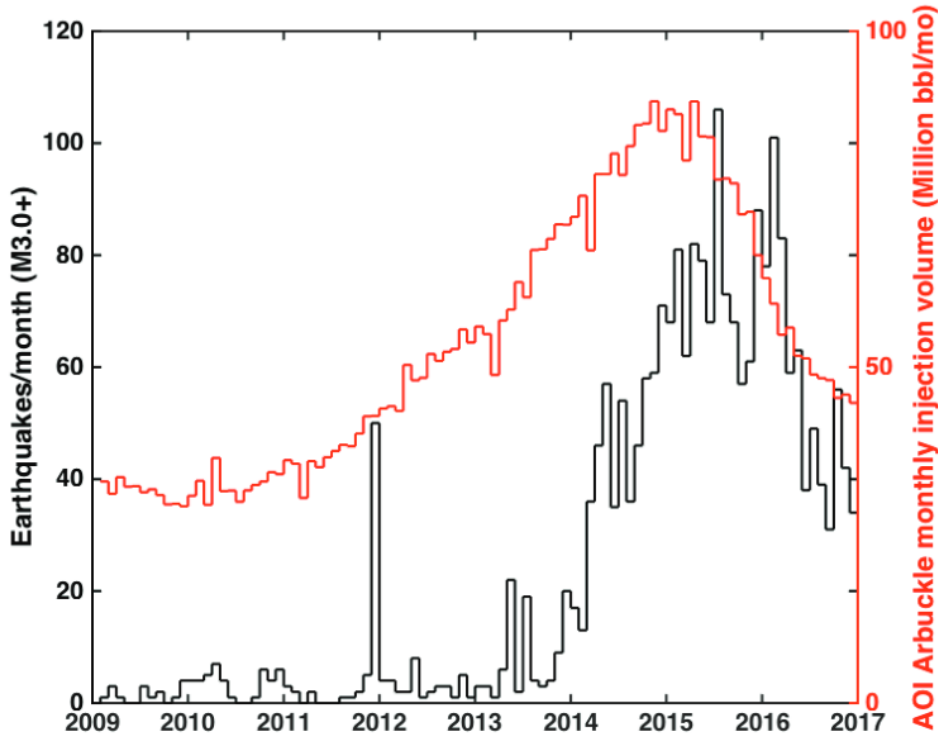
Figure 6: OCC. 2016. Regional earthquake response plan for central Oklahoma and expansion for areas of interest. Press Release 7 Mar 2016, p. 3. <http://earthquakes.ok.gov/wp-content/uploads/2015/01/03-07-16ADVISORY-AOI-VOLUME-REDUCTION.pdf>

INDUCED SEISMIC ACTIVITY v. VOLUME OF INJECTED PRODUCED FRACTURING SOLUTION



(Oklahoma Corporations Commission 2017)

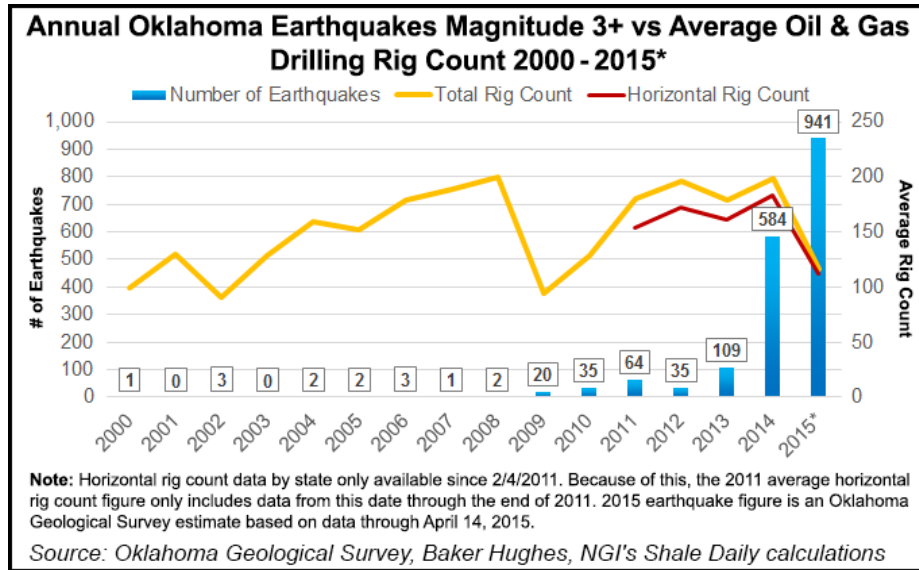
Figure 7: OCC. 2017. Statement regarding USGS seismicity hazard map. 1 Mar 2017, p. 2. <https://earthquakes.ok.gov/wp-content/uploads/2017/03/03-01-17OCC-OGS-JOINT-STATEMENT.pdf>



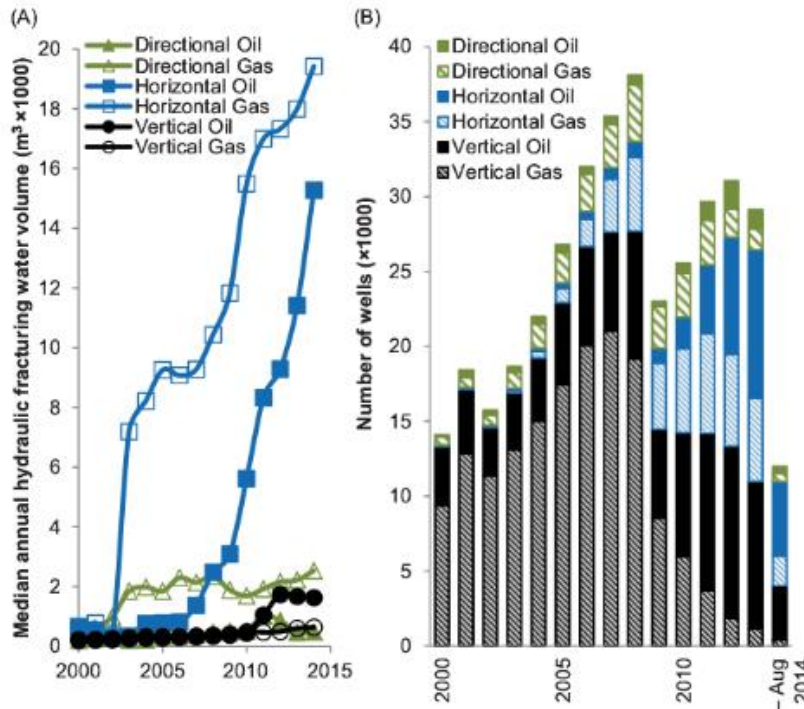
(Oklahoma Geological Survey 2017)

Figure 8: OGS. 2017. OGS (Oklahoma Geological Survey). 2017. OGS Statement on 2017 USGS assessment of continued seismic hazard in Oklahoma. 1 Mar 2017, p. 3. http://wichita.ogs.ou.edu/documents/OGS_Statement_USGS_Hazard_Map_2017.pdf

INJECTION INDUCED SEISMIC ACTIVITY (OK) v. RISE & FALL OF UNCONVENTIONAL METHODS



(Figure 9: Passut 2016; OGS 2016)



(Gallegos et al. 2015)

Figure 10: (A) Displays immense increase in the requirements for water volume necessary for unconventional hydraulic fracturing in the US from 2000 to 2014. The average water volume required per fracturing cycle, per well, in 2000 was approximately 177,000 gallons. In 2014, due to the rise of unconventional directional or horizontal drilling, that number climbed to over 5 million gallons per well, per fracture, for unconventional hydraulic fracturing methods (Gallegos et al. 2015; Krokus 2017).

SELECTED PENDING LITIGATION RESULTING FROM INDUCED SEISMIC ACTIVITY

State of Oklahoma



I....Adams v. Eagle Road Oil, LLC, No. CJ-2016-00078 (District Court of Pawnee Nation, Oklahoma, November 17, 2016), REMOVED, **No. 4:16-CV-00757-CVE-TLW** (United States District Court-North Oklahoma, December 21, 2016), REMANDED (April 12, 2017)

James Adams is the primary plaintiff involved this class action suit, which seeks to obtain property damages, fair market value loss, and also emotional harm, due to a 5.8 magnitude injection induced earthquake that occurred on September 3, 2016, in Pawnee, Oklahoma. This seismic activity was the most intense in state history. The defendants operate produced fracturing wastewater disposal wells, and are viewed as a principal contributor to the massive earthquake, and numerous subsequent aftershocks. Plaintiffs view the defendants' actions as *"ultrahazardous activities that necessarily involve a risk of serious harm to a person that cannot be eliminated by the exercise of the utmost care and is not a matter of common usage,"* and firmly believe the defendants are liable for property damages and emotional harm suffered as a *"direct and proximate result of defendants' activities."*

The US District Court of North Oklahoma believes that *"federal jurisdiction is available"* under 28 U.S.C. § 1355(a), or 25 U.S.C. § 345, regarding trespass violations conducted by the defendants.

Case is currently PENDING.

II...Reid v. White Star Petroleum, LLC, No. CJ-2016-00543 (District Court of Payne County, Oklahoma, December 5, 2016)

David Reid is the primary plaintiff involved this class action suit, which seeks to obtain property damages, fair market value loss, and also emotional harm, due to a 5.0 magnitude injection induced earthquake that occurred on November 7, 2016, in close proximity to Cushing, Oklahoma. Defendants operate produced hydraulic wastewater disposal wells, which are seen as a contributor to the massive earthquake, and numerous subsequent aftershocks. Plaintiffs view the defendant's actions as *"ultrahazardous activities that necessarily involve a risk of serious harm to a person that cannot be eliminated by the exercise of the utmost care and is not a matter of common usage"*, and firmly believe the defendants are liable for property damages and emotional harm suffered as a *"direct and proximate result of defendants' activities."*

December 30, 2016, *White Star Petroleum* moved to dismiss this class action suit. They contend that Oklahoma has refused *"market share liability"*, along with other various forms of *"collective liability."* Defendants believe that the operations conducted by their produced water injection wells are not considered *"an ultrahazardous activity as a matter of law."*

Case is currently PENDING.

III..Pawnee Nation of Oklahoma v. Eagle Road Oil LLC, No. CIV-2017-803 (District Court of Pawnee Nation, Oklahoma, March 3, 2017)

The Pawnee Nation of Oklahoma are the primary defendants in this case, stating that injection wastewater disposal wells initiated a 5.8 magnitude earthquake on September 3, 2016, which was a state record. This induced seismic activity severely damaged a majority of the Pawnee Nation of Oklahoma’s administrative buildings, and also caused extensive structural damage to numerous personal residences, and to multiple other buildings. The damage sustained was a result of 53 earthquakes that transpired between September and November 2016. According to the plaintiffs, the defendants have engaged in *“ultrahazardous activities that necessarily involve a risk of serious harm to a person that cannot be eliminated by the exercise of the utmost care and is not a matter of common usage.”*

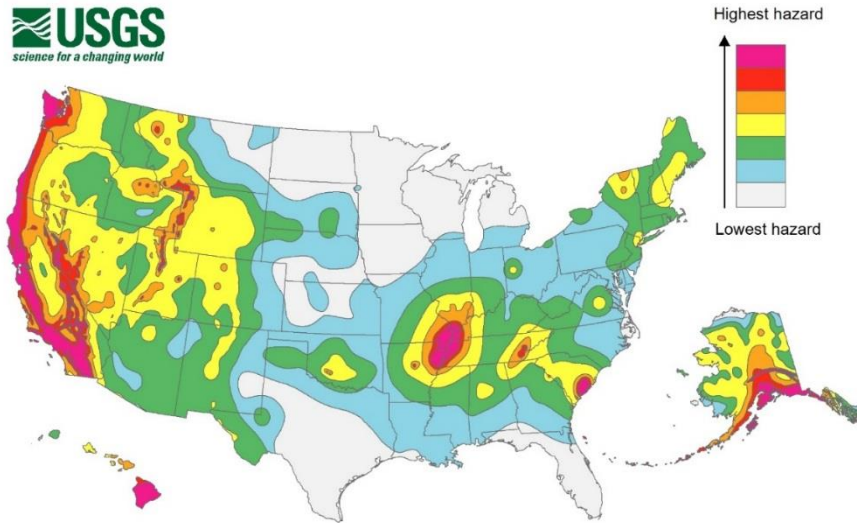
The Pawnee Nation of Oklahoma has previously filed a lawsuit against the U.S. Department of the Interior, Bureau of Indian Affairs, and the Bureau of Land Management, in federal court, on November 18, 2016. This case is regarding federal permits that were issued for hydraulic fracturing exploration on tribal lands, without first properly conducting an extensive environmental assessment before operations transpired. They are attempting to recover damages under the Resource Conservation and Recovery Act, 42 U.S.C. § 6972(a)(1)(B). In *Sierra Club v. Chesapeake Operating LLC*, 5:16-CV-00134, the plaintiffs attempted to recover from a similar complaint, wishing to receive declaratory and injunctive relief under U.S.C. § 6972(a)(1)(B), in the U.S. District Court of Western Oklahoma. Unfortunately, on April 4, 2017, the Court referred to the abstention doctrine established in *Burford v. Sun Oil Co.*, 319 U.S. 315 (1943), declaring that they should not exercise their federal jurisdiction in this particular case.

In *Montana v. United States*, 450 U.S. 544 (1981), the Supreme Court held that tribal governmental entities do not possess regulatory authority over non-Indians, stating *“although the Tribe may prohibit or regulate hunting or fishing by nonmembers on land belonging to the Tribe, or held by the United States in trust for the Tribe, it has no power to regulate non-Indian fishing and hunting on reservation land owned in fee by nonmembers of the Tribe.”* However, *“the tribe may regulate...activities of nonmembers who enter consensual relationships with the tribe or its members”*, or regulate *“the conduct of non-Indians on fee lands within its reservation when that conduct threatens or has some direct effect on the political integrity, the economic security, or the health and welfare of the tribe.”* The Supreme Court later applied this precedent established in *Montana v. United States*, regarding tribal civil adjudicatory authority in *Nevada v. Hicks*, 533 U.S. 353 (2001).

“It bothers us that the Pawnee Nation has asked for a moratorium on the Fracturing process conducted on our lands, and have largely been ignored. We have stated that we aren’t against oil and gas production, but we are certainly against methods which hurt our land base, minerals, and water. The earthquakes are a great motivator for us, to move to protect our land, resources, and people.”
(W. Bruce Pratt, President, Pawnee Nation of Oklahoma)

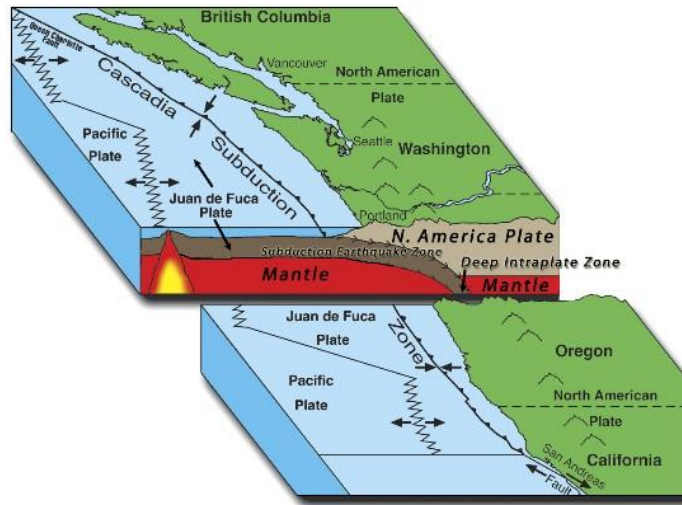
Case is currently PENDING.

USGS: SEISMIC ACTIVITY HAZARD MAP (NATURAL & INDUCED)



(Figure 11: USGS 2014c)

PACIFIC NW CASCADIA SUBDUCTION ZONE



(State of Oregon: Office of Emergency Management 2017)

Figure 12: This fault line has produced 41 earthquakes over the past 10,000 years. The time span in between occurrences has ranged between 190, and 1,200 years. The most recent seismic activity that emerged on this fault happened on January 26, 1700. Geologists predict a “40% chance that a megathrust earthquake ($M \geq 9$) will occur in the next 50 years”, and will “be felt throughout the (entire) Pacific Northwest” (State of Oregon: Office of Emergency Management 2017).

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