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ARTICLE: EARTHQUAKES IN THE OILPATCH: THE REGULATORY AND LEGAL ISSUES ARISING OUT OF OIL AND GAS OPERATION INDUCED SEISMICITY

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HIGHLIGHT: There has been a tremendous increase in earthquake activity in traditionally non-seismically active states, such as Oklahoma, Texas, Kansas, and Ohio. In fact, Oklahoma has surpassed California to become the most seismically active state in the United States. Over the last five years, many researchers have pointed to a correlation between seismic activity and certain oil and gas operations, such as wastewater fluid injection and hydraulic fracturing. Oil and gas companies, state regulatory agencies, and local and state governments are unsure of how to proceed given that most of this activity is occurring in states with a strong and economically vested interest in petroleum production. "Frackquake" litigation is on the rise in these states causing courts and parties to puzzle over causation. This Article reviews the geologic mechanism, scientific studies, applicable federal environmental legislation, state regulatory framework, and corresponding litigation related to oil and gas induced seismicity. Finally, this Article provides the foundation for further induced seismicity literature, in addition to offering strategies for and identifying challenges faced by stakeholders.
ABSTRACT

TEXT:
[*610] INTRODUCTION

The small, North Texas town of Azle, Texas (pop. 10,947) straddles the hydrocarbon-rich counties of Parker and Tarrant. [n1] Before the area became synonymous with the Barnett shale and its ensuing oil and gas development, Azle was best known as the home of Western author James Reasoner. [n2] Like most of Texas, it was not renowned for seismic activity. [n3] But all that was to change.

Between 1970 and 2007, Azle residents experienced just two earthquakes; [n4] by the start of 2008, residents reported seventy-four minor earthquakes. [n5] Around that same time, natural gas development activity climbed sharply as oil and gas operators moved into the area to develop Barnett shale prospects using a combination of horizontal drilling and hydraulic fracturing. [n6] By 2009, scientific research led some to conclude that fluid injection may be responsible for the seismic activity. [n7] Five years later, the seismic activity continued. [n8] Azle residents, frustrated with a perceived lack of action by the state, boarded a bus and traveled to the seat of Texas government. [n9] They named their trip, "Shake the Ground in

Austin." [n10] There, over 100 people attended a hearing of the state oil and gas regulatory agency--the Railroad Commission of Texas--which promised to study the seismic activity, but later denied any direct correlation with petroleum development. [n11] The next year, in 2015, a research team **[*611]** consisting of scientists at Southern Methodist University (SMU) in Dallas, the University of Texas at Austin, and the United States Geological Survey (USGS), the federal agency charged with, *inter alia*, studying and monitoring earthquake activity, concluded that oil and gas operations likely caused Azle's seismicity. [n12]

Induced seismicity is not a recent phenomenon. In the 1800s, English coal mines reported seismic activity after removal of overburden in search of coal; [n13] hydroelectric dams and geothermal energy operations have also caused seismic activity; [n14] and in the 1960s, the United States Army discovered that injection of fluids into the subsurface could induce earthquakes. [n15] However, with respect to oil and gas operations, induced seismicity is still a most unexpected and troubling phenomenon. [n16] After a spate of earthquakes in areas that were not historically seismically active, scientists began investigating a possible relationship with shale gas development. [n17]

Occurring in such states as Arkansas, Colorado, Kansas, Ohio, Oklahoma, and Texas, [n18] the earthquakes thus far have been small, with few injuries to persons or property. [n19] Public concern has led to scientific and academic studies focusing on wastewater reinjection and hydraulic fracturing as possible causes. [n20] Both processes are **[*612]** currently necessary to develop unconventional hydrocarbons, such as shale oil and gas and coal bed methane. [n21]

Many of these first studies originally classified hydraulic fracturing as low-risk with respect to seismic causation and concluded that there was no direct evidence that hydraulic fracturing triggers earthquakes; [n22] but, traditionally seismically inactive states, like Oklahoma and Kansas, continued experiencing an increase in earthquakes. [n23] In fact, in 2014, Oklahoma experienced twice as many earthquakes as California, a state recognized for its seismic activity. [n24] One year later, Oklahoma received the dubious honor of surpassing California and Alaska to become the most seismically active state in the country. [n25] To investigate this increase, scientists turned their attention to wastewater disposal wells. [n26]

In 2010, Congress requested that the National Academy of Science study the seismic events related to oil and gas operations. [n27] According to the resulting report, reinjection of wastewater posed a greater risk of man-made seismic events than hydraulic fracturing did. [n28] John Armbruster, of the Lamont-Doherty Earth Observatory at Columbia University, has been studying seismic events and hydraulic fracturing in Ohio and is "virtually certain" that wastewater reinjection caused a 4.0 magnitude tremor near Youngstown. [n29] Armbruster argues that "any disposal well that's been pumping stuff into the ground for months can cause earthquakes." [n30] In response to the tremors, Ohio state officials ordered four disposal wells in the **[*613]** area to close. [n31] In a March 6, 2015 press release, the USGS concluded that Oklahoma's heightened earthquake activity since 2009 was likely not caused by random fluctuations in natural seismicity rates, but rather by wastewater injected into deep geological formations. [n32]

Academic and scientific communities report various positive correlations regarding the induction of seismic activity by wastewater injection; however, the studies are ongoing and various stakeholders often question or dispute the conclusions. [n33] Whatever the science, the judicial and regulatory processes continue, leaving courts and regulators to review and decide the issues associated with induced seismicity *vis à vis* oil and gas development. [n34] Certainly, this lack of scientific certainty has not preempted an influx of induced seismicity litigation.

This article reviews the scientific theories and studies regarding induced seismicity, in addition to examining the current regulatory framework and litigation arising out of these seismic events. Lastly, it provides strategies to aid stakeholders and identifies challenges likely to arise in the future. Part I of this Article provides a review of the geoscience theories regarding natural and induced seismicity. [n35] Part II reviews the current scientific literature regarding a possible relationship between certain oil and gas operations and induced seismicity. [n36] Part III reviews the existing regulatory structure addressing seismicity in affected states, including possible applicable **[*614]** environmental legislation. [n37] Part IV discusses the resulting litigation involving oil and gas seismicity. [n38] Part V sets forth possible strategies for stakeholders. [n39] Finally, Part VI offers the author's conclusions, including identifying future areas of concern. [n40]

While this Article reviews and discusses various scientific studies regarding induced seismicity and the wastewater and hydraulic fracturing processes, it does not support or advocate any conclusion. It simply reports the findings issued by various scientific and engineering groups. Although the Article may address international examples, it focuses on the United States.

I. Review of the Current Science Regarding Natural and Induced Seismicity

Analyzing induced seismicity requires a basic understanding of how man-made events can generate earthquakes. This section provides a brief explanation of both naturally occurring and induced, sometimes referred to as "anthropogenic," seismicity. [n41] In the next section, this Article reviews the current literature regarding the possible relationship between seismic activity and two oil and gas operations--wastewater disposal and hydraulic fracturing. [n42]

A. Explanation of Natural Seismicity

Seismology is the study of elastic waves, including compressive waves such as sound waves and shear waves, in the earth [n43] and includes the "study of earthquakes and the structure of the earth, by **[*615]** both naturally and artificially generated seismic waves." [n44] Seismicity refers to the "geographic and historical distribution of earthquakes." [n45]

An earthquake generally occurs from the motions of the tectonic plates that make up the earth's lithosphere--"the solid, outer part of the [e]arth, including the brittle upper portion of the mantle and the crust." [n46] Originating in the 1950s and developing over two decades, the plate tectonics theory evolved out of Alfred Wegener's continental drift theory, first proposed in 1912. [n47] Plate tectonics theorizes that Earth's outer shell is divided into several tectonic plates--comprised of both continental and oceanic crust--that glide over the mantle--the rocky inner layer above the core. [n48] These plates "act like a hard and rigid shell compared to Earth's mantle." [n49] Although Wegener did not have an explanation for how continents could move around the planet, scientists now explain this movement using plate tectonics, which is considered geology's unifying theory. [n50]

Unlike puzzle pieces, the plates do not neatly connect with each other. [n51] Instead, they are part of a dynamic geologic process whereby they push up, slide against, and move away from each other. [n52] These movements result in varying terrestrial and planetary effects, such as earthquakes, but also include the creation of ocean floor, mountain ranges, and rift formations. [n53] On a larger geologic time scale, plate tectonics is responsible for the movement of the continents. [n54] The supercontinents Rodinia and Pangaea, which existed nearly one **[*616]** billion and 300 million years ago respectively, formed from the movement of the tectonic plates and have since been rifted apart by those same forces to form the current plate structure. [n55]

The release of stored stress energy "associated with rapid movement on active faults" causes most earthquakes. [n56] Although smaller micro-earthquakes rupture faults for only a small fraction of a second, [n57] the duration of very large earthquakes is measured in minutes. [n58]

Earthquake seismologists record seismic waves generated by earthquakes to understand the geometry and motion of Earth's internal structure. [n59] These waves "are generated at a *source*, which can be natural, such as an earthquake, or artificial, such as an explosion." [n60] Although "the term 'earthquake' describes a sudden shaking of the ground," [n61] geoscientists usually employ the term "to describe the 'source' of seismic waves, which is nearly always sudden shear slip on a fault within the Earth." [n62] These resulting waves travel through the earth and may be recorded by a ground receiver. [n63] Strong waves may be felt by people or may affect surface structures and are accordingly referred to as felt earthquakes. [n64] The receivers record ground motion when waves pass and collect various other information about a wave's origin and receiver arrival time. [n65] **[*617]** This data set allows for calculations of wave velocity and resulting properties of the medium through which the wave travels. [n66] In fact, petrophysicists employ similar data to understand and model subsurface oil and gas formations. [n67]

B. Induced Seismicity

Induced seismicity is earthquake activity caused by anthropogenic activities, including "fluid injection for waste disposal and secondary recovery of oil, geothermal energy production, oil and gas extraction, reservoir impoundment, mining and quarrying." [n68] It is often identified by increased seismic activity over historical levels. [n69] Thus, areas that experience "a certain level of seismic activity" before the artificial activity begins are likely to continue experiencing seismic activity. [n70] But, if seismicity increases after the onset of the human activity, induced seismicity may be the culprit. [n71] Further, if the seismic activity returns to historical levels after the artificial activity stops, it suggests the likelihood that the increase was due to induced seismicity. [n72]

Many scientific studies are underway regarding the possible mechanisms of induced seismicity. The term "mechanism" is preferable to "cause" as there is not a single cause of induced seismicity. [n73] Rather, induced seismicity likely occurs due to a complex system of subsurface stresses, fluid pressures, and fracture and faulting geology. [n74]

[*618] Subsurface rock formations contain porous spaces and fractures. [n75] Fluids may be present in these rock pores and fractures, causing an outward pressure termed "pore pressure." [n76] This pore pressure counterbalances the weight of the rock and its interstitial forces, resulting from tectonic forces. [n77] When pore pressures are low, especially compared to the stresses caused by the overlying strata, seismic activity results when imbalances of natural *in situ* earth stresses occur. [n78] When pore pressures increase, it takes less of this imbalance to trigger an earthquake, [n79] and seismicity accelerates. [n80] This type of failure is termed "shear failure." [n81] Injecting fluids into the subsurface artificially increases pore pressures, [n82] which can cause certain faults and fractures to slip, thereby releasing stored stress energy. [n83] Notably, not only can subsurface fluid injection induce seismicity, fluid extraction can also cause subsidence or slippage along planes of weakness in the earth. [n84]

Geoscientists have long been aware of induced seismicity by various human activities impacting the surface or subsurface. [n85] Such major activities include mining, water impoundment like dams and hydroelectric projects, waste disposal, and geothermal activities. [n86] Numerous studies observing and analyzing these activities "bear evidence to the presence of critically stressed rocks in the earth's crust, wherein small stress changes induced by human activity trigger earthquakes." [n87]

[*619] *1. Mining*

Seismicity in mining operations can occur when development compromises structural support of the mine. [n88] For example, in August 2007, in Utah's Crandall Canyon coal mine, six miners were trapped when a cavern carved from coal collapsed approximately 1,500 feet below the surface. [n89] Not only were the miners' bodies never recovered, three rescue workers died when a tunnel collapsed during the rescue operation. [n90] Although the mine owners initially claimed that the mine collapsed due to earthquakes, scientists at the Seismological Society of America's 2013 annual meeting discussed the possibility that the mine collapse may have caused seismic activity. [n91]

In these east-central Utah coalfields, scientists observed that seismicity caused by underground mining "is a well-recognized phenomenon that has been studied since the 1960s." [n92] Mining seismicity is often "attributed to underground mining because of its strong correlation with locations of active mining and very shallow focal depths." [n93] Here, the seismicity "is predominantly the result of: (1) implosions caused by partial or complete collapse of underground mine workings and (2) shear-slip motion on rock fractures." [n94]

Scientists now propose conducting research to determine whether monitoring earthquakes in mines may help predict the possibility of mine collapses. [n95] In fact, "researchers at the University of Utah identified up to 2,000 tiny, previously unrecognized earthquakes before, during[,] and after the coal mine collapse." [n96] Increasing the **[*620]** use of remote seismic monitoring may "reveal subtle patterns of tremors," which could help avert injuries and fatalities. [n97]

2. Water Impoundment

Seismicity caused by the impoundment of water--for example, water reservoirs and hydroelectric dams--is also a much-studied and recognized event. A global review of literature provides that there are "over [one] hundred proven or suspected 'reservoir induced seismicity' (RIS) cases since the classical case history of seismic activity at Lake Mead['s Hoover Dam] in 1936." [n98] Reservoir induced seismicity occurs when "physical processes that accompany the impoundment of large reservoirs" trigger earthquakes. [n99] It is consequently an important issue during impoundment and dam construction because of the potential to cause catastrophic structural failures. [n100]

"Hoover dam is one of the world's highest gravity dams and situated in [a] broadly aseismic area bordering Arizona and Nevada." [n101] Prior to dam construction, there was no record of any significant earthquakes in the region. [n102] Following impoundment of Lake Mead in 1935, a spurt of felt earthquakes occurred, giving some of the "first evidence of seismicity associated with water load." [n103] Notably, and similar to other RIS cases, there is a time lag between water impoundment and seismic activity. This phenomenon is adequately explained by the time needed for the diffusion of water to deeper levels to facilitate seismic slip at fault planes due to increased pore pressure. [n104]

[*621] In addition to the United States' Hoover Dam, another well-known example of RIS is Egypt's Aswan Dam, which is one of the four largest man-made reservoirs in the world. [n105] In 1981, six years after its final water level was attained, a moderate earthquake of magnitude 5.6 occurred in the prominent Kalabsha fault region. [n106] "The long and prominent Kalabsha fault naturally has involved the very shallow granitic basement and is also seismically active." [n107] Indeed, it is likely that the fault might have experienced microseismic activity prior to impoundment. [n108]

Factors favorable for RIS include volcanic terrain, fractured and porous basement rock, [n109] existing levels of seismicity, reservoir depth, etc.; "but the most dominant factor may be faults with high stress levels crossing the deeper parts of the reservoirs." [n110] Researchers acknowledge that more work needs to occur to isolate the "most effective factor responsible for RIS." [n111]

3. Waste Disposal

In the 1960s, the U.S. Military disposed of weapons waste into the subsurface within the Rocky Mountain Arsenal. [n112] After injection commenced, an unusual series of earthquakes occurred. [n113] The Military halted injection and later began extracting fluid from the Arsenal well at a very slow rate, hoping to decrease earthquake activity. [n114] The USGS conducted an experiment at the Arsenal to **[*622]** investigate the possible relationship between fluid injection and seismicity. [n115] Consisting of four tests between September 3 and October 26, 1968, the experiment's results prompted scientists and the Military to later agree that the fluid injections were responsible for the series of earthquakes in the area. [n116]

4. Geothermal Activities

Geothermal energy generation activities include those activities that utilize subsurface geothermal springs as a source of heat energy. "Induced seismicity associated with geothermal projects seems to be related in part to thermal contraction that results when the injected fluid contacts and cools hotter subsurface formations." [n117] Although they are a common source of induced seismicity, [n118] the U.S. Department of Energy considers such activities to be low-risk. [n119] A recent report estimates approximately thirty geothermal projects in the U.S. that collectively induce more than 300 felt seismic events per year. [n120]

II. Review of the Scientific Studies Regarding Induced Seismicity and Certain Oil and Gas Operations

Scientists previously observed that fluid injection could trigger earthquakes. In disposal wells, seismic activity resulted after fluid injection caused shock waves or fluids to "release strain on a preexisting fault." [n121] This high-pressure fluid squeezes into and pushes apart a planar fault, "freeing adjacent rock formations to slide **[*623]** past one another." [n122] The surmised phenomenon is often attributed to the injected fluid increasing pore pressure around a fault plane--or "lubricating the fault"--making it easier for a slip to occur. [n123] Given the increase in seismic activity in oil and gas regions, scientists have concluded that more research must and would be done on the relationship between wastewater reinjection and seismicity, and hydraulic fracturing and seismicity. [n124]

However, proving either relationship has been difficult because of a small data set with only a few discrete events. [n125] William Leith, USGS senior science advisor for earthquake and geologic hazards, believes that further "[s]cientific research needs to be done to understand the data on fluid injections and volumes." [n126] In fact, the USGS, "has re-established a project to study induced seismicity in response to the string of suspicious quakes in shale-gas areas." [n127]

Data is being collected in several states, including Illinois, Ohio, Oklahoma, and Texas. For example, in Ohio, during that state's recent onset of seismic activity, the USGS reported that over 300 earthquakes above a magnitude of 3.0 occurred between 2010-2012, "compared with an average rate of 21 events per year observed from 1967-2000." [n128] Though the magnitudes were small on a quantifiable scale, such as the Richter scale or moment magnitude scale, they were large enough for residents to notice them. [n129] The USGS studied the origin and cause of the earthquakes, in addition to asking what future measures should be taken to reduce the events and their associated risks. [n130]

[*624] Meanwhile, the Ohio earthquakes continued. In a study published in the journal Seismological Research Letters, the authors concluded that the hydraulic fracturing technology triggered a series of small earthquakes in 2013. [n131] In the Ohio seismic review, 400 small earthquakes occurred between October 1 and December 13, 2013. [n132] Prior to this spate of seismicity, there had been no known events in the area. [n133] Paul Friberg, a seismologist with Instrumental Software Technologies, Inc. (ISTI) and a co-author of the study, noted that, "[h]ydraulic fracturing has the potential to trigger earthquakes, and in this case, small ones that could not be felt, however the earthquakes were three orders of magnitude larger than normally expected." [n134] Hydraulic fracturing "involves injecting water, sand and chemicals into the rock under high pressure to create cracks [that . . .] result[] in micro-earthquakes." [n135] Review of the Ohio earthquakes also revealed an existing "east-west trending fault that lies in the basement formation at approximately two miles deep and directly below the three horizontal gas wells." [n136]

The study's key analysis "identified 190 earthquakes during a 39-hour period" between October 1 and 2, 2013, only hours after the commencement of a hydraulic fracturing operation on a nearby well. [n137] The study's data results, tracking micro-seismicity, corresponded with the fracturing activity at the wells. [n138] "The timing of the earthquakes, along with their tight linear clustering and similar waveform signals, suggest[ed] a unique source for the cause of the earthquakes--the hydraulic fracturing operation." [n139]

Conversely, researchers studying the "Jones swarm" of earthquakes in Oklahoma published their findings in *Science*, noting that "four high-rate disposal wells in southeast Oklahoma City **[*625]** probably induced a group of earthquakes . . . , which accounted for 20% of the seismicity in the central and eastern United States between 2008 and 2013." [n140] Researchers from Cornell University and the University of Colorado surmised that the activity was a result of "a few highly active disposal wells, where wastewater from drilling operations--including hydraulic fracturing--is forced into deep geological formations for storage." [n141]

Notably, only a small number of perceptible tremors have been reported out of almost 30,000 disposal wells across the country, the strongest of which, at that time, was equivalent to a 4.8-magnitude earthquake. [n142] But, there is no general scientific consensus. [n143] Frohlich believes it "almost impossible to say with certainty an earthquake is manmade . . . ." [n144] The National Research Council, the arm of the National Academy of Sciences which conducted the aforementioned report, found that "[w]hile the general mechanisms that create induced seismic events are well understood, we are currently unable to accurately predict the magnitude or occurrence of such events due to the lack of comprehensive data on complex natural rock systems and the lack of validated predictive models." [n145] By 2014, USGS acknowledged increased seismic activity coincided **[*626]** with wastewater injection, but failed to conclude that there was proof of a direct connection. [n146] Indeed, the Deputy Secretary of the United States Department of the Interior (DOI), which houses the USGS, stated that "[w]hile it appears likely that the observed seismicity rate changes in the middle part of the United States in recent years are manmade, it remains to be determined if they are related to either changes in production methodologies or to the rate of oil and gas production." [n147]

As additional data is collected and further studies performed, scientists are likely to make similar conclusions and reach a general scientific consensus about the causes of oil and gas induced seismicity. Presently, the two major theories appear to be wastewater injection and disposal, and hydraulic fracturing as triggers for seismic activity. [n148]

A. Theory One: Wastewater Injection Disposal

A majority of scientists accept that wastewater injection is capable of inducing seismic activity. [n149] During oil and gas operations, water injection primarily occurs as a disposal mechanism for wastewater generated by production and hydraulic fracturing. [n150] During the production process, exploration and production companies drill through the subsurface, targeting hydrocarbon-rich formations. [n151] These formations also contain salt water--essentially the brine from an ancient sea. [n152] Production companies cannot dispose of this non-potable salt water in public facilities or as effluent into a stream or **[*627]** other body of water because it often mixes with the produced hydrocarbons and various other minerals, chemicals, and sediments. [n153] Once the hydrocarbons and accompanying fluids flow through the production wellhead, the hydrocarbons separate from the salt water, and the salt water must be disposed of, often in deep disposal wells. [n154] Private companies and sometimes the oil and gas operator itself will operate a disposal well, [n155] which are usually depleted oil and gas wellbores. [n156] Wastewater is injected into the depleted geologic formation that formerly held oil and gas. [n157]

In addition to injection volume, other factors influence the probability of seismicity near wastewater disposal operations. [n158] For example, plate tectonics can dictate whether seismic activity will occur and in what magnitude. [n159] In Oklahoma, the plates are squeezing the region from east to west, which results in most earthquakes occurring along a northwest-southeast oriented fault. [n160] Further, a propensity for wastewater injection seismicity may be highly correlated to a region's geology. [n161] The Arbuckle formation underlies much of Oklahoma. [n162] Its porosity and geologic features allow for absorption of huge volumes of water, making it a good target for wastewater disposal. [n163] Unfortunately, it often "rests on brittle, ancient basement rocks, which can fracture along major faults under stress. [n164] Thus, "[t]he deeper you inject, the more likely it is that the injected brine is going to make its way into a seismogenic **[*628]** fault zone, prone to producing earthquakes." [n165] The resulting earthquakes range in magnitude depending on the geologic structure framework and regional *in situ* tectonic stress. [n166]

At present, there are approximately 30,000 injection wells permitted for the disposal of wastewater generated by oil and gas operations in the United States. [n167] But of those wells, only a "very small fraction" is suspected of inducing seismicity. [n168] Indeed, one recent report linked an estimate of nine such wells to induced seismic events. [n169] Although seismic events over the past few years likely have increased that number, even now, the fraction remains small. [n170] Nevertheless, in the last few years, geologists suspect that injection disposal induced hundreds of seismic events, though many were not felt events. [n171]

B. Theory Two: Hydraulic Fracturing

Another theory proposed by some scientists is that hydraulic fracturing itself may cause induced seismicity. n172 Hydraulic fracturing is a technology employed to release trapped hydrocarbons in unconventional reservoirs, such as shale. n173 A mixture of water, proppant--usually sand--and a small percentage of chemicals are mixed into a slurry and injected at high pressure into the wellbore, which is commonly deviated from vertical to horizontal during the drilling operation. n174 Very high pressure forces the slurry out of perforations in the casing and into the surrounding strata where it **[*629]** cracks the rock along natural zones of weakness--like throwing a rock against a car windshield. n175 The proppant acts as tiny wedges to hold the fractures open against the overburden pressure found at depth so that the hydrocarbons can flow through the fractures to the wellbore and up to the surface. n176 Prior to the flow of hydrocarbons, the injected fluids must be "flowed back" to the surface and removed from the wellbore. n177 This resulting waste is called "flowback" and consists of millions of gallons of water, brine, sediment, chemicals, and residual proppant. n178 Not all the injected fluid is recovered; some remains trapped in the reservoir. n179

At the 2012 annual meeting of the American Geophysical Union, Austin Holland of the Oklahoma Geological Survey suggested that "about 2 percent of the oil and gas wells hydraulically fractured in [Oklahoma] in the past [2.5] years were followed within 21 days by a quake within about five miles of the well." n180 Interestingly, Holland's fellow panelists did not agree with his conclusions. n181 Arthur McGarr, a geophysicist with the Earthquake Science Center at the USGS, and Cliff Frohlich, associate director of the Institute for Geophysics at the University of Texas at Austin, both stated that "injection wells, rather than fracturing, can likely trigger quakes." n182 At the time, many in the scientific and academic communities **[*630]** believed that, though these conclusions did not completely eliminate the possibility that there was a connection, it remained to be proven whether such causation in fact existed. n183

Some mainstream media outlets continue to suggest that hydraulic fracturing is responsible for the recent increase in seismic activity. n184 But scientists uniformly agree that the seismicity increase is more likely a result of injection disposal. n185 Recent studies indicate that hydraulic fracturing "is distinct from many types of shear-induced seismicity, because [hydraulic fracturing] by definition occurs only when the forces applied create a type of fracture called a tensile fracture, or 'driven' fracture." n186 Scientists observe that hydraulic fracturing "is such a small perturbation, it is rarely, if ever, a hazard when used to enhance permeability in oil and gas or other types of fluid-extraction activities." n187 And in fact, hydraulic fracturing "to intentionally create permeability rarely creates unwanted induced seismicity that is large enough to be detected on the surface--even with very sensitive sensors--let alone be a hazard or an annoyance." n188 Finally, another reason why induced seismicity caused by hydraulic fracturing is unlikely "is that such operations are of relatively low volume and short duration (hours or days at the very most), compared to months and years for the other types of fluid injections . . . ." n189

However, researchers have not discarded the theory that hydraulic fracturing may trigger earthquakes, as demonstrated by the aforementioned studies. Some scientists believe that hydraulic fracturing induces seismicity in unusual geologic circumstances. n190 **[*631]** For example, it is commonly estimated that more than one million wells have been hydraulically fractured; n191 but there are only about six or so locations worldwide where evidence suggests that hydraulic fracturing may have induced seismicity. n192 One of these locations is the Horn River basin area in British Columbia. n193 There, the British Columbia Oil & Gas Commission investigated a series of thirty-eight earthquakes that occurred in the area between 2009 and 2011. n194 The earthquakes ranged from 2.2 to 3.8 in magnitude. n195 Only one was a felt event. n196 The provincial commission concluded that hydraulic fracturing induced the earthquakes. n197 In Garvin County, Oklahoma, a series of earthquakes measuring between 1.0 and 2.8 in magnitude occurred in 2011. n198 An Oklahoma Geological Survey report concluded that evidence suggested "a possibility these earthquakes were induced by hydraulic-fracturing," but that it was "impossible to say with a high degree of certainty." n199

[*632] *III. Review of the Likely Applicable Regulatory Framework Governing Induced Seismicity*

A. Federal Regulations

The novelty of earthquakes induced by oil and gas operations (hereinafter referred to as "oil and gas induced seismicity") correctly suggests paucity in applicable regulations governing the triggers. n200 Because regulating oil and gas activities is the traditional domain of the state, there are consequently more state than federal regulations. n201 However, current federal regulations and environmental legislation may apply.

1. Bureau of Land Management Regulations

The Bureau of Land Management (BLM) is the federal agency charged with management of the surface of and minerals on federal lands. [n202] In particular, the agency is responsible for oil and gas leasing and development on onshore lands owned by the federal government. [n203] Current litigation regarding hydraulic fracturing regulation leaves BLM's oversight regarding oil and gas induced seismicity uncertain. [n204] In October 2015, the United States District Court for the District of Wyoming enjoined the BLM's hydraulic fracturing rules. [n205] These rules specified new requirements for well construction, water management, and chemical disclosure for hydraulically fractured wells on public and tribal lands. [n206] The Court blocked enforcement of the new regulation to consider various state **[*633]** and industry challenges. [n207] Upsetting years of BLM rule-making regarding hydraulic fracturing, the Court decided that "[t]he Obama administration [did] not have authority to regulate hydraulic fracturing on public lands." [n208] Judge Scott Skavdahl opined that "[o]ne of the fundamental questions presented in this case is whether Congress granted or delegated to the BLM the authority or jurisdiction to regulate fracking," concluding that Congress has not likely granted or delegated the requisite authority. [n209]

In the case of induced seismicity, the BLM may likely promulgate rules designed to monitor (1) waste water disposal injection and (2) hydraulic fracturing with respect to seismicity. However, the above case indicates that the latter may be more difficult to pursue. Indeed, supporters of the rule, including the Department of the Interior and the environmental community, argue that the "BLM has broad authority to regulate oil and gas production on federal land and that increased [hydraulic fracturing] regulation is crucial to ensure safety and environmental protection." [n210]

2. National Environmental Policy Act

The National Environmental Policy Act (NEPA) is heralded as the "first major statute of the modern era of environmental law." [n211] Rather than utilizing technology forcing standards or market requirements, NEPA requires that actors review relevant information "to consider the environmental impacts of their proposed actions and alternatives." [n212]

Under NEPA, federal agencies, such as the BLM, must prepare an environmental impact statement (EIS) for "major Federal actions significantly affecting the quality of the human environment." [n213] Such actions subject to NEPA include those that the federal **[*634]** government can prohibit or regulate. [n214] NEPA requires the agency to prepare an Environmental Assessment (EA), a "concise public document" that briefly provides "sufficient evidence and analysis for determining whether to prepare an [EIS] or a finding of no significant impact [('FONSI')]." [n215] If the agency determines a FONSI, an EIS is not required. Otherwise, if the federal action does not qualify for a FONSI--meaning the action will significantly impact the public's environmental quality--the agency must prepare an EIS. [n216] An EIS includes: (1) analysis of direct, indirect, and cumulative impacts of the proposed action; (2) evaluation of mitigation measures and provision of reasonable alternatives; and (3) solicitation of and response to public comments. [n217]

In the oil and gas operational context, the BLM must abide by NEPA when granting applications to drill (APD) oil and gas wells on federal and tribal lands. [n218] Recently, environmental groups and other stakeholders have argued that the BLM has not complied with its duties under NEPA to undertake the proper analysis with respect to induced seismicity. [n219] But, the relative lack of science appears to make these arguments rare. Although oil and gas operators are not incentivized to include controversial information in a new NEPA document for fear of denials or challenges, this lack of information may only serve to weaken the application, resulting in delays. [n220] Developments in science and technology may lead to a requirement that applicants provide information regarding potential induced **[*635]** seismicity issues. [n221] But, it is also likely the courts will become more heavily involved in NEPA interpretation. Either way, operators can expect setbacks and administrative or legal challenges to their projects. [n222]

3. Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) "regulates contaminants in drinking water supplied by public water systems and requires the [Environmental Protection Agency] (EPA) to set national drinking water regulations that incorporate enforceable maximum contaminant levels or treatment techniques." [n223] Specifically, the SDWA works to prevent the release of toxic contaminants in water from underground sources, such as landfills and--relevant to this article--underground injection wells. [n224] The Underground Injection Control (UIC) regulations affect those wells where fluid is injected subsurface into geologic formations. [n225] Injected fluids typically include wastewater such as brine and chemical-mixed water. [n226]

The UIC program protects underground sources of drinking water from endangerment by setting minimum quality requirements for injection wells. [n227] Therefore, injection requires authorization under either general rules or specific permits. [n228] "Injection well owners and operators may not site, construct, operate, maintain, convert, plug, or abandon wells or conduct any other injection activity that endangers underground sources of drinking water." [n229] The UIC program seeks to ensure that either (1) injected fluids stay within the well and the intended injection zone or (2) fluids that are directly or indirectly injected into an underground source of drinking water do not cause a **[*636]** public water system to violate drinking water standards or otherwise adversely affect public health. [n230]

The EPA organizes injection wells into six classes, ranging from Class I to VI. [n231] A specific set of technical requirements and regulation applies to each well class. [n232] Class II injection wells are used to inject fluids associated with oil and gas production. [n233] Under the Class II classification, wells are either (1) disposal wells, (2) enhanced recovery wells, or (3) hydrocarbon storage wells. [n234] There are approximately 180,000 Class II wells in operation in the country, about 80% of which are enhanced recovery wells. [n235]

Under the SDWA, "[s]tates (including federally recognized tribes and U.S. territories) have the option of requesting primacy for Class II wells," and indeed, a majority has primacy. [n236] States must meet EPA's minimum requirements for UIC programs under Section 1422. [n237] Disposal wells require permits that entail owners or operators meet all applicable requirements, including strict construction and conversion standards and regular testing and inspection. [n238] Section 1425 provides that states must demonstrate that their existing standards are effective in preventing endangerment of underground sources of drinking water. [n239] "These programs must include requirements for (1) permitting, (2) inspection, (3) monitoring, (4) record-keeping, and (5) reporting." [n240]

From an induced seismicity perspective, concerned parties may seek to utilize the UIC to regulate oil and gas operator activity with respect to wastewater injection and hydraulic fracturing operations to **[*637]** curb or prevent seismic activity. However, in the sweeping Energy Policy Act of 2005, Congress exempted hydraulic fracturing--provided there is no use of diesel fuel--from the SDWA. [n241] Hydraulic fracturing is therefore "excluded from the definition of underground injection" and not subject to UIC regulation. [n242] Although some operators used to mix diesel fuel in the injected slurry during the hydraulic fracturing process, today most operators prohibit the injection of diesel fuel. [n243] The UIC program is thus not likely to apply to suspected seismic activity possibly resulting from hydraulic fracturing; it is, however, likely to arise in the wastewater disposal context. [n244]

B. State Regulations

States are the traditional fora for regulation of oil and gas operations. [n245] As such, top oil and gas producing states are developing regulations in response to this relatively little-known area of oil- and gas-induced seismicity. [n246] Regulatory difficulties arise as induced seismicity "is a complex issue where the base of knowledge is changing rapidly." [n247]

1. Oklahoma

Oklahoma is the troubled heart of induced seismic activity. In 2014, the state experienced 585 magnitude 3-plus earthquakes, a **[*638]** five-fold increase from 2013. [n248] It now has the unfortunate distinction of being the most seismically active state in the United States. [n249] Scientists have observed a relationship between produced water disposal from oil and gas production operations and triggered seismic activity. [n250] With over 4,200 disposal wells in the state--3,600 actively used--wastewater injection volumes have doubled in six years, from 800 million barrels in 2009 to 1.5 billion barrels in 2014. [n251]

In January 2011, "small earthquakes of magnitude 2.9 and lower were allegedly induced by hydraulic fracturing activities," [n252] while wastewater disposal injection was the alleged cause of the November 2011 magnitude 5.7 earthquake--the largest recorded in Oklahoma. [n253] A destructive earthquake in the vicinity of Cushing, Oklahoma--home to one of the largest oil storage hubs in the world--could have global financial consequences. [n254]

Scientists from state and federal institutions began studying the activity to determine causes and correlations. An increase in oil and gas development activity leads to an increase in wastewater production. [n255] Thus, operators bear the burden of disposing of greater volumes of water, often at higher pressures, in the same decades-old Class II UIC wells. [n256] Even though Oklahoma Class II UIC wells fall under the state permitting purvey, traditionally Oklahoma did not consider seismicity risk during its permitting process. [n257] Rather, its consideration focused on risks related to underground sources of drinking water. [n258] Therefore, regulators and state officials faced **[*639]** difficulty determining a clear connection between wastewater disposal operations and seismicity. [n259] This difficulty was "exacerbated in part by the vast number of UIC wells and earthquakes in the area." [n260] Finally on April 21, 2015, the Oklahoma Geological Survey (OGS) "determined that the majority of recent earthquakes in central and north-central Oklahoma [were] very likely triggered by produced water disposal." [n261] The OGS "issued a public statement that rates and geographical patterns of seismicity observed in the state 'are very unlikely to represent a naturally occurring rate change and process.'" [n262] State geologists Richard Andrews and Austin Holland concluded that the "primary source for suspected triggered seismicity [was] not from hydraulic fracturing, but from the injection/disposal of water associated with oil and gas production." [n263]

The identification of a likely source of induced seismicity--wastewater disposal--allowed regulators and legislators to establish regulations governing operations. Adopting an approach supportive of the oil and gas sector, a large and dominant industry in Oklahoma, Governor Mary Fallin maintained the state's position that the Oklahoma Corporation Commission (OCC or the Corporation Commission), which regulates state oil and gas operations, retains exclusive authority over oil and gas operations in the state. [n264] However, with swift execution in September 2014, the Governor "directed the Oklahoma Secretary of Energy and Environment to assemble the Coordinating Council on Seismic Activity." [n265] The council's "primary responsibility is to work cooperatively to develop solutions, identify gaps in resources[,] and coordinate efforts among state agencies, researchers and the state's oil and gas industry." [n266] In January 2016, Governor Fallin further approved a $ 1.38 million **[*640]** transfer of state emergency funds to support earthquake research by certain state agencies, including the OGS. [n267] State agencies will use this funding to increase seismic monitoring in the state and hire additional geoscientists. [n268]

From the regulatory perspective, the Corporation Commission has done much to address seismic activity, while continuing oil and gas operations in the state. [n269] The OCC, an independent agency with three statewide elected commissioners, is "statutorily granted exclusive jurisdiction over the conservation of oil and gas and Class II UIC wells." [n270] And although it has legal authority "to take extraordinary measures in the interest of public safety, without notice and hearing," [n271] the OCC "normally operates under its general authority to permit oil and gas and UIC well operations." [n272] Following the state legislature, the Corporation Commission, too, "disavowed a moratorium on injection operations." [n273]

Recently, the OCC instituted several state regulations pertaining to wastewater disposal. [n274] Some of these regulations include the large-scale regional reduction in oil and gas wastewater disposal within an approximate 5,000 square mile radius in Western Oklahoma. [n275] This reduction affects over 200 disposal wells in the Arbuckle formation, identified as a formation predisposed to seismic activity. [n276] The OCC also ordered certain injection well operators to reduce wastewater disposal volumes on five wells operating within ten miles of the center of earthquake activity near Edmond, Oklahoma, a prosperous suburb north of Oklahoma City that suffered an earthquake in January 2016. [n277] But, operators are sometimes reluctant to shut down **[*641]** operations given the current low-price commodity environment and economic ramifications of halting operations. For example, SandRidge Energy, an Oklahoma corporation, faced financial distress and bankruptcy in early 2016, [n278] but it refused to shut down its disposal wells after the Commission ordered it to do so, [n279] arguing that shutting down its disposal operations would harm its physical operations, leading to negative financial impacts. [n280] Litigation commenced between the Corporation Commission and SandRidge, and the parties later settled. [n281]

The Corporation Commission has also been working with its sister agency, the Oklahoma Geological Survey, to identify faults in the state. [n282] The OGS disclosed a preliminary map of known faults. [n283] Realizing the importance of identifying the state's faulting system, the OGS began compiling a fault database with voluntary contributions from the Oklahoma Independent Petroleum Association, the state's largest oil and gas industry association. [n284]

2. Texas

Texas is the largest energy producer in the United States. [n285] And like Oklahoma, Texas faces considerable challenges balancing citizen and property concerns with the interests of a robust oil and gas **[*642]** sector. Texas is taking a slightly different path than its northern neighbor, Oklahoma, perhaps due to the fact that its earthquakes have not been as severe or frequent as Oklahoma's. Residents in the Barnett shale area of north Texas complained of earthquakes as early as 2006. [n286] But, the Railroad Commission of Texas (the RRC or Railroad Commission) denied any correlation between oil and gas operations and seismic activity. [n287] However, in recent years, and after several studies conducted by scientific and academic institutions, the RRC has moved forward with some actions relating to induced seismic activity. But some in the agency continue to deny oil and gas induced seismicity. [n288]

In 2014, the Railroad Commission amended its rules concerning wastewater disposal. [n289] Beginning November 17, 2014, "disposal well operators must research US Geological Survey data for a history of earthquakes within 100 square miles of a proposed well site before applying for a permit." [n290] The Commission also has the ability to modify or rescind a permit if it determines that the well may be contributing to seismic activity. [n291] Confident that the new measures did not substantially increase the cost of operations, the RRC estimated that the new rules "would cost companies an additional $ 300." [n292] The Commission also hired seismologist Craig Pearson, who advised a newly-formed Texas House of Representatives' Subcommittee on Seismic Activity that "regulations would help make sure injected wastewater does [not] migrate onto inactive fault **[*643]** lines and cause man-made quakes." [n293] Though Pearson noted that "most of the earthquakes occurring in Texas are too small to be felt," [n294] some scientific groups warned that the accumulation of fracturing and wastewater injection activities may result in stronger seismic movement. [n295]

But Texas falls short of Oklahoma's acceptance regarding oil and gas induced seismicity. The Railroad Commission stated that there was not yet a clear link to oil and gas activity despite a recent study by Southern Methodist University seismologists in Dallas. [n296] The SMU team, also consisting of The University of Texas at Austin and the USGS, studied the Azle-Reno earthquakes and concluded that wastewater disposal wells represented "the most likely cause of recent seismicity." [n297] The team is now turning its efforts to study the earthquakes in Irving, Texas. [n298] Undoubtedly the SMU team was troubled by the Railroad Commission's statement from Commissioner and mechanical engineer Ryan Sitton that it is "virtually impossible" for wastewater wells to be causing earthquakes in Irving and by the Commission's questioning the SMU study's alleged lack of conclusive data. [n299] Commissioner Sitton's comments may have reflected the absence of working disposal wells in the affected area. Subsequent to his comments, the SMU study theorizes that disposal wells in Johnson County, about fifteen miles away, may be responsible for the activity.

But even given the Texas regulator's doubts, the Texas legislature created the TexNet Seismic Monitoring Program, to be overseen by **[*644]** The University of Texas. [n300] The legislature approved the program last year with $ 4.5 million, including the creation of an Integrated Seismicity Research Center housed at The University of Texas **Bureau of Economic Geology.** [n301] Twenty-two permanent seismograph stations will be installed throughout the state, in addition to thirty-six temporary seismometers to deploy in areas of scientific interest. [n302] Given the increase of seismicity in the country's largest oil and gas producing state, Texas legislators and regulators may have to implement additional protective efforts.

3. California

California is in the unique position of being the country's fourth largest oil and gas producer and one familiar with earthquakes. [n303] In fact, prior to 2014, California was the country's most seismically active state. [n304] Thus, the state comfortably adopted regulations regarding oil and gas induced seismicity using its seismology experience. In 2014, the California legislature approved Well Stimulation Treatment Regulations, codified in Chapter 313. [n305] The regulations require reporting of seismic activity greater than a magnitude of 2.7. [n306] If earthquakes of magnitude greater than 2.7 occur, the State requires examination of past, lesser earthquakes to determine any patterns associated with well operations. [n307] In 2015, legislators introduced Well Stimulation Treatments: Seismic **[*645]** Activities. [n308] The bill, defeated in committee, would have placed a moratorium on nearby hydraulic fracturing operations if earthquakes with magnitude greater than 2.0 occurred. [n309] Oil and gas operations would not be able to resume until the state oil and gas regulatory agency--the California Division of Oil, Gas and Geothermal Resources--made a safety determination. [n310] To put these requirements in perspective, Oklahoma currently has approximately two magnitude 2.0 or greater earthquakes each day. [n311] The bill also would have prohibited wastewater disposal wells and all well-stimulation activity like hydraulic fracturing within ten miles of a fault active at any point in the past two hundred years. [n312]

Given the flux of academic and scientific studies, it is clear that producing states prone to seismicity will continue to look to each other for ideas on how to--and how not to--proceed.

IV. Litigation Involving Induced Seismicity

Litigation involving oil and gas induced seismic activity, sometimes misleadingly called "frackquakes," is on the rise. [n313] Plaintiffs in oil and gas producing states are filing lawsuits, including class actions, alleging claims ranging from common torts to environmental law violations. [n314] Popular common tort causes of action include negligence, private and public nuisance, and trespass. [n315] Personal injury and property damages may also be claimed, depending on the seismic event. [n316] While damages resulting from natural seismicity are usually excused as acts of God, induced **[*646]** seismicity involves human interference. [n317] The difficulty then for plaintiffs is that "[a] direct chain of causation [must] be established between the inducing activities, the [earth]quakes and the resulting damage." [n318] Causation remains the major barrier for plaintiffs to overcome and the major defense strategy for defendants. [n319]

Some lawsuits advance a strict liability theory, arguing that oil and gas operations, and in particular hydraulic fracturing, are a form of ultra-hazardous activity, which is not always the law of the state. [n320] An ultra-hazardous activity classification would give rise to strict tort liability. [n321] "Strict liability for damage caused by induced earthquakes can be based on trespass law, the doctrine of *Rylands v. Fletcher*, or the tests of the First and Second Restatements of Torts." [n322] But in states where strict liability is not recognized for oil and gas operations, "negligence may provide a basis for liability." [n323]

Lawsuits have been filed in both state and federal court in Arkansas, Texas, and Oklahoma, with most, if not all, resulting in settlement. [n324] One of the most high-profile cases regarding oil and gas induced seismicity is *Ladra v. New Dominion, LLC et al.*, arising out of an Oklahoma district court. [n325] Plaintiff Sandra Ladra sued **[*647]** Defendants New

Dominion, LLC and Spess Oil Company in the District Court of Lincoln County for injuries she sustained during an earthquake allegedly related to Defendants' wastewater disposal wells. [n326] Ladra argued that Defendants were liable for injuries to her knees and legs "after a 5.0 magnitude earthquake struck near her home, which may have caused the rock facing on the two-story fireplace and chimney to fall" in her living room. [n327] Although Ladra claimed that Defendants' wastewater injection wells proximately caused her injuries, the district court ruled that she failed to exhaust her administrative remedies before the Oklahoma Corporation Commission and dismissed her case. [n328] The district court further ruled that the OCC has exclusive jurisdiction over cases involving oil and gas operations. [n329]

On appeal, the Oklahoma Supreme Court reversed the lower court, rejecting Defendants' argument that the OCC possessed jurisdiction to decide the case. [n330] The court explained that while "the OCC has exclusive jurisdiction over the exploration, drilling, development, production and operation of wells," [n331] its "jurisdiction is limited to the resolution of public rights, and it lacks jurisdiction over disputes between two or more private persons or entities not involving public rights." [n332] In its opinion, the Oklahoma Supreme Court held that Defendants "confused the OCC's role in regulating oil and gas exploration and production activities with the state's jurisdiction over a plaintiff's right to seek a remedy when common law rights are violated." [n333] The court "reversed the trial court and remanded for a determination of whether Ladra should be awarded damages." [n334] Commenting on the decision, the Oklahoma Oil & Gas Association--a state oil and gas industry trade group--maintained **[*648]** that "even with this ruling, there has been a general inability to connect any specific earthquakes to any specific oil and gas operations, . . . [and a]s a result, [it anticipates] that the plaintiffs in any cases of this kind will face a significant obstacle in trying to make the required evidentiary showings that are needed in order to succeed in their lawsuits." [n335]

In a similar lawsuit filed January 15, 2016, twelve "residents of Oklahoma City and its suburbs filed a lawsuit against oil and gas drillers and operators of wastewater injection wells following two earthquakes in central Oklahoma." [n336] The plaintiffs in *Felts v. Devon Energy Prod. Co.* complained of negligence and strict liability arising out of Defendant Devon's underground injection of wastewater from oil and gas operations. Plaintiffs argued that these operations "are the proximate cause of 'unnatural and unprecedented' earthquakes in the area." [n337] This litigation is ongoing. [n338]

Another type of oil and gas induced seismicity litigation involves the allegation of violations of environmental statutes. On February 16, 2016, Sierra Club and Public Justice filed a federal lawsuit against Devon Energy Corporation, Chesapeake Energy Corporation, and New Dominion, LLC--three large Oklahoma energy companies. [n339] Plaintiffs brought the lawsuit under the citizen suit provision of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act. [n340] And in *Reese River Basin Citizens Against Fracking, LLC v. Bureau of Land Mgmt., et al.*, [n341] Nevada landowners tried halting fracturing in the state, **[*649]** claiming the U.S. government decided to sell oil and gas leases without fully studying all environmental risks, including an increased threat of earthquakes. [n342] The lawsuit was dismissed on September 8, 2014, for lack of subject matter jurisdiction. [n343]

Other issues remain in the litigation context. For example, *Warren Drilling Co. v. Equitable Prod. Co.* involved an indemnification lawsuit between a drilling company and operator over a tort action brought by property owners against both parties for alleged contamination of their water supply. [n344] Plaintiff property owners alleged that their water had been contaminated by oil and gas operations. [n345] From an earthquake context, future plaintiffs may argue that induced seismicity caused degradation or damage to wellbores or subsurface fractures that consequently allowed oil and gas fluids to migrate from the wellbore to the water supply. Other litigation ramifications include the "earthquake effect" on jurors. [n346] In *Hiser v. XTO Energy, Inc.*, the appellate court ruled that the oil and gas producer was not entitled to a new trial in a homeowner action for damages caused by drilling vibrations even though jurors discussed earthquakes because the content precluded any possibility of prejudice. [n347]

Oil and gas induced seismicity litigation is likely to increase. [n348] Plaintiffs will face major challenges proving causation; and defendants remain burdened with the task of fighting plaintiffs with little or no scientific expert testimony and who are angling for quick settlements.

[*650] *V. Proposed Strategies for Stakeholders*

The most difficult challenge with respect to oil and gas induced seismicity is the relative lack of data and uncertainty about the relationships between wastewater disposal and seismicity and hydraulic fracturing and seismicity. This challenge is further compounded by a lack of proposed solutions to prevent seismicity, aside from the idea of halting all disposal activities and other oil and gas related operations under state or local moratoria and bans. Developing solutions and responses should preclude prohibitions on oil and gas operations. Given the reliance on, and importance of, domestic oil and gas production, it is critical to understand that imposing moratoria or bans on wastewater disposal or hydraulic fracturing is neither practical nor wise. Alternatives to oil and gas exist, but not in globally sufficient amounts to replace petroleum hydrocarbons. [n349] Such prohibitions on development may result in the transfer of negative externalities to another population. For example, the state of New York banned high-volume hydraulic fracturing but continues to import natural gas from various other states. [n350] Thus, stakeholders should focus on continuing academic and scientific studies, while encouraging cooperative efforts between regulators and legislators and their academic and scientific counterparts, further ensuring that resulting rules and laws are adaptive and responsive to study findings and conclusions. These solutions could include regulatory, technology, risk mitigation, and acceptance of oil and gas production consequences. [n351]

A. Information Sharing

Affected groups currently function with the knowledge that while the seismicity science evolves, the risk to the public remains or **[*651]** increases. These affected groups include: (1) the general public--likely most important due to risk of injury and/or property damage; (2) oil and gas producers and wastewater disposers; (3) federal, state, and local land-management, regulatory, and permitting agencies; (4) emergency managers and responders; (5) building owners, insurers, and mortgage holders; and (6) scientists in the research community investigating induced seismicity. [n352]

To address this disconnect between evolving science and increasing risk, strategies should focus on providing relevant data and solutions to stakeholder groups, allowing them an opportunity to decrease the risk of oil and gas induced seismicity harm. Effective information collection and dissemination remains one of the most critical solutions to oil and gas induced seismicity. Academics and scientists must continue studying and analyzing data and possible relationships, while regulatory agencies, governments, and industry should use this data to adjust or adapt current and future operations.

This dissemination can be achieved through partnerships between academia, government, industry, and regulators. For example, the Interstate Oil and Gas Compact Commission and the Ground Water Protection Council sponsored a multi-state initiative called StatesFirst. [n353] The initiative's purpose is "to share and summarize current knowledge related to earthquakes potentially caused by human activity . . . ." [n354] Thirteen states participated in the program and membership comprised of state oil and natural gas and geological agencies, in addition to other advisory experts from academia, industry, non-profit organizations, and federal agencies. [n355] StatesFirst recently published a Primer, the purpose of which is to "provide a guide for regulatory agencies to evaluate and develop strategies to mitigate and manage risks of injection induced seismicity," in **[*652]** addition to outlining methods of transparent and effective dissemination of information to the public. [n356]

For scientific and regulatory stakeholders, information sharing requires "[a]ccess to high quality, state-of-the-art seismic information" possibly in the form of a "publicly credible seismic database." [n357] This database should combine the now independent state efforts to track seismic events along with fluid injection and fluid movement in the crust on a national or regional basis. [n358] Adding existing geological data also helps researchers observe whether rock characteristics contribute to the location of earthquakes; for example, researchers could overlay seismic data with permeability data to observe whether and where earthquakes occur in high- or low-permeability reservoirs. [n359] Ensuring that this database is transparent encourages both public acceptance and industry response. Additionally, "[i]t is worthwhile to have both public and private research access to the data . . . [as a]vailability of these data to a broad spectrum of researchers could result in an increased understanding of the fundamental processes involved in fluid movement within the [e]arth's crust." [n360]

There is much growth potential and a larger audience for this data as other disciplines, such as "geothermal energy production, non-geothermal electrical energy production, petroleum recovery, carbon dioxide sequestration, and natural earthquake studies," may find it useful. [n361] Better data gathering and sharing in addition to reporting of triggering event observations will reduce the uncertainty in scientific interpretations, which is of great value to all stakeholders. [n362]

[*653] *B. Technological Procedures*

In addition to possible damage and risk to affected groups, industry faces the additional burden of being subject to litigation as a possible effect of the seismicity. It is therefore likely to employ research and development funds to find new technologies or procedures that reduce the risk of oil and gas induced seismicity or to minimize the damage while allowing continued petroleum production and development.

To aid in these research efforts, or at the request of concerned surface owners, companies may decide to measure seismic activity by placing monitors near their producing and disposal wells. Scientists have proposed an early warning system, which follows "the seismic risk assessment protocol for well-blasting operations employed by geothermal-energy producers." [n363] Landowner requirements or company preference may include documenting existing surface structures using photos and videos or working with a structural engineer to determine building integrity prior to operating. Companies may also consider hiring a seismologist or working with a consulting firm that specializes in induced seismic activity to consult with on locations, hydraulic fracturing, and disposal operations. Ideally, companies should also invest research dollars into the reduction, reuse, and cleaning of wastewater to reduce or eliminate the need for wastewater disposal.

However it chooses to proceed, the oil and gas industry should not wait for a final or definitive scientific consensus on seismicity issues before taking any action on oil and gas induced seismicity. Instead, industry should take appropriate measures via contract, technology investment, and operational innovations to mitigate possible risks.

C. Risk Mitigation

Insurance is the traditional form for risk mitigation. Obviously, oil and gas induced seismicity should include an insurance strategy for **[*654]** property owners and industry. [n364] But after the onset of induced seismicity claims, insurers denied coverage even for those homeowners who had purchased a separate rider covering seismic activity. Insurance companies have argued that their policies covered *natural* seismicity and not *induced* seismicity and have thus denied claims. Interestingly, insurers have made this argument while likely understanding that "it can be difficult to make the distinction between earthquakes caused by natural and human causes." [n365]

States are quickly chastising insurers, mandating that a policy covering earthquake damage must cover all types of seismic activity. For example, in Pennsylvania, "insurers that cover earthquake damage must cover all types, including those considered to be caused by natural gas extraction, or fracking. The state's insurance department is notifying insurers with earthquake coverage as part of homeowner's policies they are not allowed to exclude coverage for earthquakes that they suspect are caused by 'human activity.'" [n366] The state also required insurers that had already written exclusions into their policies to cease enforcing them and requested the filing of new endorsements, without the exclusionary language. [n367] In October 2015, Oklahoma Insurance Commissioner John Doak ordered a similar policy to take effect on Oklahoma insurers. [n368]

D. Seismicity Impact Mitigation

A paradigm shift in the management of induced seismicity may be required. The traditional approach to induced seismicity is to control "the number, frequency or magnitude of the induced earthquakes and focus[] instead on the consequences of the earthquakes that may **[*655]** occur." [n369] That is, the management of induced seismic activity should simulate the approach to natural seismicity--acceptance. Regarding natural seismicity, stakeholders accept the fact that this seismic activity will occur and use limited resources to focus on reactionary responses to its effects and "tak[e] appropriate measures to mitigate the negative consequences of these effects on the built environment." [n370] This approach may take the form of updating building codes, reinforcing insurer policies, preparing response measures, etc. The main difference, however, between adopting a similar tactic for induced seismicity is that natural seismic activity is considered unavoidable at this time. [n371] Induced seismicity is anthropogenic seismicity and thus measures can likely be taken to prevent seismic activity. [n372] But, a large benefit to this rethinking in approach is that infrastructure and resources already exist to work with post-seismic activity. [n373]

Additional strategies and solutions will be possible as more studies are done on oil and gas induced seismicity. Necessity often drives innovation and the risk of injury, death, and property damage serve as powerful motivations for stakeholders to address wastewater usage, seismic activity predictive modeling, and deployment of resources after a seismic event.

CONCLUSION

Further challenges appear on the horizon. These challenges pose difficult questions for stakeholders given the relative lack of information on underlying causes and on whether oil and gas induced seismicity is preventable without resorting to development prohibitions. In particular, two such interesting questions include imposition of a liability regime and security.

[*656] Under the Comprehensive Environmental Response, Compensation, Liability Act (CERCLA), potential responsible parties include those operators, producers, transporters, owners, etc. who maintain or have had a tangential relationship to the hazardous outcome. Forgetting the exemption on oil and gas activities and whether wastewater disposal, in particular, is encompassed within the exemption, the question arises as to who, if anyone, would be liable. Such a liability scheme likely includes owners and operators of disposal wells, but what of the generators of the waste? They, too, are likely to be included as providers of the material that is injected into the wells. However, ownership of the product creates a predicament. Oil and gas wells often have several property interest owners, including the owner of the mineral estate--the lessee or the mineral interest owner--and the royalty interest owners, who own a cost-free share of production. Does a royalty interest owner, who receives income from a producing well but has no role in operations, subject themselves to liability by virtue of property ownership? Moreover, produced water is often comingled in storage tanks sited on the lease. If an owner, be it the mineral interest owner or royalty interest owner, owns one well which contributed one drop of wastewater to the storage tank which is later emptied by a disposal contractor and taken to an injection well and "causes" an earthquake, is there or should there be a *de minimis* standard of conduct or, at the very least, a requirement that liability be in proportion to disposal volumes?

The second issue involves security, which is a critical issue with respect to oil and gas induced seismicity. Seismic activity has a likelihood of damaging key American installations. Cushing, Oklahoma, is one of the world's largest oil storage facilities; a crossroads of crude oil pipelines from across the continent; and the pricing location for West Texas Intermediate, the standard of global crude oil pricing. In 2011, a large earthquake struck Prague, Oklahoma, which is only forty miles away. [n374] Imagine the consequences of a destructive earthquake that causes mass devastation at this major pricing point and the ensuing market chaos. **[*657]** Almost certainly, there would be those market participants who take advantage of such chaos and volatility for incredible profit--and subsequent loss for the counterparty. Do these types of implications rise to the level of concern required under NEPA, if any of the disposal activity occurs on a neighboring federal or tribal lease? Other challenges are sure to arise as more information is collected and analyzed and, unfortunately, as seismic activity increases, especially in populated regions.

All energy portfolios carry associated benefits and costs--financial, environmental, economic, social, and physical. Induced seismicity is such a cost that arises in many energy portfolios. It is simply not feasible reject an energy choice due to the effects of induced seismicity. Rather, research and mitigation or response efforts should be considered and evaluated by stakeholder groups. In particular, a concerted effort to exchange information and exchange observations and data by regulatory agencies, scientific and academic groups, and industry may further reduce the risk of damage, while maintaining domestic energy production and security of supply.

Legal Topics:

For related research and practice materials, see the following legal topics:
Energy & Utilities LawAdministrative ProceedingsGeneral OverviewEnergy & Utilities LawHydroelectric Power IndustryGeneral OverviewEnergy & Utilities LawMining IndustryCoalCoal Bed Methane

FOOTNOTES:

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